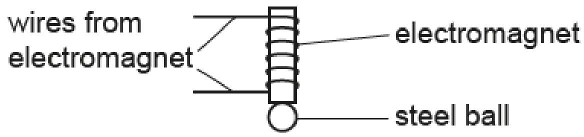
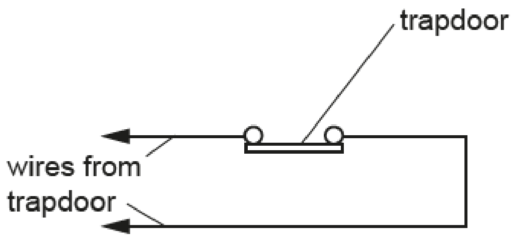
Newton's laws of motion and momentum – 2021/20 GCE Physics A Component 01

1. Nov/2020/Paper_H556_01/No.16

A student wants to determine the value of the acceleration of freefall g.

(a) 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.

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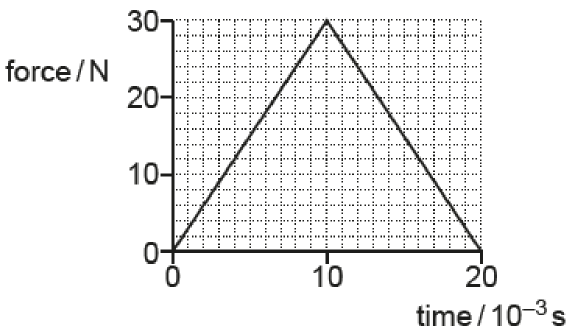
.... **[4]**

(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]**

2. Nov/2020/Paper_H556_01/No.21(b)

(b) The temperature of the kiln is 1300 °C.
A single atom of argon is travelling horizontally towards the vertical side **X** of the chamber. The initial speed of this atom is 990 $m s^{-1}$. After collision, it rebounds at the same speed.

(i) Calculate the change in momentum Δp of this atom.

- mass of argon atom = 6.6×10^{-26} kg

Δp = ... $kg m s^{-1}$ **[2]**

(ii) Assume that this atom does not collide with any other argon atoms inside the chamber. Instead, it travels horizontally, making repeated collisions with the opposite vertical walls of the chamber.

1 Show that the atom makes about 1000 collisions with side **X** in a time interval of 1.0 s.

[1]

2 Calculate the average force F on side **X** made by the atom.

F = ... N **[2]**

(iii) Without calculation, explain how your answer to **(ii)2** could be used to estimate the total pressure exerted by the atoms of the argon gas in the kiln.

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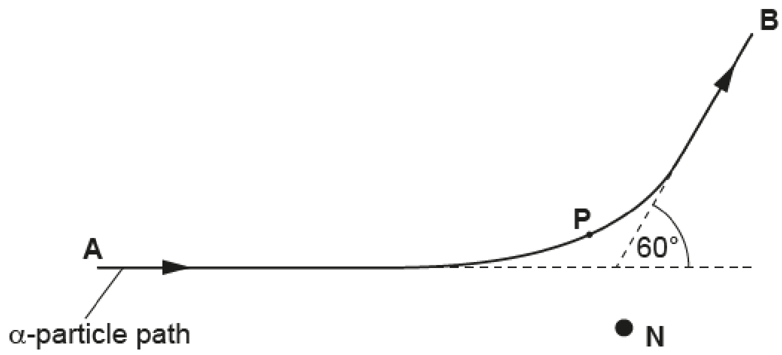
.... **[2]**

3. Nov/2020/Paper_H556_03/No.6(c_ d)

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.



(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 $10^{-19}\,\text{kg}\,\text{m}\,\text{s}^{-1}$.
Take the mass of the α-particle to be 6.6×10^{-27} kg.

[3]

(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.

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.... **[2]**