Linear Momentum

Question paper 2

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Dynamics
Sub Topic	Linear Momentum
Paper Type	Theory
Booklet	Question paper 2

Time Allowed: **66 minutes**

Score: **/55**

Percentage: **/100**

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

1 A stationary nucleus of mass 220u undergoes radioactive decay to produce a nucleus D of mass 216u and an α-particle of mass 4u, as illustrated in Fig. 3.1.

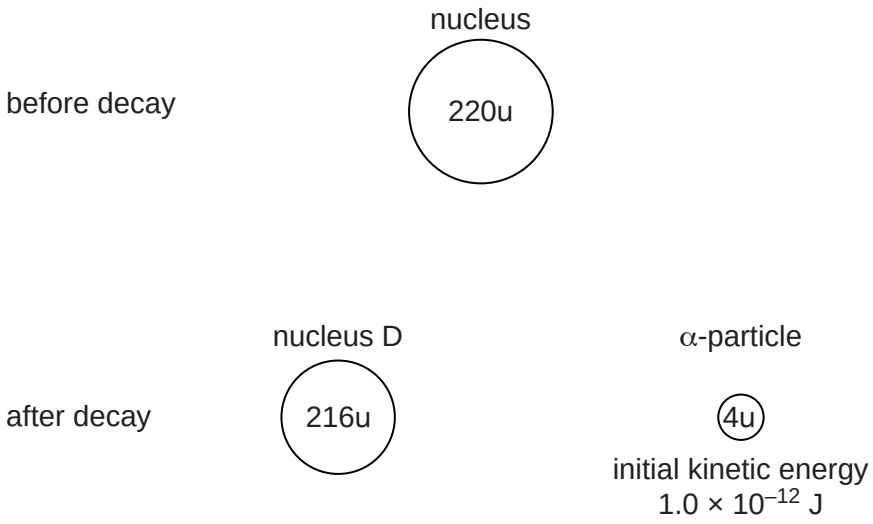

Fig. 3.1

The initial kinetic energy of the α-particle is 1.0×10^{-12} J.

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

.....

.....

..... [2]

(ii) Explain why the initial velocities of the nucleus D and the α-particle must be in opposite directions.

.....

.....

..... [2]

(b) (i) Show that the initial speed of the α-particle is $1.7 \times 10^{7}\,\text{m s}^{-1}$.

(ii) Calculate the initial speed of nucleus D.

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

(c) The range in air of the emitted α-particle is 4.5 cm.
Calculate the average deceleration of the α-particle as it is stopped by the air.

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

2 A small ball is thrown horizontally with a speed of $4.0\,m\,s^{-1}$. It falls through a vertical height of 1.96 m before bouncing off a horizontal plate, as illustrated in Fig. 3.1.

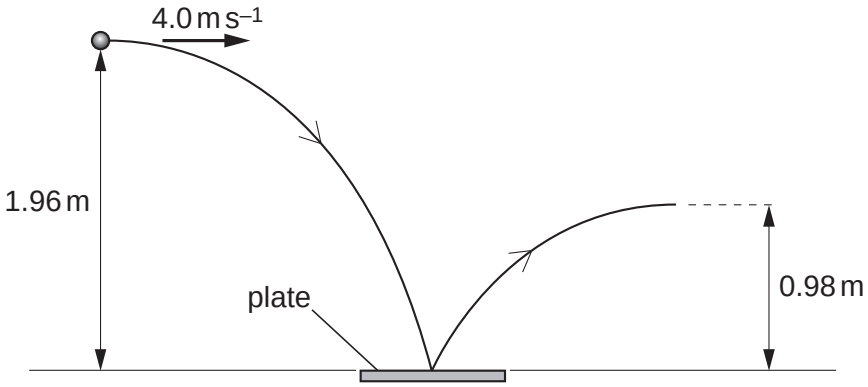

Fig. 3.1

Air resistance is negligible.

(a) For the ball, as it hits the horizontal plate,

(i) state the magnitude of the horizontal component of its velocity,

horizontal velocity = ... $m\,s^{-1}$ [1]

(ii) show that the vertical component of the velocity is $6.2\,m\,s^{-1}$.

[1]

(b) The components of the velocity in **(a)** are both vectors.

Complete Fig. 3.2 to draw a vector diagram, to scale, to determine the velocity of the ball as it hits the horizontal plate.

Fig. 3.2

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

at ..... ° to the vertical
[3]

(c) After bouncing on the plate, the ball rises to a vertical height of 0.98 m.

(i) Calculate the vertical component of the velocity of the ball as it leaves the plate.

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

(ii) The ball of mass 34 g is in contact with the plate for a time of 0.12 s.

Use your answer in **(c)(i)** and the data in **(a)(ii)** to calculate, for the ball as it bounces on the plate,

1. the change in momentum,

change = ... kg m s^{-1} [3]

2. the magnitude of the average force exerted by the plate on the ball due to this momentum change.

force = ... N [2]

3 A ball B of mass 1.2 kg travelling at constant velocity collides head-on with a stationary ball S of mass 3.6 kg, as shown in Fig. 2.1.

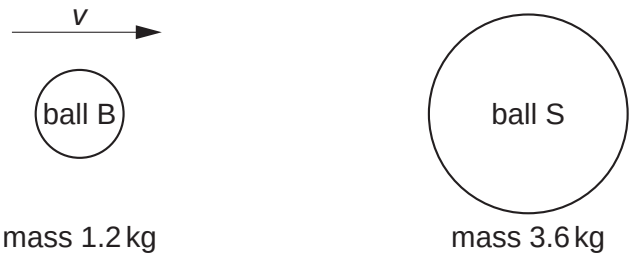

Fig. 2.1

Frictional forces are negligible.

The variation with time *t* of the velocity *v* of ball B before, during and after colliding with ball S is shown in Fig. 2.2.

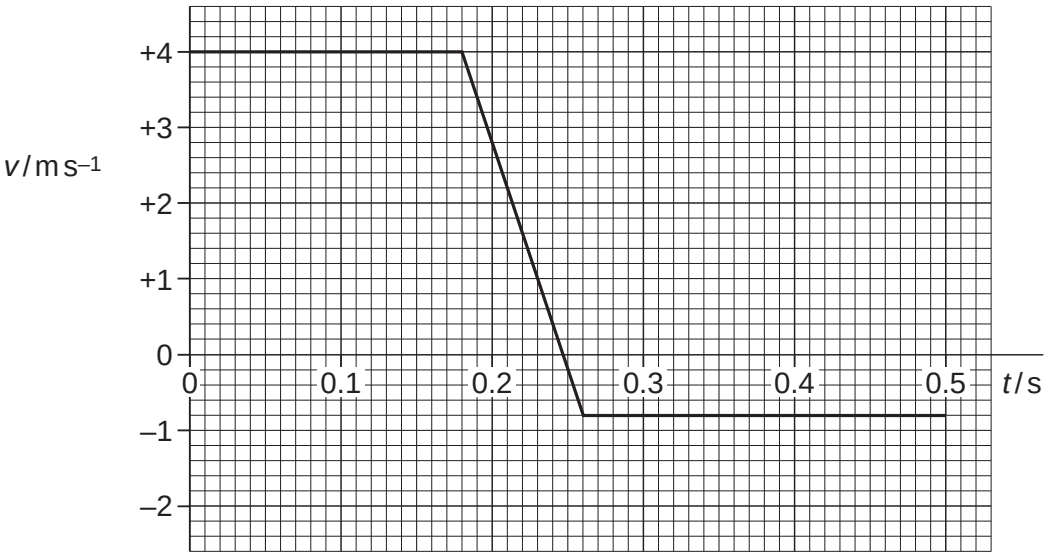

Fig. 2.2

(a) State the significance of positive and negative values for *v* in Fig. 2.2.

.....

..... [1]

(b) Use Fig. 2.2 to determine, for ball B during the collision with ball S,

(i) the change in momentum of ball B,

change in momentum = ... Ns [3]

(ii) the magnitude of the force acting on ball B.

force = ... N [3]

(c) Calculate the speed of ball S after the collision.

speed = ... ms^{-1} [2]

(d) Using your answer in **(c)** and information from Fig. 2.2, deduce quantitatively whether the collision is elastic or inelastic.

.....

..... [2]

4 Francium-208 is radioactive and emits α- particles with a kinetic energy of 1.07×10^{-12} J to form nuclei of astatine, as illustrated in Fig. 3.1.

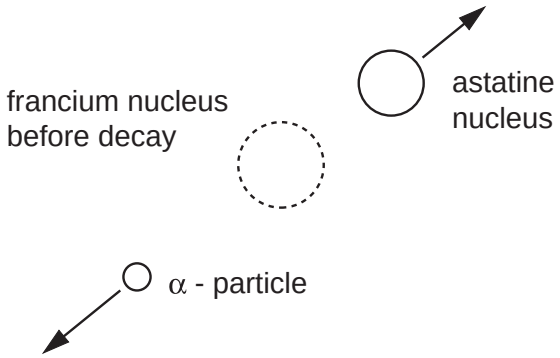

Fig. 3.1

(a) State the nature of an α-particle.

.....

..... [1]

(b) Show that the initial speed of an α-particle after the decay of a francium nucleus is approximately $1.8 \times 10^{7}\,\text{m s}^{-1}$.

[2]

(c) **(i)** State the principle of conservation of linear momentum.

.....

.....

..... [2]

(ii) The Francium-208 nucleus is stationary before the decay. Estimate the speed of the astatine nucleus immediately after the decay.

speed = …… $m\,s^{-1}$ [3]

(d) Close examination of the decay of the francium nucleus indicates that the astatine nucleus and the α-particle are not ejected exactly in opposite directions.

Suggest an explanation for this observation.

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..... [2]

5 A ball has mass m. It is dropped onto a horizontal plate as shown in Fig. 4.1.

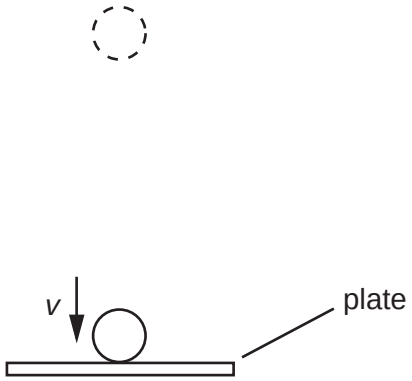

Fig. 4.1

Just as the ball makes contact with the plate, it has velocity v, momentum p and kinetic energy E_k.

(a) (i) Write down an expression for momentum p in terms of m and v.

.....

(ii) Hence show that the kinetic energy is given by the expression

$$E_k = \frac{p^2}{2m}.$$

[3]

(b) Just before impact with the plate, the ball of mass 35 g has speed 4.5 m s^{-1}. It bounces from the plate so that its speed immediately after losing contact with the plate is 3.5 m s^{-1}. The ball is in contact with the plate for 0.14 s.

Calculate, for the time that the ball is in contact with the plate,

(i) the average force, in addition to the weight of the ball, that the plate exerts on the ball,

magnitude of force = ... N

direction of force = ...
[4]

(ii) the loss in kinetic energy of the ball.

loss = ... J [2]

(c) State and explain whether linear momentum is conserved during the bounce.

.....

.....

.....

..... [3]