1 **(a)** State the *principle of conservation of momentum*.

.....

.....

..... [2]

(b) Two frictionless trolleys A and B are moving along a horizontal straight line, as illustrated in Fig. 2.1.

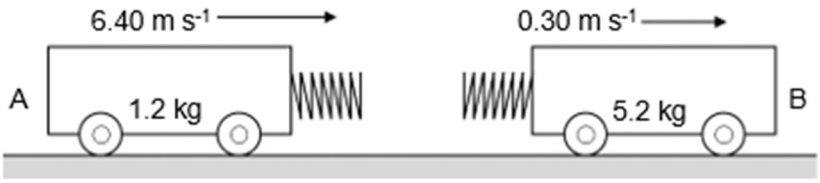

Fig. 2.1

Trolley A has mass 1.2 kg and a velocity of 6.40 m s^{-1}. Trolley B has mass 5.2 kg and a velocity of 0.30 m s^{-1}.

At 0.20 s, the two trolleys collide elastically and are in contact for a duration of 0.47 s and trolley A moves in the opposite direction after the collision.

(i) Show that the velocity of trolley B after the collision is 2.6 m s^{-1}.

[3]

1 **(ii)** Calculate the average force F that B exerts on A during the collision.

F = ... N [3]

(iii) Sketch on Fig. 2.2, the velocity-time graph for trolley A. The velocity-time graph of trolley B has been provided.

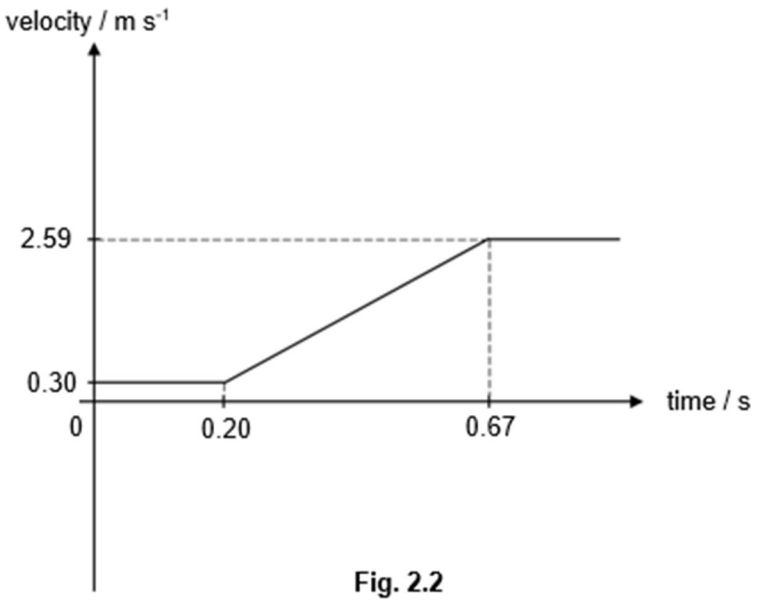

Fig. 2.2

[2]

(iv) Indicate on Fig. 2.2 the time at which the two trolleys are the closest to each other. Label this time as t_c.

[1]

(v) Discuss why the collision is elastic even though the magnitude of the kinetic energy of the system at t_c is not the same as that before the collision.

.....

.....

.....

..... [2]

2

(a) A student suggests that Newton's third law implies that the weight of a book resting on a table is equal to the support force that the table exerts on the book.

Explain why

(i) the student is wrong,

.....

.....

.....

.....

..... [2]

(ii) the two forces are equal and opposite.

.....

.....

..... [1]

(b) Use Newton's laws to deduce the principle of conservation of momentum.

[3]

2

(c) In space, an object of mass 28 kg travelling with velocity 88 m s^{-1} collides with a second object of mass 17 kg travelling in the same direction with a velocity of 53 m s^{-1}. The collision is inelastic.

After the collision, the 28 kg object continues to move in the original direction but with a velocity of 67 m s^{-1}.

Calculate the loss in kinetic energy in the collision.

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

(d) In **(c)**, the force exerted by the 28 kg object on the 17 kg object will not have a constant value during the time they are in contact with one another.

Sketch two graphs on the axes shown in Fig. 2.1 to show how the force varies with time if the collision in **(c)** is between

(i) two steel objects (label this line S),

(ii) two rubber objects (label this line R).

Fig. 2.1

[2]

[Total: 11]

3 **(a)** State the *principle of conservation of momentum*.

.....

.....

..... [2]

(b) Two blocks, A and B, are on a horizontal frictionless surface. The blocks are joined together by a spring, as shown in Fig. 2.1.

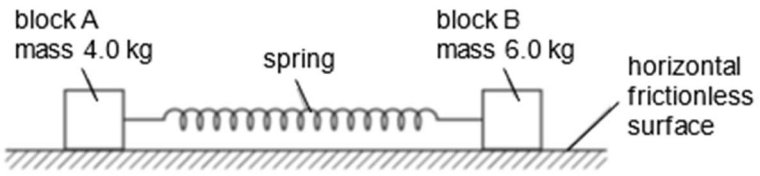

Fig. 2.1

Block A has mass 4.0 kg and block B has mass 6.0 kg. The two blocks are held apart so that the spring has an extension of 8.0 cm.The elastic potential energy of the spring at an extension of 8.0 cm is 0.48 J.

The blocks are released from rest at the same instant. When the extension of the spring becomes zero, block A has speed v_A and block B has speed v_B.

For the instant when the extension of the spring becomes zero,

(i) use the conservation of momentum to show that

$$\frac{\text{kinetic energy of block A}}{\text{kinetic energy of block B}} = 1.5$$

[3]

3 **(ii)** use the information in **(b)(i)** to determine the kinetic energy of block A. It may be assumed that the spring has negligible kinetic energy and that air resistance is negligible.

kinetic energy of block A = ...J [2]

(iii) The blocks are released at time = 0.

On Fig. 2.2, sketch a graph to show the variation with time of the momentum of block A, until the extension of the spring becomes zero.

Numerical values of momentum and time are not required.

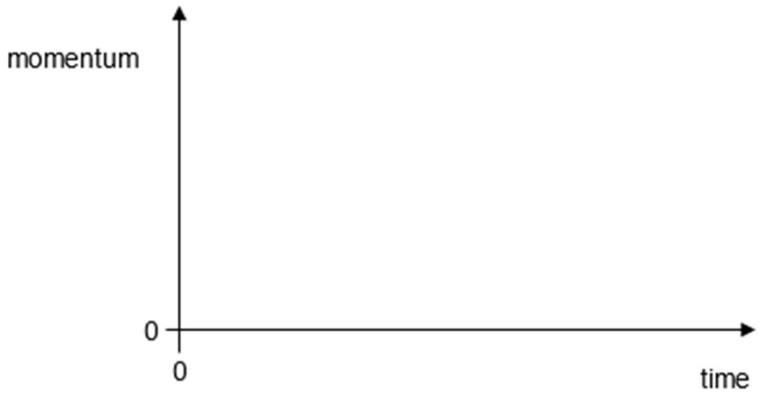

Fig. 2.2

[2]

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

.....

.....

..... [2]

(b) A soccer ball of mass 0.20 kg is kicked from point A of a sloping ground as shown in Fig. 2.1.

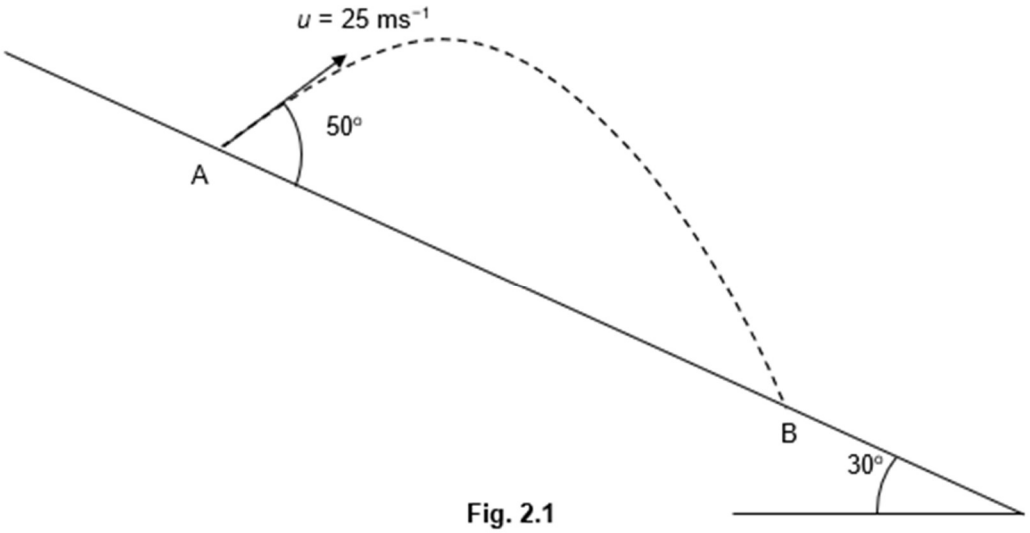

Fig. 2.1

(i) Calculate the time of travel between A and B.

time = ... s [3]

4 **(ii)** The ball hits the slope at B as illustrated in Fig. 2.2.

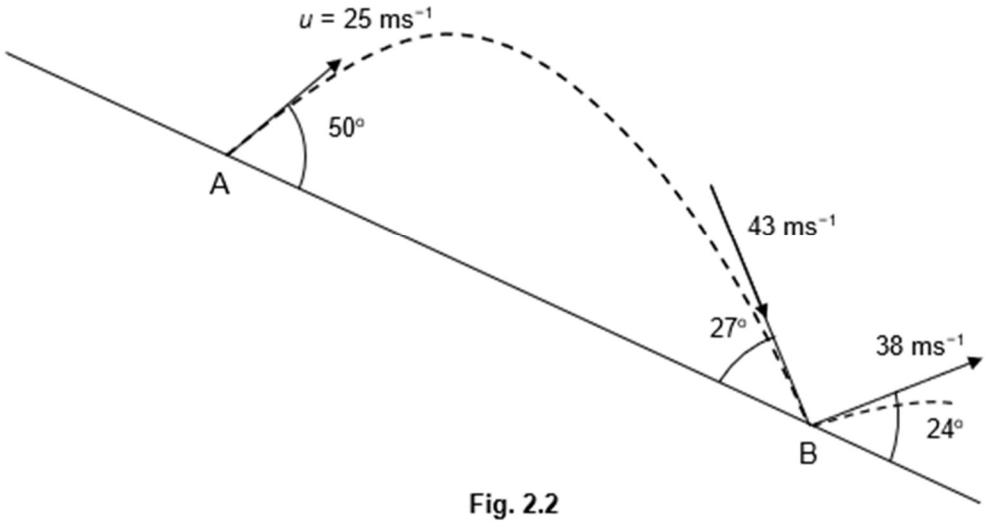

Fig. 2.2

Calculate the change in velocity of the ball at B due to the impact.

change in velocity = ... m s^{-1} [2]

(iii) Calculate the resultant force on the ball at B, given the duration of impact is 0.050 s.

resultant force = ... N [1]

[Total: 8]

5 Fig. 1.1 shows Trolleys A and B of masses m_A = 1.21 kg and m_B = 2.41 kg move towards each other on a frictionless surface. A light spring is attached to Trolley B.

Fig. 1.1

The trolleys collide head-on at time t = 0.10 s.
The momentum-time graphs for trolley A and trolley B are shown in Fig. 1.2.

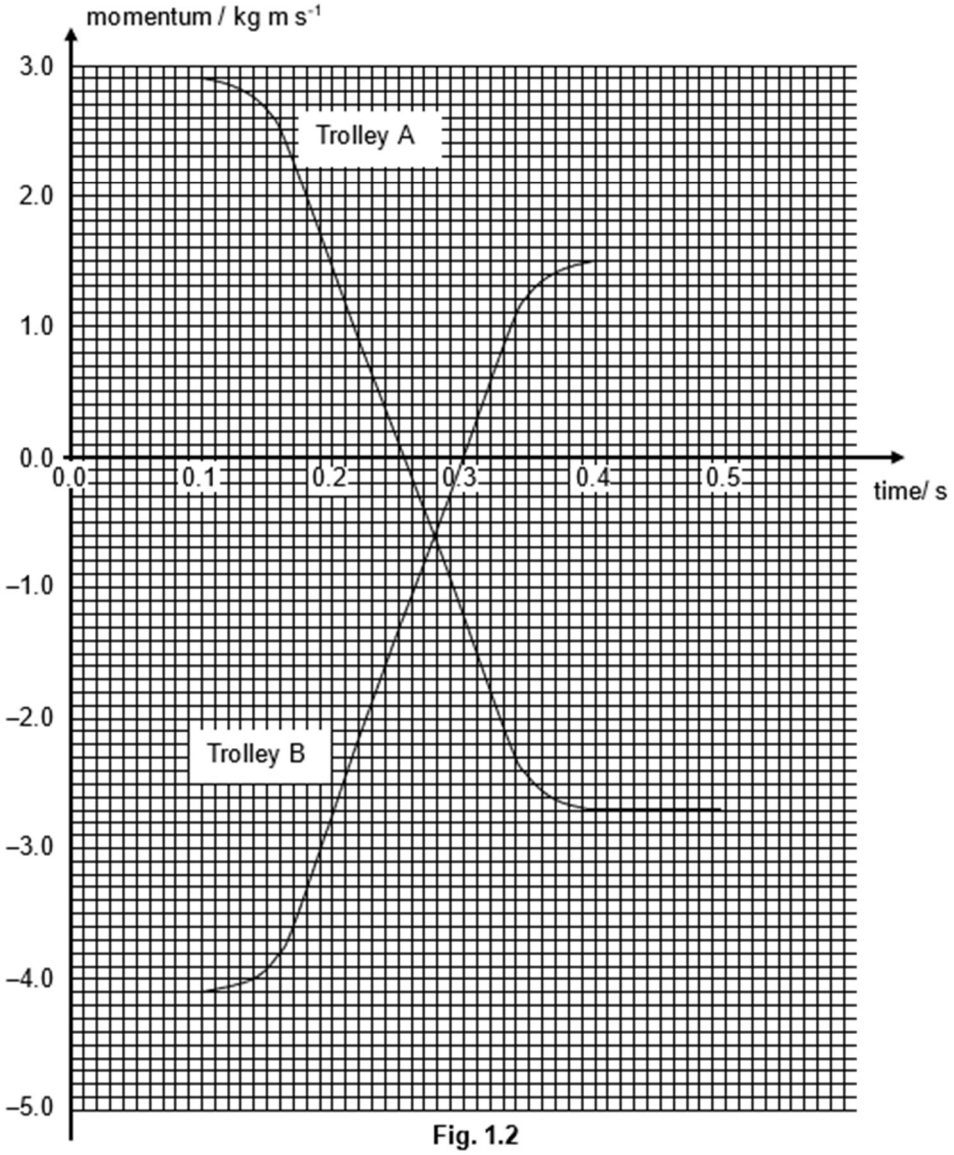

Fig. 1.2

5

(a) State the *Principle of Conservation of Momentum*.

.....

..... [2]

(b) **(i)** Read from Fig. 1.2 the momentum of trolley B when trolley A is momentarily at rest.

momentum = ... kg m s^{-1} [1]

(ii) Explain the significance of your answer in **(b)(i)**.

.....

..... [1]

(c) Explain quantitatively, but without using calculations of kinetic energy, whether the collision is elastic.

..... [3]

(d) Calculate the magnitude of the average force exerted on trolley **A** during the collision.

average force on trolley **A** = ... N [2]

(e) Explain whether the spring will be most compressed before, at or after the intersection of the two momentum-time graphs.

.....

.....

..... [2]

6 **(a)** **(i)** Define *linear momentum*.

.....

..... [1]

(ii) State the relation between force and momentum.

.....

..... [1]

(b) A projectile of mass 300 g, initially at rest, is fired from a cylindrical barrel of cross-sectional area 2.8×10^{-4} m^2 by means of compressed gas. The variation with time t of the excess pressure p of the gas in the barrel above atmospheric pressure is shown in Fig. 2.1.

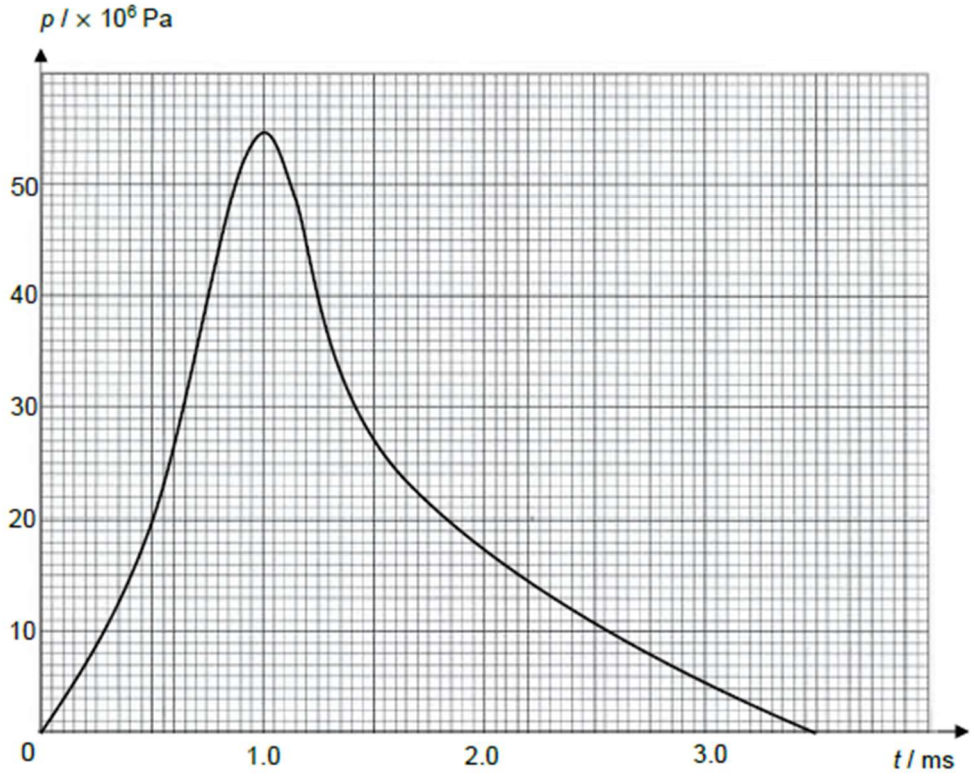

Fig. 2.1

6 **(i)** Calculate the maximum acceleration of the projectile due to the force exerted by the compressed gas on it.

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

(ii) Using Fig. 2.1, estimate the total change of momentum of the projectile due to the force exerted by the compressed gas on it.

change in momentum = ... $kg\ m\ s^{-1}$ [3]

(iii) The excess pressure exerted on the projectile is now higher than that shown in Fig. 2.1 from $t = 0$ ms to $t = 3.5$ ms. Explain how the final speed of the projectile will change.

.....

.....

..... [2]

[Total: 9]

7 Two atoms X and Y, have masses $3m$ and $2m$ respectively. The 2 atoms move head-on towards each other with the same speed v as shown in Fig. 2.1.

Fig. 2.1

Fig. 2.2 comprises two velocity-time graphs A and B, which show how the velocity of each atom varies with time. The interaction between the atoms is elastic.

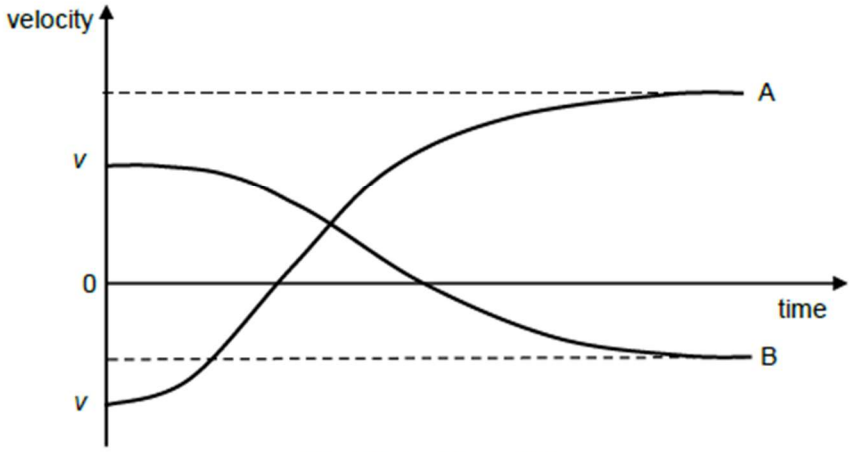

Fig. 2.2 (not to scale)

(a) (i) Explain why it is not possible for the atoms to stop at the same instant.

.....

.....

..... [1]

(ii) At one instant during the interaction between the atoms, they are both travelling in the same direction with the same speed. Calculate this speed, in terms of v.

speed = ... [2]

7 **(b) (i)** State and explain, which of the curves A or B is the velocity-time sketch for atom Y.

.....

.....

.....

.....

..... [3]

(ii) On Fig. 2.2, mark the instant in time at which the atoms are at their distance of closest approach. Label this point **T**. [1]

(iii) Determine the final speed of each atom in terms of *v*.

final speed of X = ...

final speed of Y = ... [3]

[Total: 10]

8

(a) Fig 1.1 shows two frictionless trolleys A and B of mass m_A and m_B moving horizontally towards a wall with the same speed u. The trolleys are not in contact.

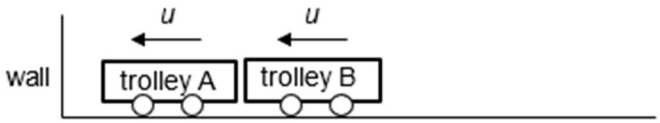

Fig. 1.1

Upon collision with the wall, trolley A rebounds with speed u and collides elastically with trolley B.

(i) State the principle of conservation of momentum.

.....

.....

.....

..... [2]

(ii) Taking motion to the right as positive, show that the speed of trolley B, v_B after the collision with trolley A is given by the expression

$$v_B = \frac{3m_A - m_B}{m_A + m_B} u .$$

[3]

8 **(b)** A student performs a similar experiment with a basketball of mass 0.62 kg and a tennis ball of mass 0.059 kg. The student places the tennis ball slightly above the basketball and releases both at the same time from a height above the ground, as shown in Fig. 1.2.

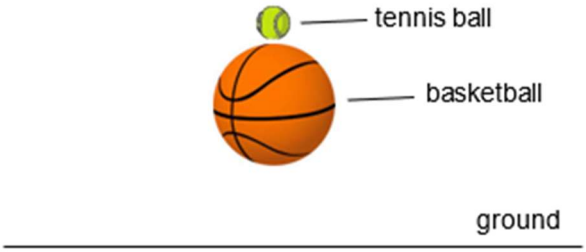

Fig. 1.2

Just before the basketball touches the ground, both the basketball and the tennis ball have the same speed of 4.4 m s^{-1}. The basketball bounces off the ground with a speed of 4.4 m s^{-1}. Its subsequent impact with the tennis ball causes the tennis ball to move up at a very large speed.

(i) Using the expression in **(a)(ii)**, determine the speed of the tennis ball after its collision with the basketball.

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

(ii) Besides the assumptions that all collisions are elastic and air resistance is negligible, state one other assumption that is necessary in order to use the result in **(a)(ii)** to determine the speed for **(b)(i)**.

.....

..... [1]

(iii) The student repeats the experiment, replacing the tennis ball with another ball of much smaller mass.

Deduce the maximum speed the ball can have after its collision with the basketball.

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

9 Fig. 2.1 shows a block of mass M_1 = 4.0 kg released from a vertical height of 6.0 m on a curved frictionless track. It slides down the track and makes a head-on elastic collision with a block of mass M_2 = 9.0 kg that is initially at rest.

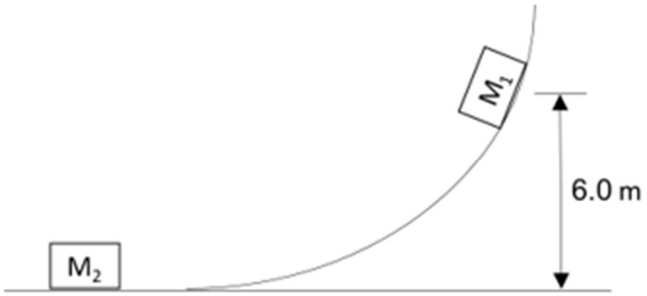

Fig. 2.1

(a) State the principle of conservation of linear momentum.

.....

..... [1]

(b) Calculate the velocity of M_1 just after it collides with M_2.

velocity of M_1 just after collision = ... m s^{-1} [4]

(c) Calculate the maximum height to which M_1 rises after the collision.

maximum height M_1 rises after collision = ... m [2]

9 **(d)** Sketch a graph, on the given axes in Fig. 2.2, to show how the velocity of M_1 varies from the time of its release to the time it reaches maximum height on its return. [3]

Fig. 2.2

10 Fig. 2.1 shows a skateboarder of mass 55 kg about to descend a curved ramp in a skate park.

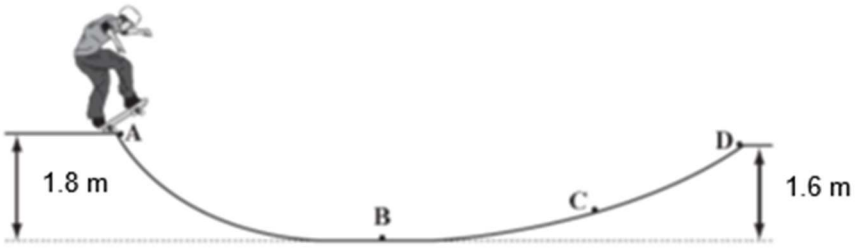

Fig. 2.1

(a) State at which of the points along the track, **A**, **B**, **C** or **D**, the magnitude of the acceleration is the greatest.

..... [1]

(b) The skateboarder is initially at rest. Assuming that there is no frictional force acting from **A** to **B**, calculate the speed the skateboarder would have at **B**.

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

(c) The skateboarder has just enough energy to reach **D** because of friction along **B** to **D**. The length of the track between **B** and **D** is 8.5 m.

Calculate

(i) the energy lost due to friction as the skateboarder moves from **A** to **D**,

energy lost = ... J [2]

(ii) the magnitude of the average frictional force from **B** to **D**.

average frictional force = ... N [2]

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

.....

.....

..... [1]

(b) Solar sail is a method of spacecraft propulsion using radiation pressure exerted by sunlight on large mirrors. The first spacecraft to make use of the technology was IKAROS, launched in 2010.

The solar sail in Fig. 2.1 uses the momentum of photons in solar radiation for propulsion.

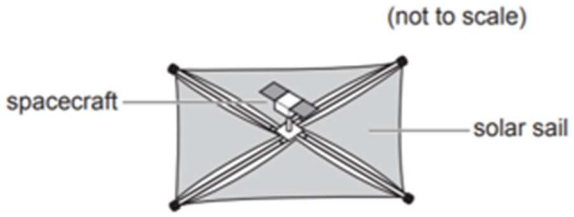

Fig. 2.1

(i) Show that the change in momentum of the spacecraft when a photon that is incident along the normal on a solar sail is reflected is given by $\frac{2E}{c}$, where E is the energy of the photon and c is the speed of light in vacuum.

[3]

(ii) The total power of the radiation received from the Sun on a 1.0 m^2 area of solar sail is 1400 W when the spacecraft is near the Earth. Using your answers from **(b)(i)**, calculate the thrust force from photons reflection.

thrust force = N [3]

11 **(iii)** The spacecraft has a mass of 1000 kg and a solar sail of area 1.0×10^6 m^2. Calculate the acceleration of the spacecraft.

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

(iv) State and explain the difference, if any, your answer in **(b)(iii)** if the solar sail is non-reflective, so that photons are absorbed instead of reflected.

.....

..... [2]

[Total: 10]