Please check the examination details below before entering your candidate information

Candidate surname	Other names

Pearson Edexcel International Advanced Level

Centre Number | Candidate Number

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.
- **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 questions 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.
- Good luck with your examination.

Turn over

Pearson

SECTION A

Answer ALL questions.

For questions 1–10, 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 a fundamental particle?

☐ **A** antiproton

☐ **B** muon

☐ **C** neutron

☐ **D** pion

(Total for Question 1 = 1 mark)

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2 In the early 20th century, scattering experiments were carried out by directing high speed alpha particles at thin metal foils.

Which of the following could **not** be concluded from these experiments?

☐ **A** Most of the atom is empty space.

☐ **B** The nucleus of the atom is positively charged.

☐ **C** There is a concentration of charge in the atom.

☐ **D** There is a concentration of mass in the atom.

(Total for Question 2 = 1 mark)

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3 Neutrinos can interact with protons to create neutrons.

Which of the following equations shows this process?

☐ **A** $\nu_e + p \rightarrow e^+ + n$

☐ **B** $\nu_e + p \rightarrow e^- + n$

☐ **C** $\bar{\nu}_e + p \rightarrow e^+ + n$

☐ **D** $\bar{\nu}_e + p \rightarrow e^- + n$

(Total for Question 3 = 1 mark)

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4 In 2015, a pentaquark was discovered.

The pentaquark was made of 5 quarks, c, $\overline{c}$, d, u, u.

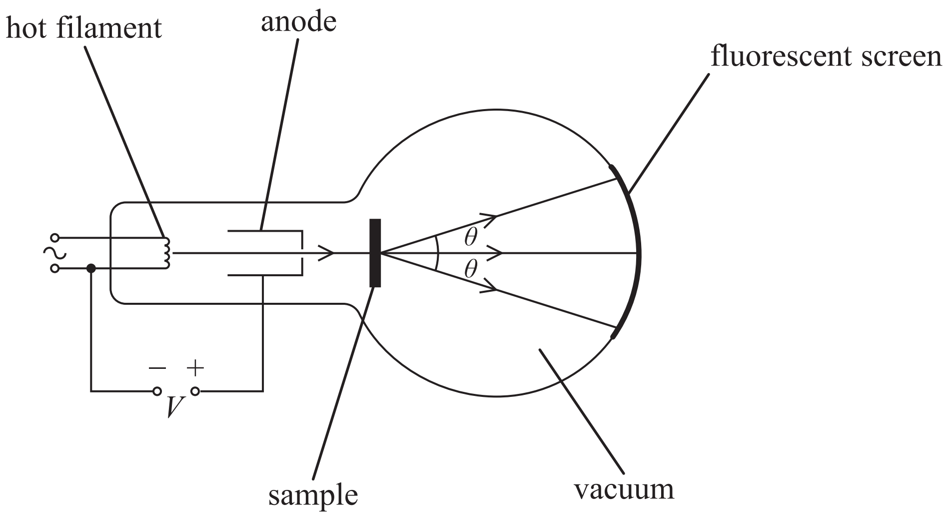
The pentaquark can form a baryon-meson combination.

Which row of the table shows a possible arrangement of the quarks?

		Quarks in baryon	Quarks in meson
☒	**A**	d u u	c $\overline{c}$
☒	**B**	u $\overline{c}$ u	d c
☒	**C**	$\overline{c}$ u	d u c
☒	**D**	u d	c $\overline{c}$ u

(Total for Question 4 = 1 mark)

5 The diagram represents an arrangement to demonstrate electron diffraction.



A beam of electrons is directed at a sample of crystalline material.

Which of the following single changes would decrease the angle of diffraction θ?

☒ **A** decrease the distance between the sample and the screen

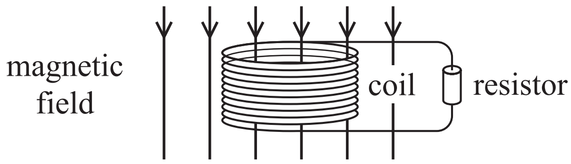
☒ **B** increase the anode potential V

☒ **C** increase the current in the filament

☒ **D** use a sample with a smaller atomic spacing

(Total for Question 5 = 1 mark)

6 A coil of wire is connected to a resistor as shown.



The magnetic flux density of the field through the coil is increased steadily from zero to a maximum value.

Which of the following single changes would result in a smaller current in the resistor?

☒ **A** increasing the area of the coil in the magnetic field

☒ **B** increasing the maximum flux density

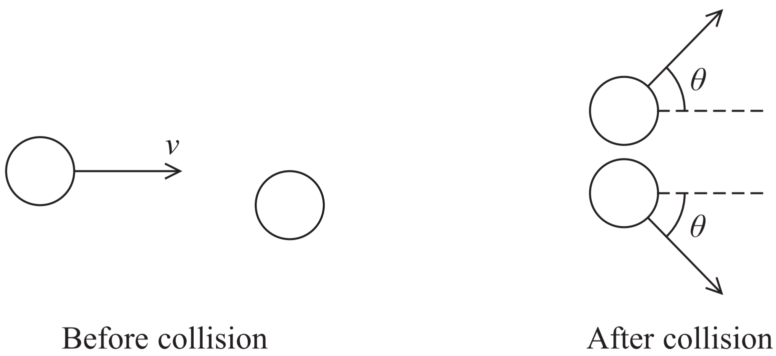
☒ **C** increasing the number of turns on the coil

☒ **D** increasing the time taken to reach the maximum flux density

(Total for Question 6 = 1 mark)

7 A sphere travelling at speed v collides elastically with an identical sphere which is at rest.

After the collision, both spheres move off at an angle θ to the direction of travel of the first sphere, as shown. The spheres have the same speed as each other.



What is the speed of the spheres after the collision?

☒ **A** v

☒ **B** $\frac{v}{\sqrt{2}}$

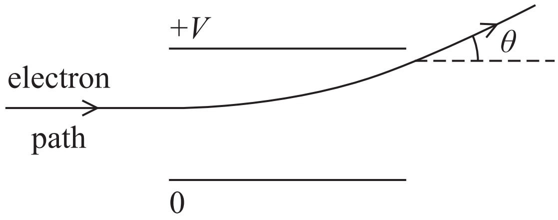
☒ **C** $\frac{v}{2}$

☒ **D** $\frac{v}{4}$

(Total for Question 7 = 1 mark)

8 The diagram shows two metal plates with a potential difference V across them.

The path of an electron travelling between the plates is shown.



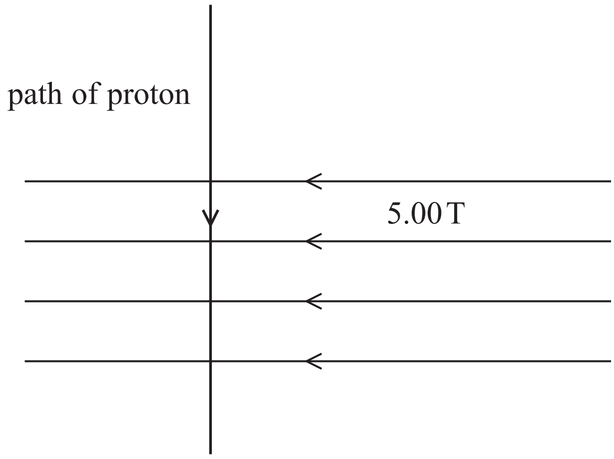
The electron is deviated through an angle θ.

Which row of the table shows changes that will cause θ to decrease?

		V	**Distance between plates**
☒	**A**	doubled	halved
☒	**B**	doubled	unchanged
☒	**C**	halved	doubled
☒	**D**	unchanged	halved

(Total for Question 8 = 1 mark)

9 A proton travelling at speed *v* enters a magnetic field of magnetic flux density 5.00 T, as shown.



A force of 1.20×10^{-11} N is exerted on the proton.

Which of the following gives the speed of the proton in m s^{-1}?

☒ **A** $\dfrac{1.20 \times 10^{-11}}{5.00 \times 1.67 \times 10^{-27}}$

☒ **B** $\dfrac{1.20 \times 10^{-11}}{5.00 \times 1.60 \times 10^{-19}}$

☒ **C** $\dfrac{5.00 \times 1.67 \times 10^{-27}}{1.20 \times 10^{-11}}$

☒ **D** $\dfrac{5.00 \times 1.60 \times 10^{-19}}{1.20 \times 10^{-11}}$

(Total for Question 9 = 1 mark)

10 The structure of nucleons can be investigated using electrons with high energies.

Which of the following is the reason why high energies are required?

☒ **A** to allow for the creation of new particles

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

☒ **C** to produce a relativistic increase in particle lifetime

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

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

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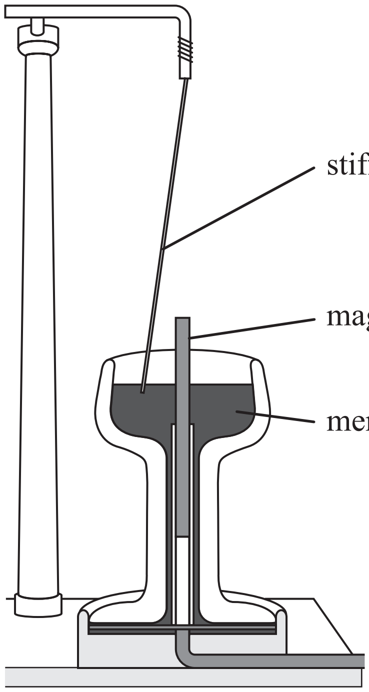
SECTION B

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

11 In 1821, Michael Faraday made what is believed to be the first electric motor.



The stiff wire was suspended freely from a stand. The mercury completed an electrical circuit, which included the wire. When there was a current in the wire, the wire moved around the magnet.

(a) The wire made 10 complete revolutions around the magnet in a time of 8.3 s.

Calculate the angular velocity of the wire.

(3)

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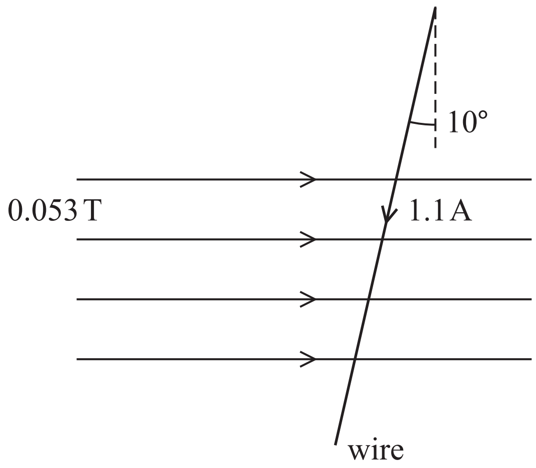
Angular velocity = ...

(b) When the current in the wire is 1.1 A, the wire is at an angle of 10º to the vertical. The length of the wire in the horizontal magnetic field is 3.5 cm.



Determine the force on the wire.

magnetic flux density = 0.053 T

(3)

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Magnitude of force on wire = ...

Direction of force on wire = ...

(Total for Question 11 = 6 marks)

12 In 1931, Sloan and Lawrence built a linear accelerator (linac) with several drift tubes. They used the linac to accelerate mercury ions up to energies of 1.26 MeV. The behaviour of the particles was non-relativistic.

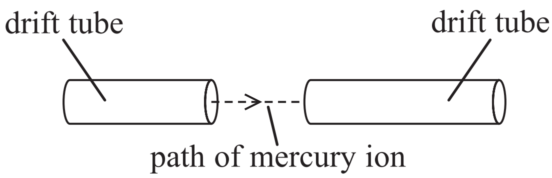
(a) The kinetic energy of a non-relativistic particle of mass m with momentum p is given by

$$E_k = \frac{p^2}{2m}$$

Derive this formula.

(2)

(b) A mercury ion with kinetic energy 6.42×10^{-15} J leaves a drift tube, as shown.



Calculate the momentum of the mercury ion when it reaches the next drift tube.

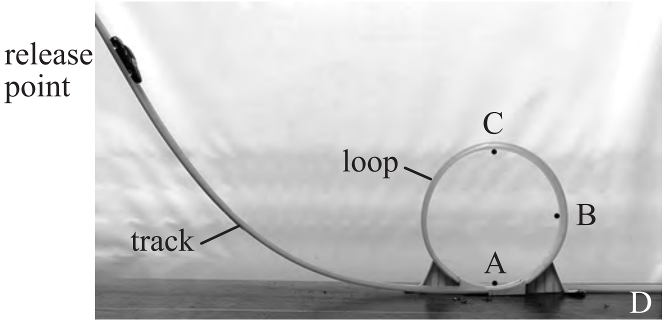
mass of mercury ion = 3.32×10^{-25} kg
charge of mercury ion = 1.60×10^{-19} C
electric field strength between drift tubes = $7.64 \times 10^{6}\,\mathrm{V\,m^{-1}}$
distance between drift tubes = 5.50×10^{-3} m

(4)

Momentum = ...

(Total for Question 12 = 6 marks)

13 The photograph shows a track for a toy car. The car moves down the track towards a circular loop. The loop starts at point A.



If the release point of the car is high enough, the car moves fast enough to pass point C and complete the loop, continuing to the end of the track at point D.

If the release point is too low, the car falls off the track between point B and point C.

Deduce whether a car released from a vertical height of 25 cm above point A will complete the loop and reach point D. You should assume that friction is negligible.

vertical height of point C above point A = 22 cm
mass of toy car = 33 g

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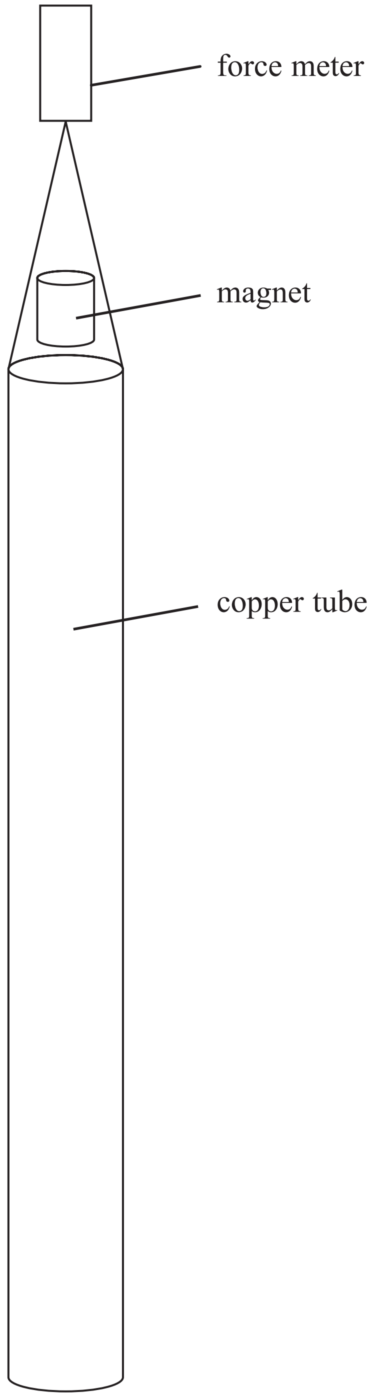
(Total for Question 13 = 6 marks)

***14** A student carried out an investigation of Lenz's law. A copper tube was suspended from a force meter, as shown.

A magnet was released at the top of the tube. When the magnet was falling through the tube, there was an increased reading on the force meter.



Explain why there was an increased reading on the force meter.

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(Total for Question 14 = 6 marks)

15 Some asteroids pass very close to the Earth. Scientists are planning methods to deflect asteroids, to prevent them hitting the Earth.

One method would involve colliding a spacecraft into the surface of the asteroid, to change the path and speed of the asteroid. The spacecraft would remain joined to the asteroid after the collision.

(a) This collision method is modelled for a spacecraft travelling in a direction at 90° to the path of the asteroid.

Sketch a labelled vector diagram to show the momenta of the bodies before and after the collision.

(2)

(b) Show that the momentum of the spacecraft is about 10^7 N s.

mass of spacecraft = 920 kg
speed of spacecraft = 12 000 m s^{-1}

(2)

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(c) Show that this collision method causes the asteroid to change its direction through an angle of about 10^{-7} radian.

momentum of asteroid = 7.6×10^{13} N s

(2)

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(d) After the collision, the asteroid and spacecraft remain joined and move together.

Calculate the component of their velocity at 90° to the original path of the asteroid after the collision.

mass of asteroid = 2.8×10^{9} kg

(2)

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Component of velocity = ...

(e) Another method would involve attaching a rocket motor to the asteroid and using the motor to apply a force to the asteroid.

In this method the force is applied at 90° to the path of the asteroid.

Deduce whether this would produce a change in momentum as great as the change produced by the collision method.

force exerted by rocket motor = 5.1×10^{6} N
time for which rocket motor applies force = 6 minutes

(2)

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(Total for Question 15 = 10 marks)

16 A point positive charge and a point negative charge are placed 8.0 cm apart at X and Y, as shown.

(a) Calculate the magnitude of the electric field strength midway between X and Y.

charge at X = + 2.5×10^{-7} C
charge at Y = – 2.5×10^{-7} C

(3)

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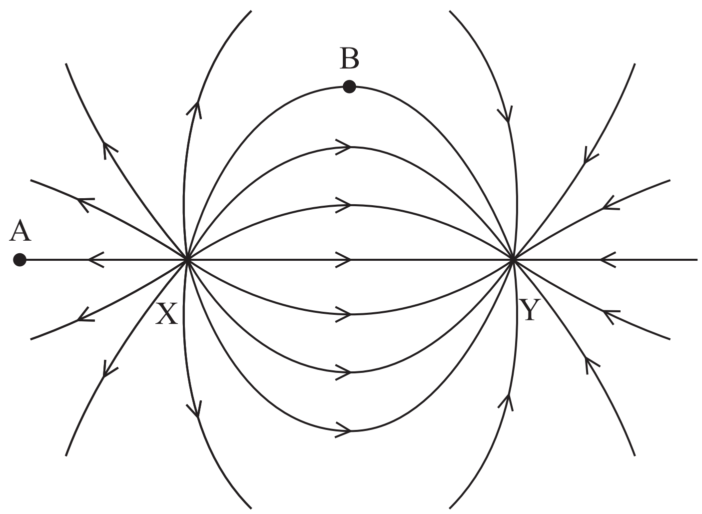
Electric field strength = ...

(b) The diagram below represents the electric field for this combination of charges.



(i) Add dashed lines to the electric field diagram to show equipotentials for this combination of charges.

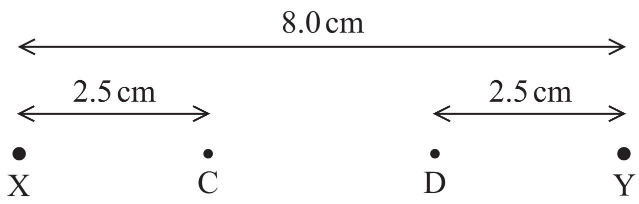
(3)

(ii) A textbook states, “An electric field line shows the path a free positive test charge follows”.

Discuss the accuracy of this statement for free positive test charges placed at point A and at point B.

(4)

(c) The charges at X and Y are replaced by charges of twice the magnitude.



C and D are points between the charges.

Determine the magnitude of the potential difference between points C and D.

charge at X = $+5.0 \times 10^{-7}$ C
charge at Y = -5.0×10^{-7} C

(4)

Magnitude of potential difference = ...

(Total for Question 16 = 14 marks)

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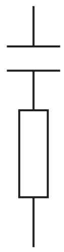
17 A student investigated the properties of capacitors.

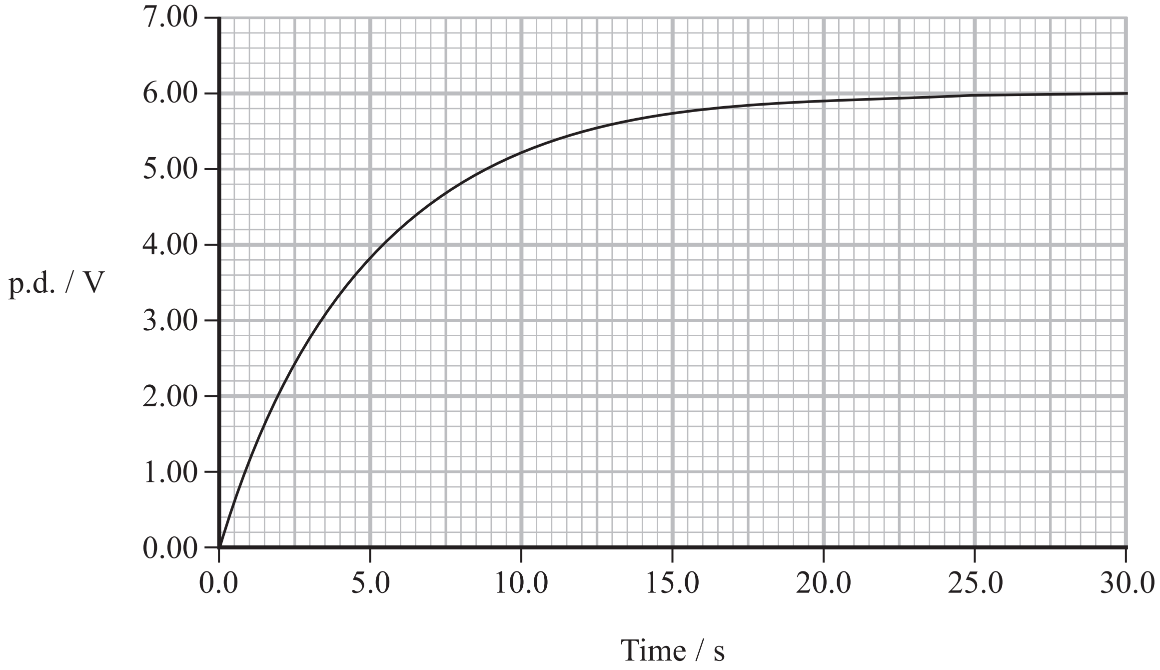
The student connected a capacitor in series with a resistor. The capacitor was charged through the resistor by applying a potential difference (p.d.) using a battery of e.m.f. 6.0 V and negligible internal resistance. The capacitor was then discharged through the resistor. The p.d. across the capacitor was measured during the charging and discharging processes.

(a) Add to the diagram to show a suitable circuit for charging and discharging the capacitor while measuring the p.d. across it.

(3)



(b) The graph shows how the p.d. across the capacitor varies with time as it is being charged by the 6.0 V battery.



(i) Sketch, on the same axes, a graph to show how the p.d. across the resistor varies with time.

(2)

(ii) Show that the p.d V across the capacitor when it is charging is given by

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

where V_0 is the e.m.f. of the battery
t is the time
R is the resistance of the resistor
and C is the capacitance of the capacitor.

(3)

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(iii) During the charging process, the student recorded the p.d. across the capacitor and the resistance of the resistor.

The capacitors available had the following values:

10 μF 15 μF 47 μF 100 μF 150 μF

Deduce the value of capacitance for the capacitor that was used.

$R = 330\,\text{k}\Omega$

(4)

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(iv) Calculate the charge on the fully charged capacitor.

(2)

Charge = ...

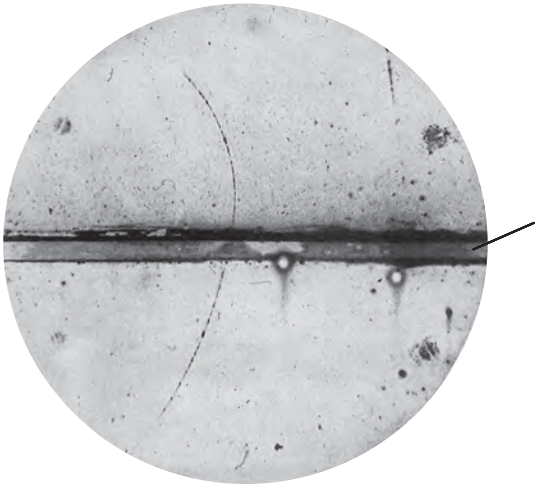
(v) Calculate the energy stored by the fully charged capacitor.

(2)

Energy stored = ...

(Total for Question 17 = 16 marks)

18 In 1932, Carl Anderson published this photograph of a track in a cloud chamber. The cloud chamber contained a lead plate. There was a magnetic field perpendicular to the plane of the track.



(Source: Anderson, Carl D. (1933). "The Positive Electron". Physical Review 43 (6): 491–494. DOI:10.1103/PhysRev.43.491.)

The photograph shows the track of a positron from cosmic rays and is the first photographic record of the existence of an antiparticle.

(a) State the properties of a positron that show it is the antiparticle to the electron.

(3)

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(b) Deduce the direction of the magnetic field.

(3)

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Direction of magnetic field = ...

(c) In the upper part of the photograph the positron had an energy of 23 MeV.

(i) Show that the positron must have been travelling at a relativistic speed. Assume that all of its energy is kinetic energy.

(3)

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(ii) For relativistic particles such as this positron, momentum obeys the relationship

$$E = pc$$

where E = particle energy, p = particle momentum and c = speed of light.

Determine the magnetic flux density of the magnetic field.

radius of curvature of path = 3.7 cm

(3)

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Magnetic flux density = ...

(d) A positron travelling at a non-relativistic speed of $1.5 \times 10^7\,\mathrm{m\,s^{-1}}$ collides with an electron travelling at the same speed in the opposite direction. This collision results in the production of gamma radiation.

Calculate the frequency of the gamma radiation produced.

(4)

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Frequency = ...

(Total for Question 18 = 16 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 $\rho = \dfrac{m}{V}$

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

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

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

Unit 4

Mechanics

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

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	$I = I_0 e^{-t/RC}$
	$V = V_0 e^{-t/RC}$
	$\ln Q = \ln Q_0 - \dfrac{t}{RC}$
	$\ln I = \ln I_0 - \dfrac{t}{RC}$
	$\ln V = \ln V_0 - \dfrac{t}{RC}$
In a magnetic field	$F = Bqv \sin \theta$
	$F = BIl \sin \theta$
Faraday's and Lenz's laws	$\mathscr{E} = \dfrac{-d(N\phi)}{dt}$

Nuclear and particle physics

In a magnetic field	$r = \dfrac{p}{BQ}$
Mass-energy	$\Delta E = c^2 \Delta m$

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