Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

# A-level PHYSICS

## Paper 2

Specimen materials (set 2)

Time allowed: 2 hours

### Materials

For this paper you must have:

- a pencil
- a ruler
- a scientific calculator
- a Data and Formulae booklet.

### Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

### Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 85.
- You are expected to use a calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

| For Examiner's Use | |
|---|---|
| Question | Mark |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| MC | |
| **TOTAL** | |

## Section A

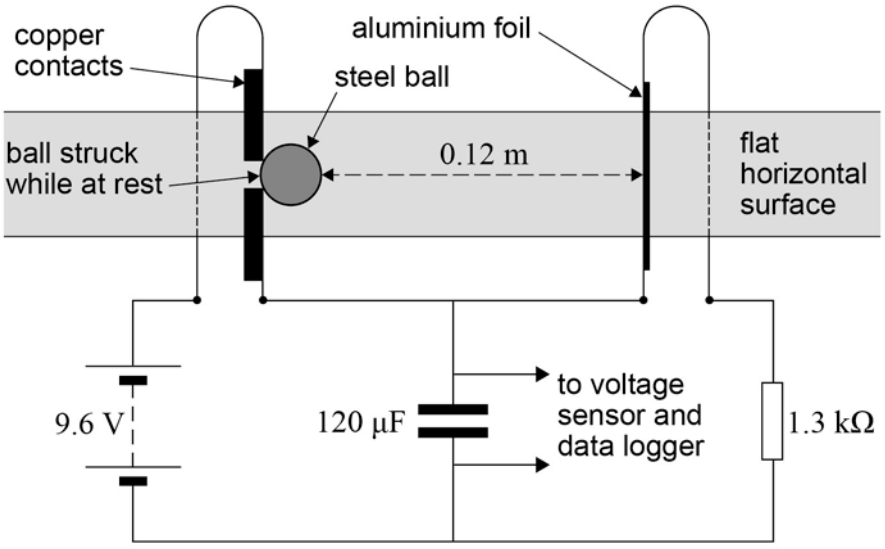
Answer **all** questions in this section.

**0 1 . 1** Explain what is meant by a capacitance of $120\ \mu\text{F}$.

**[1 mark]**

**0 1 . 2** **Figure 1** shows a plan view of the apparatus used by a student to measure the speed of a steel ball immediately after it has been struck from rest.

**Figure 1**

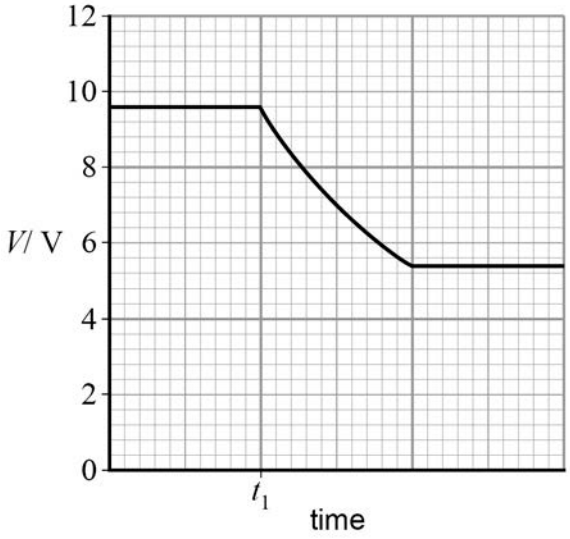



When the ball is touching the copper contacts, the $120\ \mu\text{F}$ capacitor charges to a potential difference of $9.6\ \text{V}$. Once the ball has left the contacts, the capacitor discharges through the $1.3\ \text{k}\Omega$ resistor. When the ball has travelled a distance of $0.12\ \text{m}$, it breaks the aluminium foil so that the capacitor stops discharging.

**Figure 2** shows the variation of potential difference $V$ recorded by the data logger.

The ball is struck at time $t_1$.

**Figure 2**




Calculate the charge that passes through the resistor as the capacitor discharges.

**[1 mark]**

charge = _____ C

**0 1 . 3** Calculate the maximum current in the resistor during the experiment shown in **Figure 2**.

**[1 mark]**

maximum current = _____ A

**0 1 . 4** Calculate the energy that is transferred as the capacitor discharges through the $1.3\ \text{k}\Omega$ resistor.

**[3 marks]**

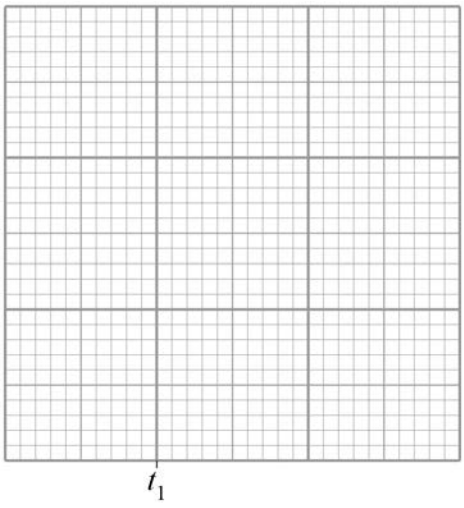
energy = _____ J

**0 1 . 5** Sketch a graph on the axes of **Figure 3** that shows the variation of the magnitude of the current in the resistor during the time interval shown in **Figure 2**.

A scale is required on the current axis but not on the time axis.

**[3 marks]**

**Figure 3**



**0 1 . 6** Calculate the time for which the capacitor is discharging and hence determine the mean speed of the ball.

**[4 marks]**

speed = _____ $m\ s^{-1}$

**0 1 . 7** Discuss **two** reasons why your answer to **Question 1.6** is likely to be lower than the speed of the ball immediately after it is struck.

**[2 marks]**

_____

_____

_____

_____

**15**

**Turn over for the next question**

**0 2** Read the following passage and answer the questions that follow.

A mass spectrometer is an instrument for measuring the masses of isotopes. The main working parts of the instrument are shown in **Figure 4**.

**Figure 4**

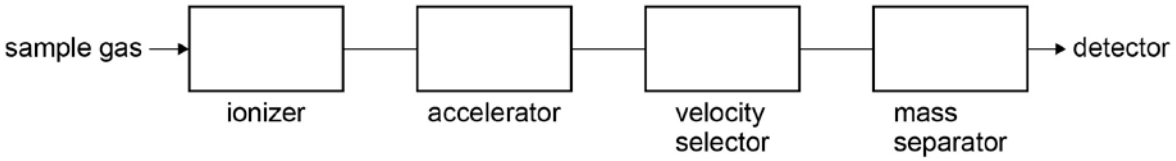
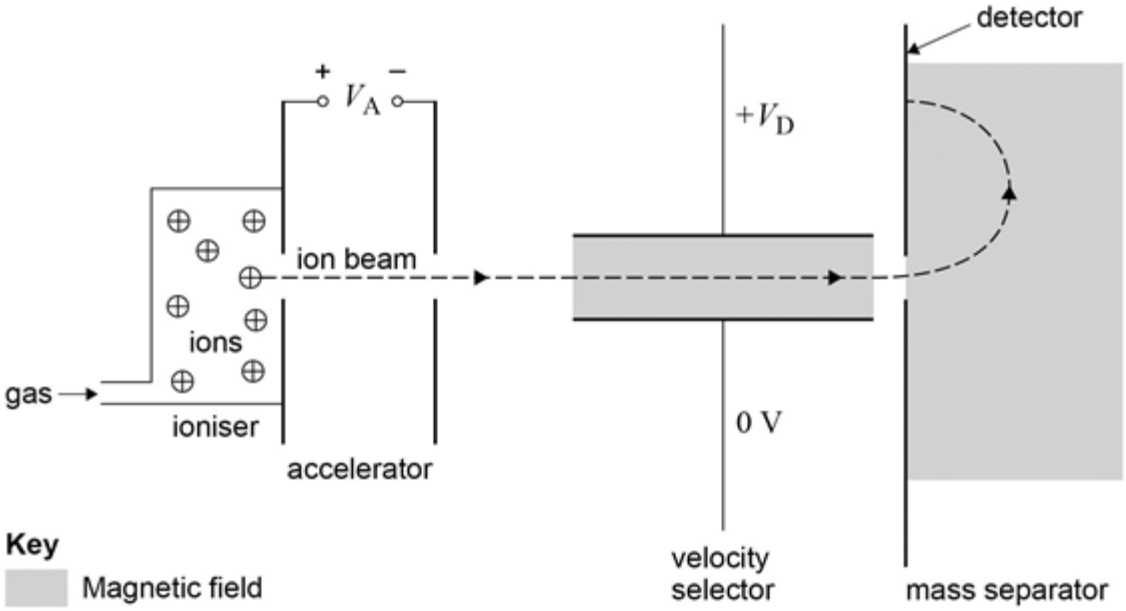



**Figure 5** shows the components in more detail. Positive ions are created in the ionizer. Some of these ions enter the accelerator where they are accelerated by a potential difference $V_A$. The ions emerge from the accelerator with different speeds and enter the velocity selector.

The velocity selector contains a region where there is a uniform magnetic field at right angles to an electric field. This electric field is formed between two parallel plates held at a potential difference $V_D$. This combination of fields only allows ions of a particular velocity to enter the mass separator. Here ions of different mass are separated by a uniform magnetic field. Finally the ions are detected.

**Figure 5**




**0 2 . 1** Explain what is meant by ionisation.

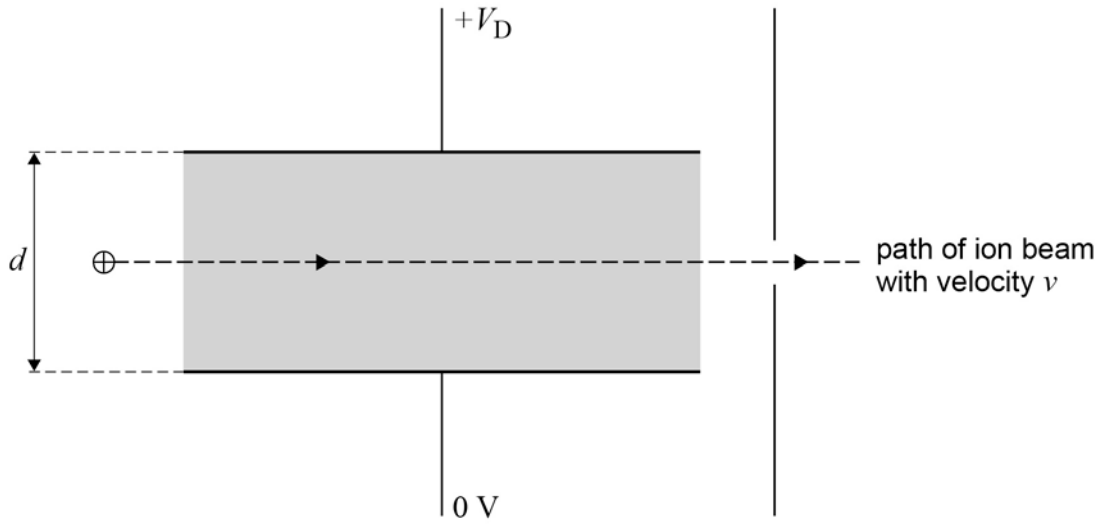
**[1 mark]**

**0 2 . 2** Discuss the energy transfers that take place in the accelerator as the ion passes through it. Assume the ions are in a perfect vacuum.

**[3 marks]**

**0 2 . 3** **Figure 6** shows the path taken by an ion that moves through the velocity selector at a velocity $v$.

**Figure 6**




Discuss how the path changes when an ion enters the velocity selector with a velocity greater than $v$.

**[3 marks]**

**0 2 . 4** Draw, on **Figure 6**, the path of the ion that is suggested by your answer to **Question 2.3**.

**[1 mark]**

**Question 2 continues on the next page**

**0 2 . 5** Ions created in the ioniser may have the same charge but a different number of nucleons.

Discuss how the path of an ion in the mass separator is affected when it has more nucleons.

**[2 marks]**

**0 2 . 6** Some ions are created with the same mass but a double charge. The path of the ions shown in **Figure 5** is that of a singly charged ion.

Compare, with justification, the path of a doubly charged ion through the mass spectrometer with that of a singly charged ion of the same mass.

**[3 marks]**

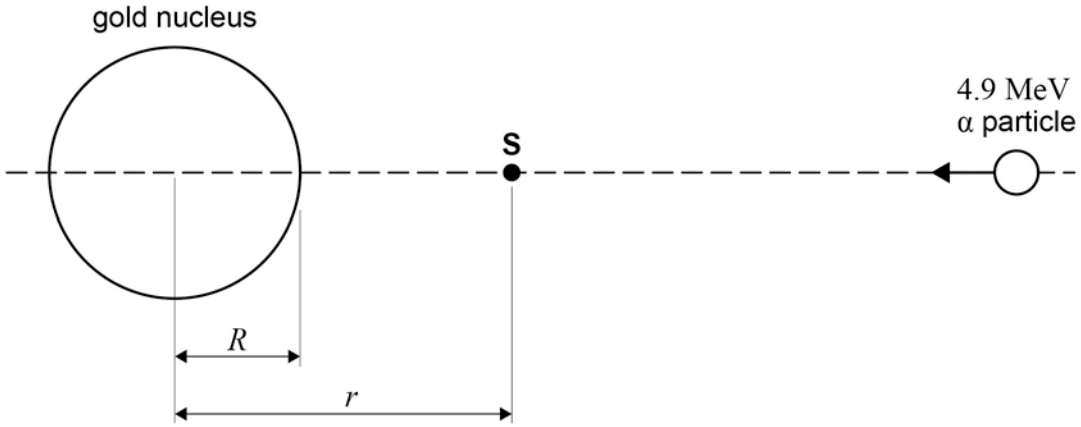
**13**

**Turn over for the next question**

**DO NOT WRITE ON THIS PAGE**
**ANSWER IN THE SPACES PROVIDED**

**0 3** An $\alpha$ particle with an initial kinetic energy of $4.9\ \text{MeV}$ is directed towards the centre of a gold nucleus of radius $R$ which contains $79$ protons. The $\alpha$ particle is brought to rest at point **S**, a distance $r$ from the centre of the nucleus as shown in **Figure 7**.

**Figure 7**




**0 3 . 1** Calculate the electric potential energy, in J, of the $\alpha$ particle at point **S**.

**[2 marks]**

electric potential energy = _____ J

**0 3 . 2** Calculate $r$, the distance of closest approach of the $\alpha$ particle to the nucleus.

**[3 marks]**

$r$ = _____ m

**0 3 . 3** Determine the number of nucleons in the gold nucleus.

$R$, radius of the gold nucleus = $7.16 \times 10^{-15}$ m
$R_0 = 1.23 \times 10^{-15}$ m

**[3 marks]**

number of nucleons = _____

**0 3 . 4** The target nucleus is changed to one that has fewer protons. The $\alpha$ particle is given the same initial kinetic energy.

Explain, without further calculation, any changes that occur to the distance $r$.
Ignore any recoil effects.

**[2 marks]**

_____

_____

_____

_____

10

**0 4 . 1** Define the gravitational potential at a point.

**[2 marks]**

**0 4 . 2** Explain why gravitational potential is always negative.

**[2 marks]**

**0 4 . 3** Show that the magnitude of the gravitational potential at the Earth's surface due to the mass of the Earth is about $6.3 \times 10^7$ J kg$^{-1}$.

**[2 marks]**

**0 4 . 4** A satellite is launched into a geostationary orbit.

Describe and explain **two** features of a geostationary orbit.

**[2 marks]**

**1**

**2**

**0 4 . 5** The satellite has a mass of $1200\ \text{kg}$ and the radius of its orbit is $4.23 \times 10^7\ \text{m}$.

Calculate the gain in gravitational potential energy of the satellite when it is placed into orbit from the Earth's surface.

**[3 marks]**

gain in potential energy = _____ J

**0 4 . 6** Impulse engines are used to place the satellite into an orbit with a longer period.

Discuss any changes this makes to the orbital motion of the satellite.

**[4 marks]**

_____

_____

_____

_____

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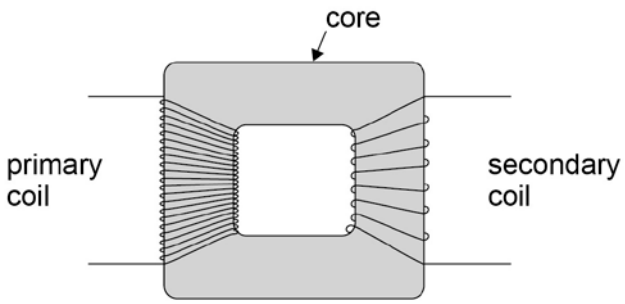
**15**

**0 5** **Figure 8** shows a step-down transformer used in a laptop power supply.

**Figure 8**




**0 5 . 1** Explain the purpose of the core in the transformer.

**[1 mark]**

**0 5 . 2** Describe and explain **two** features of the core that improve the efficiency of the transformer.

**[2 marks]**

**1**

**2**

**0 5 . 3** Explain why transformers only work continuously when supplied with an alternating current.

**[1 mark]**

**0 5 . 4** The primary coil of the transformer is connected to a $230\ V_{rms}$ ac supply. The current in the primary coil is $0.30\ A_{rms}$. The secondary coil has $300$ turns and provides an output of $20\ V_{rms}$ and a power of $65\ W$.

Calculate the number of turns on the primary coil.

**[1 mark]**

number of turns on primary = _____

**0 5 . 5** Calculate the efficiency of the transformer.

**[2 marks]**

efficiency = _____

7

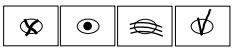
**END OF SECTION A**

**Section B**

Each of Questions **6** to **30** is followed by four responses, **A**, **B**, **C**, and **D**. For each question select the best response.

Only **one** answer per question is allowed.

For each answer completely fill in the circle alongside the appropriate answer.

CORRECT METHOD  WRONG METHODS 

If you want to change your answer you must cross out your original answer as shown. 

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown. 

You may do your working in the blank space around each question but this will not be marked.

**0 6** An ice cube of mass $0.010\ \text{kg}$ at a temperature of $0°\text{C}$ is dropped into a cup containing $0.10\ \text{kg}$ of water at a temperature of $15°\text{C}$.

What is the maximum estimated change in temperature of the contents of the cup?

specific heat capacity of water = $4200\ \text{J kg}^{-1}\ \text{K}^{-1}$
specific latent heat of fusion of ice = $3.4 \times 10^5\ \text{J kg}^{-1}$

**[1 mark]**

**A** $1.5\ \text{K}$ ⬭
**B** $8.7\ \text{K}$ ⬭
**C** $13.5\ \text{K}$ ⬭
**D** $15.0\ \text{K}$ ⬭

**0 7** Specimens **P** and **Q** of the same gas exert the same pressure. **P** is at a temperature of $280\ \text{K}$ and contains $10^{20}$ molecules per unit volume. The temperature of **Q** is $350\ \text{K}$.

What is the number of molecules per unit volume in **Q**?

**[1 mark]**

**A** $0.09 \times 10^{20}$ ⬭
**B** $0.75 \times 10^{20}$ ⬭
**C** $0.80 \times 10^{20}$ ⬭
**D** $1.25 \times 10^{20}$ ⬭

**0 8** Which of the following is **not** used as valid assumption when deriving the equation $p = \frac{1}{3}Nm(c_{\text{rms}})^2$ in the simple kinetic theory of gases?

**[1 mark]**

**A** The molecules suffer negligible change of momentum on collision with the walls of the container. ⬭

**B** Attractive forces between molecules are negligible. ⬭

**C** The duration of a collision is negligible compared with the time between collisions. ⬭

**D** The volume of the molecules is negligible compared with the volume of the gas. ⬭

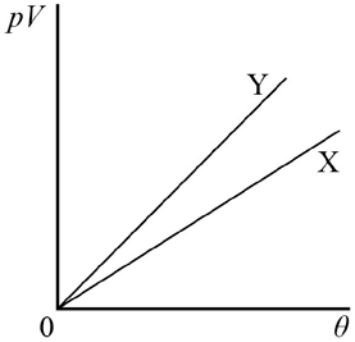
**0 9** One mole of gas occupies a volume $V$ at a pressure $p$ and Celsius temperature $\theta$.
The graphs, **A** to **D**, show variation of $pV$ with $\theta$.
Line X is for one mole of nitrogen and line Y is for one mole of oxygen.

Relative molecular mass of nitrogen = 28
Relative molecular mass of oxygen = 32

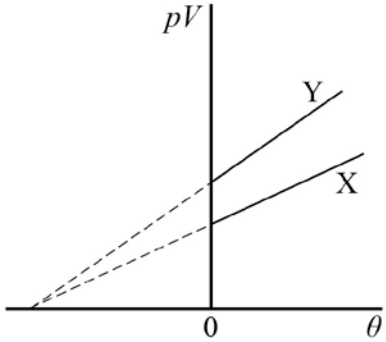
Which graph is correct?

**[1 mark]**

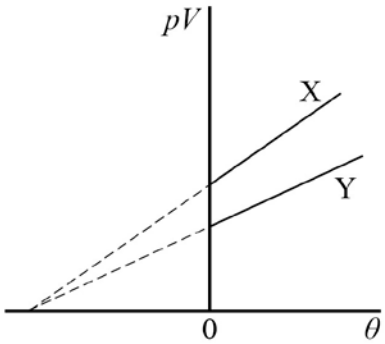
**A**



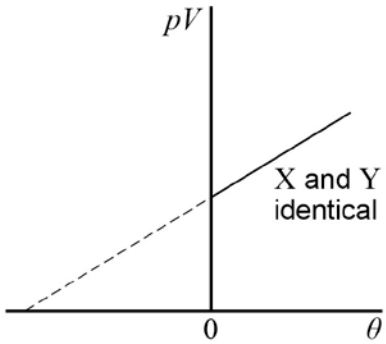

**B**




**C**




**D**




**A** ⬭
**B** ⬭
**C** ⬭
**D** ⬭

**1 0** The distance between the centres of the Earth and the Moon is $3.8 \times 10^8$ m. The mass of the Earth is $6.0 \times 10^{24}$ kg and the mass of the Moon is $7.4 \times 10^{22}$ kg.

A spacecraft of mass $10 \times 10^3$ kg is moving along a line joining their centres.

At what distance from the centre of the Earth would the spacecraft experience no resultant force due to the Earth and the Moon?

**[1 mark]**

**A** $3.8 \times 10^7$ m ⬭

**B** $4.8 \times 10^7$ m ⬭

**C** $3.4 \times 10^8$ m ⬭

**D** $3.8 \times 10^8$ m ⬭

**1 1** An electron on the surface of the Earth is placed in an electric field of strength $5000$ N C$^{-1}$.

What is $\left( \frac{\textit{electric force}}{\textit{gravitational force}} \right)$ for the electron?

**[1 mark]**

**A** $1.1 \times 10^{-14}$ ⬭

**B** $2.9 \times 10^{-10}$ ⬭

**C** $3.4 \times 10^9$ ⬭

**D** $9.0 \times 10^{13}$ ⬭

**1 2** The radius of a planet is $R$. The gravitational potential at the surface of the planet due to its mass is $-4000$ J kg$^{-1}$.

What is the gravitational potential at a distance $2R$ from the centre of the planet?

**[1 mark]**

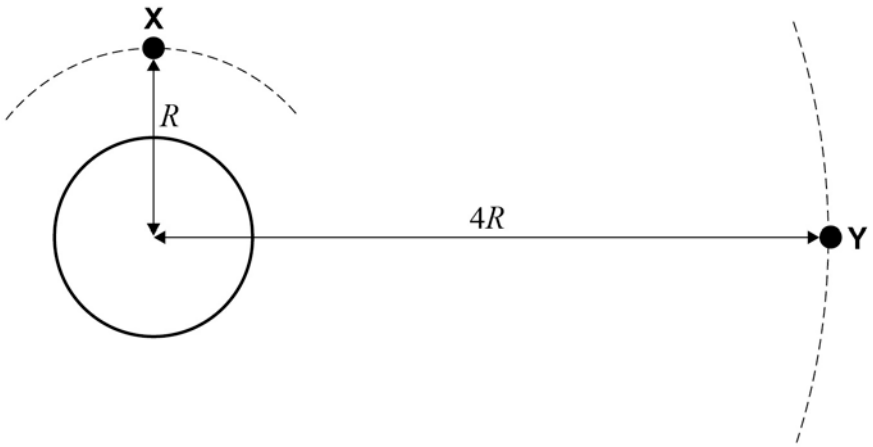
**A** $-1000$ J kg$^{-1}$ ⬭

**B** $-2000$ J kg$^{-1}$ ⬭

**C** $-4000$ J kg$^{-1}$ ⬭

**D** $-8000$ J kg$^{-1}$ ⬭

**1 3** Satellites **X** and **Y** orbit the Earth at distances $R$ and $4R$ respectively, as shown in the diagram.




Which statement is **incorrect?**

**[1 mark]**

**A** The speed of **Y** is greater than the speed of **X** ⬭

**B** The time period of **Y** is greater than the time period of **X**. ⬭

**C** The potential energy of **Y** is greater than the potential energy of **X.** ⬭

**D** The gravitational force acting on **Y** is less than the gravitational force acting on **X.** ⬭

**1 4** An $\alpha$ particle makes a head-on collision with a gold nucleus containing $79$ protons. The distance of closest approach of the $\alpha$ particle to the nucleus is $4.0 \times 10^{-14}$ m.

What electrostatic force acts on the gold nucleus when at this separation?

**[1 mark]**

**A** $9.1 \times 10^{-11}$ N ⬭

**B** $23$ N ⬭

**C** $290$ N ⬭

**D** $1.4 \times 10^{20}$ N ⬭

**1 5** An electron moving with constant speed enters a uniform electric field at right angles to the direction of the field.

What is true about the force acting on the electron?

**[1 mark]**

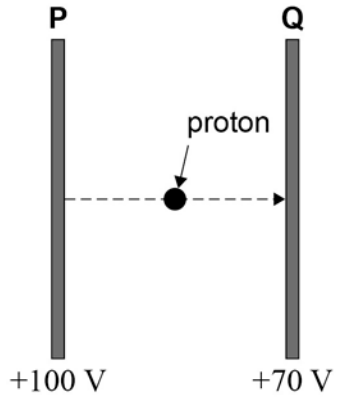
**A** It is at right angles to the direction of the field. ⬭

**B** It is in the opposite direction to the direction of the field. ⬭

**C** It causes the electron to continue in the same direction with its speed increasing steadily. ⬭

**D** It causes the electron to continue in the same direction with its speed decreasing steadily. ⬭

**1 6** Two fixed parallel metal plates **P** and **Q** are at constant electrical potentials of $+100\ \text{V}$ and $+70\ \text{V}$ respectively. A proton travelling from **P** to **Q** experiences a force $F$ due to the electric field between **P** and **Q**, and a change of potential energy of $\Delta E_\text{P}$.




Which line, **A** to **D**, in the table gives the direction of $F$ and the value of $\Delta E_\text{P}$?

**[1 mark]**

| | **Direction of $F$** | **$\Delta E_\text{P}$** | |
|---|---|---|---|
| **A** | towards **P** | $+30\ \text{eV}$ | ⬭ |
| **B** | towards **Q** | $+30\ \text{eV}$ | ⬭ |
| **C** | towards **Q** | $-30\ \text{eV}$ | ⬭ |
| **D** | towards **P** | $-30\ \text{eV}$ | ⬭ |

**1 7** Initially a capacitor stores $600\ \mu C$ of charge. When it loses half of this charge, the potential difference (pd) across it decreases by $50\ V$.

What is the capacitance of the capacitor?

**[1 mark]**

**A** $1.5\ \mu F$ ⬭

**B** $3.0\ \mu F$ ⬭

**C** $6.0\ \mu F$ ⬭

**D** $12\ \mu F$ ⬭

**1 8** The separation of the plates of an isolated charged parallel-plate capacitor is increased.

What also increases?

**[1 mark]**

**A** the capacitance of the capacitor ⬭

**B** the charge on the plates ⬭

**C** the strength of the electric field between the plates ⬭

**D** the pd between the plates ⬭

**1 9** The initial charge stored by a capacitor of capacitance $0.50\ \mu F$ is $2.0\ \mu C$. The capacitor is then discharged through a resistor.

How much energy is stored by the capacitor after a time equal to one time constant?

**[1 mark]**

**A** $0.06\ \mu J$ ⬭

**B** $0.54\ \mu J$ ⬭

**C** $1.0\ \mu J$ ⬭

**D** $4.0\ \mu J$ ⬭

**2 0** A $500\ \mu\text{F}$ capacitor is charged to a pd of $10.0\ \text{V}$. It is then discharged through a $100\ \text{k}\Omega$ resistor.

What is the time taken for the pd to fall from $10.0\ \text{V}$ to $5.0\ \text{V}$?

**[1 mark]**

**A** $35\ \text{s}$ ⬭

**B** $50\ \text{s}$ ⬭

**C** $72\ \text{s}$ ⬭

**D** $100\ \text{s}$ ⬭

**2 1** A horizontal copper wire of mass $4.0 \times 10^{-3}\ \text{kg}$ and length $80\ \text{mm}$ is placed perpendicular to a horizontal magnetic field of flux density $0.16\ \text{T}$. The magnetic force acting on the wire supports the weight of the wire.

How many electrons are passing a point in the wire in each second?

**[1 mark]**

**A** $1.9 \times 10^{18}$ ⬭

**B** $1.9 \times 10^{19}$ ⬭

**C** $1.9 \times 10^{20}$ ⬭

**D** $1.9 \times 10^{21}$ ⬭

**2 2** Two charged particles, $\mathbf{P}_1$ and $\mathbf{P}_2$, follow circular paths as they move at right angles to the same uniform magnetic field. Both particles are travelling at the same speed.
The radius of the path travelled by $\mathbf{P}_1$ is twice the radius of the path travelled by $\mathbf{P}_2$.

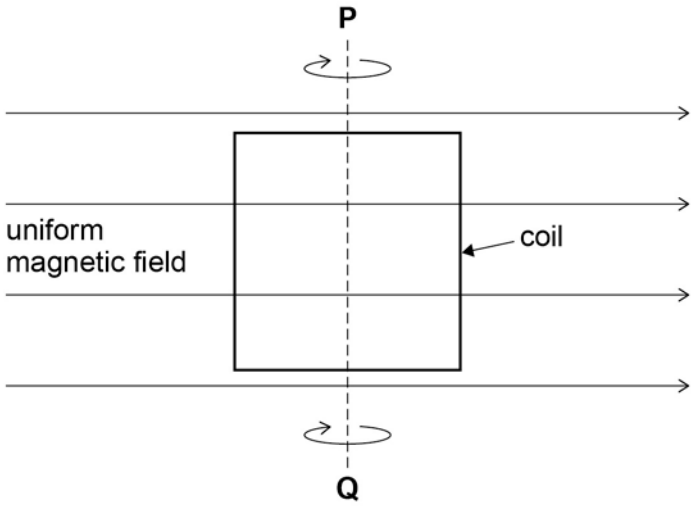
The mass of $\mathbf{P}_1$ is $m$ and its charge is $q$.

What is the mass of $\mathbf{P}_2$ and the charge of $\mathbf{P}_2$?

**[1 mark]**

| | **Mass of $\mathbf{P}_2$** | **Charge of $\mathbf{P}_2$** | |
|---|---|---|---|
| **A** | $2m$ | $q$ | ⬭ |
| **B** | $2m$ | $2q$ | ⬭ |
| **C** | $\sqrt{2}\,m$ | $\sqrt{2}\,q$ | ⬭ |
| **D** | $m$ | $2q$ | ⬭ |

**2 3** A rectangular coil of area $A$ has $N$ turns of wire. The coil is in a uniform magnetic field of flux density $B$ with its plane parallel to the field lines.




The coil is then rotated through an angle of $30°$ about axis **PQ**.

What are the correct initial value and correct final value of the magnetic flux linkage?

**[1 mark]**

| | Initial magnetic flux linkage | Final magnetic flux linkage | |
|---|---|---|---|
| **A** | 0 | $\frac{1}{2}BAN$ | ⬭ |
| **B** | 0 | $BAN$ | ⬭ |
| **C** | $BAN$ | $\frac{1}{2}BAN$ | ⬭ |
| **D** | $BAN$ | $BAN$ | ⬭ |

**2 4** In the Rutherford scattering experiment most $\alpha$ particles passed through the foil undeflected.

What is a correct deduction from this result?

**[1 mark]**

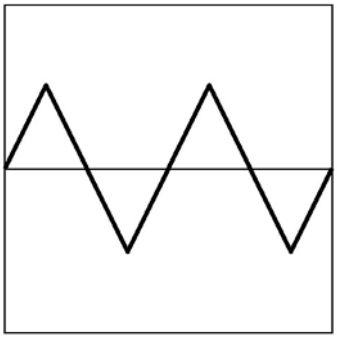
**A** Most of the mass of an atom is within the nucleus. ⬭

**B** The diameter of the nucleus is much less than the diameter of the atom. ⬭

**C** The nucleus has a positive charge. ⬭

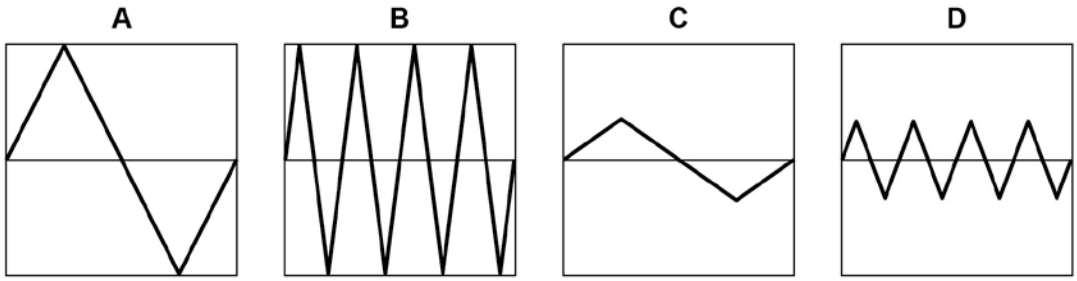
**D** The charge of the atom is neutral. ⬭

**2 5** A student is using an oscilloscope to investigate an ac voltage waveform. When the input sensitivity is set on 1 V per division and the time base setting is 10 ms per division, the trace appears as follows.



The student then changes the input sensitivity to 2 V per division and the time base setting to 20 ms per division.

What would be observed whilst applying the same signal to the input terminals?




**[1 mark]**

**A** ⬭
**B** ⬭
**C** ⬭
**D** ⬭

**2 6** β particles are emitted from a radioactive source in a school laboratory.

What is correct for these particles?

**[1 mark]**

**A** A strong magnetic field will not deflect them. ⬭
**B** They are absorbed by aluminium. ⬭
**C** They do not damage human tissue. ⬭
**D** Their range in air is shorter than that of α particles. ⬭

**2 7** A radioactive source contains a nuclide which has a half-life of 12 hours. A detector placed near the source records an average count rate of 180 counts per minute. The average background count rate is 20 counts per minute.

What will be the average count rate after 24 hours?

**[1 mark]**

**A** 40 counts per minute ⬭

**B** 45 counts per minute ⬭

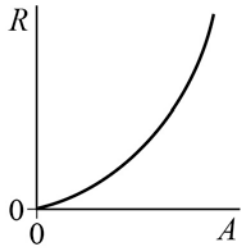
**C** 50 counts per minute ⬭

**D** 60 counts per minute ⬭

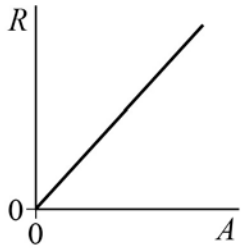
**2 8** Which graph best shows how the radius $R$ of an atomic nucleus varies with the nucleon number $A$?

**[1 mark]**

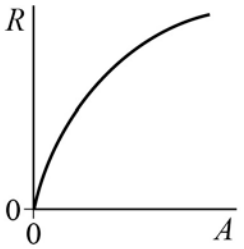
**A**



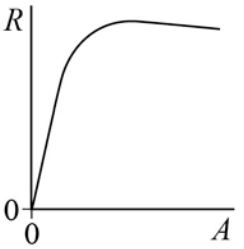

**B**




**C**




**D**




**A** ⬭

**B** ⬭

**C** ⬭

**D** ⬭

**Turn over for the next question**

**2 9** The power output of a nuclear reactor is provided by nuclear fuel which decreases in mass at a rate of $4.0 \times 10^{-6}$ kg hour$^{-1}$.

What is the maximum possible power output of the reactor?

**[1 mark]**

**A** 28 kW ⬭

**B** 50 MW ⬭

**C** 100 MW ⬭

**D** 200 MW ⬭

**3 0** The moderator of some nuclear reactors is made from graphite.

What is the principal purpose of the graphite?

**[1 mark]**

**A** to absorb all the heat produced ⬭

**B** to decrease the speed of neutrons ⬭

**C** to absorb $\alpha$ and $\beta$ radiation ⬭

**D** to prevent the reactor from going critical ⬭

**25**

**END OF QUESTIONS**

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