OCR
Oxford Cambridge and RSA

A Level Physics A

H556/02 Exploring physics

Friday 8 June 2018 – Morning

Time allowed: 2 hours 15 minutes

6905012258

You must have:
- the Data, Formulae and Relationship Booklet (sent with general stationery)

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

H 5 5 6 0 2

First name										
Last name										
Centre number						Candidate number				

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **36** pages.

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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 Which electrical quantity has S.I. units ampere-second (As)?

A charge

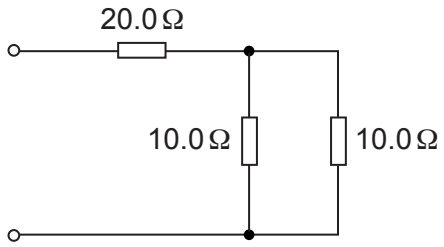
B current

C resistance

D potential difference

Your answer ☐ **[1]**

2 Three resistors are connected in a circuit.



The resistance of each resistor is shown in the circuit diagram.

What is the total resistance of this circuit?

A 10.0 Ω

B 20.2 Ω

C 25.0 Ω

D 40.0 Ω

Your answer ☐ **[1]**

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3 An electron has a de Broglie wavelength equal to the wavelength of X-rays.

What is the **best** estimate of the momentum of this electron?

A $10^{-30}\,\text{kg m s}^{-1}$

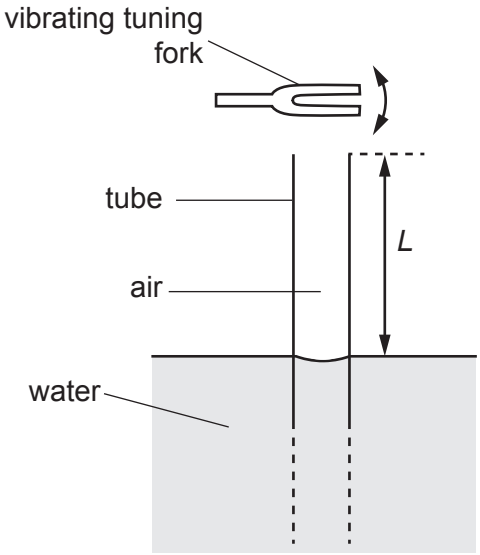
B $10^{-27}\,\text{kg m s}^{-1}$

C $10^{-23}\,\text{kg m s}^{-1}$

D $10^{-18}\,\text{kg m s}^{-1}$

Your answer ☐ **[1]**

4 A vibrating tuning fork is held above the open end of a long vertical tube. The other end of the tube, which is also open, is immersed in a tank of water. The length *L* of the air column within the tube is changed by raising or lowering the tube.



The wavelength of sound from the vibrating tuning fork is 150.0 cm.

What length *L* of air column will **not** produce a stationary wave within the tube?

A 37.5 cm

B 75.0 cm

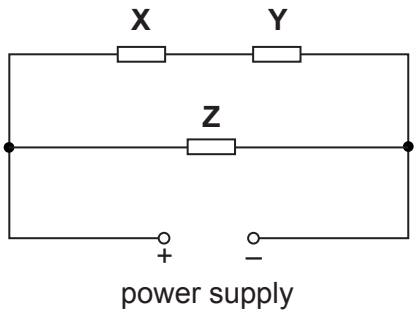
C 112.5 cm

D 187.5 cm

Your answer ☐ **[1]**

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5 Three identical resistors **X**, **Y** and **Z** are connected to a power supply.



The power dissipated in the resistor **Z** is 24 W.

What is the power dissipated in the resistor **Y**?

A 6.0 W

B 12 W

C 24 W

D 48 W

Your answer ☐ **[1]**

6 Which is the **best** value for the elementary charge *e* in terms of both accuracy and precision?

A $(1.5 \pm 0.5) \times 10^{-19}$ C

B $(1.5 \pm 0.4) \times 10^{-19}$ C

C $(1.7 \pm 0.2) \times 10^{-19}$ C

D $(1.8 \pm 0.2) \times 10^{-19}$ C

Your answer ☐ **[1]**

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7 A small loudspeaker emits sound uniformly in all directions.
The amplitude of the sound is 12 μm at a distance of 1.5 m from the loudspeaker.

What is the amplitude of the sound at a distance of 4.5 m from the loudspeaker?

A 1.3 μm

B 4.0 μm

C 6.9 μm

D 12 μm

Your answer ☐ **[1]**

8 An isolated metal sphere is charged using a power supply.

Which single quantity can be used to determine the capacitance of the sphere?

A The diameter of the sphere.

B The charge on the sphere.

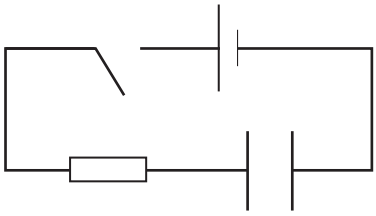
C The resistance of the metal.

D The e.m.f. of the power supply.

Your answer ☐ **[1]**

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9 A capacitor is charged through a resistor.



The cell has e.m.f. 1.50 V and negligible internal resistance.
The capacitor is initially uncharged. The time constant of the circuit is 100 s.
The switch is closed at time $t = 0$.

What is the potential difference across the capacitor at time $t = 200$ s?

A 0.20 V

B 0.55 V

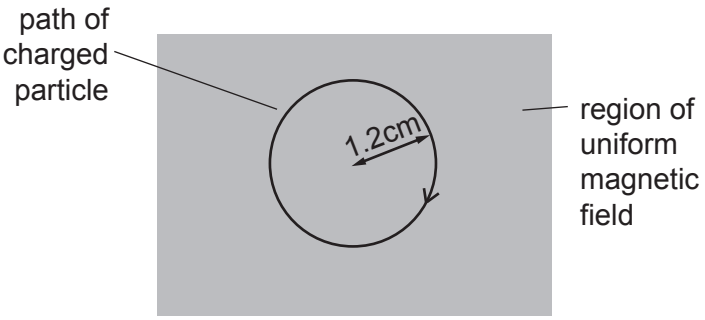
C 0.95 V

D 1.30 V

Your answer ☐ **[1]**

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10 A charged particle moves in a circular path of radius 1.2 cm in a uniform magnetic field.



The direction of the magnetic field is perpendicular to the plane of the paper.

The particle has mass m, charge $+Q$ and speed v.

Another particle of mass $3m$, charge $+2Q$ and speed v moves in a circular path of radius R in the same magnetic field.

What is the value of R?

A 0.8 cm

B 1.2 cm

C 1.8 cm

D 7.2 cm

Your answer ☐ **[1]**

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11 The acoustic impedance Z of a material in the shape of a cube can be determined using the equation

$$Z = \frac{Mc}{L^3}$$

where M is the mass of the material, L is the length of each side of the cube and c is the speed of ultrasound in the material.

The percentage uncertainty in L is 1.2% and the percentage uncertainty in c is 1.8%. The percentage uncertainty in M is negligible.

What is the percentage uncertainty in Z?

A 2.2%

B 3.0%

C 4.2%

D 5.4%

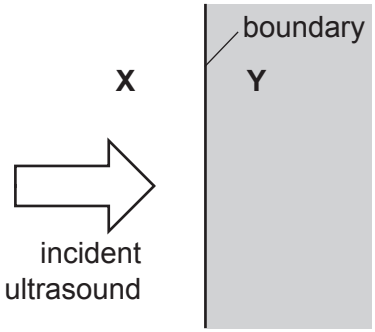
Your answer ☐ **[1]**

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12 The table shows some data on two tissues in a patient.

Tissue	Density	Acoustic impedance
X	ρ	$1.5Z$
Y	1.3ρ	Z

Ultrasound in tissue **X** is incident at the boundary between the tissues **X** and **Y**.



What is the percentage of the ultrasound intensity reflected at the boundary?

A 1.7 %

B 4.0 %

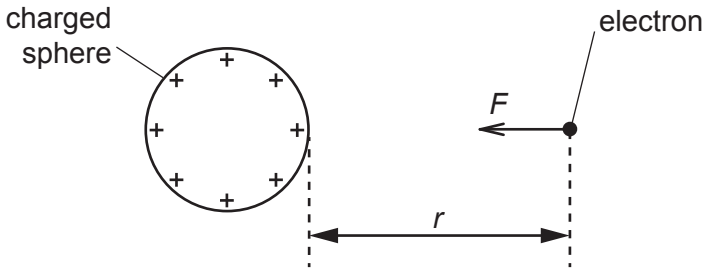
C 13 %

D 20 %

Your answer ☐ **[1]**

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13 An electron is released at a distance r from the surface of a positively charged sphere. It is attracted towards the centre of the sphere and moves until it touches the surface.



Which of the following statements is/are correct?

1 The area under the F against r graph is equal to work done on the electron.

2 The electric field strength E at distance r is equal to $\frac{F}{1.6 \times 10^{-19}}$.

3 The work done on the electron is equal to $F \times r$.

A Only 1

B Only 1 and 2

C Only 1 and 3

D 1, 2 and 3

Your answer ☐ **[1]**

14 Which lepton is emitted in the decay of an up quark and is affected by a magnetic field?

A neutrino

B electron

C positron

D antineutrino

Your answer ☐ **[1]**

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15 A contrast material is used while taking an X-ray image of a patient.

Which statement is correct?

A Iodine is a contrast material.

B Technetium is a contrast material.

C A contrast material must have a short half-life.

D A contrast material is used for acoustic matching.

Your answer ☐ **[1]**

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SECTION B

Answer **all** the questions.

16 **(a)** Derive the S.I. base units for resistance.

base units: ..... **[2]**

(b) Fig. 16.1 shows the I-V characteristics of two electrical components **L** and **R**.

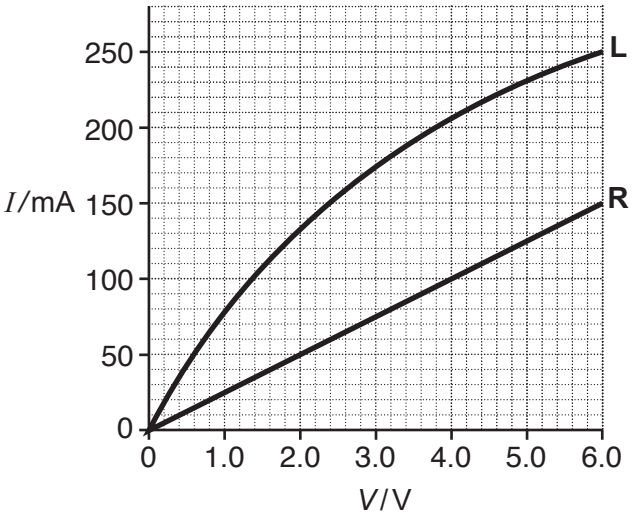


Fig. 16.1

The component **L** is a filament lamp and the component **R** is a resistor.

(i) Show that the resistance of **R** is 40 Ω.

[1]

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(ii) Fig. 16.2 shows the components **L** and **R** connected in series to a battery of e.m.f. 6.0 V.

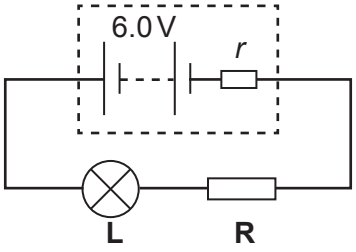


Fig. 16.2

The resistor **R** is a cylindrical rod of length 8.0 mm and cross-sectional area 2.4×10^{-6} m^2. The current in the circuit is 100 mA.

1 Use Fig. 16.1 to determine the internal resistance r of the battery.

r = ... Ω **[3]**

2 Calculate the resistivity ρ of the material of the resistor **R**.

ρ = ... Ω m **[2]**

3 There are 6.5×10^{17} charge carriers within the volume of **R**.

Calculate the mean drift velocity v of the charge carriers within the resistor **R**.

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

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17* A metal circular plate is rotated at a constant frequency by an electric motor.
The plate has a small hole close to its rim.
Fig. 17.1 shows an arrangement used by a student to determine the frequency of the rotating plate.

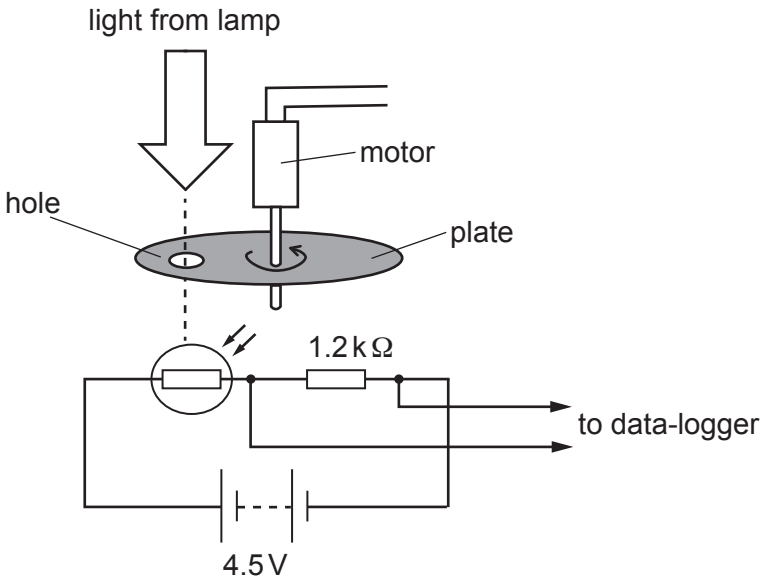


Fig. 17.1

A light-dependent resistor (LDR) and a fixed resistor of resistance 1.2 kΩ are connected in series to a battery. The battery has e.m.f. 4.5 V and has negligible internal resistance. The potential difference V across the resistor is monitored using a data-logger.

Fig. 17.2 shows the variation of V with time t.

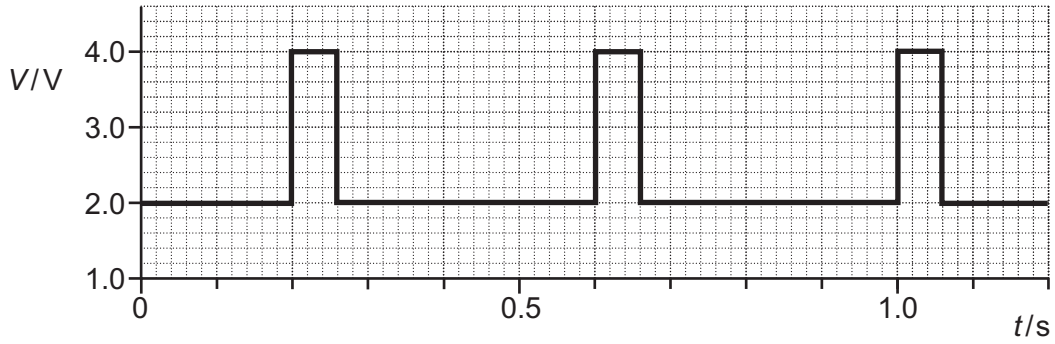


Fig. 17.2

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Use your knowledge and understanding of potential divider circuits to explain the shape of the graph shown in Fig. 17.2. Include in your answer the maximum and minimum values of the resistance of the LDR.

Describe how the student can determine the frequency of the rotating plate.

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18 A narrow beam of unpolarised light is incident at the boundary between air and glass.

Fig. 18 shows the incident ray, the reflected ray and the refracted ray at the air-glass boundary.

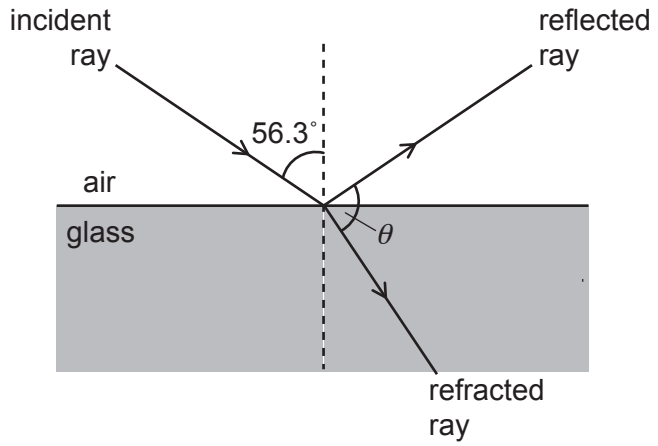


Fig. 18 (not to scale)

The refractive index of air is 1.00 and the refractive index of the glass is 1.50.
The angle of incidence of the light is 56.3°.

(a) Show that the angle θ between the refracted ray in the glass and the reflected ray in the air is 90.0°.

[3]

(b) Describe how you can demonstrate in the laboratory that the reflected light is plane polarised.

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(c) Calculate the time *t* taken for the refracted light to travel a **depth** of 6.0 cm of glass.

t = ... s **[2]**

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19 (a) Fig. 19.1 shows the image from an experiment using a ripple tank.

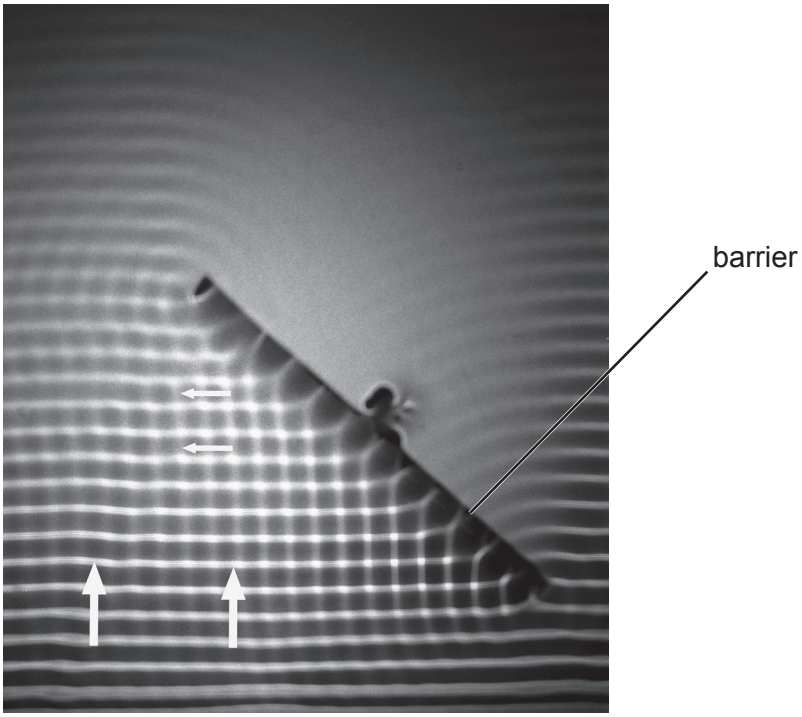


Fig. 19.1

A straight ruler repeatedly hits the surface of water. Waves on the surface of the water travel in the direction shown by the two large upward white arrows. The waves are incident at a solid barrier.

Closely examine the image shown in Fig. 19.1.

State **two** wave phenomena (properties) that can be observed in this image. You may annotate Fig. 19.1 to support your answer.

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

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(b) Two transmitters, **A** and **B**, emit coherent microwaves in all directions. A receiver is moved at constant speed along the line from **P** to **Q** which is parallel to the line joining the two transmitters, as shown in Fig. 19.2.

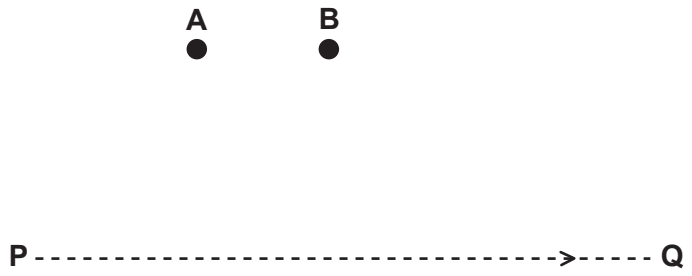


Fig. 19.2

Explain why the output signal from the receiver fluctuates between minimum and maximum values as the receiver moves from **P** to **Q**.

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20 **(a)** An approximate value of the Planck constant h can be determined in the laboratory using light-emitting diodes (LEDs). An LED suddenly starts to conduct and emit monochromatic light when the potential difference across an LED exceeds a minimum value V_0.
The potential difference V_0 and the wavelength λ of the emitted light are related by the equation

$$V_0 = \left(\frac{hc}{e}\right) \times \frac{1}{\lambda}$$

where e is the elementary charge and c is the speed of light in a vacuum.

Fig. 20.1 shows some data points plotted by a student on a V_0 against $\frac{1}{\lambda}$ graph for five different LEDs.

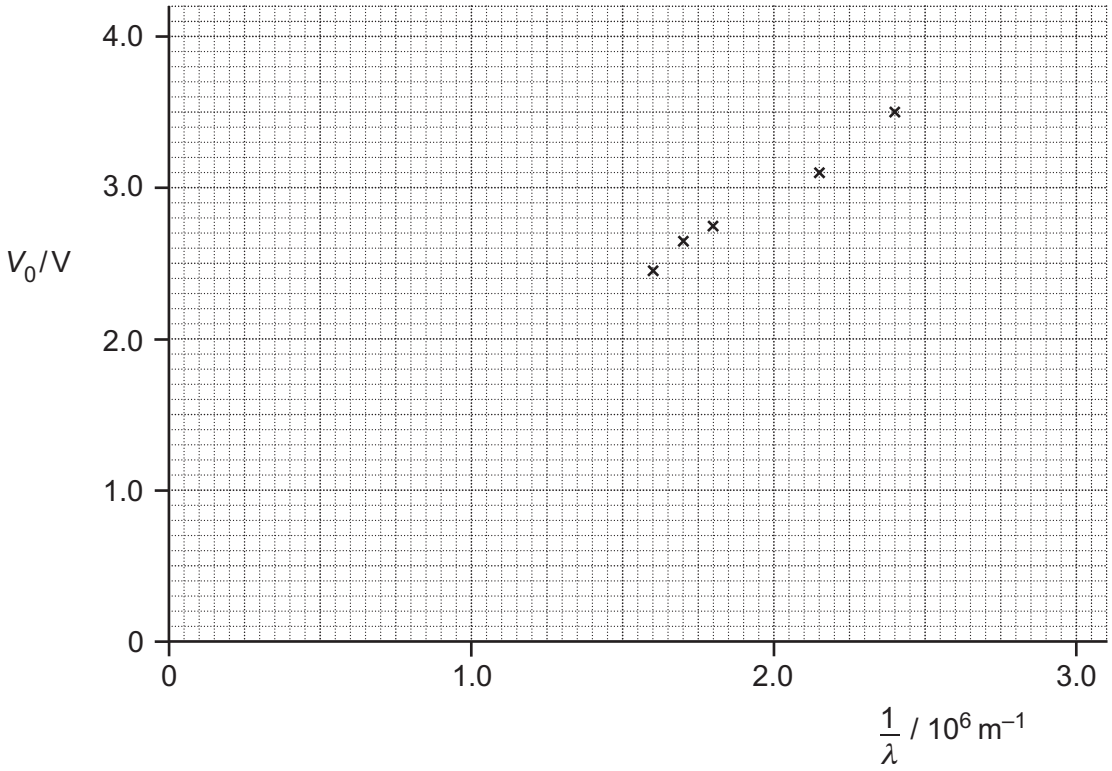


Fig. 20.1

The potential difference across each LED was measured using a digital voltmeter with divisions ±0.01 V. The values for the wavelengths are accurate and were provided by the manufacturer of the LEDs.

The value of V_0 was determined by directly observing the state of the LED in the **brightly** lit laboratory.

(i) Draw the straight line of best fit on Fig 20.1 and determine the gradient of the line.

gradient = ... V m **[2]**

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(ii) Use your answer in **(i)** and the equation on page 20 to determine a value for h to 2 significant figures. Show your working.

h = ... J s **[3]**

(iii) Calculate the percentage difference between your value in **(ii)** and the accepted value of the Planck constant.

difference = ... % **[1]**

(iv) Identify the two types of errors shown by the data in Fig. 20.1 and suggest how you could have refined the experiment to reduce or eliminate these errors.

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(b) Fig. 20.2 shows a gold-leaf electroscope with a clean zinc plate.

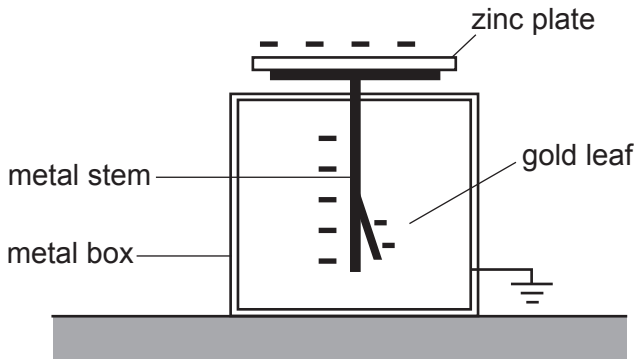


Fig. 20.2

The zinc plate, metal stem and the gold-leaf are given a negative charge by briefly connecting the zinc plate to the negative electrode of a high-voltage supply.

The gold leaf is fully diverged.

The position of the leaf is not affected by intense white light from a table lamp incident on the zinc plate. The gold leaf collapses very quickly when low-intensity ultraviolet radiation from a mercury lamp is incident on the zinc plate.

Explain these observations in terms of photons.

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Question 21 is on page 24

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21 Fig. 21.1 shows a coil of a simple generator rotating in a uniform magnetic field.

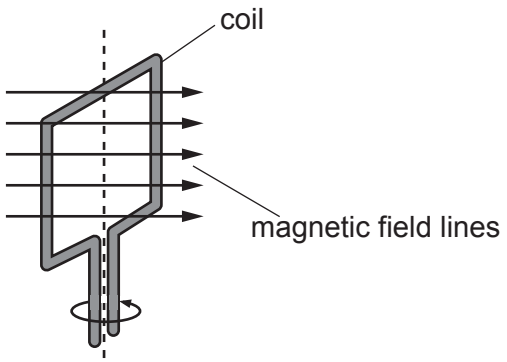


Fig. 21.1

The coil has 85 turns of insulated wire. The cross-sectional area of the coil is 14 cm^2.
Fig. 21.2 shows the variation of magnetic flux density *B* through the plane of the coil with time *t* as it rotates.

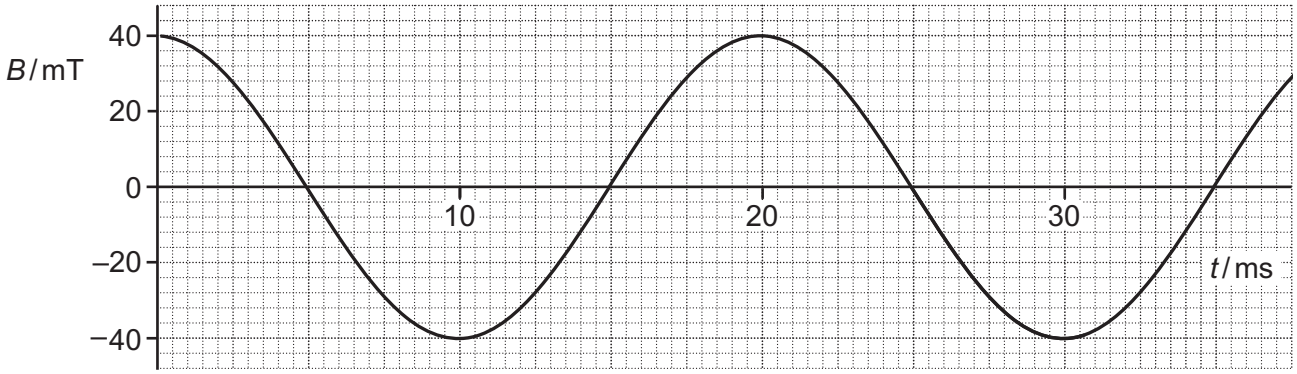


Fig. 21.2

(a) (i) Explain why the electromotive force (e.m.f.) induced across the ends of the coil is a **maximum** at the times when $B = 0$.

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

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(ii) Draw a tangent to the curve in Fig. 21.2 when $B = 0$, and hence determine the **maximum** e.m.f. induced across the ends of the coil.

maximum e.m.f. = ... V **[3]**

(b) Fig. 21.3 shows the variation of the e.m.f. induced across the ends of the coil with time t.

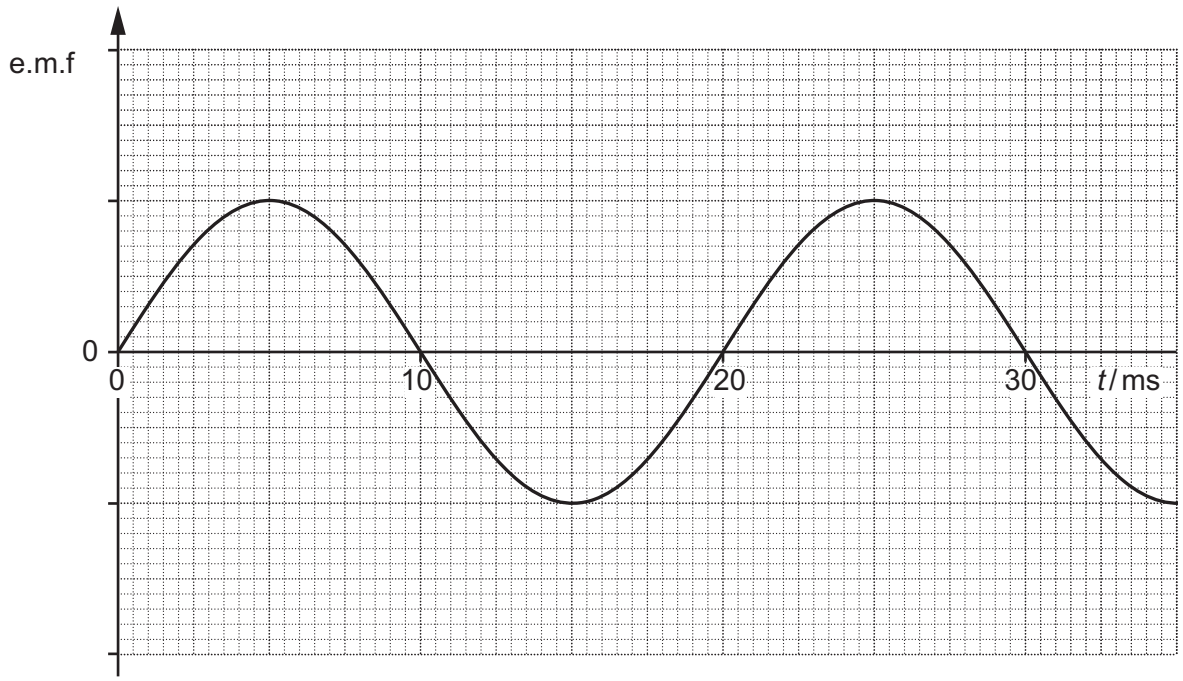


Fig. 21.3

The magnitude of the magnetic flux density of the uniform field is now halved and the coil is rotated at twice its previous frequency.

On Fig. 21.3 sketch the new variation of the e.m.f. induced with time t. **[2]**

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22 A student wishes to determine the permittivity ε of paper using a capacitor made in the laboratory.

The capacitor consists of two large parallel aluminium plates separated by a very thin sheet of paper.

The capacitor is initially charged to a potential difference V_0 using a battery. The capacitor is then discharged through a fixed resistor of resistance 1.0 MΩ.

The potential difference V across the capacitor after a time t is recorded by a data-logger. The student uses the data to draw the ln$V$ against t graph shown in Fig. 22.

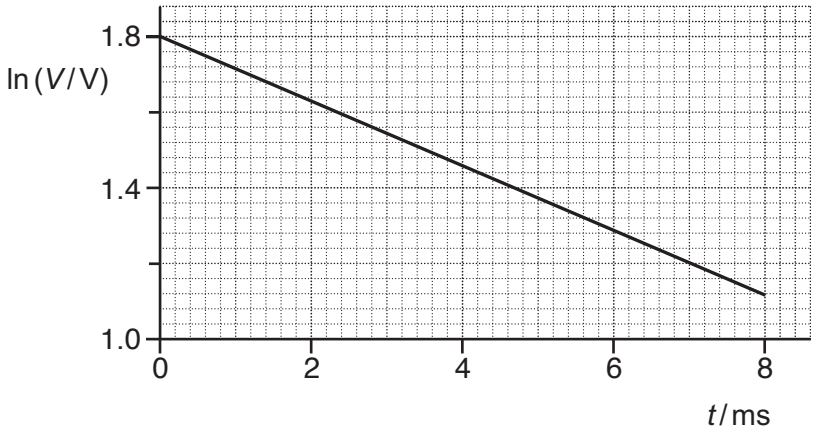


Fig. 22

(a) Show that the magnitude of the gradient of the line shown in Fig. 22 is equal to

$$\frac{1}{CR}$$

where C is the capacitance of the capacitor and R is the resistance of the resistor.

[2]

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(b)* Use Fig. 22 to determine the capacitance C of the capacitor. Describe how the student can then use this value of C to determine a value for ε.
In your description, mention any additional measurements required on the capacitor.

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23 (a) The structure of atoms was deduced in the early 1900s by Rutherford and his co-workers from the scattering of alpha-particles by a very thin sheet of gold.

Rutherford assumed that the scattering of the alpha-particles was due to electrostatic forces. Fig. 23 shows a detector used to record the number N of alpha-particles scattered through an angle θ.

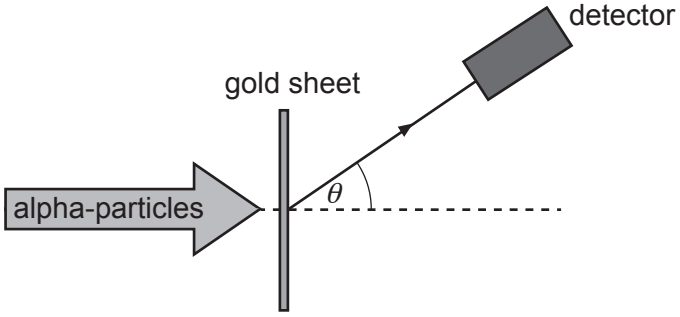


Fig. 23

At $\theta = 0°$, N was too large to be measured. The table below summarises some of the collected data.

θ / °	lg (N)
150	1.5
75	2.3
60	2.7
30	3.9
15	5.1
0	N too large

(i) Show that the number of alpha-particles scattered through 15° is about 4000 times more than those scattered through 150°.

[1]

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(ii) Use the evidence from the table to explain the structure of the atom.

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

(b) A proton with kinetic energy 0.52 MeV is travelling directly towards a stationary nucleus of cobalt-59 ($^{59}_{27}$Co) in a head-on collision.

(i) Explain what happens to the electric potential energy of the proton-nucleus system.

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

(ii) Calculate the **minimum** distance *R* between the proton and cobalt nucleus.

R = ... m **[3]**

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24 An isotope of polonium-213 ($^{213}_{84}$Po) first decays into an isotope of lead-209 ($^{209}_{82}$Pb) and this lead isotope then decays into the stable isotope of bismuth (Bi).

Fig. 24 shows two arrows on a neutron number *N* against proton number *Z* chart to illustrate these two decays.

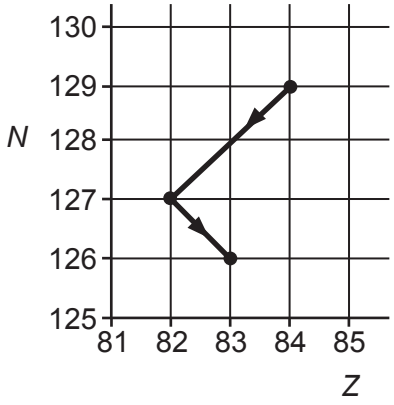


Fig. 24

(a) Complete the nuclear decay equations for

(i) the polonium isotope

$^{213}_{84}\text{Po} \longrightarrow {}^{209}_{82}\text{Pb} + \text{.....}$ **[1]**

(ii) the lead isotope.

$^{209}_{82}\text{Pb} \longrightarrow {}^{\text{.....}}_{83}\text{Bi} + {}^{0}_{-1}\text{e} + \text{.....}$ **[2]**

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(b) A pure sample of polonium-213 is being produced in a research laboratory.

The half-life of $^{213}_{84}Po$ is very small compared with the half-life of $^{209}_{82}Pb$.

After a very short time, the ionising radiation detected from the sample is mainly from the beta-minus decay of the lead-209 nuclei.

(i) Briefly describe and explain an experiment that can be carried out to confirm the beta-minus radiation emitted from the lead nuclei.

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(ii) The activity of the sample of $^{209}_{82}Pb$ after 7.0 hours is 12 kBq.

The half-life of $^{209}_{82}Pb$ is 3.3 hours.

Calculate the initial number of lead-209 nuclei in this sample.

number of nuclei = ... **[4]**

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25 (a) The nuclear reaction below shows how the isotope of fluorine-18 ($^{18}_{9}F$) is made from the isotope of oxygen-18 ($^{18}_{8}O$).

$$^{18}_{8}O + {}^{1}_{1}p \rightarrow {}^{18}_{9}F + {}^{1}_{0}n + \gamma$$

The oxygen-18 nucleus is **stationary** and the proton has kinetic energy of 0.25×10^{-11} J.
The binding energy of the $^{18}_{8}O$ nucleus is 2.24×10^{-11} J and the binding energy of the $^{18}_{9}F$ nucleus is 2.20×10^{-11} J. The proton and the neutron have zero binding energy.

(i) Explain why a high-speed proton is necessary to trigger the nuclear reaction shown above.

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

(ii) Estimate the minimum wavelength λ of the gamma ray photon (γ).

λ = ... m **[3]**

(iii) Fluorine-18 is a positron emitter.
Name a medical imaging technique that uses fluorine-18 and state one benefit of the technique.

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

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(b) Describe how the components of a computerised axial tomography (CAT) scanner can produce high-quality images of the internal structures of a patient.

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..... **[4]**

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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