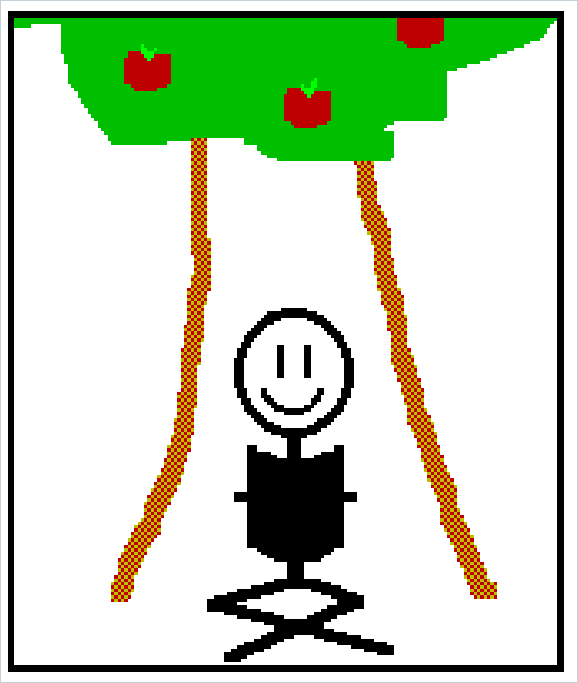
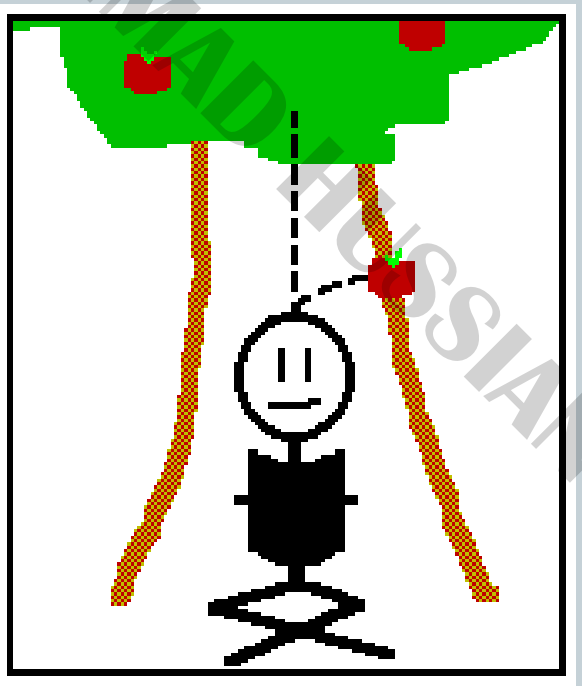
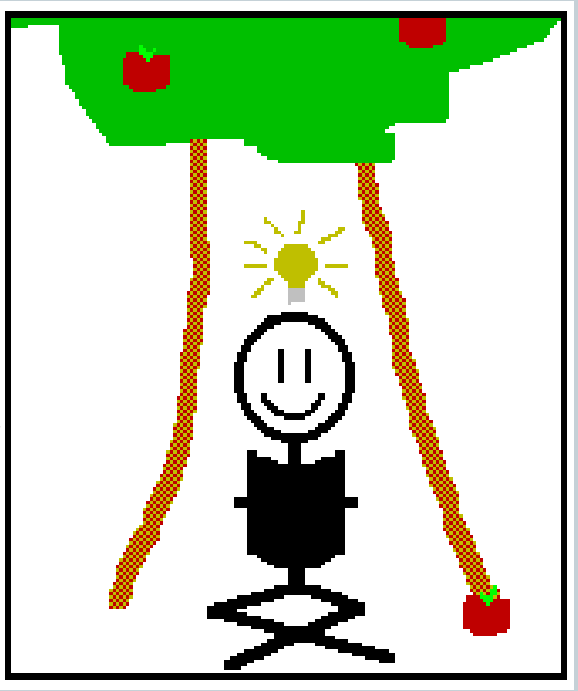
The Apple Tree







The descendant of the tree that grew in Sir Isaac Newton's garden at Woolsthorpe Manor in Linconshire, England

It is reputed to have inspired his Law of Universal Gravitation

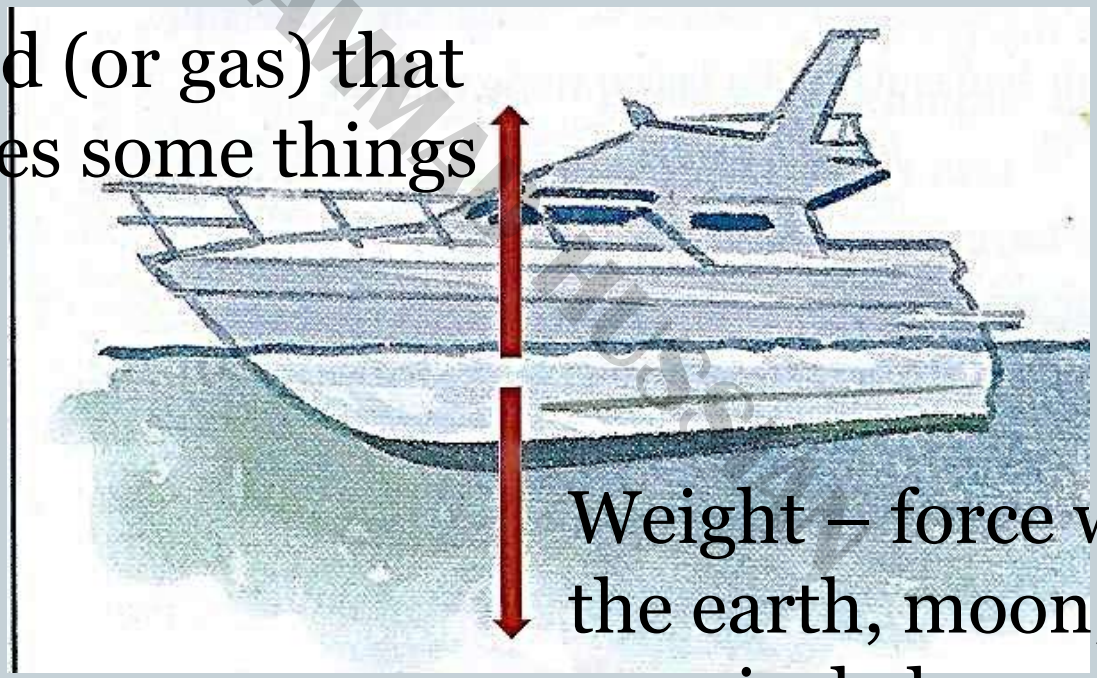
Newton's Apple Tree

Forces

- A force is a push or pull acting upon an object as a result of its interaction with another object.
- A force can….
  - ***move*** *a stationary object*
  - ***stop*** *a moving object*
  - *change the* ***shape / size*** *of an object*
  - *change the* ***direction / speed*** *of an object*
- Force is a *vector* quantity .
- The S.I. unit for force is *kg m/s²* or *newton, N*

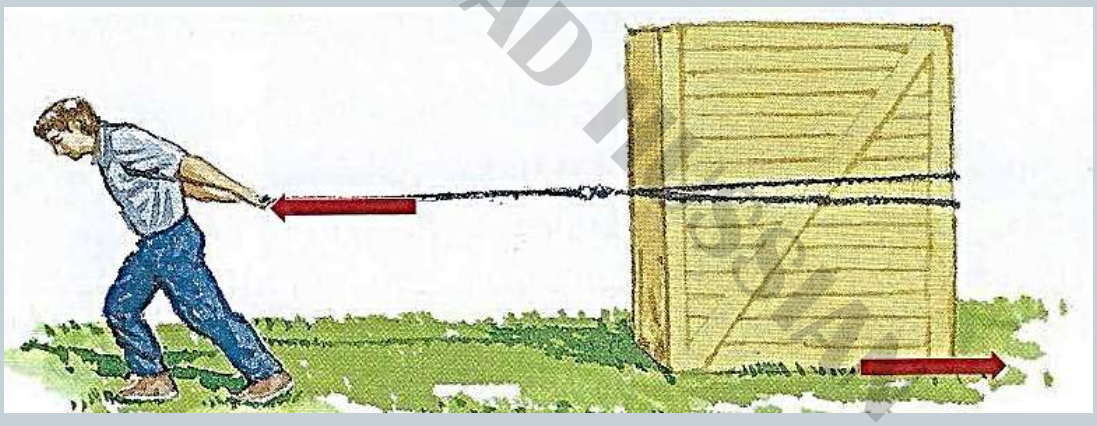
Type of Forces

Upthrust – the upward force from a liquid (or gas) that makes some things float



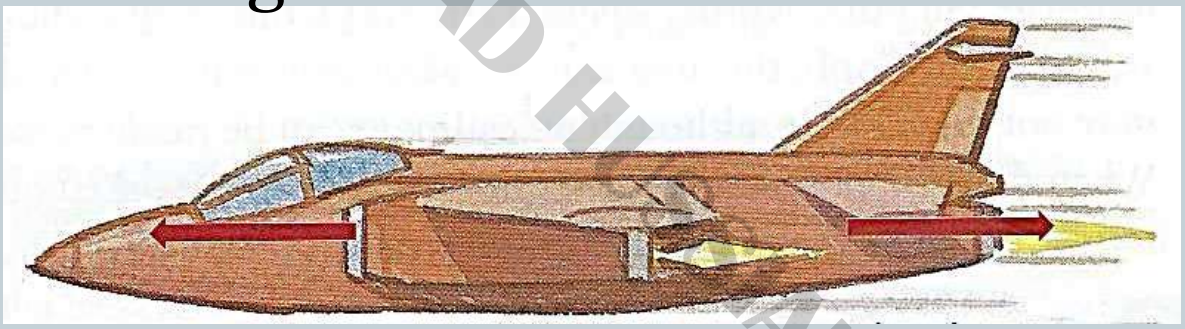
Weight – force with which the earth, moon, or other massively large object attracts another object towards itself

Tension – force which is transmitted through a string, rope, cable or wire when it is pulled tight by forces acting from opposite ends



Friction – force exerted by a surface as an object moves across it or makes an effort to move across it

Thrust – the forward force from an aircraft engine



Air Resistance (Drag) – a special type of frictional force which acts upon objects as they travel through the air.

Dynamics

7

BALANCED AND UNBALANCED FORCES
FRICTION
CIRCULAR MOTION

Balanced and Unbalance Force

STATE NEWTON'S THIRD LAW

Newton's Third Law of Motion

- When you sit in your chair, your body exerts a downward force on the chair and the chair exerts an upward force on your body. There are two forces resulting from this interaction — a force on the chair and a force on your body. These two forces are called action and reaction forces and are the subject of Newton's third law of motion.
- Formally stated, Newton's third law is:

"***For every action, there is an equal and opposite reaction.***"

Balanced and Unbalance Force

10

DESCRIBE THE EFFECT OF BALANCED AND UNBALANCED FORCES ON A BODY

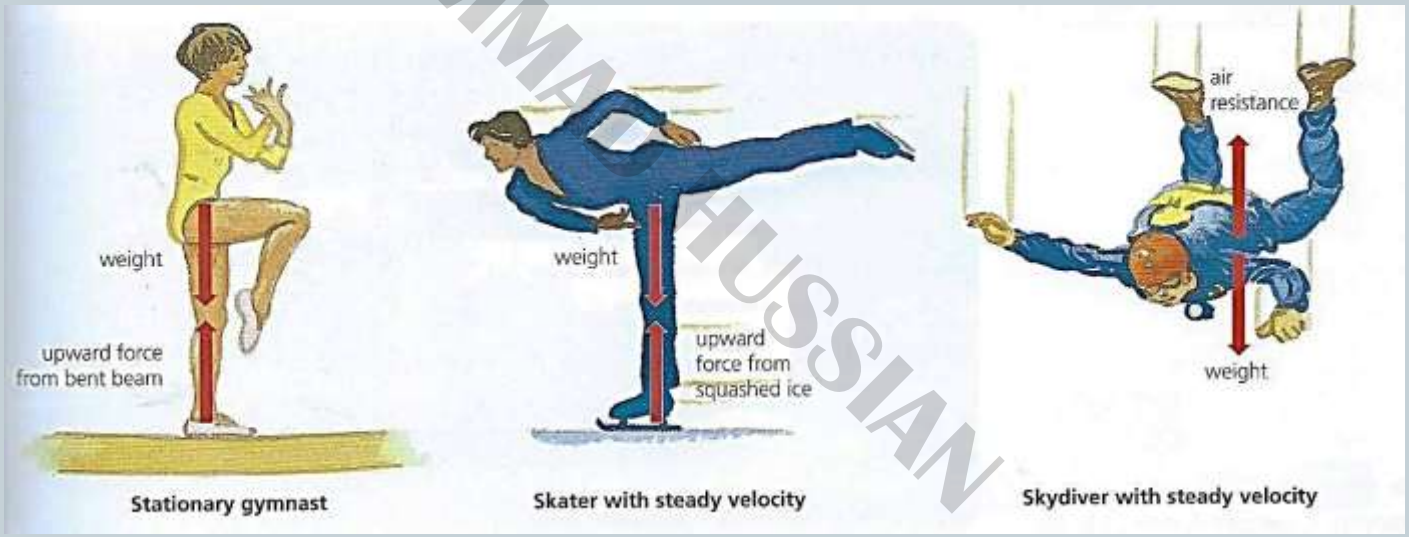
Balanced and Unbalance Force

11

DESCRIBE THE WAYS IN WHICH A FORCE MAY CHANGE THE MOTION OF A BODY

Balanced Forces

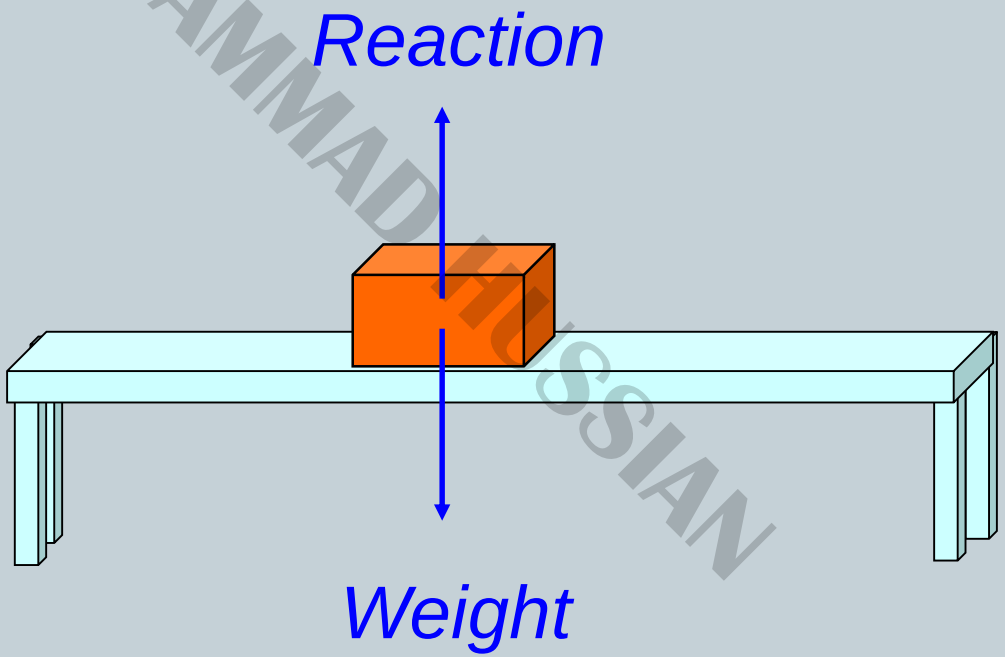
- When two forces acting on an object is balanced, the object can either be stationary or moving at constant speed.



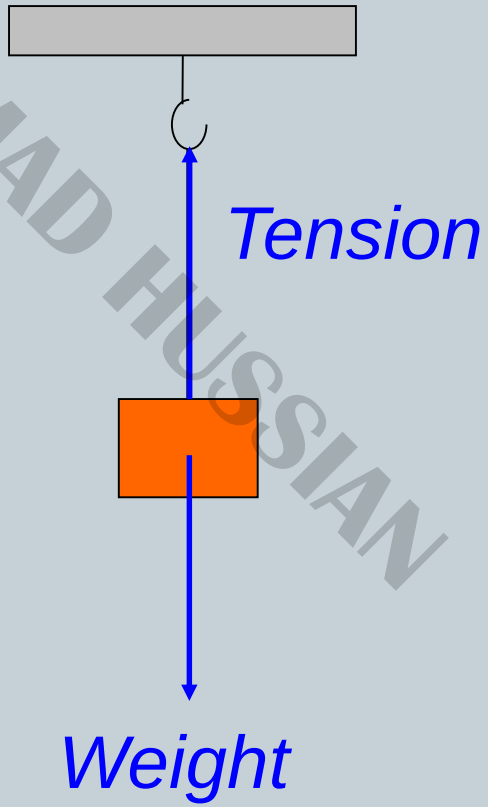
- Two forces are balanced when their magnitude is the same but they act in opposite directions.

Example

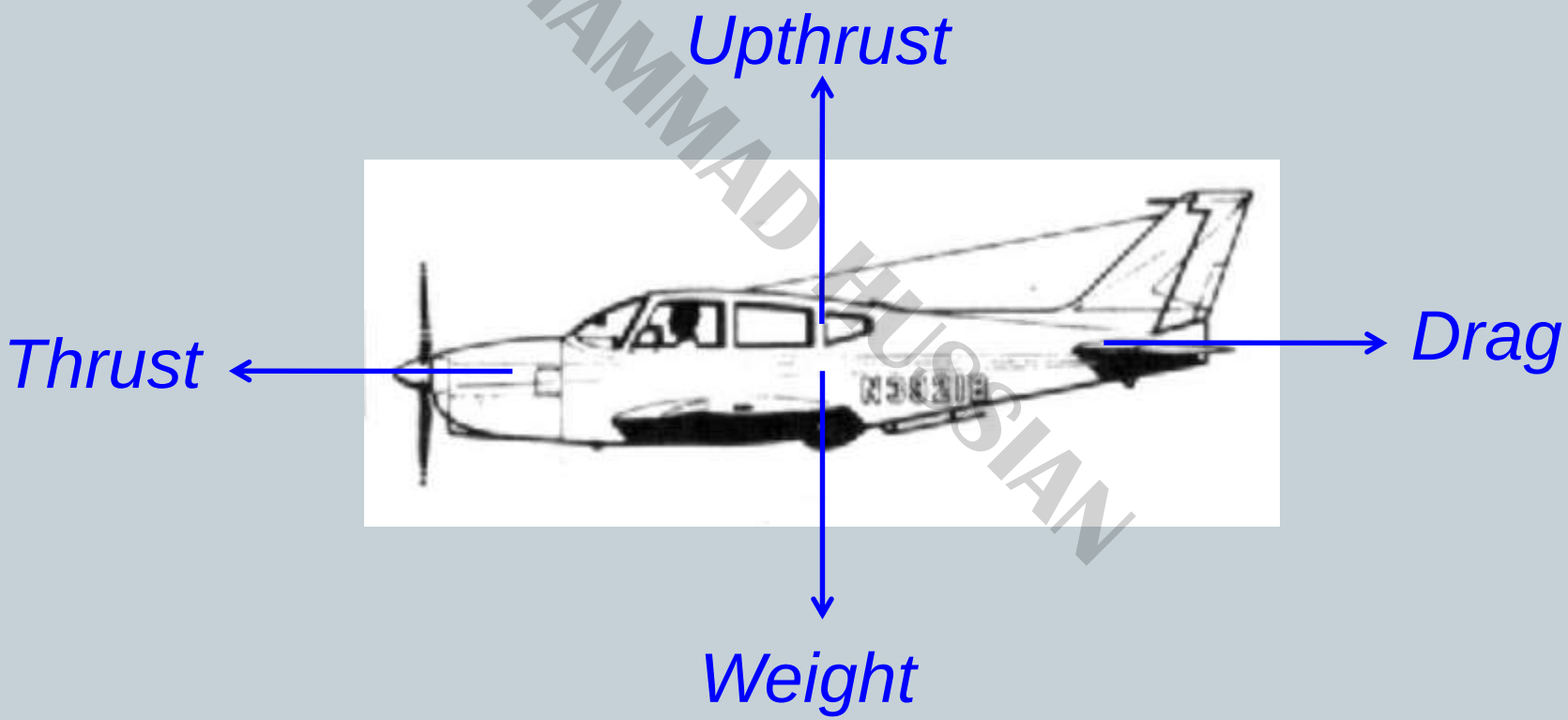
- A box is at rest on a table.



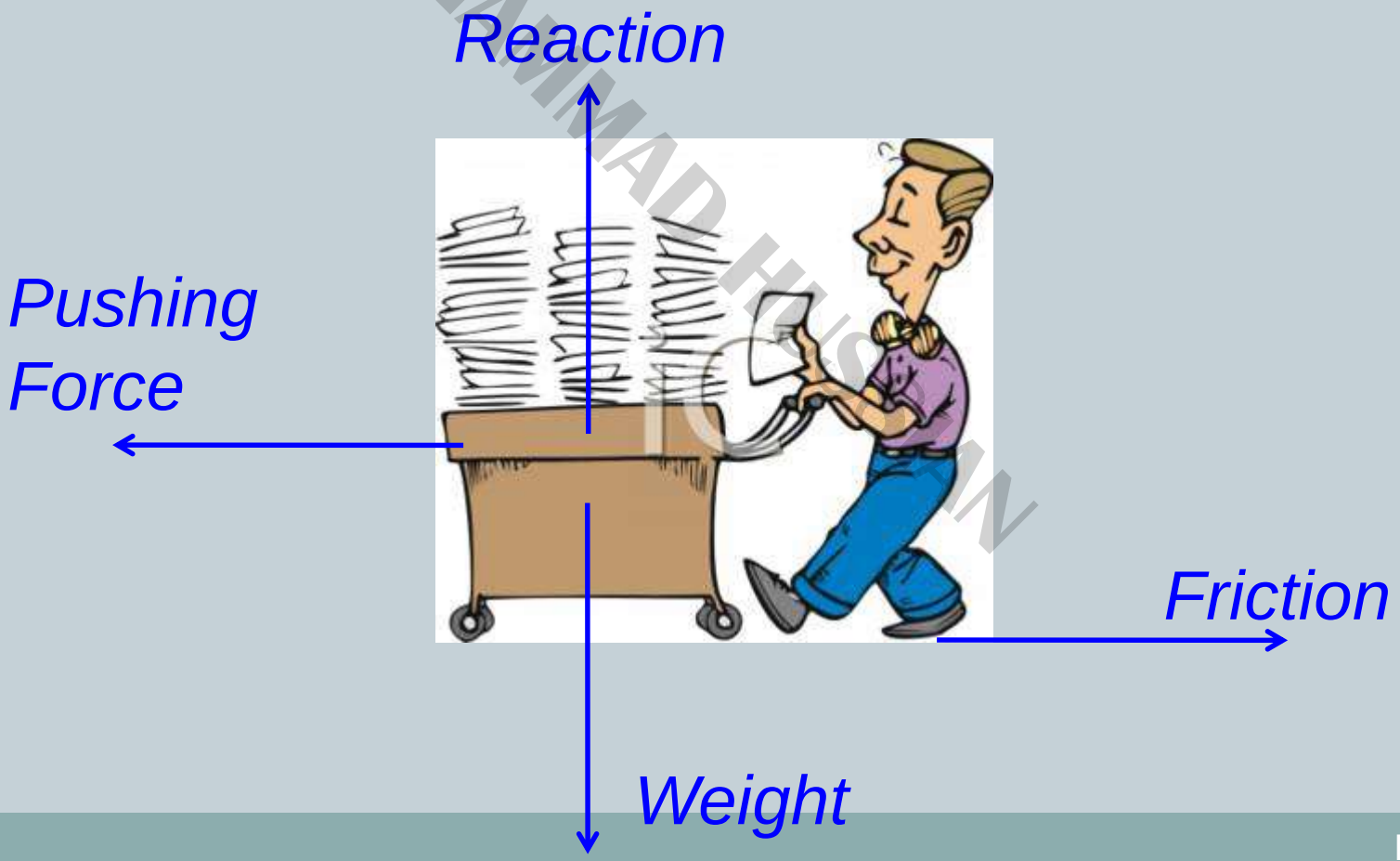
- An object that is suspended by a rope.



- An airplane flying at a constant velocity.



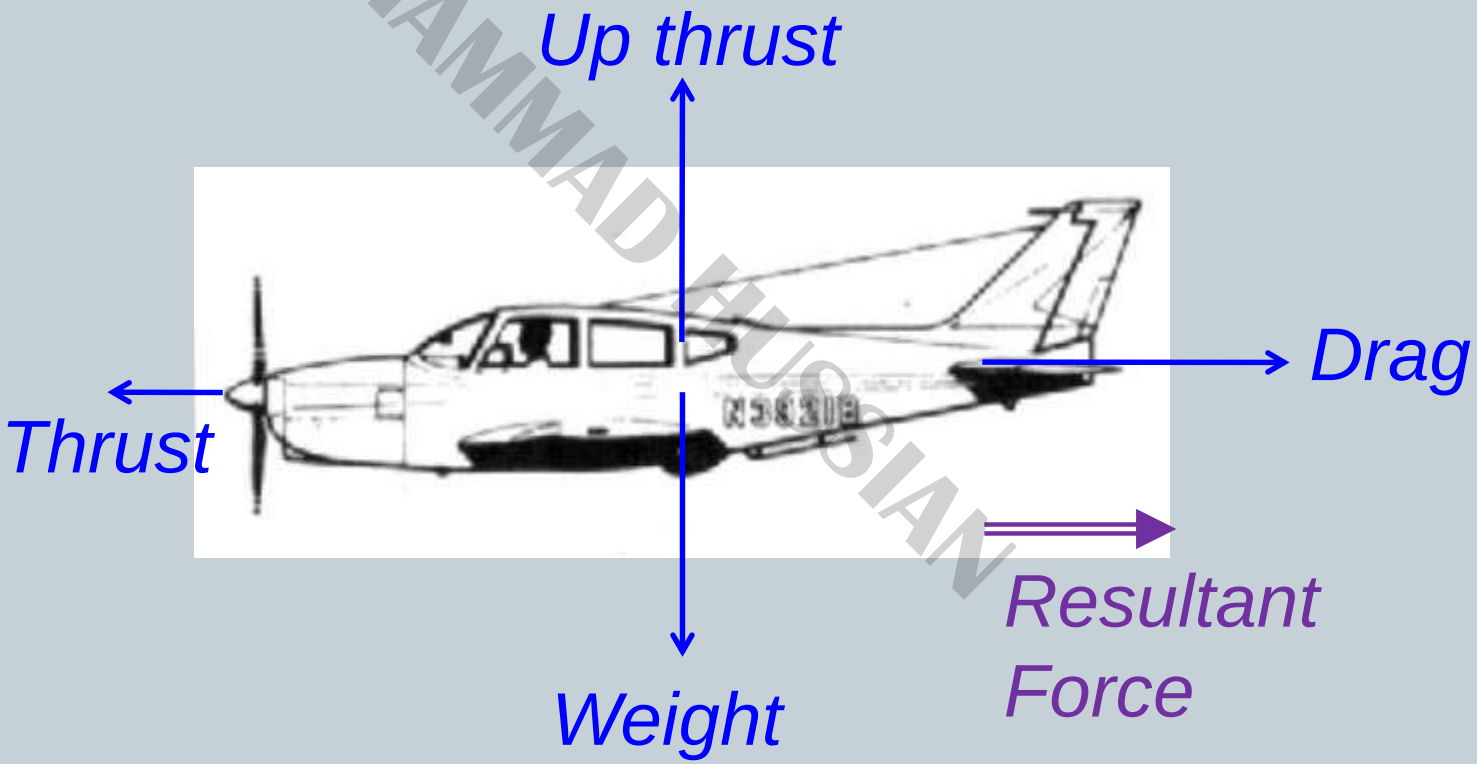
- A trolley being pushed at a constant velocity



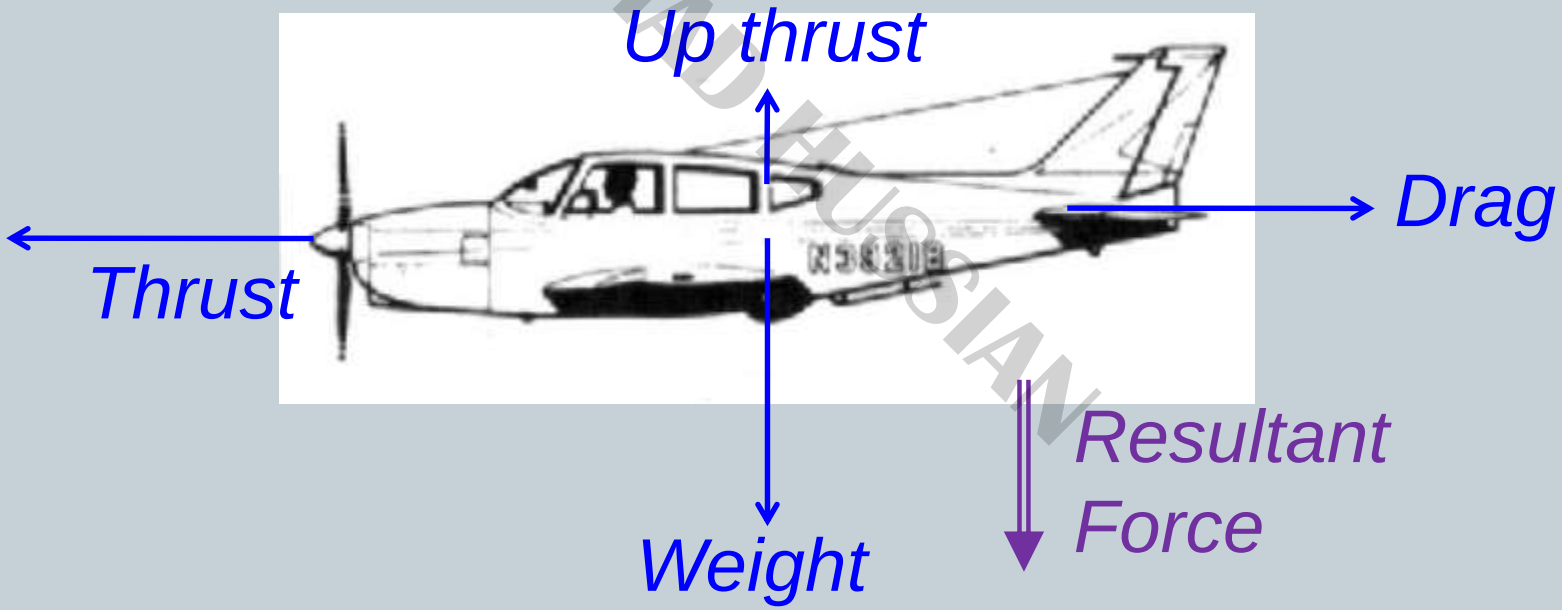
Unbalanced Forces

- When the forces acting on an object is unbalanced, the object's speed will be change.
- The resultant of two unbalanced forces can be found by considering their direction.
- Example: When the driving force on a car is 100 N to the left but the friction force is 50 N to the right, then the resultant force is 50 N to the left

- An airplane is slowing down at constant height.

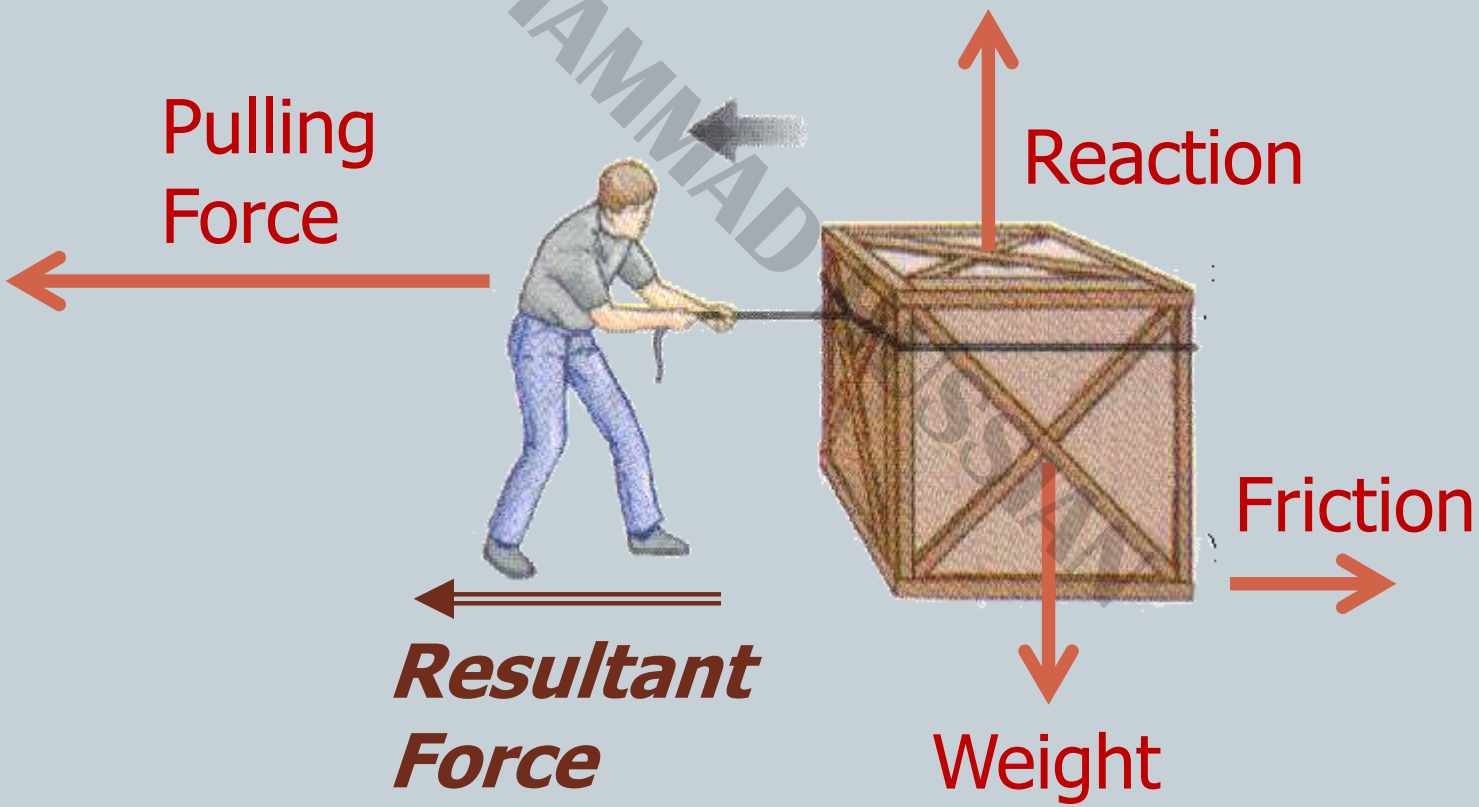


- An airplane descending at a constant velocity.



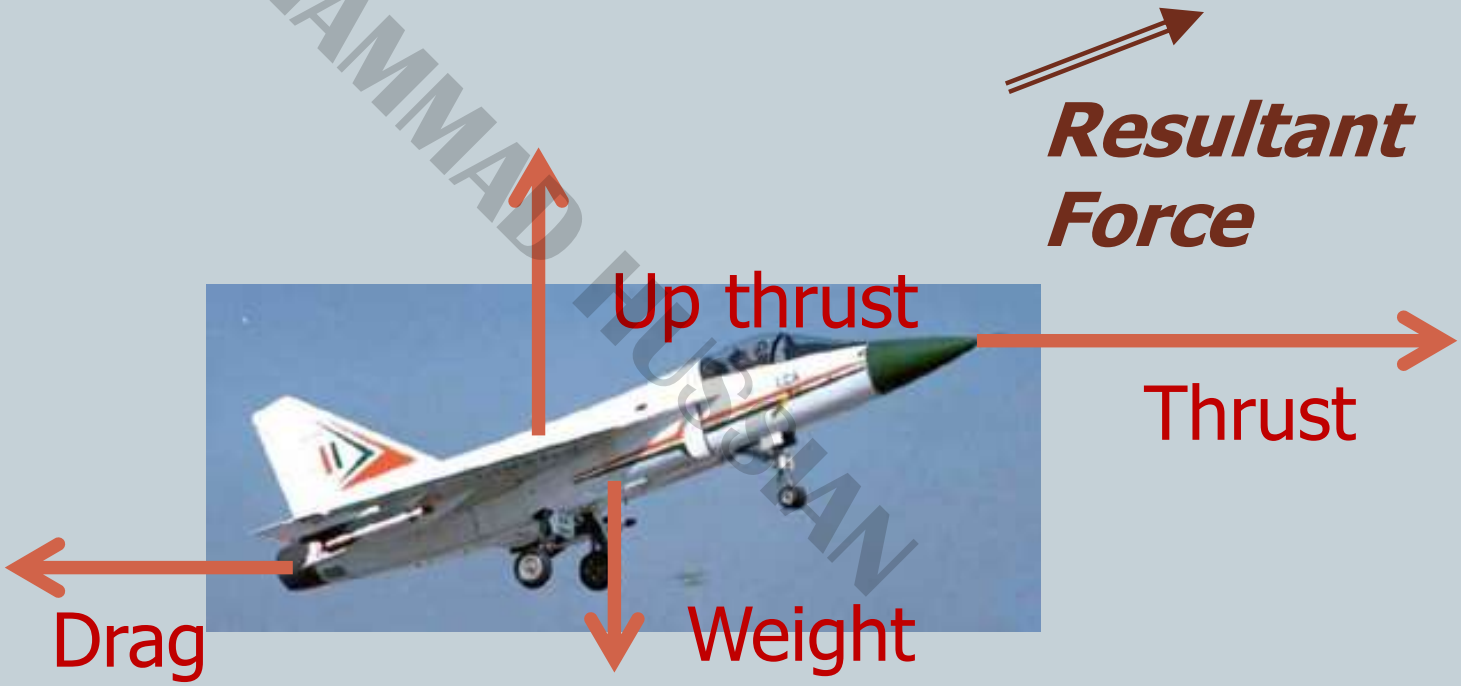
Example

- A man pulling a cart

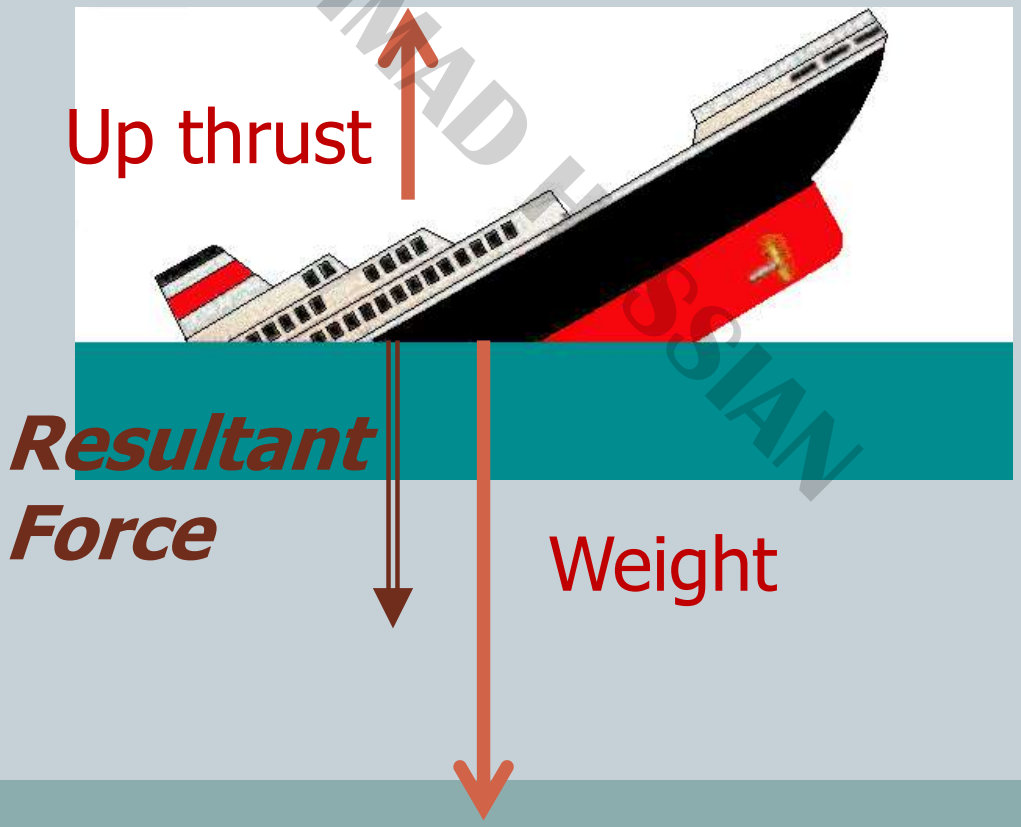


- F1 car decelerating

- Jet Fighter taking off



- Sinking ship



Balanced and Unbalance Force

24

RECALL AND USE THE EQUATION *FORCE* = *MASS* × *ACCELERATION*

Forces are Unbalanced (Resultant Force)

↓

There is an acceleration

↙ ↘

The acceleration depends directly upon the net force

The acceleration depends inversely upon the mass of the object

Mass, Force and Acceleration

- A relationship between these factors is given by the formula

force = mass × acceleration

F = ma

where

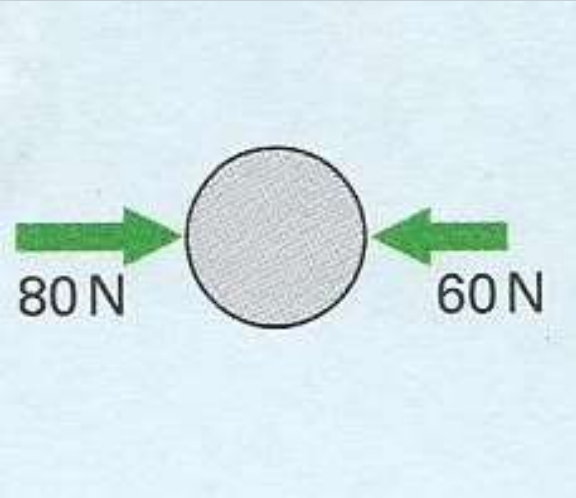
F = force in newtons

m = mass in kg

a = acceleration in m/s^2

Problem Solving

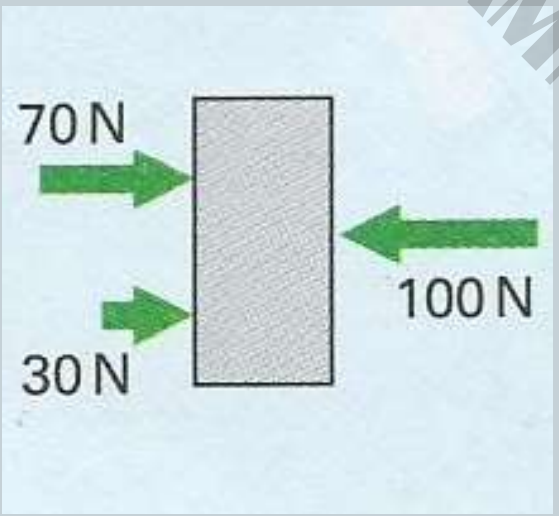
1. Figure below shows the forces acting on three objects. For each, say whether the forces are balanced or unbalanced. If the forces are unbalanced, calculate the resultant force and give its direction.



Unbalance force

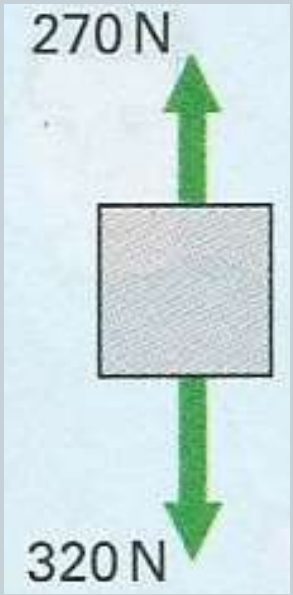
Resultant force = 80 – 60
= 20 N

Direction = to the right



Balance force

Resultant force = 0 N

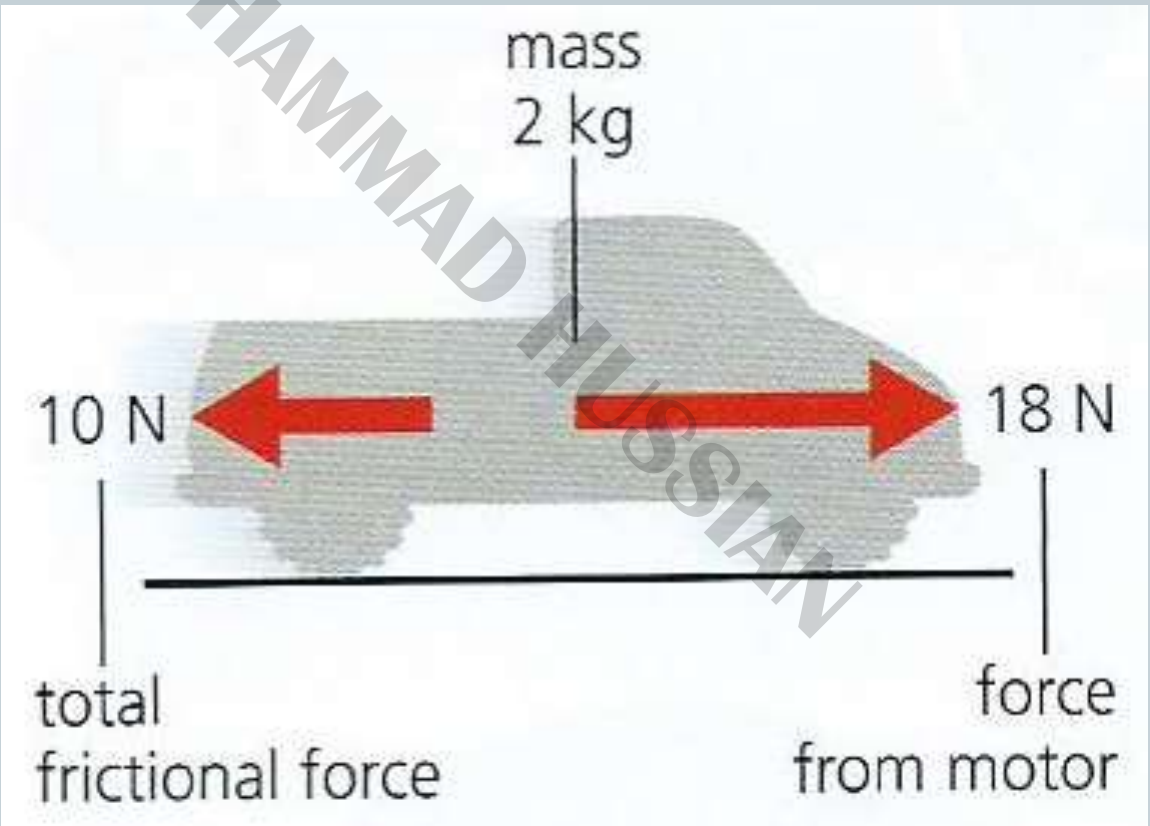


Unbalance force

Resultant force = 320 – 270
= 50 N

Direction = downward

2. What is the acceleration of the model car below.



1. Find the resultant force

$$\text{Resultant force} = 18\ \text{N} - 10\ \text{N} = 8\ \text{N}$$

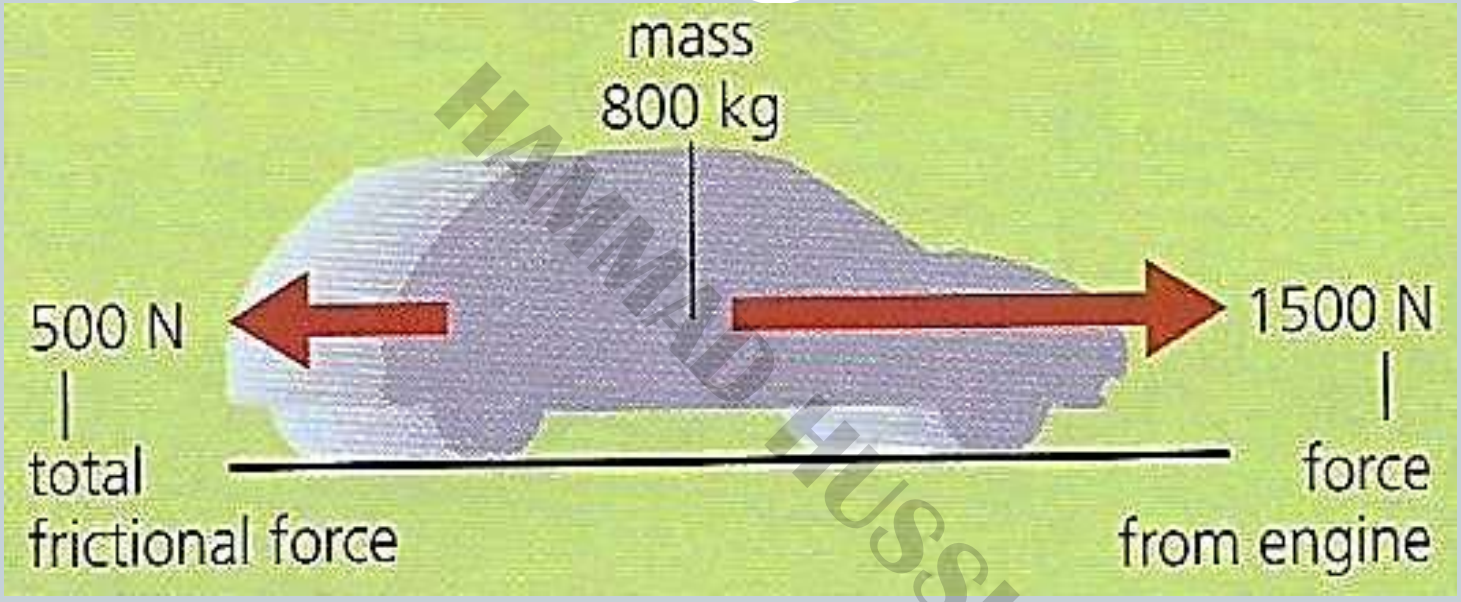
2. Use the equation

$$F = m \times a$$

$$8\ \text{N} = 2\ \text{kg} \times a$$

$$a = 4\ \text{m/s}^2$$

3.



a. What is the resultant force on the car above?

b. What is the car's acceleration?

c. If the total frictional force rises to 1500 N, what happens to the car?

a) Find the resultant force

$$\text{Resultant force} = 1500\ \text{N} - 500\ \text{N} = 1000\ \text{N}$$

b) Find the acceleration

$$F = m \times a$$

$$1000\ \text{N} = 800\ \text{kg} \times a$$

$$a = 1.25\ \text{m}/s^2$$

c) No resultant force. Car will move at constant velocity

4. A block of mass 20 kg is pulled along the ground by a force, F of 60 N. The frictional force is 10 N. Calculate the acceleration of the block.

$$\text{Resultant force} = 60\ \text{N} - 10\ \text{N} = 50\ \text{N}$$

$$F = m \times a$$

$$50\ \text{N} = 20\ \text{kg} \times a$$

$$a = 2.5\ \text{m}/s^2$$

5. A car has a mass of 800 kg. its engine provides a forward force of 400 N. There is a frictional force of 160 N, acting to oppose the car's motion. What is the resultant force acting on the car? What is its acceleration?

$$\text{Resultant force} = 400\ \text{N} - 160\ \text{N} = 240\ \text{N}$$

$$F = m \times a$$

$$240\ \text{N} = 800\ \text{kg} \times a$$

$$a = 0.3\ \text{m}/s^2$$

6. What force is needed to give a car of mass 600 kg an acceleration of 2.5 m/s²

$$F = m \times a$$

$$F = 600\,kg \times 2.5\,m/s^2$$

$$F = 1500\,N$$

7. What acceleration will result when a 12 N resultant force is applied to a 3 kg object.

$$F = m \times a$$

$$12 = 3\ kg \times a$$

$$a = 4\ m/s^2$$

8. A resultant force of 16 N causes a mass to accelerate at the rate of 5 m/s². Determine the mass.

$$F = m \times a$$

$$16 = m \times 5\ m/s^2$$

$$m = 3.2\ kg$$

9. A car of mass 1000 kg travelling at 10 ms^{-1} is brought to rest in 5 seconds. Find

a) the average deceleration,

$$a = \frac{v - u}{t}$$

$$a = \frac{0 - 10}{5} = -2\ m/s^2$$

b) the braking force.

$$F = m \times a$$

$$F = 1000\ kg \times 2\ m/s^2$$

$$F = 2000\ N$$

10. When a force of 6 N is applied to a block of mass 2 kg. It moves along a table at constant velocity.

a) What is the force of friction?

$$\text{Force of Friction} = 6\ \text{N}$$

When the force is increased to 10 N, what is

b) the resultant force?

$$\text{Resultant force} = 10\ \text{N} - 6\ \text{N} = 4\ \text{N}$$

c) the acceleration?

$$F = m \times a$$

$$4\ \text{N} = 2\ \text{kg} \times a$$

$$a = 2\ \text{m}/s^2$$

d) the velocity, if it accelerates from rest for 10 seconds?

$$a = \frac{v - u}{t}$$

$$2 = \frac{v - 0}{10}$$

$$v = 20\ m/s$$

Forces

Balanced

- Body remain stationary
- Body moves with constant velocity

Unbalanced

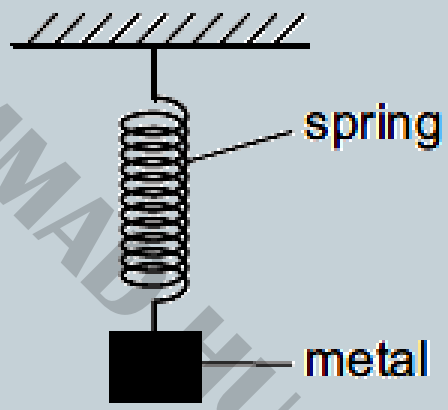
- Object velocity changes
- Direction of moving object changes

1. A newton is a unit of force.

   Which quantity is measured in newtons?

   A. acceleration
   B. density
   C. mass
   D. weight

2. A spring is stretched by hanging a piece of metal from it.

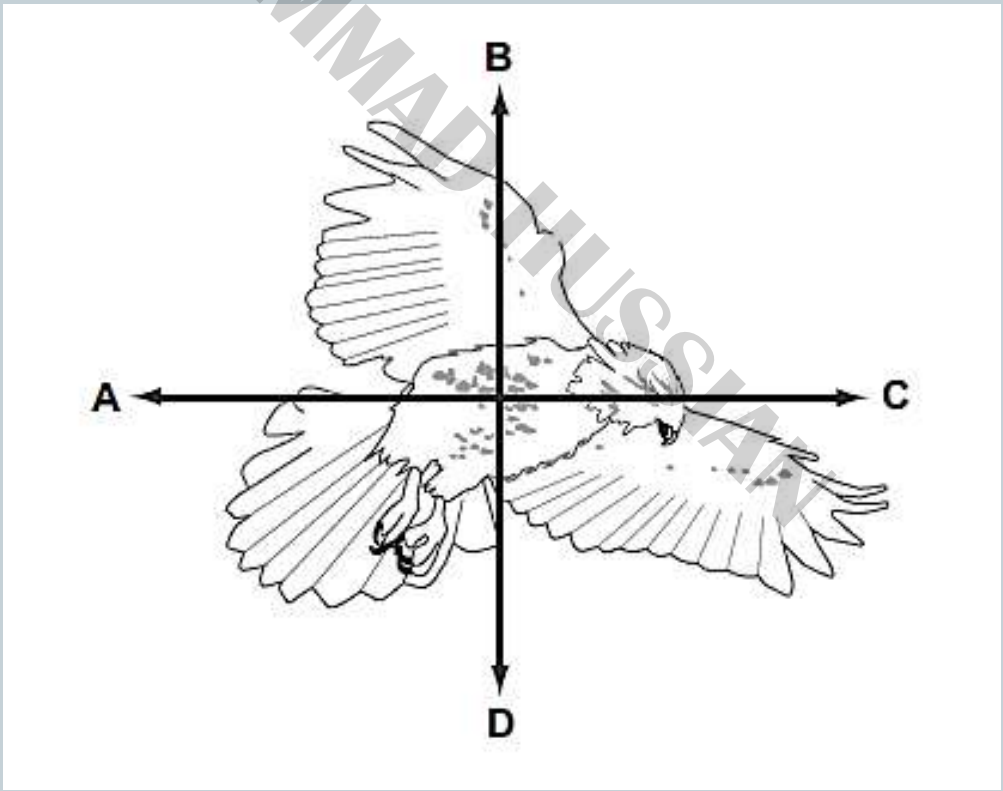


What is the name given to the force that stretches the spring?

A. friction
B. mass
C. pressure
D. weight

3. The diagram shows a bird in flight.

In which direction does the weight of the bird act?



D

4. Which property of an object cannot be changed by a force?

A. its mass
B. its motion
C. its shape
D. its size

5. A force acts on a moving rubber ball.

   How many of the following changes could happen to the ball because of the force?

   - a change in direction
   - a change in shape
   - a change in mass
   - a change in speed

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

6. Which is a statement of Newton's third law of motion?

A. Every force causes a reaction.

B. If there is no resultant force on a body then there is no acceleration.

C. The forces acting on a body are always equal and opposite.

D. To every action there is an equal but opposite reaction.

7. Below are four statements about the effects of forces on objects.

Three of the statements are correct.

Which statement is incorrect?

A. A force can change the length of an object.
B. A force can change the mass of an object.
C. A force can change the shape of an object.
D. A force can change the speed of an object.

8. In which of these situations is no resultant force needed?

A. a car changing direction
B. a car moving in a straight line at a steady speed
C. a car slowing down
D. a car speeding up

9. Two forces act on an object.

In which situation is it impossible for the object to be in equilibrium?

A. The two forces act in the same direction.
B. The two forces act through the same point.
C. The two forces are of the same type.
D. The two forces are the same size.

10. Which statement about a moving object is correct?

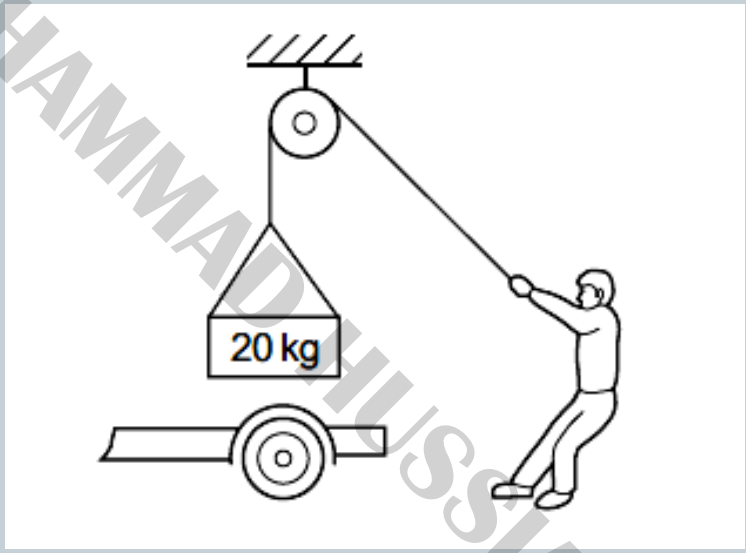
A. When an object is accelerating, the resultant force acting on it must equal zero.

B. When an object is moving at a steady speed, the air resistance acting on it must equal zero.

C. When an object is moving at a steady speed, the resultant force acting on it must equal zero.

D. When an object is moving, there must be a resultant force acting on it.

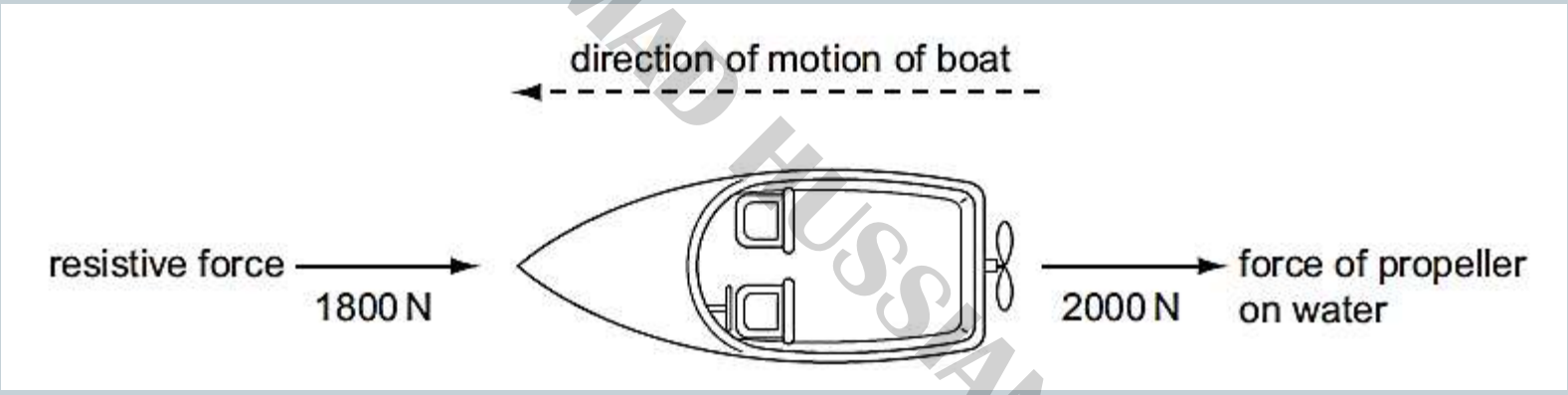
11. A person just supports a mass of 20 kg suspended from a rope.



What is the resultant force acting on the mass?

A. 0 N
B. 10 N
C. 20 N
D. 200 N

12. The propeller on a boat pushes water backwards with a force of 2000 N. The boat moves through the water against a total resistive force of 1800 N.



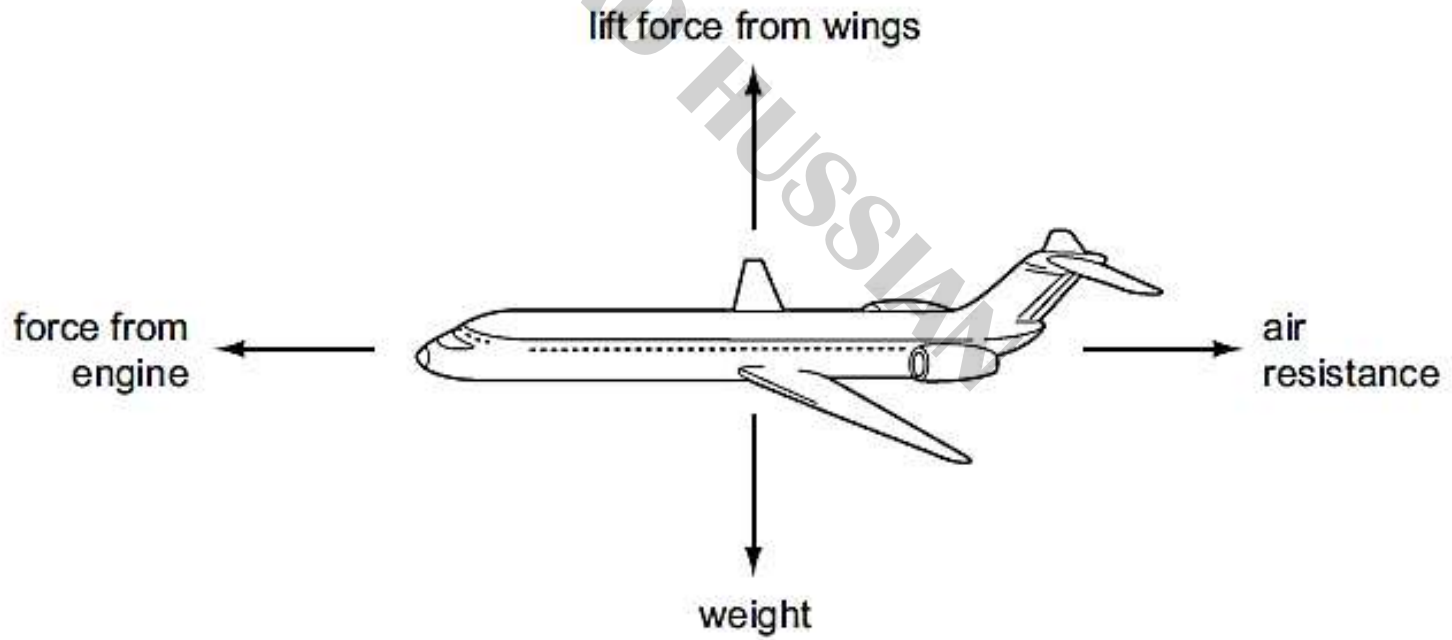
According to Newton's third law, what is the forward force on the propeller due to the water?

A	3800 N	**B**	2000 N	**C**	1800 N	**D**	200 N

B

13. An aeroplane is in equilibrium.

The diagram shows the forces acting on the aeroplane.

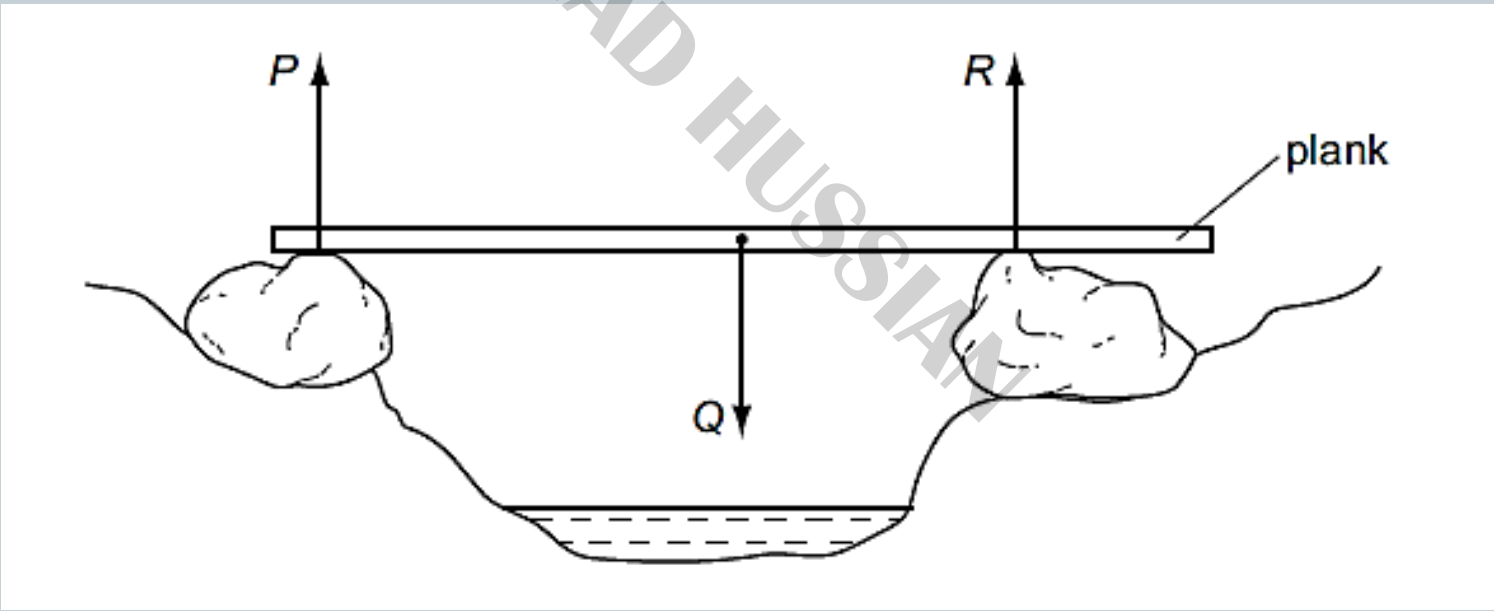


Which statement about the forces is correct?

	force from engine	lift force from wings
A	equal to air resistance	equal to weight
B	equal to air resistance	greater than weight
C	greater than air resistance	equal to weight
D	greater than air resistance	greater than weight

A

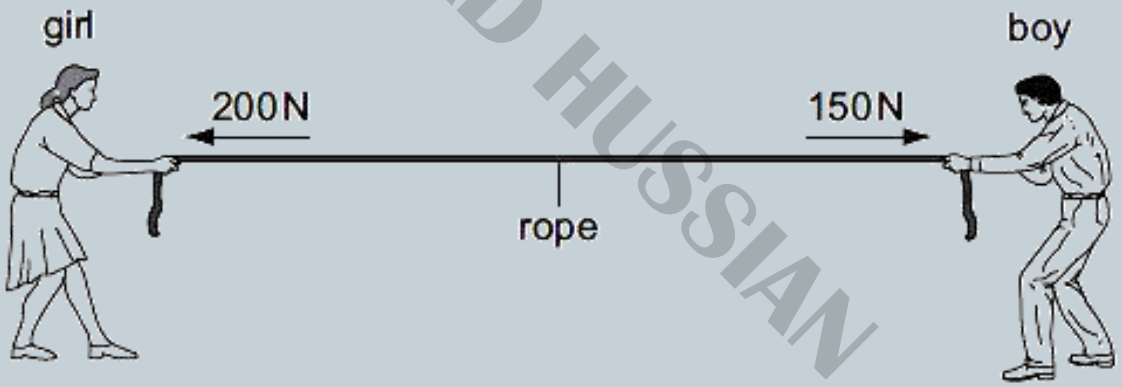
14. A wooden plank rests in equilibrium on two boulders on opposite sides of a narrow stream. Three forces of size P, Q and R act on the plank.



How are the sizes of the forces related?

A. $P + Q = R$
B. $P + R = Q$
C. $P = Q = R$
D. $P = Q + R$

15. A girl and a boy are pulling in opposite directions on a rope. The forces acting on the rope are shown in the diagram.

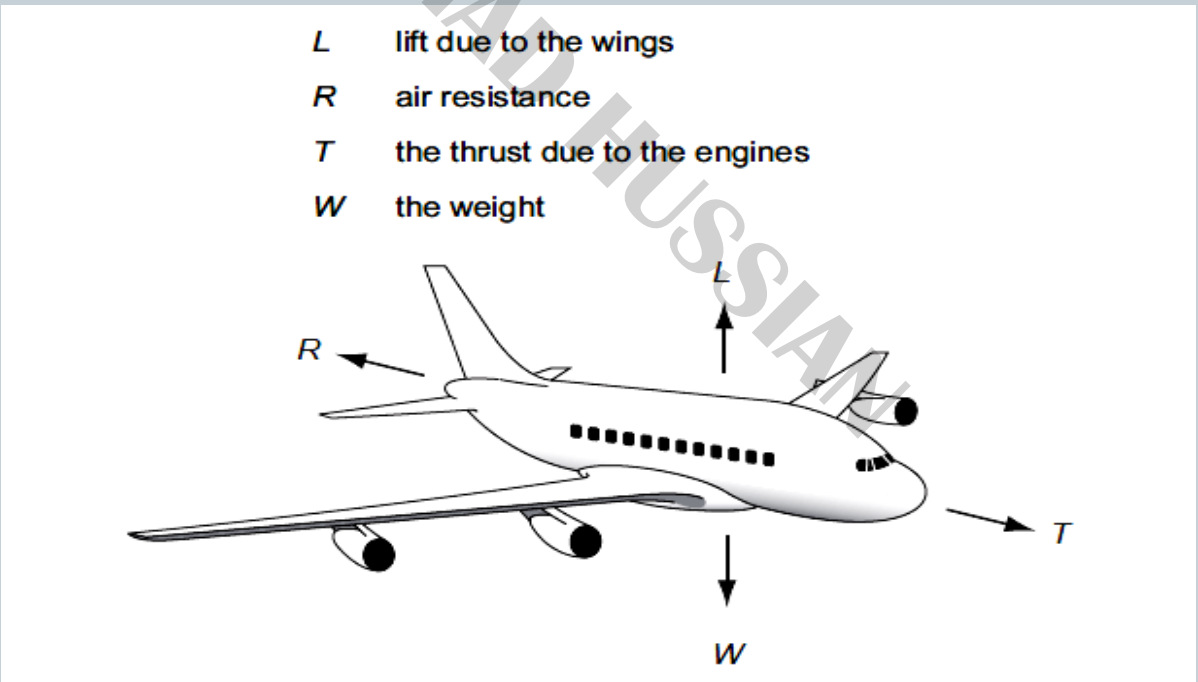


Which single force has the same effect as the two forces shown?

A. 50 N acting towards the girl
B. 350 N acting towards the girl
C. 50 N acting towards the boy
D. 350 N acting towards the boy

16. An aircraft, flying at a constant height, is gaining speed.

    The four forces acting are



What is correct?

	vertical forces	horizontal forces
A	$L = W$	$T = R$
B	$L > W$	$T > R$
C	$L = W$	$T > R$
D	$L > W$	$T = R$

C

17. A tractor pulls a trailer at a constant speed.

    The tractor exerts a forward force of 1600 N on the trailer.

    What is the force exerted by the trailer on the tractor?

    A. 0 N
    B. 1600 N backwards
    C. 1600 N forwards
    D. 3200 N forwards

18. When a block of wood of mass 2 kg is pushed along the horizontal flat surface of a bench, the friction force measured is 4 N.

    When the block is pushed along the same bench with a force of 10 N, it moves with a constant

    A. speed of 3 m/s.
    B. speed of 5 m/s.
    C. acceleration of 3 m/s^2.
    D. acceleration of 5 m/s^2.

19. A force of 20 N pushes an object of mass 5.0 kg along a rough horizontal surface where the frictional force is 5.0 N.

    What is the acceleration of the object?

A. 1.0 m/s²
B. 2.0 m/s²
C. 3.0 m/s²
D. 4.0 m/s²

20. How is the motion of a body affected by balanced and unbalanced forces acting on it?

	balanced forces	unbalanced forces
A	velocity changes	velocity changes
B	velocity changes	velocity constant
C	velocity constant	velocity changes
D	velocity constant	velocity constant

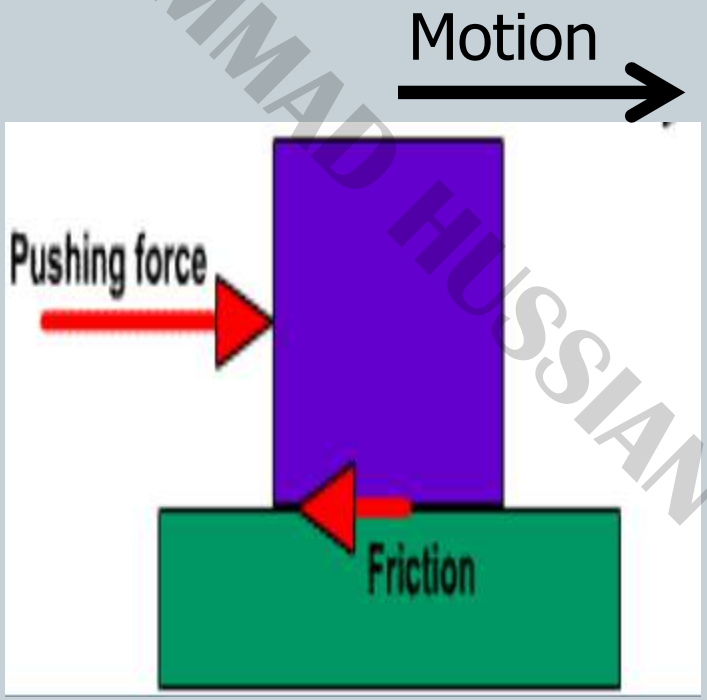
C

Friction

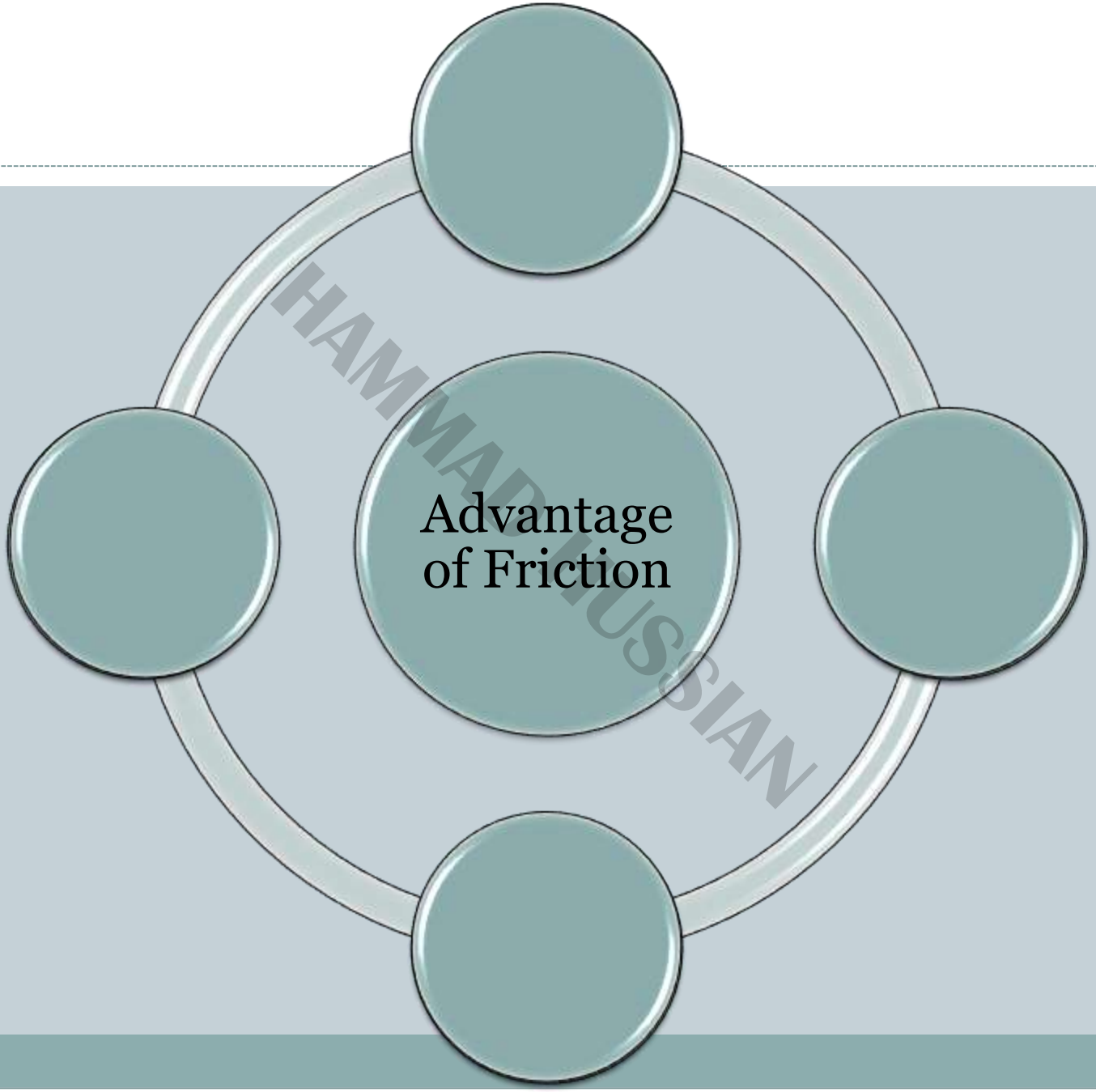
EXPLAIN THAT FRICTION IS A FORCE THAT IMPEDES MOTION AND PRODUCES HEATING

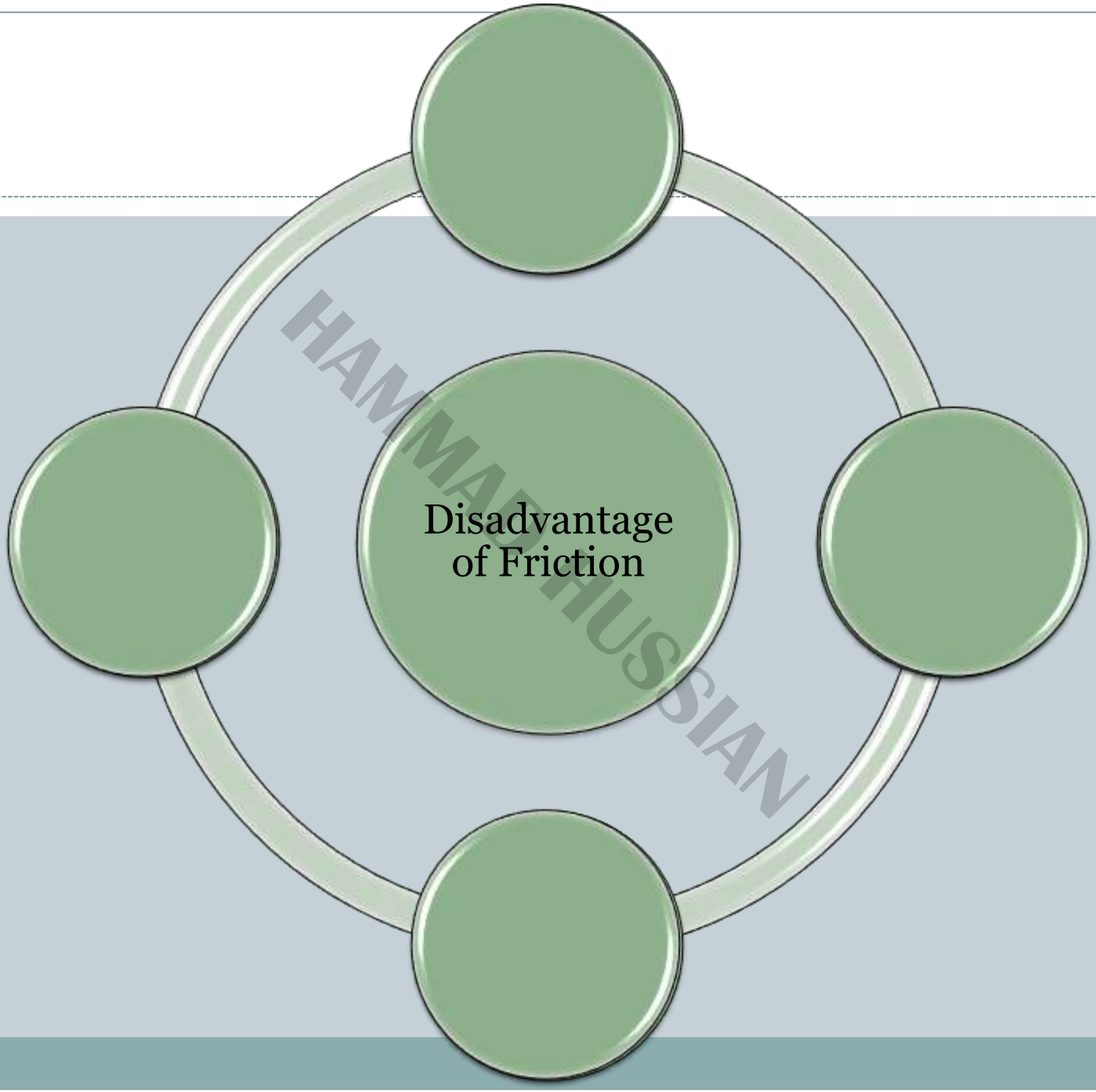
Friction

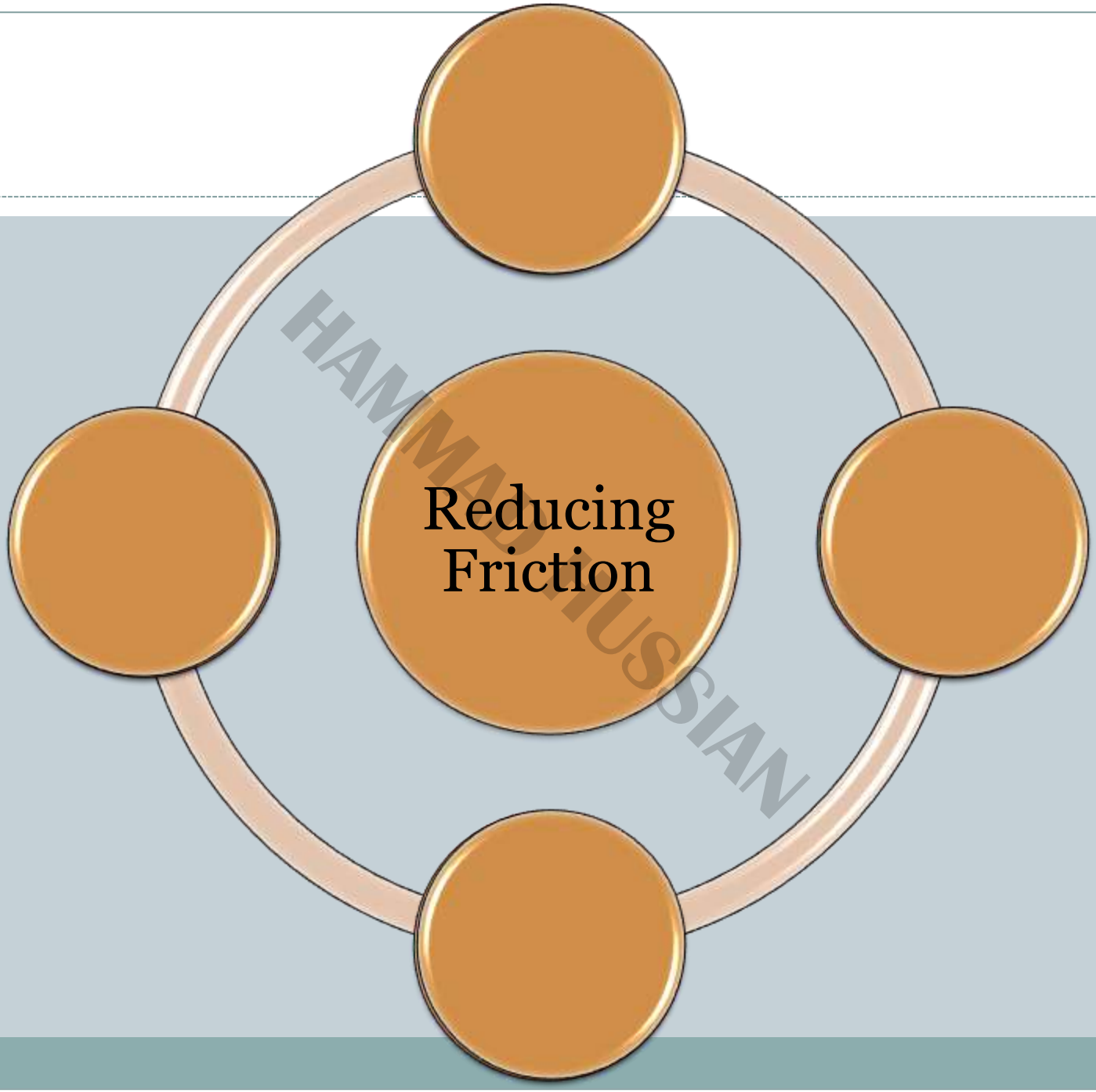
- Friction is a force that opposes motion between two surfaces that are in contact.



- The frictional force between two surfaces on a horizontal plane
  - Always act against the direction
  - Depends on the material on contact.
  - Depends on the nature of the surfaces in contact.
  - Increases as the speed of the object increases.







Friction

DISCUSS THE EFFECT OF FRICTION ON THE MOTION OF A VEHICLE IN THE CONTEXT OF TYRE SURFACE, ROAD CONDITIONS (INCLUDING SKIDDING), BRAKING FORCE, BRAKING DISTANCE, THINKING DISTANCE AND STOPPING DISTANCE

A car driver sees a family of ducks crossing the road in front of her. She brakes for 1·5 s and took 1·8 s to stop.

Stopping Distance

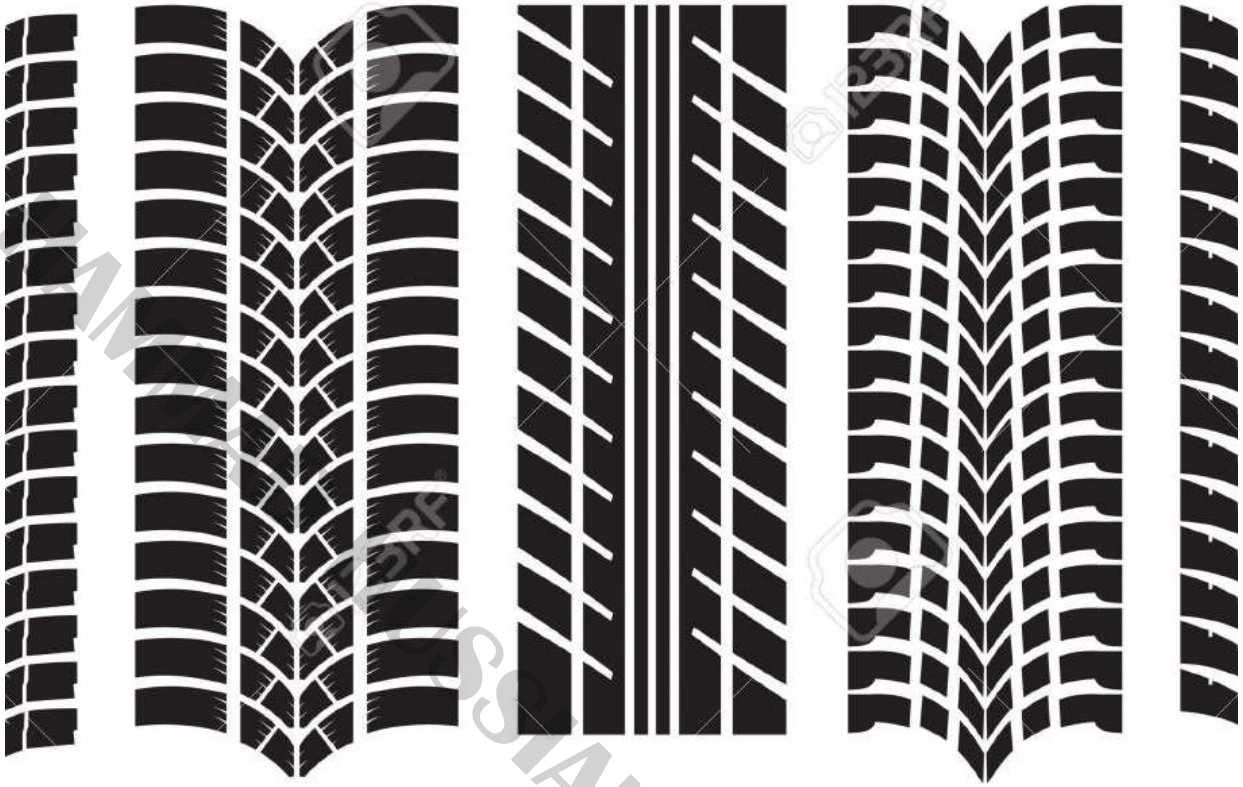
- Stopping Distance = Thinking Time + Braking Distance
- **Thinking Distance**
  - Whilst you are reacting to the hazard, the car is **still moving**! During your thinking time, you are not slowing down. We call the distance moved during this time the **thinking distance**.
- **Braking Distance**
  - With the brakes applied, the car *slows down*. The distance that the car moves whilst braking is called the **braking distance**.

- Stopping is made up of two parts: thinking and braking.
- Thinking distance is the distance travelled during the thinking time.
- Braking distance is the distance travelled during the braking time.
- Stopping distance is the sum of the thinking and braking distances.
- When speed doubles, thinking distances doubles and braking distance is four time as far

Worn brakes won't work as well, so you'll need to **brake for longer**. Modern brakes are also better than old ones - they can apply *bigger forces* without causing skidding.

Braking Factors - Brakes

Tread patterns are designed to push water out from between the tyre and road. Good tyres can **reduce braking distance** by many metres! Worn tyres (with little tread) will have good grip in the dry but in the wet will lead to much longer braking distances...



Braking Factors - Tyres

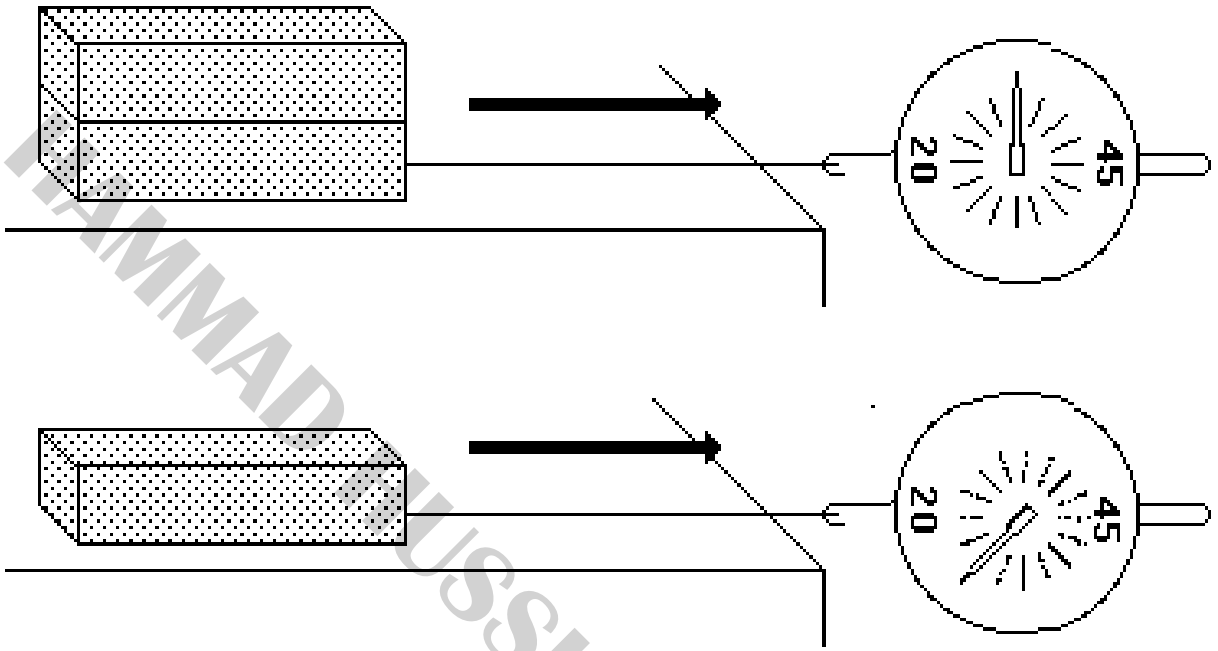
Different types of surface provide different levels of grip, especially in the wet. If the road is wet, braking distance will always be longer. Oil spills on the road, gravel, etc. all reduce grip and increase braking distances.

Braking Factors – Road Surface

The **worse** the car's aerodynamics, the *better* it will be at slowing down during braking! The reason is that the airflow at and around the car (drag or air resistance) is an additional force acting to slow you.

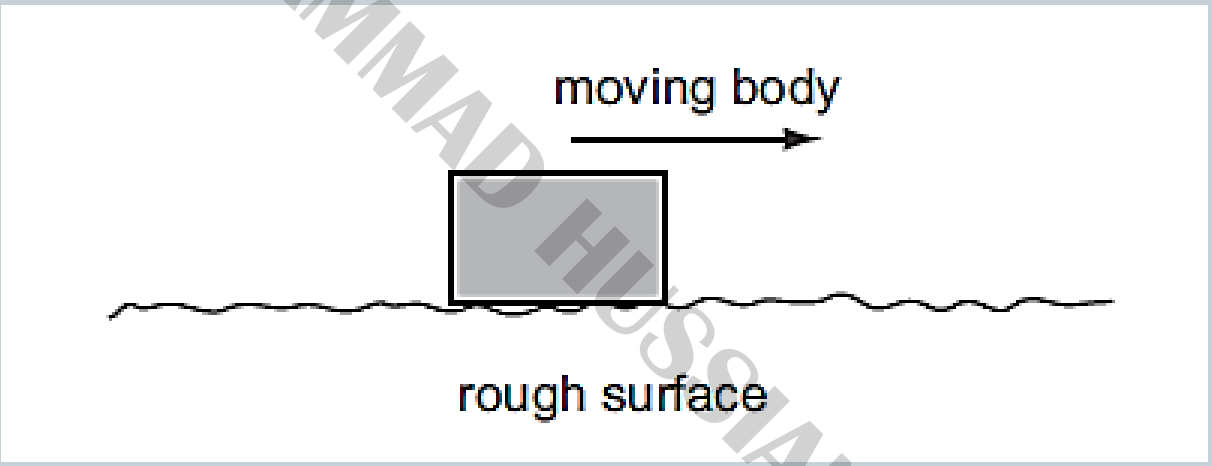
Braking Factors - aerodynamics

The larger the total mass of the vehicle, passengers and luggage, the more kinetic energy it will have at a given speed. This increases the braking distance as it is harder to slow down.



Braking Factors - Mass

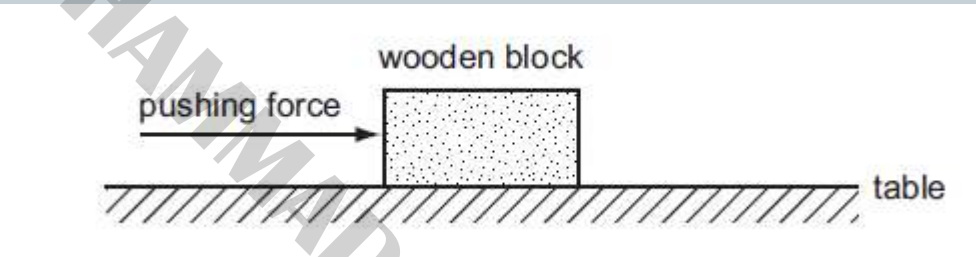
1. When a body moves across a rough surface, a frictional force is produced.



Which statement about this force is always true?

A. It acts in the direction of the motion.
B. It is equal in value to the force producing the motion.
C. It makes the body recoil in the opposite direction after stopping it.
D. It opposes the motion across the surface.

2. A wooden block is pushed across a table at constant speed.

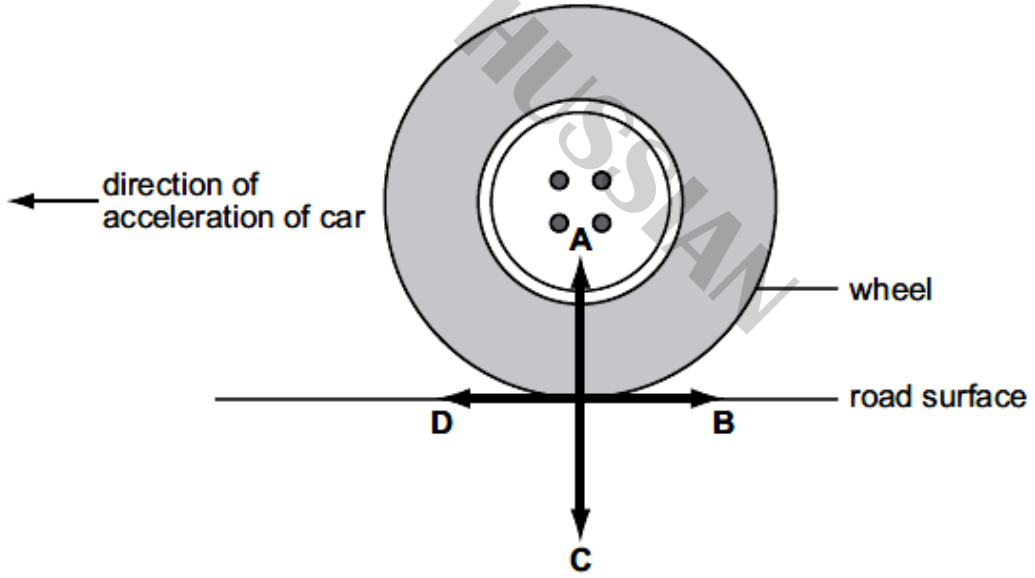


Which statement is correct?

A. The frictional force increases as the block moves at constant speed.
B. The frictional force is equal and opposite to the pushing force.
C. The frictional force is greater than the pushing force.
D. The frictional force is less than the pushing force.

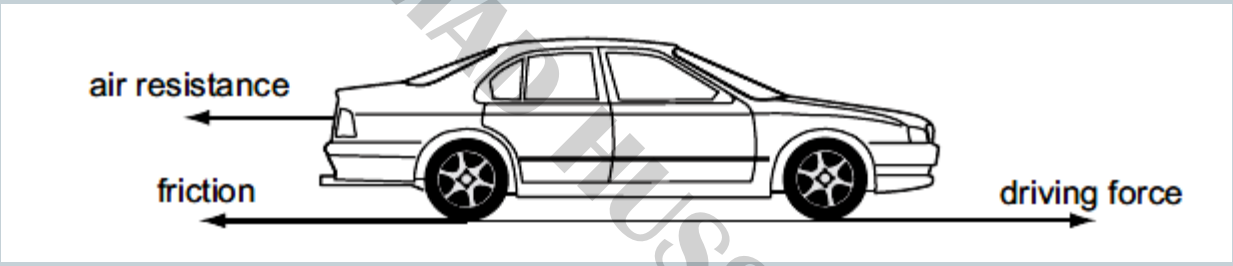
3. The wheel of a moving car is driven by the engine. The car is accelerating in the direction shown.

In which direction does the frictional force act on the wheel?



B

4. Three horizontal forces act on a car that is moving along a straight, level road.

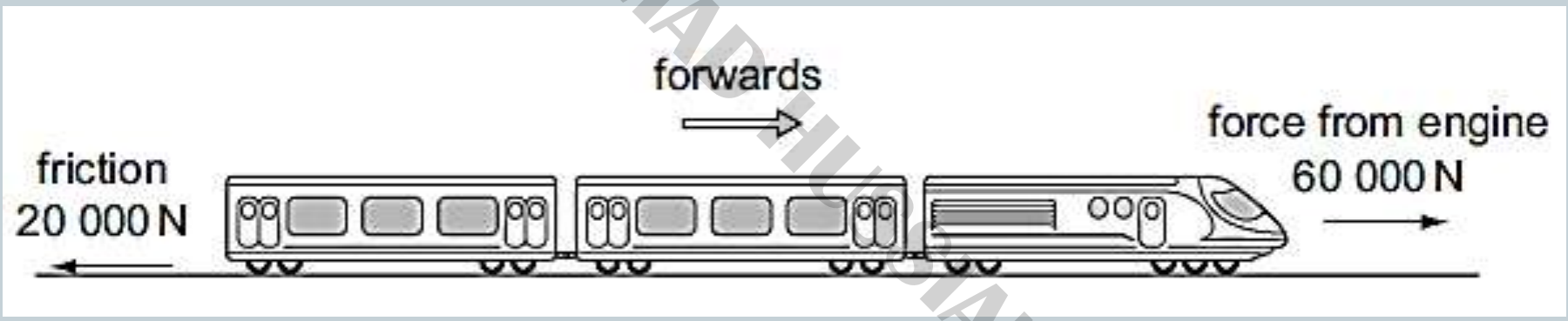


Which combination of forces would result in the car moving at constant speed?

	air resistance	friction	driving force
A	200 N	1000 N	800 N
B	800 N	1000 N	200 N
C	800 N	200 N	1000 N
D	1000 N	200 N	800 N

C

5. A train is travelling along a horizontal track at constant speed. Two of the forces acting on the train are shown in the diagram.



A force of air resistance is also acting on the train to give it a resultant force of zero.

What is this air resistance force?

A. 40 000 N backwards
B. 80 000 N backwards
C. 40 000 N forwards
D. 80 000 N forwards

6. A car is travelling at constant speed along a road and drives over a large patch of oil. The driver applies the brakes to stop the car.

   Compared to braking on a dry road, what may happen?

   A. The car slows down more quickly because of the greater friction between the tyres and the road.

   B. The car speeds up at first because of the reduced friction between the tyres and the road.

   C. The car takes longer to slow down because of the reduced friction between the tyres and the road.

   D. The car takes longer to slow down because the thinking distance of the driver is greater.

7. A car travels along a road. The driver stops the car by pushing his foot down on the brake pedal.

   What does not change if he pushes harder on the brake pedal?

   A. the braking distance
   B. the braking force
   C. the stopping distance
   D. the thinking distance

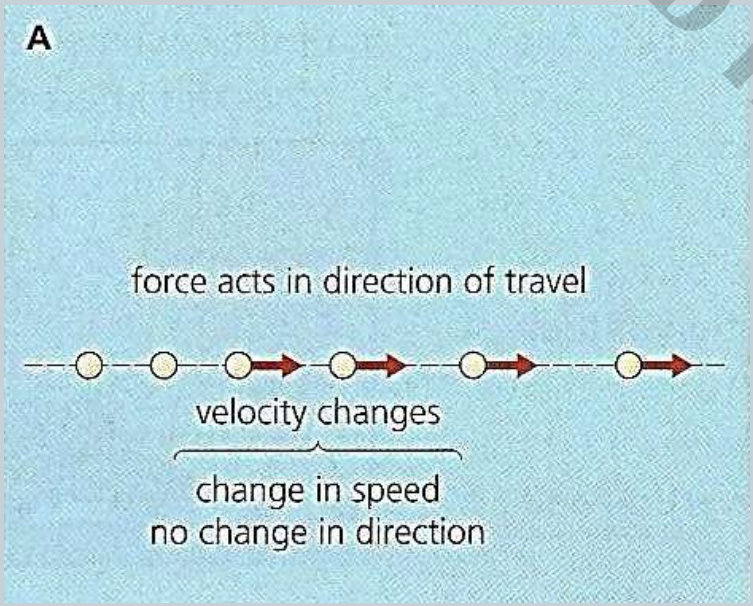
Circular Motion

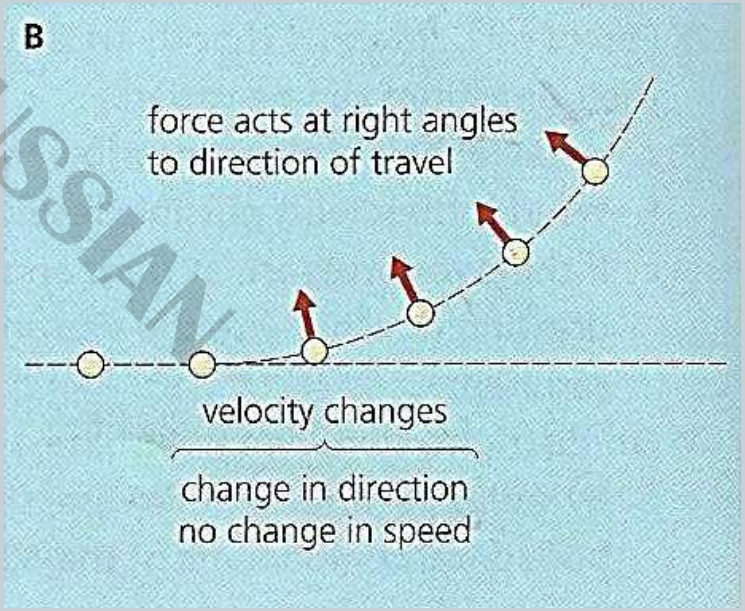
DESCRIBE QUALITATIVELY MOTION IN A CIRCULAR PATH DUE TO A CONSTANT PERPENDICULAR FORCE, INCLUDING

ELECTROSTATIC FORCES ON AN ELECTRON IN AN ATOM AND GRAVITATIONAL FORCES ON A SATELLITE

Changing Velocity

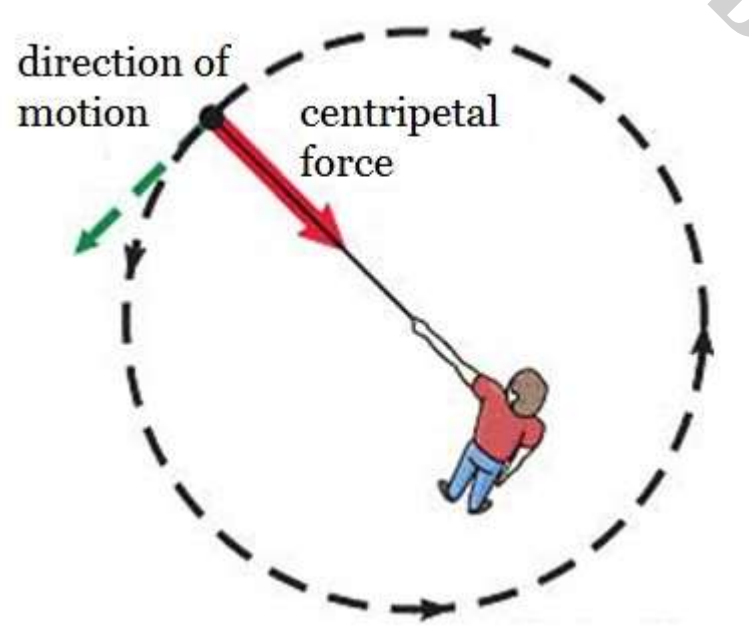
- Velocity is speed in a particular direction.
- A change in velocity can mean
  - change in speed
  - change in direction





Centripetal Force

- When an object is moving in a circle, there must be a force acting on it to change its direction.
- This force, which always act towards the centre of the circle, is **centripetal force**.



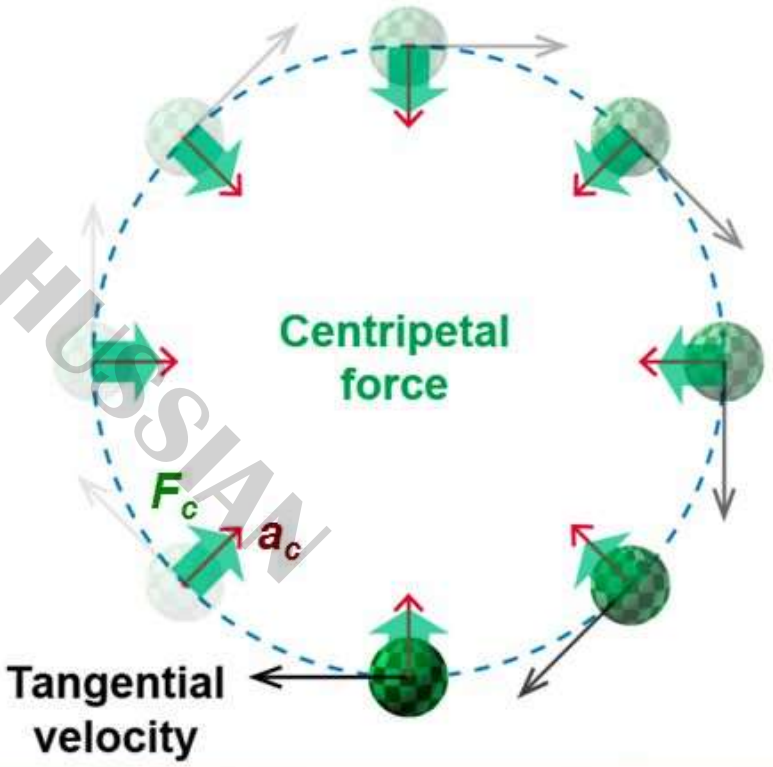
It acts perpendicularly to the direction of motion of the object at any instant

Newton's second law

A centripetal force causes an object to undergo centripetal acceleration.

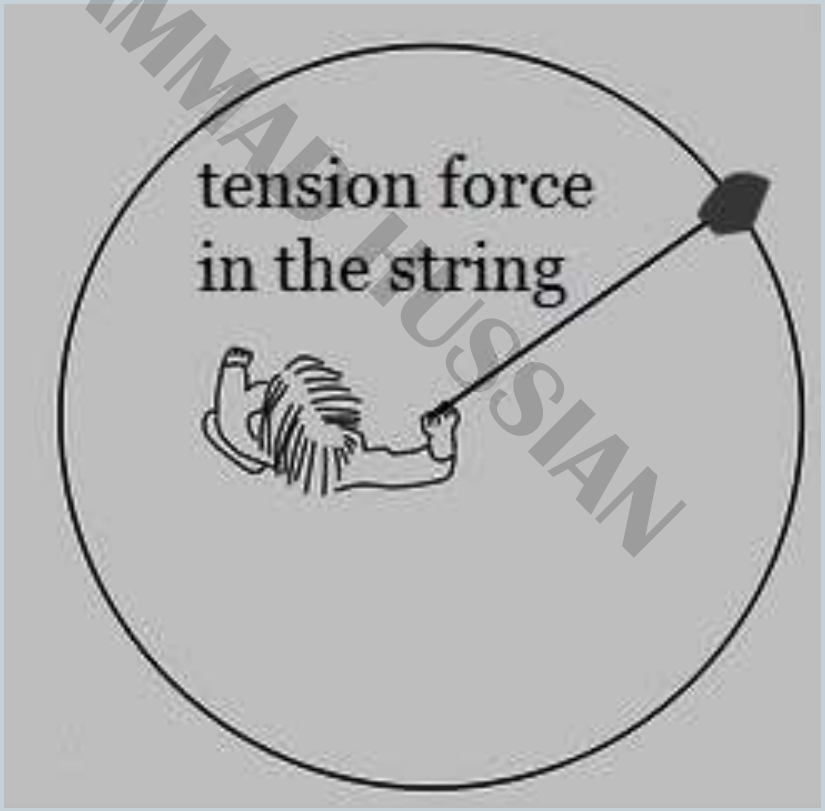
$$\vec{F}_c = m\vec{a}_c$$

The centripetal force and acceleration vectors must point in the SAME direction: toward the center of the circle.



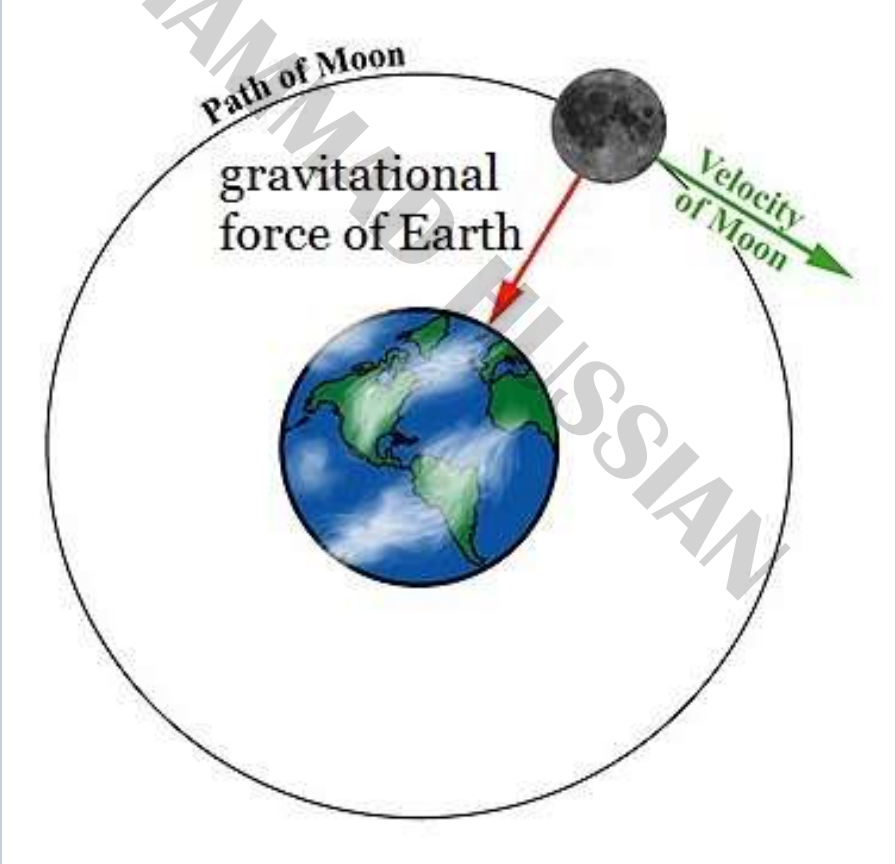
Example 1

- A stone on the end of a string, being whirled in a horizontal circle



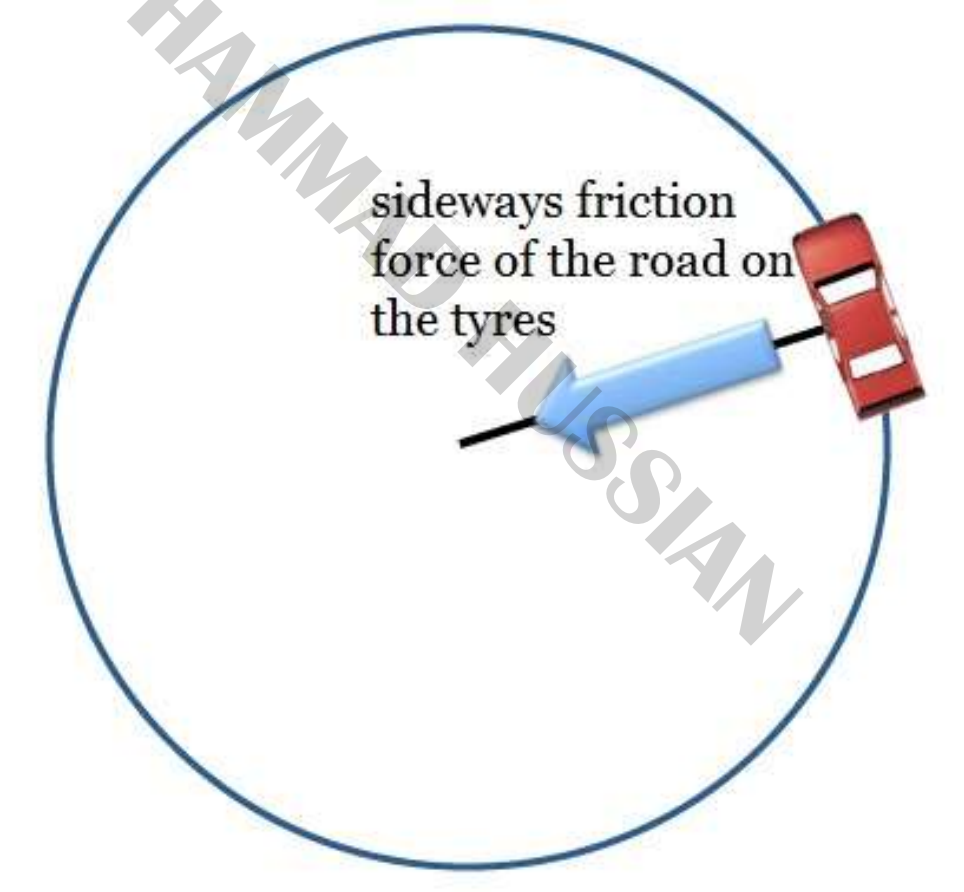
Example 2

- The Moon, orbiting the Earth



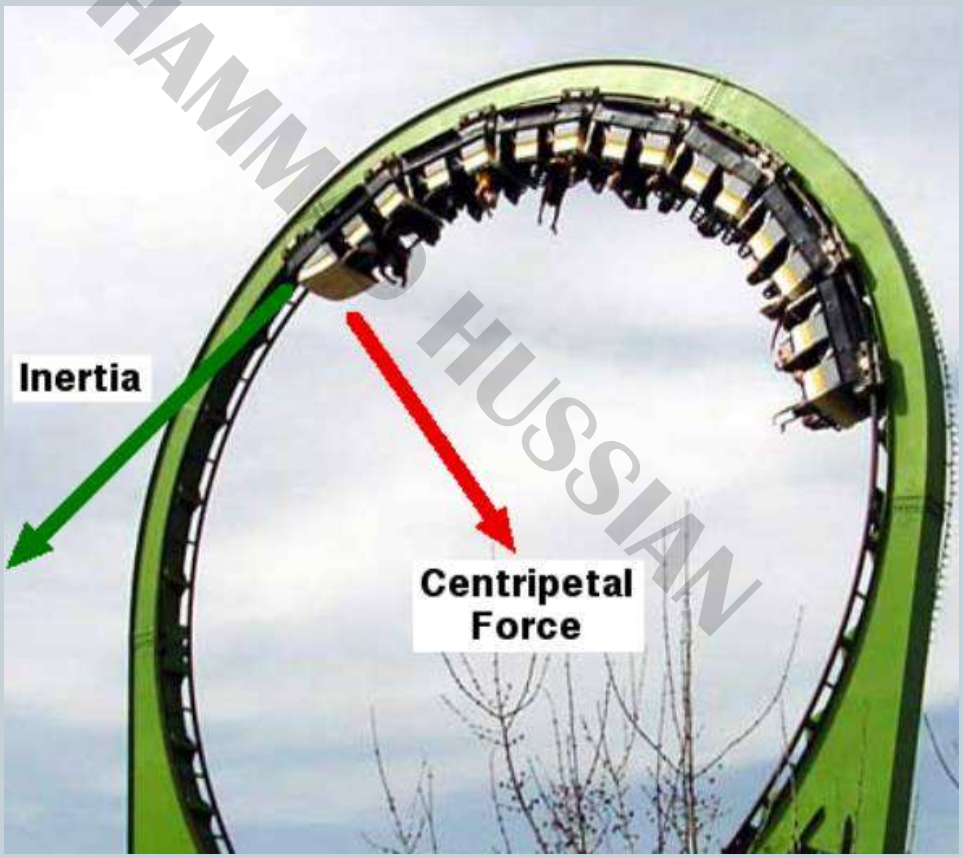
Example 3

- A car turning a corner



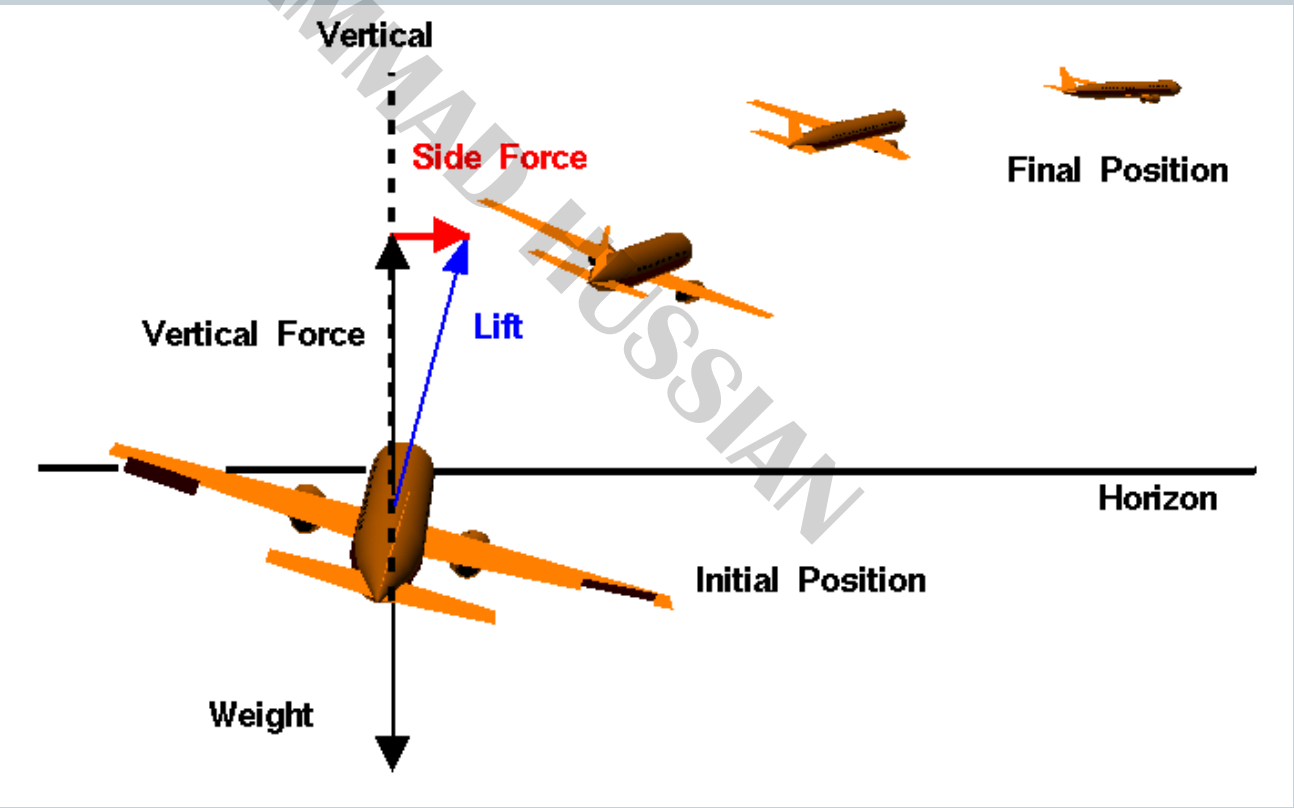
Example 4

- Roller coaster loop



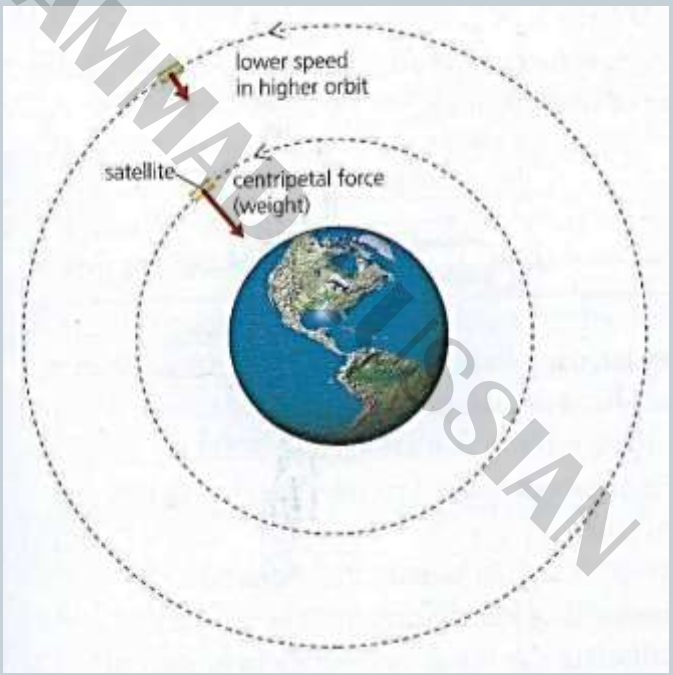
Example 5

- A banking aircraft uses the horizontal component of the lift force to provide the centripetal force for turning.



Satellites around the Earth

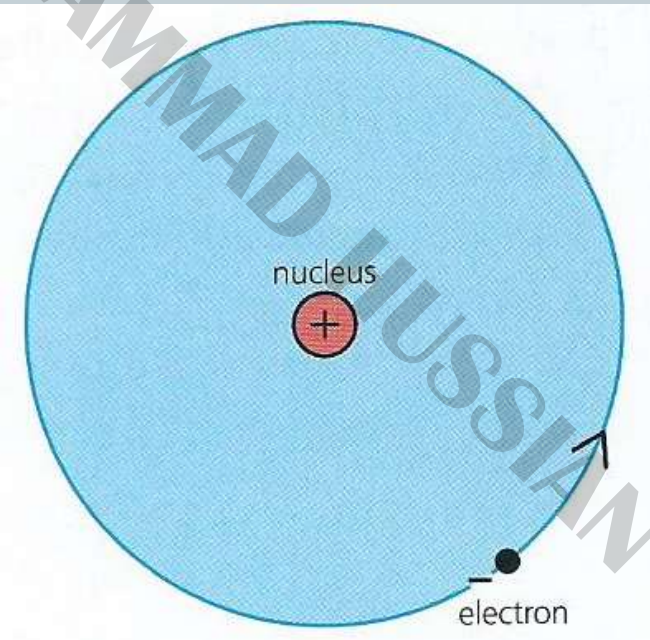
- A satellite travels round the Earth in a curved path called orbit.



- Gravitational pull (satellite's weight) provides the centripetal force needed.

Electrons around the nucleus

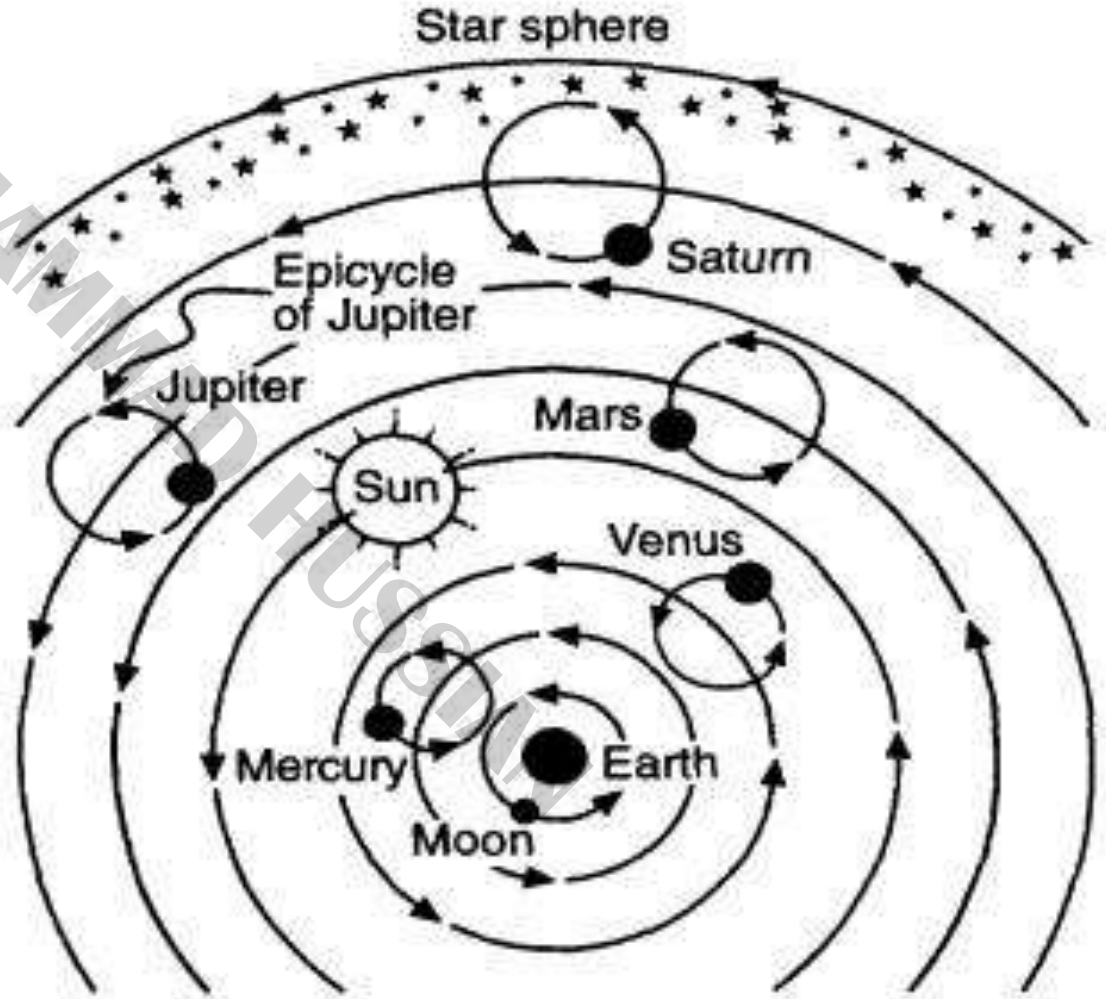
- In atom, the electrons are in orbit around a positively charged nucleus.

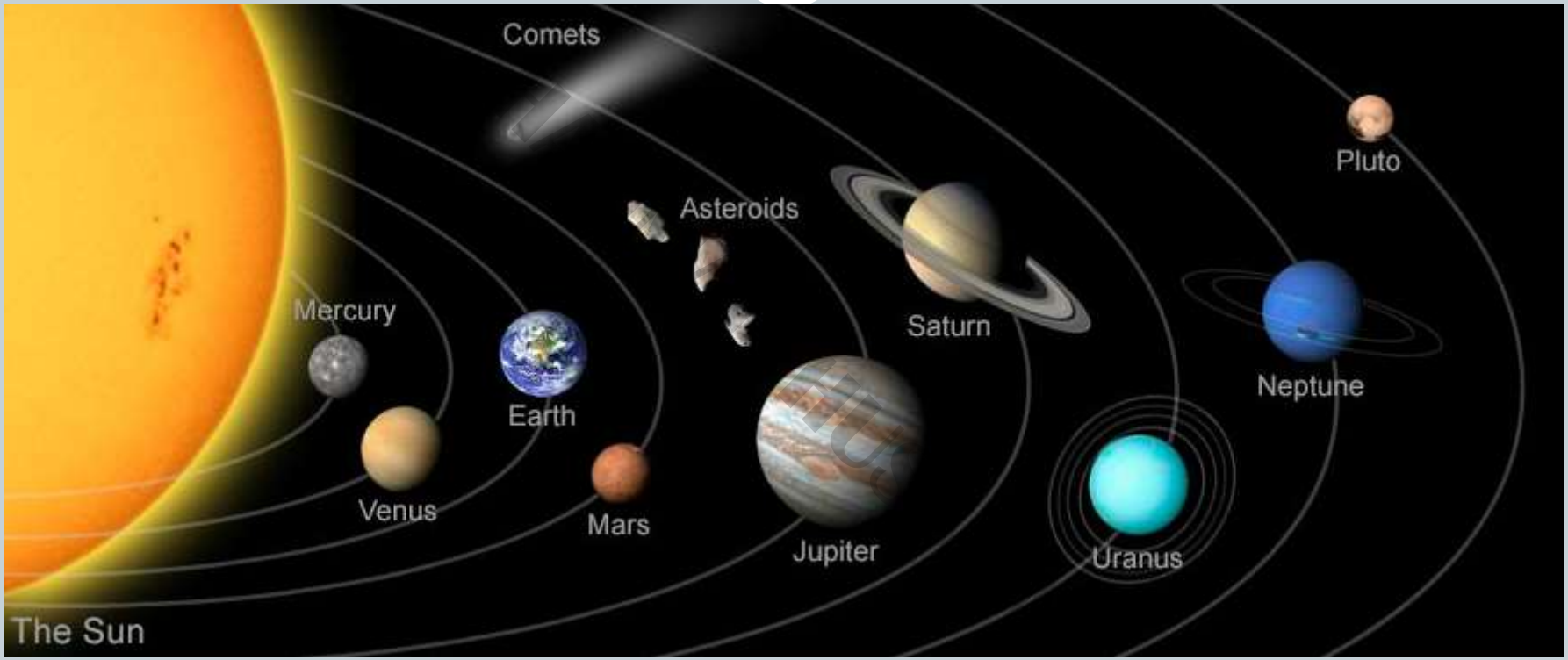


- The attraction between the opposite charges (electrostatic force) provides the centripetal force

Geocentric Model

An obsolete concept which held that the Earth was the centre of the universe and everything revolved around the Earth.





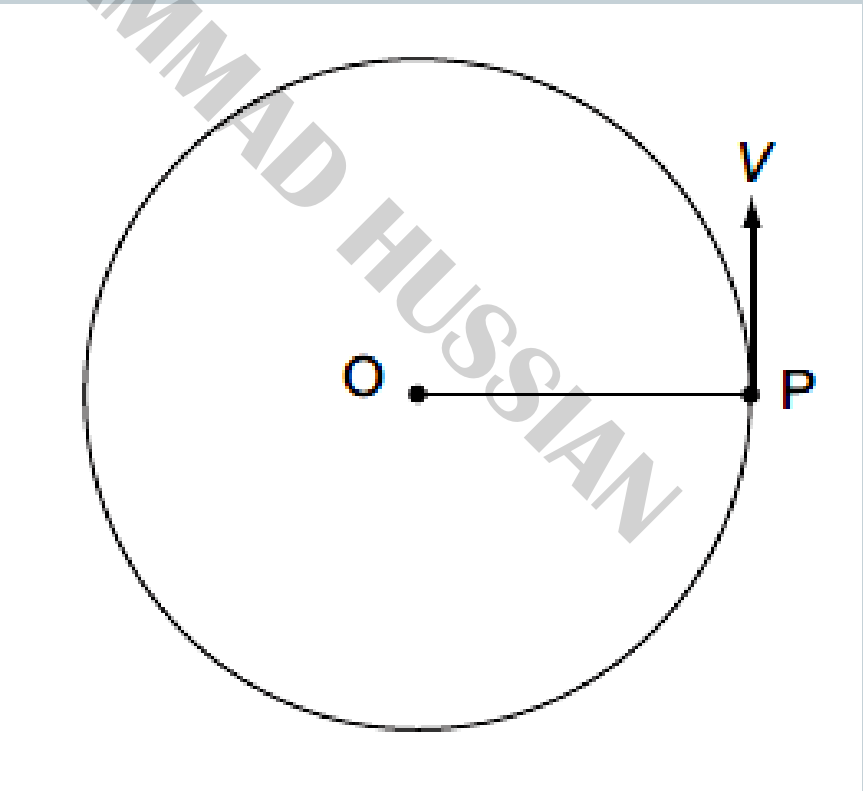
- The planetary motion is a result of the gravitational attraction of the Sun at the centre of the Solar System. As the planets are trying to fly out into deep space, the gravity of the Sun is pulling them into a curved orbit.

1. A body is moving in a circle at a constant speed.

   Which of the following statements about the body is true?

   A. There is no acceleration.
   B. There is a force acting at a tangent to the circle.
   C. There is a force acting away from the centre of the circle.
   D. There is a force acting towards the centre of the circle.

2. A particle P is moving in a horizontal circle about O. It moves at constant speed *V*.

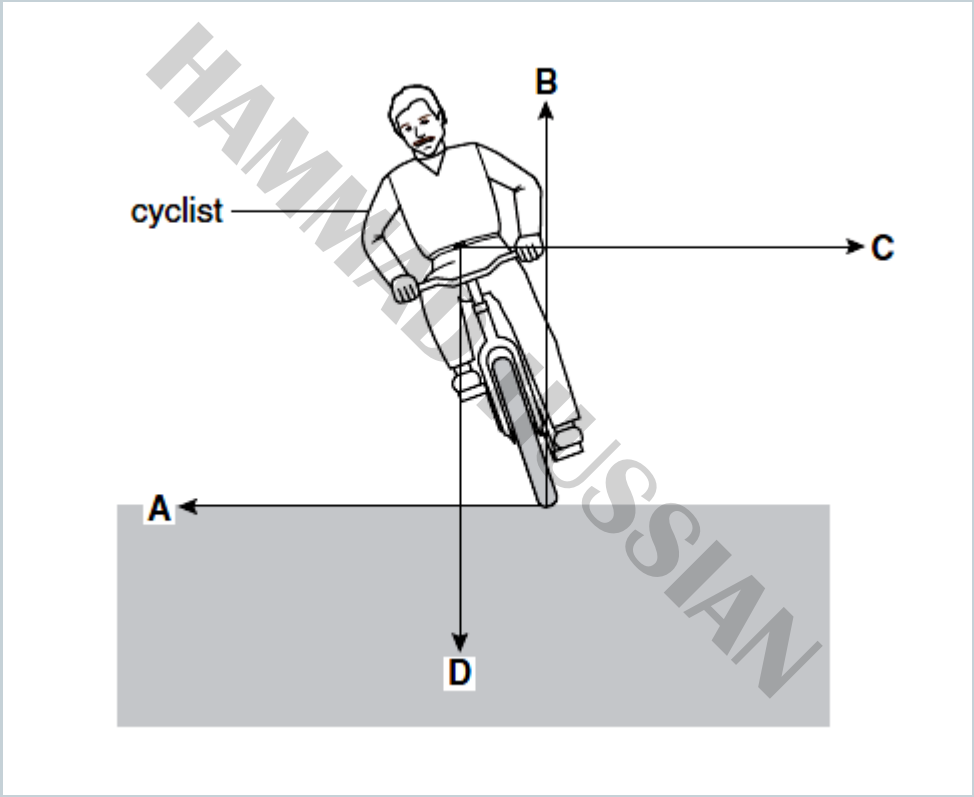


Which statement is true?

A. A force of constant size is acting in the direction of V.
B. A force of constant size is acting towards O.
C. The force on P varies in size as it moves around the circle.
D. There are no forces acting on P.

3. The diagram shows a cyclist leaning over in order to cycle around a corner.

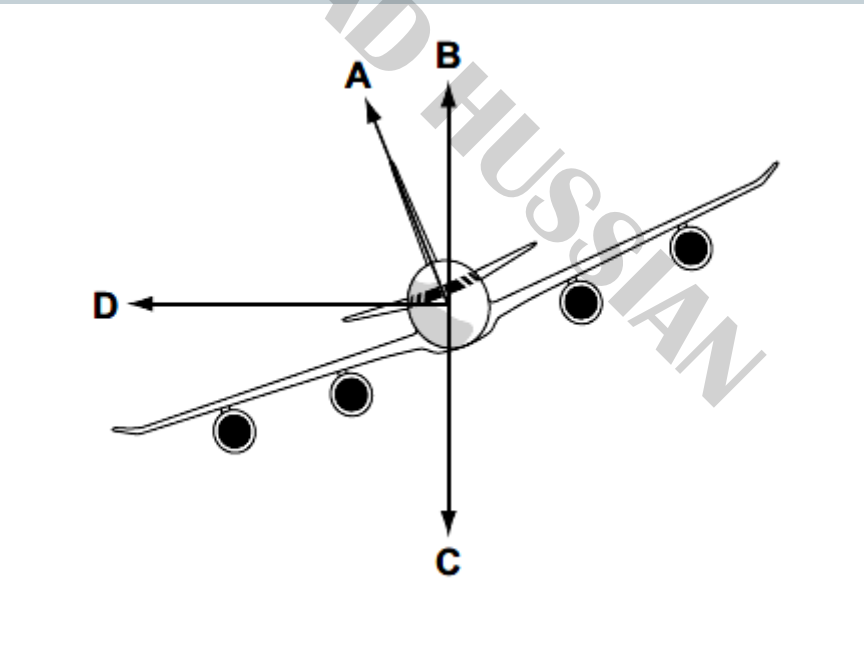
   Which force is necessary to maintain the motion around the corner?



A

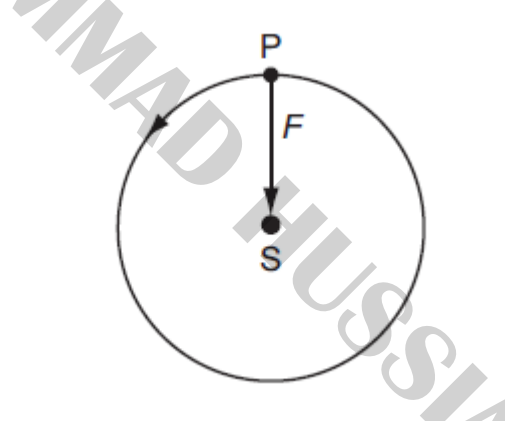
4. The diagram shows an aeroplane turning in a horizontal circle at constant speed.

   In which direction is there a resultant force?



D

5. A body P moves in a circle around a point S. A force *F* keeps it moving in the circle.

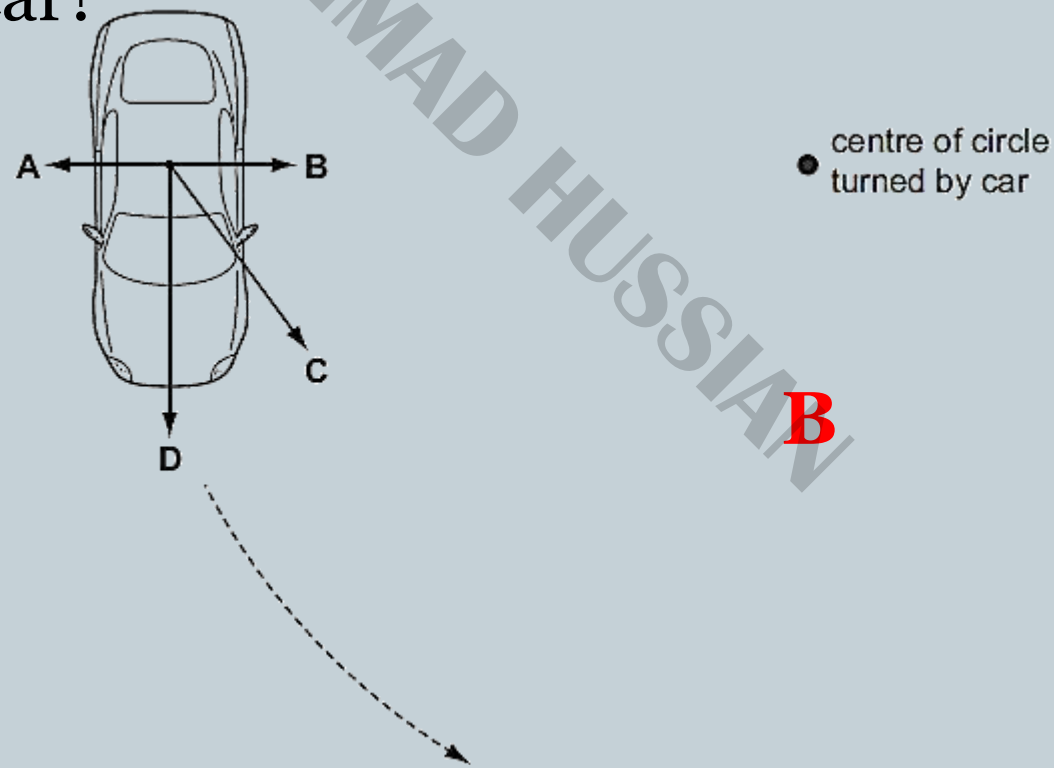


What happens if the force *F* suddenly disappears?

A. P moves directly towards S.
B. P moves in a circle closer to S.
C. P moves away from S in a curved path.
D. P goes off in a straight line.

6. A car moves in a circle at a constant speed.

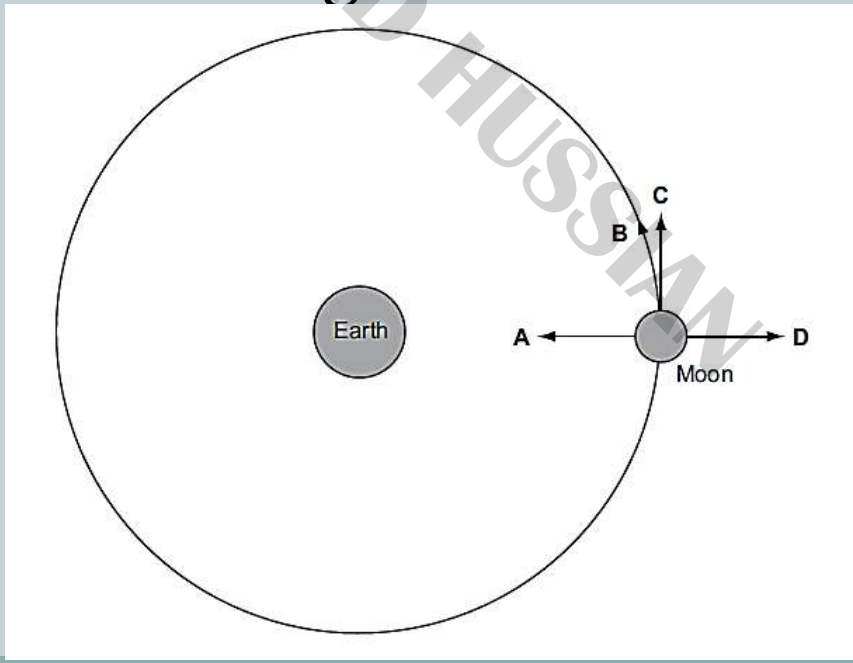
What is the direction of the resultant force acting on the car?



B

7. The diagram represents the Moon in its orbit around the Earth.

   Which arrow represents the direction of the resultant force acting on the Moon at the instant shown?

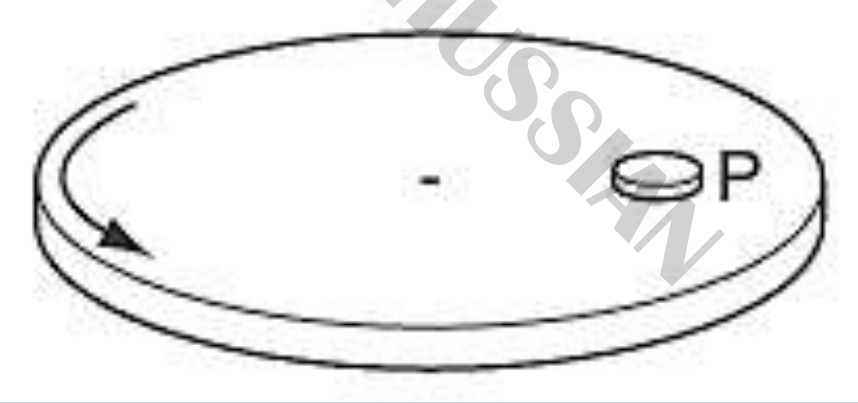


A

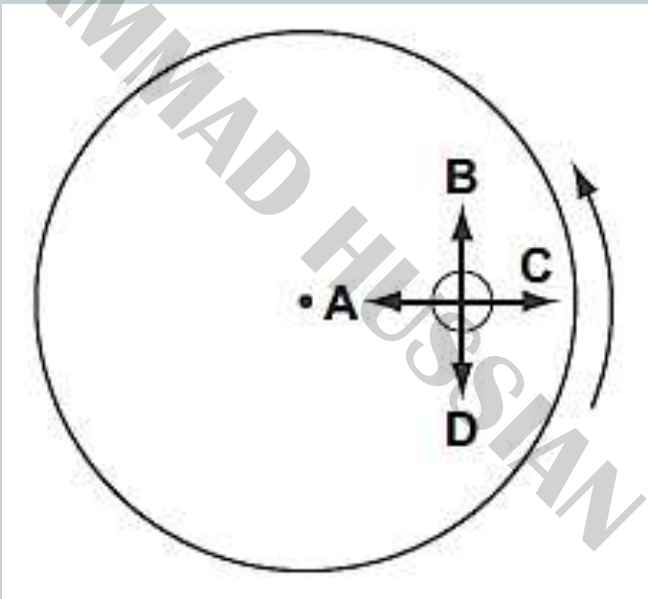
8. What keeps an electron moving in a circle around the nucleus of an atom?

A. a gravitational force away from the nucleus
B. a gravitational force towards the nucleus
C. an electrostatic force away from the nucleus
D. an electrostatic force towards the nucleus

9. A turntable rotates at constant speed. A coin is placed on the turntable at P. The friction force between the coin and the turntable keeps the coin in the same position on the turntable.



In which direction does the friction force act?



A