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 10 January 2025

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 ▶

P 7 8 4 7 8 A 0 1 3 2

Pearson

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 Two sources produce waves with a phase difference of 40°.

Which of the following gives the angle of 40° in radians?

☐ **A** $\frac{40 \times 2\pi}{360}$

☐ **B** $\frac{360}{40 \times 2\pi}$

☐ **C** $\frac{40 \times \pi}{360}$

☐ **D** $\frac{360}{40 \times \pi}$

(Total for Question 1 = 1 mark)

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2 The standard quark-lepton model includes particles called mesons.

Which of the following is a meson?

☐ **A** photon

☐ **B** pion

☐ **C** positron

☐ **D** proton

(Total for Question 2 = 1 mark)

3 Two identical charged particles were placed in a vacuum 0.020 m apart. The charge on each particle was $+8.0 \times 10^{-6}$ C.

Which of the following gives the magnitude of the force, in newtons, on each particle?

☒ **A** $\dfrac{8.99 \times 10^{9} \times (8.0 \times 10^{-6})}{0.020}$

☒ **B** $\dfrac{8.99 \times 10^{9} \times (8.0 \times 10^{-6})^{2}}{0.020^{2}}$

☒ **C** $\dfrac{8.99 \times 10^{9} \times (8.0 \times 10^{-6})^{2}}{0.020}$

☒ **D** $\dfrac{8.99 \times 10^{9} \times (8.0 \times 10^{-6})}{0.020^{2}}$

(Total for Question 3 = 1 mark)

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4 The positron is the antiparticle of the electron.

Which row of the table gives a similarity and a difference between a positron and an electron?

		Similarity	Difference
☒	**A**	same lepton number	different baryon number
☒	**B**	same lepton number	different charge
☒	**C**	same mass	different baryon number
☒	**D**	same mass	different lepton number

(Total for Question 4 = 1 mark)

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5 In alpha particle scattering experiments, alpha particles were directed at very thin gold foil.

Some alpha particles were deflected through angles up to 180°.

Which of the following could explain this observation?

☒ **A** Strong electrostatic forces act on the alpha particles.

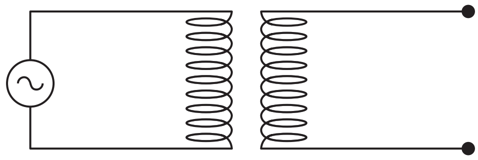
☒ **B** The atom is mainly empty space.

☒ **C** The charge is evenly distributed in the atom.

☒ **D** The gold foil was very thin.

(Total for Question 5 = 1 mark)

6 Two coils, P and Q, are close to each other. An alternating supply is connected across coil P, as shown.



The number of turns on coil Q and the separation of coil P and coil Q can be changed.

Which row of the table gives the arrangement that produces the largest e.m.f. in coil Q?

	Number of turns	Separation of P and Q
☒ **A**	fewer turns in coil Q	closer together
☒ **B**	fewer turns in coil Q	further apart
☒ **C**	more turns in coil Q	closer together
☒ **D**	more turns in coil Q	further apart

(Total for Question 6 = 1 mark)

7 In pair production, a high energy photon creates a particle-antiparticle pair.

In one interaction, a photon produces an electron and a positron.

Which of the following gives the photon energy, in joules?

☒ **A** $9.11 \times 10^{-31} \times (3 \times 10^{8})^{2}$

☒ **B** $1.67 \times 10^{-27} \times (3 \times 10^{8})^{2}$

☒ **C** $2 \times 1.67 \times 10^{-27} \times (3 \times 10^{8})^{2}$

☒ **D** $2 \times 9.11 \times 10^{-31} \times (3 \times 10^{8})^{2}$

(Total for Question 7 = 1 mark)

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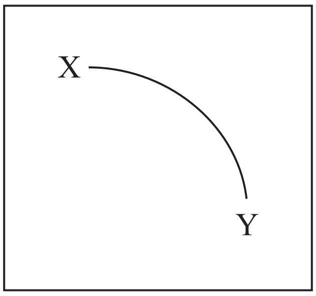
8 The diagram shows a particle track in a bubble chamber.

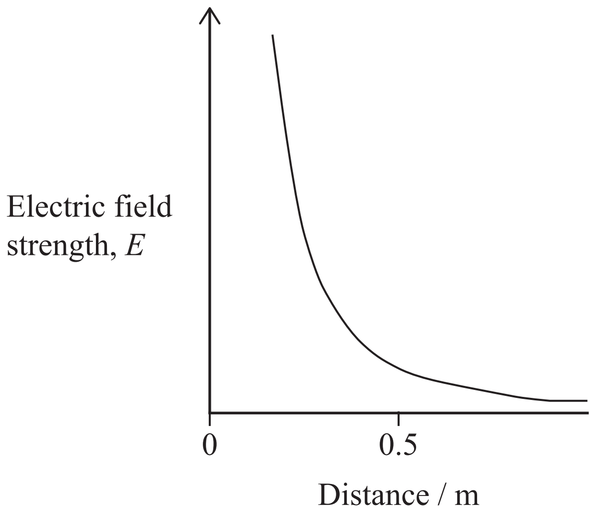


Which of the following is a valid conclusion from this track?

- ☒ **A** The particle is negatively charged.
- ☒ **B** The particle is moving from X to Y.
- ☒ **C** The speed of the particle is increasing.
- ☒ **D** The particle experiences a centripetal force.

(Total for Question 8 = 1 mark)

9 The graph shows how electric field strength varies with distance from a charged conducting sphere.



Which of the following gives the electric potential at a distance of 0.5 m from the sphere?

- ☒ **A** The area under the graph from 0 to 0.5 m.
- ☒ **B** The area under the graph from 0.5 m to infinity.
- ☒ **C** The gradient of the tangent to the graph at 0.5 m.
- ☒ **D** The value of E at 0.5 m divided by 0.5 m.

(Total for Question 9 = 1 mark)

10 A charged capacitor C_1 stores energy W_1. A charged capacitor C_2 stores energy W_2.

C_1 has half the capacitance of C_2.

C_1 is charged to half the potential difference of C_2.

Which of the following shows the ratio $\frac{W_1}{W_2}$?

☒ **A** $\frac{1}{8}$

☒ **B** $\frac{1}{4}$

☒ **C** 4

☒ **D** 8

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 A nuclear reaction that occurs in the Sun is shown.

$$p + p \rightarrow p + n + e^{+} + \nu_{e}$$

Two protons react to form a proton, a neutron, a positron, and an electron neutrino.

Energy and momentum must be conserved in this reaction.

Explain how three other conservation laws apply to this reaction.

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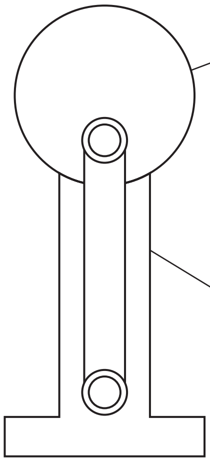
(Total for Question 11 = 3 marks)

12 The diagram shows a Van de Graaff generator. This is a device that produces a large potential difference by charging a conducting sphere.



The conducting sphere of a Van de Graaff generator has a radius of 22.5 cm.

(a) The electric potential produced at the surface of the conducting sphere is 1.75×10^4 V.

Show that the charge on the sphere is about 4.4×10^{-7} C.

(2)

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(b) Neon bulbs light when placed in a region of strong electric field.

A neon bulb is moved towards the charged sphere of the Van de Graaff generator. The neon bulb lights when the distance between the neon bulb and the centre of the charged sphere is 32.5 cm.

Determine the electric field strength at this position of the neon bulb.

(2)

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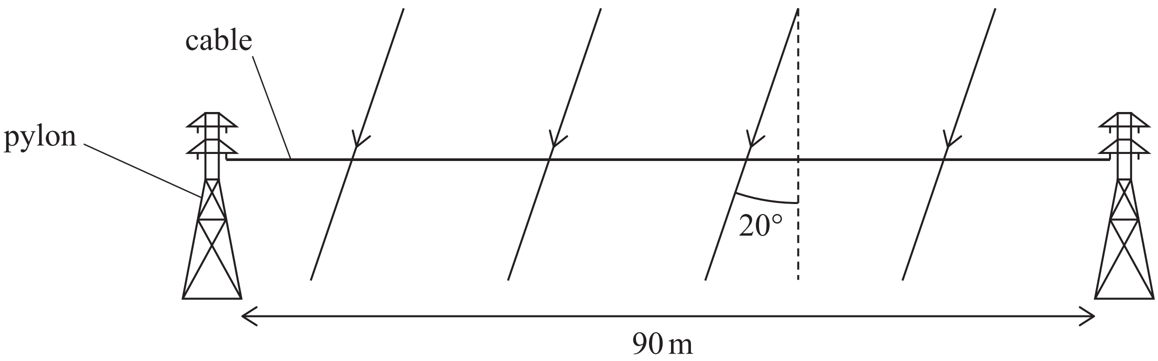
Electric field strength = ...

(Total for Question 12 = 4 marks)

13 A power cable is supported by two pylons, as shown.

The length of the cable is 90 m. The current in the cable is 700 A.

Near the pylons, the Earth's magnetic field has a magnetic flux density of 48 μT at an angle of 20° to the vertical.



Determine the force on the cable due to the Earth's magnetic field.

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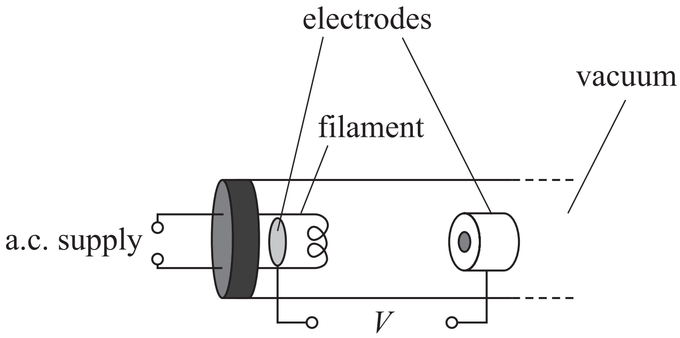
Force = ...

(Total for Question 13 = 3 marks)

14 A cathode ray tube can be used to demonstrate the properties of electrons. In the cathode ray tube, a beam of electrons is produced using the arrangement shown.



(a) Explain why electrons are released when there is a current in the filament.

(2)

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(b) In one cathode ray tube, the electrons in the beam had a de Broglie wavelength of 2.65×10^{-11} m.

Calculate the potential difference V required to accelerate these electrons between the electrodes.

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V = ...

(Total for Question 14 = 6 marks)

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15 A washing machine uses a rotating drum to wash clothes.

The photograph shows the drum inside a washing machine. The clothes are put in the drum.

(Source: © Tsetso Photo/Shutterstock)

The drum is a hollow metal cylinder with a series of holes through its surface.

At the end of the washing process the drum rotates at high speed.

(a) The drum of the washing machine rotates at 1400 revolutions per minute.

(i) Show that the angular velocity of the drum is about 150 rad s^{-1}.

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(ii) The diameter of the drum is 45 cm.

Calculate the centripetal acceleration of a point on the circumference of the drum.

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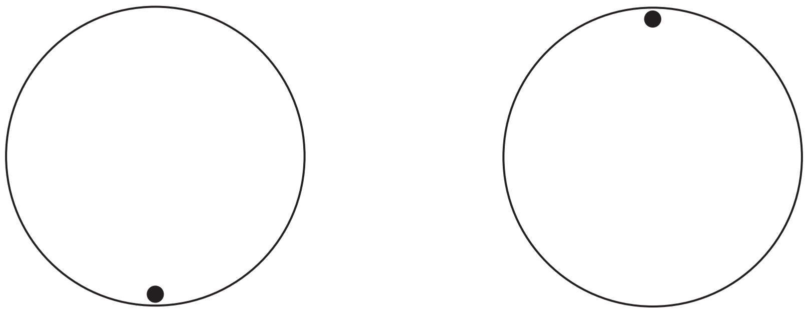
Centripetal acceleration = ...

(b) As the drum rotates at a high speed, clothes move in a vertical circle resting against the side of the drum.

The dot in the diagrams represents an item of clothing as it rotates with the drum.



(i) Add labelled arrows to each diagram to show the forces acting on the item of clothing.

(2)

(ii) The drum rotates at constant speed.

Explain how the forces on the item of clothing vary between the bottom and the top of the drum.

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(iii) Water leaves the drum through the holes as the drum rotates.

Describe the path of the water as it leaves the holes.

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(Total for Question 15 = 10 marks)

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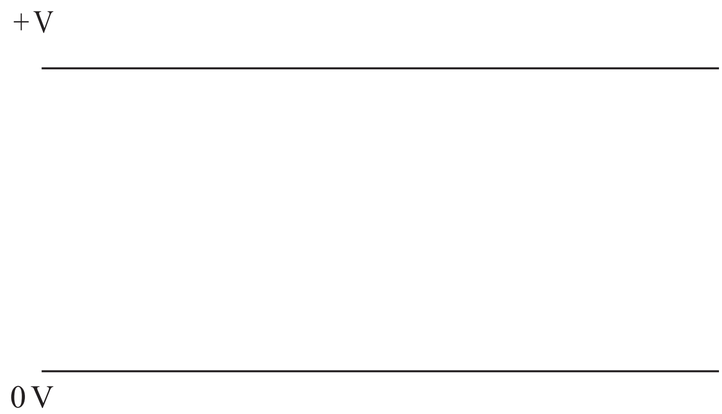
16 In the early 20th century, Millikan carried out an experiment to determine the magnitude of *e*, the electronic charge. Charged oil droplets were introduced into a region of electric field produced between two parallel plates.

A potential difference was connected across the two plates.



(a) Add to the diagram to show the field lines between the plates.

(2)

(b) A charged oil drop entered the region of electric field between the plates. The plates were 1.5 cm apart. A potential difference of 85 V was applied between the plates and the charged oil drop was brought to rest.

Deduce whether the charge on the oil drop was a whole number multiple of the electronic charge.

volume of oil drop = $5.0 \times 10^{-19}\,\text{m}^3$
density of oil = $920\,\text{kg}\,\text{m}^{-3}$

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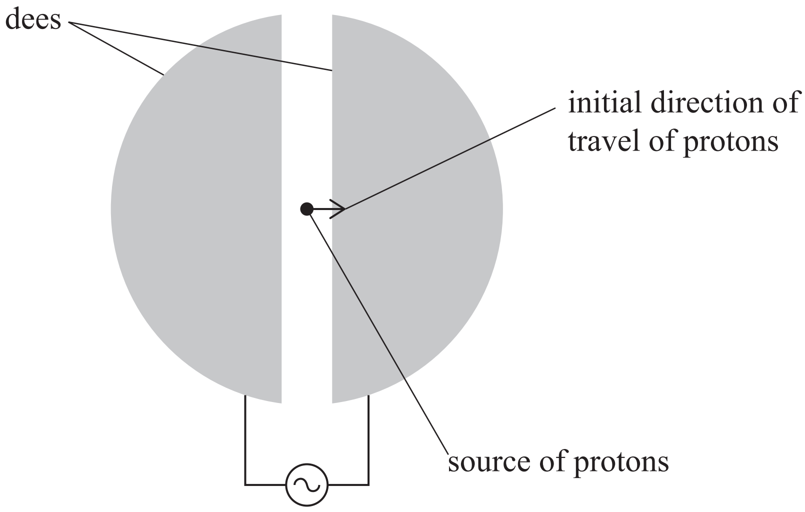
(Total for Question 16 = 7 marks)

17 A simplified diagram of a cyclotron is shown. In the cyclotron, protons gain energy. Protons are produced in the source and initially travel in the direction shown.



A magnetic field is applied perpendicular to the dees. The magnetic field direction is into the page.

(a) Add to the diagram to show the path of the protons as they gain energy in the cyclotron.

(2)

(b) The frequency f of the alternating potential difference applied to the dees is given by the equation

$$f = \frac{Bq}{2\pi m}$$

where
m is the mass of the proton
B is the magnetic flux density
q is the charge on the proton.

Calculate the time a proton spends in one of the dees.

$B = 0.55\text{T}$

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Time = ...

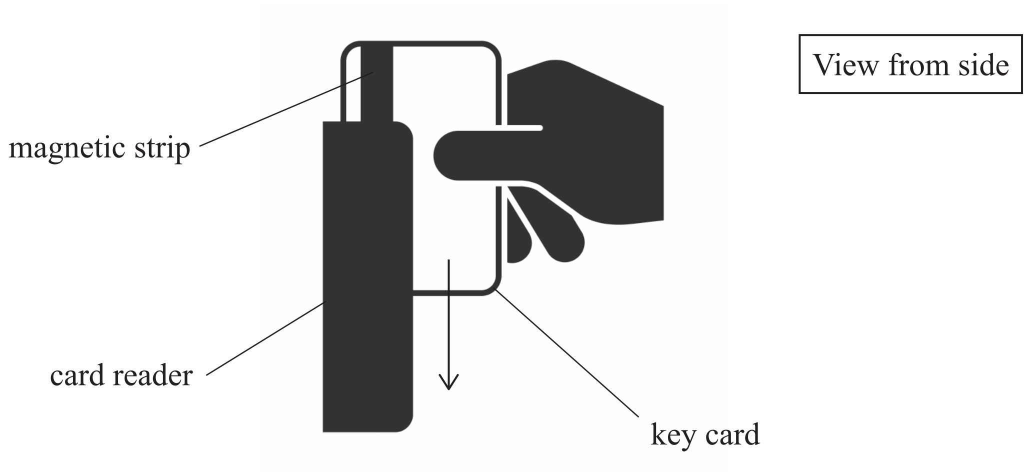
*(c) Explain how the cyclotron increases the energy of the protons.

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

(6)

(Total for Question 17 = 11 marks)

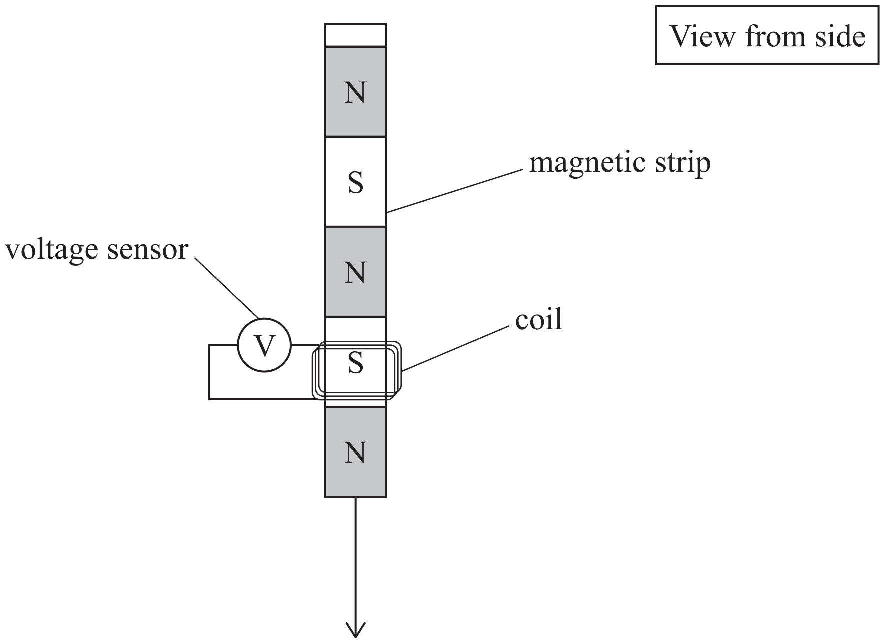
18 The diagram shows a key card and a card reader used to unlock a door. To unlock the door the key card is moved downwards through the card reader.



(Source: © Janis Abolins/Shutterstock)

The key card contains a magnetic strip consisting of many tiny bar magnets arranged side by side. The orientation of the magnetic poles of the bar magnets stores the code to unlock the door.

In the card reader there is a coil connected to a voltage sensor, as shown below.



(a) Explain how the voltage sensor detects the orientation of the magnetic poles.

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(b) The card reader can determine the orientation of a magnetic pole if the reading on the voltage sensor is greater than 1.5×10^{-6} V.

The key card is moved down a distance of 9.0 cm through the card reader in a time of 0.032 s.

Deduce whether the card reader can determine the orientation of the magnetic pole.

number of turns on coil = 25
magnetic flux density due to each magnet = 2.4×10^{-5} T
width of each magnet = 0.98 mm

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(Total for Question 18 = 9 marks)

19 The photograph shows a theme park attraction. Small electric cars are driven on a horizontal surface. The cars sometimes collide.

(Source: © Albin Raj Clicks/Alamy Stock Photo)

(a) There is a thick rubber strip around the base of each car. Two cars collide and come to rest.

Explain why the rubber strip reduces the likelihood of injury to the drivers.

You should refer to change in momentum.

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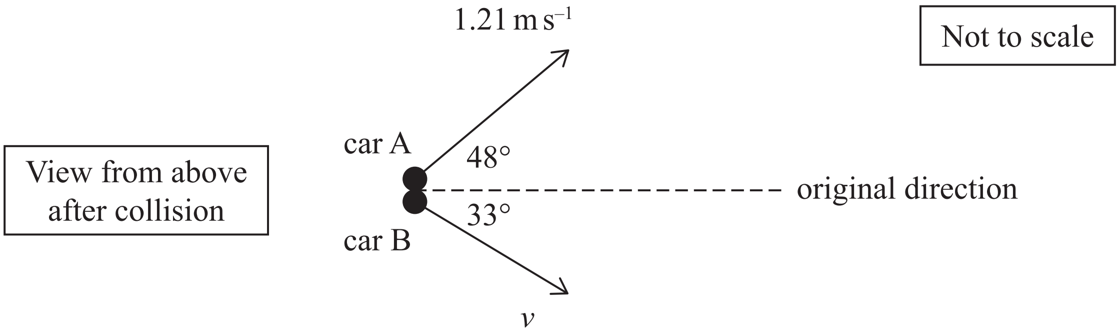
(b) In another collision, car A collides with car B.

Car A is initially travelling at $2.19\,m\,s^{-1}$ in a straight line. Car B is stationary.

After the collision, car A moves with a velocity of $1.21\,m\,s^{-1}$ at an angle of 48° to its original direction.

Car B moves with a velocity v at an angle of 33° to the original direction of car A, as shown.



Deduce whether the collision is elastic or inelastic.

mass of car A = 390 kg
mass of car B = 360 kg

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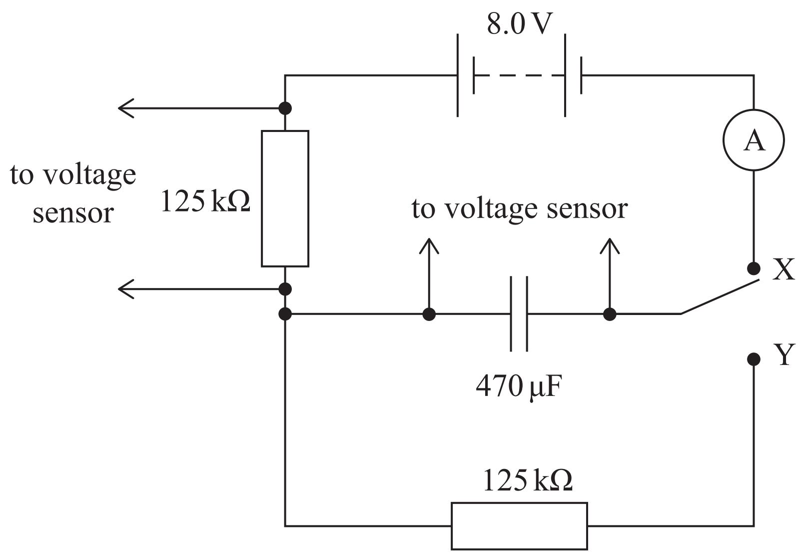
(Total for Question 19 = 9 marks)

20 A student connected the circuit shown to investigate the charging and discharging of a capacitor.



(a) She connected the switch to position X to charge the capacitor.

(i) Explain how the current in the circuit varies when the switch is connected to position X.

You do not need to do any calculations.

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(ii) Sketch a graph to show the variation of current in the circuit as the capacitor is charged.

Include the maximum value of current in the circuit.

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(b) To discharge the capacitor, the student connected the switch to position Y.

(i) Show that the time constant of the circuit is about 60 s.

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(ii) The student connected the switch to position Y for a time of 3 minutes.

Determine, using the time constant of the circuit, the percentage of the original potential difference (p.d.) remaining across the capacitor.

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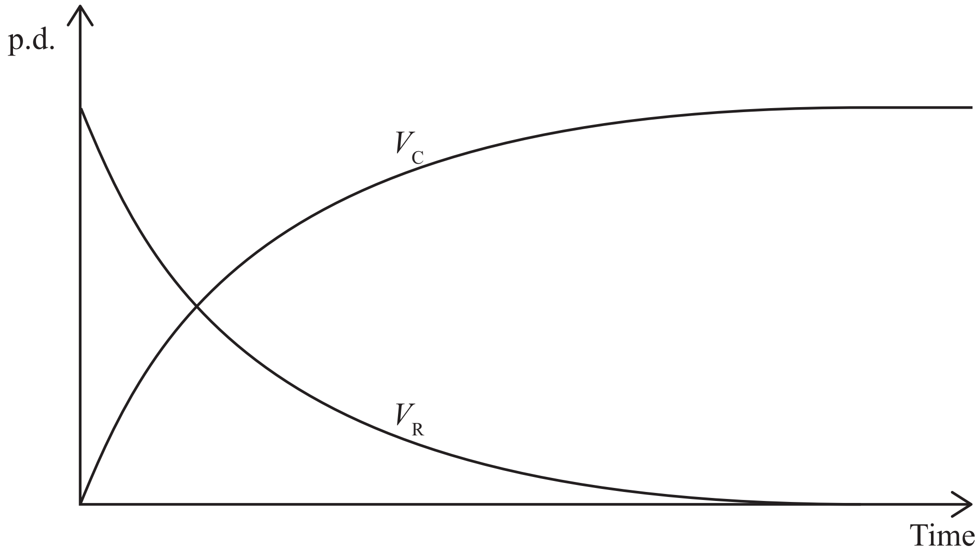
Percentage of original p.d. remaining across capacitor = ...

(c) After the capacitor was fully discharged, the student connected the switch back to position X to recharge the capacitor. The student used the voltage sensors to measure the p.d. V_C across the capacitor and the p.d. V_R across the resistor. Both sensors were attached to a data logger.

The output from the data logger is shown below.



Determine the value of the p.d. and the value of the time where the two lines intersect.

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p.d. = ...

Time = ...

(d) The student connected a second identical capacitor in series with the first capacitor. She connected the switch to position X to charge both capacitors.

Explain how the magnitude of charge stored on each capacitor compares with the charge that was stored on the single capacitor.

You do not need to do any further calculations.

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(Total for Question 20 = 18 marks)

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

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

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

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	$v = \sqrt{\dfrac{T}{\mu}}$
Intensity of radiation	$I = \dfrac{P}{A}$
Refractive index	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
	$n = \dfrac{c}{v}$
Critical angle	$\sin C = \dfrac{1}{n}$
Diffraction grating	$n\lambda = d\sin\theta$

Electricity

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

Particle nature of light

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

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Unit 4

Further mechanics

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

Electric and magnetic fields

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

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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