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.

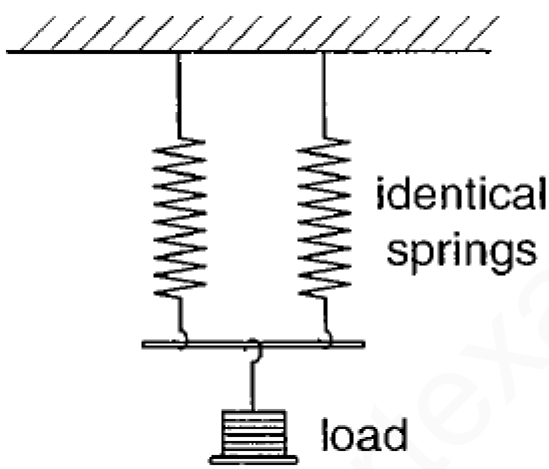
Student B:

- 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:



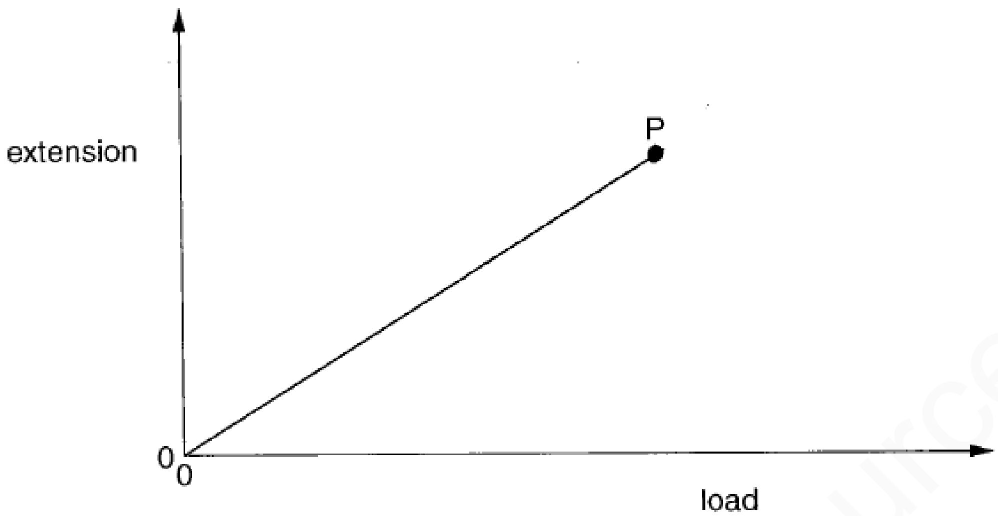
Note: Each spring experiences half the load.

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

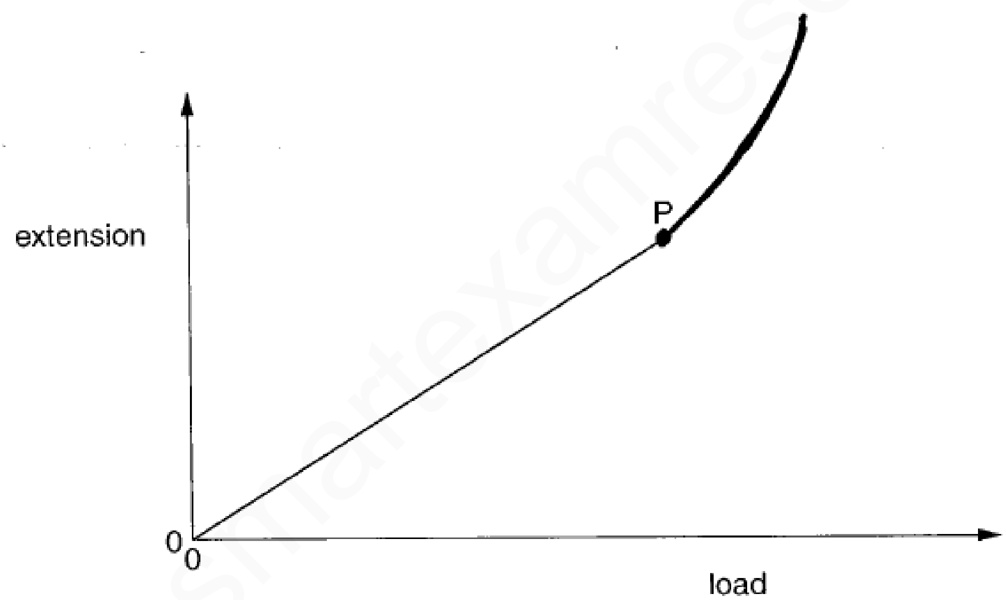
Note: Spring constant is the force per unit extension.k=F/x

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.



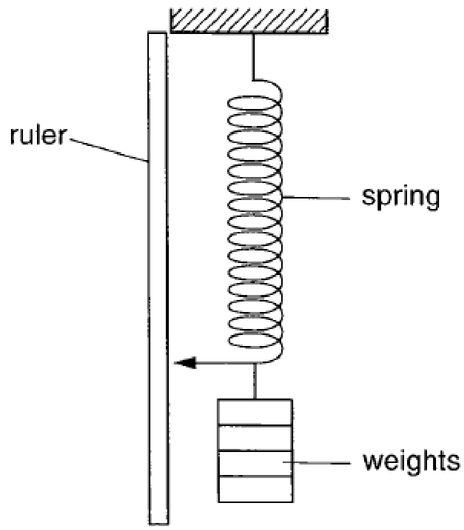
Solution would be like the one shown below.

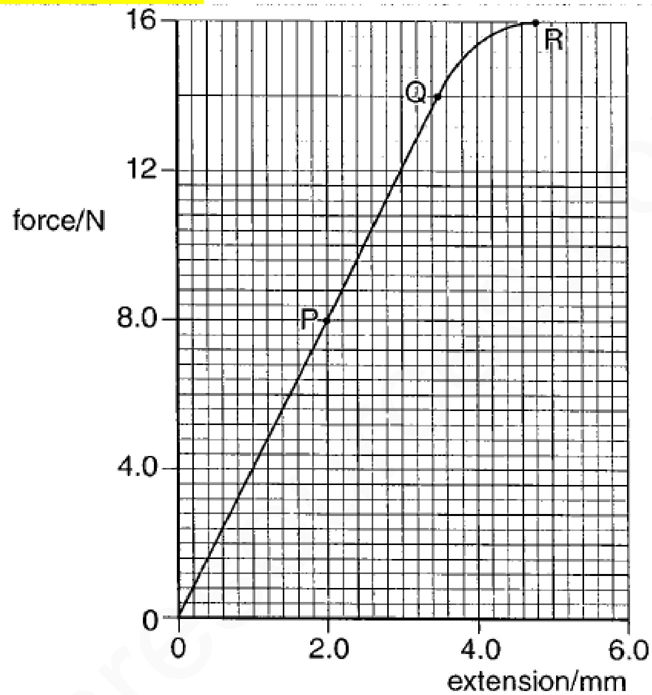


Note:

- 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.

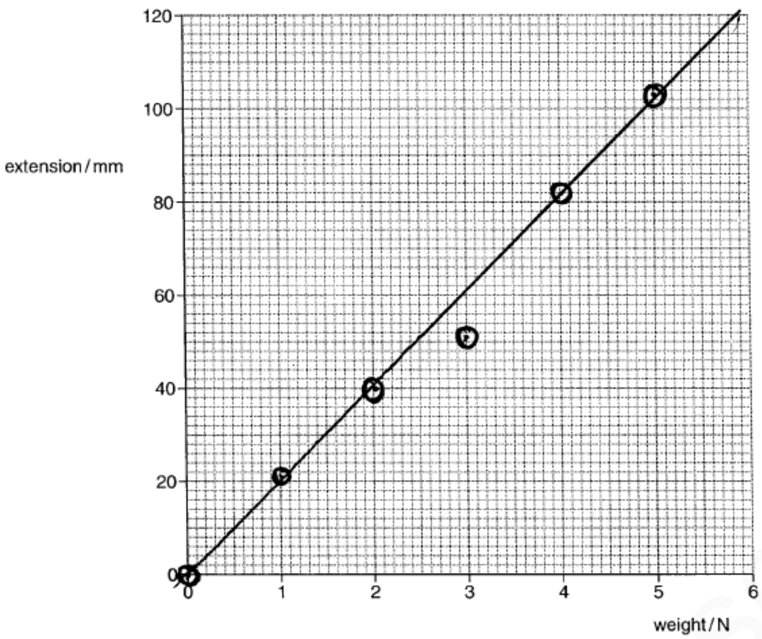




Note:

- 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:

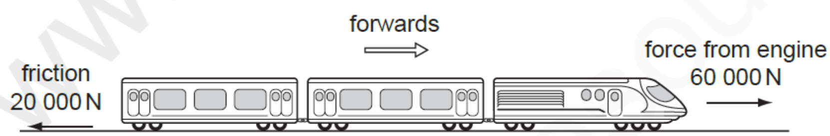
When more than one force acts on an object, we can calculate the combined effect of all the forces as a single force. This single force is called as the resultant force.

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

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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.

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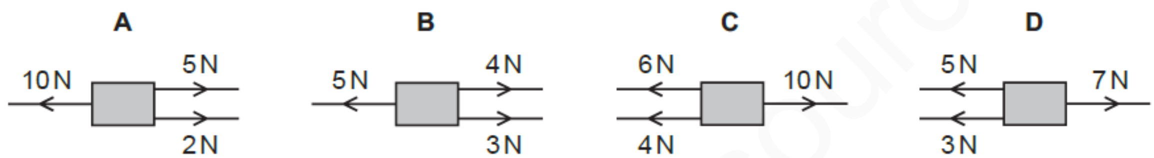
8 In which of these situations is no resultant force needed? **0625/1/O/N/02**

- **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.

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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

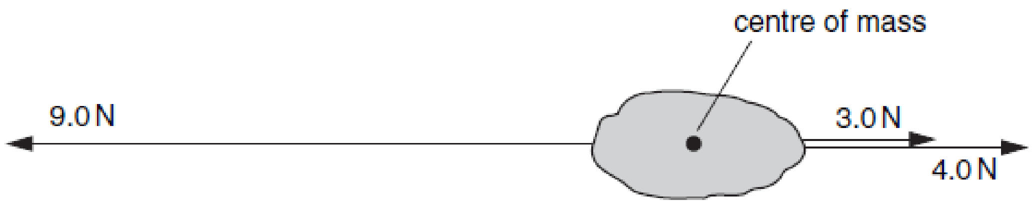


Fig. 1.1

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

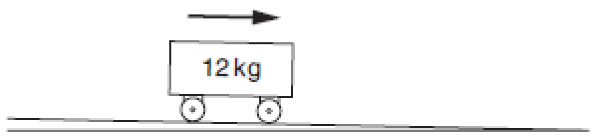


Fig. 1.1

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

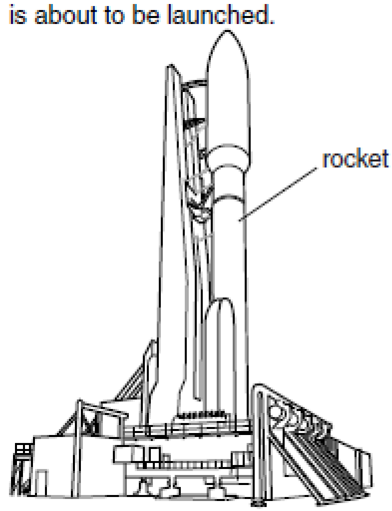


Fig. 2.1

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

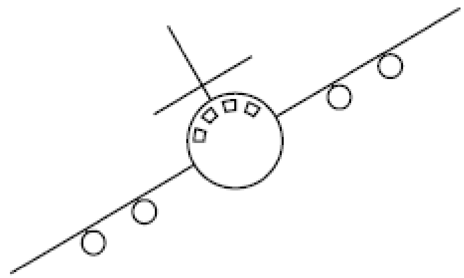


Fig. 2.1

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

....

....

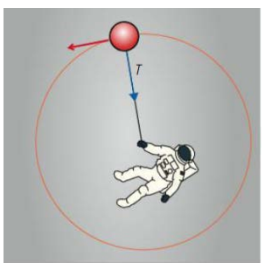
.... [3]

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.

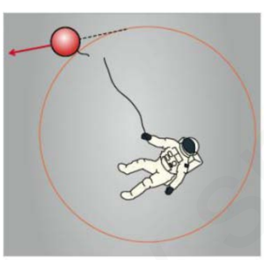
The value of this centripetal force is F= ma=$\frac{mv^2}{}$

- 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

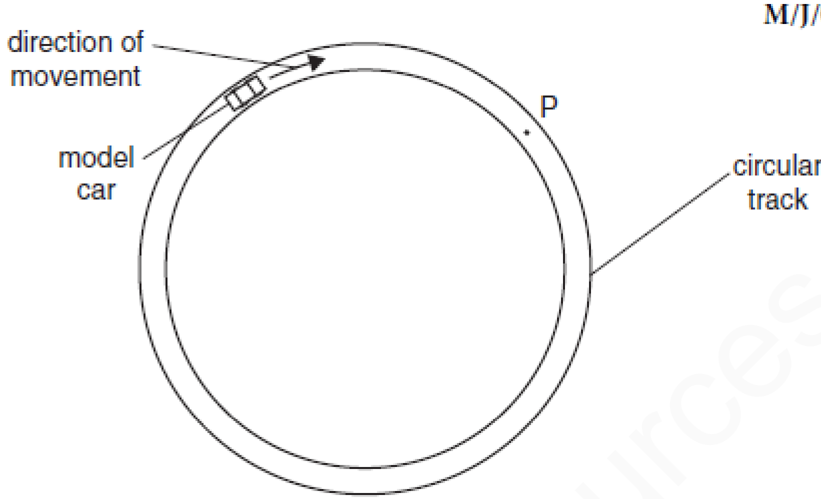


Fig. 1.1

(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

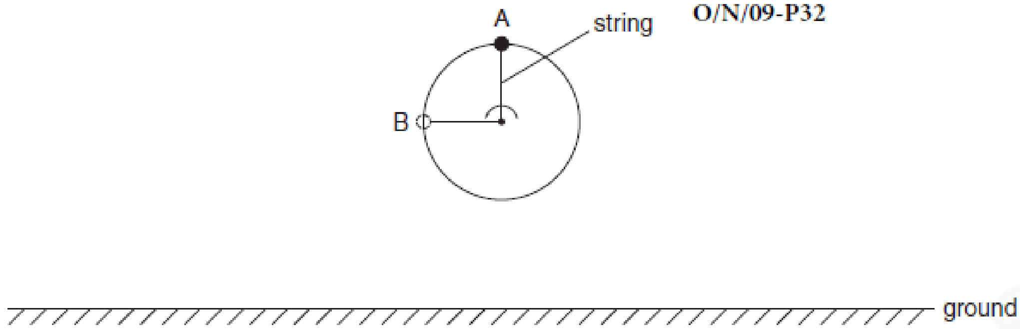


Fig. 4.1

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

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Friction:

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

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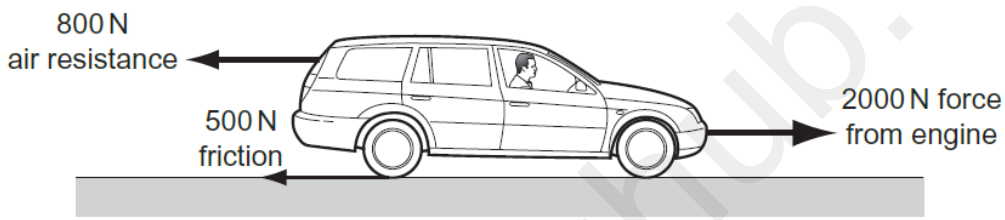
6 A car moves along a level road.

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.
