Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Tuesday 9 January 2024

Morning (Time: 1 hour 45 minutes)

Paper reference **WPH14/01**

Physics

International Advanced Level
UNIT 4: Further Mechanics, Fields and Particles

You must have:
Scientific calculator, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*
- **Show all your working out** in calculations and **include units** where appropriate.

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- In the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- The list of data, formulae and relationships is printed at the end of this booklet.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

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SECTION A

Answer ALL questions.

For questions 1–10, in Section A, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Which of the following is the number of neutrons in a nucleus of $^{121}_{51}Sb$?

☒ **A** 51

☒ **B** 70

☒ **C** 121

☒ **D** 172

(Total for Question 1 = 1 mark)

2 What is the process by which electrons are released from a heated filament?

☒ **A** excitation

☒ **B** ionisation

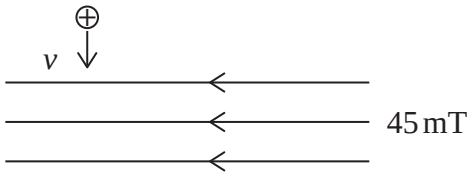
☒ **C** photoelectric emission

☒ **D** thermionic emission

(Total for Question 2 = 1 mark)

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3 A proton travelling at speed v enters a uniform magnetic field.
The magnetic flux density of the field is 45 mT, as shown.



A force of 1.35×10^{-13} N is exerted on the proton.

Which of the following expressions gives v in m s^{-1}?

☒ **A** $\dfrac{1.35 \times 10^{-13}}{45 \times 1.6 \times 10^{-19}}$

☒ **B** $\dfrac{1.35 \times 10^{-13}}{45 \times 1.66 \times 10^{-27}}$

☒ **C** $\dfrac{1.35 \times 10^{-13}}{45 \times 10^{-3} \times 1.6 \times 10^{-19}}$

☒ **D** $\dfrac{1.35 \times 10^{-13}}{45 \times 10^{-3} \times 1.66 \times 10^{-19}}$

(Total for Question 3 = 1 mark)

4 The structure of nucleons can be investigated using high energy electrons.

Which of the following is the reason high energies are needed?

☒ **A** to cause annihilation

☒ **B** to produce individual quarks

☒ **C** to produce short de Broglie wavelengths

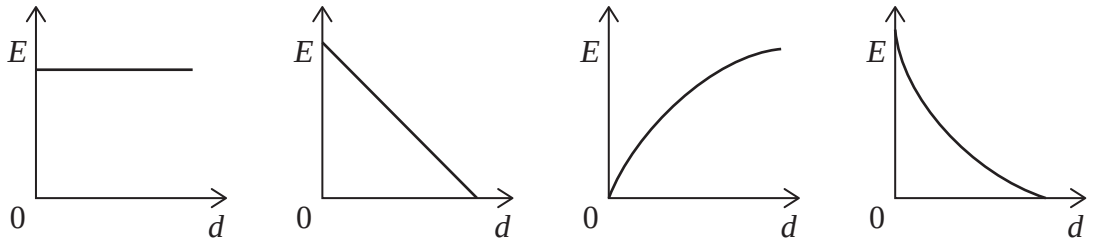
☒ **D** to overcome the repulsive electrostatic forces

(Total for Question 4 = 1 mark)

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5 A potential difference is applied across two parallel metal plates.

Which of the following graphs shows how the electric field strength E varies with distance d from the positive plate?



A **B** **C** **D**

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 5 = 1 mark)

6 A pion can decay into two leptons.

Which of the following decays is possible?

☒ **A** $\pi^- \rightarrow e^- + \nu_e$

☒ **B** $\pi^0 \rightarrow e^- + \bar{\nu}_e$

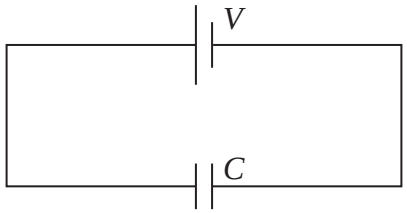
☒ **C** $\pi^0 \rightarrow e^+ + \bar{\nu}_e$

☒ **D** $\pi^+ \rightarrow e^+ + \nu_e$

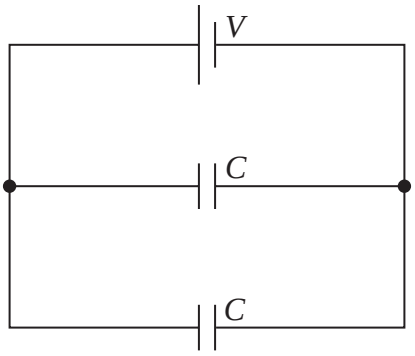
(Total for Question 6 = 1 mark)

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7 A potential difference V is connected across a capacitor of capacitance C. The charge stored on the capacitor is Q.



The capacitor is replaced with two capacitors, each of capacitance C, connected in parallel.



What is the total charge stored in the parallel circuit?

☒ **A** $\frac{Q}{4}$

☒ **B** $\frac{Q}{2}$

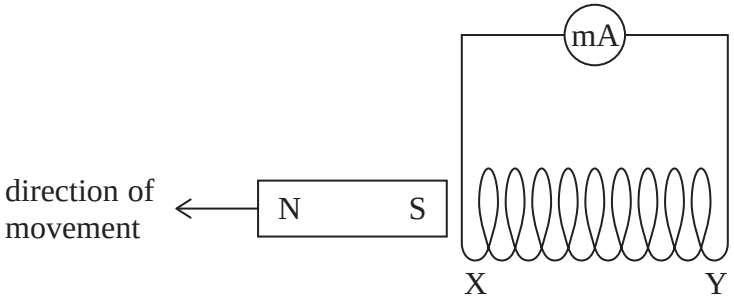
☒ **C** Q

☒ **D** $2Q$

(Total for Question 7 = 1 mark)

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8 A magnet is moved away from a coil, as shown.



A current is produced in the coil, which creates a magnetic field around the coil.

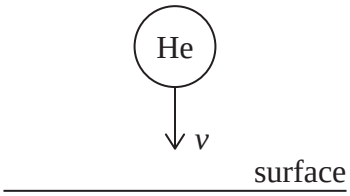
Which row of the table shows the magnetic pole at X and the magnetic pole at Y?

		Magnetic pole at X	Magnetic pole at Y
☒	**A**	north	north
☒	**B**	north	south
☒	**C**	south	north
☒	**D**	south	south

(Total for Question 8 = 1 mark)

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9 A helium atom of mass m and velocity v collides at right angles with a surface, as shown.



The atom bounces off the surface with the same speed but in the opposite direction. The collision takes time Δt.

Which of the following is the mean force acting on the atom during the collision?

☒ **A** $\frac{mv}{\Delta t}$

☒ **B** $\frac{2mv}{\Delta t}$

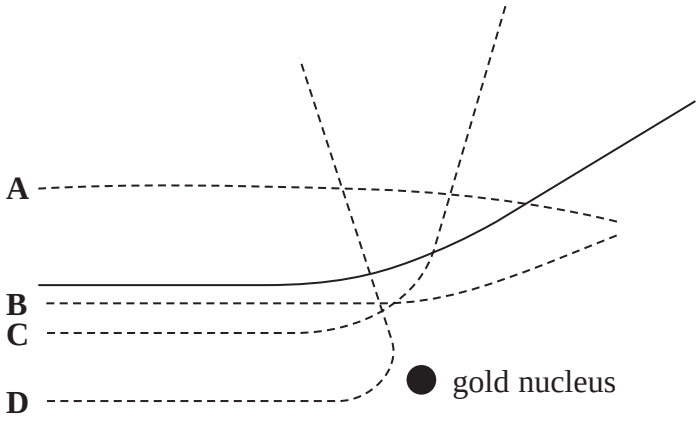
☒ **C** $\frac{-mv}{\Delta t}$

☒ **D** $\frac{-2mv}{\Delta t}$

(Total for Question 9 = 1 mark)

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10 The solid line shows the path of an alpha particle as it passes close to a gold nucleus.



A second alpha particle with the same kinetic energy approaches the gold nucleus.

Which dotted line shows a possible path for the second alpha particle?

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

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SECTION B

Answer ALL questions. Write your answers in the spaces provided.

11 A student selects the capacitor shown to use in a circuit.



(Source: © David J. Green – electrical/Alamy Stock Photo)

The tolerance of the capacitor is ± 20%.

Calculate the maximum energy such a capacitor can store.

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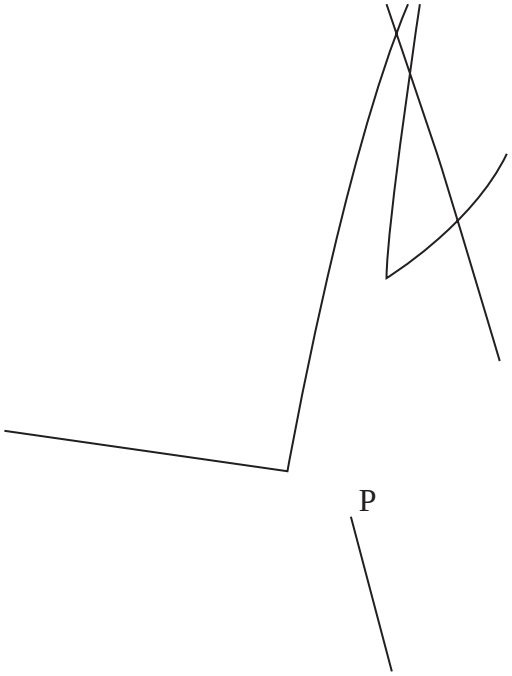
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Maximum energy = ...

(Total for Question 11 = 3 marks)

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12 The diagram shows tracks produced by particles in a bubble chamber.



A charged particle interacts with a stationary proton at P. This produces two neutral particles. Each of these neutral particles is unstable and decays into other particles.

Explain the evidence provided by the diagram for this description of the particle interactions.

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(Total for Question 12 = 3 marks)

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13 In the early universe, a helonium molecule formed when a proton joined with a helium atom.

The helium atom in the helonium molecule could lose both of its electrons in a collision. When this happened, the helium ion and the proton accelerated away from each other.

The initial separation of the helium ion and the proton was 7.9×10^{-11} m.

(a) Calculate the initial force between the helium ion and the proton.

(2)

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Initial force between helium ion and proton = ...

(b) Calculate the electric field strength due to the helium ion, at the initial position of the proton.

(2)

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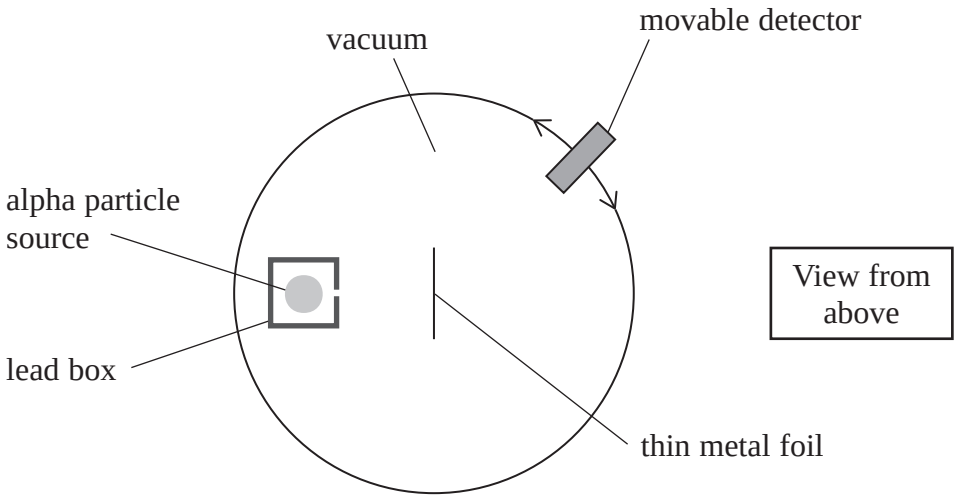
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Electric field strength due to helium ion = ...

(Total for Question 13 = 4 marks)

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14 In the early 20th century, a series of experiments was carried out in which alpha particles were directed at thin metal foils. A simplified version of the apparatus used is shown.

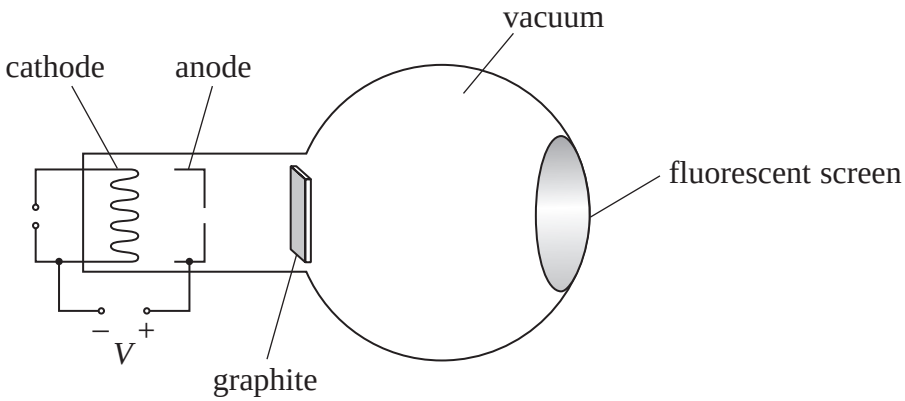


Describe the observations from these experiments and the conclusions that were made from these observations.

(Total for Question 14 = 5 marks)

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15 A beam of electrons was directed through a thin piece of graphite towards a fluorescent screen, using the apparatus shown.



A potential difference V was applied between the cathode and the anode to produce the beam of electrons.

A diffraction pattern was produced on the fluorescent screen.

From the diffraction pattern, the de Broglie wavelength of the electron beam was determined to be 2.55×10^{-11} m.

Calculate V.

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V = ...

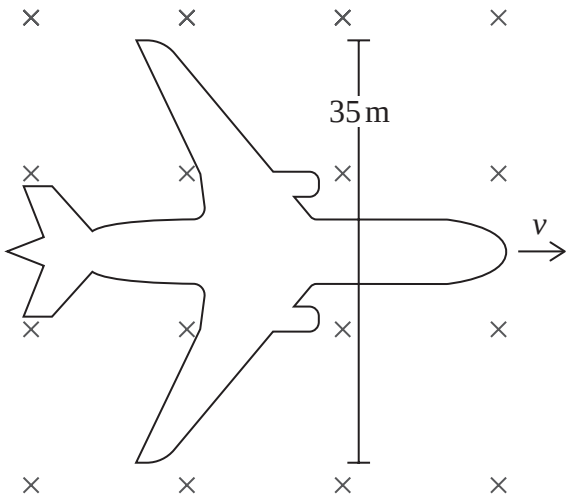
(Total for Question 15 = 4 marks)

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16 As an aeroplane flies through the Earth's magnetic field, an e.m.f. is induced across the wing tips.

An aeroplane is flying with a velocity v, at 90° to the vertical component of the Earth's magnetic field, as shown.

The distance between the wing tips is 35 m.



An e.m.f. of 0.40 V is induced across the wing tips. The pilot states that the aeroplane is flying with a speed of 250 m s^{-1}.

Deduce whether the magnitude of the induced e.m.f. supports the pilot's statement.

vertical component of Earth's magnetic field = 41 μT

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(Total for Question 16 = 4 marks)

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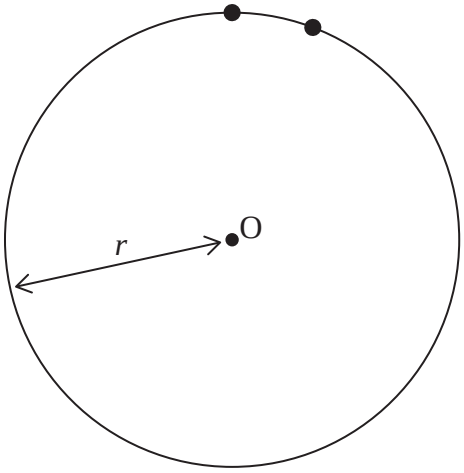
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17 A model aeroplane moves in a horizontal circle.

(a) The path of the model aeroplane is a circle of radius r, centre O.

The dots on the diagram represent two positions of the model aeroplane as it moves with a constant speed v.



View from above

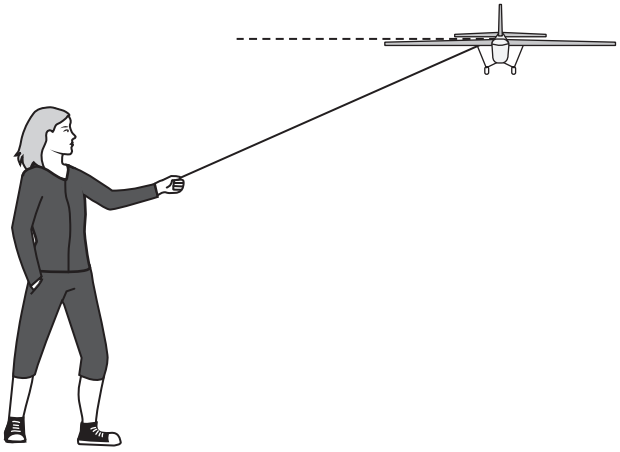
Derive the equation for centripetal acceleration, $a = \frac{v^2}{r}$, by considering the velocity of the model aeroplane at these two positions.

Your answer should include a vector diagram.

(5)

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(b) A model aeroplane is attached to a wire. The wire is held by a person, as shown.



The aeroplane moves in a horizontal circle of radius 28.5 m at a speed of 22.5 $m s^{-1}$. A lift force acts vertically upwards on the aeroplane. The lift force is equal to twice the weight of the aeroplane.

The mass of the aeroplane is 1.55 kg.

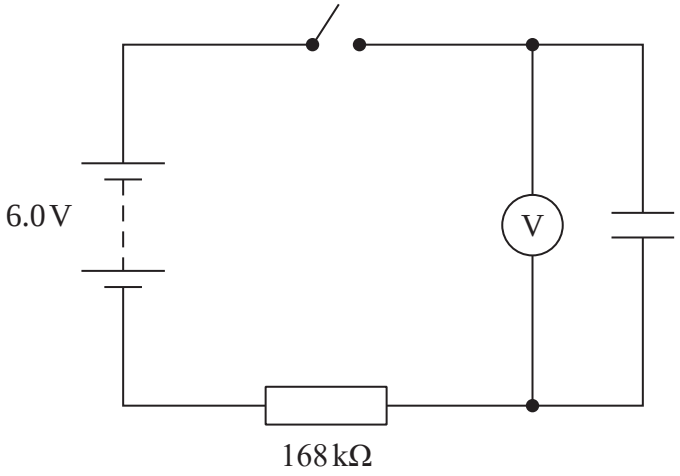
The wire will break if the tension is greater than 35 N.

Deduce whether the wire will break.

(4)

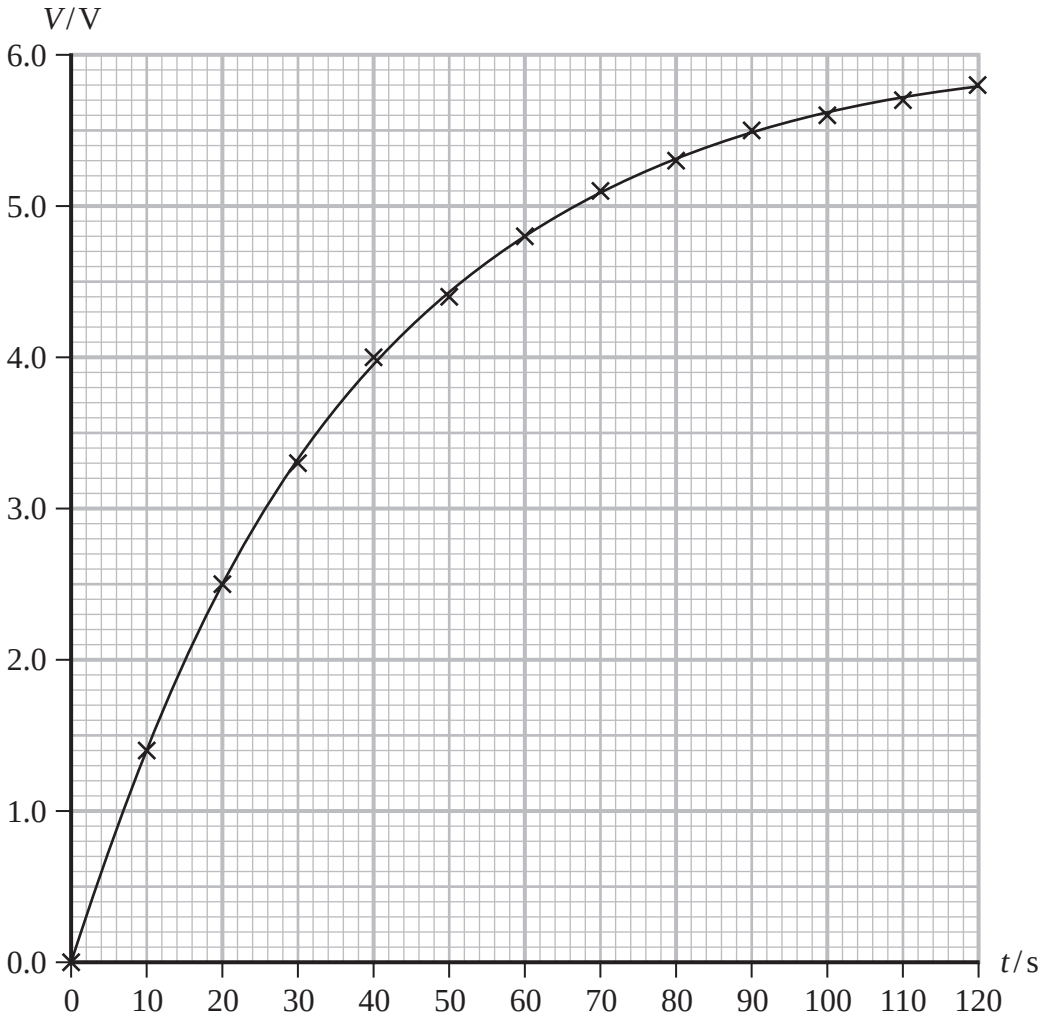
(Total for Question 17 = 9 marks)

18 A student used the circuit shown to investigate the charging of a capacitor.



The student closed the switch to charge the capacitor and started a stopwatch. She recorded the voltmeter reading V every 10 s as the capacitor charged.

The graph shows how V varied with time t.



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(a) (i) Determine a value for the capacitance C of the capacitor.

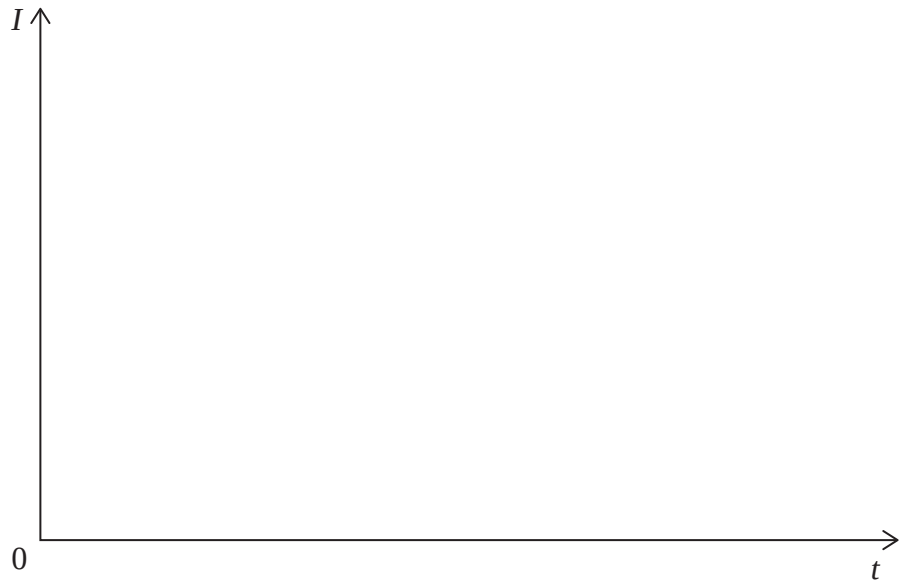
(4)

C = ...

(ii) Sketch on the axes below how current I in the circuit would vary with t.

You should include the value of the maximum current.

(3)



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(b) The student connected a second 168 kΩ resistor in parallel with the first resistor.

Explain how the time taken to charge the capacitor would change.

You do not need to do any further calculations.

(3)

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(Total for Question 18 = 10 marks)

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19 Auroras occur above the Earth's poles when charged particles collide with gases in the upper atmosphere.

These collisions produce tiny flashes that fill the sky with light, as shown.



(Source: © Jamen Percy/Shutterstock)

(a) Collisions between electrons and oxygen atoms cause the emission of green light.

Calculate the velocity of electrons that would cause green light of wavelength 560 nm to be emitted from an oxygen atom.

(3)

Velocity of electrons = ...

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(b) Radio waves are also produced during an aurora.

Electrons moving in a circular path in the atmosphere emit radio waves.
The frequency of the emitted radio waves is the same as the frequency of rotation of the electron.

An electron with a speed of $1650\,\text{km}\,\text{s}^{-1}$ is moving perpendicular to a magnetic field with magnetic flux density $48\,\mu\text{T}$.

A radio station is broadcasting at a wavelength of 220 m.

Deduce whether the radiation emitted by the electron would interfere with the signal from the radio station.

You should calculate the radius of the circular path of the electron.

(5)

(Total for Question 19 = 8 marks)

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20 Particle physicists use the principle of conservation of momentum when analysing particle interactions.

(a) State what is meant by the principle of conservation of momentum.

(2)

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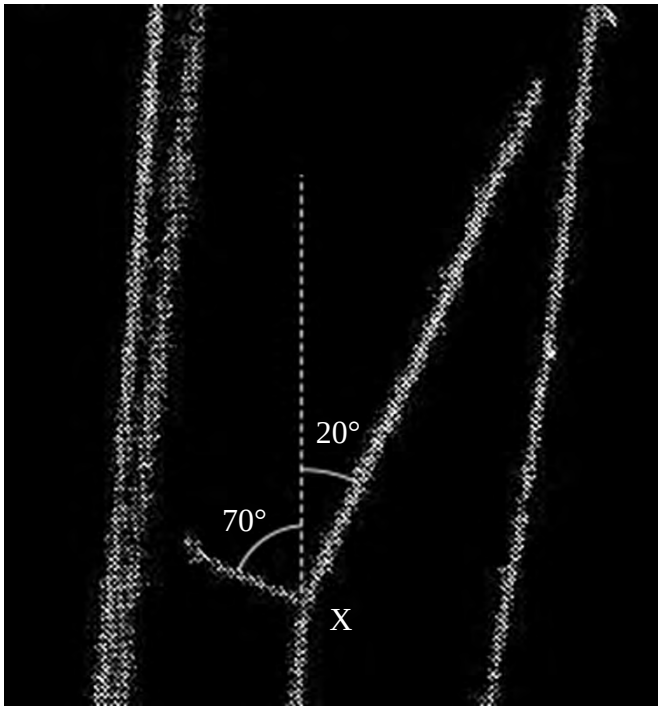
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(b) The cloud chamber photograph shows alpha particle tracks in helium.

An alpha particle collided with a helium nucleus at X. After the collision, the alpha particle moved at an angle of 20° to its initial direction, as shown.



(Source: © Institute of Physics)

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(i) Show that the speed of the helium nucleus immediately after the collision is about $5.6 \times 10^{6}\,m\,s^{-1}$.

mass of helium nucleus = 6.64×10^{-27} kg
speed of alpha particle after collision = $1.55 \times 10^{7}\,m\,s^{-1}$

(4)

(ii) The kinetic energy of the alpha particle before the collision was 9.01×10^{-13} J.

Deduce whether the collision was elastic.

(3)

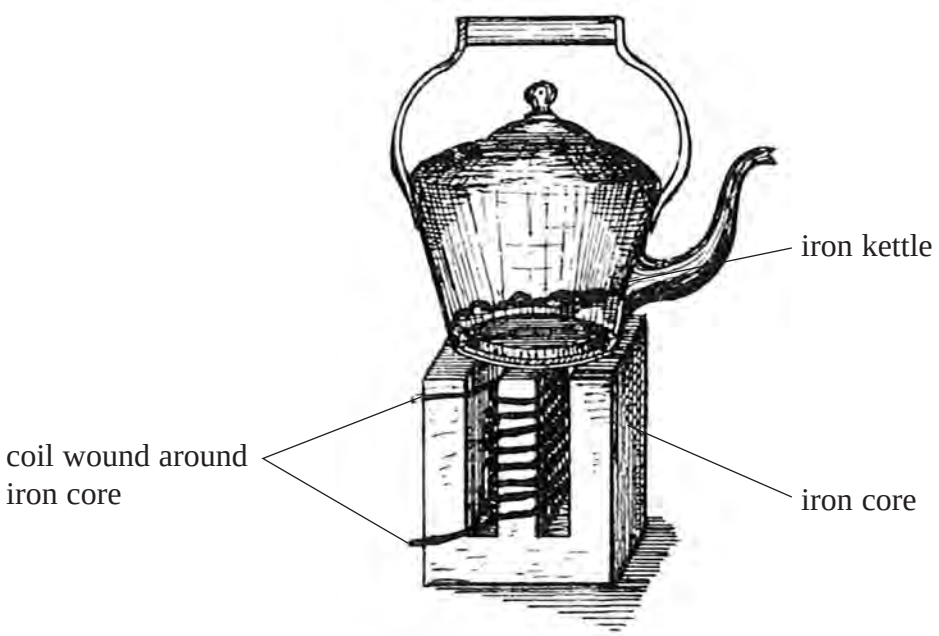
(Total for Question 20 = 9 marks)

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21 Many modern kitchens have an induction cooker.

*(a) The idea of the induction cooker was first suggested more than a century ago.

An iron kettle was heated by passing an alternating current through a coil wound around a soft iron core, as shown.



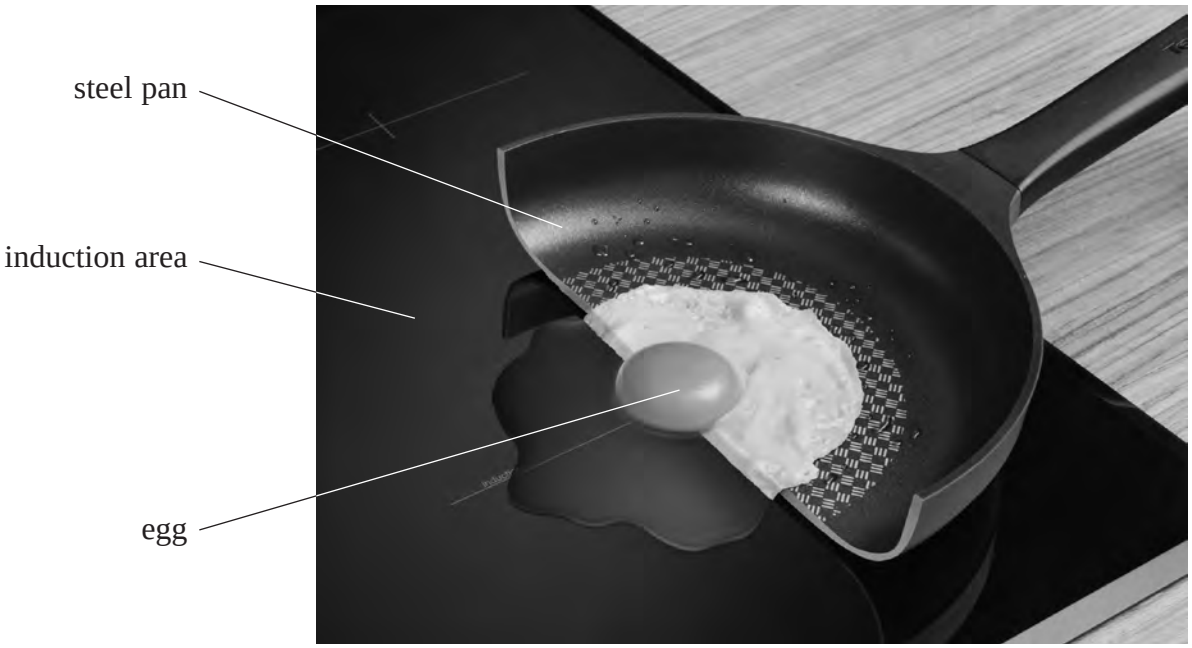
(Source: © Darling Archive/Alamy Stock Photo)

Explain why the kettle heats up when there is an alternating current in the coil.

(6)

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(b) A manufacturer demonstrated the use of an induction cooker using a raw egg and a steel frying pan that had been cut in half, as shown.



(Source: © Canan Asik/Shutterstock)

The cooker surface is not an electrical conductor.

Explain why the egg cooks only where it is in contact with the pan.

(2)

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(Total for Question 21 = 8 marks)

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22 Many sub-atomic particles are unstable and have only been detected in high energy particle collision experiments.

(a) Kaons are short-lived sub-atomic particles. They are also known as K-mesons and were the first strange particles to be discovered.

(i) The following table lists some quarks and their charge.

Quark	Charge / e
Up (u)	$+\frac{2}{3}$
Down (d)	$-\frac{1}{3}$
Strange (s)	$-\frac{1}{3}$

Explain the quark structure of a K^- meson.

(2)

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(ii) The mass of a K^- meson is $494\,MeV/c^2$.

Calculate the mass of a K^- meson in kg.

(3)

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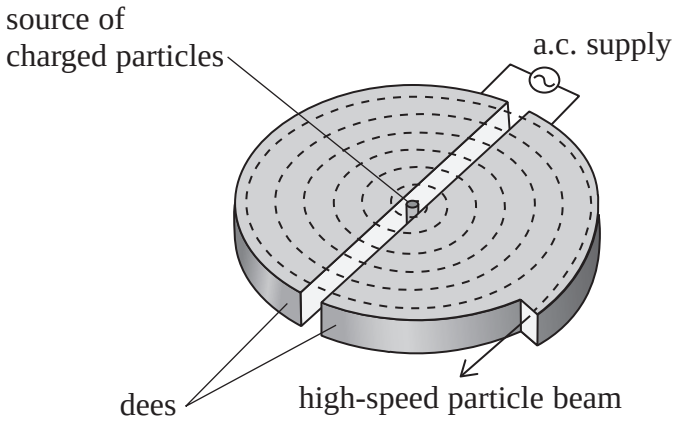
K^- meson mass = ... kg

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(b) The structure of a cyclotron is shown.



(i) Explain how the cyclotron produces a beam of high energy particles.

You should refer to the alternating potential difference and the magnetic field.

(4)

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(ii) The first cyclotron was made by Lawrence in 1929. This cyclotron was able to produce a beam of protons with a maximum kinetic energy of 80 keV.

Calculate the magnetic flux density of the magnetic field used with this cyclotron.

diameter of cyclotron = 0.11 m

(4)

Magnetic flux density = ...

(Total for Question 22 = 13 marks)

TOTAL FOR SECTION B = 80 MARKS
TOTAL FOR PAPER = 90 MARKS

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List of data, formulae and relationships

Acceleration of free fall	$g = 9.81$ m s^{-2}	(close to Earth's surface)
Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}	
Coulomb's law constant	$k = 1/4\pi\varepsilon_0$	
	$= 8.99 \times 10^{9}$ N m^2 C^{-2}	
Electron charge	$e = -1.60 \times 10^{-19}$ C	
Electron mass	$m_e = 9.11 \times 10^{-31}$ kg	
Electronvolt	$1\,\text{eV} = 1.60 \times 10^{-19}$ J	
Gravitational constant	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}	
Gravitational field strength	$g = 9.81$ N kg^{-1}	(close to Earth's surface)
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}	
Planck constant	$h = 6.63 \times 10^{-34}$ J s	
Proton mass	$m_p = 1.67 \times 10^{-27}$ kg	
Speed of light in a vacuum	$c = 3.00 \times 10^{8}$ m s^{-1}	
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}	
Unified atomic mass unit	$u = 1.66 \times 10^{-27}$ kg	

Unit 1

Mechanics

Kinematic equations of motion

$$s = \frac{(u + v)t}{2}$$

$$v = u + at$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

Forces

$$\Sigma F = ma$$

$$g = \frac{F}{m}$$

$$W = mg$$

Momentum

$$p = mv$$

Moment of force

$$\text{moment} = Fx$$

Work and energy

$$\Delta W = F\Delta s$$

$$E_k = \frac{1}{2}mv^2$$

$$\Delta E_{grav} = mg\Delta h$$

Power

$$P = \frac{E}{t}$$

$$P = \frac{W}{t}$$

Efficiency

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$$

$$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

Materials

Density $\rho = \frac{m}{V}$

Stokes' law $F = 6\pi\eta r v$

Hooke's law $\Delta F = k\Delta x$

Elastic strain energy $\Delta E_{el} = \frac{1}{2} F \Delta x$

Young modulus $E = \frac{\sigma}{\varepsilon}$ where

Stress $\sigma = \frac{F}{A}$

Strain $\varepsilon = \frac{\Delta x}{x}$

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Unit 2

Waves

Wave speed	$v = f\lambda$
Speed of a transverse wave on a string	$v = \sqrt{\frac{T}{\mu}}$
Intensity of radiation	$I = \frac{P}{A}$
Refractive index	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
	$n = \frac{c}{v}$
Critical angle	$\sin C = \frac{1}{n}$
Diffraction grating	$n\lambda = d\sin\theta$

Electricity

Potential difference	$V = \frac{W}{Q}$
Resistance	$R = \frac{V}{I}$
Electrical power, energy	$P = VI$
	$P = I^2R$
	$P = \frac{V^2}{R}$
	$W = VIt$
Resistivity	$R = \frac{\rho l}{A}$
Current	$I = \frac{\Delta Q}{\Delta t}$
	$I = nqvA$
Resistors in series	$R = R_1 + R_2 + R_3$
Resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

Particle nature of light

Photon model	$E = hf$
Einstein's photoelectric equation	$hf = \phi + \frac{1}{2}mv^2_{max}$
de Broglie wavelength	$\lambda = \frac{h}{p}$

Unit 4

Further mechanics

Impulse	$F\Delta t = \Delta p$
Kinetic energy of a non-relativistic particle	$E_k = \frac{p^2}{2m}$
Motion in a circle	$v = \omega r$
	$T = \frac{2\pi}{\omega}$
	$a = \frac{v^2}{r}$
	$a = r\omega^2$
Centripetal force	$F = ma = \frac{mv^2}{r}$
	$F = mr\omega^2$

Electric and magnetic fields

Electric field	$E = \frac{F}{Q}$
Coulomb's law	$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$
	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$
	$E = \frac{V}{d}$
Electrical potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
Capacitance	$C = \frac{Q}{V}$
Energy stored in capacitor	$W = \frac{1}{2}QV$
	$W = \frac{1}{2}CV^2$
	$W = \frac{1}{2}\frac{Q^2}{C}$
Capacitor discharge	$Q = Q_0 e^{-t/RC}$

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Resistor-capacitor discharge $I = I_0 e^{-t/RC}$

$$V = V_0 e^{-t/RC}$$

$$\ln Q = \ln Q_0 - \frac{t}{RC}$$

$$\ln I = \ln I_0 - \frac{t}{RC}$$

$$\ln V = \ln V_0 - \frac{t}{RC}$$

In a magnetic field $F = Bqv \sin \theta$

$$F = BIl \sin \theta$$

Faraday's and Lenz's laws $\mathscr{E} = \frac{-\mathrm{d}(N\phi)}{\mathrm{d}t}$

Nuclear and particle physics

In a magnetic field $r = \frac{p}{BQ}$

Mass-energy $\Delta E = c^2 \Delta m$

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