11 **(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.

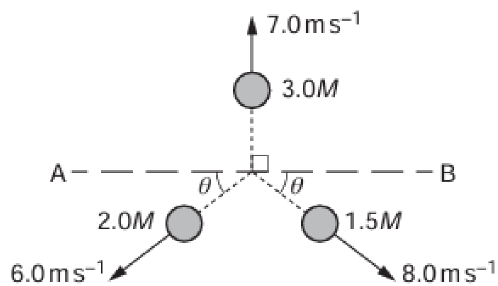

Fig. 2.1

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

9702/22/M/J/18/Q3

12 A child on a sledge slides down a steep hill and then travels in a straight line up an ice-covered slope, as illustrated in Fig. 3.1.

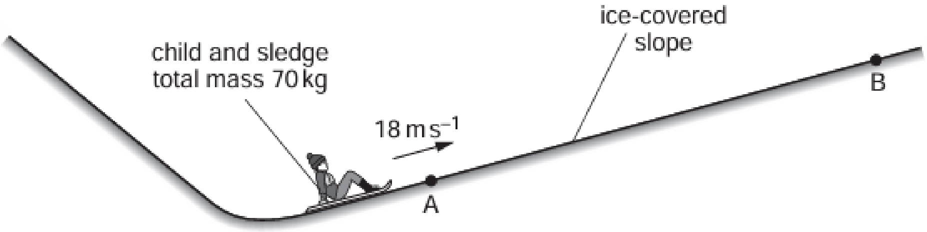

Fig. 3.1 (not to scale)

The sledge passes point A with speed $18\,\mathrm{m\,s^{-1}}$ at time $t = 0$ and then comes to rest at point B. The child applies a brake to the sledge at point B. The brake does not keep the sledge stationary and it immediately slides back down the slope towards A.

The variation with time t of the velocity v of the sledge from $t = 0$ to $t = 24\,\mathrm{s}$ is shown in Fig. 3.2.

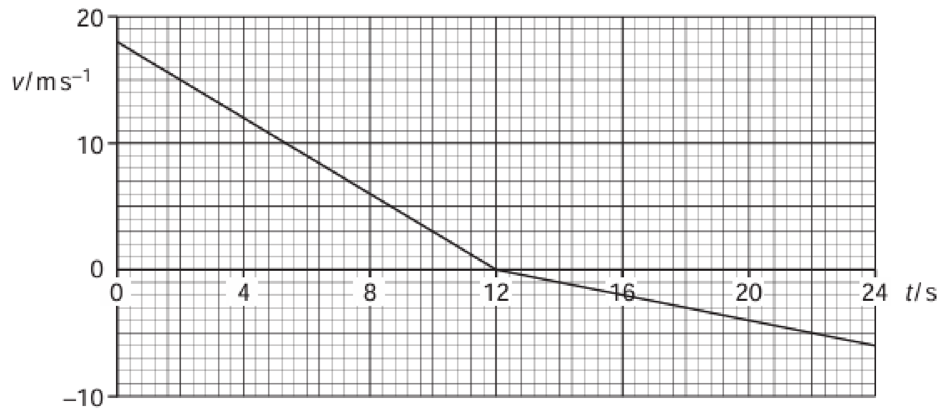

Fig. 3.2

(a) State the time taken for the sledge to travel from A to B.

time = ... s [1]

(b) Determine the displacement of the sledge up the slope from point A at time t = 24 s.

displacement = ...m [3]

(c) Show that the acceleration of the sledge as it moves from B back towards A is 0.50 m s^{-2}.

[2]

(d) The child and sledge have a total mass of 70 kg. The component of the total weight of the child and sledge that acts down the slope is 80 N.

Determine

(i) the frictional force on the sledge as it moves from B towards A,

frictional force = ... N [2]

(ii) the angle θ of the slope to the horizontal.

θ = ... ° [2]

13 A solid cylinder is lifted out of oil by a wire attached to a motor. Fig. 5.1 shows two different positions X and Y of the cylinder during the lifting process.

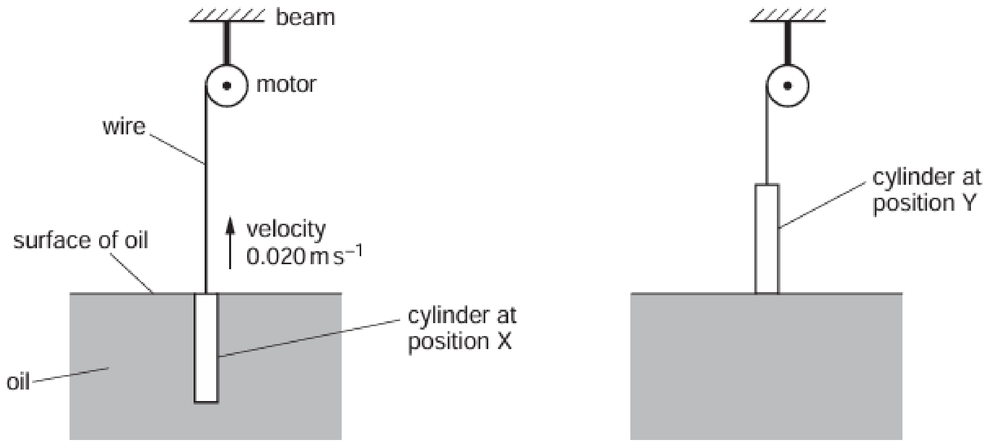

Fig. 5.1

The motor is fixed to an overhead beam.
The cylinder has cross-sectional area $0.018\,m^2$, length 1.2 m and weight 560 N.
The density of the oil is $940\,kg\,m^{-3}$.

Throughout the lifting process, the cylinder moves vertically upwards with a constant velocity of $0.020\,m\,s^{-1}$. The viscous force of the oil acting on the cylinder is negligible.

(a) Calculate the density of the cylinder.

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

(b) For the cylinder at position X, show that the upthrust due to the oil is 200 N.

[2]

(c) Calculate, for the moving cylinder at position X,

(i) the tension in the wire,

tension = ... N [1]

(ii) the power output of the motor.

power = ... W [2]

(d) The cylinder is raised with constant velocity from position X to position Y.

(i) State and explain the variation, if any, of the power output of the motor as the cylinder is raised. Numerical values are not required.

....

....

....

....

....[3]

(ii) The rate of energy output of the motor is less than the rate of increase of gravitational potential energy of the cylinder. Without calculation, explain this difference.

....

....[1]

[Total: 11]

9702/23/M/J/18/Q2

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

....

....[1]

(b) A diver releases a solid sphere of radius 16 cm from the sea bed. The sphere moves vertically upwards towards the surface of the sea.

The weight of the sphere is 20 N. The upthrust acting on the sphere is 170 N. The upthrust remains constant as the sphere moves upwards.

(i) Calculate the density of the material of the sphere.

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

(ii) Briefly explain the origin of the upthrust acting on the sphere.

....

....

....[1]

(iii) Calculate the acceleration of the sphere as it is released from rest.

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

(iv) The viscous (drag) force D acting on the sphere is given by

$$D = kr^2v^2$$

where r is the radius of the sphere and v is its speed.
The constant k is equal to $810\,kg\,m^{-3}$.

Determine the constant (terminal) speed reached by the sphere.

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

(v) The diver releases a different sphere that moves with a constant speed of $6.30\,m\,s^{-1}$ directly towards a stationary ship. The sphere emits sound of frequency 4850 Hz. The ship detects sound of frequency 4870 Hz as the sphere moves towards it.

Determine, to three significant figures, the speed of the sound in the water.

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

[Total: 11]

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

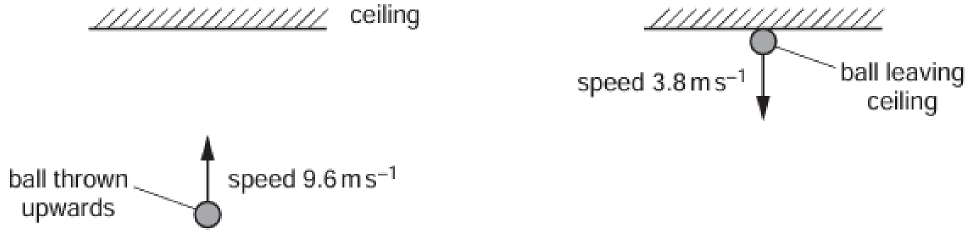

Fig. 3.1

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]

9702/21/M/J/19/Q2

16 A block X slides along a horizontal frictionless surface towards a stationary block Y, as illustrated in Fig. 2.1.

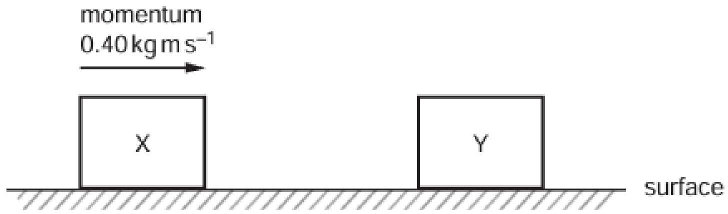

Fig. 2.1

There are no resistive forces acting on block X as it moves towards block Y. At time $t = 0$, block X has momentum $0.40\,\text{kg m s}^{-1}$. A short time later, the blocks collide and then separate.

The variation with time t of the momentum of block Y is shown in Fig. 2.2.

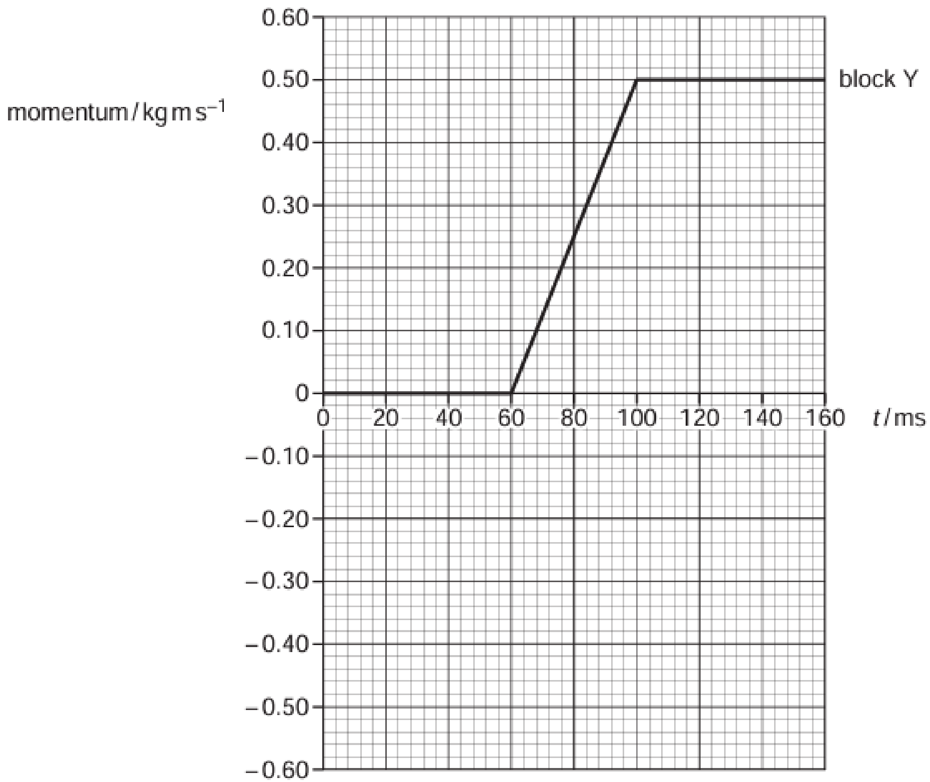

Fig. 2.2

(a) Define *linear momentum*.

....[1]

(b) Use Fig. 2.2 to:

(i) determine the time interval over which the blocks are in contact with each other

time interval = ... ms [1]

(ii) describe, without calculation, the magnitude of the acceleration of block Y from:

1. time t = 80 ms to t = 100 ms

....

2. time t = 100 ms to t = 120 ms.

....
[2]

(c) Use Fig. 2.2 to determine the magnitude of the force exerted by block X on block Y.

force = ... N [2]

(d) On Fig. 2.2, sketch the variation of the momentum of block X with time t from t = 0 to t = 160 ms. [3]

[Total: 9]

9702/22/M/J/19/Q2

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

....

....[1]

(b) A car of mass 850 kg tows a trailer in a straight line along a horizontal road, as shown in Fig. 2.1.

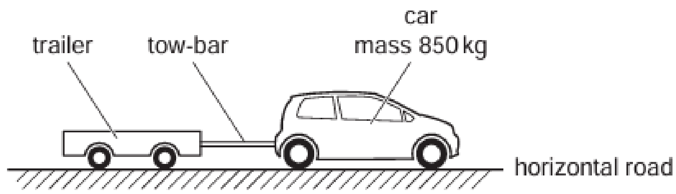

Fig. 2.1

The car and the trailer are connected by a horizontal tow-bar.

The variation with time t of the velocity v of the car for a part of its journey is shown in Fig. 2.2.

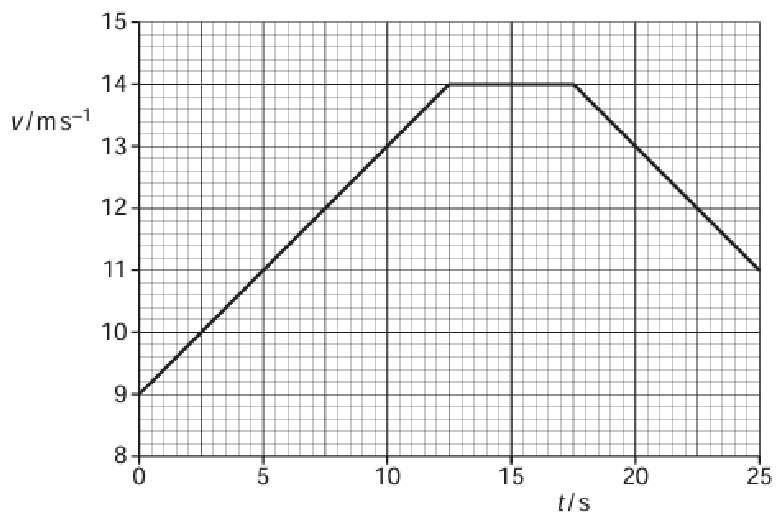

Fig. 2.2

(i) Calculate the distance travelled by the car from time $t = 0$ to $t = 10\,s$.

distance = ... m [2]

(ii) At time $t = 10\,s$, the resistive force acting on the car due to air resistance and friction is 510 N. The tension in the tow-bar is 440 N.

For the car at time $t = 10\,s$:

1. use Fig. 2.2 to calculate the acceleration

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

2. use your answer to calculate the resultant force acting on the car

resultant force = ... N [1]

3. show that a horizontal force of 1300 N is exerted on the car by its engine

[1]

4. determine the useful output power of the engine.

output power = ... W [2]

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

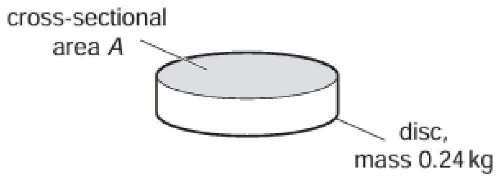

Fig. 3.1

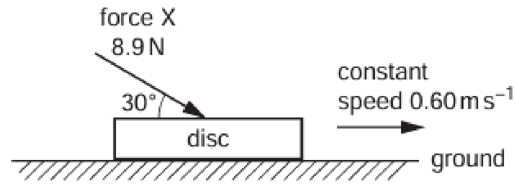

Fig. 3.2

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 m 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]

19 (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 $5.4\,\mathrm{m\,s^{-1}}$. The path of the parcel is shown in Fig. 2.1.

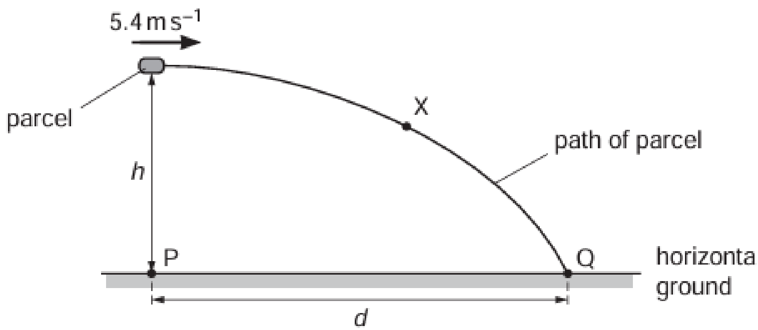

Fig. 2.1 (not to scale)

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.

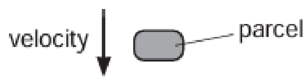

Fig. 2.2

[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]

20 **(a)** Fig. 2.1 shows the velocity–time graph for an object moving in a straight line.

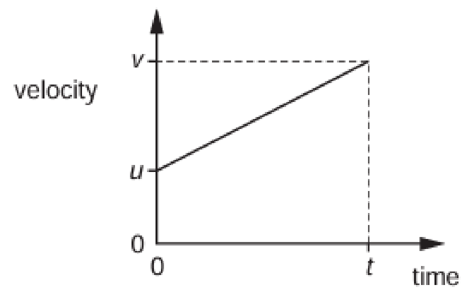

Fig. 2.1

(i) Determine an expression, in terms of u, v and t, for the area under the graph.

area = ... [1]

(ii) State the name of the quantity represented by the area under the graph.

.... [1]

(b) A ball is kicked with a velocity of $15\,\mathrm{m\,s^{-1}}$ at an angle of 60° to horizontal ground. The ball then strikes a vertical wall at the instant when the path of the ball becomes horizontal, as shown in Fig. 2.2.

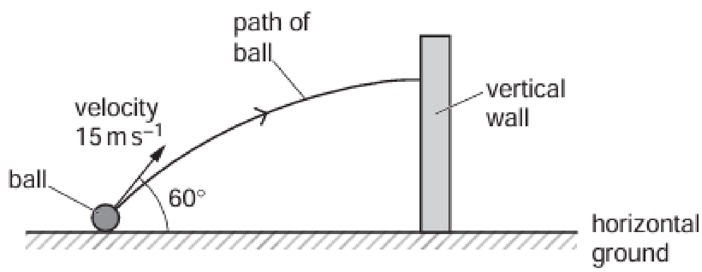

Fig. 2.2 (not to scale)

Assume that air resistance is negligible.

(i) By considering the vertical motion of the ball, calculate the time it takes to reach the wall.

time = ... s [3]

(ii) Explain why the horizontal component of the velocity of the ball remains constant as it moves to the wall.

....

.... [1]

(iii) Show that the ball strikes the wall with a horizontal velocity of $7.5\,\mathrm{m\,s^{-1}}$.

[1]

(c) The mass of the ball in **(b)** is 0.40 kg. It is in contact with the wall for a time of 0.12 s and rebounds horizontally with a speed of $4.3\,\mathrm{m\,s^{-1}}$.

(i) Use the information from **(b)(iii)** to calculate the change in momentum of the ball due to the collision.

change in momentum = ... $\mathrm{kg\,m\,s^{-1}}$ [2]

(ii) Calculate the magnitude of the average force exerted on the ball by the wall.

average force = ... N [1]

[Total: 10]