Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Friday 20 October 2023

Afternoon (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 The nucleus of an isotope of osmium (Os) contains 76 protons and 190 neutrons.

Which of the following can be used to represent this isotope?

☐ **A** $^{266}_{76}\mathrm{Os}$

☐ **B** $^{190}_{76}\mathrm{Os}$

☐ **C** $^{76}_{190}\mathrm{Os}$

☐ **D** $^{76}_{266}\mathrm{Os}$

(Total for Question 1 = 1 mark)

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2 A car travels along a straight horizontal road. A drag force of 150 N acts for 15 s causing the speed of the car to decrease.

Which of the following is the change in momentum of the car due to the drag force?

☐ **A** $10\,\mathrm{kg\,m\,s^{-1}}$

☐ **B** $1125\,\mathrm{kg\,m\,s^{-1}}$

☐ **C** $2250\,\mathrm{kg\,m\,s^{-1}}$

☐ **D** $16\,875\,\mathrm{kg\,m\,s^{-1}}$

(Total for Question 2 = 1 mark)

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3 The tubes of a linear accelerator (linac) get progressively longer along the length of the linac.

Which of the following is the reason for this?

☐ **A** The frequency of the applied potential difference decreases.

☐ **B** The frequency of the applied potential difference increases.

☐ **C** The particles gain mass as they accelerate.

☐ **D** The particles must spend the same time in each tube.

(Total for Question 3 = 1 mark)

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4 Which of the following is a possible unit for magnetic flux?

- ☒ **A** $T\,m^2$
- ☒ **B** $T\,m^{-2}$
- ☒ **C** $Wb\,m^2$
- ☒ **D** $Wb\,m^{-2}$

(Total for Question 4 = 1 mark)

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5 Which of the following is **not** a valid conclusion from Rutherford's alpha particle scattering experiments?

- ☒ **A** The nucleus contains most of the mass of the atom.
- ☒ **B** The nucleus contains protons and neutrons.
- ☒ **C** The nucleus is charged.
- ☒ **D** The nucleus is very small compared with the atom.

(Total for Question 5 = 1 mark)

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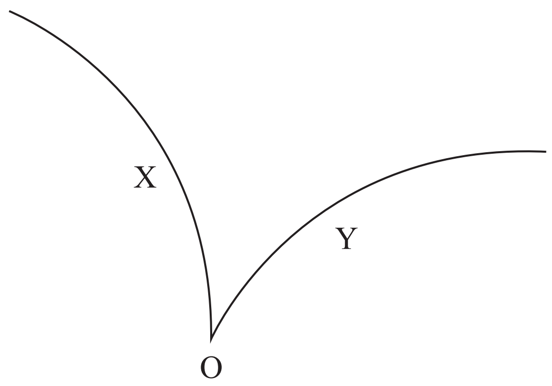
6 A particle detector shows tracks produced by two particles X and Y. The particles were created by the decay of a kaon at O.



Which of the following can be concluded from the tracks?

- ☒ **A** A magnetic field acts into the page.
- ☒ **B** X is a positively charged particle.
- ☒ **C** Y is an electron.
- ☒ **D** X and Y have opposite charge.

(Total for Question 6 = 1 mark)

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7 The diagram shows the paths of two charged particles, X and Y, moving at the same speed in a uniform magnetic field.

Which row of the table describes the properties of Y compared with the properties of X?

		Mass of Y	Charge of Y
☒	**A**	greater than	the same as
☒	**B**	less than	greater than
☒	**C**	the same as	less than
☒	**D**	greater than	less than

(Total for Question 7 = 1 mark)

8 A toy aeroplane is travelling in a circular path. The toy aeroplane completes 12 revolutions in 6 s.

Which of the following gives the angular velocity, in rad s^{-1}, of the toy aeroplane?

☒ **A** $\frac{12 \times \pi}{6}$

☒ **B** $\frac{12 \times 2\pi}{6}$

☒ **C** $\frac{6 \times \pi}{12}$

☒ **D** $\frac{6 \times 2\pi}{12}$

(Total for Question 8 = 1 mark)

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9 A capacitor discharges through a resistor. The time constant of the circuit is 5 s.

What is the time taken, in s, for the charge on the plates of the capacitor to halve?

- ☒ **A** $0.5 \ln 2$
- ☒ **B** $0.5 \ln 5$
- ☒ **C** $2 \ln 5$
- ☒ **D** $5 \ln 2$

(Total for Question 9 = 1 mark)

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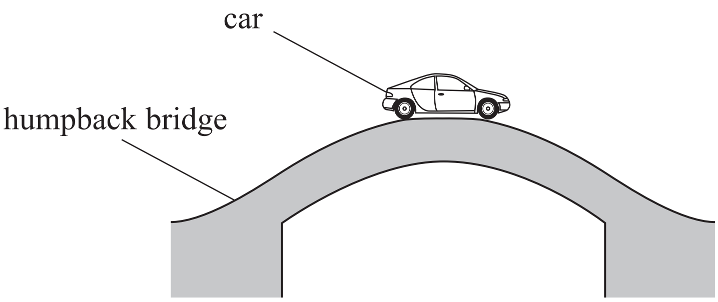
10 A car travels over a humpback bridge, as shown. The bridge forms part of a circle of radius *r*. The car has mass *m* and travels with constant speed *v*.



The car is at the top of the bridge.

Which of the following expressions gives the force, from the bridge, on the moving car?

- ☒ **A** mg
- ☒ **B** $mg + \frac{mv^2}{r}$
- ☒ **C** $mg - \frac{mv^2}{r}$
- ☒ **D** $\frac{mv^2}{r} - mg$

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 The photograph shows children on a roundabout in a playground.

(Source: © Juice Flair/Shutterstock)

The roundabout is a flat platform with bars. The children make the platform rotate by running on the ground whilst pushing on the bars.

It takes 12 s for the roundabout to make 2 complete rotations.

A child is standing on the platform 1.8 m from the centre of the roundabout.

Calculate the speed of the child.

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Speed of child = ...

(Total for Question 11 = 3 marks)

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12 An electron has kinetic energy 7.2×10^{-16} J.

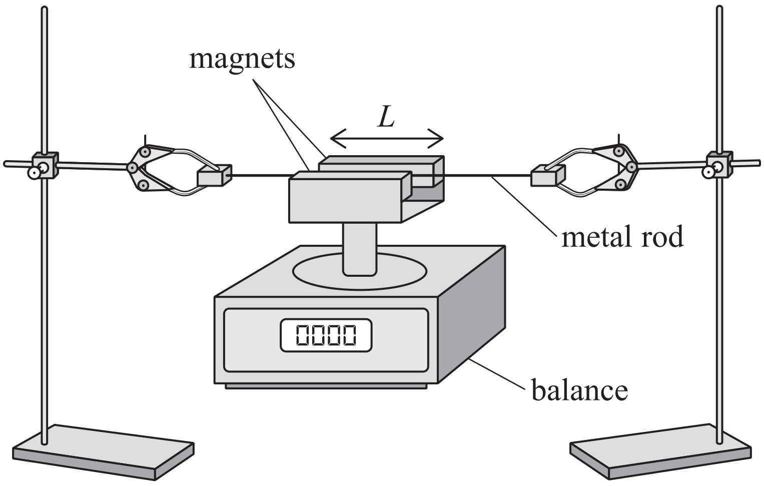
Calculate the de Broglie wavelength of the electron.

Wavelength = ...

(Total for Question 12 = 3 marks)

13 A student clamped a metal rod horizontally in a uniform magnetic field as shown.

The student connected the ends of the metal rod to a power supply, an ammeter and a switch in a series circuit. When the student closed the switch there was a current in the metal rod.



When the switch was closed, the reading on the balance increased by 2.8 g. The reading on the ammeter was 3.6 A.

The flux density of the magnetic field was 120 mT.
The length of the rod in the magnetic field was L.

Calculate L.

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L = ...

(Total for Question 13 = 3 marks)

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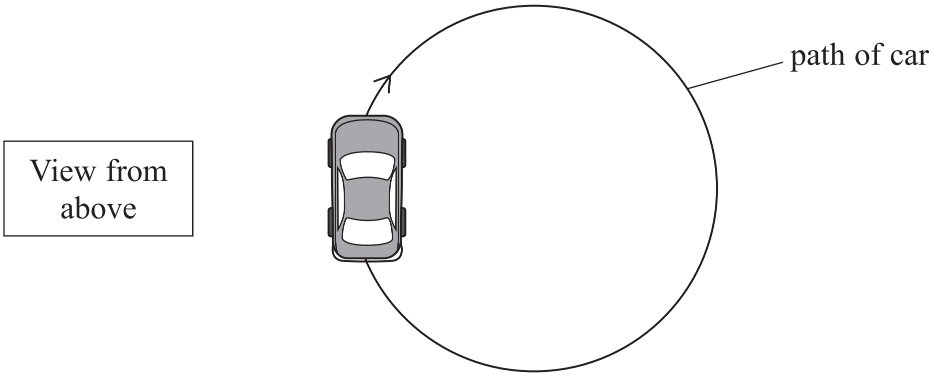
14 A car travelled in a circular path as shown.



A passenger in the car made the following claim.

"When the car was travelling at high speed around the circular path, I was thrown outwards due to a force acting on me. The outward force acting on me was the centrifugal force."

Assess the claim made by the passenger.

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(Total for Question 14 = 4 marks)

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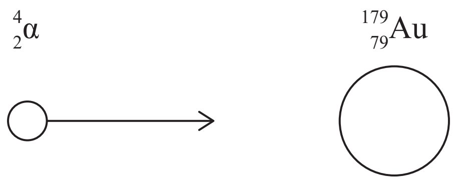
15 The nuclear model of the atom was developed after a series of experiments in which alpha particles were directed at thin gold foil.

An alpha particle $\left({}^{4}_{2}\alpha\right)$ with kinetic energy 5.52 MeV approaches a gold nucleus $\left({}^{179}_{79}\text{Au}\right)$ head-on, as shown.



The alpha particle is brought to rest and then returns along its original path.

(a) Calculate the minimum distance between the alpha particle and the gold nucleus.

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Minimum distance = ...

(b) An alpha particle with a different energy approaches the gold nucleus. The minimum distance between this alpha particle and the gold nucleus is 5.68×10^{-14} m.

Calculate the maximum electrostatic force F that acts between this alpha particle and the gold nucleus.

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F = ...

(Total for Question 15 = 6 marks)

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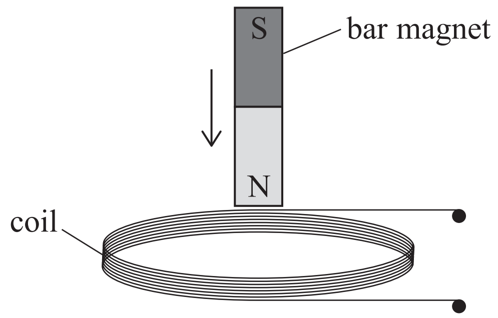
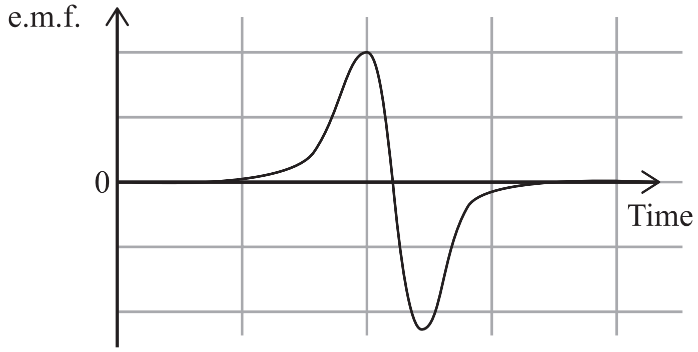
***16** A bar magnet was dropped vertically through a small coil, as shown.



The coil was attached to a data logger. The data logger recorded the variation of e.m.f. across the coil with time.

The output from the data logger is shown below.



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Explain the variation of e.m.f. with time.

(Total for Question 16 = 6 marks)

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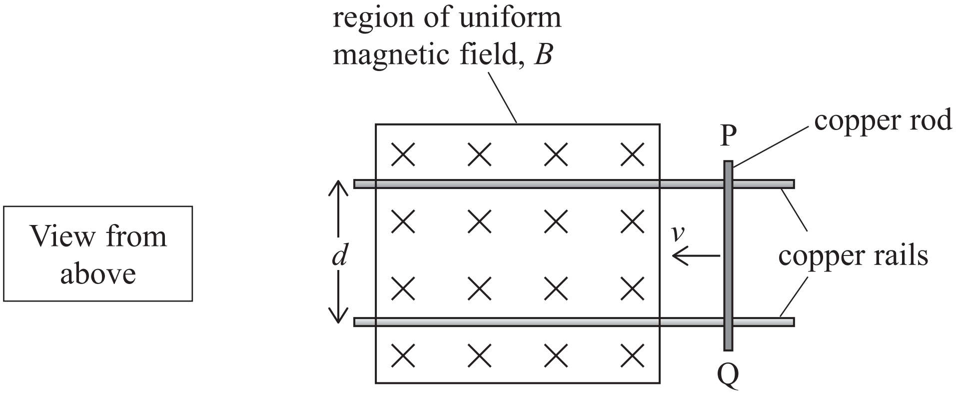
17 A copper rod, PQ, is moved with a velocity v along a pair of copper rails, as shown. The rails are a distance d apart.



The rod and rails are in a uniform magnetic field that is directed vertically downwards.

(a) Calculate the e.m.f. induced across the copper rod.

$B = 150\,\text{mT}$
$v = 3.5 \times 10^{-2}\,\text{m s}^{-1}$
$d = 7.5\,\text{cm}$

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Induced e.m.f. = ...

(b) Explain the direction of the induced e.m.f.

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(Total for Question 17 = 6 marks)

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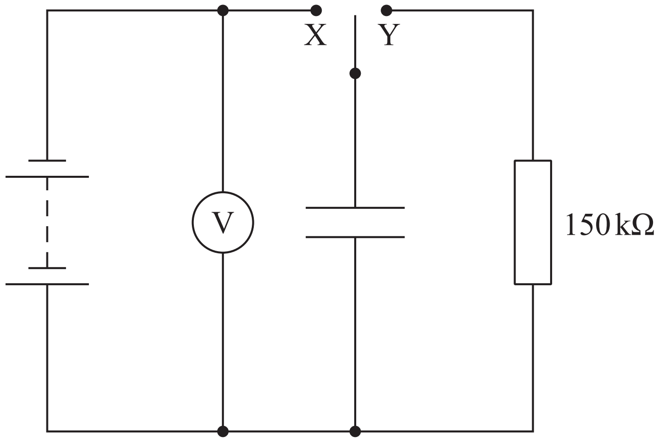
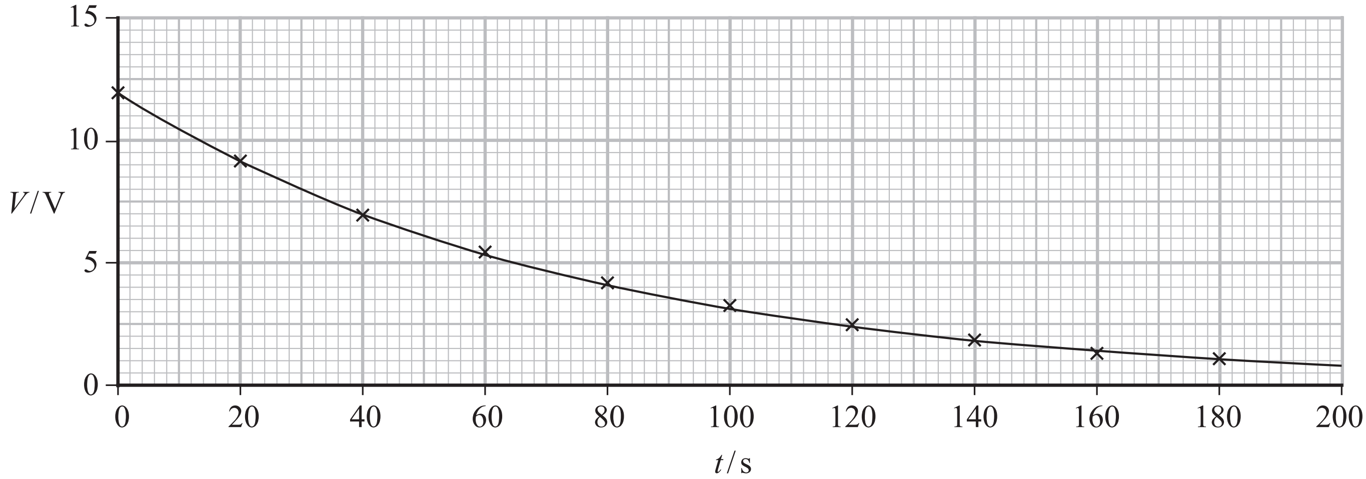
18 A student used the circuit shown to determine the capacitance of a capacitor.



The student connected the switch to X to charge the capacitor. She then connected the switch to Y so that the capacitor discharged through the 150 kΩ resistor.

The student started a stopwatch when she connected the switch to Y and recorded the voltmeter reading *V* every 20 s as the capacitor discharged.

The graph shows how *V* varied with time *t*.



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(a) The capacitor is labelled as 470 μF, with a tolerance of ±10%.

Evaluate whether the capacitance of the capacitor is within the stated tolerance.

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(b) An ultracapacitor is a high-capacity capacitor.

One ultracapacitor has a capacitance of 47 F. The maximum charge this capacitor can store is 56 C.

It is suggested that this capacitor could store 1000 times as much energy as a 470 μF capacitor charged to a potential difference of 12 V.

Assess the validity of this suggestion.

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(Total for Question 18 = 7 marks)

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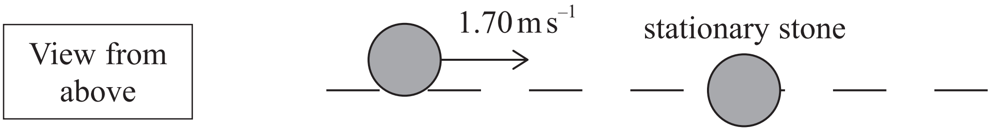
19 Curling is a sport played on ice. Players slide stones made of granite along the ice.

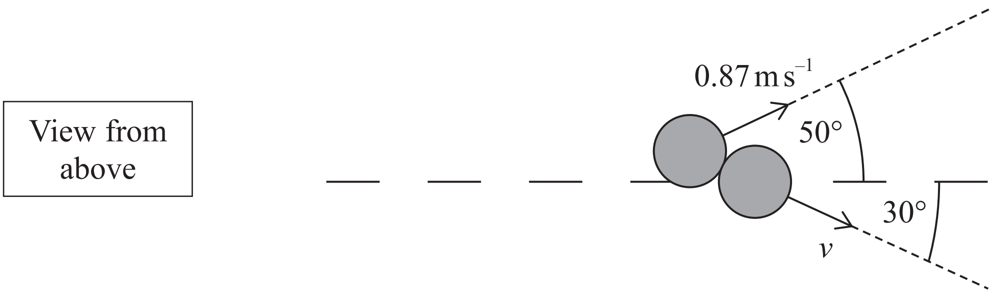
The photograph shows two of the stones. Each stone has a mass of 19.1 kg.

(Source: © MileA/Getty Images)

A player slides a stone at a velocity of $1.70\,\mathrm{m\,s^{-1}}$ towards a stationary stone, as shown below.



The stones collide. After the collision, both stones move off as shown below.



(a) Show that v is about $1.3\,\mathrm{m\,s^{-1}}$.

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(b) Deduce whether the collision was elastic. Your answer should include a calculation.

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(Total for Question 19 = 7 marks)

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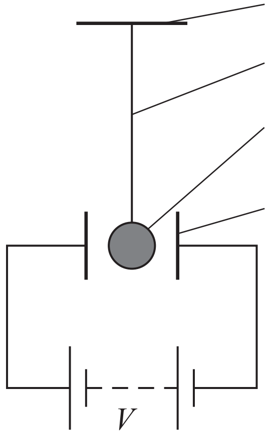
20 In the 18th century, a scientist called Gordon made the first device that used electrostatic forces to produce continuous motion.

A demonstration of the principle of Gordon's device is shown.

A light, conducting sphere of radius r is suspended from an insulating thread between two parallel metal plates. A large potential difference V is applied between the plates.



(a) There is an electrostatic force on the sphere when the sphere is charged.

The capacitance C of the sphere is given by

$$C = 4\pi\varepsilon_0 r$$

where r is the radius of the conducting sphere.

The sphere is charged by touching it onto one of the plates. The plates are a distance d apart.

Calculate the electrostatic force exerted on the sphere.

$V = 4500\,\text{V}$
$d = 5.0\,\text{cm}$
$r = 3.5\,\text{cm}$

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Electrostatic force on sphere = ...

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(b) After the sphere has been charged, the sphere starts to oscillate between the plates. The sphere touches each plate alternately.

Explain why the conducting sphere oscillates between the two plates.

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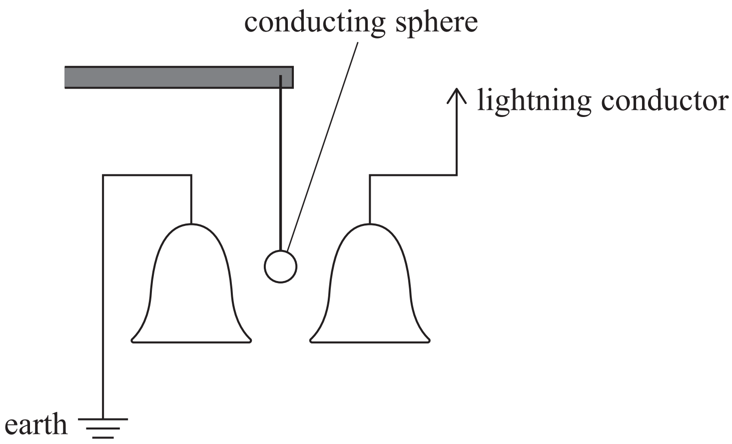
(c) A few years later, another scientist called Franklin adapted Gordon's device. Franklin suspended a conducting sphere between two metal bells.

One metal bell was connected to earth and the other metal bell was connected to a lightning conductor, as shown. During an electrical storm, the sphere oscillates between the bells and the bells ring.



The lightning conductor is a long wire, attached to the top of a building. The lightning conductor becomes positively charged when in an electric field.

The conducting sphere is initially uncharged.

Explain why the conducting sphere starts to move between the bells during an electrical storm.

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(Total for Question 20 = 10 marks)

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21 Pions are created in the upper atmosphere when high-energy cosmic rays interact with nuclei. Pions are mesons and they quickly decay to muons. Muons are leptons with a mass of 106 MeV/c^2.

(a) Give a possible quark structure of a pion.

(1)

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(b) The equation shows a pion decaying into a muon and an antineutrino.

$$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$$

Energy and momentum must be conserved in this decay.

Explain two other conservation laws that apply to this decay.

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(c) Calculate the mass, in kg, of a muon.

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Mass of muon = ... kg

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(d) When at rest, pions have an average lifetime of 26 ns. When produced in the upper atmosphere, high-energy pions have a speed of up to 0.99 c.

Explain how the average lifetime of these high-energy pions compares with the lifetime of pions at rest.

You do not need to carry out any calculations.

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(Total for Question 21 = 10 marks)

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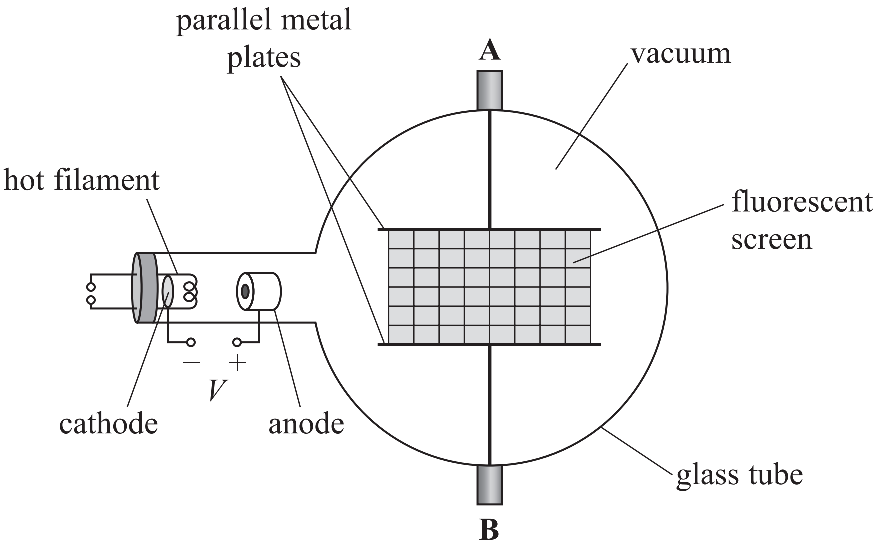
22 The electron beam tube can be used to determine the specific charge $\frac{e}{m}$ of an electron.

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



The beam is aimed at a fluorescent screen inside the tube and the path of the electrons is seen on the screen.

There are two parallel metal plates above and below the screen. A and B are connected to these plates and allow a potential difference to be applied across the plates.

(a) Explain why electrons are deflected into a parabolic path when a potential difference is applied between A and B.

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(b) A potential difference V of 850 V is applied between the cathode and the anode.

(i) Show that the maximum speed of the electrons as they emerge from the anode is about $1.7 \times 10^7\,\mathrm{m\,s^{-1}}$.

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(ii) The electric field strength between the parallel metal plates is $1.7 \times 10^4\,\mathrm{V\,m^{-1}}$. The length of each plate is 7.5 cm. The electrons pass through the region between the parallel metal plates.

Calculate the vertical deflection of the electron beam.

You should ignore the weight of the electrons.

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Vertical deflection of electron beam = ...

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(iii) The electric field between the parallel metal plates is removed. A uniform magnetic field is applied to deflect the electron beam into a circular path of radius 3.5 cm.

Assess whether this gives a value for $\frac{e}{m}$ in agreement with the standard value.

magnetic flux density = 3.0 mT

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(Total for Question 22 = 15 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	$g = 9.81 \text{ m s}^{-2}$	(close to Earth's surface)
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$	
Coulomb's law constant	$k = 1/4\pi\varepsilon_0$	
	$= 8.99 \times 10^{9} \text{ N m}^2 \text{ C}^{-2}$	
Electron charge	$e = -1.60 \times 10^{-19} \text{ C}$	
Electron mass	$m_e = 9.11 \times 10^{-31} \text{ kg}$	
Electronvolt	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$	
Gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$	
Gravitational field strength	$g = 9.81 \text{ N kg}^{-1}$	(close to Earth's surface)
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$	
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$	
Proton mass	$m_p = 1.67 \times 10^{-27} \text{ kg}$	
Speed of light in a vacuum	$c = 3.00 \times 10^{8} \text{ m s}^{-1}$	
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$	
Unified atomic mass unit	$u = 1.66 \times 10^{-27} \text{ kg}$	

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

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

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

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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 $\rho = \dfrac{m}{V}$

Stokes' law $F = 6\pi\eta rv$

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

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

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

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

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

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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	$\lambda = \frac{h}{p}$

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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 $\mathscr{E} = \frac{-d(N\phi)}{dt}$

Nuclear and particle physics

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

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

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