Length and time

Measuring length:

S.I. unit of length: meter(m)

Instrument :Measuring tape, a ruler, micrometer screw guage

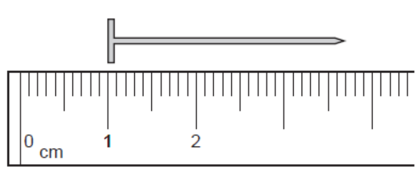
Instrument	Use	Smallest possible measurement
Measuring tape	It is a flexible rule used to measure lengths of curved objects apart from linear lengths	1mm or 0.1cm
Meter Rule	It is used to measure length of linear objects such as floor length, cloth etc	0.1cm/0.5cm or 1cm
Micrometer screw guage	It is used to measure very small lengths, example the thickness of a coin etc.	0.001cm or 0.01mm

Method of measuring with a rule:

- Place the scale right next to the object being measured.
- Place one end of the object at zero and place your eye exactly perpendicular to the other end where the object ends to avoid parallax error.
- It is fine to place the object on any other reading other than zero but do make careful calculations.

1 The diagram shows part of a ruler. The ruler is used to find the length of a nail.

0625/12/M/J/14



What is the length of the nail?

A 2.2 cm B 2.7 cm C 3.2 cm D 3.7 cm

Example: In this example, the nail is placed beginning at 1cm. Hence the length of the nail will be 3.7-1=2.7cm

This is because it is placed 1cm ahead of the zero mark.

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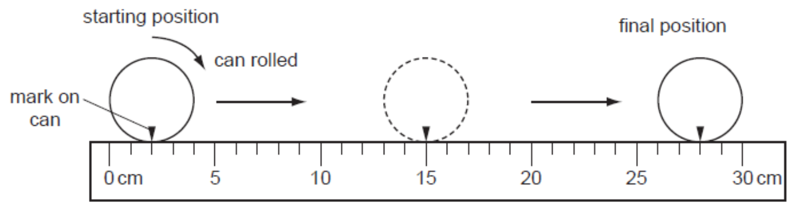
1 A cylindrical can is rolled along the ruler shown in the diagram. **0625/12/M/J/12**



The can rolls over twice.

What is the circumference (distance all round) of the can?

A 13 cm **B** 14 cm **C** 26 cm **D** 28 cm

In this case , the object is 2cm ahead of the zero mark, so from the final position of the arrow deduct 2cm. Hence the final reading is 28-2=26cm. Also the cylinder is rolled twice so it covered 2 circumferences. Hence 1 circumference=26/2=13cm

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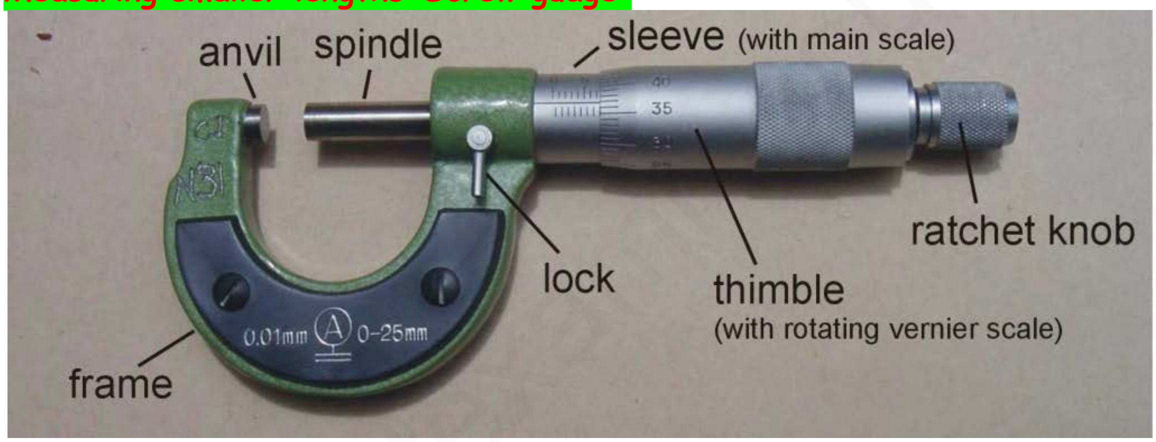
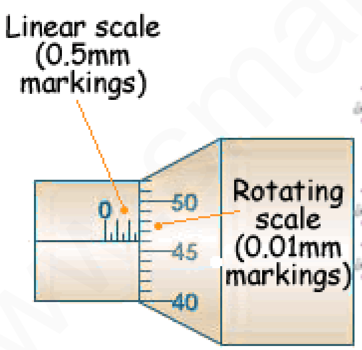
Measuring smaller lengths-Screw guage:





- **Procedure:** Place the wire between the anvil and spindle end as indicated in the diagram.
- Rotate the thimble until the wire is firmly held between the anvil and the spindle.
- The rachet is provided to avoid excessive pressure on the wire.
- It prevents the spindle from further movement and squashing the wire.

To take a reading

- First look at the main scale. This has a linear scale reading on it. The long lines are every millimetre and the shorter ones denote half a millimetre in between.
- On the diagram this reading is 2.5 mm
- Now look at the rotating scale. That denotes 46 divisions - each division is 0.01mm so we have 0.46mm from this scale.

The diameter of the wire is the sum of these readings: 2.5 + 0.46 = 2.96 mm

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Precautions:

- If you have to measure the thickness of a sheet for example, remember to take the thickness of the sheet at several different places. Then take the average thickness.

APPLICATION BASED QUESTIONS

MCQ:

1 Two digital stopwatches X and Y, which record in minutes and seconds, are used to time a race.

The readings of the two stopwatches, at the start and at the end of the race, are shown.

	start	end
stopwatch X	00:00	00:40
stopwatch Y	01:30	02:20

Which statement about the time of the race is correct?

A Both stopwatches record the same time interval.

B Stopwatch X recorded 10 s longer than stopwatch Y.

C Stopwatch Y recorded 10 s longer than stopwatch X. ✓

D Stopwatch Y recorded 50 s longer than stopwatch X.

2 A student uses a stopwatch to time a runner running around a circular track. The runner runs two laps (twice around the track). The diagrams show the reading on the stopwatch when the runner starts running, at the end of the first lap, and at the end of the second lap.

reading when runner starts — reading at end of first lap — reading at end of second lap

What is the time taken for the runner to run the second lap?

A 0 min 50 s ✓ **B** 1 min 10 s **C** 1 min 13 s **D** 2 min 03 s

3 Two digital stopwatches X and Y, which record in minutes and seconds, are used to time a race.

The readings of the two stopwatches, at the start and at the end of the race, are shown.

	start	end
stopwatch X	00:00	00:40
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Which statement about the time of the race is correct?

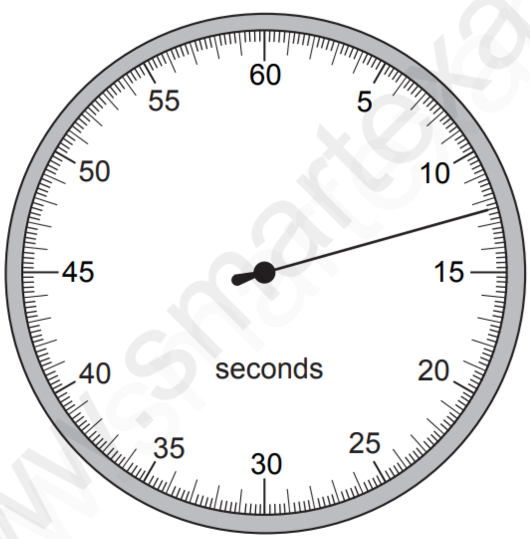
A Both stopwatches record the same time interval.

B Stopwatch X recorded 10 s longer than stopwatch Y.

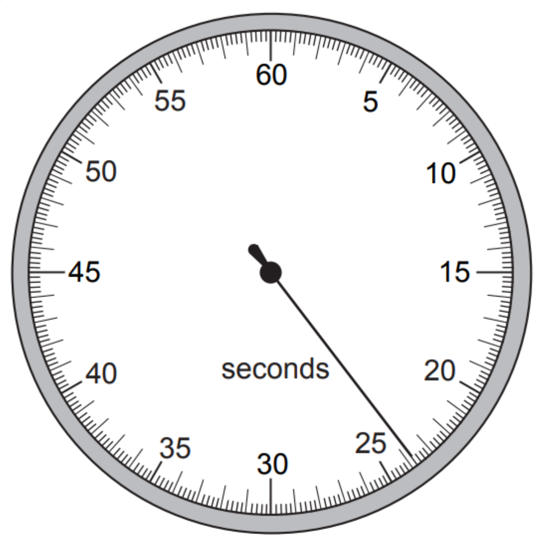
C Stopwatch Y recorded 10 s longer than stopwatch X. ✓

D Stopwatch Y recorded 50 s longer than stopwatch X.

4 A stopwatch is used to time an athlete running 100 m. The timekeeper forgets to reset the watch to zero before using it to time another athlete running 100 m.



stopwatch at end of first athlete's run



stopwatch at end of second athlete's run

How long does the second athlete take to run 100 m?

A 11.2 s **B** 11.4 s ✓ **C** 12.4 s **D** 23.8 s

2 A student has 500 identical, rectangular sheets of paper. The mass of 1.0 m^2 of the paper is 0.080 kg.

(a) Using a metre rule, she measures the length of one sheet of paper and its width. The length is 0.300 m and the width is 0.210 m.

(i) Calculate the mass of one sheet of paper.

mass = ...[1]

(ii) The student makes a single pile of the 500 sheets of paper.

With a metre rule, she measures the height of the pile. The height of the pile is 0.048 m.

Calculate the density of the paper.

density = ...[3]

(b) A second student has only 5 sheets of the same type of paper.

Suggest how this student determines the density of the paper to a similar accuracy. Additional apparatus may be used.

....

....

....

....[2]

[Total: 6]

MARKING SCHEME:

MARKING SCHEME:

(a)	**(i)** $5.0(4) \times 10^{-3}$ OR 0.0050(4) kg OR 5.0(4) g	B1
	(ii) (ρ =) m / V OR 0.00504 / (0.30 × 0.21 × 0.048) OR 0.080 / (1 × 0.048)	C1
	0.00504 × 500 / (0.30 × 0.21 × 0.048) OR 0.080 / (1 × 0.048 / 500))	C1
	$8.3(3333) \times 10^{2}$ kg / m^{3}	A1
(b)	micrometer OR screw gauge OR digital / electronic caliper	B1
	practical detail of use of micrometer OR micrometer (much) more precise than rule OR repeat and average OR measure mass with balance / scale	B1
	OR	
	tear into 500 pieces	(B1)
	pile up **and** press down OR measure mass with balance / scale	(B1)
		[Total: 6]

Measuring time

Instrument: Stopwatch

Common lab experiments include:

- Measuring period of a simple pendulum.
- Measuring the time for gathering data for creating motion time graphs

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While recording the time of a simple pendulum, note the time for 20 oscillations and divide the total time by 20 to get the average time for one oscillation.

Example:

MCQ:

1 Two digital stopwatches X and Y, which record in minutes and seconds, are used to time a race

The readings of the two stopwatches, at the start and at the end of the race, are shown.

0625/01/O/N/08

	start	end
stopwatch X	00:00	00:40
stopwatch Y	01:30	02:20

Which statement about the time of the race is correct?

A Both stopwatches record the same time interval.

B Stopwatch X recorded 10 s longer than stopwatch Y.

C Stopwatch Y recorded 10 s longer than stopwatch X.

D Stopwatch Y recorded 50 s longer than stopwatch X.

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1 A pendulum is set in motion and timed. The time measured for 20 complete swings is 30 s.

What is the time for one complete swing of the pendulum?

0625/13/O/N/12

A 0.67 s **B** 0.75 s **C** 1.5 s **D** 3.0 s

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1 A cook wants to prepare some food to be cooked by 1.15 p.m. He uses an oven with an automatic timer that can be set to switch on and off at certain times. The oven needs to be switched on for 2 hours 10 minutes.

0625/13/M/J/15

At which time does the oven need to switch on?

A 11.05 a.m. **B** 11.25 a.m. **C** 3.05 p.m. **D** 3.25 p.m.

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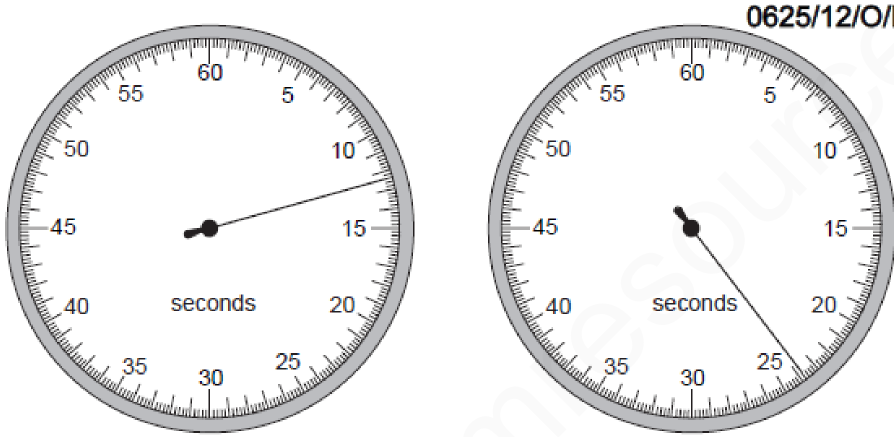
3 A stopwatch is used to time an athlete running 100 m. The timekeeper forgets to reset the watch to zero before using it to time another athlete running 100 m.

0625/12/O/N/09



stopwatch at end of first athlete's run

stopwatch at end of second athlete's run

How long does the second athlete take to run 100 m?

A 11.2 s **B** 11.4 s **C** 12.4 s **D** 23.8 s

SCALARS AND VECTORS

Scalar quantity: It has magnitude (size) only. Examples of scalars include distance, speed, time, mass, energy and temperature

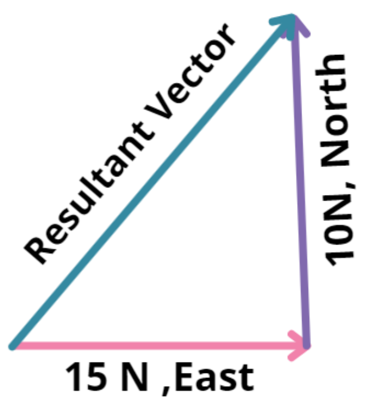
Vector quantity: It has magnitude and direction. Examples of vectors include force, weight, velocity, acceleration, momentum, electric field strength and gravitational field strength

Determine, by calculation or graphically, the resultant of two vectors at right angles:

Note that vectors have magnitude as well as direction. Hence the resultant of the two perpendicular vectors must include the magnitude as well as the direction.

The magnitude of perpendicular vectors can be found by using the Pythagoras theorem.

- **Addition of forces:**



Imagine a box being pushed with a force of 15N, in the East direction and then with a force of 10N in the North direction, Then their resultant will be in the North-East direction.

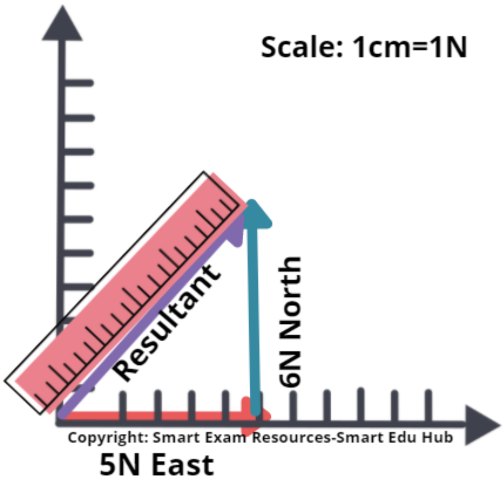
Since force is a vector, and we know that vectors are quantities that have a magnitude as well direction, we will need to find the magnitude of the resultant vector.

Since the vectors are mutually perpendicular to each other, their resultant magnitude is found by using the Pythagoras theorem.

The magnitude then becomes: $\sqrt{15^2 + 10^2}$ = $\sqrt{225 + 100}$ = $\sqrt{325}$ =18N

Thus the resultant force is 18N , North-East

Graphically we can find the resultant of the given vectors in the following way:



- The head-tail method is the graphical method of adding the two given vectors.
- Every vector has a head and a tail.
- The tail of the vector is the starting point of the vector (without the arrowhead)
- The head (or the tip) of a vector is the end point of the vector, that has an arrow.
- The tail of this vector should originate from the head of the first
- In this method, an exact scale is chosen.
- Then the given vectors are drawn to scale.
- The magnitude of the resultant is found by measuring the length using a ruler and then converting it back into the desired units
- The direction is based on the directions of the two given vectors

1.2-Motion

- **Speed:**

Definition: Speed is the distance travelled by a body in unit time.
Speed is a scalar quantity.
Units: m/s or km/hr

- **Average speed:**

Definition: Average speed is the total distance travelled by a body in total time .
Speed is a scalar quantity.
Units: m/s or km/hr

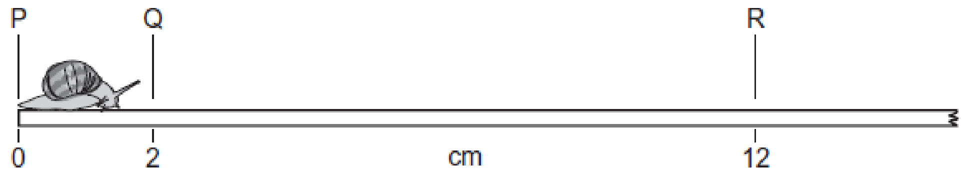
- **Speed and velocity:**

Speed	Velocity
Scalar quantity	Vector quantity
Units: m/s	Units: m/s
Speed=$\frac{distance}{time}$	Velocity= $\frac{displacement}{time}$
Speed of a body can never be negative. it can be zero	Velocity of a body can be positive, negative or zero

Sums-Speed

0625/11/M/J/10

4 A snail moves along a ruler. It takes 20s to move from Q to R.



What is its average speed from Q to R?

A $\frac{12}{20}$ cm/s

B $\frac{12-2}{20}$ cm/s

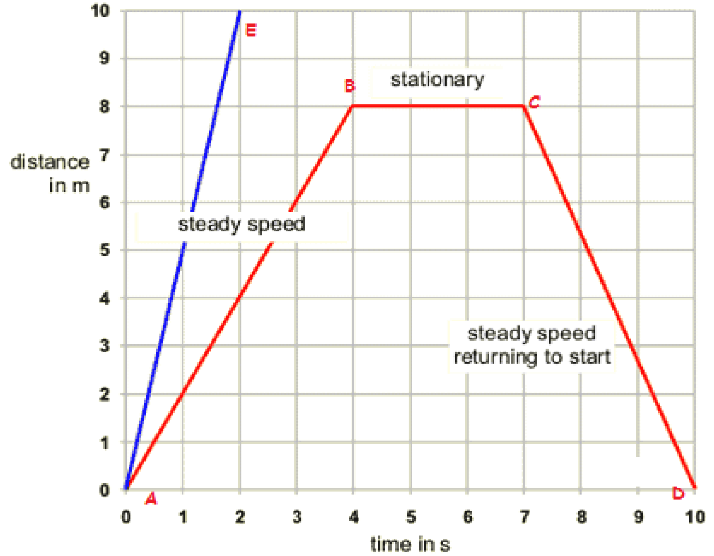
C $\frac{20}{12}$ cm/s

D $\frac{20}{12-2}$ cm/s

The concept of speed can be represented by two kinds of graphs:

- distance -time graphs
- speed-time graphs

Distance -time graphs:



A-B ⟹ Steady speed-Constant slope

B-C ⟹ Vehicle has stopped-Zero speed-Zero slope

C-D ⟹ Constant speed-Constant slope. Object returning to the starting point

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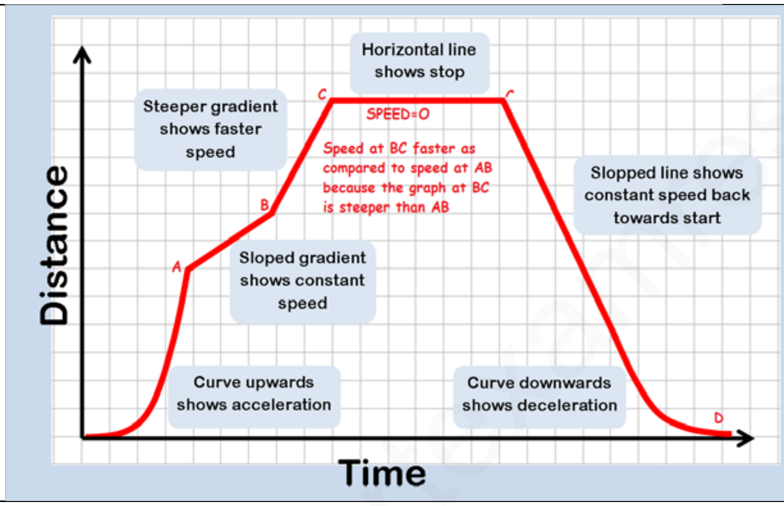
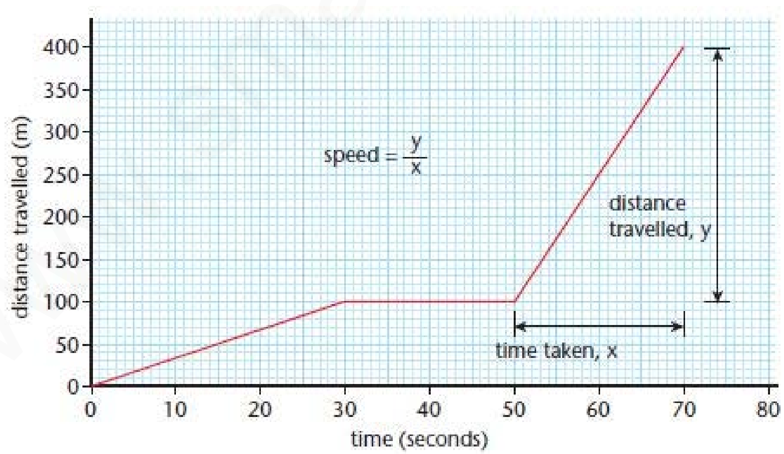
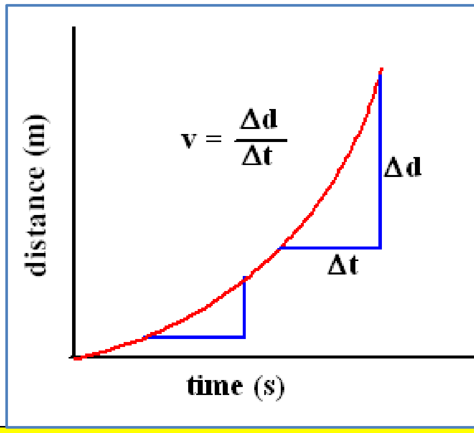


Slope of a distance time graph gives you the speed of the graph



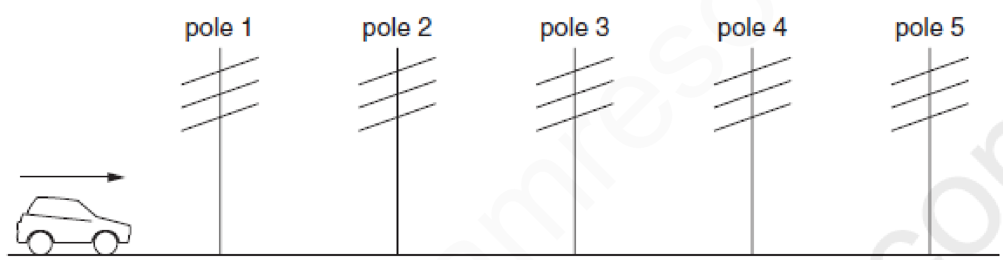


When a body covers unequal distances in equal intervals of time then the graph is a curved graph. Then the speed at a particular time is found by drawing a tangent to the point and calculating its slope.

APPLICATION BASED QUESTIONS:

3 Five telegraph poles are positioned at equal distances along the side of a road.

0625/01/O/N/03



A car accelerates until it is level with pole 4. The car then continues along the road at a steady speed. The times taken to travel between one pole and the next are measured.

Which time is the greatest?

The time between

- **A** pole 1 and pole 2.
- **B** pole 2 and pole 3.
- **C** pole 3 and pole 4.
- **D** pole · pole 5.

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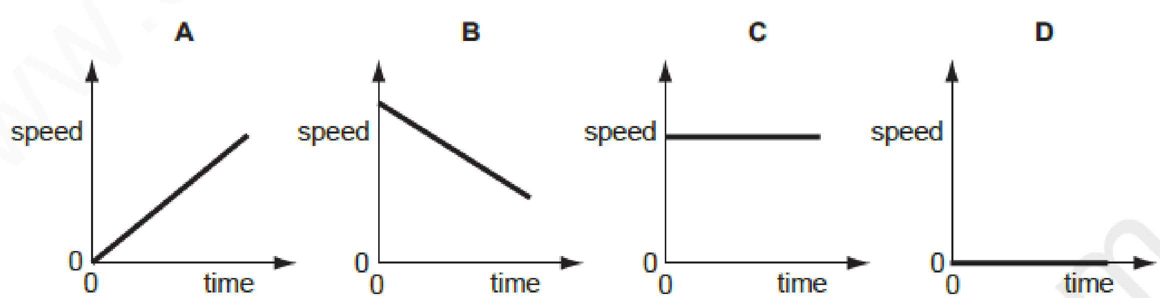
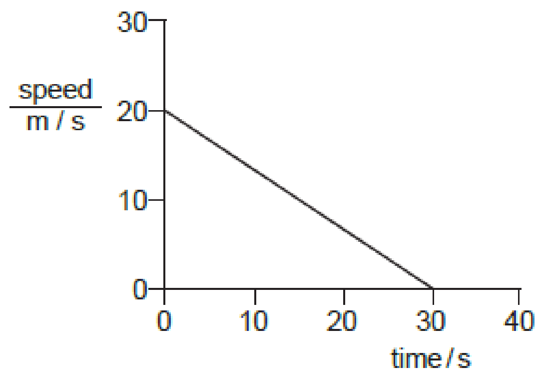
3 Which speed/time graph applies to an object at rest?

0625/01/O/N/04



2 The graph represents part of the journey of a car. **0625/01/O/N/05**



What distance does the car travel during this part of the journey?

A 150 m **B** 300 m **C** 600 m **D** 1200 m

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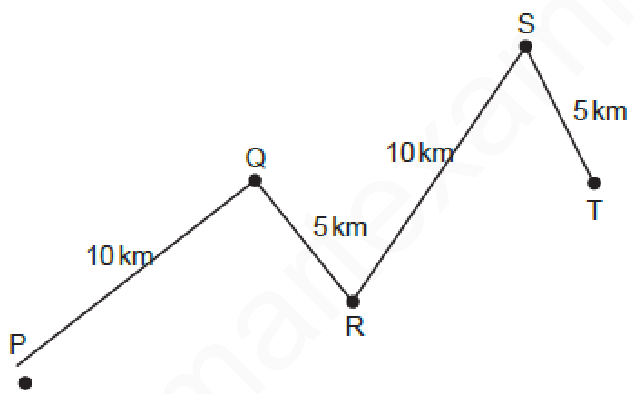
3 A car travels along the route PQRST in 30 minutes. **0625/01/O/N/06**

What is the average speed of the car?



A 10 km / hour

B 20 km / hour

C 30 km / hour

D 60 km / hour

APPLICATION BASED QUESTIONS-EXTENDED THEORY:

1 Fig. 1.1 is a distance/time graph showing the motion of an object. 20

M/J/2-P32

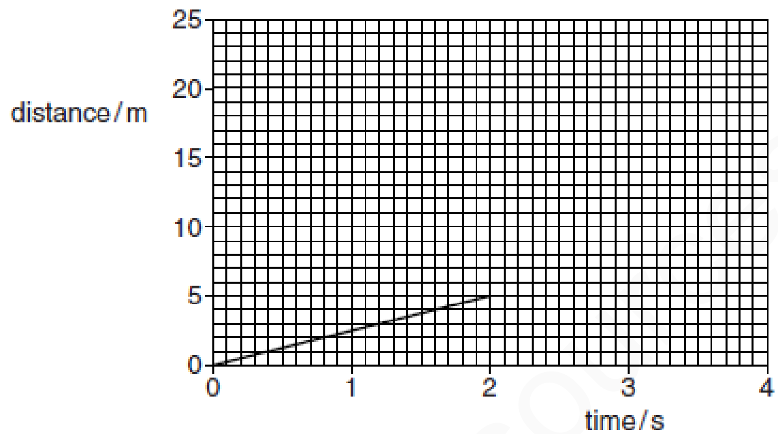


Fig. 1.1

(a) **(i)** Describe the motion shown for the first 2s, calculating any relevant quantity.

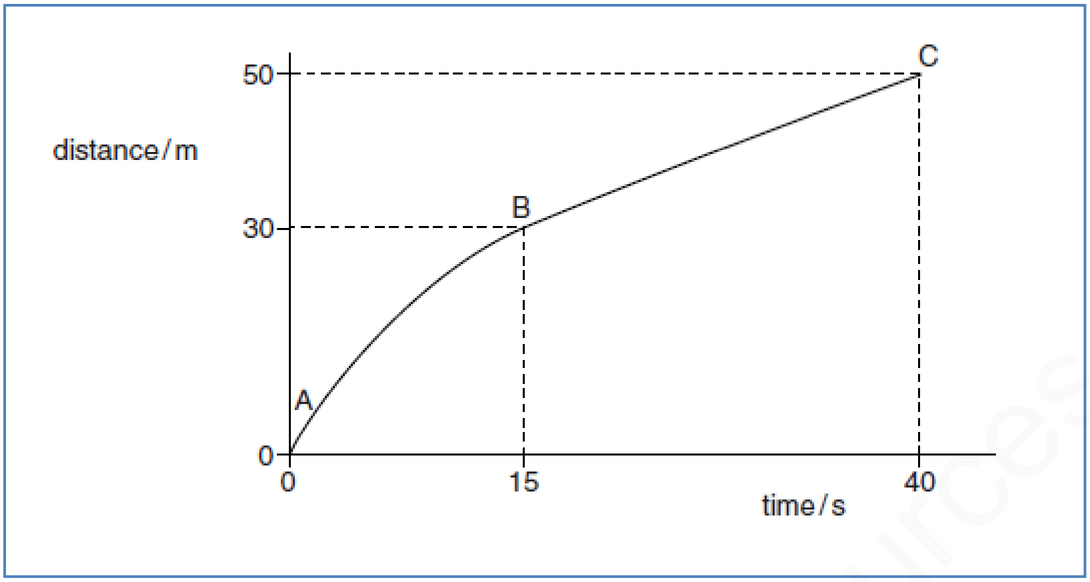
The journey during the first two seconds is described using the words:constant/steady or uniform(Speed or velocity)
You may also mathematically decribe the speed or tlee velocity as being 2.5m/s .
So remember you may decribe the graph in words or in figures through calculations , both are equally acceptabe

(ii) After 2s the object accelerates. [2]
On Fig. 1.1, sketch a possible shape of the graph for the next 2s.

The word accelerate means to speed up. So the graph has to be drwan as curving upwards
Rejected: If u draw a straight line going upwards. [1]
Note Next 2 seconds is mentioned . So u need to extend your graph to this distance. (Ms says either graph should touch 25m or upto 3.5s)

(b) Describe how a distance/time graph shows an object that is stationary.

Horizontal straight line or a line parallel to x axis or time axis is the vocab to be used. [1]



Speed of the objects between points AB can be described as:

1. Decreasing or

2. Average speed =2m/s. (The word average is important as it is the total distance /total time taken =$\frac{30}{15} = 2m/s$

3. Acceleration=negative

Speed of the objects between points BC can be described as:

1. Constant or

2. Speed =0.8m/s. (distance / time taken =$\frac{50-30}{40-15} = 0.8m/s$

3. Acceleration=Zero (Because: Velocity is constant, so change in velocity is zero)

Calculate the average speed of the object during the first 40s:

Must show calculation as = Velocity=d/t=50/40-=1.25m/s

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OBSERVATIONS:

- Describe a section of a graph: You may describe using words or even through calculations.
- Calculate means to show the formula and the steps.

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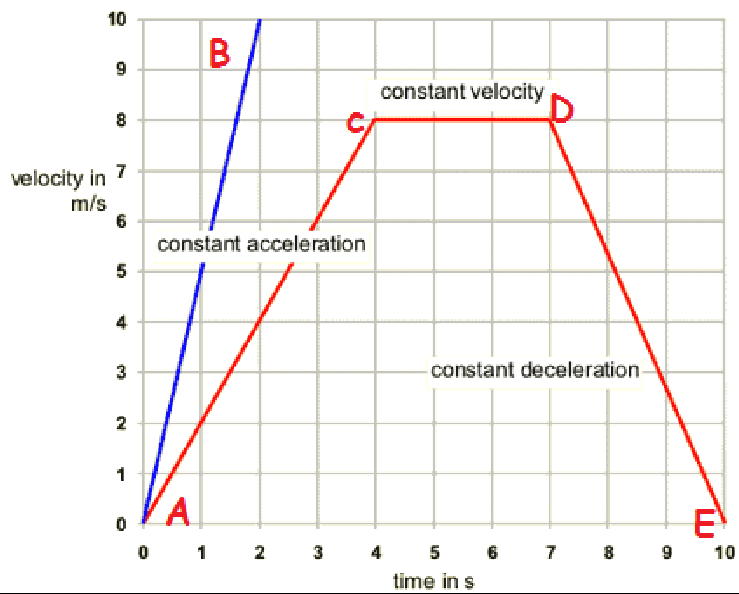
Speed/Velocity- time graph:



AB shows the journey with greater constant acceleration compared to part AC.

CD shows constant velocity as value of the value of velocity does not change

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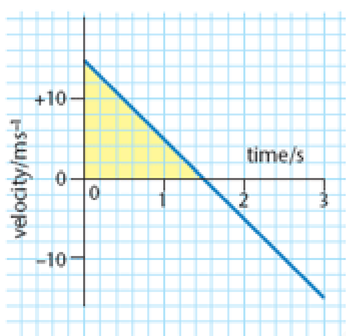
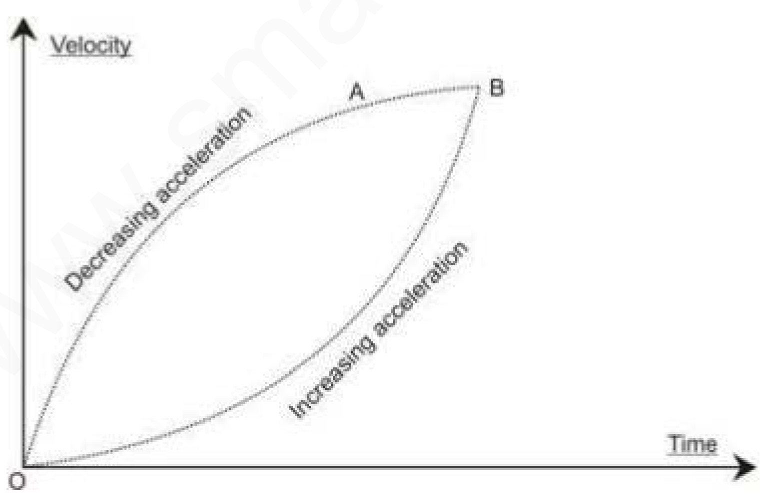
DE shows constant deceleration because the graph is sloping downwards.

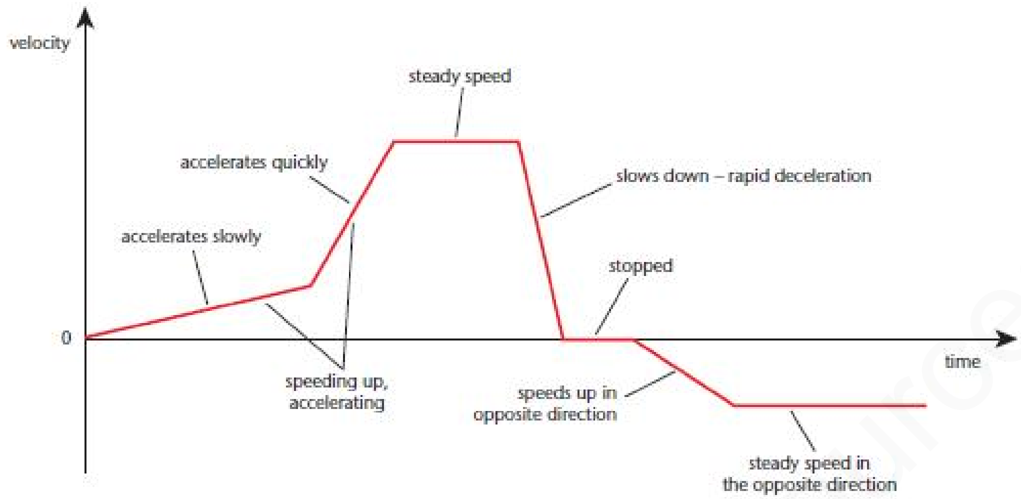


The positive and negative velocity means that the motion is in the opposite direction.

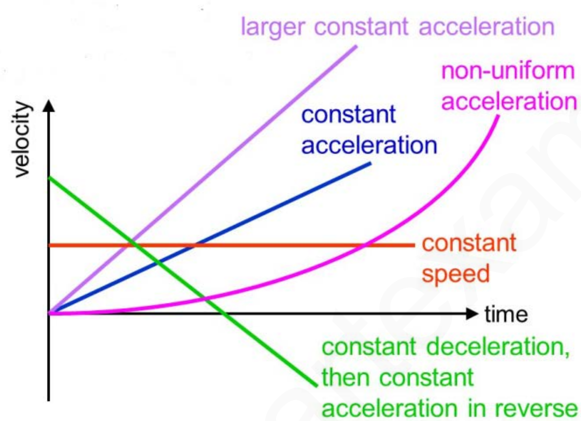
The graph shows decreasing and increasing acceleration.



In addition to the other features described in the previous graphs the following graph tells you how to represent a stopped vehicle (velocity=0)

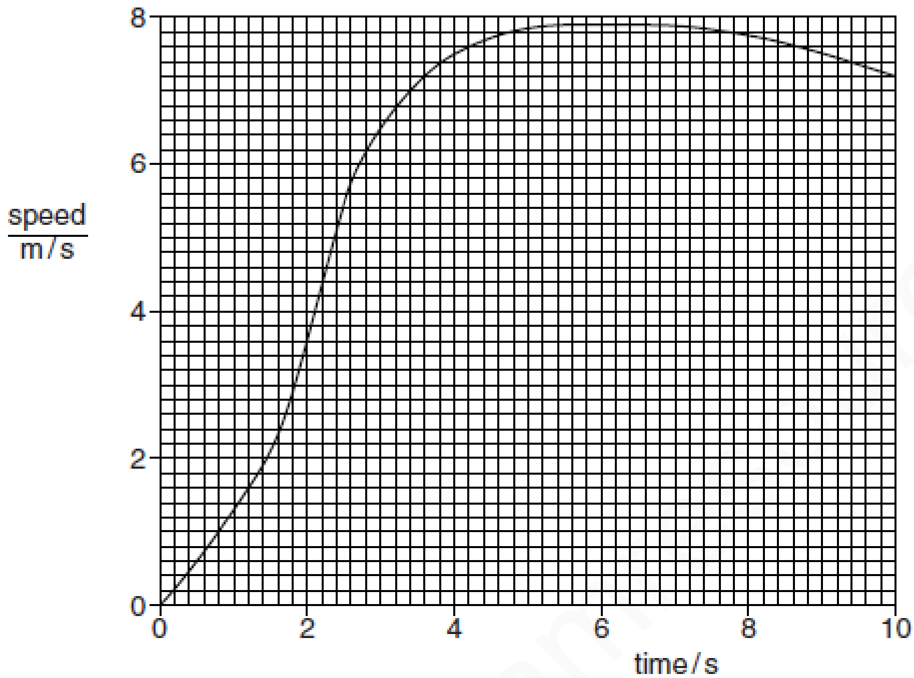


The changing acceleration is better described as non-uniform acceleration.



Application based concepts discussed

Graph of an athlete's race:



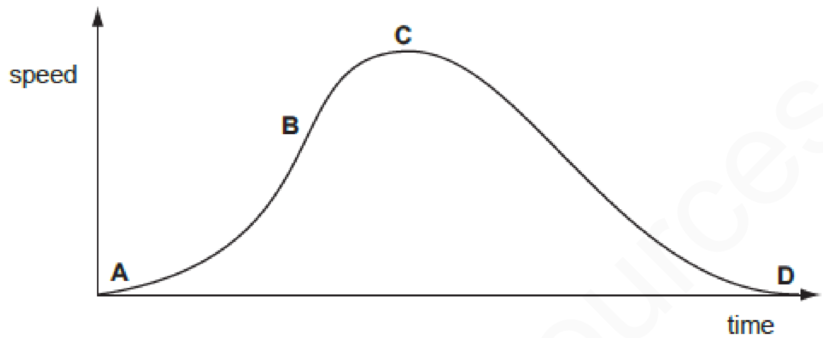
Calculate the distance that the athlete runs:
Found by calculating the area under the graph.
Maximum acceleration of the athlete: [4m] Observe the graph carefully and draw a tangent to the steepest part of the curve[1m]. Draw a tangent at this point and show the calculation of $\frac{\Delta v}{\Delta t}$ [1m].Plug in values[1m].State the final answer[1m]
If she runs a distance of 62m . Calculate her average speed:
Average speed $= \frac{Total\ distance}{Total\ time}$

$$\Rightarrow \frac{62}{10} = 6.2m/s$$

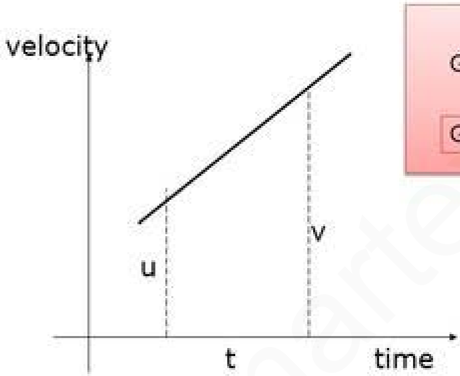
Application based questions-MCQ:

1 The speed-time graph shown is for a bus travelling between stops.

Where on the graph is the acceleration of the bus greatest? **0625/12/O/N/11**



Properties of a velocity time graph



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

Gradient = Acceleration

Area under graph = $\frac{1}{2}(u+v)t$

Area = Distance travelled

1 A comet, travelling in space, enters the atmosphere of a planet.

Fig. 1.1 is the speed-time graph for the comet from time $t = 0$ s. O/N/15-P32-Q1

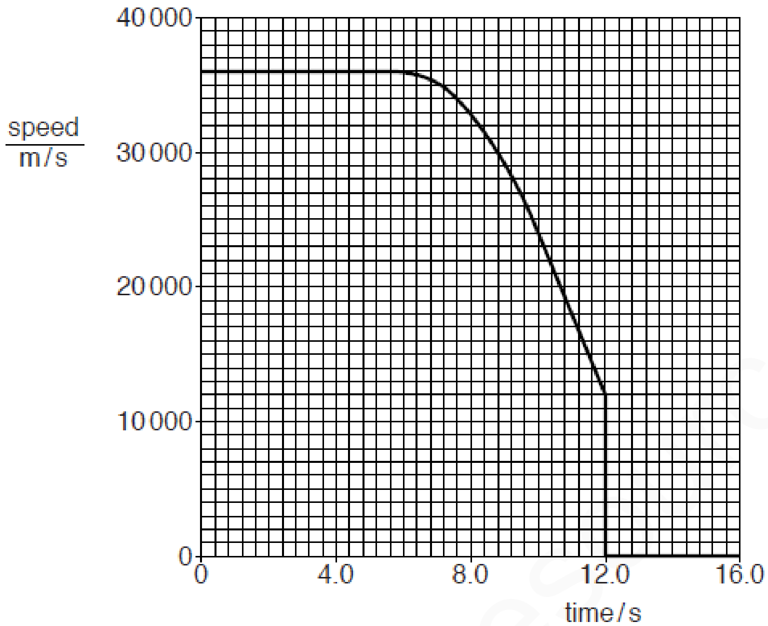


Fig. 1.1

(a) (i) During the period $t = 0$ s to $t = 6.0$ s, both the speed of the comet and the velocity of the comet remain constant.

State what this suggests about the motion of the comet.

....

....[1]

(ii) Determine the distance travelled during the period $t = 0$ s to $t = 6.0$ s.

distance = ...[2]

(b) Explain what the graph shows about the motion of the comet during the period t = 6.0 s to t = 10.0 s.

....

....

....[2]

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(c) Determine the acceleration of the comet at t = 11.0 s.

acceleration = ...[2]

(d) Suggest what happens to the comet at t = 12.0 s.

....

....[1]

[Total: 8]

1 Fig. 1.1 shows a smooth metal block about to slide down BD, along DE and up EF.
BD and DE are friction-free surfaces, but EF is rough. The block stops at F.

O/N/2002-P3-Q1

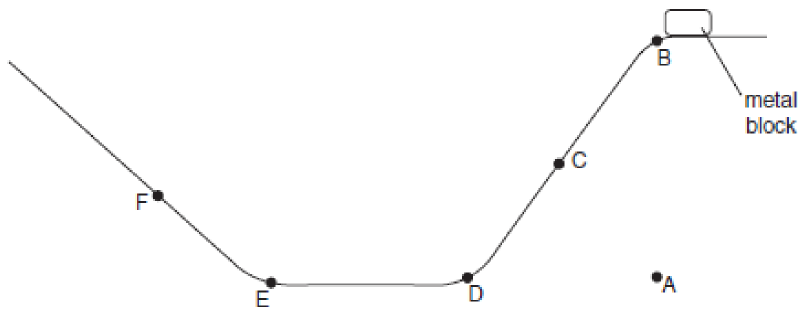


Fig. 1.1

(a) On Fig. 1.2, sketch the speed-time graph for the journey from B to F.
Label D, E and F on your graph. [3]

(c) As it passes D, the speed of the block remains almost constant but the velocity changes. Using the terms *vector* and *scalar*, explain this statement.

....

....

....[2]

1 Fig. 1.1 shows the speed–time graph of a person on a journey.

On the journey, he walks and then waits for a bus. He then travels by bus. He gets off the bus and waits for two minutes. He then walks again. His journey takes 74 minutes.

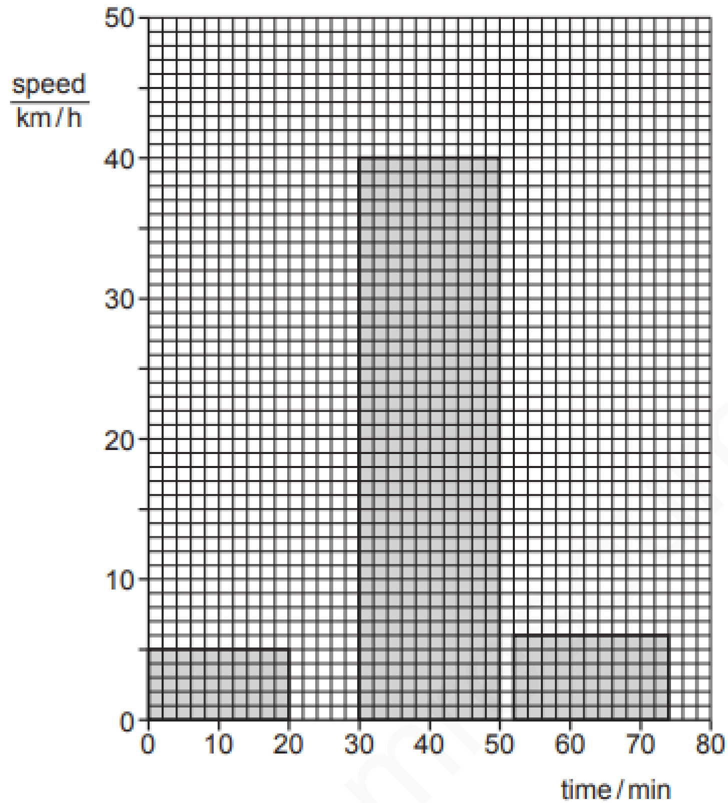


Fig. 1.1

(a) For the whole journey calculate:

(i) the distance travelled

distance = ... [3]

(ii) the average speed.

average speed = ... [2]

(b) State and explain which feature of a speed–time graph shows acceleration.

....

.... [2]

(c) State and explain the acceleration of the person at time = 40 minutes.

....

.... [2]

[Total: 9]

Acceleration of free fall:

- An object that is moving only under the influence of gravity is said to be under free fall.
- Free falling objects accelerate at a constant rate.
- The acceleration due to gravity is approximately $9.8 m/s^2$
- Under free fall, objects reach the earth at the same time , irrespective of their masses; if dropped from the same height above the earth's surface because the acceleration of free fall is constant.
- A non zero resultant force acts on a free falling object that has just been released.

FALLING OBJECTS ARE AFFECTED BY TWO TYPES OF FORCES:

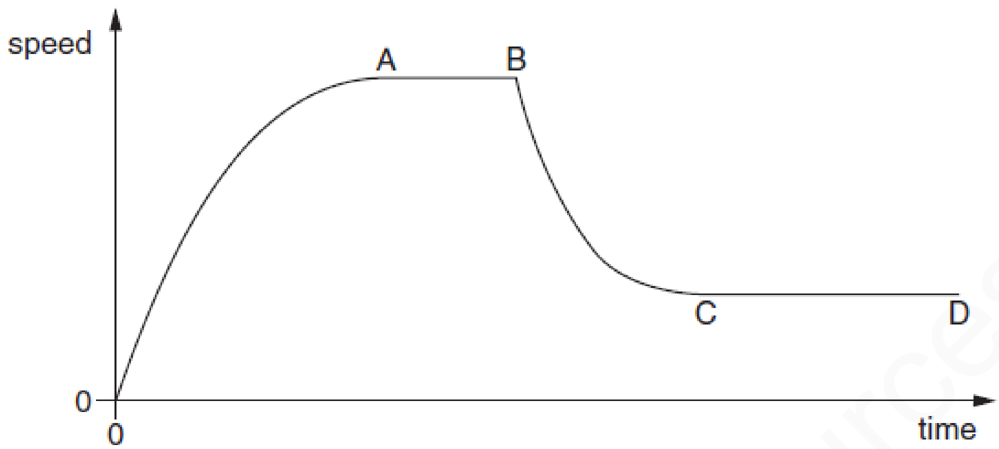
1. **The weight of the object:** This is a force acting downwards, caused by the object's mass being pulled by the Earth's gravitational field.
2. **Air resistance:** This is a frictional force acting in the opposite direction to the movement of the object.

THE ACT OF FALLING OF OBJECTS CAN BE CATEGORISED INTO 3 STAGES BEFORE IT HITS THE GROUND:

1. At the start, the object accelerates downwards because of its weight. There is no air resistance. There is a resultant force acting downwards.
2. As it gains speed, the object's weight stays the same, but the air resistance on it increases. There is a resultant force acting downwards.
3. Travelling at steady speed: Eventually, the object's weight is balanced by the air resistance. There is no resultant force and the object reaches a steady speed, called the terminal velocity.

Free fall graphs:

A parachutist jumps out of an aeroplane but does not open his parachute until some time has elapsed.



a. The value of the acceleration immediately after he has jumped from the aeroplane is:10m/s^2.
b. The acceleration decreases until point A on the graph is reached. This is because the graph becomes less steep (or the gradient decreases)
c. The parachutist's speed in region AB is: constant
d. The forces on the parachute in the AB region: There is no resultant force(Or upward force = downward force or weight= air resistance)
e. The point at which the parachutist opened his parachute: B
f. The speed decrease from B-D because: the air resistance is bigger than the weight because as the parachute is opened it provides a larger surface area

----

APPLICATION BASED QUESTIONS

4 Two stones of different weight fall at the same time from a table. Air resistance may be ignored.

What will happen and why? **0625/12/O/N/12**

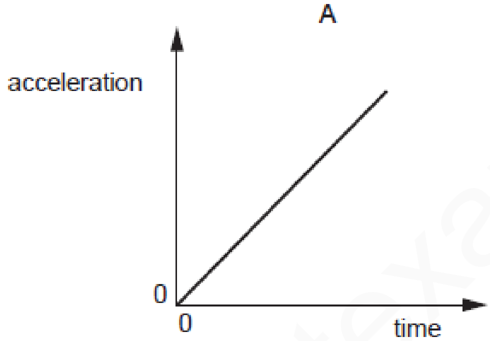
	what will happen	why
A	both stones hit the floor at the same time	acceleration of free fall is constant
B	both stones hit the floor at the same time	they fall at constant speed
C	the heavier stone hits the floor first	acceleration increases with weight
D	the heavier stone hits the floor first	speed increases with weight

3 A stone falls freely from the top of a cliff into the sea. Air resistance may be ignored.

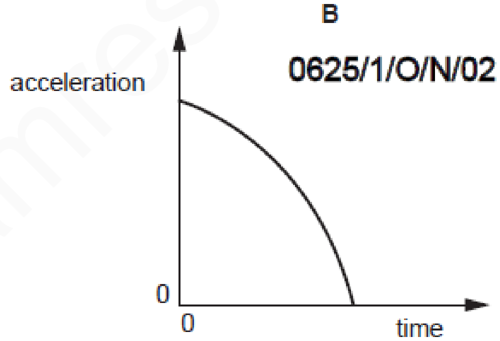
Which graph shows how the acceleration of the stone varies with time as it falls?

0625/1/O/N/02

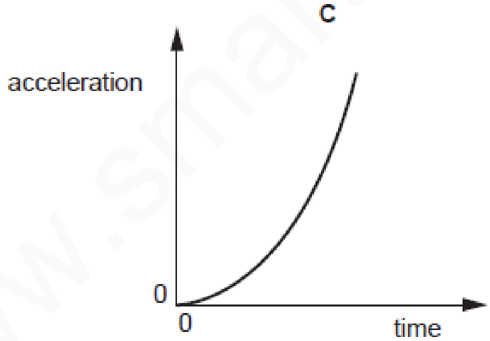
A



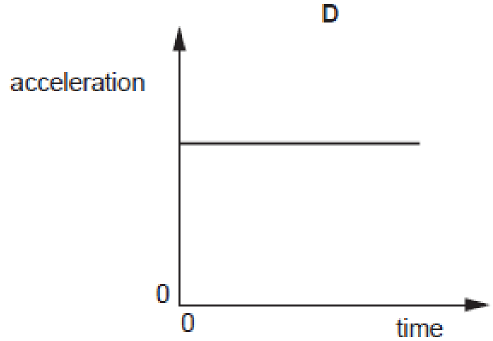
B



C



D



APPLICATION BASED QUESTIONS:

1 An experiment is carried out to find the acceleration of free fall.

A strip of paper is attached to a heavy object. The object is dropped and falls to the ground, pulling the paper strip through a timer. The timer marks dots on the paper strip at intervals of 0.020 s.

Fig. 1.1 shows a section of the paper strip with the first three dots marked. The first dot on the paper strip, labelled A, is marked at the instant the object is dropped.

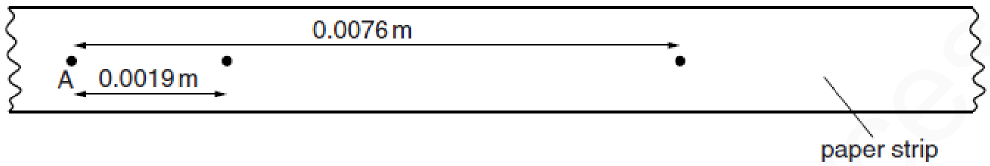


Fig. 1.1 (not to scale)

(a) State how the dots on the paper strip show that the object is accelerating.

....

....[1]

(b) Calculate the average speed of the object

(i) in the first 0.020 s after the object is dropped,

average speed = ...

(ii) in the second 0.020 s after the object is dropped.

average speed = ...

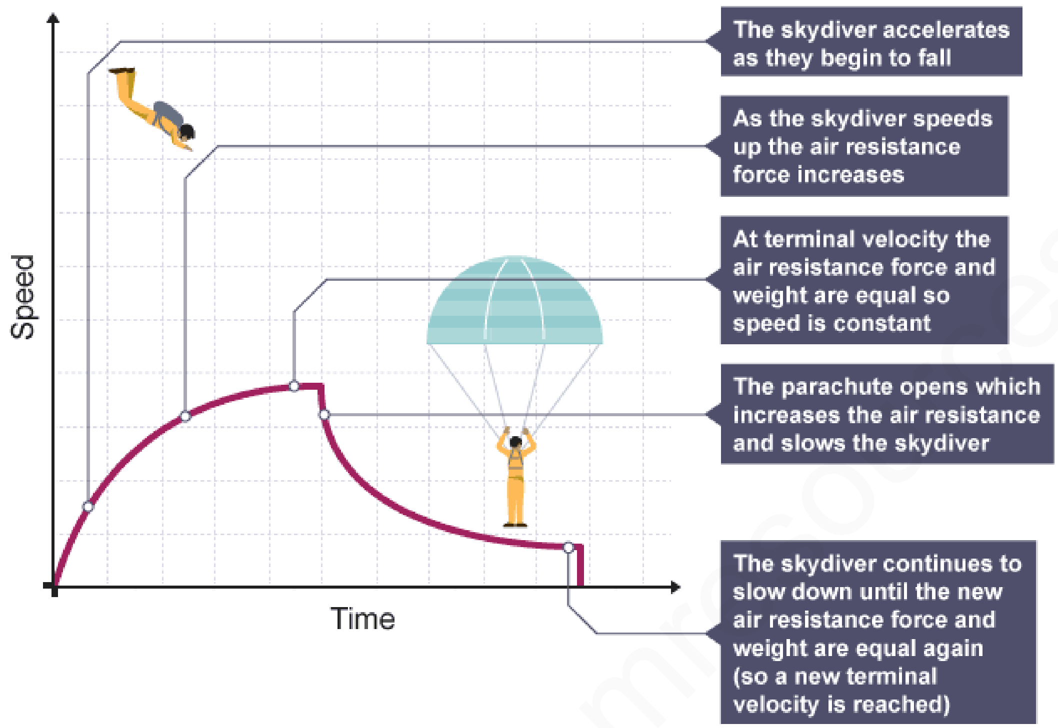
[3]

(c) Use the results from **(b)** to calculate the acceleration of the falling object.

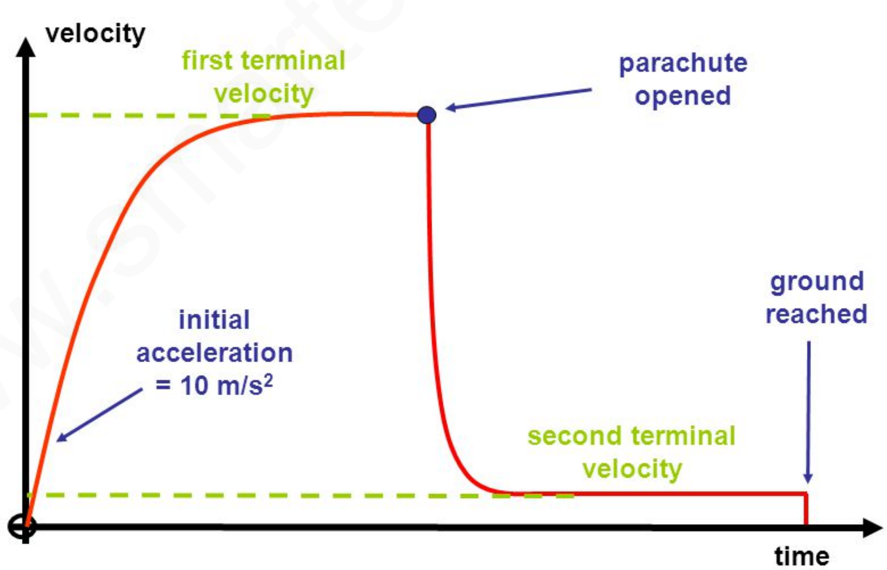
acceleration = ...[3]

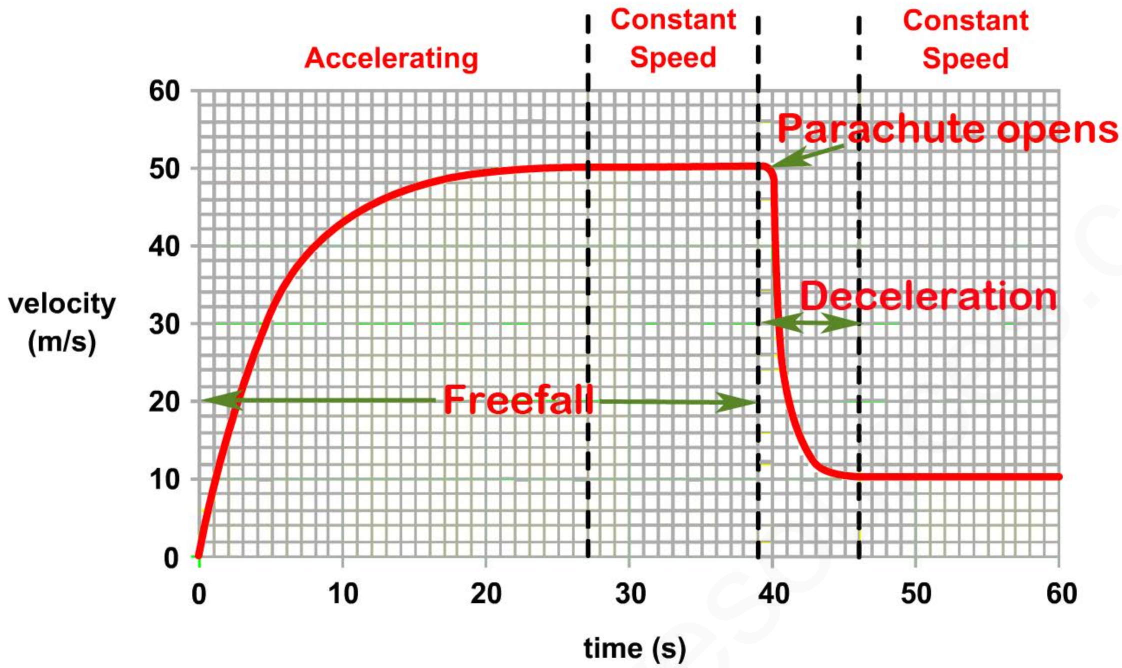
[Total: 7]

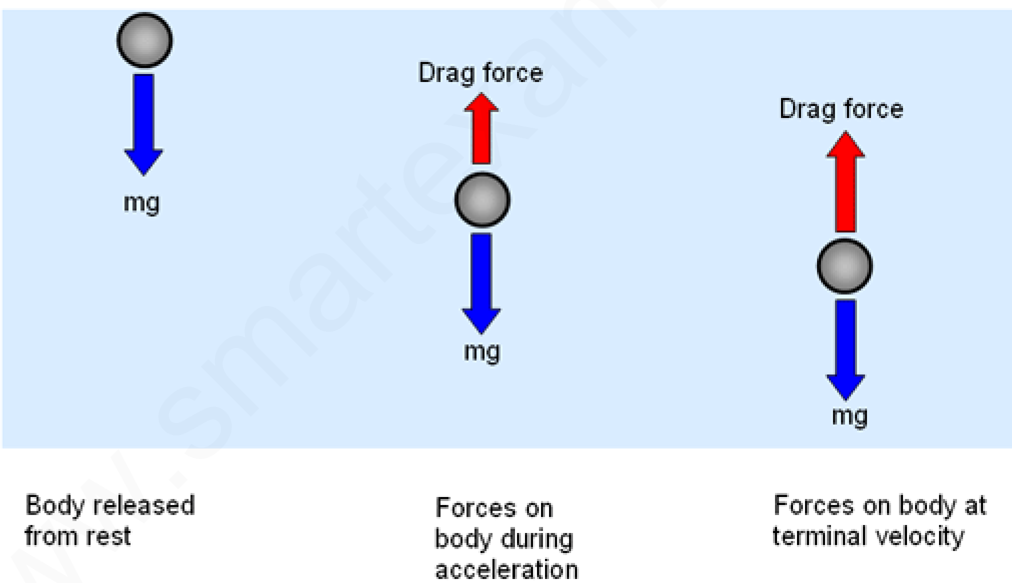
FREE FALL GRAPHS:



Velocity-time graph of a parachutist




Accelerating
Constant Speed
Constant Speed
Parachute opens
Deceleration
Freefall
velocity (m/s)
time (s)
0
10
20
30
40
50
60


mg
Drag force
mg
Drag force
mg
Body released from rest
Forces on body during acceleration
Forces on body at terminal velocity

EXTENDED THEORY

1 A free-fall parachutist jumps from a helium balloon, but does not open his parachute for some time.

O/N-P33-Q1

Fig. 1.1 shows the speed-time graph for his fall. Point B indicates when he opens his parachute.

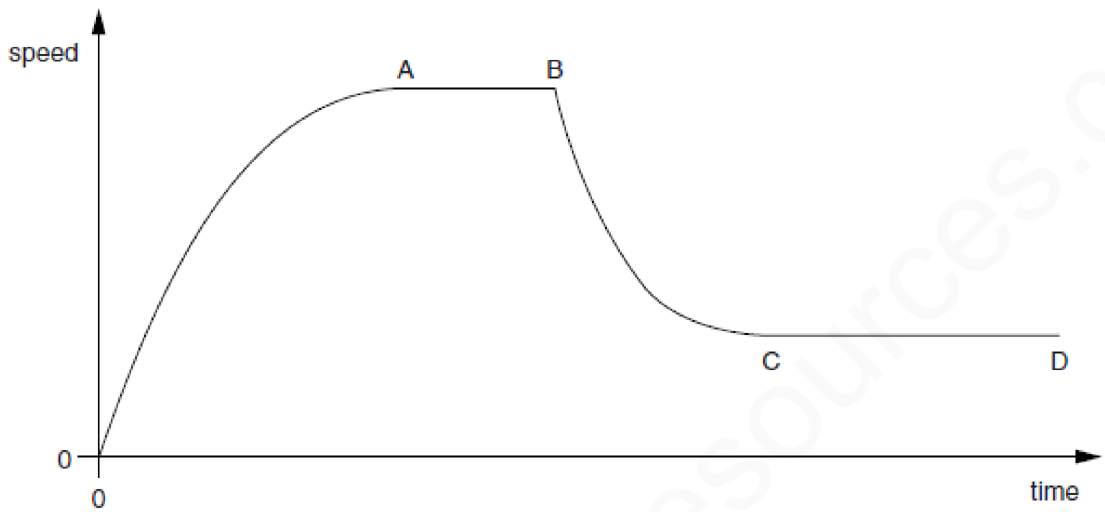


Fig. 1.1

(a) **(i)** State the value of the gradient of the graph immediately after time $t = 0$.

gradient = ... [1]

(ii) Explain why the gradient has this value.

....

....[1]

(b) State how Fig. 1.1 shows that the acceleration decreased between time $t = 0$ and the time to A.

....

....[1]

(c) Explain, in terms of forces, what is happening in section AB of the graph in Fig. 1.1.

....

....

....[2]

DENSITY, MASS AND VOLUME

Density: Density is defined as the mass per unit volume => p=m/V
Units: g/cm^3 or kg/m^3

Subtopics to be covered under density:
Finding the density :

- of a liquid
- of a regular solid
- of an irregularly shaped solid
- Predict whether an object will float on density data.

Mass: It is the measure of the quantity of matter in an object at rest relative to the observer
Mass is measured with a spring balance.
It is a scalar quantity

Weight: It is the gravitational force on an object that has mass
Weight= mass x acceleration due to gravity
W=mg
Weight is measured with a Newton meter.
Weight is a vector quantity and the unit is Newton(N)
Weights may be compared using a balance

Weight changes from place to place but the mass stays constant.

Gravitational field strength: It is the force per unit mass
g=W/m and this is eqivalent to the acceleration of free fall.

Finding the density of a liquid:

The density of a liquid can be found by the following method:

- Measure the mass of the empty measuring cylinder.(m_1)
- Pour a fixed volume of water in the measuring cylinder. Note this volume as v cm^3.
- Note the mass of measuring cylinder + water as m_2.
- Find the mass of the water by subtracting m_1 from m_2.
- Find the density of the liquid by using the formula:

$$Density = \frac{mass}{volume} = \frac{m_2 - m_1}{v} \ (g/cm^3)$$

1 Fig. 1.1 shows a side view of a large tank in a marine visitor attraction. **M/J/13-p32**

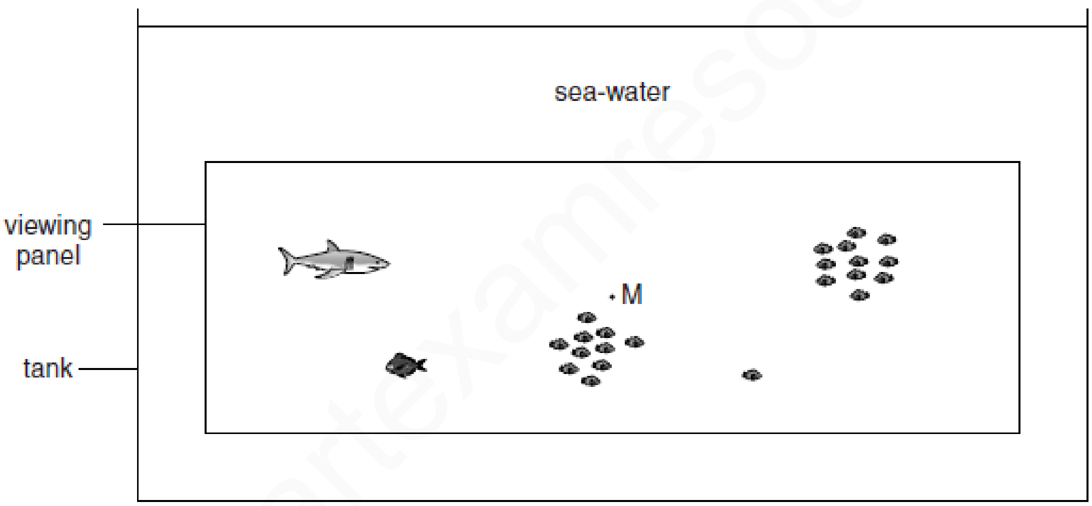


Fig. 1.1 (not to scale)

The tank is 51 m long and 20 m wide. The sea-water in the tank is 11 m deep and has a density of 1030 kg/m^3.

(a) Calculate the mass of water in the tank.

mass = ... [3]

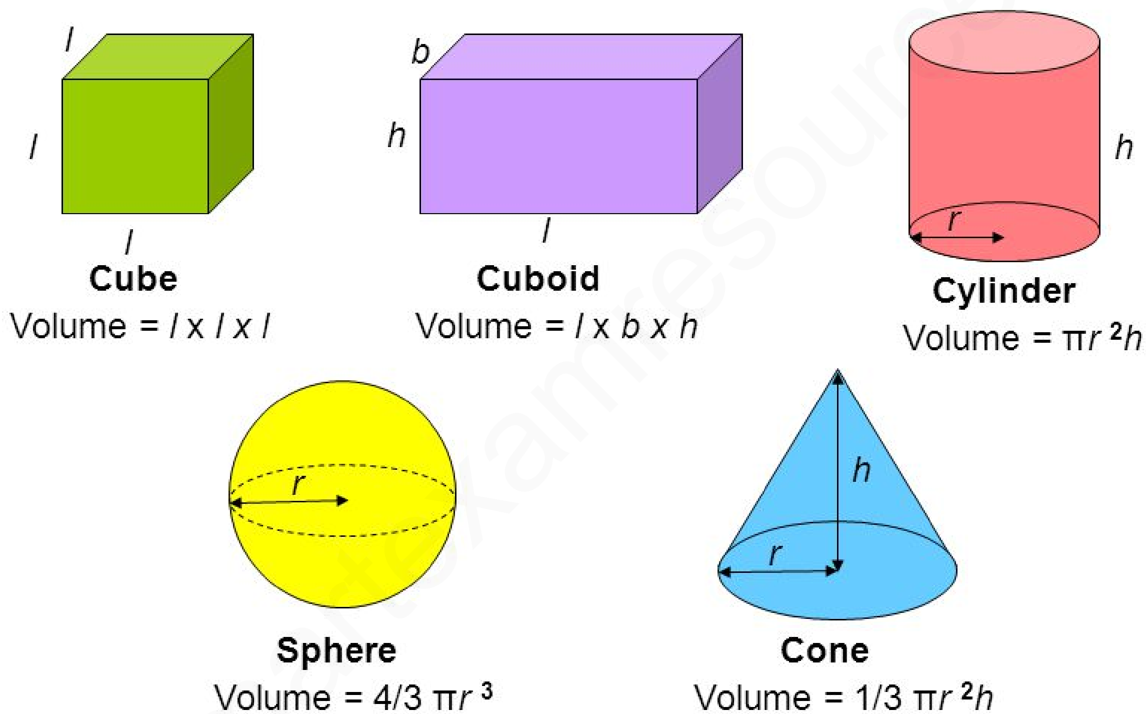
Finding the density of an irregular solid:

The density of a regular soild can be found by the following method:

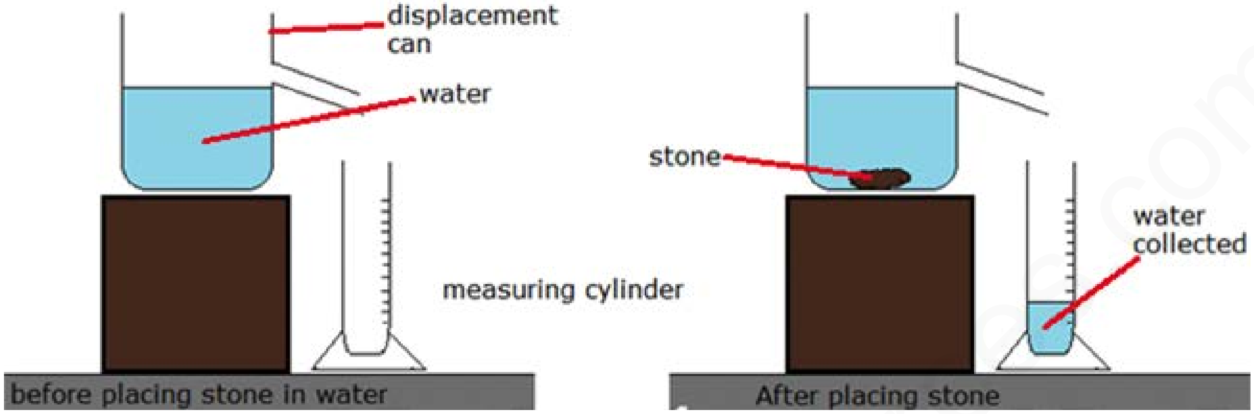
- Note the dimensions of a regular solid and use them to find the volume. Record the volume in v cm^3.
- Place the solid on a weighing pan and record its mass as m gm

Use the formula: $Density = \frac{mass}{volume} = \frac{m}{v}$ (g/cm^3)

Following are the formulae of some regular shapes:



Finding the density of an irregular solid by displacement method:



Suppose you have to find the density of an irregular object like a stone. It can be found in the following way.

- Weigh the stone and record its mass(m_1) in gm.
- Take water in a displacement can . Fill the can to the point which is exactly upto the lower level of the spout.
- Now immerse the stone in the can.
- Water will be displaced by the stone into the measuring cylinder. This volume of the displaced water in the measuring cylinder is actually the volume of the stone. Note this volume as v cm^3.
- Use the formula $Density = \frac{mass}{volume} = \frac{m}{v}$ (g/cm^3)

APPLICATION BASED QUESTION:-EXTENDED THEORY

2 A student is given the following apparatus in order to find the density of a piece of rock.

O/N/2002-P3

100 g mass
metre rule
suitable pivot on which the rule will balance
measuring cylinder that is big enough for the piece of rock to fit inside
cotton
water

The rock has a mass of approximately 90 g.

(a) **(i)** In the space below, draw a labelled diagram of apparatus from this list set up so that the student is able to find the mass of the piece of rock.

(ii) State the readings the student should take and how these would be used to find the mass of the rock.

....

....

....
[5]

(b) Describe how the volume of the rock could be found.

....

....

....[2]

(c) The mass of the rock is 88 g and its volume is 24 cm^3.
Calculate the density of the rock.

density of rock = ... [2]

O/N/2015-P32-Q2B

(ii) Describe what the student does to find the volume of the piece of wood, stating the measurements that she makes and any calculations required.

....

....

....

....

....

....

....

....

....[4]

Predict whether an object will float or sink based on density data:

- If the body is less dense than the fluid, it will float.
- If the body is denser than the fluid, it will sink.

For two immiscible liquids

The one with the lesser density will float on the top of the other and vice-versa.Example: Oil floats on water

O/N/2015-P32-Q2

(b) To find the volume of the piece of wood, the student has a measuring cylinder, a supply of water and the brass object in (a). The piece of wood and the brass object are small enough to be placed in the measuring cylinder.

(i) The piece of wood does not sink in water.

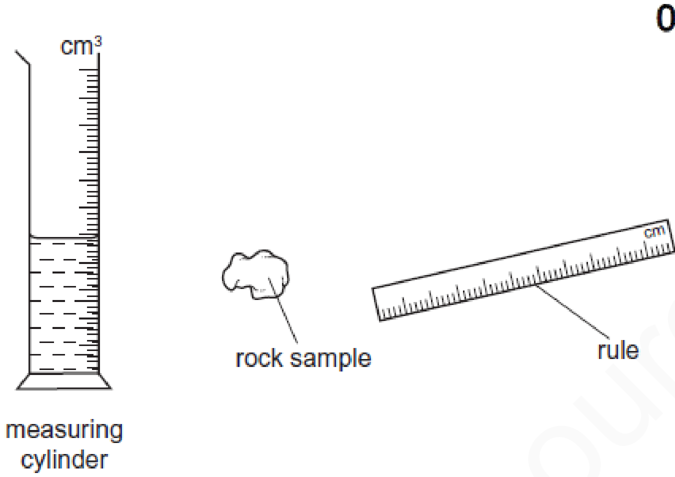
Suggest why.

....[1]

APPLICATION BASED CONCEPTS:-MCQ

1 A scientist needs to determine the volume of a small, irregularly shaped rock sample. Only a rule and a measuring cylinder, partially filled with water, are available.

0625/11/M/J/10



To determine the volume, which apparatus should the scientist use?

A both the measuring cylinder and the rule

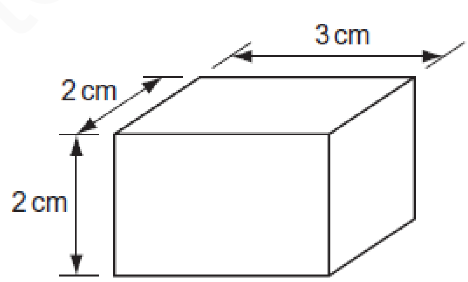
B neither the measuring cylinder nor the rule

C the measuring cylinder only

D the rule only

7 The diagram shows a rectangular block of density 2 g / cm^3.

0625/11/M/J/10



What is the mass of the block?

A 2 g **B** 6 g **C** 14 g **D** 24 g

6 A stone has a volume of $0.50\,cm^3$ and a mass of 2.0 g.

0625/13/M/J/12

What is the density of the stone?

A $0.25\,g/cm^3$

B $1.5\,g/cm^3$

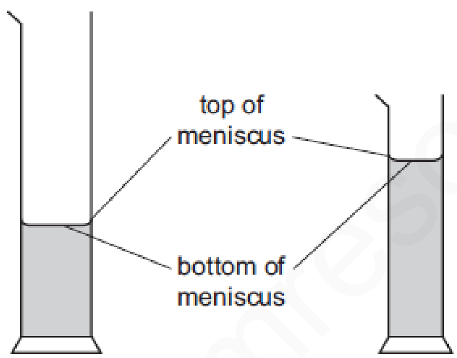
C $2.5\,g/cm^3$

D $4.0\,g/cm^3$

---

4 A student wishes to measure accurately the volume of approximately $40\,cm^3$ of water. She has two measuring cylinders, a larger one that can hold $100\,cm^3$, and a smaller one that can hold $50\,cm^3$. The water forms a meniscus where it touches the glass.

0625/13/M/J/14



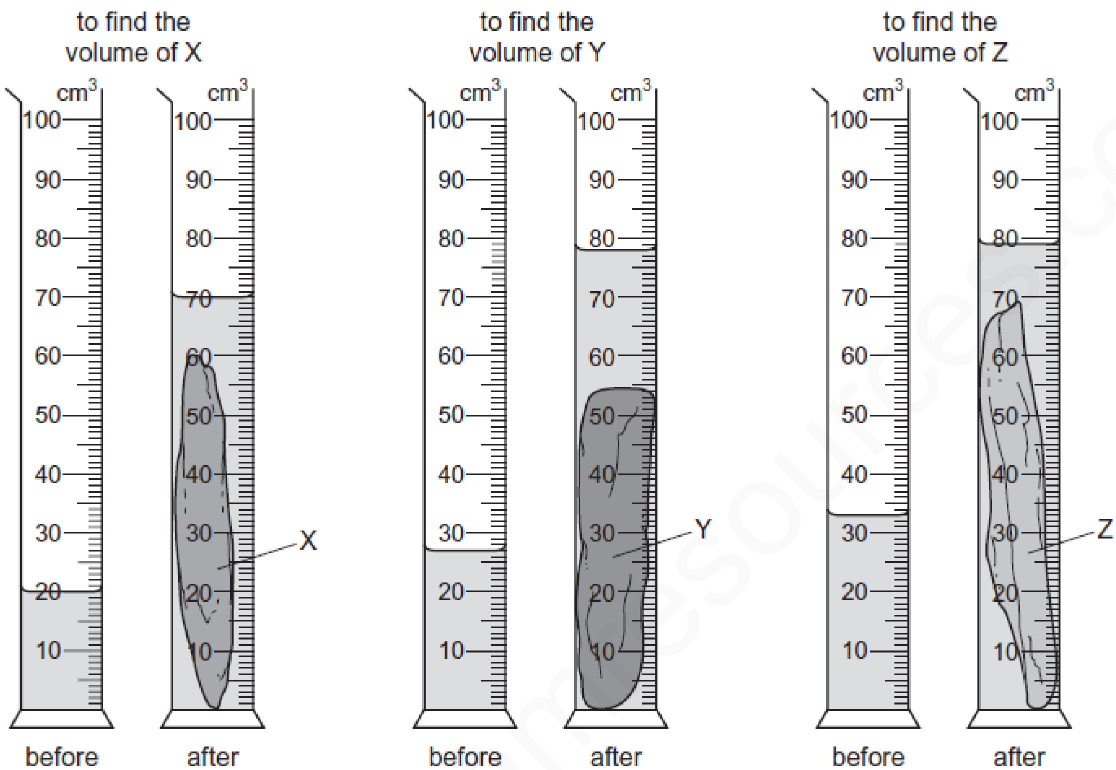
Which cylinder should the student use and which water level should she use to ensure an accurate result?

	cylinder	water level
A	larger one	bottom of meniscus
B	larger one	top of meniscus
C	smaller one	bottom of meniscus
D	smaller one	top of meniscus

---

1 A geologist compares the volumes of three rocks, X, Y and Z. Three measuring cylinders contain different volumes of water. He places each rock into one of the measuring cylinders.

The diagrams show the measuring cylinders before and after the rocks are put in.



Which row shows the volumes of X, Y and Z in order, from largest to smallest?

	largest volume	→	smallest volume
A	X	Z	Y
B	Y	X	Z
C	Y	Z	X
D	Z	Y	X

4 Diagram 1 shows a piece of foam rubber that contains many pockets of air. Diagram 2 shows the same piece of foam rubber after it has been compressed so that its volume decreases.

0625/11/M/J/15

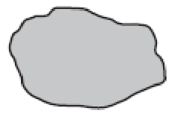


diagram 1
(before compression)

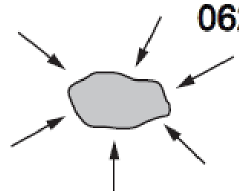


diagram 2
(after compression)

What happens to the mass and to the weight of the foam rubber when it is compressed?

	mass	weight
A	increases	increases
B	increases	no change
C	no change	increases
D	no change	no change

Effects of forces
Hooke's law-resultant forces

Force: A force is defined as a push or a pull.

Effects of forces:

- Force may change the size and the shape of a body.
- It can make an object move or stop a moving object.
- It can accelerate an object .
- It can decelerate an object.

Extension-load graphs:

Attach weights to the free end of a spring. As the force increases the extension of the spring also increases. For particular values of the force , tabulate your observations. Record the weight attached and the extension caused by it.

Note: Extension: It is the difference between the original length(unstretched length) and new length(stretched length)

Then plot a graph of force(weight) in N against extension in mm.

Hooke's law: The extension of a spring (x) is directly proportional to the load (F) it supports , provided the spring has not crossed its elastic limits.

$F \propto x$. Hence $F=k(x)$ where k= spring constant

Elastic limit:(limit of proportionality): It is the point where the proportionality between the force(weight) and the extension stops.[1m]

The weight is a force that stretches the spring.

Suppose these are the observations of four students on Hooke's law .

	student A	student B	student C	student D
load/N	spring length/cm	spring length/cm	spring length/cm	spring length/cm
0.5	6.7	9.2	9.1	10.0
1.0	7.7	10.0	9.9	11.1
1.5	8.7	10.8	10.7	12.2
2.0	9.7	11.6	11.5	13.3
2.5	10.7	12.6	12.3	14.4
3.0	11.7	13.8	13.1	15.5
3.5	12.7	15.2	13.9	16.6
4.0	13.7	16.8	14.7	17.7

Student A :

- For every 0.5N, the extension is 1cm.
- This indicates original length of the spring for 0N is 6.7-1=5.7cm.
- Spring has not crossed its elastic limit as extension is in proportion to the force applied.

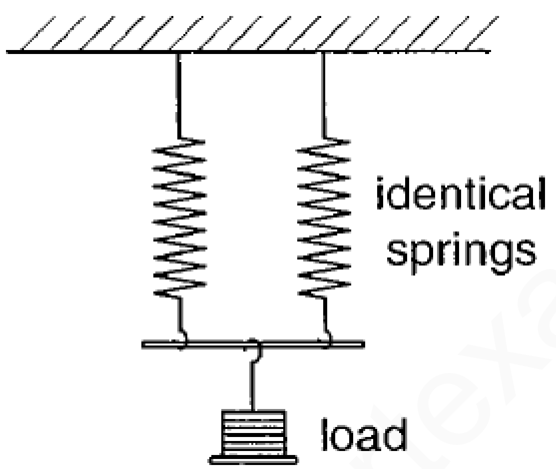
Student B:

- For every 0.5N that are added, the extension is 0.8cm
- The spring has crossed its elastic limit when a weight of 2.5N is attached to it.

Student C and D:

- The extensions are in proportion to the weights attached.
- The springs have not crossed their elastic limit

When a weight is attached to two springs as shown below:



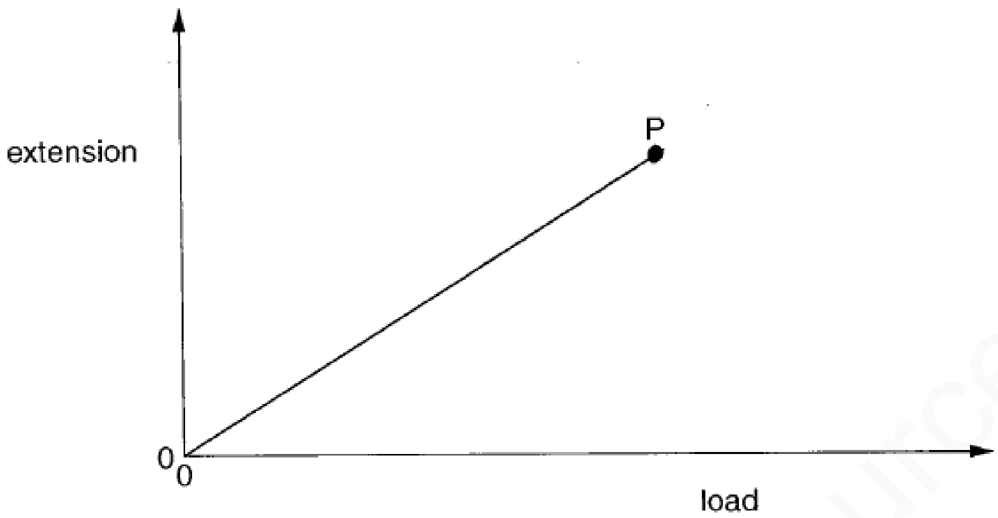
Note: Each spring experiences half the load.

Find the length of each spring ,when it is loaded with a weight of 2.5N. we can make use of the observation table. 1.25N is between 1.0 and 1.5N will produce an extension of $\frac{7.7+8.7}{2}$=8.2N

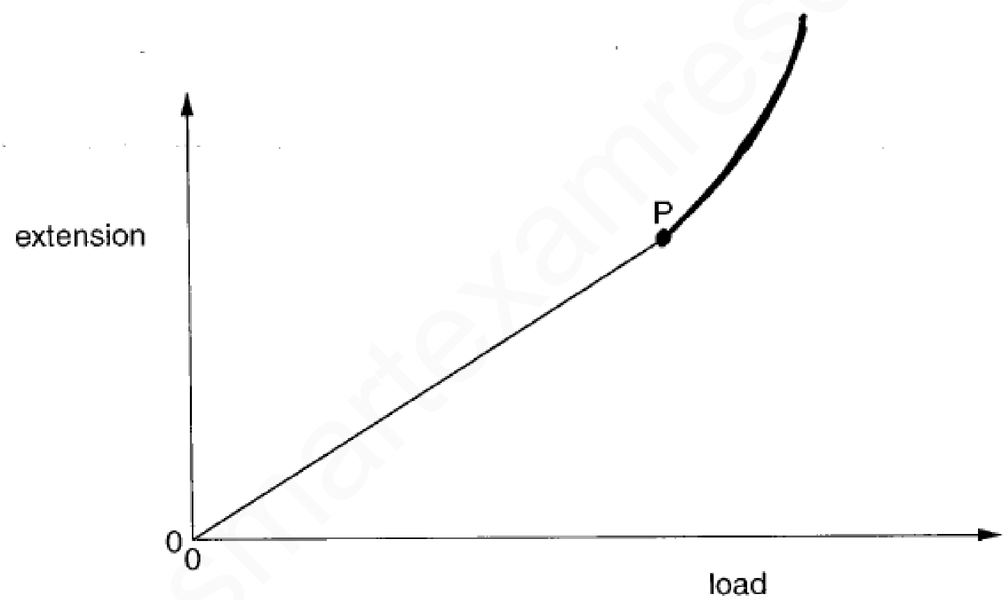
Note: Spring constant is the force per unit extension.k=F/x

You might be required to continue to plot a part of the graph

Example: Suppose point P is the elastic limit, Continue the graph beyond P.



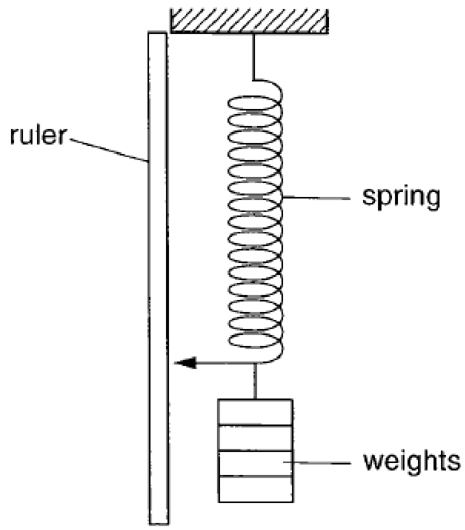
Solution would be like the one shown below.

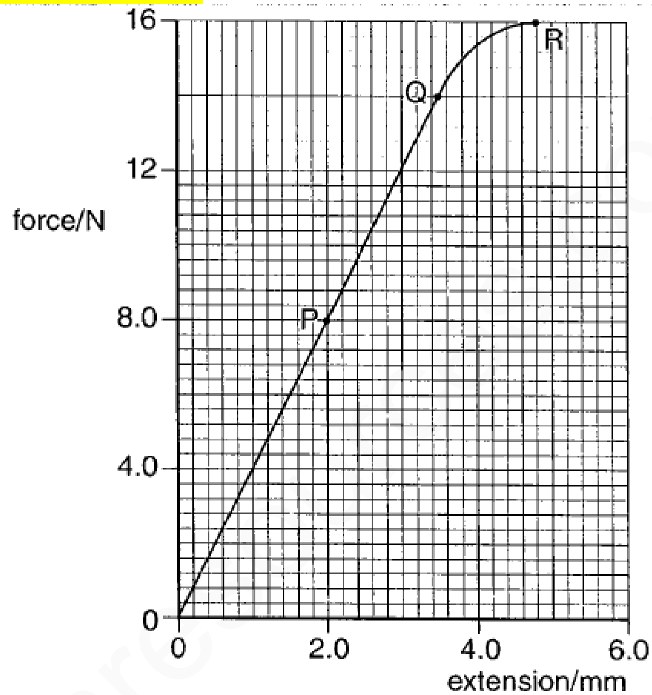


Note:

- The graph has to curve upwards as the spring will show a large extension as it has crossed its elastic limit.
- Also you know that the spring obeys Hooke's law because the graph is a straight line graph passing through the origin.
- Also the shape of the graph beyond P is described as non-linear.

The following is another representation of the Hooke's law where a graph of Force(weight) is plotted against the extension.

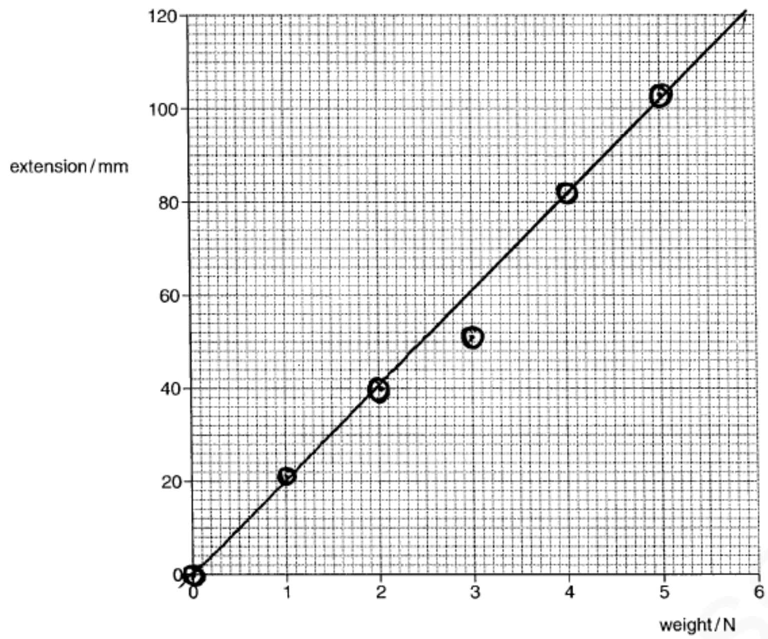




Note:

- Between OQ , Hooke's law is obeyed.
- Between QR , the extension per unit force is reduced.
- Hooke's law states that $F \propto x$. Hence F=k(x) The value of k can be found out using the graph by diving any y coordinate by its corresponding x coordinate between the region OQ. Example: $\frac{8}{2} = 4$
- Remember k=spring constant. its value is fixed for a particular spring.
- Also note that a particular reading may not fall on the graph. This is due to an experimental error.

You may be asked to estimate



Will adding a 45N load produce an extension of 920mm?

You must know that such an estimate will be unrealistic as the spring will have crossed its elastic limit by then.

Resultant of forces:

When more than one force acts on an object, we can calculate the combined effect of all the forces as a single force. This single force is called as the resultant force.

Two cases of resultant forces acting along the same line:

- **When the resultant force is zero:**

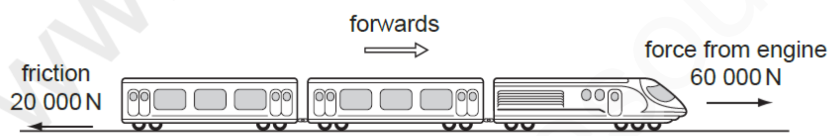
➢ Then the object will remain at rest if it is already at rest.

➢ The object will move at the steady speed and in the same direction if it was already moving.

- **When the resultant force is non-zero:**

Example:

9 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? **0625/01/O/N/08**

A 40 000 N backwards

B 80 000 N backwards

C 40 000 N forwards

D 80 000 N forwards

Note: If only two forces would have acted on the engine, then the net resultant force would have been 40 000N forwards. But the air resistance is also acting on the train such that the net force is zero. hence the air resistance must be equal to 40 000N backwards .

[Forward force= backward force]-Ans: A

APPLICATION BASED QUESTIONS:-MCQ

---

6 Which statement about a moving object is correct? **0625/12/M/J/10**

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.

---

8 In which of these situations is no resultant force needed? **0625/1/O/N/02**

A a car changing direction

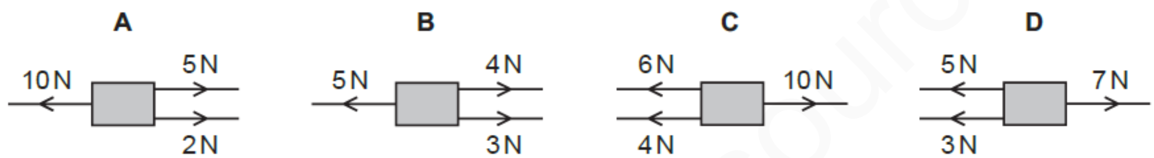
B a car moving in a straight line at a steady speed

C a car slowing down

D a car speeding up

0625/12/O/N/11

6 Which combination of forces produces a resultant force acting towards the right?



Hint: Add the LHS forces and RHS forces. The resultant would be the difference between the greater force and smaller forces and in the direction of the greater force.

---

7 A box is being moved by a fork-lift truck. The total weight of the box is 3000 N.

0625/12/O/N/13

The force exerted by the fork-lift truck on the box is 3500 N upwards.

What is the resultant force on the box?

A 500 N downwards

B 500 N upwards

C 6500 N downwards

D 6500 N upwards

APPLICATION BASED QUESTIONS:-EXTENDED THEORY:

O/N/2017-P42

2 (a) An object is moving in a straight line at constant speed. A resultant force begins to act upon the object.

State the ways in which the force may change the motion of the object.

It may accelerate the object
or it may change the direction of the object [2]

(b) State **one** other effect a force could have on the object.

It can change the shape of the object [1]

NEWTONS SECOND LAW

Relationship between force, mass and acceleration: F= ma

Newton's second law states that the " Acceleration of a body is directly proportional to the applied force and is inversely proportional to its mass."

F= ma

Hence:

Resultant force(N)= Mass(kg) X acceleration(m/s^2)

Example⟹F=ma

Newton's second law of motion :

1.This law pertains to the behavior of objects for which all existing forces are not balanced.

2. The second law states that the acceleration of an object is dependent upon two variables - the net force acting upon the object and the mass of the object.

3.The acceleration of an object depends directly upon the net force acting upon the object, and inversely upon the mass of the object.

4.As the force acting upon an object is increased, the acceleration of the object is increased.

5.As the mass of an object is increased, the acceleration of the object is decreased.

6.The equation is written as :F_{net}=ma

7.The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object.

(c) Fig. 1.1 shows three forces acting on an object of mass 0.5 kg. All three forces act through the centre of mass of the object.

O/N/05-P3-Q1

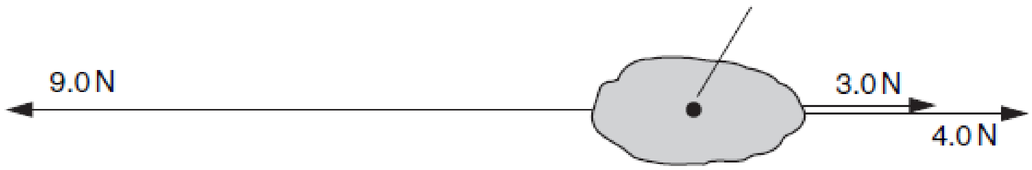


Fig. 1.1

Calculate

(i) the magnitude and direction of the resultant force on the object,

magnitude = ... direction .... [2]

(ii) the magnitude of the acceleration of the object.

acceleration =........................ [2]

1 (a) A truck of mass 12 kg is rolling down a very slight incline as shown in Fig. 1.1.

O/N/08-P32

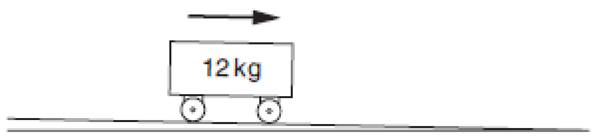


Fig. 1.1

The truck travels at constant speed.

Explain why, although the truck is on an incline, it nevertheless does not accelerate.

....

.... [1]

B (ii) Write down an equation linking the resultant force on the truck and the acceleration of the truck.

[1]

(iii) The truck's acceleration is 2.0 m/s^2.

Calculate the resultant force on the truck.

resultant force = ... [2]

2 The rocket shown in Fig. 2.1 is about to be launched.

F/M15-P32

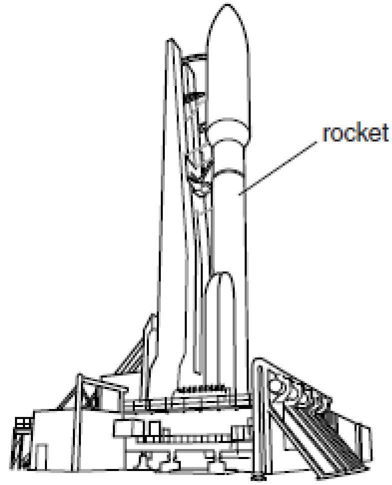


Fig. 2.1

The total mass of the rocket and its full load of fuel is 2.8×10^6 kg. The constant force provided by the rocket's motors is 3.2×10^7 N.

(a) Calculate

(i) the total weight of the rocket and the fuel,

weight = ... [1]

(ii) the resultant force acting on the rocket,

resultant force = ... [2]

(iii) the vertical acceleration of the rocket immediately after lift-off.

acceleration = ... [2]

2 Fig. 2.1 is a head-on view of an airliner flying at constant speed in a circular horizontal path. The centre of the circle is to the left of the diagram.

O/N/12-P32-Q2

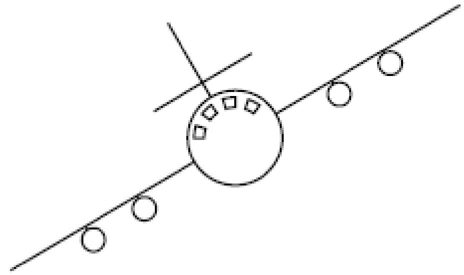


Fig. 2.1

(a) On Fig. 2.1, draw the resultant force acting on the airliner. Explain your answer.

....

....

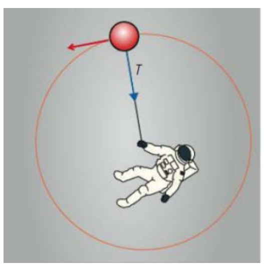
.... [3]

Motion in a circular path due to a perpendicular force

- Objects may travel at a constant speed in a circular path, but their velocity changes because their direction changes.
- Since the object's velocity is changing , it experiences an acceleration. This acceleration is called as the centripetal acceleration and is directed towards the centre of the circular path.
- This implies in a circular motion, the acceleration is perpendicular to the velocity.

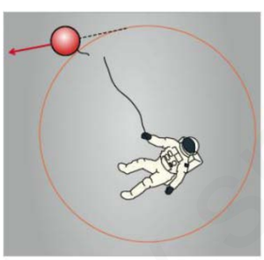
The value of this centripetal force is F= ma=$\frac{mv^2}{}$

- When a body moves with a constant speed in a circular path, it will have a constant kinetic energy.



- The force that keeps an object in a circular path is the tension force in a string(if the object is being whirled around)

- Sun's gravitational force keeps the planets orbiting around it in circular paths



- If the string breaks, the object continues to move in the direction of velocity and is then later acted upon by gravity.

Note:
The resultant force may change the velocity of an object by changung its direction of motion or its speed

MOTION IN A CIRCULAR PATH DUE O A FORCE PERPENDICULAR TO THE MOTION

The following is true fo all objects in circular motion:
1.The speed increases if the force increases. with mass and radius constant.
2.The radius decreases if force increases with mass and speed constant
3.An increased mass requires an increased force to keep speed and radius constant.

1 Fig. 1.1 shows a model car moving clockwise around a horizontal circular track.

M/J/07--P3

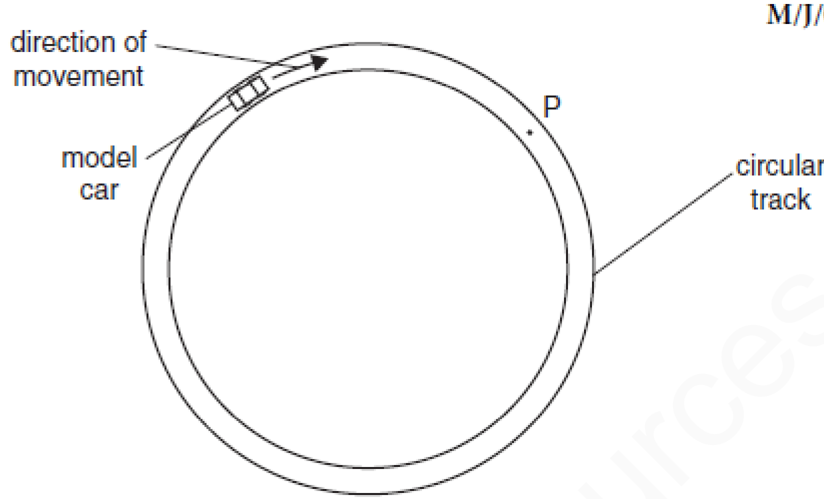


Fig. 1.1

(a) A force acts on the car to keep it moving in a circle.

(i) Draw an arrow on Fig. 1.1 to show the direction of this force. [1]

(ii) The speed of the car increases. State what happens to the magnitude of this force.

.... [1]

(b) **(i)** The car travels too quickly and leaves the track at P. On Fig. 1.1, draw an arrow to show the direction of travel after it has left the track. [1]

(ii) In terms of the forces acting on the car, suggest why it left the track at P.

....

....

.... [2]

4 Fig. 4.1 illustrates an object on a string being whirled anticlockwise in a vertical circle.

O/N/09-P32

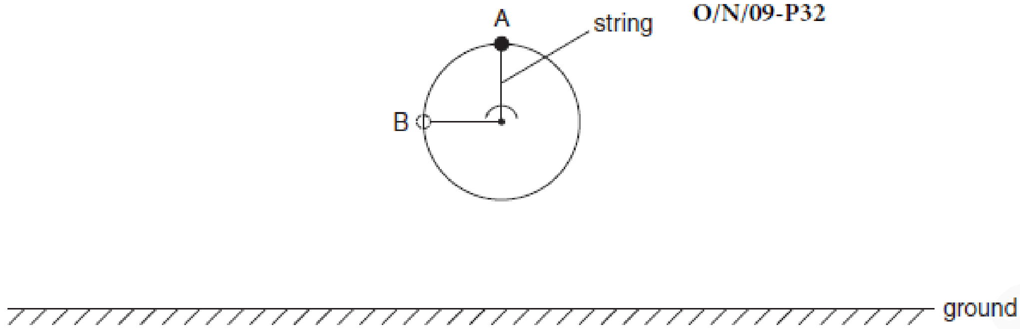


Fig. 4.1

The lowest point of the circle is a small distance above the ground. The diagram shows the object at the top A of the circle, and at B, when it is at the same height as the centre of the circle.

(a) On Fig. 4.1, mark clearly

(i) the force of the string on the object

1. at A,

2. at B. [2]

(ii) the path the object would take until it hit the ground, if the string broke

1. at A,

2. at B. [3]

(b) The mass of the object is 0.05 kg. At A, the tension in the string is 3.6 N.

(i) Calculate the weight of the object.

weight = ... [1]

(ii) Calculate the total force on the object at A.

total force = ... [2]

[Total: 8]

(c) After travelling 4.0 km, the train reaches its maximum speed. It continues at this constant speed on the next section of the track where the track follows a curve which is part of a circle.

State the direction of the resultant force on the train as it follows the curved path.

....[1]

M/J/15-P33-Q2

Note:
The resultant force may change the velocity of an object by changung its direction of motion or its speed

MOTION IN A CIRCULAR PATH DUE O A FORCE PERPENDICULAR TO THE MOTION

The following is true fo all objects in circular motion:
1.The speed increases if the force increases. with mass and radius constant.
2.The radius decreases if force increases with mass and speed constant
3.An increased mass requires an increased force to keep speed and radius constant.

SOLID FRICTION:

It is the force between two surfaces that may impede motion and produce heat.

DRAG:

This is the friction that acts on an abject moving through the liquid or a gas

---

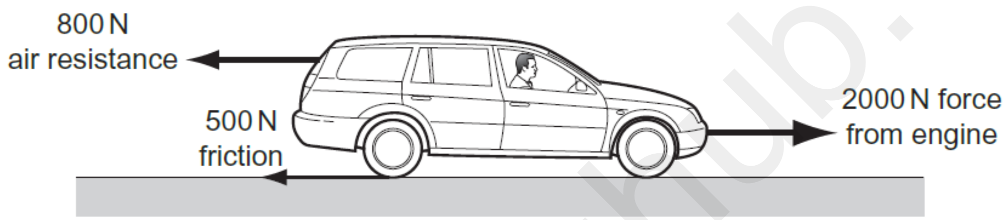
Friction:

- Friction is a force between two surfaces that impedes motion and causes heating.
- Air resistance is a form of friction.

---

6 A car moves along a level road.

The diagram shows all of the horizontal forces acting on the car.



Which statement is correct? 0625/13/M/J/13

A The car is slowing down.

B The car is speeding up.

C The car is moving at a constant speed.

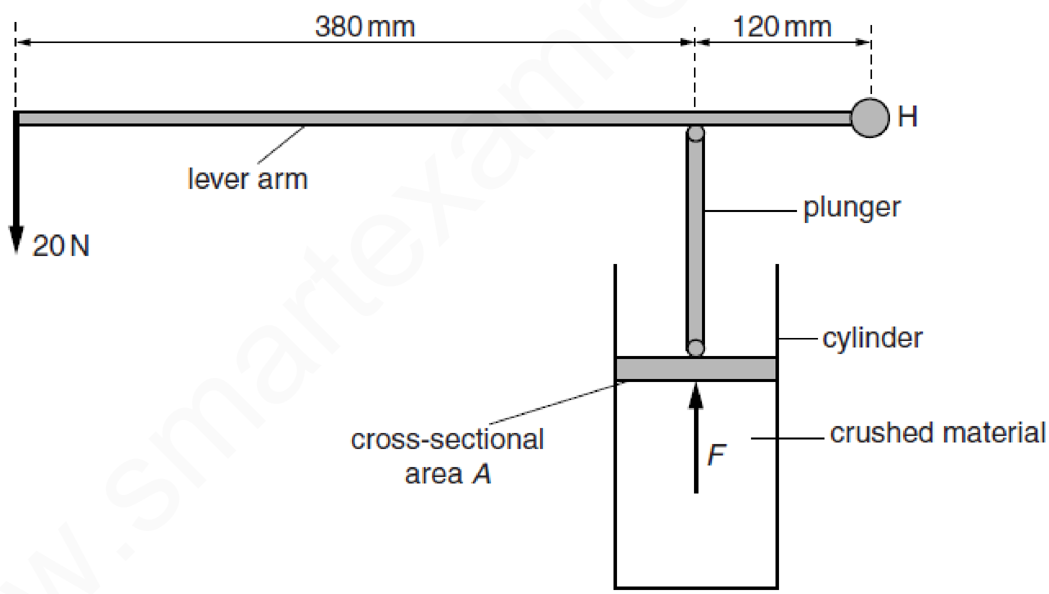
D The car is moving backwards.

Turning effects of forces
Equilibrium
Centre of mass

Turning effect (moment of a force):

Definition: The turning effect of a force is termed as the moment of a force.
Moment of a force= Force X perpendicular distance from the pivot
Unit: Nm

Clockwise moment and anti-clockwise moment:
Following is a device used for compressing crushed material:
lockwise moment



The lever arm rotates about the hinge H at its right-hand end. A force of 20 N acts downwards on the left-hand end of the lever arm. The force F of the crushed material on the plunger acts upwards. Ignore the weight of the lever arm.

Moment of a force is the measure of its turning effect.Example: turning a door, Movement of a see-saw.

Two types of moments are present about point H:

- Clockwise moment: It is moment that causes the lever arm to turn in the clockwise direction.

Clockwise moment is caused by the crushed material at F.

- Anticlockwise moment: It is moment that causes the lever arm to turn in the anti-clockwise direction. In this case it is caused by the 20N weight.

In this example:

Clockwise moment= anticlockwise moment

20 x 500= F x 120

F=83.3N

Pivot (Fulcrum): The point about which the object rotates is called as the pivot or the fulcrum.

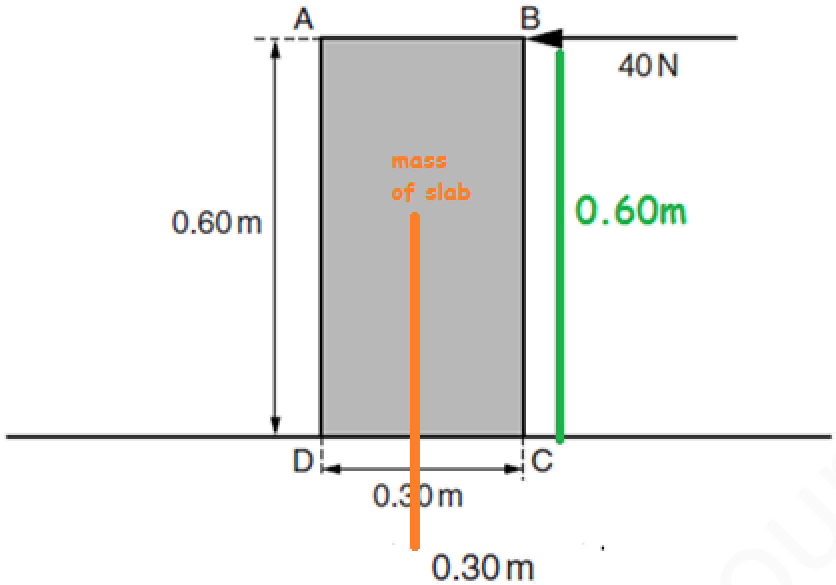
For an object in equilibrium:

- There is no resulting turning effect (Clockwise moment= anticlockwise moment)
- There is no resultant force.

Principle of moments:

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

Example:



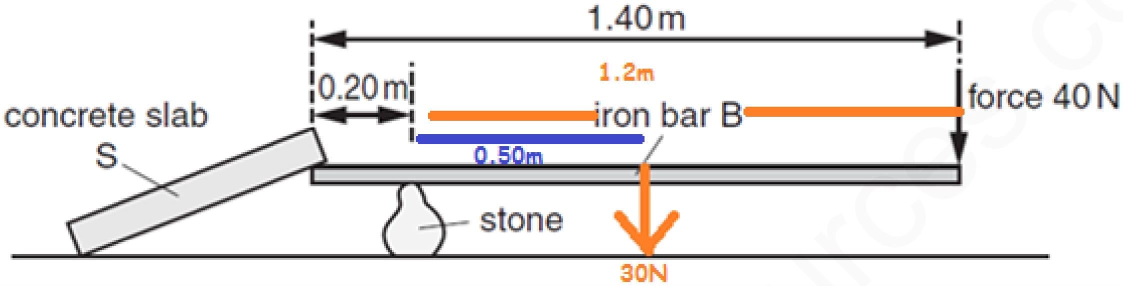
The moment of 40N force about the point D=40 x 0.60 =24Nm (ACM)
Suppose the weight of slab W=180N.
Then the moment due to W about point D=180 x 0.30=27Nm (CM).
Suppose the ground is rough and the slab does not slide. But if the horizontal force at B is gradually increased, the corner C lifts from the ground because anticlockwise moment becomes greater than the clockwise moment.

Note:

ACM=Anticlockwise moment
CM= Clockwise moment

Moment of a force when the weight of the bar is not considered negligible

Fig. 3.1 shows a uniform iron bar B of weight 30 N and length 1.40 m. The bar is being used to lift one edge of a concrete slab S. A stone, placed 0.20 m from one end of B, acts as a pivot. A force of 40 N pushing down at the other end of B is just enough to lift the slab and hold it as shown.



- The weight of the bar acts through the center of the mass.
  (at a distance of 0.70m from the corner of the bar and at 0.50m from the stone)as shown by the orange arrow.
- Clockwise moment on the bar B:
  Due to the weight of the bar + Due to the 40N force
  ⟹(30 x 0.50) + (40 x 1.2)=63Nm
  Note here how the perpendicular distance is calculated.
- Slab S exerts a downward force on the bar B
  ⟹ F x 0.2=63
  $$F \Rightarrow \frac{63}{0.2} = 315N$$
- We can reduce the force needed to lift the slab by:moving the pivot(stone) to the left.

Uses of moment of a force:

Man-made devices in everyday use that depend upon their action on the moment of a force.

- Spanners
- Scissors
- Taps
- Nut crackers
- Sea-saw

A uniform rod AB is acted upon by three equal forces but the rod is not in equilibrium because:

- There is a resultant force. (Example: there may be more force up then down)
- There is a resultant moment. (Clockwise moment is not equal to the anticlockwise moment.

Suppose two forces act on an object. Then it is impossible for an object to be in equilibrium if both the forces act in the same direction.

---

3 **(a)** Complete the following statement. F/M15-P32

An object is in equilibrium when both the .... and the

.... on the object are zero. [2]

(b) Fig. 3.1 shows a ladder AB. End A of the ladder rests against a vertical wall. End B rests on rough ground.

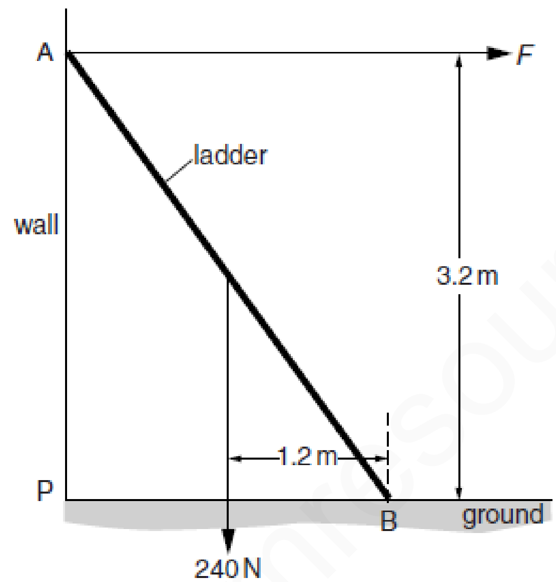


Fig. 3.1

Fig. 3.1 shows two of the forces acting on the ladder. The only force on the ladder at A is *F*, which acts at right-angles to the wall. The weight of the ladder is 240 N acting at the centre of mass of the ladder.

(i) **1.** Calculate the moment of the weight of the ladder about point B.

moment = ... [1]

2. Write an expression, in terms of *F*, for the moment of *F* about point B.

moment = ... [1]

(ii) Use your answers from **(i)** to calculate *F*.

F = ... [2]

2 Fig. 2.1 shows apparatus for investigating moments of forces.

O/N/05-P3

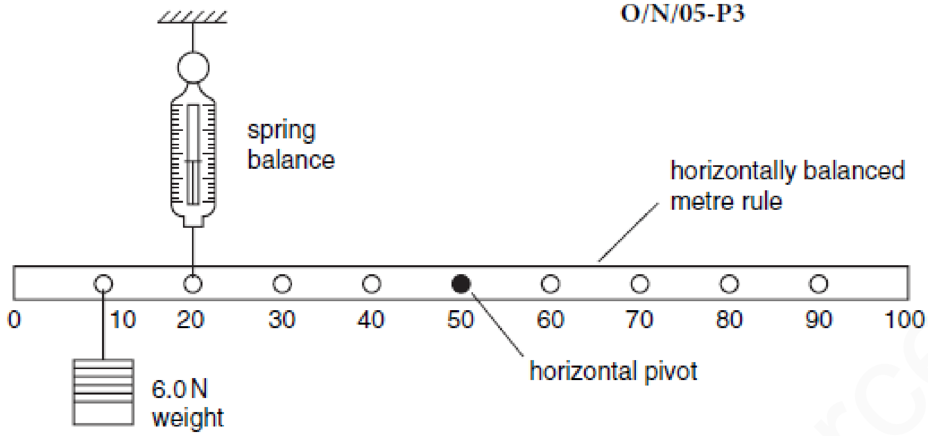


Fig. 2.1

The uniform metre rule shown in Fig. 2.1 is in equilibrium.

(a) Write down two conditions for the metre rule to be in equilibrium.

condition 1 ....

....

....

condition 2 ....

....

.... [2]

(b) Show that the value of the reading on the spring balance is 8.0 N. [2]

(c) The weight of the uniform metre rule is 1.5 N.

Calculate the force exerted by the pivot on the metre rule.

magnitude of force = ...

direction of force .... [2]

3 **(a)** A uniform metre rule is pivoted at its centre, which is also the position of its centre of mass.

Three loads, 2.0 N, *F* and 3.0 N are positioned on the rule at the 20 cm, 30 cm and 90 cm marks respectively, as shown in Fig. 3.1. **O/N/10-P32**

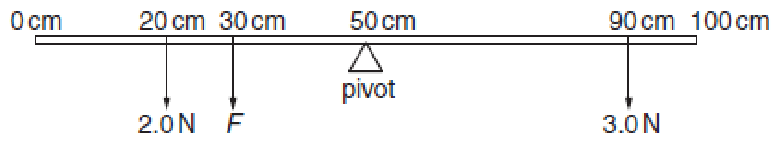


Fig. 3.1

(i) Calculate the moment of the 3.0 N load about the pivot.

moment = ... [1]

(ii) Calculate the moment of the 2.0 N load about the pivot.

moment = ... [1]

(iii) The force *F* maintains the metre rule in equilibrium on the pivot.

Calculate the value of *F*.

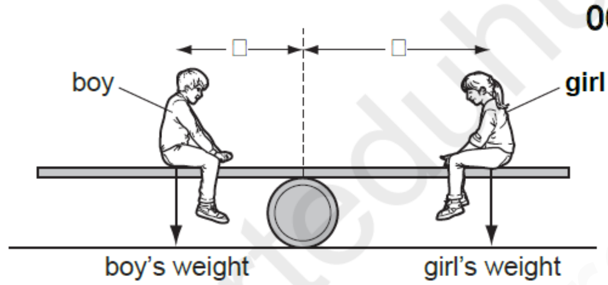
F = ... [3]

APPLICATION BASED QUESTIONS-MCQ:

11 A see-saw is made by resting a long plank of wood with its centre of mass on a barrel.

A boy sits on one side of the barrel and a girl sits on the other side so that the see-saw is balanced.

0625/12/O/N/12



Which statement **must** be true?

A boy's weight = girl's weight

B distance *x* = distance *y*

C total downward force = total moment about the barrel

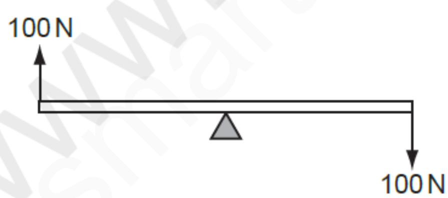
D resultant force and resultant moment are both zero

9 A uniform rod rests on a pivot at its centre. The rod is not attached to the pivot. Forces are then applied to the rod in four different ways, as shown. The weight of the rod can be ignored.

Which diagram shows the rod in equilibrium?

0625/12/O/N/11

A



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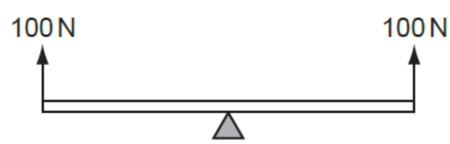

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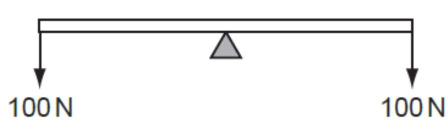

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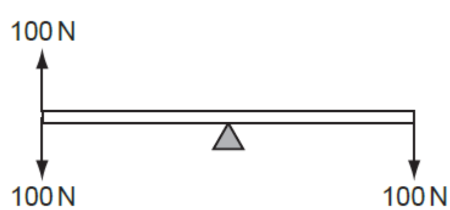


7 Two forces act on an object. **0625/01/M/J/06**

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.

---

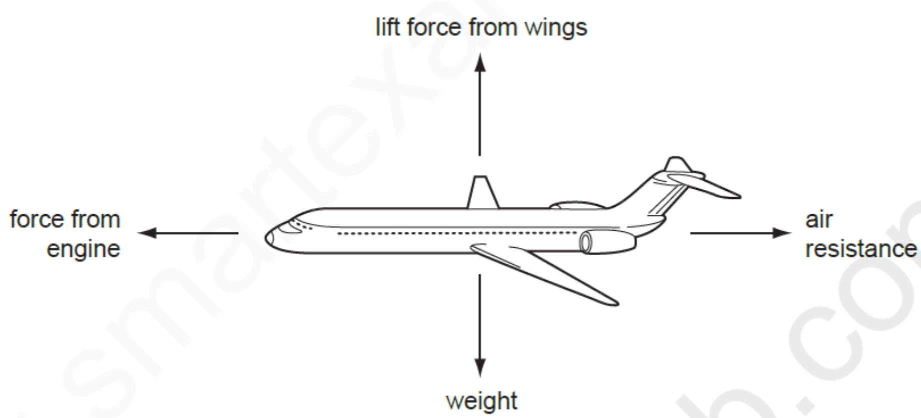
8 What are the conditions for equilibrium? **0625/01/M/J/08**

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

---

9 An aeroplane is in equilibrium. **0625/01/O/N/07**

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

Centre of gravity

Centre of gravity: The center of gravity (G) is a point which locates the resultant weight of a system of particles or body. [or]
It is the theoretical point at which all of the body's weight is considered to be concentrated.

Method to find the centre of gravity:

- Take a lamina and punch 3 holes such that they are towards any three edges of the lamina.
- Now suspend the lamina through a stand though one of the holes.
- Also attach a plumbline keeping it very close to the hole used for suspending the lamina.
- Take care to see that the plumbline does not touch the lamina.
- Allow it to oscillate and come to rest.
- When the lamina is steady, mark the point on the lamina which is exactly vertically down and just behind the plumb line.
- Remove the lamina and connect the punched hole and the marked point with a pencil line.
- Repeat the above process by suspending the lamina through the other two holes.
- The point of intersection of the pencil lines drawn on the lamina is the position of the centre of gravity.
- Draw a line of equilibrium for each suspension point.
- The point of intersection of these three lines would be the centre of gravity.

Note:

- The centre of gravity's location is dependent on the weight and the distribution of this weight within the body.
- An object hanging from any point will automatically rotate so that its centre of gravity is along this vertical line from the hanging point.
- The centre of gravity does NOT have to lie within the physical matter of the body.
- Example: tire, football and helmet
- In humans, the centre of gravity may also fall outside body's physical matter: • (e.g., high jumper, pole vaulter)

Effect of the position of the centre of gravity on the stability of simple objects:

- An object will topple over once its centre of gravity falls outside its base of support.
  Example:
  The Leaning Tower of Pisa does not topple over: its centre of gravity is still above its base
- Objects with lower centre of gravity are more stable.

Momentum

Momentum (ρ)

- Every moving object has momentum.
- Linear momentum is defined as the product of mass and velocity of an object.

momentum (kg m/s) = mass (kg) × velocity (m/s)

$\rho = mv$

- Momentum is a vector quantity and has the direction of velocity.

Newton's second law of motion states that:

The rate of change of momentum is directly proportional to the unbalanced force acting on that body and takes place in the same direction.

Hence in terms of momentum Newton's second law is:

$$F_{net} = \frac{\Delta p}{\Delta t}$$

If mass stays constant , then the above equation can be re-written as:

$$F_{net} = \frac{\Delta p}{\Delta t} = \frac{p_{final} - p_{initial}}{\Delta t} = \frac{mv_{final} - mv_{initial}}{\Delta t} = \frac{m(v_{final} - v_{initial})}{\Delta t} = \frac{m\Delta v}{\Delta t}$$

$$F_{net} = ma$$

Numerical:

A ball of mass 640g that is moving vertically downwards, hits the ground with a velocity of 12 m/s. Post impact, it bounces upwards with a velocity of 8m/s.

a. Calculate the momentum of the ball before and after impact.

b. Calculate the change in momentum during impact

Solution:

(a)Convert the mass from g to kg

Momentum of the ball before impact

= mass x velocity before impact

=0.64 x 12=7.68kgm/s= +7.78kgm/s

Momentum of the ball after impact

=mass x velocity after impact

=0.64 x 8 =5.12kgm/s =-5.12kgm/s

(b)Change in momentum

=Final momentum- Initial momentum

=(-5.12) - (7.78) =-12.9kgm/s

- Since momentum is a vector quantity, it has magnitude as well as direction.
- We can take any direction positive and any direction negative.
- In our sum , we have assumed that the upward direction is positive and the downward direction is negative.

Example:

A bullet with a mass of 0.03 kg leaves a gun at 1000 m/s. If the gun's mass is 1.5 kg, what is the velocity of the recoil on the gun?

momentum of bullet = mass × velocity

= 0.03 kg × 1,000 m/s

= 30 kg m/s

Rearrange the equation:

velocity = momentum ÷ mass

velocity of recoil on gun = 30 kg m/s ÷ 1.5 kg

= 20 m/s

Impulse

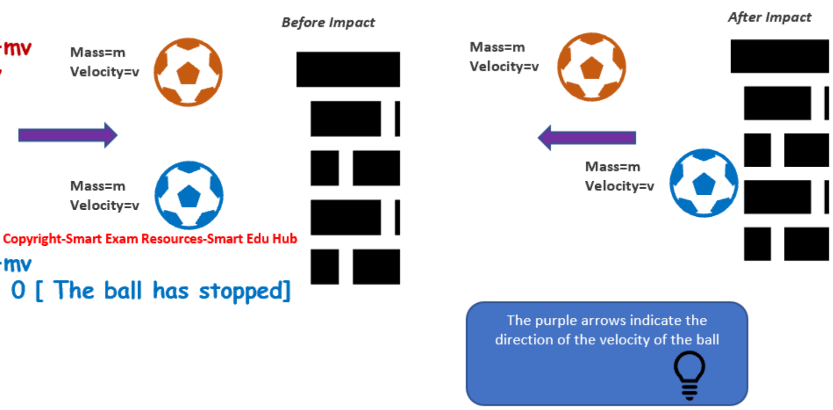
- If you get hit by a ball, the effect is greater if it bounces off you than if you catch it. This is because the change in momentum is greater if the ball bounces off you.
- Unit of impulse=kgm/s
- Impulse is a vector

Example:

Comparing momentum of two objects

Solution:

For the orange ball:
Momentum before impact=Initial momentum=+mv
Momentum after impact=Final momentum=-mv
Change in momentum
=Final momentum-Initial momentum
=-mv - (+mv)
=-2mv



For the blue ball:
Momentum before impact=Initial momentum=+mv
Momentum after impact=Final momentum-mv= 0 [The ball has stopped]
Change in momentum
=Final momentum-Initial momentum
=-mv - (0)
=-mv

Conclusion: The red ball has a greater change in momentum as compared to the blue ball.

Solved examples from past papers:

7 An object of mass 50 kg accelerates from a velocity of 2.0 m/s to a velocity of 10 m/s in the same direction.

0625/21/M/J/16

What is the impulse provided to cause this acceleration?

A 250 Ns B 400 Ns C 850 Ns D 2500 Ns

Explanation:
Change on velocity= (10-2)=8 m/s
mass =50kg
Hence the impulse that caused this acceleration
=F= m x (Change in velocity)= 50 x 8 =400Ns

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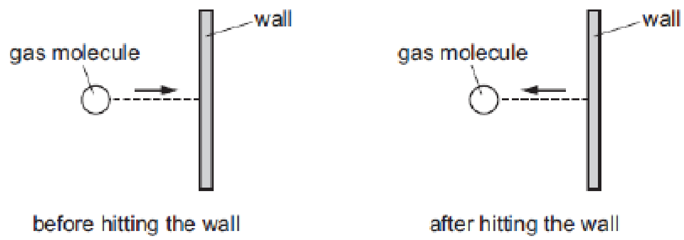
8 A gas molecule strikes the wall of a container. The molecule rebounds with the same speed.



What happens to the kinetic energy and what happens to the momentum of the molecule?

0625/23/M/J/16

	kinetic energy	momentum
A	changes	changes
B	changes	stays the same
C	stays the same	changes
D	stays the same	stays the same

Answer =C

Explanation:

Since there is no change in the speed, so the kinetic energy stays the same. The momentum changes because the direction of motion and hence the velocity changes. So the momentum which is a product of mass and velocity changes too.

Principle of momentum

Statement:

The total linear momentum of any system is constant, provided that no external forces are acting on it.

The following points should be kept in mind while using the principle of momentum:

- Momentum is a vector quantity so its direction must always be included in calculations.
- The system must be isolated- only the interacting objects must be considered and there can be no forces acting on that system from outside.
- Immediately after an interaction, external forces like friction will usually affect the motion of objects.

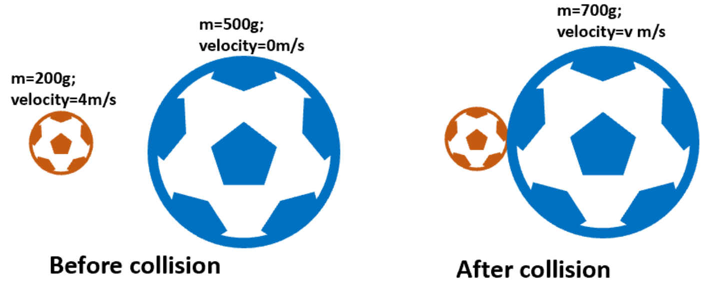
In real lives:

- Loss of momentum will happen because the system is not isolated as the system will be acted upon by external forces.
- Some or all momentum may appear to be lost when something collides with an object that has a much greater mass. The motion after impact may be too small to observe or measure .Example: a person jumping on the earth's surface. The predicted motion of the " person-earth system" is insignificant after impact.
- The force of gravity generally increases the momentum of falling objects. But the objects are not in isolated systems, there are external forces acting on them. For example: a 3kg rock experiences a gravitational force towards the earth of approximately 30N and therefore gains momentum as it accelerates downwards. The law of conservation of momentum clearly predicts that the earth must gain an equal momentum upwards towards the rock. Because the mass of the earth is so large, its gain of momentum is insignificant.

Change in momentum, where the colliding bodies stick to each other and then move together

In an isolated system, one ball with a mass of 200g and velocity 4m/s, collides with a stationary ball of mass 500g that is at rest. After collision, the two balls stick to each other and move with a velocity "v".

a. Calculate the velocity of the ball after collision



Solution:

(a)Momentum of the red ball before impact
= mass x velocity before impact
=(0.2x 4)kgm/s
Momentum of the blue ball before impact
= mass x velocity before impact
=(0.5x 0)kgm/s

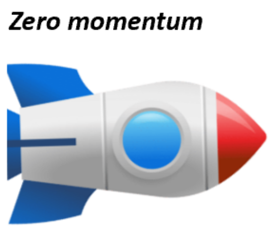
Momentum of the red and the blue ball after impact
=(their combined mass) x(velocity after impact)
=[(0.7) x v]kgm/s

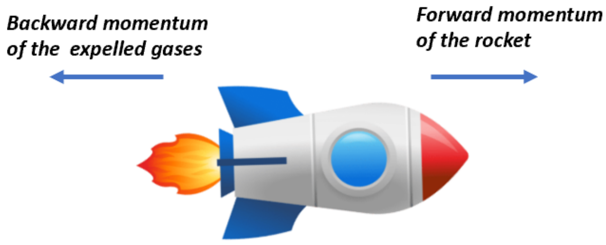
According to the conservation of momentum, the momentum before impact=Momentum after impact
Hence; [(0.2x 4) +(0)] = [(0.7) x v]
⇒ v= 0.8/0.7= 1.14m/s =1m/s
⇒ Hence their velocity after impact= 1 m/s

- Direction of velocity is the same as the balls are not travelling in the opposite direction
- It is important to change the mass of the balls into kilograms to get the value of momentum in kgm/s

Rocket engine:

- What is the momentum of a rocket and its fuel, when it in simply floating space? Well it is zero
- It is only when the rocket engines are fired and the gases are expelled at high speed, they develop a momentum. The reason being the gases that are expelled have a backward momentum and in order to conserve the momentum, the rocket and its fuel then develops a forward momentum.

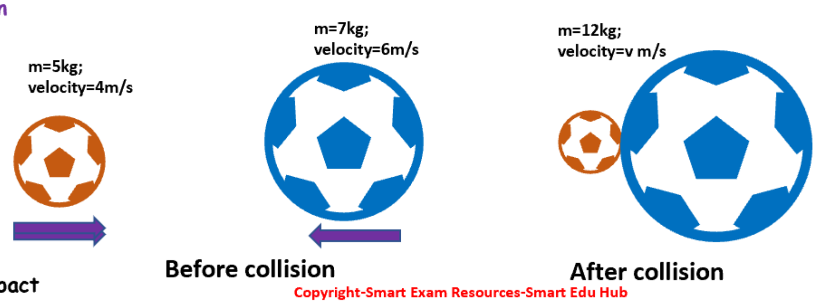




Numerical

Change in momentum, where the two bodies travelling in the opposite direction collide with each other and then stick together and move.

In an isolated system, one red ball with a mass of 5kg and velocity 4m/s moving to the right ,collides with a blue ball of mass 7kg and a velocity of65m/s to the left.. After collision, the two balls stick to each other and move with a velocity "v".
a. Calculate the velocity of the ball after collision



Solution:

(a)Momentum of the red ball before impact
= mass x velocity before impact
=(5 x 4)kgm/s
Momentum of the blue ball before impact
= mass x velocity before impact
=-(7x 6)kgm/s

Momentum of the red and the blue ball after impact
=(their combined mass) x(velocity after impact)
=[(12) x v]kgm/s

According to the conservation of momentum: Momentum before impact=Momentum after impact
Hence; [(5 x (+4)) +(7 x (-6))] = [(12) x v]
⇒ v= (20-42)/12= -1.8m/s
⇒ Hence their velocity after impact is in the left direction and has a magnitude of 1.8m/s

- Direction of velocity to the right is taken as positive and to the left is taken as negative

APPLICATION BASED QUESTIONS:

MCQ

0625/22/O/N/16

8 A girl of mass 50 kg runs at 6.0 m/s.

What is her momentum?

A 300 J **B** 300 kg m/s **C** 900 J **D** 900 kg m/s

8 A moving body undergoes a change of momentum.

F/M/17-P22

What is a unit for change of momentum?

A N m **B** N/m **C** N s **D** N/s

9 A ball of mass 2.0 kg is travelling at a speed of 12 m/s. It moves towards an object of mass 3.0 kg which is at rest.

M/J/17-P22

The ball hits the object and sticks to it.

Which row gives the total momentum, and the speed of both objects immediately after the collision?

	total momentum kg m/s	speed m/s
A	0	4.8
B	0	8.0
C	24	4.8
D	24	8.0

EXPENDED THEORY

2 Fig. 2.1 shows a hammer being used to drive a nail into a piece of wood.

F/M/2016-P42

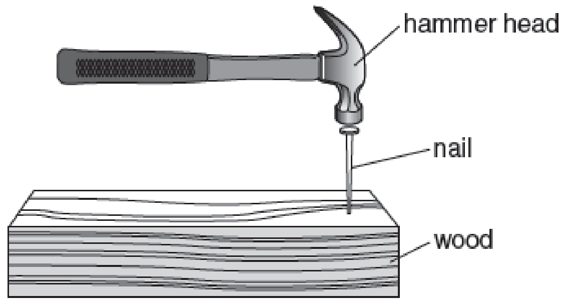


Fig. 2.1

The mass of the hammer head is 0.15 kg.
The speed of the hammer head when it hits the nail is 8.0 m/s.
The time for which the hammer head is in contact with the nail is 0.0015 s.

The hammer head stops after hitting the nail.

(a) Calculate the change in momentum of the hammer head.

change in momentum = ...[2]

(b) State the impulse given to the nail.

impulse = ...[1]

(c) Calculate the average force between the hammer and the nail.

average force = ...[2]

[Total: 5]

2 (a) Explain why momentum is a vector quantity. **F/M/2017-P42**

....[1]

(b) The crumple zone at the front of a car is designed to collapse during a collision.

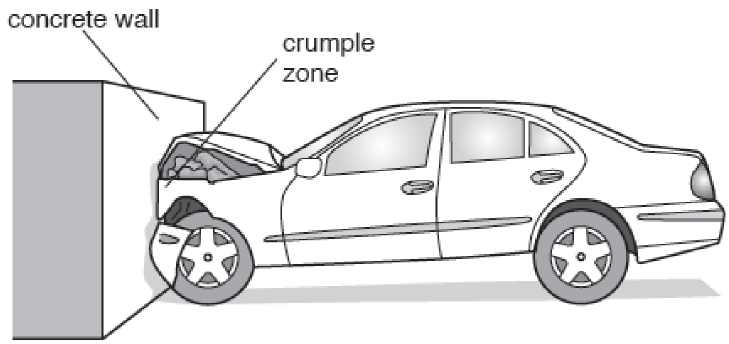


Fig. 2.1

In a laboratory test, a car of mass 1200 kg is driven into a concrete wall, as shown in Fig. 2.1.

A video recording of the test shows that the car is brought to rest in 0.36 s when it collides with the wall. The speed of the car before the collision is 7.5 m/s.

Calculate

(i) the change of momentum of the car,

change of momentum = ...[2]

(ii) the average force acting on the car.

average force = ...[2]

(c) A different car has a mass of 1500 kg. It collides with the same wall and all of the energy transferred during the collision is absorbed by the crumple zone.

(i) The energy absorbed by the crumple zone is 4.3×10^5 J. Show that the speed of the car before the collision is 24 m/s.

[2]

(ii) Suggest what would happen to the car if it is travelling faster than 24 m/s when it hits the wall.

....

....[1]

[Total: 8]

3 **(a)** Underline the pair of quantities which must be multiplied together to calculate *impulse*.

force and mass　　force and velocity　　mass and time

time and velocity　　weight and velocity　　force and time [1]

(b) Fig. 3.1 shows a collision between two blocks A and B on a smooth, horizontal surface.

M/J/17-P42

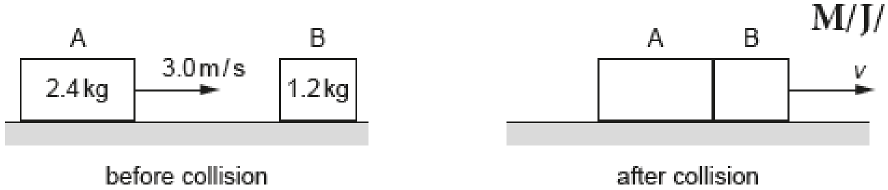


Fig. 3.1

Before the collision, block A, of mass 2.4 kg, is moving at 3.0 m/s. Block B, of mass 1.2 kg, is at rest.

After the collision, blocks A and B stick together and move with velocity *v*.

(i) Calculate

1. the momentum of block A before the collision,

momentum = ...[2]

2. the velocity *v*,

velocity = ...[2]

3. the impulse experienced by block B during the collision.

impulse = ...[2]

(ii) Suggest why the total kinetic energy of blocks A and B after the collision is less than the kinetic energy of block A before the collision.

....

....[1]

[Total: 8]

4 A balloon contains a fixed mass of gas.

(a) Explain, in terms of the momentum of molecules, how the gas in the balloon exerts a pressure.

....

....

....

....[2]

Energy, work and power

ENERGY:

✓ **Different forms of energy:**

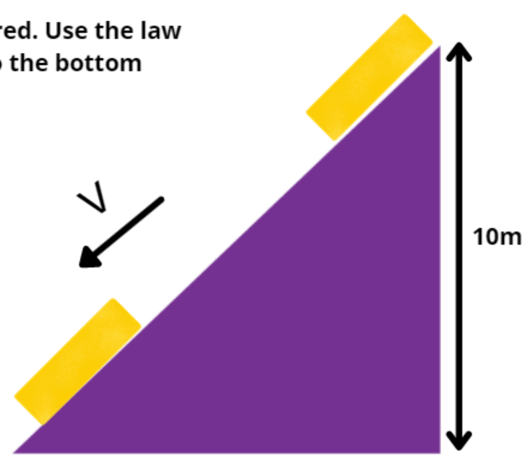
- **Internal energy:** The energy of an object due to the internal motion and positions of its molecules is called internal energy. Example: a magnetised object or a hot object has internal energy
- **Gravitational potential energy:** The energy of an object due to its position is called as the gravitational potential energy. Example: Water stored behind a dam.
- **Kinetic energy:** The energy of an object due to its motion is called as kinetic energy. Example: A moving train.
- **Elastic strain energy:** The energy stored in an object when it is stretched or squashed is called as the elastic strain energy. Example: A stretched spring.
- **Nuclear energy:** The energy released when the nucleus of an atom splits or disintegrates is called as the nuclear energy. Examples: nuclear fission, nuclear fusion and radioactive decay.

✓ **Principle of conservation of energy:**

Statement: Energy can neither be created nor destroyed. It can be converted from one form to another. The total amount of energy before and after a change is the same.

A block slides down a ramp. The frictional force may be ignored. Use the law of conservation of energy to find its speed when it gets to the bottom

Solution:
Loss of PE= Gain of KE
$mgh=0.5mv^2$
$v=\sqrt{2gh}=\sqrt{2(10)(10)}=14m/s$



Energy may be stored as kinetic, gravitational potential, chemical, elastic(strain), nuclear, electrostatic and internal(thermal)

Energy transfers:

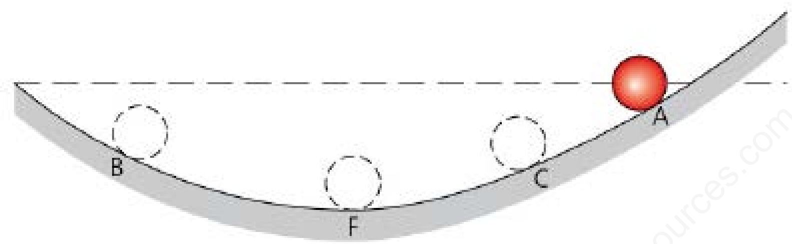
Energy is transferred during stores during events and processess.
This transfer of energy may take place by the following ways:

1. Transfer by fprces (mechanical work done)
2. Electrical currents (electrical work done)
3. Heating

Electromagnetic waves such as sound and other waves

Equation fopr kinetic energy: $E_k = \frac{1}{2}mv^2$

Equation for gravitational potential energy, $\Delta E_p = mg\Delta h$

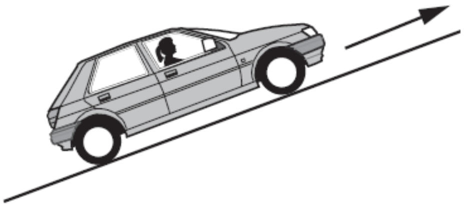


A ball is released from A and rolls back and forth at various positions till it comes to rest at F.

Explaining the energy transfers we have:

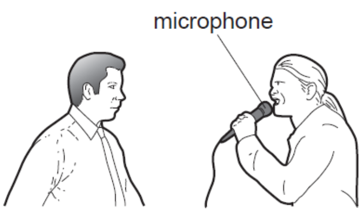
- ✓ As the ball rolls backwards and forwards, there is a continuous transfer of energy between gravitational potential energy and kinetic energy.
- ✓ The ball would only be able to reach the same height as A if there is no force of friction. Because of friction, some kinetic energy is transferred to internal energy in the ball and the slope. So it does not reach the same height. So the ball reaches a max height C on the other side.
- ✓ The ball accelerates as it moves down the slope. When it reaches F, all of the extra gravitational potential that it had because of its position at B has been transferred to the kinetic energy and the ball has its highest speed.
- ✓ The ball decelerates as it moves up to C as the kinetic energy is transferred back to gravitational potential energy.
- ✓ At all times that the ball is moving, some energy is being transferred to internal energy, so the maximum height and the maximum speed of the ball decreases each time, till it finally stops at F.

Conversion of energy from one form to another:



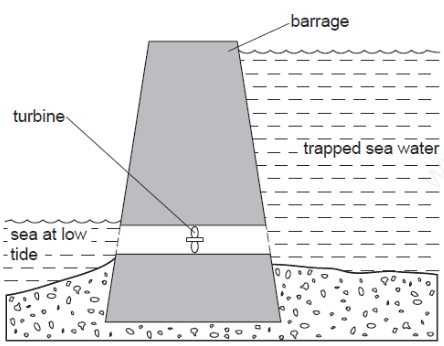
If a car is accelerating while rising uphill, then its gravitational potential energy is increasing and its kinetic energy is also increasing.

In a car engine the energy stored in the fuel is in the form of chemical energy.



For a microphone, the sound energy is being converted into electrical energy

----



In a tidal power station, the potential energy is being converted to electrical energy

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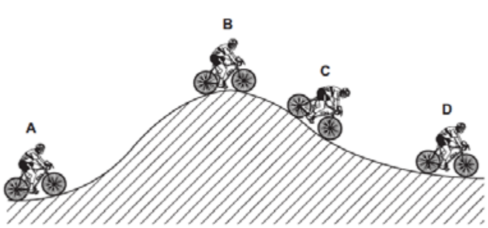
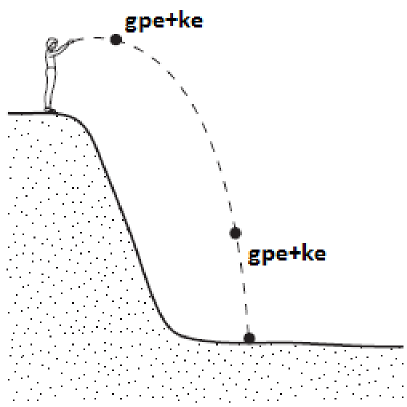
If a car moving on a leveled ground slows down, then the energy conversion taking place are: kinetic energy⟹heat energy

----



The position A has the least gravitational potential energy.

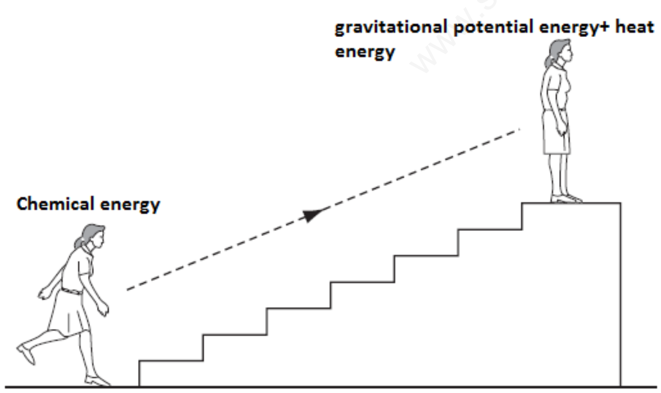


The ball is already in the air so it will possess kinetic and gravitational potential energy while in the air.

The type of power station that does not use steam from boiling water to generate electricity is the hydroelectric power station.

Geothermal, nuclear and oil powered fire stations all use the steam from boiling water to generate electricity.

Coal, natural gas, oil and nuclear energy use their fuel to turn water into steam and use that steam to turn the turbine to generate electricity.



At the top of the stair case , the chemical energy gets changed into gravitational potential energy and heat energy

----

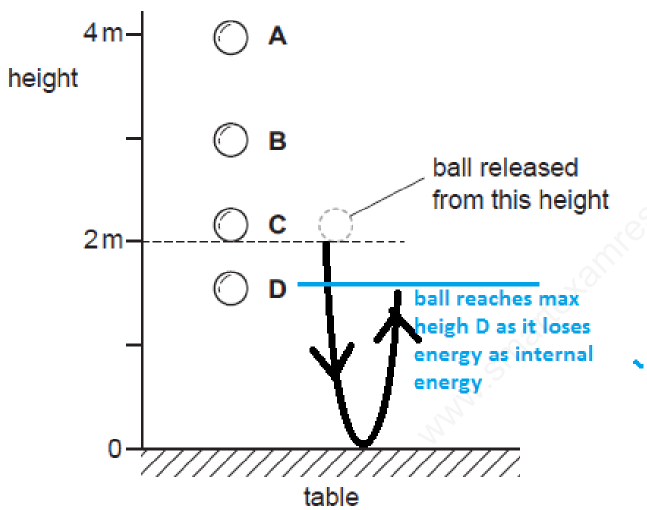
The order of energy transfer in nuclear fission is:

nuclear fuel → reactor and boiler → turbines → generator

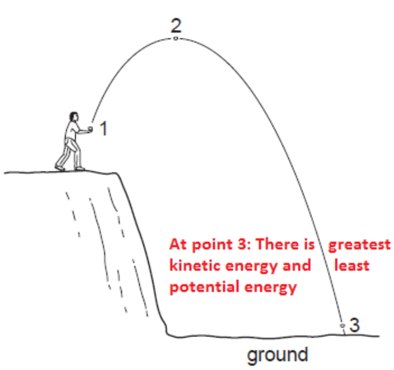
A cyclist travels down a hill from rest at point X without pedalling.

The cyclist applies his brakes and the cycle stops at point Y.

gravitational potential → kinetic → internal (heat)

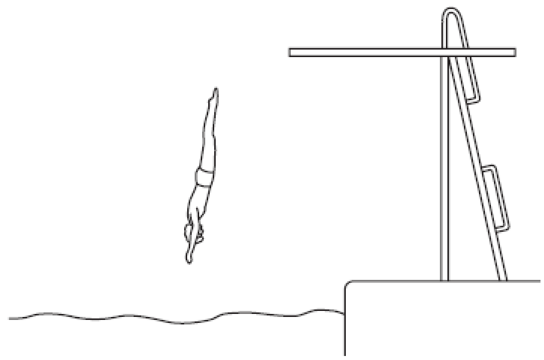


Nuclear fission and geothermal energy is available at all times as against solar energy which is unpredictable



APPLICATION BASED QUESTIONS:

10 The diagram shows a man diving into water. 0625/01



Which form of energy is increasing as he falls?

A chemical

B gravitational

C kinetic

D strain

9 What is designed to change electrical energy into kinetic energy? 0625/01/M/J/05

A capacitor

B generator

C motor

D transformer

10 A power station uses nuclear fission to obtain energy. 0625/01/M/J/05

In this process, nuclear energy is **first** changed into

A chemical energy.

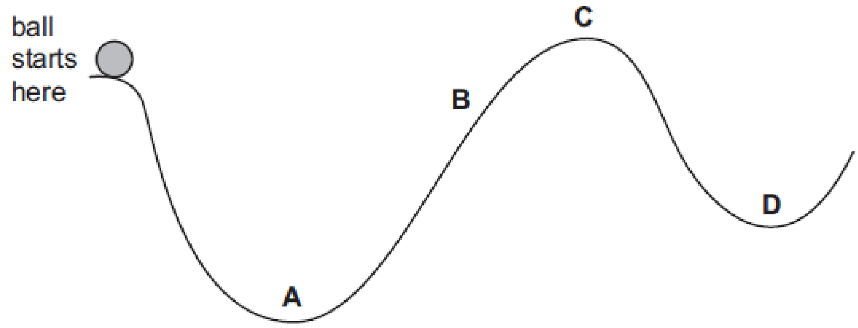
B electrical energy.

C gravitational energy.

D internal energy.

11 A ball is released from rest and rolls down a track from the position shown.

What is the furthest position the ball could reach? 0625/01/M/J/05



9 Which form of energy do we receive directly from the Sun? 0625/01/M/J/0

A chemical

B light

C nuclear

D sound

0625/01/M/J/07

10 Which form of energy is used to generate electrical energy in a tidal power station?

A chemical energy

B gravitational energy

C internal energy (thermal energy)

D nuclear energy

11 Which line in the table gives an example of the stated form of energy? 0625/01/M/J/07

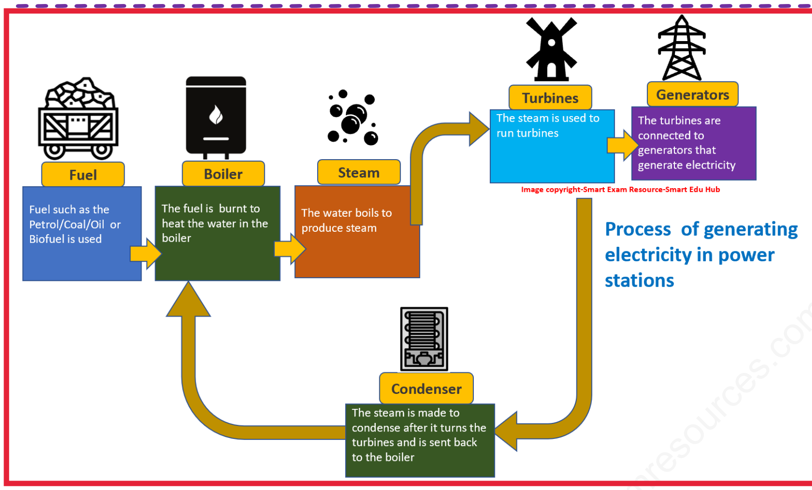
	form of energy	example
A	gravitational	the energy due to the movement of a train
B	internal	the energy due to the flow of cathode rays in a cathode ray tube
C	kinetic	the energy due to the position of a swimmer standing on a high diving board
D	strain	the energy due to the compression of springs in a car seat

Understanding each type of energy:

Generating electricity in power stations:

Depending on the type of fuel used, the power stations are divided into the following types:

- coal/oil/biofuel fired power stations
- gas fired power station.



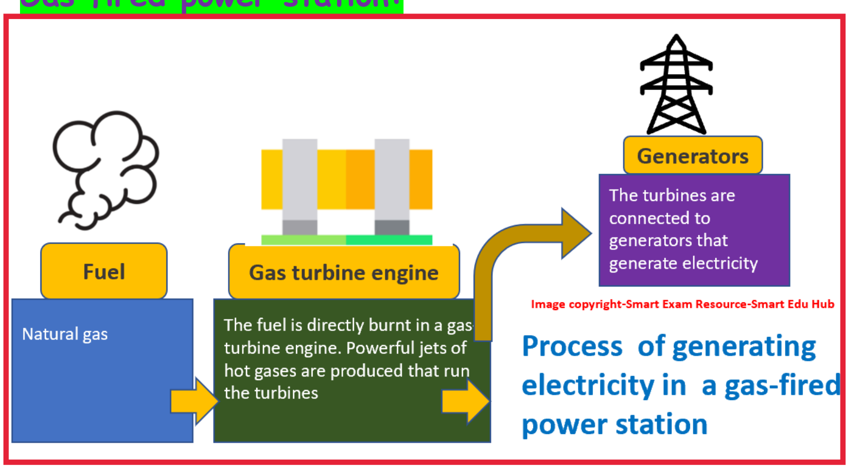
Petrol/coal/oil/biofuel fired power station:

Fuel to be burnt: Petrol, coal or oil or biofuel.

Process:

- Fuel is burnt to heat the water in a boiler.
- Water boils to produce steam.
- The steam drives the turbines,
- The turbines turn an electricity generator.
- The steam is made to condense after it turns the turbines. This condensed steam(water) returns to the boiler. Steam is condensed by passing cold water through the pipes.

Gas fired power station:



Fuel to be burnt: natural gas.

The gas is directly burnt in a gas turbine engine. this produces a powerful jet of hot gases and air that drives the turbines. Such turbines can be switched on very quickly.

Energy conversions taking place in power stations:

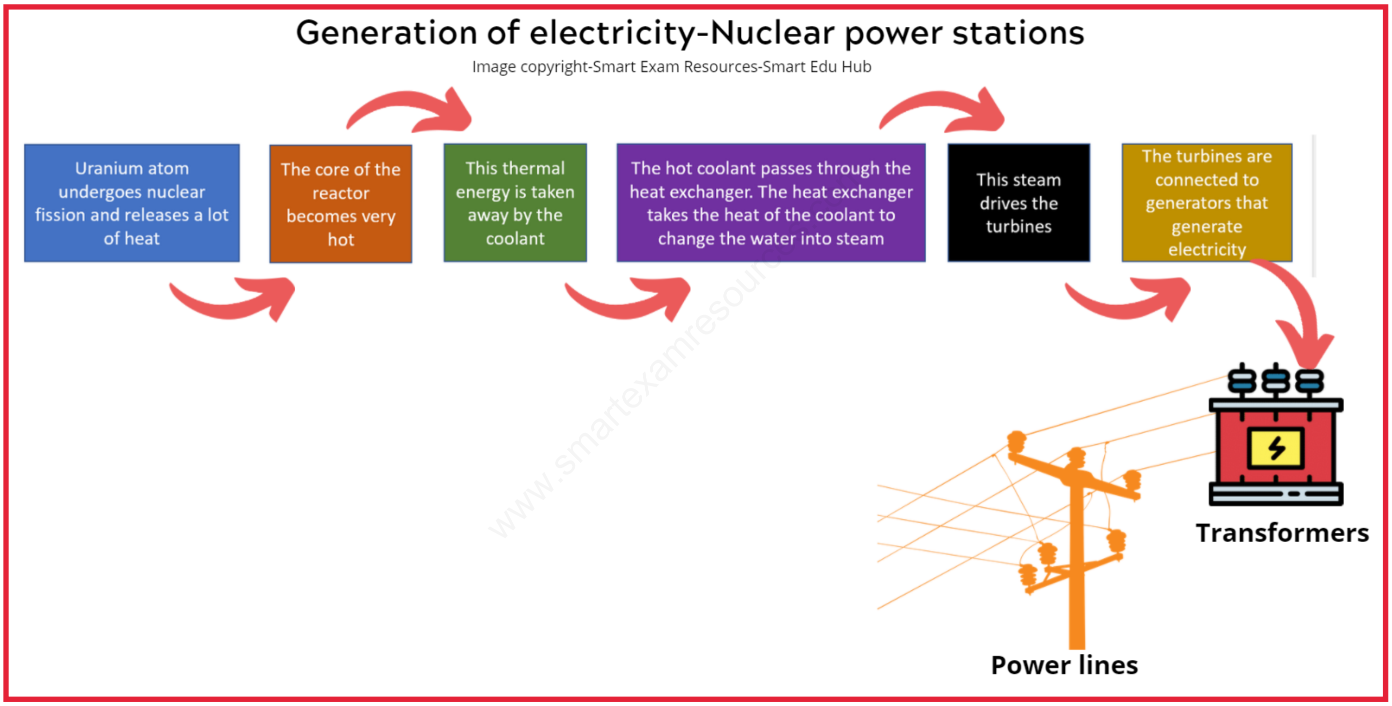
chemical ⟹ heat⟹ kinetic⟹ electrical

Energy from nuclear fission:

- Nuclear energy is released in nuclear power station.
- The fuel used is uranium.
- It releases 10 000 times more energy than that released by fossil fuel or biofuel

---

Process:



- A lot of heat is released when the uranium atoms undergo a chain reaction.
- The core of the reactor becomes very hot. The thermal energy of the core is taken away by a liquid called as the coolant. This coolant is pumped through the core to absorb the heat.
- The coolant is very hot when it leaves the core.
- The coolant passes through a heat exchanger where the heat of the coolant is used to change water into steam.
- The steam drives the turbines.
- The turbines are connected to generators that generate electricity.

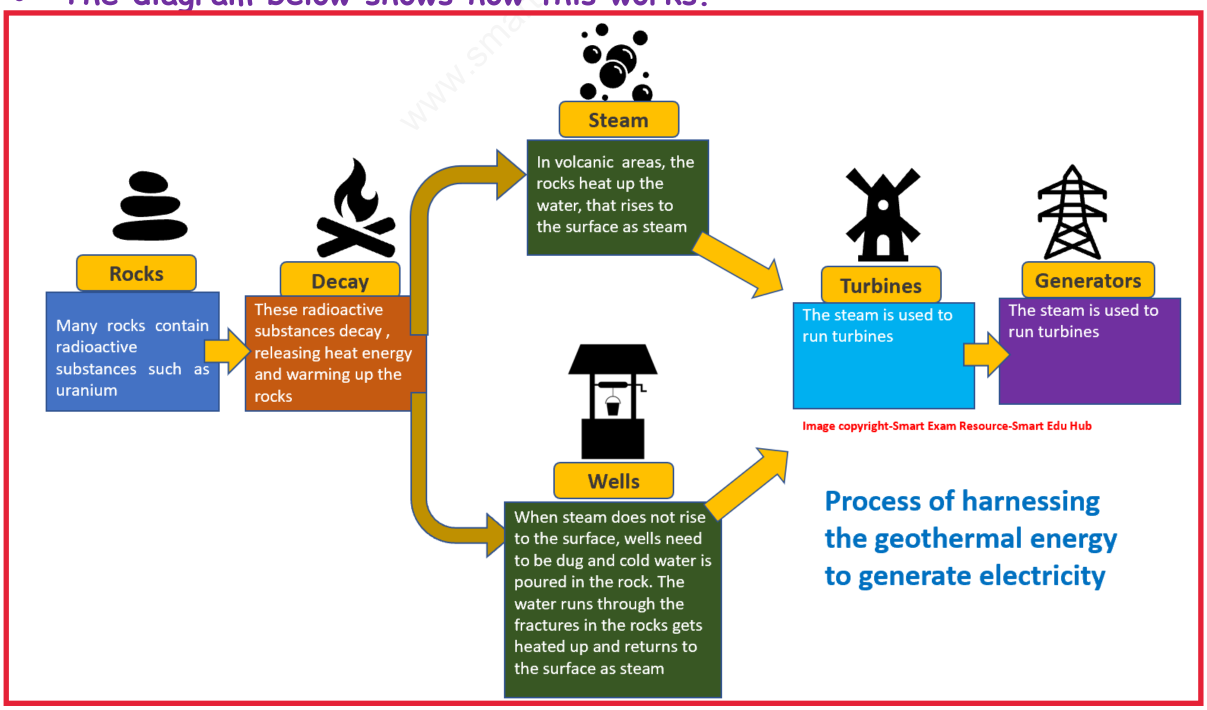
Geothermal resources

Volcanic areas

- Several types of rock contain radioactive substances such as uranium. Radioactive decay of these substances releases heat energy, which warms up the rocks.
- In volcanic areas, the rocks may heat water so that it rises to the surface naturally as hot water and steam.
- Here the steam can be used to drive *turbines* and electricity generators.
- This type of geothermal power station exists in places such as Iceland, California and Italy.

Hot rocks

- In some places, the rocks are hot, but no hot water or steam rises to the surface. In this situation, deep wells can be drilled down to the hot rocks and cold water pumped down.
- The water runs through fractures in the rocks and is heated up. It returns to the surface as hot water and steam, where its energy can be used to drive turbines and electricity generators.
- The diagram below shows how this works.



Solar energy:

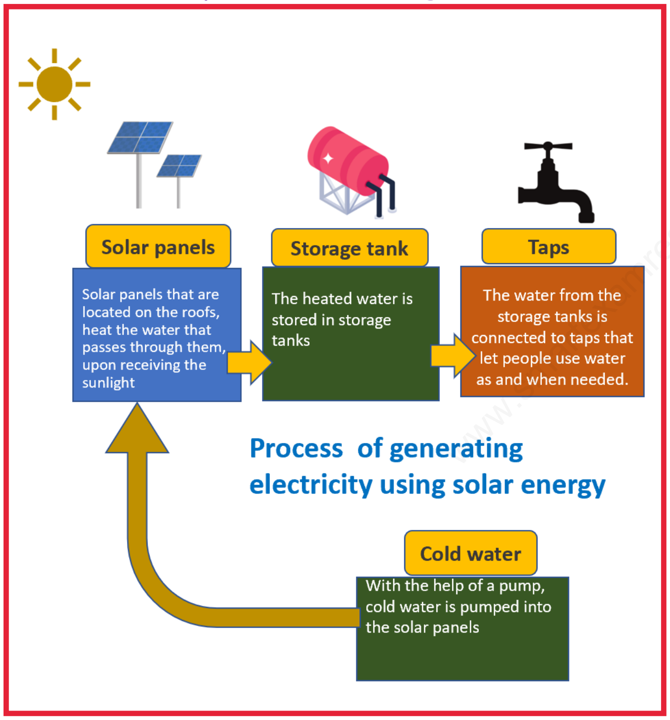
Solar energy is used to work solar cells and solar panels.

Solar cells

- Solar cells are devices that convert light energy directly into electrical energy.
- You may have seen small solar cells in calculators.
- Larger arrays of solar cells are used to power road signs in remote areas, and even larger arrays are used to power satellites in orbit around Earth.

Solar panels

- Solar panels do not generate electricity, but rather they heat up water. They are often located on the roofs of buildings where they can receive heat energy from the sun. The diagram outlines how they work.



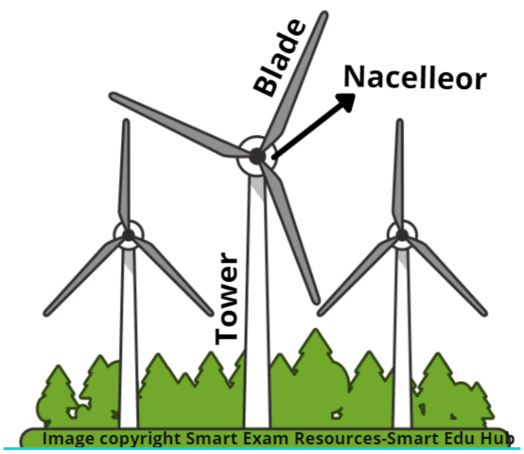
- A pump pushes cold water from the storage tank through pipes in the solar panel. The water is heated by heat energy from the sun and returns to the tank. In some systems, a conventional boiler may be used to increase the temperature of the water.

Wind energy:

Big convection currents

The wind is produced as a result of giant *convection* currents in the Earth's atmosphere, which are driven by heat energy from the sun. This means that the kinetic energy in wind is a renewable energy resource: as long as the sun exists, the wind will too.

Wind turbines



Wind turbines have huge blades mounted on a tall tower. The blades are connected to a *nacelleor* housing that contains gears linked to a *generator*. As the wind blows, it transfers some of its kinetic energy to the blades, which turn and drive the generator. A cable between the generator and the shore delivers the electricity to local users or via a network of cables to distant users. Several wind turbines may be grouped together in windy locations to form wind farms.

Note: Nacelleor is a casing in which the generator is enclosed.

Energy from water:

Energy from the water can be harnessed in 3 ways as :

- Tidal energy
- Wave energy
- Hydroelectric energy

Tidal energy:

Huge amounts of water move in and out of river mouths each day because of the tides. A tidal barrage is a barrier built over a river estuary to make use of the kinetic energy in the moving water. The barrage contains electricity generators, which are driven by the water rushing through tubes in the barrage.

Wave energy:

The water in the sea rises and falls because of waves on the surface. . This motion drives the turbines and the kinetic energy of turbines which turns a generator.

Hydroelectric energy

Hydroelectric power stations use the kinetic energy in moving water. This water is stored behind the dam built across a river valley. The water high up behind the dam contains *gravitational potential energy*. This is transferred to kinetic energy as the water rushes down through tubes inside the dam. The moving water drives electrical generators, which may be built inside the dam.

Advantages and disadvantages of generating electricity from various energy sources

Nuclear fuel	Advantages	Disadvantages
Environmental impact	1.Does not produce toxic and acidic gases like CO_2 and SO_2 2. Low greenhouse gas emissions	1. They are non-renewable energy resources 2. If there is an accident, large amounts of radioactive material could be released into the environment. 3.Nuclear waste remains radioactive and is hazardous to health for thousands of years
Reliability	It is reliable	-
Cost	Nuclear power plants are expensive to build but relatively cheap to run	-
Scale	Large scale production of electricity is possible	-
Renewability	It is a non renewable source	-

	Advantages	Disadvantages
Solar energy		
Environmental Impact	1.No harmful polluting gases are produced.	-
Cost	Solar power plants are usually cheaper than new coal, nuclear, or natural gas power plants.	-
Scale	It is possible to install solar power plants in most places in the world.	-
Renewablility	It is a renewable source	-
Reliability	-	When the sun goes down or is heavily shaded, solar PV panels stop producing electricity. If we need electricity at that time, we have to get it from some other source. In other words, we couldn't be 100% powered by solar panels.

	Advantages	Disadvantages
Geothermal energy		
Environmental Impact	1. Geothermal fields produce only about one-sixth of the carbon dioxide that a relatively clean natural-gas-fueled power plant produces.	1. It releases hydrogen sulfide gas that smells like rotten egg at low concentrations. 2. Another concern is the disposal of some geothermal fluids, which may contain low levels of toxic materials.
Reliability	1. Geothermal energy is always available, 365 days a year	Although geothermal sites are capable of providing heat for many decades, eventually specific locations may cool down.
Cost	1. There are no fuel costs. 2. It's also relatively inexpensive; savings from direct use can be as much as 80 percent over fossil fuels. 3. Maintenance cost of geothermal power plants is very less	There is no guarantee that the amount of energy which is produced will justify the capital expenditure and operations costs.
Scale	-	Total generation potential of this source is too small.
Renewablilty	1. It is a renewable energy resource	Most parts of the world do not have suitable areas where geothermal energy can be exploited.

	Advantages	Disadvantages
Water		
Environmental Impact	1. Does not pollute the air.	1.Tidal barrages destroy the habitat of estuary species, including wading birds. 2.Hydroelectricity dams flood farmland and push people from their homes. 3.The rotting vegetation underwater releases methane, which is a greenhouse gas.
Reliability	Tidal barrages and hydroelectric power stations are very reliable and can be turned on quickly to produce electricity on demand.	Hydropower plants can be impacted by drought. When water is not available, the hydropower plants can't produce electricity
Cost	No fuel costs are involved	
Scale	-	It has been difficult to scale up the designs for wave machines to produce large amounts of electricity.
Renewability	Hydropower relies on the water cycle,which is driven by the sun. Thus it is a renewable power source	-

----

	Advantages	Disadvantages
Wind		
Environmental Impact	1.No harmful polluting gases are produced	Wind farms are noisy and may spoil the view for people living near them/visual pollution 2. requires large acres of land. 3. turbines kills birds at times
Reliability	It is non-reliable. The amount of electricity generated depends on the strength of the wind. If there is no wind, there is no electricity.	-
Cost	There are no fuel costs	Initial cost of setting up wind farms are high
Scale	Available only locally	-
Renewability	It is renewable	-

Note:

1.Radiation from the sun is the main source of energy for all our energy resources except geothermal, nuclear and tidal.

2. Energy is released by nuclear fusin in the sun

3. research is being carried out to investigate how energy released by nuclear fusion can be used to produce electrical energy on a large scale

Work:
Mechanical or electrical work done is equal to the energy transferred.
Equation for mechanical work done:
$W = Fd = \Delta E$

Energy efficiency in terms of energy efficiency and power efficiency

---

(a)

$$(\%)\ \text{efficiency} = \frac{(\text{useful energy output})}{(\text{total energy input})}\ (\times 100\%)$$

(b)

$$(\%)\ \text{efficiency} = \frac{(\text{useful power output})}{(\text{total power input})}\ (\times 100\%)$$

recall and use these equations

Numerical:

Example:1

In an experiment, an electric motor was provided energy at the rate of 0.80W. This was used to raise a 30g load by 70cm an 2.3 s. calculate the efficiency of this motor.

Solution:

Efficiency= Useful power output/Total input power

Useful Output power (P) r=Power that was used in lifting the 30g load in 2.3s

P= E/t=mgh/t

Convert mass in grams to kg and distance from cm to m , since power is in watts.

Useful output power=P=(0.03 x 10 x 0.70)/ 2.3=0.09W

Thus ,

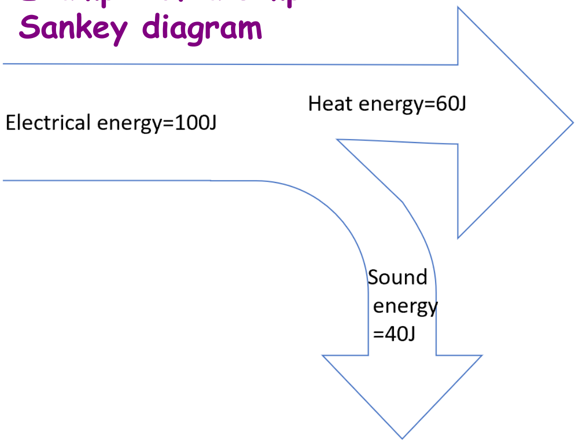
Efficiency=(0.09/0.80) x 100 = 11%

Applying the principle of conservation of energy:

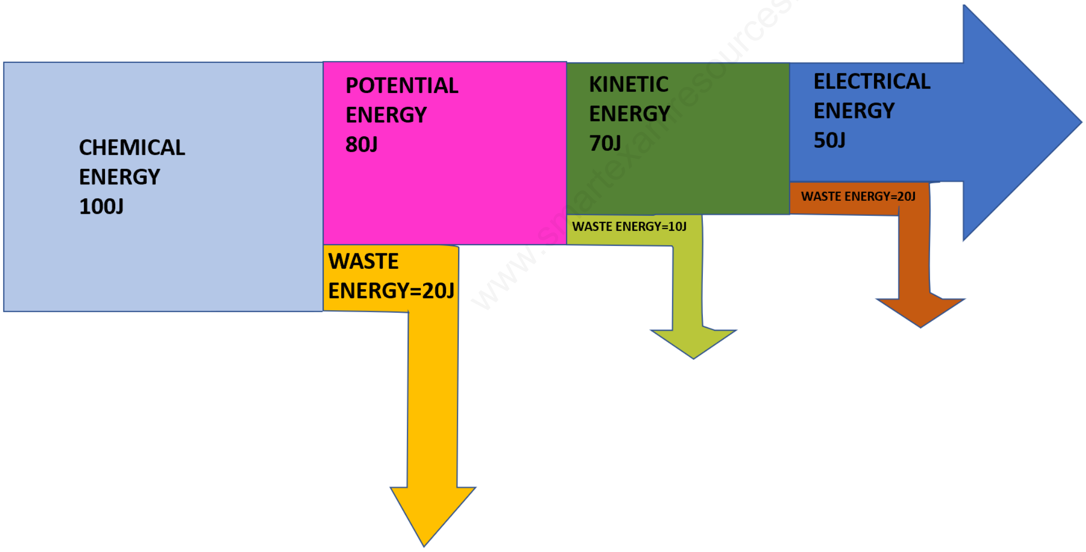
1. Simple energy flow diagrams:
2. Sankey diagrams

Sankey diagrams are flow charts used to visualize material and energy flows with arrows that have a width proportional to the flow quantity.

Example of a simple Sankey diagram



Example of a complex Sankey diagram



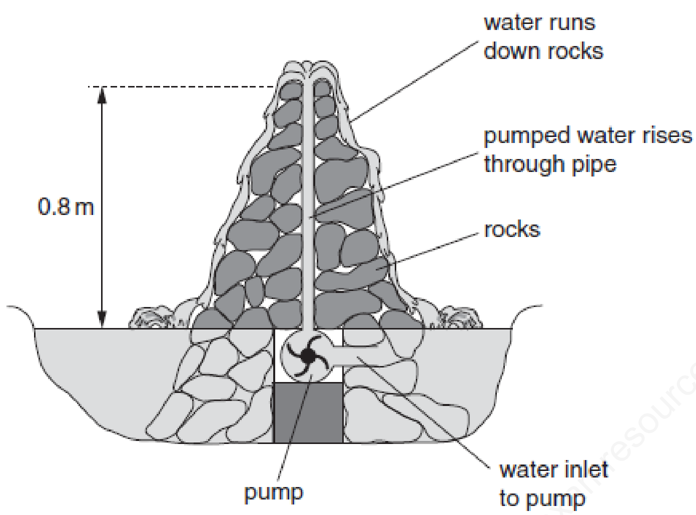
Work:

Work done by a force depends upon the force and the distance moved. Work is defined as:

Work= Force x distance moved in the direction of the force

Units: Joule or Nm

Work done in raising an object above the earth's surface



Suppose we need to calculate the work done while lifting 1 litre[$0.001m^3$] of water up through 0.8m:[density of water=$1000kg/m^3$]

We know that work done= Force x distance in the direction of the force

W=f x d

= (mg) x 0.8

=(dXv)g x 0.8

=1000 x 0.001 x 10 x 0.8

=8J

Thus Work done on an object being lifted upwards= mgh

Note: The gain of gravitational potential energy(change in potential energy)= work done to raise it through a vertical distance. Hence work done=mgh=F x d

---

Work done in moving an object horizontally on the earth's surface:

(b) Another athlete using a different spring exerts an **average** force of 400 N to enable her to extend the spring by 0.210 m

M/J/04-P3-Q3

(i) Calculate the work done by this athlete in extending the spring once.

work done = ...

Here the spring is stretched horizontally in the direction of the force. Hence work= force x displacement= 400 x 0.210 =84.0J

---

3 Fig. 3.1 shows a skier taking part in a downhill race.

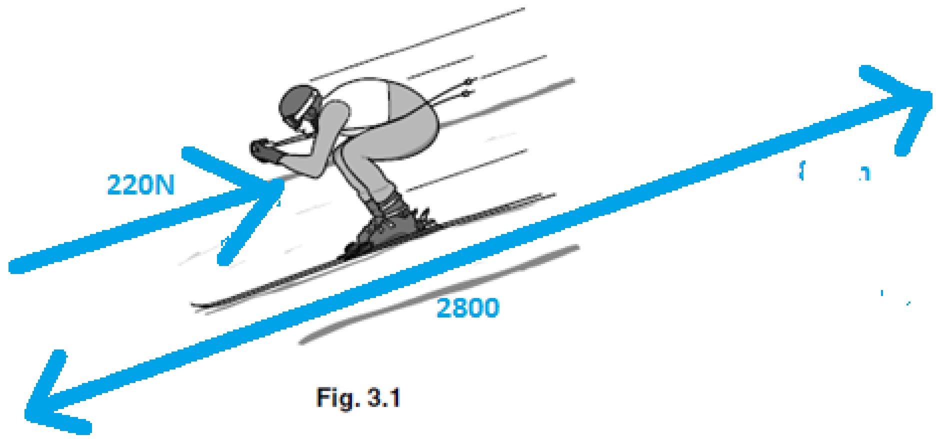


Fig. 3.1

(a) The mass of the skier, including his equipment, is 75 kg. In the ski race, the total vertical change in height is 880 m.

O/N/15-P31-Q3

Calculate the decrease in the gravitational potential energy (g.p.e.) of the skier.

(a) The mass of the skier, including his equipment, is 75 kg. In the ski race, the total vertical change in height is 880 m.

O/N/15-P31-Q3

Calculate the decrease in the gravitational potential energy (g.p.e.) of the skier.

Decrease in the gpe= mgh= 75 x 10 x 880=6.6 x 10^5J.Nm

(b) The skier starts from rest. The total distance travelled by the skier during the descent is 2800 m. The average resistive force on the skier is 220 N.

Calculate

(i) the work done against the resistive force,

Work done against the resistive force= Force x distance = 220 x 2800 =6.2 x 10^5Nm [This is equal to the loss of gpe]

(ii) the kinetic energy of the skier as he crosses the finishing line at the end of the race.

As he crosses the finishing line all the gpe gets changed into his kinetic energy=6.6 x 10^5J.Nm-6.2 x 10^5J/Nm= 4 x 10^4J

Note that the skier bends his body to reduce the air resistance.

Kinetic energy:

If an object of mass v moves with a velocity of v , then the kinetic energy is given by:

K.E= $\frac{1}{2}mv^2$

m- mass object in kg

v= velocity in m/s

In a roller coaster type of motion.

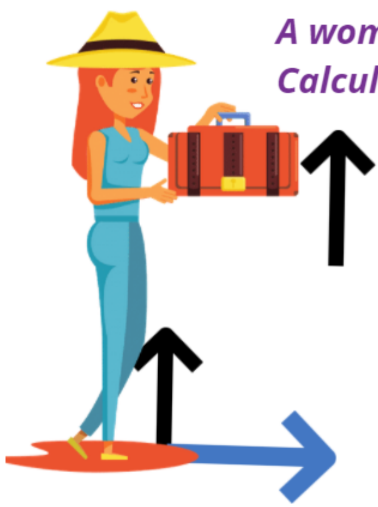
Assume that all the loss of g.p.e gets transformed into the k.e of the train; then;

$\frac{1}{2}mv^2$= mgh

where;

h=distance between the highest point of the track and the bottom of the descent.

v= speed at the bottom of the descent.



A woman with a suitcase, walks with a constant velocity. Calculate the work done by the force in holding the suitcase

Solution:

The force applied by the woman in lifting the suitcase is upwards. This upward force is not making the bag move in the upward direction. Hence work done by the force is zero

----

Power:

Power is the work done per unit time [or]

Power is defined as the energy transferred per unit time Hence:

Power (Watts)= $\frac{Work\ done(J)}{Time\ taken\ (s)}$

or

Power(Watts)= $\frac{useful\ energy\ transferred\ (J)}{Time\ taken\ (s)}$

Hence: 1W= 1J/s

Making some interpretations:

If a torch has a power of 5W it means that it transfers 5J of energy per second

---

Whenever a machine does work on an object, energy is transferred to the object.

Numerical:

---

9 The table shows the times taken for four children to run up a set of stairs.

0625/12/O/N/09

Which child's power is greatest?

	mass of child / kg	time / s
A	40	10
B	40	20
C	60	10
D	60	20

The answer here is obviously C. Explanation:

Power (Watts)= $\frac{Work\ done(J)}{Time\ taken\ (s)} = \frac{mgh}{t}$

Let's assume that the vertical height=10m for each child. Substituting we get the highest value of power for child C

0625/01/M/J/03

11 A labourer on a building site lifts heavy concrete blocks onto a lorry. Lighter blocks are now lifted the same distance in the same time.

What happens to the work done in lifting each block and the power exerted by the labourer?

	work done in lifting each block	power exerted by labourer
A	decreases	decreases
B	decreases	remains the same
C	increases	increases
D	remains the same	increases

Power (Watts)= $\frac{Work\ done(J)}{Time\ taken\ (s)} = \frac{mgh}{t}$

Obviously if bricks become lighter, then numerator decreases but denominator stays the same, so the power decreases. Also work = mgh, so work too decreases.

Application based questions:

---

11 A worker is lifting boxes of identical weight from the ground onto a moving belt.

0625/01/M/J/08

At first, it takes him 2 s to lift each box. Later in the day, it takes him 3 s.

Which statement is correct?

A Later in the day, less work is done in lifting each box.

B Later in the day, more work is done in lifting each box.

C Later in the day, less power is developed in lifting each box.

D Later in the day, more power is developed in lifting each box.

(b) Another athlete using a different spring exerts an **average** force of 400 N to enable her to extend the spring by 0.210 m

M/J/04-P3-Q3

(i) Calculate the work done by this athlete in extending the spring once.

work done = ...

(ii) She is able to extend the spring by this amount and to release it 24 times in 60 s. Calculate the power used by this athlete while doing this exercise.

power = ...

(b) A road is covered with a layer of snow. The temperature of the snow is 0 °C. The specific latent heat of fusion of snow is 3.3×10^5 J / kg.

O/N/16-p43

The snow forms a layer of uniform thickness on the road surface.

(i) Calculate the power needed to melt 0.12 kg of the snow in 220 s.

power = ... [4]

4 **(a)** The source of solar energy is the Sun.

Tick the box next to those resources for which the Sun is also the source of energy.

F/M/16-P42

☐ coal

☐ geothermal

☐ hydroelectric

☐ nuclear

☐ wind [2]

O/N/14-P33-Q6

6 (a) Explain why

(i) metals are good conductors of electricity,

....

....

(ii) insulators do not conduct electricity.

....

....
[3]

(b) The battery of an electric car supplies a current of 96 A at 120 V to the motor which drives the car.

(i) State the useful energy change that takes place in the battery.

....[1]

(ii) Calculate the energy delivered to the motor in 10 minutes.

energy = ... [2]

(iii) The motor operates with an efficiency of 88 %.

Calculate the power output of the motor.

power = ... [2]

[Total: 8]

Pressure

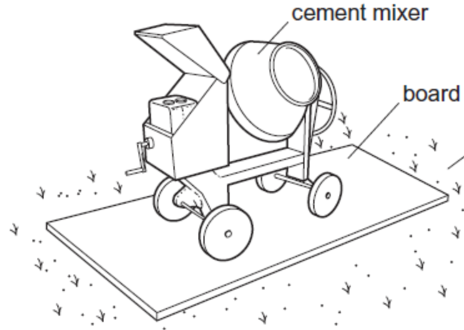
Definition: Pressure is defined as force per unit area

Formula: $P=\frac{F}{A}$

Units: N/m^2 or Pascal.

12 To prevent a cement mixer sinking into soft ground, the mixer is placed on a large flat board.

0625/11/M/J/10



Why does this prevent the mixer sinking?

A The large area decreases the pressure on the ground.

B The large area increases the pressure on the ground.

C The large area decreases the weight on the ground.

D The large area increases the weight on the ground.

Here, the large area decreases the pressure on the ground. This is because the mass of the mixer does not change and hence nor does its weight. Ans: A

Pressure exerted by solids can be found using the formula :$P=\frac{F}{A}$

Numerical:

(c) The area of the piston is $5.5 \times 10^{-3}m^2$ ($0.0055m^2$). M/J/15-P32-Q2

Calculate the force exerted by the gas on the piston when the pressure is 800 kPa.

SOLUTION:

Pressure=$\frac{F}{A}$

It is important to convert 800kPa to 800 000Pa .Then substitute in the formula $\Rightarrow$ F=$P \ x \ A = 800000 \ x \ 0.0055 =$=4400N

6 (a) A man squeezes a pin between his thumb and finger, as shown in Fig. 6.1.

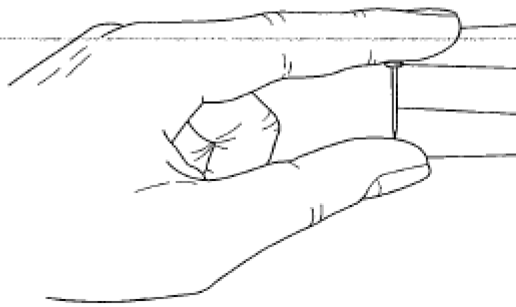


Fig. 6.1

The finger exerts a force of 84 N on the pinhead.

The pinhead has an area of $6.0 \times 10^{-5}\,m^2$.

(i) Calculate the pressure exerted by the finger on the pinhead.

$P = F/A$

$= 84 / 6 X 10^{-5}$

$= 1.4 X 10^{6}$

(ii) State the value of the force exerted by the pin on the thumb.

84n

(b) The density of the water in a swimming pool is $1000\,kg/m^3$. The pool is 3 m deep.

(i) Calculate the pressure of the water at the bottom of the pool.

$P = hpg$

$= 3 x 1000 x 10$

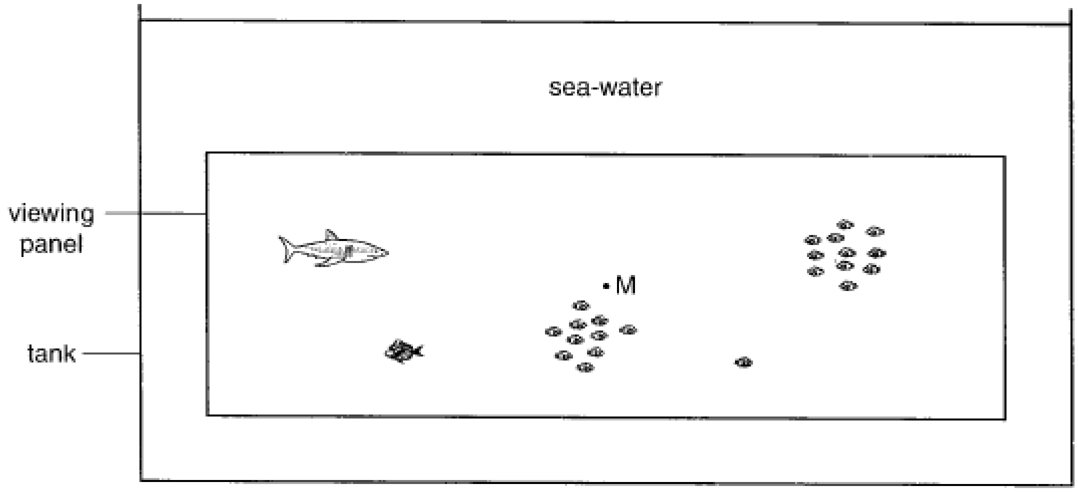
$3 x 10^{4}$

(ii) Another pool has the same depth of water but has twice the area.

State the pressure of the water at the bottom of this pool.

$3 x 10^{4}$

1 Fig. 1.1 shows a side view of a large tank in a marine visitor attraction.



The tank is 51 m long and 20 m wide. The sea-water in the tank is 11 m deep and has a density of 1030 kg / m^3.

(a) Calculate the mass of water in the tank.

d=m/v

m= d x v

= 1030 x 51 × 20 × 11

= 11 556 600

=1.2 × 107 kg

(b) The pressure at point M, halfway down the large viewing panel, is 60 kPa more than atmospheric pressure.

Calculate the depth of M below the surface of the water.

$p = \rho g(\Delta)h$

$\Delta h = 60\,000 / (1030 \times 10)$

$= 5.8 m$

(c) The viewing panel is 32.8 m wide and 8.3 m high.

Calculate the outward force of the water on the panel. Assume that the pressure at M is the average pressure on the whole panel.

use of $F = pA$

$= 60\,000 \times 32.8 \times 8.3$

$= 60\,000 \times 272.2$

$= 1.6 \times 10^7$ N

Application based questions:

10 A man stands on the ground. **0625/13/M/J/13**

Which action will increase the pressure that the man exerts on the ground?

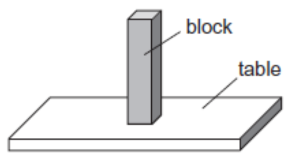
A The man slowly bends his knees.

B The man slowly lies down on the ground.

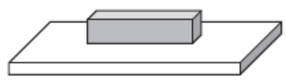
C The man slowly raises his arms.

D The man slowly raises one foot off the ground.

11 A block with flat, rectangular sides rests on a table. **0625/11/M/J/15**



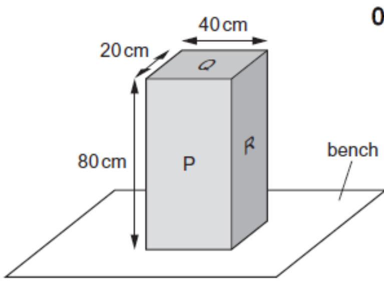
The block is now turned so that it rests with its largest side on the table.



How has this change affected the force and the pressure exerted by the block on the table?

	force	pressure
A	decreased	decreased
B	decreased	unchanged
C	unchanged	decreased
D	unchanged	unchanged

11 The diagram shows a solid block resting on a bench. The dimensions of the block are shown. **0625/13/M/J/15**



On which labelled surface should the block rest to produce the smallest pressure on the bench?

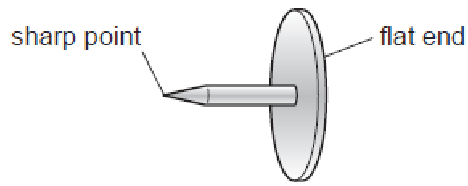
A P

B Q

C R

D any of P, Q or R

11 A drawing pin (thumb tack) has a sharp point and a flat end. **0625/12/O/N/13**



The pin is pushed into a wooden board.

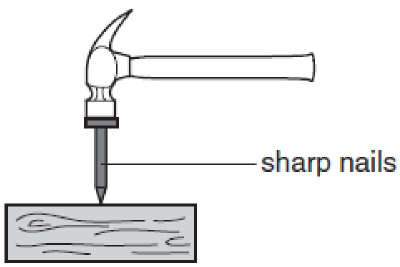
How do the pressure and the force at the sharp point compare with the pressure and the force at the flat end?

	force at the sharp point	pressure at the sharp point
A	greater than at the flat end	greater than at the flat end
B	greater than at the flat end	less than at the flat end
C	the same as at the flat end	greater than at the flat end
D	the same as at the flat end	less than at the flat end

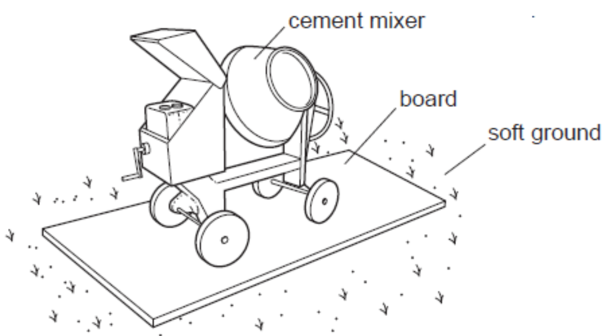
0625/12/O/N/13

Real life applications of solid pressure:

- Hammering objects using a nail with the sharp tip.



- Placing cement mixers on flat boards in case they tend to sink



- By using sharp knives to cut objects with ease: A sharp knife has a much smaller are in contact with the object being cut . So the force applied acts on a very small area and cuts the object with ease.

DISADVANTAGES OF PRESSURE:

People confined to bed suffer from bed sores. The entire weight of the person falls on the small area of the skin. The skin is not strong enough to bear this weight and the skin is rubbed away causing bed sores.

Pressure exerted by fluids:

Properties of pressure exerted by fluids are:

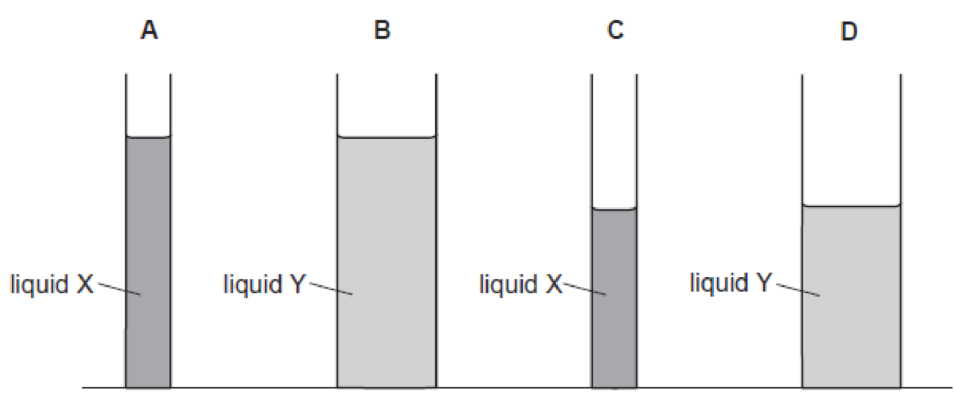
- Pressure of a liquid increases with depth
- The pressure in a liquid depends on the density of the liquid.
- Pressure of a liquid acting alone the same horizontal line is the same.

Example:

2 Liquid X has a density of 1010 kg / m^3. Liquid Y has a density of 950 kg / m^3.

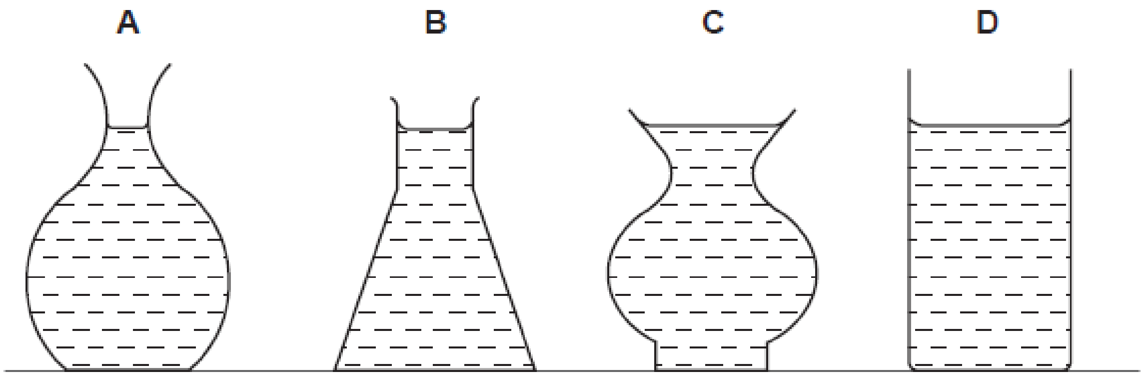
The liquids are poured into tubes as shown. 0625/13/O/N/10

Which tube has the greatest pressure on its base?



Here , the greatest pressure can be exerted either by diagrams shown in A or B. Since the density of Liquid X is greater than the density of liquid Y, hence liquid X in figure A exerts the greatest pressure.

In this diagram , assuming that the mass of liquid is the same in all the 4 containers, and all the four containers have the liquid at the same level, then



the pressure exerted by the liquid column is the same for each container. But container C will exert the maximum pressure on the table as the surface area in contact with the table is the least so the entire mass falls on a small surface area so exerts the greatest pressure.

Application based questions:

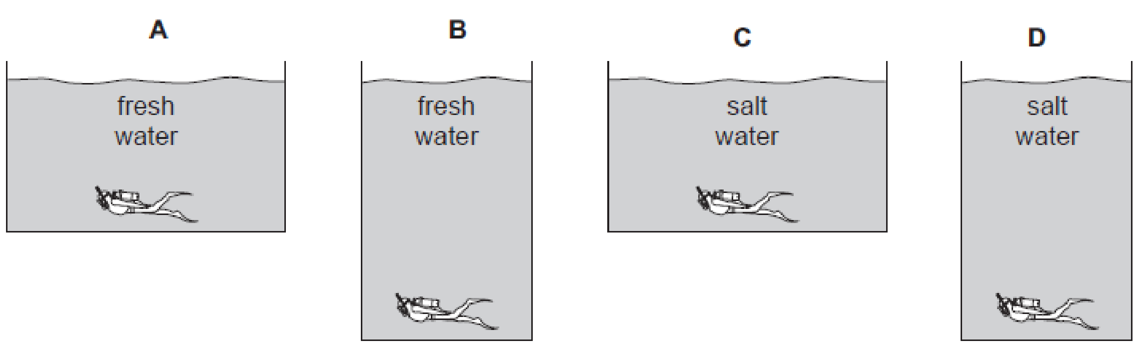
MCQ:

12 The diagrams show four divers at the bottom of four different swimming pools.

Two swimming pools contain fresh water and two contain salt water. Fresh water is less dense than salt water.

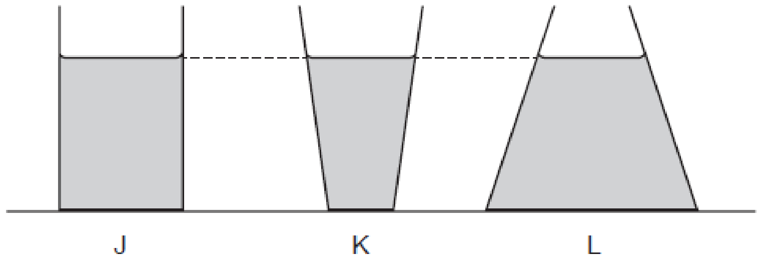
0625/12/O/N/13

Which diver feels the least pressure from the water?



9 The diagram shows three different containers J, K and L. Each container contains water of the same depth.

0625/12/O/N/14



Which statement about the pressure of the water on the base of each container is correct?

A The water pressure is greatest in container J.

B The water pressure is greatest in container K.

C The water pressure is greatest in container L.

D The water pressure is the same for all three containers.

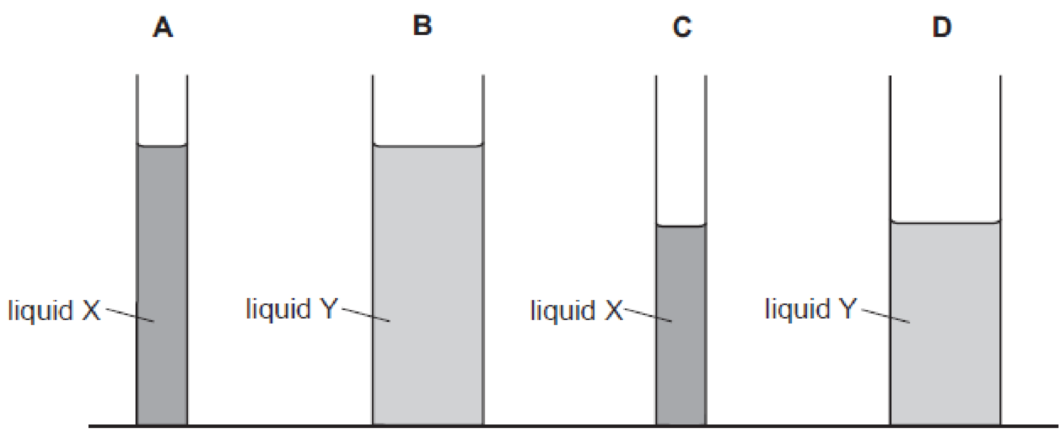
---

12 Liquid X has a density of 1010 kg / m^3. Liquid Y has a density of 950 kg / m^3.

The liquids are poured into tubes as shown.

0625/12/O/N/10

Which tube has the greatest pressure on its base?



Pressure exerted by a liquid column can be found out by using the formula:

Pressure $(P) = h\rho g$

where h= height of the liquid column

ρ= density of the liquid

g= acceleration due to gravity

NUMERICAL:

2 Fig. 2.1 shows a reservoir that stores water. 76

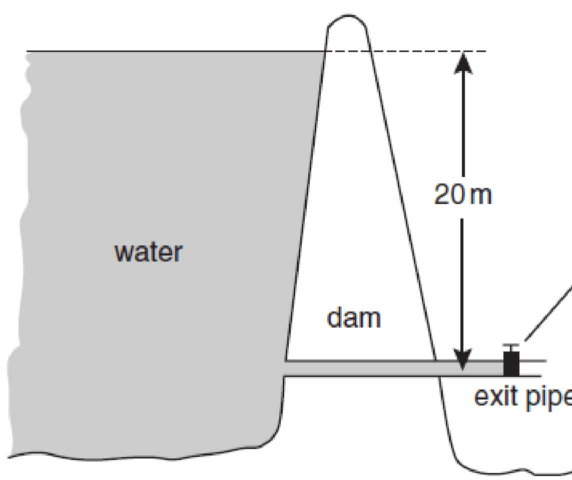


Fig. 2.1

(a) The valve in the exit pipe is closed. The density of water is 1000 kg/m^3 and the acceleration of free fall is 10 m/s^2.
Calculate the pressure of the water acting on the closed valve in the exit pipe.

Pressure=$h\rho g$ = 20 × 1000 × 10= 2 × 10^5Pa

(b) The cross-sectional area of the pipe is 0.5 m^2.
Calculate the force exerted by the water on the closed valve.

Force= Pressure X Area

= 2 × 10^5 × 0.5= 1 ×10^5 N

4 An archaeologist is investigating a shipwreck and discovers a wooden box on the seabed.

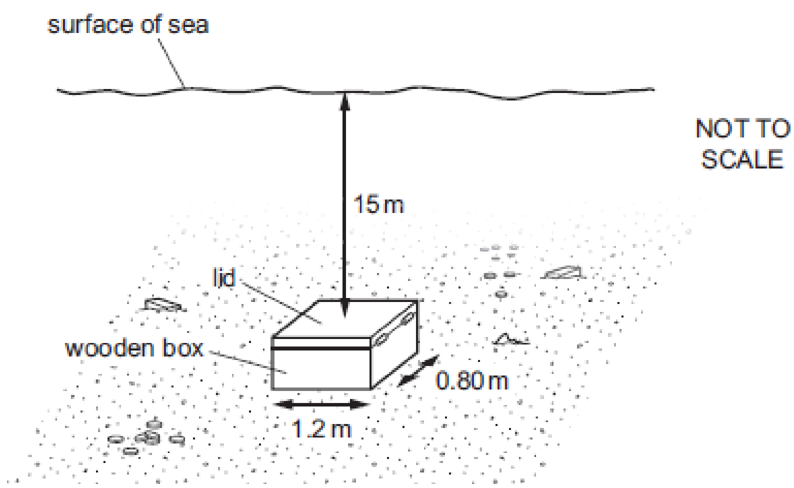


Fig. 4.1

The dimensions of the lid of the box are 1.2 m by 0.80 m and the pressure of the atmosphere is 1.0×10^5 Pa. The lid is 15 m below the surface of the sea.

(a) The density of sea-water is 1020 kg / m^3.

Calculate

(i) the pressure on the lid of the box due to the sea-water,

$P = h\rho g$

$= 15 \times 1020 \times 10$

$= 150\,000$ Pa / 150 kPa

pressure = 150kPa [2]

(ii) the total pressure on the lid,

pressure due to sea water + atmospheric pressure

pressure = 250kPa [1]

(iii) the downward force that the total pressure produces on the lid.

P = F / A

Force =(253 000 × 1.2 × 0.8 =)

240 000 N

force = 240 000N [2]

(b) The force needed to open the lid is **not** equal to the value calculated in **(a)(iii)**.

Suggest two reasons for this.

1. Drag of water

2. Friction of the hinge [2]

(a) The pond is kept at a depth of 2.0 m. The density of water is 1000 kg/m^3.

Calculate the water pressure on the valve.

O/N/2005-P3=Q3

pressure =……………………. [2]

(b) The force required to open the valve is 50 N. The valve will open when the water depth reaches 2.0 m.

Calculate the area of the valve.

area = ……………………….. [2]

77

2 Fig. 2.1 shows a diver 50 m below the surface of the water.

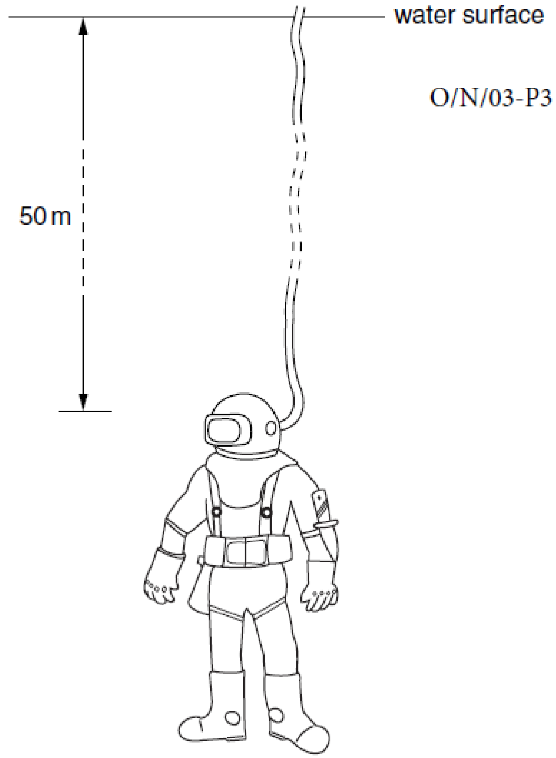


Fig. 2.1

(a) The density of water is 1000 kg/m^3 and the acceleration of free fall is 10 m/s^2. Calculate the pressure that the water exerts on the diver.

pressure = ... [3]

(b) The window in the diver's helmet is 150 mm wide and 70 mm from top to bottom.

Calculate the force that the water exerts on this window.

force = ... [3]

APPLICATIONS OF FLUID PRESSURE:

Vehicles are stopped due to the friction between the road and the tyres. This occurs when forces are applied to stop the rotating wheels. These forces originate when the driver puts the foot on the brake pedal.

The force provided by the foot acts on a piston in a master cylinder to push the brake fluid (oil) along very strong flexible tubes all the way to the braking mechanisms close to the wheels. Figure shows the connection to only one of the wheels. In the braking mechanisms at each wheel the fluid pressure acts on pistons to force the brake pads onto a metal disc on the wheel, creating fiction which slows its rotational speed. Because the total area of all the brake cylinders is much larger than the area of the master cylinder, the magnitude of the force is greatly increased.
