A Level

Article: 274

TOPICAL PAST PAPERS

9709

MATHEMATICS

PAPER-4 (M1)

- ✓ All Variants
- ✓ Mark Schemes Included
- ✓ Questions order new to old

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A
Level

Article No. 274

Mustafa Asif BDC

Mathematics 9709

Paper-4 (M1)

(Topical Past Paper with Mark Scheme)

(2002-2017)

Features:

- ✓ All Variants
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4 Mechanics (for Paper 4)

Questions set will be mainly numerical, and will aim to test mechanical principles without involving difficult algebra or trigonometry. However, candidates should be familiar in particular with the following trigonometrical results:

$$\sin(90^\circ - \theta) \equiv \cos\theta,\ \cos(90^\circ - \theta) \equiv \sin\theta,\ \tan\theta \equiv \frac{\sin\theta}{\cos\theta},\ \sin^2\theta + \cos^2\theta \equiv 1.$$

Knowledge of algebraic methods from the content for Paper 1: Pure Mathematics 1 is assumed.

This content list refers to the equilibrium or motion of a 'particle'. Examination questions may involve extended bodies in a 'realistic' context, but these extended bodies should be treated as particles, so any force acting on them is modelled as acting at a single point.

Vector notation will not be used in the question papers.

4.1 Forces and equilibrium

Candidates should be able to:	Notes and examples
• identify the forces acting in a given situation	e.g. by drawing a force diagram.
• understand the vector nature of force, and find and use components and resultants	Calculations are always required, not approximate solutions by scale drawing.
• use the principle that, when a particle is in equilibrium, the vector sum of the forces acting is zero, or equivalently, that the sum of the components in any direction is zero	Solutions by resolving are usually expected, but equivalent methods (e.g. triangle of forces, Lami's Theorem, where suitable) are also acceptable; these other methods are not required knowledge, and will not be referred to in questions.
• understand that a contact force between two surfaces can be represented by two components, the normal component and the frictional component	
• use the model of a 'smooth' contact, and understand the limitations of this model	
• understand the concepts of limiting friction and limiting equilibrium, recall the definition of coefficient of friction, and use the relationship $F = \mu R$ or $F \leqslant \mu R$, as appropriate	Terminology such as 'about to slip' may be used to mean 'in limiting equilibrium' in questions.
• use Newton's third law.	e.g. the force exerted by a particle on the ground is equal and opposite to the force exerted by the ground on the particle.

4.2 Kinematics of motion in a straight line

Candidates should be able to:	Notes and examples
• understand the concepts of distance and speed as scalar quantities, and of displacement, velocity and acceleration as vector quantities	Restricted to motion in one dimension only. The term 'deceleration' may sometimes be used in the context of decreasing speed.
• sketch and interpret displacement–time graphs and velocity–time graphs, and in particular appreciate that – the area under a velocity–time graph represents displacement, – the gradient of a displacement–time graph represents velocity, – the gradient of a velocity–time graph represents acceleration	
• use differentiation and integration with respect to time to solve simple problems concerning displacement, velocity and acceleration	Calculus required is restricted to techniques from the content for Paper 1: Pure Mathematics 1.
• use appropriate formulae for motion with constant acceleration in a straight line.	Questions may involve setting up more than one equation, using information about the motion of different particles.

4.3 Momentum

Candidates should be able to:	Notes and examples
• use the definition of linear momentum and show understanding of its vector nature	For motion in one dimension only.
• use conservation of linear momentum to solve problems that may be modelled as the direct impact of two bodies.	Including direct impact of two bodies where the bodies coalesce on impact. Knowledge of impulse and the coefficient of restitution is not required.

4.4 Newton's laws of motion

Candidates should be able to:	Notes and examples
• apply Newton's laws of motion to the linear motion of a particle of constant mass moving under the action of constant forces, which may include friction, tension in an inextensible string and thrust in a connecting rod	If any other forces resisting motion are to be considered (e.g. air resistance) this will be indicated in the question.
• use the relationship between mass and weight	$W = mg$. In this component, questions are mainly numerical, and use of the approximate numerical value 10 (m s^{-2}) for g is expected.
• solve simple problems which may be modelled as the motion of a particle moving vertically or on an inclined plane with constant acceleration	Including, for example, motion of a particle on a rough plane where the acceleration while moving up the plane is different from the acceleration while moving down the plane.
• solve simple problems which may be modelled as the motion of connected particles.	e.g. particles connected by a light inextensible string passing over a smooth pulley, or a car towing a trailer by means of either a light rope or a light rigid tow-bar.

4.5 Energy, work and power

Candidates should be able to:	Notes and examples
• understand the concept of the work done by a force, and calculate the work done by a constant force when its point of application undergoes a displacement not necessarily parallel to the force	$W = Fd\cos\theta$; Use of the scalar product is not required.
• understand the concepts of gravitational potential energy and kinetic energy, and use appropriate formulae	
• understand and use the relationship between the change in energy of a system and the work done by the external forces, and use in appropriate cases the principle of conservation of energy	Including cases where the motion may not be linear (e.g. a child on a smooth curved 'slide'), where only overall energy changes need to be considered.
• use the definition of power as the rate at which a force does work, and use the relationship between power, force and velocity for a force acting in the direction of motion	Including calculation of (average) power as $\frac{\text{Work done}}{\text{Time taken}}$. $P = Fv$.
• solve problems involving, for example, the instantaneous acceleration of a car moving on a hill against a resistance.	

CONTENTS

Unit-1: Forces and Equilibrium

1. **O/N 17/P42/Q1**

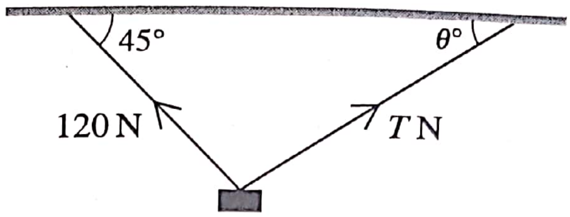
A particle of mass 0.2 kg is resting in equilibrium on a rough plane inclined at 20° to the horizontal.

(i) Show that the friction force acting on the particle is 0.684 N, correct to 3 significant figures. [1]

The coefficient of friction between the particle and the plane is 0.6. A force of magnitude 0.9 N is applied to the particle down a line of greatest slope of the plane. The particle accelerates down the plane.

(ii) Find this acceleration. [4]

2. **O/N 17/P42/Q2**

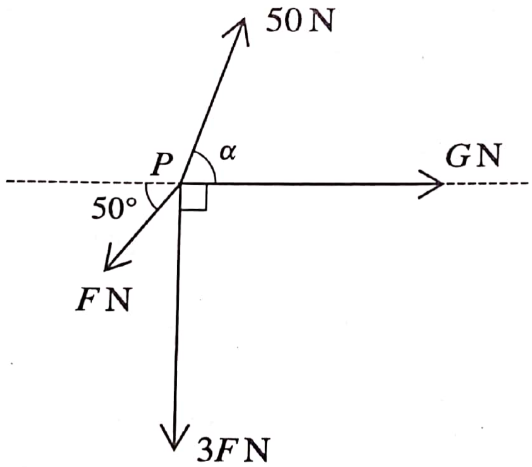


A block of mass 15 kg hangs in equilibrium below a horizontal ceiling attached to two strings as shown in the diagram. One of the strings is inclined at 45° to the horizontal and the tension in this string is 120 N. The other string is inclined at $\theta°$ to the horizontal and the tension in this string is T N. Find the values of T and θ. [6]

3. **O/N 17/P41/Q1**

A block of mass 3 kg is initially at rest on a smooth horizontal floor. A force of 12 N, acting at an angle of 25° above the horizontal, is applied to the block. Find the distance travelled by the block in the first 5 seconds of its motion. [4]

4. **O/N 17/P41/Q6**

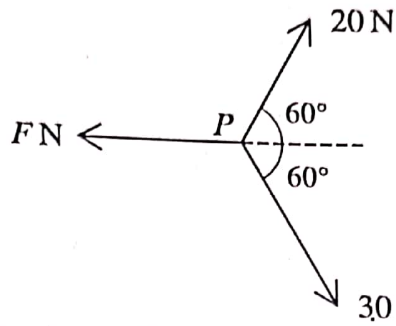


Coplanar forces, of magnitudes F N, $3F$ N, G N and 50 N, act at a point P, as shown in the diagram.

(i) Given that $F = 0$, $G = 75$ and $\alpha = 60°$, find the magnitude and direction of the resultant force. [4]

(ii) Given instead that $G = 0$ and the forces are in equilibrium, find the values of F and α. [5]

5. O/N 17/P43/Q1



Three coplanar forces of magnitudes F N, 20 N and 30 N act at a point P, as shown in the diagram. The resultant of the three forces acts in a direction perpendicular to the force of magnitude F N. Find the value of F. [3]

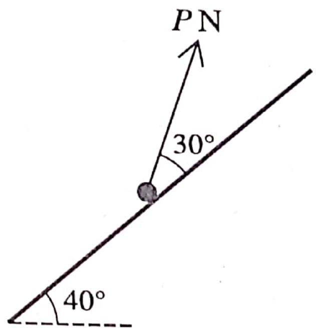
6. O/N 17/P43/Q3

A particle is released from rest and slides down a line of greatest slope of a rough plane which is inclined at 25° to the horizontal. The coefficient of friction between the particle and the plane is 0.4.

(i) Find the acceleration of the particle. [4]

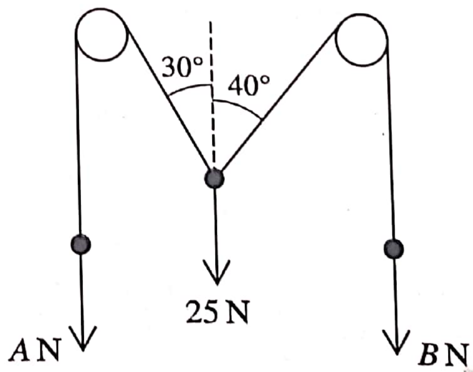
(ii) Find the distance travelled by the particle in the first 3 s after it is released. [2]

7. M/J 17/P42/Q5



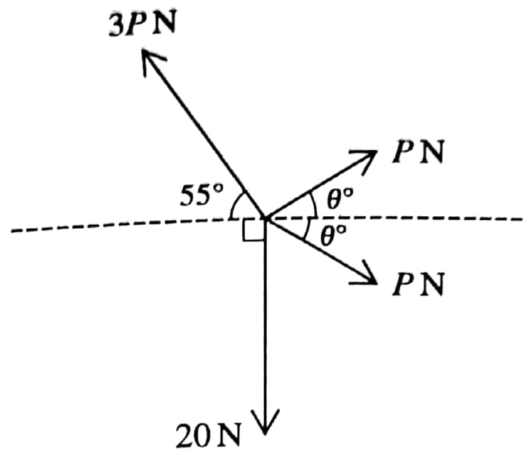
A particle of mass 0.12 kg is placed on a plane which is inclined at an angle of 40° to the horizontal. The particle is kept in equilibrium by a force of magnitude P N acting up the plane at an angle of 30° above a line of greatest slope, as shown in the diagram. The coefficient of friction between the particle and the plane is 0.32. Find the set of possible values of P. [8]

8. M/J 17/P41/Q3



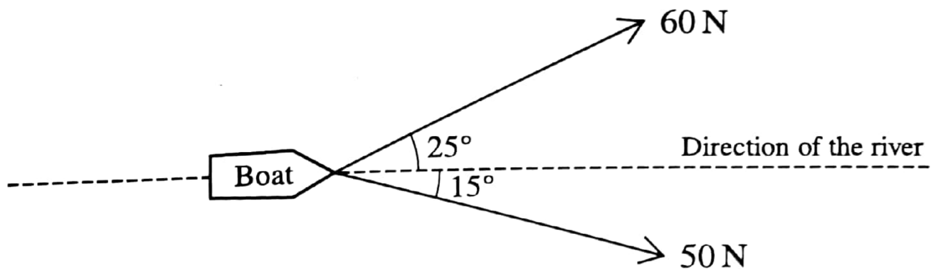
Two light inextensible strings are attached to a particle of weight 25 N. The strings pass over two smooth fixed pulleys and have particles of weights A N and B N hanging vertically at their ends. The sloping parts of the strings make angles of 30° and 40° respectively with the vertical (see diagram). The system is in equilibrium. Find the values of A and B. [6]

9. M/J 17/P41/Q2



The four coplanar forces shown in the diagram are in equilibrium. Find the values of P and θ. [5]

10. O/N 16/P42/Q3



A boat is being pulled along a river by two people. One of the people walks along a path on one side of the river and the other person walks along a path on the opposite side of the river. The first person exerts a horizontal force of 60 N at an angle of 25° to the direction of the river. The second person exerts a horizontal force of 50 N at an angle of 15° to the direction of the river (see diagram).

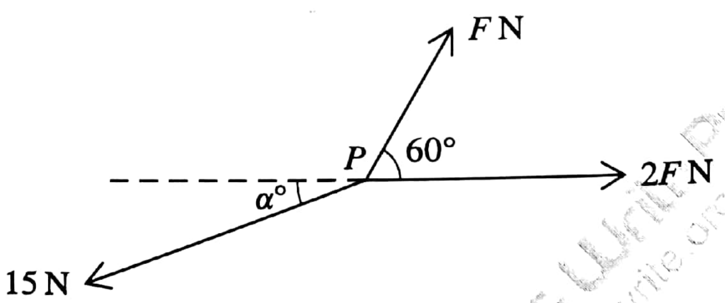
(i) Find the total force exerted by the two people in the direction of the river. [2]

(ii) Find the magnitude and direction of the resultant force exerted by the two people. [4]

11. O/N 16/P42/Q5

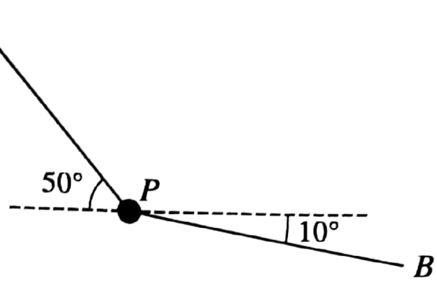
A particle of mass m kg is resting on a rough plane inclined at 30° to the horizontal. A force of magnitude 10 N applied to the particle up a line of greatest slope of the plane is just sufficient to stop the particle sliding down the plane. When a force of 75 N is applied to the particle up a line of greatest slope of the plane, the particle is on the point of sliding up the plane. Find m and the coefficient of friction between the particle and the plane. [6]

12. O/N 16/P41/Q4



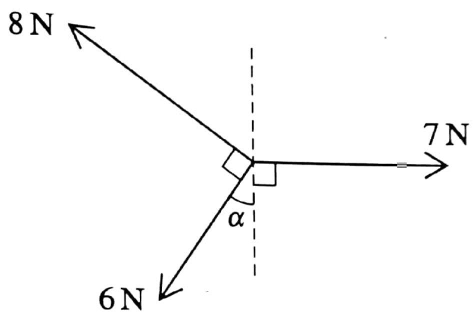
Three coplanar forces of magnitudes F N, $2F$ N and 15 N act at a point P, as shown in the diagram. Given that the forces are in equilibrium, find the values of F and α. [6]

13. O/N 16/P43/Q2



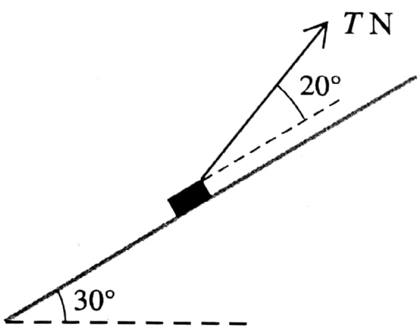
The diagram shows a small object P of mass 20 kg held in equilibrium by light ropes attached to fixed points A and B. The rope PA is inclined at an angle of 50° above the horizontal, the rope PB is inclined at an angle of 10° below the horizontal, and both ropes are in the same vertical plane. Find the tension in the rope PA and the tension in the rope PB. [5]

14. M/J 16/P42/Q1



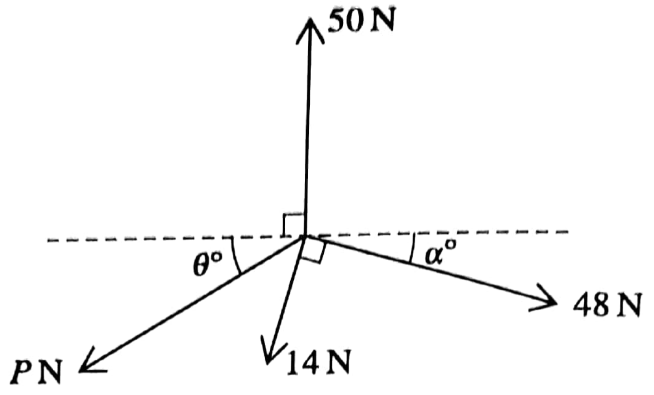
Coplanar forces of magnitudes 7 N, 6 N and 8 N act at a point in the directions shown in the diagram. Given that $\sin\alpha = \frac{3}{5}$, find the magnitude and direction of the resultant of the three forces. [5]

15. M/J 16/P42/Q5



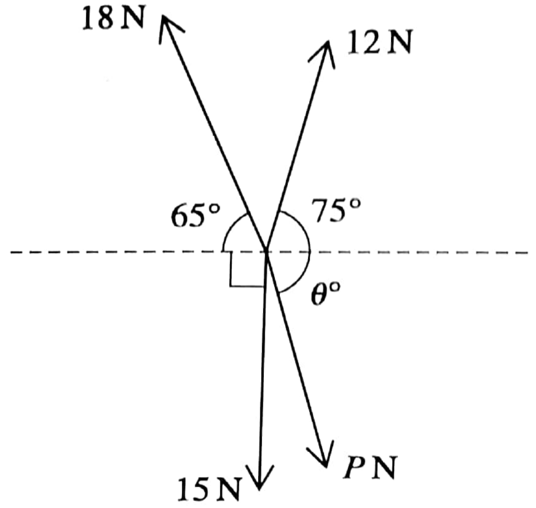
A block of mass 2.5 kg is placed on a plane which is inclined at an angle of 30° to the horizontal. The block is kept in equilibrium by a light string making an angle of 20° above a line of greatest slope. The tension in the string is T N, as shown in the diagram. The coefficient of friction between the block and plane is $\frac{1}{4}$. The block is in limiting equilibrium and is about to move up the plane. Find the value of T. [7]

16. M/J 16/P41/Q4



Coplanar forces of magnitudes 50 N, 48 N, 14 N and P N act at a point in the directions shown in the diagram. The system is in equilibrium. Given that $\tan\alpha = \frac{7}{24}$, find the values of P and θ. **[6]**

17. M/J 16/P43/Q3

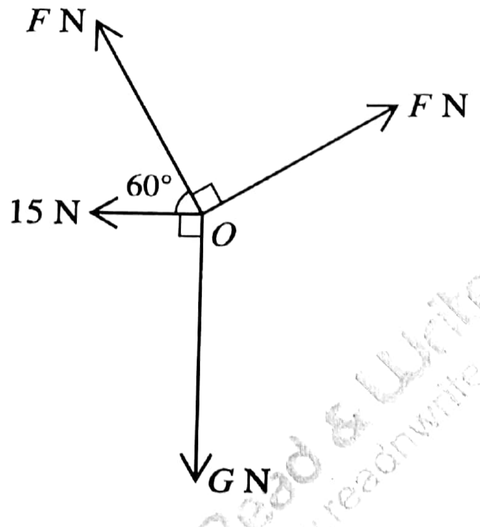


The coplanar forces shown in the diagram are in equilibrium. Find the values of P and θ. **[6]**

18. M/J 16/P43/Q4

A particle of mass 15 kg is stationary on a rough plane inclined at an angle of 20° to the horizontal. The coefficient of friction between the particle and the plane is 0.2. A force of magnitude X N acting parallel to a line of greatest slope of the plane is used to keep the particle in equilibrium. Show that the least possible value of X is 23.1, correct to 3 significant figures, and find the greatest possible value of X. **[7]**

19. O/N 15/P42/Q1

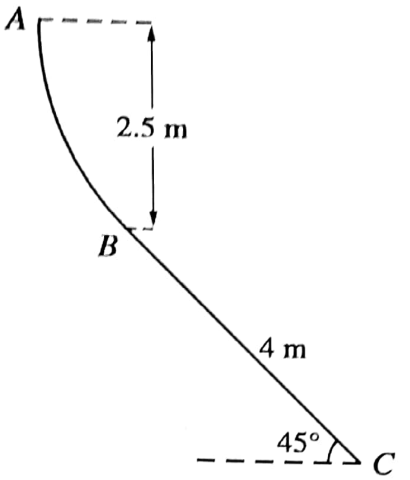


Four horizontal forces act at a point O and are in equilibrium. The magnitudes of the forces are F N, G N, 15 N and F N, and the forces act in directions as shown in the diagram.

(i) Show that $F = 41.0$, correct to 3 significant figures. [3]

(ii) Find the value of G. [2]

20. O/N 15/P42/Q4



The diagram shows a vertical cross-section ABC of a surface. The part of the surface containing AB is smooth and A is 2.5 m above the level of B. The part of the surface containing BC is rough and is at 45° to the horizontal. The distance BC is 4 m (see diagram). A particle P of mass 0.2 kg is released from rest at A and moves in contact with the curve AB and then with the straight line BC. The coefficient of friction between P and the part of the surface containing BC is 0.4. Find the speed with which P reaches C. [6]

21. O/N 15/P42/Q6

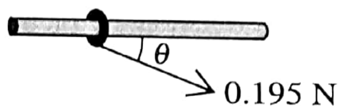


Fig. 1

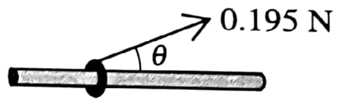


Fig. 2

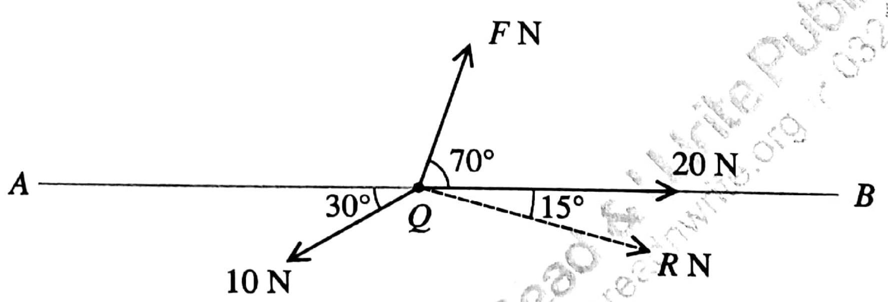
A small ring of mass 0.024 kg is threaded on a fixed rough horizontal rod. A light inextensible string is attached to the ring and the string is pulled with a force of magnitude 0.195 N at an angle of θ with the horizontal, where $\sin\theta = \frac{5}{13}$. When the angle θ is below the horizontal (see Fig. 1) the ring is in limiting equilibrium.

(i) Find the coefficient of friction between the ring and the rod. [6]

When the angle θ is above the horizontal (see Fig. 2) the ring moves.

(ii) Find the acceleration of the ring. [4]

22. O/N 15/P41/Q5

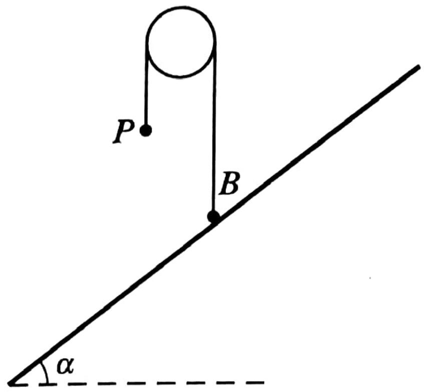


A small bead Q can move freely along a smooth horizontal straight wire AB of length 3 m. Three horizontal forces of magnitudes F N, 10 N and 20 N act on the bead in the directions shown in the diagram. The magnitude of the resultant of the three forces is R N in the direction shown in the diagram.

(i) Find the values of F and R. [5]

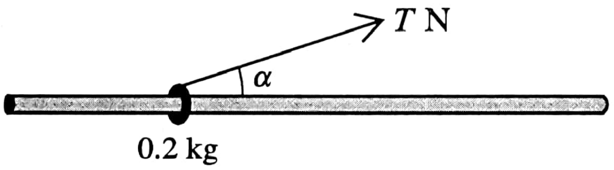
(ii) Initially the bead is at rest at A. It reaches B with a speed of $11.7\,\text{m}\,\text{s}^{-1}$. Find the mass of the bead. [3]

23. O/N 15/P43/Q1



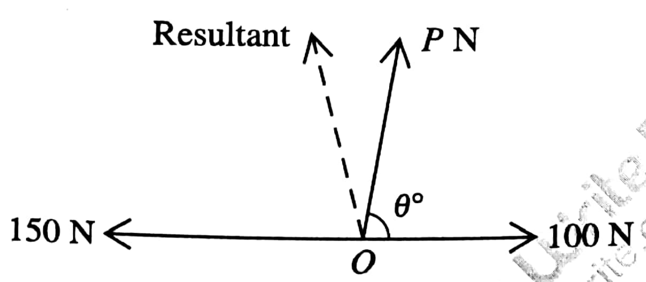
A small ball B of mass 4 kg is attached to one end of a light inextensible string. A particle P of mass 3 kg is attached to the other end of the string. The string passes over a fixed smooth pulley. The system is in equilibrium with the string taut and its straight parts vertical. B is at rest on a rough plane inclined to the horizontal at an angle of α, where $\cos\alpha = 0.8$ (see diagram). State the tension in the string and find the normal component of the contact force exerted on B by the plane. [3]

24. O/N 15/P43/Q2



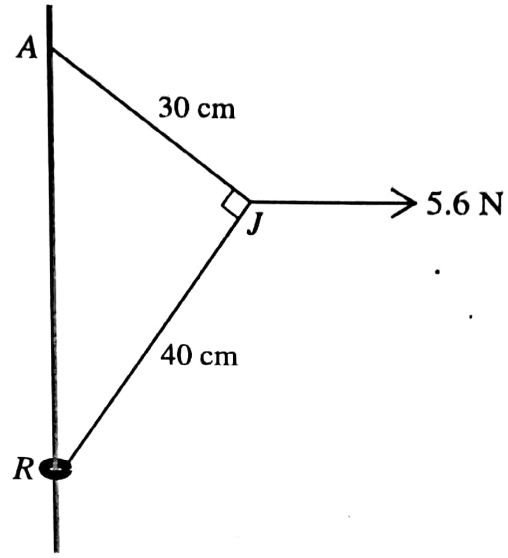
A ring of mass 0.2 kg is threaded on a fixed rough horizontal rod and a light inextensible string is attached to the ring at an angle α above the horizontal, where $\cos\alpha = 0.96$. The ring is in limiting equilibrium with the tension in the string T N (see diagram). Given that the coefficient of friction between the ring and the rod is 0.25, find the value of T. [5]

25. O/N 15/P43/Q3



Three horizontal forces of magnitudes 150 N, 100 N and P N have directions as shown in the diagram. The resultant of the three forces is shown by the broken line in the diagram. This resultant has magnitude 120 N and makes an angle 75° with the 150 N force. Find the values of P and θ. [7]

26. M/J 15/P42/Q7



A small ring R is attached to one end of a light inextensible string of length 70 cm. A fixed rough vertical wire passes through the ring. The other end of the string is attached to a point A on the wire, vertically above R. A horizontal force of magnitude 5.6 N is applied to the point J of the string 30 cm from A and 40 cm from R. The system is in equilibrium with each of the parts AJ and JR of the string taut and angle AJR equal to 90° (see diagram).

(i) Find the tension in the part AJ of the string, and find the tension in the part JR of the string. **[5]**

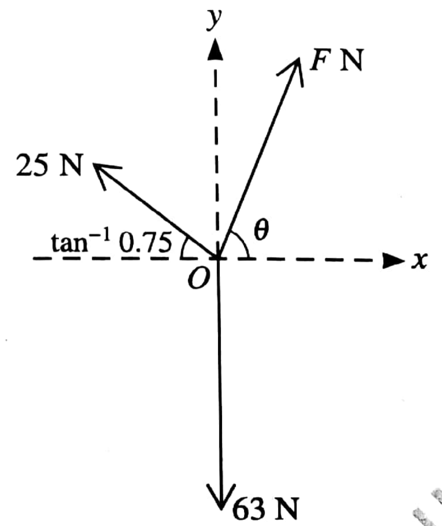
The ring R has mass 0.2 kg and is in limiting equilibrium, on the point of moving up the wire.

(ii) Show that the coefficient of friction between R and the wire is 0.341, correct to 3 significant figures. **[4]**

A particle of mass m kg is attached to R and R is now in limiting equilibrium, on the point of moving down the wire.

(iii) Given that the coefficient of friction is unchanged, find the value of m. **[3]**

27. M/J 15/P41/Q2



Three horizontal forces of magnitudes F N, 63 N and 25 N act at O, the origin of the x-axis and y-axis. The forces are in equilibrium. The force of magnitude F N makes an angle θ anticlockwise with the positive x-axis. The force of magnitude 63 N acts along the negative y-axis. The force of magnitude 25 N acts at $\tan^{-1} 0.75$ clockwise from the negative x-axis (see diagram). Find the value of F and the value of $\tan\theta$. **[5]**

28. M/J 15/P41/Q3

A block of weight 6.1 N slides down a slope inclined at $\tan^{-1}\left(\frac{11}{60}\right)$ to the horizontal. The coefficient of friction between the block and the slope is $\frac{1}{4}$. The block passes through a point A with speed $2\,\text{m s}^{-1}$. Find how far the block moves from A before it comes to rest. [5]

29. M/J 15/P43/Q5

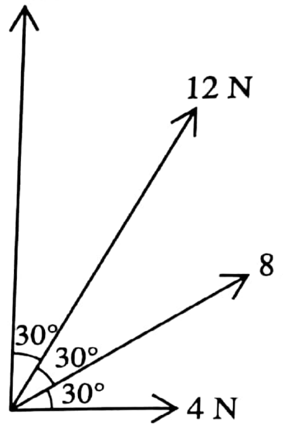


Fig. 1

Four coplanar forces of magnitudes 4 N, 8 N, 12 N and 16 N act at a point. The directions in which the forces act are shown in Fig. 1.

(i) Find the magnitude and direction of the resultant of the four forces. [5]

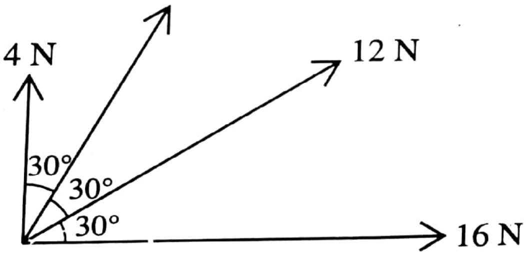


Fig. 2

The forces of magnitudes 4 N and 16 N exchange their directions and the forces of magnitudes 8 N and 12 N also exchange their directions (see Fig. 2).

(ii) State the magnitude and direction of the resultant of the four forces in Fig. 2. [2]

30. M/J 15/P43/Q6

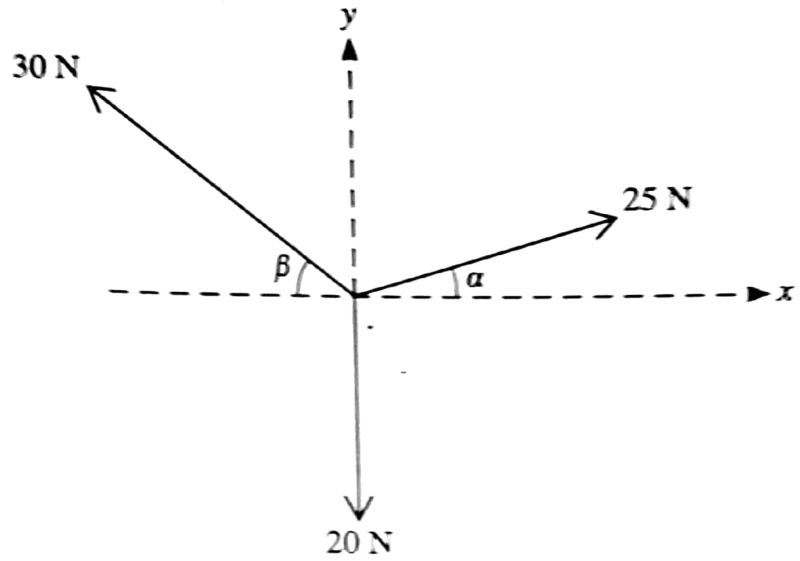
A small box of mass 5 kg is pulled at a constant speed of $2.5\,\text{m s}^{-1}$ down a line of greatest slope of a rough plane inclined at 10° to the horizontal. The pulling force has magnitude 20 N and acts downwards parallel to a line of greatest slope of the plane. [5]

(i) Find the coefficient of friction between the box and the plane.

The pulling force is removed while the box is moving at $2.5\,\text{m s}^{-1}$.

(ii) Find the distance moved by the box after the instant at which the pulling force is removed. [4]

31. O/N 14/P42/Q2



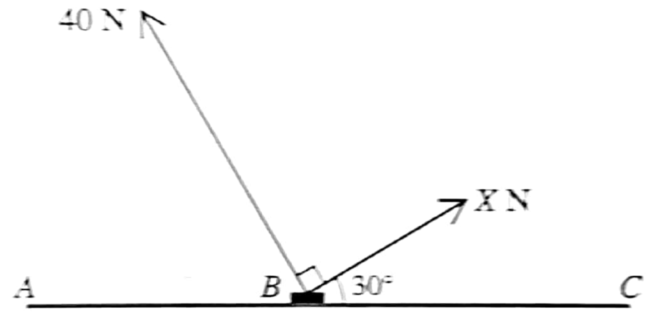
Three coplanar forces act at a point. The magnitudes of the forces are 20 N, 25 N and 30 N, and the directions in which the forces act are as shown in the diagram, where $\sin\alpha = 0.28$ and $\cos\alpha = 0.96$, and $\sin\beta = 0.6$ and $\cos\beta = 0.8$.

(i) Show that the resultant of the three forces has a zero component in the x-direction. [2]

(ii) Find the magnitude and direction of the resultant of the three forces. [2]

(iii) The force of magnitude 20 N is replaced by another force. The effect is that the resultant force is unchanged in magnitude but reversed in direction. State the magnitude and direction of the replacement force. [1]

32. O/N 14/P42/Q4

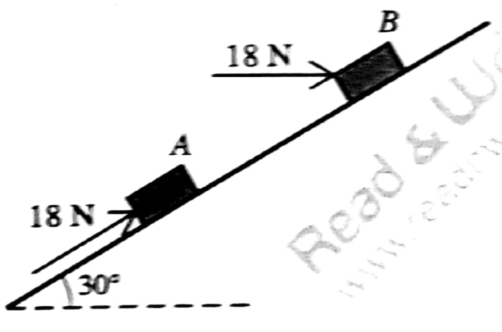


Forces of magnitude X N and 40 N act on a block B of mass 15 kg, which is in equilibrium in contact with a horizontal surface between points A and C on the surface. The forces act in the same vertical plane and in the directions shown in the diagram.

(i) Given that the surface is smooth, find the value of X. [2]

(ii) It is given instead that the surface is rough and that the block is in limiting equilibrium. The frictional force acting on the block has magnitude 10 N in the direction towards A. Find the coefficient of friction between the block and the surface. [5]

33. O/N 14/P41/Q2



Small blocks A and B are held at rest on a smooth plane inclined at 30° to the horizontal. Each is held in equilibrium by a force of magnitude 18 N. The force on A acts upwards parallel to a line of greatest slope of the plane, and the force on B acts horizontally in the vertical plane containing a line of greatest slope (see diagram). Find the weight of A and the weight of B. [4]

34. O/N 14/P41/Q3

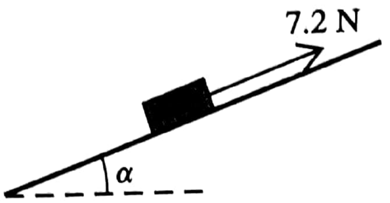


Fig. 1

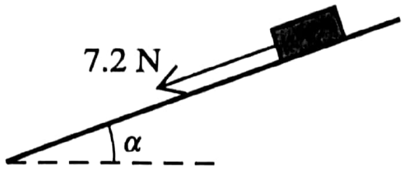


Fig. 2

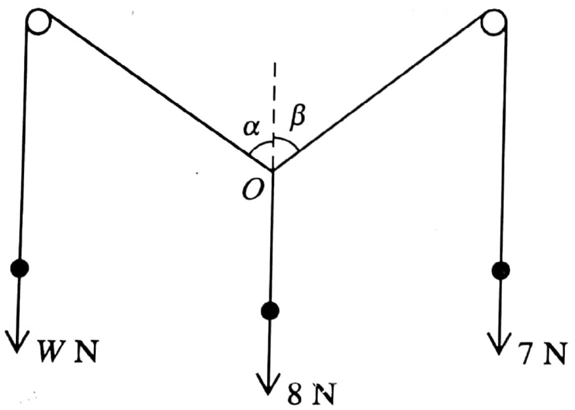
A block of weight 7.5 N is at rest on a plane which is inclined to the horizontal at angle α, where $\tan\alpha = \frac{7}{24}$. The coefficient of friction between the block and the plane is μ. A force of magnitude 7.2 N acting parallel to a line of greatest slope is applied to the block. When the force acts up the plane (see Fig. 1) the block remains at rest.

(i) Show that $\mu \geqslant \frac{17}{24}$. [4]

When the force acts down the plane (see Fig. 2) the block slides downwards.

(ii) Show that $\mu < \frac{31}{24}$. [2]

35. O/N 14/P43/Q3

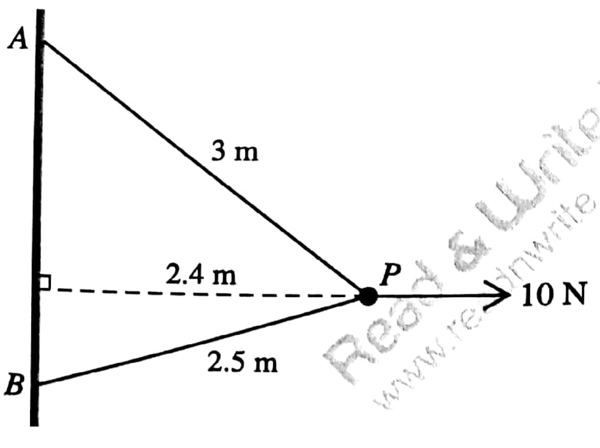


Each of three light inextensible strings has a particle attached to one of its ends. The other ends of the strings are tied together at a point O. Two of the strings pass over fixed smooth pegs and the particles hang freely in equilibrium. The weights of the particles and the angles between the sloping parts of the strings and the vertical are as shown in the diagram. It is given that $\sin\beta = 0.8$ and $\cos\beta = 0.6$.

(i) Show that $W\cos\alpha = 3.8$ and find the value of $W\sin\alpha$. [3]

(ii) Hence find the values of W and α. [3]

36. M/J 14/P42/Q3



A and B are fixed points of a vertical wall with A vertically above B. A particle P of mass 0.7 kg is attached to A by a light inextensible string of length 3 m. P is also attached to B by a light inextensible string of length 2.5 m. P is maintained in equilibrium at a distance of 2.4 m from the wall by a horizontal force of magnitude 10 N acting on P (see diagram). Both strings are taut, and the 10 N force acts in the plane APB which is perpendicular to the wall. Find the tensions in the strings. **[6]**

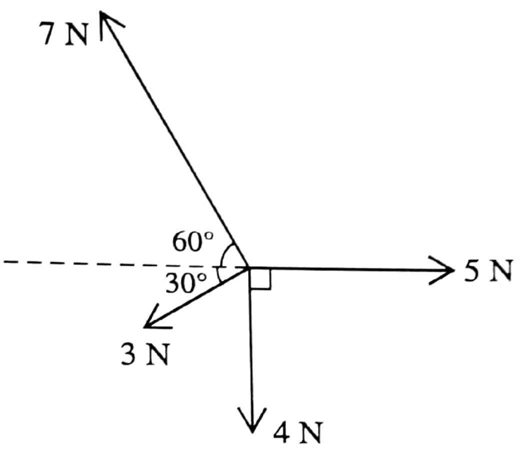
37. M/J 14/P41/Q2

A rough plane is inclined at an angle of $\alpha°$ to the horizontal. A particle of mass 0.25 kg is in equilibrium on the plane. The normal reaction force acting on the particle has magnitude 2.4 N. Find

(i) the value of α, **[2]**

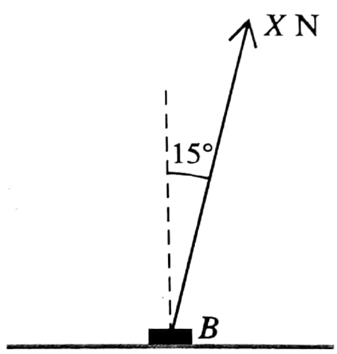
(ii) the least possible value of the coefficient of friction. **[2]**

38. M/J 14/P41/Q3



Four coplanar forces act at a point. The magnitudes of the forces are 5 N, 4 N, 3 N and 7 N, and the directions in which the forces act are shown in the diagram. Find the magnitude and direction of the resultant of the four forces. **[6]**

39. M/J 14/P43/Q1



A block B of mass 7 kg is at rest on rough horizontal ground. A force of magnitude X N acts on B at an angle of 15° to the upward vertical (see diagram).

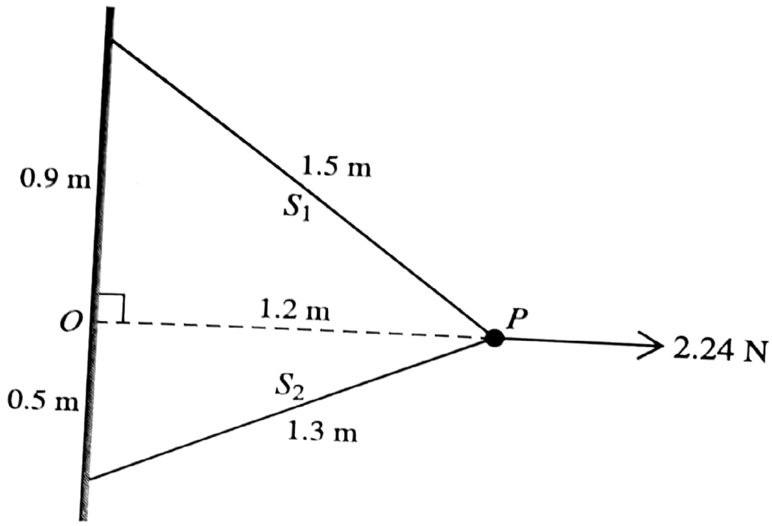
(i) Given that B is in equilibrium find, in terms of X, the normal component of the force exerted on B by the ground. **[2]**

(ii) The coefficient of friction between B and the ground is 0.4. Find the value of X for which B is in limiting equilibrium. **[3]**

40. M/J 14/P41/Q2

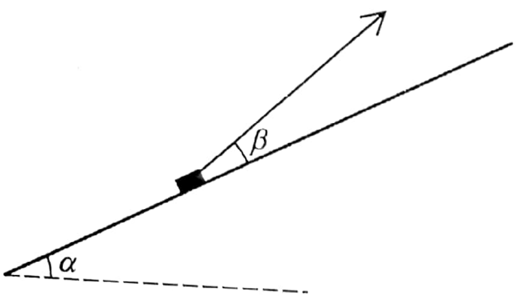
A car of mass 1250 kg travels up a straight hill inclined at an angle α to the horizontal, where $\sin\alpha = 0.02$. The power provided by the car's engine is 23 kW. The resistance to motion is constant and equal to 600 N. Find the speed of the car at an instant when its acceleration is $0.5\ \mathrm{m\,s^{-2}}$. [5]

41. M/J 14/P43/Q3



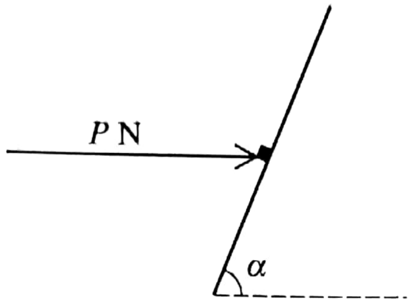
A particle P of weight 1.4 N is attached to one end of a light inextensible string S_1 of length 1.5 m, and to one end of another light inextensible string S_2 of length 1.3 m. The other end of S_1 is attached to a wall at the point 0.9 m vertically above a point O of the wall. The other end of S_2 is attached to the wall at the point 0.5 m vertically below O. The particle is held in equilibrium, at the same horizontal level as O, by a horizontal force of magnitude 2.24 N acting away from the wall and perpendicular to it (see diagram). Find the tensions in the strings. [6]

42. O/N 13/P42/Q1



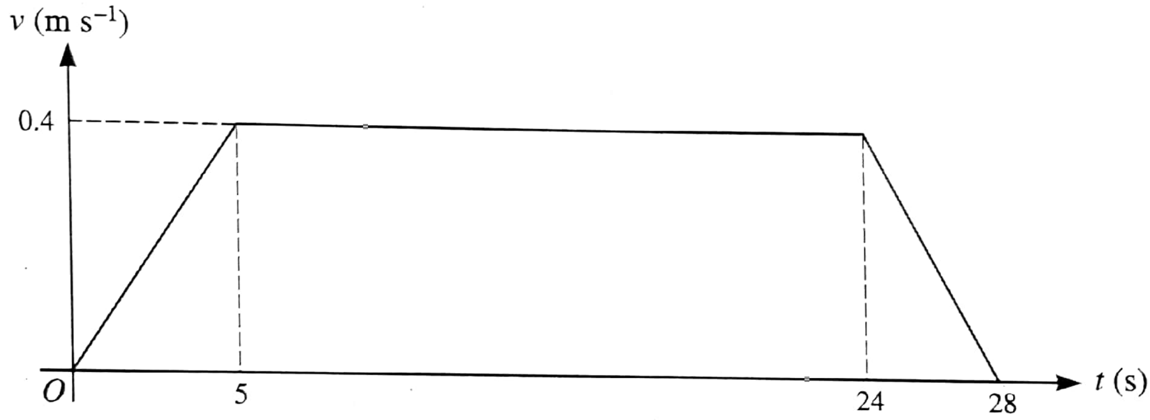
A small block of weight 5.1 N rests on a smooth plane inclined at an angle α to the horizontal, where $\sin\alpha = \frac{8}{17}$. The block is held in equilibrium by means of a light inextensible string. The string makes an angle β above the line of greatest slope on which the block rests, where $\sin\beta = \frac{7}{25}$ (see diagram). Find the tension in the string. [3]

43. O/N 13/P42/Q4



A rough plane is inclined at an angle α to the horizontal, where $\tan\alpha = 2.4$. A small block of mass 0.6 kg is held at rest on the plane by a horizontal force of magnitude P N. This force acts in a vertical plane through a line of greatest slope (see diagram). The coefficient of friction between the block and the plane is 0.4. The block is on the point of slipping down the plane. By resolving forces parallel to and perpendicular to the inclined plane, or otherwise, find the value of P. **[8]**

44. O/N 13/P42/Q7



An elevator is pulled vertically upwards by a cable. The velocity-time graph for the motion is shown above. Find

(i) the distance travelled by the elevator, **[2]**

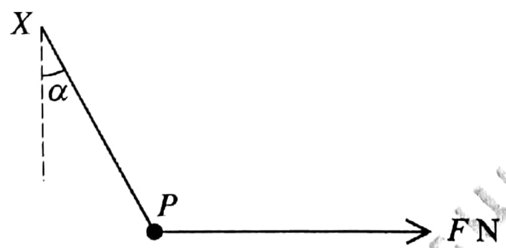
(ii) the acceleration during the first stage and the deceleration during the third stage. **[2]**

The mass of the elevator is 800 kg and there is a box of mass 100 kg on the floor of the elevator.

(iii) Find the tension in the cable in each of the three stages of the motion. **[3]**

(iv) Find the greatest and least values of the magnitude of the force exerted on the box by the floor of the elevator. **[3]**

45. O/N 13/P41/Q1



A particle P of mass 0.3 kg is attached to one end of a light inextensible string. The other end of the string is attached to a fixed point X. A horizontal force of magnitude F N is applied to the particle, which is in equilibrium when the string is at an angle α to the vertical, where $\tan\alpha = \frac{8}{15}$ (see diagram). Find the tension in the string and the value of F. **[4]**

46. O/N 13/P41/Q3

A cyclist exerts a constant driving force of magnitude F N while moving up a straight hill inclined at an angle α to the horizontal, where $\sin\alpha = \frac{36}{325}$. A constant resistance to motion of 32 N acts on the cyclist. The total weight of the cyclist and his bicycle is 780 N. The cyclist's acceleration is $-0.2\,\text{m s}^{-2}$.

(i) Find the value of F. [4]

The cyclist's speed is $7\,\text{m s}^{-1}$ at the bottom of the hill.

(ii) Find how far up the hill the cyclist travels before coming to rest. [2]

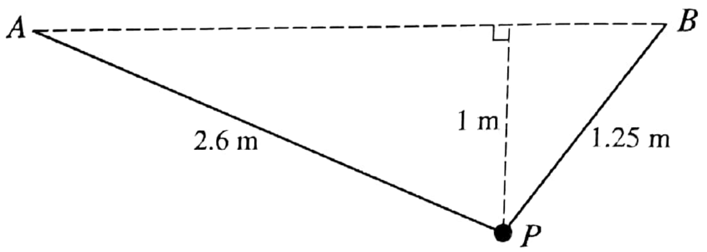
47. O/N 13/P43/Q1

A particle moves up a line of greatest slope of a rough plane inclined at an angle α to the horizontal, where $\sin\alpha = 0.28$. The coefficient of friction between the particle and the plane is $\frac{1}{3}$.

(i) Show that the acceleration of the particle is $-6\,\text{m s}^{-2}$. [3]

(ii) Given that the particle's initial speed is $5.4\,\text{m s}^{-1}$, find the distance that the particle travels up the plane. [2]

48. O/N 13/P43/Q3



A particle P of mass 1.05 kg is attached to one end of each of two light inextensible strings, of lengths 2.6 m and 1.25 m. The other ends of the strings are attached to fixed points A and B, which are at the same horizontal level. P hangs in equilibrium at a point 1 m below the level of A and B (see diagram). Find the tensions in the strings. [6]

49. O/N 13/P43/Q4

A box of mass 30 kg is at rest on a rough plane inclined at an angle α to the horizontal, where $\sin\alpha = 0.1$, acted on by a force of magnitude 40 N. The force acts upwards and parallel to a line of greatest slope of the plane. The box is on the point of slipping up the plane.

(i) Find the coefficient of friction between the box and the plane . [5]

The force of magnitude 40 N is removed.

(ii) Determine, giving a reason, whether or not the box remains in equilibrium. [2]

50. M/J 13/P42/Q1

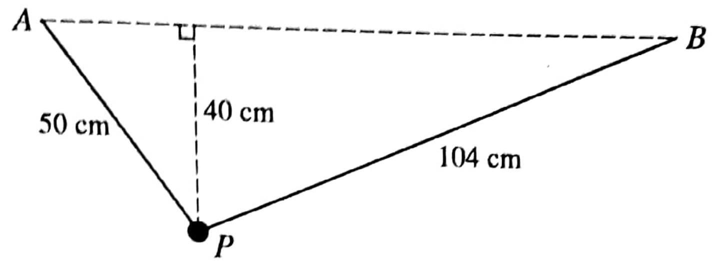
A string is attached to a block of weight 30 N, which is in contact with a rough horizontal plane. When the string is horizontal and the tension in it is 24 N, the block is in limiting equilibrium.

(i) Find the coefficient of friction between the block and the plane. [2]

The block is now in motion and the string is at an angle of 30° upwards from the plane. The tension in the string is 25 N.

(ii) Find the acceleration of the block. [4]

51. M/J 13/P42/Q3



A particle P of mass 2.1 kg is attached to one end of each of two light inextensible strings. The other ends of the strings are attached to points A and B which are at the same horizontal level. P hangs in equilibrium at a point 40 cm below the level of A and B, and the strings PA and PB have lengths 50 cm and 104 cm respectively (see diagram). Show that the tension in the string PA is 20 N, and find the tension in the string PB. **[5]**

52. M/J 13/P42/Q4

A particle P is released from rest at the top of a smooth plane which is inclined at an angle α to the horizontal, where $\sin\alpha = \frac{16}{65}$. The distance travelled by P from the top to the bottom is S metres, and the speed of P at the bottom is 8 m s^{-1}.

(i) Find the value of S and hence find the speed of P when it has travelled $\frac{1}{2}S$ metres. [5]

The time taken by P to travel from the top to the bottom of the plane is T seconds.

(ii) Find the distance travelled by P at the instant when it has been moving for $\frac{1}{2}T$ seconds. [2]

53. M/J 13/P41/Q1

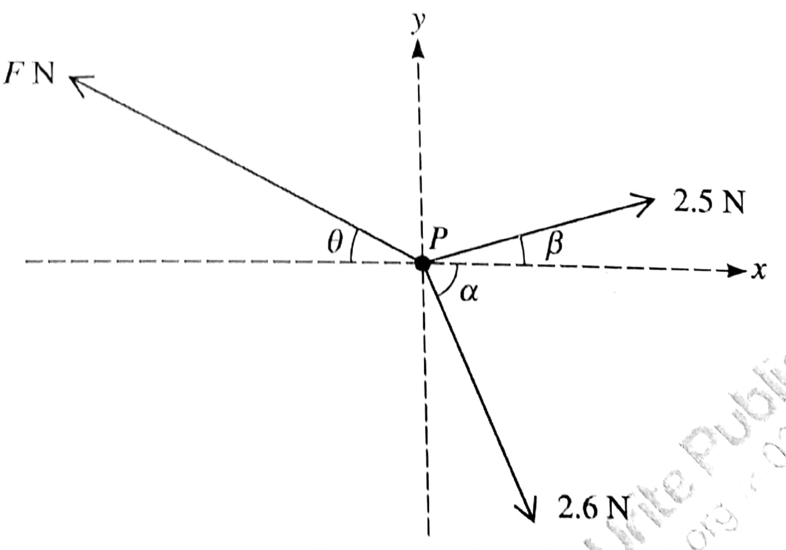
A block is at rest on a rough horizontal plane. The coefficient of friction between the block and the plane is 1.25.

(i) State, giving a reason for your answer, whether the minimum vertical force required to move the block is greater or less than the minimum horizontal force required to move the block. **[2]**

A horizontal force of continuously increasing magnitude P N and fixed direction is applied to the block.

(ii) Given that the weight of the block is 60 N, find the value of P when the acceleration of the block is 4 m s^{-2}. **[2]**

54. M/J 13/P41/Q6



A particle P of mass 0.5 kg lies on a smooth horizontal plane. Horizontal forces of magnitudes F N, 2.5 N and 2.6 N act on P. The directions of the forces are as shown in the diagram, where $\tan\alpha = \frac{12}{5}$ and $\tan\beta = \frac{7}{24}$.

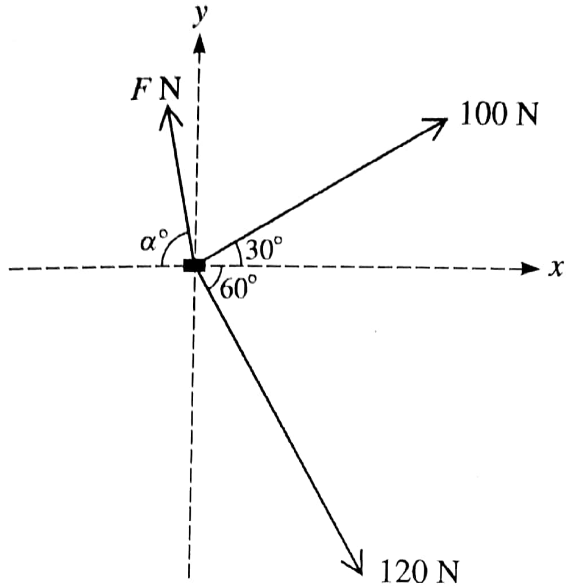
(i) Given that P is in equilibrium, find the values of F and $\tan\theta$. **[6]**

(ii) The force of magnitude F N is removed. Find the magnitude and direction of the acceleration with which P starts to move. **[3]**

55. M/J 13/P43/Q1

A straight ice track of length 50 m is inclined at 14° to the horizontal. A man starts at the top of the track, on a sledge, with speed $8\,\text{m}\,\text{s}^{-1}$. He travels on the sledge to the bottom of the track. The coefficient of friction between the sledge and the track is 0.02. Find the speed of the sledge and the man when they reach the bottom of the track. [4]

56. M/J 13/P43/Q6

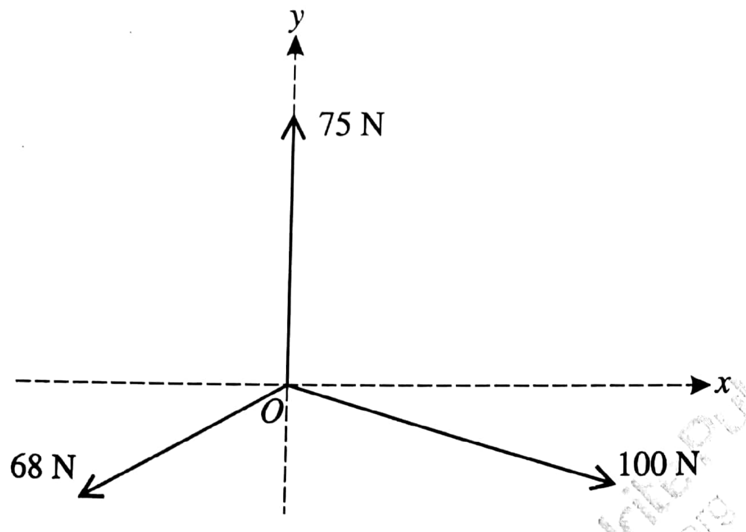


A small box of mass 40 kg is moved along a rough horizontal floor by three men. Two of the men apply horizontal forces of magnitudes 100 N and 120 N, making angles of 30° and 60° respectively with the positive x-direction. The third man applies a horizontal force of magnitude F N making an angle of α° with the negative x-direction (see diagram). The resultant of the three horizontal forces acting on the box is in the positive x-direction and has magnitude 136 N.

(i) Find the values of F and α. [6]

(ii) Given that the box is moving with constant speed, state the magnitude of the frictional force acting on the box and hence find the coefficient of friction between the box and the floor. [3]

57. O/N 12/P42/Q4

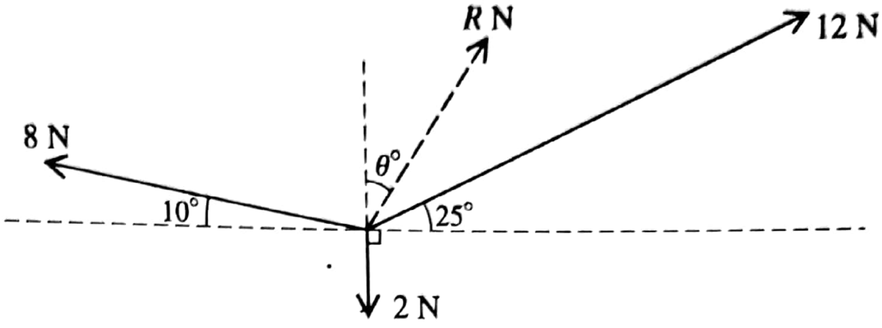


Three coplanar forces of magnitudes 68 N, 75 N and 100 N act at an origin O, as shown in the diagram. The components of the three forces in the positive x-direction are −60 N, 0 N and 96 N, respectively. Find

(i) the components of the three forces in the positive y-direction, [3]

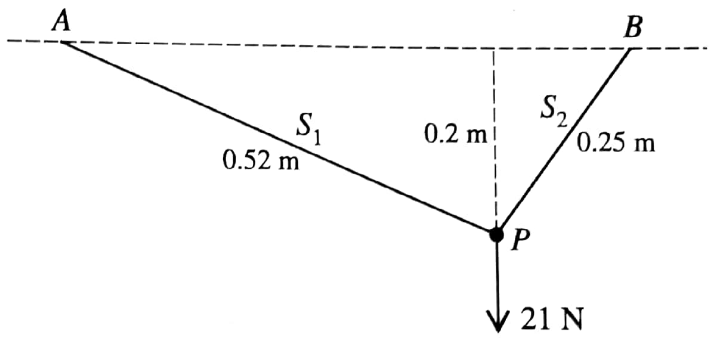
(ii) the magnitude and direction of the resultant of the three forces. [4]

58. O/N 12/P41/Q4



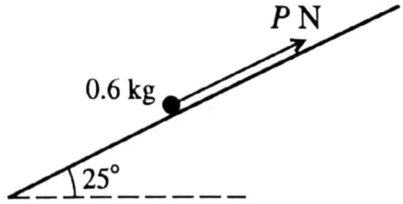
Three coplanar forces of magnitudes 8 N, 12 N and 2 N act at a point. The resultant of the forces has magnitude R N. The directions of the three forces and the resultant are shown in the diagram. Find R and θ. **[7]**

59. O/N 12/P43/Q4



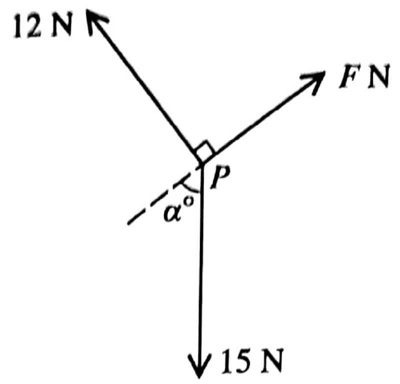
A particle P of weight 21 N is attached to one end of each of two light inextensible strings, S_1 and S_2, of lengths 0.52 m and 0.25 m respectively. The other end of S_1 is attached to a fixed point A, and the other end of S_2 is attached to a fixed point B at the same horizontal level as A. The particle P hangs in equilibrium at a point 0.2 m below the level of AB with both strings taut (see diagram). Find the tension in S_1 and the tension in S_2. **[6]**

60. O/N 12/P43/Q6



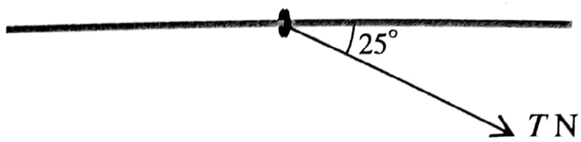
The diagram shows a particle of mass 0.6 kg on a plane inclined at 25° to the horizontal. The particle is acted on by a force of magnitude P N directed up the plane parallel to a line of greatest slope. The coefficient of friction between the particle and the plane is 0.36. Given that the particle is in equilibrium, find the set of possible values of P. **[9]**

61. M/J 12/P42/Q2



Three coplanar forces of magnitudes F N, 12 N and 15 N are in equilibrium acting at a point P in the directions shown in the diagram. Find α and F. [4]

62. M/J 12/P42/Q4



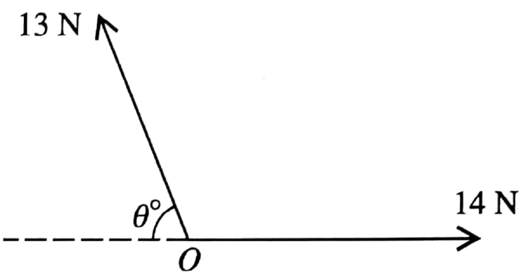
A ring of mass 4 kg is attached to one end of a light string. The ring is threaded on a fixed horizontal rod and the string is pulled at an angle of 25° below the horizontal (see diagram). With a tension in the string of T N the ring is in equilibrium.

(i) Find, in terms of T, the horizontal and vertical components of the force exerted on the ring by the rod. [4]

The coefficient of friction between the ring and the rod is 0.4.

(ii) Given that the equilibrium is limiting, find the value of T. [3]

63. M/J 12/P41/Q2

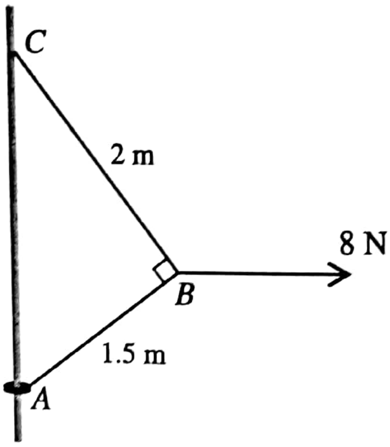


Forces of magnitudes 13 N and 14 N act at a point O in the directions shown in the diagram. The resultant of these forces has magnitude 15 N. Find

(i) the value of θ, [3]

(ii) the component of the resultant in the direction of the force of magnitude 14 N. [2]

64. M/J 12/P41/Q7



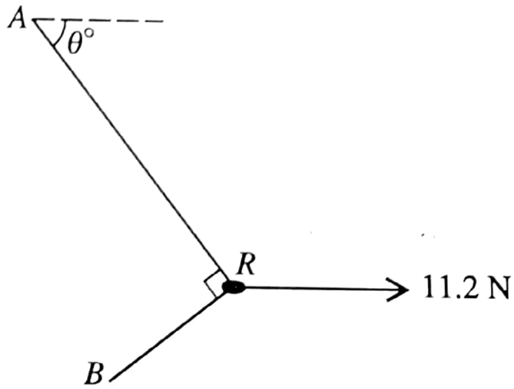
A small ring of mass 0.2 kg is threaded on a fixed vertical rod. The end A of a light inextensible string is attached to the ring. The other end C of the string is attached to a fixed point of the rod above A. A horizontal force of magnitude 8 N is applied to the point B of the string, where $AB = 1.5$ m and $BC = 2$ m. The system is in equilibrium with the string taut and AB at right angles to BC (see diagram).

(i) Find the tension in the part AB of the string and the tension in the part BC of the string. **[5]**

The equilibrium is limiting with the ring on the point of sliding up the rod.

(ii) Find the coefficient of friction between the ring and the rod. **[5]**

65. M/J 12/P43/Q2

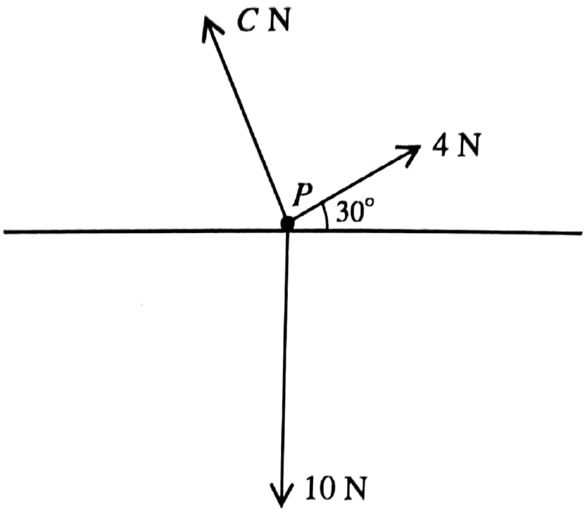


A smooth ring R of mass 0.16 kg is threaded on a light inextensible string. The ends of the string are attached to fixed points A and B. A horizontal force of magnitude 11.2 N acts on R, in the same vertical plane as A and B. The ring is in equilibrium. The string is taut with angle $ARB = 90°$, and the part AR of the string makes an angle of $\theta°$ with the horizontal (see diagram). The tension in the string is T N.

(i) Find two simultaneous equations involving $T \sin \theta$ and $T \cos \theta$. **[3]**

(ii) Hence find T and θ. **[3]**

66. O/N 11/P42/Q4

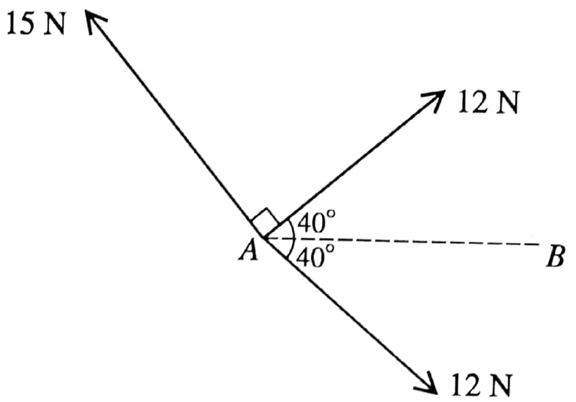


A particle P has weight 10 N and is in limiting equilibrium on a rough horizontal table. The forces shown in the diagram represent the weight of P, an applied force of magnitude 4 N acting on P in a direction at 30° above the horizontal, and the contact force exerted on P by the table (the resultant of the frictional and normal components) of magnitude C N.

(i) Find the value of C. [3]

(ii) Find the coefficient of friction between P and the table. [2]

67. O/N 11/P41/Q3



Three coplanar forces of magnitudes 15 N, 12 N and 12 N act at a point A in directions as shown in the diagram.

(i) Find the component of the resultant of the three forces

(a) in the direction of AB,

(b) perpendicular to AB. [3]

(ii) Hence find the magnitude and direction of the resultant of the three forces. [3]

68. O/N 11/P41/Q5

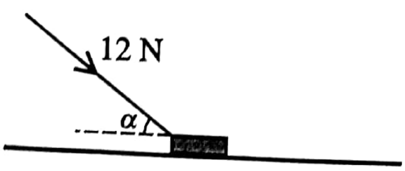


Fig. 1

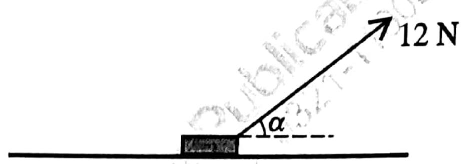


Fig. 2

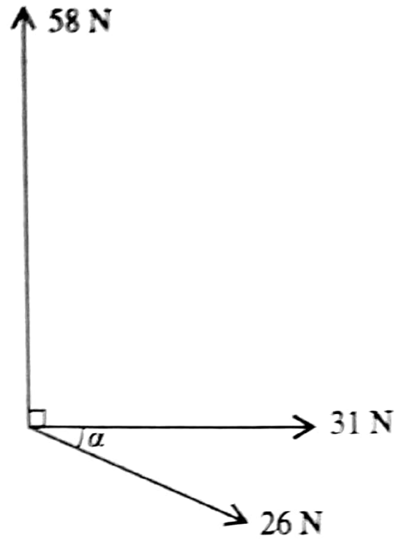
A block of mass 2 kg is at rest on a horizontal floor. The coefficient of friction between the block and the floor is μ. A force of magnitude 12 N acts on the block at an angle α to the horizontal, where $\tan \alpha = \frac{3}{4}$. When the applied force acts downwards as in Fig. 1 the block remains at rest.

(i) Show that $\mu \geqslant \frac{6}{17}$. [5]

When the applied force acts upwards as in Fig. 2 the block slides along the floor.

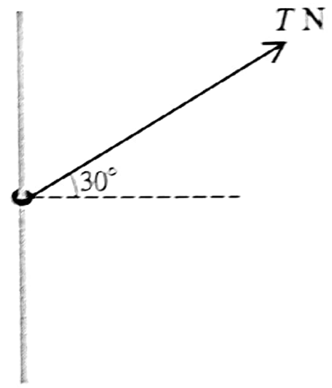
(ii) Find another inequality for μ. [3]

69. O/N 11/P43/Q2



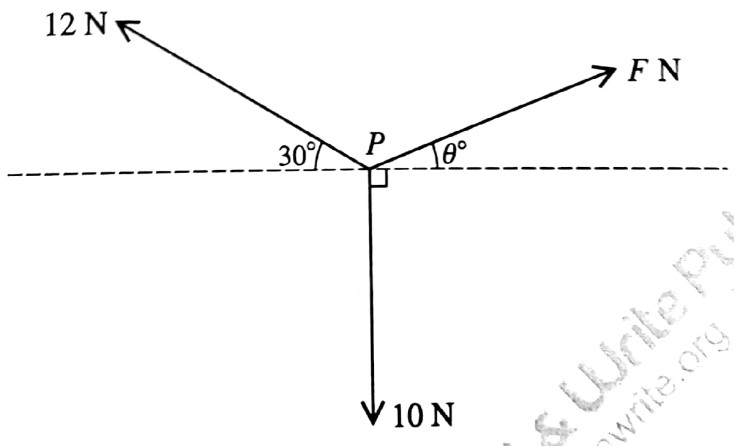
Coplanar forces of magnitudes 58 N, 31 N and 26 N act at a point in the directions shown in the diagram. Given that $\tan\alpha = \frac{5}{12}$, find the magnitude and direction of the resultant of the three forces. [6]

70. O/N 11/P43/Q6



The diagram shows a ring of mass 2 kg threaded on a fixed rough vertical rod. A light string is attached to the ring and is pulled upwards at an angle of 30° to the horizontal. The tension in the string is T N. The coefficient of friction between the ring and the rod is 0.24. Find the two values of T for which the ring is in limiting equilibrium. [8]

71. M/J 11/P42/Q4

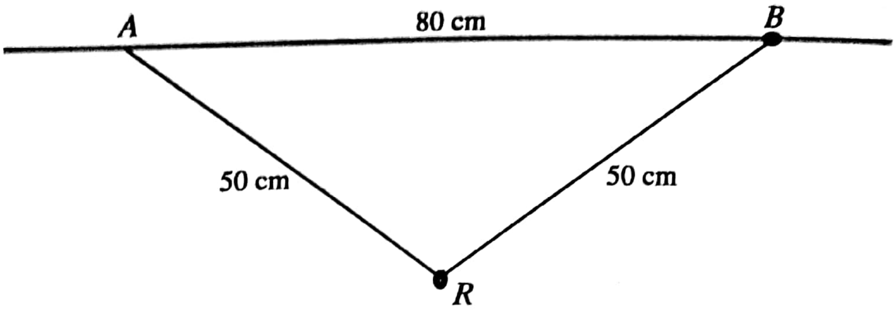


The three coplanar forces shown in the diagram act at a point P and are in equilibrium.

(i) Find the values of F and θ. [6]

(ii) State the magnitude and direction of the resultant force at P when the force of magnitude 12 N is removed. [2]

72. M/J 11/P42/Q6



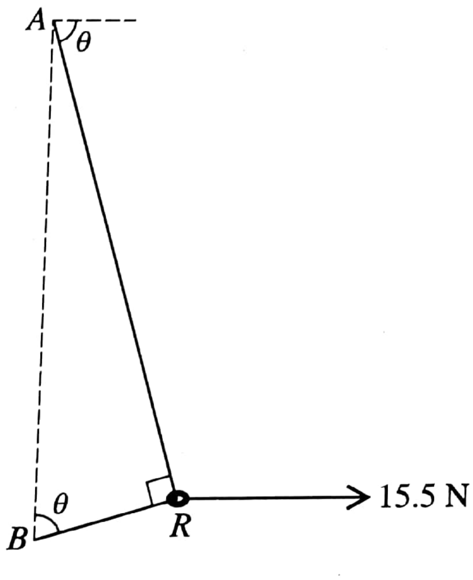
A small smooth ring R, of mass 0.6 kg, is threaded on a light inextensible string of length 100 cm. One end of the string is attached to a fixed point A. A small bead B of mass 0.4 kg is attached to the other end of the string, and is threaded on a fixed rough horizontal rod which passes through A. The system is in equilibrium with B at a distance of 80 cm from A (see diagram).

(i) Find the tension in the string. [3]

(ii) Find the frictional and normal components of the contact force acting on B. [4]

(iii) Given that the equilibrium is limiting, find the coefficient of friction between the bead and the rod. [2]

73. M/J 11/P41/Q3



A small smooth ring R of weight 8.5 N is threaded on a light inextensible string. The ends of the string are attached to fixed points A and B, with A vertically above B. A horizontal force of magnitude 15.5 N acts on R so that the ring is in equilibrium with angle $ARB = 90°$. The part AR of the string makes an angle θ with the horizontal and the part BR makes an angle θ with the vertical (see diagram). The tension in the string is T N. Show that $T \sin \theta = 12$ and $T \cos \theta = 3.5$ and hence find θ. [6]

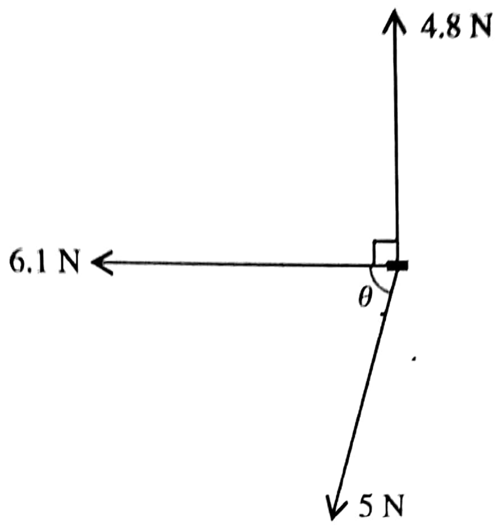
74. M/J 11/P41/Q4

A block of mass 11 kg is at rest on a rough plane inclined at 30° to the horizontal. A force acts on the block in a direction up the plane parallel to a line of greatest slope. When the magnitude of the force is $2X$ N the block is on the point of sliding down the plane, and when the magnitude of the force is $9X$ N the block is on the point of sliding up the plane. Find

(i) the value of X, [3]

(ii) the coefficient of friction between the block and the plane. [4]

75. M/J 11/P43/Q5



A small block of mass 1.25 kg is on a horizontal surface. Three horizontal forces, with magnitudes and directions as shown in the diagram, are applied to the block. The angle θ is such that $\cos\theta = 0.28$ and $\sin\theta = 0.96$. A horizontal frictional force also acts on the block, and the block is in equilibrium.

(i) Show that the magnitude of the frictional force is 7.5 N and state the direction of this force. **[4]**

(ii) Given that the block is in limiting equilibrium, find the coefficient of friction between the block and the surface. **[2]**

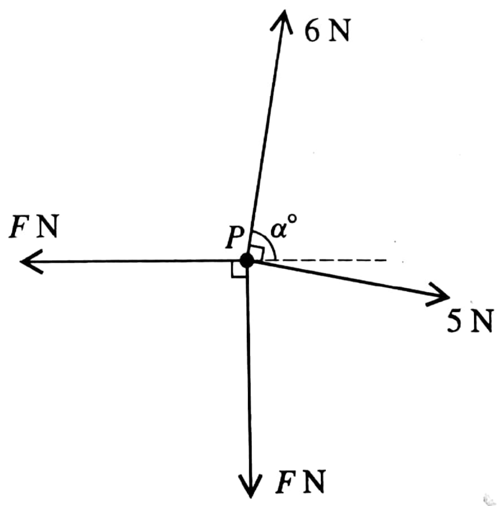
The force of magnitude 6.1 N is now replaced by a force of magnitude 8.6 N acting in the same direction, and the block begins to move.

(iii) Find the magnitude and direction of the acceleration of the block. **[3]**

76. O/N 10/P42/Q1

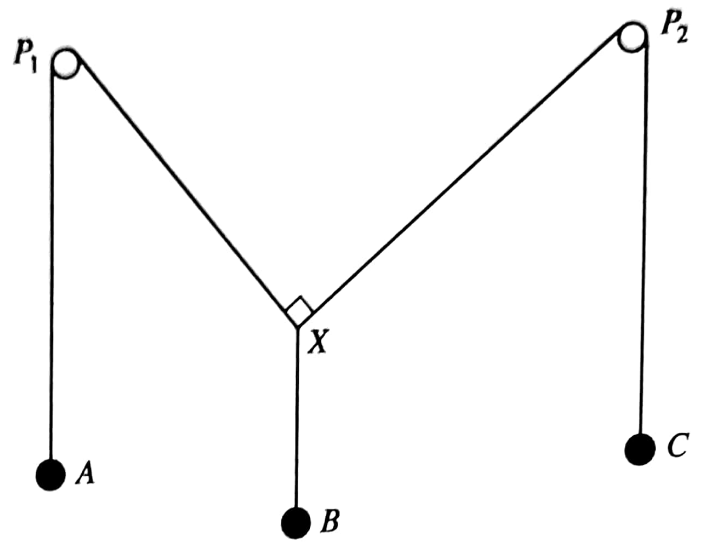
A block of mass 400 kg rests in limiting equilibrium on horizontal ground. A force of magnitude 2000 N acts on the block at an angle of 15° to the upwards vertical. Find the coefficient of friction between the block and the ground, correct to 2 significant figures. **[5]**

77. O/N 10/P42/Q3



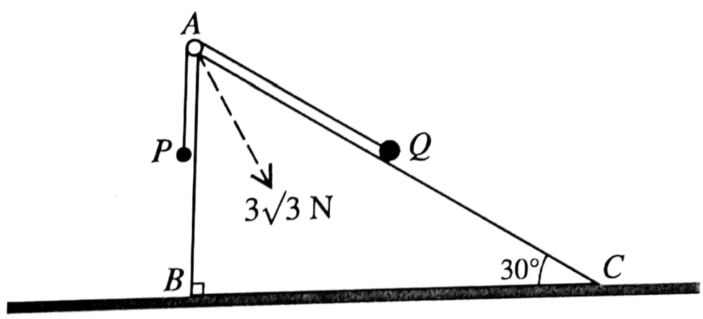
A particle P is in equilibrium on a smooth horizontal table under the action of four horizontal forces of magnitudes 6 N, 5 N, F N and F N acting in the directions shown. Find the values of α and F. **[6]**

78. O/N 10/P41/Q3



The diagram shows three particles A, B and C hanging freely in equilibrium, each being attached to the end of a string. The other ends of the three strings are tied together and are at the point X. The strings carrying A and C pass over smooth fixed horizontal pegs P_1 and P_2 respectively. The weights of A, B and C are 5.5 N, 7.3 N and W N respectively, and the angle P_1XP_2 is a right angle. Find the angle AP_1X and the value of W. [5]

79. O/N 10/P43/Q3



A small smooth pulley is fixed at the highest point A of a cross-section ABC of a triangular prism. Angle $ABC = 90°$ and angle $BCA = 30°$. The prism is fixed with the face containing BC in contact with a horizontal surface. Particles P and Q are attached to opposite ends of a light inextensible string, which passes over the pulley. The particles are in equilibrium with P hanging vertically below the pulley and Q in contact with AC. The resultant force exerted on the pulley by the string is $3\sqrt{3}$ N (see diagram).

(i) Show that the tension in the string is 3 N. [2]

The coefficient of friction between Q and the prism is 0.75.

(ii) Given that Q is in limiting equilibrium and on the point of moving upwards, find its mass. [5]

80. O/N 10/P43/Q5

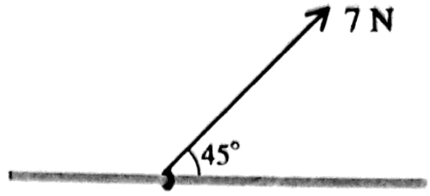
A force of magnitude F N acts in a horizontal plane and has components 27.5 N and −24 N in the x-direction and the y-direction respectively. The force acts at an angle of $\alpha°$ below the x-axis.

(i) Find the values of F and α. [4]

A second force, of magnitude 87.6 N, acts in the same plane at 90° anticlockwise from the force of magnitude F N. The resultant of the two forces has magnitude R N and makes an angle of $\theta°$ with the positive x-axis.

(ii) Find the values of R and θ. [3]

81. M/J 10/P42/Q3

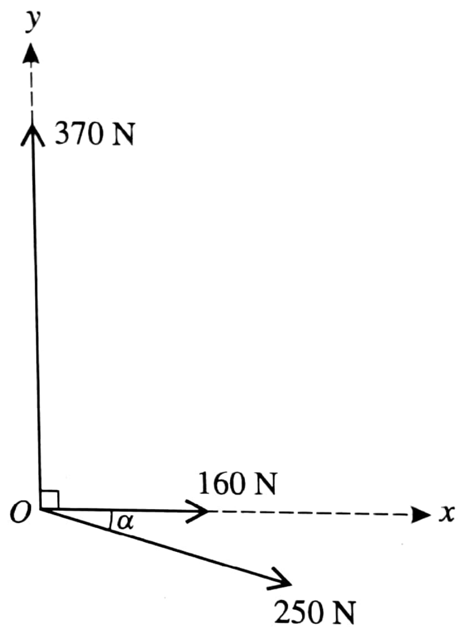


A small ring of mass 0.8 kg is threaded on a rough rod which is fixed horizontally. The ring is in equilibrium, acted on by a force of magnitude 7 N pulling upwards at 45° to the horizontal (see diagram).

(i) Show that the normal component of the contact force acting on the ring has magnitude 3.05 N, correct to 3 significant figures. **[2]**

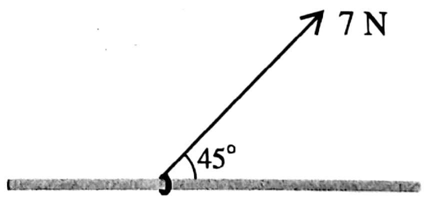
(ii) The ring is in limiting equilibrium. Find the coefficient of friction between the ring and the rod. **[3]**

82. M/J 10/P42/Q4



Coplanar forces of magnitudes 250 N, 160 N and 370 N act at a point O in the directions shown in the diagram, where the angle α is such that $\sin\alpha = 0.28$ and $\cos\alpha = 0.96$. Calculate the magnitude of the resultant of the three forces. Calculate also the angle that the resultant makes with the x-direction. **[7]**

83. M/J 10/P41/Q3

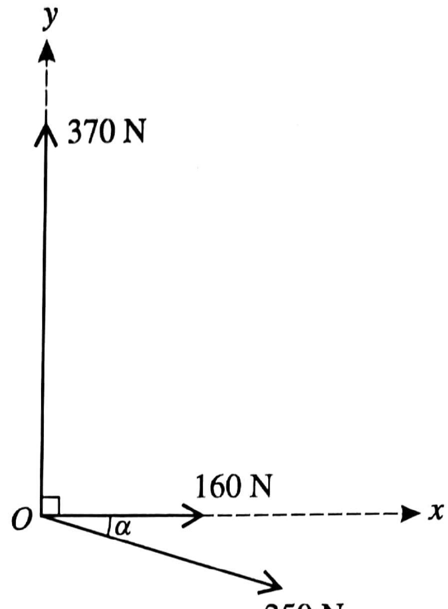


A small ring of mass 0.8 kg is threaded on a rough rod which is fixed horizontally. The ring is in equilibrium, acted on by a force of magnitude 7 N pulling upwards at 45° to the horizontal (see diagram).

(i) Show that the normal component of the contact force acting on the ring has magnitude 3.05 N, correct to 3 significant figures. **[2]**

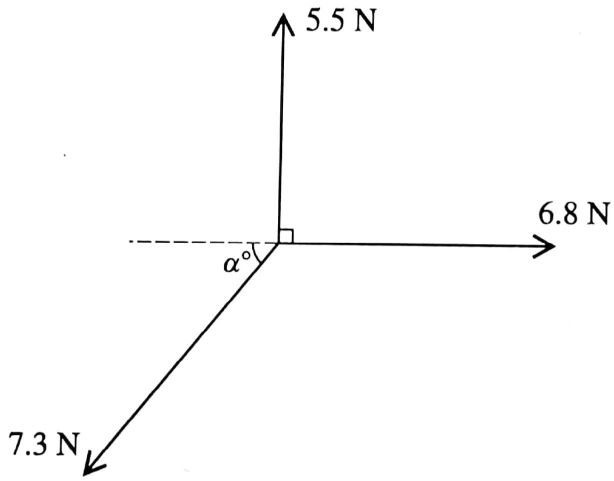
(ii) The ring is in limiting equilibrium. Find the coefficient of friction between the ring and the rod. **[3]**

84. M/J 10/P41/Q4



Coplanar forces of magnitudes 250 N, 160 N and 370 N act at a point O in the directions shown in the diagram, where the angle α is such that $\sin\alpha = 0.28$ and $\cos\alpha = 0.96$. Calculate the magnitude of the resultant of the three forces. Calculate also the angle that the resultant makes with the x-direction. [7]

85. M/J 10/P43/Q1



Three coplanar forces act at a point. The magnitudes of the forces are 5.5 N, 6.8 N and 7.3 N, and the directions in which the forces act are as shown in the diagram. Given that the resultant of the three forces is in the same direction as the force of magnitude 6.8 N, find the value of α and the magnitude of the resultant. [4]

86. O/N 09/P42/Q1

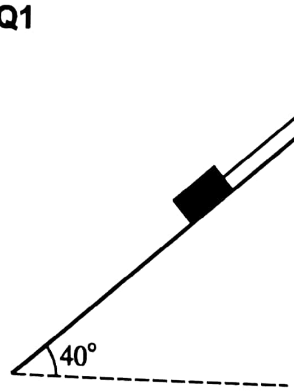


Fig. 1

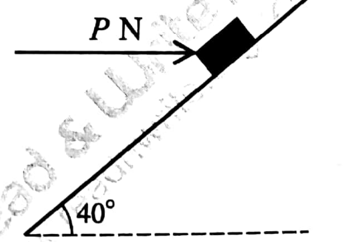


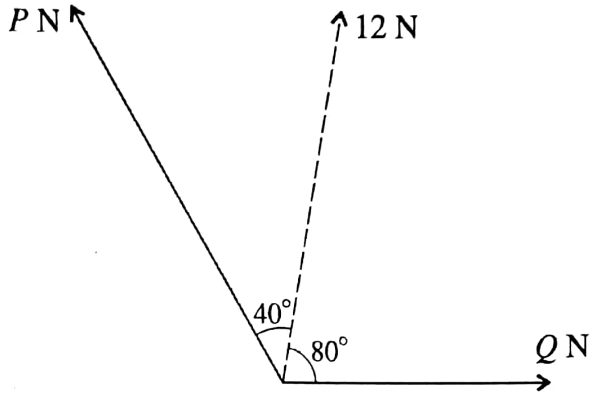
Fig. 2

A small block of weight 12 N is at rest on a smooth plane inclined at 40° to the horizontal. The block is held in equilibrium by a force of magnitude P N. Find the value of P when

(i) the force is parallel to the plane as in Fig. 1, [2]

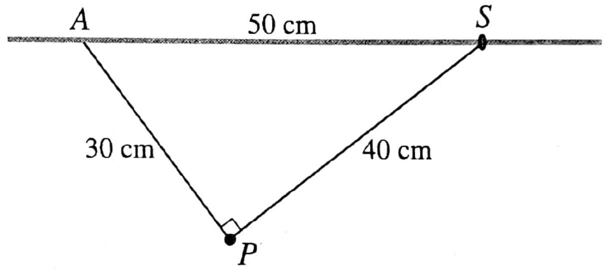
(ii) the force is horizontal as in Fig. 2. [2]

87. O/N 09/P41/Q3



Two forces have magnitudes P N and Q N. The resultant of the two forces has magnitude 12 N and acts in a direction 40° clockwise from the force of magnitude P N and 80° anticlockwise from the force of magnitude Q N (see diagram). Find the value of Q. [4]

88. O/N 09/P41/Q4



A particle P of weight 5 N is attached to one end of each of two light inextensible strings of lengths 30 cm and 40 cm. The other end of the shorter string is attached to a fixed point A of a rough rod which is fixed horizontally. A small ring S of weight W N is attached to the other end of the longer string and is threaded on to the rod. The system is in equilibrium with the strings taut and $AS = 50$ cm (see diagram).

(i) By resolving the forces acting on P in the direction of PS, or otherwise, find the tension in the longer string. [3]

(ii) Find the magnitude of the frictional force acting on S. [2]

(iii) Given that the coefficient of friction between S and the rod is 0.75, and that S is in limiting equilibrium, find the value of W. [3]

89. O/N 09/P41/Q5

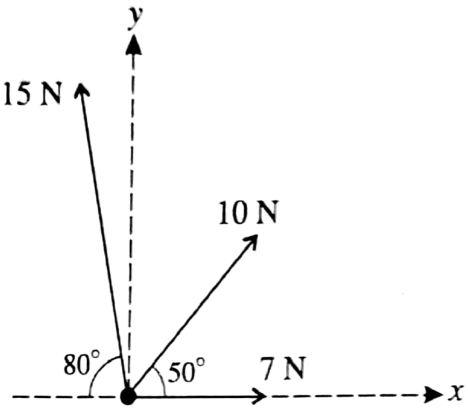
A particle P of mass 0.6 kg moves upwards along a line of greatest slope of a plane inclined at 18° to the horizontal. The deceleration of P is 4 m s^{-2}.

(i) Find the frictional and normal components of the force exerted on P by the plane. Hence find the coefficient of friction between P and the plane, correct to 2 significant figures. [6]

After P comes to instantaneous rest it starts to move down the plane with acceleration a m s^{-2}.

(ii) Find the value of a. [2]

90. M/J 09/P04/Q3



Forces of magnitudes 7 N, 10 N and 15 N act on a particle in the directions shown in the diagram.

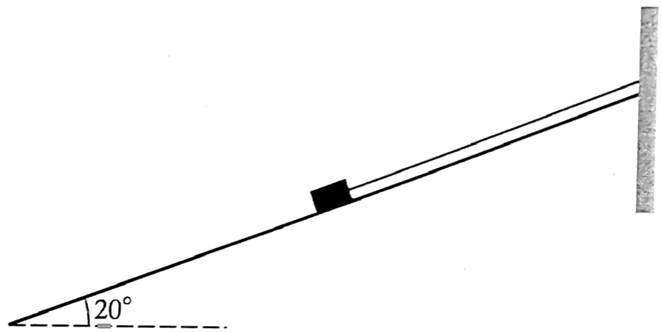
(i) Find the component of the resultant of the three forces

(a) in the x-direction,

(b) in the y-direction. [3]

(ii) Hence find the direction of the resultant. [2]

91. M/J 09/P04/Q4



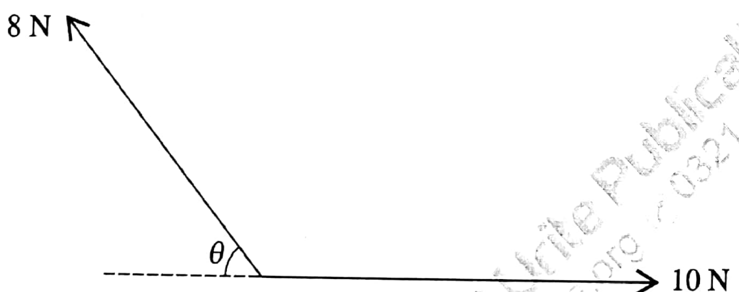
A block of mass 8 kg is at rest on a plane inclined at 20° to the horizontal. The block is connected to a vertical wall at the top of the plane by a string. The string is taut and parallel to a line of greatest slope of the plane (see diagram).

(i) Given that the tension in the string is 13 N, find the frictional and normal components of the force exerted on the block by the plane. [4]

The string is cut; the block remains at rest, but is on the point of slipping down the plane.

(ii) Find the coefficient of friction between the block and the plane. [2]

92. O/N 08/P04/Q1



Forces of magnitudes 10 N and 8 N act in directions as shown in the diagram.

(i) Write down in terms of θ the component of the resultant of the two forces

(a) parallel to the force of magnitude 10 N, [1]

(b) perpendicular to the force of magnitude 10 N. [1]

(ii) The resultant of the two forces has magnitude 8 N. Show that $\cos\theta = \frac{5}{8}$. [3]

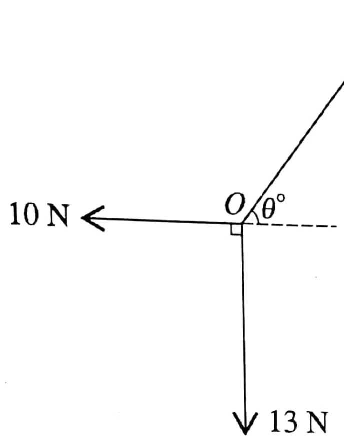
93. O/N 08/P04/Q2

A block of mass 20 kg is at rest on a plane inclined at 10° to the horizontal. A force acts on the block parallel to a line of greatest slope of the plane. The coefficient of friction between the block and the plane is 0.32. Find the least magnitude of the force necessary to move the block,

(i) given that the force acts up the plane,

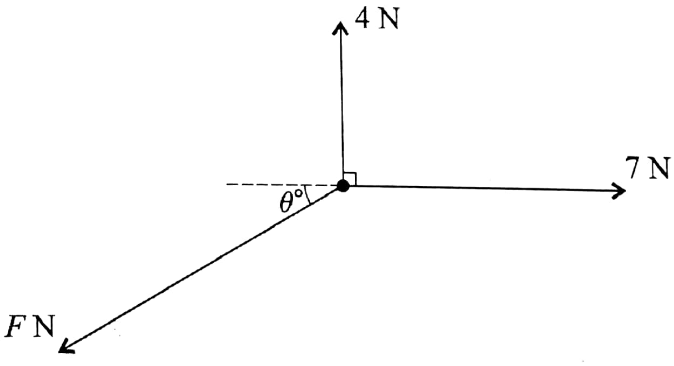
(ii) given instead that the force acts down the plane. [6]

94. M/J 08/P04/Q3



Three horizontal forces of magnitudes F N, 13 N and 10 N act at a fixed point O and are in equilibrium. The directions of the forces are as shown in the diagram. Find, in either order, the value of θ and the value of F. [5]

95. O/N 07/P04/Q3

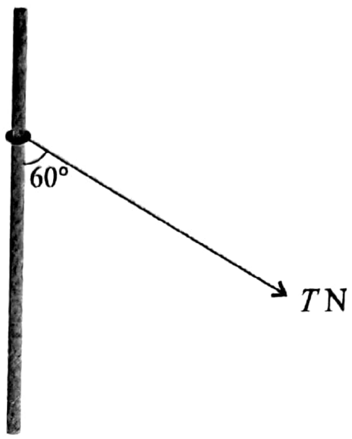


A particle is in equilibrium on a smooth horizontal table when acted on by the three horizontal forces shown in the diagram.

(i) Find the values of F and θ. [4]

(ii) The force of magnitude 7 N is now removed. State the magnitude and direction of the resultant of the remaining two forces. [2]

96. O/N 07/P04/Q5

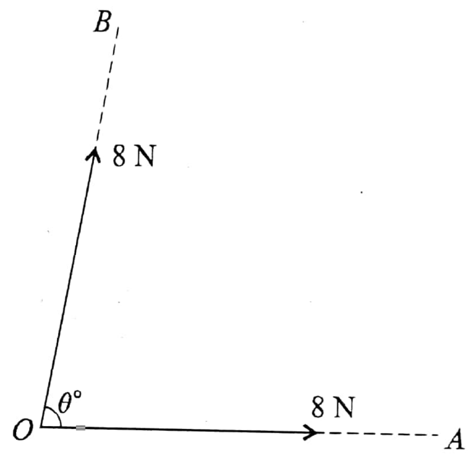


A ring of mass 4 kg is threaded on a fixed rough vertical rod. A light string is attached to the ring and is pulled with a force of magnitude T N acting at an angle of 60° to the downward vertical (see diagram). The ring is in equilibrium.

(i) The normal and frictional components of the contact force exerted on the ring by the rod are R N and F N respectively. Find R and F in terms of T. [4]

(ii) The coefficient of friction between the rod and the ring is 0.7. Find the value of T for which the ring is about to slip. [3]

97. M/J 07/P04/Q2

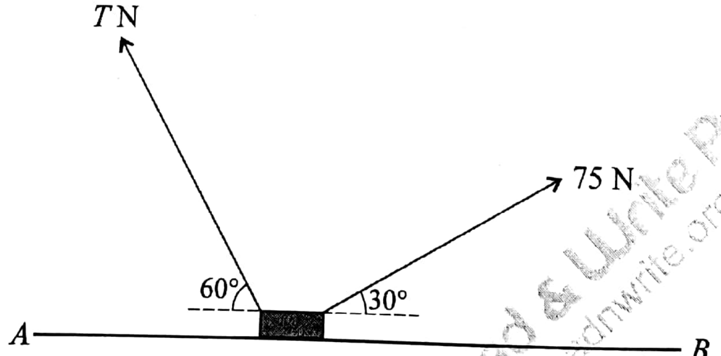


Two forces, each of magnitude 8 N, act at a point in the directions OA and OB. The angle between the forces is $\theta°$ (see diagram). The resultant of the two forces has component 9 N in the direction OA. Find

(i) the value of θ, [2]

(ii) the magnitude of the resultant of the two forces. [3]

98. M/J 07/P04/Q7

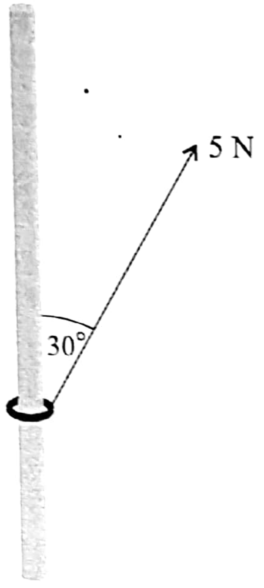


Two light strings are attached to a block of mass 20 kg. The block is in equilibrium on a horizontal surface AB with the strings taut. The strings make angles of 60° and 30° with the horizontal, on either side of the block, and the tensions in the strings are T N and 75 N respectively (see diagram).

(i) Given that the surface is smooth, find the value of T and the magnitude of the contact force acting on the block. [5]

(ii) It is given instead that the surface is rough and that the block is on the point of slipping. The frictional force on the block has magnitude 25 N and acts towards A. Find the coefficient of friction between the block and the surface. [6]

99. O/N 06/P04/Q2

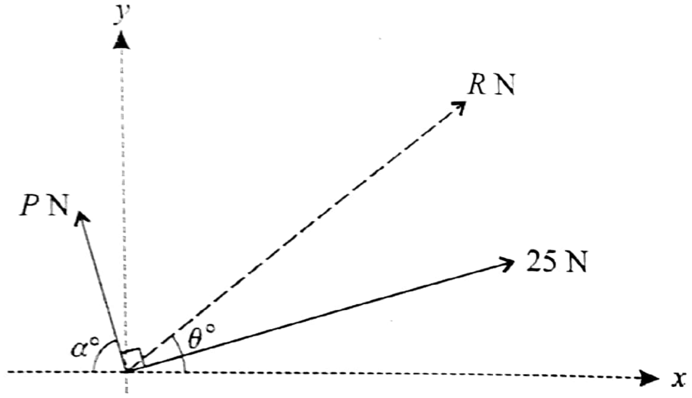


A small ring of mass 0.6 kg is threaded on a rough rod which is fixed vertically. The ring is in equilibrium, acted on by a force of magnitude 5 N pulling upwards at 30° to the vertical (see diagram).

(i) Show that the frictional force acting on the ring has magnitude 1.67 N, correct to 3 significant figures. [2]

(ii) The ring is on the point of sliding down the rod. Find the coefficient of friction between the ring and the rod. [3]

100. O/N 06/P04/Q6



Forces of magnitudes P N and 25 N act at right angles to each other. The resultant of the two forces has magnitude R N and makes an angle of $\theta°$ with the x-axis (see diagram). The force of magnitude P N has components −2.8 N and 9.6 N in the x-direction and the y-direction respectively, and makes an angle of $\alpha°$ with the negative x-axis.

(i) Find the values of P and R. [3]

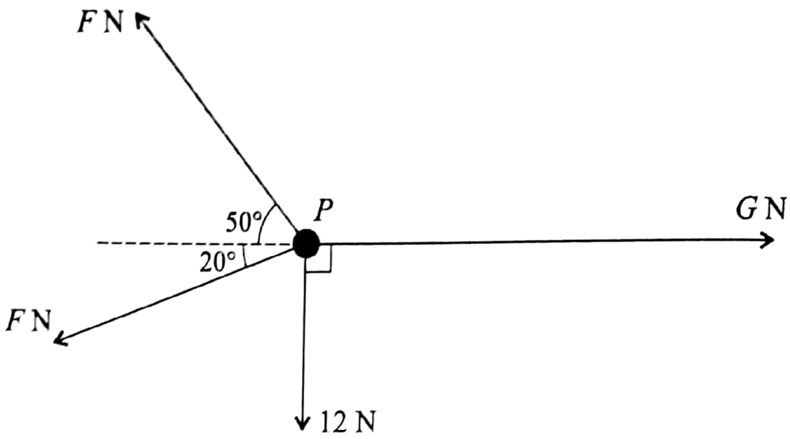
(ii) Find the value of α, and hence find the components of the force of magnitude 25 N in

(a) the x-direction,

(b) the y-direction. [4]

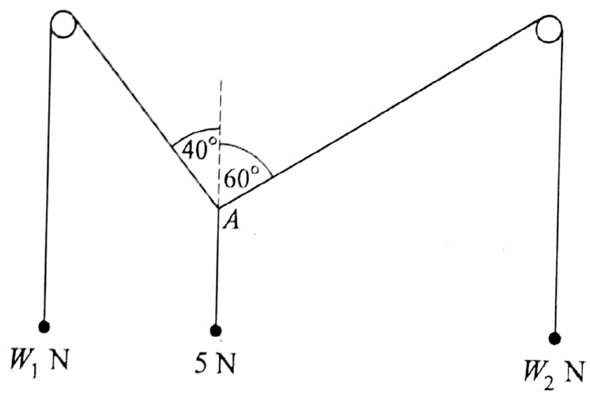
(iii) Find the value of θ. [3]

101. M/J 06/P04/Q3



A particle P is in equilibrium on a smooth horizontal table under the action of horizontal forces of magnitudes F N, F N, G N and 12 N acting in the directions shown. Find the values of F and G. [6]

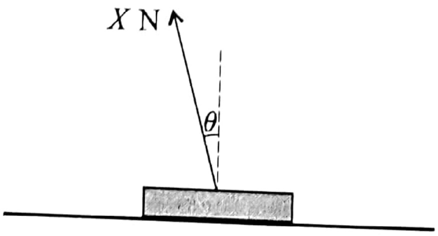
102. O/N 05/P04/Q3



Each of three light strings has a particle attached to one of its ends. The other ends of the strings are tied together at a point A. The strings are in equilibrium with two of them passing over fixed smooth horizontal pegs, and with the particles hanging freely. The weights of the particles, and the angles between the sloping parts of the strings and the vertical, are as shown in the diagram. Find the values of W_1 and W_2.

[6]

103. O/N 05/P04/Q4

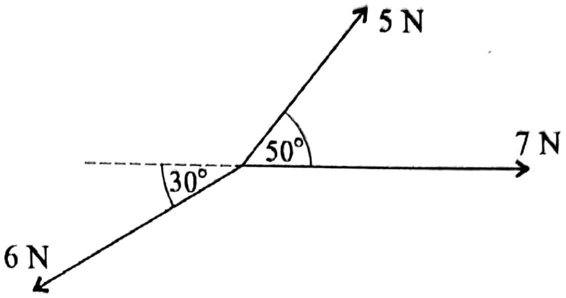


A stone slab of mass 320 kg rests in equilibrium on rough horizontal ground. A force of magnitude X N acts upwards on the slab at an angle of θ to the vertical, where $\tan\theta = \frac{7}{24}$ (see diagram).

(i) Find, in terms of X, the normal component of the force exerted on the slab by the ground. [3]

(ii) Given that the coefficient of friction between the slab and the ground is $\frac{3}{8}$, find the value of X for which the slab is about to slip. [3]

104. M/J 05/P04/Q2



Three coplanar forces act at a point. The magnitudes of the forces are 5 N, 6 N and 7 N, and the directions in which the forces act are shown in the diagram. Find the magnitude and direction of the resultant of the three forces. [6]

105. M/J 05/P04/Q3

A and B are points on the same line of greatest slope of a rough plane inclined at 30° to the horizontal. A is higher up the plane than B and the distance AB is 2.25 m. A particle P, of mass m kg, is released from rest at A and reaches B 1.5 s later. Find the coefficient of friction between P and the plane. [6]

106. O/N 04/P04/Q2

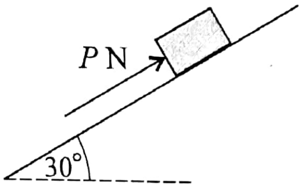


Fig. 1

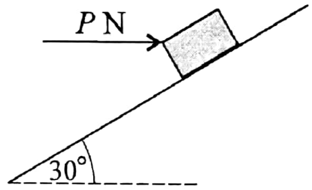


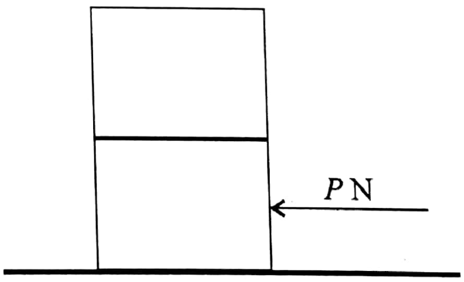
Fig. 2

A small block of weight 18 N is held at rest on a smooth plane inclined at 30° to the horizontal, by a force of magnitude P N. Find

(i) the value of P when the force is parallel to the plane, as in Fig. 1, [2]

(ii) the value of P when the force is horizontal, as in Fig. 2. [3]

107. O/N 04/P04/Q6



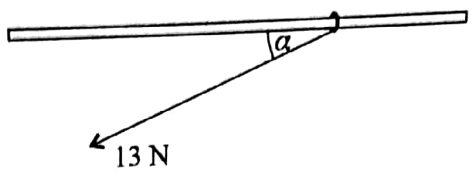
Two identical boxes, each of mass 400 kg, are at rest, with one on top of the other, on horizontal ground. A horizontal force of magnitude P newtons is applied to the lower box (see diagram). The coefficient of friction between the lower box and the ground is 0.75 and the coefficient of friction between the two boxes is 0.4.

(i) Show that the boxes will remain at rest if $P \leqslant 6000$. [2]

The boxes start to move with acceleration a m s^{-2}.

(ii) Given that no sliding takes place between the boxes, show that $a \leqslant 4$ and deduce the maximum possible value of P. [7]

108. M/J 04/P04/Q1



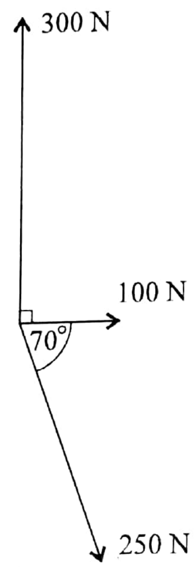
A ring of mass 1.1 kg is threaded on a fixed rough horizontal rod. A light string is attached to the ring and the string is pulled with a force of magnitude 13 N at an angle α below the horizontal, where $\tan\alpha = \frac{5}{12}$ (see diagram). The ring is in equilibrium.

(i) Find the frictional component of the contact force on the ring. [2]

(ii) Find the normal component of the contact force on the ring. [2]

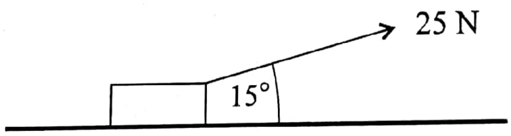
(iii) Given that the equilibrium of the ring is limiting, find the coefficient of friction between the ring and the rod. [1]

109. M/J 04/P04/Q2



Coplanar forces of magnitudes 250 N, 100 N and 300 N act at a point in the directions shown in the diagram. The resultant of the three forces has magnitude R N, and acts at an angle $\alpha°$ anticlockwise from the force of magnitude 100 N. Find R and α. [6]

110. O/N 03/P04/Q3

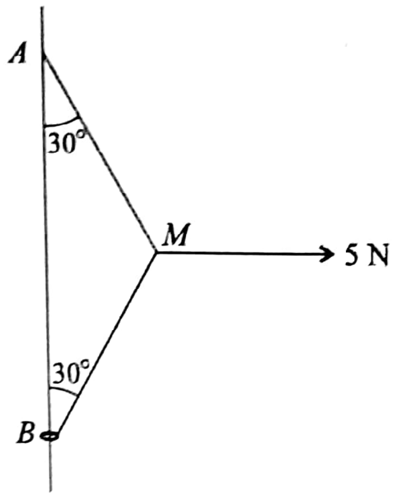


A crate of mass 3 kg is pulled at constant speed along a horizontal floor. The pulling force has magnitude 25 N and acts at an angle of 15° to the horizontal, as shown in the diagram. Find

(i) the work done by the pulling force in moving the crate a distance of 2 m, [2]

(ii) the normal component of the contact force on the crate. [3]

111. O/N 03/P04/Q6



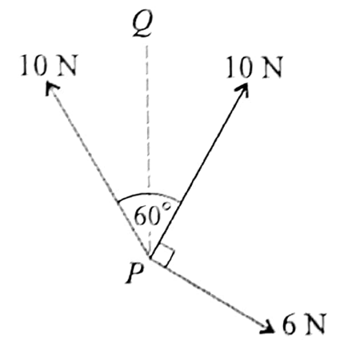
One end of a light inextensible string is attached to a fixed point A of a fixed vertical wire. The other end of the string is attached to a small ring B, of mass 0.2 kg, through which the wire passes. A horizontal force of magnitude 5 N is applied to the mid-point M of the string. The system is in equilibrium with the string taut, with B below A, and with angles ABM and BAM equal to 30° (see diagram).

(i) Show that the tension in BM is 5 N. [3]

(ii) The ring is on the point of sliding up the wire. Find the coefficient of friction between the ring and the wire. [5]

(iii) A particle of mass m kg is attached to the ring. The ring is now on the point of sliding down the wire. Given that the coefficient of friction between the ring and the wire is unchanged, find the value of m. [2]

112. M/J 03/P04/Q2



Three coplanar forces of magnitudes 10 N, 10 N and 6 N act at a point P in the directions shown in the diagram. PQ is the bisector of the angle between the two forces of magnitude 10 N.

(i) Find the component of the resultant of the three forces

(a) in the direction of PQ, [2]

(b) in the direction perpendicular to PQ. [1]

(ii) Find the magnitude of the resultant of the three forces. [2]

113. M/J 03/P04/Q6

A small block of mass 0.15 kg moves on a horizontal surface. The coefficient of friction between the block and the surface is 0.025.

(i) Find the frictional force acting on the block. [2]

(ii) Show that the deceleration of the block is $0.25\ \mathrm{m\,s^{-2}}$. [2]

The block is struck from a point A on the surface and, 4 s later, it hits a boundary board at a point B. The initial speed of the block is $5.5\ \mathrm{m\,s^{-1}}$.

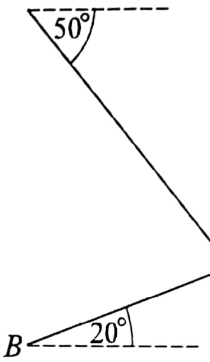
(iii) Find the distance AB. [2]

The block rebounds from the board with a speed of $3.5\,\text{m s}^{-1}$ and moves along the line BA. Find

(iv) the speed with which the block passes through A, [2]

(v) the total distance moved by the block, from the instant when it was struck at A until the instant when it comes to rest. [2]

114. O/N 02/P04/Q3



A light inextensible string has its ends attached to two fixed points A and B, with A vertically above B. A smooth ring R, of mass 0.8 kg, is threaded on the string and is pulled by a horizontal force of magnitude X newtons. The sections AR and BR of the string make angles of 50° and 20° respectively with the horizontal, as shown in the diagram. The ring rests in equilibrium with the string taut. Find

(i) the tension in the string, [3]

(ii) the value of X. [3]

115. O/N 02/P04/Q5

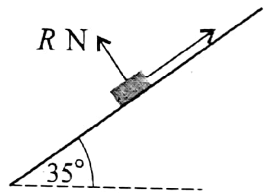
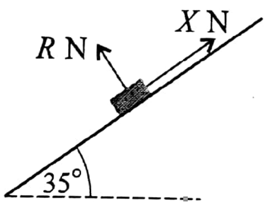


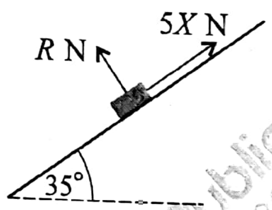
Fig. 1

A force, whose direction is upwards parallel to a line of greatest slope of a plane inclined at 35° to the horizontal, acts on a box of mass 15 kg which is at rest on the plane. The normal component of the contact force on the box has magnitude R newtons (see Fig. 1).

(i) Show that $R = 123$, correct to 3 significant figures. [1]



about to move down



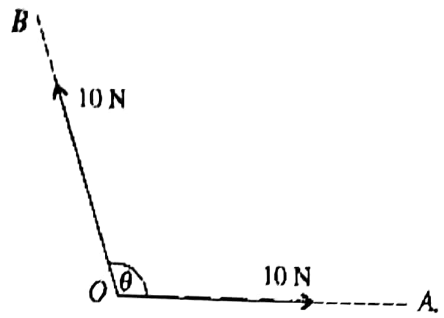
about to move up

Fig. 2

When the force parallel to the plane acting on the box has magnitude X newtons the box is about to move *down* the plane, and when this force has magnitude $5X$ newtons the box is about to move *up* the plane (see Fig. 2).

(ii) Find the value of X and the coefficient of friction between the box and the plane. [7]

116. M/J 02/P04/Q3



Two forces, each of magnitude 10N, act at a point O in the directions of OA and OB, as shown in the diagram. The angle between the forces is θ. The resultant of these two forces has magnitude 12 N.

(i) Find θ. **[3]**

(ii) Find the component of the resultant force in the direction of OA. **[2]**

117. M/J 02/P04/Q4

A box of mass of 4.5 kg is pulled at a constant speed of 2 ms^{-1} along a rough horizontal floor by a horizontal force of magnitude 15N.

(i) Find the coefficient of friction between the box and the floor. **[3]**

The horizontal pulling force is now removed. Find

(ii) the deceleration of the box in the subsequent motion, **[2]**

(iii) the distance travelled by the box from the instant the horizontal force is removed until the box comes to rest. **[2]**

Answers Section

1. O/N 17/P42/Q1

(i) $F = 0.2g \sin 20 = 0.684$ N [1]

(ii) $R = 0.2g \cos 20$

$F = \mu R$ [$= 0.6 \times 0.2g \cos 20$]

$g \sin 20 - F = 0.2a$]

$a = 2.28 \text{ ms}^{-2}$ [4]

2. O/N 17/P42/Q2

EITHER:

$T \sin \theta + 120 \sin 45 = 15g$

$T \cos \theta = 120 \cos 45$

[$\tan \theta = \dfrac{(15g - 120\sin 45)}{(120\cos 45)}$

or $T = \sqrt{65.15^2 + 84.85^2}$]

$\theta = 37.5$

$T = 107$

OR1:

$$\frac{120}{\sin(90+\theta)} = \frac{T}{\sin 135} = \frac{15g}{\sin(135-\theta)}$$

$\theta = 37.5$

$T = 107$

OR2:

$$\frac{T}{\sin 45} = \frac{15g}{\sin(45+\theta)} = \frac{120}{\sin(90-\theta)}$$

$\theta = 37.5$

$T = 107$

OR3:

[$T^2 = 150^2 + 120^2 - 2(150)(120) \cos 45$]

$T = 107$

$120/\sin(90 - \theta) = 106.97/\sin 45$

$\theta = 37.5$ [6]

3. O/N 17/P41/Q1

[$12 \cos 25 = 3a$]

$a = 4 \cos 25 = 3.625$

[$s = ½ \times 4\cos 25 \times 5^2$]

Distance = 45.3 m [4]

4. O/N 17/P41/Q6

(i) $X = 75 + 50 \cos 60$ (= 100)

$Y = 50 \sin 60$ (= 43.3)

Resultant = $\sqrt{(100^2 + 43.3^2)} = 109$ N

Angle = $\arctan\left(\dfrac{43.3}{100}\right) = 23.4°$

(ii) $50 \cos \alpha - F \cos 50 = 0$

$50 \sin \alpha - 3F - F \sin 50 = 0$

$\tan \alpha = \dfrac{(3F + F\sin 50)}{(F\cos 50)}$

$\alpha = 80.3$

$F = 13.1$

5. O/N 17/P43/Q1

(X=) $20 \cos 60 + 30 \cos 60 - F$

[$F = 20 \cos 60 + 30 \cos 60$]

$F = 25$ [3]

6. O/N 17/P43/Q3

(i) $R = mg \cos 25$

[$F = 0.4mg \cos 25$]

[$mg \sin 25 - 0.4mg \cos 25 = ma$]

$a = 0.601 \text{ ms}^{-2}$ [4]

(ii) [$s = ½ \times 0.601 \times 3^2$]

Distance = 2.70 m [2]

7. M/J 17/P42/Q5

$R + P \sin 30 = 0.12g \cos 40$

$F = 0.32R$

[$P_{min} \cos 30 + F = 0.12g \sin 40$]

[$P_{max} \cos 30 - F = 0.12g \sin 40$]

[$P \cos 30 = 0.12g \sin 40$

$\pm 0.32\ (0.12g \cos 40 - P \sin 30)$]

OR

[$P \cos 30 \pm 0.32R = 0.12g \sin 40$

$R + P \sin 30 = 0.12g \cos 40$]

Must reach P =… in either method

$P_{max} = 1.04$ $P_{min} = 0.676$

$0.676 \leqslant P \leqslant 1.04$ 8

8. M/J 17/P41/Q3

EITHER:

$A \cos 30 + B \cos 40 = 25$

$A \sin 30 = B \sin 40$

$A = 17.1$

$B = 13.3$

OR: $\dfrac{25}{\sin 70} = \dfrac{A}{\sin 140} = \dfrac{B}{\sin 150}$

$A = 17.1$

$B = 13.3$ 6

9. M/J 17/P42/Q2

EITHER:

$3P \sin 55 + P \sin \theta = 20 + P \sin \theta$

or $3P \sin 55 = 20$

$P = 8.14$

$3P\cos 55 = 2P\cos\theta$

$\cos\theta = 1.5\cos 55 \rightarrow \theta = \ldots$

$\theta = 30.6$

OR:

$\dfrac{3P}{\sin 90} = \dfrac{20}{\sin 125}$

$P = 8.14$

$\dfrac{3P}{\sin 90} = \dfrac{2P\cos\theta}{\sin 145}$

$\theta = 1.5\sin 145 \rightarrow \theta = \ldots$

$\theta = 30.6$ [5]

10. O/N 16/P42/Q3

(i) $[X = 60\cos 25 + 50\cos 15]$

$= 103\text{N}$ [2]

(ii) $Y = 60\sin 25 - 50\sin 15$ $[= 12.4]$

$[R^2 = X^2 + Y^2]$

or

$[\alpha = \arctan(Y/X)]$

Magnitude is 103 N

(or $\alpha = 6.9°$ with direction specified unambiguously)

$\alpha = 6.9°$ with direction specified unambiguously

(or Magnitude = 103 N) [4]

11. O/N 16/P42/Q5

$F = \mu mg\cos 30$

$[10 + F - mg\sin 30 = 0]$

$[75 - F - mg\sin 30 = 0]$

$[85 = 2mg\sin 30]$

or

$[10 + \mu mg\cos 30 - mg\sin 30 = 0$

$75 - \mu mg\cos 30 - mg\sin 30 = 0]$

$m = 8.5\text{kg}$ or $\mu = 0.442$

$\mu = 0.442$ or $m = 8.5\text{kg}$ [6]

12. O/N 16/P41/Q4

$2F + F\cos 60 = 15\cos\alpha$

$F\sin 60 = 15\sin\alpha$

$F = 5.67$ and $\alpha = 19.1$ [6]

13. O/N 16/P43/Q2

$T_A\cos 50° - T_B\cos 10° = 0$ **and**

$T_A\sin 50° - T_B\sin 10° - 20\text{g} = 0$

Tension in PA is 306N

Tension in PB is 200N [5]

Alternative (Lami's Theorem)

$[T_A/\sin 80° = T_B/\sin 140° = 20g/\sin 140°]$

$[T_A = 20g\sin 80°/\sin 140°]$

Tension in PA is 306 N

$[T_B = 20g\sin 140°/\sin 140°]$

Tension in PB is 200 N [5]

14. M/J 16/P42/Q1

$[X = 7 - 8\cos\alpha - 6\sin\alpha = -3]$

$X = 7 - 8 \times (4/5) - 6 \times (3/5) = -3$

$[Y = 8\sin\alpha - 6\cos\alpha = 0]$

$Y = 8 \times (3/5) - 6 \times (4/5) = 0$

Resultant force is 3N to the left [5]

15. M/J 16/P42/Q5

$R + T\sin 20 = 2.5g\cos 30$

$F = 0.25 \times R$

$T\cos 20 = F + 2.5g\sin 30$

$T = 17.5$ [7]

Alternative scheme

$F = 0.25 \times R$

$T\cos 50 = F\cos 30 + R\sin 30$

$R\cos 30 + T\sin 50 = F\sin 30 + 2.5g$

$T = 17.5$ [7]

16. M/J 16/P41/Q4

$P\cos\theta = 48\cos\alpha - 14\sin\alpha$

and/or

$P\sin\theta = 50 - 48\sin\alpha - 14\cos\alpha$

$P\cos\theta = 48(24/25) - 14(7/25)$

$= 42.16$

$P\sin\theta = 50 - 48(7/25) - 14(24/25)$

$= 23.12$

$P = \sqrt{42.16^2 + 23.12^2} = 48.1$

$\tan\theta = \dfrac{23.12}{42.16}$

$\theta = 28.7$ [6]

17. M/J 16/P43/Q3

$12\cos 75° + P\cos\theta° = 18\cos 65°$

$18\sin 65° + 12\sin 75° = 15 + P\sin\theta°$

$[P^2 = (18\sin 65° + 12\sin 75° - 15)^2 + (18\cos 65° - 12\cos 75°)^2]$

or

$[\theta = \tan^{-1}(18\sin 65° + 12\sin 75° - 15)/(18\cos 65° - 12\cos 75°)]$

$P = 13.7$ or $\theta = 70.8$

$\theta = 70.8$ or $P = 13.7$ [6]

18. M/J 16/P43/Q4

$R = 15g\cos20°$

$F = \mu R = 0.2 \times 15g\cos20°$

$X + 0.2 \times 15g\cos20° =$

$15g\sin20°$

Least value of X is 23.1

$[X = 15g\sin20° +$

$0.2 \times 15g\cos20°]$

Greatest value of X is 79.5 [7]

19. O/N 15/P42/Q1

(i) $15 + F\cos60° = F\cos30°$

$F = 41.0$ [3]

(ii) $[G = F(\sin30° + \sin60°)]$

$G = 56.0$ [2]

20. O/N 15/P42/Q4

Frictional force $= 0.4 \times 2\cos45$

$= 0.4\sqrt{2}$

KE gain $= \frac{1}{2} \times 0.2 \times V_C^2$ and

PE loss $= 0.2 \times g \times (2.5 + 2\sqrt{2})$

$0.1\,V_C^2 = (5 + 4\sqrt{2}) - 0.4\sqrt{2} \times 4$

Speed at C is 9.16ms^{-1} [6]

First alternative for the last four marks

$\frac{1}{2} \times 0.2 \times V_B^2 = 0.2 \times g \times 2.5 \rightarrow$

$V_B^2 = 50$

$0.1\,(V_C^2 - V_B^2)$

$= 0.2 \times g \times (4 \div \sqrt{2}) -$

$0.4\sqrt{2} \times 4$

Speed at C is 9.16ms^{-1}

Second alternative for the last four marks

$\frac{1}{2} \times 0.2 \times V_B^2 = 0.2 \times g \times 2.5 \rightarrow$

$V_B^2 = 50$

$\sqrt{2} - 0.4\sqrt{2} = 0.2a \rightarrow a$

$= 3\sqrt{2}\text{ ms}^{-2}$

and $V_C^2 = V_B^2 + 2 \times 3\sqrt{2} \times 4$

Speed at C is 9.16ms^{-1}

21. O/N 15/P42/Q6

(i) $[0.195\cos\theta = F]$

$F = 0.195\cos22.6 = 0.195 \times \frac{12}{13}$

$= 0.18 = \frac{9}{50}$

$[R = 0.24 + 0.195\sin\theta]$

$R = 0.24 + 0.195\sin22.6 =$

$0.24 + 0.195 \times \frac{5}{13} = 0.315$

$= \frac{63}{200}$

Coefficient $\mu = 4/7$ or 0.571 [6]

(ii) $R = 0.24 - 0.195\sin22.6$

$= 0.24 - 0.195 \times \frac{5}{13}$

$= 0.165 = \frac{33}{200}$

$0.195 \times \frac{12}{13} - \left(\frac{4}{7}\right) \times 0.165$

$= 0.024a$

Acceleration is 3.57 ms^{-2} [4]

22. O/N 15/P41/Q5

(i) $F\cos70 + 20 - 10\cos30$

$= R\cos15$

$10\sin30 - F\sin70 = R\sin15$

$F = 1.90$ N **and** $R = 12.4$ N [5]

Alternative method for 5(i)

$[X = 0.342F + 11.34$

$Y = 0.94F - 5]$

$(0.342F + 11.34)^2 + (0.94F - 5)^2$

$= R^2$

$\tan15$

$= (5 - 0.94F) / (0.342F + 11.34)$

$F = 1.90$ N **and** $R = 12.4$ N [5]

(ii) $11.7^2 = 0 + 2a \times 3$

$a = 22.815$

$R\cos15 = m \times 22.815$

Mass of bead = 0.526 kg [3]

23. O/N 15/P43/Q1

Tension is 30 N

$[R = (4g - 30) \times 0.8]$

Normal component is 8 N [3]

24. O/N 15/P43/Q2

$F = T\cos\alpha = 0.96T$

$R = 0.2g - T\sin\alpha = 2 - 0.28T$

$[0.96\,T = 0.25(2 - 0.28T)]$

$[(0.96 + 0.07)\,T = 0.5 \rightarrow T = ...]$

$T = 0.485$ [5]

25. O/N 15/P43/Q3

$120\cos 75° = 150 - 100 - P\cos\theta°$

$120\sin 75° = P\sin\theta°$

$[P^2 = 14400 - 12000\cos 75° + 2500]$

or

$\tan\theta = [120\sin 75°/(50 - 120\cos 75°)]$

$P = 117$ or $\theta = 80.7$

$\theta = 80.7$ or $P = 117$ [7]

26. M/J 15/P42/Q7

(i)

$0.8\,T_A + 0.6T_R = 5.6$

$0.6T_A = 0.8T_R$

Tension in AJ is 4.48 N

and tension in RJ is 3.36 N [5]

First Alternative Method for (i)

(i) $\dfrac{5.6}{\sin 90} = \dfrac{T_A}{\sin\alpha} = \dfrac{T_R}{\sin(270-\alpha)}$ m

$\dfrac{5.6}{\sin 90} = \dfrac{T_A}{0.8} = \dfrac{T_R}{0.6}$ m

$T_A = 4.48$ and $T_R = 3.36$ [5]

Second Alternative Method for (i)

(ii) $0.2g + F = T_R \times \cos 36.9$

$N = T_R \times \sin 36.9$

$[0.2g + \mu \times T_R \times 0.6 = T_R$

$\mu = 0.688 \div 2.016 = 0.341$ [4]

(iii) $[0.2g + mg = \mu N + 0.8T_R]$

$0.2g + mg = 0.341 \times 2.016 + 3.36 \times 0.8$

$m = 0.137$ or 0.138 [3]

27. M/J 15/P41/Q2

$F_x = F\cos\theta = 25 \times 0.8 = 20,$

$F_y = F\sin\theta = 63 - 25 \times 0.6 = 48$

$F = 52$ N or $\tan\theta = 2.4$

$\theta = 2.4$ or $F = 52$ N [5]

28. M/J 15/P41/Q3

$F = 0.25\left(6.1 \times \dfrac{60}{61}\right)$ $[= 1.5]$

$[W\sin\alpha - F = ma]$

$6.1 \times \left(\dfrac{11}{61}\right) - 0.25\left(6.1 \times \dfrac{60}{61}\right) = 0.61\,a$

or

$6.1\sin 10.4 - 0.25 \times 6.1\cos 10.4 = 0.61\,a$

Distance is $4 \div \left(2 \times \dfrac{40}{61}\right)$

$= 3.05$ m [5]

Alternative method

$F = 0.25\left(6.1 \times \dfrac{60}{61}\right)$ $[= 1.5]$

KE loss $= \dfrac{1}{2} \times 0.61 \times 2^2$

PE loss $= 0.61 \times 10 \times x\left(\dfrac{11}{61}\right)$

$[1.5\,x = 1.22 + 1.1x]$

$0.4\,x = 1.22 \rightarrow$ distance $= 3.05$ m [5]

29. M/J 15/P43/Q5

(i) x-component $= 4 + 8\cos 30° + 12\cos 60°$

$[= 10 + 4\sqrt{3}]$

y-component $= 8\sin 30° + 12\sin 60° + 16$

$[= 20 + 6\sqrt{3}]$

$R = 34.8$ or $\theta = 60.9°$ with the 4N force

$\theta = 60.9°$ with the 4N force or $R = 34.8$

(ii) $R = 34.8$

$\theta = 29.1°$ with the 16N force [2]

30. M/J 15/P43/Q6

(i)

$20 + 5g\sin 10° - F = 0$

$R = 5g\cos 10°$

$[\mu = (20 + 8.6824) \div 49.24]$

Coefficient of friction is 0.582 [5]

(ii)

$5g\sin 10° - 0.582 \times 49.24 = 5a$

$[0 = 2.5^2 - 2 \times 4s]$

Distance is 0.781 m [4]

Alternative Method for part (ii)

(ii) PE loss $= 5gd\sin 10°$

$\dfrac{1}{2} \times 5 \times 2.5^2 + 5gd\sin 10° = 0.582 \times 5gd\cos 10°$

Distance is 0.781 m [4]

31. O/N 14/P42/Q2

(i) $[X = 25 \times 0.96 - 30 \times 0.8 = 0]$

Component in x-direction is zero [2]

(ii) $[Y = 25 \times 0.28 - 20 + 30 \times 0.6 = 5]$

Resultant has magnitude 5 N and acts in the positive y direction [2]

(iii) Replacement has magnitude 30 N and acts in the –ve y-direction [1]

32. O/N 14/P42/Q4

(i) $[X\cos30^\circ = 40\cos60^\circ$
$X = 23.1\ (= 40/\sqrt{3})$ [2]

(ii) $[X\cos30^\circ - 10 = 40\cos60^\circ]$
$X = 60 \div \sqrt{3}$ or 34.6
$[R + X\sin30^\circ + 40\sin60^\circ = 15g]$
$[\mu = 10 \div (150 - 30/\sqrt{3} - 20\sqrt{3})]$
Coefficient is 0.102 [5]

33. O/N 14/P41/Q2

For A: right angle between 18 and R and
30° opposite 18 or
$W_A\sin30^\circ = 18$ or
For B: right angle between 18 and W and
30° opposite 18 or
$W_B\sin30^\circ = 18\cos30^\circ$

For B: right angle between 18 and W and
30° opposite 18 or
$W_B\sin30^\circ = 18\cos30^\circ$ or
For A: right angle between 18 and R and
30° opposite 18 or
$W_A\sin30^\circ = 18$

Weight of A is 36N
and weight of B is 31.2N [4]

34. O/N 14/P41/Q3

(i) F + Wsin = 7.2
[[$\mu \times 7.5\cos \geqslant 7.2 - 7.5\sin$]
[$\mu \geqslant 17/24$] [4]

(ii) $[7.2 + 7.5 \times (7/25) - \mu(7.5 \times 24/25) > 0]$
$\mu < 31/24$ [2]

35. O/N 14/P43/Q3

(i) $[W\cos a + 7 \times 0.6 = 8]$
$W\cos a = 3.8$ (cwo)
$W\sin a = 5.6$ [3]

(ii) $W = 6.77$ or $a = 55.8$
$a = 55.8$ or $W = 6.77$ [3]

36. M/J 14/P42/Q3

$0.8T_1 + 0.96T_2 = 10$ or
$T_1\cos36.9 + T_2\cos16.3 = 10$
$0.6T_1 - 0.28T_2 = 0.7g$ or
$T_1\sin36.9 - T_2\sin16.3 = 0.7g$
$T_1 = 11.9$ and $T_2 = 0.5$ [6]

37. M/J 14/P41/Q2

(i) $2.4 = 0.25g\cos a$
$a = 16.3$ [2]

(ii) $[\mu = 0.28 \div 0.96]$
Least possible value of μ
is 7/24 or 0.292 [2]

38. M/J 14/P41/Q3

$X = 5 - 7\cos60^\circ - 3\cos30^\circ\quad (= -1.098)$
$Y = 7\sin60^\circ - 3\sin30^\circ - 4\quad (= 0.5622)$
Resultant is 1.23 N and
Direction is 152.9° anticlockwise from
+ve x-axis oe [6]

39. M/J 14/P43/Q1

(i) [N + component of X = Weight of B]
Normal component is $(70 - X\cos15^\circ)$ N [2]

(ii) $F = X\sin15^\circ$
$[X\sin15^\circ = 0.4(70 - X\cos15^\circ)]$
Value of X is 43.4 [3]

40. M/J 14/P41/Q2

$DF - 600 - 1250 \times 0.02g = 1250 \times 0.5$
$v = 23000 \div (625 + 600 + 250)$
Speed of car is 15.6 ms^{-1} [5]

Alternative Method

$WD = 1250 \times 0.5s + 1250g \times 0.02s + 600s$
$v = 23000 \div (625 + 600 + 250)$
Speed of car is 15.6ms^{-1} [5]

41. M/J 14/P43/Q3

$0.8T_1 + 12T_2/13 = 2.24$
$0.6T_1 - 5T_2/13 = 1.4$
$T_1 = 2.5$ <u>and</u> $T_2 = 0.26$ [6]

42. O/N 13/P42/Q1

Applying
$T\cos\beta = W\sin\alpha$
Tension is 2.5 N [3]

First Alternative Marking Scheme

Applying
$R\cos\alpha + T\sin(\alpha + \beta) = W$ and
$R\sin\alpha = T\cos(\alpha + \beta)$
Tension is 2.5 N [3]

Second Alternative Marking Scheme

Applying
$T/\sin\alpha = 5.1/\sin(90 + \beta)$
Tension is 2.5 N [3]

43. O/N 13/P42/Q4

$0.6g \sin \alpha = F + P \cos \alpha$

$R = 0.6g \cos \alpha + P \sin \alpha$

$0.6g \sin \alpha - P \cos \alpha = 0.4 (0.6g \cos \alpha + P \sin \alpha)$

$6(12/13) - P(5/13) = 2.4(5/13) + 0.4P(12/13)$

$P = 6.12$ [8]

44. O/N 13/P42/Q7

(i) [$s = ½ 5 \times 0.4 + 19 \times 0.4 + ½ 4 \times 0.4$]

Distance = 9.4 [2]

(ii) Acceleration is 0.08 ms^{-2}

Deceleration is 0.1ms^{-2} [2]

(iii) [$T - (800 + 100) g = (800 + 100)a$]

$T - 900g = 900a$

T = 9072 N in 1st stage

T = 9000 N in 2nd stage

T = 8910 N in 3rd stage [3]

(iv) [$R - 100g = 100a$]

R = 1008 N

R = 990 N [3]

45. O/N 13/P41/Q1

[$T\cos\alpha = mg$]

Tension is 3.4 N

[$F = T\sin\alpha$]

F = 1.6 [4]

46. O/N 13/P41/Q3

(i) $F - 780 \times (36 \div 325) - 32 = 78 \times (-0.2)$

F = 103 (102.8 exact) [4]

(ii) [$0 = 7^2 + 2(-0.2)s$]

Distance is 122.5 m

(accept 122 or 123) [2]

47. O/N 13/P43/Q1

(i) [$-(1 \div 3)(W\cos\alpha) - W\sin\alpha = (W/g)a$]

$(-0.32 - 0.28)g = a$

$a = -6.$ [3]

(ii) [$0 = 5.4^2 + 2(-6)s$] or

[$mgs(0.28) = ½ m(5.4)^2 - mgs(0.96)/3$]

Distance is 2.43 m [2]

48. O/N 13/P43/Q3

$T_A(1/2.6) + T_B(1/1.25) = 10.5$

$T_A(2.4/2.6) = T_B(0.75/1.25)$

Tension in AP is 6.5 N and tension in BP is 10 N. 6

First Alternative

75.7(5)° opposite to 10.5 N

36.8(7)° opposite to T_A

67.3(8)° opposite to T_B

T_A + sin36.8(7) = 10.5 + sin75.7(5) and

T_B + sin67.3(8) = 10.5 + sin75.7(5)

Tension in AP is 6.5 N and tension in BP is 10 N. 6

Second Alternative

104.2(5)° opposite to 10.5 N

143.1(3)° opposite to T_A

112.6(2)° opposite to T_B

T_A ÷ sin143.1(3) = 10.5 ÷ sin104.2(5)&

T_B ÷ sin112.6(2) = 10.5 ÷ sin104.2(5)

Tension in AP is 6.5 N and tension in BP is 10 N. 6

49. O/N 13/P43/Q4

(i) [$W\sin\alpha + F = 40$]

$F = 40 - 300 \times 0.1$ (= 10)

$R = 300\sqrt{(1 - 0.1^2)}$ (= 298.496..) [5]

Coefficient is 0.0335

(ii) [The component of weight (30 N) is greater than the frictional force (10 N)]

Box does not remain in equilibrium [2]

50. M/J 13/P42/Q1

(i) [$24 = \mu 30$]

Coefficient is 0.8 [2]

(ii) $F = 0.8(30 - 25\sin30^\circ)$ (=14)

[$25 \cos 30^\circ - F = (30 \div g)a$]

Acceleration is 2.55 ms^{-2} [4]

51. M/J 13/P42/Q3

$T_A \times (40/50) + T_B \times (40/104) = 21$ or

$T_A \times (30/50) = T_B \times (96/104)$

$T_A \times (30/50) = T_B \times (96/104)$ or

$T_A \times (40/50) + T_B \times (40/104) = 21$

Solve for T_A and T_B

Tension in AP is 20 N and tension in BP is 13 N [5]

First Alternative Marking Scheme

21/sin 75.75 (or 75.7 or 75.8) = T_A/sin 67.4 (or T_B/sin 36.9)

21/sin 75.75 (or 75.7 or 75.8) = T_B/sin 36.9 (or T_A/sin 67.4)

or T_B/sin 36.9 = 20/sin 67.4

Solve for T_A and T_B

Tension in AP is 20N and tension in BP is 13N [5]

Second Alternative Marking Scheme

21/sin 104.3 = T_A/sin 112.6
(or T_B/sin 143.1)
21/sin 104.3 = T_B/sin 143.1
(or T_A/sin 112.6)
or T_B/sin 143.1 = 20/sin 112.6
or T_A/sin 112.6 = 13/sin 143.1
Solve for T_A and T_B
Tension in AP is 20 N and tension in BP is 13 N [5]

52. M/J 13/P42/Q4

(i) $a = (16 \div 65)g$
$[8^2 = 2(16 \div 65)gS]$
$S = 13$
$[v^2 = 2(16 \div 65)g \times 6.5$
or $v^2 \div 8^2 = ½]$
Speed is 5.66 ms^{-1} [5]

(ii) $[s = ½ a \times (64 \div 4a^2)$
or $s \div 13 = (½)^2]$
Distance is 3.25 m [2]

Alternative Marking Scheme

(i) $[½ m v^2 = mgh$
and $S = h \div \sin\alpha$
$S = (8^2 \div 20) \div (16 \div 65)$
$S = 13$
$½ m v^2 = mg(½\ 13 \times (16/65))$
Speed is 5.66 ms^{-1} [5]

(ii) Distance is 3.25 m [2]

53. M/J 13/P41/Q1

(i) Less than
F = 1.25W so W< F [2]

(ii) $[P - 60 \times 1.25 = 6 \times 4]$
P = 99 [2]

54. M/J 13/P41/Q6

(i) $F\cos\theta = 2.5 \times 24 \div 25 + 2.6 \times 5 \div 13$
$F\sin\theta = 2.6 \times 12 \div 13 - 2.5 \times 7 \div 25$
For F = 3.80 N or $\tan\theta = 0.5$
For $\tan\theta = 0.5$ or F = 3.80 N [6]

(ii) [3.80 = 0.5a]
Acceleration is 7.60 ms^{-2}
Direction is 26.6° clockwise from +ve x-axis. [3]

55. M/J 13/P43/Q1

$[(W / g) a = W \sin\alpha - 0.02 W \cos\alpha]$
$a = (\sin 14° - 0.02 \cos 14°) g$
(= 2.225 …)
$[v^2 = 8^2 + 2 \times 2.225 \ldots \times 50]$

Speed is 16.9 m s^{-1} [4]

Alternative Scheme

WD against friction = 0.02 W cos α × 50
PE loss = W × 50 sin α
Speed is 16.9 m s^{-1} [4]

56. M/J 13/P43/Q6

(i) 100 cos 30° + 120 cos 60° – F cosα = 136 (F cos α = 10.6025 …)
or
100 sin 30° – 120 sin 60° + F sin α =0
(F sin α =53.9230 …).

100 sin 30° – 120 sin 60° + F sin α = 0
(F sin α =53.9230 …)
or
100 cos 30° + 120 cos 60° – F cos α = 136 (F cos α = 10.6025 …)

F = 55.0 or α = 78.9
α = 78.9 or F = 55.0 [6]

(ii) Magnitude is 136 N
R = 40 g
Coefficient is 0.34 [3]

57. O/N 12/P42/Q4

(i) $[Y_1{}^2 = 68^2 - (-60)^2,\ Y_3{}^2 = 100^2 - 96^2.$
$Y_1 = 68\sin 28.1°,\ Y_3 = 100\sin16.3°]$
For correct magnitudes (32, 75, 28)
Components are –32, 75 and –28 [3]

(ii) $[R^2=(-60 + 0 + 96)^2 + (-32 + 75 - 28)^2]$
Magnitude is 39 N
$[\theta = \tan^{-1}\{(-32 + 75 - 28)\div(-60 + 0 + 96)\}]$
Direction is 22.6° (or 0.395rad^c)
anticlockwise from +ve x-axis. [4]

58. O/N 12/P41/Q4

X = 12cos25 ° – 8cos10 ° (= 2.9972....)
Y = 12sin25° + 8sin10° – 2 (= 4.4606....)
R = 5.37
θ = 33.9 [7]

59. O/N 12/P43/Q4

$[T_1\sin APN = T_2\sin BPN]$
$(12 \div 13)T_1 = (15 \div 25)T_2$ or
$T_1\sin67.4° = T_2\sin36.9°$
$[T_1\cos APN + T_2\cos BPN = 21]$
$(5 \div 13)T_1 + (20 \div 25)T_2 = 21$ or
$T_1\cos67.4° + T_2\cos36.9° = 21$
Tension in S_1 is 13 N, tension in S_2 is 20 N [6]

Alternative solution using Lami's Theorem

[$T_1/\sin(180 - BPN) = 21/\sin(APN + BPN)$]

$T_1/\sin(180 - \cos^{-1}(20/25)) = 21/\sin(\cos^{-1}(20/25) + \cos^{-1}(20/52))$

or

$T_1/\sin(180 - 36.9) = 21/\sin(36.9 + 67.4)$

[$T_2/\sin(180 - APN) = 21/\sin(APN + BPN)$]

$T_2/\sin(180 - \cos^{-1}(20/52)) = 21/\sin(\cos^{-1}(20/25) + \cos^{-1}(20/52))$

or

$T_2/\sin(180-67.4) = 21/\sin(36.9 + 67.4)$

Tension in S_1 is 13 N, tension in S_2 is 20 N [6]

Alternative solution using Sine Rule

[$T_1/\sin BPN = 21/\sin(180 - (APN + BPN))$]

$T_1/(15/25) = 21/\sin(\cos^{-1}(20/25) + \cos^{-1}(20/52))$

or

$T_1/\sin 36.9° = 21/\sin(180 - (36.9 + 67.4))$

[$T_2/\sin APN = 21/\sin(180 - (APN + BPN))$]

$T_2/(12/13) = 21/\sin(\cos^{-1}(20/25) + \cos^{-1}(20/52))$

or

$T_2/\sin 67.4^0 = 21/\sin(180 - (36.9 + 67.4))$

Tension in S_1 is 13 N, tension in S_2 is 20 N [6]

60. O/N 12/P43/Q6

[$P = \pm F + 0.6g\sin 25°$]

$P_{max} = F + 0.6g\sin 25°$ or '$P = F + 0.6g\sin 25°$ when the particle is about to slide upwards'

$P_{min} = -F + 0.6g\sin 25°$ or '$P = -F + 0.6g\sin 25°$ when the particle is about to slide downwards'

$R = 0.6g\cos 25°$

[$F = 0.36 \times 0.6g\cos 25°$]

[$F = 0.36 \times 0.6$

[$P_{max} = 0.36 \times 0.6g\cos 25° + 0.6g\sin 25°$,

$P_{min} = -0.36 \times 0.6g\cos 25° + 0.6g\sin 25°$]

$P_{max} = 4.49$, $P_{min} = 0.578$ (accept 0.58)

Set of values is $\{P;\ 0.578 \le P \le 4.49\}$ [9]

61. M/J 12/P42/Q2

[$12 = 15\sin\alpha$]

$\alpha = 53.1$

[$F = 15\cos\alpha$]

$F = 9N$ [4]

ALTERNATIVE 1

[$F\sin\alpha = 12\cos\alpha$ and $F\cos\alpha + 12\sin\alpha = 15$ ➔ $\sin\alpha \div \cos\alpha = 12\cos\alpha \div 15 - 12\sin\alpha$

$15\sin\alpha - 12\sin^2\alpha = 12\cos^2\alpha$ ➔ $15\sin\alpha = 12$ ➔ $\alpha = 53.1$

$F = 9N$ [4]

ALTERNATIVE 2

[$\sin\alpha = 12/15$]

$\alpha = 53.1$

[$F^2 = 15^2 - 12^2$]

ALTERNATIVE 3

[$12 \div \sin(180 - \alpha) = 15 \div \sin 90$

➔ $12 = 15\sin\alpha$]

$\alpha = 53.1$

[$F \div \sin 143.1 = 15 \div \sin 90$]

$F = 9N$ [4]

SR (max 2/4) For candidates who have sin and cos interchanged.

Allow B1 for $\alpha = 36.9$ and allow B1 for $F = 9$ following correct work relative to the cos/sin interchange error.

62. M/J 12/P42/Q4

(i) Horizontal component is $T\cos 25°$ (0.906T)
Vertical component is $4g + T\sin 25°$
(40 + 0.423T) [3]

(ii) $0.906T = 16 + 0.169T$
$T = 21.7N$ [2]

63. M/J 12/P41/Q2

(i) $X = 14 - 13\cos\theta$ and $Y = 13\sin\theta$ or triangle with sides 13, 14, 15 and θ opposite 15
[$14^2 + 13^2 - 2 \times 13 \times 14\cos\theta = 15^2$]
$\theta = 67.4$ [3]

(ii) Component is 9 N [2]

64. M/J 12/P41/Q7

(i) $T_C \times (2/2.5) - T_A \times (1.5/2.5) = 0$
$T_C \times (1.5/2.5) + T_A \times (2/2.5) = 8$
[$0.6\,T_C + 0.8\,(4T_C/3) = 8 \rightarrow (5/3)\,T_C = 8$ or $0.6(0.75T_A) + 0.8T_A = 8 \rightarrow 1.25T_A = 8$]
Tension in AB is 6.4 N; tension in BC is 4.8 N [5]

(ii) $F + 0.2\,g = T_A \times (1.5/2.5)$
$N = T_A \times (2/2.5)$
[$\mu = (3.84 - 2)/5.12$]
Coefficient is 0.359 [5]

65. M/J 12/P43/Q2

(i) $T\cos\theta + T\sin\theta = 11.2$
(or $-T\cos\theta + T\sin\theta = 0.16g$)
$-T\cos\theta + T\sin\theta = 0.16g$
(or $T\cos\theta + T\sin\theta = 11.2$) [3]

(ii) [$T\cos\theta = 4.8$ and $T\sin\theta = 6.4$ and $T^2 = 4.8^2 + 6.4^2$ or $\tan\theta = 6.4/4.8$]
[$4T^2(\cos^2\theta + \sin^2\theta) = (11.2 - 1.6)^2 + (11.2 + 1.6)^2$
or $2T\sin\theta \div 2T\cos\theta = (11.2 + 1.6) \div (11.2 - 1.6)$
or $(T\cos\theta + T\sin\theta) \div (-T\cos\theta + T\sin\theta) = 11.2 \div 1.6$]
$T = 8$ (or $\theta = 53.1$)
$\theta = 53.1$ or $T = 8$ [3]

66. O/N 11/P42/Q4

(i) For triangle of forces with 60° shown correctly, or
$C\cos\phi = 4\cos30$ and $C\sin\phi = 10 - 4\sin30$, or
$F = 4\cos30$ and $R = 10 - 4\sin30$
[$C^2 = 4^2 + 10^2 - 2 \times 4 \times 10\cos60$ or
$C^2 = (4\cos30)^2 + (10 - 4\sin30)^2$]
$C = 8.72$

(ii) [$\mu = 4\cos30/(10 - 4\sin30)$]
Coefficient is 0.433 (accept 0.43) [2]

Alternative Method

(i) For obtaining $\phi = 66.6°$ or
$\tan\phi = 4 \div \sqrt{3}$ from
$4 \div \sin(90° + \phi) = 10 \div \sin(150° - \phi)$
For using C N and (4 N or 10 N) in Lami's theorem to find C
[$C \div \sin120° = (4 \div \sin156.6°$ or $10 \div \sin83.4°)$]
$C = 8.72$ [3]

(ii) [$\mu = \sqrt{3} \div 4$ or $\mu = \cos66.6° \div \sin66.6°$]
Coefficient is 0.433 (accept 0.43) [2]

67. O/N 11/P41/Q3

(i) (a) [$2 \times 12\cos40 - 15\cos50$]
Component is 8.74 N
(b) Component is 11.5 N

(ii) Magnitude is 14.4 N or direction is 52.7° (or 0.920^c) anticlockwise from **i** dir'n
Direction is 52.7° (or 0.920^c) anticlockwise from **i** dir'n or magnitude is 14.4 N [3]

68. O/N 11/P41/Q5

(i) $F = 12\cos\alpha$
$R_1 = 2g + 12\sin\alpha$
[$12 \times 0.8 \le \mu(2g + 12 \times 0.6)$]
$\mu \ge 9.6/27.2 = 6/17$ [5]

(ii) $12\cos\alpha > \mu R_2$
$R_2 = 2g - 12 \times 0.6$
$\mu < 9.6/12.8 = 3/4$ [3]

69. O/N 11/P43/Q2

$X = 31 + 26\cos\alpha$, $Y = 58 - 26\sin\alpha$
$X = 55$, $Y = 48$
Resultant is 73N or
Direction is at 41.1° to **i** direction
Direction is at 41.1° to **i** direction or
Resultant is 73N

Alternative solution for Q2
[$\tan\theta_{12} = 58/31$, $R_{12}^2 = 31^2 + 58^2$]
$\theta_{12} = 61.9°$ and $R_{12} = 65.76$
[Incl. angle = $(180 - \theta_{12} - \alpha)°$,
$R^2 = 26^2 + R_{12}^2 - 2 \times 26R_{12}\cos$ (incl. angle)]
Incl. angle = 95.5°, Resultant is 73 N
[$\sin\beta = 26\sin95.5/73$; $\theta = 61.9 - \beta$]
Direction is at 41.1° to **i** direction

70. O/N 11/P43/Q6

$R = T\cos30$
$F = T\sin30 - 2g$
$-F = T\sin30 - 2g$
$T = 2g/(\sin30 \pm 0.24\cos30)$ either case
$T = 28.3$ and $T = 68.5$ [8]

71. M/J 11/P42/Q4

(i) $F\cos\theta = 12\cos30°$ (= 10.932)
$F\sin\theta = 10 - 12\sin30°$ (= 4)
$F = 11.1$ or $\theta = 21.1$ (accept 21.0)
$\theta = 21.1$ (accept 21.0) or $F = 11.1$ [6]

(ii) Magnitude is 12N
Direction is 30° clockwise from +ve 'x' axis [2]

alternative for 4(i)
For triangle of forces with sides 12, F and 10 and at least one of the angles $(90° - \theta)$ or 60° or $(\theta + 30°)$
$F^2 = 12^2 + 10^2 - 2 \times 12 \times 10\cos60°$ or
$(12\cos30°)\sin\theta = (10 - 12\sin30°)\cos\theta$
$F = 11.1$ or $\theta = 21.1$ (accept 21.0)
$\theta = 21.1$ (accept 21.0) or $F = 11.1$ [6]

second alternative for 4(i)
For using Lami's theorem with 12 N and 10 N
$12/\sin(90 + \theta) = 10/\sin(150 - \theta)$
$12/\cos\theta = 20 \div (\cos\theta + 3^{1/2}\sin\theta)$
$\rightarrow 12 \times 3^{1/2}\sin\theta = 8\cos\theta$
$\rightarrow \tan\theta = 2 \div (3 \times 3^{1/2})$
$\rightarrow \theta = 21.1$

For using Lami's theorem with F N and (12 N or 10 N)
$F/\sin 120° = 12/\sin 111.1°$ (or $10/\sin 128.9°$)
$F = 11.1$ [6]

Alternative for 4(ii)

For $X = 11.1\cos 21.1°$ and
$Y = 11.1\sin 21.1° - 10$,
$R^2 = X^2 + Y^2$ and $\tan\Phi = Y/X$
Magnitude 12 N and direction 30° clockwise from +ve x-axis [2]

72. M/J 11/P42/Q6

(i) $2T\cos\alpha = 0.6g$
Tension is 5N [3]

(ii) [$F = T\sin\alpha$]
Frictional component is 4N
[$N = 0.4g + T\cos\alpha$]
Normal component is 7 N [4]

(iii) Coefficient is 4/7 or 0.571 [2]

Alternative for Q6(i)/(ii)

(i) For finding the relevant angles and using Lami's theorem
$6/\sin 106.26° = T/\sin 126.87°$
Tension is 5N [3]

(ii) $F/\sin 126.87° = 5/\sin 90°$
Frictional component is 4N
$(R - 4)/\sin 143.13° = 5/\sin 90°$
Normal component is 7 N [4]

73. M/J 11/P41/Q3

$T\cos\theta + T\sin\theta = 15.5$
$-T\cos\theta + T\sin\theta = 8.5$
$T\sin\theta = 12$ and $T\cos\theta = 3.5$
$\theta = 73.7°$ (or 1.29^c) [6]

74. M/J 11/P41/Q4

(i) $2X + F = 11g\sin 30°$ and
$9X - F = 11g\sin 30°$
$X = 10$ [3]

(ii) $F = 35$
$R = 11g\cos 30°$
Coefficient is 0.367 [4]

75. M/J 11/P43/Q5

(i) $F_x - 6.1 - 5 \times 0.28 = 0$ and
$F_y + 4.8 - 5 \times 0.96 = 0$
Frictional force acts parallel to x axis and to the right
$F_y = 0 \rightarrow F = F_x$
$\rightarrow$ Frictional force has magnitude 7.5 N [4]

(ii) [$\mu = 7.5/(1.25 \times 10)$]
Coefficient is 0.6 [2]

(iii) [$7.5 - 8.6 - 1.4 = 1.25a \rightarrow a = -2$]
Magnitude of acceleration is 2 ms^{-2}
Direction of acceleration is parallel to x axis and to the left [3]

76. O/N 10/P42/Q1

$R + 2000\cos 15° = 400g$
$F = 2000\sin 15°$
[$2000\sin 15° = \mu(400g - 2000\cos 15°)$]
Coefficient is 0.25 [5]
SR(max. 4/5) for candidates who either: have sin and cos interchanged or have angle 15° above the horizontal
$R + 2000\sin 15° = 400g$ and $F = 2000\cos 15°$
[$2000\cos 15° = \mu(400g - 2000\sin 15°)$]
Coefficient is 0.55

77. O/N 10/P42/Q3

$6\cos\alpha° + 5\cos(90° - \alpha°) = F$ and
$6\sin\alpha° - 5\sin(90° - \alpha°) = F$
[$6\cos\alpha° + 5\sin\alpha° = 6\sin\alpha° - 5\cos\alpha°$
$\rightarrow 11\cos\alpha° = \sin\alpha°$]
$\alpha = 84.8$
[$F = 6\cos 84.8° + 5\sin 84.8°$; $F = 6\sin 84.8° - 5\cos 84.8°$]
$F = 5.52$ [6]

First alternative scheme

[$2F^2 = 25 + 36$]
$F = 5.52$
$\tan(\alpha° - 45°) = 5/6$ or $\tan(135° - \alpha°) = 6/5$ or
$\cos(\alpha° - 45°)$ or $\sin(135° - \alpha°) = 6/\sqrt{61}$ or
$\sin(\alpha° - 45°)$ or $\cos(135° - \alpha°) = 5/\sqrt{61}$
$\alpha = 84.8$

Second alternative scheme

[$6\cos\alpha° + 5\cos(90° - \alpha°) = 6\sin\alpha° - 5\sin(90° - \alpha°)$]
[$11\cos\alpha° - \sin\alpha° = 0$]
$\alpha = 84.8$
For $F = 6\cos\alpha° + 5\cos(90° - \alpha°)$ or
$F = 6\sin\alpha° - 5\sin(90° - \alpha°)$
$F = 5.52$

78. O/N 10/P41/Q3

For correct Δ or resolve XP_1
and $\cos\alpha = 5.5/7.3$;
or $5.5/\sin(90° + \alpha) = 7.3/\sin90°$ (Lami);
or $5.5\cos\alpha + W\sin\alpha = 7.3$
and $5.5\sin\alpha = W\cos\alpha$.
Angle $AP_1X = 41.1°$ or 0.718^c
For correct triangle and $W^2 = 7.3^2 - 5.5^2$;
or $W/\sin(180° - 41.1°) = 7.3/\sin90°$;
or $W\sin41.1° = 7.3 - 5.5\cos41.1°$
or $W\cos41.1° = 5.5\sin41.1°$
$W = 4.8$ [5]

79. O/N 10/P43/Q3

(i) [$2T\cos30° = 3\sqrt{3}$
or $T/\sin30° = 3\sqrt{3}/\sin120°$
or $T^2 = T^2 + (3\sqrt{3})^2 - 2T(3\sqrt{3})\cos30°$
or $\sqrt{\{(T\cos30°)^2 + (T + T\cos60°)^2\}} = 3\sqrt{3}$]
Tension is 3 N **[2]**

(ii) [$T = F + mg\sin30$]
$R = mg\cos30$
$3 = 0.75(10\cos30°)m + 10m\sin30°$
Mass is 0.261 kg **[5]**

80. O/N 10/P43/Q5

(i) [$F^2 = 27.5^2 + (-24)^2$]
$F = 36.5$
[$\tan\alpha° = -(-24/27.5)$]
$\alpha = 41.1$ **[4]**

(ii) $R = 94.9$
[$\alpha° + \theta° = \tan^{-1}(87.6/36.5)$;
or $(\alpha° + \theta°) = \cos^{-1}(36.5/94.9)$
or $\theta° = \tan^{-1}(87.6\sin48.9° - 24)/(27.5 + 87.6\cos48.9°)$]
$\theta = 26.3$ **[3]**

81. M/J 10/P42/Q3

(i) [$R + 7\sin45° = 0.8g$]
Normal component is 3.05 N **[2]**

(ii) $F = 7\cos45°$
Coefficient is 1.62 **[3]**

82. M/J 10/P42/Q4

$X = 160 + 250\cos\alpha$
$Y = 370 - 250\sin\alpha$
Magnitude is 500
Required angle is 36.9°
Alternative for **4**
Triangle has angle opposite R equal to 97.1°
[$R^2 = 403^2 + 250^2 - 2 \times 403 \times 250\cos97.1°$
Magnitude is 500 N
[$\sin(66.6° - z) \div 250 = \sin97.1° \div R$]
Required angle is 36.9° [7]

83. M/J 10/P41/Q3

(i) [$R + 7\sin45° = 0.8g$]
Normal component is 3.05 [2]

(ii) $F = 7\cos45°$
Coefficient is 1.62 [3]

84. M/J 10/P41/Q4

$X = 160 + 250\cos\alpha$
$Y = 370 - 250\sin\alpha$
Magnitude is 500 N
Required angle is 36.9° (or 0.644 rads) [7]
Alternative for **4**
Triangle has sides 403, 250 and R
Triangle has angle opposite R equal to 97.1°
[$R^2 = 403^2 + 250^2 - 2 \times 403 \times 250\cos97.1°$]
Magnitude is 500 N
[$\sin(66.6° - z) \div 250 = \sin97.1° \div R$]
Re uired an le is 36.9°

85. M/J 10/P43/Q1

[$7.3\sin\alpha = 5.5$]
$\alpha = 48.9$
[$R = 6.8 - 7.3\cos48.9°$]
Magnitude of resultant is 2 N [4]

86. O/N 09/P42/Q1

(i) [$P = W\sin40°$]
$P = 7.71$ [2]

(ii) [$P\cos40° = W\sin40°$
$P = 10.1$ [2]

87. O/N 09/P41/Q3

$Q - P\cos60° = 12\cos80°$ and $P\sin60° = 12\sin80°$
$Q\cos80° + P\cos40° = 12$ and $P\sin40° = Q\sin80°$
[$Q - 12\sin80°\cos60°/\sin60° = 12\cos80°$
$Q\cos80° + Q\sin80°\cos40°/\sin40° = 12$]
$Q = 8.91$ [4]

(First alternative)
$Q\cos30° = 12\cos50°$
$Q = 8.91$ [4]

(Second alternative)
Angles opposite Q and 12 are 40° and 60° respectively
$Q/\sin40° = 12/\sin60°$
$Q = 8.91$ [4]

(Third alternative)
Angle between P and Q is 120° and between P and –R is 140°
[Q/sin140° = 12/sin120°
Q = 8.91 **[4]**

88. O/N 09/P41/Q4

(i) For angle between AP and vertical = 36.9° (or $\sin^{-1}0.6$) or for angle between PS and vertical = 53.1° (or $\sin^{-1}0.8$)
[T_{PS}+ (T_{PA}cos90°) = 5sin36.9°]

(First alternative)
For the angle between PA and the horizontal through P is 53.1° and the angle between PS and the horizontal through P is 36.9°
[$0.6T_{PA} = 0.8T_{PS}$ and $0.8T_{PA} + 0.6T_{PS} = 5$ ➔ $\{0.8(0.8/0.6) + 0.6\}T_{PS} = 5$]

(Second alternative)
For Δ of forces with sides T_{PA}, T_{PS} and 5, with angles opposite T_{PS} and 5 shown as 36.9° and 90°
[T_{PS} = 5sin36.9°]

(Third alternative)
For force diag. showing T_{PA}, T_{PS} and 5, with angles between T_{PS} and T_{PA}, and between 5 and T_{PA} being shown as 90° and 143.1°
[T_{PS} /sin143.1° = 5/sin90°
Tension is 3N **[3]**

(ii) [F = T cos($\sin^{-1}$ 0.6)]
Frictional force is 2.4N **[2]**

(iii) [W + T sin($\sin^{-1}$ 0.6) = R]
W = 1.4 **[3]**

89. O/N 09/P41/Q5

(i) – F – 0.6gsin 18° = 0.6(–4)
Frictional component is 0.546N
[R = 0.6gcos18°]
Normal component is 5.71N
Coefficient is 0.096 **[6]**

(ii) 0.6gsin18° – 0.546 = 0.6a or 2(0.6gsin18°) = 0.6(a + 4)
a = 2.18 **[2]**

90. M/J 09/P04/Q3

(i) [X = 7 + 10cos50° – 15cos80°, Y = 10sin50° + 15sin80°]
(a) x-component is 10.8
(b) y-component is 22.4 **[3]**

(ii) [$\theta = \tan^{-1}(22.4/10.8)$]
Direction 64.2° anticlockwise from x-axis **[2]**

91. M/J 09/P04/Q4

(i) [F + T = 8×10sin20°]
Frictional component is 14.4
[R = 80cos20°]
Normal component is 75.2 **[4]**

Alternative scheme for part (i)
[Tcos20° + Fcos20° = Rsin20° and Tsin20° + Fsin20° + Rcos20° = 8 g]
[tan20° = (13cos20° + Fcos20°) ÷ (80 – 13sin20° – Fsin20°) → F = 80sin20° – 13 or tan20° = (80 – Rcos20° – 13sin20°) ÷ (Rsin20° – 13cos20°) → R = 80cos20°]
Frictional component is 14.4
Normal component is 75.2

(ii) F = 8×10sin20° or μ = tan20°
Coefficient is 0.364 (accept 0.36) **[2]**

92. O/N 08/P04/Q1

(i) **(a)** $10 - 8\cos\theta$
(b) $8\sin\theta$ **[2]**

(ii) $(10 - 8\cos\theta)^2 + (8\sin\theta)^2 = 8^2$ or
$10^2 + 8^2 - 2\text{x}10\text{x}8\cos\theta = 8^2$
$\cos\theta = 5/8$ **[3]**

First alternative for **(ii)**
[$\cos\varphi = (10 - 8\cos\theta)/8$ and $\sin\varphi = 8\sin\theta/8$]
$8\cos\varphi = (10 - 8\cos\theta)$ and $\varphi = \theta$
$\cos\theta = 5/8$

Second alternative for **(ii)**
[5, $\sqrt{39}$, 64]
8 = R
➔ assumption correct

SR for **(ii)** (max 2/3)
R = 8 or 8.0 or 8.00 or 7.997.
➔ assumption correct

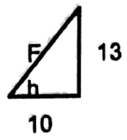
93. O/N 08/P04/Q2

[R = 197, F = 63.0]
(i) P = F + 20gsin 10°
Least magnitude is 97.8N

(ii) P = F –20gsin 10°
Least magnitude is 28.3N **[6]**

SR (for candidates who omit g) (max 3/6)
For P = F + 20sin 10° in **(i)** and P = F – 20sin 10° in **(ii)**
Least magnitude is 9.78N in **(i)** and 2.83 in **(ii)**

94. M/J 08/P04/Q3



[$F\cos\theta° = 10$, $F\sin\theta° = 13$;]

[$\tan\theta° = 13/10$, $\sqrt{269}\sin\theta° = 13$]

$\theta = 52.4$

[$F^2 = 10^2 + 13^2$, $F\cos 52.4° = 10$]

F = 16.4 [5]

Alternative scheme for candidates who use scale drawing:

$\theta = 52.4$

F = 16.4 [5]

95. O/N 07/P04/Q3

(i) [$7 = F\cos\theta$ and $4 = F\sin\theta$ →
$F^2 = 7^2 + 4^2$ (or $\tan\theta = 4/7$)]
[$7 = 8.06\cos\theta$ or $4 = 8.06\sin\theta$]
(or $7 = F\cos 29.7°$ or $4 = F\sin 29.7°$)
$\theta = 29.7$ [4]

(ii) Direction opposite to that of the force of magnitude 7 N [2]

96. O/N 07/P04/Q5

(i) $R = T\sin 60°$
[$F = W + T\cos]60°$
$F = 40 + T\cos 60°$

(ii) $40 + 0.5T = 0.7 \times 0.866T$
T = 377 [3]

97. M/J 07/P04/Q2

(i) [$8 + 8\cos\theta = 9$]
$\theta = 82.8$ [2]

(ii) For showing θ or $(180° - \theta)$ or $\theta/2$, in a triangle representing the two forces and the resultant, or for using $Y = 8\sin\theta$ in $R^2 = X^2 + Y^2$
[$R^2 = 8^2 + 8^2 - 2\times8\times8\cos(180 - \theta)$,
$R^2 = 8^2 + 8^2 + 2\times8\times8\cos\theta$,
$\cos(\theta/2) = (R/2) \div 8$,
$R\cos(\theta/2) = 9$,
$R\sin(\theta/2) = 8\sin\theta$,
$R^2 = 9^2 + (8\sin\theta)^2$,
$R^2 = (8 + 8\cos\theta)^2 + (8\sin\theta)^2$]
Magnitude is 12 N [3]

98. M/J 07/P04/Q7

(i) $T\cos 60° = 75\cos 30° \rightarrow T = 130$
$T\sin 60° + 75\sin 30° + R = 20g$
[$130\sin 60° + 75\sin 30° + R = 200$]
Magnitude is 50 N [5]

(ii) $T\cos 60° + 25 = 75\cos 30°$
(T = 79.9)
[$79.9\sin 60° + 75\sin 30° + R = 200$]
R = 93.3
[$\mu = 25/93.3$]
Coefficient is 0.268 ($= 2 - \sqrt{3}$) [6]

99. O/N 06/P04/Q2

(i) [$F + 5\cos 30° = 0.6$ g]
Frictional force is 1.67 N [2]

(ii) $R = 5\sin 30°$ [= 2.5]
Coefficient is 0.668 [3]

100. O/N 06/P04/Q6

(i) P = 10
R = 26.9 [3]

(ii) $\alpha = 73.7$
(a) 24 N
(b) 7N [4]

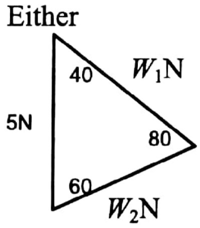
(iii) $\cos\theta = (24 - 2.8)\ 26.9$ ... or
$\sin\theta = (7 + 9.6)/26.9$ ... or
$\tan\theta = (7 + 9.6)/24 - 2.8)$
$\theta = 38.1$ [3]

101. M/J 06/P04/Q3

$F\sin 50° = F\sin 20° + 12$
F = 28.3
$G = F\cos 50° + F\cos 20°$
G = 44.8 [6]

102. O/N 05/P04/Q3

Either



$$\frac{W_1}{\sin 60°} = \frac{5}{\sin 80°}$$

$W_1 = 4.40$

$$\frac{W_2}{\sin 40°} = \frac{5}{\sin 80°}$$

$W_2 = 3.26$

Or

$W_1\sin 40° = W_2\sin 60°$

$W_1\cos 40° + W_2\cos 60° = 5$

$W_1\cos 40° + W_1\dfrac{\sin 40°}{\sin 60°}\cos 60° = 5$

$W_1 = 4.40$

$W_2 = 4.40\dfrac{\sin 40°}{\sin 60°}$

$W_2 = 3.26$ [6]

103. O/N 05/P04/Q4

(i) $N + X\cos\theta = mg$

$N + X(24/25) = 320 \times 10$

$N = 3200 - (24/25)X$ 3

(ii) $F = X\sin\theta$

$\frac{7}{25}X = \frac{3}{8}(3200 - \frac{24}{25}X)$

$X = 1875$ 3

104. M/J 05/P04/Q2

$X = 7 + 5\cos50° - 6\cos30°$

$Y = 5\sin50° - 6\sin30°$

$R^2 = 5.01..^2 + 0.83..^2$

$\tan\theta = 0.8302/5.0178$

Magnitude is 5.09 N and direction is 9.4° anti-clockwise from force of magnitude 7 N [6]

OR

10.9N and 20.6° anticlockwise from x-axis

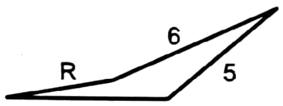
or 3.50 N and 59.0° clockwise from x-axis

or 2.15 N and 157.3° anticlockwise from x-axis

5.09 N

9.4° anticlockwise from the x-axis [6]

OR



$R = 5.09$ (**A2**) (or some value such that $4.9 \le R \le 5.3$ (**A1**))

9.4° (**A2**) (or some value such that $9° \le \theta \le 9.8°$ (**A1**)) anticlockwise from the x-axis [6]

105. M/J 05/P04/Q3

$2.25 = ½ a(1.5^2)$

$a = 2$

$R = mg\cos30°$

$mg\sin30° - \mu\ mg\cos30° = 2m$

Coefficient of friction is 0.346 [6]

OR

KE gain = $½ m3^2$

$R = mg\cos30°$

$2.25\mu mg\cos30° = mg(2.25\sin30°) - ½ m3^2$

Coefficient of friction is 0.346 [6]

106. O/N 04/P04/Q2

(i) $P = 18\cos60°$ or $\sin30° = P/18$

$P = 9$ [2]

(ii)
- $P\cos30° = 18\cos60°$ or
- $\tan30° = P/18$ or
- $18 = R\cos30°$ and $P = R\sin30°$

P = 10.4 (accept $6\sqrt{3}$) [3]

107. O/N 04/P04/Q6

(i) $R = 8000$ N

For obtaining $P \le 6000$ [2]

(ii) $F \le 0.4 \times 4000$ or

$F_{max} = 0.4 \times 4000$

$400a \le 1600$ or $400a_{max} = 1600$

$a \le 4$

$P_{max} - 6000 = 800 \times 4$ or

$P - 6000 = 800a \le 800 \times 4$

Maximum possible value of P is 9200 [7]

108. M/J 04/P04/Q1

(i) $F = 13\cos\alpha$

Frictional component is 12 N [2]

(ii) $R = 1.1 \times 10 + 13\sin\alpha$

Normal component is 16 N [2]

(iii) Coefficient of friction is 0.75 [1]

109. M/J 04/P04/Q2

$X = 100 + 250\cos70°$

$Y = 300 - 250\sin70°$

$R^2 = 185.5^2 + 65.1^2$

$R = 197$

$\tan\alpha = 65.1/185.5$

$\alpha = 19.3$ [6]

OR

316(.227766..) or 107(.4528..) or 299(.3343..)

71.565 ...° or 37.2743 .. ° or –51.7039 .. °

$R^2 = 316.2^2 + 250^2 - 2 \times 316.2 \times 250\cos38.4°$

$R^2 = 107.5^2 + 100^2 - 2 \times 107.5 \times 100\cos142.7°$

$R^2 = 299.3^2 + 300^2 - 2 \times 299.3 \times 300\cos38.3°$

$R = 197$

$\sin(71.6 - \alpha) = 250\sin38.4 \div 197$

$\sin(37.3 - \alpha) = 100\sin142.7 \div 197$

$\sin(51.7 + \alpha) = 300\sin38.3 \div 197$

$\alpha = 19.3°$

110. O/N 03/P04/Q3

(i) For using the idea of work as a force times a distance
$(25 \times 2\cos 15^\circ)$
Work done is 48.3 J [2]
$N + 25\sin 15^\circ = 3 \times 10$
(√ cos instead of sin following sin instead of cos in (i))
Component is 23.5 N

111. O/N 03/P04/Q6

(i) $T_{BM} = T_{AM}$ or $T_{BM}\cos 30^\circ = T_{AM}\cos 30^\circ$
For resolving forces at M horizontally
$(2T \sin 30^\circ = 5)$
For resolving forces at M horizontally
$(2T \sin 30^\circ = 5)$
or for using the sine rule in the triangle of forces
$(T \div \sin 60^\circ = 5 \div \sin 60^\circ)$
or for using Lami's theorem
$(T \div \sin 120^\circ = 5 \div \sin 120^\circ)$
Tension is 5 N A.G. [3]

(ii) For resolving forces on B horizontally
$(N = T\sin 30)$ or
from symmetry ($N = 5/2$) or for using Lami's theorem
$(N \div \sin 150^\circ = 5 \div \sin 90^\circ)$
For resolving forces on B vertically (3 terms needed) or for using Lami's theorem
$0.2 \times 10 + F = T\cos 30^0$ or
$(0.2g + F) \div \sin 120^\circ = T \div \sin 90^\circ$
For using $F = \mu R$ $(233 = 2.5\mu)$
Coefficient is 0.932 [5]

112. M/J 03/P04/Q2

(i) (a) For resolving in the direction PQ
Component is 2 x 10cos30° – 6cos60°
or 14.3 N or $10\sqrt{3} - 3$ N [2]

(b) Component is ± 6cos30° – 6cos60°
or ± 5.20 N or ± $3\sqrt{3}$ N [1]

SR (for candidates who resolve parallel to and perpendicular to the force of magnitude 6 N) (Max 2 out of 3)
For resolving in both directions
For X = 6 – 10cos 30° or –2.66 N and
Y = 10 + 10sin 30° or 15 N

SR (for candidates who give a combined answer for **(a)** and **(b)** (Max 2 out of 3)
For resolving in both directions
For (6cos30°)**i** + (2 x10cos30° – 6cos60°)**j** or any vector equivalent

(ii) For using Magnitude
$= \sqrt{ans(i)^2 + ans(ii)^2}$
Magnitude is 15.2 N [2]
ft only following sin/cos mix and for answer 5.66 N

113. M/J 03/P04/Q6

(i) For using $F = \mu R$ and $R = mg$
$(F = 0.025 \times 0.15 \times 10)$
Frictional force is 0.0375 N or 3/80 N [2]
Accept 0.0368 from 9.8 or 9.81

(ii) For using $F = ma$ ($-0.0375 = 0.15a$)
or $d = \mu g$
Deceleration is 0.25 ms^{-2}
(or a = - 0.25) A.G. [2]

(iii) For using $s = ut + \frac{1}{2}at^2$
$(s = 5.5 \times 4 + \frac{1}{2}(-0.25)16)$
Distance AB is 20m [2]

(iv) For using $v^2 = u^2 + 2as$
$(v^2 = 3.5^2 - 2 \times 0.25 \times 20)$
Speed is 1.5 ms^{-1}
(ft $\sqrt{(24.5 - (iii))/2}$) [2]

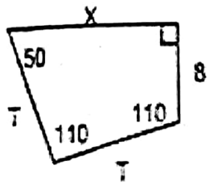
(v) Return dist. = $\frac{3.5^2}{2 \times 0.25}$
or distance beyond A = $\frac{(iv)^2}{2 \times 0.25}$
Total distance is 44.5 m [2]
(ft 24.5 + **(iii)** or 2(**(iv)**^{2} + **(iii)**))

114. O/N 02/P04/Q3

(i) For resolving forces on R vertically
(3 terms needed)
$T\sin 50° = T\sin 20° + 0.8g$
Tension is 18.9 N
(18.5 from $g = 9.81$ or $g = 9.8$) **[3]**

(ii) For resolving forces on R horizontally
$X = T\cos 50° + T\cos 20°$
$X = 29.9$ ($8\tan 75°$)
(29.3 from $g = 9.81$ or $g = 9.8$) **[3]**

Alternatively (by scale drawing):
Correct quadrilateral drawn to scale



$18.4 \le T \le 19.4$
$29.4 \le X \le 30.4$
$T = 18.9$ and $X = 29.9$

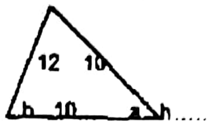
115. O/N 02/P04/Q5

(i) $R = 15\times10\times\cos 35° = 123$ (AG) **[1]**

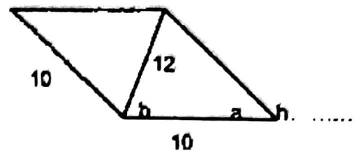
(ii) For resolving forces along the plane
(either case)
$150\sin 35° = X + F$ and $150\sin 35° = 5X - F$
For eliminating F or X
$X = 28.7$ (ft from wrong F or wrong positive μ)
(28.1 from $g = 9.81$ or $g = 9.8$)
F or $\mu R = 10g\sin 35°$ or equivalent
(may be implied) (57.36)
For using $F = \mu R$ [$57.36 = \mu\, 122.9$
or $100\sin 35° = \mu\, 150\cos 35°$]
Coefficient of friction is 0.467
(ft for positive value from wrong X) **[7]**
[$(2/3)\tan 35°$]

SR for the case where a candidate does not use F explicitly and uses $F \le \mu R$ (and not $F = \mu R$) implicitly (max 4 out of 7)
For resolving forces along the plane (either case)
$150\sin 35° - X \le \mu R$ and $5X - 150\sin 35° \le \mu R$
For eliminating X (it is not possible to eliminate μR)
$\mu R \ge 100\sin 35°$ or equivalent

116. M/J 02/P04/Q3



or



(may be implied)

(i) or recognizing that resultant acts along bisector
or $12\cos\beta = 10 + 10\cos\theta$
and $12\sin\beta = 10\sin\theta$
or $X = 10 - 10\cos\alpha$
and $Y = 10\sin\alpha$
Complete method for α
[$\alpha = 2\sin^{-1}\dfrac{6}{12}$ or $12^2 = 10^2 + 10^2 - 2\times10^2\cos\alpha$]
or resolving forces along the bisector
[$2\times10\cos\dfrac{\theta}{2} = 12$]
or squaring and adding and using
$c^2\beta + s^2\beta = 1$ and $c^2\theta + s^2\theta = 1$
[$144 = 100 + 200\cos\theta + 100$]
$\theta = 106.3°$ or 1.85 rads **[3]**

(ii) For using component $= 12\cos\dfrac{\theta}{2}$ [12×0.6]
or 10 $10\cos\alpha$
Component is 7.2 N (ft only when B1 in part (i) is scored) **[2]**

SR for candidates whose diagram in (i) (actual or implied) has triangle with sides 10, 10, 12 and angle θ opposite the 12.
(max 1 out of 2)

Alternative: For candidates who draw a scale diagram.
As for first mark in scheme above.
Value of θ in the range 105° to 107° obtained
$\theta = 106.3°$

For drawing relevant perpendicular and measuring appropriate length
Component is 7.2 N

Unit-2: Kinematics of Motion in a Straight Line

1. O/N 17/P42/Q3

A car travels along a straight road with constant acceleration. It passes through points A, B and C. The car passes point A with velocity $14\,\text{m s}^{-1}$. The two sections AB and BC are of equal length. The times taken to travel along AB and BC are $5\,\text{s}$ and $3\,\text{s}$ respectively.

(i) Write down an expression for the distance AB in terms of the acceleration of the car. Write down a similar expression for the distance AC. Hence show that the acceleration of the car is $4\,\text{m s}^{-2}$. [4]

(ii) Find the speed of the car as it passes point C. [2]

2. O/N 17/P42/Q4

A particle P is projected vertically upwards from horizontal ground with speed $12\,\text{m s}^{-1}$.

(i) Find the time taken for P to return to the ground. [2]

The time in seconds after P is projected is denoted by t. When $t = 1$, a second particle Q is projected vertically upwards with speed $10\,\text{m s}^{-1}$ from a point which is $5\,\text{m}$ above the ground. Particles P and Q move in different vertical lines.

(ii) Find the set of values of t for which the two particles are moving in the same direction. [4]

3. O/N 17/P42/Q7

A particle starts from rest and moves in a straight line. The velocity of the particle at time t s after the start is $v\,\text{m s}^{-1}$, where

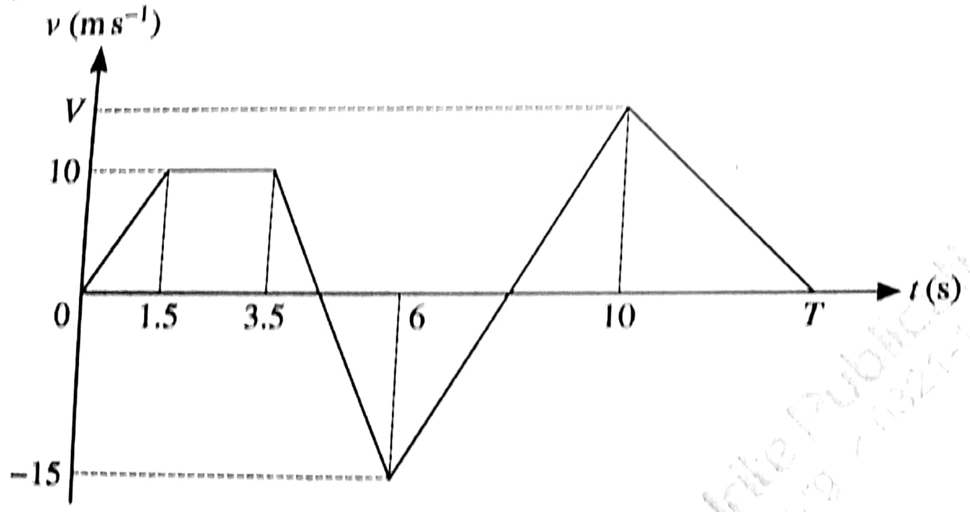
$$v = -0.01t^3 + 0.22t^2 - 0.4t.$$

(i) Find the two positive values of t for which the particle is instantaneously at rest. [2]

(ii) Find the time at which the acceleration of the particle is greatest. [3]

(iii) Find the distance travelled by the particle while its velocity is positive. [4]

4. O/N 17/P41/Q4



The diagram shows the velocity-time graph of a particle which moves in a straight line. The graph consists of 5 straight line segments. The particle starts from rest at a point A at time $t = 0$, and initially travels towards point B on the line.

(i) Show that the acceleration of the particle between $t = 3.5$ and $t = 6$ is $-10\,\text{m s}^{-2}$. [1]

(ii) The acceleration of the particle between $t = 6$ and $t = 10$ is $7.5\,\text{m s}^{-2}$. When $t = 10$ the velocity of the particle is $V\,\text{m s}^{-1}$. Find the value of V. [2]

(iii) The particle comes to rest at B at time T s. Given that the total distance travelled by the particle between $t = 0$ and $t = T$ is 100 m, find the value of T. [4]

5. O/N 17/P41/Q5

A particle starts from a point O and moves in a straight line. The velocity of the particle at time t s after leaving O is $v\,\text{m s}^{-1}$, where

$$v = 1.5 + 0.4t \quad \text{for } 0 \leqslant t \leqslant 5,$$

$$v = \frac{100}{t^2} - 0.1t \quad \text{for } t \geqslant 5.$$

(i) Find the acceleration of the particle during the first 5 seconds of motion. [1]

(ii) Find the value of t when the particle is instantaneously at rest. [2]

(iii) Find the total distance travelled by the particle in the first 10 seconds of motion. [5]

6. O/N 17/P43/Q5

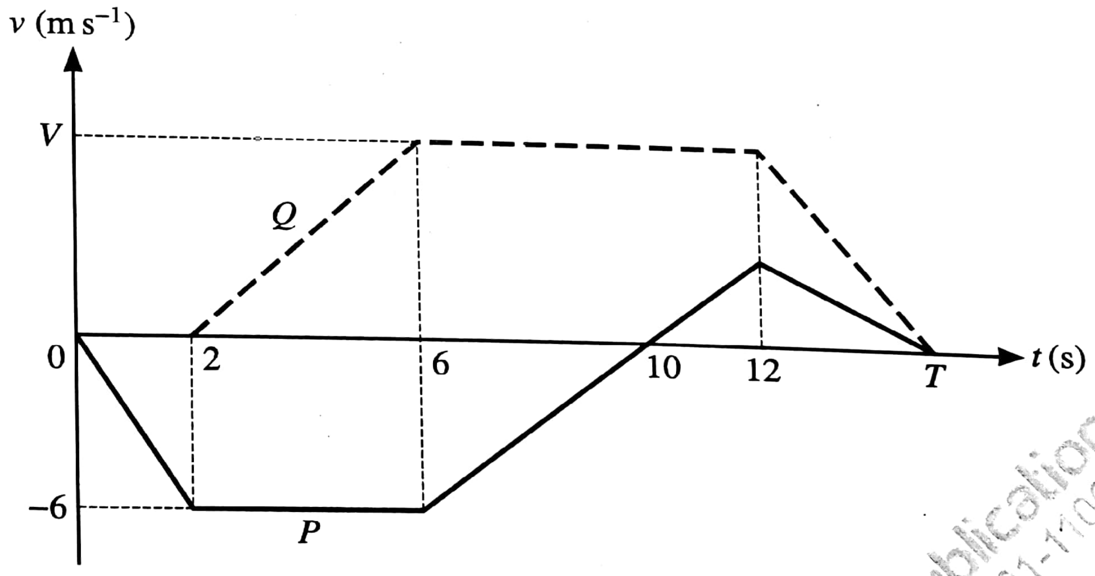
A particle starts from a fixed origin with velocity $0.4\,\text{m s}^{-1}$ and moves in a straight line. The acceleration $a\,\text{m s}^{-2}$ of the particle t s after it leaves the origin is given by $a = k(3t^2 - 12t + 2)$, where k is a constant. When $t = 1$, the velocity of P is $0.1\,\text{m s}^{-1}$.

(i) Show that the value of k is 0.1. [5]

(ii) Find an expression for the displacement of the particle from the origin in terms of t. [2]

(iii) Hence verify that the particle is again at the origin at $t = 2$. [1]

7. O/N 17/P43/Q6



The diagram shows the velocity-time graphs for two particles, P and Q, which are moving in the same straight line. The graph for P consists of four straight line segments. The graph for Q consists of three straight line segments. Both particles start from the same initial position O on the line. Q starts 2 seconds after P and both particles come to rest at time $t = T$. The greatest velocity of Q is $V\,\text{m s}^{-1}$.

(i) Find the displacement of P from O at $t = 10$. [1]

(ii) Find the velocity of P at $t = 12$. [2]

(iii) Given that the total distance covered by P during the T seconds of its motion is 49.5 m, find the value of T. [3]

(iv) Given also that the acceleration of Q from $t = 2$ to $t = 6$ is $1.75\,\text{m s}^{-2}$, find the value of V and hence find the distance between the two particles when they both come to rest at $t = T$. [3]

8. M/J 17/P42/Q3

A particle A moves in a straight line with constant speed $10\,\text{m s}^{-1}$. Two seconds after A passes a point O on the line, a particle B passes through O, moving along the line in the same direction as A. Particle B has speed $16\,\text{m s}^{-1}$ at O and has a constant deceleration of $2\,\text{m s}^{-2}$.

(i) Find expressions, in terms of t, for the displacement from O of each particle t s after B passes through O. [3]

(ii) Find the distance between the particles when B comes to instantaneous rest. [3]

(iii) Find the minimum distance between the particles. [3]

9. M/J 17/P41/Q5

A particle P moves in a straight line $ABCD$ with constant deceleration. The velocities of P at A, B and C are $20\,\text{m s}^{-1}$, $12\,\text{m s}^{-1}$ and $6\,\text{m s}^{-1}$ respectively.

(i) Find the ratio of distances $AB : BC$. [4]

(ii) The particle comes to rest at D. Given that the distance AD is 80 m, find the distance BC. [3]

10. M/J 17/P41/Q6

A particle P moves in a straight line passing through a point O. At time t s, the velocity of P, $v\,\text{m s}^{-1}$, is given by $v = qt + rt^2$, where q and r are constants. The particle has velocity $4\,\text{m s}^{-1}$ when $t = 1$ and when $t = 2$.

(i) Show that, when $t = 0.5$, the acceleration of P is $4\,\text{m s}^{-2}$. [4]

(ii) Find the values of t when P is at instantaneous rest. [2]

(iii) The particle is at O when $t = 3$. Find the distance of P from O when $t = 0$. [4]

11. M/J 17/P43/Q3

A train travels between two stations, A and B. The train starts from rest at A and accelerates at a constant rate for T s until it reaches a speed of $25\,\text{m s}^{-1}$. It then travels at this constant speed before decelerating at a constant rate, coming to rest at B. The magnitude of the train's deceleration is twice the magnitude of its acceleration. The total time taken for the journey is 180 s.

(i) Sketch the velocity-time graph for the train's journey from A to B. [1]

(ii) Find an expression, in terms of T, for the length of time for which the train is travelling with constant speed. [2]

(iii) The distance from A to B is 3300 m. Find how far the train travels while it is decelerating. [3]

12. M/J 17/P43/Q4

A particle P moves in a straight line starting from a point O. At time t s after leaving O, the velocity, $v\,\mathrm{m\,s^{-1}}$, of P is given by $v = (2t - 5)^3$.

(i) Find the values of t when the acceleration of P is $54\,\mathrm{m\,s^{-2}}$. [3]

(ii) Find an expression for the displacement of P from O at time t s. [3]

13. M/J 17/P43/Q5

A particle is projected vertically upwards from a point O with a speed of $12\,\mathrm{m\,s^{-1}}$. Two seconds later a second particle is projected vertically upwards from O with a speed of $20\,\mathrm{m\,s^{-1}}$. At time t s after the second particle is projected, the two particles collide.

(i) Find t. [5]

(ii) Hence find the height above O at which the particles collide. [1]

14. O/N 16/P42/Q1

A particle of mass 2 kg is initially at rest on a rough horizontal plane. A force of magnitude 10 N is applied to the particle at 15° above the horizontal. It is given that 10 s after the force is applied, the particle has a speed of $3.5\,\mathrm{m\,s^{-1}}$.

(i) Show that the magnitude of the frictional force is 8.96 N, correct to 3 significant figures. [3]

(ii) Find the coefficient of friction between the particle and the plane. [3]

15. O/N 16/P42/Q2

A particle moves in a straight line. Its displacement t s after leaving a fixed point O on the line is s m, where $s = 2t^2 - \frac{80}{3}t^{\frac{3}{2}}$.

(i) Find the time at which the acceleration of the particle is zero. [4]

(ii) Find the displacement and velocity of the particle at this instant. [2]

16. O/N 16/P42/Q4

A girl on a sledge starts, with a speed of $5\,\mathrm{m\,s^{-1}}$, at the top of a slope of length 100 m which is at an angle of 20° to the horizontal. The sledge slides directly down the slope.

(i) Given that there is no resistance to the sledge's motion, find the speed of the sledge at the bottom of the slope. [3]

(ii) It is given instead that the sledge experiences a resistance to motion such that the total work done against the resistance is 8500 J, and the speed of the sledge at the bottom of the slope is $21\,\mathrm{m\,s^{-1}}$. Find the total mass of the girl and the sledge. [3]

17. O/N 16/P42/Q7

A car starts from rest and moves in a straight line from point A with constant acceleration $3\,\mathrm{m\,s^{-2}}$ for 10 s. The car then travels at constant speed for 30 s before decelerating uniformly, coming to rest at point B. The distance AB is 1.5 km.

(i) Find the total distance travelled in the first 40 s of motion. [3]

When the car has been moving for 20 s, a motorcycle starts from rest and accelerates uniformly in a straight line from point A to a speed $V\,\mathrm{m\,s^{-1}}$. It then maintains this speed for 30 s before decelerating uniformly to rest at point B. The motorcycle comes to rest at the same time as the car.

(ii) Given that the magnitude of the acceleration $a\,\mathrm{m\,s^{-2}}$ of the motorcycle is three times the magnitude of its deceleration, find the value of a. [6]

(iii) Sketch the displacement-time graph for the motion of the car. [3]

18. O/N 16/P41/Q2

A particle of mass 0.1 kg is released from rest on a rough plane inclined at 20° to the horizontal. It is given that, 5 seconds after release, the particle has a speed of $2\,\text{m s}^{-1}$.

(i) Find the acceleration of the particle and hence show that the magnitude of the frictional force acting on the particle is 0.302 N, correct to 3 significant figures. [3]

(ii) Find the coefficient of friction between the particle and the plane. [2]

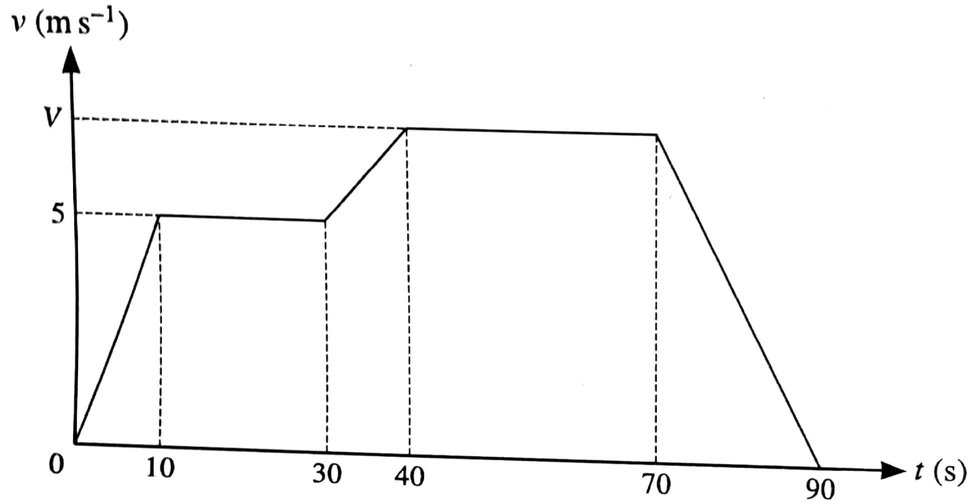
19. O/N 16/P41/Q3

A particle P is projected vertically upwards from a point O. When the particle is at a height of 0.5 m, its speed is $6\,\text{m s}^{-1}$. Find

(i) the greatest height reached by the particle above O, [3]

(ii) the time after projection at which the particle returns to O. [3]

20. O/N 16/P41/Q5



The diagram shows a velocity-time graph which models the motion of a cyclist. The graph consists of five straight line segments. The cyclist accelerates from rest to a speed of $5\,\text{m s}^{-1}$ over a period of 10 s, and then travels at this speed for a further 20 s. The cyclist then descends a hill, accelerating to speed $V\,\text{m s}^{-1}$ over a period of 10 s. This speed is maintained for a further 30 s. The cyclist then decelerates to rest over a period of 20 s.

(i) Find the acceleration of the cyclist during the first 10 seconds. [1]

(ii) Show that the total distance travelled by the cyclist in the 90 seconds of motion may be expressed as $(45V + 150)$ m. Hence find V, given that the total distance travelled by the cyclist is 465 m. [3]

(iii) The combined mass of the cyclist and the bicycle is 80 kg. The cyclist experiences a constant resistance to motion of 20 N. Use an energy method to find the vertical distance which the cyclist descends during the downhill section from $t = 30$ to $t = 40$, assuming that the cyclist does no work during this time. [4]

21. O/N 16/P41/Q7

A racing car is moving in a straight line. The acceleration $a\,\text{m s}^{-2}$ at time t s after the car starts from rest is given by

$$a = 15t - 3t^2 \qquad \text{for } 0 \leqslant t \leqslant 5,$$

$$a = -\frac{625}{t^2} \qquad \text{for } 5 < t \leqslant k,$$

where k is a constant.

(i) Find the maximum acceleration of the car in the first five seconds of its motion. [3]

(ii) Find the distance of the car from its starting point when $t = 5$. [3]

(iii) The car comes to rest when $t = k$. Find the value of k. [5]

22. O/N 16/P43/Q4

A ball A is released from rest at the top of a tall tower. One second later, another ball B is projected vertically upwards from ground level near the bottom of the tower with a speed of $20\,\text{m s}^{-1}$. The two balls are at the same height 1.5 s after ball B is projected.

(i) Show that the height of the tower is 50 m. [3]

(ii) Find the length of time for which ball B has been in motion when ball A reaches the ground. Hence find the total distance travelled by ball B up to the instant when ball A reaches the ground. [5]

23. O/N 16/P43/Q5

A particle P starts from a fixed point O and moves in a straight line. At time t s after leaving O, the velocity $v\,\text{m s}^{-1}$ of P is given by $v = 6t - 0.3t^2$. The particle comes to instantaneous rest at point X.

(i) Find the distance OX. [4]

A second particle Q starts from rest from O, at the same instant as P, and also travels in a straight line. The acceleration $a\,\text{m s}^{-2}$ of Q is given by $a = k - 12t$, where k is a constant. The displacement of Q from O is 400 m when $t = 10$.

(ii) Find the value of k. [4]

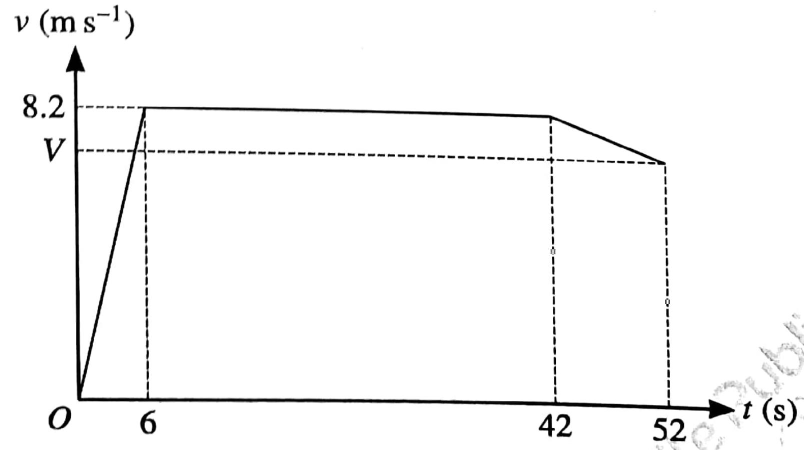
24. M/J 16/P42/Q2

A particle P moves in a straight line, starting from a point O. At time t s after leaving O, the velocity of P, $v\,\text{m s}^{-1}$, is given by $v = 4t^2 - 8t + 3$.

(i) Find the two values of t at which P is at instantaneous rest. [2]

(ii) Find the distance travelled by P between these two times. [3]

25. M/J 16/P42/Q4



A sprinter runs a race of 400 m. His total time for running the race is 52 s. The diagram shows the velocity-time graph for the motion of the sprinter. He starts from rest and accelerates uniformly to a speed of $8.2\,\text{m s}^{-1}$ in 6 s. The sprinter maintains a speed of $8.2\,\text{m s}^{-1}$ for 36 s, and he then decelerates uniformly to a speed of $V\,\text{m s}^{-1}$ at the end of the race.

(i) Calculate the distance covered by the sprinter in the first 42 s of the race. [2]

(ii) Show that $V = 7.84$. [3]

(iii) Calculate the deceleration of the sprinter in the last 10 s of the race. [2]

26. M/J 16/P41/Q1

A lift moves upwards from rest and accelerates at $0.9\,\text{m}\,\text{s}^{-2}$ for 3 s. The lift then travels for 6 s at constant speed and finally slows down, with a constant deceleration, stopping in a further 4 s.

(i) Sketch a velocity-time graph for the motion. [3]

(ii) Find the total distance travelled by the lift. [2]

27. M/J 16/P41/Q7

A particle of mass 30 kg is on a plane inclined at an angle of 20° to the horizontal. Starting from rest, the particle is pulled up the plane by a force of magnitude 200 N acting parallel to a line of greatest slope.

(i) Given that the plane is smooth, find

(a) the acceleration of the particle, [2]

(b) the change in kinetic energy after the particle has moved 12 m up the plane. [2]

(ii) It is given instead that the plane is rough and the coefficient of friction between the particle and the plane is 0.12.

(a) Find the acceleration of the particle. [4]

(b) The direction of the force of magnitude 200 N is changed, and the force now acts at an angle of 10° above the line of greatest slope. Find the acceleration of the particle. [4]

28. M/J 16/P43/Q2

Alan starts walking from a point O, at a constant speed of $4\,\text{m}\,\text{s}^{-1}$, along a horizontal path. Ben walks along the same path, also starting from O. Ben starts from rest 5 s after Alan and accelerates at $1.2\,\text{m}\,\text{s}^{-2}$ for 5 s. Ben then continues to walk at a constant speed until he is at the same point, P, as Alan.

(i) Find how far Ben has travelled when he has been walking for 5 s and find his speed at this instant. [2]

(ii) Find the distance OP. [3]

29. M/J 16/P43/Q7

A particle P moves in a straight line. At time t s, the displacement of P from O is s m and the acceleration of P is $a\,\text{m}\,\text{s}^{-2}$, where $a = 6t - 2$. When $t = 1$, $s = 7$ and when $t = 3$, $s = 29$.

(i) Find the set of values of t for which the particle is decelerating. [2]

(ii) Find s in terms of t. [5]

(iii) Find the time when the velocity of the particle is $10\,\text{m}\,\text{s}^{-1}$. [3]

30. **O/N 15/P42/Q2**

A particle is released from rest at a point H m above horizontal ground and falls vertically. The particle passes through a point 35 m above the ground with a speed of $(V - 10)\ \text{m s}^{-1}$ and reaches the ground with a speed of $V\ \text{m s}^{-1}$. Find

(i) the value of V, [3]

(ii) the value of H. [2]

31. **O/N 15/P42/Q3**

A particle P moves along a straight line for 100 s. It starts at a point O and at time t seconds after leaving O the velocity of P is $v\ \text{m s}^{-1}$, where

$$v = 0.000\,04t^3 - 0.006t^2 + 0.288t.$$

(i) Find the values of t at which the acceleration of P is zero. [3]

(ii) Find the displacement of P from O when $t = 100$. [3]

32. **O/N 15/P42/Q7**

A car of mass 1600 kg moves with constant power 14 kW as it travels along a straight horizontal road. The car takes 25 s to travel between two points A and B on the road.

(i) Find the work done by the car's engine while the car travels from A to B. [2]

The resistance to the car's motion is constant and equal to 235 N. The car has accelerations at A and B of $0.5\ \text{m s}^{-2}$ and $0.25\ \text{m s}^{-2}$ respectively. Find

(ii) the gain in kinetic energy by the car in moving from A to B, [5]

(iii) the distance AB. [3]

33. **O/N 15/P41/Q2**

A particle of mass 0.5 kg starts from rest and slides down a line of greatest slope of a smooth plane. The plane is inclined at an angle of 30° to the horizontal.

(i) Find the time taken for the particle to reach a speed of $2.5\ \text{m s}^{-1}$. [3]

When the particle has travelled 3 m down the slope from its starting point, it reaches rough horizontal ground at the bottom of the slope. The frictional force acting on the particle is 1 N.

(ii) Find the distance that the particle travels along the ground before it comes to rest. [3]

34. **O/N 15/P41/Q6**

A particle P moves in a straight line, starting from a point O. The velocity of P, measured in m s^{-1}, at time t s after leaving O is given by

$$v = 0.6t - 0.03t^2.$$

(i) Verify that, when $t = 5$, the particle is 6.25 m from O. Find the acceleration of the particle at this time. [4]

(ii) Find the values of t at which the particle is travelling at half of its maximum velocity. [6]

35. O/N 15/P41/Q7

A cyclist starts from rest at point A and moves in a straight line with acceleration $0.5\,\text{m s}^{-2}$ for a distance of 36 m. The cyclist then travels at constant speed for 25 s before slowing down, with constant deceleration, to come to rest at point B. The distance AB is 210 m.

(i) Find the total time that the cyclist takes to travel from A to B. [5]

24 s after the cyclist leaves point A, a car starts from rest from point A, with constant acceleration $4\,\text{m s}^{-2}$, towards B. It is given that the car overtakes the cyclist while the cyclist is moving with constant speed.

(ii) Find the time that it takes from when the cyclist starts until the car overtakes her. [5]

36. O/N 15/P43/Q5

A cyclist and his bicycle have a total mass of 90 kg. The cyclist starts to move with speed $3\,\text{m s}^{-1}$ from the top of a straight hill, of length 500 m, which is inclined at an angle of $\sin^{-1} 0.05$ to the horizontal. The cyclist moves with constant acceleration until he reaches the bottom of the hill with speed $5\,\text{m s}^{-1}$. The cyclist generates 420 W of power while moving down the hill. The resistance to the motion of the cyclist and his bicycle, R N, and the cyclist's speed, $v\,\text{m s}^{-1}$, both vary.

(i) Show that $R = \dfrac{420}{v} + 43.56$. [5]

(ii) Find the cyclist's speed at the mid-point of the hill. Hence find the decrease in the value of R when the cyclist moves from the top of the hill to the mid-point of the hill, and when the cyclist moves from the mid-point of the hill to the bottom of the hill. [3]

37. O/N 15/P43/Q6

A particle P starts from rest at a point O of a straight line and moves along the line. The displacement of the particle at time t s after leaving O is x m, where

$$x = 0.08t^2 - 0.0002t^3.$$

(i) Find the value of t when P returns to O and find the speed of P as it passes through O on its return. [4]

(ii) For the motion of P until the instant it returns to O, find

(a) the total distance travelled, [3]

(b) the average speed. [2]

38. M/J 15/P42/Q4

A particle P moves in a straight line. At time t seconds after starting from rest at the point O on the line, the acceleration of P is $a\,\text{m s}^{-2}$, where $a = 0.075t^2 - 1.5t + 5$.

(i) Find an expression for the displacement of P from O in terms of t. [4]

(ii) Hence find the time taken for P to return to the point O. [3]

39. M/J 15/P42/Q5

A particle P starts from rest at a point O on a horizontal straight line. P moves along the line with constant acceleration and reaches a point A on the line with a speed of $30\,\text{m s}^{-1}$. At the instant that P leaves O, a particle Q is projected vertically upwards from the point A with a speed of $20\,\text{m s}^{-1}$. Subsequently P and Q collide at A. Find

(i) the acceleration of P, [4]

(ii) the distance OA. [2]

40. M/J 15/P41/Q6

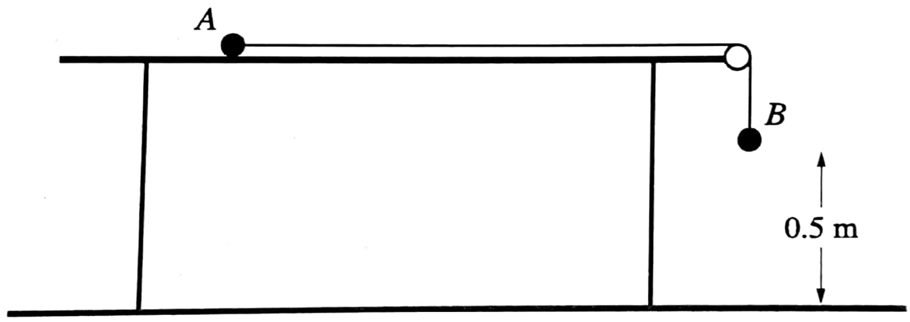
Two particles A and B start to move at the same instant from a point O. The particles move in the same direction along the same straight line. The acceleration of A at time t s after starting to move is $a\,\text{m s}^{-2}$, where $a = 0.05 - 0.0002t$.

(i) Find A's velocity when $t = 200$ and when $t = 500$. [4]

B moves with constant acceleration for the first 200 s and has the same velocity as A when $t = 200$. B moves with constant retardation from $t = 200$ to $t = 500$ and has the same velocity as A when $t = 500$.

(ii) Find the distance between A and B when $t = 500$. [6]

41. M/J 15/P43/Q7



Particles A and B, of masses 0.3 kg and 0.7 kg respectively, are attached to the ends of a light inextensible string. Particle A is held at rest on a rough horizontal table with the string passing over a smooth pulley fixed at the edge of the table. The coefficient of friction between A and the table is 0.2. Particle B hangs vertically below the pulley at a height of 0.5 m above the floor (see diagram). The system is released from rest and 0.25 s later the string breaks. A does not reach the pulley in the subsequent motion. Find

(i) the speed of B immediately before it hits the floor, [9]

(ii) the total distance travelled by A. [3]

2. O/N 14/P42/Q1

A particle P is projected vertically upwards with speed $11\,\text{m s}^{-1}$ from a point on horizontal ground. At the same instant a particle Q is released from rest at a point h m above the ground. P and Q hit the ground at the same instant, when Q has speed $V\,\text{m s}^{-1}$.

(i) Find the time after projection at which P hits the ground. [2]

(ii) Hence find the values of h and V. [2]

43. O/N 14/P42/Q6

ABC is a line of greatest slope of a plane inclined at angle α to the horizontal, where $\sin\alpha = 0.28$ and $\cos\alpha = 0.96$. The point A is at the top of the plane, the point C is at the bottom of the plane and the length of AC is 5 m. The part of the plane above the level of B is smooth and the part below the level of B is rough. A particle P is released from rest at A and reaches C with a speed of $2\,\text{m s}^{-1}$. The coefficient of friction between P and the part of the plane below B is 0.5. Find

(i) the acceleration of P while moving

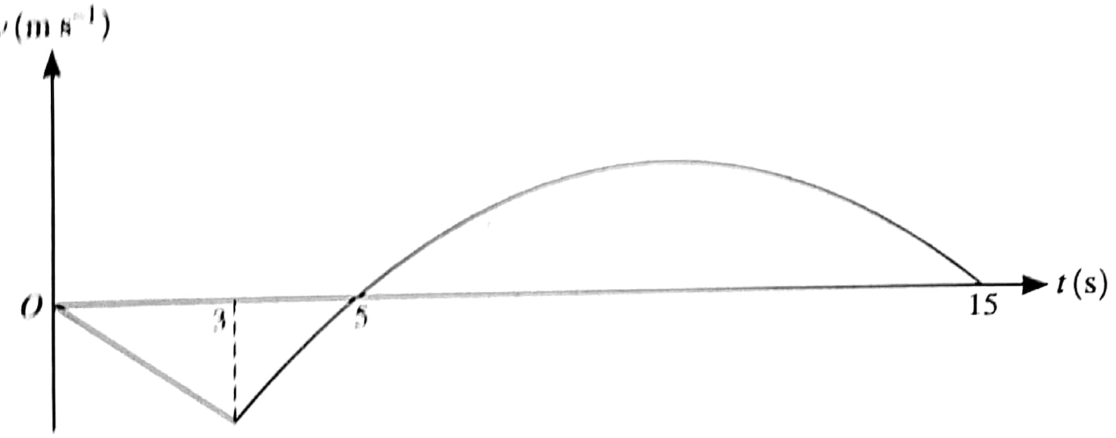
(a) from A to B,

(b) from B to C, [3]

(ii) the distance AB, [3]

(iii) the time taken for P to move from A to C. [3]

44. O/N 14/P42/Q7



The diagram shows the velocity-time graph for the motion of a particle P which moves on a straight line BAC. It starts at A and travels to B taking 5 s. It then reverses direction and travels from B to C taking 10 s. For the first 3 s of P's motion its acceleration is constant. For the remaining 12 s the velocity of P is $v\,\text{m s}^{-1}$ at time t s after leaving A, where

$$v = -0.2t^2 + 4t - 15 \quad \text{for } 3 \leqslant t \leqslant 15.$$

(i) Find the value of v when $t = 3$ and the magnitude of the acceleration of P for the first 3 s of its motion. [3]

(ii) Find the maximum velocity of P while it is moving from B to C. [3]

(iii) Find the average speed of P,

(a) while moving from A to B,

(b) for the whole journey. [6]

45. O/N 14/P41/Q4

Particles P and Q move on a straight line AOB. The particles leave O simultaneously, with P moving towards A and with Q moving towards B. The initial speed of P is $1.3\,\mathrm{m\,s^{-1}}$ and its acceleration in the direction OA is $0.1\,\mathrm{m\,s^{-2}}$. Q moves with acceleration in the direction OB of $0.016t\,\mathrm{m\,s^{-2}}$, where t seconds is the time elapsed since the instant that P and Q started to move from O. When $t = 20$, particle P passes through A and particle Q passes through B.

(i) Given that the speed of Q at B is the same as the speed of P at A, find the speed of Q at time $t = 0$. [4]

(ii) Find the distance AB. [3]

46. O/N 14/P41/Q6

A particle of mass 3 kg falls from rest at a point 5 m above the surface of a liquid which is in a container. There is no instantaneous change in speed of the particle as it enters the liquid. The depth of the liquid in the container is 4 m. The downward acceleration of the particle while it is moving in the liquid is $5.5\,\mathrm{m\,s^{-2}}$.

(i) Find the resistance to motion of the particle while it is moving in the liquid. [2]

(ii) Sketch the velocity-time graph for the motion of the particle, from the time it starts to move until the time it reaches the bottom of the container. Show on your sketch the velocity and the time when the particle enters the liquid, and when the particle reaches the bottom of the container. [7]

47. O/N 14/P43/Q1

A car of mass 1400 kg moves on a horizontal straight road. The resistance to the car's motion is constant and equal to 800 N and the power of the car's engine is constant and equal to P W. At an instant when the car's speed is $18\,\mathrm{m\,s^{-1}}$ its acceleration is $0.5\,\mathrm{m\,s^{-2}}$.

(i) Find the value of P. [3]

The car continues and passes through another point with speed $25\,\mathrm{m\,s^{-1}}$.

(ii) Find the car's acceleration at this point. [2]

48. O/N 14/P43/Q4

A particle P starts from rest and moves in a straight line for 18 seconds. For the first 8 seconds of the motion P has constant acceleration $0.25\,\mathrm{m\,s^{-2}}$. Subsequently P's velocity, $v\,\mathrm{m\,s^{-1}}$ at time t seconds after the motion started, is given by

$$v = -0.1t^2 + 2.4t - k,$$

where $8 \leqslant t \leqslant 18$ and k is a constant.

(i) Find the value of v when $t = 8$ and hence find the value of k. [2]

(ii) Find the maximum velocity of P. [2]

(iii) Find the displacement of P from its initial position when $t = 18$. [3]

49. M/J 14/P42/Q2

A and B are two points which are 10 m apart on the same horizontal plane. A particle P starts to move from rest at A, directly towards B, with constant acceleration 0.5 m s^{-2}. Another particle Q is moving directly towards A with constant speed 0.75 m s^{-1}, and passes through B at the instant that P starts to move. At time T s after this instant, particles P and Q collide. Find

(i) the value of T, [4]

(ii) the speed of P immediately before the collision. [1]

50. M/J 14/P42/Q4

A particle P moves on a straight line, starting from rest at a point O of the line. The time after P starts to move is t s, and the particle moves along the line with constant acceleration $\frac{1}{4}\text{ m s}^{-2}$ until it passes through a point A at time $t = 8$. After passing through A the velocity of P is $\frac{1}{2}t^{\frac{2}{3}}\text{ m s}^{-1}$.

(i) Find the acceleration of P immediately after it passes through A. Hence show that the acceleration of P decreases by $\frac{1}{12}\text{ m s}^{-2}$ as it passes through A. [4]

(ii) Find the distance moved by P from $t = 0$ to $t = 27$. [3]

51. M/J 14/P42/Q6

A particle P of mass 0.2 kg is released from rest at a point 7.2 m above the surface of the liquid in a container. P falls through the air and into the liquid. There is no air resistance and there is no instantaneous change of speed as P enters the liquid. When P is at a distance of 0.8 m below the surface of the liquid, P's speed is 6 m s^{-1}. The only force on P due to the liquid is a constant resistance to motion of magnitude R N.

(i) Find the deceleration of P while it is falling through the liquid, and hence find the value of R. [5]

The depth of the liquid in the container is 3.6 m. P is taken from the container and attached to one end of a light inextensible string. P is placed at the bottom of the container and then pulled vertically upwards with constant acceleration. The resistance to motion of R N continues to act. The particle reaches the surface 4 s after leaving the bottom of the container.

(ii) Find the tension in the string. [4]

52. M/J 14/P41/Q4

A particle is projected vertically upwards with speed 9 m s^{-1} from a point 3.15 m above horizontal ground. The particle moves freely under gravity until it hits the ground. For the particle's motion from the instant of projection until the particle hits the ground, find the total distance travelled and the total time taken. [6]

53. M/J 14/P41/Q7

Two cyclists P and Q travel along a straight road ABC, starting simultaneously at A and arriving simultaneously at C. Both cyclists pass through B 400 s after leaving A. Cyclist P starts with speed 3 m s^{-1} and increases this speed with constant acceleration 0.005 m s^{-2} until he reaches B.

(i) Show that the distance AB is 1600 m and find P's speed at B. [3]

Cyclist Q travels from A to B with speed $v\text{ m s}^{-1}$ at time t seconds after leaving A, where

$$v = 0.04t - 0.0001t^2 + k,$$

and k is a constant.

(ii) Find the value of k and the maximum speed of Q before he has reached B. [6]

Cyclist P travels from B to C, a distance of 1400 m, at the speed he had reached at B. Cyclist Q travels from B to C with constant acceleration a m s^{-2}.

(iii) Find the time taken for the cyclists to travel from B to C and find the value of a. [4]

54. M/J 14/P43/Q6

A particle starts from rest at a point O and moves in a horizontal straight line. The velocity of the particle is v m s^{-1} at time t s after leaving O. For $0 \leqslant t < 60$, the velocity is given by

$$v = 0.05t - 0.0005t^2.$$

The particle hits a wall at the instant when $t = 60$, and reverses the direction of its motion. The particle subsequently comes to rest at the point A when $t = 100$, and for $60 < t \leqslant 100$ the velocity is given by

$$v = 0.025t - 2.5.$$

(i) Find the velocity of the particle immediately before it hits the wall, and its velocity immediately after its hits the wall. [2]

(ii) Find the total distance travelled by the particle. [4]

(iii) Find the maximum speed of the particle and sketch the particle's velocity-time graph for $0 \leqslant t \leqslant 100$, showing the value of t for which the speed is greatest. [4]

55. O/N 13/P42/Q5

A particle P moves in a straight line. P starts from rest at O and travels to A where it comes to rest, taking 50 seconds. The speed of P at time t seconds after leaving O is v m s^{-1}, where v is defined as follows.

For $0 \leqslant t \leqslant 5$, $\quad v = t - 0.1t^2$,

for $5 \leqslant t \leqslant 45$, $\quad v$ is constant,

for $45 \leqslant t \leqslant 50$, $\quad v = 9t - 0.1t^2 - 200$.

(i) Find the distance travelled by P in the first 5 seconds. [3]

(ii) Find the total distance from O to A, and deduce the average speed of P for the whole journey from O to A. [6]

56. O/N 13/P41/Q7

A particle P starts from rest at a point O and moves in a straight line. P has acceleration $0.6t$ m s^{-2} at time t seconds after leaving O, until $t = 10$.

(i) Find the velocity and displacement from O of P when $t = 10$. [5]

After $t = 10$, P has acceleration $-0.4t$ m s^{-2} until it comes to rest at a point A.

(ii) Find the distance OA. [7]

57. O/N 13/P43/Q5

A car travels in a straight line from A to B, a distance of 12 km, taking 552 seconds. The car starts from rest at A and accelerates for T_1 s at 0.3 m s^{-2}, reaching a speed of V m s^{-1}. The car then continues to move at V m s^{-1} for T_2 s. It then decelerates for T_3 s at 1 m s^{-2}, coming to rest at B.

(i) Sketch the velocity-time graph for the motion and express T_1 and T_3 in terms of V. [3]

(ii) Express the total distance travelled in terms of V and show that $13V^2 - 3312V + 72\,000 = 0$. Hence find the value of V. [5]

58. O/N 13/P43/Q7

A vehicle starts from rest at a point O and moves in a straight line. Its speed v m s^{-1} at time t seconds after leaving O is defined as follows.

$$\text{For } 0 \leqslant t \leqslant 60, \quad v = k_1 t - 0.005t^2,$$

$$\text{for } t \geqslant 60, \quad v = \frac{k_2}{\sqrt{t}}.$$

The distance travelled by the vehicle during the first 60 s is 540 m.

(i) Find the value of the constant k_1 and show that $k_2 = 12\sqrt{(60)}$. [5]

(ii) Find an expression in terms of t for the total distance travelled when $t \geqslant 60$. [2]

(iii) Find the speed of the vehicle when it has travelled a total distance of 1260 m. [3]

59. M/J 13/P42/Q6

A particle P moves in a straight line. It starts from rest at a point O and moves towards a point A on the line. During the first 8 seconds P's speed increases to 8 m s^{-1} with constant acceleration. During the next 12 seconds P's speed decreases to 2 m s^{-1} with constant deceleration. P then moves with constant acceleration for 6 seconds, reaching A with speed 6.5 m s^{-1}.

(i) Sketch the velocity-time graph for P's motion. [2]

The displacement of P from O, at time t seconds after P leaves O, is s metres.

(ii) Shade the region of the velocity-time graph representing s for a value of t where $20 \leqslant t \leqslant 26$. [1]

(iii) Show that, for $20 \leqslant t \leqslant 26$,

$$s = 0.375t^2 - 13t + 202.$$ [6]

60. M/J 13/P41/Q3

The top of a cliff is 40 metres above the level of the sea. A man in a boat, close to the bottom of the cliff, is in difficulty and fires a distress signal vertically upwards from sea level. Find

(i) the speed of projection of the signal given that it reaches a height of 5 m above the top of the cliff, [2]

(ii) the length of time for which the signal is above the level of the top of the cliff. [2]

The man fires another distress signal vertically upwards from sea level. This signal is above the level of the top of the cliff for $\sqrt{(17)}$ s.

(iii) Find the speed of projection of the second signal. [3]

61. M/J 13/P41/Q7

A car driver makes a journey in a straight line from A to B, starting from rest. The speed of the car increases to a maximum, then decreases until the car is at rest at B. The distance travelled by the car t seconds after leaving A is $0.000\,011\,7(400t^3 - 3t^4)$ metres.

(i) Find the distance AB. [3]

(ii) Find the maximum speed of the car. [4]

(iii) Find the acceleration of the car

(a) as it starts from A,

(b) as it arrives at B.

[2]

(iv) Sketch the velocity-time graph for the journey. [2]

62. M/J 13/P43/Q4

An aeroplane moves along a straight horizontal runway before taking off. It starts from rest at O and has speed $90\,\text{m s}^{-1}$ at the instant it takes off. While the aeroplane is on the runway at time t seconds after leaving O, its acceleration is $(1.5 + 0.012t)\,\text{m s}^{-2}$. Find

(i) the value of t at the instant the aeroplane takes off, [4]

(ii) the distance travelled by the aeroplane on the runway. [3]

63. M/J 13/P43/Q5

A particle P is projected vertically upwards from a point on the ground with speed $17\,\text{m s}^{-1}$. Another particle Q is projected vertically upwards from the same point with speed $7\,\text{m s}^{-1}$. Particle Q is projected T seconds later than particle P.

(i) Given that the particles reach the ground at the same instant, find the value of T. [2]

(ii) At a certain instant when both P and Q are in motion, P is 5 m higher than Q. Find the magnitude and direction of the velocity of each of the particles at this instant. [6]

64. O/N 12/P42/Q2

Particles A and B of masses m kg and $(1 - m)$ kg respectively are attached to the ends of a light inextensible string which passes over a fixed smooth pulley. The system is released from rest with the straight parts of the string vertical. A moves vertically downwards and 0.3 seconds later it has speed $0.6\,\text{m s}^{-1}$. Find

(i) the acceleration of A, [2]

(ii) the value of m and the tension in the string. [4]

65. O/N 12/P42/Q7

A particle P starts to move from a point O and travels in a straight line. The velocity of P is $k(60t^2 - t^3)$ m s^{-1} at time t s after leaving O, where k is a constant. The maximum velocity of P is 6.4 m s^{-1}.

(i) Show that $k = 0.0002$. [3]

P comes to instantaneous rest at a point A on the line. Find

(ii) the distance OA, [5]

(iii) the magnitude of the acceleration of P at A, [2]

(iv) the speed of P when it subsequently passes through O. [2]

66. O/N 12/P41/Q1

An object is released from rest at a height of 125 m above horizontal ground and falls freely under gravity, hitting a moving target P. The target P is moving on the ground in a straight line, with constant acceleration 0.8 m s^{-2}. At the instant the object is released P passes through a point O with speed 5 m s^{-1}. Find the distance from O to the point where P is hit by the object. [4]

67. O/N 12/P41/Q5

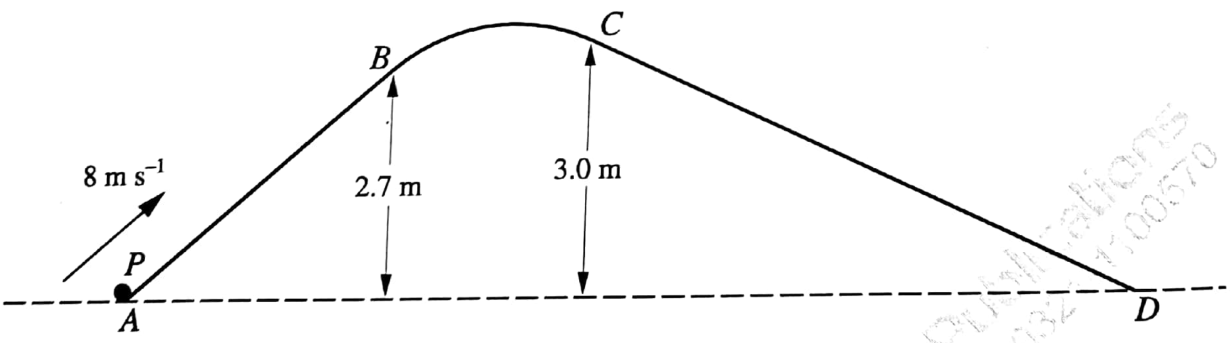
Particle P travels along a straight line from A to B with constant acceleration 0.05 m s^{-2}. Its speed at A is 2 m s^{-1} and its speed at B is 5 m s^{-1}.

(i) Find the time taken for P to travel from A to B, and find also the distance AB. [3]

Particle Q also travels along the same straight line from A to B, starting from rest at A. At time t s after leaving A, the speed of Q is kt^3 m s^{-1}, where k is a constant. Q takes the same time to travel from A to B as P does.

(ii) Find the value of k and find Q's speed at B. [5]

68. O/N 12/P41/Q6



The diagram shows the vertical cross-section $ABCD$ of a surface. BC is a circular arc, and AB and CD are tangents to BC at B and C respectively. A and D are at the same horizontal level, and B and C are at heights 2.7 m and 3.0 m respectively above the level of A and D. A particle P of mass 0.2 kg is given a velocity of 8 m s^{-1} at A, in the direction of AB (see diagram). The parts of the surface containing AB and BC are smooth.

(i) Find the decrease in the speed of P as P moves along the surface from B to C. [4]

The part of the surface containing CD exerts a constant frictional force on P, as it moves from C to D, and P comes to rest as it reaches D.

(ii) Find the speed of P when it is at the mid-point of CD. [5]

69. O/N 12/P43/Q2

A particle moves in a straight line. Its velocity t seconds after leaving a fixed point O on the line is $v\,\mathrm{m\,s^{-1}}$, where $v = 0.2t + 0.006t^2$. For the instant when the acceleration of the particle is 2.5 times its initial acceleration,

(i) show that $t = 25$, [3]

(ii) find the displacement of the particle from O. [3]

70. O/N 12/P43/Q3

A particle P is projected vertically upwards, from a point O, with a velocity of $8\,\mathrm{m\,s^{-1}}$. The point A is the highest point reached by P. Find

(i) the speed of P when it is at the mid-point of OA, [4]

(ii) the time taken for P to reach the mid-point of OA while moving upwards. [2]

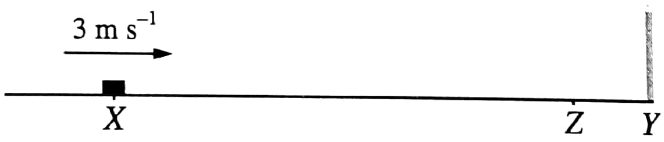
71. M/J 12/P42/Q3

A particle P moves in a straight line, starting from the point O with velocity $2\,\mathrm{m\,s^{-1}}$. The acceleration of P at time t s after leaving O is $2t^{\frac{2}{3}}\,\mathrm{m\,s^{-2}}$.

(i) Show that $t^{\frac{5}{3}} = \frac{5}{6}$ when the velocity of P is $3\,\mathrm{m\,s^{-1}}$. [4]

(ii) Find the distance of P from O when the velocity of P is $3\,\mathrm{m\,s^{-1}}$. [3]

72. M/J 12/P42/Q7



The frictional force acting on a small block of mass 0.15 kg, while it is moving on a horizontal surface, has magnitude 0.12 N. The block is set in motion from a point X on the surface, with speed $3\,\mathrm{m\,s^{-1}}$. It hits a vertical wall at a point Y on the surface 2 s later. The block rebounds from the wall and moves directly towards X before coming to rest at the point Z (see diagram). At the instant that the block hits the wall it loses 0.072 J of its kinetic energy. The velocity of the block, in the direction from X to Y, is $v\,\mathrm{m\,s^{-1}}$ at time t s after it leaves X.

(i) Find the values of v when the block arrives at Y and when it leaves Y, and find also the value of t when the block comes to rest at Z. Sketch the velocity-time graph. [9]

(ii) The displacement of the block from X, in the direction from X to Y, is s m at time t s. Sketch the displacement-time graph. Show on your graph the values of s and t when the block is at Y and when it comes to rest at Z. [4]

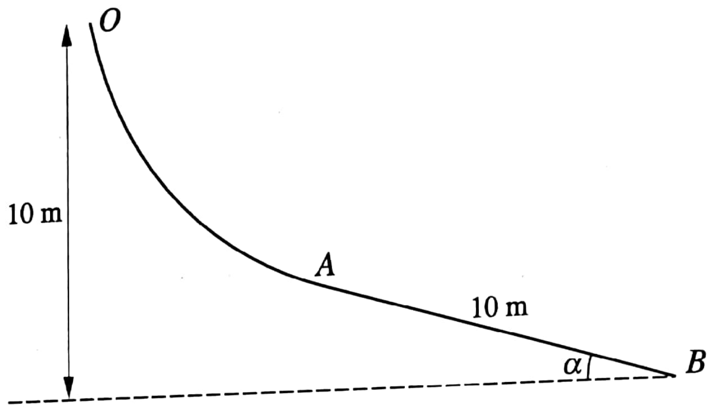
73. M/J 12/P41/Q4

A particle P starts at the point O and travels in a straight line. At time t seconds after leaving O the velocity of P is $v\,\text{m}\,\text{s}^{-1}$, where $v = 0.75t^2 - 0.0625t^3$. Find

(i) the positive value of t for which the acceleration is zero, [3]

(ii) the distance travelled by P before it changes its direction of motion. [5]

74. M/J 12/P41/Q5



The diagram shows the vertical cross-section OAB of a slide. The straight line AB is tangential to the curve OA at A. The line AB is inclined at α to the horizontal, where $\sin\alpha = 0.28$. The point O is 10 m higher than B, and AB has length 10 m (see diagram). The part of the slide containing the curve OA is smooth and the part containing AB is rough. A particle P of mass 2 kg is released from rest at O and moves down the slide.

(i) Find the speed of P when it passes through A. [3]

The coefficient of friction between P and the part of the slide containing AB is $\frac{1}{12}$. Find

(ii) the acceleration of P when it is moving from A to B, [3]

(iii) the speed of P when it reaches B. [2]

75. M/J 12/P43/Q3

A particle P travels from a point O along a straight line and comes to instantaneous rest at a point A. The velocity of P at time t s after leaving O is $v\,\text{m}\,\text{s}^{-1}$, where $v = 0.027(10t^2 - t^3)$. Find

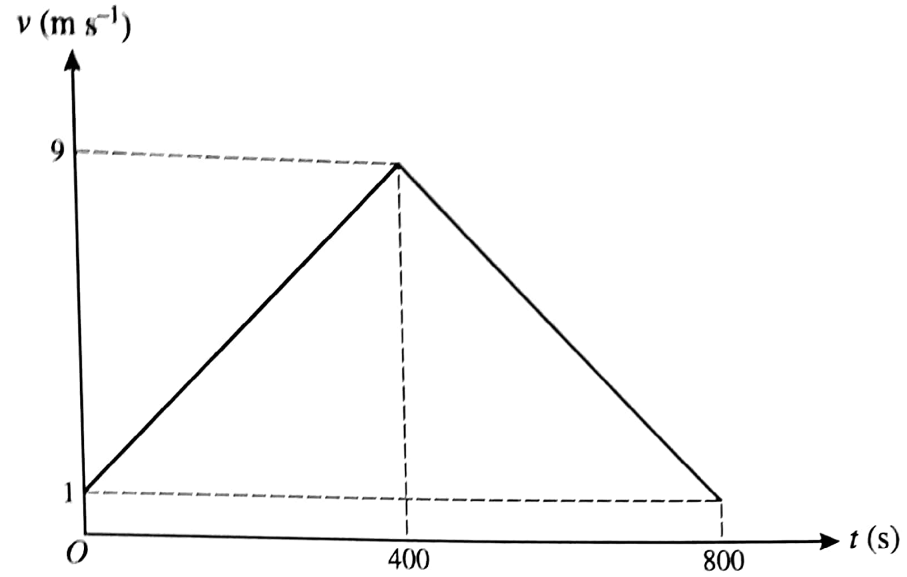
(i) the distance OA, [4]

(ii) the maximum velocity of P while moving from O to A. [3]

76. O/N 11/P42/Q7

A tractor travels in a straight line from a point A to a point B. The velocity of the tractor is $v \text{ m s}^{-1}$ at time t s after leaving A.

(i)



The diagram shows an approximate velocity-time graph for the motion of the tractor. The graph consists of two straight line segments. Use the graph to find an approximation for

(a) the distance AB, [2]

(b) the acceleration of the tractor for $0 < t < 400$ and for $400 < t < 800$. [2]

(ii) The actual velocity of the tractor is given by $v = 0.04t - 0.000\,05t^2$ for $0 \leqslant t \leqslant 800$.

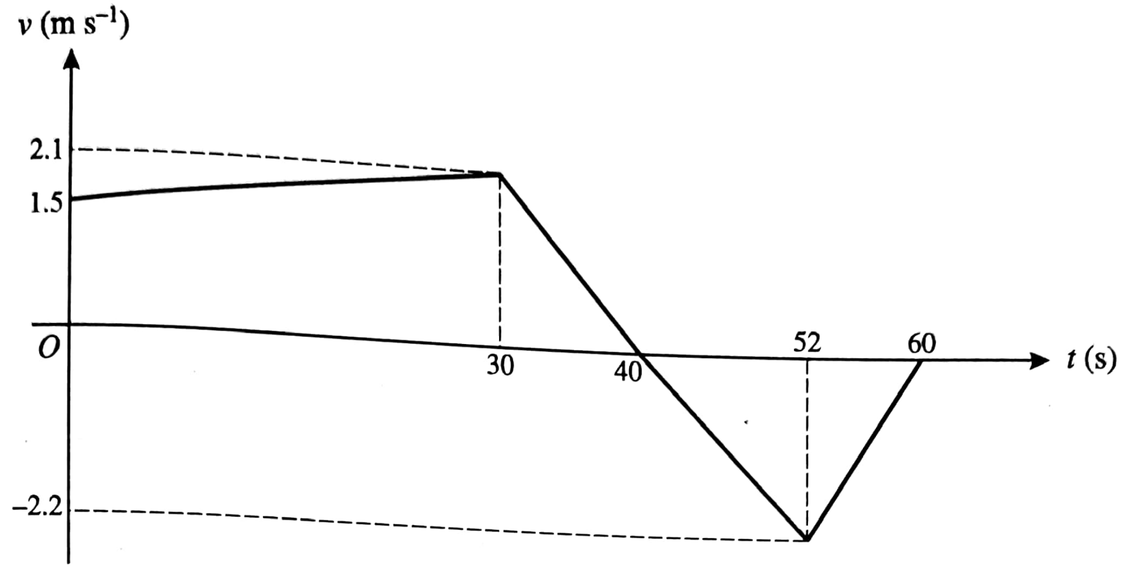
(a) Find the values of t for which the actual acceleration of the tractor is given correctly by the approximate velocity-time graph in part **(i)**. [3]

For the interval $0 \leqslant t \leqslant 400$, the approximate velocity of the tractor in part **(i)** is denoted by $v_1 \text{ m s}^{-1}$.

(b) Express v_1 in terms of t and hence show that $v_1 - v = 0.000\,05(t - 200)^2 - 1$. [2]

(c) Deduce that $-1 \leqslant v_1 - v \leqslant 1$. [2]

79. O/N 11/P43/Q1



A woman walks in a straight line. The woman's velocity t seconds after passing through a fixed point A on the line is $v\,\text{m s}^{-1}$. The graph of v against t consists of 4 straight line segments (see diagram). The woman is at the point B when $t = 60$. Find

(i) the woman's acceleration for $0 < t < 30$ and for $30 < t < 40$, [3]

(ii) the distance AB, [2]

(iii) the total distance walked by the woman. [1]

80. O/N 11/P43/Q5

A particle P moves in a straight line. It starts from rest at A and comes to rest instantaneously at B. The velocity of P at time t seconds after leaving A is $v\,\text{m s}^{-1}$, where $v = 6t^2 - kt^3$ and k is a constant.

(i) Find an expression for the displacement of P from A in terms of t and k. [2]

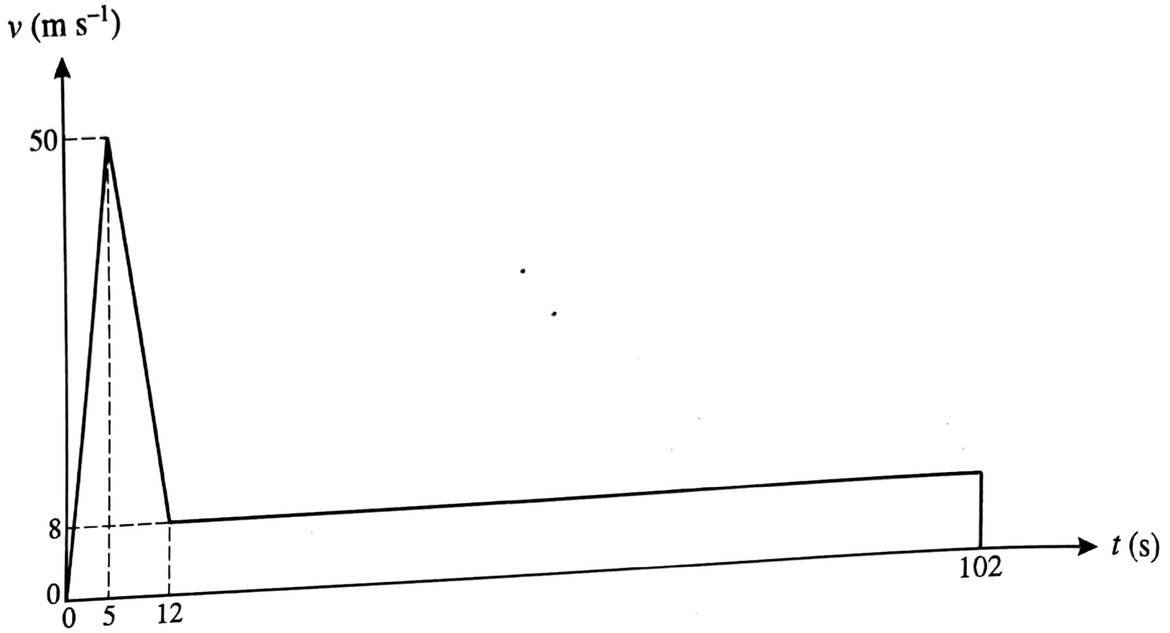
(ii) Find an expression for t in terms of k when P is at B. [1]

Given that the distance AB is 108 m, find

(iii) the value of k, [2]

(iv) the maximum value of v when the particle is moving from A towards B. [3]

81. M/J 11/P42/Q3



The velocity-time graph shown models the motion of a parachutist falling vertically. There are four stages in the motion:

- falling freely with the parachute closed,
- decelerating at a constant rate with the parachute open,
- falling with constant speed with the parachute open,
- coming to rest instantaneously on hitting the ground.

(i) Show that the total distance fallen is 1048 m. [2]

The weight of the parachutist is 850 N.

(ii) Find the upward force on the parachutist due to the parachute, during the second stage. [5]

82. M/J 11/P42/Q5

Two particles P and Q are projected vertically upwards from horizontal ground at the same instant. The speeds of projection of P and Q are $12\,\text{m s}^{-1}$ and $7\,\text{m s}^{-1}$ respectively and the heights of P and Q above the ground, t seconds after projection, are h_P m and h_Q m respectively. Each particle comes to rest on returning to the ground.

(i) Find the set of values of t for which the particles are travelling in opposite directions. [3]

(ii) At a certain instant, P and Q are above the ground and $3h_P = 8h_Q$. Find the velocities of P and Q at this instant. [5]

83. M/J 11/P42/Q7

A walker travels along a straight road passing through the points A and B on the road with speeds $0.9\,\text{m s}^{-1}$ and $1.3\,\text{m s}^{-1}$ respectively. The walker's acceleration between A and B is constant and equal to $0.004\,\text{m s}^{-2}$.

(i) Find the time taken by the walker to travel from A to B, and find the distance AB. [3]

A cyclist leaves A at the same instant as the walker. She starts from rest and travels along the straight road, passing through B at the same instant as the walker. At time t s after leaving A the cyclist's speed is kt^3 m s^{-1}, where k is a constant.

(ii) Show that when $t = 64.05$ the speed of the walker and the speed of the cyclist are the same, correct to 3 significant figures. [5]

(ii) Find the cyclist's acceleration at the instant she passes through B. [2]

84. M/J 11/P41/Q5

A train starts from rest at a station A and travels in a straight line to station B, where it comes to rest. The train moves with constant acceleration 0.025 m s^{-2} for the first 600 s, with constant speed for the next 2600 s, and finally with constant deceleration 0.0375 m s^{-2}.

(i) Find the total time taken for the train to travel from A to B. [4]

(ii) Sketch the velocity-time graph for the journey and find the distance AB. [3]

(iii) The speed of the train t seconds after leaving A is 7.5 m s^{-1}. State the possible values of t. [1]

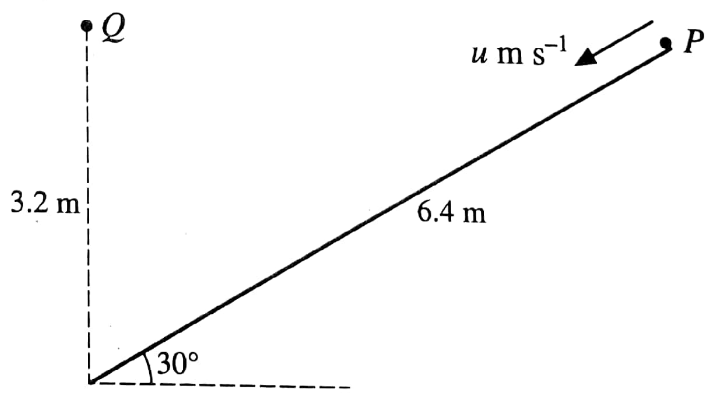
85. M/J 11/P41/Q6

A particle travels in a straight line from a point P to a point Q. Its velocity t seconds after leaving P is v m s^{-1}, where $v = 4t - \frac{1}{16}t^3$. The distance PQ is 64 m.

(i) Find the time taken for the particle to travel from P to Q. [5]

(ii) Find the set of values of t for which the acceleration of the particle is positive. [4]

86. M/J 11/P43/Q3

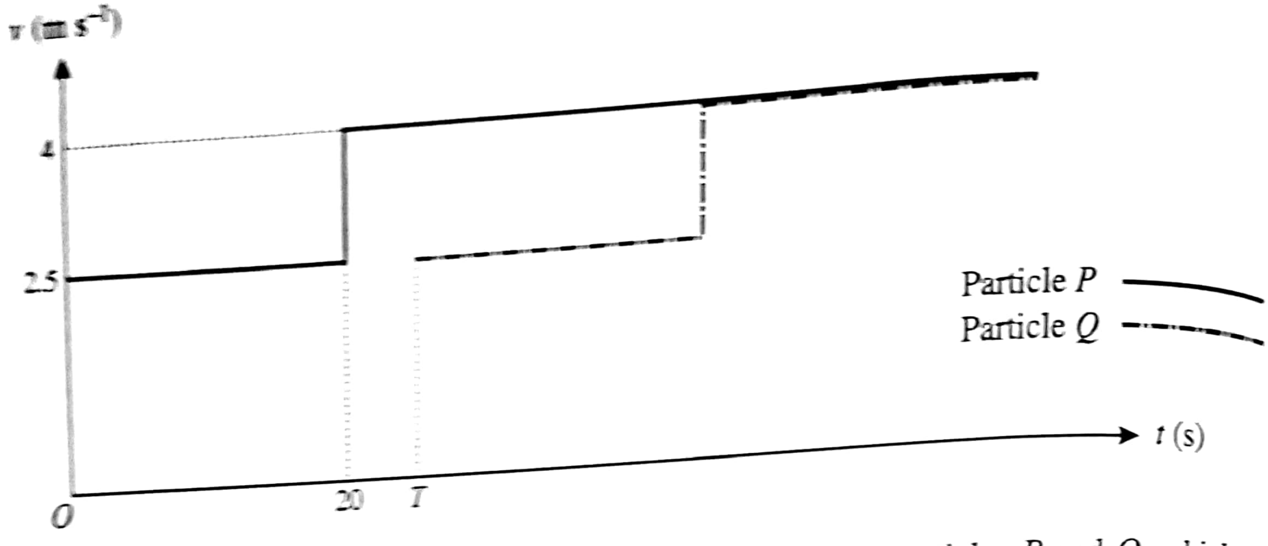


A particle P is projected from the top of a smooth ramp with speed u m s^{-1}, and travels down a line of greatest slope. The ramp has length 6.4 m and is inclined at 30° to the horizontal. Another particle Q is released from rest at a point 3.2 m vertically above the bottom of the ramp, at the same instant that P is projected (see diagram). Given that P and Q reach the bottom of the ramp simultaneously, find

(i) the value of u, [4]

(ii) the speed with which P reaches the bottom of the ramp. [2]

87. M/J 11/P43/Q4



The diagram shows the velocity-time graphs for the motion of two particles P and Q, which travel in the same direction along a straight line. P and Q both start at the same point X on the line, but Q starts to move T s later than P. Each particle moves with speed $2.5\,\text{m s}^{-1}$ for the first 20 s of its motion. The speed of each particle changes instantaneously to $4\,\text{m s}^{-1}$ after it has been moving for 20 s and the particle continues at this speed.

(i) Make a rough copy of the diagram and shade the region whose area represents the displacement of P from X at the instant when Q starts. [1]

It is given that P has travelled 70 m at the instant when Q starts.

(ii) Find the value of T. [2]

(iii) Find the distance between P and Q when Q's speed reaches $4\,\text{m s}^{-1}$. [2]

(iv) Sketch a single diagram showing the displacement-time graphs for both P and Q, with values shown on the t-axis at which the speed of either particle changes. [2]

88. M/J 11/P43/Q7

A particle travels in a straight line from A to B in 20 s. Its acceleration t seconds after leaving A is $a\,\text{m s}^{-2}$, where $a = \frac{3}{160}t^2 - \frac{1}{800}t^3$. It is given that the particle comes to rest at B.

(i) Show that the initial speed of the particle is zero. [4]

(ii) Find the maximum speed of the particle. [2]

(iii) Find the distance AB. [4]

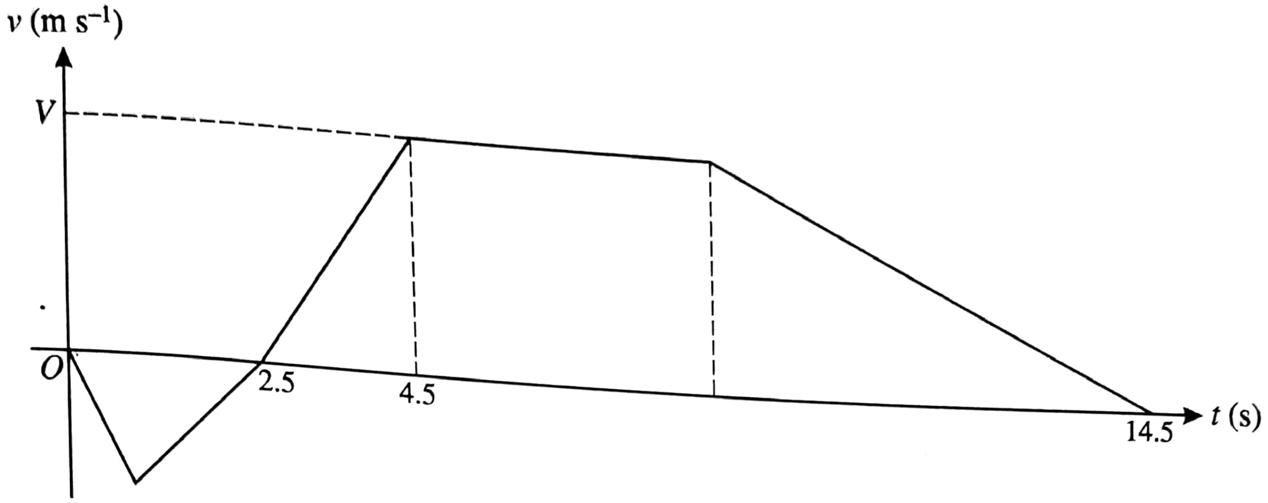
89. O/N 10/P42/Q5

Particles P and Q are projected vertically upwards, from different points on horizontal ground, with velocities of $20\,\text{m s}^{-1}$ and $25\,\text{m s}^{-1}$ respectively. Q is projected 0.4 s later than P. Find

(i) the time for which P's height above the ground is greater than 15 m, [3]

(ii) the velocities of P and Q at the instant when the particles are at the same height. [5]

90. O/N 10/P42/Q6



The diagram shows the velocity-time graph for a particle P which travels on a straight line AB, where $v\,\mathrm{m\,s^{-1}}$ is the velocity of P at time t s. The graph consists of five straight line segments. The particle starts from rest when $t = 0$ at a point X on the line between A and B and moves towards A. The particle comes to rest at A when $t = 2.5$.

(i) Given that the distance XA is 4 m, find the greatest speed reached by P during this stage of the motion. [2]

In the second stage, P starts from rest at A when $t = 2.5$ and moves towards B. The distance AB is 48 m. The particle takes 12 s to travel from A to B and comes to rest at B. For the first 2 s of this stage P accelerates at $3\,\mathrm{m\,s^{-2}}$, reaching a velocity of $V\,\mathrm{m\,s^{-1}}$. Find

(ii) the value of V, [2]

(iii) the value of t at which P starts to decelerate during this stage, [3]

(iv) the deceleration of P immediately before it reaches B. [2]

91. O/N 10/P42/Q7

A particle P travels in a straight line. It passes through the point O of the line with velocity $5\,\mathrm{m\,s^{-1}}$ at time $t = 0$, where t is in seconds. P's velocity after leaving O is given by

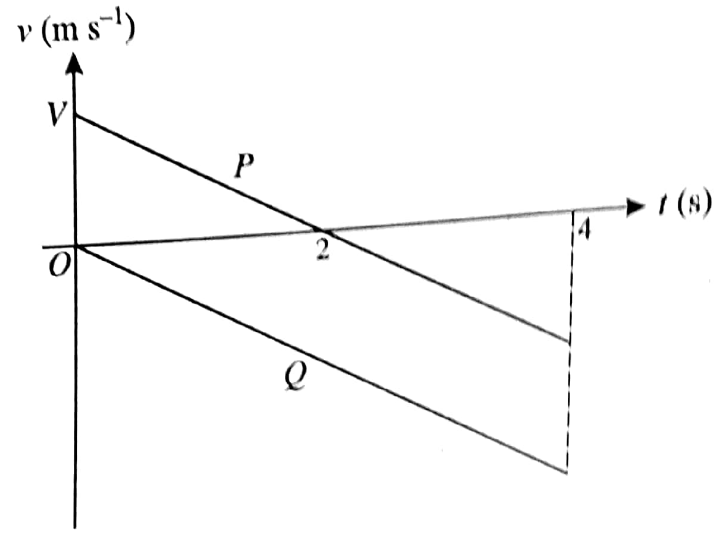
$$(0.002t^3 - 0.12t^2 + 1.8t + 5)\,\mathrm{m\,s^{-1}}.$$

The velocity of P is increasing when $0 < t < T_1$ and when $t > T_2$, and the velocity of P is decreasing when $T_1 < t < T_2$.

(i) Find the values of T_1 and T_2 and the distance OP when $t = T_2$. [7]

(ii) Find the velocity of P when $t = T_2$ and sketch the velocity-time graph for the motion of P. [3]

92. O/N 10/P41/Q1



Two particles P and Q move vertically under gravity. The graphs show the upward velocity v m s^{-1} of the particles at time t s, for $0 \leqslant t \leqslant 4$. P starts with velocity V m s^{-1} and Q starts from rest.

(i) Find the value of V. [2]

Given that Q reaches the horizontal ground when $t = 4$, find

(ii) the speed with which Q reaches the ground, [1]

(iii) the height of Q above the ground when $t = 0$. [2]

93. O/N 10/P41/Q4

A particle P starts from a fixed point O at time $t = 0$, where t is in seconds, and moves with constant acceleration in a straight line. The initial velocity of P is 1.5 m s^{-1} and its velocity when $t = 10$ is 3.5 m s^{-1}.

(i) Find the displacement of P from O when $t = 10$. [2]

Another particle Q also starts from O when $t = 0$ and moves along the same straight line as P. The acceleration of Q at time t is $0.03t$ m s^{-2}.

(ii) Given that Q has the same velocity as P when $t = 10$, show that it also has the same displacement from O as P when $t = 10$. [5]

94. O/N 10/P43/Q1

A particle P is released from rest at a point on a smooth plane inclined at 30° to the horizontal. Find the speed of P

(i) when it has travelled 0.9 m,

(ii) 0.8 s after it is released.

[4]

95. O/N 10/P43/Q4

A particle starts from rest at a point X and moves in a straight line until, 60 seconds later, it reaches a point Y. At time t s after leaving X, the acceleration of the particle is

$$0.75\,\text{m s}^{-2} \quad \text{for} \quad 0 < t < 4,$$
$$0\,\text{m s}^{-2} \quad \text{for} \quad 4 < t < 54,$$
$$-0.5\,\text{m s}^{-2} \quad \text{for} \quad 54 < t < 60.$$

(i) Find the velocity of the particle when $t = 4$ and when $t = 60$, and sketch the velocity-time graph. [5]

(ii) Find the distance XY. [2]

96. O/N 10/P43/Q6

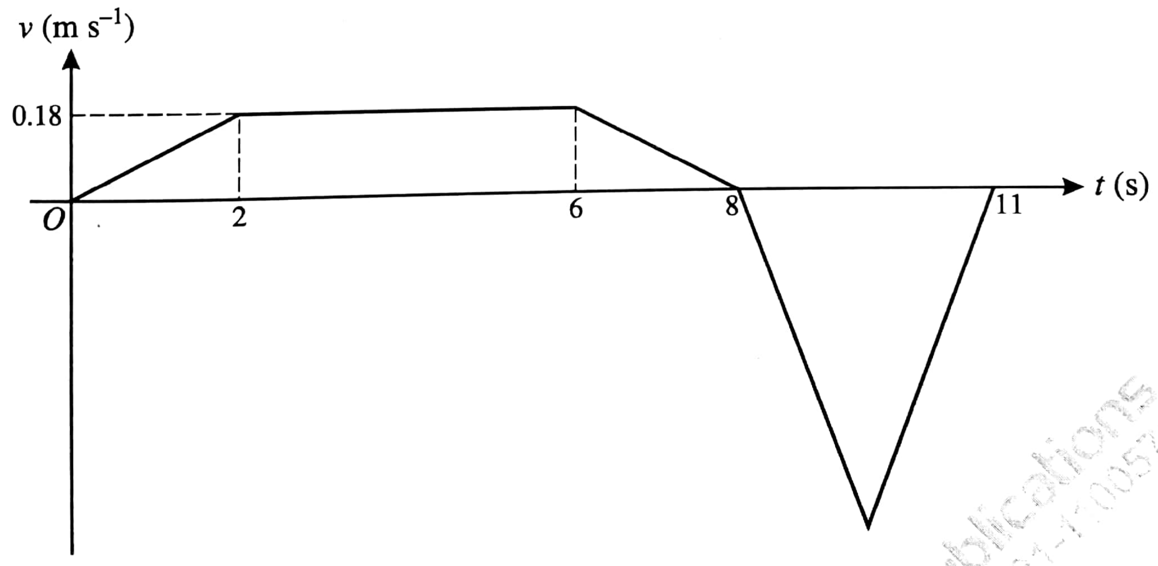
A particle travels along a straight line. It starts from rest at a point A on the line and comes to rest again, 10 seconds later, at another point B on the line. The velocity t seconds after leaving A is

$$0.72t^2 - 0.096t^3 \quad \text{for} \quad 0 \leqslant t \leqslant 5,$$
$$2.4t - 0.24t^2 \quad \text{for} \quad 5 \leqslant t \leqslant 10.$$

(i) Show that there is no instantaneous change in the acceleration of the particle when $t = 5$. [4]

(ii) Find the distance AB. [4]

97. M/J 10/P42/Q2



The diagram shows the velocity-time graph for the motion of a machine's cutting tool. The graph consists of five straight line segments. The tool moves forward for 8 s while cutting and then takes 3 s to return to its starting position. Find

(i) the acceleration of the tool during the first 2 s of the motion, [1]

(ii) the distance the tool moves forward while cutting, [2]

(iii) the greatest speed of the tool during the return to its starting position. [2]

98. M/J 10/P42/Q7

A vehicle is moving in a straight line. The velocity $v\,\text{m s}^{-1}$ at time t s after the vehicle starts is given by

$$v = A(t - 0.05t^2) \quad \text{for } 0 \leqslant t \leqslant 15,$$
$$v = \frac{B}{t^2} \quad \text{for } t \geqslant 15,$$

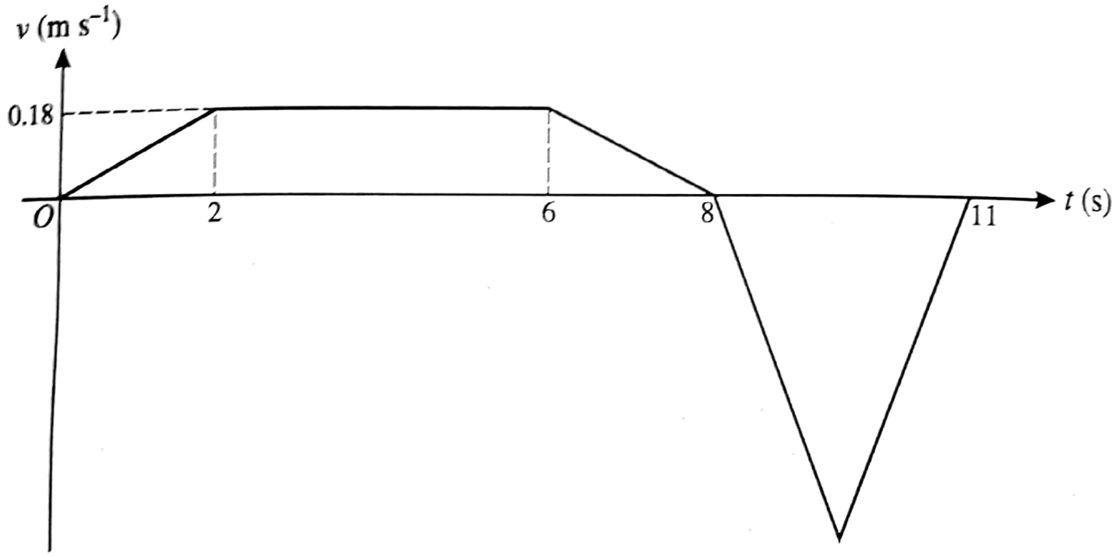
where A and B are constants. The distance travelled by the vehicle between $t = 0$ and $t = 15$ is 225 m.

(i) Find the value of A and show that $B = 3375$. [5]

(ii) Find an expression in terms of t for the total distance travelled by the vehicle when $t \geqslant 15$. [3]

(iii) Find the speed of the vehicle when it has travelled a total distance of 315 m. [3]

99. M/J 10/P41/Q2



The diagram shows the velocity-time graph for the motion of a machine's cutting tool. The graph consists of five straight line segments. The tool moves forward for 8 s while cutting and then takes 3 s to return to its starting position. Find

(i) the acceleration of the tool during the first 2 s of the motion, [1]

(ii) the distance the tool moves forward while cutting, [2]

(iii) the greatest speed of the tool during the return to its starting position. [2]

100. M/J 10/P41/Q7

A vehicle is moving in a straight line. The velocity $v\,\text{m s}^{-1}$ at time t s after the vehicle starts is given by

$$v = A(t - 0.05t^2) \quad \text{for } 0 \leqslant t \leqslant 15,$$
$$v = \frac{B}{t^2} \quad \text{for } t \geqslant 15,$$

where A and B are constants. The distance travelled by the vehicle between $t = 0$ and $t = 15$ is 225 m.

(i) Find the value of A and show that $B = 3375$. [5]

(ii) Find an expression in terms of t for the total distance travelled by the vehicle when $t \geqslant 15$. [3]

(iii) Find the speed of the vehicle when it has travelled a total distance of 315 m. [3]

101. M/J 10/P43/Q2

A particle starts at a point O and moves along a straight line. Its velocity t s after leaving O is $(1.2t - 0.12t^2)$ m s^{-1}. Find the displacement of the particle from O when its acceleration is 0.6 m s^{-2}. [5]

102. M/J 10/P43/Q5

A ball moves on the horizontal surface of a billiards table with deceleration of constant magnitude d m s^{-2}. The ball starts at A with speed 1.4 m s^{-1} and reaches the edge of the table at B, 1.2 s later, with speed 1.1 m s^{-1}.

(i) Find the distance AB and the value of d. [3]

AB is at right angles to the edge of the table containing B. The table has a low wall along each of its edges and the ball rebounds from the wall at B and moves directly towards A. The ball comes to rest at C where the distance BC is 2 m.

(ii) Find the speed with which the ball starts to move towards A and the time taken for the ball to travel from B to C. [3]

(iii) Sketch a velocity-time graph for the motion of the ball, from the time the ball leaves A until it comes to rest at C, showing on the axes the values of the velocity and the time when the ball is at A, at B and at C. [2]

103. M/J 10/P43/Q6

Particles P and Q move on a line of greatest slope of a smooth inclined plane. P is released from rest at a point O on the line and 2 s later passes through the point A with speed 3.5 m s^{-1}.

(i) Find the acceleration of P and the angle of inclination of the plane. [4]

At the instant that P passes through A the particle Q is released from rest at O. At time t s after Q is released from O, the particles P and Q are 4.9 m apart.

(ii) Find the value of t. [5]

104. O/N 09/P42/Q7

A motorcyclist starts from rest at A and travels in a straight line. For the first part of the motion, the motorcyclist's displacement x metres from A after t seconds is given by $x = 0.6t^2 - 0.004t^3$.

(i) Show that the motorcyclist's acceleration is zero when $t = 50$ and find the speed V m s^{-1} at this time. [5]

For $t \geqslant 50$, the motorcyclist travels at constant speed V m s^{-1}.

(ii) Find the value of t for which the motorcyclist's average speed is 27.5 m s^{-1}. [5]

105. O/N 09/P41/Q7

A particle P starts from rest at the point A at time $t = 0$, where t is in seconds, and moves in a straight line with constant acceleration $a\,\text{m s}^{-2}$ for 10 s. For $10 \leqslant t \leqslant 20$, P continues to move along the line with velocity $v\,\text{m s}^{-1}$, where $v = \dfrac{800}{t^2} - 2$. Find

(i) the speed of P when $t = 10$, and the value of a, [2]

(ii) the value of t for which the acceleration of P is $-a\,\text{m s}^{-2}$, [4]

(iii) the displacement of P from A when $t = 20$. [6]

106. M/J 09/P4/Q7

A particle P travels in a straight line from A to D, passing through the points B and C. For the section AB the velocity of the particle is $(0.5t - 0.01t^2)\,\text{m s}^{-1}$, where t s is the time after leaving A.

(i) Given that the acceleration of P at B is $0.1\,\text{m s}^{-2}$, find the time taken for P to travel from A to B. [3]

The acceleration of P from B to C is constant and equal to $0.1\,\text{m s}^{-2}$.

(ii) Given that P reaches C with speed $14\,\text{m s}^{-1}$, find the time taken for P to travel from B to C. [3]

P travels with constant deceleration $0.3\,\text{m s}^{-2}$ from C to D. Given that the distance CD is 300 m, find

(iii) the speed with which P reaches D, [2]

(iv) the distance AD. [6]

107. O/N 08/P4/Q6

A train travels from A to B, a distance of 20 000 m, taking 1000 s. The journey has three stages. In the first stage the train starts from rest at A and accelerates uniformly until its speed is $V\,\text{m s}^{-1}$. In the second stage the train travels at constant speed $V\,\text{m s}^{-1}$ for 600 s. During the third stage of the journey the train decelerates uniformly, coming to rest at B.

(i) Sketch the velocity-time graph for the train's journey. [2]

(ii) Find the value of V. [3]

(iii) Given that the acceleration of the train during the first stage of the journey is $0.15\,\text{m s}^{-2}$, find the distance travelled by the train during the third stage of the journey. [4]

108. O/N 08/P4/Q7

A particle P is held at rest at a fixed point O and then released. P falls freely under gravity until it reaches the point A which is 1.25 m below O.

(i) Find the speed of P at A and the time taken for P to reach A. [3]

The particle continues to fall, but now its downward acceleration t seconds after passing through A is $(10 - 0.3t)\,\text{m s}^{-2}$.

(ii) Find the total distance P has fallen, 3 s after being released from O. [7]

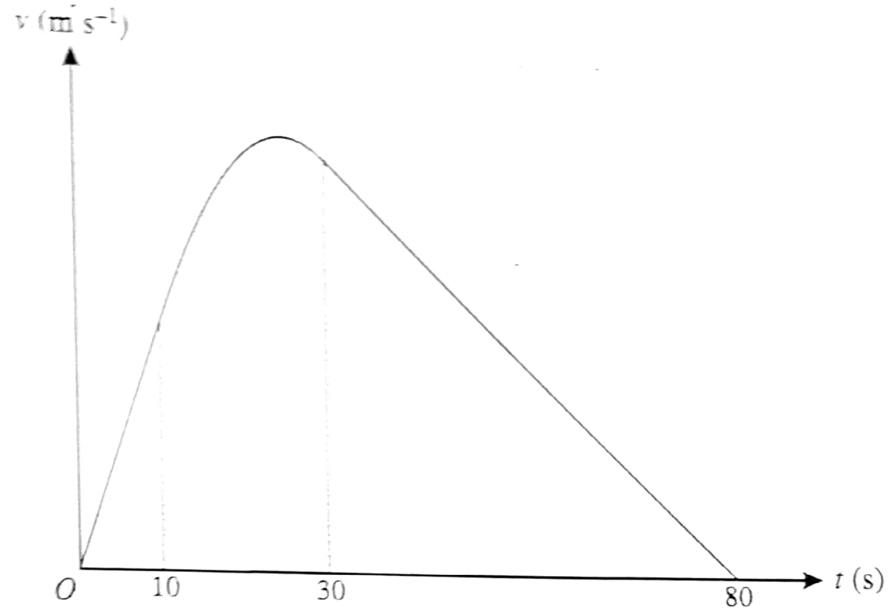
109. M/J 08/P4/Q1

A particle slides down a smooth plane inclined at an angle of $\alpha°$ to the horizontal. The particle passes through the point A with speed $1.5\,\text{m s}^{-1}$, and 1.2 s later it passes through the point B with speed $4.5\,\text{m s}^{-1}$. Find

(i) the acceleration of the particle, [2]

(ii) the value of α. [2]

110. M/J 08/P4/Q7



An object P travels from A to B in a time of 80 s. The diagram shows the graph of v against t, where $v\,\text{m s}^{-1}$ is the velocity of P at time t s after leaving A. The graph consists of straight line segments for the intervals $0 \leqslant t \leqslant 10$ and $30 \leqslant t \leqslant 80$, and a curved section whose equation is $v = -0.01t^2 + 0.5t - 1$ for $10 \leqslant t \leqslant 30$. Find

(i) the maximum velocity of P, [4]

(ii) the distance AB. [9]

111. O/N 07/P4/Q2

A particle is projected vertically upwards from a point O with initial speed $12.5\,\text{m s}^{-1}$. At the same instant another particle is released from rest at a point 10 m vertically above O. Find the height above O at which the particles meet. [5]

112. O/N 07/P4/Q6

(i) A man walks in a straight line from A to B with constant acceleration $0.004\,\text{m s}^{-2}$. His speed at A is $1.8\,\text{m s}^{-1}$ and his speed at B is $2.2\,\text{m s}^{-1}$. Find the time taken for the man to walk from A to B, and find the distance AB. [3]

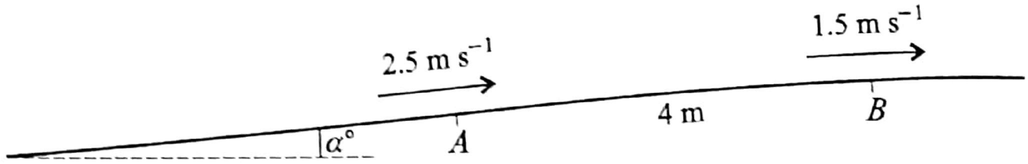
(ii) A woman cyclist leaves A at the same instant as the man. She starts from rest and travels in a straight line to B, reaching B at the same instant as the man. At time t s after leaving A the cyclist's speed is $k(200t - t^2)\,\text{m s}^{-1}$, where k is a constant. Find

(a) the value of k, [4]

(b) the cyclist's speed at B. [1]

(iii) Sketch, using the same axes, the velocity-time graphs for the man's motion and the woman's motion from A to B. [3]

113. M/J 07/P4/Q1

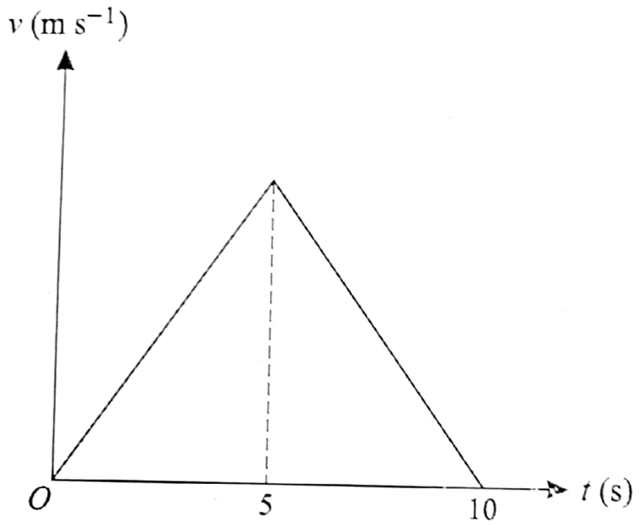


A particle slides up a line of greatest slope of a smooth plane inclined at an angle $\alpha°$ to the horizontal. The particle passes through the points A and B with speeds $2.5\,\text{m s}^{-1}$ and $1.5\,\text{m s}^{-1}$ respectively. The distance AB is 4 m (see diagram). Find

(i) the deceleration of the particle, [2]

(ii) the value of α. [2]

114. M/J 07/P4/Q6



A particle P starts from rest at the point A and travels in a straight line, coming to rest again after 10 s. The velocity-time graph for P consists of two straight line segments (see diagram). A particle Q starts from rest at A at the same instant as P and travels along the same straight line as P. The velocity of Q is given by $v = 3t - 0.3t^2$ for $0 \leqslant t \leqslant 10$. The displacements from A of P and Q are the same when $t = 10$.

(i) Show that the greatest velocity of P during its motion is $10\,\text{m s}^{-1}$. [6]

(ii) Find the value of t, in the interval $0 < t < 5$, for which the acceleration of Q is the same as the acceleration of P. [3]

15. O/N 06/P4/Q4

The velocity of a particle t s after it starts from rest is $v\,\text{m s}^{-1}$, where $v = 1.25t - 0.05t^2$. Find

(i) the initial acceleration of the particle, [2]

(ii) the displacement of the particle from its starting point at the instant when its acceleration is $0.05\,\text{m s}^{-2}$. [5]

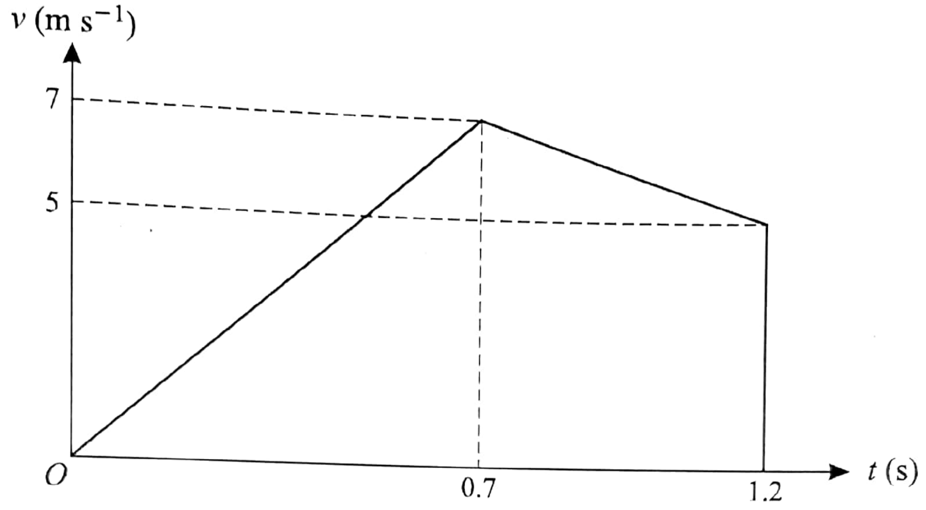
116. M/J 06/P4/Q2

A motorcyclist starts from rest at A and travels in a straight line until he comes to rest again at B. The velocity of the motorcyclist t seconds after leaving A is $v\,\mathrm{m\,s^{-1}}$, where $v = t - 0.01t^2$. Find

(i) the time taken for the motorcyclist to travel from A to B, [2]

(ii) the distance AB. [3]

117. M/J 06/P4/Q4



The diagram shows the velocity-time graph for the motion of a small stone which falls vertically from rest at a point A above the surface of liquid in a container. The downward velocity of the stone t s after leaving A is $v\,\mathrm{m\,s^{-1}}$. The stone hits the surface of the liquid with velocity $7\,\mathrm{m\,s^{-1}}$ when $t = 0.7$. It reaches the bottom of the container with velocity $5\,\mathrm{m\,s^{-1}}$ when $t = 1.2$.

(i) Find

(a) the height of A above the surface of the liquid,

(b) the depth of liquid in the container. [3]

(ii) Find the deceleration of the stone while it is moving in the liquid. [2]

(iii) Given that the resistance to motion of the stone while it is moving in the liquid has magnitude 0.7 N, find the mass of the stone. [3]

118. M/J 06/P4/Q7

Two particles P and Q move on a line of greatest slope of a smooth inclined plane. The particles start at the same instant and from the same point, each with speed $1.3\,\mathrm{m\,s^{-1}}$. Initially P moves down the plane and Q moves up the plane. The distance between the particles t seconds after they start to move is d m.

(i) Show that $d = 2.6t$. [4]

When $t = 2.5$ the difference in the vertical height of the particles is 1.6 m. Find

(ii) the acceleration of the particles down the plane, [3]

(iii) the distance travelled by P when Q is at its highest point. [3]

119. O/N 05/P4/Q1

A car travels in a straight line with constant acceleration a m s^{-2}. It passes the points A, B and C, in this order, with speeds 5 m s^{-1}, 7 m s^{-1} and 8 m s^{-1} respectively. The distances AB and BC are d_1 m and d_2 m respectively.

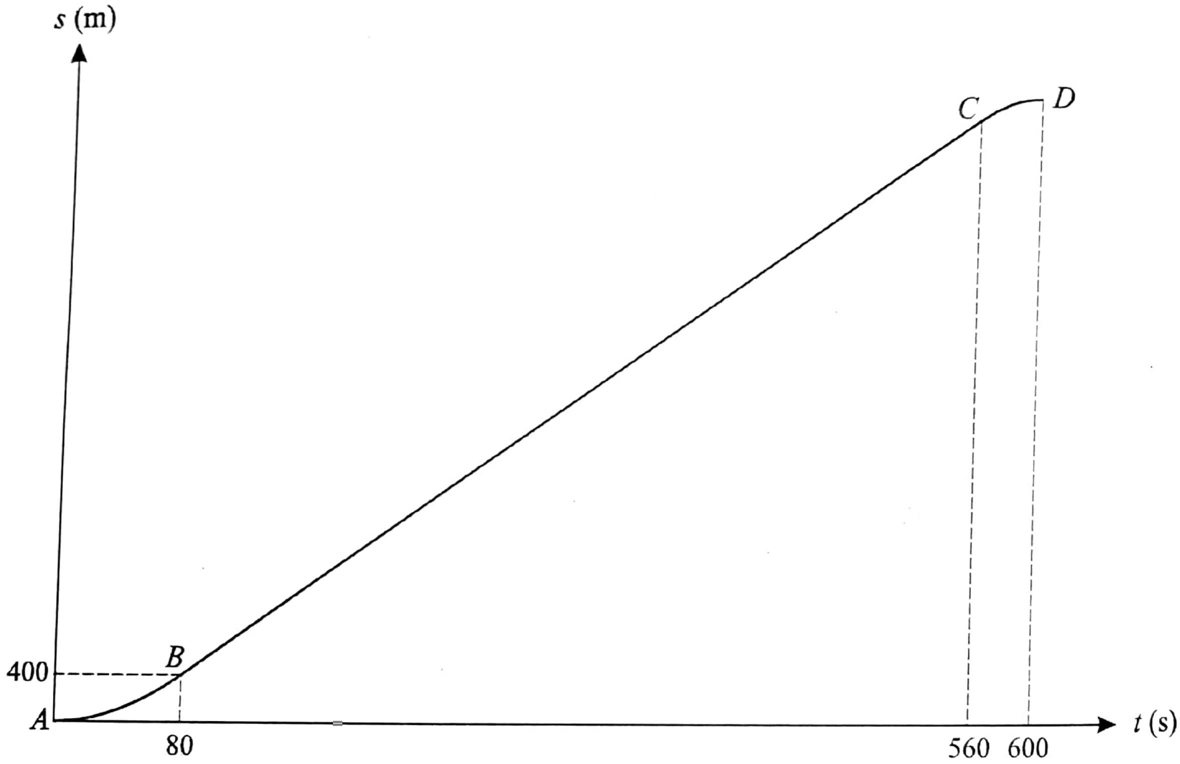
(i) Write down an equation connecting

(a) d_1 and a,

(b) d_2 and a. [2]

(ii) Hence find d_1 in terms of d_2. [2]

120. O/N 05/P4/Q5



The diagram shows the displacement-time graph for a car's journey. The graph consists of two curved parts AB and CD, and a straight line BC. The line BC is a tangent to the curve AB at B and a tangent to the curve CD at C. The gradient of the curves at $t = 0$ and $t = 600$ is zero, and the acceleration of the car is constant for $0 < t < 80$ and for $560 < t < 600$. The displacement of the car is 400 m when $t = 80$.

(i) Sketch the velocity-time graph for the journey. [3]

(ii) Find the velocity at $t = 80$. [2]

(iii) Find the total distance for the journey. [2]

(iv) Find the acceleration of the car for $0 < t < 80$. [2]

121. **O/N 05/P4/Q6**

A particle P starts from rest at O and travels in a straight line. Its velocity $v\,\text{m}\,\text{s}^{-1}$ at time t s is given by $v = 8t - 2t^2$ for $0 \leqslant t \leqslant 3$, and $v = \frac{54}{t^2}$ for $t > 3$. Find

(i) the distance travelled by P in the first 3 seconds, [4]

(ii) an expression in terms of t for the displacement of P from O, valid for $t > 3$, [3]

(iii) the value of v when the displacement of P from O is 27 m. [3]

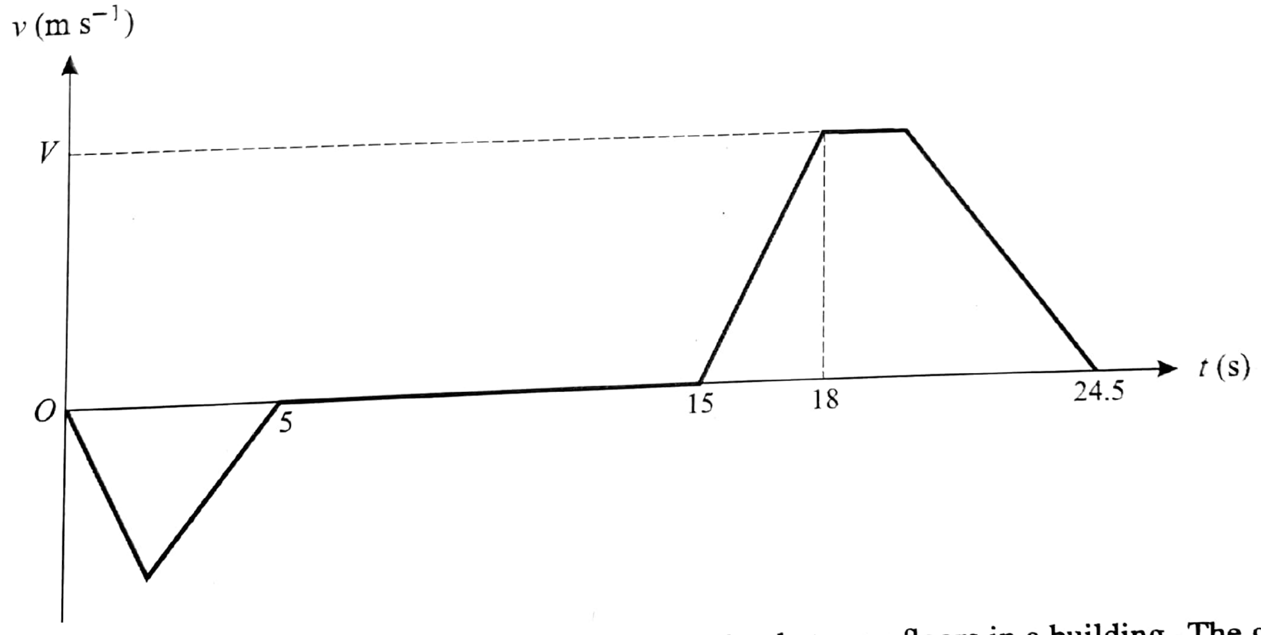
122. **M/J 05/P4/Q5**

A particle P moves along the x-axis in the positive direction. The velocity of P at time t s is $0.03t^2\,\text{m}\,\text{s}^{-1}$. When $t = 5$ the displacement of P from the origin O is 2.5 m.

(i) Find an expression, in terms of t, for the displacement of P from O. [4]

(ii) Find the velocity of P when its displacement from O is 11.25 m. [3]

123. **M/J 05/P4/Q6**



The diagram shows the velocity-time graph for a lift moving between floors in a building. The graph consists of straight line segments. In the first stage the lift travels downwards from the ground floor for 5 s, coming to rest at the basement after travelling 10 m.

(i) Find the greatest speed reached during this stage. [2]

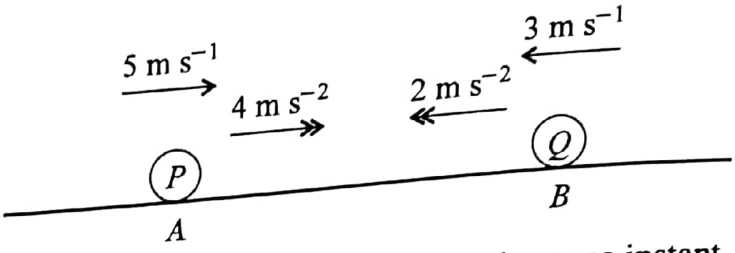
The second stage consists of a 10 s wait at the basement. In the third stage, the lift travels upwards until it comes to rest at a floor 34.5 m above the basement, arriving 24.5 s after the start of the first stage. The lift accelerates at $2\,\text{m}\,\text{s}^{-2}$ for the first 3 s of the third stage, reaching a speed of $V\,\text{m}\,\text{s}^{-1}$. Find

(ii) the value of V, [2]

(iii) the time during the third stage for which the lift is moving at constant speed, [3]

(iv) the deceleration of the lift in the final part of the third stage. [2]

124. O/N 04/P4/Q5



Particles P and Q start from points A and B respectively, at the same instant, and move towards each other in a horizontal straight line. The initial speeds of P and Q are 5 m s^{-1} and 3 m s^{-1} respectively. The accelerations of P and Q are constant and equal to 4 m s^{-2} and 2 m s^{-2} respectively (see diagram).

(i) Find the speed of P at the instant when the speed of P is 1.8 times the speed of Q. [4]

(ii) Given that $AB = 51$ m, find the time taken from the start until P and Q meet. [4]

125. O/N 04/P4/Q7

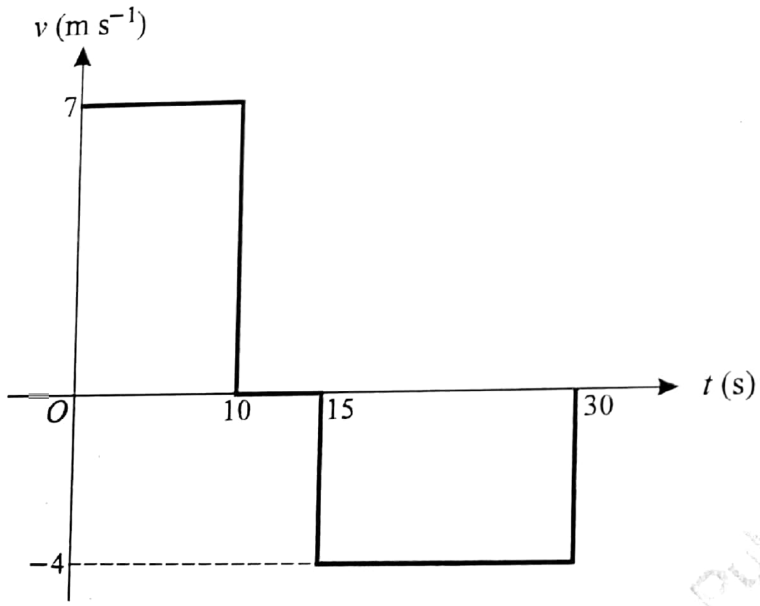
A particle starts from rest at the point A and travels in a straight line until it reaches the point B. The velocity of the particle t seconds after leaving A is $v\text{ m s}^{-1}$, where $v = 0.009t^2 - 0.0001t^3$. Given that the velocity of the particle when it reaches B is zero, find

(i) the time taken for the particle to travel from A to B, [2]

(ii) the distance AB, [4]

(iii) the maximum velocity of the particle. [4]

126. M/J 04/P4/Q3



A boy runs from a point A to a point C. He pauses at C and then walks back towards A until reaching the point B, where he stops. The diagram shows the graph of v against t, where $v\text{ m s}^{-1}$ is the boy's velocity at time t seconds after leaving A. The boy runs and walks in the same straight line throughout.

(i) Find the distances AC and AB. [3]

(ii) Sketch the graph of x against t, where x metres is the boy's displacement from A. Show clearly the values of t and x when the boy arrives at C, when he leaves C, and when he arrives at B. [3]

127. M/J 04/P4/Q5

A particle P moves in a straight line that passes through the origin O. The velocity of P at time t seconds is $v\,\text{m s}^{-1}$, where $v = 20t - t^3$. At time $t = 0$ the particle is at rest at a point whose displacement from O is -36 m.

(i) Find an expression for the displacement of P from O in terms of t. [3]

(ii) Find the displacement of P from O when $t = 4$. [1]

(iii) Find the values of t for which the particle is at O. [3]

128. M/J 04/P4/Q7

A particle P_1 is projected vertically upwards, from horizontal ground, with a speed of $30\,\text{m s}^{-1}$. At the same instant another particle P_2 is projected vertically upwards from the top of a tower of height 25 m, with a speed of $10\,\text{m s}^{-1}$. Find

(i) the time for which P_1 is higher than the top of the tower, [3]

(ii) the velocities of the particles at the instant when the particles are at the same height, [5]

(iii) the time for which P_1 is higher than P_2 and is moving upwards. [3]

129. O/N 03/P4/Q2

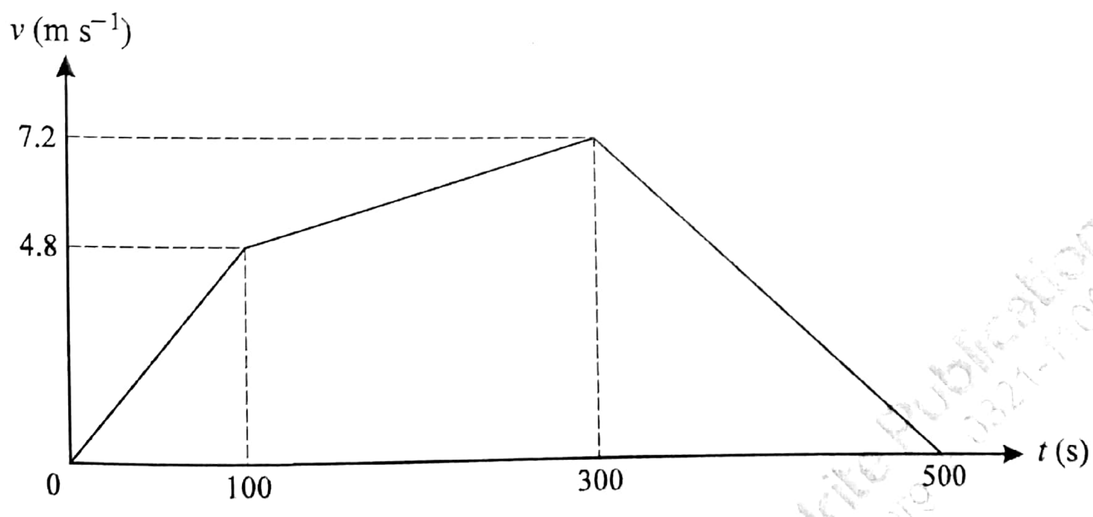
A stone is released from rest and falls freely under gravity. Find

(i) the speed of the stone after 2 s, [1]

(ii) the time taken for the stone to fall a distance of 45 m from its initial position, [2]

(iii) the distance fallen by the stone from the instant when its speed is $30\,\text{m s}^{-1}$ to the instant when its speed is $40\,\text{m s}^{-1}$. [2]

130. O/N 03/P4/Q7



A tractor A starts from rest and travels along a straight road for 500 seconds. The velocity-time graph for the journey is shown above. This graph consists of three straight line segments. Find

(i) the distance travelled by A, [3]

(ii) the initial acceleration of A. [2]

Another tractor B starts from rest at the same instant as A, and travels along the same road for 500 seconds. Its velocity t seconds after starting is $(0.06t - 0.00012t^2)\ \text{m s}^{-1}$. Find

(iii) how much greater B's initial acceleration is than A's, [2]

(iv) how much further B has travelled than A, at the instant when B's velocity reaches its maximum. [6]

131. M/J 03/P4/Q3

Solve the inequality $|x - 2| < 3 - 2x$. [4]

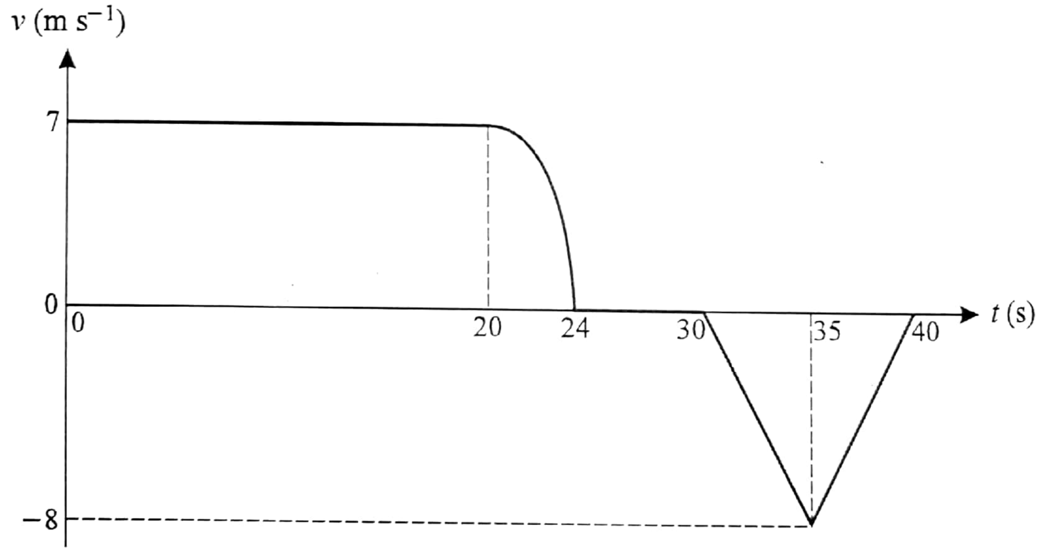
132. M/J 03/P4/Q4

The polynomial $x^4 - 2x^3 - 2x^2 + a$ is denoted by $f(x)$. It is given that $f(x)$ is divisible by $x^2 - 4x + 4$.

(i) Find the value of a. [3]

(ii) When a has this value, show that $f(x)$ is never negative. [4]

133. O/N 02/P4/Q2



A man runs in a straight line. He passes through a fixed point A with constant velocity $7\ \text{m s}^{-1}$ at time $t = 0$. At time t s his velocity is $v\ \text{m s}^{-1}$. The diagram shows the graph of v against t for the period $0 \leqslant t \leqslant 40$.

(i) Show that the man runs more than 154 m in the first 24 s. [2]

(ii) Given that the man runs 20 m in the interval $20 \leqslant t \leqslant 24$, find how far he is from A when $t = 40$. [2]

134. O/N 02/P4/Q4

Two particles A and B are projected vertically upwards from horizontal ground at the same instant. The speeds of projection of A and B are $5\ \text{m s}^{-1}$ and $8\ \text{m s}^{-1}$ respectively. Find [4]

(i) the difference in the heights of A and B when A is at its maximum height, [4]

(ii) the height of A above the ground when B is 0.9 m above A.

135. O/N 02/P4/Q7

A particle P starts to move from a point O and travels in a straight line. At time t s after P starts to move its velocity is $v\,\text{m s}^{-1}$, where $v = 0.12t - 0.0006t^2$.

(i) Verify that P comes to instantaneous rest when $t = 200$, and find the acceleration with which it starts to return towards O. [3]

(ii) Find the maximum speed of P for $0 \leqslant t \leqslant 200$. [3]

(iii) Find the displacement of P from O when $t = 200$. [3]

(iv) Find the value of t when P reaches O again. [2]

136. M/J 02/P4/Q5

(i) A cyclist travels in a straight line from A to B with constant acceleration $0.06\ \text{ms}^{-2}$. His speed at A is $3\ \text{ms}^{-1}$ and his speed at B is $6\ \text{ms}^{-1}$. Find

(a) the time taken by the cyclist to travel from A to B, [2]

(b) the distance AB. [2]

(ii) A car leaves A at the same instant as the cyclist. The car starts from rest and travels in a straight line to B. The car reaches B at the same instant as the cyclist. At time t s after leaving A the speed of the car is $kr^2\ \text{ms}^{-1}$, where k is a constant. Find

(a) the value of k, [4]

(b) the speed of the car at B. [1]

Answers Section

1. O/N 17/P42/Q3

(i) $s_{AB} = 14 \times 5 + ½a \times 5^2$

$s_{AC} = 14 \times 8 + ½a \times 8^2$

$[112 + 32a = 2(70 + 12.5a)]$

$a = 4 \text{ m s}^{-2}$ 4

(ii) $[v = 14 + 4 \times 8]$

Velocity = 46 m s^{-1} 2

2. O/N 17/P42/Q4

(i) $[12t - ½gt^2 = 0]$

or

$[0 = 12 - gT]$ with $t = 2T$ used

$t = 2.4$ s 2

(ii) Critical point at $t = 1.2$

Critical point at $t = 2$

Both moving in same direction

$1 < t < 1.2$

Both moving in same direction

$2 < t < 2.4$ 4

3. O/N 17/P42/Q7

(i) $-0.01t(t^2 - 22t + 40) = 0$

$-0.01t(t - 20)(t - 2) = 0$

$t = 2$ or $t = 20$ 2

(ii) $a = -0.03t^2 + 0.44t - 0.4$

a is greatest (maximum) when

$0.44 - 0.06t = 0$

Max acceleration when $t = 7.33$ 3

(iii) $\int\left(-0.01t^3 + 0.22t^2 - 0.4t\right)dt$

$s(t) = -\frac{0.01}{4}t^4 + \frac{0.22}{3}t^3 - 0.2t^2$

$s(20) - s(2)$

Distance = 107 m 4

4. O/N 17/P41/Q4

(i) Acceleration = $\frac{(-25)}{2.5} = -10 \text{ m s}^{-2}$ 1

(ii) $V = -15 + 7.5 \times 4$

$V = 15 \text{ m s}^{-1}$ 2

(iii) Using $v = 0$ at $t = 4.5$ and $t = 8$

$½ \times (4.5 + 2) \times 10$

$+ ½ \times (8 - 4.5) \times 15$

$+ ½ \times (T - 8) \times 15 = 100$

$T = 13.5$ 4

5. O/N 17/P41/Q5

(i) Acceleration = 0.4 m s^{-2} 1

(ii) $\frac{100}{t^2} - 0.1t = 0$

$t = 10$ s 2

(iii) Distance $t = 0$ to $t = 5$ is

$½\,(1.5 + 3.5) \times 5 = 12.5$

$s(t) = \int\left(\frac{100}{t^2} - 0.1t\right)dt$

$= -\frac{100}{t} - 0.05t^2\,(+C)$

$s(10) - s(5)$

Total distance = 12.5 + 6.25 = 18.75 m 5

6. O/N 17/P43/Q5

(i) $v = \int k(3t^2 - 12t + 2)\,dt$

$= k(3t^3/3 - 12t^2/2 + 2t) + C$

$v = k\left(t^3 - 6t^2 + 2t\right) + C$

$C = 0.4$

$0.1 = k(1 - 6 + 2) + 0.4\ [-0.3 = -3k]$

$k = 0.1$ 5

(ii) $[s = \int 0.1(t^3 - 6t^2 + 2t) + 0.4\,dt$

$= 0.1(t^4/4 - 6t^3/3 + 2t^2/2) + 0.4t + C]$

$s = 0.025t^4 - 0.2t^3 + 0.1t^2 + 0.4t$ 2

(iii) Substitutes $t = 2$ to show $s = 0$ 1

7. O/N 17/P43/Q6

(i) [Area = $½\,(10 + 4) \times 6 = 42$ m]

Displacement = 42 m 1

(ii) $\frac{v}{2} = \frac{6}{4}$

or [gradient = 1.5, $v = 6 + 1.5 \times 6$]

$v = 3 \text{ ms}^{-1}$ 2

(iii) Total distance travelled
$= 42 + ½ (T - 10) \times 3$
$[42 + ½ (T - 10) \times 3 = 49.5] \rightarrow T = \dots$
$T = 15$ s
3

(iv) $V = 1.75 \times 4 = 7$ ms^{-1}
Q travels [½ (13 + 6) × 7 = 66.5 m]
Distance apart = [66.5 + 42 – 7.5]
Distance between P and Q = 101 m
3

8. M/J 17/P42/Q3

(i)
$s_A = 20 + 10t$
$s_B = 16t + ½(-2)t^2$ $[= 16t - t^2]$
3

(ii) $v_B = 16 - 2t \rightarrow v_B = 0,\ t = 8$
$s = s_A - s_B$
$[= 20 + 10t + t^2 - 16t = t^2 - 6t + 20]$
$t = 8,\ s = 36$ (m)
3

(iii) $\frac{ds}{dt} = 2t - 6$

or
$s = t^2 - 6t + 20 = (t - 3)^2 + 11$
$[t = 3]$
$s = s_A - s_B = 11$ m
3

9. M/J 17/P41/Q5

(i) $[12^2 = 20^2 - 2a \times AB$
$6^2 = 12^2 - 2a \times BC]$
$AB = 128/a$
$BC = 54/a$
$AB : BC = 64:27$
4

(ii) $0 = 20^2 - 2a \times 80 \rightarrow a = 2.5$
$BC = 54/2.5$
$BC = 21.6$ m
3

10. M/J 17/P41/Q6

(i) $[q + r = 4$ and $2q + 4r = 4]$
$q = 6$ and $r = -2$ so $v = 6t - 2t^2$
$a = 6 - 4t$
At $t = 0.5$, $a = 4$
4

(ii) $v = 6t - 2t^2 = 0$
$t = 0$ and $t = 3$
2

(iii) *EITHER*:
$s = \int(6t - 2t^2)\,dt$
$s = 3t^2 - ⅔t^3 + C$
$0 = 3 \times 3^2 - ⅔ \times 3^3 + C$
$C = -9$ so distance = 9 m
OR:
$$s = \int_0^3 \left(6t - 2t^2\right)dt$$
$$\left[3t^2 - \frac{2}{3}t^3\right]_0^3$$
[27 – 18 = 9]
Distance from O at $t = 0$ is 9 m
4

11. M/J 17/P43/Q3

(i) Trapezium, right-hand steeper than left-hand slope 1

(ii) Deceleration 0.5 T
Constant speed 180 – 1.5 T 2

(iii) $0.5[180 + (180 - 1.5T)] \times 25 = 3300$
$T = 64$
Distance decelerating = [0.5 × 32 × 25 =] 400 m 3

12. M/J 17/P43/Q4

(i) $a = 3 \times 2 \times (2t - 5)^2$ [= 54]
$6(t2 - 5)^2 = 54 \rightarrow t = \dots$
$t = 1, 4$
3

(ii) $s = \frac{(2t-5)^4}{4 \times 2}$ $(+ C)$
$C = -\frac{625}{8}$
$s = \frac{(2t-5)^4}{8} - \frac{625}{8}$
3

Alternative method for Question 4

(i) $v = 8t^3 - 60t^2 + 150t - 125$
$\rightarrow a = 24t^2 - 120t + 150$
$24t^2 - 120t + 150 = 54 \rightarrow t = \dots$
$t = 1, 4$
3

(ii) $s = \int 8t^3 - 60t^2 + 150t - 125\,dt$
$\rightarrow s = \frac{8}{4}t^4 - \frac{60}{3}t^3 + \frac{150}{2}t^2 - 125t\ (+ C)$
$C = 0$
$s = 2t^4 - 20t^3 + 75t^2 - 125t$
3

13. M/J 17/P43/Q5

(i) $s_2 = 20t - 0.5gt^2$

$s_1 = 12(t+2) - 0.5g(t+2)^2$

$12\,t(+2) - 0.5g(t+2)^2 = 20t - 0.5gt^2$

$\rightarrow$ t= ⋯

$t = \dfrac{1}{7} = 0.143$ 5

(ii) $[s = 20 \times \frac{1}{7} - 5 \times (\frac{1}{7})^2 = 2.755\ldots]$

Height is 2.76 m 1

14. O/N 16/P42/Q1

(i) $3.5 = 10a \quad \rightarrow \quad a = 0.35\,\text{ms}^{-2}$

$[10\cos 15 - F = 2 \times 0.35]$

$F = 8.96\,\text{N}$ [3]

Alternative to 1(i)

$s = ½\,(0 + 3.5) \times 10 = 17.5\,\text{m}$

$[10\cos 15 \times 17.5 = F \times 17.5 + ½\,2\,(3.5)^2]$

$F = 8.96\,\text{N}$ [3]

(ii) $[R = 2g - 10\sin 15]$

$[\mu = 8.96/(2g - 10\sin 15)]$

$\mu = 0.515$ [3]

15. O/N 16/P42/Q2

(i) $[v = 4t - 40t^{0.5}]$

$[a = 4 - 20t^{-0.5}]$

$[4 - 20t^{-0.5} = 0]$

$t = 25\,\text{s}$

(ii) Substitute their t into s **or** v

Displacement= $-2083.3\,\text{m}(= -2080$ 3sf)

and Velocity $= -100\,\text{ms}^{-1}$ [2]

16. O/N 16/P42/Q4

(i) PE loss $= mg \times 100\sin 20$

$[½mv^2 - ½m \times 5^2 = mg \times 100\sin 20]$

$v = 26.6\,\text{ms}^{-1}$

Alternative method for 4(i)

$a = g\sin 20\;[= 3.42]$

$v^2[= 5^2 + 2 \times a \times 100]$

$v = 26.6\,\text{ms}^{-1}$

(ii) KE =

$\pm(0.5m \times 441 - 0.5m \times 25)\;[= \pm 208m]$

$[mg \times 100\sin 20 = 8500 + 208m]$

Mass $m = 63.4\,\text{kg}$

17. O/N 16/P42/Q7

(i) $v = 3 \times 10 = 30\,\text{ms}^{-1}$

$s[= ½\,(30 + 40) \times 30\,]$

or equivalent complete method

Total distance = 1050 m

(ii) [Distance = 450 m

Time taken = 450/15 = 30 s]

Total time of motion for car = 70 s

[Motorcycle takes 50 s to travel 1500 m

$1500 = ½\,(30 + 50) \times V$

or $1500 = 30V + 0.5 \times 20V$]

$V = 37.5\,\text{ms}^{-1}$

[20 s is split between 5 s accelerating and 15 s decelerating]

$a = 37.5/5 = 7.5\,\text{ms}^{-2}$

(iii) Displacement-time graph

[3]

18. O/N 16/P41/Q2

(i) $2 = 5a \rightarrow a = 0.4\,\text{ms}^{-2}$

$[0.1g\sin 20 - F = 0.1 \times 0.4]$

$F = 0.302\,\text{N}$ AG [3]

(ii) $[R = 0.1g\cos 20\;\;(= 0.9397)]$

$\mu = 0.3020/0.9397 = 0.321$ [2]

19. O/N 16/P41/Q3

(i) $[0 = 6^2 - 2g \times s]$

$s = 1.8$

Total height = 2.3 m

Alternative for 3(i)

$[6^2 = u^2 - 2g \times 0.5]$

$u^2 = 46$

$0^2 = 46 - 2gs \rightarrow s =$ total height = 2.3m

(ii) $[2.3 = 0 + 0.5gt^2]$

$t = 0.678$

Total time $= 2 \times 0.678 = 1.36\,\text{s}$ [3]

Alternative for 3(ii)

$[0 = \sqrt{46} - gt]$

$t = \dfrac{\sqrt{46}}{10} = 0.678$

Total time = 2 × 0.678 = 1.36 s [3]

20. O/N 16/P41/Q5

(i) $a = 0.5\,\text{m s}^{-2}$

(ii) [Distance
$= 25 + 100 + 5(5 + V) + 30V + 10V]$

$150 + 45V$ AG

$150 + 45V = 465 \rightarrow V = 7\,\text{ms}^{-1}$ [3]

(iii) $\frac{1}{2} \times 80 \times 7^2 - \frac{1}{2} \times 80 \times 5^2$ [= 960]

$20 \times (5 + 7)/2 \times 10$ [=1200]

[$80gh = 960 + 1200$]

$h = 2.7\,\text{m}$ [4]

21. O/N 16/P41/Q7

(i) [$15 - 6t = 0$]

Max acceleration when $t = 2.5\,\text{s}$

Max acceleration = $18.75\,\text{ms}^{-2}$ [3]

(ii) [Speed = $7.5t^2 - t^3$ (+ c)]

[Distance = $2.5t^3 - 0.25t^4$ (+ ct + d)]

$= 2.5\times125 - 0.25\times625 = 156.25\,\text{m}$ [3]

(iii) $v(5) = 7.5\times25 - 125 = 62.5\,\text{m s}^{-1}$

$\int_5^k -\dfrac{625}{t^2}\,dt = \left[\dfrac{625}{t}\right]_5^k$

$= \dfrac{625}{k} - \dfrac{625}{5} = \dfrac{625}{k} - 125$

$\dfrac{625}{k} - 125 = v(k) - v(5) = -62.5$

$k = 10$ [5]

Alternative for 7(iii)

$v(5) = 7.5\times25 - 125 = 62.5\,\text{m s}^{-1}$

$v(t) = \int -\dfrac{625}{t^2}\,dt = \dfrac{625}{t} + c$

$c[= -62.5]$

$v(t) = \dfrac{625}{t} - 62.5$

$v(k) = \dfrac{625}{k} - 62.5 = 0$

$k = 10$ [5]

22. O/N 16/P43/Q4

(i) $s_A = \frac{1}{2}g \times 2.5^2$ (= 31.25)

[$s_B = 20 \times 1.5 - \frac{1}{2}g \times 1.5^2$] (= 18.75)

$\frac{1}{2}g \times 2.5^2 + 20 \times 1.5 - \frac{1}{2}g \times 1.5^2$

Height is 50 m AG [3]

(ii) $50 = 0.5gt_A^2$ ($t_A = 3.16$)

$t_B = \sqrt{10} - 1 = 2.16$

To top,
$0^2 = 20^2 - 2gs_B$ $\rightarrow s_B = 20$

To top, [$0 = 20 - gt_B$] $\rightarrow t_B = 2$

Downwards,
[$s_B = \frac{1}{2}g(0.16)^2$] (= 0.13)

Total distance is 20.1 m [5]

23. O/N 16/P43/Q5

(i) $6t - 0.3t^2 = 0 \rightarrow t = 20$ (or 0)

$s[= 6t^2/2 - 0.3t^3/3$ (+C)]

$s[= 6(20)^2/2 - 0.3(20)^3/3]$

Distance OX is 400 m [4]

(ii) [$v = kt - 6t^2$ (+C)]

$s[= kt^2/2 - 6t^3/3]$

[$400 = 0.5k \times 10^2 - 2 \times 10^3$]

$k = 48$ [4]

24. M/J 16/P42/Q2

(i) $4t^2 - 8t + 3 = 0$

$(2t - 3)(2t - 1)$

$t = 0.5$ and $t = 1.5$ 2

(ii) $s = -\int(4t^2 - 8t + 3)\,dt$

$-\left[\dfrac{4}{3}t^3 - 4t^2 + 3t\right]_{0.5}^{1.5}$

Distance travelled =2/3 m 3

25. M/J 16/P42/Q4

(i) $\frac{1}{2} \times 6 \times 8.2 + 36 \times 8.2$

Or $\frac{1}{2} \times 8.2 \times (36 + 42)$

Distance = 319.8 m 2

(ii) $s = 80.2$

$80.2 = \dfrac{8.2 + V}{2} \times 10$

$V = 7.84$ 3

(iii) $d = \dfrac{8.2 - 7.84}{10} = 0.036$ 2

Alternative for 4(iii)

(iii) $80.2 = 8.2 \times 10 + \frac{1}{2} a \times 10^2$
$a = -0.036\ \text{ms}^{-2}$ or $d = 0.036\ \text{ms}^{-2}$ 2

26. M/J 16/P41/Q1

(i) Trapezium seen
0, 3, 9, 13 shown on the t axis
$v = 2.7$ soi in either part [3]

(ii) $[0.5 \times (6 + 13) \times 2.7]$
Total distance = 25.65 m [2]

Alternative method for 1(ii)

(ii) Stage 1
$s_1 = 0.5 \times 0.9 \times 3^2 = 4.05$
Stage 2
$s_2 = 2.7 \times 6 = 16.2$
Stage 3
$s_3 = 0.5 \times (2.7 + 0) \times 4 = 5.4$
Total distance = 25.65 m [2]

27. M/J 16/P41/Q7

(i) (a) $200 - 30g \sin 20 = 30a$
$a = 3.25\ \text{ms}^{-2}$ [2]

(b) $[v^2 = 2 \times 3.2465 \times 12 = 77.9]$
KE change = $0.5 \times 30 \times 77.9 = 1170$ J [2]

Alternative method for 7(i)(b)

(b) KE change =
$200 \times 12 - 30g \times 12 \sin 20$
KE change = 1170 J [2]

(ii)(a) $N = 30g \cos 20$
$F = 0.12 \times 30g \cos 20\ [= 33.8]$
$200 - 30g \sin 20 - 33.8 = 30a$
$a = 2.12\ \text{ms}^{-2}$ [4]

(b) $N + 200 \sin 10 = 30g \cos 20$
$[N = 247.2]$
$F = 0.12N\ [= 0.12 \times 247.2 = 29.66]$
$200 \cos 10 - 29.66 - 30g \sin 20 = 30a$
$a = 2.16\ \text{ms}^{-2}$ [4]

28. M/J 16/P43/Q2

(i) $s_B = \frac{1}{2} \times 1.2 \times 5^2$
Distance travelled is 15 m
$v_B = 1.2 \times 5$
Speed is 6 ms^{-1} 2

(ii) $[4T = 15 + 6(T - 10)]$
or
$[4(T + 5) = 15 + 6(T - 5)]$
or
$[4(T + 10) = 15 + 6T]$
$T = 22.5$ or $T = 17.5$ or $T = 12.5$
Distance OP = $4 \times 22.5 = 90$ m 3

29. M/J 16/P43/Q7

(i) $[6t - 2 < 0 \rightarrow t < .....]$
$0 < t < 1/3$ 2

(ii) $[v = 3t^2 - 2t + c]$
$s = t^3 - t^2 + ct + d$
$[c + d = 7$
$3c + d = 11 \rightarrow c = \ldots, d = \ldots]$
$s = t^3 - t^2 + 2t + 5$ 5

(iii) $[3t^2 - 2t + 2 = 10]$
$t = 2$ 3

30. O/N 15/P42/Q2

(i) $[V^2 = (V - 10)^2 + 2g \times 35]$
$20V = 100 + 70g$
$V = 40$ 3

Alternative for 2(i)

(i) $V = V - 10 + 10t \rightarrow t = 1$ and
$35 = (V - 10) \times 1 + \frac{1}{2} \times 10 \times 1^2$ or
$35 = (V - 10 + V)/2 \times 1$
$V = 40$ 3

(ii) $[40^2 = 0^2 + 20H]$
$H = 80$ 2

31. O/N 15/P42/Q3

(i) $[a(t) = 0.00012t^2 - 0.012t + 0.288]$
$[a(t) = 0.00012(t^2 - 100t + 2400)$
$= 0.00012(t - 40)(t - 60) = 0]$
$a(t) = 0$ when $t = 40$ and $t = 60$ 3

(ii) $[0.00001t^4 - 0.002t^3 + 0.144t^2]$
$[0.00001(100)^4 - 0.002(100)^3 + 0.144(100)^2]$
Displacement is 440 m 3

32. O/N 15/P42/Q7

(i) [WD = 14000 × 25]
Work done is 350kJ or 350 000 J — 2

(ii) $14000/v_A - 235 = 1600 \times 0.5 \to$
$v_A = 13.53\ \text{ms}^{-1}$
$14000/v_B - 235 = 1600 \times 0.25 \to$
$v_B = 22.05\ \text{ms}^{-1}$
[KE gain =
$\frac{1}{2}$ 1600($22.05^2 - 13.53^2$)]
KE gain = 242.5kJ or 242 500 J — 5

(iii)
350 000 = 242 500 + 235 × AB
Distance AB is 457 m — 3

33. O/N 15/P41/Q2

(i) $a = g\sin 30 = 5$
$2.5 = 0 + 5t$
$t = 0.5$ Time = 0.5 s — 3

(ii) $v^2 = 0 + 2 \times 5 \times 3 = 30$
$-1 = 0.5a \to a = -2$
$0 = 30 + 2 \times (-2) \times s$
Distance = 7.5 m — 3

First alternative method for 2(ii)

$v^2 = 0 + 2 \times 5 \times 3 = 30$
0.5 × 0.5 × 30 = 1 × distance
Distance = 7.5 m — 3

Second alternative method for 2(ii)

PE lost = 0.5 × 10 × 3 sin30 = 7.5
7.5 = 1 × distance
Distance = 7.5 m — 3

34. O/N 15/P41/Q6

(i) $s = 0.3t^2 - 0.01t^3$
$s(5) = 0.3 \times 5^2 - 0.01 \times 5^3 = 6.25$
$a = 0.6 - 0.06t$
$a(5) = 0.6 - 0.0 \times 5 = 0.3\ \text{ms}^{-2}$ — 4

(ii) Maximum velocity is when
$0.6 - 0.06t = 0$
[$t = 10$]
Max velocity = 3 ms^{-1}
$0.6t - 0.03t^2 = 1.5$
[$t^2 - 20t + 50 = 0$]
Times are 2.93 s
and 17.07 s — 6

35. O/N 15/P41/Q7

(i) $36 = 0 + 0.5 \times 0.5t^2$
$t = 12$
$v^2 = 0 + 2 \times 0.5 \times 36$
$v = 6$
$s = 6 \times 25$
remaining distance
$= 210 - 36 - 150 = 24$
$24 = (6 + 0)/2 \times t$
$t = 8$
Total Time = 12 + 25 + 8 = 45 s — 5

(ii) Distance travelled by cyclist
$= 36 + 6(t - 12)$
Distance travelled by car
$= 0.5 \times 4 \times (t - 24)^2$
$2t^2 - 96t + 1152$
$= 36 + 6t - 72$
[$t^2 - 51t + 594 = 0$]
$t = 33$ or $t = 18$
Time = 33 s — 5

36. O/N 15/P43/Q5

(i) $a =$
$(5^2 - 3^2) \div (2 \times 500) = 0.016$

$DF + 90g \times 0.05 - R = 90 \times 0.016$

$[R = \frac{420}{v} - 90(0.016 - 0.5)]$

$R = \frac{420}{v} + 43.56$ — 5

(ii) $v_M^2 = 3^2 + 2 \times 0.016 \times 250 \to$
speed at mid-point is 4.12ms^{-1}
[Decrease in R from top to mid-way
$= 420[(1 \div 3) - (1 \div \sqrt{17})]$
or
[Decrease in R from midway to b'm =
$420[(1 \div \sqrt{17}) - (1 \div 5)]$
38.1 and 17.9 — 3

37. O/N 15/P43/Q6

(i) Time taken
$= \frac{0.08}{0.0002} = 400$ s

$v = \frac{dx}{dt} = 0.16t - 0.0006t^2$
[speed
$= -0.16 \times 400 + 0.0006 \times 400^2$]
Speed at O is 32 ms^{-1} — 4

(ii)(a) Time to furthest point is $0.16/0.0006$ s
$[0.08(800/3)^2 - 0.0002(800/3)^3]$
$(\times 2)$
Distance moved is 3790 m — 3

(b) [speed = $3790/400$ ms^{-1}]

Average speed is 9.48 ms^{-1} — 2

38. M/J 15/P42/Q4

(i)

$v(t) = 0.025t^3 - 0.75t^2 + 5t \quad (+0)$

$s(t) = 0.00625t^4 - 0.25t^3 + 2.5t^2 (+0)$ — 4

(ii)

$[t^4 - 40t^3 + 400t^2 = 0 \Rightarrow t^2(t-20)^2 = 0]$
Time taken is 20 s — 3

39. M/J 15/P42/Q5

(i) $-20 = 20 - 10t \Rightarrow$ time taken is 4s
or $0 = 20 - 10t \Rightarrow$ time taken is 2×2s = 4s

$[30 = 0 + 4a]$
Acceleration of P is 7.5 ms^{-2} — 4

(ii)

Either $30^2 = 2 \times 7.5 \times OA$ — 2

or $OA = \dfrac{(0+30)}{2} \times 4$

or $OA = \dfrac{1}{2} \times 7.5 \times 4^2$

or $OA = 30 \times 4 - \dfrac{1}{2} \times 7.5 \times 4^2$

$\Rightarrow$ Distance OA is 60 m

40. M/J 15/P41/Q6

(i)

$v(t) = 0.05t - 0.0001t^2 \quad (+0)$
$v(200) = 10 - 4 = 6$ ms^{-1}
$v(500) = 25 - 25 = 0$ — 4

(ii)

$\int_0^{500} \left(0.05t - 0.0001t^2\right)dt$

$\left[\dfrac{0.05t^2}{2} - \dfrac{0.0001t^3}{3}\right]_0^{500}$

Distance $= 0.025 \times 500^2 - 0.0001 \times 500^3 \div 3$
$= 2083$ m

Distance $= \dfrac{1}{2} \times 6 \times 500 = 1500$ m or

distance $= \dfrac{1}{2}(0+6)\times 200 + \dfrac{1}{2}(6+0)\times 300$

or distance $= \left(0 + \dfrac{1}{2}0.03 \times 200^2\right)$

$+\left(6 \times 300 + \dfrac{1}{2}(-0.02)300^2\right)$

Distance between A and B is
$2083 - 1500 = 583$ m — 6

41. M/J 15/P43/Q7

(i) $[0.0001t(t-50)(t-100) = 0$
or $v(0) = 0, v(50) = 0, v(100) = 0]$
$v(t) = 0$ when $t = 0$, 50 & 100 — 2

(ii) $[0.0003t^2 - 0.03t + 0.5 = 0]$
$t^2 - 100t + 1667 = 0 \Rightarrow$
$t = \left[\dfrac{1}{2}\left\{100 \pm \sqrt{(100^2 - 4 \times 1667)}\right\}\right]$

$a = 0$ when $t = 21.1$ and when $t = 78.9$
$v(21.1) = 4.81$
$v(78.9) = -4.81$
Convex curve from (0,0) to (50,0) with $v > 0$ and has a maximum point.
The curve for (50, 0) to (100, 0) is exactly the same as the first curve positioned by rotating the first curve through 180° about the point (50, 0). — 7

(iii)

$s(t) = 0.000025t^4 - 0.005t^3 + 0.25t^2 (+c)$
$[156.25 - 625 + 625]$
Greatest distance is 156 m — 4

42. O/N 14/P42/Q1

(i) $[-11 = 11 - 10t]$
Time after projection is 2.2 seconds — 2

(ii) $h = 0 + ½\, g \times 2.2^2 = 24.2$
$V = 0 + g \times 2.2 = 22$ — 2

43. O/N 14/P42/Q6

(i) (a) (a) Acceleration is 2.8 ms^{-2}

(b) $[mg \times 0.28 - 0.5mg \times 0.96 = ma]$
Acceleration is -2 ms^{-2} — 3

(ii)

$v_B^2 = 2 \times 2.8(AB)$ and
$2^2 = 5.6(AB) - 2 \times 2(5 - AB)$ — 3
Distance is 2.5 m

Alternative method for (ii)

$[mg \times 5 \times 0.28 = ½\, m\, 2^2 + \mu \times mg \times 0.96 \times BC]$

$14 = 2 + 4.8 \times BC$

$BC = 12/4.8 = 2.5$ m — 3

(iii) $T = 2 \times 2.5 \div (0 + \sqrt{14}) + 2 \times 2.5 \div (\sqrt{14} + 2)$

Time taken is 2.21 s — 3

44. O/N 14/P42/Q7

(i) $v = -4.8$

$[\pm 4.8 = 3a]$

Magnitude of acceleration is 1.6 ms^{-2} — 3

(ii) $[-0.4t + 4\ (= 0 \text{ when } t = 10)]$

$v_{max} = -0.2 \times 100 + 4 \times 10 - 15 \rightarrow$ Maximum velocity is 5 ms^{-1} — 3

(iii)(a) Distance 0 to 3 s = ½ × 3 × 4.8 (= 7.2)

Distance 3 to 5s $= -\int_3^5 \left(-0.2t^2 + 4t - 15\right) dt$

Distance = ± 4.5333…m

Average speed = (7.2 + 4.533) ÷ 5 = 2.35 ms^{-1}

(b) Distance BC

$= \left[-\dfrac{0.2t^3}{3} + 2t^2 - 15t\right]_5^{15}$

and

Av speed = $(AB + BC) \div 15$

Av speed = (45.066 ÷ 15) = 3.00 ms^{-1} — 6

45. O/N 14/P41/Q4

(i) End speed = 1.3 + 0.1 × 20

$v_Q(t) = 0.008t^2 + v_Q(0)$

$[3.3 = 0.008 \times 20^2 + v_Q(0)]$

Speed of Q when $t = 0$ is 0.1 ms^{-1} — 4

(ii) Distance $AO = (3.3^2 - 1.3^2) \div (2 \times 0.1)$ or $20 \times ½\,(1.3 + 3.3)$ [= 46]

Distance $OB = 0.008 \times 20^3 \div 3 + 0.1 \times 20$ [= 70/3 = 23.3]

Distance AB is 69.3 m — 3

46. O/N 14/P41/Q6

(i) $[3g - R = 3 \times 5.5]$

Resistance is 13.5 N — 2

(ii) Graph consists of two line segments; the first starts at the origin and has a positive gradient.

The second starts where first one ends and has positive but less steep gradient. — 2

(iii) $[v_S^2 = 2 \times 10 \times 5 = 100$ **or** $v_B^2 = v_T^2 + 2 \times 5.5 \times 4]$

$v_S = 10$ ms^{-1} at surface **and**

$v_B = 12$ ms^{-1} at bottom

– both shown on sketch

$[10 = 0 + 10\,t_1$ or $12 = 10 + 5.5(t_2 - t_1)]$

$t_1 = 1$ s at surface and shown on sketch

$t_2 = 1.36$ s at bottom and shown on sketch. — 5

47. O/N 14/P43/Q1

(i) DF = $P \div 18$

$[P \div 18 - 800 = 1400 \times 0.5]$

$P = 27000$ — 3

(ii) $[1080 - 800 = 1400a]$

Acceleration is 0.2 ms^{-2} — 2

48. O/N 14/P43/Q4

(i) $v(8) = 0.25 \times 8 = 2$

$2 = -6.4 + 19.2 - k \Rightarrow k = 10.8$ — 2

(ii) $[dv/dt = -0.2t + 2.4\ (= 0 \text{ when } t = 12)$

$v_{max} = -0.1 \times 144 + 2.4 \times 12 - 10.8]$

Maximum speed is 3.6 ms^{-1} — 2

(iii) Displacement $s_1 = ½\ 0.25 \times 8^2$ (= 8)

[Displacement $s_2 = [-0.1t^3/3 + 1.2t^2 - 10.8t]_8^{18}$ (=26.7)]

Displacement is 34.7 m — 3

49. M/J 14/P42/Q2

(i)

$½\ 0.5T^2 + 0.75T = 10$

$[T^2 + 3T - 40 = 0 = (T + 8)(T - 5)]$

T = 5 only — 4

Alternative mark scheme for 2(i)

(i) $x = ½\ ½\ T^2$ $\quad 10 - x = ¾\ T$

Eliminate T

$x = ¼\,[4/3(10 - x)]^2$

$x = 6.25$

$10 - 6.25 = ¾\ T$ or $6.25 = ¼\ T^2$

T = 5

(ii) Speed is 2.5 ms^{-1} — 1

50. M/J 14/P42/Q4

(i)

$a(t) = t^{-1/3}/3$

$[0.25 - (1/2)/3 = 1/4 - 1/6]$

Decrease is $1/12\,ms^{-2}$ 4

(ii)

$s_2 = \int_8^{27} \frac{1}{2} t^{2/3} dt = [0.3t^{5/3}]_8^{27}$

Distance is 71.3 m 3

Alternative method for the final two marks

$s = \int \frac{1}{2} t^{2/3} dt = 0.3t^{5/3} + c$

$s(8) = 8$ gives $c = -1.6$

$s(27) = 0.3(27)^{5/3} - 1.6 = 71.3$

51. M/J 14/P42/Q6

(i) $v^2 = 2 \times g \times 7.2$

➔ speed at surface is 12 ms^{-1}

$[6^2 = 12^2 + 2a \times 0.8]$

Deceleration is 67.5 ms^{-2}

$[0.2g - R = -0.2 \times 67.5]$

$R = 15.5$ 5

(ii) $[3.6 = ½\, a \times 4^2]$

$a = 0.45\,ms^{-2}$

$[T - R - 0.2g = 0.2 \times 0.45]$

Tension is 17.6 N (17.59 exact) 4

Alternative Energy Method

(i)

$0.2g \times 8 = R(0.8) + ½\,(0.2)\,6^2$

$R = 15.5$

$0.2g - 15.5 = 0.2a$

$a = -67.5$ 5

(ii)

$3.6 = v/2 \times 4 \qquad v = 1.8$

$T(3.6) = R(3.6) + 0.2g(3.6) + ½(0.2)1.8^2$

$T = 17.6\,N$ 4

52. M/J 14/P41/Q4

For s = 4.05

Total distance = 4.05 + (3.15 + 4.05)

= 11.25 m

$t_{upwards} = 0.9$

For downwards motion

$(3.15 + 4.05) = \frac{1}{2} gt^2 \rightarrow t = 1.2$

Time taken is 2.1 s [6]

Alternative Mark Scheme for final 3 marks

$[-3.15 = 9T + \frac{1}{2}(-g)\,T^2]$

$[100t^2 - 180t - 63 = 0]$

$(10T - 21)(10T + 3) = 0$

53. M/J 14/P41/Q7

(i) $AB = 3 \times 400 + \frac{1}{2}\, 0.005 \times 400^2 = 1600\,m$

(AG)

or

$v_B = 3 + 0.005 \times 400 = 5\,ms^{-1}$

$v_B = 3 + 0.005 \times 400 = 5\,ms^{-1}$

or

$AB = 3 \times 400 + \frac{1}{2}\, 0.005 \times 400^2 = 1600\,m$

(AG) [3]

(ii)

$[0.02t^2 - 0.0001t^3/3 + kt]_0^{400} = 1600$

$400k = 1600 - 0.02 \times 400^2 +$

$0.0001 \times 400^3 \div 3 \rightarrow$

$k = 4 - 8 + 16/3 = 4/3$

$[dv/dt = 0.04 - 0.0002t$

$(= 0$ when $t = 200)$

$v_{max} = 0.04 \times 200 - 0.0001 \times 200^2 + 4/3$

Maximum speed is 5.33 ms^{-1} [6]

(iii)

Time taken is 280 s

$[1400 = 4/3 \times 280 + \frac{1}{2}\, 280^2 a]$

$a = 0.0262$ [4]

54. M/J 14/P43/Q6

(i) Velocity immediately before is 1.2 ms^{-1}

Velocity immediately after is $-1\,ms^{-1}$ [2]

(ii)

Distance $OW = 0.025 \times 60^2 -$

$0.0005 \times 60^3 \div 3$

Distance WA =

$-[(0.0125 \times 100^2 - 2.5 \times 100) -$

$(0.0125 \times 60^2 - 2.5 \times 60]$ [4]

Distance is 54 + 20 = 74 m

(iii) $[dv/dt = 0.05 - 0.001t = 0$ or $0.0005t(100 - t) = 0 \rightarrow t = 0$ or $100]$
Maximum speed
$(= 0.05 \times 50 - 0.0005 \times 50^2)$ is $1.25 ms^{-1}$
Plausible quadratic curve starting at (0,0), with max. at (50, 1.25) and terminating at (60, 1.2)
Straight line segment from (60,–1) to (100,0) [4]

55. O/N 13/P42/Q5

(i) $[s = t^2/2 - 0.1t^3/3]$
$[s_1 = 25/2 - 0.1 \times 125/3]$
$s_1 = 8.33$ 3

(ii) $s_2 = 2.5 \times 40$
$[s = 9t^2/2 - 0.1t^3/3 - 200t$ for $45 \leq t \leq 50]$
$s_3 = [9(50)^2/2 - 0.1(50)^3/3 - 200(50)] - [9(45)^2/2 - 0.1(45)^3/3 - 200(45)]$
$[= 8.33]$

Alternative mark scheme for previous 2 marks

Recognising the symmetry of the velocity distribution due to the correspondence of the points
$(0,0) \rightarrow (50,0)$ and $(5,2.5) \rightarrow (45,2.5)$
Complete the idea of symmetry with one further property and hence
State $s_3 = s_1 = 8.33$
Distance from O to A is 117m
Average speed is $2.33 ms^{-1}$ 6

56. O/N 13/P41/Q7

(i) $[s = ½\,5 \times 0.4 + 19 \times 0.4 + ½\,4 \times 0.4]$
Distance = 9.4 2

(ii) Acceleration is $0.08 ms^{-2}$
Deceleration is $0.1 ms^{-2}$ 2

(iii) $[T - (800 + 100) g = (800 + 100)a]$
$T - 900g = 900a$
T = 9072 N in 1st stage
T = 9000 N in 2nd stage
T = 8910 N in 3rd stage 3

(iv) $[R - 100g = 100a]$
R = 1008 N
R = 990 N 3

57. O/N 13/P43/Q5

(i)
$T_1 = V \div 0.3,\ T_3 = V$ 3

(ii) $[S = ½\,T_1V + T_2V + ½\,T_3V]$
$S = 552V - V\{0.5(T_1 + T_3)\}$
$= 552V - 13V^2/6$
$13V^2 - 3312V + 72000 = 0$
$V = 24$ 5

58. O/N 13/P43/Q7

(i) $[s = k_1t^2/2 - 0.005t^3/3 + (C)]$
$[k_1(60^2/2) - 0.005(60^3/3) = 540]$
$k_1 = 0.5$
$0.5 \times 60 - 0.005 \times 60^2 = k_2 \div \sqrt{60}$
$k_2 = 12\sqrt{60}$ 5

(ii)
$[s = 540 + 12\sqrt{60}(2\sqrt{t} - 2\sqrt{60}) =]$
$24\sqrt{(60t)} - 900$ 2

(iii) $[24\sqrt{(60t)} - 900 = 1260]$
$t = 135$
$v = 12\sqrt{60} \div \sqrt{135} \Rightarrow$ speed is $8 ms^{-1}$ 3

59. M/J 13/P42/Q6

(i) For sketch of single valued, continuous graph consisting of 3 straight line segments with $+^{ve}$, then $-^{ve}$, then $+^{ve}$ slope
Sketch appears to show v(0) = 0 and v(8) > v(26) > v(20) [2]

(ii) For shading the triangle from t = 0 to t = 8, the trapezium from t = 8 to t = 20 and the trapezium from t = 20 to a value of t seen to be between 20 and 26 [1]

(iii) $s(20) = ½(8 \times 8) + ½(8 + 2) \times 12\ (= 92)$
$a = (6.5 - 2)/6\ \ (= 0.75)$
$[s(t) = 92 + 2(t - 20) + 0.375(t - 20)^2$
Displacement is
$0.375t^2 - 13t + 202$ metres [6]

Alternative Marking Scheme for final 2 marks of Q6

$[v(t) = 2 + 0.75(t - 20)$
$s(t) = 0.375t^2 - 13t + A$ where
$92 = 0.375 \times 400 - 13 \times 20 + A]$
Displacement is
$0.375t^2 - 13t + 202$ metres

First Alternative Marking Scheme for part (iii) of Q6

(iii) $a = (6.5 - 2) / (26 - 20) = 0.75$
$v = 0.75t (+ C1)$
$v = 0.75t - 13$

60. M/J 13/P41/Q3

(i)
$u^2 = 2 \times 10 \times 45$; speed is $30ms^{-1}$ [2]

(ii) $[40 = 30t - 5t^2 \rightarrow t = 2, 4]$
$[5 = ½\ 10t^2 \rightarrow t = 1]$
Time above the ground is 2 s [2]

Special Ruling for candidates who assume, without justification, that the length of time required is that of the upward movement only. (maximum mark 1).

(ii) $5 = ½\ 10t^2 \rightarrow t = 1$, the length of time required is 1 s

(iii) Max. height above top of cliff = $½\ g(17 \div 4)$ (= 21.25)
$[0 = V^2 - 2g(40 + 21.25)$
Speed is $35\ ms^{-1}$ [3]

Alternative Marking Scheme for (iii)

(iii) $17 = V^2/25 - 32$
Speed is $35\ ms^{-1}$ [3]

61. M/J 13/P41/Q7

(i) $[0.0000117(1200t^2 - 12t^3) = 0]$
$1200t^2 = 12t^3 \rightarrow t = 0, 100$
Distance AB = 1170 m [3]

(ii) $2400t - 36t^2 = 0 \rightarrow t = 0, 200/3$
$[v_{max} = 0.0000117\{1200(200/3)^2 - 12(200/3)^3\}]$
Maximum speed is $20.8\ ms^{-1}$ [4]

(iii) At A $a(t) = 0$
At B $a(t) = 0.0000117(2400 \times 100 - 36 \times 100^2) = -1.40\ ms^{-2}$ (−1.404 exact) [2]

(iv) Sketch has v increasing from 0 to maximum and decreasing to 0, with maximum closer to t = 100 than t = 0.
Sketch has zero gradient at t = 0 and inflexion closer to t = 0 than t = 100. [2]

62. M/J 13/P43/Q4

(i)
$V(t) = 1.5t + 0.006t^2$
$[0.006t^2 + 1.5t - 90 = 0 \rightarrow$
$t^2 + 250t - 15000 = 0] \rightarrow$
$(t - 50)(t + 300) = 0]$
Leaves the ground when t = 50 [4]

(ii) $s = 0.75t^2 + 0.002t^3$
Distance is 2125 m [3]

63. M/J 13/P43/Q5

(i)
$[T = 2 \times 1.7 - 2 \times 0.7]$
[for P $17t - 5t^2 = 0$
and
for Q $7t = 5t^2 = 0]$
$T = 2$ [2]

(ii) $17(t + 2) - 5(t + 2)^2 - (7t - 5t^2) = 5$ or
$17t - 5t^2 - 7(t - 2) + 5(t - 2)^2 = 5$
$t = 0.9$ or $t = 2.9$
$v_P = 17 - 10(0.9 + 2)$,
$v_Q = 7 - 10 \times 0.9 \rightarrow$
Magnitudes are $12\ m\ s^{-1}$ & $2\ m\ s^{-1}$
The direction for both is vertically downwards [6]

64. O/N 12/P42/Q2

(i) $[0.6 = 0 + 0.3a]$
Acceleration is $2\ ms^{-2}$ 2

(ii) $[mg - T = 2m,\ T - (1 - m)g = 2(1 - m)]$
$[m = T/8 \rightarrow T - (10 - 1.25T) = 2 - 0.25T$
or
$T = 8m \rightarrow 8m - (10 - 10m) = 2 - 2m]$
$T + 1.25T + 0.25T = 10 + 2$
or
$m = 0.6$ and $T = 8m$
$m = 0.6$ and tension is 4.8 N 4

Alternative for part (ii)

$[\{m + (1 - m)\} \times 2 = \{m - (1 - m)\} \times g]$
$m = 0.6$
$[mg - T = 2m$ or $T - (1 - m)g = 2(1 - m)]$
Tension is 4.8 N

65. O/N 12/P42/Q7

(i) $dv/dt = k(120t - 3t^2)$

$[v(40) = k(60 \times 40^2 - 40^3) = 6.4]$

$k = 0.0002$ 3

(ii) $t = 60$ at A

$s(t) = 0.0002(20t^3 - t^4/4) \quad (+ C)$

$[OA = 0.0002 \times (20 \times 60^3 - 60^4/4)]$

Distance is 216 m 5

(iii) $[dv/dt = 0.0002(120 \times 60 - 3 \times 60^2)]$

Magnitude of acceleration is 0.72 ms^{-2} 2

(iv) $[20t^3 - 0.25\, t^4 = 0,$
$v = 0.0002(60 \times 80^2 - 80^3)]$

Speed is 25.6 ms^{-1} 2

66. O/N 12/P41/Q1

$[125 = ½\, 10t^2$

$t = 5$ s

$[s = 5 \times 5\ ½\ 0.8 \times 5^2]$

Distance is 35 m 4

67. O/N 12/P41/Q5

(i) $[5 = 2 + 0.05t$ or $25 = 4 + 2 \times 0.05(AB)]$

Time taken is 60 s (or Distance is 210 m)

Distance is 210 m (or Time taken is 60 s) 3

(ii) $s = kt^4/4\ (+C)$

$C = 0$ (may be implied by its absence)

$[210 = k \times 60^4/4]$

$k = 7/108000$ or 0.0000648

Speed of Q at B is 14 ms^{-1} 5

68. O/N 12/P41/Q6

(i) $½\, mv_B^2 = ½\, mv_A^2 - mg \times 2.7$
and $½\, mv_c^2 = ½\, mv_A^2 - mg \times 3$

$[v_B^2 = 8^2 - 20 \times 2.7,\ v_C^2 = 8^2 - 20 \times 3]$

Loss of speed $= 10^{½} - 2 = 1.16$ ms^{-1} 4

(ii) Work done $= ½\, 0.2 \times 2^2 + 0.2 \times g \times 3$ $(= 6.4)$

$½\,(0.4 + 6) = ½\, 0.2v_M^2 + 0.2g \times 1.5$

Speed at midpoint is 1.41 ms^{-1} 5

69. O/N 12/P43/Q2

(i) $[a = 0.2 + 0.012t]$

$[0.2 + 0.012t = 2.5 \times 0.2]]$

$t = 25$ 3

(ii) $[s = 0.1t^2 + 0.002t^3\ (+ C)]$

$[s = 0.1 \times 625 + 0.002 \times 15625]$

Displacement is 93.75 (accept 93.7 or 93.8) 3

70. O/N 12/P43/Q3

(i) $[0 = 8^2 - 2gs]$

Maximum height is 3.2 m

$[v^2 = 8^2 - 2g \times 1.6]$

Speed is 5.66 ms^{-1} 4

(ii) $[5.65685... = 8 - 10t]$

Time is 0.234 s 2

71. M/J 12/P42/Q3

(i)

$v = 1.2t^{5/3} + 2$

$t^{5/3} = 5/6$ [4]

(ii) $s = 0.45t^{8/3} + 2t$

Distance is 2.13 m [3]

72. M/J 12/P42/Q7

(i) $[-0.12 = 0.15a]$

$a = -0.8$ ms^{-2}

$[v = 3 - 0.8 \times 2]$

$v_{approach} = 1.4$

$[½\, 0.15(1.4^2 - v_r^2)]$

$v_{return} = -1$

$t = 3.25$ s when block comes to rest

For correct sketch [9]

(ii) $[XY = ½\,(3 + 1.4) \times 2,\ YZ = ½\, 1.25 \times 1]$

$s = 4.4$ at Y and 3.775 at Z, stated or on graph

Curve starts at origin, s increases, slope decreases (convex upwards) for $0 < t < 2$, value of s(2) shown

Curve starts at (2, 4.4), s decreases, magnitude of slope decreases to zero at (3.25, 3.775) [4]

73. M/J 12/P41/Q4

(i) $[a = 1.5t - 0.1875t^2]$
$[0.1875t(8 - t) = 0]$
Acceleration is zero when $t = 8$ [3]

(ii) Changes direction when $t = 12$

$s = 0.25t^3 - 0.0625t^4 \div 4 \quad (+\text{C})$
$[s = 0.25 \times 1728 - 0.0625 \times 20736 \div 4]$
Distance is 108 m [5]

74. M/J 12/P41/Q5

(i) PE loss = 2g(10 − 10 × 0.28)
$[\frac{1}{2}\, 2v^2 = 144]$
Speed is 12 ms^{-1} [3]

(ii) R = 2g x 0.96
$[2g \times 0.28 - 2g \times 0.96 \div 12 = 2a]$
Acceleration is 2 ms^{-1} [3]

(iii) $[v^2 = 12^2 + 2 \times 2 \times 10]$
Speed is 13.6 ms^{-1} [2]

75. M/J 12/P43/Q3

(i)
$s = 0.027(10t^3/3 - t^4/4) \quad (+C)$
$s = 0.027[10\,000/3 - 10000/4]$
Distance is 22.5 m [4]

(ii) $[0.027(20t - 3t^2) = 0 \rightarrow t = 20/3]]$
$v_{max} = 0.027(4000/9 - 8000/27)$
Maximum speed is 4 ms^{-1} [3]

76. O/N 11/P42/Q7

(i)(a) $[2 \times \frac{1}{2}(1 + 9)400]$
Approximation is 4000 m 2

(b) Accelerations are 0.02 ms^{-2} and − 0.02 ms^{-2} 2

(ii)(a) $0.04 - 0.0001t = \pm 0.02$
Values of t are 200 and 600 3

(b) $v_1 - v = 0.02t + 1 - 0.04t + 0.00005t^2$
$v_1 - v = [0.00005t^2 - 0.02t + 2 - 1]$
$= 0.00005(t^2 - 400t + 40000) - 1$
$= 0.00005(t - 200)^2 - 1$ 2

(c) For using $(v_1 - v)_{min}$ occurs when
$t = 200 \rightarrow -1 \leq v_1 - v$
For using $(v_1 - v)_{max}$ occurs when t = 0 and
when $t = 400 \rightarrow v_1 - v \leq 1$ 2

77. O/N 11/P41/Q4

(i) $1.76 = 0.8u + 0.32a$
$[1.76 + 2.16 = (0.8 + 0.6)u + \frac{1}{2}(0.8 + 0.6)^2 a$ or
$2.16 = (u + 0.8a)0.6 + \frac{1}{2}0.6^2 a]$
$3.92 = 1.4u + 0.98a$ or $2.16 = 0.6u + 0.66a$
$u = 1.4$ and $a = 2$ 6

(ii) $[2 = 10\sin\theta]$
$\theta = 11.5$ 2

78. O/N 11/P41/Q7

(i) v(100) = 0.16 × 1000 − 0.016 × 10000 = 0 1

(ii) $a = 1.5 \times 0.16t^{1/2} - 0.032t$
$[t^{1/2} = 0.24/0.032 \rightarrow t = 56.25 \rightarrow$
$v_{max} = 0.16 \times 421.875 - 0.016 \times 3164.0625]$
Maximum speed is 16.9 ms^{-1} (or $16\frac{7}{8}\,ms^{-1}$) 4

(iii) $s = 2/5 \times 0.16t^{5/2} - 0.016t^3/3$
Distance is 1070 m 3

(iv) $\frac{1}{3}t^{5/2}(0.192 - 0.016\sqrt{t}) = 0$
Value of t is 144 2

79. O/N 11/P43/Q1

(i)
Acceleration is 0.02 ms^{-2}
Acceleration is – 0.21 ms^{-2} 3

(ii) $[\frac{1}{2}(1.5 + 2.1) \times 30 + \frac{1}{2}\, 2.1 \times 10 - \frac{1}{2}\, 2.2 \times 20]$
Distance AB is 42.5 m 2

(iii) Total distance walked is 86.5 m 1

80. O/N 11/P43/Q5

(i)
Displacement is $2t^3 - kt^4/4$ 2

(ii) t = 6/k 1

(iii) $[2 \times 216/k^3 - k \times 1296/4k^4 = 108$
$\rightarrow 2 \times 216 - 1296/4 = 108k^3]$
k = 1 2

(iv) $dv/dt = 12t - 3kt^2$
= 0 when t = (0), 4
maximum value is 32 3

81. M/J 11/P42/Q3

(i) $[\frac{1}{2}5 \times 50 + \frac{1}{2}7(8 + 50) + 90 \times 8]$
Distance is 1048 m [2]

(ii) $a = (8 - 50)/(12 - 5)$ or $d = (50 - 8)/(12 - 5)$

$850 - F = 85a$ (or $-85d$)

Upward force is 1360 N **[5]**

82. M/J 11/P42/Q5

(i) Times to max. height are 1.2s and 0.7s

Range of values is $0.7 < t < 1.2$ **[3]**

(ii) $36t - 1.5gt^2 = 56t - 4gt^2$

$t = 8/g$

Velocities are 4m^{-1} and -1ms^{-1} **[5]**

Alternative for part 5(ii)

For using $3h_P = 8h_Q \rightarrow 3(v_P^2 - 144) \div (-20) = 8(v_Q^2 - 49) \div (-20) \rightarrow 3v_P^2 - 8v_Q^2 = 40$

For using $v_P = 12 - 10t$ and $v_Q = 7 - 10t \rightarrow v_P - v_Q = 5$

For eliminating v_Q (or v_P) and solving for v_P (or v_Q).

$v_P^2 - 16v_P + 48 = 0 \rightarrow v_P = 4$ (or 4, 12)

Upward velocities are 4 ms^{-1} and -1 ms^{-1} **[5]**

83. M/J 11/P42/Q7

(i) $[1.3 = 0.9 + 0.004T,$
$1.3^2 = 0.9^2 + 2 \times 0.004S]$

Time is 100 s (or distance is 110 m)

Distance is 110 m (or time is 100 s) **[3]**

(ii) $\int kt^3 dt = \frac{1}{4} kt^4$

$[k(\frac{1}{4} 100^4 - 0) = 110]$

$k = 4.4 \times 10^{-6}$

$[v_W = 0.9 + 0.004 \times 64.05,$
$v_C = 4.4 \times 10^{-6} \times 64.05^3]$

Both are equal to 1.16 ms^{-1} correct to 3 sf. **[5]**

(iii) Acceleration $= 3kt^2$

Acceleration at B is 0.132 ms^{-2} **[2]**

84. M/J 11/P41/Q5

(i) $v(600) = 0.025 \times 600$

$0 = 15 - 0.0375t_3$

Total time is 3600 s **[4]**

(ii) For correct graph

$[d = \frac{1}{2}(2600 + 3600) \times 15$ or
$d = \frac{1}{2}\, 0.025 \times 600^2 + 2600 \times 15 + \frac{1}{2}\, 0.0375 \times 400^2]$

Distance is 46500 **[3]**

(iii) Values of t are 300 and 3400 **[1]**

85. M/J 11/P41/Q6

(i)

$s = 2t^2 - t^4/64\ (+ C)$

$[t^4 - 128t^2 + 64^2 = 0]$

$(t^2 - 64)^2 = 0$

Time taken is 8 s **[5]**

(ii)

$a = 4 - 3t^2/16$

a is positive for $0 < t < \frac{8}{\sqrt{3}}$ or $0 < t < 4.62$ **[4]**

86. M/J 11/P43/Q3

(i) $a_P = g\sin 30^\circ$

$3.2 = \frac{1}{2} g t_q^2$

$[6.4 = u(0.8) + \frac{1}{2}\, 5 \times (0.8)^2]$

$u = 6$ **[4]**

(ii) $[v = 6 + 5 \times 0.8$ or $v^2 = 36 + 2\times5\times6.4]$

Speed of P is 10 ms^{-1} **[2]**

Alternative for Parts (i) and (ii) when a is not used:

<u>Part (i)</u>

$3.2 = \frac{1}{2} g t_q^2$

For using KE gain = PE loss to obtain an equation in u and v

$[\frac{1}{2}(v^2 - u^2) = 6.4g\sin 30^\circ]$

For using $s = \frac{1}{2}(u + v)t$ to obtain a second equation in u and v

$[6.4 = \frac{1}{2}(u + v) \times 0.8]$

$u = 6$ **[4]**

<u>Part (ii)</u>

Substitutes for u to find v

Speed is 10 ms^{-1} **[2]**

87. M/J 11/P43/Q4

(i) For correct shading composite figure consisting of 2 rectangles: 1st has boundaries $t = 0$ & $t = 20$, $v = 0$ and $v = 2.5$; 2nd has boundaries $t = 20$ & $t = T$, $v = 0$ and $v = 4$ [1]

(ii) $[50 + 4(T - 20) = 70$ or $4T - 30 = 70]$

$T = 25$ [2]

(iii) [Distance $= 70 + (4 - 2.5)20$ or $50 + 4[(T - 20) + 20] - 50]$

Distance between P and Q is 100 m [2]

(iv) For 2 straight line segments representing P, 1st with +ve slope and 2nd with steeper slope, $t = 20$ indicated appropriately

For Q, 1st & 2nd segments parallel to P's and displaced to the right, $t = 25$ and $t = 45$ indicated appropriately [2]

88. M/J 11/P43/Q7

(i) $v = \frac{1}{160}t^3 - \frac{1}{3200}t^4 \quad (+C_1)$

$[0 = 8000/160 - 160000/3200 + C_1 \rightarrow C_1 = 0]$

Initial speed is zero [4]

(ii) $[t^2/800(15 - t) = 0]$

$v_{max} = v(15) = 5.27\ ms^{-1}$ [2]

(iii) $s = \frac{1}{640}t^4 - \frac{1}{16000}t^5 \ (+C_2)$

$[250 - 200]$

Distance AB is 50 m [4]

89. O/N 10/P42/Q5

(i) $[15 = 20t - 5t^2 \rightarrow 5(t^2 - 4t + 3) = 0]$

$t = 1, 3$

Duration is 2 s (accept $1 < t < 3$) [3]

(ii)

$20t - 5t^2 = 25(t - 0.4) - 5(t - 0.4)^2$ (or $20(t + 0.4) - 5(t + 4)^2 = 25t - 5t^2$ or $(20 \times 0.4 - 5 \times 0.4^2) + 16t - 5t^2 = 25t - 5t^2$)

$t = 1.2$ (or $t = 0.8$)

$[v_P = 20 - 10 \times 1.2;\ v_Q = 25 - 10 \times (1.2 - 0.4)$ (or $v_P = 20 - 10 \times (0.8 + 0.4);\ v_Q = 25 - 10 \times 0.8)]$

Velocities are $8\ ms^{-1}$ and $17\ ms^{-1}$ [5]

90. O/N 10/P42/Q6

(i) $[\frac{1}{2}\, 2.5(\text{speed}_{max}) = 4]$

Greatest speed is $3.2\ ms^{-1}$ [2]

SR (max. 1/2) for candidates who (implicitly) make the u occurs when $t = 1.25$

Greatest speed is $3.2\ ms^{-1}$ from $2 \times \frac{1}{2}\, 1.25(\text{speed}_{max})v = 4$

(ii) $[V = 3 \times 2]$

$V = 6$ [2]

(iii) $\frac{1}{2}\, 6(12 + T) = 48$ or

$\frac{1}{2}\, 6 \times 2 + 6T + \frac{1}{2}\, 6(10 - T) = 48$ or

$\frac{1}{2}\, 6 \times 2 + 6(10 - \tau) + \frac{1}{2}\, 6\tau = 48$

$t = 8.5$ [3]

(iv) Deceleration is $1\ ms^{-2}$ [2]

91. O/N 10/P42/Q7

(i) $a(t) = 0.006t^2 - 0.24t + 1.8$

$[0.006(t^2 - 40t + 300) = 0]$

$T_1 = 10,\ T_2 = 30$

$s(t) = 0.0005t^4 - 0.04t^3 + 0.9t^2 + 5t + (C)$

$[405 - 1080 + 810 + 150]$

Distance is 285 m [7]

(ii) Velocity is $5\ ms^{-1}$

For curve with v increasing from a +ve value at $t = 0$ to a maximum

Then decreases to a +ve minimum and thereafter increases [3]

92. O/N 10/P41/Q1

(i) $V = 20$ [2]

(ii) Speed is $40\ ms^{-1}$ [1]

(iii) Height is 80 m [2]

93. O/N 10/P41/Q4

(i) $(1.5 + 3.5)/2 = s/10$

Displacement is 25 m [2]

(ii) $v = 0.015t^2\ (+C)$

$[3.5 = 0.015 \times 100 + C \rightarrow C = 2]$

$[s = 0.005t^3 + 2t + (0)]$

Displacement is 25 m, same as P. [5]

94. O/N 10/P43/Q1

$a = g\sin30^\circ$

[(i) $v_1^2 = 2(g\sin30^\circ)0.9$
or $\frac{1}{2}mv_1^2 = mg(0.9\sin30^\circ)$
or (ii) $v_2 = (g\sin30^\circ)0.8$]

(i) Speed is 3 ms^{-1} or (ii) Speed is $4ms^{-1}$
(ii) Speed is $4ms^{-1}$ or (i) Speed is 3 ms^{-1} [4]

95. O/N 10/P43/Q4

(i) $v(4) = 0.75x4$
$v(54) = v(4)$ and $v(60) = v(54) - 0.5(60 - 54)$
Velocity is $3ms^{-1}$ when t = 4 and 0 when t = 60
2nd segment has zero slope; end points of segments are seen to be correct{(0,0), (4,3), (54,3), (60,0)} [5]

(ii) [XY = ½ (60 + 50)x3
or
XY = ½ x0.75x4² + 3x50 – ½ x0.5x6²]
Distance is 165 m [2]

96. O/N 10/P43/Q6

(i) $a_1(t) = 1.44t - 0.288t^2$, $a_2(t) = 2.4 - 0.48t$
[$a_1 = 1.44x5 - 0.288x25$, $a_2 = 2.4 - 0.48x5$]
$a_1 = a_2$ (= 0) ➔ no instantaneous change [4]

(ii) $s_1 = 0.24t^3 - 0.024t^4$, $s_2 = 1.2t^2 - 0.08t^3$
[{(0.24x5³ – 0.024x5⁴) – (0 – 0)} + {(1.2x10² – 0.08x10³) – (1.2x5² – 0.08x5³)}]
Distance is 35 m [4]

97. M/J 10/P42/Q2

(i) Acceleration is $0.09 ms^{-2}$ [1]

(ii) [D = ½ (8 + 4)0.18 or
D = (0 + ½ 0.09 × 2²) + (0.18 × 4 + ½ 0 × 4²) + (0.18 × 2 – ½ 0.09 × 2²)]
Distance is 1.08 m [2]

(iii) [½ 3V = 1.08]
Greatest speed is $0.72 ms^{-1}$ [2]

98. M/J 10/P42/Q7

(i) $\int_0^{15} v_1 dt = 225$ ➔
$A[(15^2/2 - 0.05 \times 15^3/3) - (0 - 0)] = 225$
$A = 4$
$[4(15 - 0.05 \times 15^2) = B/15^2]$
$B = 3375$ [5]

(ii) $s_2(t) = Bt^{-1}/(-1)$ (+ C)
[–3375/15 + C = 225]
Distance travelled is [450 – 3375/t] m (for t ⩾ 15) [3]

(iii) [450 – 3375/t = 315]
[$v = 3375/25^2$]
Speed is $5.4 ms^{-1}$ [3]

Alternative for 7(ii)

$$s = \int_{15}^{t} 3375t^{-2}dt = -3375\left(\frac{1}{t} - \frac{1}{15}\right)$$
= 225 – 3375/t
Distance travelled = 225 + (225 – 3375/t)
Distance travelled is [450 – 3375/t] m (for t ⩾ 15)

99. M/J 10/P41/Q2

(i) Acceleration is $0.09 ms^{-2}$ [1]

(ii) [D = ½ (8 + 4)0.18 or
D = (0 + ½ 0.09 × 2²) + (0.18 × 4 + ½ 0 × 4²) + (0.18 × 2 – ½ 0.09 × 2²)]
Distance is 1.08 m [2]

(iii) [½ 3V = 1.08]
Greatest speed is $0.72 ms^{-1}$ [2]

100. M/J 10/P41/Q7

(i) $\int_0^{15} v_1 dt = 225$ ➔
$A[(15^2/2 - 0.05 \times 15^3/3) - (0 - 0)] = 225$
$A = 4$
$[4(15 - 0.05 \times 15^2) = B/15^2]$
$B = 3375$ [5]

(ii) $s_2(t) = Bt^{-1}/(-1)$ (+ C)
[–3375/15 + C = 225]
Distance travelled is [450 – 3375/t] m (for t ⩾ 15) [3]

(iii) [450 – 3375/t = 315]
[$v = 3375/25^2$]
Speed is $5.4 ms^{-1}$ [3]

Alternative for 7(ii)

$s = \int_{15}^{t} 3375t^{-2}dt = -3375(\frac{1}{t} - \frac{1}{15})$

$= 225 - 3375/t$

Distance travelled = 225 + (225 – 3375/t)

Distance travelled is [450 – 3375/t] m (for t ⩾ 15)

101. M/J 10/P43/Q2

[1.2 – 0.24t = 0.6]
t = 2.5
[$s = 0.6t^2 - 0.04t^3$]

$s = (0.6 \times 2.5^2 - 0.04 \times 2.5^3) - (0 - 0)$

Displacement is 3.125 m [5]

102. M/J 10/P43/Q5

(i) [s = ½ (1.4 + 1.1) × 1.2; 1.1 = 1.4 + (–d) × 1.2]
AB = 1.5 m **or** d = 0.25
d = 0.25 **or** AB = 1.5 m [3]

(ii) [$0 = u^2 + 2(-0.25)2$; $2 = 0 - ½(-0.25)t^2$]
Speed is 1 ms^{-1} **or** time is 4 s
Time is 4 s **or** speed is 1 ms^{-1} [3]

(iii) For line joining (0, 1.4) and (1.2, 1.1)
For line joining (1.2, –1) and (5.2, 0) [2]

103. M/J 10/P43/Q6

(i) [2a = 3.5]
Acceleration is 1.75 ms^{-2}
[1.75 = gsin α] or
[$0.5 \times 3.5^2 = gh$; s = 0.5 × 3.5 × 2 and sinα = h/s]
Angle is 10.1° or 0.176^c [4]

(ii) [$s_P = ½ a2^2 + \{(a2)t + ½ at^2\}$]
or [$s_P = ½ a (t + 2)^2$]
[$s_P - s_Q = ½ a2^2 + (a2)t + ½ at^2 - ½ at^2$]
2 × 1.75 + 2 × 1.75t
[4.9 = 2a + 2at]
t = 0.4 [5]

104. O/N 09/P42/Q7

(i) $v = 1.2t - 0.012t^2$
[a(50) = 1.2 – 0.024 × 50]
a = 0
V = 30 5

(ii) $s_1 = 0.6 \times 50^2 - 0.004 \times 50^3$ (= 1000)
$\left[\frac{1000 + s_2}{50 + t_2} = 27.5\right]$
[$1000 + 30t_2 = 27.5(50 + t_2)$]
$t_2 = 150$
t = 200 5

(Alternative for part (ii))

$s_1 = 0.6 \times 50^2 - 0.004 \times 50^3$ (= 1000)
[$(1000 + s_2)/t = 27.5$]
(1000 + 30(t – 50))/t = 27.5
[27.5t = 1000 + 30(t – 50)]
t = 200 5

105. O/N 09/P41/Q7

(i) Speed is 6ms^{-1}
a = 0.6 2

(ii) $a(t) = -1600/t^3$ (second stage)
[$0.6 = 1600/t^3 \Rightarrow t^3 = (1600/0.6)$]
t = 13.9 4

(iii) $s_1 = 30m$
$s = (800t^{-1})/(-1) - 2t$ (+ C)
$s_2 = (-40 - 40) - (-80 - 20)$ or s = –40 – 40 + 130
Displacement from A is 50m 6

106. M/J 09/P4/Q7

(i) a = 0.5 – 0.02t
[0.5 – 0.02t = 0.1]
Time taken is 20 s [3]

(ii) $u = 0.5 \times 20 - 0.01 \times 20^2$ (= 6)
[14 = 6 + 0.1t]
Time taken is 80 s [3]

(iii) [$v^2 = 14^2 - 2 \times 0.3 \times 300$]
Speed is 4 ms^{-1} [2]

(iv) $s = 0.25t^2 - 0.01t^3/3$ (+ *C*)
$AB = 0.25 \times 20^2 - 0.01 \times 20^3/3$ (= 73.3)
$BC = ½ (6 + 14) \times 80$ or $6 \times 80 + ½\, 0.1 \times 80^2$
or $(14^2 - 6^2)/(2 \times 0.1)$ (= 800)
Distance *AD* is 1170 m [6]

107. O/N 08/P4/Q6

(i)
- v is single valued, continuous and positive for $0 < t < 1000$.
- 1st segment has +ve slope

And two or more of
- $v(0) = 0$
- $v(1000) = 0$
- 2nd segment has zero slope
- 3rd segment has -ve slope

Correct sketch [2]

(ii) $\frac{1}{2}(600 + 1000)V = 20\,000$
$V = 25$ [3]

SR for candidates who assume 1st and 3rd time intervals are each 200 s (max 2/3)

$\frac{1}{2}V \times 200 + V \times 600 + \frac{1}{2}V \times 200 = 20000$
$V = 25$

(iii) $[V/t_1 = 0.15 \rightarrow t_1 = 166.6\ldots]$
$t_3 = 233.3\ldots$
$[s_3 = \frac{1}{2}\, 233.3\ldots \times 25]$
Distance is 2920m [4]

108. O/N 08/P4/Q7

(i) $[v^2 = 2 \times 10 \times 1.25$ or $\frac{1}{2}mv^2 = mg(1.25)$, $1.25 = \frac{1}{2}10t^2]$
Speed of P is 5ms^{-1}
Time taken is 0.5s [3]

(ii) $v = 10t - 0.15t^2 \quad (+C)$
$v = 10t - 0.15t^2 + 5$
$x = 5t^2 - 0.05t^3 + 5t$
$[x = 5 \times 2.5^2 - 0.05 \times 2.5^3 + 5 \times 2.5\ (= 42.97)]$
Distance OP is 44.2m [7]

109. M/J 08/P4/Q1

(i) $[4.5 = 1.5 + 1.2a]$
Acceleration is 2.5 ms^{-2} [2]

(ii) $\alpha = 14.5$ [2]

110. M/J 08/P4/Q7

(i) $(dv/dt) = -0.02t + 0.5$ **or**
$v = -0.01[(t - T)^2 - 100V]$ where
$T = 25$ and $V = 5.25$ (or equivalent)
$t = 25$
Maximum velocity is 5.25ms^{-1} [4]

(ii) $s_2 = -0.01t^3/3 + 0.5t^2/2 - t$
$s_2 = (-90 + 225 - 30) - (-10/3 + 25 - 10)$
$(= 93.3\text{m})$
$v(10) = 3$ and $v(30) = 5$
$s_1 = \frac{1}{2}\, 3 \times 10$ and $s_3 = \frac{1}{2}\, 5 \times 50$
Distance is 233m [9]

111. O/N 07/P4/Q2

$s_1 = 12.5t - \frac{1}{2}gt^2$, $s_2 = \pm \frac{1}{2}gt^2$ or
$(12.5 - gt)^2 = 12.5^2 - 2gs_1$ and
$(gt)^2 = 2gs_2$
$[12.5t - \frac{1}{2}gt^2 + \frac{1}{2}gt^2 = 10]$
$t = 0.8\text{s}$
or
$2s_1 = 25\sqrt{2 - 0.2s_1} - (20 - 2s_1)$
(or better)
Height is 6.8m 5

112. O/N 07/P4/Q6

(i) $[2.2 = 1.8 + 0.004t]$
Time taken is 100s
(or Distance is 200 m)
Distance is 200 m 3
(or Time taken is 100s)

(ii)(a)
$s = k(100t^2 - t^3/3)\ (+C)$
$[k(100 \times 100^2 - 100^3/3) = 200]$
$k = 0.0003$ 4

(b) Speed is 3 ms^{-1} 1

(iii) Parabolic segment has decreasing slope; sketches correct relative to each other (line crosses curve once) 3

113. M/J 07/P4/Q1

(i) $[1.5^2 = 2.5^2 + 2a \times 4]$
Deceleration is 0.5 ms^{-2} 2

(ii) $\alpha = 2.9$ 2

114. M/J 07/P4/Q6

(i) $s_Q = 1.5t^2 - 0.1t^3\ (+C)$
$s_Q(10) = 50$ (or $s_Q(5) = 25$)
Greatest velocity is 10 ms^{-1} 6

(ii) $a_P = 10/5$
$[3 - 0.6t = 2]$
$t = 1.67$ (or $1^2/_3$) 3

115. O/N 06/P4/Q4

(i) $a(t) = 1.25 - 0.1t$
Initial acceleration is $1.25 ms^{-2}$ — 2

(ii) [t = 12]
$1.25t^2/2 - 0.05t^3/3$ (+C)
$[1.25 \times 12^2/2 - 0.05 - 12^3/3 = 90 - 28.8]$
Displacement is 61.2m — 5

116. M/J 06/P4/Q2

(i) Time taken is 100 s — 2
(ii) $t^2/2 - t^3/300$
Distance AB is 1670 m (1666 2/3) — 3

117. M/J 06/P4/Q4

(i) (a) Height is 2.45 m
(b) Depth is 3 m — 2
(ii) Deceleration is $4 ms^{-2}$
(iii) $0.7 - mg = 4m$
Mass is 0.05 kg — 3

118. M/J 06/P4/Q7

(i) Acceleration down (or up) the plane is the same for both particles

$d = (1.3t + ½ at^2) - (-1.3t + ½ at^2)$
$d = 2.6t$ — 4

(ii) $\sin \alpha = 1.6/(2.6 \times 2.5)$
$a = 32/13 ms^{-2}$ (2.46)
(iii) $0 = -1.3 + 2.46t$ (0.528125)
$d_p = 1.3(0.528..) + ½ 2.46(0.528..)^2$
or $s_p = 2.6(0.528..) - 0.343..$
$= 1.373... - 0.343...$
Distance travelled is 1.03 m — 3

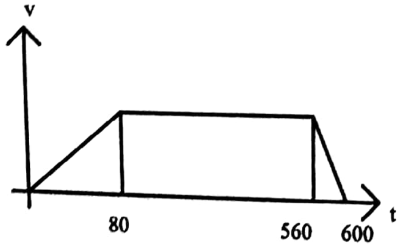
119. O/N 05/P4/Q1

(i) (a) $7^2 - 5^2 = 2ad_1$,
(b) $8^2 - 7^2 = 2ad_2$ — 2

(ii) $\frac{24}{15} = \frac{d_1}{d_2}$
$d_1 = 1.6d_2$ — 2

120. O/N 05/P4/Q5

(i)



3

(ii) $½ 80v = 400$
Velocity is $10 ms^{-1}$ — 2

(iii) $D = ½ (600 + 480)10$
Total distance is 5400 m — 2

(iv) Acceleration is $0.125 ms^{-2}$ for $0 < t < 80$ — 2

121. O/N 05/P4/Q6

(i) $s = 4t^2 - 2t^3/3$ (+C)
$s = 4 \times 9 - (2/3)27$
Distance is 18 m — 4

(ii) $s = -54/t$ (+C)
$18 = -54/3 + C$
Displacement is $36 - 54/t$ — 3

(iii) $36 - 54/t = 27 \rightarrow t = 6$
$v = 54/36$
$v = 1.5$ — 3

122. M/J 05/P4/Q5

(i) $x = 0.01 t^3$ (+C)
$2.5 = 0.01 \times 5^3 + C$
$x = 0.01 t^3 + 1.25$ — 4

(ii) $0.01 t^3 + 1.25 = 11.25$
$t = 10$
Velocity is $3ms^{-1}$ — 3

123. M/J 05/P4/Q6

(i) $½ 5 v_{max} = \pm 10$
Greatest speed is $4 ms^{-1}$ — 2

(ii) $V/3 = 2$ or $V = 0 + 2 \times 3$
$V = 6$ — 2

(iii) $½ (T + 9.5)6 = 34.5$ or
$½ (t - 18 + 9.5)6 = 34.5$
Time is 2 s — 3

(iv) $d = \frac{6}{24.5 - (18 + 2)}$
Deceleration is $4/3 ms^{-2}$ — 2

124. O/N 04/P4/Q5

(i)
- $5 + 4t = 1.8(3 + 2t)$ or
- $1.8 v_Q = 5 + 4t$ and $v_Q = 3 + 2t$ or
- $v_P = 5 + 4t$ and $(5/9)v_P = 3 + 2t$

$t = 1$ or $v_Q = 5$
or correct equation in v_P only
[eg $(10/9 - 1)$ $v_P = 6 - 5$]
Speed of $P = 9ms^{-1}$ — 4

(ii) $5t + \frac{1}{2}4t^2 + 3t + \frac{1}{2}\,2t^2 = 51$

$3t^2 + 8t - 51 = 0$

$\rightarrow (3t + 17)(t - 3)$

Time is 3 s **4**

125. O/N 04/P4/Q7

(i) $t^2(0.009 - 0.0001\ t) = 0$

Time is 90 s **2**

(ii) $s = 0.003\ t^3 - 0.000025\ t^4\ (+C)$

$(2187 - 1640.25) - (0 - 0)$

Distance is 547 m **4**

(iii) $0.018\,t - 0.0003\ t^2 = 0 \rightarrow$

$t(0.018 - 0.0003\ t) = 0$

$t = 60$ (may be implied)

$32.4 - 21.6$

Maximum speed is 10.8 ms^{-1} **4**

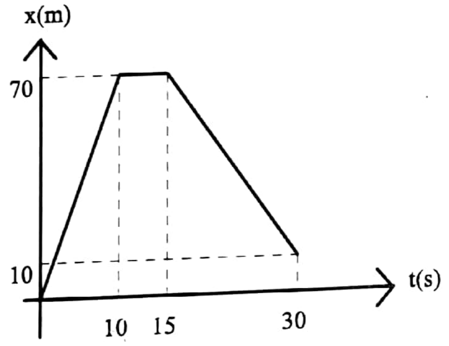
126. M/J 04/P4/Q3

(i) Distance AC is 70 m

$7 \times 10 - 4 \times 15$

Distance AB is 10 m **3**

(ii)



127. M/J 04/P4/Q5

(i) $10t^2 - 0.25\ t^4$ (+C)

Expression is $10\ t^2 - 0.25\ t^4 - 36$ **3**

(ii) Displacement is 60 m **1**

(iii) $(t^2 - 36)(1 - 0.25\ t^2) = 0$

Roots of quadratic are 4, 36

$t = 2, 6$ **3**

128. M/J 04/P4/Q7

(i) $25 = 30\,t - 5t^2 \rightarrow t^2 - 6t + 5 = 0 \rightarrow$

$(t - 1)(t - 5) = 0$

or

$v^2 = 30^2 - 500;\ t_{up} = (20 - 0)/10$

$t = 1, 5$ or $t_{up} = 2$

Time $= 5 - 1 = 4$ s or

Time $= 2 \times 2 = 4$s or $1 < t < 5$ **3**

(ii) $s_1 = 30t - 5t^2$ and $s_2 = 10t - 5t^2$

$30t - 10t = 25$

$t = 1.25$

$v_1 = 30 - 10 \times 1.25$ or

$v_2 = 10 - 10 \times 1.25$

or

$v_1^2 = 30^2 - 2 \times 10(29.6875)$ or

$v_2^2 = 10^2 - 2 \times 10(4.6875)$

Velocities 17.5ms^{-1} and $-2.5ms^{-1}$ **5**

OR

(ii) $v_1 = 30 - 10\,t,\ v_2 = 10 - 10\,t$

$\rightarrow v_1 - v_2 = 20$

$(30^2 - v_1^2) \div 20 =$

$(10^2 - v_2^2) \div 20 + 25$

$v_1 - v_2 = 20,\ v_1^2 - v_2^2 = 300$

Velocities are 17.5 ms^{-1} and $-2.5\ ms^{-1}$ **5**

(iii) $t_{up} = 3$

$3 - 1.25$

Time is 1.75 s or $1.25 < t < 3$ **3**

OR

(iii) $0 = 17.5 - 10t$

Time is 1.75 s or $1.25 < t < 3$

129. O/N 03/P4/Q2

(i) Speed is 20 ms^{-1} **1**

(ii) For using $s = \frac{1}{2}gt^2$ $\quad 45 = \frac{1}{2}10t^2$

Time taken is 3 s **2**

(iii) For using $v^2 = u^2 + 2gs$

$(40^2 = 30^2 + 2 \times 10s)$

Distance fallen is 35 m **2**

130. O/N 03/P4/Q7

(i) For using the idea that area represents the distance travelled.
For any two of $\frac{1}{2} \times 100 \times 4.8$, $\frac{1}{2} \times 200(4.8 + 7.2)$,
$\frac{1}{2} \times 200 \times 7.2$ (240, 1200, 720)
Distance is 2160 m 3

(ii) For using the idea that the initial acceleration is the gradient of the first line segment or for using $v = at$ ($4.8 = 100a$) or
$v^2 = 2as$ ($4.8^2 = 2a \times 240$)
Acceleration is 0.048 ms^{-2}. 2

(iii) $a = 0.06 - 0.00024t$
Acceleration is greater by 0.012 ms^{-2} [√ for 0.06 – ans(ii) (must be +ve) and/or wrong coefficient of t in $a(t)$] 2
[Accept 'acceleration is 1.25 times greater']

(iv) B's velocity is a maximum when $0.06 - 0.00024t = 0$
[√ wrong coefficient of t in $a(t)$]
For the method of finding the area representing s_A (250)
$240 + \frac{1}{2}(4.8 + 6.6)150$ or
$240 + (4.8 \times 150 + \frac{1}{2}\, 0.012 \times 150^2)$ (1095)
For using the idea that s_B is obtained from integration
$0.03t^2 - 0.00004t^3$
Required distance is 155 m 6
(√ dependent on both M marks)

131. M/J 03/P4/Q3

(i) Region under $v = 2t$ from $t = 0$ to $t = T$ indicated 1

(ii) For attempting to set up and solve an equation using area $\Delta = 16$ or for using $s = \frac{1}{2}\, 2\, t^2$
For $16 = \frac{1}{2}\, 2\, T^2$ 3
$T = 4$
SR (for candidates who find the height of the Δ but do not score M1) (Max 1 out of 3)
For $h/T = 2$ or $h = 2T$ or $v = 8$

(iii) For using distance = $10 \times$ ans (ii) or
for using the idea that the distance is represented by the area of the relevant parallelogram or
by the area of the trapezium (with parallel sides 9 and 4 and height 10) minus the area of the triangle (with base 5 and height 10)
Distance is 40m 2

132. M/J 03/P4/Q4

(i) For differentiating x
$\dot{x} = t + \frac{1}{10}t^2$
Speed is 20 ms^{-1} 3

(ii) $\ddot{x} = 1 + \frac{1}{5}t$

For attempting to solve $\ddot{x}(t) = 2\ddot{x}(0)$ $(1 + \frac{1}{5}t = 2)$

$t = 5$ 3

133. O/N 02/P4/Q2

(i) For 20 × 7 or 140 and ½ 4 × 7 or 14
Valid argument that $s_1 \div s_2 > 154$ 2

Alternatively:

Approx distance is 20 × 7 + 4 × 7 k (where ½ < k < 1)
Whose value (shown) is (clearly) > 154

(ii) For using area property with correct signs [140 + 20 – ½ 10 × 8]
Distance is 120 m 2

134. O/N 02/P4/Q4

(i) For using v = u – gt, with v = 0, to find t [5 – 10t = 0]
Time to maximum height of A is 5/g
For using $h = ut - \frac{1}{2}gt^2$ and evaluating $h_B(0.5) - h_A(0.5)$
Difference in heights is 1.5m (1.53 from g = 9.81 or g = 9.8) 4
SR for difference in maximum heights (max 1 out of 4)
1.95 m (1.99) from g = 9.81 or 9.8)

(ii) For attempting to solve $h_B - h_A = 0.9$ for t [8t – 5t = 0.9]
t = 0.3
For using $h = ut - \frac{1}{2}gt^2$ with the value of t found
[h = 5 × 0.3 – ½ 10 × 0.09]
Height of A is 1.05 m (1.06 from g = 9.81 or g = 9.8) 4

135. O/N 02/P4/Q7

(i) v(200) = 0.12 × 200 – 0.0006 × 40 000 = 0
For using a = dv/dt and evaluating a(200) or a(200 + ε) for suitably small ε
[a = 0.12 – 0.0012 × 200]
Acceleration is $0.12ms^{-2}$ (accept a = – 0.12) (must be from ε = 0) 3

(ii) For attempting to solve dv/dt = 0 or using t = ½ 200 (may be implied)
t = 100 (ft incorrect 2-term dv/dt in (i))
Maximum speed is $6m^{-1}$ 3

(iii) For integrating v
$s = 0.06t^2 - 0.0002t^3$ (+C)
Displacement is 800m 3

(iv) For attempting to solve s = 0
t = 300 2

136. M/J 02/P4/Q5

(i) (a) For using $v = u + at$ [$6 = 3 + (0.06)t$]
Time taken is 50s

(b) For using $v^2 = u^2 + 2as$ [$36 = 9 + 2(0.06)s$]
Or $s = ut + \frac{1}{2}at^2$ [$s = 3(50) + \frac{1}{2}(0.06)2500$]

Or $s = \frac{u+v}{2}t$ [$s = \frac{1}{2}(3 + 6)50$]

Distance is 225m — **2**

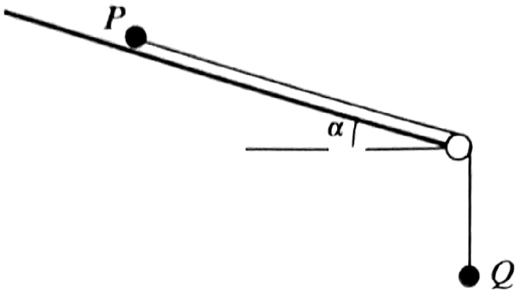
(ii)(a) For attempting to integrate kt^2
$s = kt^3/3$
For finding k by substituting for s and t in the expression for s obtained by integration or using appropriate limits in the integration
[$k50^3/3 = 225$]
$k = 0.0054$ or 27/5000 — ft for $3 \times (\text{ans i(b)}/(\text{ans i(a)})^3$ — **4**

(b) Speed is 13.5ms^{-1} — ft for $(\text{ans ii(a)} \times (\text{ans i(a)})^2$ — **1**

SR (for candidates who use constant acceleration formulae in part (ii)
(max 1 out of 5)
For $k = 0.0036$ and speed at B is 9ms^{-1} (in either order)

Unit-3: Newton's Laws of Motion

1. **O/N 17/P42/Q6**



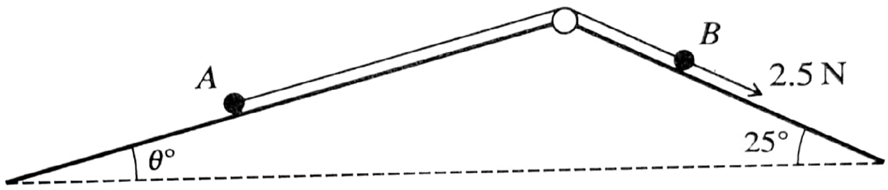
Two particles P and Q, each of mass m kg, are attached to the ends of a light inextensible string. The string passes over a fixed smooth pulley which is attached to the edge of a rough plane. The plane is inclined at an angle α to the horizontal, where $\tan\alpha = \frac{7}{24}$. Particle P rests on the plane and particle Q hangs vertically, as shown in the diagram. The string between P and the pulley is parallel to a line of greatest slope of the plane. The system is in limiting equilibrium.

(i) Show that the coefficient of friction between P and the plane is $\frac{4}{3}$. [5]

A force of magnitude 10 N is applied to P, acting up a line of greatest slope of the plane, and P accelerates at $2.5\ \text{m s}^{-2}$.

(ii) Find the value of m. [5]

2. **O/N 17/P41/Q7**



Two particles A and B of masses 0.9 kg and 0.4 kg respectively are attached to the ends of a light inextensible string. The string passes over a fixed smooth pulley which is attached to the top of two inclined planes. The particles are initially at rest with A on a smooth plane inclined at angle $\theta°$ to the horizontal and B on a plane inclined at angle 25° to the horizontal. The string is taut and the particles can move on lines of greatest slope of the two planes. A force of magnitude 2.5 N is applied to B acting down the plane (see diagram).

(i) For the case where $\theta = 15$ and the plane on which B rests is smooth, find the acceleration of B. [5]

(ii) For a different value of θ, the plane on which B rests is rough with coefficient of friction between the plane and B of 0.8. The system is in limiting equilibrium with B on the point of moving in the direction of the 2.5 N force. Find the value of θ. [5]

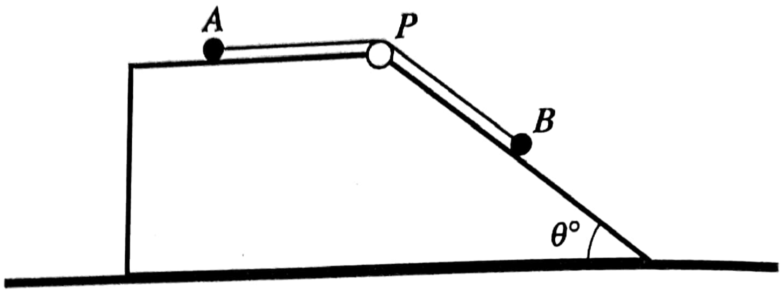
3. **O/N 17/P43/Q4**

Two particles A and B have masses 0.35 kg and 0.45 kg respectively. The particles are attached to the ends of a light inextensible string which passes over a small fixed smooth pulley which is 1 m above horizontal ground. Initially particle A is held at rest on the ground vertically below the pulley, with the string taut. Particle B hangs vertically below the pulley at a height of 0.64 m above the ground. Particle A is released.

(i) Find the speed of A at the instant that B reaches the ground. [5]

(ii) Assuming that B does not bounce after it reaches the ground, find the total distance travelled by A between the instant that B reaches the ground and the instant when the string becomes taut again. [2]

4. M/J 17/P42/Q6



The diagram shows a fixed block with a horizontal top surface and a surface which is inclined at an angle of $\theta°$ to the horizontal, where $\sin\theta = \frac{3}{5}$. A particle A of mass 0.3 kg rests on the horizontal surface and is attached to one end of a light inextensible string. The string passes over a small smooth pulley P fixed at the edge of the block. The other end of the string is attached to a particle B of mass 1.5 kg which rests on the sloping surface of the block. The system is released from rest with the string taut.

(i) Given that the block is smooth, find the acceleration of particle A and the tension in the string. [5]

(ii) It is given instead that the block is rough. The coefficient of friction between A and the block is μ and the coefficient of friction between B and the block is also μ. In the first 3 seconds of the motion, A does not reach P and B does not reach the bottom of the sloping surface. The speed of the particles after 3 s is $5\,\text{m}\,\text{s}^{-1}$. Find the acceleration of particle A and the value of μ. [9]

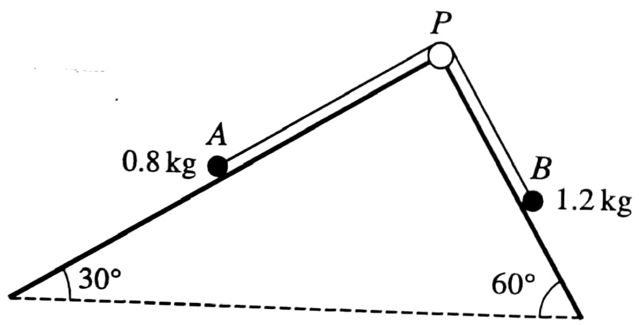
5. M/J 17/P41/Q2

A particle of mass 0.8 kg is projected with a speed of $12\,\text{m}\,\text{s}^{-1}$ up a line of greatest slope of a rough plane inclined at an angle of 10° to the horizontal. The coefficient of friction between the particle and the plane is 0.4.

(i) Find the acceleration of the particle. [4]

(ii) Find the distance the particle moves up the plane before coming to rest. [2]

6. M/J 17/P41/Q7

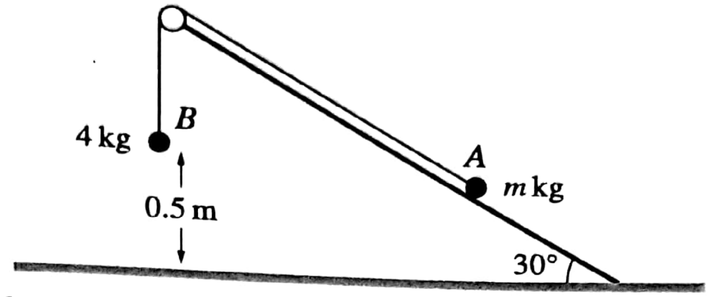


As shown in the diagram, a particle A of mass 0.8 kg lies on a plane inclined at an angle of 30° to the horizontal and a particle B of mass 1.2 kg lies on a plane inclined at an angle of 60° to the horizontal. The particles are connected by a light inextensible string which passes over a small smooth pulley P fixed at the top of the planes. The parts AP and BP of the string are parallel to lines of greatest slope of the respective planes. The particles are released from rest with both parts of the string taut.

(i) Given that both planes are smooth, find the acceleration of A and the tension in the string. [6]

(ii) It is given instead that both planes are rough, with the same coefficient of friction, μ, for both particles. Find the value of μ for which the system is in limiting equilibrium. [6]

7. **M/J 17/P43/Q7**

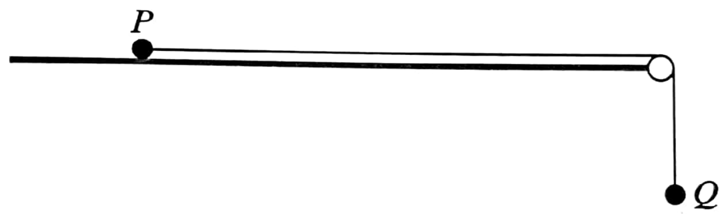


Two particles A and B of masses m kg and 4 kg respectively are connected by a light inextensible string that passes over a fixed smooth pulley. Particle A is on a rough fixed slope which is at an angle of 30° to the horizontal ground. Particle B hangs vertically below the pulley and is 0.5 m above the ground (see diagram). The coefficient of friction between the slope and particle A is 0.2.

(i) In the case where the system is in equilibrium with particle A on the point of moving directly up the slope, show that $m = 5.94$, correct to 3 significant figures. **[6]**

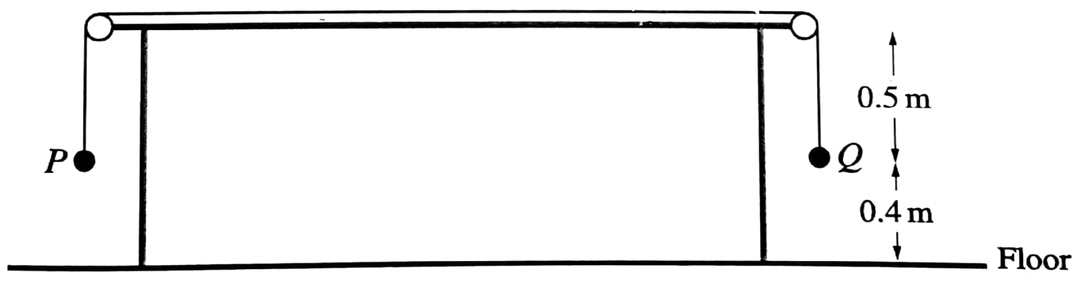
(ii) In the case where $m = 3$, the system is released from rest with the string taut. Find the total distance travelled by A before coming to instantaneous rest. You may assume that A does not reach the pulley. **[8]**

8. **O/N 16/P41/Q1**



Two particles P and Q, of masses 0.6 kg and 0.4 kg respectively, are connected by a light inextensible string. The string passes over a small smooth light pulley fixed at the edge of a smooth horizontal table. Initially P is held at rest on the table and Q hangs vertically (see diagram). P is then released. Find the tension in the string and the acceleration of Q. **[4]**

9. **O/N 16/P43/Q3**



Particles P and Q, of masses 7 kg and 3 kg respectively, are attached to the two ends of a light inextensible string. The string passes over two small smooth pulleys attached to the two ends of a horizontal table. The two particles hang vertically below the two pulleys. The two particles are both initially at rest, 0.5 m below the level of the table, and 0.4 m above the horizontal floor (see diagram).

(i) Find the acceleration of the particles and the speed of P immediately before it reaches the floor. **[4]**

(ii) Determine whether Q comes to instantaneous rest before it reaches the pulley directly above it. **[2]**

10. O/N 16/P43/Q7

A box of mass 50 kg is at rest on a plane inclined at $10°$ to the horizontal.

(i) Find an inequality for the coefficient of friction between the box and the plane. [2]

In fact the coefficient of friction between the box and the plane is 0.19.

(ii) A girl pushes the box with a force of 50 N, acting down a line of greatest slope of the plane, for a distance of 5 m. She then stops pushing. Use an energy method to find the speed of the box when it has travelled a further 5 m. [5]

The box then comes to a plane inclined at $20°$ below the horizontal. The box moves down a line of greatest slope of this plane. The coefficient of friction is still 0.19 and the girl is not pushing the box.

(iii) Find the acceleration of the box. [2]

11. M/J 16/P42/Q7

A particle A of mass 1.6 kg rests on a horizontal table and is attached to one end of a light inextensible string. The string passes over a small smooth pulley P fixed at the edge of the table. The other end of the string is attached to a particle B of mass 2.4 kg which hangs freely below the pulley. The system is released from rest with the string taut and with B at a height of 0.5 m above the ground, as shown in the diagram. In the subsequent motion A does not reach P before B reaches the ground.

(i) Given that the table is smooth, find the time taken by B to reach the ground. [5]

(ii) Given instead that the table is rough and that the coefficient of friction between A and the table is $\frac{3}{8}$, find the total distance travelled by A. You may assume that A does not reach the pulley. [7]

12. M/J 16/P41/Q5

Two particles of masses 5 kg and 10 kg are connected by a light inextensible string that passes over a fixed smooth pulley. The 5 kg particle is on a rough fixed slope which is at an angle of α to the horizontal, where $\tan\alpha = \frac{3}{4}$. The 10 kg particle hangs below the pulley (see diagram). The coefficient of friction between the slope and the 5 kg particle is $\frac{1}{2}$. The particles are released from rest. Find the acceleration of the particles and the tension in the string. [7]

13. M/J 16/P43/Q6

Two particles of masses 1.3 kg and 0.7 kg are connected by a light inextensible string that passes over a fixed smooth pulley. The particles are held at the same vertical height with the string taut. The distance of each particle above a horizontal plane is 2 m, and the distance of each particle below the pulley is 4 m. The particles are released from rest.

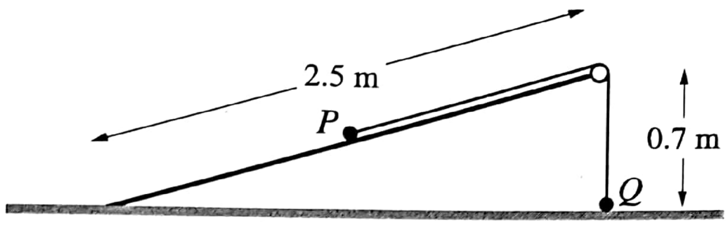
(i) Find

(a) the tension in the string before the particle of mass 1.3 kg reaches the plane,

(b) the time taken for the particle of mass 1.3 kg to reach the plane. **[6]**

(ii) Find the greatest height of the particle of mass 0.7 kg above the plane. **[4]**

14. O/N 15/P42/Q5



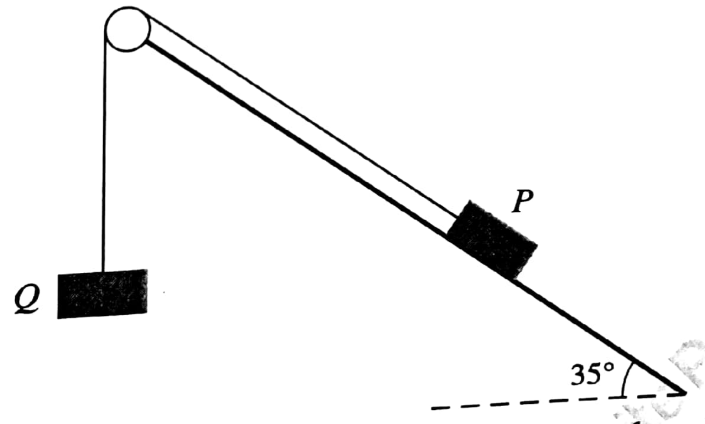
A smooth inclined plane of length 2.5 m is fixed with one end on the horizontal floor and the other end at a height of 0.7 m above the floor. Particles P and Q, of masses 0.5 kg and 0.1 kg respectively, are attached to the ends of a light inextensible string which passes over a small smooth pulley fixed at the top of the plane. Particle Q is held at rest on the floor vertically below the pulley. The string is taut and P is at rest on the plane (see diagram). Q is released and starts to move vertically upwards towards the pulley and P moves down the plane.

(i) Find the tension in the string and the magnitude of the acceleration of the particles before Q reaches the pulley. **[5]**

At the instant just before Q reaches the pulley the string breaks; P continues to move down the plane and reaches the floor with a speed of $2\ \mathrm{m\,s^{-1}}$.

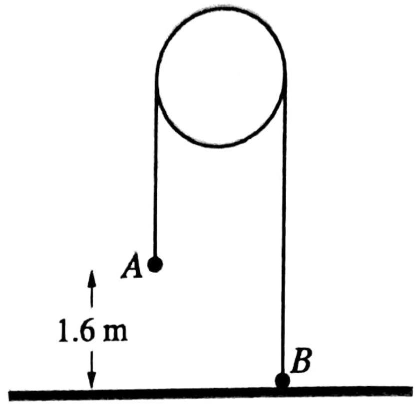
(ii) Find the length of the string. **[3]**

15. O/N 15/P41/Q4



Blocks P and Q, of mass m kg and 5 kg respectively, are attached to the ends of a light inextensible string. The string passes over a small smooth pulley which is fixed at the top of a rough plane inclined at 35° to the horizontal. Block P is at rest on the plane and block Q hangs vertically below the pulley (see diagram). The coefficient of friction between block P and the plane is 0.2. Find the set of values of m for which the two blocks remain at rest. **[6]**

16. O/N 15/P43/Q4



Particles A and B, of masses 0.35 kg and 0.15 kg respectively, are attached to the ends of a light inextensible string which passes over a fixed smooth pulley. The system is at rest with B held on the horizontal floor, the string taut and its straight parts vertical. A is at a height of 1.6 m above the floor (see diagram). B is released and the system begins to move; B does not reach the pulley. Find

(i) the acceleration of the particles and the tension in the string before A reaches the floor, [4]

(ii) the greatest height above the floor reached by B. [3]

17. M/J 15/P42/Q6

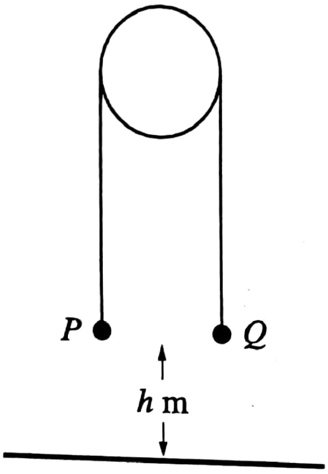


Fig. 1

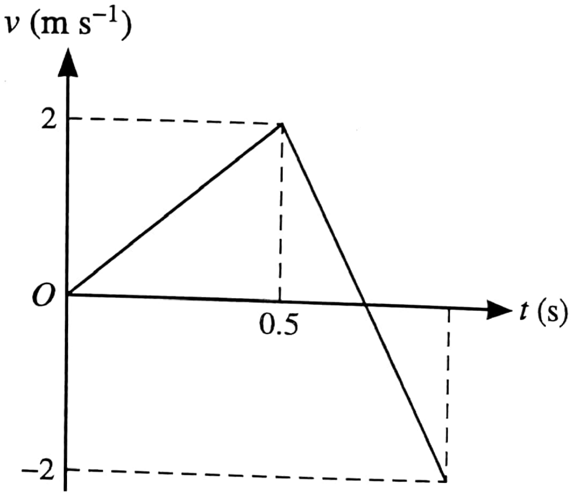


Fig. 2

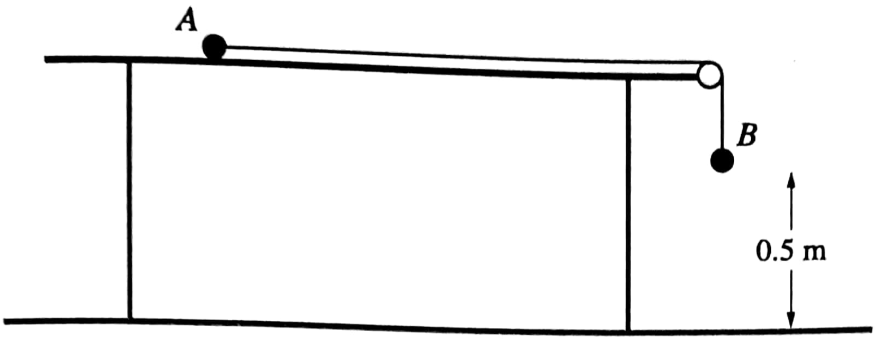
Two particles P and Q have masses m kg and $(1 - m)$ kg respectively. The particles are attached to the ends of a light inextensible string which passes over a smooth fixed pulley. P is held at rest with the string taut and both straight parts of the string vertical. P and Q are each at a height of h m above horizontal ground (see Fig. 1). P is released and Q moves downwards. Subsequently Q hits the ground and comes to rest. Fig. 2 shows the velocity-time graph for P while Q is moving downwards or is at rest on the ground.

(i) Find the value of h. [2]

(ii) Find the value of m, and find also the tension in the string while Q is moving. [6]

(iii) The string is slack while Q is at rest on the ground. Find the total time from the instant that P is released until the string becomes taut again. [3]

18. M/J 15/P41/Q7

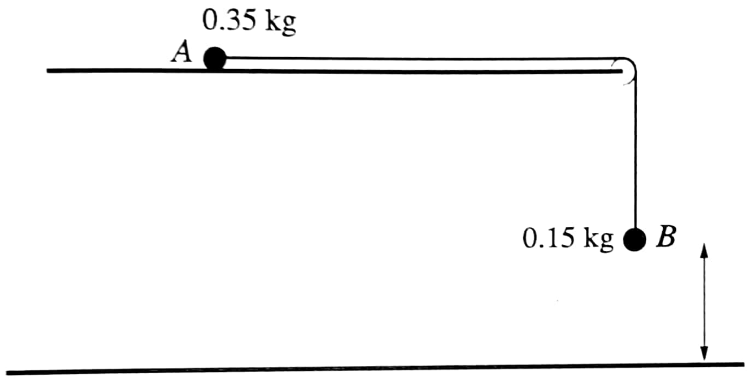


Particles A and B, of masses 0.3 kg and 0.7 kg respectively, are attached to the ends of a light inextensible string. Particle A is held at rest on a rough horizontal table with the string passing over a smooth pulley fixed at the edge of the table. The coefficient of friction between A and the table is 0.2. Particle B hangs vertically below the pulley at a height of 0.5 m above the floor (see diagram). The system is released from rest and 0.25 s later the string breaks. A does not reach the pulley in the subsequent motion. Find

(i) the speed of B immediately before it hits the floor, **[9]**

(ii) the total distance travelled by A. **[3]**

19. M/J 15/P43/Q2

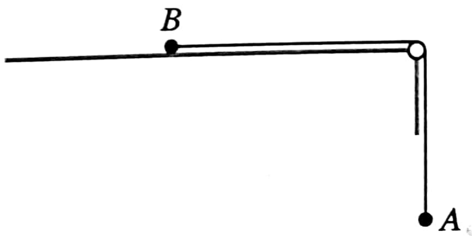


Particles A and B, of masses 0.35 kg and 0.15 kg respectively, are attached to the ends of a light inextensible string. A is held at rest on a smooth horizontal surface with the string passing over a small smooth pulley fixed at the edge of the surface. B hangs vertically below the pulley at a distance h m above the floor (see diagram). A is released and the particles move. B reaches the floor and A subsequently reaches the pulley with a speed of $3\ \mathrm{m\,s^{-1}}$.

(i) Explain briefly why the speed with which B reaches the floor is $3\ \mathrm{m\,s^{-1}}$. **[1]**

(ii) Find the value of h. **[4]**

20. O/N 14/P42/Q5



Particles A and B, each of mass 0.3 kg, are connected by a light inextensible string. The string passes over a small smooth pulley fixed at the edge of a rough horizontal surface. Particle A hangs freely and particle B is held at rest in contact with the surface (see diagram). The coefficient of friction between B and the surface is 0.7. Particle B is released and moves on the surface without reaching the pulley.

(i) Find, for the first 0.9 m of B's motion,

(a) the work done against the frictional force acting on B, [2]

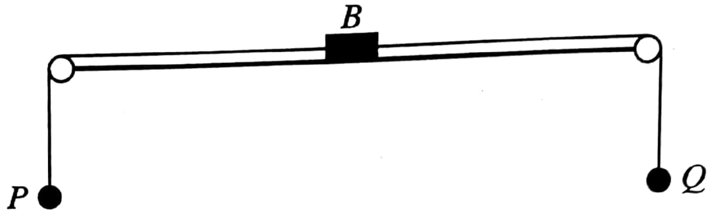
(b) the loss of potential energy of the system, [1]

(c) the gain in kinetic energy of the system. [2]

At the instant when B has moved 0.9 m the string breaks. A is at a height of 0.54 m above a horizontal floor at this instant.

(ii) Find the speed with which A reaches the floor. [3]

21. O/N 14/P41/Q5



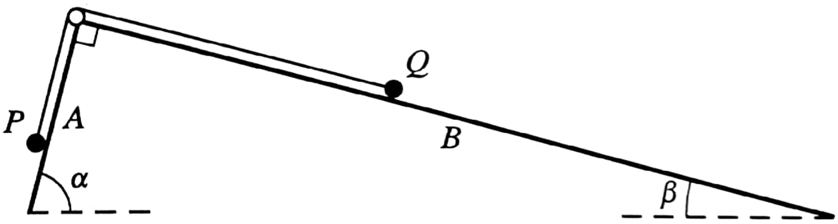
A small block B of mass 0.25 kg is attached to the mid-point of a light inextensible string. Particles P and Q, of masses 0.2 kg and 0.3 kg respectively, are attached to the ends of the string. The string passes over two smooth pulleys fixed at opposite sides of a rough table, with B resting in limiting equilibrium on the table between the pulleys and particles P and Q and block B are in the same vertical plane (see diagram).

(i) Find the coefficient of friction between B and the table. [3]

Q is now removed so that P and B begin to move.

(ii) Find the acceleration of P and the tension in the part PB of the string. [6]

22. O/N 14/P43/Q2



The tops of each of two smooth inclined planes A and B meet at a right angle. Plane A is inclined at angle α to the horizontal and plane B is inclined at angle β to the horizontal, where $\sin\alpha = \frac{63}{65}$ and $\sin\beta = \frac{16}{65}$. A small smooth pulley is fixed at the top of the planes and a light inextensible string passes over the pulley. Two particles P and Q, each of mass 0.65 kg, are attached to the string, one at each end. Particle Q is held at rest at a point of the same line of greatest slope of the plane B as the pulley. Particle P rests freely below the pulley in contact with plane A (see diagram). Particle Q is released and the particles start to move with the string taut. Find the tension in the string. [5]

23. O/N 14/P43/Q5

A box of mass 8 kg is on a rough plane inclined at 5° to the horizontal. A force of magnitude P N acts on the box in a direction upwards and parallel to a line of greatest slope of the plane. When $P = 7X$ the box moves up the line of greatest slope with acceleration $0.15\,\text{m s}^{-2}$ and when $P = 8X$ the box moves up the line of greatest slope with acceleration $1.15\,\text{m s}^{-2}$. Find the value of X and the coefficient of friction between the box and the plane. [8]

24. O/N 14/P43/Q6

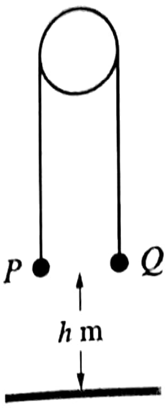


Fig. 1

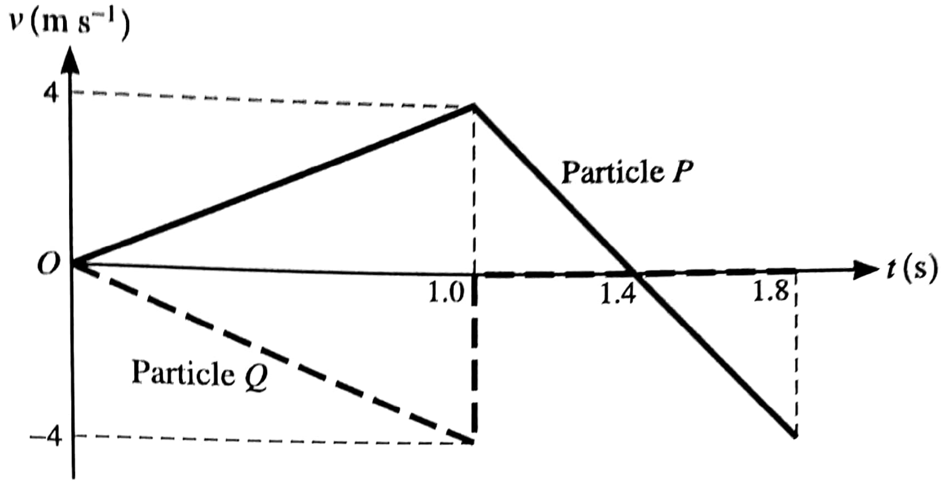


Fig. 2

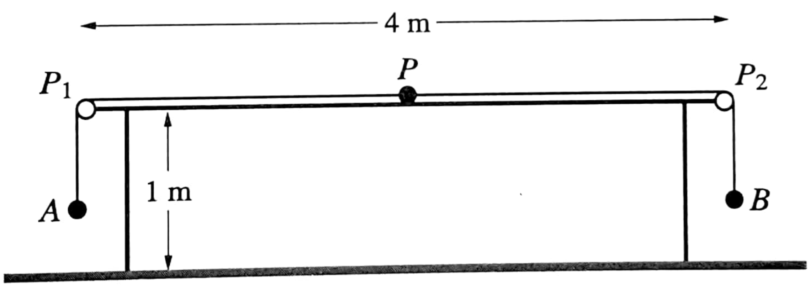
Particles P and Q have a total mass of 1 kg. The particles are attached to opposite ends of a light inextensible string which passes over a smooth fixed pulley. P is held at rest and Q hangs freely, with both straight parts of the string vertical. Both particles are at a height of h m above the floor (see Fig. 1). P is released from rest and the particles start to move with the string taut. Fig. 2 shows the velocity-time graphs for P's motion and for Q's motion, where the positive direction for velocity is vertically upwards. Find

(i) the magnitude of the acceleration with which the particles start to move and the mass of each of the particles, [5]

(ii) the value of h, [1]

(iii) the greatest height above the floor reached by particle P. [2]

25. M/J 14/P42/Q7



A light inextensible string of length 5.28 m has particles A and B, of masses 0.25 kg and 0.75 kg respectively, attached to its ends. Another particle P, of mass 0.5 kg, is attached to the mid-point of the string. Two small smooth pulleys P_1 and P_2 are fixed at opposite ends of a rough horizontal table of length 4 m and height 1 m. The string passes over P_1 and P_2 with particle A held at rest vertically below P_1, the string taut and B hanging freely below P_2. Particle P is in contact with the table halfway between P_1 and P_2 (see diagram). The coefficient of friction between P and the table is 0.4. Particle A is released and the system starts to move with constant acceleration of magnitude a m s^{-2}. The tension in the part AP of the string is T_A N and the tension in the part PB of the string is T_B N.

(i) Find T_A and T_B in terms of a. [3]

(ii) Show by considering the motion of P that $a = 2$. [3]

(iii) Find the speed of the particles immediately before B reaches the floor. [2]

(iv) Find the deceleration of P immediately after B reaches the floor. [2]

26. M/J 14/P41/Q6

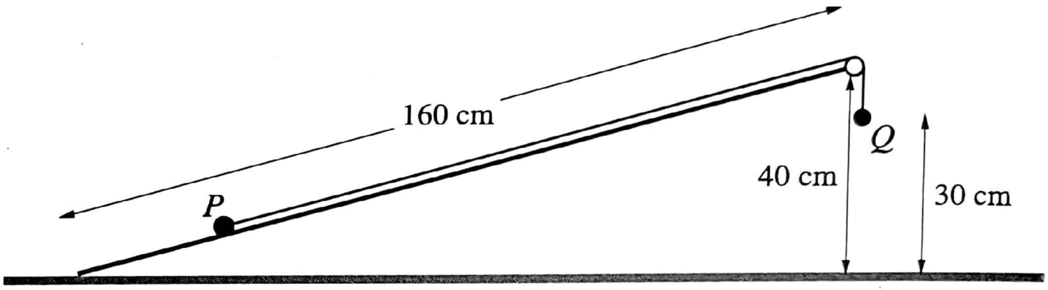
A particle P of mass 0.2 kg is released from rest at a point 7.2 m above the surface of the liquid in a container. P falls through the air and into the liquid. There is no air resistance and there is no instantaneous change of speed as P enters the liquid. When P is at a distance of 0.8 m below the surface of the liquid, P's speed is $6\,\text{m s}^{-1}$. The only force on P due to the liquid is a constant resistance to motion of magnitude R N.

(i) Find the deceleration of P while it is falling through the liquid, and hence find the value of R. [5]

The depth of the liquid in the container is 3.6 m. P is taken from the container and attached to one end of a light inextensible string. P is placed at the bottom of the container and then pulled vertically upwards with constant acceleration. The resistance to motion of R N continues to act. The particle reaches the surface 4 s after leaving the bottom of the container.

(ii) Find the tension in the string. [4]

27. M/J 14/P43/Q7



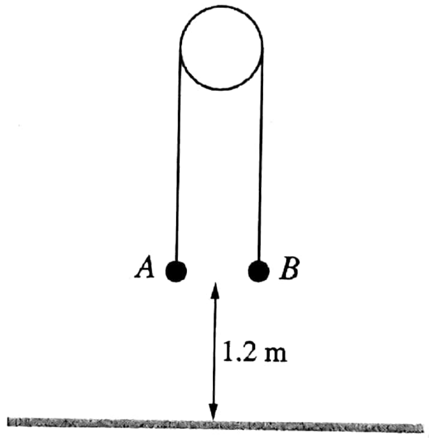
A smooth inclined plane of length 160 cm is fixed with one end at a height of 40 cm above the other end, which is on horizontal ground. Particles P and Q, of masses 0.76 kg and 0.49 kg respectively, are attached to the ends of a light inextensible string which passes over a small smooth pulley fixed at the top of the plane. Particle P is held at rest on the same line of greatest slope as the pulley and Q hangs vertically below the pulley at a height of 30 cm above the ground (see diagram). P is released from rest. It starts to move up the plane and does not reach the pulley. Find

(i) the acceleration of the particles and the tension in the string before Q reaches the ground, [4]

(ii) the speed with which Q reaches the ground, [2]

(iii) the total distance travelled by P before it comes to instantaneous rest. [3]

28. O/N 13/P42/Q6



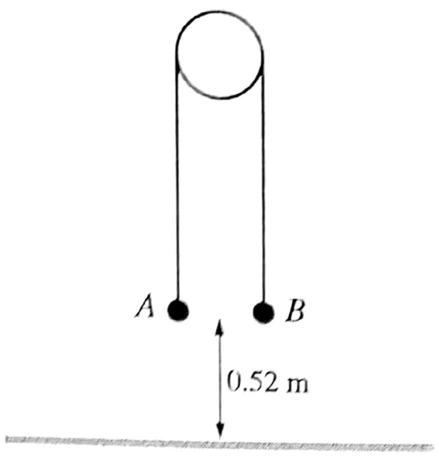
Particles A of mass 0.4 kg and B of mass 1.6 kg are attached to the ends of a light inextensible string which passes over a fixed smooth pulley. A is held at rest and B hangs freely, with both straight parts of the string vertical and both particles at a height of 1.2 m above the floor (see diagram). A is released and both particles start to move.

(i) Find the work done on B by the tension in the string, as B moves to the floor. **[5]**

When particle B reaches the floor it remains at rest. Particle A continues to move upwards.

(ii) Find the greatest height above the floor reached by particle A. **[4]**

29. O/N 13/P41/Q6



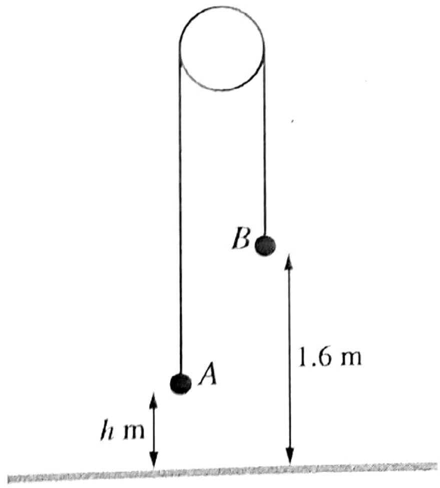
Particles A and B, of masses 0.3 kg and 0.7 kg respectively, are attached to the ends of a light inextensible string. The string passes over a fixed smooth pulley. A is held at rest and B hangs freely, with both straight parts of the string vertical and both particles at a height of 0.52 m above the floor (see diagram). A is released and both particles start to move.

(i) Find the tension in the string. **[4]**

When both particles are moving with speed $1.6\,\text{m s}^{-1}$ the string breaks.

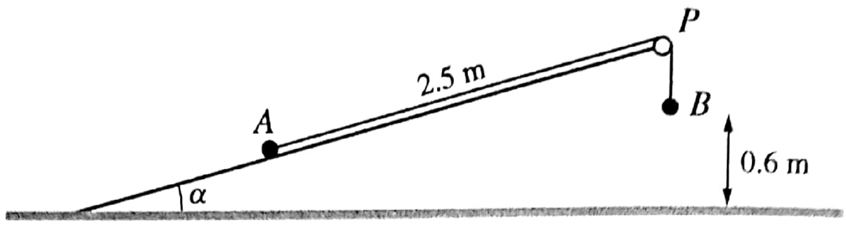
(ii) Find the time taken, from the instant that the string breaks, for A to reach the floor. **[5]**

30. O/N 13/P43/Q2



Particle A of mass 0.2 kg and particle B of mass 0.6 kg are attached to the ends of a light inextensible string. The string passes over a fixed smooth pulley. B is held at rest at a height of 1.6 m above the floor. A hangs freely at a height of h m above the floor. Both straight parts of the string are vertical (see diagram). B is released and both particles start to move. When B reaches the floor it remains at rest, but A continues to move vertically upwards until it reaches a height of 3 m above the floor. Find the speed of B immediately before it hits the floor, and hence find the value of h. **[6]**

31. M/J 13/P42/Q7

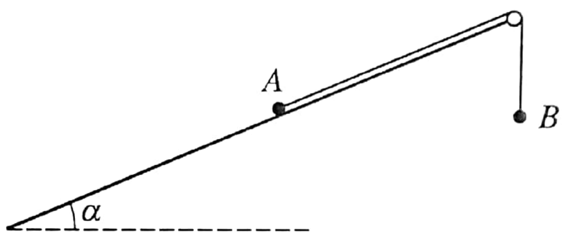


Particles A of mass 0.26 kg and B of mass 0.52 kg are attached to the ends of a light inextensible string. The string passes over a small smooth pulley P which is fixed at the top of a smooth plane. The plane is inclined at an angle α to the horizontal, where $\sin\alpha = \frac{16}{65}$ and $\cos\alpha = \frac{63}{65}$. A is held at rest at a point 2.5 metres from P, with the part AP of the string parallel to a line of greatest slope of the plane. B hangs freely below P at a point 0.6 m above the floor (see diagram). A is released and the particles start to move. Find

(i) the magnitude of the acceleration of the particles and the tension in the string, [5]

(ii) the speed with which B reaches the floor and the distance of A from P when A comes to instantaneous rest. [6]

32. M/J 13/P41/Q5



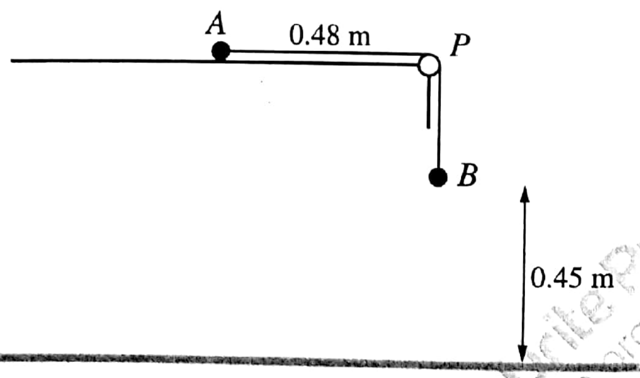
A light inextensible string has a particle A of mass 0.26 kg attached to one end and a particle B of mass 0.54 kg attached to the other end. The particle A is held at rest on a rough plane inclined at angle α to the horizontal, where $\sin\alpha = \frac{5}{13}$. The string is taut and parallel to a line of greatest slope of the plane. The string passes over a small smooth pulley at the top of the plane. Particle B hangs at rest vertically below the pulley (see diagram). The coefficient of friction between A and the plane is 0.2. Particle A is released and the particles start to move.

(i) Find the magnitude of the acceleration of the particles and the tension in the string. [6]

Particle A reaches the pulley 0.4 s after starting to move.

(ii) Find the distance moved by each of the particles. [2]

33. M/J 13/P43/Q7



Particle A of mass 1.26 kg and particle B of mass 0.9 kg are attached to the ends of a light inextensible string. The string passes over a small smooth pulley P which is fixed at the edge of a rough horizontal table. A is held at rest at a point 0.48 m from P, and B hangs vertically below P, at a height of 0.45 m above the floor (see diagram). The coefficient of friction between A and the table is $\frac{2}{7}$. A is released and the particles start to move.

(i) Show that the magnitude of the acceleration of the particles is $2.5\,\text{m s}^{-2}$ and find the tension in the string. [5]

(ii) Find the speed with which B reaches the floor. [2]

(iii) Find the speed with which A reaches the pulley. [4]

34. O/N 12/P42/Q5

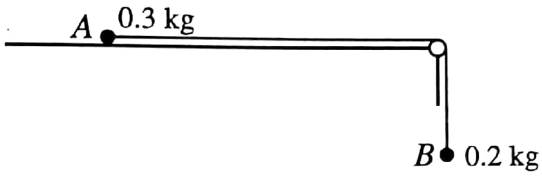
A, B and C are three points on a line of greatest slope of a plane which is inclined at $\theta°$ to the horizontal, with A higher than B and B higher than C. Between A and B the plane is smooth, and between B and C the plane is rough. A particle P is released from rest on the plane at A and slides down the line ABC. At time 0.8 s after leaving A, the particle passes through B with speed $4\,\text{m s}^{-1}$.

(i) Find the value of θ. [3]

At time 4.8 s after leaving A, the particle comes to rest at C.

(ii) Find the coefficient of friction between P and the rough part of the plane. [5]

35. O/N 12/P41/Q2

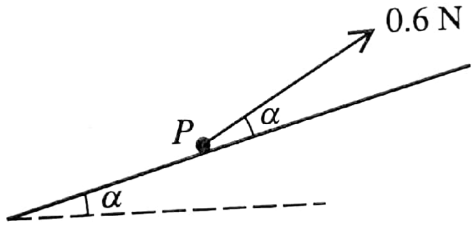


Particles A and B, of masses 0.3 kg and 0.2 kg respectively, are attached to the ends of a light inextensible string. A is held at rest on a rough horizontal table with the string passing over a small smooth pulley at the edge of the table. B hangs vertically below the pulley (see diagram). The system is released and B starts to move downwards with acceleration $1.6\,\text{m s}^{-2}$. Find

(i) the tension in the string after the system is released, [2]

(ii) the frictional force acting on A. [3]

36. O/N 12/P41/Q3



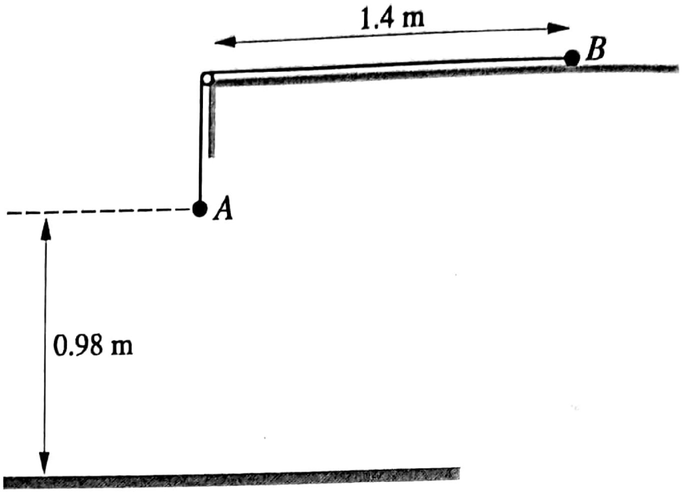
A particle P of mass 0.5 kg rests on a rough plane inclined at angle α to the horizontal, where $\sin\alpha = 0.28$. A force of magnitude 0.6 N, acting upwards on P at angle α from a line of greatest slope of the plane, is just sufficient to prevent P sliding down the plane (see diagram). Find

(i) the normal component of the contact force on P, [2]

(ii) the frictional component of the contact force on P, [3]

(iii) the coefficient of friction between P and the plane. [2]

37. O/N 12/P43/Q7



Particles A and B have masses 0.32 kg and 0.48 kg respectively. The particles are attached to the ends of a light inextensible string which passes over a small smooth pulley fixed at the edge of a smooth horizontal table. Particle B is held at rest on the table at a distance of 1.4 m from the pulley. A hangs vertically below the pulley at a height of 0.98 m above the floor (see diagram). A, B, the string and the pulley are all in the same vertical plane. B is released and A moves downwards.

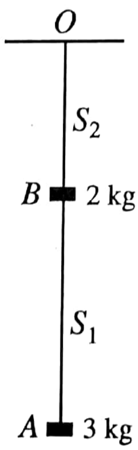
(i) Find the acceleration of A and the tension in the string. [5]

A hits the floor and B continues to move towards the pulley. Find the time taken, from the instant that B is released, for

(ii) A to reach the floor, [2]

(iii) B to reach the pulley. [3]

38. M/J 12/P42/Q5



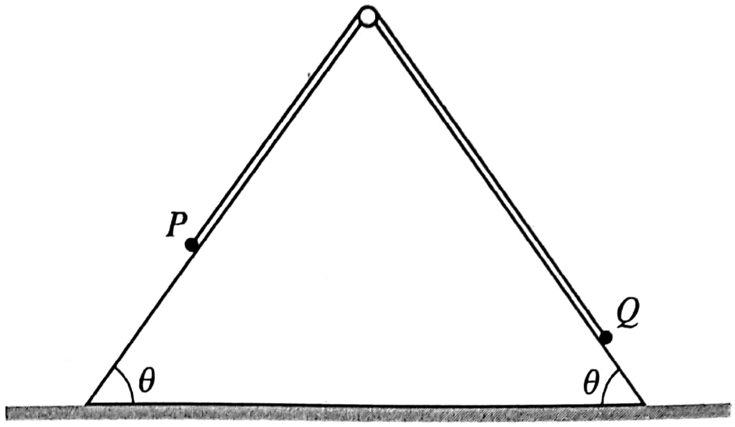
A block A of mass 3 kg is attached to one end of a light inextensible string S_1. Another block B of mass 2 kg is attached to the other end of S_1, and is also attached to one end of another light inextensible string S_2. The other end of S_2 is attached to a fixed point O and the blocks hang in equilibrium below O (see diagram).

(i) Find the tension in S_1 and the tension in S_2. [2]

The string S_2 breaks and the particles fall. The air resistance on A is 1.6 N and the air resistance on B is 4 N.

(ii) Find the acceleration of the particles and the tension in S_1. [5]

39. M/J 12/P41/Q6



Particles P and Q, of masses 0.6 kg and 0.4 kg respectively, are attached to the ends of a light inextensible string. The string passes over a small smooth pulley which is fixed at the top of a vertical cross-section of a triangular prism. The base of the prism is fixed on horizontal ground and each of the sloping sides is smooth. Each sloping side makes an angle θ with the ground, where $\sin\theta = 0.8$. Initially the particles are held at rest on the sloping sides, with the string taut (see diagram). The particles are released and move along lines of greatest slope.

(i) Find the tension in the string and the acceleration of the particles while both are moving. [5]

The speed of P when it reaches the ground is $2\,\mathrm{m\,s^{-1}}$. On reaching the ground P comes to rest and remains at rest. Q continues to move up the slope but does not reach the pulley.

(ii) Find the time taken from the instant that the particles are released until Q reaches its greatest height above the ground. [4]

40. M/J 12/P43/Q6

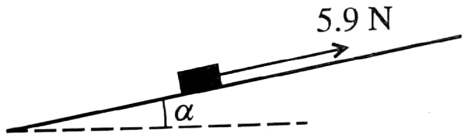


Fig. 1

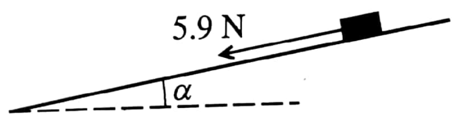


Fig. 2

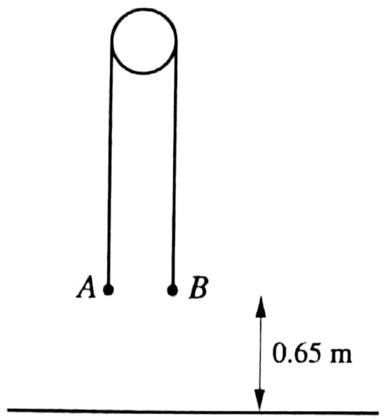
A block of weight 6.1 N is at rest on a plane inclined at angle α to the horizontal, where $\tan\alpha = \frac{11}{60}$. The coefficient of friction between the block and the plane is μ. A force of magnitude 5.9 N acting parallel to a line of greatest slope is applied to the block.

(i) When the force acts up the plane (see Fig. 1) the block remains at rest. Show that $\mu \geqslant \frac{4}{5}$. [5]

(ii) When the force acts down the plane (see Fig. 2) the block slides downwards. Show that $\mu < \frac{7}{6}$. [2]

(iii) Given that the acceleration of the block is $1.7\,\mathrm{m\,s^{-2}}$ when the force acts down the plane, find the value of μ. [2]

41. M/J 12/P43/Q7



Two particles A and B have masses 0.12 kg and 0.38 kg respectively. The particles are attached to the ends of a light inextensible string which passes over a fixed smooth pulley. A is held at rest with the string taut and both straight parts of the string vertical. A and B are each at a height of 0.65 m above horizontal ground (see diagram). A is released and B moves downwards. Find

(i) the acceleration of B while it is moving downwards, [2]

(ii) the speed with which B reaches the ground and the time taken for it to reach the ground. [3]

B remains on the ground while A continues to move with the string slack, without reaching the pulley. The string remains slack until A is at a height of 1.3 m above the ground for a second time. At this instant A has been in motion for a total time of T s.

(iii) Find the value of T and sketch the velocity-time graph for A for the first T s of its motion. [3]

(iv) Find the total distance travelled by A in the first T s of its motion. [2]

42. O/N 11/P42/Q2

A block of mass 6 kg is sliding down a line of greatest slope of a plane inclined at 8° to the horizontal. The coefficient of friction between the block and the plane is 0.2.

(i) Find the deceleration of the block. [3]

(ii) Given that the initial speed of the block is 3 m s^{-1}, find how far the block travels. [2]

43. O/N 11/P42/Q3

A particle P moves in a straight line. It starts from a point O on the line with velocity 1.8 m s^{-1}. The acceleration of P at time t s after leaving O is $0.8t^{-0.75}$ m s^{-2}. Find the displacement of P from O when $t = 16$. [6]

44. O/N 11/P42/Q5

Particles A and B, of masses 0.9 kg and 0.6 kg respectively, are attached to the ends of a light inextensible string. The string passes over a fixed smooth pulley. The system is released from rest with the string taut, with its straight parts vertical and with the particles at the same height above the horizontal floor. In the subsequent motion, B does not reach the pulley.

(i) Find the acceleration of A and the tension in the string during the motion before A hits the floor. [4]

After A hits the floor, B continues to move vertically upwards for a further 0.3 s.

(ii) Find the height of the particles above the floor at the instant that they started to move. [4]

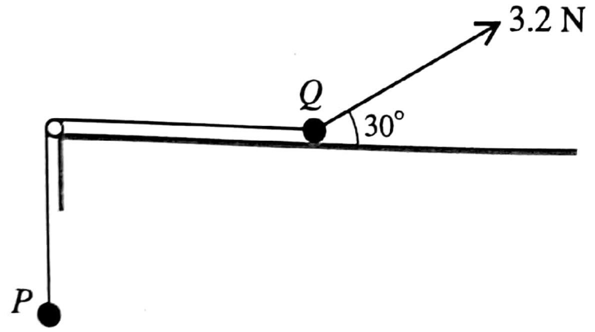
45. O/N 11/P41/Q2

Particles A of mass 0.65 kg and B of mass 0.35 kg are attached to the ends of a light inextensible string which passes over a fixed smooth pulley. B is held at rest with the string taut and both of its straight parts vertical. The system is released from rest and the particles move vertically. Find the tension in the string and the magnitude of the resultant force exerted on the pulley by the string. [5]

46. O/N 11/P43/Q3

Particles P and Q are attached to opposite ends of a light inextensible string which passes over a fixed smooth pulley. The system is released from rest with the string taut, with its straight parts vertical, and with both particles at a height of 2 m above horizontal ground. P moves vertically downwards and does not rebound when it hits the ground. At the instant that P hits the ground, Q is at the point X, from where it continues to move vertically upwards without reaching the pulley. Given that P has mass 0.9 kg and that the tension in the string is 7.2 N while P is moving, find the total distance travelled by Q from the instant it first reaches X until it returns to X. **[6]**

47. O/N 10/P41/Q7



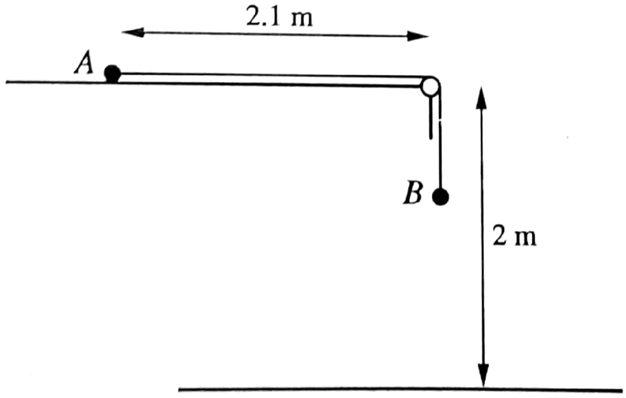
Particles P and Q, of masses 0.2 kg and 0.5 kg respectively, are connected by a light inextensible string. The string passes over a smooth pulley at the edge of a rough horizontal table. P hangs freely and Q is in contact with the table. A force of magnitude 3.2 N acts on Q, upwards and away from the pulley, at an angle of 30° to the horizontal (see diagram).

(i) The system is in limiting equilibrium with P about to move upwards. Find the coefficient of friction between Q and the table. **[6]**

The force of magnitude 3.2 N is now removed and P starts to move downwards.

(ii) Find the acceleration of the particles and the tension in the string. **[4]**

48. M/J 10/P42/Q6

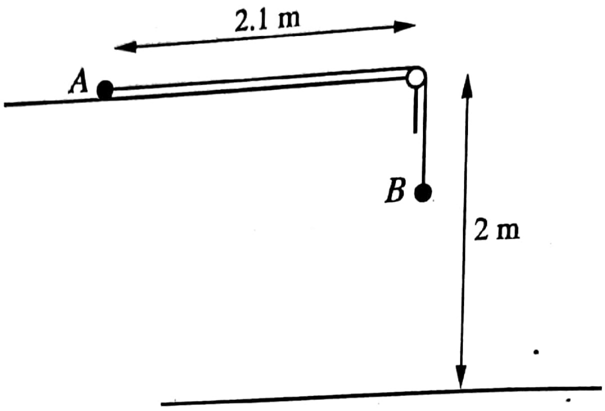


Particles A and B, of masses 0.2 kg and 0.45 kg respectively, are connected by a light inextensible string of length 2.8 m. The string passes over a small smooth pulley at the edge of a rough horizontal surface, which is 2 m above the floor. Particle A is held in contact with the surface at a distance of 2.1 m from the pulley and particle B hangs freely (see diagram). The coefficient of friction between A and the surface is 0.3. Particle A is released and the system begins to move.

(i) Find the acceleration of the particles and show that the speed of B immediately before it hits the floor is 3.95 m s^{-1}, correct to 3 significant figures. **[7]**

(ii) Given that B remains on the floor, find the speed with which A reaches the pulley. **[4]**

49. M/J 10/P41/Q6

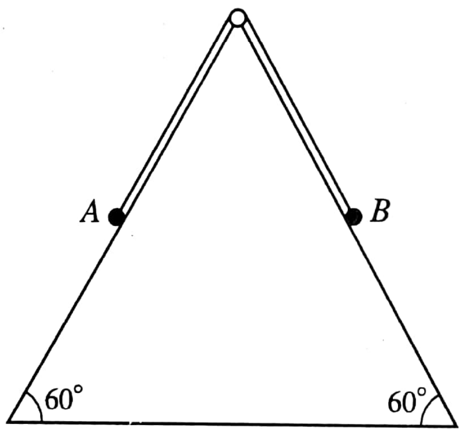


Particles A and B, of masses 0.2 kg and 0.45 kg respectively, are connected by a light inextensible string of length 2.8 m. The string passes over a small smooth pulley at the edge of a rough horizontal surface, which is 2 m above the floor. Particle A is held in contact with the surface at a distance of 2.1 m from the pulley and particle B hangs freely (see diagram). The coefficient of friction between A and the surface is 0.3. Particle A is released and the system begins to move.

(i) Find the acceleration of the particles and show that the speed of B immediately before it hits the floor is $3.95\,\text{m s}^{-1}$, correct to 3 significant figures. [7]

(ii) Given that B remains on the floor, find the speed with which A reaches the pulley. [4]

50. M/J 10/P43/Q4

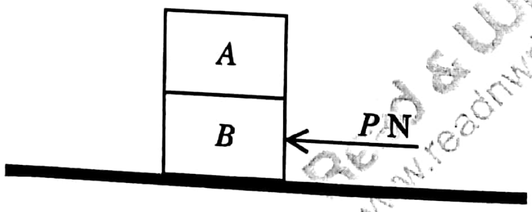


The diagram shows a vertical cross-section of a triangular prism which is fixed so that two of its faces are inclined at 60° to the horizontal. One of these faces is smooth and one is rough. Particles A and B, of masses 0.36 kg and 0.24 kg respectively, are attached to the ends of a light inextensible string which passes over a small smooth pulley fixed at the highest point of the cross-section. B is held at rest at a point of the cross-section on the rough face and A hangs freely in contact with the smooth face (see diagram). B is released and starts to move up the face with acceleration $0.25\,\text{m s}^{-2}$.

(i) By considering the motion of A, show that the tension in the string is 3.03 N, correct to 3 significant figures. [2]

(ii) Find the coefficient of friction between B and the rough face, correct to 2 significant figures. [6]

51. M/J 10/P43/Q7



Two rectangular boxes A and B are of identical size. The boxes are at rest on a rough horizontal floor with A on top of B. Box A has mass 200 kg and box B has mass 250 kg. A horizontal force of magnitude P N is applied to B (see diagram). The boxes remain at rest if $P \leqslant 3150$ and start to move if $P > 3150$.

(i) Find the coefficient of friction between B and the floor. [3]

The coefficient of friction between the two boxes is 0.2. Given that $P > 3150$ and that no sliding takes place between the boxes,

(ii) show that the acceleration of the boxes is not greater than 2 m s^{-2}, [3]

(iii) find the maximum possible value of P. [3]

52. O/N 09/P42/Q4

A particle moves up a line of greatest slope of a rough plane inclined at an angle α to the horizontal, where $\cos\alpha = 0.96$ and $\sin\alpha = 0.28$.

(i) Given that the normal component of the contact force acting on the particle has magnitude 1.2 N, find the mass of the particle. [2]

(ii) Given also that the frictional component of the contact force acting on the particle has magnitude 0.4 N, find the deceleration of the particle. [3]

The particle comes to rest on reaching the point X.

(iii) Determine whether the particle remains at X or whether it starts to move down the plane. [2]

53. O/N 09/P42/Q5

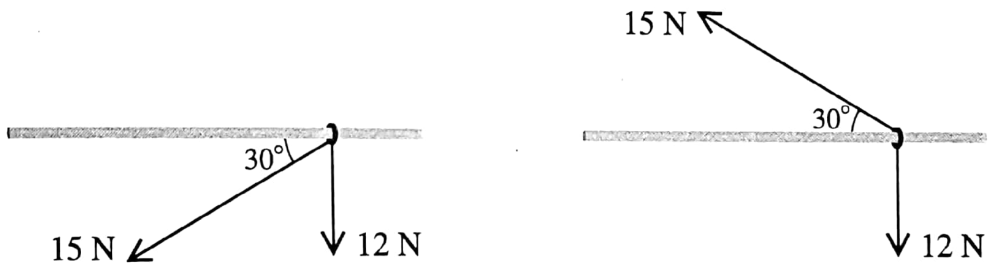


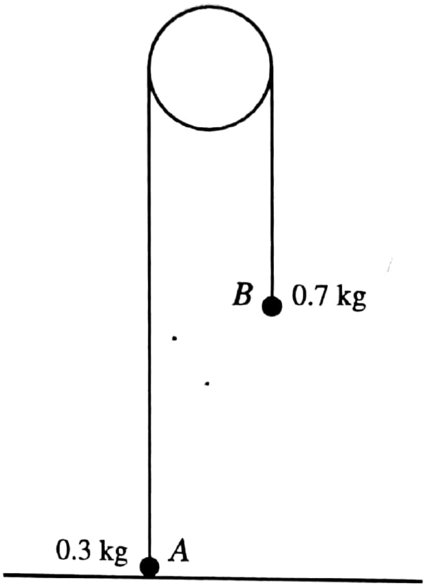
Fig. 1 Fig. 2

A small ring of weight 12 N is threaded on a fixed rough horizontal rod. A light string is attached to the ring and the string is pulled with a force of 15 N at an angle of 30° to the horizontal.

(i) When the angle of 30° is **below** the horizontal (see Fig. 1), the ring is in limiting equilibrium. Show that the coefficient of friction between the ring and the rod is 0.666, correct to 3 significant figures. [5]

(ii) When the angle of 30° is **above** the horizontal (see Fig. 2), the ring is moving with acceleration $a \text{ m s}^{-2}$. Find the value of a. [4]

54. O/N 09/P42/Q6



Particles A and B, of masses 0.3 kg and 0.7 kg respectively, are attached to the ends of a light inextensible string which passes over a smooth fixed pulley. Particle A is held on the horizontal floor and particle B hangs in equilibrium. Particle A is released and both particles start to move vertically.

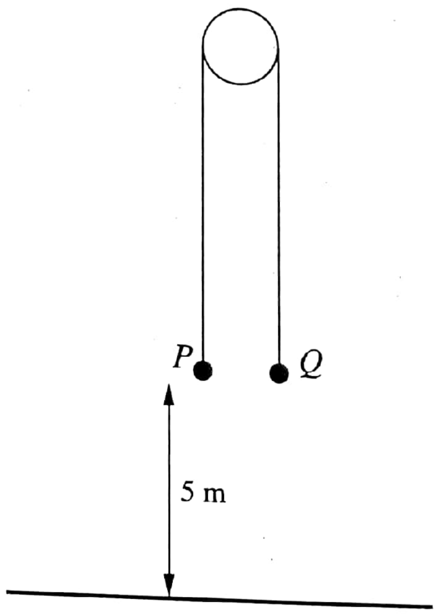
(i) Find the acceleration of the particles. [3]

The speed of the particles immediately before B hits the floor is $1.6\,\text{m s}^{-1}$. Given that B does not rebound upwards, find

(ii) the maximum height above the floor reached by A, [3]

(iii) the time taken by A, from leaving the floor, to reach this maximum height. [3]

55. O/N 09/P41/Q6



Particles P and Q, of masses 0.55 kg and 0.45 kg respectively, are attached to the ends of a light inextensible string which passes over a smooth fixed pulley. The particles are held at rest with the string taut and its straight parts vertical. Both particles are at a height of 5 m above the ground (see diagram). The system is released.

(i) Find the acceleration with which P starts to move. [3]

The string breaks after 2 s and in the subsequent motion P and Q move vertically under gravity.

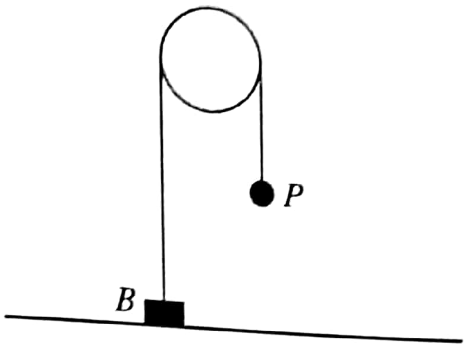
(ii) At the instant that the string breaks, find

(a) the height above the ground of P and of Q, [2]

(b) the speed of the particles. [1]

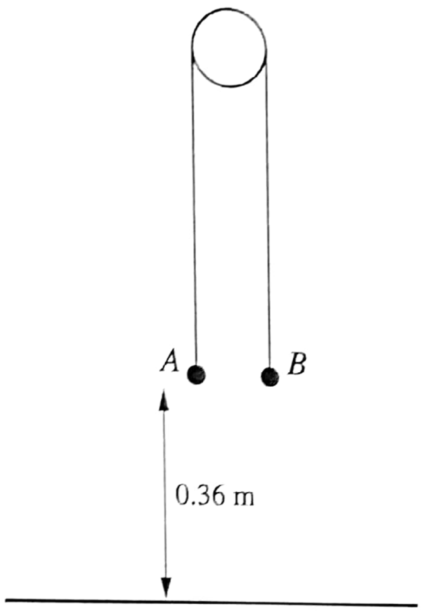
(iii) Show that Q reaches the ground 0.8 s later than P. [4]

56. M/J 09/P4/Q1



A block B of mass 5 kg is attached to one end of a light inextensible string. A particle P of mass 4 kg is attached to other end of the string. The string passes over a smooth pulley. The system is in equilibrium with the string taut and its straight parts vertical. B is at rest on the ground (see diagram). State the tension in the string and find the force exerted on B by the ground. **[3]**

57. M/J 09/P4/Q6



Particles A and B are attached to the ends of a light inextensible string which passes over a smooth pulley. The system is held at rest with the string taut and its straight parts vertical. Both particles are at a height of 0.36 m above the floor (see diagram). The system is released and A begins to fall, reaching the floor after 0.6 s.

(i) Find the acceleration of A as it falls. **[2]**

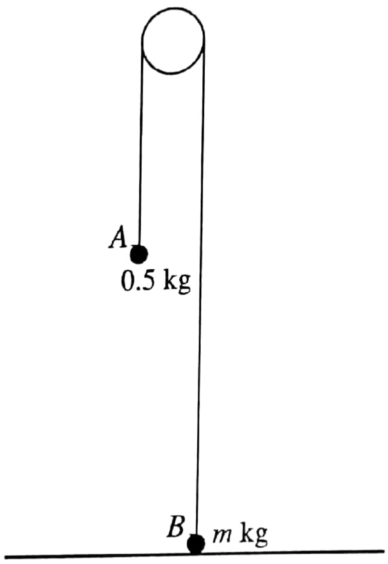
The mass of A is 0.45 kg. Find

(ii) the tension in the string while A is falling, **[2]**

(iii) the mass of B, **[3]**

(iv) the maximum height above the floor reached by B. **[3]**

58. O/N 08/P4/Q5



Particles A and B, of masses 0.5 kg and m kg respectively, are attached to the ends of a light inextensible string which passes over a smooth fixed pulley. Particle B is held at rest on the horizontal floor and particle A hangs in equilibrium (see diagram). B is released and each particle starts to move vertically. A hits the floor 2 s after B is released. The speed of each particle when A hits the floor is 5 m s^{-1}.

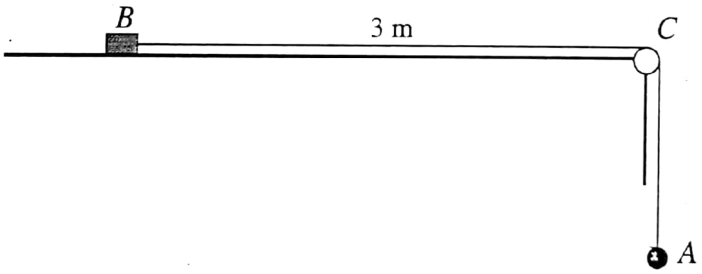
(i) For the motion while A is moving downwards, find

(a) the acceleration of A, [2]

(b) the tension in the string. [3]

(ii) Find the value of m. [3]

59. M/J 08/P4/Q5

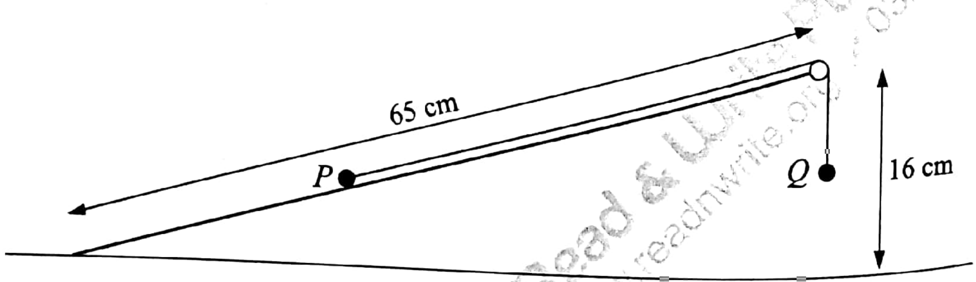


A block B of mass 0.6 kg and a particle A of mass 0.4 kg are attached to opposite ends of a light inextensible string. The block is held at rest on a rough horizontal table, and the coefficient of friction between the block and the table is 0.5. The string passes over a small smooth pulley C at the edge of the table and A hangs in equilibrium vertically below C. The part of the string between B and C is horizontal and the distance BC is 3 m (see diagram). B is released and the system starts to move.

(i) Find the acceleration of B and the tension in the string. [6]

(ii) Find the time taken for B to reach the pulley. [2]

60. O/N 07/P4/Q7



A rough inclined plane of length 65 cm is fixed with one end at a height of 16 cm above the other end. Particles P and Q, of masses 0.13 kg and 0.11 kg respectively, are attached to the ends of a light inextensible string which passes over a small smooth pulley at the top of the plane. Particle P is held at rest on the plane and particle Q hangs vertically below the pulley (see diagram). The system is released from rest and P starts to move up the plane.

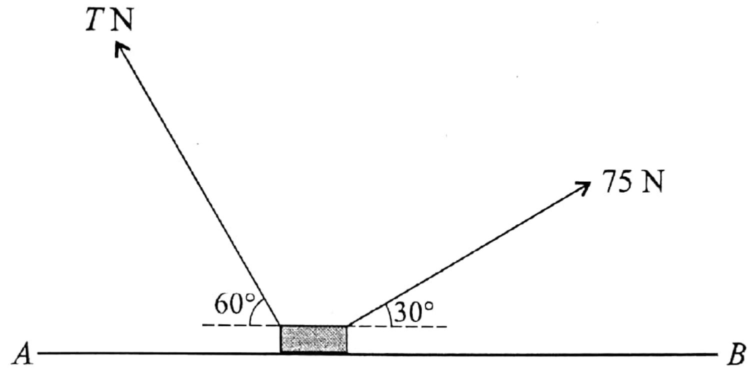
(i) Draw a diagram showing the forces acting on P during its motion up the plane. [1]

(ii) Show that $T - F > 0.32$, where T N is the tension in the string and F N is the magnitude of the frictional force on P. [4]

The coefficient of friction between P and the plane is 0.6.

(iii) Find the acceleration of P. [6]

61. M/J 07/P4/Q7



Two light strings are attached to a block of mass 20 kg. The block is in equilibrium on a horizontal surface AB with the strings taut. The strings make angles of 60° and 30° with the horizontal, on either side of the block, and the tensions in the strings are T N and 75 N respectively (see diagram).

(i) Given that the surface is smooth, find the value of T and the magnitude of the contact force acting on the block. [5]

(ii) It is given instead that the surface is rough and that the block is on the point of slipping. The frictional force on the block has magnitude 25 N and acts towards A. Find the coefficient of friction between the block and the surface. [6]

62. O/N 06/P4/Q7

A particle of mass m kg moves up a line of greatest slope of a rough plane inclined at 21° to the horizontal. The frictional and normal components of the contact force on the particle have magnitudes F N and R N respectively. The particle passes through the point P with speed 10 m s^{-1}, and 2 s later it reaches its highest point on the plane.

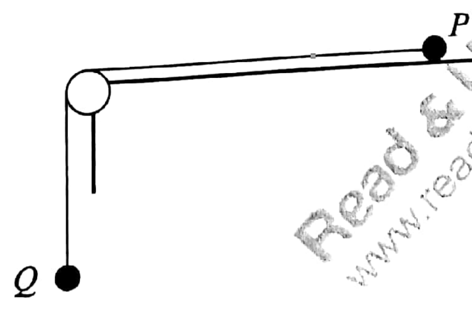
(i) Show that $R = 9.336m$ and $F = 1.416m$, each correct to 4 significant figures. [5]

(ii) Find the coefficient of friction between the particle and the plane. [1]

After the particle reaches its highest point it starts to move down the plane.

(iii) Find the speed with which the particle returns to P. [5]

63. M/J 06/P4/Q5



Particles P and Q are attached to opposite ends of a light inextensible string. P is at rest on a rough horizontal table. The string passes over a small smooth pulley which is fixed at the edge of the table. Q hangs vertically below the pulley (see diagram). The force exerted on the string by the pulley has magnitude $4\sqrt{2}$ N. The coefficient of friction between P and the table is 0.8.

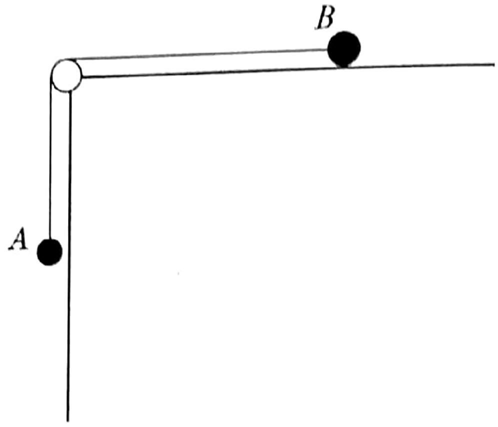
(i) Show that the tension in the string is 4 N and state the mass of Q. [2]

(ii) Given that P is on the point of slipping, find its mass. [2]

A particle of mass 0.1 kg is now attached to Q and the system starts to move.

(iii) Find the tension in the string while the particles are in motion. [4]

64. M/J 05/P4/Q4



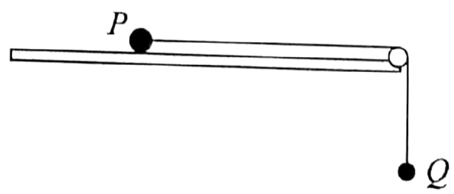
Particles A and B, of masses 0.2 kg and 0.3 kg respectively, are connected by a light inextensible string. The string passes over a smooth pulley at the edge of a rough horizontal table. Particle A hangs freely and particle B is in contact with the table (see diagram).

(i) The system is in limiting equilibrium with the string taut and A about to move downwards. Find the coefficient of friction between B and the table. [4]

A force now acts on particle B. This force has a vertical component of 1.8 N upwards and a horizontal component of X N directed away from the pulley.

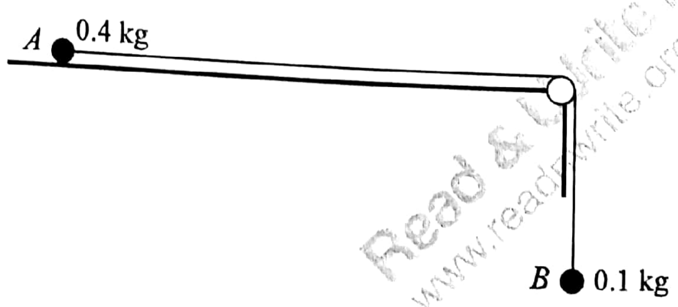
(ii) The system is now in limiting equilibrium with the string taut and A about to move **upwards**. Find X. [3]

65. O/N 04/P4/Q1



Two particles P and Q, of masses 1.7 kg and 0.3 kg respectively, are connected by a light inextensible string. P is held on a smooth horizontal table with the string taut and passing over a small smooth pulley fixed at the edge of the table. Q is at rest vertically below the pulley. P is released. Find the acceleration of the particles and the tension in the string. [5]

66. O/N 03/P4/Q5

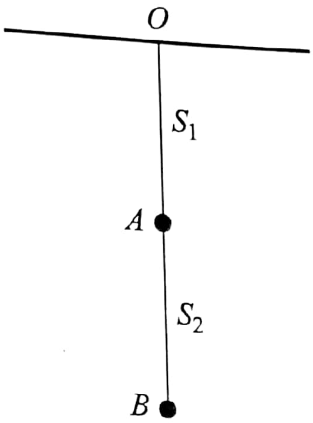


Particles A and B, of masses 0.4 kg and 0.1 kg respectively, are attached to the ends of a light inextensible string. Particle A is held at rest on a horizontal table with the string passing over a smooth pulley at the edge of the table. Particle B hangs vertically below the pulley (see diagram). The system is released from rest. In the subsequent motion a constant frictional force of magnitude 0.6 N acts on A. Find

(i) the tension in the string, [4]

(ii) the speed of B 1.5 s after it starts to move. [3]

67. M/J 03/P4/Q5



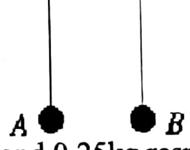
S_1 and S_2 are light inextensible strings, and A and B are particles each of mass 0.2 kg. Particle A is suspended from a fixed point O by the string S_1, and particle B is suspended from A by the string S_2. The particles hang in equilibrium as shown in the diagram.

(i) Find the tensions in S_1 and S_2. [3]

The string S_1 is cut and the particles fall. The air resistance acting on A is 0.4 N and the air resistance acting on B is 0.2 N.

(ii) Find the acceleration of the particles and the tension in S_2. [5]

68. M/J 02/P4/Q7



Particles A and B, of masses 0.15kg and 0.25kg respectively, are attached to the ends of a light inextensible string which passes over a smooth fixed pully. The system is held at rest with the string taut and with A and B at the same horizontal level, as shown in the diagram. The system is then released.

(i) Find the downward acceleration of B. [4]

After 2s B hits the floor and comes to rest without rebounding. The string becomes slack and A moves freely under gravity.

(ii) Find the time that elapses until the string becomes taut again. [4]

(iii) Sketch on a single diagram the velocity-time graphs for both particles, for the period from their release until the instant that B starts to move upwards. [3]

Answers Section

1. O/N 17/P42/Q6

(i) $R = mg\cos\alpha \quad (R = 9.6m)$

$[T = mg$

$F = mg\sin\alpha + T\,]$

$F = mg\sin\alpha + mg$

Coefficient of friction = $1\frac{1}{3} = \frac{4}{3}$ 5

(ii) *EITHER:*

P equation is

$10 - mg\sin\alpha - F - T = 2.5\,m$

Q equation is

$T - mg = 2.5m$

$10 - mg\sin\alpha - \mu mg\cos\alpha$

$- mg = 2m\,(2.5)$

$m = 0.327$

OR:

$[10 - mg\sin\alpha - F - mg = m(2.5 + 2.5)]$

$10 - mg\sin\alpha - \mu mg\cos\alpha$

$- mg = 2m\,(2.5)$

$m = 0.327$ 5

2. O/N 17/P41/Q7

(i) $T - 0.9\,g\sin 15 = 0.9a$

$2.5 + 0.4\,g\sin 25 - T = 0.4a$

$1.3a = 1.86\ldots$

$a = 1.43\text{ m s}^{-2}$ 5

(ii) $F = 0.8 \times 0.4g\cos 25$

$2.5 + 0.4\,g\sin 25 - T - F = 0$

$T - 0.9\,g\sin\theta = 0$

$\theta = 8.2°$ 5

3. O/N 17/P43/Q4

(i) *EITHER:*

$[T - 0.35g = 0.35a$

or $0.45g - T = 0.45a$

or $0.45g - 0.35g = 0.8a]$

$[0.45g - T = 0.45a$

or $T - 0.35g = 0.35a] \rightarrow a = \ldots$

$a = 1.25\text{ m s}^{-2}$

$[v^2 = 2 \times 1.25 \times 0.64] \quad (= 1.6)$

Velocity = 1.26 ms^{-1}

OR:

[PE loss = $0.45g \times 0.64 - 0.35g \times 0.64$]

[KE gain = $\frac{1}{2}(0.35 + 0.45)\,v^2$]

PE loss = $0.45g \times 0.64 - 0.35g \times 0.64$

and KE gain = $\frac{1}{2}(0.35 + 0.45)\,v^2$

$[\frac{1}{2}(0.8)\,v^2 = 0.1g \times 0.64] \quad (v^2 = 1.6)$

Velocity = 1.26 ms^{-1} 5

(ii) *EITHER:*

$[0 = 1.6 - 2\,gs] \quad (s = 0.08)$

Distance = 0.16 m

OR:

$[0.35gh = \frac{1}{2}(0.35) \times 1.6] \quad (h = 0.08)$

Distance = 0.16 m 2

4. M/J 17/P42/Q6

(i) $A\,[T = 0.3a]$

$B\,[1.5g\sin\theta - T = 1.5a]$

System $[1.5g\sin\theta = 1.8a]$

$a = 9/1.8 = 5\text{ ms}^{-2}$

$T = 1.5\text{ N}$ 5

(ii) $[5 = 3a]$

$a = 5/3 = 1.67$

$R_A = 3\; R_B = 15\cos 36.9 = 12$

$[F_A = 3\mu\; F_B = 12\mu]$

EITHER:

$A\,[T - F_A = 0.3a]$

$B\,[15\sin 36.9 - T - F_B = 1.5a]$

System equation is

$[1.5g\sin 36.9 - F_A - F_B = 1.8a]$ 1/0

$[9 - 15\mu = 3]$

$\mu = 0.4 = 2/5$

OR:

$s = \frac{1}{2}(5/3) \times 3^2 = 7.5$

PE loss =

$1.5 \times 10 \times 7.5 \times (3/5) = 67.5$

KE gain = $\frac{1}{2}(1.8) \times 5^2 = 22.5$

$[67.5 = 22.5 + 3\mu \times 7.5 + 12\mu \times 7.5]$

$\mu = 2/5 = 0.4$ 9

5. M/J 17/P41/Q2

(i) $R = 0.8g\cos 10\;[= 7.88]$

$F = 0.4 \times 8\cos 10\;[= 3.15]$

$-8\sin 10 - 3.2\cos 10 = 0.8a$

$a = -5.68\text{ ms}^{-2}$ 4

(ii) $0 = 12^2 - 2 \times 5.68 \times s$

$s = 144/(2 \times 5.68) = 12.7\text{ m}$ 2

6. M/J 17/P41/Q7

(i) $[T - 0.8g\sin 30 = 0.8a$

$1.2g\sin 60 - T = 1.2a$

$1.2g\sin 60 - 0.8g\sin 30 = 2a]$

For A $\quad T - 4 = 0.8a$

For B $\quad 6\sqrt{3} - T = 10.4 - T = 1.2a$

$a = 3\sqrt{3} - 2 = 3.20$ ms^{-2}

$T = \frac{12}{5}\left(1+\sqrt{3}\right) = 6.56$ N — 6

(ii) $R_A = 0.8g\cos 30 = 4\sqrt{3}$

$R_B = 1.2g\cos 60 = 6$

$F_A = 4\sqrt{3}\,\mu$ and $F_B = 6\mu$

$12\sin 60 - 6\mu - T = 0$

or

$T - 8\sin 30 - 4\sqrt{3}\,\mu = 0$

$\mu = \left(6\sqrt{3} - 4\right)/\left(6 + 4\sqrt{3}\right)$

$= 0.494$ — 6

7. M/J 17/P43/Q7

(i) $R = mg\cos 30$

$F = 2m\cos 30\ [= m\sqrt{3}]$

$T = 4g\ [= 40]$

$T = mg\sin 30 + F$

$40 = 5m + m\sqrt{3}$

$m = \frac{40}{5+\sqrt{3}} = 5.94$ — 6

(ii) *EITHER:*

$[R = 3g\cos 30]$

$F = 0.2 \times 3g\cos 30\ (3\sqrt{3} = 5.196)$

$4g - T = 4a$

or $T - 3g\sin 30 - F = 3a$

or $4g - 3g\sin 30 - F = 7a$

$T - 3g\sin 30 - 3\sqrt{3} = 3a$

or $40 - T = 4a$

or $4g - 3g\sin 30 - 3\sqrt{3} = 7a \rightarrow a = \ldots$

$a = \frac{25 - 3\sqrt{3}}{7}$

$= 2.83.$

$v^2 = 2 \times 2.83 \times 0.5$

$v = 1.68\ldots$

$-3g\sin 30 - 0.2(3g\cos 30) = 3a$

$-15 - 3\sqrt{3} = 3a$

$\rightarrow a = \ldots(-5 - \sqrt{3} = -6.73)$

$0 = 1.68^2 - 2 \times 6.73s$

$s = \ldots(0.210)$

Total distance = 0.710 m

OR:

$[R = 3g\cos 30]$

$F = 0.2 \times 3g\cos 30 \qquad (3\sqrt{3} = 5.196)$

$4g(0.5) - 0.5T = \frac{1}{2}(4v^2)$ and

$0.5T = \frac{1}{2}(3v^2) + 3g(0.5\sin 30) + 3\sqrt{3}(0.5)$

$v^2 = (25 - 3\sqrt{3})/7$ or $v = 1.68$

$\frac{1}{2}(3)(1.68)^2 = 3g(s\sin 30) + 3\sqrt{3}s$

$s = \ldots(0.210)$

Total distance = 0.710 m — 8

8. O/N 16/P41/Q1

$[0.4g - T = 0.4a \qquad T = 0.6a$

System equation $\qquad 0.4g = (0.4 + 0.6)a]$

$a = 4$ m s^{-2}

$T = 2.4$ N — [4]

9. O/N 16/P43/Q3

(i) $[7g - T = 7a$ **and** $T - 3g = 3a]$

or $[7g - 3g = 10a]$

Acceleration is 4 ms^{-2}

$[v^2 = 0 + 2 \times 4 \times 0.4]\ (v^2 = 3.2)$

Speed is 1.79 ms^{-1} — [4]

(ii) $[0 = 3.2 + 2 \times (-g) \times s]\ (s = 0.16)$

$0.16 + 0.4 = 0.56$

So particle Q does not come to rest before it reaches the pulley — [2]

Alternative

$[v^2 = 3.2 + 2 \times (-g) \times 0.1]$

$v = \sqrt{1.2}\ (= 1.10)$

So particle Q does not come to rest before it reaches the pulley — [2]

10. O/N 16/P43/Q7

(i) $R = 50g\cos 10°$ and

$F = 50g\sin 10°$

$\mu \geqslant 0.176$ — [2]

(ii) PE loss $= 50g \times d\sin 10°$

WD against friction =

$0.19 \times 50g\cos 10° \times d$

$50 \times 5 + 50g \times 10\sin 10° - 0.19 \times 50g\cos 10° \times 10 = 0.5 \times 50v^2$

Speed is 2.70 ms^{-1} — [5]

(iii) $50g\sin 20° - 0.19 \times 50g\cos 20° = 50a$

Acceleration is 1.63 ms^{-2} — [2]

11. M/J 16/P42/Q7

(i) $[2.4g - T = 2.4aT = 1.6a$

or the system equation

$2.4g = (1.6 + 2.4)a]$

$a = 6$ ms^{-2}

$0.5 = \frac{1}{2} \times 6 \times t^2$

$t = 0.408$s — 5

Alternative for 7(i)

(i) [PE loss = $2.4 \times g \times 0.5 = 12$
KE gain = $½(1.6 + 2.4)v^2 = 2v^2$]
[$12 = 2v^2$]
$v^2 = 6 \rightarrow v = 2.45$ ms^{-1}
[$0.5 = ½ \times (0 + 2.45) \times t$]
$t = 0.408$s 5

(ii) $R = 1.6g = 16$ and $F = 3/8\ R = 6$
System is
[$2.4g - 6 = (1.6 + 2.4)a$]
$2.4g - T = 2.4a$ and $T - 6 = 1.6a$
[$a = 4.5$]
$v = \sqrt{2 \times 4.5 \times 0.5} = \sqrt{4.5} = 2.12$ ms^{-1}
$-6 = 1.6a \rightarrow a = -3.75$ ms^{-2}
$0 = 4.5 + 2 \times (-3.75) \times (s - 0.5)$
$s = 1.1$ m 7

First Alternative for 7(ii)

(ii) $R = 1.6g = 16$ and $F = 3/8\ R = 6$
PE loss = $2.4 \times g \times 0.5$[= 12]
KE gain = $½ \times (1.6 + 2.4) \times v^2$[$= 2v^2$]
$12 = 2v^2 + 6 \times 0.5 \rightarrow v^2 = 4.5 \rightarrow v = 2.12$
Loss of KE = WD against F
[$½ \times 1.6 \times 4.5 = 6 \times (s - 0.5)$]
$s = 1.1$ m 7

12. M/J 16/P41/Q5

$R = 5g\cos\alpha = 4g$
$F = 0.5 \times 4g = 2g$
$T - 2g - 5g\sin\alpha = 5a \rightarrow$
$T - 5g = 5a$
$10g - T = 10a$
[$5g = 15a$]
$a = g/3 = 3.33$ ms ^{2}
$T = 10g - 10(g/3)$
$= 20g/3 = 66.7$ N [7]

13. M/J 16/P43/Q6

(i) (a) $1.3g - T = 1.3a$ and $T - 0.7g = 0.7a$
or
$1.3g - 0.7g = (1.3 + 0.7)a$ and either $1.3g - T = 1.3a$ or $T - 0.7g = 0.7a$
Tension is 9.1 N

(b) Acceleration is 3 ms^{-2}
[$2 = ½ \times 3 \times t^2$]
Time taken is 1.15 seconds 6

(ii) [$v^2 = 2 \times 3 \times 2$]
$v = \sqrt{12}(3.464)$
[$0 = 12 - 2gs \rightarrow s = ...$]
Greatest height is 4.6 m 4

Alternative

(ii) [$1.3g \times 2 = ½(1.3)v^2 + 9.1 \times 2$]
or
[$9.1 \times 2 = ½(0.7)v^2 + 0.7g \times 2$]
$v = \sqrt{12}(3.464)$
[$½ \times 0.7v^2 = 0.7gs \rightarrow s = ...$]
Greatest height is 4.6 m 4

14. O/N 15/P42/Q5

(i) $0.5g \times \frac{7}{25} - T = 0.5a$
$T - 0.1g = 0.1a$
$1.4 - 1 = 0.6a$
For eliminating T and obtaining
$a = \frac{2}{3}$ ms^{-2}
Tension is 1.07 N 5

(ii) [$v^2 = 2 \times \left(\frac{2}{3}\right) \times 0.7$]
[$2^2 = 2 \times \frac{2}{3} \times 0.7 + 2 \times 0.28g \times s$]
Length of string = $2.5 - s = 1.95$m 3

15. O/N 15/P41/Q4

$F = 0.2 \times mg\cos 35$
$5g - mg\sin 35 - 0.2\ mg\cos 35 = 0$
$5g - Mg\sin 35 + 0.2\ Mg\cos 35 = 0$
$m = 6.78$ or $M = 12.2$
$6.78 \leqslant$ mass $\leqslant 12.2$ 6

16. O/N 15/P43/Q4

(i) $0.35g - T = 0.35a$
$T - 0.15g = 0.15a$
$(0.35 - 0.15)g = (0.35 + 0.15)a$
Acceleration is 4 ms^{-2} 4
Tension is 2.1 N

(ii) $[v_1^2 = 0 + 8 \times 1.6\ (= 12.8)]$
$[H = 1.6 + (-12.8) \div (-20)]$
Greatest height is 2.24 m

17. M/J 15/P42/Q6

(i) $\left[h = \frac{1}{2} \times 0.5 \times 2\right]$
$h = 0.5$

(ii) $[a = 2 \div 0.5]$
$[T - mg = ma$
and
$(1 - m)g - T = (1 - m)a$
or
$a = \{(1 - 2m) \div (1 - m + m)\}g]$
$m = 0.3$
$[T - 0.3 \times 10 = 4 \times 0.3$ or
$0.7 \times 10 - T = 4 \times 0.7]$
Tension is 4.2 N 6

(iii) $(-2 - 2) \div (t - 0.5) = -10$
$T = 0.9$ 3

First Alternative method for (iii)

(iii) $[-2 = 2 - 10t]$
$t = 0.4$
Required time = 0.5 + 0.4 = 0.9 3

Second Alternative method for (iii)

(iii) $t = 0.2$ s
$t = 0.2 \times 2 = 0.4$ s
Total time = 0.9 s 3

18. M/J 15/P41/Q7

(i) $T - 0.2 \times 3 = 0.3a$ and $7 - T = 0.7a$
Acceleration = 6.4 ms^{-2}
$[v = 0 + 6.4 \times 0.25]$
$v = 1.6\ ms^{-1}$
$\left[\text{Distance} = 0 + \frac{1}{2}6.4 \times 0.25^2\right]$
Distance = 0.2 m
$[v^2 = 1.6^2 + 2g \times (0.5 - 0.2)]$
Speed is 2.93 ms^{-1} 9

(ii) Distance travelled after break
$= (0 - 1.6^2) \div (2 \times -2) = 0.64$
Total distance travelled
$= 0.2 + 0.64 = 0.84$ 3

Alternative method for 7(ii)

$T = 2.52$, $F = 0.2 \times 3$
WD by $T = 2.52 \times 0.2$
WD by $F = 0.2 \times 3 \times d$
$[0.6d = 2.52 \times 0.2]$
WD by T = WD by $F \rightarrow d = 0.84$ 3

19. M/J 15/P43/Q2

(i) Answer not available in Mark Scheme

(ii) Loss of PE = $0.15gh$ 1
Gain of KE = $\frac{1}{2}(0.35 + 0.15) \times 3^2$
$1.5h = 0.25 \times 9$
$h = 1.5$ 4

Alternative Method for part (ii)

(ii) $[0.15g - T = 0.15a$ and $T = 0.35a$
or $0.15g = (0.35+0.15)a]$
$a = 3ms^{-2}$ ➔ $a = ...$
$[3^2 = 0 + 2 \times 3h]$
$h = 1.5$ 4

Alternative Method for part (ii)

(ii) $[0.15g - T = 0.15a$ and $T = 0.35a$
$T = 1.05$N ➔ $T = ...$
$\left[0.15gh - \frac{1}{2} \times 0.15 \times 3^2 = 1.05h\right]$
or
$\left[\frac{1}{2} \times 0.35 \times 3^2 = 1.05h\right]$
$h = 1.5$ 4

20. O/N 14/P42/Q5

(i) (a) $[F = 0.7 \times 3$, WD $= 2.1 \times 0.9]$
Work done is 1.89 J 2

(b) Loss of PE = 3 × 0.9 = 2.7 J 1

(c) [KE gain = 2.7 – 1.89]
Gain in KE = 0.81 J 2

(ii) $½(0.3 + 0.3)v_{\text{at break}}^2 = 0.81]$
$v_{\text{floor}}^2 = v_{\text{at break}}^2 + 2g \times 0.54$
Speed at the floor is 3.67 ms^{-1} 3

Alternative method for (i) (c) and (ii)

(c) $[T - 2.1 = 0.3a$ and $3 - T = 0.3a$
$\rightarrow a = 1.5]$
$[v^2 = 2 \times 1.5 \times 0.9 = 2.7]$
KE = 0.5 × (0.3 + 0.3) × 2.7 = 0.81 J 2

(ii) $[v_{at\ break}^2 = 2.7]$

$v_{floor}^2 = v_{at\ break}^2 + 2g \times 0.54$

Speed at floor = 3.67 ms^{-1} (= $1.5\sqrt{6}$) 3

Alternative method for (ii)

(ii) $[0.3 \times g \times 0.54]$ **or** $[\frac{1}{2} \times 0.3 \times (v^2 - 2.7)]$

$[1.62 = \frac{1}{2} \times 0.3 \times (v^2 - 2.7)]$

Speed at floor = 3.67 ms^{-1} (= $1.5\sqrt{6}$) 3

21. O/N 14/P41/Q5

(i) Frictional force = $\mu \times 0.25g$

$0.3g = 0.2g + \mu 0.25g$ ➔

Coefficient of friction is 0.4 3

(ii) $0.2g - T = 0.2a$ or

$T - 0.4 \times 0.25g = 0.25a$

$T - 0.4 \times 0.25g = 0.25a$ or

$0.2g - T = 0.2a$ or

$0.2g - \mu 0.25g = (0.2 + 0.25)a$

Acceleration is 2.22 ms^{-2}

Tension is 1.56 N 2

22. O/N 14/P43/Q2

$0.65 \times 10 \times (63/65) - T = 0.65a$ or

$T - 0.65 \times 10 \times (16/65) = 0.65a$

$T - 0.65 \times 10 \times (16/65) = 0.65a$ or

$0.65 \times 10 \times (63/65) - T = 0.65a$ or

$0.65 \times 10 \times (63 - 16)/65 = 2 \times 0.65a$

$[T - 1.6 = 6.3 - T]$ or

$[T = 6.3 - 0.65 \times (47/13)]$ or

$[T = 1.6 + 0.65 \times (47/13)]$

Tension is 3.95 N 2

23. O/N 14/P43/Q5

$[P - 8g\sin5° - F = 8a]$

$7X - 8g\sin5° - F = 8 \times 0.15$ **and**

$8X - 8g\sin5° - F = 8 \times 1.15$

$X = 8$

$F = 56 - 8g\sin5° - 8 \times 0.15$ **or**

$F = 64 - 8g\sin5° - 8 \times 1.15$ **or**

$F = 56 \times 1.15 - 64 \times 0.15 - 8g\sin5°$ **or**

$F = 47.8(275...)$

$R = 8g\cos5°$ (= 79.695...)

$[\mu = 47.8 \div 79.7]$

Coefficient is 0.600 (accept 0.6) **8**

24. O/N 14/P43/Q6

(i) Acceleration is 4 ms^{-2}

For $T - mg = 4m$ **and** $(1 - m)g - T = 4(1 - m)$

or $4 = (1 - m - m)g$

P has mass 0.3 kg and Q has mass 0.7 kg 5

(ii) For using the area property of the graph or $h = \frac{1}{2}at^2$ to obtain $h = 2$ 1

(iii) Distance travelled upwards by

$P = \frac{1}{2} 1.4 \times 4$

Height is 4.8 m 2

25. M/J 14/P42/Q7

(i) $[T_A - 2.5 = 0.25 \times a]$ $[7.5 - T_B = 0.75 \times a]$

$T_A = 2.5 + 0.25a$

$T_B = 7.5 - 0.75a$ 3

(ii) $F = 0.4 \times 5$

$[T_B - T_A - F = 0.5a]$

$7.5 - 0.75a - (2.5 + 0.25a) - 2 = 0.5a$ ➔ $a = 2$ 3

Alternative method for (ii)

(ii) $F = 0.4 \times 5$

$a = 2$ used to find $T_A = 3$, $T_B = 6$ and used in $T_B - T_A - F = 0.5 \times a$

$a = 2$

(iii) $v^2 = [2 \times 2 \times 0.36]$

Speed is 1.2 ms^{-1} A1.

(iv) $- T_A - 2 = 0.5a$ and $T_A - 2.5 = 0.25a$

Deceleration is 6 ms^{-2} 2

26. M/J 14/P41/Q6

(i) Acceleration is 5 ms^{-2}

Distance is 0.9 m [4]

(ii) $\frac{1}{2}\ 0.6 \times V = 0.9 \rightarrow V = 3$

$T = 0.9$ [3]

(iii) $[s_{up} = \frac{1}{2}\ 0.9 \times 3$ and

$s_{down} = 0 + \frac{1}{2}\ g(1.6 - 0.9)^2]$

Distance upwards is 1.35 m and distance downwards is 2.45 m

$h = 1.1$ [3]

27. M/J 14/P43/Q7

(i) For $T - (40 \div 160) \times 0.76g = 0.76a$ or

$0.49g - T = 0.49a$

For $0.49g - T = 0.49a$ or

$T - (40 \div 160) \times 0.76g = 0.76a$ or

$0.49g - (400 \div 160) \times 0.76g = (0.49 + 0.76)a$

Acceleration is 2.4 ms^{-2}

and tension is 3.72 N (3.724 exact)

(ii) $[v^2 = 2 \times 2.4 \times 0.3]$
Speed is 1.20ms^{-1}

(iii) Distance while Q is on the ground
$= (2 \times 2.4 \times 0.3) \div 2(40g \div 160)$
$(= 0.288\text{m})$
Distance travelled is 0.588 m [3]

28. O/N 13/P42/Q6

(i) $T - 0.4g = 0.4a$ or $1.6g - T = 1.6a$
$1.6g - T = 1.6a$ or $T - 0.4g = 0.4a$
or $1.6g - 0.4g = (1.6 + 0.4)a$
$T = 6.4$
Work done by tension is 7.68 J 5

Alternative mark scheme for 6 (i)

(i) $T - 0.4g = 0.4a$ or $1.6g - T = 1.6a$
$1.6g - T = 1.6a$ or $T - 0.4g = 0.4a$
or $1.6g - 0.4g = (1.6 + 0.4)a$
WD by T = initial PE – final KE
$= 1.6 \times g \times 1.2 - \frac{1}{2} \times 1.6 \times 14.4$
WD by T = 19.2 – 11.52 = 7.68 5

(ii) $[1.6 \times 10 \times 1.2 = \frac{1}{2}\, 1.6\, v^2 + 7.68]$
$v^2 = 14.4$
$14.4 = 2 \times 10 \times h$
$h = 0.72$
$H = 2 \times 1.2 + h$
Greatest height is 3.12 m

First Alternative Marking Scheme for 6 (ii)

$[v^2 = 2 \times 6 \times 1.2]$
$v^2 = 14.4$
$14.4 = 2 \times 10 \times h$
$h = 0.72$
$H = 2 \times 1.2 + h$
Greatest height is 3.12 m 4

Second Alternative Marking Scheme for 6 (ii)

WD by T = Increase in PE
$7.68 = 0.4 \times g \times s$
$s = 1.92$
$H = 1.2 + s$
$H = 1.2 + 1.92 = 3.12$ Height = 3.12 m 4

29. O/N 13/P41/Q6

(i) $T - 0.3g = 0.3a$ or
$0.7g - T = 0.7a$
$0.7g - T = 0.7a$ or
$T - 0.3g = 0.3a$ or
$0.7g - 0.3g = (0.7 + 0.3)a$
Tension is 4.2 N 4

(ii) $a = 4$
$s_{taut} = 1.6^2/(2 \times 4)$ $(= 0.32)$
$[(0.52 + 0.32) = -1.6t + 5t^2]$
$[(t - 0.6)(5t + 1.4) = 0]$
Time taken is 0.6 s 5

Alternative Marking Scheme for the last three marks

$0^2 = 1.6^2 - 2gs_{up}$,
$t_{up} = 2s_{up}/(1.6 + 0)$ $(= 0.16)$
$0.52 + s_{taut} + s_{up} = 0 + \frac{1}{2}\, g t_{down}^2$
$(t_{down} = 0.44)$
Time taken $= t_{up} + t_{down} = 0.6$ s

30. O/N 13/P43/Q2

$a = 5$
When B reaches the floor
$v^2 = 2 \times 5 \times 1.6$; speed is 4ms^{-1}
$0 = 16 - 20s$ $(s = 0.8)$
$h + 1.6 + 0.8 = 3 \rightarrow h = 0.6$ 6

31. M/J 13/P42/Q7

(i) $T - 0.26g(16 \div 65) = 0.26a$ or
$0.52g - T = 0.52a$
For $\{0.52g - T = 0.52a$ or
$T - 0.26g(16 \div 65) = 0.26a\}$
or $0.52g - 0.26g(16 \div 65) = (0.52 + 0.26)a$
Acceleration is 5.85 ms^{-2}
Tension is 2.16 N [5]

(ii) $[v^2 = 2 \times (76/13) \times 0.6]$
Speed is 2.65 ms^{-1}
$0 = 91.2/13 - 2(160/65)s$
$S = 57/40$ $(= 1.425)$
$[AP = 2.5 - 0.6 - 1.425]$
Distance AP is 0.475 m [6]

32. M/J 13/P41/Q5

(i) $R = 2.6 \times (12 \div 13)$ $(= 2.4)$
$[F = 0.2 \times 2.4]$
$[T - 2.6(5 \div 13) - F = 0.26a,\ 5.4 - T = 0.54a]$
For any two of $T - 1 - 0.48 = 0.26a$, $5.4 - T = 0.54a$ or
$(5.4 - 1 - 0.48) = (0.54 + 0.26)a$
Acceleration is 4.9 ms^{-2}
Tension is 2.75 N (2.754 exact) [6]

(ii) $[s = \frac{1}{2}\, 4.9 \times 0.4^2]$
Distance is 0.392 m [2]

33. M/J 13/P43/Q7

(i) $T - (2/7)\,1.26\,g = 1.26\,a$ or
$0.9\,g - T = 0.9\,a$
$0.9g - T = 0.9\,a$ or
$T - (2/7)\,1.26\,g = 1.26\,a$
or
$0.9\,g - (2/7)\,1.26\,g = (0.9 + 1.26)\,a$
Acceleration is 2.5 m s^{-2}
Tension is 6.75 N [5]

$[v^2 = 2 \times (2.5) \times 0.45]$
Speed is 1.5 m s^{-1} [2]

$[-(2/7)\,1.26\,g = 1.26\,a]$
$a = -20/7$
$[v^2 = 2.25 + 2(-20/7)(0.03)]$
Speed is 1.44 m s^{-1} [4]

34. O/N 12/P42/Q5

(i) Acceleration for $t < 0.8$ is 4/0.8
$[5 = 10\sin\theta]$
$\theta = 30°$ 3

Alternative for part (i)

(i) $[mgh = \frac{1}{2} m4^2$ and $s = \{(0 + 4) \div 2\} \times 0.8]$
$\sin\theta = 0.8/1.6$
$\theta = 30°$

(ii) Acceleration for $0.8 < t < 4.8$ is
$-4/(4.8 - 0.8)$
$[mg\sin30° - F = m(-1)]$

$$\mu = \frac{mg\sin 30° + m}{mg\cos 30°}$$

Coefficient is 0.693 5

35. O/N 12/P41/Q2

(i) $a = g\sin30 = 5$
$2.5 = 0 + 5t$
$t = 0.5$ Time = 0.5 s

(ii) $v^2 = 0 + 2 \times 5 \times 3 = 30$
$-1 = 0.5a \rightarrow a = -2$
$0 = 30 + 2 \times (-2) \times s$
Distance = 7.5 m 3

First alternative method for 2(ii)

$v^2 = 0 + 2 \times 5 \times 3 = 30$
$0.5 \times 0.5 \times 30 = 1 \times$ distance
Distance = 7.5 m 3

Second alternative method for 2(ii)

PE lost = $0.5 \times 10 \times 3\sin30 = 7.5$
$7.5 = 1 \times$ distance
Distance = 7.5 m 3

36. O/N 12/P41/Q3

(i) $[R + 0.6\sin\alpha = 0.5g\cos\alpha]$
Normal component is 4.63(2) N 2

(ii) $F + 0.6\cos\alpha = 0.5g\sin\alpha$
Frictional component is 0.824 N 3

(iii) Coefficient is 0.178 2

37. O/N 12/P43/Q7

(i) $0.32g - T = 0.32a$ (or $T = 0.48a$)
$T = 0.48a$ (or $0.32g - T = 0.32a$) OR
$0.32g = (0.32 + 0.48)a$
Acceleration is 4 ms^{-2} and tension is 1.92 N 5

(ii) $[0.98 = \frac{1}{2} 4t^2]$
Time taken is 0.7 s 2

(iii) $v = 4 \times 0.7$ and $t = (1.4 - 0.98)/v$ (= 0.15)
Time taken is 0.85 s 3

38. M/J 12/P42/Q5

(i) Tension in S_1 is 30 N
Tension in S_2 is 50 N [2]

(ii) $3g - T - 1.6 = 3a$ (or $2g + T - 4 = 2a$)
$2g + T - 4 = 2a$ (or $3g - T - 1.6 = 3a$) or
$(3g + 2g) - (1.6 + 4) = (3 + 2)a$
Acceleration is 8.88 ms^{-2}
Tension is 1.76 N [5]

SR (max. 1 / 2) for candidates who do not give numerical answers in (i).
Allow B1 for Tension in S_1 is 3g and Tension in S_2 is 5g

39. M/J 12/P41/Q6

(i) $0.6g \times 0.8 - T = 0.6a$ and $T - 0.4g \times 0.8 = 0.4a$
or $(0.6 - 0.4)g \times 0.8 = (0.6 + 0.4)a$
Tension is 3.84 N or acceleration is 1.6ms^{-2}
Acceleration is 1.6 ms^{-2} or tension is 3.84 N [5]

(ii) $2 = 1.6t_1$ $(t_1 = 1.25)$
$0 = 2 - 0.8gt_2$ $(t_2 = 0.25)$ [4]
Time taken in 1.5 s

40. M/J 12/P43/Q6

(i) $F = 5.9 - 6.1\sin\alpha$
$R = 6.1\cos\alpha$
$[5.9 - 6.1\sin\alpha \le \mu(6.1\cos\alpha)]$ [5]
$\mu > \frac{4}{5}$

(ii) $[6.1 \times (11/61) + 5.9 - \mu 6.1 \times (60/61) > 0]$

$\mu < \frac{7}{6}$ [2]

(iii) $[6.1 \times (11/61) + 5.9 - \mu\, 6.1 \times (60/61) = 0.61 \times 1.7]$

$\mu = 0.994$ [2]

41. M/J 12/P43/Q7

(i) $[T - 0.12g = 0.12a$ & $0.38g - T = 0.38a;$

$a = \frac{0.38 \quad 0.12}{0.38 + 0.12} g]$

Acceleration is 5.2 ms^{-2} [2]

(ii) $[v^2 = 2 \times 5.2 \times 0.65; 0.65 = ½\, 5.2T_B^2]$

Speed of B is 2.6ms^{-1} or $T_B = 0.5$

$T_B = 0.5$ or Speed of B is 2.6ms^{-1} **[3]**

(iii) $[-2.6 = 2.6 - 10(T - 0.5)]$

$T = 1.02$

Correct graph for $0 < t < 1.02$ **[3]**

ft incorrect values of V, T and T_B

(iv) $[0.65 + 0.5(1.02 - 0.5)2.6]$

Total distance is 1.326 m (accept 1.33) [2]

42. O/N 11/P42/Q2

(i) $F = 0.2 \times 6g \cos 8$

$[6g \sin 8 - F = 6a]$

Deceleration is 0.589 ms^{-2}

(ii) Distance is 7.64 m 2

43. O/N 11/P42/Q3

$v = (0.8/0.25)\, t^{0.25} + (C)$

$C = 1.8$

$s = (3.2/1.25)t^{1.25} + 1.8t + (K)$

Distance is 111 m 6

44. O/N 11/P42/Q5

(i) $0.9g - T = 0.9a$ or $T - 0.6g = 0.6a$

$T - 0.6g = 0.6a$ or $0.9g - T = 0.9a$ or

$(0.9 - 0.6)g = (0.9 + 0.6)a$

Acceleration is 2 ms^{-2} and tension is 7.2 N 4

(ii) $u = 3$

$[3^2 = 2 \times 2\, h]$

$[½\,(0.9 + 0.6)3^2 = (0.9 - 0.6)gh]$

Height is 2.25 m 4

45. O/N 11/P41/Q2

$0.65g - T = 0.65a$ and $T - 0.35g = 0.35a$

Tension in the string is 4.55 N

M... 5

46. O/N 11/P43/Q3

$0.9g - 7.2 = 0.9a$ $(a = 2)$

$[v^2 = 2 \times (0.9g - 7.2)/0.9 \times 2]$ $(v = \sqrt{8})$

$u_{slack} = v_{taut} = 2\sqrt{g \quad 8}$

[distance = 4 – 32/g]

Distance is 0.8 m 6

47. O/N 10/P41/Q7

(i) $R + 3.2\sin 30° = 0.5g$

$F + 0.2g = 3.2\cos 30°$

$[\mu = (3.2\cos 30° - 2)/(5 - 3.2\sin 30°)]$

Coefficient is 0.227 [6]

(ii) $2 - T = 0.2a$

$T - 0.227 \times 5 = 0.5a$

Acceleration is 1.24 ms^{-2} and tension is 1.75 N [4]

48. M/J 10/P42/Q6

(i) $0.45a = 0.45g - T$ and $0.2a = T - F$ or

$(0.45 + 0.2)a = 0.45g - F$

$F = 0.3 \times 0.2g$

Acceleration is 6 ms^{-2}

$[v^2 = 2 \times 6 \times [2 - (2.8 - 2.1)]$

Speed is 3.95 ms^{-1} [7]

(ii) $0.2a_2 = -0.06g$

$v^2 = 15.6 + 2(-3)(0.8)$

Speed is 3.29 ms^{-1} [4]

Alternative for **6(ii)**

WD against friction = $0.06g \times [2.1 - (2 - 0.7)]$

$½\, 0.2 \times 3.95^2 - ½\, 0.2v^2 = 0.48$

Speed is 3.29 ms^{-1}

49. M/J 10/P41/Q6

(i) $0.45a = 0.45g - T$ and $0.2a = T - F$ or

$(0.45 + 0.2)a = 0.45g - F$

$F = 0.3 \times 0.2g$

Acceleration is 6 ms^{-2}

$[v^2 = 2 \times 6 \times [2 - (2.8 - 2.1)]$

Speed is 3.95 ms^{-1} [7]

$0.2a_2 = -0.06g$

(ii) $v^2 = 15.6 + 2(-3)(0.8)$

Speed is 3.29 ms^{-1} [4]

Alternative for **6(ii)**

WD against friction = $0.06g \times [2.1 - (2 - 0.7)]$

$½\, 0.2 \times 3.95^2 - ½\, 0.2v^2 = 0.48$

Speed is 3.29 ms^{-1}

50. M/J 10/P43/Q4

(i) $0.36g\sin60° - T = 0.36 \times 0.25$
Tension is 3.03 N [2]

(ii) $T \pm F - 0.24g\sin60° = 0.24 \times 0.25$
$F = 3.03 - 0.24g\sin60° - 0.24 \times 0.25$ $(F = 0.889)$
$R = 0.24g\cos60°$ $(R = 1.2)$
Coefficient is 0.74 [6]

51. M/J 10/P43/Q7

(i) $R = 4500$ N
$3150 = \mu 4500$
Coefficient is 0.7 [3]

(ii) $0.2 \times 200g = 200a$
No sliding ➔ $a \leqslant 2$ [3]

(iii) $[P - F = 450a; P - F - F_2 = 250a]$
$P_{max} = 3150 + 450 \times 2$ or
$P_{max} = 3150 + 0.2 \times 2000 + 250 \times 2$
$P_{max} = 4050$ N [3]

52. O/N 09/P42/Q4

(i) $[1.2 = mg\cos\alpha]$
Mass is 0.125 kg 2

(ii) $[-mg\sin\alpha - F = ma]$
$-0.125 \times 10 \times 0.28 - 0.4 = 0.125a$
$a = -6$ ➔ deceleration is 6 ms^{-2} 3

(iii) $\mu R > mg\sin\alpha$ ➔ particle remains at rest 2

53. O/N 09/P42/Q5

(i) $12 + 15\sin30° = R$
$F = 15\cos30°$
$[\mu = 15\cos30°/(12 + 15\sin30°)]$
Coefficient is 0.666 5

(ii) $F = 0.666(12 - 15\sin30°)$
$15\cos30° - F = 1.2a$
Acceleration is 8.33 ms^{-2} 4

54. O/N 09/P42/Q6

(i) $T - 0.3g = 0.3a$ and $0.7g - T = 0.7a$ or
$(0.7 + 0.3)a = (0.7 - 0.3)g$
Acceleration is 4 ms^{-2} 3

(ii) $s_1 = 1.6^2/(2 \times 4)$
Height is 0.448 m 3

(iii) $t_1 = 1.6/4$
Time taken is 0.56 s 3

(Alternative for part (iii))
➔$t_1 + t_2 = (s_1 + s_2)/0.8$
Time taken is 0.56 s 3

(Alternatively for parts ii and iii using v–t graph)
$t_1 = 1.6/4$ and $t_2 = 1.6/10$
Time taken is 0.56s

$s_1 = 0.4 \times 1.6/2$ or $s_2 = 0.16 \times 1.6/2$
or
$s_1 + s_2 = (0.4 + 0.16) \times 1.6/2$
Height is 0.448m 6

55. O/N 09/P41/Q6

(i) $0.55g - T = 0.55a$ and $T - 0.45g = 0.45a$ or
$a = [(0.55 - 0.45)/(0.55 + 0.45)]g$
Acceleration is $1ms^{-2}$ 3

(ii) (a) Height of P is 3m and height of Q is 7m 2
(b) Speed is $2ms^{-1}$ 1

(iii) $[3 = 2t_P + 5t_P^2,\ 7 = -2t_Q + 5t_Q^2]$
$t_P = 0.6$
$t_Q = 1.4$
Q is 0.8s later than P 4

56. M/J 09/P4/Q1

Tension is 40 N
$[R + T = W]$
Force exerted is 10 N [3]

57. M/J 09/P4/Q6

(i) $[0.36 = ½a(0.6)^2]$
Acceleration is 2 ms^{-2} [2]

(ii) $[0.45g - T = 0.45 \times 2]$
Tension is 3.6 N [2]

(iii) $[T - mg = 2m$ or
$0.9 + 2m = 4.5 - 10m]$
$(2 + g)m = 3.6$ (must have m terms combined)
Mass is 0.3 kg [3]

(iv) $u = 1.2$
$[0 = 1.44 - 20s \rightarrow 0.072]$
Maximum height is 0.792 [3]

58. O/N 08/P4/Q5

(i) (a) $[5 = 0 + 2a]$
Acceleration is $2.5ms^{-2}$ [2]

(b) $0.5g - T = 0.5 \times 2.5$
Tension is 3.75N [3]

(ii) $T - mg = 2.5m$
or $0.5g - mg = 0.5 \times 2.5 + 2.5m$
$[(10 + 2.5)m = 3.75]$
$m = 0.3$ [3]

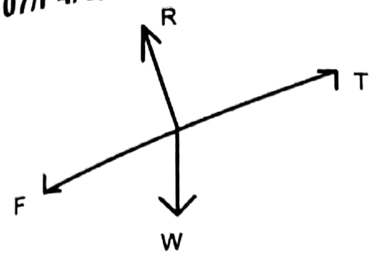
59. M/J 08/P4/Q5

(i) $F = 0.5(0.6g)$
$0.4g - T = 0.4a$
$T - F = 0.6a$
Acceleration is $1ms^{-2}$ and tension is 3.6N [6]

(ii) Time taken is 2.45s [2]

60. O/N 07/P4/Q7

(i)



(ii)
$T - F - 0.13g\,(16/65)$
$[T - F - 0.13g\,(16/65) > 0]$
$T - F > 0.32$ 4

(iii) $R = 0.13g(63/65)$ or $0.13g\cos 14.25\ldots$ $(= 1.26)$
$F = 0.6 \times 1.26$ $(= 0.756)$
$T - F - 0.32 = 0.13a$ and
$0.11g - T = 0.11a$
or $0.11g - F - 0.32 = (0.13 + 0.11)a$
Acceleration is $0.1\ \text{ms}^{-2}$ 6

61. M/J 07/P4/Q7

(i) $T\cos 60° = 75\cos 30° \rightarrow T = 130$
$T\sin 60° + 75\sin 30° + R = 20g$
$[130\sin 60° + 75\sin 30° + R = 200]$
Magnitude is 50 N 5

(ii) $T\cos 60° + 25 = 75\cos 30°$
$(T = 79.9)$
$[79.9\sin 60° + 75\sin 30° + R = 200]$
$R = 93.3$
$[\mu = 25/93.3]$
Coefficient is 0.268 $(= 2 - \sqrt{3})$ 6

62. O/N 06/P4/Q7

(i) $R = mg\cos 21° = 9.336m$
$a = -5$
$[-mg\sin 21° - F = -5m]$
$F = 1.41m$ 5

(ii) Coefficient is 0.152 1

(iii) $s = 10$
Speed is $6.58\ \text{ms}^{-1}$ 5

$mg\sin 21° - 1.416m = ma$ $[a = 2.167\ldots]$
$[v^2 = 2(g\sin 21° - 1.416)10]$

63. M/J 06/P4/Q5

(i) $T = 4\sqrt{2}\cos 45° = 4N$
Mass of Q is 0.4 kg 2

(ii) $4 = 0.8m_p \times 10$
Mass of P is 0.5 kg 2

(iii) $T - 0.8 \times 0.5g = 0.5\alpha$
$0.5g - T = 0.5\alpha$
Tension is 4.5 N 4

64. M/J 05/P4/Q4

(i) $T = 0.2g$ and $T = F$
$R = 0.3g$ and $0.2g = \mu R$ 4
Coefficient is 2/3

(ii) $F = 2/3(0.3g - 1.8)$ $(= 0.8)$
$X = 2.8$ 3

65. O/N 04/P4/Q1

$T = 1.7a$
$0.3g - T = 0.3a$
Acceleration is $1.5\ \text{ms}^{-2}$ and tension is 2.55 N 5

66. O/N 03/P4/Q5

(i) applying Newton's second law to A or to B (3 terms needed)
$T - 0.6 = 0.4a$ or $0.1g - T = 0.1a$
For a second of the above 2 equations or for
$0.1g - 0.6 = 0.5a$ *[Can be scored in part (ii)]*
(Sign of a must be consistent with that in first equation)
Tension is 0.92 N 4

(ii) $a = 0.8$
For using $v = at$
Speed $= 1.2\ \text{ms}^{-1}$ 3

67. M/J 03/P4/Q5

(i) For resolving forces on any two of A, or B, or A and B combined $(T_1 = W_A + T_2, T_2 = W_B, T_1 = W_A + W_B)$
Tension in S_1 is 4 N or Tension in S_2 is 2 N
Accept $0.4g$ or 3.92 (from 9.8 or 9.81) for T_1
Tension in S_2 is 2 N or Tension in S_1 is 4 N 3
Accept $0.2g$ or 1.96 (from 9.8 or 9.81) for T_2
SR (for candidates who omit g) (Max 1 out of 3)
$T_1 = 0.4$ and $T_2 = 0.2$

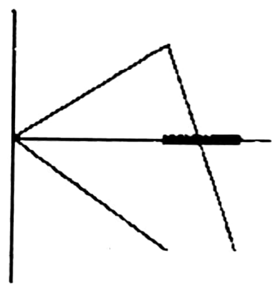
(ii) For applying Newton's second law to A, or to B, or to A and B combined
For any one of the equations $T + 2 - 0.4 = 0.2a$, $2 - T - 0.2 = 0.2a$, $4 - 0.4 - 0.2 = 0.4a$
For a second of the above equations
For solving the simultaneous equations for a and T
Acceleration is $8.5\ \text{ms}^{-2}$, tension is 0.1 N 5
Accept 8.3 from 9.8 or 8.31 from 9.81
SR(for candidates who obtain only the 'combined' equation) (Max 3 out of 5)
For applying Newton's second law to A and B combined
For $4 - 0.4 - 0.2 = 0.4a$
Acceleration is $8.5\ \text{ms}^{-2}$

68. M/J 02/P4/Q7

(i) For applying Newton's 2nd law to A or B or for using
(m1+m2)a = (m2-m1)g
0.15 = T 0.15g
0.25 = 0.25g T
Alternative for the above 2 A marks:
(0.15 + 0.25) = (0.25 - 0.15)g
Acceleration is 2.5ms-2 (ft only for 0.25 following the absence of g)
(2.45 from g=9.8 or g=9.81) 4

(ii) v=5 ft for 2 ans (i)
(4.9 from g=9.8 and 4.90(5) from g=9.81)
For using v=u + at to find time up or time down or total time up and down
acceleration must be g
or -5 = 5 10t
Slack for 1s 4

(iii)



For 2 line segments representing motion with the string taut.
For the line segment representing motion of A with the string slack
For the line segment v=0 Representing B stationary with the string slack 3

Unit-4: Energy, Work and Power

1. O/N 17/P42/Q5

A cyclist is riding up a straight hill inclined at an angle α to the horizontal, where $\sin\alpha = 0.04$. The total mass of the bicycle and rider is 80 kg. The cyclist is riding at a constant speed of 4 m s^{-1}. There is a force resisting the motion. The work done by the cyclist against this resistance force over a distance of 25 m is 600 J.

(i) Find the power output of the cyclist. [4]

The cyclist reaches the top of the hill, where the road becomes horizontal, with speed 4 m s^{-1}. The cyclist continues to work at the same rate on the horizontal part of the road.

(ii) Find the speed of the cyclist 10 seconds after reaching the top of the hill, given that the work done by the cyclist during this period against the resistance force is 1200 J. [4]

2. O/N 17/P41/Q2

A tractor of mass 3700 kg is travelling along a straight horizontal road at a constant speed of 12 m s^{-1}. The total resistance to motion is 1150 N.

(i) Find the power output of the tractor's engine. [1]

The tractor comes to a hill inclined at 4° above the horizontal. The power output is increased to 25 kW and the resistance to motion is unchanged.

(ii) Find the deceleration of the tractor at the instant it begins to climb the hill. [3]

(iii) Find the constant speed that the tractor could maintain on the hill when working at this power. [2]

3. O/N 17/P41/Q3

A roller-coaster car (including passengers) has a mass of 840 kg. The roller-coaster ride includes a section where the car climbs a straight ramp of length 8 m inclined at 30° above the horizontal. The car then immediately descends another ramp of length 10 m inclined at 20° below the horizontal. The resistance to motion acting on the car is 640 N throughout the motion.

(i) Find the total work done against the resistance force as the car ascends the first ramp and descends the second ramp. [2]

(ii) The speed of the car at the bottom of the first ramp is 14 m s^{-1}. Use an energy method to find the speed of the car when it reaches the bottom of the second ramp. [4]

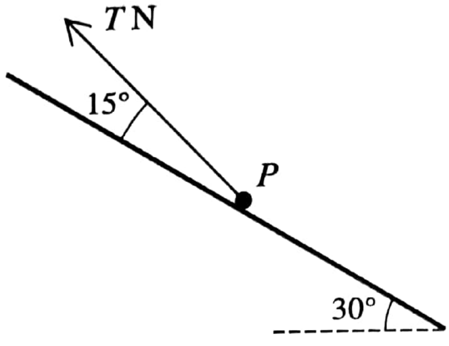
4. O/N 17/P43/Q2

A lorry of mass 7850 kg travels on a straight hill which is inclined at an angle of 3° to the horizontal. There is a constant resistance to motion of 1480 N.

(i) Find the power of the lorry's engine when the lorry is going up the hill at a constant speed of 10 m s^{-1}. [3]

(ii) Find the power of the lorry's engine at an instant when the lorry is going down the hill at a speed of 15 m s^{-1} with an acceleration of 0.8 m s^{-2}. [3]

5. O/N 17/P43/Q7



A particle P of mass 0.2 kg rests on a rough plane inclined at 30° to the horizontal. The coefficient of friction between the particle and the plane is 0.3. A force of magnitude T N acts upwards on P at 15° above a line of greatest slope of the plane (see diagram).

(i) Find the least value of T for which the particle remains at rest. [6]

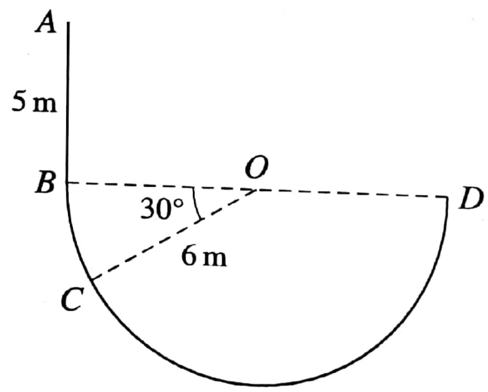
The force of magnitude T N is now removed. A new force of magnitude 0.25 N acts on P up the plane, parallel to a line of greatest slope of the plane. Starting from rest, P slides down the plane. After moving a distance of 3 m, P passes through the point A.

(ii) Use an energy method to find the speed of P at A. [5]

6. M/J 17/P42/Q1

One end of a light inextensible string is attached to a block. The string makes an angle of $\theta°$ with the horizontal. The tension in the string is 20 N. The string pulls the block along a horizontal surface at a constant speed of 1.5 m s^{-1} for 12 s. The work done by the tension in the string is 50 J. Find θ. [3]

7. M/J 17/P42/Q2



The diagram shows a wire $ABCD$ consisting of a straight part AB of length 5 m and a part BCD in the shape of a semicircle of radius 6 m and centre O. The diameter BD of the semicircle is horizontal and AB is vertical. A small ring is threaded onto the wire and slides along the wire. The ring starts from rest at A. The part AB of the wire is rough, and the ring accelerates at a constant rate of 2.5 m s^{-2} between A and B.

(i) Show that the speed of the ring as it reaches B is 5 m s^{-1}. [1]

The part BCD of the wire is smooth. The mass of the ring is 0.2 kg.

(ii) (a) Find the speed of the ring at C, where angle $BOC = 30°$. [4]

(b) Find the greatest speed of the ring. [2]

8. M/J 17/P42/Q4

A car of mass 1200 kg is moving on a straight road against a constant force of 850 N resisting the motion.

(i) On a part of the road that is horizontal, the car moves with a constant speed of $42\,\mathrm{m\,s^{-1}}$.

(a) Calculate, in kW, the power developed by the engine of the car. [2]

(b) Given that this power is suddenly increased by 6 kW, find the instantaneous acceleration of the car. [3]

(ii) On a part of the road that is inclined at $\theta°$ to the horizontal, the car moves up the hill at a constant speed of $24\,\mathrm{m\,s^{-1}}$, with the engine working at 80 kW. Find θ. [4]

9. M/J 17/P41/Q1

A particle of mass 0.6 kg is dropped from a height of 8 m above the ground. The speed of the particle at the instant before hitting the ground is $10\,\mathrm{m\,s^{-1}}$. Find the work done against air resistance. [3]

10. M/J 17/P41/Q4

A car of mass 800 kg is moving up a hill inclined at $\theta°$ to the horizontal, where $\sin\theta = 0.15$. The initial speed of the car is $8\,\mathrm{m\,s^{-1}}$. Twelve seconds later the car has travelled 120 m up the hill and has speed $14\,\mathrm{m\,s^{-1}}$.

(i) Find the change in the kinetic energy and the change in gravitational potential energy of the car. [3]

(ii) The engine of the car is working at a constant rate of 32 kW. Find the total work done against the resistive forces during the twelve seconds. [3]

11. M/J 17/P43/Q1

A man pushes a wheelbarrow of mass 25 kg along a horizontal road with a constant force of magnitude 35 N at an angle of 20° below the horizontal. There is a constant resistance to motion of 15 N. The wheelbarrow moves a distance of 12 m from rest.

(i) Find the work done by the man. [2]

(ii) Find the speed attained by the wheelbarrow after 12 m. [3]

12. M/J 17/P43/Q6

A car of mass 1200 kg is travelling along a horizontal road.

(i) It is given that there is a constant resistance to motion.

(a) The engine of the car is working at 16 kW while the car is travelling at a constant speed of $40\,\mathrm{m\,s^{-1}}$. Find the resistance to motion. [2]

(b) The power is now increased to 22.5 kW. Find the acceleration of the car at the instant it is travelling at a speed of $45\,\mathrm{m\,s^{-1}}$. [3]

(ii) It is given instead that the resistance to motion of the car is $(590 + 2v)$ N when the speed of the car is $v\,\mathrm{m\,s^{-1}}$. The car travels at a constant speed with the engine working at 16 kW. Find this speed. [3]

13. O/N 16/P42/Q6

A van of mass 3000 kg is pulling a trailer of mass 500 kg along a straight horizontal road at a constant speed of $25\,\mathrm{m\,s^{-1}}$. The system of the van and the trailer is modelled as two particles connected by a light inextensible cable. There is a constant resistance to motion of 300 N on the van and 100 N on the trailer.

(i) Find the power of the van's engine. [2]

(ii) Write down the tension in the cable. [1]

The van reaches the bottom of a hill inclined at 4° to the horizontal with speed $25\,\mathrm{m\,s^{-1}}$. The power of the van's engine is increased to 25 000 W.

(iii) Assuming that the resistance forces remain the same, find the new tension in the cable at the instant when the speed of the van up the hill is $20\,\mathrm{m\,s^{-1}}$. [5]

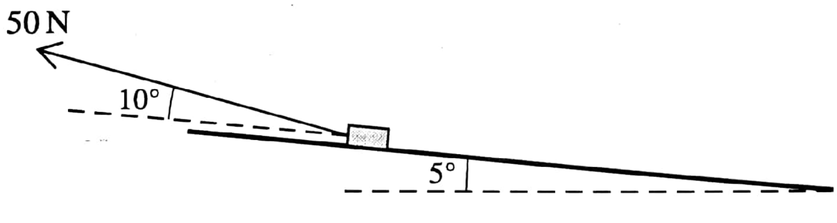
14. O/N 16/P41/Q6

A block of mass 25 kg is pulled along horizontal ground by a force of magnitude 50 N inclined at 10° above the horizontal. The block starts from rest and travels a distance of 20 m. There is a constant resistance force of magnitude 30 N opposing motion.

(i) Find the work done by the pulling force. [2]

(ii) Use an energy method to find the speed of the block when it has moved a distance of 20 m. [2]

(iii) Find the greatest power exerted by the 50 N force. [2]



After the block has travelled the 20 m, it comes to a plane inclined at 5° to the horizontal. The force of 50 N is now inclined at an angle of 10° to the plane and pulls the block directly up the plane (see diagram). The resistance force remains 30 N.

(iv) Find the time it takes for the block to come to rest from the instant when it reaches the foot of the inclined plane. [4]

15. O/N 16/P43/Q1

A crane is used to raise a block of mass 50 kg vertically upwards at constant speed through a height of 3.5 m. There is a constant resistance to motion of 25 N.

(i) Find the work done by the crane. [3]

(ii) Given that the time taken to raise the block is 2 s, find the power of the crane. [2]

16. O/N 16/P43/Q6

A cyclist is cycling with constant power of 160 W along a horizontal straight road. There is a constant resistance to motion of 20 N. At an instant when the cyclist's speed is $5\ \text{m s}^{-1}$, his acceleration is $0.15\ \text{m s}^{-2}$.

(i) Show that the total mass of the cyclist and bicycle is 80 kg. [3]

The cyclist comes to a hill inclined at 2° to the horizontal. When the cyclist starts climbing the hill, he increases his power to a constant 300 W. The resistance to motion remains 20 N.

(ii) Show that the steady speed up the hill which the cyclist can maintain when working at this power is $6.26\ \text{m s}^{-1}$, correct to 3 significant figures. [2]

(iii) Find the acceleration at an instant when the cyclist is travelling at 90% of the speed in part (ii). [4]

17. M/J 16/P42/Q3

A particle of mass 8 kg is projected with a speed of $5\ \text{m s}^{-1}$ up a line of greatest slope of a rough plane inclined at an angle α to the horizontal, where $\sin\alpha = \frac{5}{13}$. The motion of the particle is resisted by a constant frictional force of magnitude 15 N. The particle comes to instantaneous rest after travelling a distance x m up the plane.

(i) Express the change in gravitational potential energy of the particle in terms of x. [2]

(ii) Use an energy method to find x. [4]

18. M/J 16/P42/Q6

A car of mass 1100 kg is moving on a road against a constant force of 1550 N resisting the motion.

(i) The car moves along a straight horizontal road at a constant speed of $40\ \text{m s}^{-1}$.

(a) Calculate, in kW, the power developed by the engine of the car. [2]

(b) Given that this power is suddenly decreased by 22 kW, find the instantaneous deceleration of the car. [3]

(ii) The car now travels at constant speed up a straight road inclined at 8° to the horizontal, with the engine working at 80 kW. Assuming the resistance force remains the same, find this constant speed. [3]

19. M/J 16/P41/Q2

A box of mass 25 kg is pulled, at a constant speed, a distance of 36 m up a rough plane inclined at an angle of 20° to the horizontal. The box moves up a line of greatest slope against a constant frictional force of 40 N. The force pulling the box is parallel to the line of greatest slope. Find

(i) the work done against friction, [1]

(ii) the change in gravitational potential energy of the box, [2]

(iii) the work done by the pulling force. [2]

20. M/J 16/P41/Q3

A car of mass 1000 kg is moving along a straight horizontal road against resistances of total magnitude 300 N.

(i) Find, in kW, the rate at which the engine of the car is working when the car has a constant speed of $40\ \text{m s}^{-1}$. [3]

(ii) Find the acceleration of the car when its speed is $25\ \text{m s}^{-1}$ and the engine is working at 90% of the power found in part (i). [3]

21. M/J 16/P43/Q1

A particle of mass 8 kg is pulled at a constant speed a distance of 20 m up a rough plane inclined at an angle of 30° to the horizontal by a force acting along a line of greatest slope.

(i) Find the change in gravitational potential energy of the particle. [2]

(ii) The total work done against gravity and friction is 1146 J. Find the frictional force acting on the particle. [2]

22. M/J 16/P43/Q5

The motion of a car of mass 1400 kg is resisted by a constant force of magnitude 650 N.

(i) Find the constant speed of the car on a horizontal road, assuming that the engine works at a rate of 20 kW. [2]

(ii) The car is travelling at a constant speed of $10\,\text{m}\,\text{s}^{-1}$ up a hill inclined at an angle of θ to the horizontal, where $\sin\theta = \frac{1}{7}$. Find the power of the car's engine. [3]

(iii) The car descends the same hill with the engine working at 80% of the power found in part (ii). Find the acceleration of the car at an instant when the speed is $20\,\text{m}\,\text{s}^{-1}$. [3]

23. O/N 15/P41/Q1

A weightlifter performs an exercise in which he raises a mass of 200 kg from rest vertically through a distance of 0.7 m and holds it at that height.

(i) Find the work done by the weightlifter. [2]

(ii) Given that the time taken to raise the mass is 1.2 s, find the average power developed by the weightlifter. [2]

24. O/N 15/P41/Q3

A lorry of mass 24 000 kg is travelling up a hill which is inclined at 3° to the horizontal. The power developed by the lorry's engine is constant, and there is a constant resistance to motion of 3200 N.

(i) When the speed of the lorry is $25\,\text{m}\,\text{s}^{-1}$, its acceleration is $0.2\,\text{m}\,\text{s}^{-2}$. Find the power developed by the lorry's engine. [4]

(ii) Find the steady speed at which the lorry moves up the hill if the power is 500 kW and the resistance remains 3200 N. [2]

25. O/N 15/P43/Q7

A straight hill AB has length 400 m with A at the top and B at the bottom and is inclined at an angle of 4° to the horizontal. A straight horizontal road BC has length 750 m. A car of mass 1250 kg has a speed of $5\,\text{m}\,\text{s}^{-1}$ at A when starting to move down the hill. While moving down the hill the resistance to the motion of the car is 2000 N and the driving force is constant. The speed of the car on reaching B is $8\,\text{m}\,\text{s}^{-1}$.

(i) By using work and energy, find the driving force of the car. [5]

On reaching B the car moves along the road BC. The driving force is constant and twice that when the car was on the hill. The resistance to the motion of the car continues to be 2000 N. Find

(ii) the acceleration of the car while moving from B to C, [3]

(iii) the power of the car's engine as the car reaches C. [3]

26. M/J 15/P42/Q1

One end of a light inextensible string is attached to a block. The string makes an angle of 60° above the horizontal and is used to pull the block in a straight line on a horizontal floor with acceleration $0.5\,\text{m s}^{-2}$. The tension in the string is 8 N. The block starts to move with speed $0.3\,\text{m s}^{-1}$. For the first 5 s of the block's motion, find

(i) the distance travelled, [2]

(ii) the work done by the tension in the string. [2]

27. M/J 15/P42/Q2

The total mass of a cyclist and his cycle is 80 kg. The resistance to motion is zero.

(i) The cyclist moves along a horizontal straight road working at a constant rate of P W. Find the value of P given that the cyclist's speed is $5\,\text{m s}^{-1}$ when his acceleration is $1.2\,\text{m s}^{-2}$. [2]

(ii) The cyclist moves up a straight hill inclined at an angle α, where $\sin\alpha = 0.035$. Find the acceleration of the cyclist at an instant when he is working at a rate of 450 W and has speed $3.6\,\text{m s}^{-1}$. [3]

28. M/J 15/P42/Q3

A plane is inclined at an angle of $\sin^{-1}\left(\frac{1}{8}\right)$ to the horizontal. A and B are two points on the same line of greatest slope with A higher than B. The distance AB is 12 m. A small object P of mass 8 kg is released from rest at A and slides down the plane, passing through B with speed $4.5\,\text{m s}^{-1}$. For the motion of P from A to B, find

(i) the increase in kinetic energy of P and the decrease in potential energy of P, [3]

(ii) the magnitude of the constant resisting force that opposes the motion of P. [2]

29. M/J 15/P41/Q1

A block B of mass 2.7 kg is pulled at constant speed along a straight line on a rough horizontal floor. The pulling force has magnitude 25 N and acts at an angle of θ above the horizontal. The normal component of the contact force acting on B has magnitude 20 N.

(i) Show that $\sin\theta = 0.28$. [2]

(ii) Find the work done by the pulling force in moving the block a distance of 5 m. [2]

30. M/J 15/P41/Q4

A lorry of mass 14 000 kg moves along a road starting from rest at a point O. It reaches a point A, and then continues to a point B which it reaches with a speed of $24\,\text{m s}^{-1}$. The part OA of the road is straight and horizontal and has length 400 m. The part AB of the road is straight and is inclined downwards at an angle of $\theta°$ to the horizontal and has length 300 m.

(i) For the motion from O to B, find the gain in kinetic energy of the lorry and express its loss in potential energy in terms of θ. [3]

The resistance to the motion of the lorry is 4800 N and the work done by the driving force of the lorry from O to B is 5000 kJ.

(ii) Find the value of θ. [3]

31. M/J 15/P41/Q5

A cyclist and her bicycle have a total mass of 84 kg. She works at a constant rate of P W while moving on a straight road which is inclined to the horizontal at an angle θ, where $\sin\theta = 0.1$. When moving uphill, the cyclist's acceleration is $1.25\,\text{m s}^{-2}$ at an instant when her speed is $3\,\text{m s}^{-1}$. When moving downhill, the cyclist's acceleration is $1.25\,\text{m s}^{-2}$ at an instant when her speed is $10\,\text{m s}^{-1}$. The resistance to the cyclist's motion, whether the cyclist is moving uphill or downhill, is R N. Find the values of P and R. [8]

32. M/J 15/P43/Q1

A block is pulled along a horizontal floor by a horizontal rope. The tension in the rope is 500 N and the block moves at a constant speed of $2.75\,\text{m s}^{-1}$. Find the work done by the tension in 40 s and find the power applied by the tension. [4]

33. M/J 15/P43/Q4

A lorry of mass 12 000 kg moves up a straight hill of length 500 m, starting at the bottom with a speed of $24\,\text{m s}^{-1}$ and reaching the top with a speed of $16\,\text{m s}^{-1}$. The top of the hill is 25 m above the level of the bottom of the hill. The resistance to motion of the lorry is 7500 N. Find the driving force of the lorry. [6]

34. O/N 14/P42/Q3

A train of mass 200 000 kg moves on a horizontal straight track. It passes through a point A with speed $28\,\text{m s}^{-1}$ and later it passes through a point B. The power of the train's engine at B is 1.2 times the power of the train's engine at A. The driving force of the train's engine at B is 0.96 times the driving force of the train's engine at A.

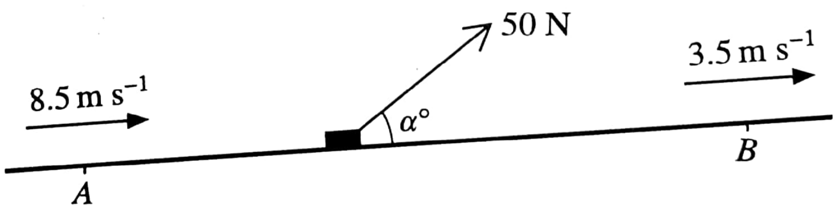
(i) Show that the speed of the train at B is $35\,\text{m s}^{-1}$. [2]

(ii) For the motion from A to B, find the work done by the train's engine given that the work done against the resistance to the train's motion is 2.3×10^6 J. [3]

35. O/N 14/P41/Q1

A car of mass 800 kg is moving on a straight horizontal road with its engine working at a rate of 22.5 kW. Find the resistance to the car's motion at an instant when the car's speed is $18\,\text{m s}^{-1}$ and its acceleration is $1.2\,\text{m s}^{-2}$. [4]

36. O/N 14/P41/Q7



A block of mass 60 kg is pulled up a hill in the line of greatest slope by a force of magnitude 50 N acting at an angle $\alpha°$ above the hill. The block passes through points A and B with speeds $8.5\,\text{m s}^{-1}$ and $3.5\,\text{m s}^{-1}$ respectively (see diagram). The distance AB is 250 m and B is 17.5 m above the level of A. The resistance to motion of the block is 6 N. Find the value of α. [11]

37. O/N 14/P43/Q1

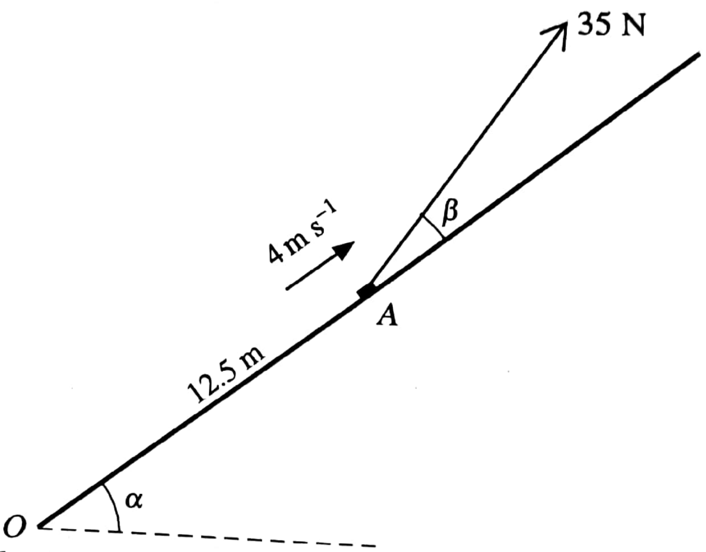
A car of mass 1400 kg moves on a horizontal straight road. The resistance to the car's motion is constant and equal to 800 N and the power of the car's engine is constant and equal to P W. At an instant when the car's speed is $18\,\text{m s}^{-1}$ its acceleration is $0.5\,\text{m s}^{-2}$.

(i) Find the value of P. [3]

The car continues and passes through another point with speed $25\,\text{m s}^{-1}$.

(ii) Find the car's acceleration at this point. [2]

38. O/N 14/P43/Q7



A small block of mass 3 kg is initially at rest at the bottom O of a rough plane inclined at an angle α to the horizontal, where $\sin\alpha = 0.6$ and $\cos\alpha = 0.8$. A force of magnitude 35 N acts on the block at an angle β above the plane, where $\sin\beta = 0.28$ and $\cos\beta = 0.96$. The block starts to move up a line of greatest slope of the plane and passes through a point A with speed 4 m s^{-1}. The distance OA is 12.5 m (see diagram).

(i) For the motion of the block from O to A, find the work done against the frictional force acting on the block. [4]

(ii) Find the coefficient of friction between the block and the plane. [3]

At the instant that the block passes through A the force of magnitude 35 N ceases to act.

(iii) Find the distance the block travels up the plane after passing through A. [4]

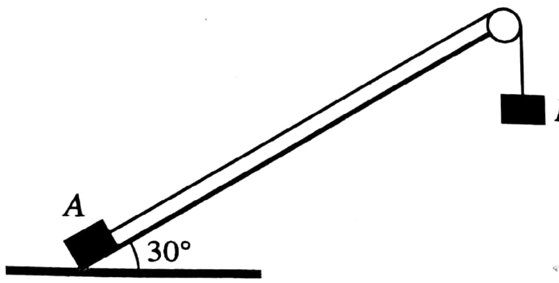
39. M/J 14/P42/Q1

A car of mass 600 kg travels along a straight horizontal road. The resistance to the car's motion is constant and equal to R N.

(i) Find the value of R, given that the car's acceleration is 1.4 m s^{-2} at an instant when the car's speed is 18 m s^{-1} and its engine is working at a rate of 22.5 kW. [4]

(ii) Find the rate of working of the car's engine when the car is moving with a constant speed of 15 m s^{-1}. [1]

40. M/J 14/P42/Q5



A light inextensible rope has a block A of mass 5 kg attached at one end, and a block B of mass 16 kg attached at the other end. The rope passes over a smooth pulley which is fixed at the top of a rough plane inclined at an angle of 30° to the horizontal. Block A is held at rest at the bottom of the plane and block B hangs below the pulley (see diagram). The coefficient of friction between A and the plane is $\frac{1}{\sqrt{3}}$. Block A is released from rest and the system starts to move. When each of the blocks has moved a distance of x m each has speed v m s^{-1}.

(i) Write down the gain in kinetic energy of the system in terms of v. [1]

(ii) Find, in terms of x,

(a) the loss of gravitational potential energy of the system, [2]

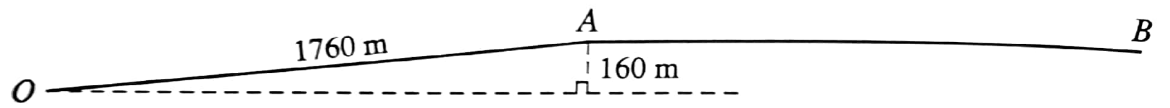
(b) the work done against the frictional force. [3]

(iii) Show that $21v^2 = 220x$. [2]

41. M/J 14/P41/Q1

A train is moving at constant speed $V\,\text{m s}^{-1}$ along a horizontal straight track. Given that the power of the train's engine is 1330 kW and the total resistance to the train's motion is 28 kN, find the value of V. [3]

42. M/J 14/P41/Q5



A car of mass 1100 kg starts from rest at O and travels along a road OAB. The section OA is straight, of length 1760 m, and inclined to the horizontal with A at a height of 160 m above the level of O. The section AB is straight and horizontal (see diagram). While the car is moving the driving force of the car is 1800 N and the resistance to the car's motion is 700 N. The speed of the car is $v\,\text{m s}^{-1}$ when the car has travelled a distance of x m from O.

(i) For the car's motion from O to A, write down its increase in kinetic energy in terms of v and its increase in potential energy in terms of x. Hence find the value of k for which $kv^2 = x$ for $0 \leqslant x \leqslant 1760$. [4]

(ii) Show that $v^2 = 2x - 3200$ for $x \geqslant 1760$. [4]

43. M/J 14/P43/Q4

A small ball of mass 0.4 kg is released from rest at a point 5 m above horizontal ground. At the instant the ball hits the ground it loses 12.8 J of kinetic energy and starts to move upwards.

(i) Show that the greatest height above the ground that the ball reaches after hitting the ground is 1.8 m. [4]

(ii) Find the time taken for the ball's motion from its release until reaching this greatest height. [3]

44. M/J 14/P43/Q5

A lorry of mass 16 000 kg travels at constant speed from the bottom, O, to the top, A, of a straight hill. The distance OA is 1200 m and A is 18 m above the level of O. The driving force of the lorry is constant and equal to 4500 N.

(i) Find the work done against the resistance to the motion of the lorry. [3]

On reaching A the lorry continues along a straight horizontal road against a constant resistance of 2000 N. The driving force of the lorry is not now constant, and the speed of the lorry increases from $9\,\text{m s}^{-1}$ at A to $21\,\text{m s}^{-1}$ at the point B on the road. The distance AB is 2400 m.

(ii) Use an energy method to find F, where F N is the average value of the driving force of the lorry while moving from A to B. [3]

(iii) Given that the driving force at A is 1280 N greater than F N and that the driving force at B is 1280 N less than F N, show that the power developed by the lorry's engine is the same at B as it is at A. [2]

45. O/N 13/P42/Q2

A box of mass 25 kg is pulled in a straight line along a horizontal floor. The box starts from rest at a point A and has a speed of $3\ \text{m s}^{-1}$ when it reaches a point B. The distance AB is 15 m. The pulling force has magnitude 220 N and acts at an angle of $\alpha°$ above the horizontal. The work done against the resistance to motion acting on the box, as the box moves from A to B, is 3000 J. Find the value of α. [5]

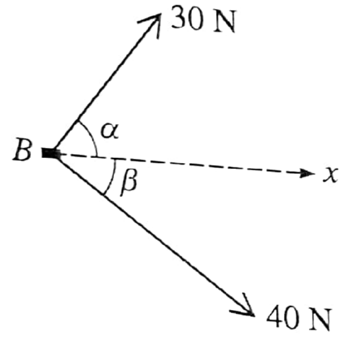
46. O/N 13/P42/Q3

The resistance to motion acting on a runner of mass 70 kg is kv N, where $v\ \text{m s}^{-1}$ is the runner's speed and k is a constant. The greatest power the runner can exert is 100 W. The runner's greatest steady speed on horizontal ground is $4\ \text{m s}^{-1}$.

(i) Show that $k = 6.25$. [2]

(ii) Find the greatest steady speed of the runner while running uphill on a straight path inclined at an angle α to the horizontal, where $\sin\alpha = 0.05$. [4]

47. O/N 13/P41/Q2



A block B lies on a rough horizontal plane. Horizontal forces of magnitudes 30 N and 40 N, making angles of α and β respectively with the x-direction, act on B as shown in the diagram, and B is moving in the x-direction with constant speed. It is given that $\cos\alpha = 0.6$ and $\cos\beta = 0.8$.

(i) Find the total work done by the forces shown in the diagram when B has moved a distance of 20 m. [2]

(ii) Given that the coefficient of friction between the block and the plane is $\frac{5}{8}$, find the weight of the block. [3]

48. O/N 13/P41/Q5

A lorry of mass 15 000 kg climbs from the bottom to the top of a straight hill, of length 1440 m, at a constant speed of $15\ \text{m s}^{-1}$. The top of the hill is 16 m above the level of the bottom of the hill. The resistance to motion is constant and equal to 1800 N.

(i) Find the work done by the driving force. [4]

On reaching the top of the hill the lorry continues on a straight horizontal road and passes through a point P with speed $24\ \text{m s}^{-1}$. The resistance to motion is constant and is now equal to 1600 N. The work done by the lorry's engine from the top of the hill to the point P is 5030 kJ.

(ii) Find the distance from the top of the hill to the point P. [3]

49. O/N 13/P43/Q6

A lorry of mass 12 500 kg travels along a road from A to C passing through a point B. The resistance to motion of the lorry is 4800 N for the whole journey from A to C.

(i) The section AB of the road is straight and horizontal. On this section of the road the power of the lorry's engine is constant and equal to 144 kW. The speed of the lorry at A is $16\,\text{m s}^{-1}$ and its acceleration at B is $0.096\,\text{m s}^{-2}$. Find the acceleration of the lorry at A and show that its speed at B is $24\,\text{m s}^{-1}$. [3]

(ii) The section BC of the road has length 500 m, is straight and inclined upwards towards C. On this section of the road the lorry's driving force is constant and equal to 5800 N. The speed of the lorry at C is $16\,\text{m s}^{-1}$. Find the height of C above the level of AB. [5]

50. M/J 13/P42/Q2

A and B are two points 50 metres apart on a straight path inclined at an angle θ to the horizontal, where $\sin\theta = 0.05$, with A above the level of B. A block of mass 16 kg is pulled down the path from A to B. The block starts from rest at A and reaches B with a speed of $10\,\text{m s}^{-1}$. The work done by the pulling force acting on the block is 1150 J.

(i) Find the work done against the resistance to motion. [3]

The block is now pulled up the path from B to A. The work done by the pulling force and the work done against the resistance to motion are the same as in the case of the downward motion.

(ii) Show that the speed of the block when it reaches A is the same as its speed when it started at B. [2]

51. M/J 13/P42/Q5

A car of mass 1000 kg is travelling on a straight horizontal road. The power of its engine is constant and equal to P kW. The resistance to motion of the car is 600 N. At an instant when the car's speed is $25\,\text{m s}^{-1}$, its acceleration is $0.2\,\text{m s}^{-2}$. Find

(i) the value of P, [4]

(ii) the steady speed at which the car can travel. [3]

52. M/J 13/P41/Q2

A car of mass 1250 kg travels from the bottom to the top of a straight hill of length 600 m, which is inclined at an angle of 2.5° to the horizontal. The resistance to motion of the car is constant and equal to 400 N. The work done by the driving force is 450 kJ. The speed of the car at the bottom of the hill is $30\,\text{m s}^{-1}$. Find the speed of the car at the top of the hill. [5]

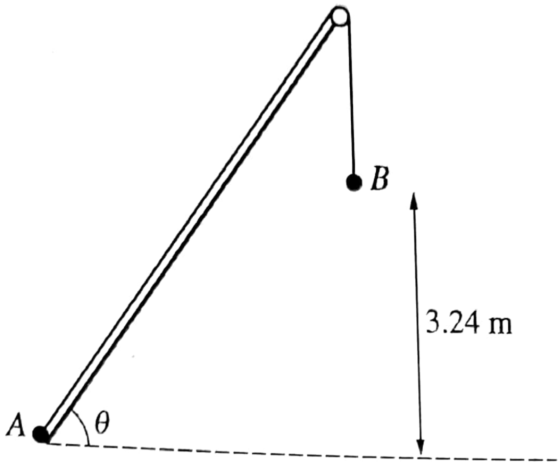
53. M/J 13/P41/Q4

A train of mass 400 000 kg is moving on a straight horizontal track. The power of the engine is constant and equal to 1500 kW and the resistance to the train's motion is 30 000 N. Find

(i) the acceleration of the train when its speed is $37.5\,\text{m s}^{-1}$, [4]

(ii) the steady speed at which the train can move. [2]

54. M/J 13/P43/Q2



Particle A of mass 1.6 kg and particle B of mass 2 kg are attached to opposite ends of a light inextensible string. The string passes over a small smooth pulley fixed at the top of a smooth plane, which is inclined at angle θ, where $\sin\theta = 0.8$. Particle A is held at rest at the bottom of the plane and B hangs at a height of 3.24 m above the level of the bottom of the plane (see diagram). A is released from rest and the particles start to move.

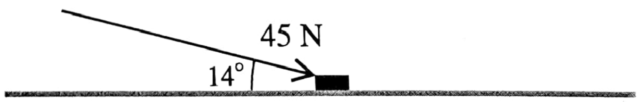
(i) Show that the loss of potential energy of the system, when B reaches the level of the bottom of the plane, is 23.328 J. [3]

(ii) Hence find the speed of the particles when B reaches the level of the bottom of the plane. [2]

55. M/J 13/P43/Q3

A car has mass 800 kg. The engine of the car generates constant power P kW as the car moves along a straight horizontal road. The resistance to motion is constant and equal to R N. When the car's speed is $14\,\mathrm{m\,s^{-1}}$ its acceleration is $1.4\,\mathrm{m\,s^{-2}}$, and when the car's speed is $25\,\mathrm{m\,s^{-1}}$ its acceleration is $0.33\,\mathrm{m\,s^{-2}}$. Find the values of P and R. [6]

56. O/N 12/P42/Q1



A block is pushed along a horizontal floor by a force of magnitude 45 N acting at an angle of 14° to the horizontal (see diagram). Find the work done by the force in moving the block a distance of 25 m. [3]

57. O/N 12/P42/Q6

A car of mass 1250 kg moves from the bottom to the top of a straight hill of length 500 m. The top of the hill is 30 m above the level of the bottom. The power of the car's engine is constant and equal to 30 000 W. The car's acceleration is $4\,\mathrm{m\,s^{-2}}$ at the bottom of the hill and is $0.2\,\mathrm{m\,s^{-2}}$ at the top. The resistance to the car's motion is 1000 N. Find

(i) the car's gain in kinetic energy, [5]

(ii) the work done by the car's engine. [3]

58. O/N 12/P41/Q7

A car of mass 1200 kg moves in a straight line along horizontal ground. The resistance to motion of the car is constant and has magnitude 960 N. The car's engine works at a rate of 17 280 W.

(i) Calculate the acceleration of the car at an instant when its speed is $12\,\text{m s}^{-1}$. [3]

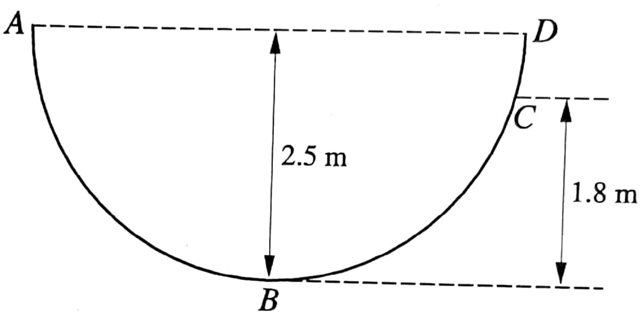
The car passes through the points A and B. While the car is moving between A and B it has constant speed $V\,\text{m s}^{-1}$.

(ii) Show that $V = 18$. [2]

At the instant that the car reaches B the engine is switched off and subsequently provides no energy. The car continues along the straight line until it comes to rest at the point C. The time taken for the car to travel from A to C is 52.5 s.

(iii) Find the distance AC. [5]

59. O/N 12/P43/Q1



$ABCD$ is a semi-circular cross-section, in a vertical plane, of the inner surface of half a hollow cylinder of radius 2.5 m which is fixed with its axis horizontal. AD is horizontal, B is the lowest point of the cross-section and C is at a height of 1.8 m above the level of B (see diagram). A particle P of mass 0.8 kg is released from rest at A and comes to instantaneous rest at C.

(i) Find the work done on P by the resistance to motion while P travels from A to C. [2]

The work done on P by the resistance to motion while P travels from A to B is 0.6 times the work done while P travels from A to C.

(ii) Find the speed of P when it passes through B. [3]

60. O/N 12/P43/Q5

An object of mass 12 kg slides down a line of greatest slope of a smooth plane inclined at 10° to the horizontal. The object passes through points A and B with speeds $3\,\text{m s}^{-1}$ and $7\,\text{m s}^{-1}$ respectively.

(i) Find the increase in kinetic energy of the object as it moves from A to B. [2]

(ii) Hence find the distance AB, assuming there is no resisting force acting on the object. [3]

The object is now pushed up the plane from B to A, with constant speed, by a horizontal force.

(iii) Find the magnitude of this force. [3]

61. M/J 12/P42/Q1

A block is pulled in a straight line along horizontal ground by a force of constant magnitude acting at an angle of 60° above the horizontal. The work done by the force in moving the block a distance of 5 m is 75 J. Find the magnitude of the force. [3]

62. M/J 12/P42/Q6

A car of mass 1250 kg travels from the bottom to the top of a straight hill which has length 400 m and is inclined to the horizontal at an angle of α, where $\sin\alpha = 0.125$. The resistance to the car's motion is 800 N. Find the work done by the car's engine in each of the following cases.

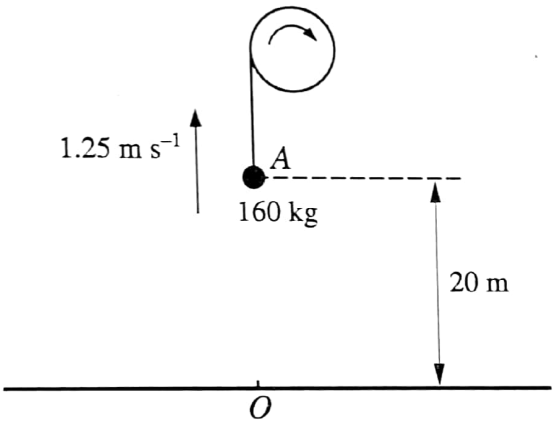
(i) The car's speed is constant. **[4]**

(ii) The car's initial speed is $6\,\text{m s}^{-1}$, the car's driving force is 3 times greater at the top of the hill than it is at the bottom, and the car's power output is 5 times greater at the top of the hill than it is at the bottom. **[5]**

63. M/J 12/P41/Q1

A car of mass 880 kg travels along a straight horizontal road with its engine working at a constant rate of P W. The resistance to motion is 700 N. At an instant when the car's speed is $16\,\text{m s}^{-1}$ its acceleration is $0.625\,\text{m s}^{-2}$. Find the value of P. **[4]**

64. M/J 12/P41/Q3



A load of mass 160 kg is pulled vertically upwards, from rest at a fixed point O on the ground, using a winding drum. The load passes through a point A, 20 m above O, with a speed of $1.25\,\text{m s}^{-1}$ (see diagram). Find, for the motion from O to A,

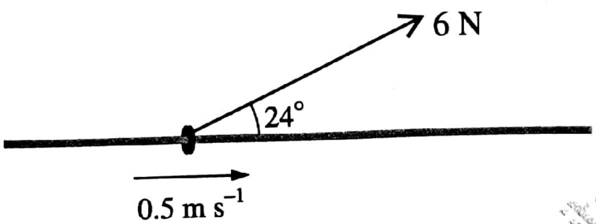
(i) the gain in the potential energy of the load, **[1]**

(ii) the gain in the kinetic energy of the load. **[2]**

The power output of the winding drum is constant while the load is in motion.

(iii) Given that the work done against the resistance to motion from O to A is 20 kJ and that the time taken for the load to travel from O to A is 41.7 s, find the power output of the winding drum. **[3]**

65. M/J 12/P43/Q1



A ring is threaded on a fixed horizontal bar. The ring is attached to one end of a light inextensible string which is used to pull the ring along the bar at a constant speed of $0.5\,\text{m s}^{-1}$. The string makes a constant angle of 24° with the bar and the tension in the string is 6 N (see diagram). Find the work done by the tension in a period of 8 s. **[3]**

66. M/J 12/P43/Q4

A car of mass 1230 kg increases its speed from $4\,\text{m s}^{-1}$ to $21\,\text{m s}^{-1}$ in 24.5 s. The table below shows corresponding values of time t s and speed $v\,\text{m s}^{-1}$.

t	0	0.5	16.3	24.5
v	4	6	19	21

(i) Using the values in the table, find the average acceleration of the car for $0 < t < 0.5$ and for $16.3 < t < 24.5$. [2]

While the car is increasing its speed the power output of its engine is constant and equal to P W, and the resistance to the car's motion is constant and equal to R N.

(ii) Assuming that the values obtained in part (i) are approximately equal to the accelerations at $v = 5$ and at $v = 20$, find approximations for P and R. [5]

67. O/N 11/P42/Q1

A racing cyclist, whose mass with his cycle is 75 kg, works at a rate of 720 W while moving on a straight horizontal road. The resistance to the cyclist's motion is constant and equal to R N.

(i) Given that the cyclist is accelerating at $0.16\,\text{m s}^{-2}$ at an instant when his speed is $12\,\text{m s}^{-1}$, find the value of R. [3]

(ii) Given that the cyclist's acceleration is positive, show that his speed is less than $15\,\text{m s}^{-1}$. [2]

68. O/N 11/P42/Q6

A lorry of mass 16 000 kg climbs a straight hill $ABCD$ which makes an angle θ with the horizontal, where $\sin\theta = \frac{1}{20}$. For the motion from A to B, the work done by the driving force of the lorry is 1200 kJ and the resistance to motion is constant and equal to 1240 N. The speed of the lorry is $15\,\text{m s}^{-1}$ at A and $12\,\text{m s}^{-1}$ at B.

(i) Find the distance AB. [5]

For the motion from B to D the gain in potential energy of the lorry is 2400 kJ.

(ii) Find the distance BD. [1]

For the motion from B to D the driving force of the lorry is constant and equal to 7200 N. From B to C the resistance to motion is constant and equal to 1240 N and from C to D the resistance to motion is constant and equal to 1860 N.

(iii) Given that the speed of the lorry at D is $7\,\text{m s}^{-1}$, find the distance BC. [4]

69. O/N 11/P41/Q1

One end of a light inextensible string is attached to a block. The string is used to pull the block along a horizontal surface with a speed of $2\,\text{m s}^{-1}$. The string makes an angle of 20° with the horizontal and the tension in the string is 25 N. Find the work done by the tension in a period of 8 seconds. [3]

70. O/N 11/P41/Q6

AB and BC are straight roads inclined at 5° to the horizontal and 1° to the horizontal respectively. A and C are at the same horizontal level and B is 45 m above the level of A and C (see diagram, which is not to scale). A car of mass 1200 kg travels from A to C passing through B.

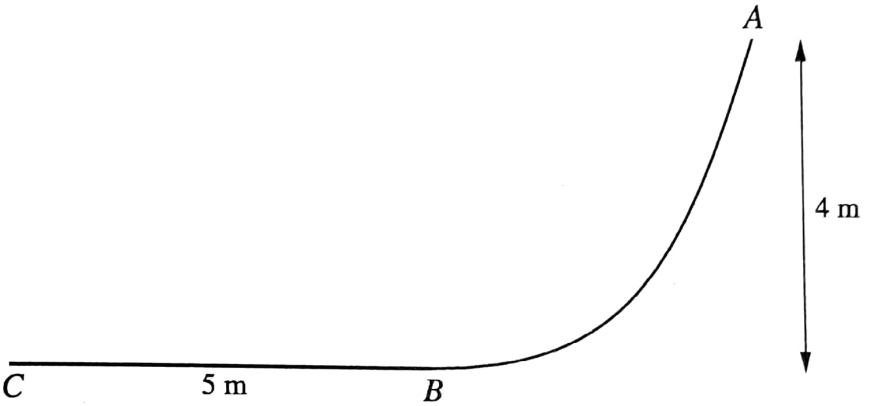
(i) For the motion from A to B, the speed of the car is constant and the work done against the resistance to motion is 360 kJ. Find the work done by the car's engine from A to B. [3]

The resistance to motion is constant throughout the whole journey.

(ii) For the motion from B to C the work done by the driving force is 1660 kJ. Given that the speed of the car at B is $15\,\text{m s}^{-1}$, show that its speed at C is $29.9\,\text{m s}^{-1}$, correct to 3 significant figures. [4]

(iii) The car's driving force immediately after leaving B is 1.5 times the driving force immediately before reaching C. Find, correct to 2 significant figures, the ratio of the power developed by the car's engine immediately after leaving B to the power developed immediately before reaching C. [3]

71. O/N 11/P43/Q4



ABC is a vertical cross-section of a surface. The part of the surface containing AB is smooth and A is 4 m higher than B. The part of the surface containing BC is horizontal and the distance BC is 5 m (see diagram). A particle of mass 0.8 kg is released from rest at A and slides along ABC. Find the speed of the particle at C in each of the following cases.

(i) The horizontal part of the surface is smooth. [3]

(ii) The coefficient of friction between the particle and the horizontal part of the surface is 0.3. [3]

72. O/N 11/P43/Q7

A car of mass 600 kg travels along a straight horizontal road starting from a point A. The resistance to motion of the car is 750 N.

(i) The car travels from A to B at constant speed in 100 s. The power supplied by the car's engine is constant and equal to 30 kW. Find the distance AB. [3]

(ii) The car's engine is switched off at B and the car's speed decreases until the car reaches C with a speed of $20\,\text{m s}^{-1}$. Find the distance BC. [3]

(iii) The car's engine is switched on at C and the power it supplies is constant and equal to 30 kW. The car takes 14 s to travel from C to D and reaches D with a speed of $30\,\text{m s}^{-1}$. Find the distance CD. [4]

73. M/J 11/P42/Q1

A load is pulled along horizontal ground for a distance of 76 m, using a rope. The rope is inclined at 5° above the horizontal and the tension in the rope is 65 N.

(i) Find the work done by the tension. [2]

At an instant during the motion the velocity of the load is $1.5\,\text{m s}^{-1}$.

(ii) Find the rate of working of the tension at this instant. [2]

74. M/J 11/P42/Q2

An object of mass 8 kg slides down a line of greatest slope of an inclined plane. Its initial speed at the top of the plane is $3\,\text{m}\,\text{s}^{-1}$ and its speed at the bottom of the plane is $8\,\text{m}\,\text{s}^{-1}$. The work done against the resistance to motion of the object is 120 J. Find the height of the top of the plane above the level of the bottom. [4]

75. M/J 11/P41/Q1

A car of mass 700 kg is travelling along a straight horizontal road. The resistance to motion is constant and equal to 600 N.

(i) Find the driving force of the car's engine at an instant when the acceleration is $2\,\text{m}\,\text{s}^{-2}$. [2]

(ii) Given that the car's speed at this instant is $15\,\text{m}\,\text{s}^{-1}$, find the rate at which the car's engine is working. [2]

76. M/J 11/P41/Q2

A load of mass 1250 kg is raised by a crane from rest on horizontal ground, to rest at a height of 1.54 m above the ground. The work done against the resistance to motion is 5750 J.

(i) Find the work done by the crane. [3]

(ii) Assuming the power output of the crane is constant and equal to 1.25 kW, find the time taken to raise the load. [2]

77. M/J 11/P41/Q7

Loads A and B, of masses 1.2 kg and 2.0 kg respectively, are attached to the ends of a light inextensible string which passes over a fixed smooth pulley. A is held at rest and B hangs freely, with both straight parts of the string vertical. A is released and starts to move upwards. It does not reach the pulley in the subsequent motion.

(i) Find the acceleration of A and the tension in the string. [4]

(ii) Find, for the first 1.5 metres of A's motion,

(a) A's gain in potential energy,

(b) the work done on A by the tension in the string,

(c) A's gain in kinetic energy.

[3]

B hits the floor 1.6 seconds after A is released. B comes to rest without rebounding and the string becomes slack.

(iii) Find the time from the instant the string becomes slack until it becomes taut again. [4]

78. M/J 11/P43/Q1

A block is pulled for a distance of 50 m along a horizontal floor, by a rope that is inclined at an angle of $\alpha°$ to the floor. The tension in the rope is 180 N and the work done by the tension is 8200 J. Find the value of α. [3]

79. M/J 11/P43/Q2

A car of mass 1250 kg is travelling along a straight horizontal road with its engine working at a constant rate of P W. The resistance to the car's motion is constant and equal to R N. When the speed of the car is $19\,\text{m}\,\text{s}^{-1}$ its acceleration is $0.6\,\text{m}\,\text{s}^{-2}$, and when the speed of the car is $30\,\text{m}\,\text{s}^{-1}$ its acceleration is $0.16\,\text{m}\,\text{s}^{-2}$. Find the values of P and R. [6]

80. M/J 11/P43/Q6

A lorry of mass 15 000 kg climbs a hill of length 500 m at a constant speed. The hill is inclined at 2.5° to the horizontal. The resistance to the lorry's motion is constant and equal to 800 N.

(i) Find the work done by the lorry's driving force. [4]

On its return journey the lorry reaches the top of the hill with speed $20\,\text{m s}^{-1}$ and continues down the hill with a constant driving force of 2000 N. The resistance to the lorry's motion is again constant and equal to 800 N.

(ii) Find the speed of the lorry when it reaches the bottom of the hill. [5]

81. O/N 10/P42/Q2

A cyclist, working at a constant rate of 400 W, travels along a straight road which is inclined at 2° to the horizontal. The total mass of the cyclist and his cycle is 80 kg. Ignoring any resistance to motion, find, correct to 1 decimal place, the acceleration of the cyclist when he is travelling

(i) uphill at $4\,\text{m s}^{-1}$,

(ii) downhill at $4\,\text{m s}^{-1}$. [5]

82. O/N 10/P42/Q4

A block of mass 20 kg is pulled from the bottom to the top of a slope. The slope has length 10 m and is inclined at 4.5° to the horizontal. The speed of the block is $2.5\,\text{m s}^{-1}$ at the bottom of the slope and $1.5\,\text{m s}^{-1}$ at the top of the slope.

(i) Find the loss of kinetic energy and the gain in potential energy of the block. [3]

(ii) Given that the work done against the resistance to motion is 50 J, find the work done by the pulling force acting on the block. [2]

(iii) Given also that the pulling force is constant and acts at an angle of 15° upwards from the slope, find its magnitude. [2]

83. O/N 10/P41/Q5

A particle of mass 0.8 kg slides down a rough inclined plane along a line of greatest slope AB. The distance AB is 8 m. The particle starts at A with speed $3\,\text{m s}^{-1}$ and moves with constant acceleration $2.5\,\text{m s}^{-2}$.

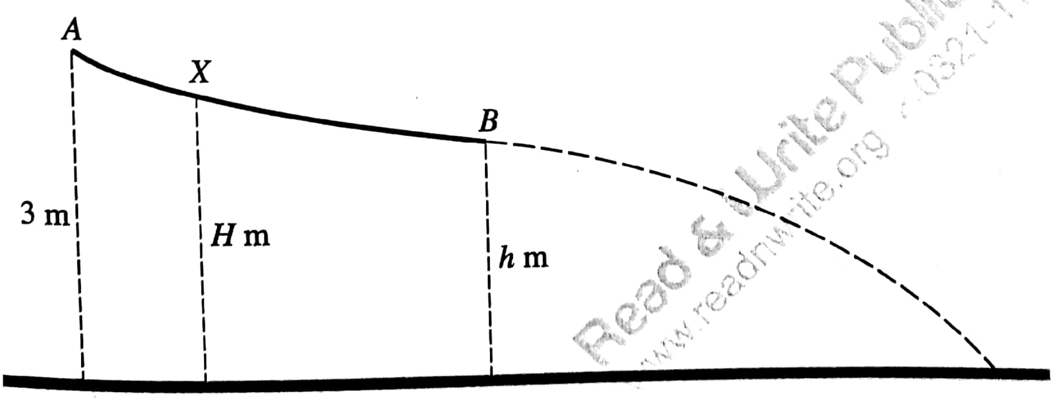
(i) Find the speed of the particle at the instant it reaches B. [2]

(ii) Given that the work done against the frictional force as the particle moves from A to B is 7 J, find the angle of inclination of the plane. [4]

When the particle is at the point X its speed is the same as the average speed for the motion from A to B.

(iii) Find the work done by the frictional force for the particle's motion from A to X. [3]

84. O/N 10/P41/Q6



A smooth slide AB is fixed so that its highest point A is 3 m above horizontal ground. B is h m above the ground. A particle P of mass 0.2 kg is released from rest at a point on the slide. The particle moves down the slide and, after passing B, continues moving until it hits the ground (see diagram). The speed of P at B is v_B and the speed at which P hits the ground is v_G.

(i) In the case that P is released at A, it is given that the kinetic energy of P at B is 1.6 J. Find

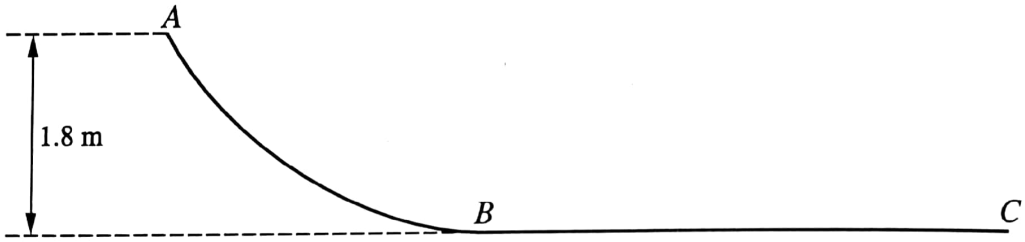
(a) the value of h, [3]

(b) the kinetic energy of the particle immediately before it reaches the ground, [1]

(c) the ratio $v_G : v_B$. [2]

(ii) In the case that P is released at the point X of the slide, which is H m above the ground (see diagram), it is given that $v_G : v_B = 2.55$. Find the value of H correct to 2 significant figures. [3]

85. O/N 10/P43/Q2



The diagram shows the vertical cross-section ABC of a fixed surface. AB is a curve and BC is a horizontal straight line. The part of the surface containing AB is smooth and the part containing BC is rough. A is at a height of 1.8 m above BC. A particle of mass 0.5 kg is released from rest at A and travels along the surface to C.

(i) Find the speed of the particle at B. [2]

(ii) Given that the particle reaches C with a speed of 5 m s^{-1}, find the work done against the resistance to motion as the particle moves from B to C. [2]

86. O/N 10/P43/Q7

A car of mass 1250 kg travels along a horizontal straight road. The power of the car's engine is constant and equal to 24 kW and the resistance to the car's motion is constant and equal to R N. The car passes through the point A on the road with speed 20 m s^{-1} and acceleration 0.32 m s^{-2}.

(i) Find the value of R. [3]

The car continues with increasing speed, passing through the point B on the road with speed 29.9 m s^{-1}. The car subsequently passes through the point C.

(ii) Find the acceleration of the car at B, giving the answer in m s^{-2} correct to 3 decimal places. [2]

(iii) Show that, while the car's speed is increasing, it cannot reach 30 m s^{-1}. [2]

(iv) Explain why the speed of the car is approximately constant between B and C. [1]

(v) State a value of the approximately constant speed, and the maximum possible error in this value at any point between B and C. [1]

The work done by the car's engine during the motion from B to C is 1200 kJ.

(vi) By assuming the speed of the car is constant from B to C, find, in either order,

(a) the approximate time taken for the car to travel from B to C,

(b) an approximation for the distance BC. [4]

87. M/J 10/P42/Q5, M/J 10/P41/Q5

P and Q are fixed points on a line of greatest slope of an inclined plane. The point Q is at a height of 0.45 m above the level of P. A particle of mass 0.3 kg moves upwards along the line PQ.

(i) Given that the plane is smooth and that the particle just reaches Q, find the speed with which it passes through P. **[3]**

(ii) It is given instead that the plane is rough. The particle passes through P with the same speed as that found in part (i), and just reaches a point R which is between P and Q. The work done against the frictional force in moving from P to R is 0.39 J. Find the potential energy gained by the particle in moving from P to R and hence find the height of R above the level of P. **[4]**

88. M/J 10/P41/Q1

A car of mass 1150 kg travels up a straight hill inclined at 1.2° to the horizontal. The resistance to motion of the car is 975 N. Find the acceleration of the car at an instant when it is moving with speed 16 m s^{-1} and the engine is working at a power of 35 kW. **[4]**

89. M/J 10/P43/Q3

A load is pulled along a horizontal straight track, from A to B, by a force of magnitude P N which acts at an angle of 30° upwards from the horizontal. The distance AB is 80 m. The speed of the load is constant and equal to 1.2 m s^{-1} as it moves from A to the mid-point M of AB.

(i) For the motion from A to M the value of P is 25. Calculate the work done by the force as the load moves from A to M. **[2]**

The speed of the load increases from 1.2 m s^{-1} as it moves from M towards B. For the motion from M to B the value of P is 50 and the work done against resistance is the same as that for the motion from A to M. The mass of the load is 35 kg.

(ii) Find the gain in kinetic energy of the load as it moves from M to B and hence find the speed with which it reaches B. **[5]**

90. O/N 09/P42/Q2

A lorry of mass 15 000 kg moves with constant speed 14 m s^{-1} from the top to the bottom of a straight hill of length 900 m. The top of the hill is 18 m above the level of the bottom of the hill. The total work done by the resistive forces acting on the lorry, including the braking force, is 4.8×10^6 J. Find

(i) the loss in gravitational potential energy of the lorry, **[1]**

(ii) the work done by the driving force. **[1]**

On reaching the bottom of the hill the lorry continues along a straight horizontal road against a constant resistance of 1600 N. There is no braking force acting. The speed of the lorry increases from 14 m s^{-1} at the bottom of the hill to 16 m s^{-1} at the point X, where X is 2500 m from the bottom of the hill.

(iii) By considering energy, find the work done by the driving force of the lorry while it travels from the bottom of the hill to X. **[3]**

91. O/N 09/P42/Q3

A car of mass 1250 kg travels along a horizontal straight road with increasing speed. The power provided by the car's engine is constant and equal to 24 kW. The resistance to the car's motion is constant and equal to 600 N.

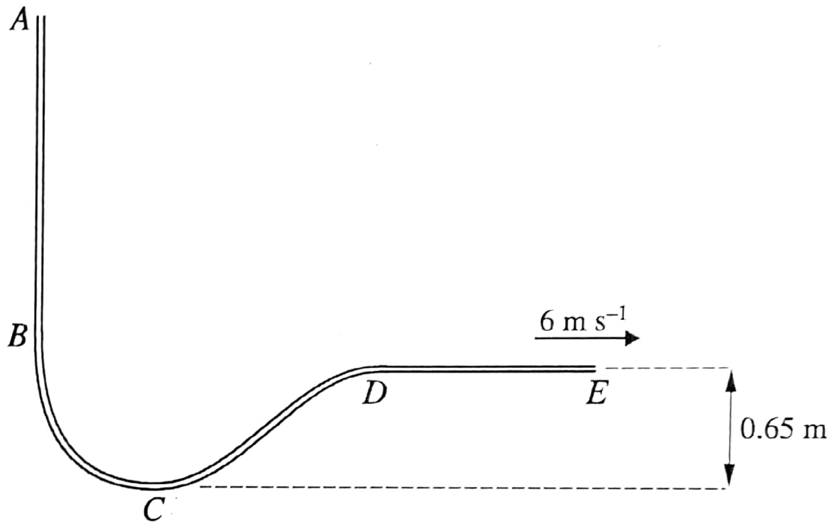
(i) Show that the speed of the car cannot exceed $40\,\text{m s}^{-1}$. [3]

(ii) Find the acceleration of the car at an instant when its speed is $15\,\text{m s}^{-1}$. [3]

92. O/N 09/P41/Q1

A car of mass 1000 kg moves along a horizontal straight road, passing through points A and B. The power of its engine is constant and equal to 15 000 W. The driving force exerted by the engine is 750 N at A and 500 N at B. Find the speed of the car at A and at B, and hence find the increase in the car's kinetic energy as it moves from A to B. [4]

93. O/N 09/P41/Q2

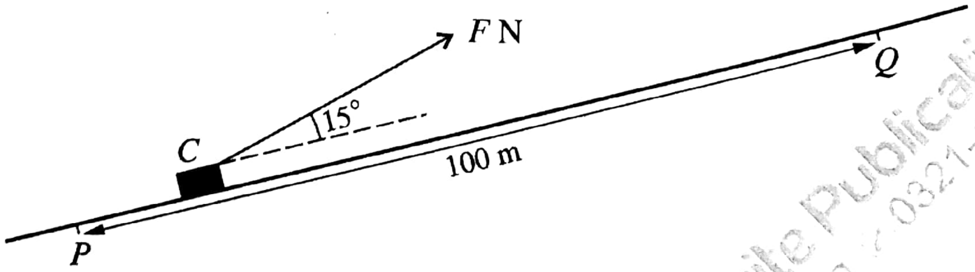


A smooth narrow tube AE has two straight parts, AB and DE, and a curved part BCD. The part AB is vertical with A above B, and DE is horizontal. C is the lowest point of the tube and is 0.65 m below the level of DE. A particle is released from rest at A and travels through the tube, leaving it at E with speed $6\,\text{m s}^{-1}$ (see diagram). Find

(i) the height of A above the level of DE, [2]

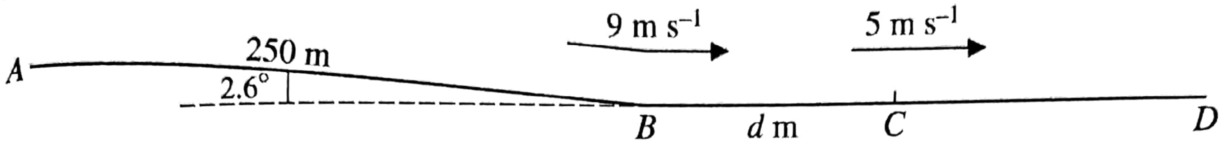
(ii) the maximum speed of the particle. [2]

94. M/J 09/P04/Q2



A crate C is pulled at constant speed up a straight inclined path by a constant force of magnitude F N, acting upwards at an angle of 15° to the path. C passes through points P and Q which are 100 m apart (see diagram). As C travels from P to Q the work done against the resistance to C's motion is 900 J, and the gain in C's potential energy is 2100 J. Write down the work done by the pulling force as C travels from P to Q, and hence find the value of F. [3]

95. M/J 09/P04/Q5



A cyclist and his machine have a total mass of 80 kg. The cyclist starts from rest at the top A of a straight path AB, and freewheels (moves without pedalling or braking) down the path to B. The path AB is inclined at 2.6° to the horizontal and is of length 250 m (see diagram).

(i) Given that the cyclist passes through B with speed $9\,\text{m}\,\text{s}^{-1}$, find the gain in kinetic energy and the loss in potential energy of the cyclist and his machine. Hence find the work done against the resistance to motion of the cyclist and his machine. [3]

The cyclist continues to freewheel along a horizontal straight path BD until he reaches the point C, where the distance BC is d m. His speed at C is $5\,\text{m}\,\text{s}^{-1}$. The resistance to motion is constant, and is the same on BD as on AB.

(ii) Find the value of d. [3]

The cyclist starts to pedal at C, generating 425 W of power.

(iii) Find the acceleration of the cyclist immediately after passing through C. [3]

96. O/N 08/P04/Q3

A car of mass 1200 kg is travelling on a horizontal straight road and passes through a point A with speed $25\,\text{m}\,\text{s}^{-1}$. The power of the car's engine is 18 kW and the resistance to the car's motion is 900 N.

(i) Find the deceleration of the car at A. [4]

(ii) Show that the speed of the car does not fall below $20\,\text{m}\,\text{s}^{-1}$ while the car continues to move with the engine exerting a constant power of 18 kW. [2]

97. O/N 08/P04/Q4

A load of mass 160 kg is lifted vertically by a crane, with constant acceleration. The load starts from rest at the point O. After 7 s, it passes through the point A with speed $0.5\,\text{m}\,\text{s}^{-1}$. By considering energy, find the work done by the crane in moving the load from O to A. [6]

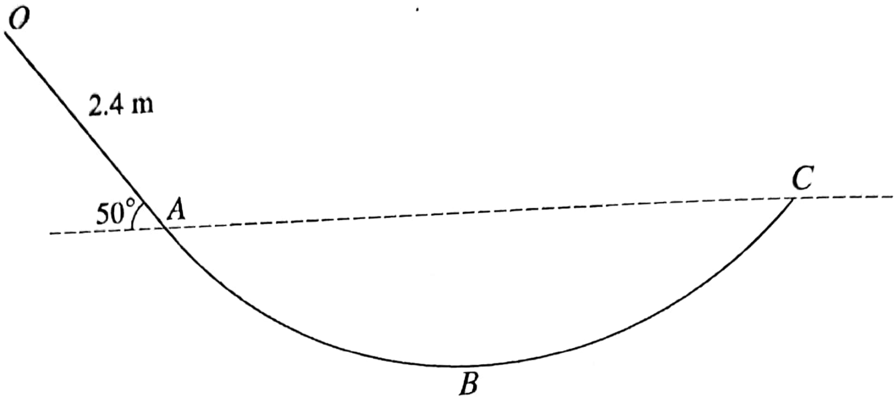
98. M/J 08/P04/Q2

A block is being pulled along a horizontal floor by a rope inclined at 20° to the horizontal. The tension in the rope is 851 N and the block moves at a constant speed of $2.5\,\text{m}\,\text{s}^{-1}$.

(i) Show that the work done on the block in 12 s is approximately 24 kJ. [3]

(ii) Hence find the power being applied to the block, giving your answer to the nearest kW. [1]

99. M/J 08/P04/Q4



$OABC$ is a vertical cross-section of a smooth surface. The straight part OA has length 2.4 m and makes an angle of 50° with the horizontal. A and C are at the same horizontal level and B is the lowest point of the cross-section (see diagram). A particle P of mass 0.8 kg is released from rest at O and moves on the surface. P remains in contact with the surface until it leaves the surface at C. Find

(i) the kinetic energy of P at A, [2]

(ii) the speed of P at C. [2]

The greatest speed of P is 8 m s^{-1}.

(iii) Find the depth of B below the horizontal through A and C. [3]

100. M/J 08/P04/Q6

A particle P of mass 0.6 kg is projected vertically upwards with speed 5.2 m s^{-1} from a point O which is 6.2 m above the ground. Air resistance acts on P so that its deceleration is 10.4 m s^{-2} when P is moving upwards, and its acceleration is 9.6 m s^{-2} when P is moving downwards. Find

(i) the greatest height above the ground reached by P, [3]

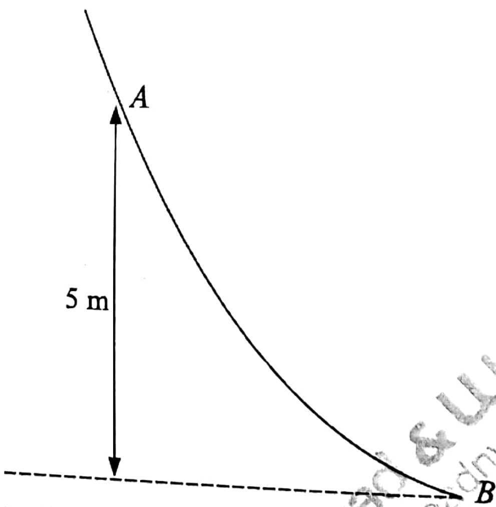
(ii) the speed with which P reaches the ground, [2]

(iii) the total work done on P by the air resistance. [4]

101. O/N 07/P04/Q1

A car of mass 900 kg travels along a horizontal straight road with its engine working at a constant rate of P kW. The resistance to motion of the car is 550 N. Given that the acceleration of the car is 0.2 m s^{-2} at an instant when its speed is 30 m s^{-1}, find the value of P. [4]

102. O/N 07/P04/Q4



The diagram shows the vertical cross-section of a surface. A and B are two points on the cross-section, and A is 5 m higher than B. A particle of mass 0.35 kg passes through A with speed 7 m s^{-1}, moving on the surface towards B.

(i) Assuming that there is no resistance to motion, find the speed with which the particle reaches B. [3]

(ii) Assuming instead that there is a resistance to motion, and that the particle reaches B with speed $11\,\text{m s}^{-1}$, find the work done against this resistance as the particle moves from A to B. [3]

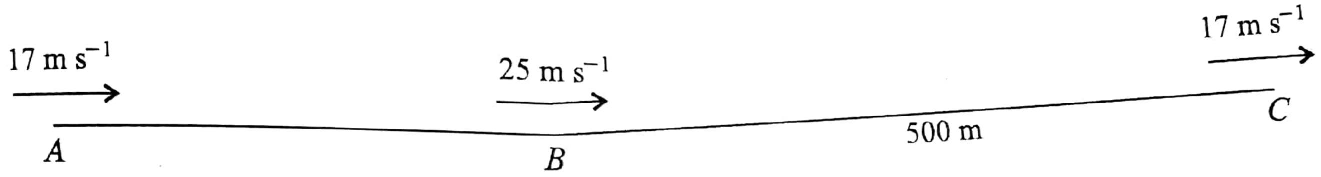
103. M/J 07/P04/Q3

A car travels along a horizontal straight road with increasing speed until it reaches its maximum speed of $30\,\text{m s}^{-1}$. The resistance to motion is constant and equal to R N, and the power provided by the car's engine is 18 kW.

(i) Find the value of R. [3]

(ii) Given that the car has mass 1200 kg, find its acceleration at the instant when its speed is $20\,\text{m s}^{-1}$. [3]

104. M/J 07/P04/Q5

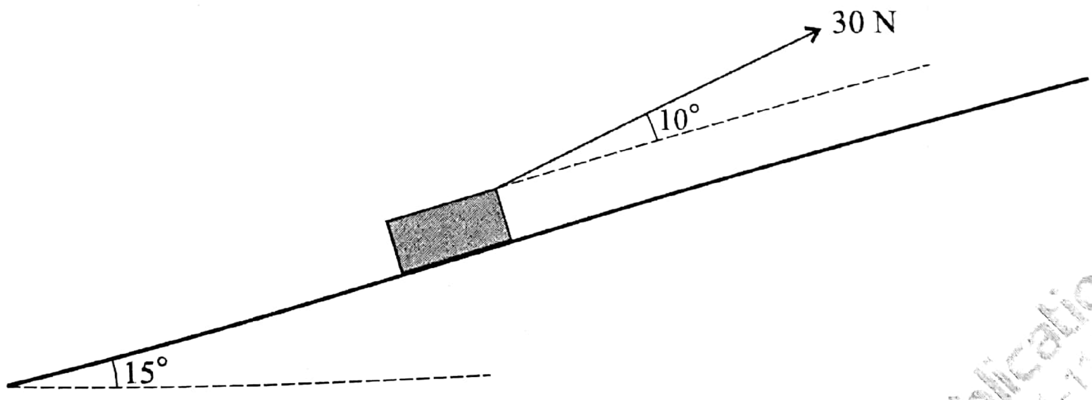


A lorry of mass 12 500 kg travels along a road that has a straight horizontal section AB and a straight inclined section BC. The length of BC is 500 m. The speeds of the lorry at A, B and C are $17\,\text{m s}^{-1}$, $25\,\text{m s}^{-1}$ and $17\,\text{m s}^{-1}$ respectively (see diagram).

(i) The work done against the resistance to motion of the lorry, as it travels from A to B, is 5000 kJ. Find the work done by the driving force as the lorry travels from A to B. [4]

(ii) As the lorry travels from B to C, the resistance to motion is 4800 N and the work done by the driving force is 3300 kJ. Find the height of C above the level of AB. [4]

105. O/N 06/P04/Q1



A box of mass 8 kg is pulled, at constant speed, up a straight path which is inclined at an angle of 15° to the horizontal. The pulling force is constant, of magnitude 30 N, and acts upwards at an angle of 10° from the path (see diagram). The box passes through the points A and B, where $AB = 20$ m and B is above the level of A. For the motion from A to B, find

(i) the work done by the pulling force, [2]

(ii) the gain in potential energy of the box, [2]

(iii) the work done against the resistance to motion of the box. [1]

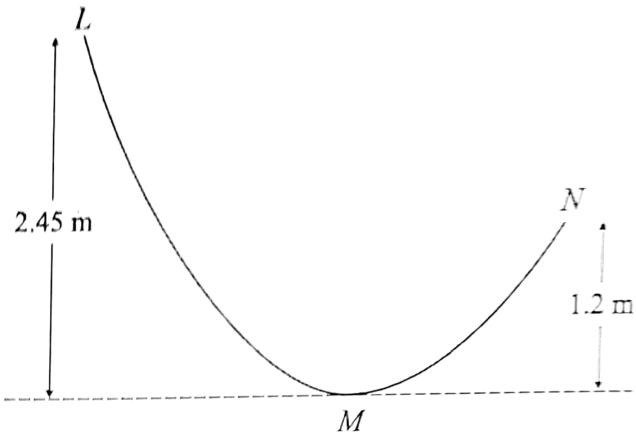
106. O/N 06/P04/Q3

A cyclist travels along a straight road working at a constant rate of 420 W. The total mass of the cyclist and her cycle is 75 kg. Ignoring any resistance to motion, find the acceleration of the cyclist at an instant when she is travelling at $5\,\text{m s}^{-1}$,

(i) given that the road is horizontal,

(ii) given instead that the road is inclined at $1.5°$ to the horizontal and the cyclist is travelling up the slope. [5]

107. O/N 06/P04/Q5



The diagram shows the vertical cross-section LMN of a fixed smooth surface. M is the lowest point of the cross-section. L is 2.45 m above the level of M, and N is 1.2 m above the level of M. A particle of mass 0.5 kg is released from rest at L and moves on the surface until it leaves it at N. Find

(i) the greatest speed of the particle, [3]

(ii) the kinetic energy of the particle at N. [2]

The particle is now projected from N, with speed $v\,\text{m s}^{-1}$, along the surface towards M.

(iii) Find the least value of v for which the particle will reach L. [2]

108. M/J 06/P04/Q1

A car of mass 1200 kg travels on a horizontal straight road with constant acceleration $a\,\text{m s}^{-2}$.

(i) Given that the car's speed increases from $10\,\text{m s}^{-1}$ to $25\,\text{m s}^{-1}$ while travelling a distance of 525 m, find the value of a. [2]

The car's engine exerts a constant driving force of 900 N. The resistance to motion of the car is constant and equal to R N.

(ii) Find R. [2]

109. M/J 06/P04/Q6

A block of mass 50 kg is pulled up a straight hill and passes through points A and B with speeds $7\,\text{m s}^{-1}$ and $3\,\text{m s}^{-1}$ respectively. The distance AB is 200 m and B is 15 m higher than A. For the motion of the block from A to B, find

(i) the loss in kinetic energy of the block, [2]

(ii) the gain in potential energy of the block. [2]

The resistance to motion of the block has magnitude 7.5 N.

(iii) Find the work done by the pulling force acting on the block. [2]

The pulling force acting on the block has constant magnitude 45 N and acts at an angle $\alpha°$ upwards from the hill.

(iv) Find the value of α. [3]

110. O/N 05/P04/Q2

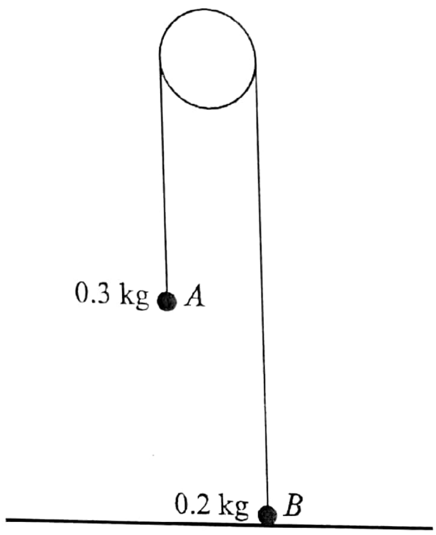
A crate of mass 50 kg is dragged along a horizontal floor by a constant force of magnitude 400 N acting at an angle $\alpha°$ upwards from the horizontal. The total resistance to motion of the crate has constant magnitude 250 N. The crate starts from rest at the point O and passes the point P with a speed of $2\,\text{m s}^{-1}$. The distance OP is 20 m. For the crate's motion from O to P, find

(i) the increase in kinetic energy of the crate, [1]

(ii) the work done against the resistance to the motion of the crate, [1]

(iii) the value of α. [3]

111. O/N 05/P04/Q7



Two particles A and B, of masses 0.3 kg and 0.2 kg respectively, are attached to the ends of a light inextensible string which passes over a smooth fixed pulley. Particle B is held on the horizontal floor and particle A hangs in equilibrium. Particle B is released and each particle starts to move vertically with constant acceleration of magnitude $a\,\text{m s}^{-2}$.

(i) Find the value of a. [4]

Particle A hits the floor 1.2 s after it starts to move, and does not rebound upwards.

(ii) Show that A hits the floor with a speed of $2.4\,\text{m s}^{-1}$. [1]

(iii) Find the gain in gravitational potential energy by B, from leaving the floor until reaching its greatest height. [5]

112. M/J 05/P04/Q1

A small block is pulled along a rough horizontal floor at a constant speed of $1.5\,\text{m s}^{-1}$ by a constant force of magnitude 30 N acting at an angle of $\theta°$ upwards from the horizontal. Given that the work done by the force in 20 s is 720 J, calculate the value of θ. [3]

113. M/J 05/P04/Q7

A car of mass 1200 kg travels along a horizontal straight road. The power provided by the car's engine is constant and equal to 20 kW. The resistance to the car's motion is constant and equal to 500 N. The car passes through the points A and B with speeds $10\,\text{m s}^{-1}$ and $25\,\text{m s}^{-1}$ respectively. The car takes 30.5 s to travel from A to B.

(i) Find the acceleration of the car at A. [4]

(ii) By considering work and energy, find the distance AB. [8]

114. O/N 04/P04/Q3

A car of mass 1250 kg travels down a straight hill with the engine working at a power of 22 kW. The hill is inclined at 3° to the horizontal and the resistance to motion of the car is 1130 N. Find the speed of the car at an instant when its acceleration is $0.2\,\text{m s}^{-2}$. [5]

115. O/N 04/P04/Q4

A lorry of mass 16 000 kg climbs from the bottom to the top of a straight hill of length 1000 m at a constant speed of $10\,\text{m s}^{-1}$. The top of the hill is 20 m above the level of the bottom of the hill. The driving force of the lorry is constant and equal to 5000 N. Find

(i) the gain in gravitational potential energy of the lorry, [1]

(ii) the work done by the driving force, [1]

(iii) the work done against the force resisting the motion of the lorry. [1]

On reaching the top of the hill the lorry continues along a straight horizontal road against a constant resistance of 1500 N. The driving force of the lorry is not now constant, and the speed of the lorry increases from $10\,\text{m s}^{-1}$ at the top of the hill to $25\,\text{m s}^{-1}$ at the point P. The distance of P from the top of the hill is 2000 m.

(iv) Find the work done by the driving force of the lorry while the lorry travels from the top of the hill to P. [5]

116. M/J 04/P04/Q4

The top of an inclined plane is at a height of 0.7 m above the bottom. A block of mass 0.2 kg is released from rest at the top of the plane and slides a distance of 2.5 m to the bottom. Find the kinetic energy of the block when it reaches the bottom of the plane in each of the following cases:

(i) the plane is smooth, [2]

(ii) the coefficient of friction between the plane and the block is 0.15. [5]

117. M/J 04/P04/Q6

A car of mass 1200 kg travels along a horizontal straight road. The power of the car's engine is 20 kW. The resistance to the car's motion is 400 N.

(i) Find the speed of the car at an instant when its acceleration is $0.5\,\text{m s}^{-2}$. [4]

(ii) Show that the maximum possible speed of the car is $50\,\text{m s}^{-1}$. [2]

The work done by the car's engine as the car travels from a point A to a point B is 1500 kJ.

(iii) Given that the car is travelling at its maximum possible speed between A and B, find the time taken to travel from A to B. [2]

118. O/N 03/P04/Q1

A motorcycle of mass 100 kg is travelling on a horizontal straight road. Its engine is working at a rate of 8 kW. At an instant when the speed of the motorcycle is $25\,\text{m s}^{-1}$ its acceleration is $0.5\,\text{m s}^{-2}$. Find, at this instant,

(i) the force produced by the engine, [1]

(ii) the resistance to motion of the motorcycle. [3]

119. O/N 03/P04/Q4

The diagram shows a vertical cross-section of a surface. A and B are two points on the cross-section. A particle of mass 0.15 kg is released from rest at A.

(i) Assuming that the particle reaches B with a speed of 8 m s^{-1} and that there are no resistances to motion, find the height of A above B. [3]

(ii) Assuming instead that the particle reaches B with a speed of 6 m s^{-1} and that the height of A above B is 4 m, find the work done against the resistances to motion. [3]

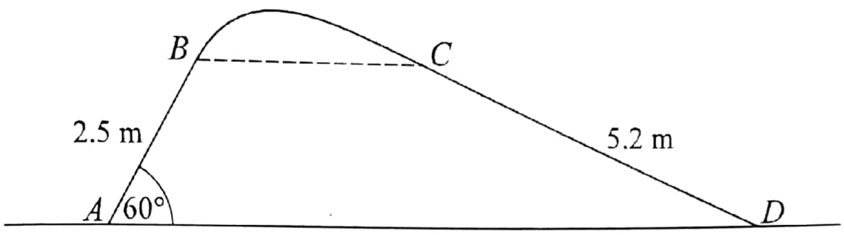
120. M/J 03/P04/Q1

A crate of mass 800 kg is lifted vertically, at constant speed, by the cable of a crane. Find

(i) the tension in the cable, [1]

(ii) the power applied to the crate in increasing the height by 20 m in 50 s. [3]

121. M/J 03/P04/Q7



The diagram shows a vertical cross-section $ABCD$ of a surface. The parts AB and CD are straight and have lengths 2.5 m and 5.2 m respectively. AD is horizontal, and AB is inclined at $60°$ to the horizontal. The points B and C are at the same height above AD. The parts of the surface containing AB and BC are smooth. A particle P is given a velocity of 8 m s^{-1} at A, in the direction AB, and it subsequently reaches D. The particle does not lose contact with the surface during this motion.

(i) Find the speed of P at B. [4]

(ii) Show that the maximum height of the cross-section, above AD, is less than 3.2 m. [2]

(iii) State briefly why P's speed at C is the same as its speed at B. [1]

(iv) The frictional force acting on the particle as it travels from C to D is 1.4 N. Given that the mass of P is 0.4 kg, find the speed with which P reaches D. [4]

122. O/N 02/P04/Q1

A car of mass 1000 kg travels along a horizontal straight road with its engine working at a constant rate of 20 kW. The resistance to motion of the car is 600 N. Find the acceleration of the car at an instant when its speed is 25 m s^{-1}. [3]

123. O/N 02/P04/Q6

(i) A particle P of mass 1.2 kg is released from rest at the top of a slope and starts to move. The slope has length 4 m and is inclined at $25°$ to the horizontal. The coefficient of friction between P and the slope is $\frac{1}{4}$. Find

(a) the frictional component of the contact force on P, [2]

(b) the acceleration of P, [2]

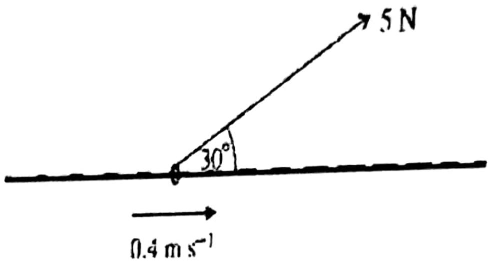
(c) the speed with which P reaches the bottom of the slope. [2]

(ii) After reaching the bottom of the slope, P moves freely under gravity and subsequently hits a horizontal floor which is 3 m below the bottom of the slope.

(a) Find the loss in gravitational potential energy of P during its motion from the bottom of the slope until it hits the floor. [1]

(b) Find the speed with which P hits the floor. [3]

124. M/J 02/P04/Q1



One end of a light inextensible string is attached to a ring which is threaded on a fixed horizontal bar. The string is used to pull the ring along the bar at a constant speed of 0.4 ms^{-1}. The string makes a constant angle of 30° with the bar and the tension in the string is 5 N (see diagram). Find the work done by the tension in 10s. [3]

125. M/J 02/P04/Q6

(i) A lorry P of mass 15 000 kg climbs a straight hill of length 800 m at a steady speed. The hill is inclined at 2° to the horizontal. For P's journey from the bottom of the hill to the top, find

(a) the gain in gravitational potential energy, [2]

(b) the work done by the driving force, which has magnitude 7000 N, [1]

(c) the done against the force resisting the motion. [2]

(ii) A second lorry, Q, also has mass 15 000 kg and climbs the same hill as P. The motion of Q is subject to a constant resisting force of magnitude 900N, and Q's speed falls from 20ms^{-1} at the bottom of the hill to 10ms^{-1} at the top. Find the work done by the driving force as Q climbs from the bottom of the hill to the top. [5]

Answers Section

1. **O/N 17/P42/Q5**

(i) *EITHER*:

Resistance force = $\frac{600}{25}$ = 24 N

Weight component = 80 g (0.04)
= 32 N

[Power = 56 × 4]
Power = 224 W [4]

OR:
PE gain = 80g × 25 (0.04)
= 800

Time taken = $\frac{25}{4}$ = 6.25
[WD by cyclist = P × 6.25 = 800 + 600]
Power = 224 W [4]

(ii) Work done by cyclist
= 224 × 10 (= 2240J)
Initial KE = ½ × 80 × 4^2 [= 640 J]
[½ × 80v^2 = 640 + P×10 –1200]
Speed = 6.48 m s^{-1} [4]

2. **O/N 17/P41/Q2**

(i) Power = 1150 × 12 = 13 800W [1]

(ii) Driving force = $\frac{25000}{12}$

$\frac{25000}{12} - 1150 - 3700g \sin 4 = 3700a$

$a = -0.445$ m s^{-2} [3]

(iii) $\frac{25000}{v} - 1150 - 3700g\sin 4 = 0$

v = 6.70 m s^{-1} [2]

3. **O/N 17/P41/Q3**

(i) 640 × 18
Work done = 11 520 J [2]

(ii) KE at start
= ½ × 840 × 14^2 = 82 320 J
PE gained = 840g × 8sin 30
– 840g × 10sin 20 = 4870 J
½ × 840 × v^2 = 82 320 – 11 520 – 4870
v = 12.5 m s^{-1} [4]

4. **O/N 17/P43/Q2**

(i) [F = 1480 + 7850g sin 3] (= 5588)

[$\frac{P}{10}$ = 1480 + 7850g sin 3] →P = …

Power = 55 900 W [3]

(ii) [F + 7850g sin 3 – 1480 = 7850 × 0.8]
(F = 3652)

[$\frac{P}{15}$ + 7850g sin 3 – 1480 = 7850 × 0.8]
→P = …
Power = 54800 W [3]

5. **O/N 17/P43/Q7**

(i) $R = 0.2g \cos 30 - T \sin 15$
[$F = 0.3 \times (0.2g \cos 30 - T \sin 15)$]

$T \cos 15 + 0.3 \times (0.2g \cos 30 - T \sin 15)$
= 0.2gsin30 [6]

T = 0.541

(ii) 0.3 × 0.2g cos 30 × 3 [= 1.5588 J]
WD = 0.25 × 3 [= 0.75 J]
0.2g × 3 sin 30 [= 3 J]
[½ (0.2) v^2 = 3 – 1.5588 – 0.75]
Speed = 2.63 ms^{-1} [5]

6. **M/J 17/P42/Q1**

EITHER:
WD = 20 cos θ × 1.5 × 12 (J)
[cos θ = 50/360] θ = ...
θ = 82(.0)
OR:
Power P = 50/12 = 4.1666…
[50/12 = 20 cos θ × 1.5] θ = ...
θ = 82(.0) [3]

7. **M/J 17/P42/Q2**

(i) $v = \sqrt{2 \times 2.5 \times 5}$ (ms^{-1}) [1]

(ii)(a) PE loss = 0.2×10× 6 sin 30 [= 6]
and
KE gain = 0.5×0.2 ×($v^2 - 5^2$)
[6 = 0.1($v^2 - 5^2$)]
v^2 = 85→ v = 9.22ms^{-1} [4]

(b) Max velocity at lowest point
[0.2×10 × 6 =
0.5×0.2×($v^2 - 5^2$)]
v^2 = 145→ v = 12(.0)ms^{-1} [2]

8. M/J 17/P42/Q4

(i) (a) $[P = 850 \times 42]$
$P = 35700\text{ W} = 35.7\text{ kW}$ [2]

(b) $P = 41700$
$\rightarrow$ [DF = 41700/42]
$[(993 - 850) = 1200a]$
$a = 5/42 = 0.119\text{ ms}^{-2}$ [3]

(ii) DF = 80000/24
$[\text{DF} - 850 - mg\sin\theta = 0]$
$[12000\sin\theta = 80000/24 - 850]$
$\theta = \ldots$
$\theta = 11.9$ [4]

9. M/J 17/P41/Q1

PE loss = $0.6 \times 10 \times 8$ [= 48]
KE gain = $\frac{1}{2}(0.6)10^2$ [= 30]
WD against Res = 48 – 30 = 18 J [3]

10. M/J 17/P41/Q4

(i) KE gain =
$\frac{1}{2} \times 800 \times (14^2 - 8^2) = 52800$ J
PE gain =
$800 \times 10 \times 120 \times 0.15 = 144000$ J [3]

(ii) WD by engine = 32000×12
$32000 \times 12 =$
$144000 + 52800 +$ WD against F
WD against $F = 187200$ J [3]

11. M/J 17/P43/Q1

(i) WD = $35\cos 20 \times 12$
395 J [2]

(ii) *EITHER:*
WD against resistance = 15×12
$35\cos 20 \times 12 = 15 \times 12 + \frac{1}{2}(25v^2)$
$v = 4.14\text{ ms}^{-1}$
OR:
$35\cos 20 - 15 = 25a$ $[a = 0.716]$
$v^2 = 2 \times 0.7155. \times 12$
$v = 4.14\text{ ms}^{-1}$ [3]

12. M/J 17/P43/Q6

(i)(a) $16\,000 = F \times 40$
Resistance is 400N [2]

(b) $22\,500 = F \times 45$
$F = 500$
$500 - 400 = 1200a$
$a = \frac{1}{12} = 0.0833\ (\text{ms}^{-2})$ [3]

(ii) $16\,000 = (590 + 2v)v$
$v^2 + [290v - 16\,000 = 0] \rightarrow v = \ldots$
$v = 25\ (\text{ms}^{-1})$ [3]

13. O/N 16/P42/Q6

(i) [Power = 400×25]
Power = 10000 W [2]

(ii) Tension = 100 N [1]

(iii) New driving force
$= 25000/20 = 1250$ N
$[\text{DF} - 300 - T - 3000g\sin 4 = 3000a]$
or
$[T - 100 - 500g\sin 4 = 500a]$
or
$[\text{DF} - 400 - 3500g\sin 4 = 3500a]$
[$a = -0.4547$ may be seen]
$T = 221$ N [5]

14. O/N 16/P41/Q6

(i) [Work done = $50\cos 10 \times 20$]
= 984.8 J [2]

(ii) $[984.8 = \frac{1}{2} \times 25v^2 + 30 \times 20]$
$v = 5.55\text{ m s}^{-1}$ [2]

(iii) Max power = $50\cos 10 \times 5.55 = 273$ W [2]

(iv) $[50\cos 10 - 30 - 25g\sin 5 = 25a]$
$a = -0.102\text{ m s}^{-2}$
$[0 = 5.55 - 0.102t]$
Time $t = 54.4$ s [4]

Alternative for 6(iv)

$50\cos 10 \times s + \frac{1}{2} \times 25 \times 5.55^2 =$
$25g \times s\sin 5 + 30 \times s$
$t = 302/5.55 = 54.4$ s [4]

15. O/N 16/P43/Q1

(i) PE gain = $50g \times 3.5$ (=1750)
[WD = $50g \times 3.5 + 25 \times 3.5$]
Work done = 1837.5 J or 1840 J [3]

(ii) [$P = 1837.5/2$] or
[$P/v = 50g + 25$ **and** $3.5 = 2v$]
Power = 919 W [2]

16. O/N 16/P43/Q6

(i) Driving force = 160/5 (= 32N)
$[160/5 - 20 = m \times 0.15]$
Total mass is 80 kg AG [3]

(ii) $[300/v - 20 - 80g\sin 2° = 0]$
Speed is 6.26 ms^{-1} AG [2]

(iii) Driving force =
$300/(0.9 \times 6.26)$ (= 53.2 N)
$300/(0.9 \times 6.26) - 20 - 80g\sin 2° = 80a$
Acceleration is 0.0666 ms^{-2} [4]

17. M/J 16/P42/Q3

(i) [80x sin 22.6 or 80x(5/13)]
$= \frac{400}{13}x = 30.8x$ [2]

(ii) WD against friction = $15 \times x$
$\frac{1}{2}\times 8\times 5^2$
$\frac{1}{2}\times 8\times 5^2 = \frac{400}{13}x + 15x$
$x = \frac{260}{119} = 2.18$ [4]

18. M/J 16/P42/Q6

(i) (a) Power = 1550×40 W
Power = 62000 W = 62 kW [2]

(b) (62000 – 22000) = DF × 40
[DF = 1000]
DF – 1550 = $1100a$
$a = -0.5$ ms^{-2} or $d = 0.5$ ms^{-2} [3]

(ii) DF = $1100g \sin 8 + 1550$
[= 3081]
$80000 = 3081v$
$v = 26(.0)$ ms^{-1} [3]

19. M/J 16/P41/Q2

(i) WD = 40 × 36 = 1440 J [1]
(ii) PE = $25 \times g \times 36 \sin 20$ = 3080 J [2]
(iii) WD by pulling force =
(i) + (ii) [2]
WD = 4520 J

Alternative for (iii)

(iii) [($25g \sin 20$+ 40) × 36]
WD = 4520 J [2]

20. M/J 16/P41/Q3

(i) Driving Force = 300
$P = 300 \times 40$
P = 12000 W = 12 kW [3]

(ii) $P = 0.9 \times 12000 = 10800$
$\frac{10\,800}{25} - 300 = 1000a$
$a = 132/1000 = 0.132$ ms^{-2} [3]

21. M/J 16/P43/Q1

(i) [PE gain = $8g \times 20\sin 30°$]
Change in PE is 800 J [2]

(ii) [$8g \times 20\sin 30° + 20F$ = 1146]
Frictional force is 17.3 N [2]

22. M/J 16/P43/Q5

(i) [$20000/v = 650$]
Speed is 30.8 ms^{-1} [2]

(ii) [DF = $650 + 1400g \times {}^1/_7$]
$P/10 = 650 + 1400g \times {}^1/_7$
Power is 26500 W [3]

(iii) $P = 0.8 \times 26500(21200)$
[$21200/20 + 1400g \times {}^1/_7 - 650 = 1400a$]
Acceleration is 1.72 ms^{-2} [3]

23. O/N 15/P41/Q1

(i) $200g \times 0.7$
Work done = 1400 J [2]

(ii) 1400 / 1.2
Average Power = 1170 W [2]

24. O/N 15/P41/Q3

(i) $F - 24000g \sin 3 - 3200 = 24000 \times (0.2)$
Power = Fv = 20561 × 25
Power = 514 kW [4]

(ii) DF = $3200 + 24000g \sin 3$
[=15761]
v = 500000 / 15761 = 31.7 ms^{-1} [2]

25. O/N 15/P43/Q7

(i) Gain in KE
$= \frac{1}{2}\, 1250(8^2 - 5^2)$
Loss in PE = $1250g \times 400\sin 4°$
$400(DF) = \frac{1}{2}\, 1250\,(8^2 - 5^2) - 1250g \times 400\sin 4° + 2000 \times 400$
Driving force is 1189 N or 1190 N [5]

(ii) $1189 \times 2 - 2000 = 1250a$ or
$22.75^2 = 8^2 + 2a \times 750$
Acceleration is 0.302 ms^{-2} [3]

(iii) $v_c^2 = 64 + 2 \times 0.302 \times 750$
[$P/ 22.75 - 2000 = 1250 \times 0.302$]
Power is 54.1 kW or 54100 W [3]

26. M/J 15/P42/Q1

(i)

$\left[s = 0.3\times5+\frac{1}{2}\ \ 0.5\times5^2\right]$

$[v = 0.3 + 0.5 \times 5 = 2.8\text{m}]$

Complete method for finding s required

Distance = 7.75 m [2]

(ii) $[WD = 8 \times 7.75 \times 0.5]$

Work done is 31 J [2]

27. M/J 15/P42/Q2

(i) $\left[\frac{P}{5} = 80\times1.2\right]$

$P = 480$ [2]

(ii)

$\frac{450}{3.6} - 80g \times 0.035 = 80a$

Acceleration is 1.21 ms^{-2} [3]

28. M/J 15/P42/Q3

(i)

KE gain $\left[=\frac{1}{2}\times8\times4.5^2\right] = 81$ J

$\left[\text{Decrease} = 8g\times12\times\left(\frac{1}{8}\right)\right]$

PE loss = 120 J [3]

(ii)

$[81 = 120 - 12R]$

Resisting force is 3.25 N [2]

Alternative method for (ii)

(ii) $[4.5^2 = 2 \times a \times 12]$ ➔

$[a = \frac{27}{32} = 0.84375]$

$[8g\sin\alpha - R = 8 \times \frac{27}{32}]$

Resisting force is 3.25 N [2]

29. M/J 15/P41/Q1

(i) $[20 + 25\sin\theta = 2.7g$

$\sin\theta = 0.28$ [2]

(ii) $[25 \times 5 \times \sqrt{(1 - 0.28^2)}]$

Work done is 120 J [2]

30. M/J 15/P41/Q4

(i)

For KE gain $= 4032 \times 10^3$

or PE loss $= 42 \times 10^6\sin\theta$

PE loss $= 42 \times 10^6\sin\theta$ or

KE gain $= 4032 \times 10^3$ [3]

(ii) $5000 = 4032 - 42000\sin\theta + 3360$

$\theta \doteq 3.3^\circ$ [3]

31. M/J 15/P41/Q5

$\frac{P}{3} - R - 84g \times 0.1 = 84 \times 1.25$

$\frac{P}{10} - R + 84g \times 0.1 = 84 \times 1.25$

$\left[P\left(\frac{1}{3}-\frac{1}{10}\right)-168=0\right]$

P

$\left[R = \frac{720}{3} - 84 - 105\right]$

$R = 51$ [8]

32. M/J 15/P43/Q1

$[WD = 500 \times 2.75 \times 40]$

Work done = 55000 J

Power $= \frac{55000}{40} = 1375$ W [4]

or Power $= 500 \times 2.75 = 1375$ W

33. M/J 15/P43/Q4

KE loss $= \frac{1}{2} \times 12000(24^2 - 16^2)$

PE gain $= 12000\,g \times 25$

WD by DF

$= 3000000 - 1920000 + 7500\times500$

Driving force = 4830000÷500

Driving force is 9660 N [6]

34. O/N 14/P42/Q3

(i) $[v_B = 1.2 \times 28 \div 0.96]$

Speed of the train at B is 35 ms^{-1} [2]

(ii) KE increase $= 100\,000(35^2 - 28^2)$

WD by engine

$= 44.1 \times 10^6 + 2.3 \times 10^6$ J

Work done is 46 400 kJ or 46.4×10^6 J [3]

35. O/N 14/P41/Q1

$DF - R = 800 \times 1.2$

$DF = 22500/18$ [= 1250]

Resistance is 290 N [4]

36. O/N 14/P41/Q7

PE change = $60g \times 17.5$ **or**
KE change = ½ $60(8.5^2 - 3.5^2)$

KE change = ½ $60(8.5^2 - 3.5^2)$ **or**
PE change = $60g \times 17.5$

WD against resistance = 6×250

WD by pulling force = $50\cos\alpha \times 250$

WD = 10500 – 1800 + 1500

WD by the pulling force is 10200 J or 10.2 kJ

For using WD = $Fd\cos\alpha$

$10200 = 50 \times 250 \cos\alpha$

$\alpha = 35.3$ [11]

37. O/N 14/P43/Q1

(i) DF = $P \div 18$
[$P \div 18 - 800 = 1400 \times 0.5$]
$P = 27000$ [3]

(ii) [$1080 - 800 = 1400a$]
Acceleration is 0.2 ms^{-2} [2]

38. O/N 14/P43/Q7

(i) $4^2 = 0^2 + 2a \times 12.5$ ➔ $a = 0.64$
[$35 \times 0.96 - 3g \times 0.6 - F = 3 \times 0.64$]
$F = 13.68$
WD against $F = 13.68 \times 12.5 = 171$ J [4]

(ii) $R_{\text{from O to A}} = 3g \times 0.8 - 35 \times 0.28$
[$\mu = 13.68 \div 14.2$ (= 0.96338)]
Coefficient is 0.963 (accept 0.96) [3]

(iii) [$-3g \times 0.6 - 0.96338 \times (3g \times 0.8) = 3a$]
Acceleration is –13.7 ms^{-2}
[$0 = 16 + 2(-13.7)s$]
Distance travelled is 0.584 m [4]

Alternative for part (i)

(i) Gain in KE = ½ 3×4^2 (= 24 J)
Gain in PE = $3g \times 12.5 \times 0.6$ (= 225 J)
[WD = $35 \times 12.5 \times 0.96 -$ ½ $3 \times 4^2 - 3g \times 12.5 \times 0.6$]
WD against F is 171 J [4]

Alternative for part (iii)

(iii) WD against $F = 0.96(338..) \times 3g \times 0.8s$
½ $3 \times 4^2 = 3gs(0.6) + 0.96(338..) \times 3g \times 0.8s$
Distance travelled is 0.584 m [4]

39. M/J 14/P42/Q1

(i) DF = 22500 ÷ 18
22500/18 – R = 600 × 1.4
R = 410 N [4]

(ii) Rate of working is 6150 W [1]

40. M/J 14/P42/Q5

(i) KE gain is $10.5v^2$ J [1]

(ii) (a)
[PE Loss = 16 (10) x – 5 (10) x sin 30]
PE loss by system is $135x$ J [2]

(b) R = 5 (10) × (√3 ÷ 2)
F = 25
Work done is $25x$ J [3]

(iii) [$10.5v^2 = 135x - 25x$]
$21v^2 = 220x$ [2]

41. M/J 14/P41/Q1

DF = 28000
[1330 000 = 28000V]
V = 47.5 [3]

42. M/J 14/P41/Q5

(i) KE gain = $550v^2$
PE gain = $1000x$
[$1800x = 550v^2 + 1000x + 700x$]
$k = 5.5$ [4]

(ii) At A $5.5v^2 = 1760 \rightarrow v^2 = 320$
$550(v^2 - 320) = 1800(x - 1760) - 700(x - 1760)$
$v^2 = 2x - 3200$ (cwo) [4]

Alternative for part (ii)

[$1800 - 700 = 1100a$ and $5.5v^2 = 1760$]
$a = 1$ and $v^2 = 320$
[$v^2 = 320 + 2 \times 1 \times (x - 1760)$]
$v^2 = 2x - 3200$ [4]

43. M/J 14/P43/Q4

(i) PE loss = 0.4g × 5 J = 20 J
Initial KE_{up} = 0.4g × 5 – 12.8 = 7.2 J
[0.4gh = 2g – 12.8]
Height reached is 1.8 m [4]

(ii) $5 = 0 + \frac{1}{2} g t_{down}^2$ ($t_{down} = 1$)
$0 = 6 - g t_{up}$ or $1.8 = \frac{1}{2} g t_{up}^2$ ($t_{up} = 0.6$)
Total time is 1.6 s [3]

First Alternative for part (i)

$v^2 = 2 \times 10 \times 5 \rightarrow \quad (v = 10)$

KE loss $= \frac{1}{2}\, 0.4(10^2 - v_{up}{}^2) = 12.8$

$[v_{up} = 60, \quad 0 = 6^2 - 2gh]$

Height reached is 1.8 m [4]

Second Alternative for part (i)

$0.4gh = 12.8$

$h = 3.2$ m

[Height reached = 5 – 12.8/0.4g]

Height reached is 1.8 m

$\frac{1}{2} \times 0.4v^2 = 12.8 \quad (v=8)$ and

$[8^2 = 0^2 + 2gh]$

$h = 3.2$ m

[Height reached = 5 – 3.2]

Height reached is 1.8 m [4]

44. M/J 14/P43/Q5

(i) WD against resistance

$= 4500 \times 1200 - 16000g \times 18$

WD against resistance $= 2.52 \times 10^6$ J [3]

Alternative Method for part (i)

$[R + 16000g \times 18/1200 = 4500]$

$[WD = (4500 - 16000g \times 18/1200) \times 1200]$

WD against resistance $= 2.52 \times 10^6$ J [3]

(ii) KE gain $= \frac{1}{2}\, 16000(21^2 - 9^2)$ J

$F = 7680000 \div 2400 = 3200$ [3]

(iii) $[P_A = (3200 + 1280) \times 9$ and $P_B = (3200 - 1280) \times 21]$

$P_A = P_B = 40320$ W [2]

45. O/N 13/P42/Q2

Gain in KE $= ½\, 25 \times 3^2$

or

WD by pulling force $= 220 \times 15 \cos \alpha$

WD by pulling force $= 220 \times 15 \cos \alpha$

or

Gain in KE $= ½\, 25 \times 3^2$

$[3300 \cos \alpha = 112.5 + 3000]$

$\alpha = 19.4$

[5]

46. O/N 13/P42/Q3

(i) $100/4 - 4k = 0 \rightarrow k = 6.25$ [2]

(ii) $100/v - 70g \times 0.05 - 6.25v = 0$

$[6.25v^2 + 35v - 100 = 0]$ or

$[v^2 + 5.6v - 16 = 0]$

Maximum speed is 2.08 ms^{-1} [4]

47. O/N 13/P41/Q2

(i) $[WD = 30 \times 20 \times 0.6 + 40 \times 20 \times 0.8]$

Work done is 1000 J [2]

(ii) $30 \times 0.6 + 40 \times 0.8 - 0.625W = 0$

Weight is 80 N [3]

48. O/N 13/P41/Q5

(i) Gain in PE $= 15000g \times 16$

WD against resistance $= 1800 \times 1440$

Work done is 4.99×10^6 J [4]

(ii) $5030\,000 = ½\, 15\,000(24^2 - 15^2) + 1600d$

Distance is 1500 m [3]

49. O/N 13/P43/Q6

(i) $[144000/v - 4800 = 12500a]$

Acceleration at A is 0.336 ms^{-2}

The speed at B 24 ms^{-1} [3]

(ii)

WD against res'ce $= 4800 \times 500$

Loss in KE $= ½12500(24^2 - 16^2)$

$5800 \times 500 = 12500gh - ½12500(24^2 - 16^2) + 4800 \times 500$

Height of C is 20 m [5]

(ii) Alternative

$[16^2 = 24^2 + 2 \times 500a]$

$a = -0.32\ ms^{-2}$

$5800 - 4800 - 12500g \times (h \div 500) = 12500(-0.32)$

Height of C is 20 m [5]

50. M/J 13/P42/Q2

(i) $1150 = \frac{1}{2}\, 16 \times 10^2 - 16g(50 \times 0.05)$ + WD by resistance

WD by resistance = 750 J [3]

(ii) 1150= increase in KE + $16g(50 \times 0.05) + 750$

KE gain= 0 → speed at top= speed at bottom [2]

51. M/J 13/P42/Q5

(i) Driving force = 1000P/25

1000P/25 – 600 = 1000 × 0.2

P = 20 [4]

(ii) $20000/v_{max} - 600 = 0$

Steady speed is 33.3 ms^{-1} [3]

52. M/J 13/P41/Q2

Increase in PE = 1250 × 10 × 600 sin2.5°

Decrease in KE = $\frac{1}{2}\, 1250(30^2 - v_{top}^2)$

WD against resistance = 400 × 600

[$562500 - 625v_{top}^2 = 327145 + 240000 - 450000$]

Speed is 26.7 ms^{-1} [5]

Special Ruling for candidates who assume, without justification, that the driving force (DF) is constant (maximum mark 4).

[DF – Weight component – Resistance = Mass × Accel'n]

750 – 545 – 400 = 1250a

$v^2 = 30^2 + 2 \times (-0.156) \times 600$

Speed is 26.7 ms^{-1} [4]

53. M/J 13/P41/Q4

(i) DF = 1500 000/37.5 (= 40 000)

[DF – R = ma]

DF – 30 000 = 400 000a

Acceleration is 0.025 ms^{-2} [4]

(ii) [1500 000/v – 30 000 = 0]

Steady speed is 50 ms^{-1} [2]

54. M/J 13/P43/Q2

(i) Loss of PE = 2g × 3.24 – 1.6 g (3.24 × 0.8)

Loss is 23.328 J. [3]

(ii) $\frac{1}{2}(1.6 + 2)\, v^2 = 23.328$

Speed is 3.6 m s^{-1} [2]

55. M/J 13/P43/Q3

1000 P / 14 – R = 800 x 1.4 and
1000 P / 25 – R = 800 x 0.33

P = 27.2

R = 825 [6]

56. O/N 12/P42/Q1

WD = 45 × 25cos 14°

Work done is 1090 J (1.09 kJ) [3]

57. O/N 12/P42/Q6

(i)

[$30000/v - 1000 - 1250g \times 30/500 = 1250a$]

$v_{bottom} = 30000/(1250 \times 4 + 1000 + 750)$ and

$v_{top} = 30000/(1250 \times 0.2 + 1000 + 750)$

[$\frac{1}{2}\, 1250(15^2 - 4.44\ldots^2)$]

Increase in KE is 128000 J (128 kJ) [5]

Alternative for part **(i)**

(i) [$F - 1000 - 1250g \times 30/500 = 1250a$]

$F_{bottom} = 1250 \times 4 + 1000 + 750 = 6750$ and
$F_{top} = 1250 \times 0.2 + 1000 + 750 = 2000$

[$v_{bottom} = 30000/6750$ and $v_{top} = 30000/2000$]

[$\frac{1}{2}\, 1250(15^2 - 4.44\ldots^2)$]

Increase in KE is 128000 J (128 kJ) [5]

(ii) PE gain = $1250g$

WD against resistance = 1000 × 500

[$WD_{car} = 128000 + 375000 + 500000$]

Work done is 1000 000 J (1000 kJ) [3]

Special Ruling applying to part **(i)** for candidates who omit the weight component in applying Newton's second law. (Max 3 out of 5)

(i) $v_{bottom} = 30000/(1250 \times 4 + 1000)$ and
$v_{top} = 30000/(1250 \times 0.2 + 1000)$

[$\frac{1}{2}\, 1250(24^2 - 5^2)$]

Increase in KE is 344000 J (344 kJ)

58. O/N 12/P41/Q7

(i) DF = 17280/12 (= 1440 N)

[$DF - R = ma$ ➔ $1440 - 960 = 1200a$]

Acceleration is 0.4 ms^{-2} [3]

(ii) [$17280/V - 960 = 0$]

$V = 18$ [2]

(iii) For BC, $-960 = 1200a$ ($a = -0.8$)

$t_{BC} = (0 - 18)/(-0.8)$ and $s_{BC} = (0 - 18^2)/(-1.6)$
(= 22.5 s and 202.5 m)

Distance AB = 18(52.5 – 22.5)

Distance is AC is 742.5 m [5]

59. O/N 12/P43/Q1

(i) PE loss = $0.8g \times (2.5 - 1.8)$ (= 5.6J)
Work done is 5.6 J [2]

(ii)
$\frac{1}{2}\, 0.8v^2 = 0.8g \times 2.5 - 0.6 \times 5.6$
Speed at B is 6.45 ms^{-1} [3]

60. O/N 12/P43/Q5

(i) [$\frac{1}{2}\, 12(7^2 - 3^2)$].
Increase is 240 J [2]

(ii) $12g \times AB\sin 10° = 240$
Distance is 11.5 m [3]

(iii) F x $11.5\cos 10° = 240$ or
$F\cos 10° - 12g\sin 10° = 0$
Magnitude is 21.2 N [3]

61. M/J 12/P42/Q1

F × 5cos60° = 75
Magnitude of the force is 30 N [3]

62. M/J 12/P42/Q6

(i) PE gain = 1250 × 10 x 400 × 0.125
WD against resistance is 800 × 400 J
WD by car's engine is 945 000 J (945 kJ) [4]

(ii) [$v_2/6 = 5 \times (1/3)$]
$v_2 = 10$
KE gain = $\frac{1}{2}\, 1250(10^2 - 6^2)$
[WD by car's engine = 945 000 + 40 000]
WD by car's engine is 985 000 J (985 kJ) [5]

63. M/J 12/P41/Q1

DF – 700 = 880 × 0.625
[P = 1250 × 16]
P = 20 000 [4]

64. M/J 12/P41/Q3

(i) PE gain is 32 000 J [1]

(ii) [KE gain = $\frac{1}{2}\, 160 \times 1.25^2$]
KE gain is 125 J [2]

(iii) WD by drum = 32 000 + 125 + 20 000
[P = 52 125 ÷ 41.7]
Power is 1250 W [3]

65. M/J 12/P43/Q1

WD = 6 × (0.5 × 8)cos24°
Work done is 21.9 J [3]

66. M/J 12/P43/Q4

(i) [When $4 < v < 6$, $a_{ave} = (6 - 4)/(0.5 - 0)$;
when $19 < v < 21$
$a_{ave} = (21 - 19)/(24.5 - 16.3)$]
Average accelerations are
4 ms^{-2} and 0.244 ms^{-2} [2]

(ii) DF(5) = P/5 and DF(20) = P/20
[DF – R = ma]
P/5 – R = 1230 × 4 and
P/20 – R = 1230 × 0.244
P = 30800 (or R = 1240)
R = 1240 (or P = 30800) [5]

67. O/N 11/P42/Q1

(i) F = 720/12
[F – R = 75 × 0.16]
R = 48 [3]

(ii) [720/v > 48]
v < 15 i.e. speed is less than 15 ms^{-1} [2]

68. O/N 11/P42/Q6

(i) KE loss = $\frac{1}{2}\, 16000(15^2 - 12^2)$
PE gain = 16000g(AB/20)
1200 = 0.8g(AB) + 1.24(AB) – 648
Distance AB is 200m [5]

(ii) Distance BD is 300m [1]

(iii) WD against resistance =
1240(BC) + 1860(300 – BC)
$\frac{1}{2}\, 16000(12^2 - 7^2)$ =
2400000 + (558000 – 620BC) – 7200 × 300
Distance BC is 61.3 m [4]

Alternative for Q6 part **(iii)**.
For BC16000a = 7200 – 1240 – 8000 and
for CD 16000a = 7200 – 1860 – 8000
For using $v^2 = u^2 + 2as$ for both BC and CD
$v_C^2 = 144 - 2 \times 0.1275(BC)$ and
$49 = v_c^2 - 2 \times 0.16625(300 - BC)$
For eliminating v_c^2 and obtaining BC = 61.3 m

SR for candidates who assume that the acceleration is constant in part **(i)**, although there is no justification for the assumption (max. 3/5)
For appropriate use of Newton's second law and $v^2 = u^2 + 2as$
[1200000÷AB – 1240 – 160000/20 = 16000a
and a = $(12^2 - 15^2)/2(AB)$]
For eliminating a and attempting to solve for AB Distance AB is 200m

... O/N 11/P41/Q1

$d = 2 \times 8$

$[25 \times 16\cos 20]$

Work done is 376 J [3]

... O/N 11/P41/Q6

(i) PE gain = 1200g × 45

WD = 1200g × 45 + 360 000

Work done is 900 000 J or 900 kJ [3]

(ii) WD against resistance

= 360 × sin5/sin1 (kJ) or

{360000 ÷ (45/sin5°)} × (45/sin1°) (J) or

697.24... × 2578.44... (J) or

1798 (kJ)

KE gain = 1660 + 540 − 1798

$[402000 = \frac{1}{2}1200(v^2 - 225)]$

Speed is 29.9 ms^{-1} [4]

(iii) $\frac{P_B}{P_C} = \left(\frac{DF_B}{DF_C}\right) \times \frac{v_B}{v_C} = 1.5 \times 15/29.9$

Ratio is 0.75 [3]

71. O/N 11/P43/Q4

(i) 0.8g × 4

$[\frac{1}{2}\, 0.8v^2 = 32]$

Speed at C = 8.94 ms^{-1} [3]

(ii) [Either F = 0.3(0.8g) and − 2.4 = 0.8a or F = 0.3(0.8g) and WD = 2.4 × 5]

$[v^2 = \text{ans(i)}^2 - 2 \times 3 \times 5$ or $\frac{1}{2}\, 0.8v^2 = 32 - 12]$

Speed at C = 7.07 ms^{-1} [3]

72. O/N 11/P43/Q7

(i) DF = 30000/v or

WD by DF = 30000 × 100

DF = R = 750 (v = 40) or

WD by DF = WD by R = 750 × AB

Distance AB is 4000 m [3]

(ii) −750 = 600 a (a = − 1.25)

$20^2 = 40^2 + 2(-1.25)BC$

Distance BC = 480 m [3]

<u>Alternative for (ii)</u>

$\frac{1}{2}\, 600(40^2 - 20^2) = 750(BC)$

Distance BC = 480 m

(iii) WD by engine = 30000 × 14

Gain in KE = $\frac{1}{2}\, 600\,(30^2 - 20^2)$

[750 × CD = 420 000 − 150 000]

Distance CD is 360 m [4]

73. M/J 11/P42/Q1

(i) [WD = 65 × 76cos5°]

Work done is 4920 J [2]

(ii) [P = 65 cos5° × 1.5]

Rate of working is 97.1 W [2]

74. M/J 11/P42/Q2

PE loss = $\frac{1}{2}\, 8(8^2 - 3^2) + 120$ (= 340 J)

[340 = 8gh]

Height is 4.25 m [4]

75. M/J 11/P41/Q1

(i) [DF − 600 = 700 × 2]

Driving force is 2000 N [2]

(ii) [P = 2000 × 15]

Rate of working is 30000 W (or 30 kW) [2]

76. M/J 11/P41/Q2

(i) Gain in PE = 1250g × 1.54 (= 19250 J)

[WD = 1250g × 1.54 + 5750]

Work done is 25000 J (or 25 kJ) [3]

(ii) [1250 = 25000 / T]

Time is 20 s [2]

77. M/J 11/P41/Q7

(i) T − 12 = 1.2a and 20 −T = 2a

Acceleration is 2.5 ms^{-2}

Tension is 15 N [4]

(ii) (a) PE gain = 12 × 1.5 = 18 J

(b) WD on A = 15 × 1.5 = 22.5J

(c) Gain in KE = ans(**b**) − ans(**a**) = 4.5 J [3]

(iii) v = 1.6 × 2.5

t = 0.4 s

Total time taken is 0.8 s [4]

78. M/J 11/P43/Q1

$8200 = 180 \times 50 \cos\alpha$

$\alpha = 24.3$ [3]

79. M/J 11/P43/Q2

P/19 − R = 1250 × 0.6 and

P/30 − R = 1250 × 0.16

[19R + 19 × 1250 × 0.6

= 30R + 30 × 1250 × 0.16]

R = 750 or P = 28500

P = 28500 or R = 750 [6]

80. M/J 11/P43/Q6

(i) Gain in PE = 15000g × 500sin2.5° J

WD against the resistance = 800 × 500 J

[3271454 + 400000]

Work done is 3670000 J or 3670 kJ [4]

(ii) Work done by DF = 2000 × 500 J
Gain in KE = ½ 15000($v^2 - 20^2$)

½ 15000($v^2 - 20^2$) = 3271454 – 400000 + 1000000

Speed of the lorry is 30.3 ms^{-1} [5]

81. O/N 10/P42/Q2

Driving force = 400/4

DF – 80g sin2° = 80a **(i)** or
DF + 80g sin2° = 80a **(ii)**

Acceleration is 0.9ms^{-2} **(i)** or
Acceleration is 1.6ms^{-2} **(ii)**

Acceleration is 1.6ms^{-2} **(ii)** and
Acceleration is 0.9ms^{-2} **(i)** [5]

SR(max. 3/5) for candidates who have sin and cos interchanged

Driving force = 400/4

a = –8.74 **(i)** and a = 11.2 **(ii)**

82. O/N 10/P42/Q4

(i) [½ 20($2.5^2 - 1.5^2$), 20x10x10sin 4.5°]

KE loss = 40 J or PE gain = 157 J

PE gain = 157 J or KE loss = 40 J [3]

(ii) [WD = 157 – 40 + 50]

Work done is 167 J [2]

(iii) [167 = Fx10cos15°]

Magnitude is 17.3 N [2]

SR (max. 1/2) for candidates who (implicitly) make the unjustifiable assumption that acceleration is constant and apply Newton's second law

For magnitude is 17.3 N from
Fcos 15° – 20gsin4.5° – 50/10 = 20 × (–0.2)

83. O/N 10/P41/Q5

(i) [$v^2 = 3^2 + 2 \times 2.5 \times 8$]

Speed is 7 ms^{-1} [2]

(ii) KE gain = ½ 0.8($7^2 - 3^2$) (= 16)

PE loss = 16 + 7

[0.8 × 10 × 8sinα = 23]

Angle is 21.1° or 0.368^c [4]

(ii) ALTERNATIVELY

F = 7/8

[0.8 × 10sinα – F = 0.8 × 2.5]

0.8 × 10sinα – 0.875 = 0.8 × 2.5

Angle is 21.1° or 0.368^c

(iii) $5^2 = 3^2 + 2 \times 2.5s$ (s = 3.2)

[WD/7 = 3.2/8
or WD = 0.875 × 3.2
or WD = 8 × 3.2 × (23/64)
– ½ 0.8($5^2 - 3^2$)]

Work done is 2.8 J [3]

84. O/N 10/P41/Q6

(i) (a) PE loss = 0.2g(3 – h)

[0.2g(3 – h) = 1.6]

h = 2.2 [3]

(b) KE is 6 J [1]

(c) [$v_G / v_B = (3/(3 - 2.2))^{½}$
or $v_G / v_B = \sqrt{6/1.6}$]

Ratio is 1.94 [2]

(ii) H/(H – 2.2) = 2.55^2

H = 2.6 [3]

85. O/N 10/P43/Q2

(i) [½ v^2 = 10x1.8]
Speed is 6 ms^{-1} [2]

(ii) [WD = ½x0.5($6^2 - 5^2$) or
0.5x10x1.8 = ½x0.5x5^2]
Work done is 2.75 J [2]

86. O/N 10/P43/Q7

(i) DF = 24000/20
[DF – R = 1250x0.32]
R = 800 [3]

(ii) 24000/29.9 – 800 = 1250a
Acceleration is 0.002 ms^{-2} [2]

(iii) [a = (24000/30 – 800)/1250
24000/v – 800 > 0 ➔ v < 30]
Car not accelerating when v = 30 or
Speed cannot reach 30 ms^{-1} [2]

(iv) 29.9 ≤ v < 30 ➔ speed approximately constant [1]

(v) 30 ms^{-1} (max error 0.1) or 29.95 ms^{-1} (max error 0.05) or 29.9 ms^{-1} (max error 0.1) [1]

(vi) (a) [24 = 1200/T]
Time taken is 50 s

(b) [s = 30x50 or 29.95x50 or 29.9x50]
Distance BC is 1500 m or 1500 m or 1495 m [4]

ALTERNATIVE FOR PART (vi)

(b) [1200 000 = 800d]
Distance BC is 1500 m

(a) [t = 1500/30 or 1500/29.95 or 1500/29.9]
Time taken is 50 s or 50.1 s or 50.2 s

87. M/J 10/P42/Q5, M/J 10/P41/Q5

(i) $\frac{1}{2}(m)u^2 = (m)g(0.45)$
Speed is 3 ms^{-1} [3]

(ii) [PE gain = $\frac{1}{2}$ 0.3 × 3^2 – 0.39]
PE gain is 0.96 J
[0.3gh = 0.96]
R is 0.32 m higher than the level of P [4]

88. M/J 10/P41/Q1

DF = 35000/16
DF – 1150g sin1.2° – 975 = 1150a
Acceleration is 0.845 ms^{-2} [4]

89. M/J 10/P43/Q3

(i) [WD = 25 × 40 cos30°]
Work done is 866 J [2]

(ii) [50 × 40 cos30° = 866 + KE gain]
KE gain is 866 J
$\frac{1}{2}35(v^2 - 1.2^2) = 866$
Speed is 7.14 ms^{-1} [5]

90. O/N 09/P42/Q2

(i) Loss in PE is 2.7 × 10 J [1]
(ii) WD is 2.1 × 10^6 J [1]
(iii) KE change = $\frac{1}{2}$ 15000($16^2 - 14^2$)
[WD = $\frac{1}{2}$ 15000($16^2 - 14^2$) + 1600 × 2500]
WD is 4.45 × 10^6 J [3]

91. O/N 09/P42/Q3

(i) [DF = 600 at max speed]
[DF = 24000/v]
Speed cannot exceed 40 ms^{-1} [3]

(ii) DF – R = ma]
24000/15 – 600 = 1250a
Acceleration is 0.8 ms^{-2} [3]

92. O/N 09/P41/Q1

[15000 = 750v_A, 15000 = 500v_B]
Speeds are 20ms^{-1} and 30ms^{-1}
[KE gain = $\frac{1}{2}$ 1000($30^2 - 20^2$)]
Increase is 250 000J (or 250kJ) [4]

93. O/N 09/P41/Q2

(i) [mgh = $\frac{1}{2}$ m6^2]
Height is 1.8m [2]

(ii) $\frac{1}{2}mv^2 = mg(1.8 + 0.65)$ or
$\frac{1}{2}mv^2 - \frac{1}{2}m6^2 = mg \times 0.65$
Maximum speed is 7ms^{-1} [2]

94. M/J 09/P04/Q2

Work done is 3000 J
[3000 = F×100cos15°]
F = 31.1 N [3]

95. M/J 09/P04/Q5

(i) Gain in KE is 3240 J
Loss in PE is 9070 J
Work done is 5830 J [3]

(ii) R = 5830/250 (= 23.3)
[23.3d = $\frac{1}{2}$80($9^2 - 5^2$) or
–23.3 = 80a and $5^2 = 9^2 + 2(-23.3/80)d$]
d = 96.0 [3]

(iii) Driving force = 425/5
[DF – 23.3 = 80a]
Acceleration is 0.771 ms^{-2} [3]

96. O/N 08/P04/Q3

(i) F – 900 = 1200a
[18000/25 – 900 = 1200a]
Deceleration is 0.15ms^{-2} [4]

(ii) 18000/v – 900 = 0
Least speed is 20ms^{-1} [2]

97. O/N 08/P04/Q4

[s = (0 + 0.5)/2 x 7]
s = 1.75m
PE gain = 160g x 1.75
KE gain = $\frac{1}{2}$ 160 x 0.5^2
[WD = 2800 + 20]
Work done is 2820J [6]

SR (max 4/6) for candidates who use a non-energy method
[s = (0 + 0.5)/2 x 7]
s = 1.75m
[a = 1/14, T = 160g + 160/14, WD = 1611.4... x 1.75]
Work done is 2820J

98. M/J 08/P04/Q2

(i) Distance is 2.5x12m or
power = 851cos20° x 2.5
[WD = 851x30cos20°]
Work done is 24 kJ [3]

(ii) Power is 2 kW [1]

99. M/J 08/P04/Q4

(i) [KE = Loss of PE = 0.8g(2.4sin50°),
KE = ½ 0.8 x 2(gsin50°)2.4]
Kinetic energy at A is 14.7J [2]

(ii) [14.7 = ½ mv^2]
Speed at C is 6.06ms^{-1} [2]

(iii) [½ $m8^2$ = mgH, ½ $m8^2$ – ½ $m6.06^2$ = mgh]
h = 3.2 – 2.4sin50° or 10h = ½ (8^2 – 6.06^2)
Depth is 1.36m [3]

100. M/J 08/P04/Q6

(i) 0 = 5.2^2 – 2x10.4s_1 or s_1 = 5.2x0.5 - ½ 10.4x0.5^2
or s_1 = (5.2 + 0)x0.5/2
Greatest height is 7.5m [3]

(ii) [v^2 = 2x9.6x7.5, v = 9.6x1.25,
v = 2x7.5/1.25]
Speed is 12ms^{-1} [2]

(iii) PE loss = 0.6g x 6.2 (= 37.2) or
Initial total energy = 0.6gx6.2 + ½ 0.6x5.2^2 (= 45.312) or
Energy loss upward
= ½ 0.6x5.2^2 – 0.6gx1.3 (= 0.312)
KE gain = ½ 0.6(12^2 – 5.2^2) (= 35.088) or
Final total energy = ½ 0.6x12^2 (= 43.2)
Energy loss downward
= - ½ 0.6x12^2 + 0.6gx7.5 (=1.8)

[WD = 37.2 – 35.088 or 45.312 – 43.2 or 0.312 + 1.8]
Work done is 2.11(2) J [4]

Alternatively

[0.6g + R_{up} = 0.6x10.4 or 0.6g - R_{down} = 0.6x9.6]

R_{up} = 0.24 or R_{down} = 0.24

Work done is 2.11(2) J [4]

101. O/N 07/P04/Q1

DF – 550 = 900x0.2
[P = 730x30 ÷ 1000]
P = 21.9 [4]

102. O/N 07/P04/Q4

(i)
[½ mv^2- ½ $m7^2$ = mgx5]
Speed is 12.2ms^{-1} [3]

(ii)
WD = 0.35x10x5 – ½ 0.35(11^2 – 7^2) or
WD = ½ 0.35(12.2^2 – 11^2)
Work done is 4.9 J [3]

103. M/J 07/P04/Q3

(i) [DF = 18000/30]
[R = DF]
R = 600 N [3]

(ii) 18000/20 – 600 = 1200a
Acceleration is 0.25ms^{-2} [3]

104. M/J 07/P04/Q5

(i) Increase in KE
= ½ 12500(25^2 – 17^2)
[WD = 2100 + 5000]
Work done by driving force is 7100 kJ (or 7100 000 J) [4]

(ii) PE gain = (7100 + 3300) – (5000 + 4800×500 ÷ 1000) or
PE gain = 3300 + 2100 – 4800×500 ÷ 1000
[3000 000 = 12500×10h]
Height is 24m [4]

105. O/N 06/P04/Q1

(i) [WD = 30×20cos10°]
Work done is 591J [2]

(ii) [PE gain = 8×10×20sin15°]
PE gain is 414J [2]

(iii) Work done is 177J [1]

106. O/N 06/P04/Q3

F = 420/5 [= 84]

(i) Acceleration is 1.12 ms^{-2}

(ii) [420/5 – 750sin 1.5° = 75a or a = 1.12 –gsin1.5°]

Acceleration is 0.858ms^{-2} [5]

107. O/N 06/P04/Q5

(i) Loss of PE = mgx2.45

[½ mv^2 = 24.5m]

Greatest speed is 7ms^{-1} [3]

(ii) KE = 0.5g(2.45 – 1.2) or

KE = ½ 0.5×7^2 – 0.5g×1.2

Kinetic energy is 6.25J [2]

(iii) [½ 0.5v^2 = 6.25]

Least value is 5 [2]

108. M/J 06/P04/Q1

(i) $25^2 = 10^2 + 1050a$

$a = 0.5$ [2]

(ii) 900 – R = 1200 × 0.5

R = 300 [2]

109. M/J 06/P04/Q6

(i) ½ 50(7^2 – 3^2)

Loss is 1000J [2]

(ii) 50×10×15

Gain is 7500J [2]

(iii) WD by pulling force = 7500 + 1500 –1000

Work done is 8000J [2]

(iv) 8000 = 45×200cosα

cosα = 8000/(45×200)

α = 27.3 [3]

110. O/N 05/P04/Q2

(i) ½ 50 × 2^2 = 100 J [1]

(ii) 250 × 20 = 5000 J [1]

(iii) WD by the force = 5100 J or

$a = 1/10$

5100 = 400 × 20cos α

or

400 cos α – 250 = 50 × 1/10

$\alpha = 50.4$ [3]

111. O/N 05/P04/Q7

(i) $0.3g - T = 0.3a$, $T - 0.2g = 0.2a$

$0.3g - 0.2g = 0.3a + 0.2a$

$a = 2$ [4]

(ii) $v = 2 \times 1.2$; Speed is 2.4 ms^{-1} [1]

(iii) $s_1 = ½ (0 + 2.4)1.2$

$2.4^2 = 2gs_2$ or

PE gain while string is slack = ½ 0.2×2.4^2

$(s_1 + s_2) = 1.728$ or

PE gain while string is slack =0.576J

Total PE gain = 0.2g × 1.728

(or PE gain while string is taut = 0.2g × 1.44)

T tal PE ain = 3 456 [5]

112. M/J 05/P04/Q1

720 = 30(1.5×20)cos θ

θ = 36.9 [3]

113. M/J 05/P04/Q7

(i) Driving force = 20 000/10

DF – R = ma

2000 – 500 = 1200a

Acceleration is 1.25ms^{-1} [4]

(ii) KE change = ½ 1200 (25^2 – 10^2)

Difference in KE is 315 000 J

20 000 = WD by car's engine/30.5

Work done is 610 000 J

610 000 =315 000 + WD against resistance

500(AB) = 295 000

Distance is 590 m [8]

114. O/N 04/P04/Q3

Equation

F – 1130 + 1250$g$sin3°

= 1250 x 0.2

contains not more than one error

Equation is correct

22000 = 725.8v

Speed is 30.3 ms^{-1} [5]

115. O/N 04/P04/Q4

(i) Gain in GPE = 3.2 x 10^6 J [1]

(ii) WD by driving force = 5 x 10^6 J [1]

(iii) Work done is 1.8 x 10^6 J [1]

(iv) Increase in KE

= ½ 16000 (25^2 – 10^2)

WD by resistance

= 1500 x 2000

WD by driving force

= 4.2 x 10^6 + 3 x 10^6

WD by driving force

= 7.2 x 10^6 J [5]

116. M/J 04/P04/Q4

(i) KE = 0.2g(0.7)

Kinetic energy is 1.4 J [2]

(ii) $R = 0.2 \times 10 \times \cos 16.3°$
$F = 0.288$ N
WD = 0.72 J or $a = 1.36$
or resultant downward force
= 0.272 N

KE = 1.4 – 0.72 or
KE = ½ 0.2(2 × 1.36 × 2.5) or
0.272 × 2.5

Kinetic ener is 0.68 J [5]

117. M/J 04/P04/Q6

(i) DF – 400 = 1200 × 0.5
20000 = 1000v
Speed is 20 ms^{-1}

(ii) 20000/v - 400 = 0 [4]
$v_{max} = 50\ ms^{-1}$ [2]

(iii) $20000 = \frac{1500000}{\Delta T}$ or
distance = 1500 000/400 = 3750
and
time = 3750/50
Time taken is 75 s [2]

118. O/N 03/P04/Q1

(i) The force is 320 N [1]

(ii) For using Newton's second law (3 terms needed)

320 – R = 100 × 0.5

Resistance is 270 N [3]

119. O/N 03/P04/Q4

(i) KE (gain) = ½ 0.15×8^2

For using PE loss = KE gain

Height is 3.2 m [3]

(ii) For using WD is difference in PE loss and KE gain

WD = $0.15 \times 10 \times 4$ - ½ 0.15×6^2

Work Done is 3.3 J [3]

SR For candidates who treat AB as if it is straight and vertical
(implicitly or otherwise) Max 2 out of 6 marks.

(i) $s = 8^2 \div (2 \times 10) = 3.2$

(ii) $a = 6^2 \div (2 \times 4) = 4.5$ and
$R = 0.15 \times 10 - 0.15 \times 4.5 = 0.825$ and
$WD = 4 \times 0.825 = 3.3$

120. M/J 03/P04/Q1

(i) Tension is 8000 N or 800g [1]
Accept 7840 N (from 9.8) or 7850 (from 9.81)

(ii) For using $P = \frac{\Delta W}{\Delta t}$ or $P = Tv$

$\Delta W = 8000 \times 20$ or $v = \frac{20}{50}$

Power applied is 3200 W [3]
Accept 3140 W (from 9.8 or 9.81)
SR (for candidates who omit g)
(Max 2 out of 3)

P = 800 × 20 ÷ 50 B1

Power applied is 320 W B1

121. M/J 03/P04/Q7

(i) PE gain = mg(2.5sin60°)
For using KE = ½ mv^2
For using the principle of conservation of energy
(½ $m8^2$ - ½ mv^2 = mg(2.5sin60°))
Alternative for the above 3 marks:
For using Newton's Second Law or stating $a = -g \sin 60^0$
a = -8.66 (may be implied)
For using $v^2 = u^2 + 2as$
$(v^2 = 64 - 2 \times 8.66 \times 2.5)$
Speed is 4.55 ms^{-1} [4]
Accept 4.64 from 9.8 or 9.81

(ii) For using ½ mu^2 (>) $mg\,h_{max}$
(½ $8^2 > 10\,h_{max}$)

For obtaining 3.2m A.G. [2]

(iii) Energy is conserved or absence of friction or curve BC is smooth [1]
(or equivalent) and B and C are at the same height or the PE is the same at A and B (or equivalent)

(iv) WD against friction is 1.4 × 5.2

For WD = KE loss (or equivalent) used
$1.4 \times 5.2 = \frac{1}{2}0.4(8^2 - v^2)$ or

$1.4 \times 5.2 = \frac{1}{2}0.4((i)^2 - v^2) + 0.4 \times 10(2.5\sin 60°)$

(12.8 or 4.14 + 8.66)
Alternative for the above 3 marks:
For using Newton's Second Law
$0.4g(2.5\sin 60° \div 5.2) - 1.4 = 0.4a$ (a=0.6636)
For using $v^2 = u^2 + 2as$ with u≠0
$(v^2 = 4.55^2 + 2 \times 0.6636 \times 5.2)$
Speed is 5.25 ms^{-1} [4]

122. O/N 02/P04/Q1

Driving force = 20 000/25
For using Newton's 2nd law (3 terms needed)
[20 000/25 – 600 = 1000a]
Acceleration is 0.2ms^{-2} [3]

Notes: $\frac{20000-600}{25} = 1000a$ scores B0M1; $\frac{20000}{25} - \frac{600}{25} = 1000a$ scores B1 M0
$20000 = 25(1000a + 600)$ scores B1 M1 20000/25 – 600 = 1000ga scores B1 M0

123. O/N 02/P04/Q6

(i)(a) For using $F = \mu mg \cos a$ [$0.25\times1.2g \cos25°$]
Frictional component is 2.72 N (2.719)
(2.67 from g = 9.81 or 2.66 from g = 9.8) [2]
SR for the candidate who uses $F \leq \mu R$ instead of $F = \mu R$ (max 1 out of 2)
$F \leq 2.72$
(b) For using Newton's 2nd law (3 terms needed)
[$1.2g\sin25° - 2.719 = 1.2a$]
Acceleration is 1.96 ms^{-2} (1.92 from g = 9.81 or 9.8) [2]
(ft for positive value of a from incorrect F)

(c) For using $v^2 = 2as$ [$v^2 = 2\times1.96\times4$]
Speed is 3.96ms^{-1} (3.92 from g = 9.81 or 9.8)
(ft for 8.00 (accept 8.0 or 8) following a sin/cos mix) [2]
(ii)(a) PE Loss is 36J (35.3 from g = 9.81 or 9.8) [1]
(b) For using PE loss = KE gain from bottom of slope, or
PE loss = KE gain WD against friction from top of slope, or
$v^2 = v_{vert}^2 + v_{horiz}^2$ and $v_{vert}^2 = (-3.96\sin35°)^2 + 2g\times3$
$36 = ½\ 1.2(v^2 - 3.96^2)$ or $1.2g(4\sin25° + 3) = ½\ 1.2v^2 + 2.719\times4$ or
$v^2 = [(-3.96\sin35°)^2 + 2g\times3] + (3.96\cos35°)^2$
Speed is 8.70 ms^{-1} (8.62 from g = 9.81 or 8.61 from g = 9.8) [3]
SR (max 1 out of 3)
$v^2 = 3.96^2 + 2g \times 3$
Notes: Allow sin 25 instead of cos 25 for M1 in (i)(a).
Allow cos 25 instead of sin 25 for M1 in (i)(b).
$1.2g\sin25° - 2.719 = 1.2ga$ scores M0 in (i)(b).
Accept ± 36 in (ii)(a).
Allow M1 for $½\ 1.2v^2 = 36$ in (ii)(b).
Accept 8.7 (for 8.70) in (ii)(b).

124. M/J 02/P04/Q1

For using WD = $Fd \cos a$ or P = $Fv\cos a$ and WD Pt
WD = 5(0.4 × 10)cos30°

Work done is 17.3 J (or $10\sqrt{3}$) [3]

SR For candidates who calculate power (only) (max 1 out of 3)

Power is 1.73 W

Notes:

M1 – their distance; cos or sin but not just 5×4

Radians M1 A1 A0 (max 2 out of 3); answer 3.085 does not score final A mark but may imply the previous A1

Summary exercise 9

1. Two particles, P and Q, are projected towards each other on a smooth horizontal surface. P has mass 0.6 kg and initial speed 2.8 m s^{-1}, and Q has mass 0.8 kg and initial speed 1.2 m s^{-1}. After a collision between P and Q the speed of P is 0.1 m s^{-1} and the direction of its motion is reversed.

   a) Calculate the change in momentum of P.

   b) Find the speed and direction of motion of Q after the collision.

2. Two particles of masses 50 g and 80 g are moving towards each other on a smooth horizontal surface. The initial speed of the 50 g mass is 3.9 m s^{-1} and that of the 80 g mass is 3.25 m s^{-1}. The particles collide and coalesce. Find the speed and direction of motion of the combined particle.

EXAM-STYLE QUESTIONS

3. Each of two wagons has an unloaded mass of 1500 kg. One of the wagons carries a load of mass m kg and the other wagon is unloaded. The wagons are moving towards each other on the same rails, each with a speed of 2 m s^{-1}, when they collide. Immediately after the collision the loaded wagon is at rest and the speed of the unloaded wagon is 3 m s^{-1}. Find the value of m.

4. A spacecraft of mass 40 000 kg docks with a space station of mass 160 000 kg. The spacecraft is travelling at 202 m s^{-1} immediately before docking takes place and the space station is travelling at 200 m s^{-1}. The docking is modelled by two particles moving in the same straight line that collide and coalesce.

   a) Calculate the exact speed of the spacecraft and space station after the docking.

   b) Calculate the total loss in kinetic energy during the docking.

5. Two spheres, P and Q, have masses 0.4 kg and 0.3 kg, respectively. The spheres are moving directly towards each other on a smooth horizontal surface and collide. Immediately before the collision, P has a speed of 6 m s^{-1} and Q has a speed of 4 m s^{-1}. Immediately after the collision the spheres move away from each other, P at a speed of v m s^{-1} and Q at a speed of $(5 - v)$ m s^{-1}. Find the value of v.

EXAM-STYLE QUESTION

6. A railway wagon A of mass 1200 kg, moving at a speed of 4 m s^{-1}, collides with a railway wagon B, which has mass 1800 kg and is moving towards A at a speed of 2 m s^{-1}. Immediately after the collision the speeds of A and B are equal.

   a) Given that the two wagons are moving in the same direction after the collision, find their common speed. **Determine** which wagon has changed its direction of motion.

   b) It is given instead that A and B are moving with equal speeds in opposite directions after the collision.

      i) Calculate the speed of the wagons after the collision.

      ii) Calculate the change in the momentum of A as a result of the collision.

7. A toy car of mass 240 g collides directly with a stationary toy lorry of mass 360 g. The car's speed is reduced by 3 m s^{-1}. Find the speed of the lorry after the collision.

EXAM-STYLE QUESTIONS

8. Two particles, of masses 0.2 kg and *m* kg, are moving towards each other and collide directly. Immediately before the collision the 0.2 kg particle has a speed of $4\,m\,s^{-1}$ and the *m* kg particle has a speed of $2\,m\,s^{-1}$.

a) Given that both particles are brought to rest by the collision, find the value of *m*.

b) Given instead that after the collision both particles move at a speed of $0.5\,m\,s^{-1}$, find all the possible values of *m*.

9. Two particles, *A* and *B*, of masses 2 kg and 1 kg, respectively, are initially moving towards each other on a smooth horizontal surface. Initially, the speed of *A* is $3\,m\,s^{-1}$ and the speed of *B* is $1\,m\,s^{-1}$. The particles collide. The direction of motion of *A* remains unchanged and the direction of motion of *B* is reversed. The loss of kinetic energy due to the collision is 5.25 J. Find the speeds of the particles after the collision.

10. Three smooth spheres, *P*, *Q* and *R*, of equal radii and of masses 5 kg, 4 kg and 6 kg, respectively, lie in that order in a straight line on a smooth horizontal plane. Initially, *Q* and *R* are at rest and *P* is moving towards *Q* at a speed of $9\,m\,s^{-1}$. After colliding with *Q*, sphere *P* continues to move in the same direction but at a speed of $2\,m\,s^{-1}$.

a) Find the speed of *Q* after this collision.

Sphere *Q* collides with sphere *R*. In this collision these two spheres coalesce to form an object *S*.

b) Find the speed of *S* after this collision.

c) Show that the total loss of kinetic energy in the system due to the two collisions is 131.25 J.

11. Two particles, *A* and *B*, are travelling in the same direction at different but constant speeds along a straight line when they collide. Particle *A* has mass 1.5 kg and speed $6\,m\,s^{-1}$. Particle *B* has mass 2.5 kg and speed $2\,m\,s^{-1}$. The particles coalesce during the collision. Find the speed of the combined particle after the collision.

12. Two model cars, *A* and *B*, have masses 250 grams and *m* grams, respectively. The cars move towards each other in a straight line on a horizontal table. They collide directly when the speed of *A* is $4\,m\,s^{-1}$ and the speed of *B* is $2\,m\,s^{-1}$. As a result of the collision the speed of *A* is reduced to $2\,m\,s^{-1}$ and it continues to move in the same direction as before the collision. The direction of *B*'s motion is reversed and its speed immediately after the collision is $3\,m\,s^{-1}$. Find the value of *m*.

13. A particle *P* moves across a smooth horizontal surface in a straight line. *P* has mass 2 kg and speed $6\,m\,s^{-1}$. A particle *Q*, of mass 3 kg, is at rest on the surface. Particle *P* collides with particle *Q*.

a) Given that after the collision, *P* is at rest and *Q* moves away from *P*, find the speed of *Q*.

b) Given instead that after the collision, *P* and *Q* move away from each other with the same speed $v\,m\,s^{-1}$, find *v*.

14. Two particles, *P* and *Q*, have masses 1.2 kg and 0.4 kg, respectively. They are moving towards each other on a horizontal surface when they collide directly. Immediately before the collision the speed of *P* is $2.5\,m\,s^{-1}$ and the speed of *Q* is $1.5\,m\,s^{-1}$. Immediately after the collision, *P* and *Q* move in the same direction and the speed of *Q* is three times the speed of *P*.

a) Find the speed of P immediately after the collision.

b) Find the change in momentum of *P*.