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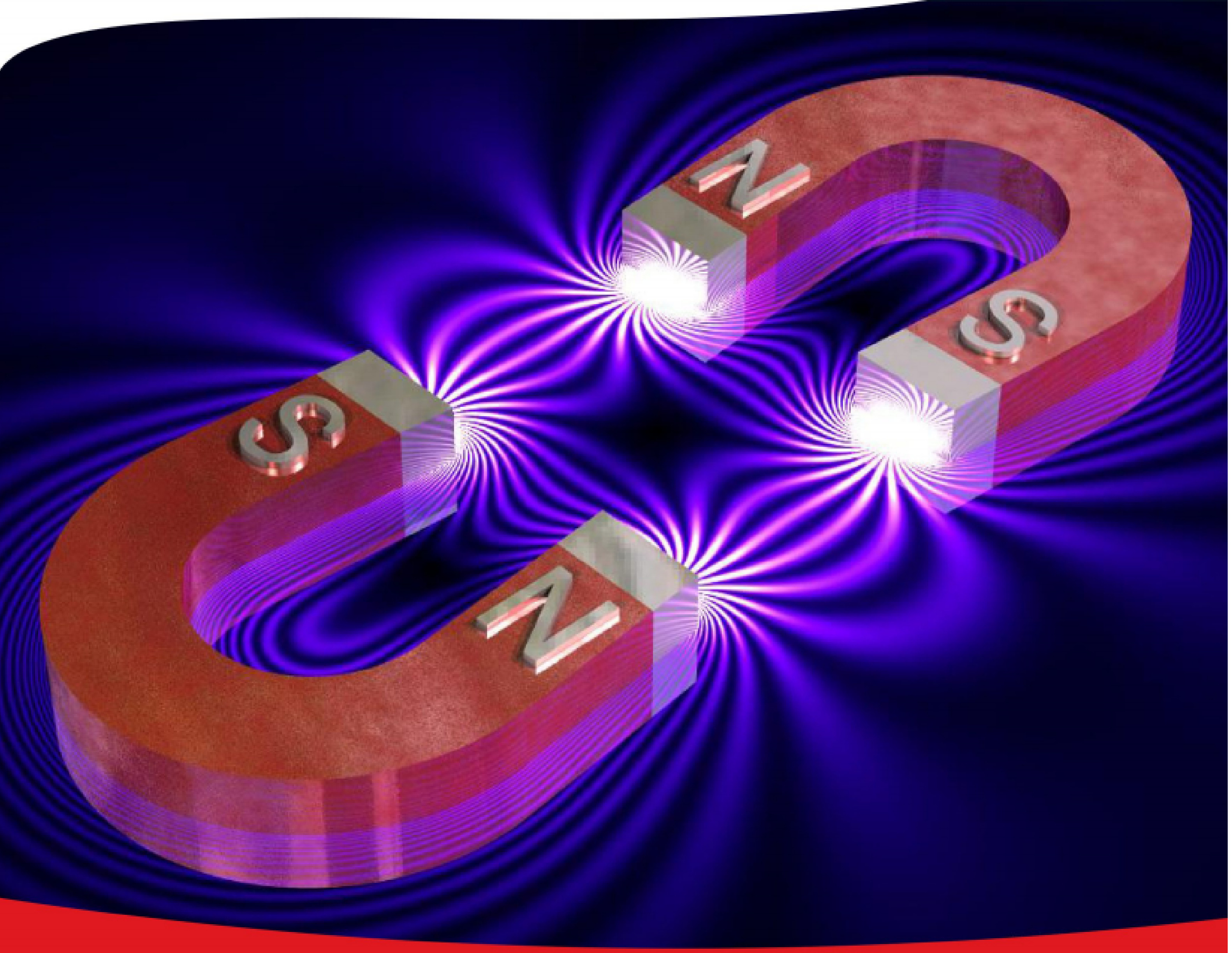
Cambridge International AS & A Level

PHYSICS (9702) P2

TOPIC WISE QUESTIONS + ANSWERS | COMPLETE SYLLABUS



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Chapter 6

Work, energy and power

6.1 Energy conversion and conservation

68. 9702_s20_qp_21 Q: 2

(a) State Newton's second law of motion.

....

.... [1]

(b) A delivery company suggests using a remote-controlled aircraft to drop a parcel into the garden of a customer. When the aircraft is vertically above point P on the ground, it releases the parcel with a velocity that is horizontal and of magnitude 5.4 m s^{-1}. The path of the parcel is shown in Fig. 2.1.

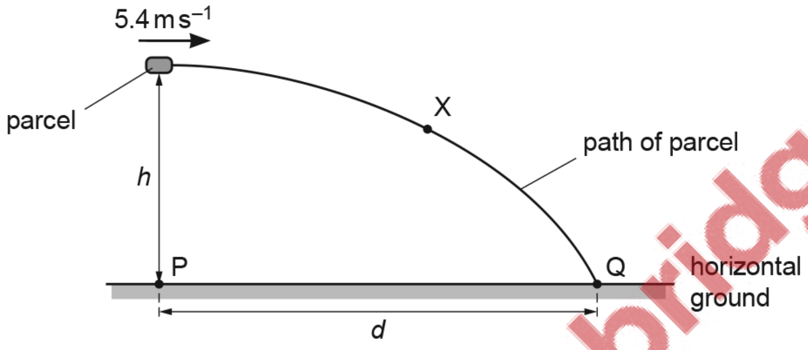

Fig. 2.1 (not to scale)

The parcel takes a time of 0.81 s after its release to reach point Q on the horizontal ground. Assume air resistance is negligible.

(i) On Fig. 2.1, draw an arrow from point X to show the direction of the acceleration of the parcel when it is at that point. [1]

(ii) Determine the height h of the parcel above the ground when it is released.

h = ... m [2]

(iii) Calculate the horizontal distance d between points P and Q.

d = ... m [1]

(c) Another parcel is accidentally released from rest by a different aircraft when it is hovering at a great height above the ground. Air resistance is now significant.

(i) On Fig. 2.2, draw arrows to show the directions of the forces acting on the parcel as it falls vertically downwards. Label each arrow with the name of the force.

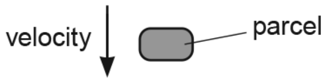

Fig. 2.2

[2]

(ii) By considering the forces acting on the parcel, state and explain the variation, if any, of the acceleration of the parcel as it moves downwards before it reaches constant (terminal) speed.

[3]

(iii) Describe the energy conversion that occurs when the parcel is falling through the air at constant (terminal) speed.

[1]

[Total: 11]

69. 9702_s17_qp_22 Q: 4

(a) State Newton's first law of motion.

....

....[1]

(b) An object A of mass 100 g is moving in a straight line with a velocity of 0.60 m s^{-1} to the right. An object B of mass 200 g is moving in the same straight line as object A with a velocity of 0.80 m s^{-1} to the left, as shown in Fig. 4.1.

Fig. 4.1

Objects A and B collide. Object A then moves with a velocity of 0.40 m s^{-1} to the left.

(i) Calculate the magnitude of the velocity of B after the collision.

magnitude of velocity = ... m s^{-1} [2]

(ii) The collision between A and B is inelastic.

Explain how the collision is inelastic and still obeys the law of conservation of energy.

....

....

....[1]

[Total: 4]

70. 9702_w17_qp_23 Q: 2

A liquid of density ρ fills a container to a depth h, as shown in Fig. 2.1.

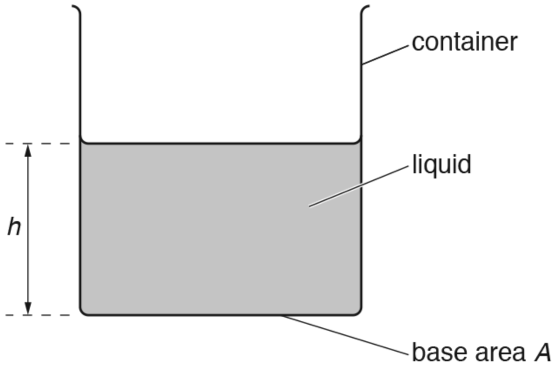

Fig. 2.1

The base of the container has area A.

(a) Derive, from the definitions of pressure and density, the equation

$$p = \rho g h$$

where p is the pressure exerted by the liquid on the base of the container and g is the acceleration of free fall.

[3]

(b) A small solid sphere falls with constant velocity through the liquid.

(i) State

1. the names of the three forces acting on the sphere,

....

....

2. a word equation that relates the magnitudes of these forces.

....
[2]

(ii) State and explain the changes in energy that occur as the sphere falls.

....

....

....

....[2]

(c) The liquid in the container is liquid L. Liquid M is now added to the container. The two liquids do not mix. The total depth of the liquids is 0.17 m.

Fig. 2.2 shows how the pressure p inside the liquids varies with height x above the base of the container.

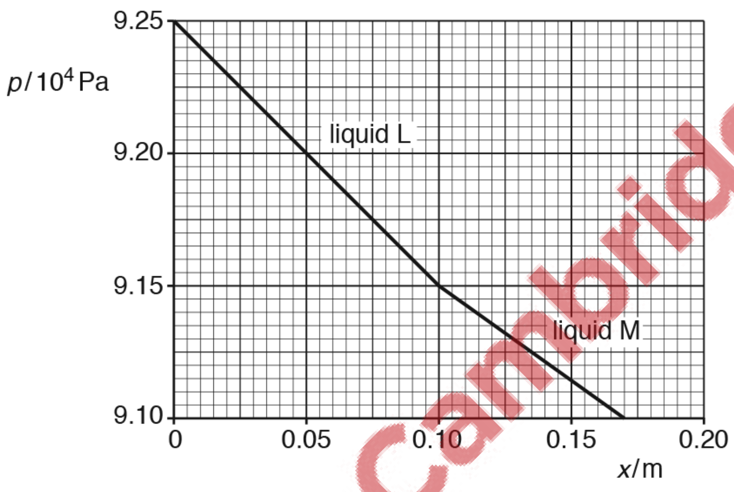

Fig. 2.2

Use Fig. 2.2 to

(i) state the value of atmospheric pressure,

atmospheric pressure = ... Pa [1]

(ii) determine the density of liquid M.

density = ... kg m^{-3} [2]

[Total: 10]

71. 9702_s15_qp_22 Q: 2

A stone is thrown vertically upwards. The variation with time t of the displacement s of the stone is shown in Fig. 2.1.

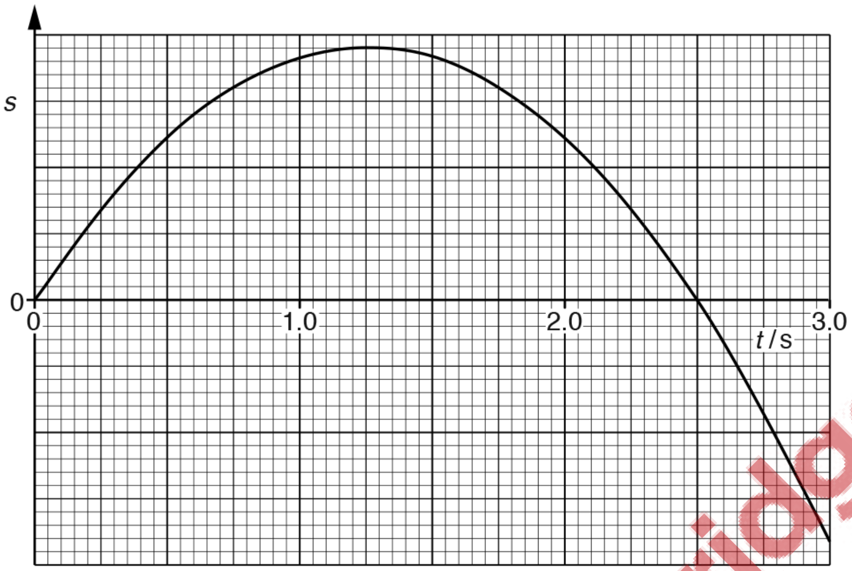

Fig. 2.1

(a) Use Fig. 2.1 to describe, without calculation, the speed of the stone from $t = 0$ to $t = 3.0$ s.

....

....

.... [2]

(b) Assume air resistance is negligible and therefore the stone has constant acceleration.

Calculate, for the stone,

(i) the speed at 3.0 s,

speed = ... $m s^{-1}$ [3]

(ii) the distance travelled from $t = 0$ to $t = 3.0$ s,

distance = ... m [3]

(iii) the displacement from $t = 0$ to $t = 3.0$ s.

displacement = ... m

direction ....

[2]

(c) On Fig. 2.2, draw the variation with time t of the velocity v of the stone from $t = 0$ to $t = 3.0$ s.

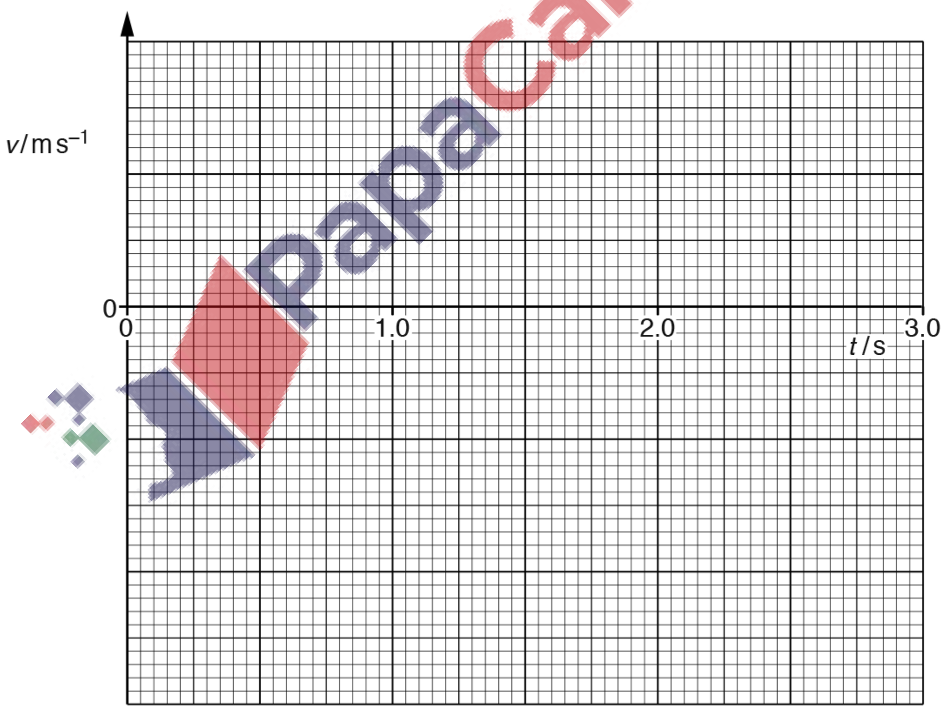

Fig. 2.2

[3]

6.2 Work and efficiency

72. 9702_w15_qp_23 Q: 4

A block is pulled on a horizontal surface by a force *P* as shown in Fig. 4.1.

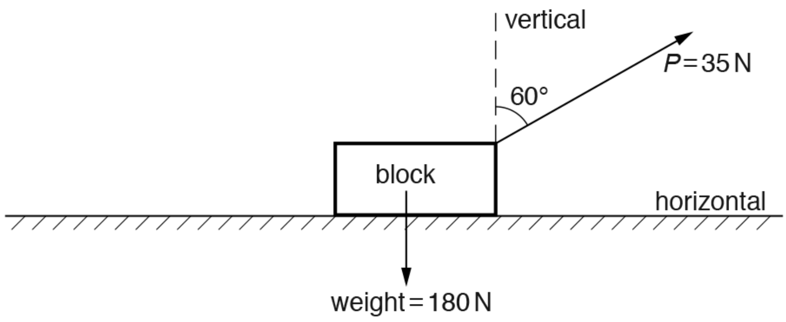

Fig. 4.1

The weight of the block is 180 N. The force *P* is 35 N at 60° to the vertical.
The block moves a distance of 20 m at constant velocity.

(a) Calculate

(i) the vertical force that the surface applies to the block (normal reaction force),

force = ... N [2]

(ii) the work done by force *P*.

work done = ... J [2]

(b) **(i)** Explain why the block continues to move at constant velocity although work is done on the block by force *P*.

....

....

....[1]

(ii) Explain, in terms of the forces acting, why the block remains in equilibrium.

....

....

....

....[2]

6.3 Potential energy and kinetic energy

73. 9702_s20_qp_21 Q: 3

(a) State **two** conditions for an object to be in equilibrium.

1. ....

....

2. ....

.... [2]

(b) A sphere of weight 2.4 N is suspended by a wire from a fixed point P. A horizontal string is used to hold the sphere in equilibrium with the wire at an angle of 53° to the horizontal, as shown in Fig. 3.1.

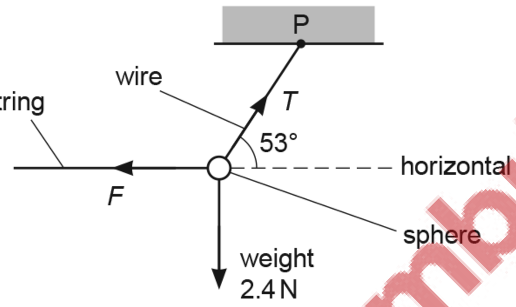

Fig. 3.1 (not to scale)

(i) Calculate:

1. the tension T in the wire

T = ... N

2. the force F exerted by the string on the sphere.

F = ... N
[2]

(ii) The wire has a circular cross-section of diameter 0.50 mm. Determine the stress σ in the wire.

σ = ... Pa [3]

(c) The string is disconnected from the sphere in **(b)**. The sphere then swings from its initial rest position A, as illustrated in Fig. 3.2.

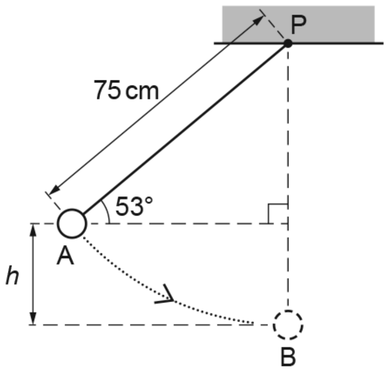

Fig. 3.2 (not to scale)

The sphere reaches maximum speed when it is at the bottom of the swing at position B. The distance between P and the centre of the sphere is 75cm.
Air resistance is negligible and energy losses at P are negligible.

(i) Show that the vertical distance h between A and B is 15 cm.

[1]

(ii) Calculate the change in gravitational potential energy of the sphere as it moves from A to B.

change in gravitational potential energy = ... J [2]

(iii) Use your answer in **(c)(ii)** to determine the speed of the sphere at B.
Show your working.

speed = ... $m s^{-1}$ [3]

[Total: 13]

74. 9702_s20_qp_22 Q: 3

(a) Explain what is meant by *work done*.

....

.... [1]

(b) A ball of mass 0.42 kg is dropped from the top of a building. The ball falls from rest through a vertical distance of 78 m to the ground. Air resistance is significant so that the ball reaches constant (terminal) velocity before hitting the ground. The ball hits the ground with a speed of 23 m s^{-1}.

(i) Calculate, for the ball falling from the top of the building to the ground:

1. the decrease in gravitational potential energy

decrease in gravitational potential energy = ... J [2]

2. the increase in kinetic energy.

increase in kinetic energy = ... J [2]

(ii) Use your answers in **(b)(i)** to determine the average resistive force acting on the ball as it falls from the top of the building to the ground.

average resistive force = ... N [2]

(c) The ball in **(b)** is dropped at time t = 0 and hits the ground at time t = T. The acceleration of free fall is g.

On Fig. 3.1, sketch a line to show the variation of the acceleration a of the ball with time t from time t = 0 to t = T.

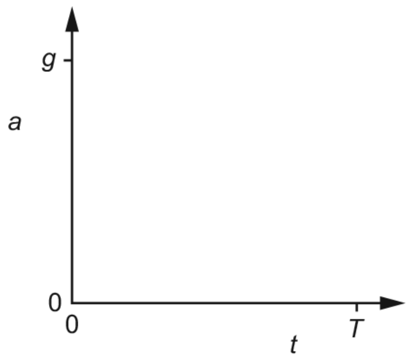

Fig. 3.1

[2]

[Total: 9]

75. 9702_w20_qp_21 Q: 2

A small block is lifted vertically upwards by a toy aircraft, as illustrated in Fig. 2.1.

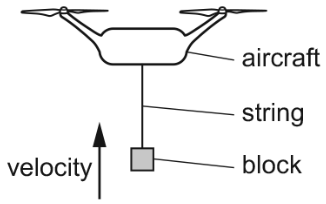

Fig. 2.1

As the block is moving upwards, the string breaks at time t = 0. The block initially continues moving upwards and then falls and hits the ground at time t = 0.90 s. The variation with time t of the velocity v of the block is shown in Fig. 2.2.

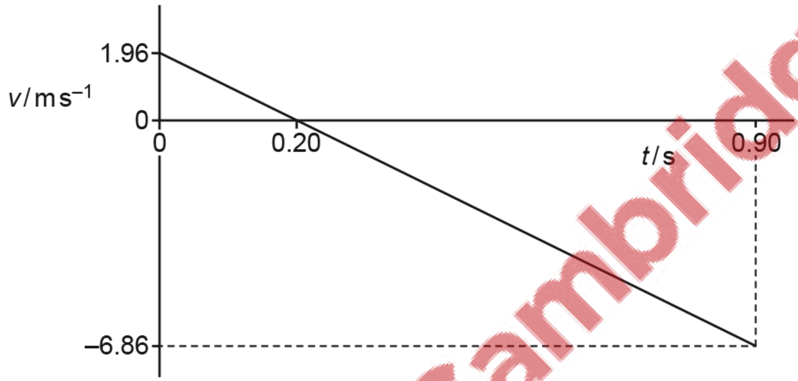

Fig. 2.2

Air resistance is negligible.

(a) State the feature of the graph in Fig. 2.2 that shows the block has a constant acceleration.

.... [1]

(b) Use Fig. 2.2 to determine the height of the block above the ground when the string breaks at time t = 0.

height = ... m [3]

(c) The block has a weight of 0.86 N.

Calculate the difference in gravitational potential energy of the block between time t = 0 and time t = 0.90 s.

difference in gravitational potential energy = ... J [2]

(d) On Fig. 2.3, sketch a line to show the variation of the distance moved by the block with time t from t = 0 to t = 0.20 s. Numerical values of distance are not required.

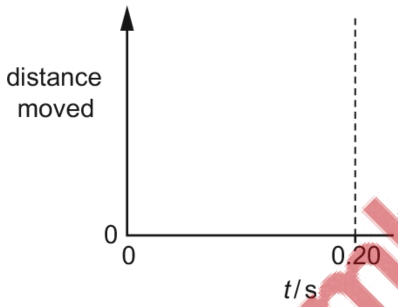

Fig. 2.3

[2]

(e) A block of greater mass is now released from the same height with the same upward velocity. Air resistance is still negligible.

State and explain the effect, if any, of the increased mass on the speed with which the block hits the ground.

....

.... [1]

[Total: 9]

76. 9702_m19_qp_22 Q: 2

(a) Define:

(i) *displacement*

....

....[1]

(ii) *acceleration*.

....

....[1]

(b) A man wearing a wingsuit glides through the air with a constant velocity of $47\,m\,s^{-1}$ at an angle of 24° to the horizontal. The path of the man is shown in Fig. 2.1.

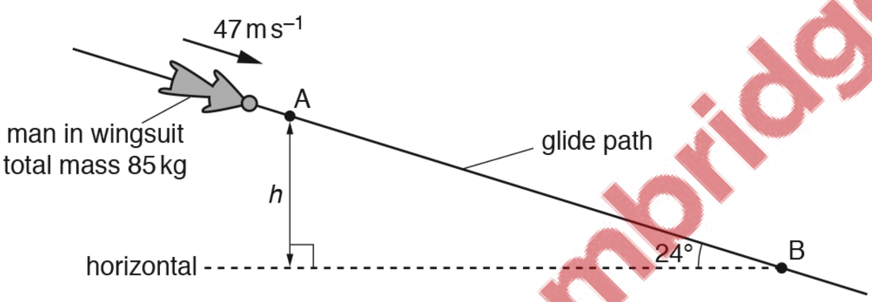

Fig. 2.1 (not to scale)

The total mass of the man and the wingsuit is 85 kg. The man takes a time of 2.8 minutes to glide from point A to point B.

(i) With reference to the motion of the man, state and explain whether he is in equilibrium.

....

....

....

....[2]

(ii) Show that the difference in height h between points A and B is 3200 m.

[1]

(iii) For the movement of the man from A to B, determine:

1. the decrease in gravitational potential energy

decrease in gravitational potential energy = ... J [2]

2. the magnitude of the force on the man due to air resistance.

force = ... N [2]

(iv) The pressure of the still air at A is 63 kPa and at B is 92 kPa. Assume the density of the air is constant between A and B.

Determine the density of the air between A and B.

density = ... kg m^{-3} [2]

[Total: 11]

77. 9702_m19_qp_22 Q: 3

Two balls, X and Y, move along a horizontal frictionless surface, as illustrated in Fig. 3.1.

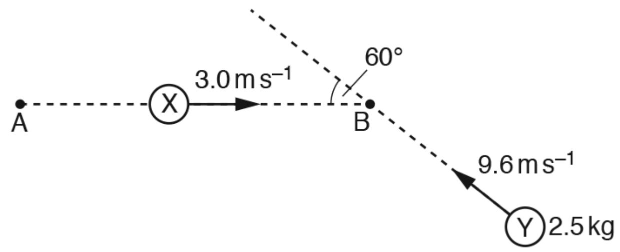

Fig. 3.1 (not to scale)

Ball X has an initial velocity of $3.0\,\mathrm{m\,s^{-1}}$ in a direction along line AB. Ball Y has a mass of 2.5 kg and an initial velocity of $9.6\,\mathrm{m\,s^{-1}}$ in a direction at an angle of 60° to line AB.

The two balls collide at point B. The balls stick together and then travel along the horizontal surface in a direction at right-angles to the line AB, as shown in Fig. 3.2.

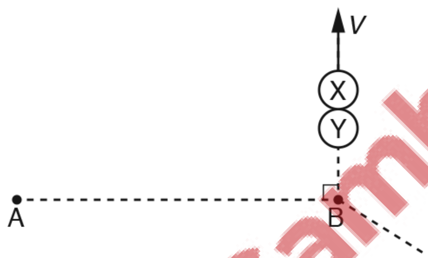

Fig. 3.2

(a) By considering the components of momentum in the direction from A to B, show that ball X has a mass of 4.0 kg.

[2]

(b) Calculate the common speed V of the two balls after the collision.

V = ... $m\,s^{-1}$ [2]

(c) Determine the difference between the initial kinetic energy of ball X and the initial kinetic energy of ball Y.

difference in kinetic energy = ... J [2]

[Total: 6]

78. 9702_s19_qp_22 Q: 3

(a) State what is meant by the *centre of gravity* of a body.

....

....[1]

(b) A uniform square sign with sides of length 0.68 m is fixed at its corner points A and B to a wall. The sign is also supported by a wire CD, as shown in Fig. 3.1.

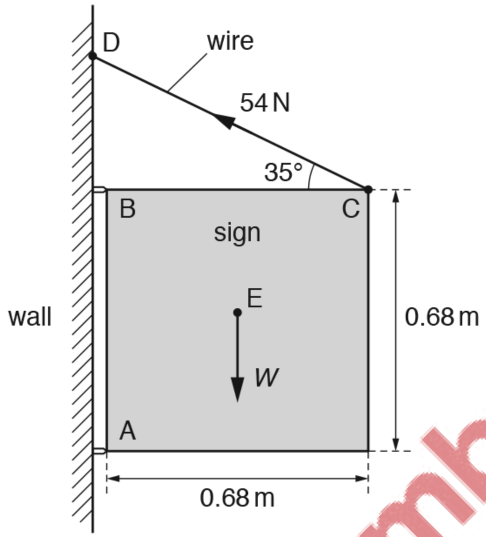

Fig. 3.1 (not to scale)

The sign has weight *W* and centre of gravity at point E. The sign is held in a vertical plane with side BC horizontal. The wire is at an angle of 35° to side BC. The tension in the wire is 54 N.

The force exerted on the sign at B is only in the vertical direction.

(i) Calculate the vertical component of the tension in the wire.

vertical component of tension = ... N [1]

(ii) Explain why the force on the sign at B does not have a moment about point A.

....

....[1]

(iii) By taking moments about point A, show that the weight *W* of the sign is 150 N.

[2]

(iv) Calculate the total vertical force exerted by the wall on the sign at points A and B.

total vertical force = ... N [1]

(c) The sign in **(b)** is held together by nuts and bolts. One of the nuts falls vertically from rest through a distance of 4.8 m to the pavement below. The nut lands on the pavement with a speed of $9.2\,\text{m}\,\text{s}^{-1}$.

Determine, for the nut falling from the sign to the pavement, the ratio

$$\frac{\text{change in gravitational potential energy}}{\text{final kinetic energy}}.$$

ratio = ... [4]

[Total: 10]

79. 9702_s19_qp_23 Q: 2

(a) A resultant force F moves an object of mass m through distance s in a straight line. The force gives the object an acceleration a so that its speed changes from initial speed u to final speed v.

(i) State an expression for:

1. the work W done by the force, in terms of a, m and s

W = ... [1]

2. the distance s, in terms of a, u and v.

s = ... [1]

(ii) Use your answers in **(i)** to show that the kinetic energy of the object is given by

$$\text{kinetic energy} = \frac{1}{2} \times \text{mass} \times (\text{speed})^2.$$

Explain your working.

[2]

(b) A ball of mass 0.040 kg is projected into the air from horizontal ground, as illustrated in Fig. 2.1.

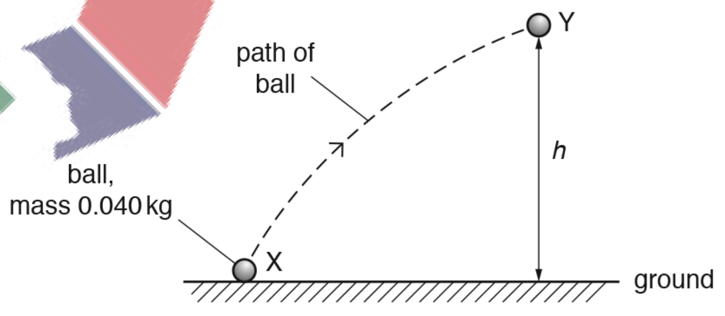

Fig. 2.1

The ball is launched from a point X with a kinetic energy of 4.5 J. At point Y, the ball has a speed of 9.5 m s^{-1}. Air resistance is negligible.

(i) For the movement of the ball from X to Y, draw a solid line on Fig. 2.1 to show:

1. the distance moved (label this line D)

2. the displacement (label this line S).

[2]

(ii) By consideration of energy transfer, determine the height *h* of point Y above the ground.

h = ... m [3]

(iii) On Fig. 2.2, sketch the variation of the kinetic energy of the ball with its vertical height above the ground for the movement of the ball from X to Y.
Numerical values are not required.

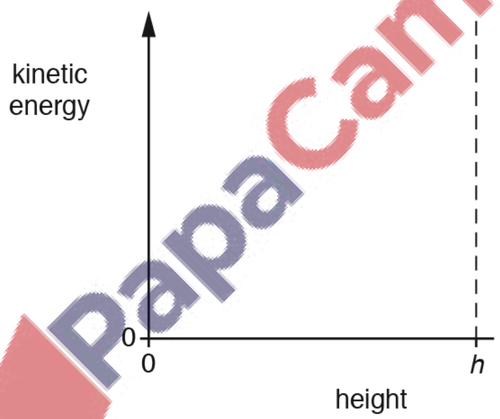

Fig. 2.2

[2]

[Total: 11]

80. 9702_w19_qp_21 Q: 4

The variation with extension x of the force F applied to a spring is shown in Fig. 4.1.

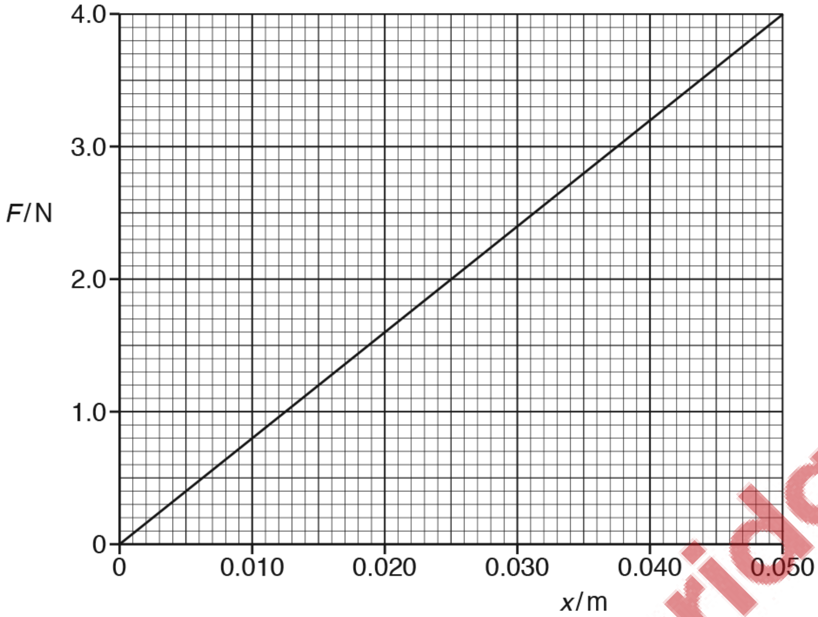

Fig. 4.1

The spring has an unstretched length of 0.080 m and is suspended vertically from a fixed point, as shown in Fig. 4.2.

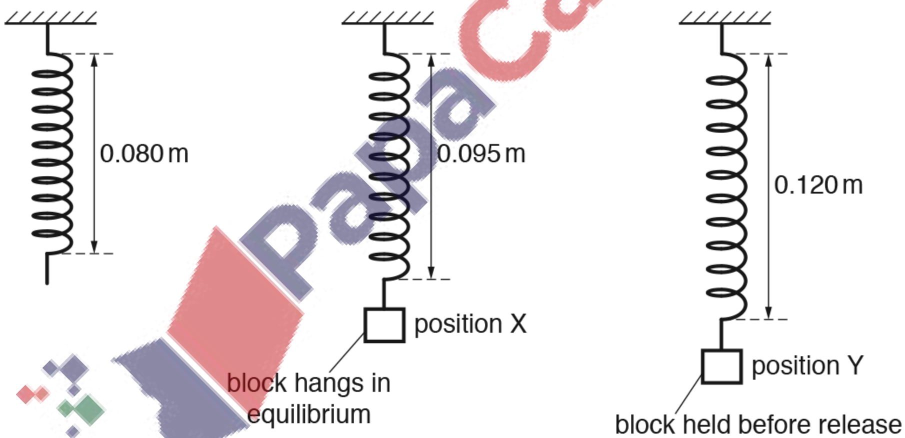

Fig. 4.2 **Fig. 4.3** **Fig. 4.4**

A block is attached to the lower end of the spring. The block hangs in equilibrium at position X when the length of the spring is 0.095 m, as shown in Fig. 4.3.

The block is then pulled vertically downwards and held at position Y so that the length of the spring is 0.120 m, as shown in Fig. 4.4. The block is then released and moves vertically upwards from position Y back towards position X.

(a) Use Fig. 4.1 to determine the spring constant of the spring.

spring constant = ... $N m^{-1}$ [2]

(b) Use Fig. 4.1 to show that the decrease in elastic potential energy of the spring is 0.055 J when the block moves from position Y to position X.

[2]

(c) The block has a mass of 0.122 kg. Calculate the increase in gravitational potential energy of the block for its movement from position Y to position X.

increase in gravitational potential energy = ... J [2]

(d) Use the decrease in elastic potential energy stated in **(b)** and your answer in **(c)** to determine, for the block, as it moves through position X:

(i) its kinetic energy

kinetic energy = ... J [1]

(ii) its speed.

speed = ... $m s^{-1}$ [2]

[Total: 9]

81. 9702_w19_qp_22 Q: 3

(a) State Newton's third law of motion.

....

....

.... [2]

(b) A block X of mass m_X slides in a straight line along a horizontal frictionless surface, as shown in Fig. 3.1.

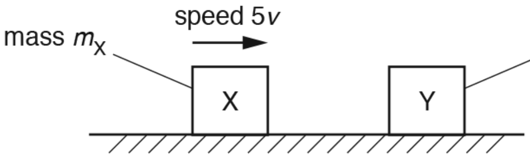

Fig. 3.1

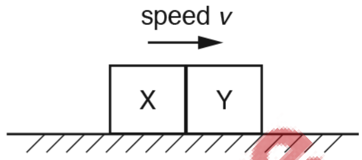

Fig. 3.2

The block X, moving with speed 5v, collides head-on with a stationary block Y of mass m_Y. The two blocks stick together and then move with common speed v, as shown in Fig. 3.2.

(i) Use conservation of momentum to show that the ratio $\frac{m_Y}{m_X}$ is equal to 4.

[2]

(ii) Calculate the ratio

$$\frac{\text{total kinetic energy of X and Y after collision}}{\text{total kinetic energy of X and Y before collision}}.$$

ratio = ... [3]

(iii) State the value of the ratio in **(ii)** for a perfectly elastic collision.

ratio = ... [1]

(c) The variation with time t of the momentum of block X in **(b)** is shown in Fig. 3.3.

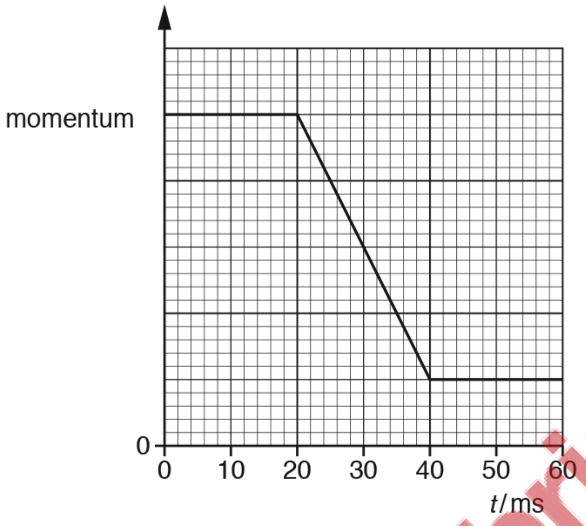

Fig. 3.3

Block X makes contact with block Y at time $t = 20\,\text{ms}$.

(i) Describe, qualitatively, the magnitude and direction of the resultant force, if any, acting on block X in the time interval:

1. $t = 0$ to $t = 20\,\text{ms}$

....

2. $t = 20\,\text{ms}$ to $t = 40\,\text{ms}$.

....

....

[3]

(ii) On Fig. 3.3, sketch the variation of the momentum of block Y with time t from $t = 0$ to $t = 60\,\text{ms}$. [3]

[Total: 14]

82. 9702_m18_qp_22 Q: 2

(a) Explain what is meant by

(i) *work done*,

....

....[1]

(ii) *kinetic energy*.

....

....[1]

(b) A leisure-park ride consists of a carriage that moves along a railed track. Part of the track lies in a vertical plane and follows an arc XY of a circle of radius 13 m, as shown in Fig. 2.1.

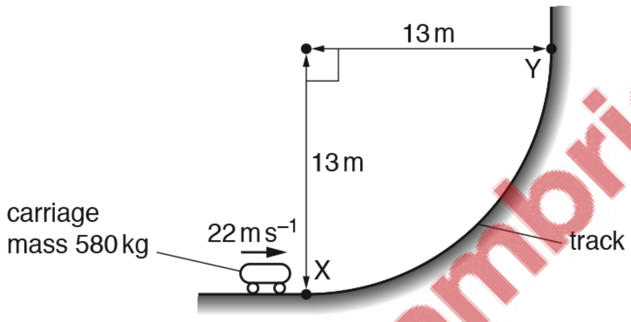

Fig. 2.1

The mass of the carriage is 580 kg. At point X, the carriage has velocity 22 m s^{-1} in a horizontal direction. The velocity of the carriage then decreases to 12 m s^{-1} in a vertical direction at point Y.

(i) For the carriage moving from X to Y

1. show that the decrease in kinetic energy is 9.9×10^4 J,

[2]

2. calculate the gain in gravitational potential energy.

gain in gravitational potential energy = ... J [2]

(ii) Show that the length of the track from X to Y is 20 m.

[1]

(iii) Use your answers in **(b)(i)** and **(b)(ii)** to calculate the average resistive force acting on the carriage as it moves from X to Y.

resistive force = ... N [2]

(iv) Describe the change in the direction of the linear momentum of the carriage as it moves from X to Y.

....

....[1]

(v) Determine the magnitude of the change in linear momentum when the carriage moves from X to Y.

change in momentum = ... N s [3]

[Total: 13]

83. 9702_s18_qp_22 Q: 2

(a) State the principle of conservation of momentum.

....

....

....[2]

(b) A stationary firework explodes into three different fragments that move in a horizontal plane, as illustrated in Fig. 2.1.

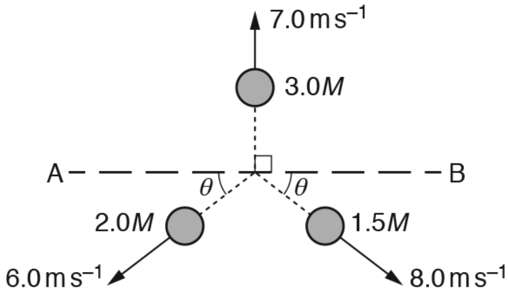

Fig. 2.1

The fragment of mass 3.0M has a velocity of 7.0 m s^{-1} perpendicular to line AB.
The fragment of mass 2.0M has a velocity of 6.0 m s^{-1} at angle θ to line AB.
The fragment of mass 1.5M has a velocity of 8.0 m s^{-1} at angle θ to line AB.

(i) Use the principle of conservation of momentum to determine θ.

θ = ... ° [3]

(ii) Calculate the ratio

$$\frac{\text{kinetic energy of fragment of mass } 2.0M}{\text{kinetic energy of fragment of mass } 1.5M}.$$

ratio = ...[2]

[Total: 7]

84. 9702_s18_qp_23 Q: 3

A ball is thrown vertically upwards towards a ceiling and then rebounds, as illustrated in Fig. 3.1.

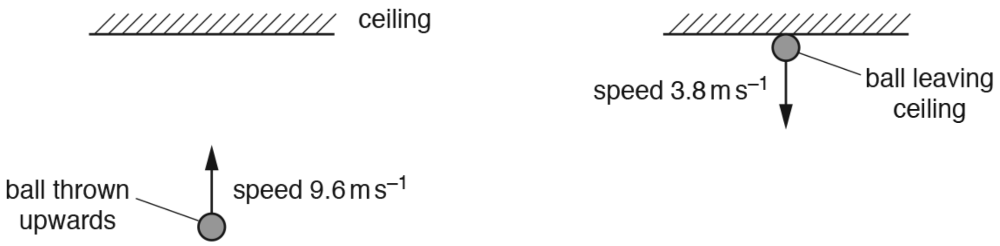

Fig. 3.1

The ball is thrown with speed 9.6 m s^{-1} and takes a time of 0.37 s to reach the ceiling. The ball is then in contact with the ceiling for a further time of 0.085 s until leaving it with a speed of 3.8 m s^{-1}. The mass of the ball is 0.056 kg. Assume that air resistance is negligible.

(a) Show that the ball reaches the ceiling with a speed of 6.0 m s^{-1}.

[1]

(b) Calculate the height of the ceiling above the point from which the ball was thrown.

height = ... m [2]

(c) Calculate

(i) the increase in gravitational potential energy of the ball for its movement from its initial position to the ceiling,

increase in gravitational potential energy = ... J [2]

(ii) the decrease in kinetic energy of the ball while it is in contact with the ceiling.

decrease in kinetic energy = ... J [2]

(d) State how Newton's third law applies to the collision between the ball and the ceiling.

....

....

....

....[2]

(e) Calculate the change in momentum of the ball during the collision.

change in momentum = ... N s [2]

(f) Determine the magnitude of the average force exerted by the ceiling on the ball during the collision.

average force = ... N [2]

[Total: 13]

85. 9702_w18_qp_21 Q: 1

(a) Define

(i) *displacement*,

....

.... [1]

(ii) *acceleration*.

....

.... [1]

(b) A remote-controlled toy car moves up a ramp and travels across a gap to land on another ramp, as illustrated in Fig. 1.1.

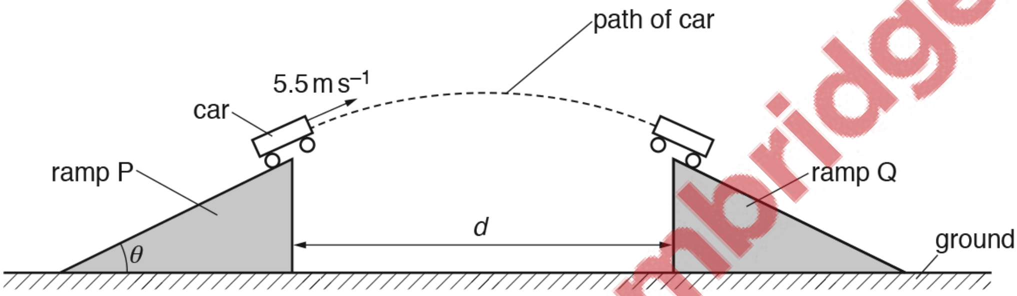

Fig. 1.1

The car leaves ramp P with a velocity of $5.5\,\mathrm{m\,s^{-1}}$ at an angle θ to the horizontal. The horizontal component of the car's velocity as it leaves the ramp is $4.6\,\mathrm{m\,s^{-1}}$. The car lands at the top of ramp Q. The tops of both ramps are at the same height and are distance d apart. Air resistance is negligible.

(i) Show that the car leaves ramp P with a vertical component of velocity of $3.0\,\mathrm{m\,s^{-1}}$.

[1]

(ii) Determine the time taken for the car to travel between the ramps.

time taken = ... s [2]

(iii) Calculate the horizontal distance d between the tops of the ramps.

d = ... m [1]

(iv) Calculate the ratio

$$\frac{\text{kinetic energy of the car at its maximum height}}{\text{kinetic energy of the car as it leaves ramp P}}.$$

ratio = ... [3]

(c) Ramp Q is removed. The car again leaves ramp P as in **(b)** and now lands directly on the ground. The car leaves ramp P at time $t = 0$ and lands on the ground at time $t = T$.

On Fig. 1.2, sketch the variation with time t of the vertical component v_y of the car's velocity from $t = 0$ to $t = T$. Numerical values of v_y and t are not required.

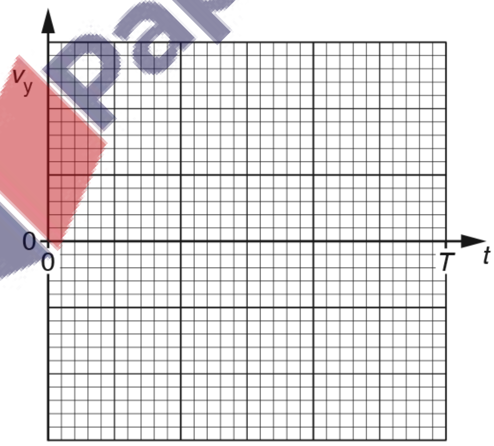

Fig. 1.2

[2]

[Total: 11]

86. 9702_w18_qp_22 Q: 1

A golfer strikes a ball so that it leaves horizontal ground with a velocity of 6.0 m s^{-1} at an angle θ to the horizontal, as illustrated in Fig. 1.1.

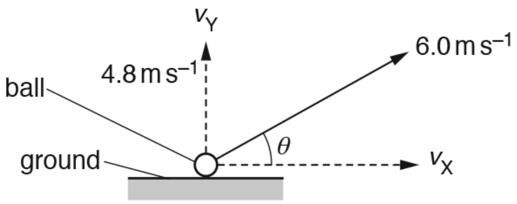

Fig. 1.1 (not to scale)

The magnitude of the initial vertical component v_Y of the velocity is 4.8 m s^{-1}.
Assume that air resistance is negligible.

(a) Show that the magnitude of the initial horizontal component v_X of the velocity is 3.6 m s^{-1}.

[1]

(b) The ball leaves the ground at time $t = 0$ and reaches its maximum height at $t = 0.49$ s.

On Fig. 1.2, sketch separate lines to show the variation with time t, until the ball returns to the ground, of

(i) the vertical component v_Y of the velocity (label this line Y), [2]

(ii) the horizontal component v_X of the velocity (label this line X). [2]

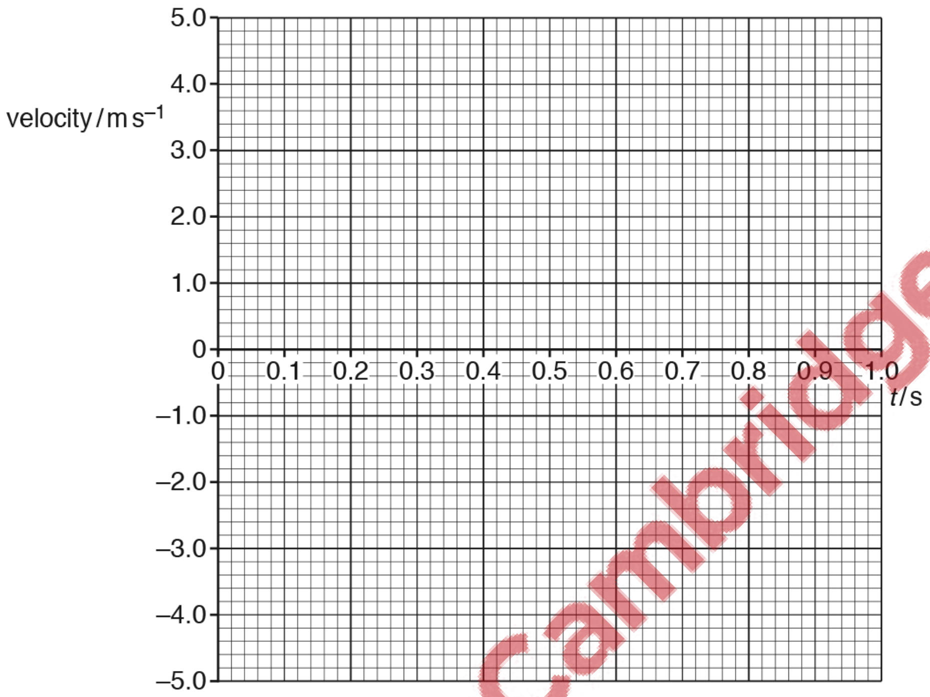

Fig. 1.2

(c) Calculate the maximum height reached by the ball.

maximum height = ... m [2]

(d) For the movement of the ball from the ground to its maximum height, determine the ratio

$$\frac{\text{kinetic energy at maximum height}}{\text{change in gravitational potential energy}}.$$

ratio = ...[4]

(e) In practice, significant air resistance acts on the ball. Explain why the actual time taken for the ball to reach maximum height is less than the time calculated when air resistance is assumed to be negligible.

....

....

....[1]

[Total: 12]

87. 9702_w18_qp_23 Q: 2

(a) State what is meant by *kinetic energy*.

....

....[1]

(b) A cannon fires a shell vertically upwards. The shell leaves the cannon with a speed of $80\,m\,s^{-1}$ and a kinetic energy of 480 J. The shell then rises to a maximum height of 210 m. The effect of air resistance is significant.

(i) Show that the mass of the shell is 0.15 kg.

[2]

(ii) For the movement of the shell from the cannon to its maximum height, calculate

1. the gain in gravitational potential energy,

gain in gravitational potential energy = ... J [2]

2. the work done against air resistance.

work done = ... J [1]

(iii) Determine the average force due to the air resistance acting on the shell as it moves from the cannon to its maximum height.

force = ... N [2]

(iv) The shell leaves the cannon at time $t = 0$ and reaches maximum height at time $t = T$.

On Fig. 2.1, sketch the variation with time t of the velocity v of the shell from time $t = 0$ to time $t = T$. Numerical values of v and t are not required.

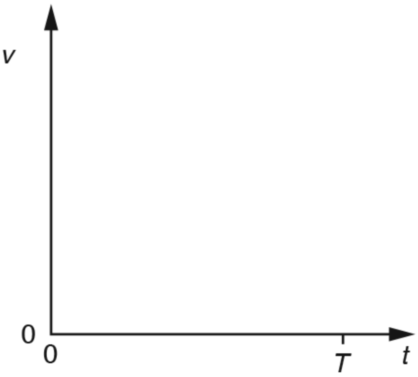

Fig. 2.1

[2]

(v) The force due to the air resistance is a vector quantity.

Compare the force due to the air resistance acting on the shell as it rises with the force due to the air resistance as it falls.

....

....

....

....

....[2]

[Total: 12]

88. 9702_s17_qp_21 Q: 2

(a) State the two conditions for a system to be in equilibrium.

1. ....

....

2. ....

.... [2]

(b) A paraglider P of mass 95 kg is pulled by a wire attached to a boat, as shown in Fig. 2.1.

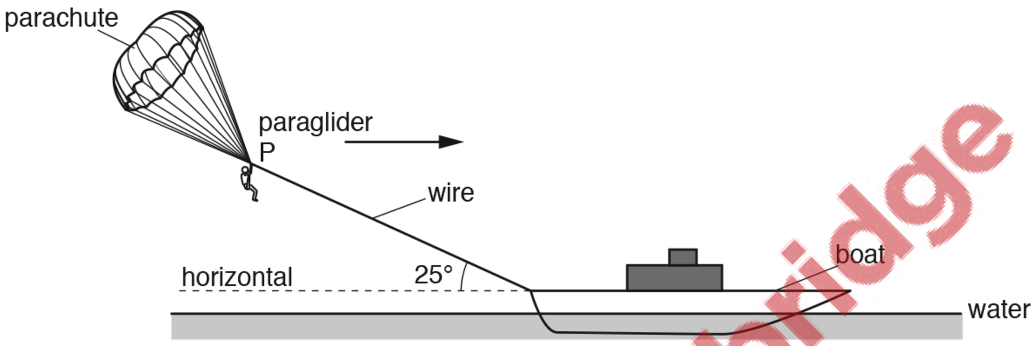

Fig. 2.1

The wire makes an angle of 25° with the horizontal water surface. P moves in a straight line parallel to the surface of the water.

The variation with time t of the velocity v of P is shown in Fig. 2.2.

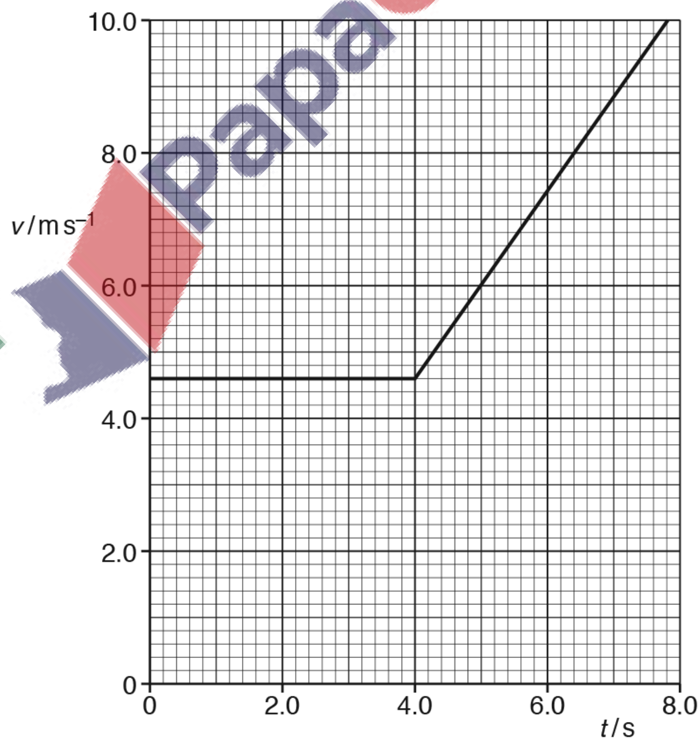

Fig. 2.2

(i) Show that the acceleration of P is $1.4\,\text{m}\,\text{s}^{-2}$ at time $t = 5.0\,\text{s}$.

[2]

(ii) Calculate the total distance moved by P from time $t = 0$ to $t = 7.0\,\text{s}$.

distance = ...m [2]

(iii) Calculate the change in kinetic energy of P from time $t = 0$ to $t = 7.0\,\text{s}$.

change in kinetic energy = ...J [2]

(iv) The tension in the wire at time $t = 5.0\,\text{s}$ is 280 N.

Calculate, for the horizontal motion,

1. the vertical lift force F supporting P,

F = ...N [3]

2. the force R due to air resistance acting on P in the horizontal direction.

R = ...N [3]

[Total: 14]

89. 9702_s17_qp_22 Q: 2

(a) Define *velocity*.

....

....[1]

(b) A ball of mass 0.45 kg leaves the edge of a table with a horizontal velocity *v*, as shown in Fig. 2.1.

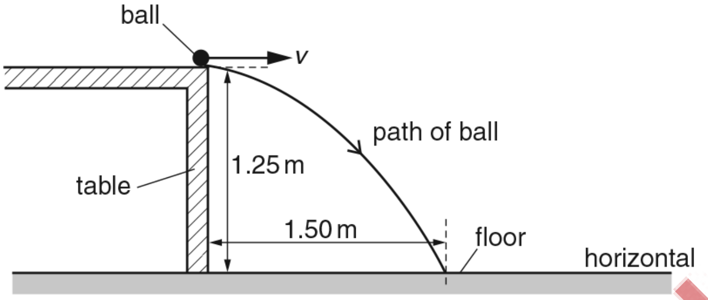

Fig. 2.1

The height of the table is 1.25 m. The ball travels a distance of 1.50 m horizontally before hitting the floor.

Air resistance is negligible.

Calculate, for the ball,

(i) the horizontal velocity *v* as it leaves the table,

v = ... $m\,s^{-1}$ [3]

(ii) the velocity just as it hits the floor,

magnitude of velocity = ... $m\,s^{-1}$

angle to the horizontal = ... °
[4]

(iii) the kinetic energy just as it hits the floor,

kinetic energy = ... J [2]

(iv) the loss in gravitational potential energy as it falls from the table to the floor.

loss in potential energy = ... J [2]

(c) Explain why the kinetic energy of the ball in **(b)(iii)** does not equal the loss of gravitational potential energy in **(b)(iv)**.

....

....[1]

[Total: 13]

90. 9702_m16_qp_22 Q: 2

(a) Define *acceleration*.

....

.... [1]

(b) A ball is kicked from horizontal ground towards the top of a vertical wall, as shown in Fig. 2.1.

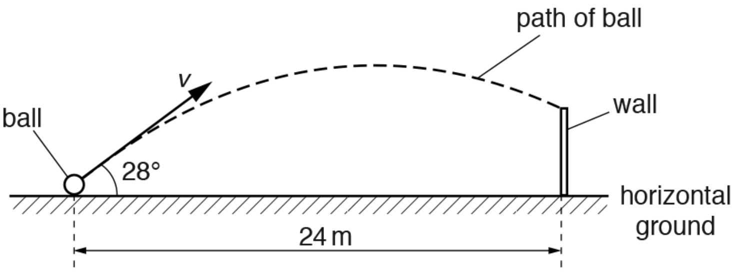

Fig. 2.1 (not to scale)

The horizontal distance between the initial position of the ball and the base of the wall is 24 m. The ball is kicked with an initial velocity v at an angle of 28° to the horizontal. The ball hits the top of the wall after a time of 1.5 s. Air resistance may be assumed to be negligible.

(i) Calculate the initial horizontal component v_X of the velocity of the ball.

v_X = ... m s^{-1} [1]

(ii) Show that the initial vertical component v_Y of the velocity of the ball is 8.5 m s^{-1}.

[2]

(iii) Calculate the time taken for the ball to reach its maximum height above the ground.

time = ... s [2]

(iv) The ball is kicked at time $t = 0$. On Fig. 2.2, sketch the variation with time t of the vertical component v_Y of the velocity of the ball until it hits the wall. It may be assumed that velocity is positive when in the upwards direction.

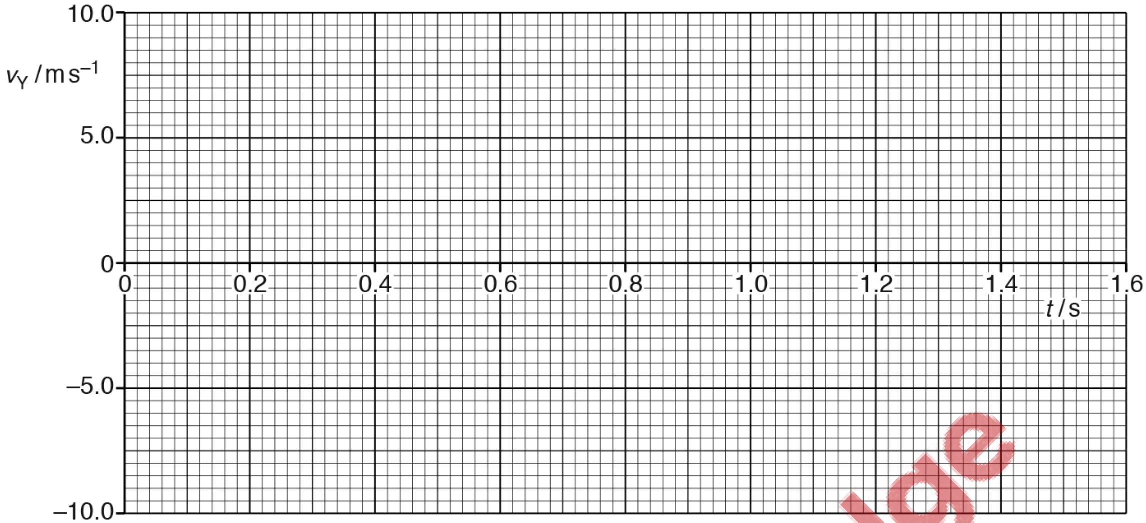

Fig. 2.2

[2]

(c) **(i)** Use the information in **(b)** to determine the maximum height of the ball above the ground.

maximum height = ... m [2]

(ii) The maximum gravitational potential energy of the ball above the ground is 22 J. Calculate the mass of the ball.

mass = ... kg [2]

(d) A ball of greater mass is kicked with the same velocity as the ball in **(b)**.
State and explain the effect, if any, of the increased mass on the maximum height reached by the ball. Air resistance is still assumed to be negligible.

....

.... [1]

[Total: 13]

91. 9702_s16_qp_22 Q: 1

(a) Define *acceleration*.

....

....[1]

(b) A man travels on a toboggan down a slope covered with snow from point A to point B and then to point C. The path is illustrated in Fig. 1.1.

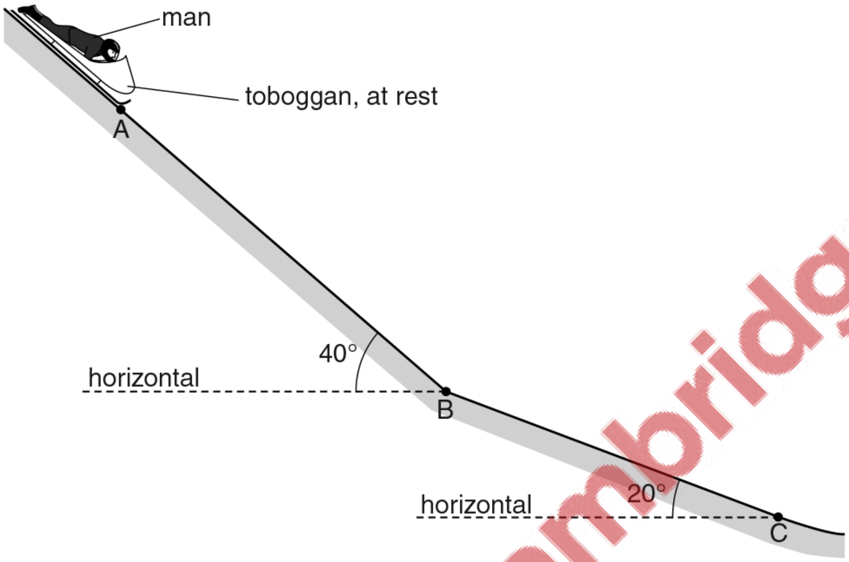

Fig. 1.1 (not to scale)

The slope AB makes an angle of 40° with the horizontal and the slope BC makes an angle of 20° with the horizontal. Friction is not negligible.

The man and toboggan have a combined mass of 95 kg.

The man starts from rest at A and has constant acceleration between A and B. The man takes 19 s to reach B. His speed is 36 m s^{-1} at B.

(i) Calculate the acceleration from A to B.

acceleration = ... m s^{-2} [2]

(ii) Show that the distance moved from A to B is 340 m.

[1]

(iii) For the man and toboggan moving from A to B, calculate

1. the change in kinetic energy,

change in kinetic energy = ... J [2]

2. the change in potential energy.

change in potential energy = ... J [2]

(iv) Use your answers in **(iii)** to determine the average frictional force that acts on the toboggan between A and B.

frictional force = ... N [2]

(v) A parachute opens on the toboggan as it passes point B. There is a constant deceleration of $3.0\,\mathrm{m\,s^{-2}}$ from B to C.

Calculate the frictional force that produces this deceleration between B and C.

frictional force = ... N [2]

[Total: 12]

92. 9702_s16_qp_23 Q: 3

(a) Explain what is meant by *gravitational potential energy* and by *kinetic energy*.

gravitational potential energy: ....

....

kinetic energy: ....

....

[2]

(b) A motion sensor is used to measure the velocity of a ball falling vertically towards the ground, as illustrated in Fig. 3.1.

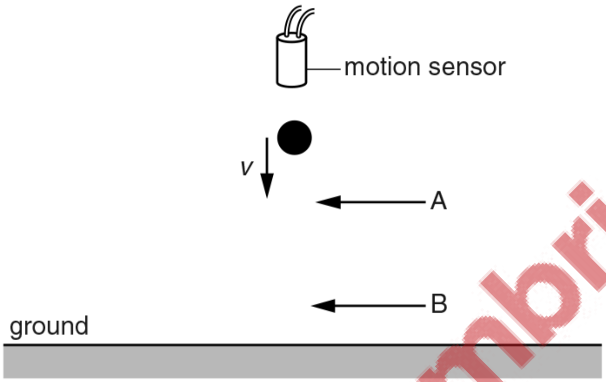

Fig. 3.1

The ball passes through points A and B as it falls. The ball has a mass of 1.5 kg.

The variation with time *t* of the velocity *v* of the ball as it falls from A to B is shown in Fig. 3.2.

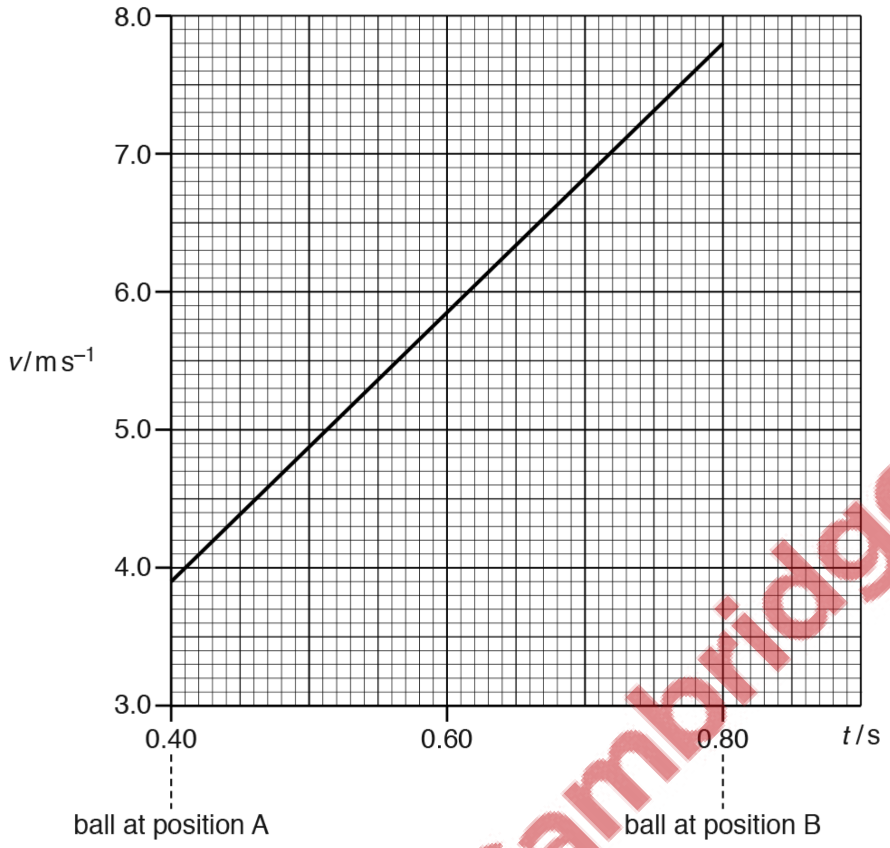

Fig. 3.2

Use Fig. 3.2 to calculate, for the ball falling from A to B,

(i) the displacement,

displacement = ...m [3]

(ii) the acceleration,

acceleration = ... m s^{-2} [2]

(iii) the change in kinetic energy.

change in kinetic energy = ...J [3]

(c) Show that the work done by the gravitational field on the ball in **(b)** as it moves from A to B is equal to the change in kinetic energy.

[2]

[Total: 12]

93. 9702_w16_qp_22 Q: 2

A ball of mass 0.030 kg moves along a curved track, as shown in Fig. 2.1.

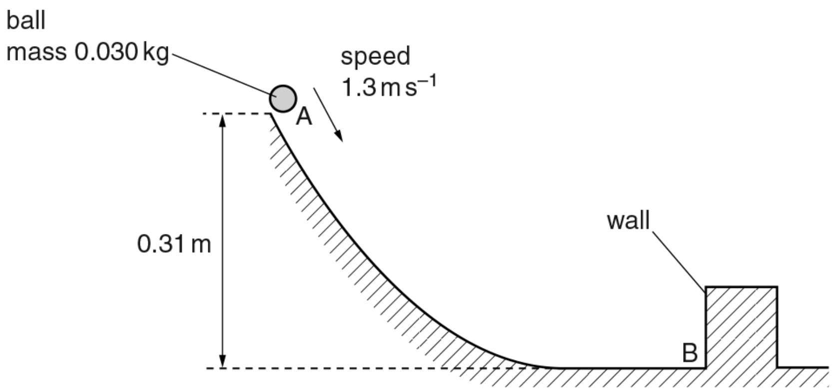

Fig. 2.1

The speed of the ball is 1.3 m s^{-1} when it is at point A at a height of 0.31 m.
The ball moves down the track and collides with a vertical wall at point B. The ball then rebounds back up the track. It may be assumed that frictional forces are negligible.

(a) Calculate the change in gravitational potential energy of the ball in moving from point A to point B.

change in gravitational potential energy = ... J [2]

(b) Show that the ball hits the wall at B with a speed of 2.8 m s^{-1}.

[3]

(c) The change in momentum of the ball due to the collision with the wall is 0.096 kg m s^{-1}. The ball is in contact with the wall for a time of 20 ms.

Determine, for the ball colliding with the wall,

(i) the speed immediately after the collision,

speed = ... m s^{-1} [2]

(ii) the magnitude of the average force on the ball.

force = ... N [2]

(d) State and explain whether the collision is elastic or inelastic.

....

....[1]

(e) In practice, frictional effects are significant so that the actual increase in kinetic energy of the ball in moving from A to B is 76 mJ. The length of the track between A and B is 0.60 m.

Use your answer in **(a)** to determine the average frictional force acting on the ball as it moves from A to B.

frictional force = ... N [2]

[Total: 12]

94. 9702_s15_qp_23 Q: 2

The variation with time t of the velocity v of a ball is shown in Fig. 2.1.

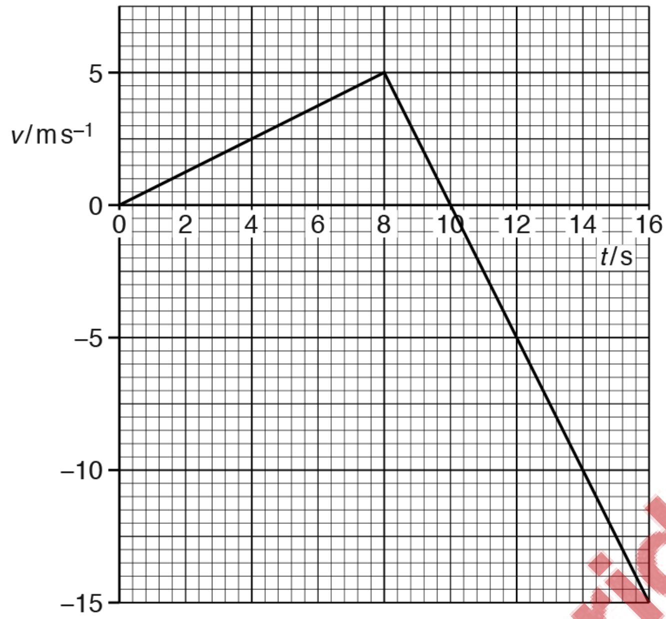

Fig. 2.1

The ball moves in a straight line from a point P at $t = 0$. The mass of the ball is 400 g.

(a) Use Fig. 2.1 to describe, without calculation, the velocity of the ball from $t = 0$ to $t = 16$ s.

....

....

....

....

....[2]

(b) Use Fig. 2.1 to calculate, for the ball,

(i) the displacement from P at $t = 10\,s$,

displacement = ... m [2]

(ii) the acceleration at $t = 10\,s$,

acceleration = ... $m\,s^{-2}$ [2]

(iii) the maximum kinetic energy.

kinetic energy = ... J [2]

(c) Use your answers in **(b)(i)** and **(b)(ii)** to determine the time from $t = 0$ for the ball to return to P.

time = ... s [2]

95. 9702_w15_qp_21 Q: 3

(a) An object is moved from point P to point R either by a direct path or by the path P to Q to R, as shown in Fig. 3.1.

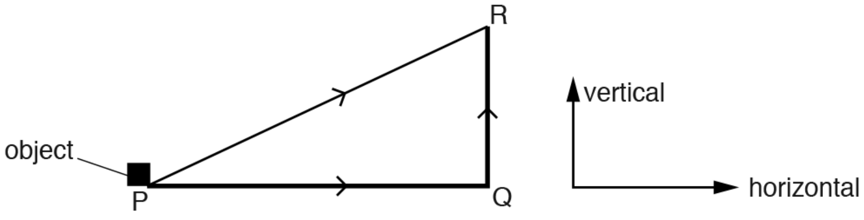

Fig. 3.1

P and Q are on the same horizontal level. R is vertically above Q.

Explain whether the work done moving the object against the gravitational field is the same or different along paths PR and PQR.

....

....

....

....[2]

(b) A ball is thrown with an initial velocity *V* at an angle *θ* to the horizontal, as shown in Fig. 3.2.

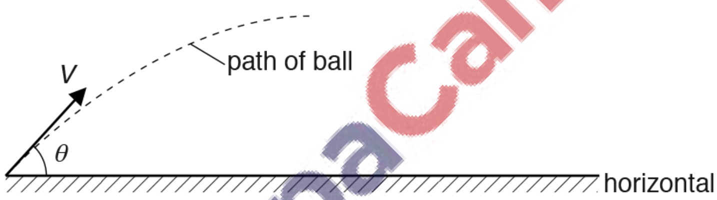

Fig. 3.2 (not to scale)

The variation with time *t* of the height *h* of the ball is shown in Fig. 3.3.

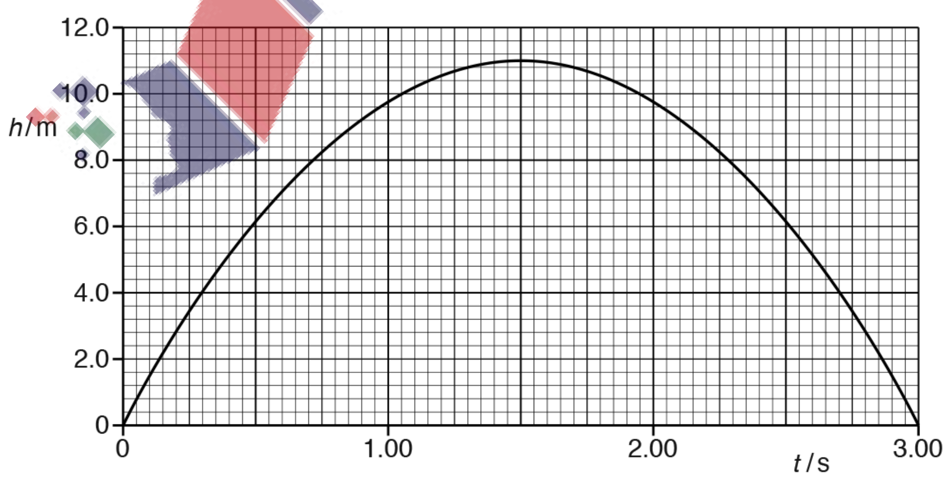

Fig. 3.3

(i) Use the time to reach maximum height to determine the vertical component V_v of the velocity of the ball for time $t = 0$.

V_v = ... m s^{-1} [2]

(ii) The horizontal displacement of the ball at $t = 3.00$ s is 25.5 m.
On Fig. 3.4, draw the variation with t of the horizontal displacement x of the ball.

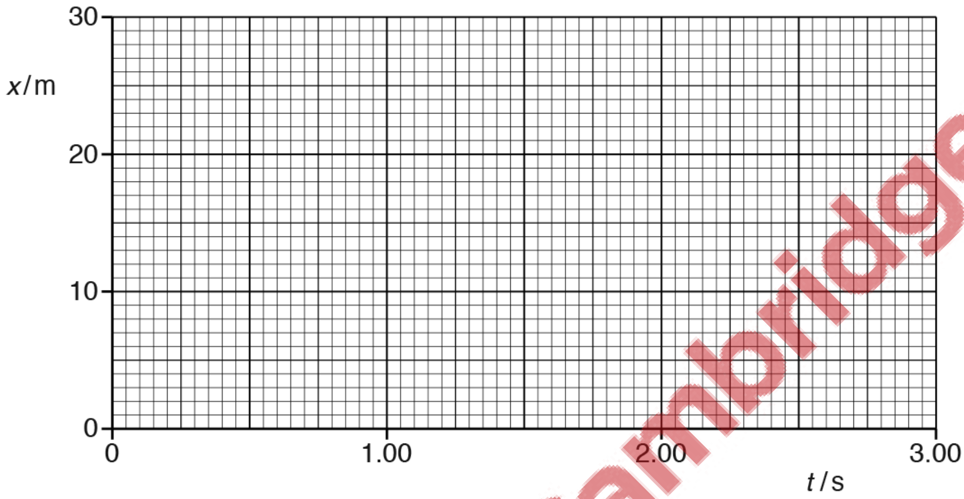

Fig. 3.4

[1]

(iii) For the ball at maximum height, calculate the ratio

$$\frac{\text{potential energy of the ball}}{\text{kinetic energy of the ball}}.$$

ratio = ... [3]

(iv) In practice, air resistance is not negligible. State and explain the effect of air resistance on the time taken for the ball to reach maximum height.

....

....

....

....[2]

96. 9702_w15_qp_22 Q: 2

Fig. 2.1 shows an object M on a slope.

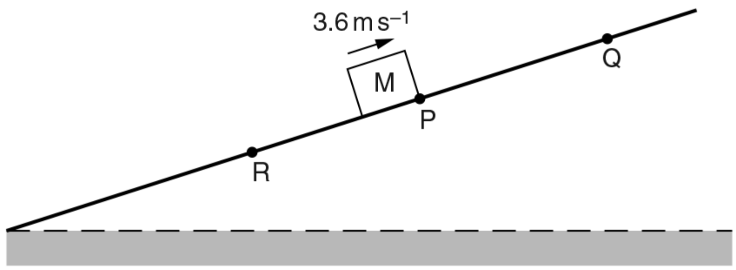

Fig. 2.1

M moves up the slope, comes to rest at point Q and then moves back down the slope to point R.
M has a constant acceleration of $3.0\,m\,s^{-2}$ down the slope at all times.
At time $t = 0$, M is at point P and has a velocity of $3.6\,m\,s^{-1}$ up the slope.
The total distance from P to Q and then to R is 6.0 m.

(a) Calculate, for the motion of M from P to Q,

(i) the time taken,

time = ... s [2]

(ii) the distance travelled.

distance = ... m [1]

(b) Show that the speed of M at R is $4.8\,m\,s^{-1}$.

(c) On Fig. 2.2, draw the variation with time t of the velocity v of M for the motion P to Q to R.

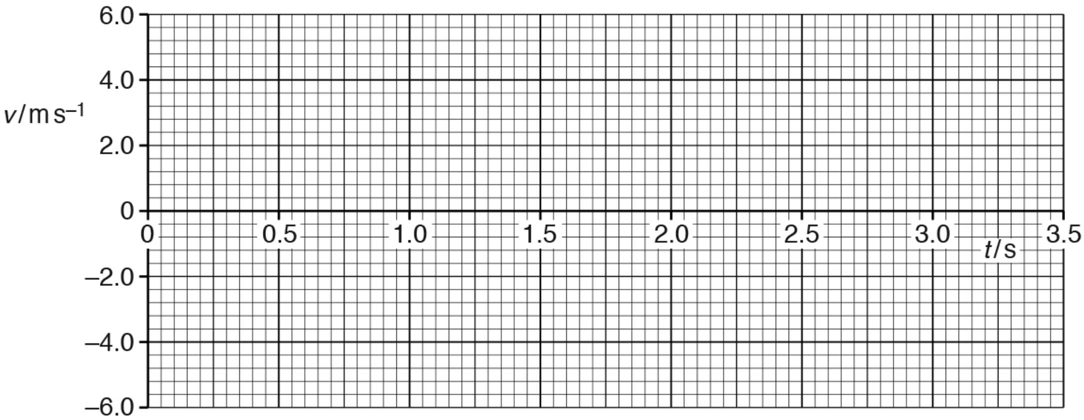

Fig. 2.2

[3]

(d) The mass of M is 450 g.

Calculate the difference in the kinetic energy of M at P and at R.

difference in kinetic energy = ... J [2]

97. 9702_w15_qp_23 Q: 3

A steel ball falls from a platform on a tower to the ground below, as shown in Fig. 3.1.

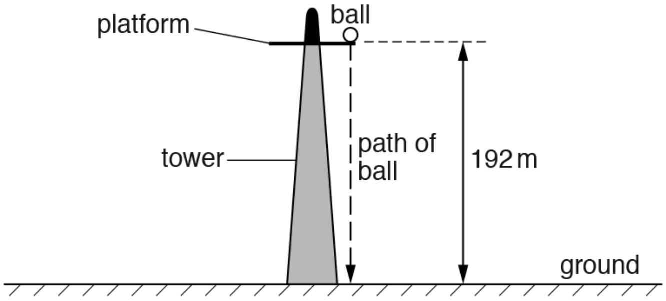

Fig. 3.1

The ball falls from rest through a vertical distance of 192 m. The mass of the ball is 270 g.

(a) Assume air resistance is negligible.

(i) Calculate

1. the time taken for the ball to fall to the ground,

time taken = ... s [2]

2. the maximum kinetic energy of the ball.

maximum kinetic energy = ... J [2]

(ii) State and explain the variation of the velocity of the ball with time as the ball falls to the ground.

....

....[1]

(iii) Show that the velocity of the ball on reaching the ground is approximately 60 m s^{-1}.

[1]

(b) In practice, air resistance is not negligible. The variation of the air resistance R with the velocity v of the ball is shown in Fig. 3.2.

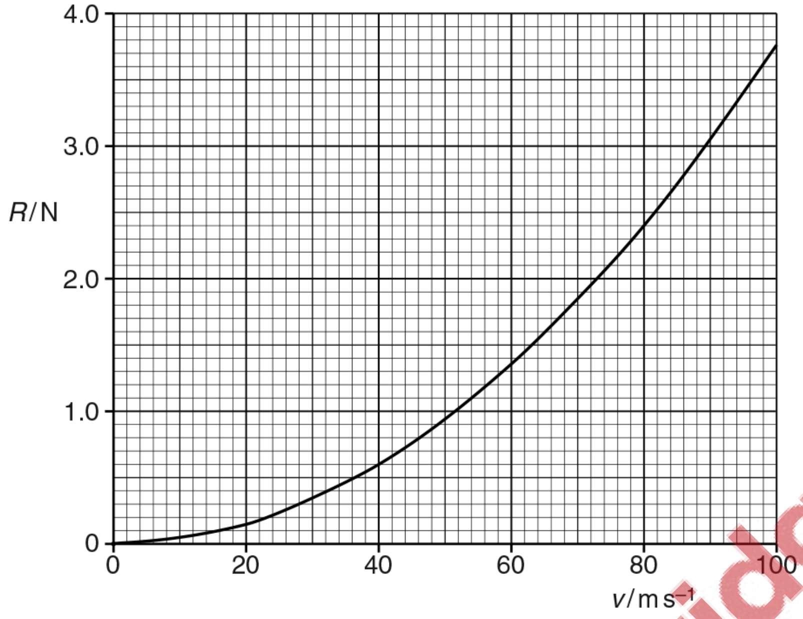

Fig. 3.2

(i) Use Fig. 3.2 to state and explain qualitatively the variation of the acceleration of the ball with the distance fallen by the ball.

....

....

....

....[3]

(ii) The speed of the ball reaches $40\,m\,s^{-1}$. Calculate its acceleration at this speed.

acceleration = ... $m\,s^{-2}$ [2]

(iii) Use information from **(a)(iii)** and Fig. 3.2 to state and explain whether the ball reaches terminal velocity.

....

....

....[2]

6.4 Power

98. 9702_s20_qp_22 Q: 1

(a) Define *velocity*.

....

.... [1]

(b) The drag force F_D acting on a car moving with speed v along a straight horizontal road is given by

$$F_D = v^2 Ak$$

where k is a constant and A is the cross-sectional area of the car.

Determine the SI base units of k.

SI base units .... [2]

(c) The value of k, in SI base units, for the car in **(b)** is 0.24. The cross-sectional area A of the car is $5.1\,m^2$.

The car is travelling with a constant speed along a straight road and the output power of the engine is 4.8×10^4 W. Assume that the output power of the engine is equal to the rate at which the drag force F_D is doing work against the car.

Determine the speed of the car.

speed = ... $m\,s^{-1}$ [3]

[Total: 6]

99. 9702_s19_qp_23 Q: 3

A cylindrical disc of mass 0.24 kg has a circular cross-sectional area *A*, as shown in Fig. 3.1.

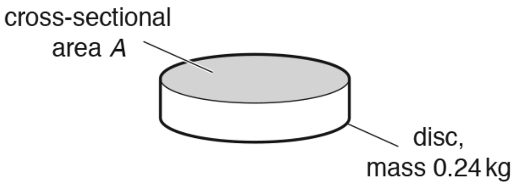

Fig. 3.1

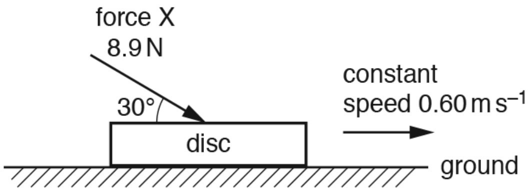

Fig. 3.2

The disc is on horizontal ground, as shown in Fig. 3.2. A force X of magnitude 8.9 N acts on the disc in a direction of 30° to the horizontal. The disc moves at a constant speed of $0.60\,\text{m}\,\text{s}^{-1}$ along the ground.

(a) Determine the rate of doing work on the disc by the force X.

rate of doing work = ... W [2]

(b) The force X and the weight of the disc exert a combined pressure on the ground of 3500 Pa.

Calculate the cross-sectional area *A* of the disc.

A = ... m^2 [3]

(c) Newton's third law describes how forces exist in pairs. One such pair of forces is the weight of the disc and another force Y. State:

(i) the direction of force Y

....[1]

(ii) the name of the body on which force Y acts.

....[1]

[Total: 7]

100. 9702_w19_qp_23 Q: 2

(a) State what is meant by *work done*.

....

.... [1]

(b) A lift (elevator) of weight 13.0 kN is connected by a cable to a motor, as shown in Fig. 2.1.

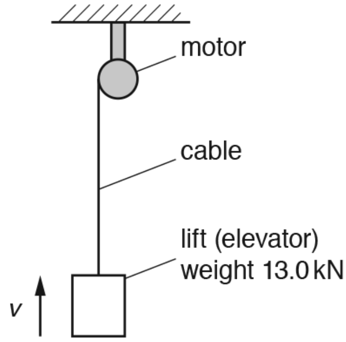

Fig. 2.1

The lift is pulled up a vertical shaft by the cable. A constant frictional force of 2.0 kN acts on the lift when it is moving. The variation with time *t* of the speed *v* of the lift is shown in Fig. 2.2.

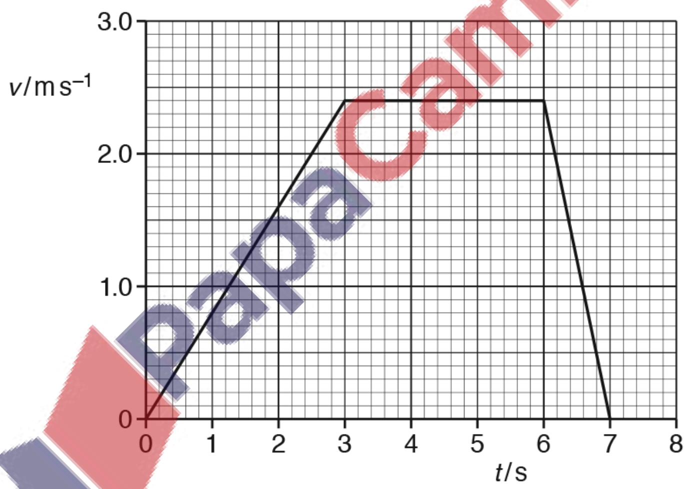

Fig. 2.2

(i) Use Fig. 2.2 to determine:

1. the acceleration of the lift between time $t = 0$ and $t = 3.0\,s$

acceleration = ... $m\,s^{-2}$ [2]

2. the work done by the motor to raise the lift between time $t = 3.0\,s$ and $t = 6.0\,s$.

work done = ... J [2]

(ii) The motor has an efficiency of 67%. The tension in the cable is $1.6 \times 10^4\,N$ at time $t = 2.5\,s$.

Determine the input power to the motor at this time.

input power = ... W [3]

(iii) State and explain whether the increase in gravitational potential energy of the lift from time $t = 0$ to $t = 7.0\,s$ is less than, the same as, or greater than the work done by the motor. A calculation is not required.

....

.... [1]

[Total: 9]

101. 9702_w18_qp_21 Q: 3

(a) **(i)** Define *power*.

....

.... [1]

(ii) State what is meant by *gravitational potential energy*.

....

.... [1]

(b) An aircraft of mass 1200 kg climbs upwards with a constant velocity of 45 m s^{-1}, as shown in Fig. 3.1.

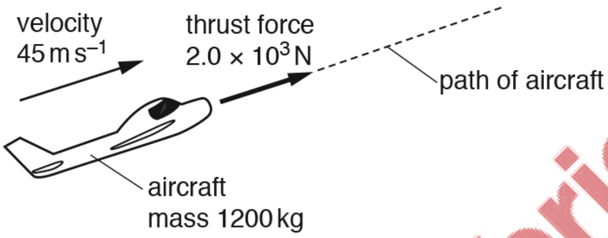

Fig. 3.1 (not to scale)

The aircraft's engine produces a thrust force of 2.0×10^3 N to move the aircraft through the air. The rate of increase in height of the aircraft is 3.3 m s^{-1}.

(i) Calculate the power produced by the thrust force.

power = ... W [2]

(ii) Determine, for a time interval of 3.0 minutes,

1. the work done by the thrust force to move the aircraft,

work done = ... J [2]

2. the increase in gravitational potential energy of the aircraft,

increase in gravitational potential energy = ... J [2]

3. the work done against air resistance.

work done = ... J [1]

(iii) Use your answer in **(b)(ii) part 3** to calculate the force due to air resistance acting on the aircraft.

force = ... N [1]

(iv) With reference to the motion of the aircraft, state and explain whether the aircraft is in equilibrium.

....

....

.... [2]

[Total: 12]

102. 9702_m17_qp_22 Q: 3

(a) Define *velocity*.

....

....[1]

(b) A car travels in a straight line up a slope, as shown in Fig. 3.1.

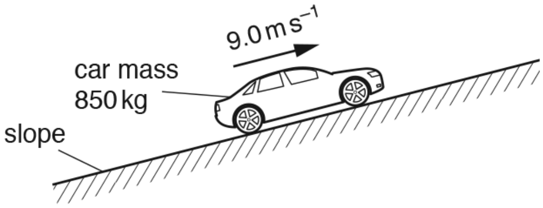

Fig. 3.1

The car has mass 850 kg and travels with a constant speed of 9.0 m s^{-1}. The car's engine exerts a force on the car of 2.0 kN up the slope.

A resistive force F_D, due to friction and air resistance, opposes the motion of the car.

The variation of F_D with the speed v of the car is shown in Fig. 3.2.

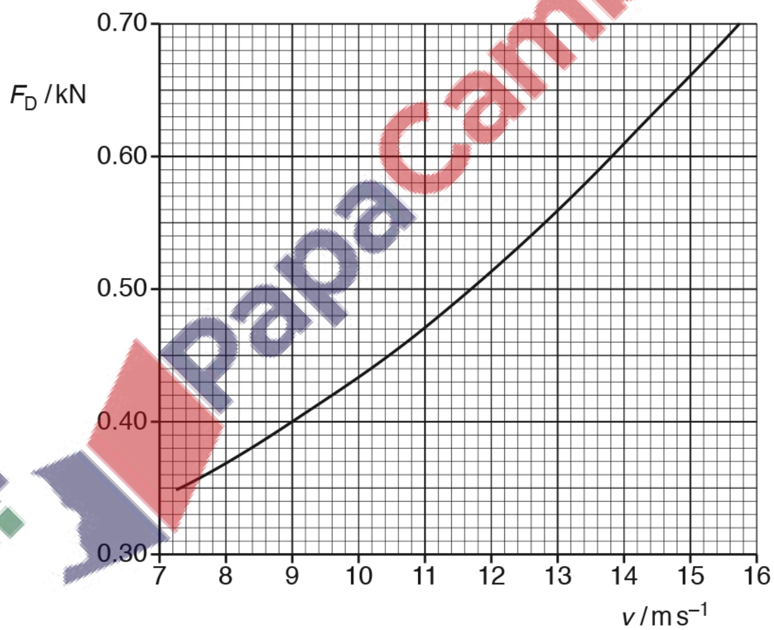

Fig. 3.2

(i) State and explain whether the car is in equilibrium as it moves up the slope.

....

....

....[2]

(ii) Consider the forces that act along the slope. Use data from Fig. 3.2 to determine the component of the weight of the car that acts down the slope.

component of weight = ... N [2]

(iii) Show that the power output of the car is 1.8×10^4 W.

[2]

(iv) The car now travels along horizontal ground. The output power of the car is maintained at 1.8×10^4 W. The variation of the resistive force F_D acting on the car is given in Fig. 3.2.

Calculate the acceleration of the car when its speed is $15\,\text{m}\,\text{s}^{-1}$.

acceleration = ... $\text{m}\,\text{s}^{-2}$ [3]

[Total: 10]

103. 9702_s15_qp_23 Q: 3

(a) Define *power*.

....

....[1]

(b) Fig. 3.1 shows a car travelling at a speed of $22\,m\,s^{-1}$ on a horizontal road.

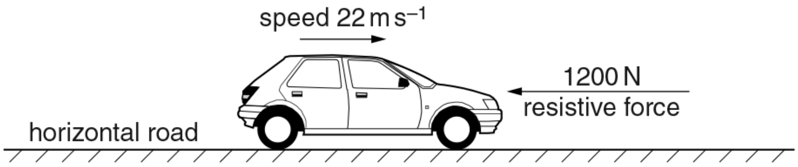

Fig. 3.1

The car has a mass of 1500 kg. A resistive force of 1200 N acts on the car.

Calculate

(i) the force *F* required from the car to produce an acceleration of $0.82\,m\,s^{-2}$,

F = ... N [3]

(ii) the power required to produce this acceleration.

power = ... W [2]

(c) The resistive force on the car is proportional to v^2, where v is the speed of the car. Suggest why the car has a maximum speed.

....

....[1]