OCR
Oxford Cambridge and RSA

# Thursday 15 October 2020 – Morning

## A Level Physics A

### H556/02 Exploring physics

**Time allowed: 2 hours 15 minutes**

**You must have:**
- the Data, Formulae and Relationships booklet

**You can use:**
- a scientific or graphical calculator
- a ruler (cm/mm)

*8255066181*

*H556/02*

Please write clearly in black ink. **Do not write in the barcodes.**

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

First name(s) _____

Last name _____

**INSTRUCTIONS**
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

**INFORMATION**
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **32** pages.

**ADVICE**
- Read each question carefully before you start your answer.

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## SECTION A

**You should spend a maximum of 30 minutes on this section.**

Write your answer to each question in the box provided.

Answer **all** the questions.

**1** The Doppler effect is used to measure the speed of blood flow in arteries.

Which medical diagnostic method uses this technique?

**A** barium scan

**B** CAT scan

**C** PET scan

**D** ultrasound scan

Your answer ☐ **[1]**

**2** Which sequence shows the materials arranged in the order of increasing number density of charge carriers?

increasing number density ⟶

**A** conductor, insulator, semiconductor

**B** conductor, semiconductor, insulator

**C** insulator, semiconductor, conductor

**D** semiconductor, insulator, conductor

Your answer ☐ **[1]**

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**3** Electromagnetic radiation is incident on a metal of work function 2.3 eV.
The maximum kinetic energy (KE) of the photoelectrons is 1.7 eV.

The frequency of this incident electromagnetic radiation is kept the same but its intensity is doubled.

What is the maximum KE of the photoelectrons now?

**A** 1.7 eV

**B** 2.9 eV

**C** 3.4 eV

**D** 4.0 eV

Your answer ☐ **[1]**

**4** A student is doing an experiment on the magnetic force experienced by a current-carrying wire in a uniform magnetic field. The magnetic flux density *B* can be varied.

For a particular flux density, the current in the wire is 2.0 A. The length of the wire in the field is 0.12 m. The angle between the current and the magnetic field is 30°. The force experienced by the wire is $7.7 \times 10^{-2}$ N.

The student calculates *B* and records the results in a table.

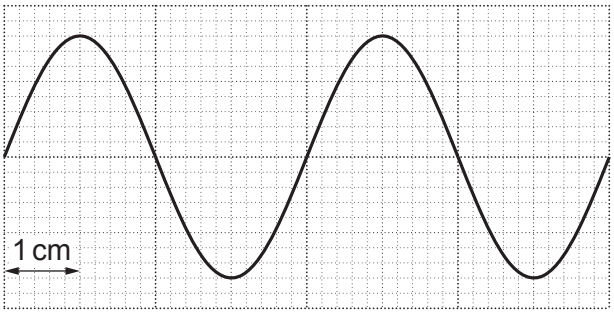
Which row shows the correct table heading for *B* and the correct value for *B*?

| | **Table heading for *B*** | **Value for *B*** |
|---|---|---|
| **A** | *B*/T | 0.37 |
| **B** | *B*/T | 0.64 |
| **C** | *B*/Wb | 0.37 |
| **D** | *B*/Wb | 0.64 |

Your answer ☐ **[1]**

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**5** The diagram below shows the oscilloscope trace for an electrical signal.




The time-base setting of the oscilloscope is $2\,\mu s\,cm^{-1}$.

What is the frequency of the signal?

**A** 125 Hz

**B** 250 Hz

**C** 125 kHz

**D** 250 kHz

Your answer ☐ **[1]**

**6** This question is about a progressive wave and a stationary wave.

Which statement is correct?

**A** A progressive wave has at least one node.

**B** All progressive waves are longitudinal.

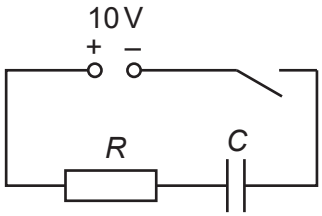
**C** All particles oscillating between two adjacent nodes in a stationary wave are in phase.

**D** The superposition of two waves travelling in the same direction produces a stationary wave.

Your answer ☐ **[1]**

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**7** The diagram below shows a circuit used to charge a capacitor.




The power supply has electromotive force (e.m.f.) 10 V and negligible internal resistance.
The capacitor has capacitance $C$ and the resistor has resistance $R$.
The switch is closed at time $t = 0$.
The table below shows potential difference $V$ across the resistor at various values of time $t$.

| **$V$/V** | 10 | 6.3 | 5.0 | 3.7 |
|---|---|---|---|---|
| **$t$/s** | 0 | 2.8 | 4.2 | 6.0 |

What is the product $C \times R$ for this circuit?

**A** 0 s

**B** 2.8 s

**C** 4.2 s

**D** 6.0 s

Your answer ☐ **[1]**

**8** A capacitor discharges through a resistor.
At time $t = 0$ the potential difference $V$ across the capacitor is $V_0$.
At time $t = 2.0$ s, $V = 0.90\,V_0$.

Which statement is **not** correct?

**A** At $t = 4.0$ s, $V = 0.81\,V_0$.

**B** The capacitor is fully discharged after $t = 10$ s.

**C** The potential difference across the resistor is the same as that for the capacitor.

**D** The potential difference $V$ decreases exponentially with time $t$.

Your answer ☐ **[1]**

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**9** A student is modelling the decay of a radioactive source using the equation $\Delta N / \Delta t = -0.5N$.
The student decides to use $\Delta t = 0.10\,\text{s}$.
The number $N$ of radioactive nuclei is 2000 at $t = 0$.

Part of the modelling spreadsheet from the student is shown below.

| ***t*/ s** | **Number *N* of radioactive nuclei remaining at time *t*** | **Number of nuclei decaying in the next 0.10 s** |
|---|---|---|
| 0 | 2000 | 100 |
| 0.10 | 1900 | |
| 0.20 | | |
| 0.30 | | |
| | | |

What is the value of $N$ at $t = 0.30\,\text{s}$?

**A** 1700

**B** 1710

**C** 1715

**D** 1805

Your answer ☐ **[1]**

**10** The total energy released in a single fusion reaction is 4.0 MeV.

What is the change in mass in this fusion reaction?

**A** $7.1 \times 10^{-36}\,\text{kg}$

**B** $7.1 \times 10^{-30}\,\text{kg}$

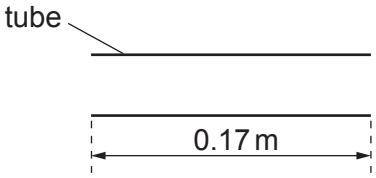
**C** $2.1 \times 10^{-21}\,\text{kg}$

**D** $4.4 \times 10^{-17}\,\text{kg}$

Your answer ☐ **[1]**

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**11** A stationary sound wave, in its fundamental mode of vibration, is formed in a tube open at both ends.




The length of the tube is 0.17 m. The speed of sound in air is 340 m s$^{-1}$.

Which row for this stationary wave is correct?

| | Number of nodes | Frequency of stationary wave / Hz |
|---|---|---|
| **A** | 1 | 500 |
| **B** | 1 | 1000 |
| **C** | 2 | 1000 |
| **D** | 2 | 2000 |

Your answer ☐ **[1]**

**12** The table below shows the quark compositions of four particles **A**, **B**, **C** and **D**.

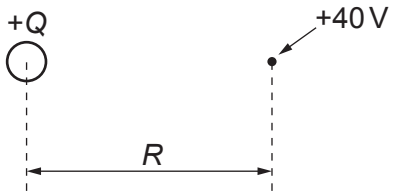
| A | B | C | D |
|---|---|---|---|
| u u d | u d d | u d s | s s s |

Which particle has a positive charge?

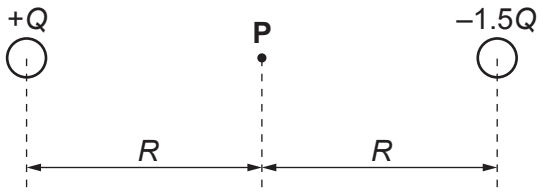
Your answer ☐ **[1]**

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**13** The electric potential at a distance $R$ from the centre of a charge $+Q$ is + 40 V.




What is the potential at the point **P** for the arrangement of the charges $+Q$ and $-1.5Q$ as shown below?




**A** − 20 V

**B** − 60 V

**C** + 80 V

**D** + 100 V

Your answer ☐ **[1]**

**14** The potential difference across a lamp is 2.5 V. The current in the lamp is 20 mA.

What is the energy dissipated in the lamp in 3.0 hours?

**A** 0.050 J

**B** 0.15 J

**C** 9.0 J

**D** 540 J

Your answer ☐ **[1]**

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**15** What can be deduced from the diffraction of electrons by a thin film of graphite?

**A** Electrons are leptons.

**B** Electrons are negatively charged.

**C** Electrons interact with atoms on a one-to-one basis.

**D** Electrons travel as waves.

Your answer [ ] **[1]**

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## SECTION B

Answer **all** the questions.

**16** This question is about the medical use of ultrasound.

**(a)** In ultrasound scanning, explain what is meant by **impedance (acoustic) matching** and how it may be achieved.

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**(b)** There are several different types of ultrasound scanning techniques.

Explain how an A-scan could be used to measure the thickness of a patient's eye lens. You may draw a diagram to help with your answer.

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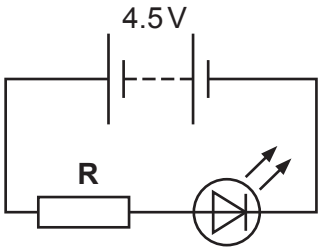
**17** A light-emitting diode (LED) emits red light when it is positively biased and has a potential difference (p.d.) greater than about 1.8 V.

**(a)** The energy of a photon of red light is about 1.8 eV.

Calculate the wavelength $\lambda$ of this red light.

$\lambda$ = ..... m **[3]**

**(b)** The LED is connected into a circuit, as shown below.



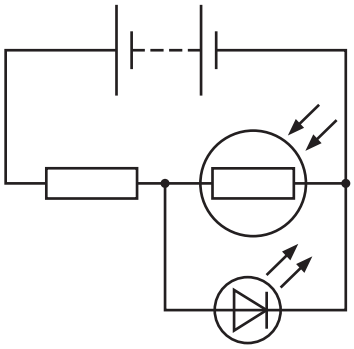

The battery has electromotive force (e.m.f.) 4.5 V and negligible internal resistance.
The resistor **R** has resistance 150 Ω.
Assume the p.d. across the LED is 1.8 V.

Calculate the ratio $\frac{\text{power dissipated by LED}}{\text{power dissipated by resistor}}$.

ratio = ..... **[2]**

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**(c)** The diagram below shows a circuit designed by a student.



The LED is very close to, and facing the light dependent resistor (LDR).
The circuit is taken into a dark room.

**(i)** The student thought that the LED would switch on.
Instead, the LED was found to repeatedly switch on and off.

Explain this behaviour of the LED in this potential divider circuit.

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**(ii)** Suggest a possible refinement so that the LED switches on permanently when taken into the dark room.

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**18*** A resistance wire is coiled around a thermistor. The coil of wire will warm the thermistor.

It is suggested that the relationship between the power $P$ dissipated in the coiled wire and the stable resistance $R$ of the thermistor is given by the expression $P = kR^n$, where $k$ and $n$ are constants.

Describe how an experiment can be conducted to assess the validity of this expression and how the data collected can be analysed to determine $k$ and $n$.

Use the space below for a circuit diagram. **[6]**

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Additional answer space if required

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**19** **(a)** The Planck constant $h$ is an important fundamental constant in quantum physics.

Determine the S.I. base units for $h$.

base units = ..... **[2]**

**(b)** A researcher is investigating the de Broglie wavelength of charged particles.

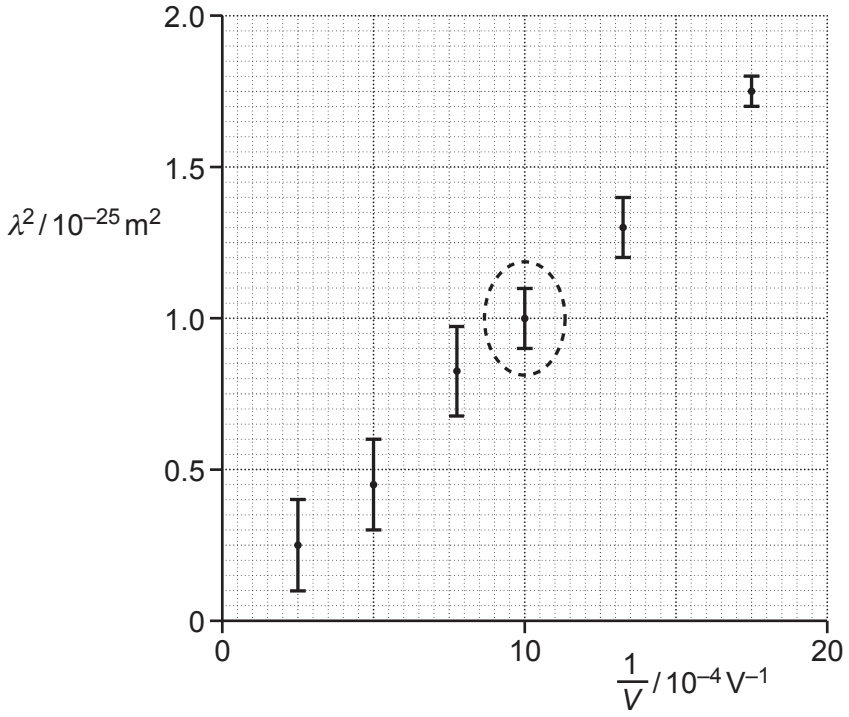
The charged particles are accelerated through a potential difference $V$. The de Broglie wavelength $\lambda$ of these particles is then determined by the researcher.

Each particle has mass $m$ and charge $q$.

**(i)** Show that the de Broglie wavelength $\lambda$ is given by the expression $\lambda^2 = \frac{h^2}{2mq} \times \frac{1}{V}$.

**[2]**

**(ii)** The researcher plots data points on a $\lambda^2$ against $\frac{1}{V}$ grid, as shown below.




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**1** Calculate the percentage uncertainty in $\lambda$ for the data point circled on the grid.

percentage uncertainty = ..... % **[2]**

**2** Draw a straight line of best fit through the data points. **[1]**

**3** The charge $q$ on the particle is $2e$, where $e$ is the elementary charge.

Use your best fit straight line to show that the mass $m$ of the particle is about $10^{-26}$ kg.

**[4]**

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**20** **(a)** A sound wave is incident at the ear.

The amplitude of the sound wave is 7.8 nm. The intensity of the sound at the earhole is $4.8 \times 10^{-7}\,\text{W m}^{-2}$.

**(i)** Determine the power of the sound incident at the earhole by estimating the diameter of the earhole in mm.

diameter of earhole ≈ ..... mm

power = ..... W **[2]**

**(ii)** A different sound wave is now incident at the ear.
The intensity of this wave is $9.6 \times 10^{-7}\,\text{W m}^{-2}$.

Calculate the amplitude $A$ in nm of this sound wave.

$A$ = ..... nm **[2]**

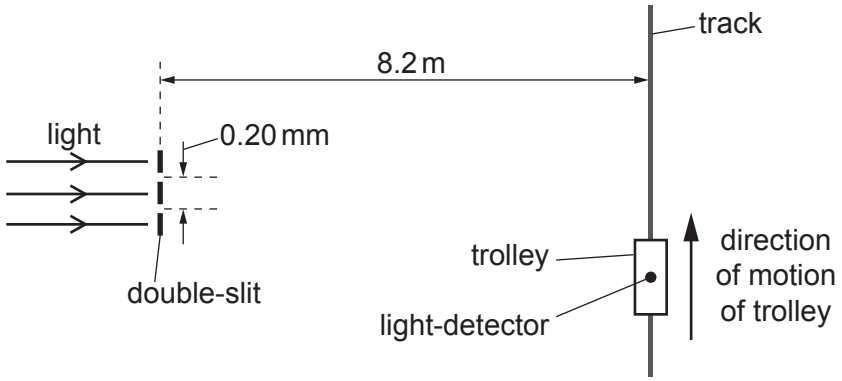
**(b)** State the **principle of superposition**.

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..... **[1]**

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**(c)** The diagram below shows monochromatic light from a laser incident normally at a double-slit.




The diagram is **not** drawn to scale.

A small light-detector is mounted onto a trolley on a frictionless track. The trolley travels along the track at a constant speed.

The separation between the slits is 0.20 mm. The perpendicular distance between the slits and the track is 8.2 m.

A series of bright and dark fringes are detected at the moving light-detector.

**(i)** Explain, in terms of phase difference, the origin of the fringes.

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..... **[2]**

**(ii)** The speed of the trolley is $0.18\,m\,s^{-1}$ and the frequency of the light is $4.75 \times 10^{14}$ Hz.

Calculate the time interval $t$ between successive bright fringes.
Write your answer to 2 significant figures.

$t$ = ..... s **[3]**

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**21** **(a)** In the 1800s, the atom was considered to be a fundamental particle. It was an indivisible particle of matter. Modern physics shows that this idea is not correct.

Describe the fundamental particles within an atom of carbon-14 ($^{14}_{6}C$).
In your answer state the composition of the hadrons.

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**(b)** The half-life of the isotope carbon-14 is 5700 years (y).

**(i)** Show that the decay constant $\lambda$ for this isotope is about $1.2 \times 10^{-4}\,y^{-1}$.

**[1]**

**(ii)** Carbon-dating is a technique used to date an ancient wooden axe.
The ratio of carbon-14 to carbon-12 in the axe material is 78% of the current ratio of carbon-14 to carbon-12 in a living tree.

Calculate the age in years of the wooden axe.

age = ..... y **[3]**

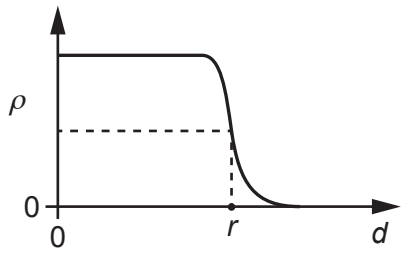
**(iii)** State **one** assumption made in the calculation in **(ii)**.

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..... **[1]**

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**(c)*** A graph of the density $\rho$ of a nucleus against distance $d$ from the centre of the nucleus is shown below.




The radius of the nucleus $r$ is taken as the distance $d$ where the density is half the maximum density.

**Fig. 21.1** shows the density $\rho$ variation for three different nuclei and **Table 21.1** shows the nucleon number $A$ of each nucleus.

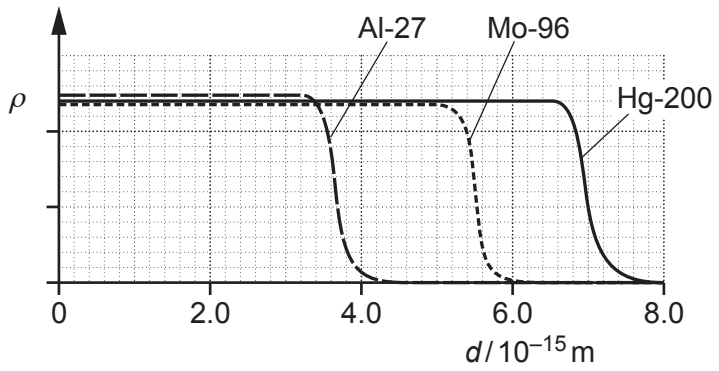



**Fig. 21.1**

| **Nucleus** | **Nucleon number *A*** |
|---|---|
| Al-27 | 27 |
| Mo-96 | 96 |
| Hg-200 | 200 |

**Table 21.1**

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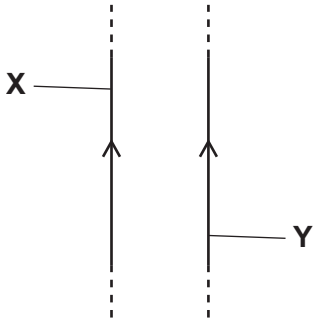
Use the information provided opposite to

- describe how the density of a nucleus depends on its nucleon number $A$
- show numerically that $r \propto A^{1/3}$
- estimate the mean density of the nuclei. **[6]**

Additional answer space if required

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**22** **(a)** The diagram below shows two long vertical current-carrying wires **X** and **Y**.




The direction of the current in each wire is the same.

Explain why wire **Y** experiences a force and deduce the direction of this force.

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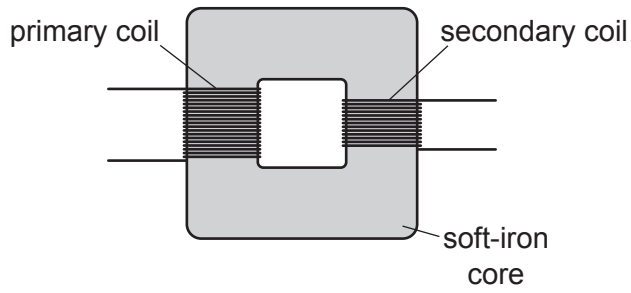
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**(b) (i)** State **Faraday's law of electromagnetic induction**.

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..... **[1]**

**(ii)** The diagram below shows a simple transformer constructed by a student.




Describe how the student can do an experiment in the laboratory to show that the maximum electromotive force (e.m.f.) $E$ induced in the secondary coil is directly proportional to the number of turns $N$ on the secondary coil.

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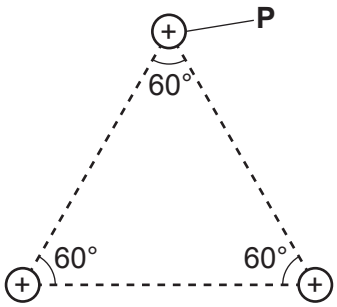
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**23** **(a)** The diagram below shows the arrangement of the 3 protons inside the nucleus of lithium-6 ($^{6}_{3}$Li).




The separation between each proton is about $1.0 \times 10^{-15}$ m.

**(i)** Calculate the magnitude of the repulsive electric force $F$ experienced by the proton **P**.

$F$ = ..... N **[4]**

**(ii)** On the diagram above, draw an arrow to show the direction of the electric force $F$ experienced by **P**. **[1]**

**(iii)** Explain how protons stay within the nucleus of lithium-6.

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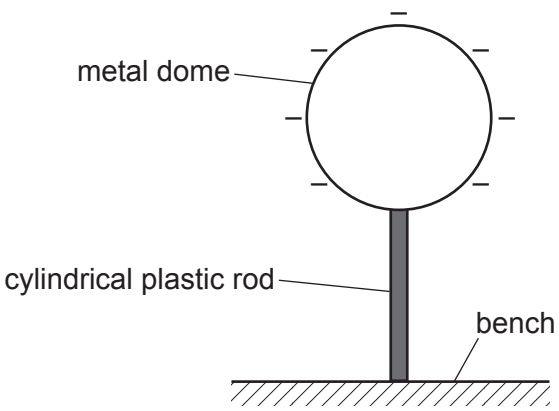
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**(b)** A spherical metal dome shown below is charged to a potential of −12 kV.




The dome is supported by a cylindrical plastic rod. The radius of the dome is 0.19 m.

**(i)** Show that the magnitude of the total charge $Q$ on the dome is $2.5 \times 10^{-7}$ C.

**[2]**

**(ii)** The dome discharges slowly through the plastic rod.
It takes 78 hours for the dome to completely discharge.

**1** Show that the mean current $I$ in the plastic rod is about $9 \times 10^{-13}$ A.

**[2]**

**2** The average potential difference across the plastic rod during discharge is 6000 V.
The rod has cross-sectional area $1.1 \times 10^{-4}$ m$^2$ and length 0.38 m.

Calculate the resistivity $\rho$ of the plastic.

$\rho$ = ..... Ω m **[3]**

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**24** The medical tracer technetium-99m is used in imaging organs such as the brain.

**(a)** Explain the advantages of using technetium-99m for this purpose.

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**(b)** A gamma-camera uses powerful computers and sophisticated software to produce three-dimensional images of the patient's organ.

Name and describe the remaining three main components of the gamma camera.

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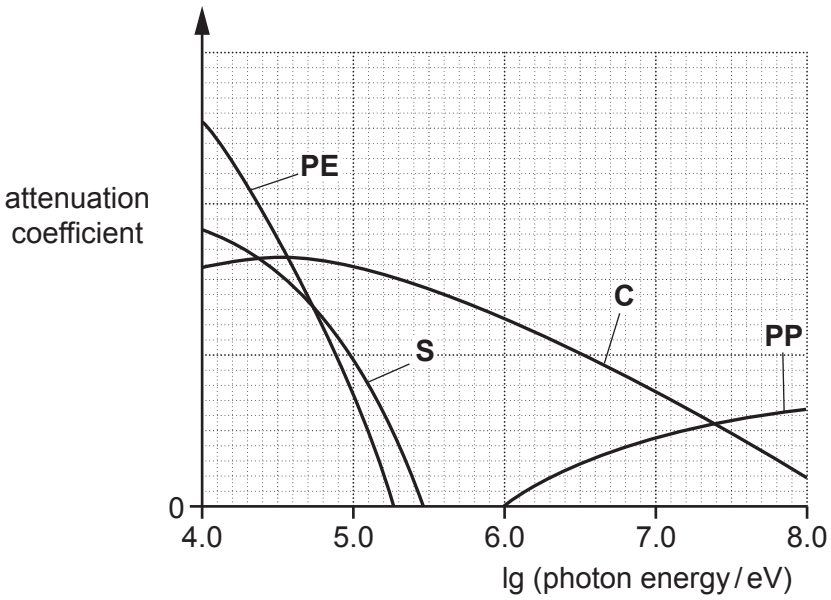
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**25** X-ray photons interact with atoms.

The attenuation coefficient against lg(photon energy) graphs for simple scattering (**S**), photoelectric effect (**PE**), Compton effect (**C**) and pair production (**PP**) are shown below.




**(a)** For the X-ray tubes used in hospital, the X-ray photons have energy of about $10^5$ eV.

State the attenuation mechanisms for these photons.

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..... **[1]**

**(b)** With the help of a calculation, explain the minimum photon energy shown on the graph for pair production.

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..... **[3]**

**END OF QUESTION PAPER**

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## ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

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