A Level · OCR · Physics

41 mins · 4 questions

Structured Questions

Newton's Laws of Motion & Momentum

Newton's Three Laws of Motion / Linear Momentum / Impulse / Impulse on a Force-Time Graph / Conservation of Momentum / Collisions

Medium (3 questions)	/29
Hard (1 question)	/12
Total Marks	**/41**

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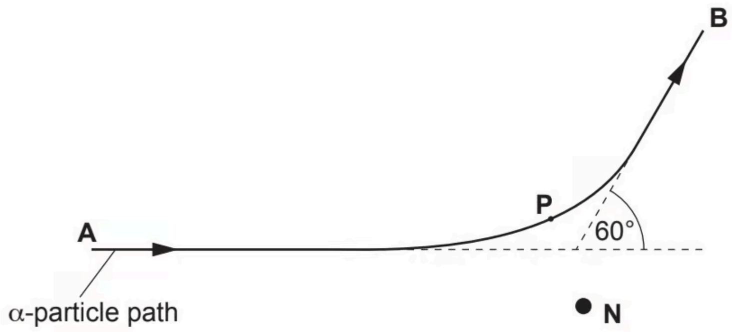
Medium Questions

1 (a) A beam of α-particles is incident on a thin gold foil. Most α-particles pass straight through the foil.

A few are deflected by gold nuclei.

The diagram shows the path of one α-particle which passes close to a gold nucleus **N** in the foil. The α-particle is deflected through an angle of 60° as it travels from **A** to **B**.

P marks its position of closest approach to the gold nucleus.



Another α-particle in the beam is deflected by the same gold nucleus **N** through an angle of 30°.

Sketch its path onto the diagram above.

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(2 marks)

(b) The distance between **P** and **N** is 6.8×10^{-14} m.

Calculate the magnitude of the electrostatic force F between the α-particle ($^{4}_{2}\text{He}$) and the gold nucleus ($^{197}_{79}\text{Au}$) when the α-particle is at **P**.

F = ... N

(4 marks)

(c) The initial kinetic energy of each α-particle is 5.0 MeV.

Show that the magnitude of the initial momentum of each α-particle is about 10^{-19} kg m s^{-1}.

Take the mass of the α-particle to be 6.6×10^{-27} kg.

(3 marks)

(d) The magnitude of the final momentum of the α-particle at **B** is equal to its initial value at **A**.

The gold nucleus **N** is initially at rest. During the passage of the α-particle from **A** to **B**, no other forces act on the two particles.

In the following questions label any relevant angles.

i) Draw two vectors in the spaces below to represent the initial momentum and the final momentum of the α-particle.

initial momentum at **A**

final momentum at **B**

[2]

ii) Draw a vector in the space below to represent the momentum of the nucleus **N** when the α-particle reaches **B**.

Explain how you determined this momentum.

[2]

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(4 marks)

2 (a) A bicycle manufacturer carries out tests on the braking system of their new model.

A cyclist on this new bicycle travels at a constant initial speed U.

The cyclist applies the brakes at time t = 0 and the bicycle comes to a stop at time t = 2.0 s.

Fig. 20.1 shows the variation of the braking force F on the bicycle with time t.

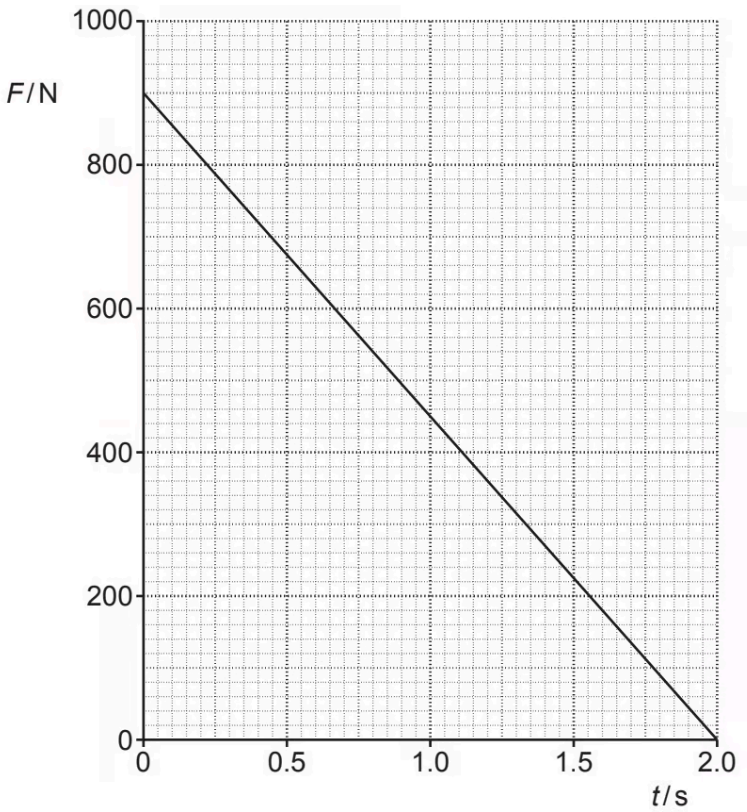

Fig. 20.1

Use Newton's second law of motion to explain the physical quantity represented by the area under the graph shown in Fig. 20.1.

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(2 marks)

(b) The total mass of cyclist and bicycle is 71 kg.

Use Fig. 20.1 to calculate the initial speed U.

U = ... ms^{-1}

(2 marks)

(c) Complete Fig. 20.2 to show the variation of the speed of the bicycle from t = 0 to t = 2.0 s.

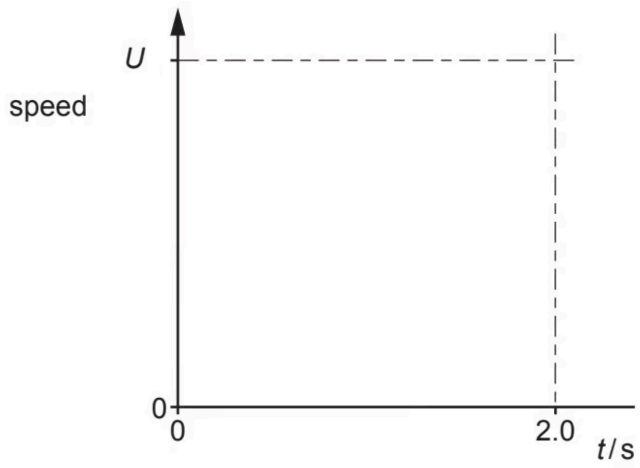

Fig. 20.2

(2 marks)

3 (a) A helium atom **X** travelling at 610 m s^{-1} makes an elastic collision with a stationary helium atom **Y**. The magnitude of the velocity of **X** after the collision is 258 m s^{-1}.

The directions of the velocities of **X** and **Y** are as shown in Fig. 22.

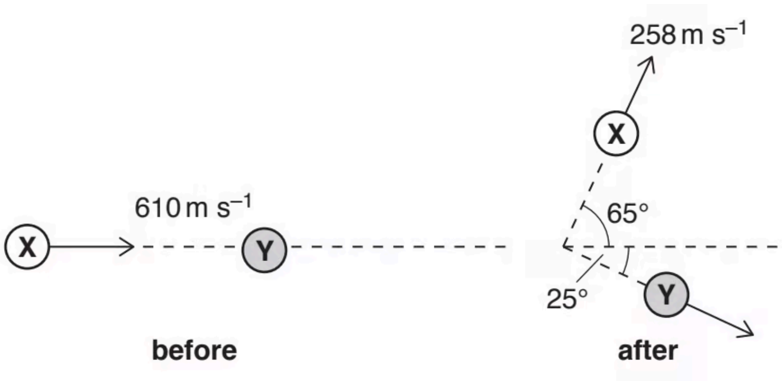

Fig. 22

i) Explain what is meant by an *elastic collision*.

[1]

ii) The mass of a helium atom is 6.64×10^{-27} kg.

Calculate the magnitude of the momentum p of **Y** after the collision.

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

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(4 marks)

(b) There is a lot of helium in the Universe. This was also true of the Earth when it was formed billions of years ago. However, only small traces of helium are now found in the atmosphere of the Earth.

Use the kinetic theory of gases to explain why only small amounts of helium are found in the Earth's atmosphere. Use the information below to do suitable calculations to support your answer.

- typical atmospheric temperature = 10°C
- mass of helium atom = 6.64×10^{-27} kg
- escape velocity from the Earth = 11 km s^{-1}

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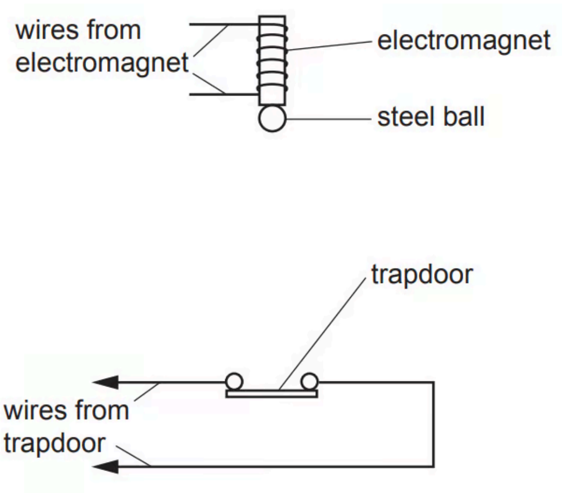
(6 marks)

Hard Questions

1 (a) A student wants to determine the value of the acceleration of freefall *g*.

The diagram below shows part of the arrangement which the student used.



A steel ball is dropped from an electromagnet. The ball falls vertically. The ball hits a trapdoor and opens the trapdoor.

The ball travels a distance *s* from the bottom of the electromagnet to the trapdoor in a time *t*.

The student uses the equation $s = \frac{1}{2}gt^2$ to determine *g*.

i) Show that the equation $s = \frac{1}{2}gt^2$ is homogeneous, with both sides of the equation having the same base units.

[2]

ii) Describe how the student could use standard laboratory equipment to take accurate measurements of the distance *s* and the time t.

[4]

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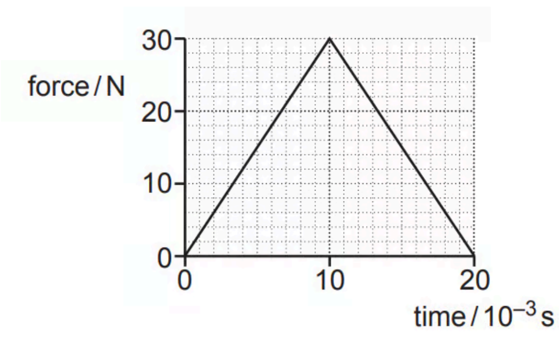
(6 marks)

(b) The trapdoor falls downwards when the ball hits it.

The ball collides **elastically** with the trapdoor with a speed of 4.4 m s^{-1}.

The graph of force acting on the ball against time is shown below.



The mass of the ball is 0.050 kg.

i) Calculate the initial momentum p_1 of the ball just before it hits the trapdoor.

p_1 = ... kg m s^{-1} **[1]**

ii) Use the graph to calculate the magnitude of the final momentum p_2 of the ball immediately after the collision.

p_2 = ... kg m s^{-1} **[3]**

iii) The mass of the trapdoor is 100 g.

Calculate the final speed v of the trapdoor immediately after the collision.

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

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(6 marks)