Linear Momentum

Question paper 3

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Dynamics
Sub Topic	Linear Momentum
Paper Type	Theory
Booklet	Question paper 3

Time Allowed: **75 minutes**

Score: **/62**

Percentage: **/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 A ball is thrown vertically down towards the ground with an initial velocity of $4.23\,m\,s^{-1}$. The ball falls for a time of 1.51 s before hitting the ground. Air resistance is negligible.

(a) **(i)** Show that the downwards velocity of the ball when it hits the ground is $19.0\,m\,s^{-1}$.

[2]

(ii) Calculate, to three significant figures, the distance the ball falls to the ground.

distance = ... m [2]

(b) The ball makes contact with the ground for 12.5 ms and rebounds with an upwards velocity of $18.6\,m\,s^{-1}$. The mass of the ball is 46.5 g.

(i) Calculate the average force acting on the ball on impact with the ground.

magnitude of force = ... N

direction of force .....
[4]

(ii) Use conservation of energy to determine the maximum height the ball reaches after it hits the ground.

height = ... m [2]

(c) State and explain whether the collision the ball makes with the ground is elastic or inelastic.

.....

.....

.....[1]

2 **(a)** State the relation between force and momentum.

..... [1]

(b) A rigid bar of mass 450 g is held horizontally by two supports A and B, as shown in Fig. 3.1.

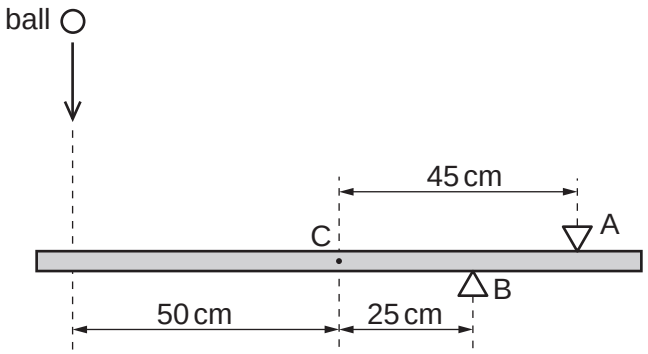

Fig. 3.1

The support A is 45 cm from the centre of gravity C of the bar and support B is 25 cm from C.

A ball of mass 140 g falls vertically onto the bar such that it hits the bar at a distance of 50 cm from C, as shown in Fig. 3.1.
The variation with time *t* of the velocity *v* of the ball before, during and after hitting the bar is shown in Fig. 3.2.

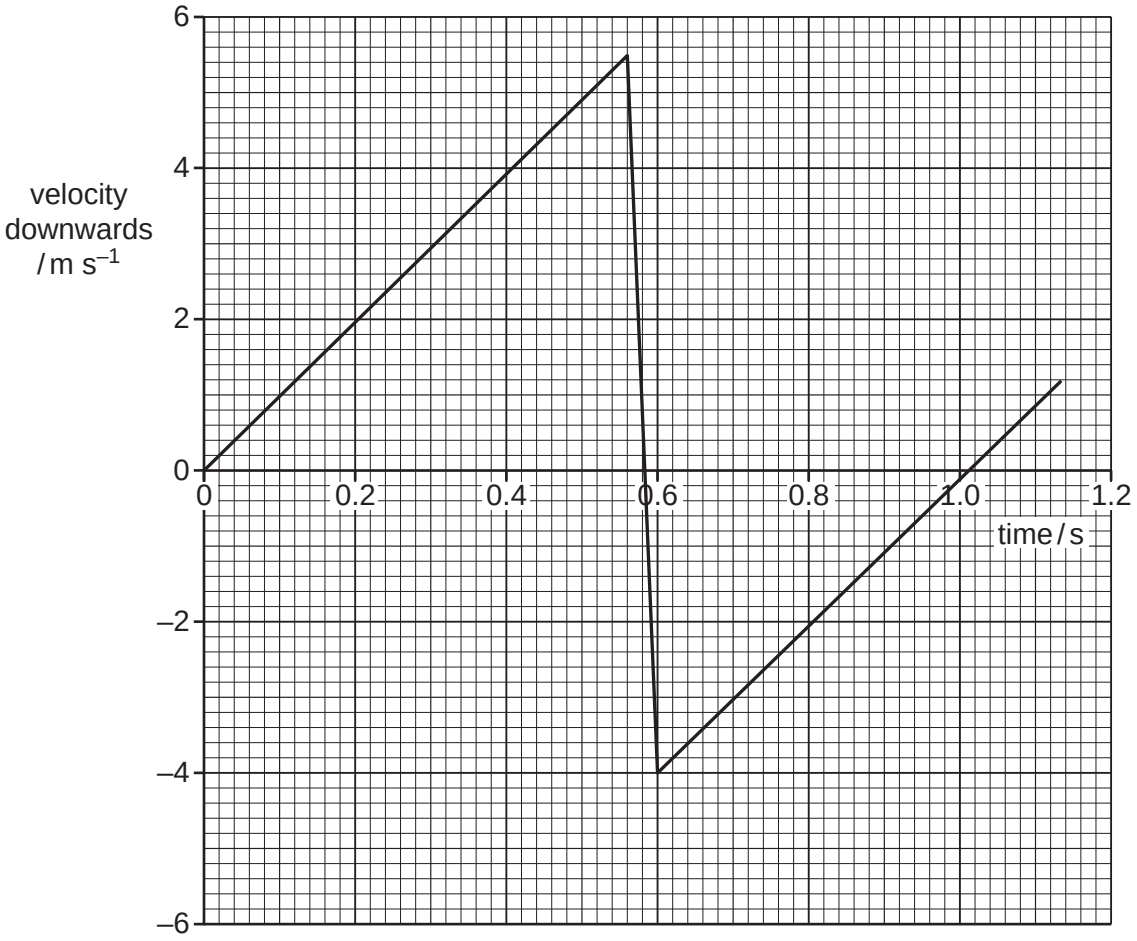

Fig. 3.2

For the time that the ball is in contact with the bar, use Fig. 3.2

(i) to determine the change in momentum of the ball,

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

(ii) to show that the force exerted by the ball on the bar is 33 N.

[1]

(c) For the time that the ball is in contact with the bar, use data from Fig. 3.1 and **(b)(ii)** to calculate the force exerted on the bar by

(i) the support A,

force = ... N [3]

(ii) the support B.

force = ... N [2]

3 Two oppositely-charged parallel metal plates are situated in a vacuum, as shown in Fig. 7.1.

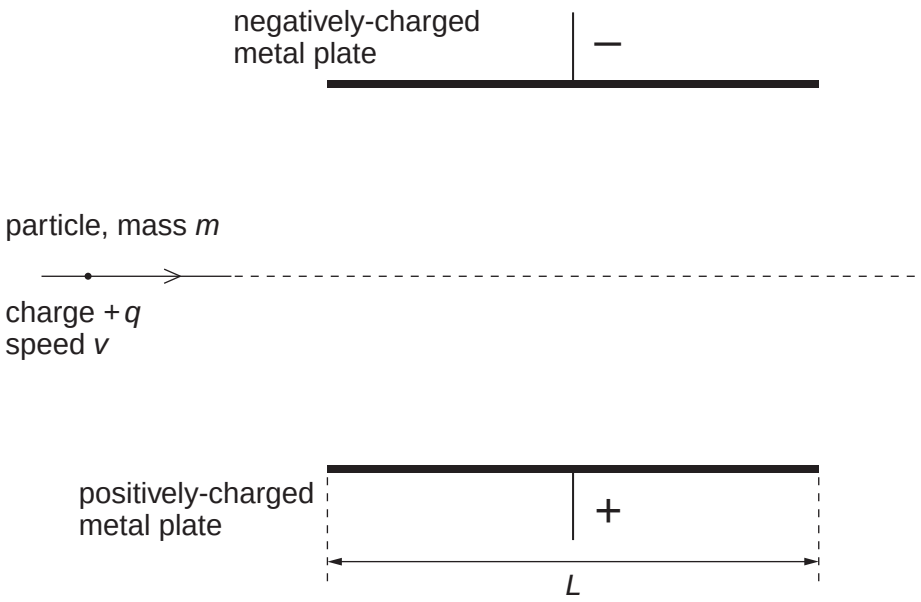

Fig. 7.1

The plates have length *L*.
The uniform electric field between the plates has magnitude *E*. The electric field outside the plates is zero.

A positively-charged particle has mass *m* and charge +*q*. Before the particle reaches the region between the plates, it is travelling with speed *v* parallel to the plates.
The particle passes between the plates and into the region beyond them.

(a) (i) On Fig. 7.1, draw the path of the particle between the plates and beyond them. [2]

(ii) For the particle in the region between the plates, state expressions, in terms of *E*, *m*, *q*, *v* and *L*, as appropriate, for

1. the force *F* on the particle,

..... [1]

2. the time *t* for the particle to cross the region between the plates.

..... [1]

(b) (i) State the law of conservation of linear momentum.

.....

.....

..... [2]

(ii) Use your answers in **(a)(ii)** to state an expression for the change in momentum of the particle.

..... [1]

(iii) Suggest and explain whether the law of conservation of linear momentum applies to the particle moving between the plates.

.....

.....

..... [2]

4 **(a)** **(i)** Define *force*.

.....

.....[1]

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

.....

.....

.....

.....[3]

(b) Two spheres approach one another along a line joining their centres, as illustrated in Fig. 3.1.

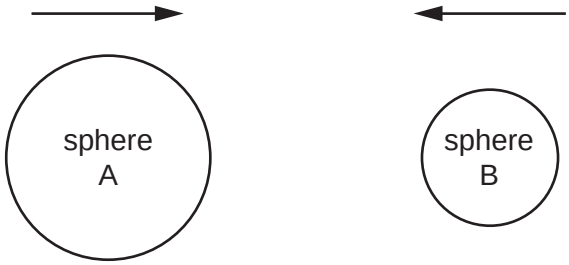

Fig. 3.1

When they collide, the average force acting on sphere A is F_A and the average force acting on sphere B is F_B.

The forces act for time t_A on sphere A and time t_B on sphere B.

(i) State the relationship between

1. F_A and F_B,

.....[1]

2. t_A and t_B.

.....[1]

(ii) Use your answers in **(i)** to show that the change in momentum of sphere A is equal in magnitude and opposite in direction to the change in momentum of sphere B.

.....

.....[1]

(c) For the spheres in **(b)**, the variation with time of the momentum of sphere A before, during and after the collision with sphere B is shown in Fig. 3.2.

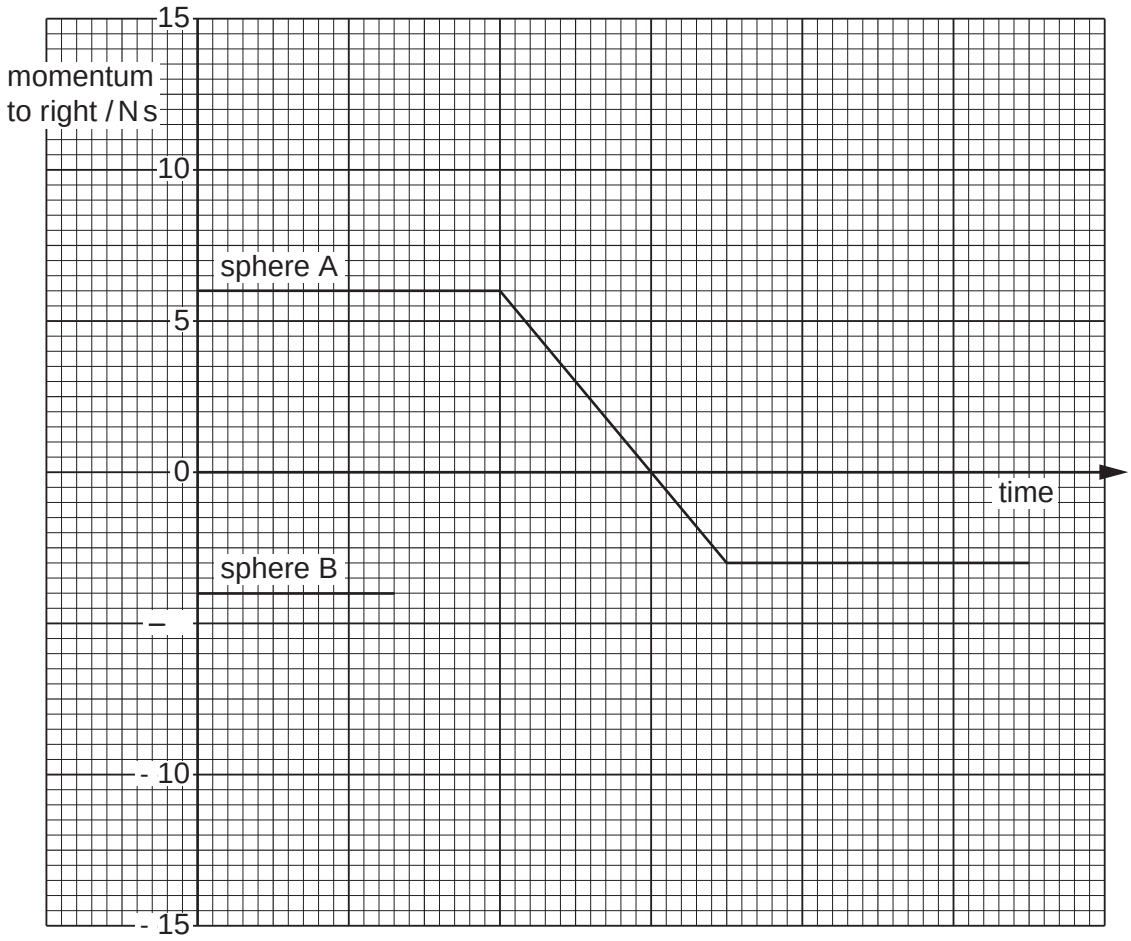

Fig. 3.2

The momentum of sphere B before the collision is also shown on Fig. 3.2.

Complete Fig. 3.2 to show the variation with time of the momentum of sphere B during and after the collision with sphere A. [3]

5 A spring is placed on a flat surface and different weights are placed on it, as shown in Fig. 2.1.

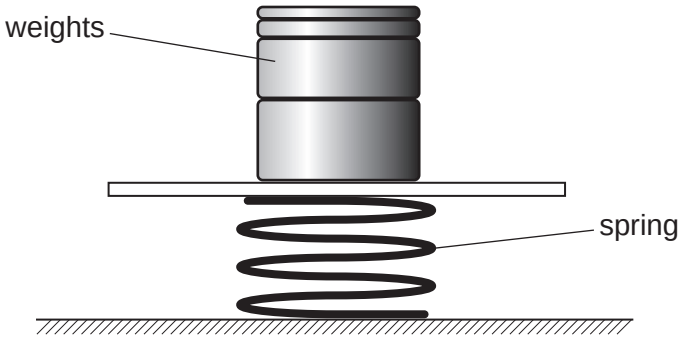

Fig. 2.1

The variation with weight of the compression of the spring is shown in Fig. 2.2.

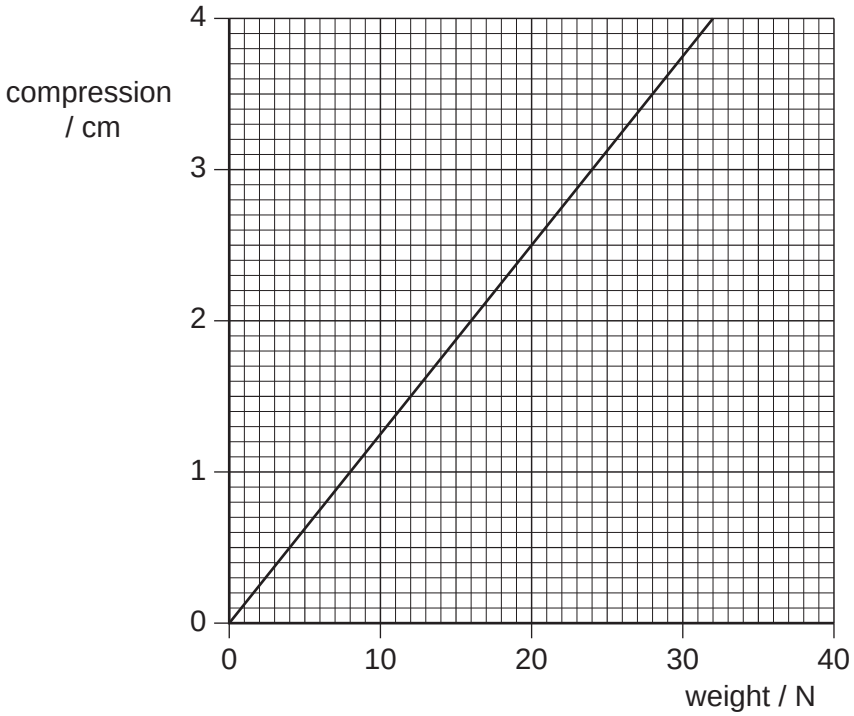

Fig. 2.2

The elastic limit of the spring has not been exceeded.

(a) (i) Determine the spring constant *k* of the spring.

k = ... $N\,m^{-1}$ [2]

(ii) Deduce that the strain energy stored in the spring is 0.49 J for a compression of 3.5 cm.

[2]

(b) Two trolleys, of masses 800 g and 2400 g, are free to move on a horizontal table. The spring in **(a)** is placed between the trolleys and the trolleys are tied together using thread so that the compression of the spring is 3.5 cm, as shown in Fig. 2.3.

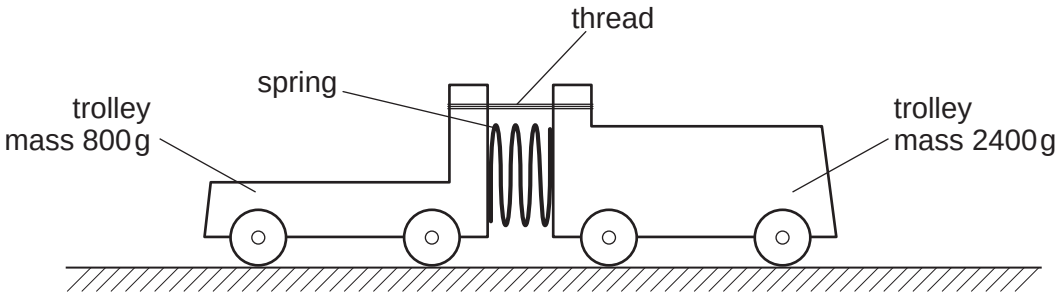

Fig. 2.3

Initially, the trolleys are not moving.
The thread is then cut and the trolleys move apart.

(i) Deduce that the ratio

$$\frac{\text{speed of trolley of mass 800 g}}{\text{speed of trolley of mass 2400 g}}$$

is equal to 3.0.

[2]

(ii) Use the answers in **(a)(ii)** and **(b)(i)** to calculate the speed of the trolley of mass 800 g.

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

6 A girl stands at the top of a cliff and throws a ball vertically upwards with a speed of $12\,m\,s^{-1}$, as illustrated in Fig. 3.1.

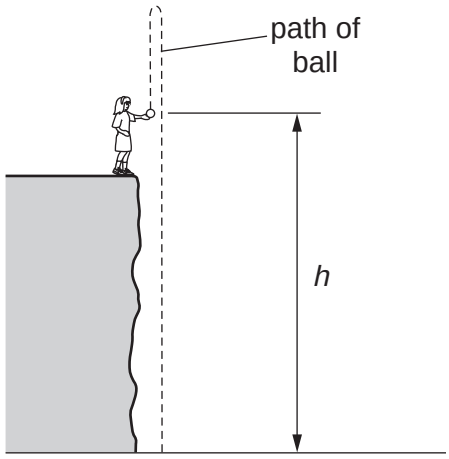

Fig. 3.1

At the time that the girl throws the ball, her hand is a height *h* above the horizontal ground at the base of the cliff.
The variation with time *t* of the speed *v* of the ball is shown in Fig. 3.2.

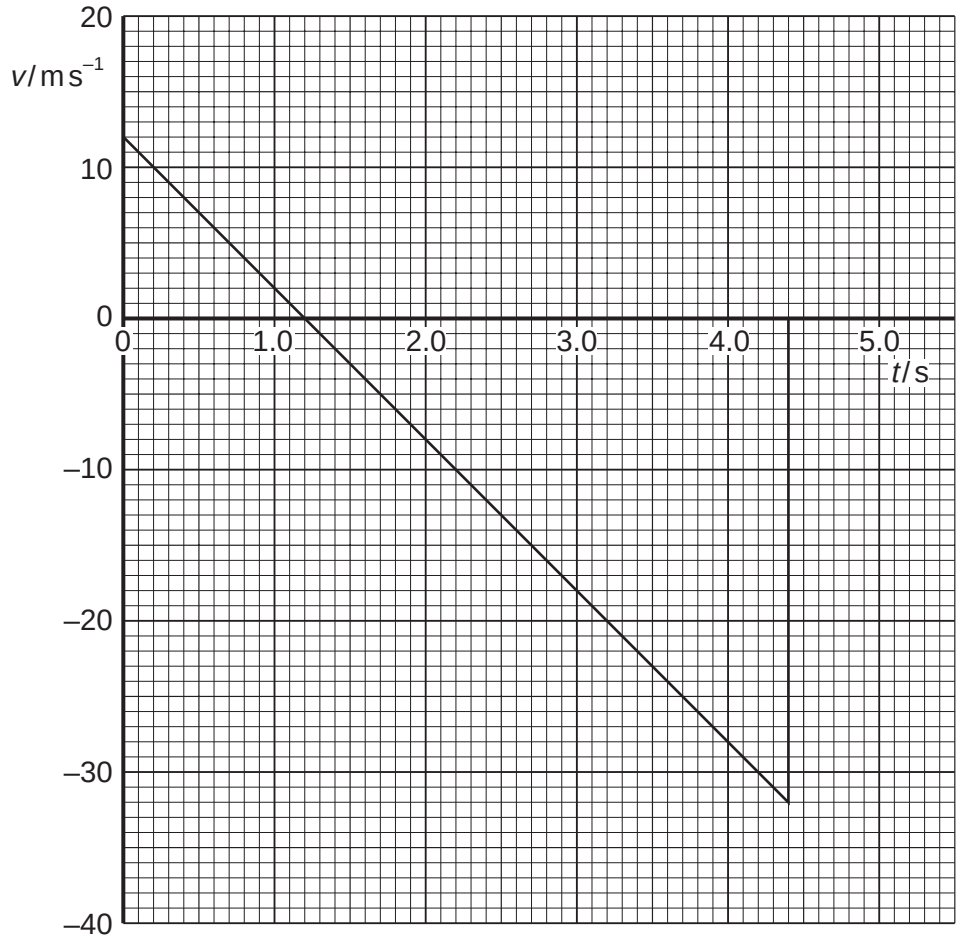

Fig. 3.2

Speeds in the upward direction are shown as being positive. Speeds in the downward direction are negative.

(a) State the feature of Fig. 3.2 that shows that the acceleration is constant.

..... [1]

(b) Use Fig. 3.2 to determine the time at which the ball

(i) reaches maximum height,

time = ... s

(ii) hits the ground at the base of the cliff.

time = ... s
[2]

(c) Determine the maximum height above the base of the cliff to which the ball rises.

height = ... m [3]

(d) The ball has mass 250 g. Calculate the magnitude of the change in momentum of the ball between the time that it leaves the girl's hand to time t = 4.0 s.

change = ... N s [3]

(e) **(i)** State the principle of conservation of momentum.

.....

.....

..... [2]

(ii) Comment on your answer to **(d)** by reference to this principle.

.....

.....

.....

..... [3]