TURNING EFFECT OF FORCES

i)Moments

ii)Centre of

iii)mass

Stability

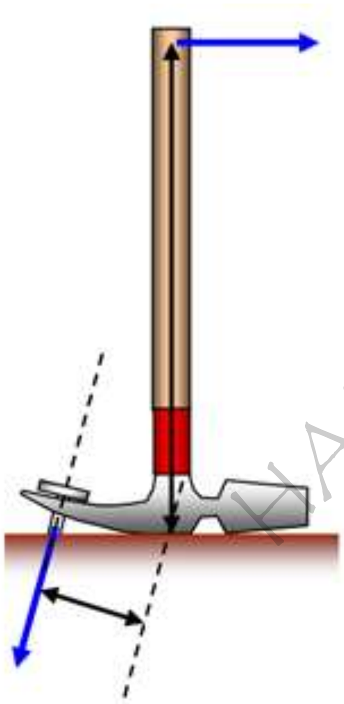
Moments

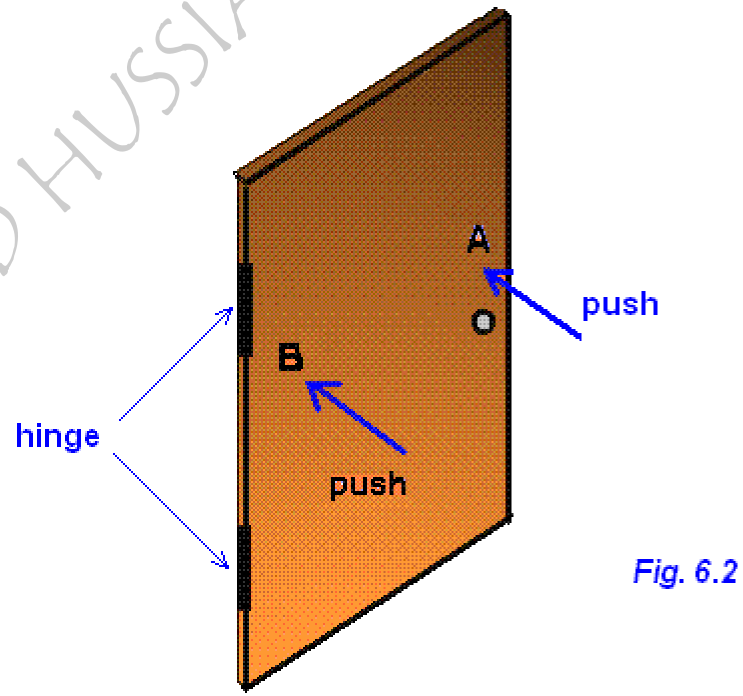
- Describe the moment of a force in terms of its turning effect and relate this to everyday examples.

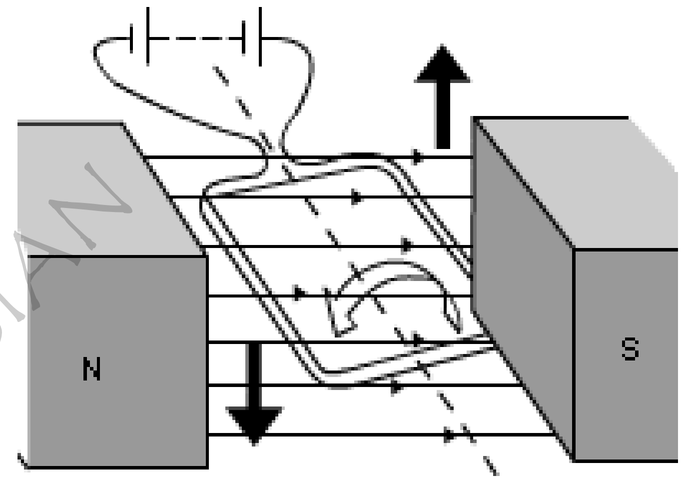
- .

Moments

- The turning effect of a force is called its **moment** or **torque**



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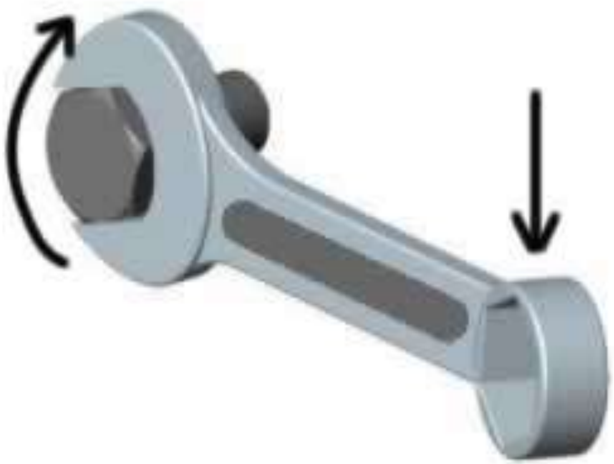

Moment factor

- The moment of a force is bigger if the force is bigger.
- The moment of a force is bigger if it acts further from the pivot.
- The moment of force is greatest if it acts at 90° to the object it acts on

Moments

- Make calculations using moment of a force = force x perpendicular distance from the pivot and the principle of moments.

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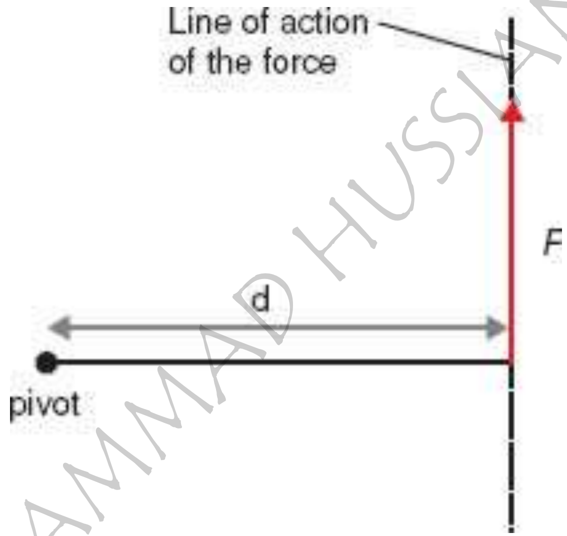
Calculating Moment

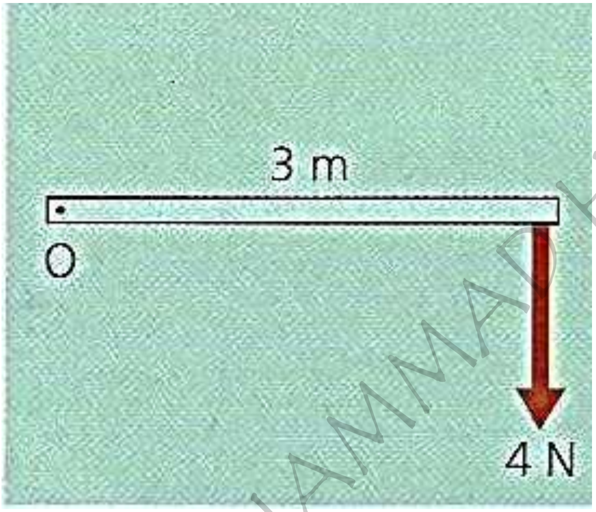


Moment of a Force =	**Force × Perpendicular distance from the line of action of the force to the pivot**
=	F × d

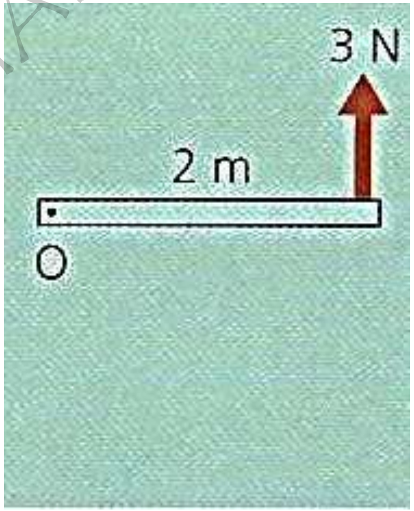
Problem Solving

1. Calculate the moment for each of the following

(a)



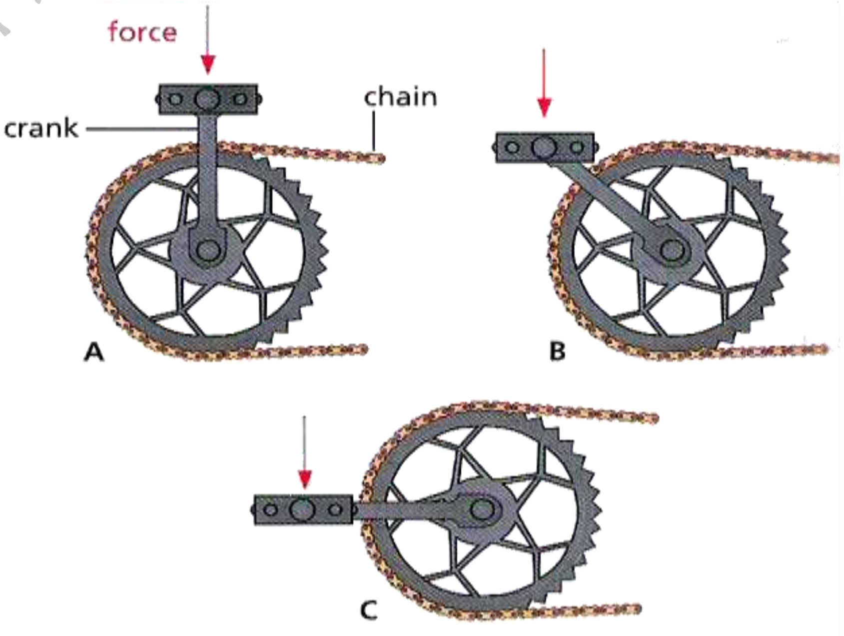
(b)



2. A mechanic uses a 15 cm long spanner and applies a force of 300 N at the end of the spanner to undo a nut. What is the moment he applies?
3. The radius of the wheel of fortune is 1.2 m, and the operator applies a force of 45 N tangentially to get it spinning. What torque has he supplied?
4. A 32 kg child sits on a seesaw. If she is 2.2 m from the pivot, what is the moment that her weight exerts?
5. A force of 40 N is acting at the end of a beam. If the distance of this force from the pivot is 2.0 m, what is the moment by this force?

6. Figure below shows three positions of the pedal on a bicycle which has a crank 0.20 m long. If the cyclist exerts the same vertically downward push of 25 N with his foot, in which case A, B and C, is the turning effect

   i. 0,
   ii. between 0 and 5 Nm,
   iii. $25 \times 0.2 = 5$ Nm?



1. If a nut and bolt are difficult to undo, it may be easier to turn the nut by using a longer spanner.

   This is because the longer spanner gives

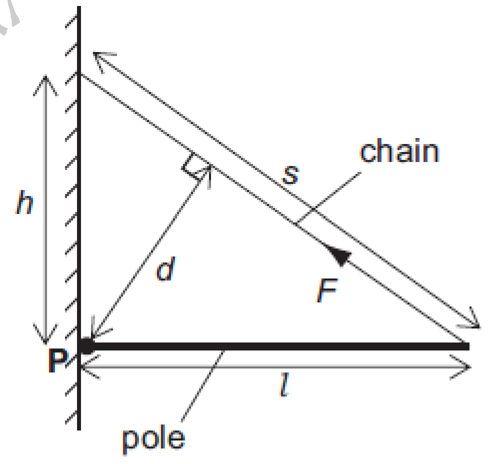
   A. a larger turning moment.
   B. a smaller turning moment.
   C. less friction.
   D. more friction.

2. A horizontal pole is attached to the side of a building. There is a pivot P at the wall and a chain is connected from the end of the pole to a point higher up the wall.

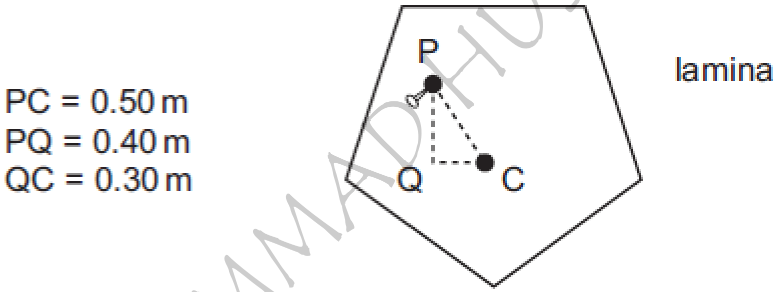
   There is a tension force F in the chain.

   What is the moment of the force F about the pivot P?

A. F x d
B. F x h
C. F x l
D. F x s



3. A plane lamina is freely suspended from point P.
The weight of the lamina is 2.0 N and the centre of mass is at C.



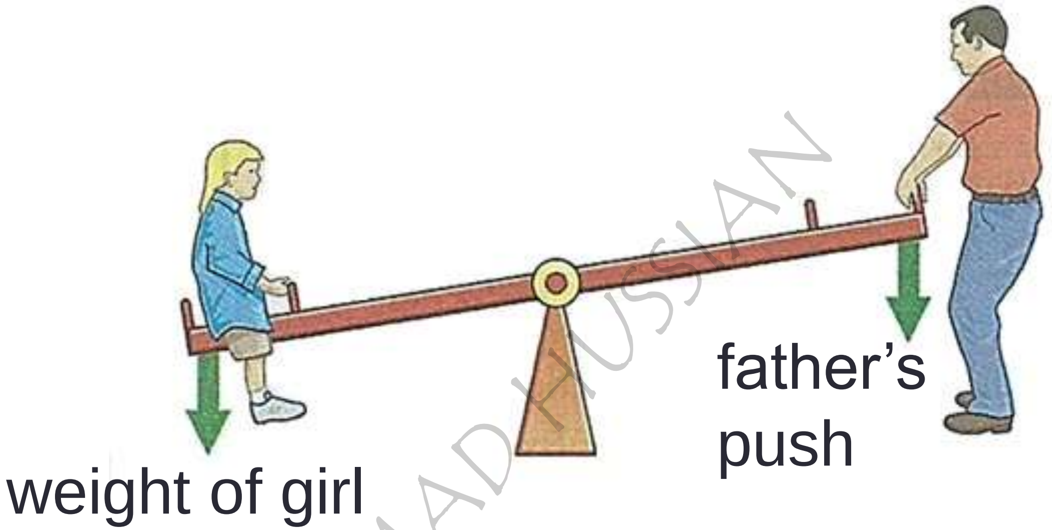
The lamina is displaced to the position shown. What is the moment that will cause the lamina to swing?

A. 0.60 N m clockwise
B. 0.80 N m anticlockwise
C. 1.0 N m clockwise
D. 1.0 N m anticlockwise

Moments

- State the principle of moments for a body in equilibrium.

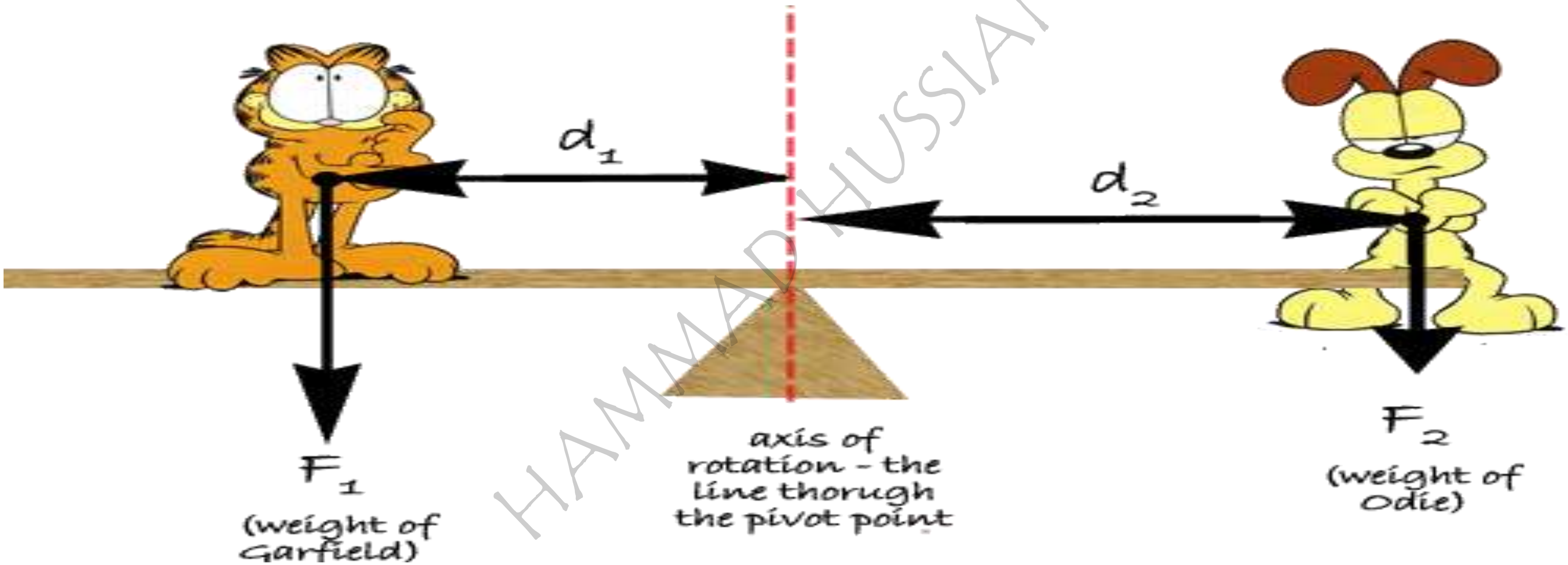
Balance Beam



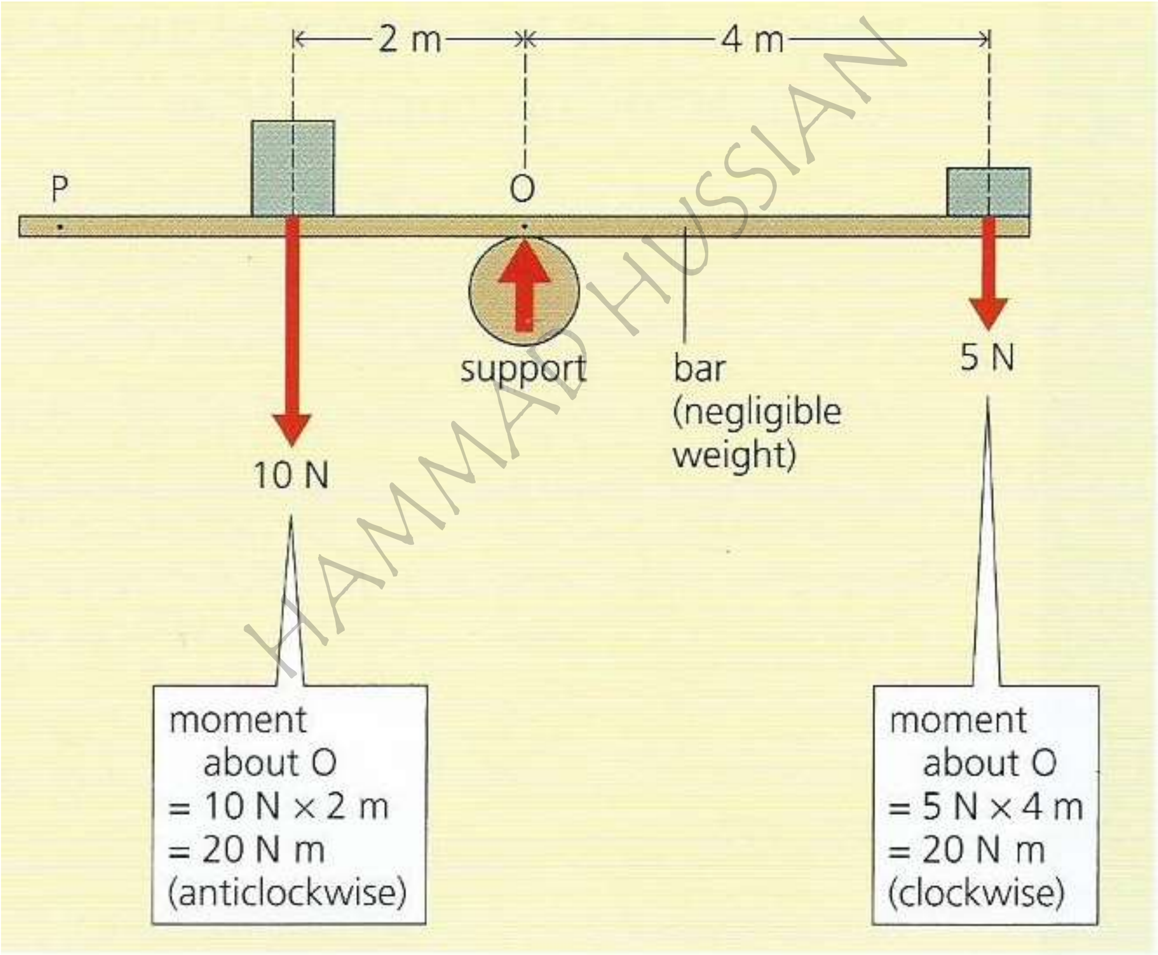
- Two forces are causing this see-saw to tip.
- The girl's weight causes it to tip to the left, while her father provides a force to tip it to the right.
- He can increase the turning effect of his force by increasing the force, or by pushing down at a greater distance from the pivot.

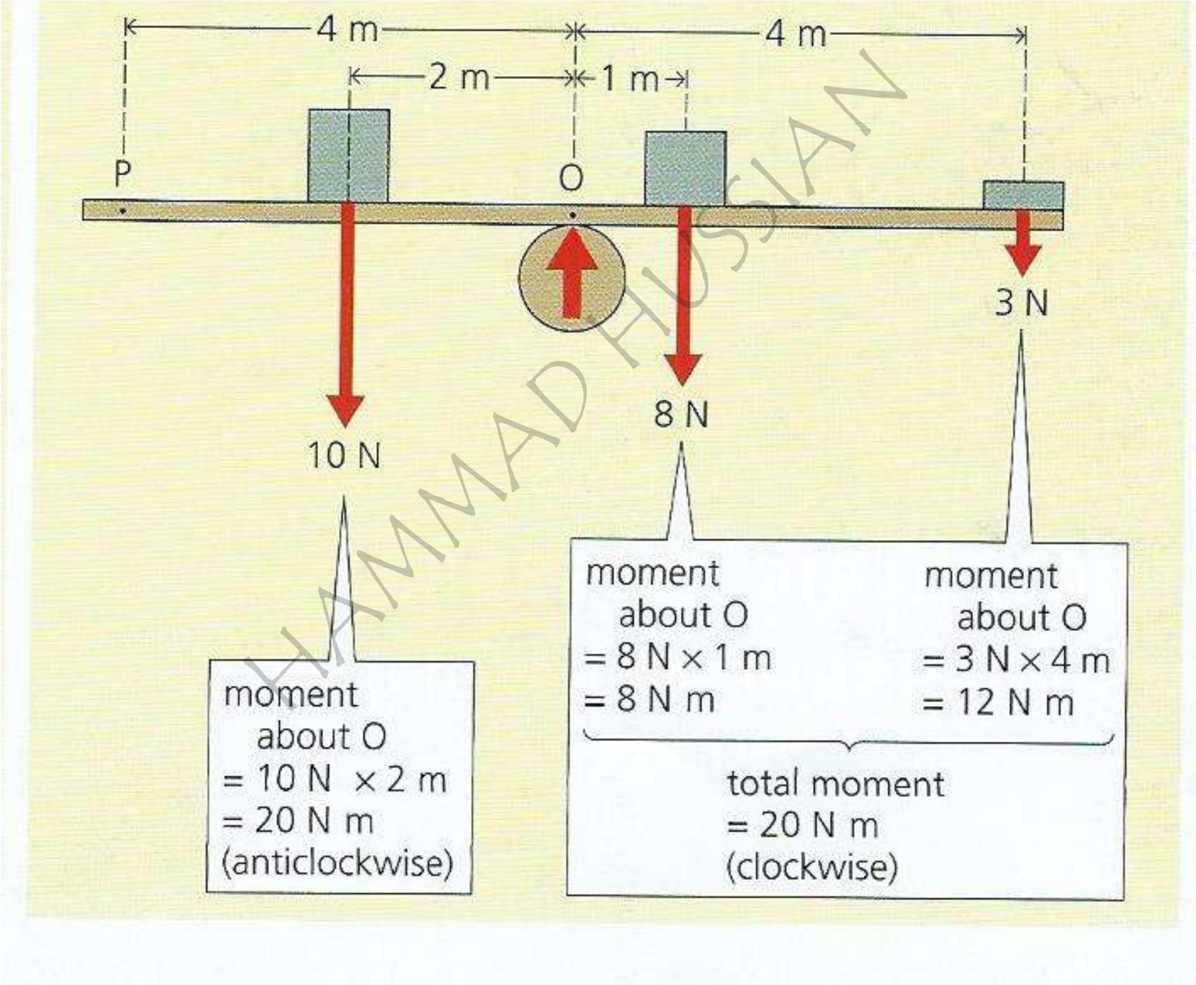
Principle of Moments

- Moment can be clockwise or anticlockwise.



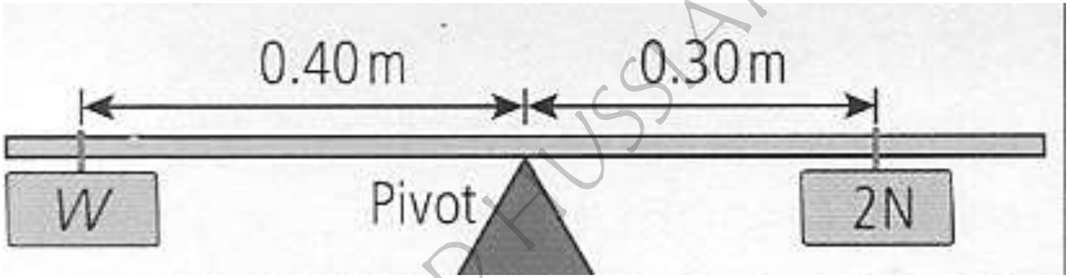
- When an object is in equilibrium, the sum of clockwise moments about any point is equal to the sum of anticlockwise moments about the same point.


2 m
4 m
P
O
support
bar
(negligible
weight)
5 N
10 N
moment
about O
= 10 N × 2 m
= 20 N m
(anticlockwise)
moment
about O
= 5 N × 4 m
= 20 N m
(clockwise)

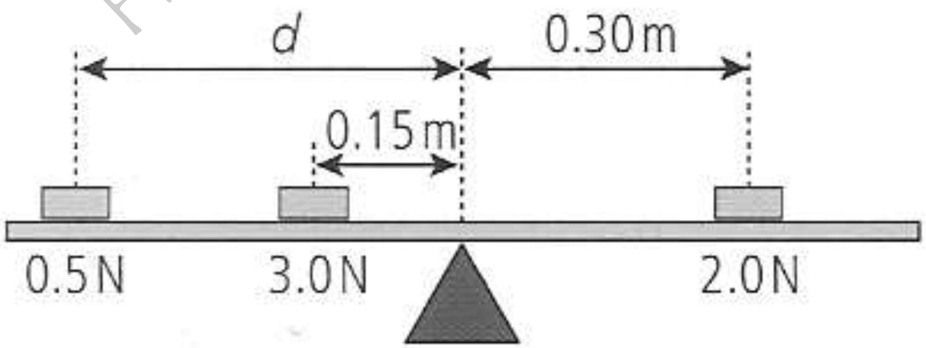

4 m
4 m
2 m
1 m
P
O
10 N
8 N
3 N
moment about O = 10 N × 2 m = 20 N m (anticlockwise)
moment about O = 8 N × 1 m = 8 N m
moment about O = 3 N × 4 m = 12 N m
total moment = 20 N m (clockwise)

Example

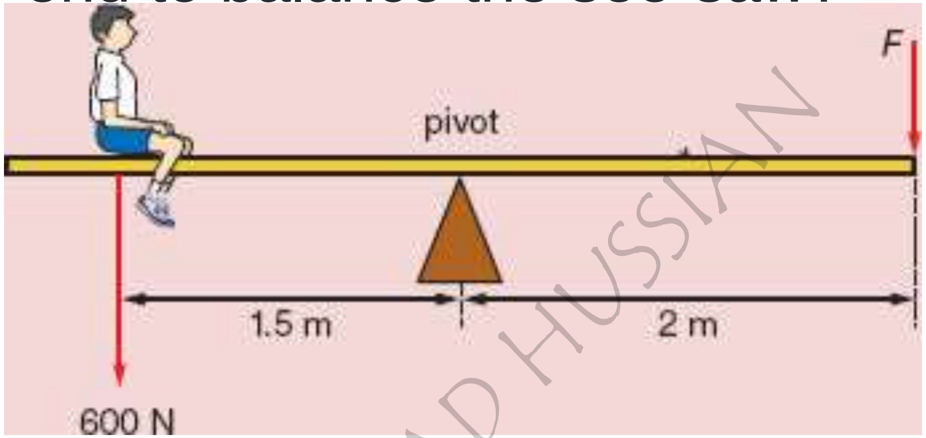
1. For the beam balance below, work out the unknown weight?



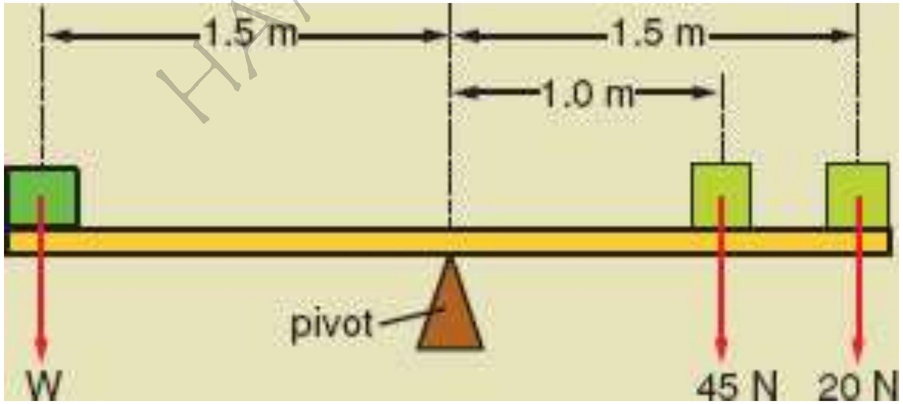
2. Figure below shows three weights on a beam that is balanced at its centre. Calculate the distance *d* from the 0.5 N weight to the pivot.



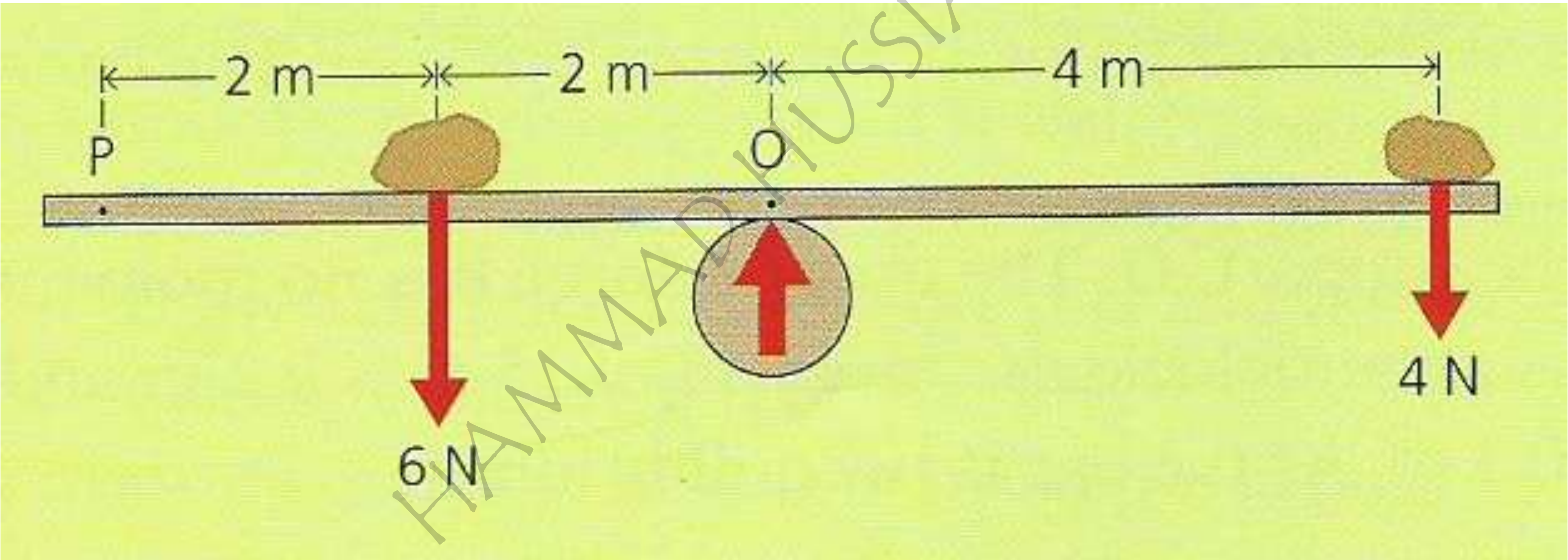
3. A boy weighing 600 N sits on the see-saw at a distance of 1.5 m from the pivot. What is the force *F* required at the other end to balance the see-saw?



4. The diagram shows a uniform rod balance at its centre. Use the principle of moments to calculate the weight W.

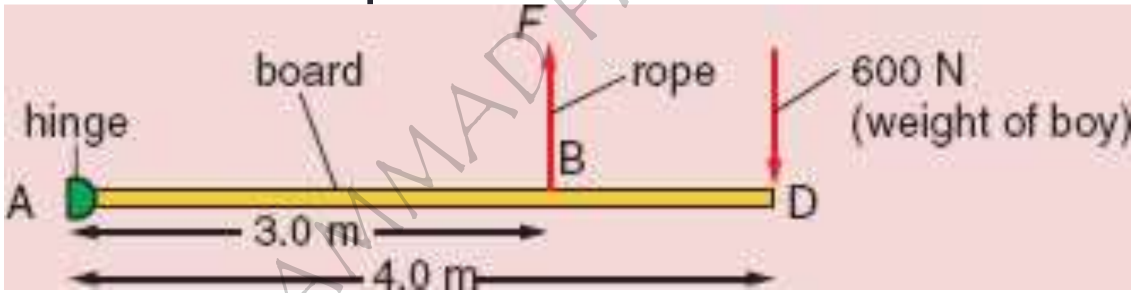


5. Figure below, someone is trying to balance a plank with stones. The plank has negligible weight.



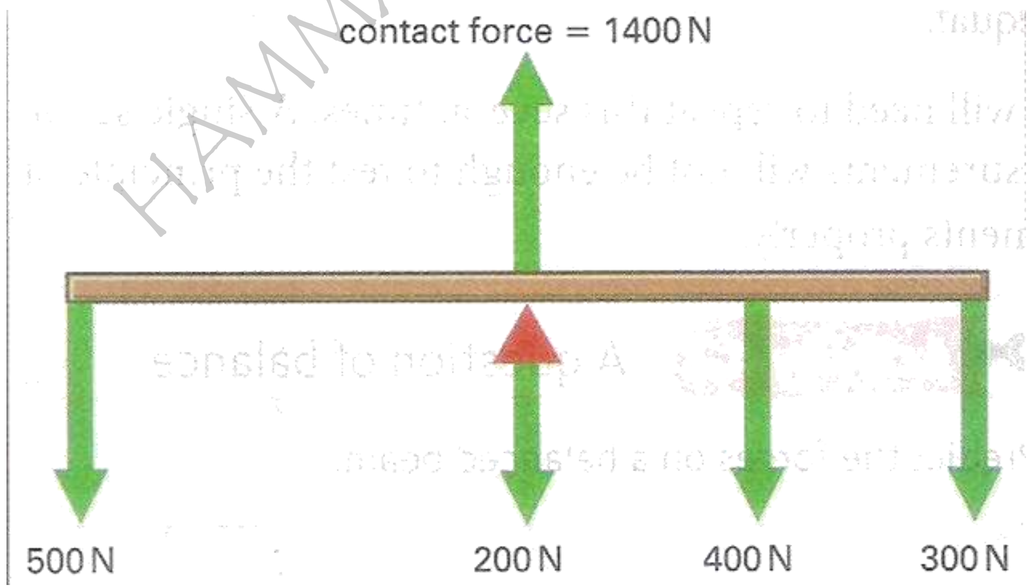
a. Calculate the moment of the 4 N force about O.
b. Calculate the moment of the 6 N force about O.
c. Will the plank balance? If not which way will it tip?
d. What extra force is needed at point P to balance the plank?
e. In which direction must the force at P act?

6. The board shown is hinged at A and supported by a vertical rope at B, 3.0 m from A. A boy weighing 600 N stands at the end D of the board, which is 4.0 m from the hinge. Neglecting the weight of the board, calculate the force *F* on the rope.

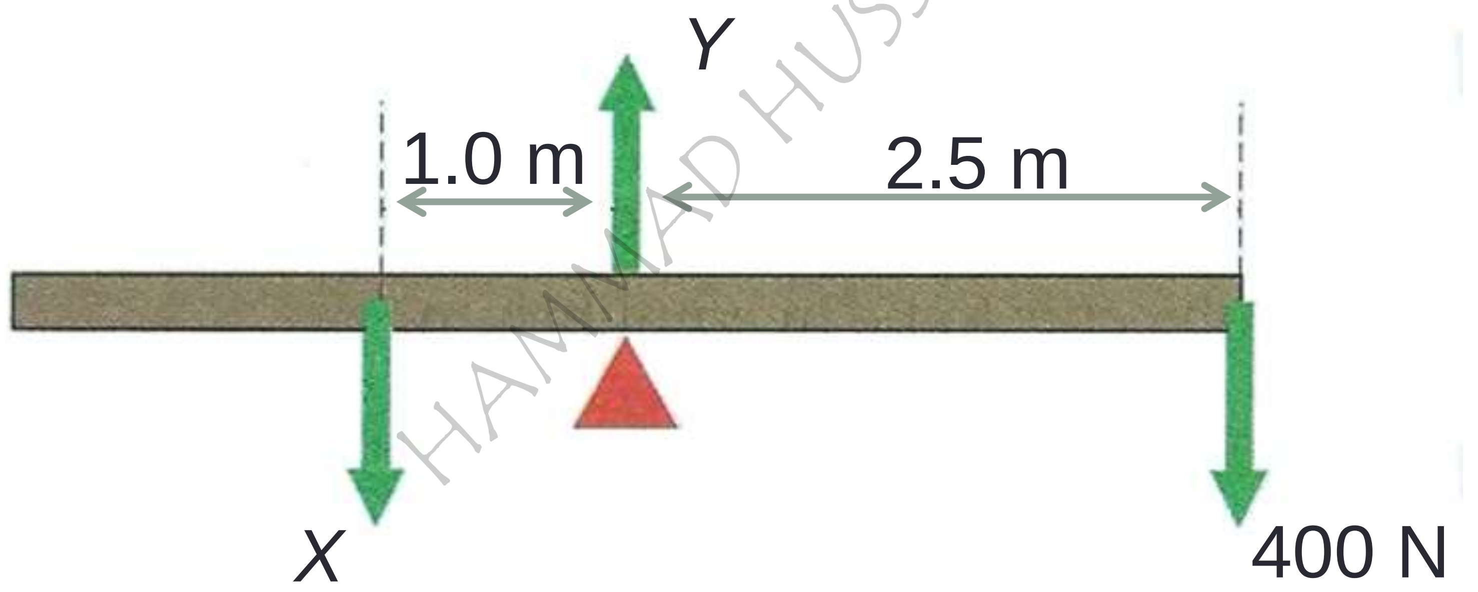


Conditions for equilibrium

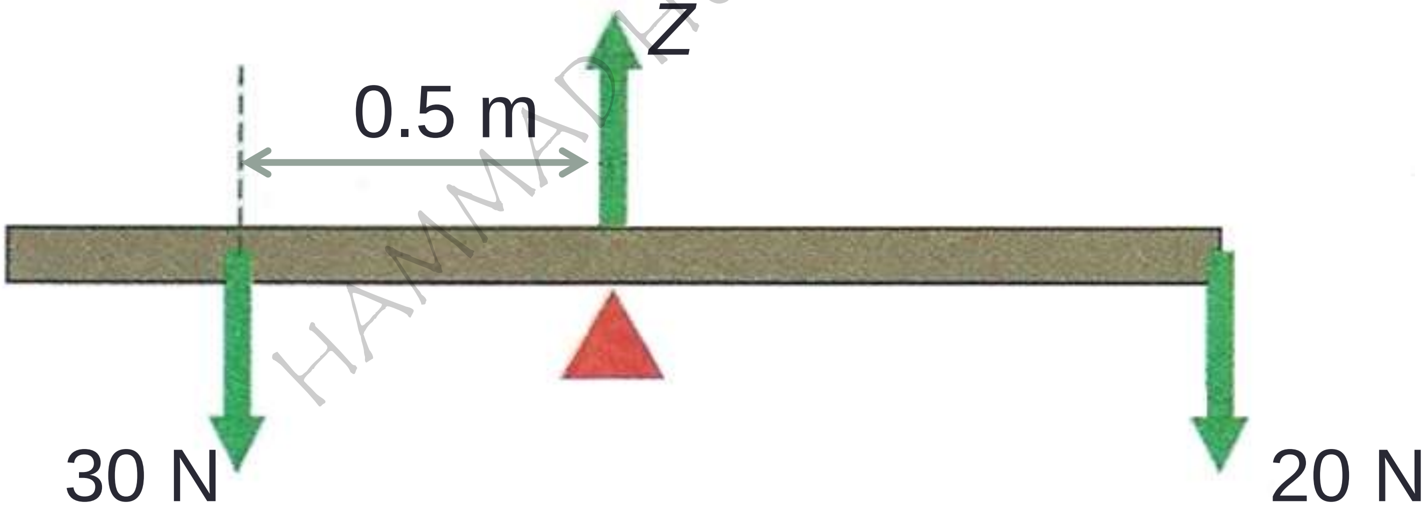
- If an object is in equilibrium, the forces on it must balance as well as their turning effect.
- So:
  - The sum of the forces in one direction must equal to the sum of the forces in the opposite direction.
  - The principle of moments must apply.



1. Figure below shows a balanced beam. Calculate the unknown forces X and Y.

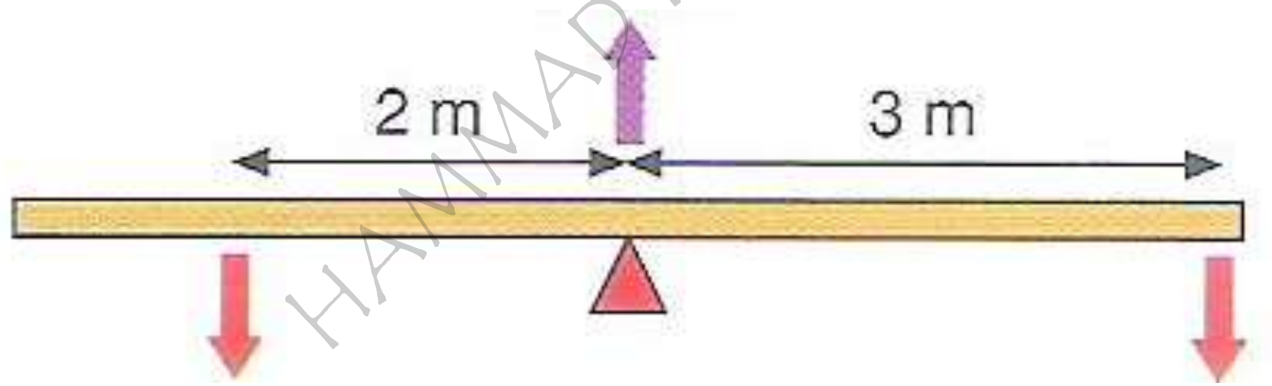


2. Figure below shows a beam, balanced at its midpoint. The weight of the beam is 40 N. Calculate the unknown force Z, and the length of the beam.



3. Figure below shows a balanced beam. Calculate the unknown forces X and Y.

Y



600 N

X

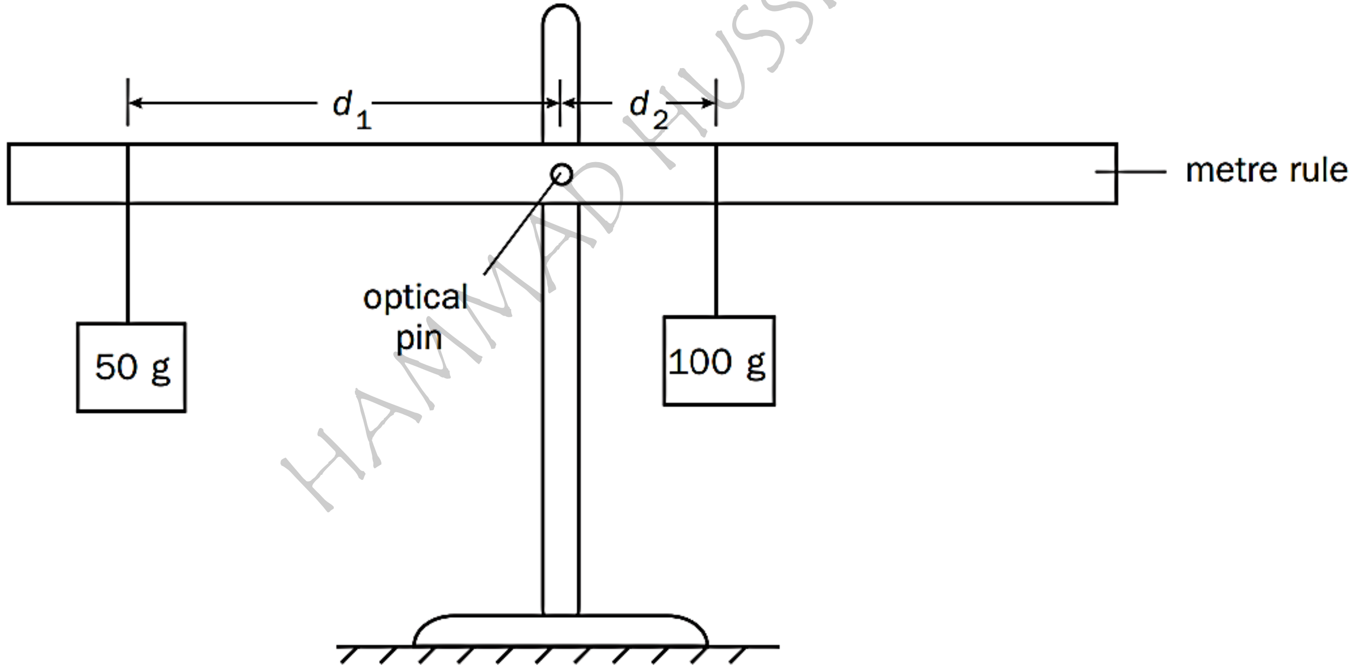
Moments

- Describe how to verify the principle of moments

Experiment

- Aim: To verify the principle of moments
- Apparatus:
  1. Retort stand
  2. Metre rule with drill hole at the 50 cm mark.
  3. Pivot
  4. 10 g slotted mass with hanger labelled W_1
  5. 100 g slotted mass with hanger labelled W_2

- Procedure:
  1. Arrange the apparatus as shown



- Procedure:
  2. Suspend different weights, W_1 and W_2 at different distances d_1 and d_2 from the pivot.
  3. Carefully adjust the distances d_1 and d_2 until the rule balances horizontally.
  4. Record the values of W_1,W_2,d_1 and d_2.
  5. Repeat procedure 2, 3 and 4 for different values of W_1,W_2,d_1 and d_2.

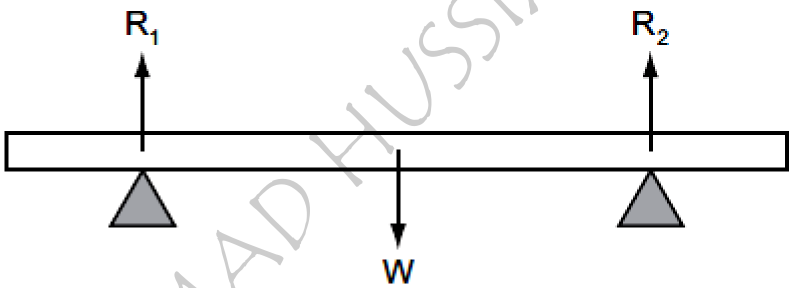
- Results
  - For each set of results, calculate ($W_1 \times d_1$) and ($W_2 \times d_2$).
- Conclusion
  - For each set of readings, within the limits of experimental accuracy, ($W_1 \times d_1$) and ($W_2 \times d_2$) will be equal for each set of readings.
  - Hence clockwise moment equal anticlockwise moment.

1. What are the conditions for equilibrium?

	resultant force acting	resultant turning effect acting
A	yes	yes
B	yes	no
C	no	yes
D	no	no

D

2. A heavy beam is resting on two supports, so that there are three forces acting on it.



The beam is in equilibrium.

Which statement is correct?

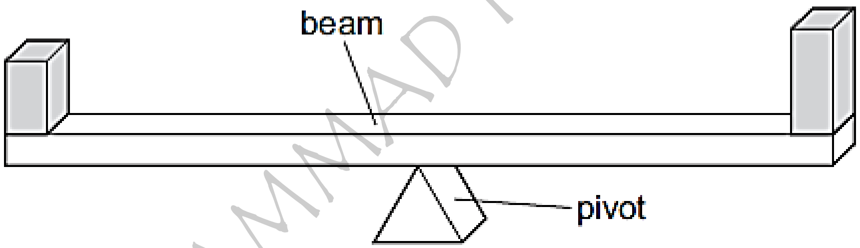
A. All the forces are equal in value.

B. The forces are in one direction and their turning effects are in the opposite direction.

C. The resultant force is zero and the resultant turning effect is zero.

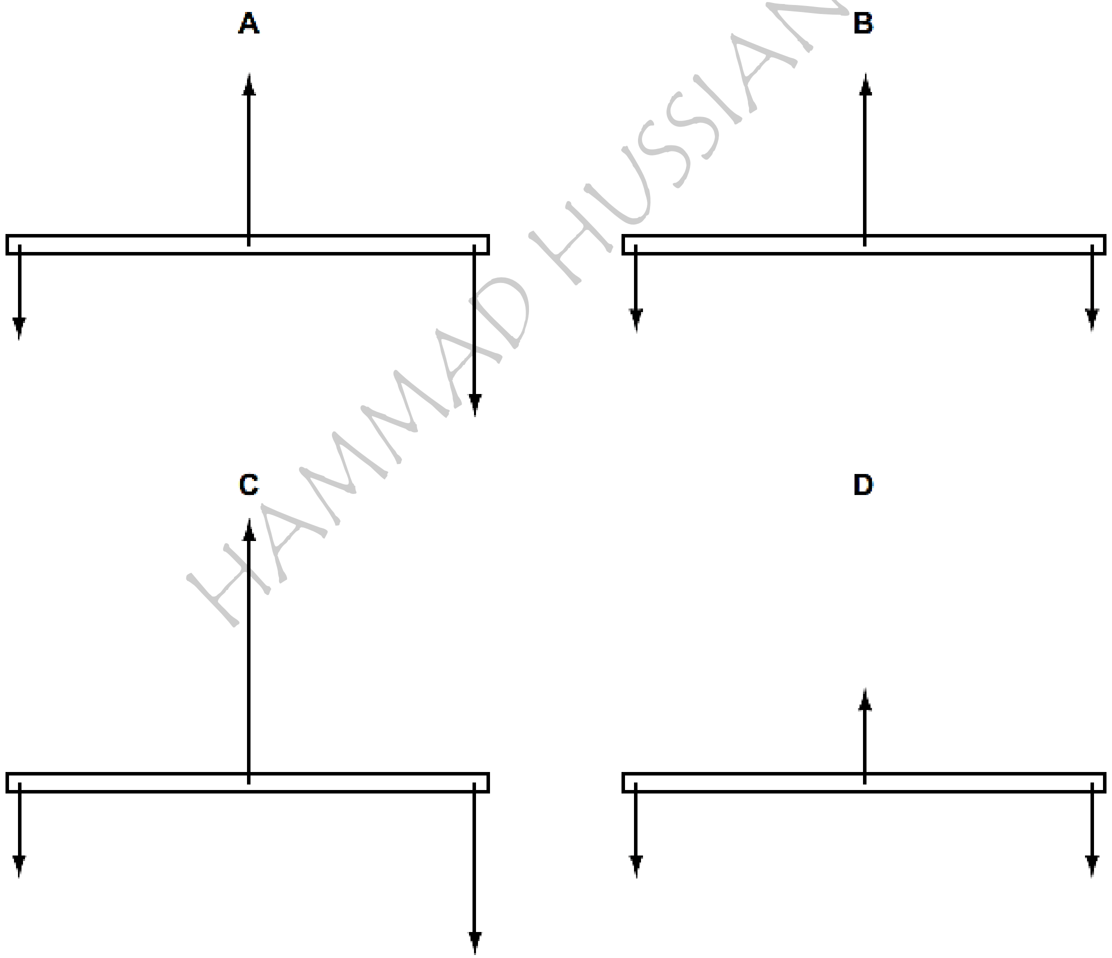
D. The total upward force is twice the total downward force.

3. Two blocks are placed on a beam which balances on a pivot at its centre. The weight of the beam is negligible.



Which diagram shows the forces acting on the beam?

(The length of each arrow represents the size of a force.)



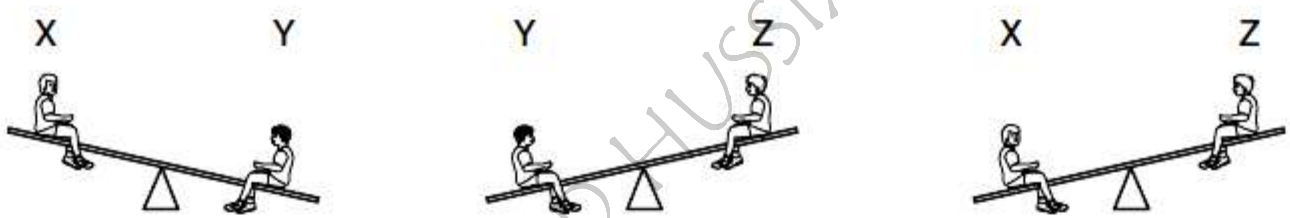
B

4. The weights of four objects, 1 to 4, are compared using a balance.

Which object is the lightest?

A. object 1
B. object 2
C. object 3
D. object 4

5. Three children, X, Y and Z, are using a see-saw to compare their weights.

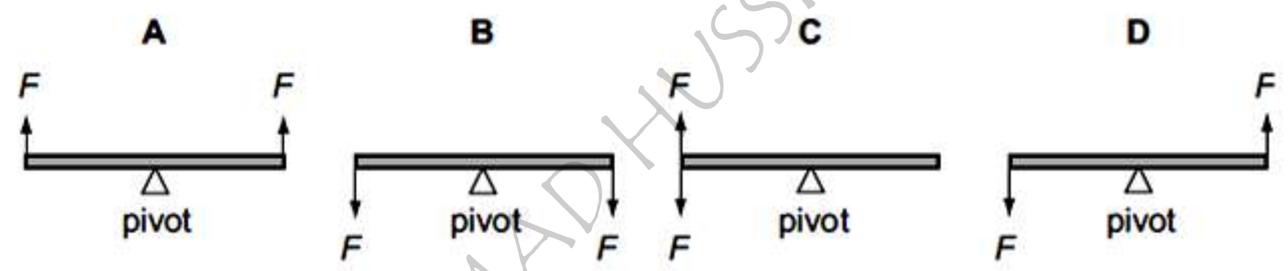


Which line in the table shows the correct order of the children's weights?

	heaviest ⟵	⟶	lightest
A	X	Y	Z
B	X	Z	Y
C	Y	X	Z
D	Y	Z	X

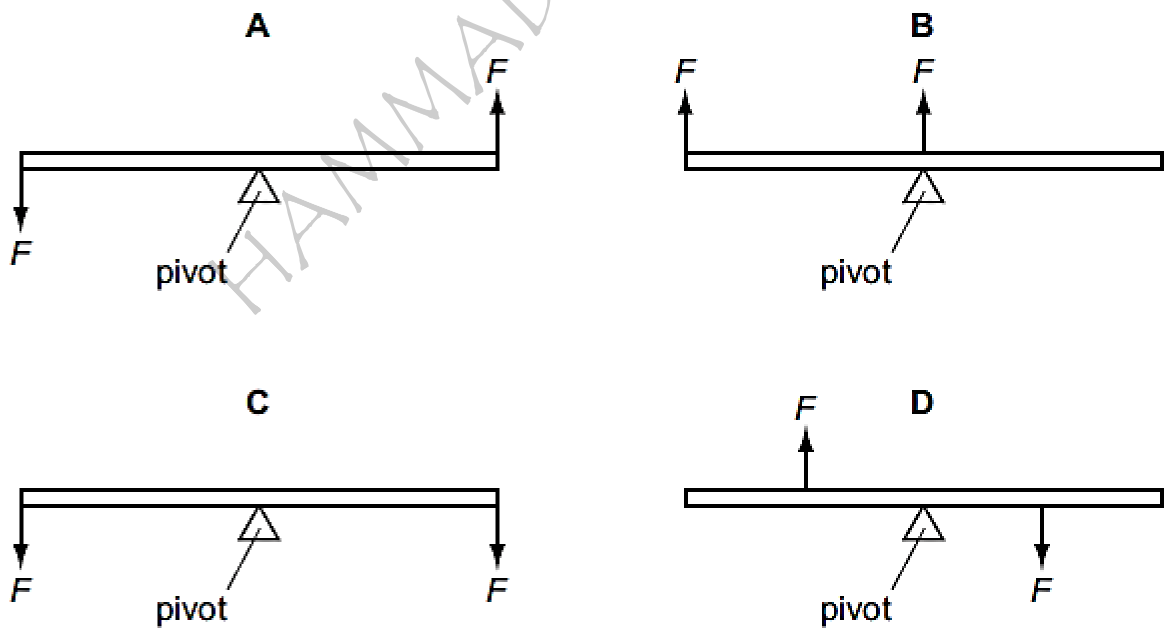
C

6. Two equal forces F act on each of four planks.
Which plank turns?



D

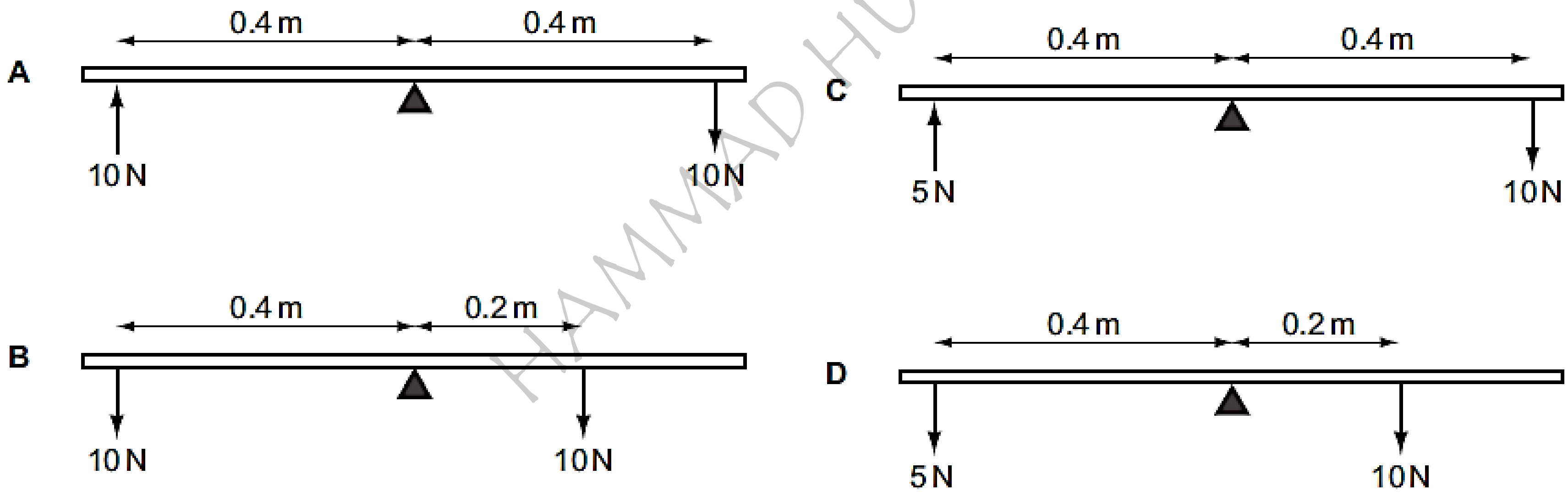
7. The diagrams show a uniform rod with its midpoint on a pivot.
8. Two equal forces *F* are applied to the rod, as shown.
9. Which diagram shows the rod in equilibrium?



C

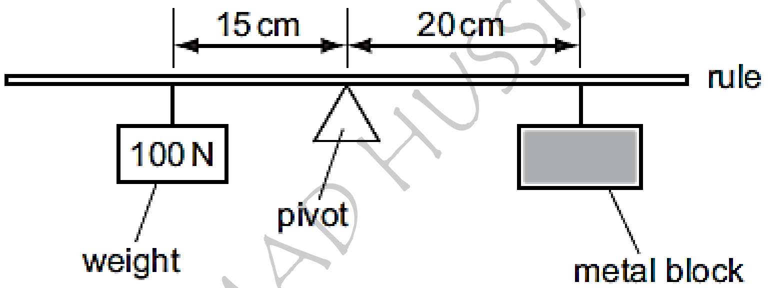
8. Forces are applied to a uniform beam pivoted at its centre.

9. Which beam is balanced?



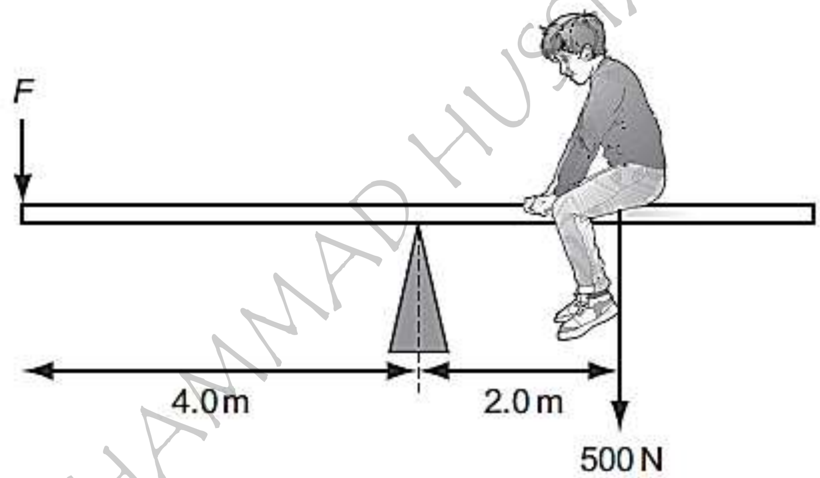
D

9. The diagram shows a uniform half-metre rule balanced at its mid-point.



1. What is the weight of the metal block?
   - A. 50 N
   - B. 75 N
   - C. 100 N
   - D. 150 N

10. The diagram shows a boy of weight 500 N sitting on a see-saw. He sits 2.0 m from the pivot.

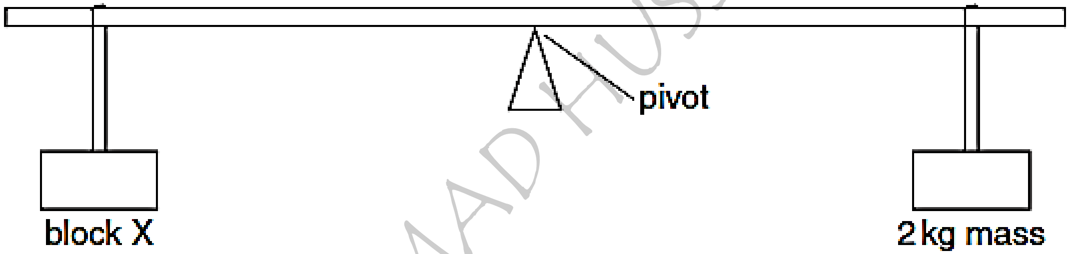


1. What is the force F needed to balance the see-saw?

A	250 N	**B**	750 N	**C**	1000 N	**D**	3000 N

A

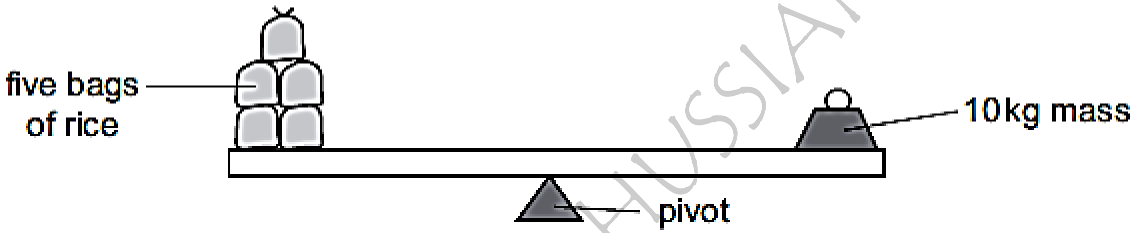
11. A beam is pivoted at its centre. Two masses are suspended at equal distances from the pivot as shown in the diagram.



Which statement is correct?

A. If X has a mass of exactly 2 kg, it will rise.
B. If X has a mass of less than 2 kg, it will fall.
C. If X has a mass of more than 2 kg, it will fall.
D. If X has a mass of more than 2 kg, it will rise.

12. In an experiment, five identical bags of rice are balanced by a 10 kg mass.

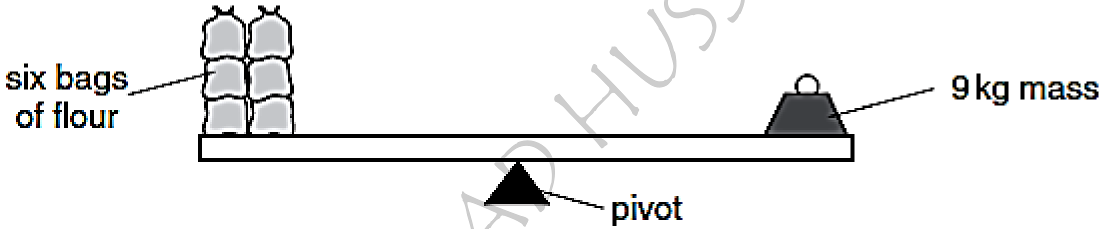


Two bags of rice are added to the other five.

What mass will now balance the bags?

A. 3.5 kg
B. 7.0 kg
C. 10 kg
D. 14 kg

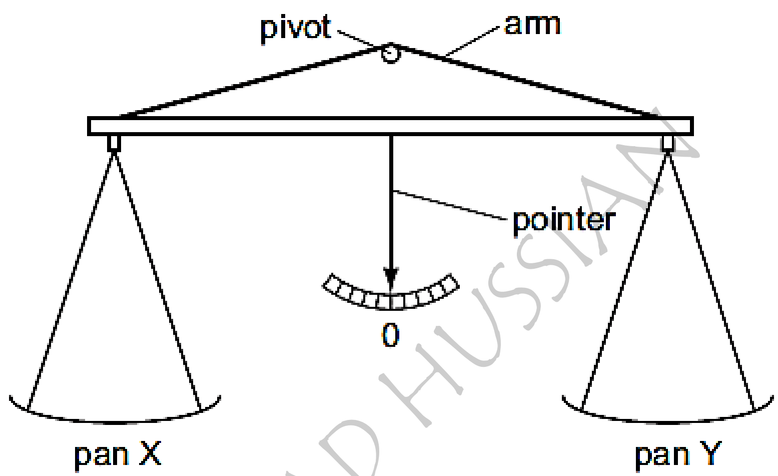
13. In an experiment, six identical bags of flour are balanced by a 9 kg mass.



Two bags of flour are removed. What mass will balance the remaining bags?

A. 3 kg
B. 6 kg
C. 7 kg
D. 9 kg

14. A simple balance has two pans suspended from the ends of arms of equal length. When it is balanced, the pointer is at 0.



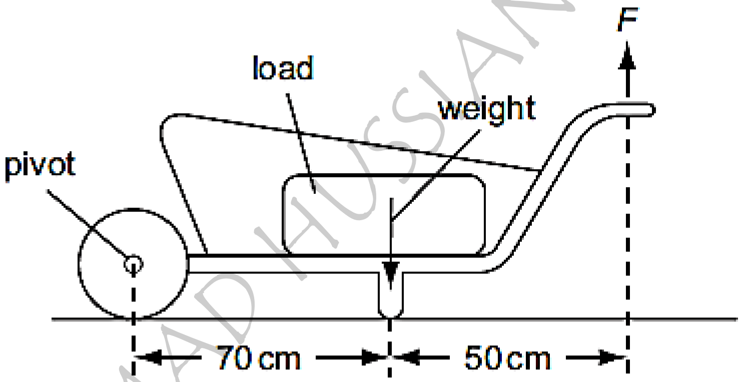
Four masses (in total) are placed on the pans, with one or more on pan X and the rest on pan Y.

Which combination of masses can be used to balance the pans?

A. 1 g, 1 g, 5 g, 10 g
B. 1 g, 2 g, 2 g, 5 g
C. 2 g, 5 g, 5 g, 10 g
D. 2 g, 5 g, 10 g, 10 g

15. A load is to be moved using a wheelbarrow. The total mass of the load and wheelbarrow is 60 kg.

The gravitational field strength is 10 N / kg.



What is the size of force F needed just to lift the loaded wheelbarrow?

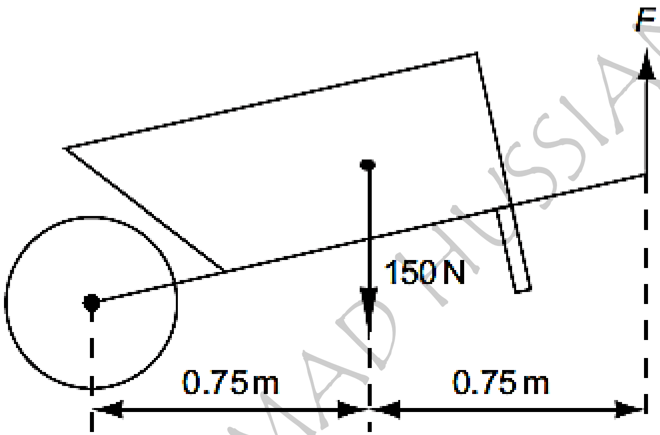
A. 350 N

B. 430 N

C. 600 N

D. 840 N

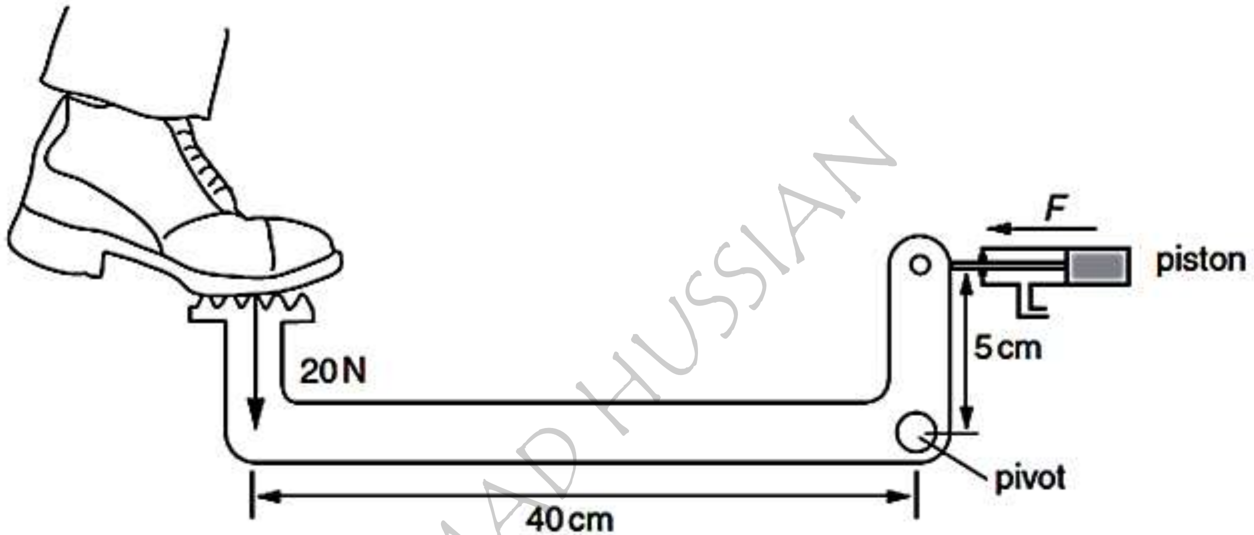
16. The diagram shows a wheelbarrow and its load, which have a total weight of 150 N. This is supported by a vertical force F at the ends of the handles.



What is the value of F?

A. 75 N
B. 150 N
C. 225 N
D. 300 N

17. A driver's foot presses with a steady force of 20 N on a pedal in a car as shown.



What is the force F pulling on the piston?

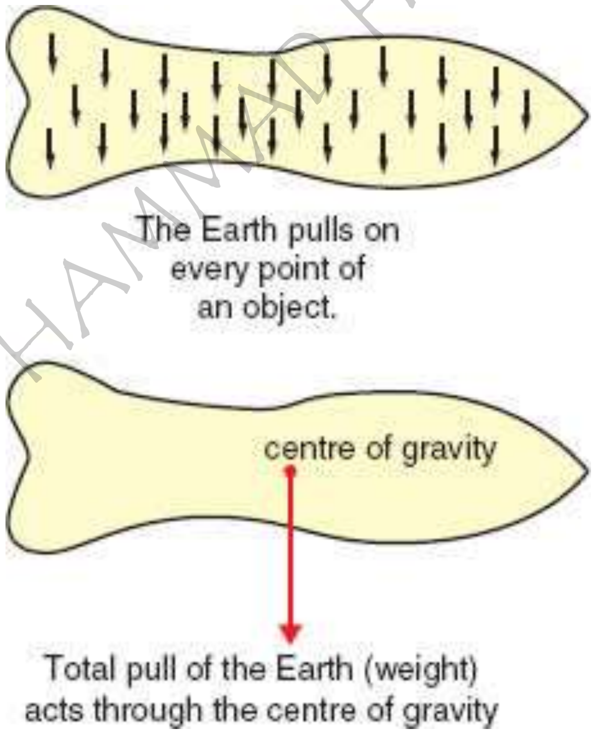
A. 2.5 N
B. 10 N
C. 100 N
D. 160 N

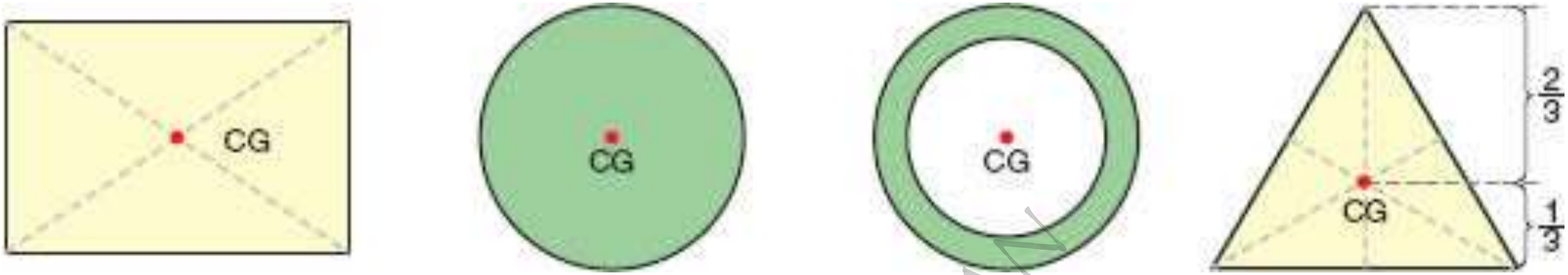
Centre of mass

- Describe how to determine the position of the centre of mass of a plane lamina.

Centre of Mass

- The weight of an object is due to the attraction of the Earth on all these particles.
- The **centre of mass** is the point through which the entire weight of the object appears to act.



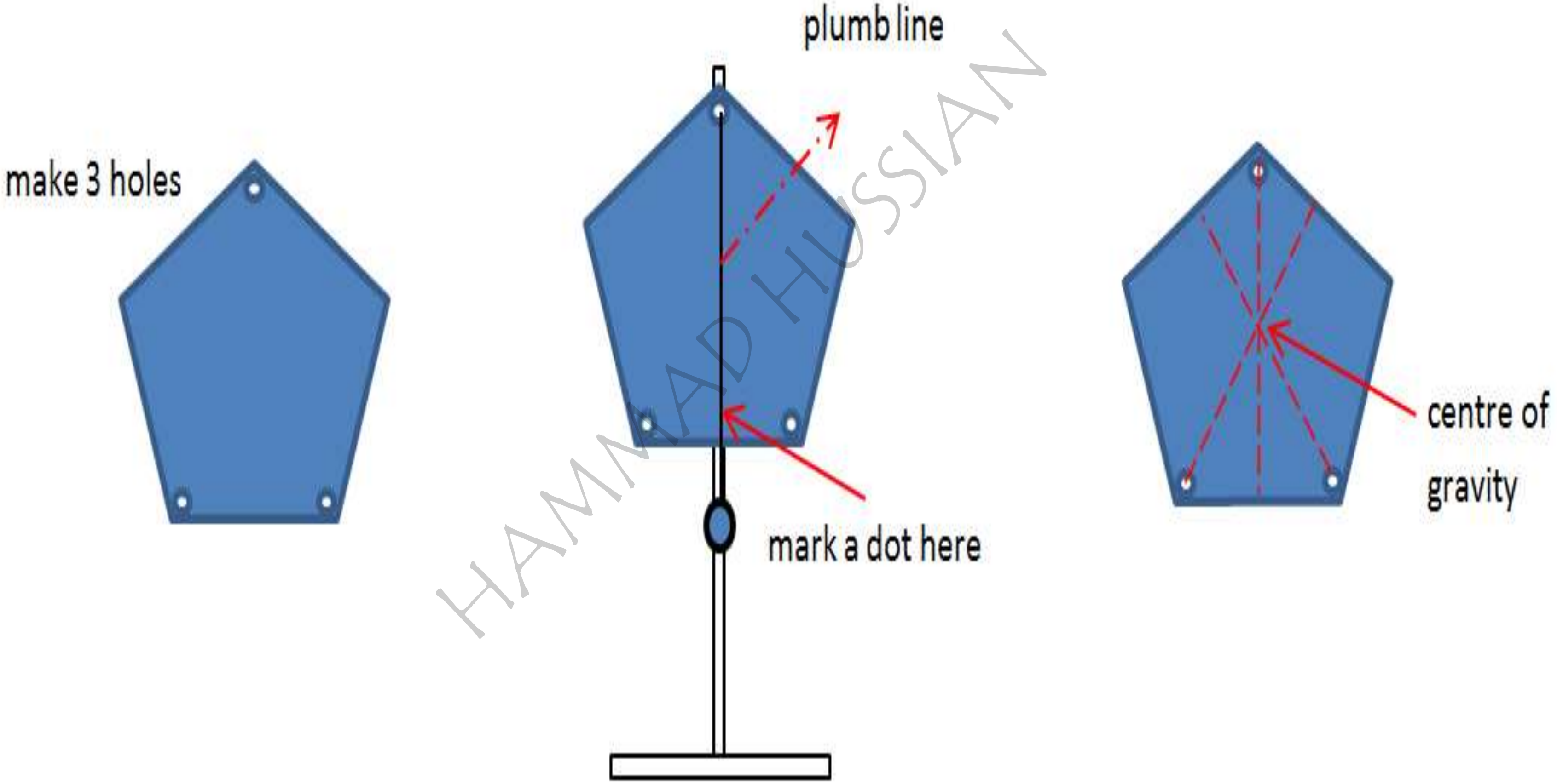


- Above diagram shows the positions of the centre of gravity for regular-shaped objects with uniform thickness.
- If the line of action of the weight of an object does not go through the pivot, then a moment exists makes the object to turn.
- The object will turn until where it reaches where there is no moment.
- This fact enable us to find the centre of gravity of an irregular shaped object.

Experiment

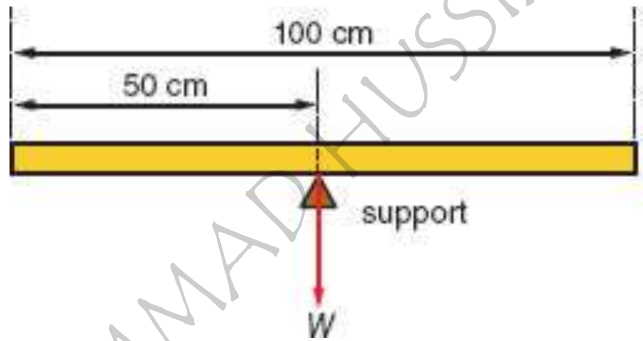
- Aim: To determine the centre of mass of a plane lamina
- Apparatus:
  - Retort stand
  - Cork
  - Plumb line
  - Lamina

- Procedure:
  - On the lamina, make three holes near the edge of the lamina.
  - Suspend the lamina through one of the holes.
  - Hang the plumb line on the pin.
  - When the plumb line is steady, make a dot on the position of the line at the edge of the lamina
  - Repeat steps 2-4 for the other two holes
- Conclusion
  - The point where the lines meet is the centre of mass of the body.

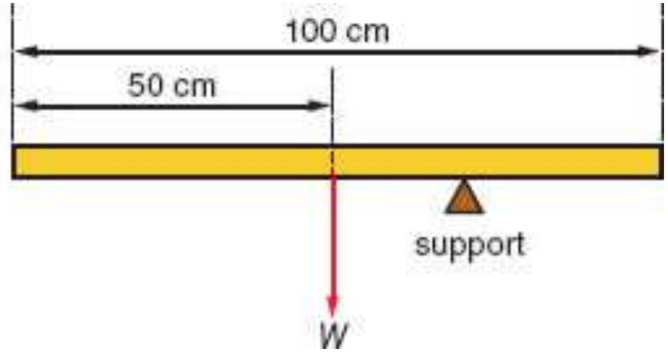

make 3 holes
plumb line
mark a dot here
centre of
gravity

Applying the Principle of Moment

- For a regular object such as uniform metre ruler, the centre of gravity is at its centre and, when supported there the object will be balanced

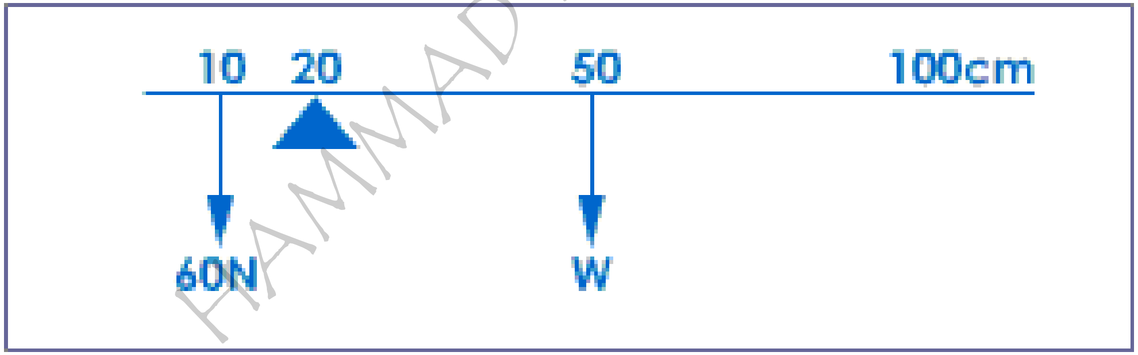


- If it supported at any other point, it will topple because there will be a resultant moment about the point of support.

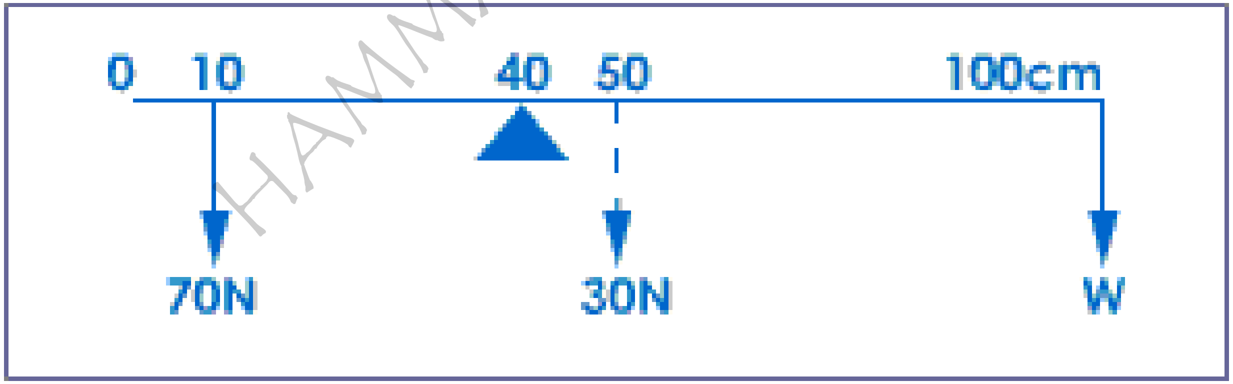


Example

1. The illustration in figure below represents a metre scale balancing on a knife edge at 20 cm mark when a weight of 60 N is suspended from 10 cm mark. Calculate the weight of the ruler.

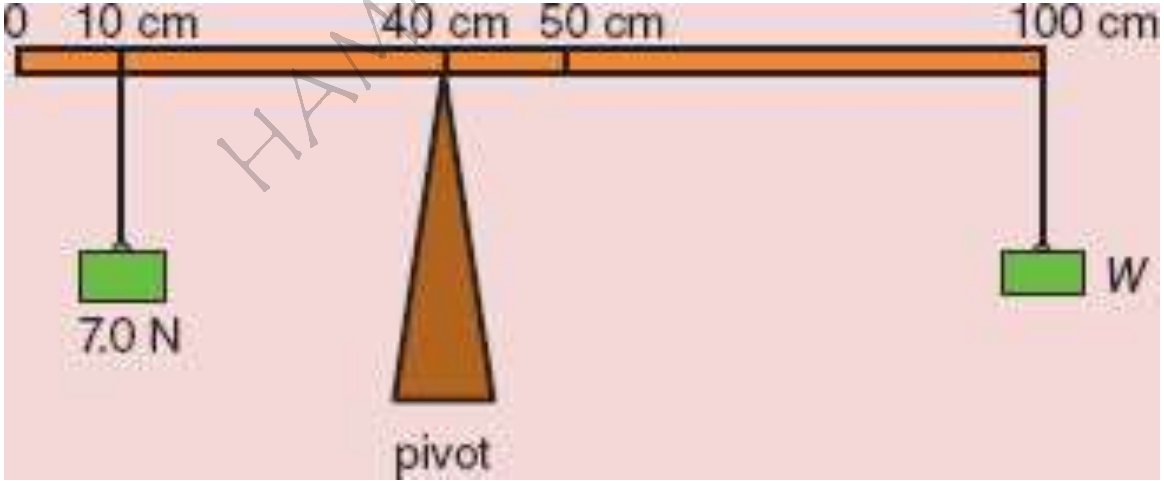


2. Figure below shows a uniform metre rule weighing 30 N pivoted on a wedge placed under the 40 cm mark and carrying a weight of 70 N hanging from the 10 cm mark. The ruler is balanced horizontally by a weight W hanging from the 100 cm mark. Calculate the value of the weight W.

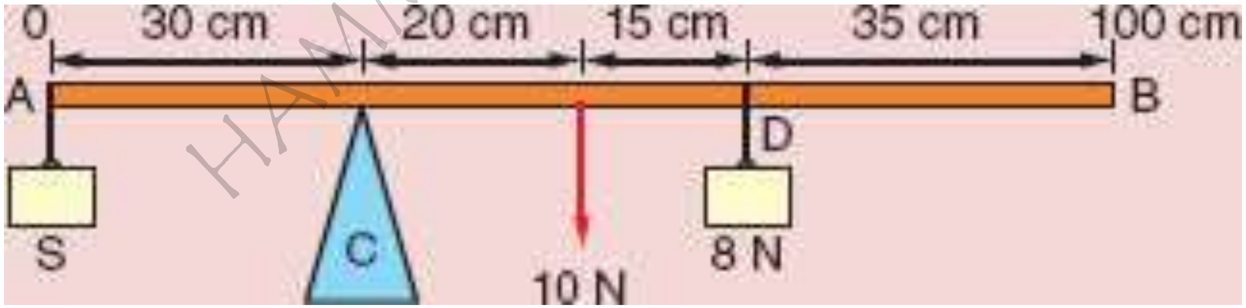


3. Figure below shows a uniform metre rule pivoted off-centre but maintained in equilibrium by a suspended weight of 2.4 N. The weight is hung 5 cm from one end of the metre rule. What is the weight of the metre rule?

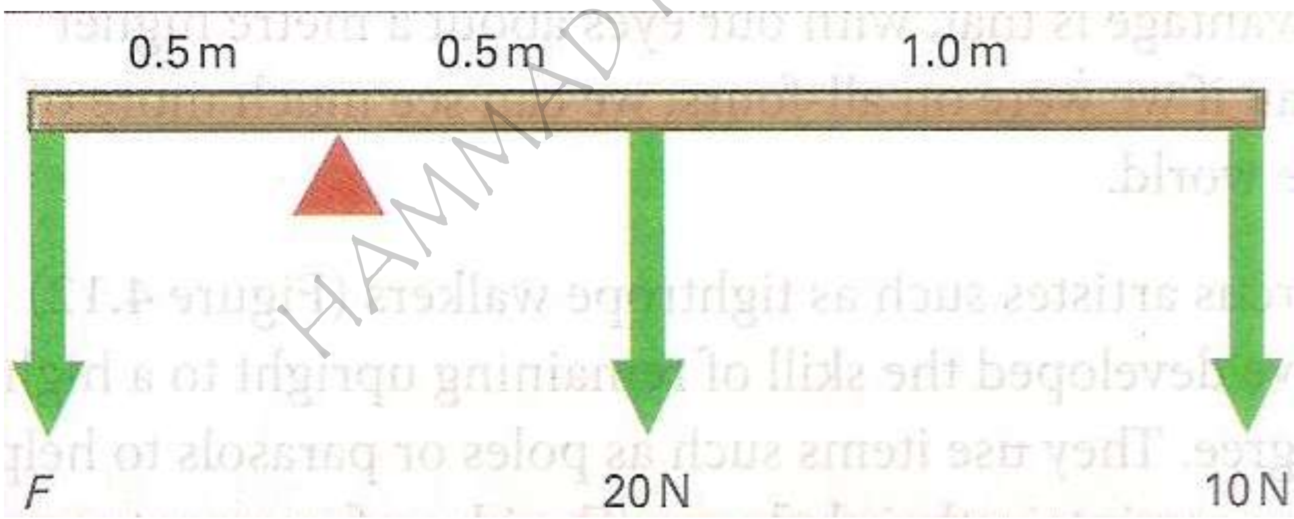
4. Figure below shows a uniform metre rule weighing 3.0 N pivoted on a wedge placed under the 40 cm mark and carrying a weight of 7.0 N hanging from the 10 cm mark. The rule is kept horizontally by a weight *W* hanging from the 100 cm end. Calculate the value of the weight *W*.



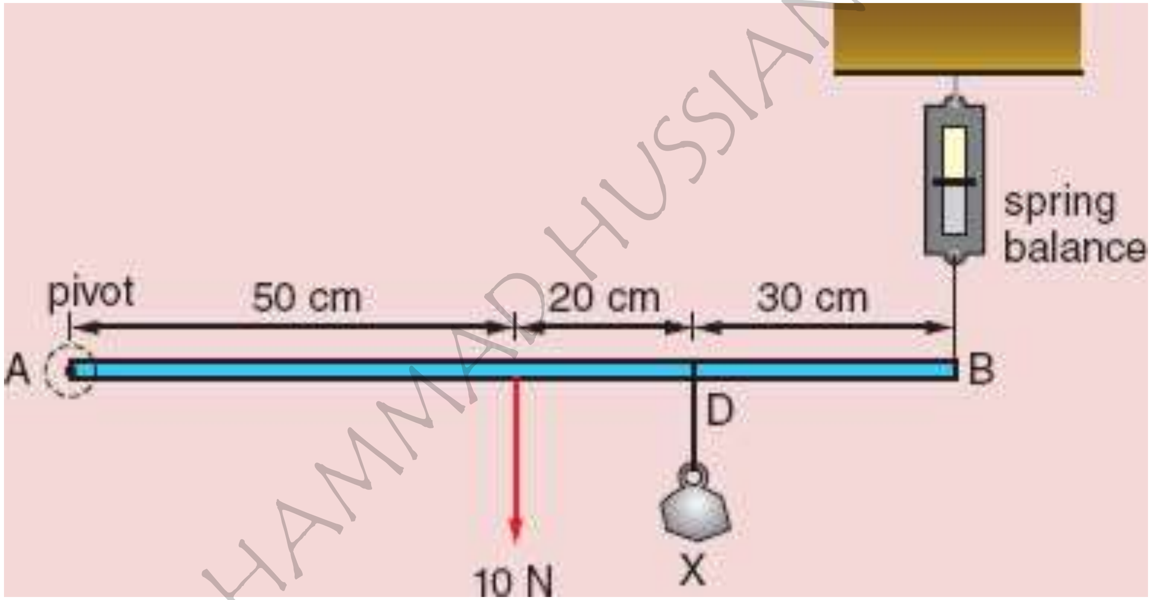
5. Figure below represents a uniform horizontal rod weighing 10 N and of length 100 cm. The rod is balanced on a knife-edge at C, when a weight of 8 N is suspended from the point D and a solid S, of unknown weight is suspended from A. Calculate the weight of the solid S.



6. The beam shown below is 2.0 m long and has a weight of 20 N. It is pivoted as shown. A force of 10 N acts at one end. What force F must be applied downwards at the other end to balance the beam?



7. Figure below represents a horizontal uniform rod AB of weight 10 N and length 100 cm, pivoted at A. An irregular solid X, is suspended 30 cm from the end B. The end B is supported by a spring balance which reads 19 N



a) Calculate the weight of the irregular solid X.

b) What is the mass of the solid if g = 10 m s^{-2}

Stability

- Describe qualitatively the effect of the position of the centre of mass on the stability of simple objects.

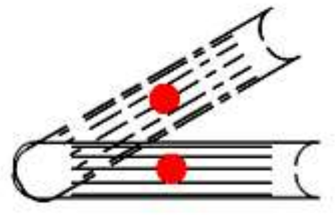
Stability

- Stability is the measure of a body’s ability to maintain its original position.
- The degree of stability in an object's position depends on how must its center of gravity will be changed if it is moved.
- There are three states of equilibrium:
  - **Stable equilibrium**
  - **Unstable equilibrium**
  - **Neutral equilibrium**

Stable equilibrium

- If the body returns to its original position after being displaced slightly it is said to be in **stable equilibrium**.

Explanation



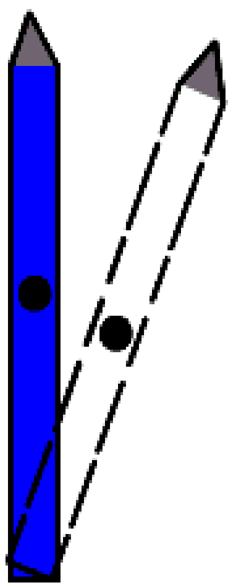
If the book is lifted from one edge and then allowed to fall, it will come back to its original position.

Reason of stability

When the book is lifted its center of gravity is raised. The line of action of weight passes through the base of the book. A moment due to weight of the book brings it back to the original position.

Unstable equilibrium

- If the body continues to move away from its original position after being displaced, it is said to be in **unstable equilibrium**.



Explanation

If thin rod standing vertically is slightly disturbed from its position it will not come back to its original position.

Reason of instability

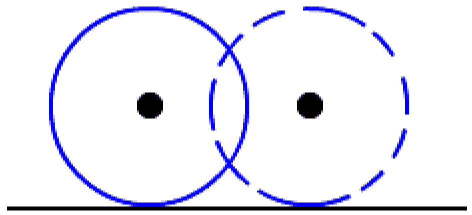
When the rod is slightly disturbed its center of gravity is lowered . The line of action of its weight lies outside the base of rod. The moment due to weight of the rod toppled it down.

Neutral equilibrium

- If an object remains wherever it is after being displaced, it is said to be in **neutral equilibrium.**

Explanation

If a ball is pushed slightly to roll, it will neither come back to its original nor it will roll forward rather it will remain at rest.

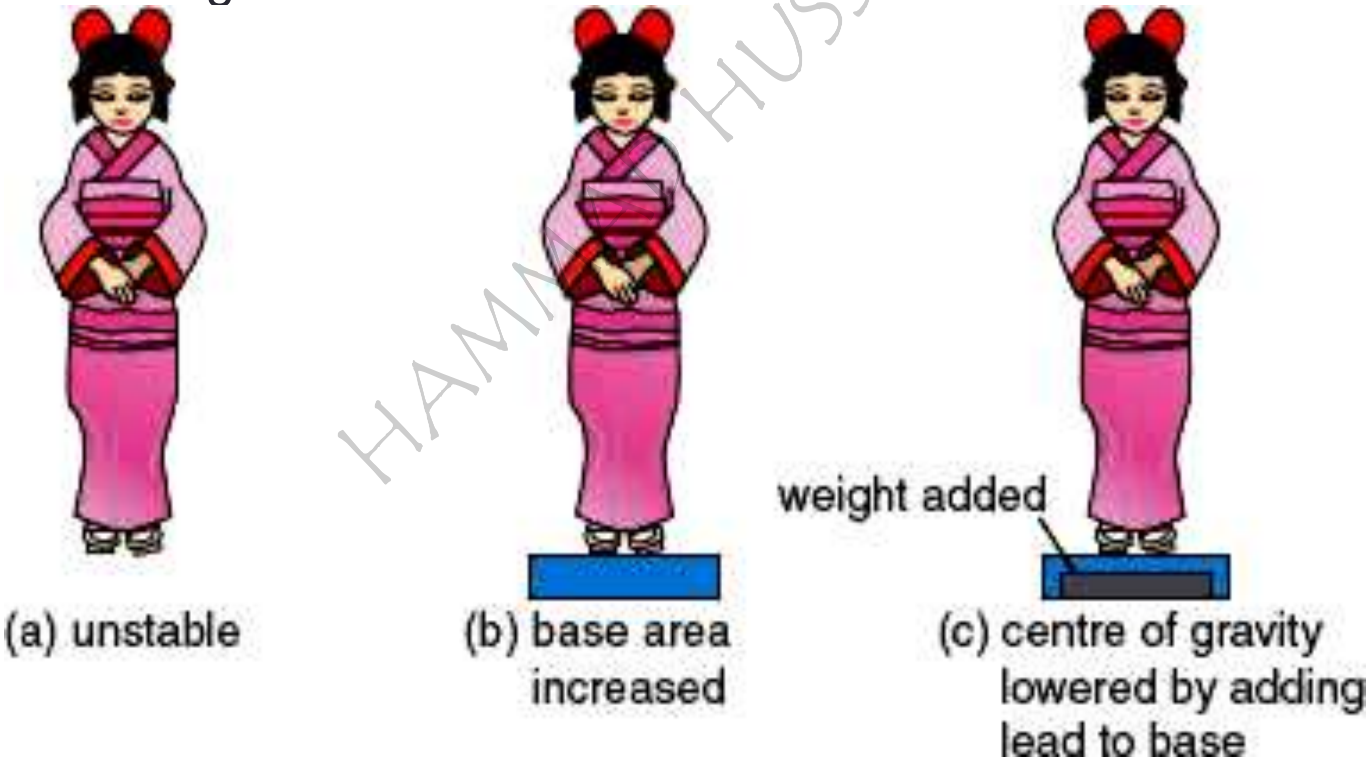


Reason of neutral equilibrium

If the ball is rolled, its center of gravity is neither raised nor lowered. This means that its center of gravity is at the same height as before.

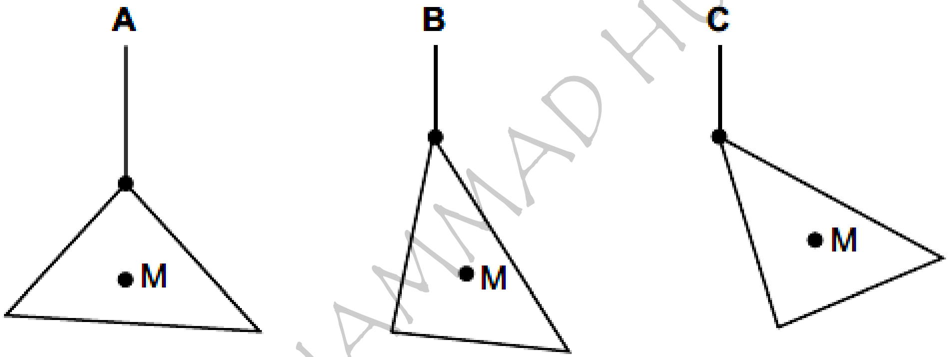
Designing for Stability

- There are two ways to make a body more stable.
  1. Lowering its centre of gravity;
  2. Increasing the area of its base.



1. A piece of card has its centre of mass at M.

Which diagram shows how it hangs when suspended by a thread?

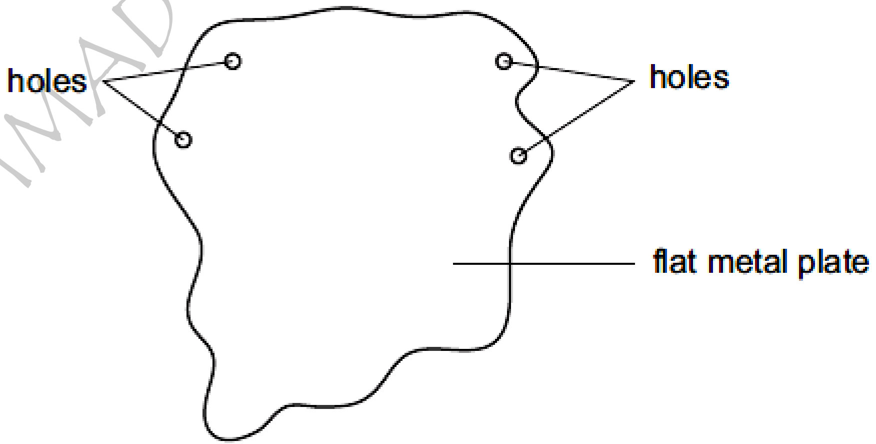


A

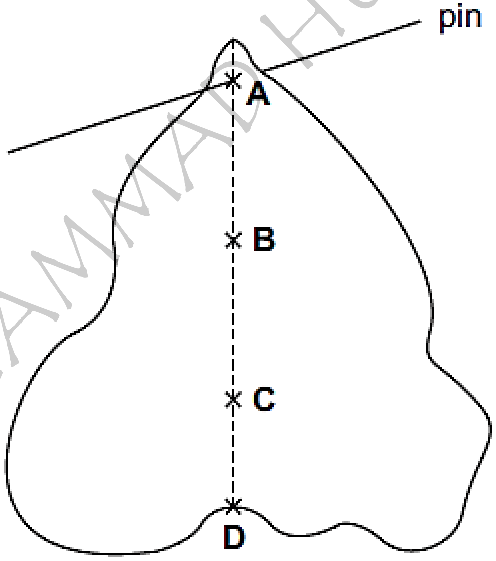
2. The diagram shows a flat metal plate that may be hung from a nail so that it can rotate about any of four holes.

   What is the smallest number of holes from which the flat metal plate should be hung in order to find its centre of gravity?

   A. 1
   B. 2
   C. 3
   D. 4

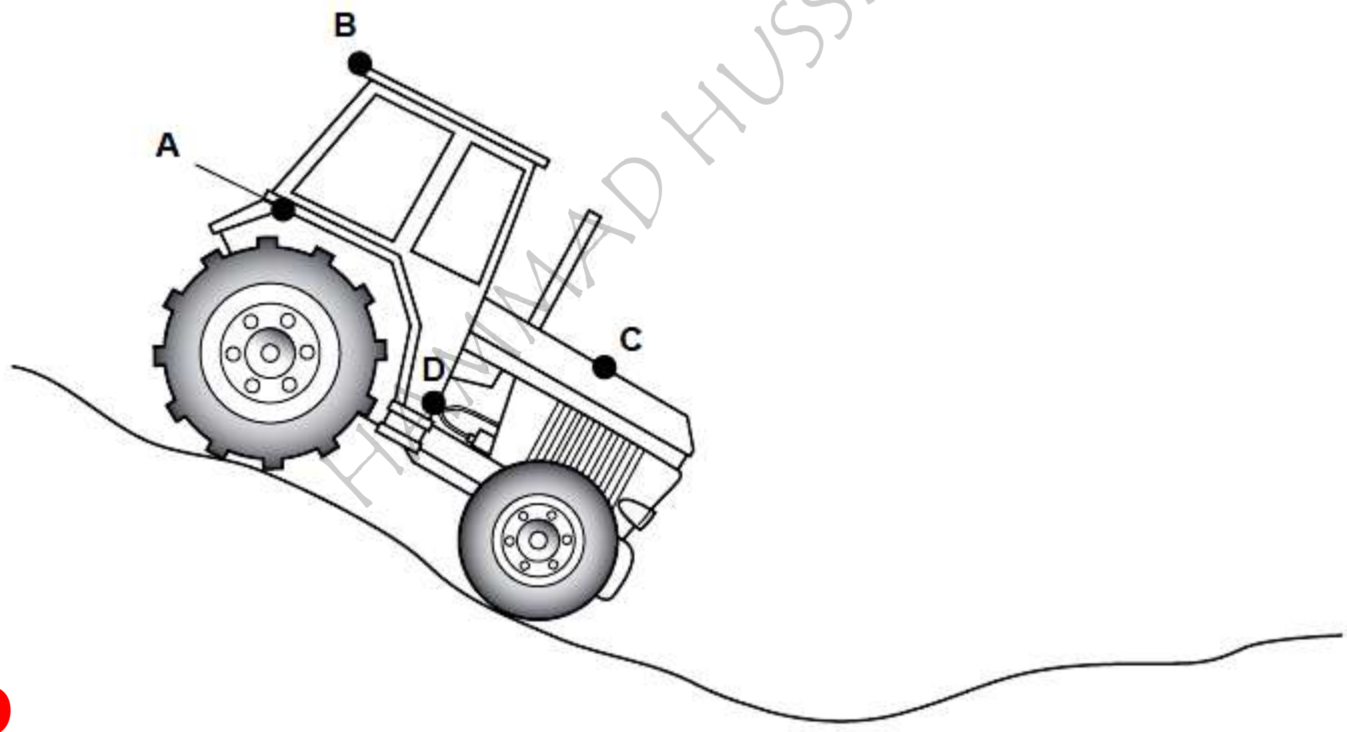


3. A piece of uniform card is suspended freely from a horizontal pin.
4. At which of the points shown is its centre of gravity?



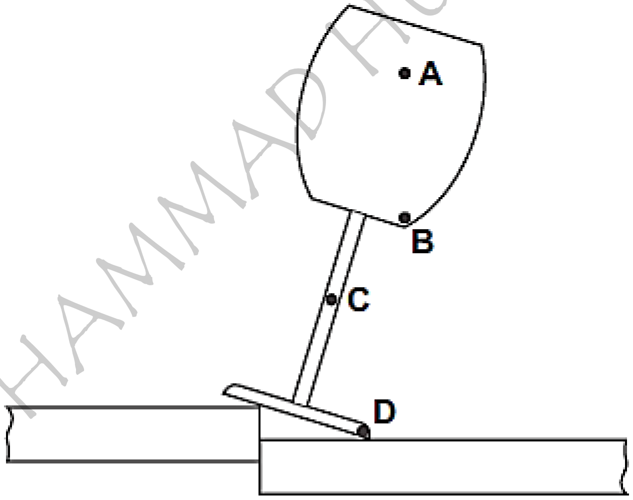
C

4. A tractor is being used on rough ground.
What is the safest position for its centre of mass?



D

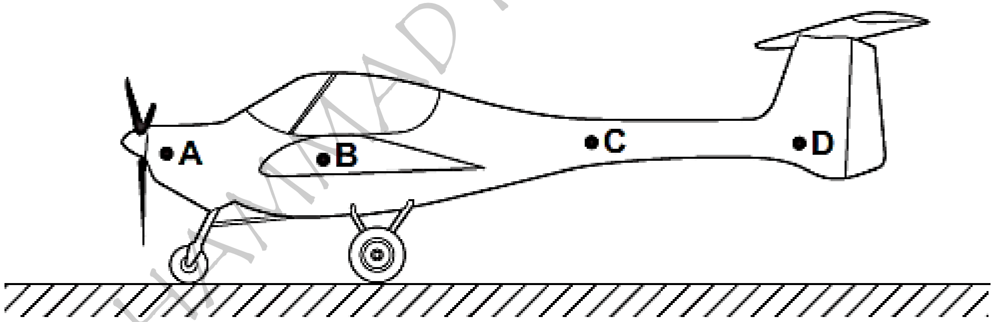
5. An empty glass is placed on a join between two tables as shown. The glass remains stable.
6. Which point is the centre of mass of the glass?



C

6. A light aircraft stands at rest on the ground. It stands on three wheels, one at the front and two further back.

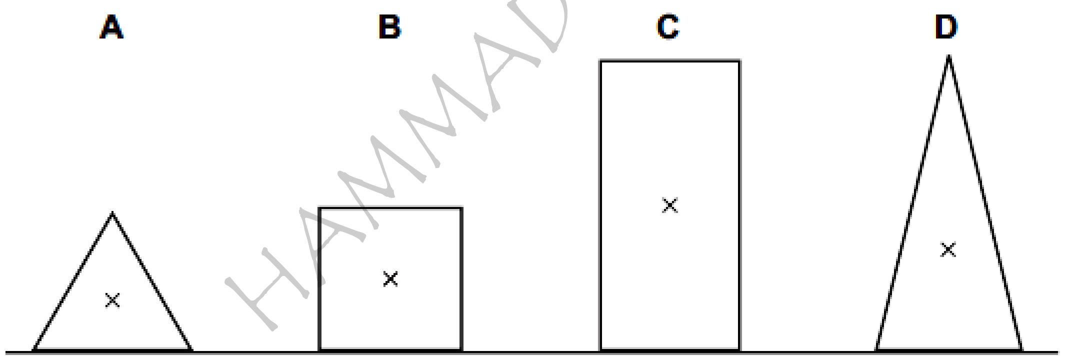
7. Which point could be its centre of mass?



B

7. The diagram shows sections of four objects of equal mass. The position of the centre of mass of each object has been marked with a cross.

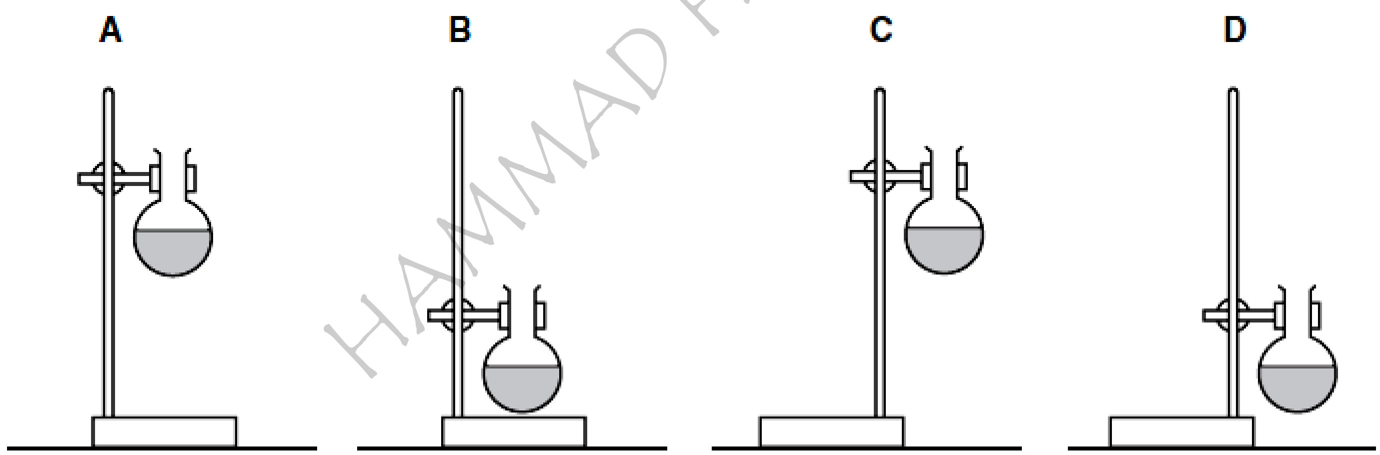
Which object is the most stable?



A

8. A student uses a stand and clamp to hold a flask of liquid.

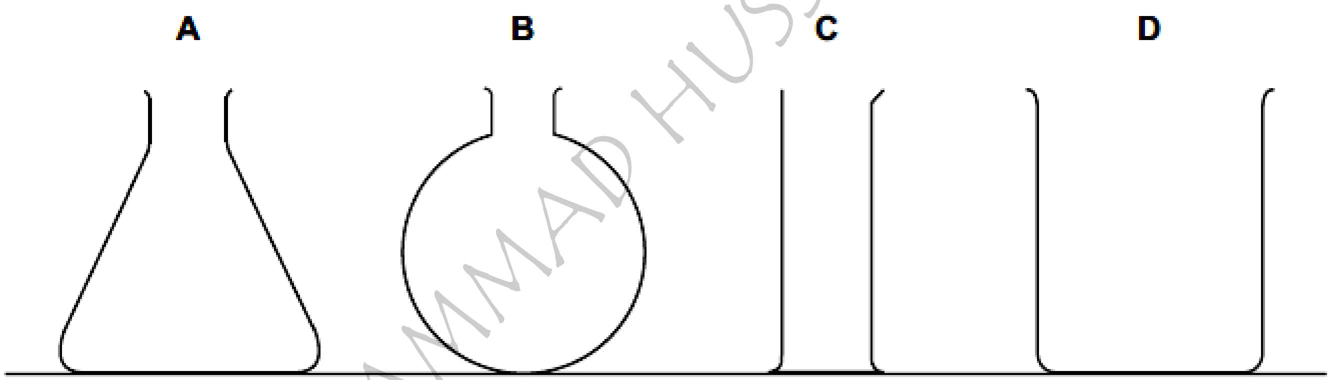
Which diagram shows the most stable arrangement?



B

9. Some containers are made from thin glass.

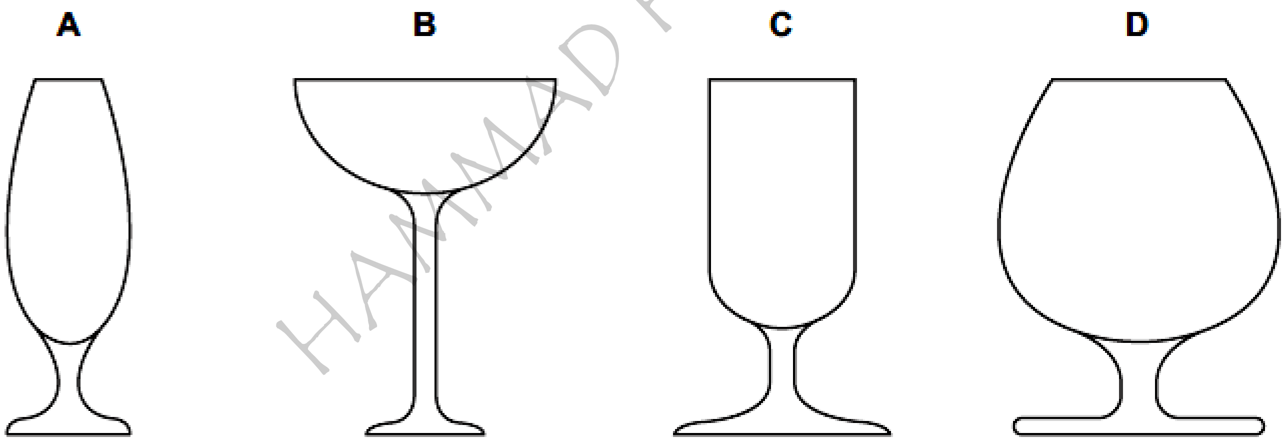
Which empty container is the most stable?



A

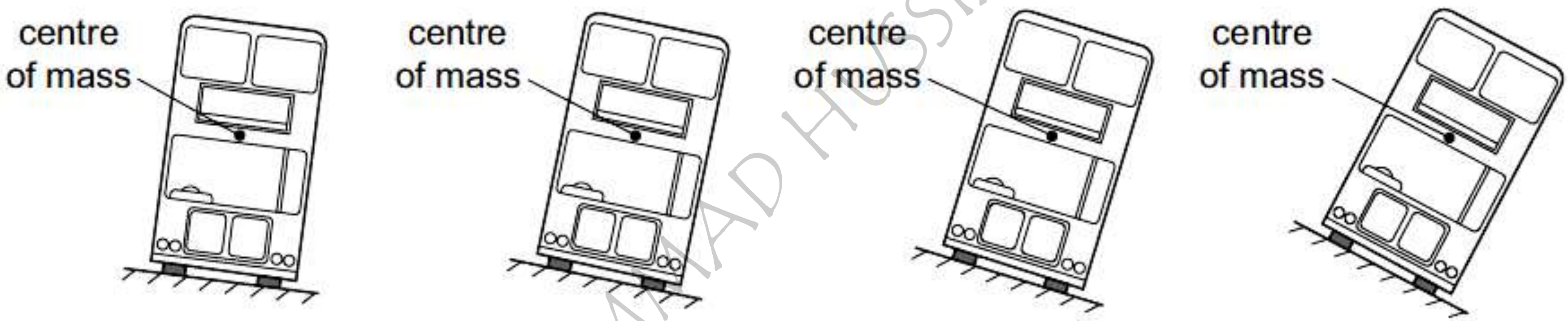
10. The diagrams show the cross-sections of different glasses.

Which one is the least stable when filled with a liquid?



B

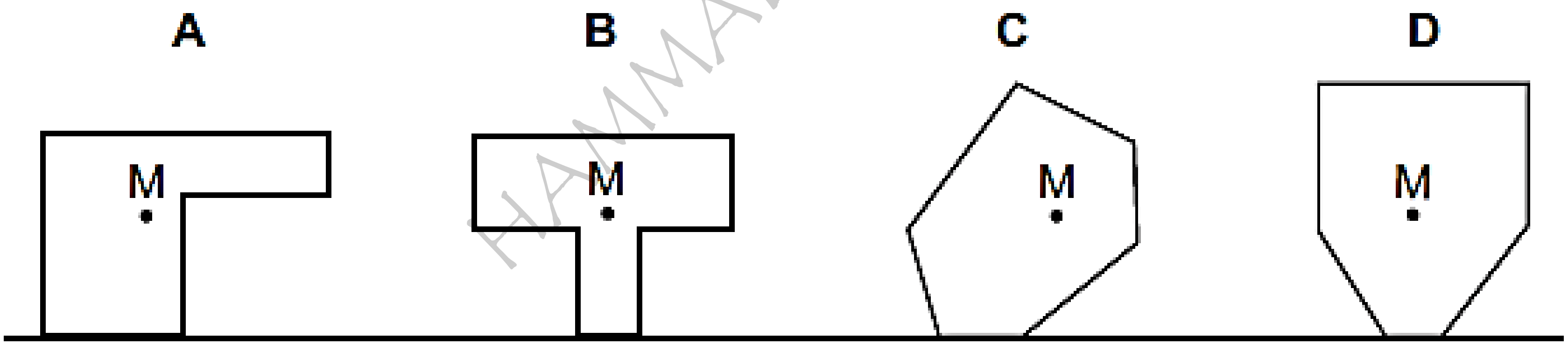
11. The diagram shows four models of buses placed on different ramps.



How many of these models will fall over?

A. 1
B. 2
C. 3
D. 4

12. The diagram shows four objects standing on a flat surface.
13. The centre of mass of each object is marked M.
14. Which object will fall over?

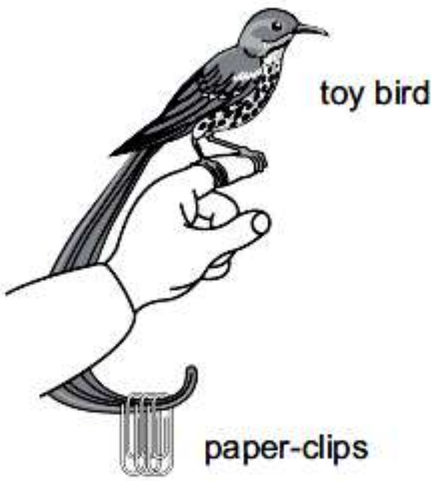


C

13. A girl uses paper-clips to balance a toy bird on her finger as shown.

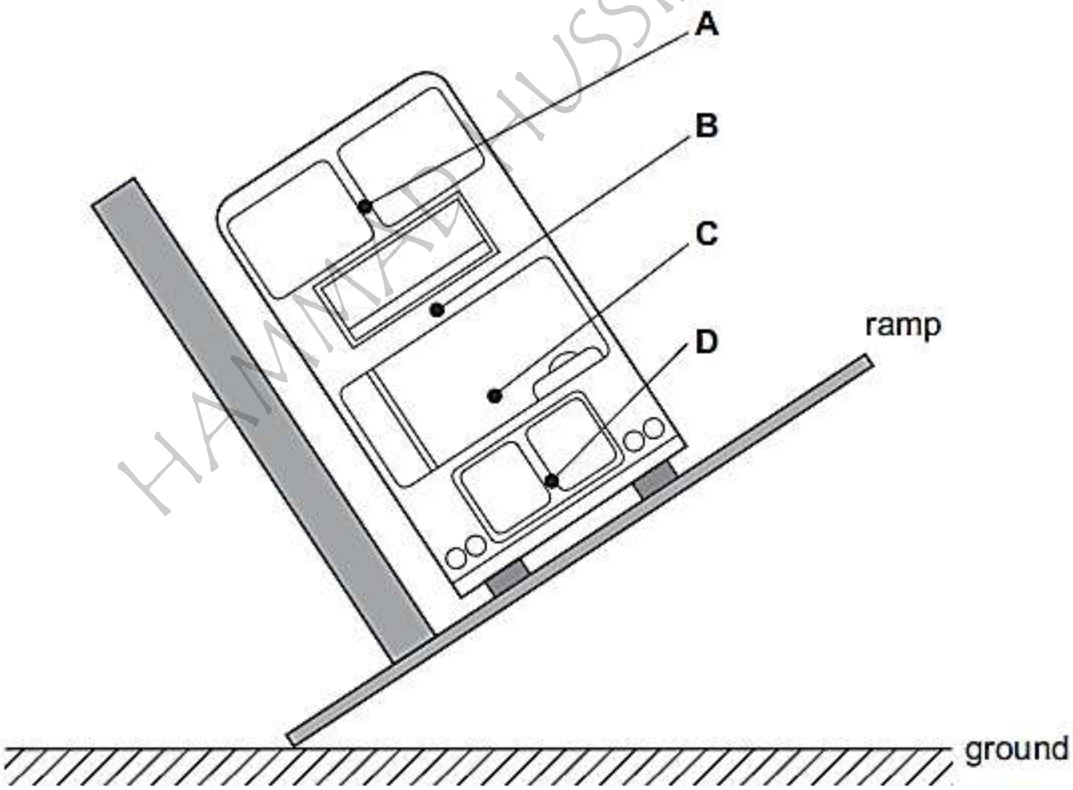
What is the effect of the paper-clips?

A. They help to raise the centre of mass above her finger.
B. They help to raise the centre of mass to her finger.
C. They help to lower the centre of mass below her finger.
D. They do not affect the centre of mass but increase the weight.



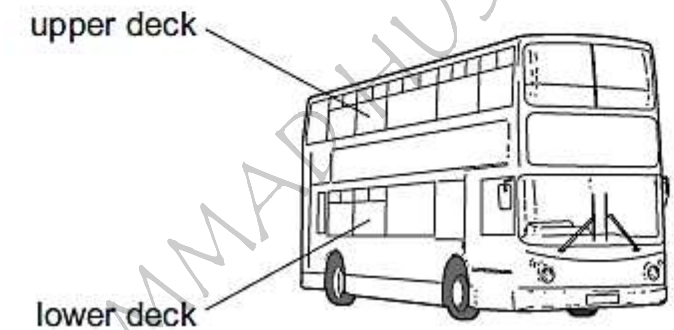
14. The stability of a bus is tested by tilting it on a ramp. The diagram shows a bus that is just about to topple over.

Where is the centre of mass of the bus?



C

15. Passengers are not allowed to stand on the upper deck of double-decker buses.



Why is this?

A. They would cause the bus to become unstable.
B. They would cause the bus to slow down.
C. They would increase the kinetic energy of the bus.
D. They would lower the centre of mass of the bus.