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 30 May 2023

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

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 In an electron gun, electrons are released from a heated filament.

Which of the following is the name of this process?

☐ **A** annihilation

☐ **B** ionisation

☐ **C** photoelectric effect

☐ **D** thermionic emission

(Total for Question 1 = 1 mark)

2 There is a potential difference of 6 V across a 220 μF capacitor.

Which of the following expressions gives the charge stored on the capacitor?

☐ **A** $0.5 \times 2.2 \times 10^{-4} \times 6$

☐ **B** $2.2 \times 10^{-4} \times 6$

☐ **C** $\dfrac{0.5 \times 2.2 \times 10^{-4}}{6}$

☐ **D** $\dfrac{2.2 \times 10^{-4}}{6}$

(Total for Question 2 = 1 mark)

3 A nucleus of $^{38}_{19}K$ emits a β^+ particle.

Which row of the table shows the proton number and nucleon number of the nucleus that is produced?

	Proton number	Nucleon number
☐ **A**	18	39
☐ **B**	18	38
☐ **C**	20	38
☐ **D**	20	37

(Total for Question 3 = 1 mark)

4 Which of the following gives the base units of impulse?

- ☒ **A** kg m s^{-1}
- ☒ **B** kg m s^{-2}
- ☒ **C** N m
- ☒ **D** N s

(Total for Question 4 = 1 mark)

5 Scientists use particles with high energy to investigate the structure of nucleons.

Which of the following statements is **not** a reason why particles with high energy are required?

- ☒ **A** to allow forces between particles to be overcome
- ☒ **B** to ensure particles have a very high momentum
- ☒ **C** to ensure particles have a very small de Broglie wavelength
- ☒ **D** to provide sufficient energy for the production of new particles

(Total for Question 5 = 1 mark)

6 Which of the following is a fundamental particle?

- ☒ **A** neutrino
- ☒ **B** neutron
- ☒ **C** pion
- ☒ **D** proton

(Total for Question 6 = 1 mark)

7 A particle has mass $6.5\,\text{MeV}/c^2$.

Which of the following gives the mass, in kg, of the particle?

- ☒ **A** $\dfrac{6.5 \times 1.6 \times 10^{-19}}{(3 \times 10^8)^2}$
- ☒ **B** $\dfrac{6.5 \times 1.6 \times 10^{-13}}{(3 \times 10^8)^2}$
- ☒ **C** $\dfrac{6.5 \times (3 \times 10^8)^2}{1.6 \times 10^{-19}}$
- ☒ **D** $\dfrac{6.5 \times (3 \times 10^8)^2}{1.6 \times 10^{-13}}$

(Total for Question 7 = 1 mark)

8 In the early 20th century, scientists carried out alpha particle scattering experiments.

Which of the following is **not** a conclusion from the scientists' observations during these experiments?

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

☒ **B** The nucleus contains most of the mass of the atom.

☒ **C** The nucleus is made up of protons and neutrons.

☒ **D** There is a concentration of charge in the atom.

(Total for Question 8 = 1 mark)

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9 Which of the following shows the β^- decay of a nucleon?

☒ **A** $n \rightarrow p + \beta^- + \nu_e$

☒ **B** $n \rightarrow p + \beta^- + \bar{\nu}_e$

☒ **C** $p \rightarrow n + \beta^- + \nu_e$

☒ **D** $p \rightarrow n + \beta^- + \bar{\nu}_e$

(Total for Question 9 = 1 mark)

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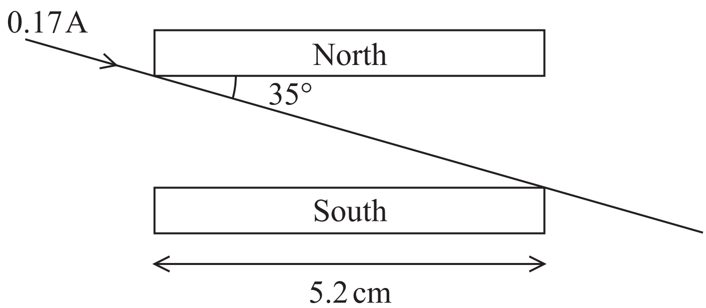
10 The diagram shows a current-carrying wire between two magnetic poles.



The magnetic flux density between the poles is 0.85 T.

Which of the following gives the force on the wire in newtons?

☒ **A** $0.085 \times 0.17 \times 0.052$ into the page

☒ **B** $0.085 \times 0.17 \times 0.052 \times \sin 35°$ into the page

☒ **C** $0.085 \times 0.17 \times 0.052$ out of the page

☒ **D** $0.085 \times 0.17 \times 0.052 \times \sin 35°$ out of the page

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

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

11 In 2022, CERN announced the discovery of a new particle known as a pentaquark which is made of five quarks.

The table shows the charges on some quarks.

Quark	Charge / e
u	+2/3
d	–1/3
s	–1/3
c	+2/3

The five quarks in the pentaquark are c, $\bar{c}$, d, s and u.

Some scientists said the pentaquark is made of a meson and a baryon, held together by the attraction of their equal and opposite charges.

Determine the quark combination and charge of a meson and of a baryon that could make up the pentaquark.

Meson

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Quark combination = ...

Charge = ...

Baryon

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Quark combination = ...

Charge = ...

(Total for Question 11 = 5 marks)

12 A particle with charge Q and momentum p follows a circular path of radius r. The path is at right angles to a magnetic field of magnetic flux density B.

(a) Derive the following equation for the particle.

$$r = \frac{p}{BQ}$$

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(b) The particle is an alpha particle of energy 5.4 MeV.

Calculate B.

mass of alpha particle = 6.64×10^{-27} kg
$r = 0.096$ m

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B = ...

(Total for Question 12 = 6 marks)

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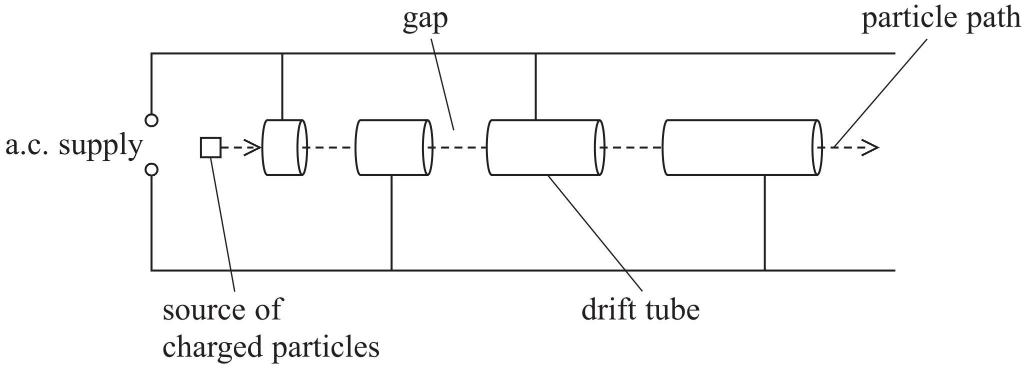
13 Linacs and cyclotrons both accelerate charged particles to very high speeds.

(a) The diagram shows a linac.

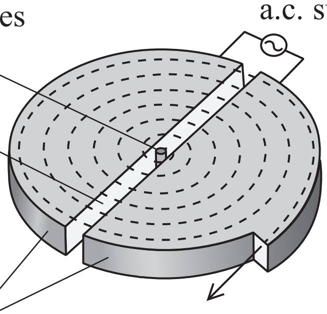


Explain the use of electric fields in a linac.

You should refer to the frequency of the a.c. supply.

(4)

(b) The diagram shows a cyclotron.



Explain why a magnetic field is applied at right angles to the dees in the cyclotron.

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(Total for Question 13 = 6 marks)

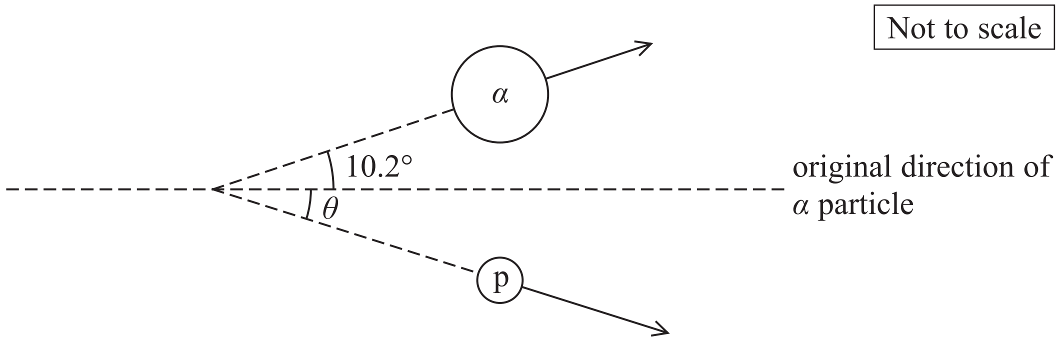
14 In the 1930s, scientists investigated collisions of alpha particles with protons to determine whether the collisions were elastic.

The diagrams show an alpha particle before and after a collision with a stationary proton.
The proton moves off at an angle θ to the original direction of the alpha particle.

<u>Before collision</u>

momentum of alpha particle = 1.26×10^{-19} N s

<u>After collision</u>



momentum of alpha particle = 8.06×10^{-20} N s

(a) Show that the momentum of the proton after the collision is about 5×10^{-20} N s at an angle θ, where θ is about 20°.

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(b) Deduce whether the collision was elastic.

mass of alpha particle = 6.64×10^{-27} kg

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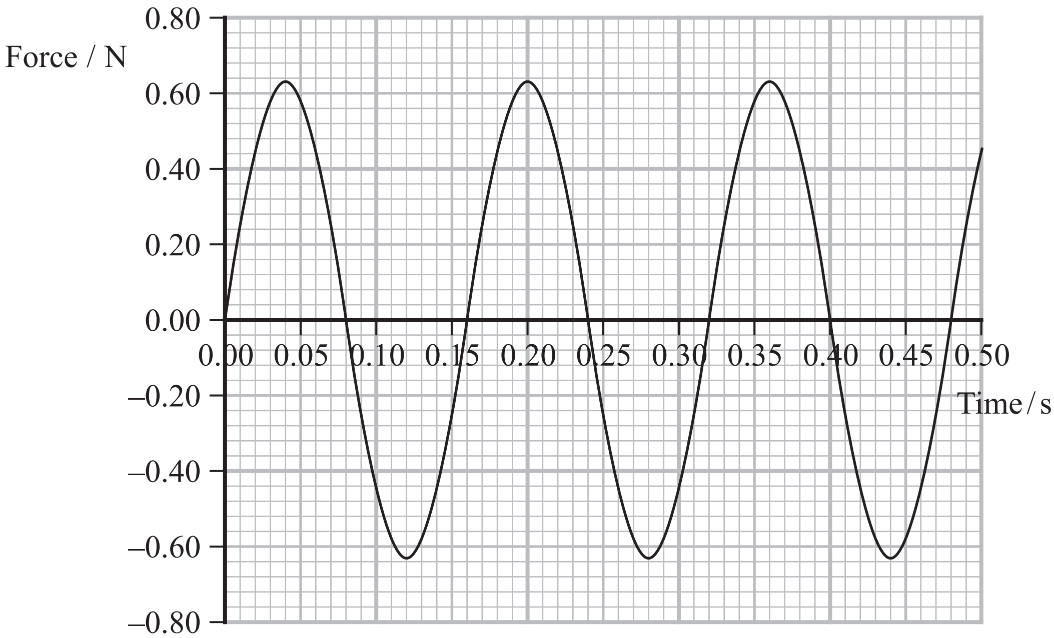
(Total for Question 14 = 10 marks)

15 The photograph shows a toy car inside a plastic ball. The car has an electric motor and follows a circular path in a vertical plane. The car travels at a constant speed.

A student determined how the resultant vertical force on the car varied over a period of time.

The graph shows the student's data. A positive value represents an upwards force.



(a) (i) Show that the angular velocity of the car's motion about the centre of the ball is about 40 radian s^{-1}.

(3)

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P 7 6 8 7 9 A 0 1 2 3 2

(ii) The student took measurements of the ball and wrote down a value of 86 mm.

Deduce whether 86 mm was the radius or the diameter of the ball.

mass of car = 9.5 g

(4)

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*(b) The magnitude of the force exerted by the ball on the car was greatest at 0.04 s and least at 0.12 s.

Discuss the position of the car at these two times.

You should consider the forces acting on the car.
You do not need to do any further calculations.

(6)

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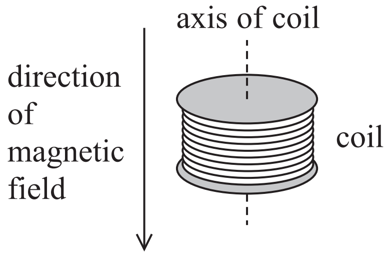
(Total for Question 15 = 13 marks)

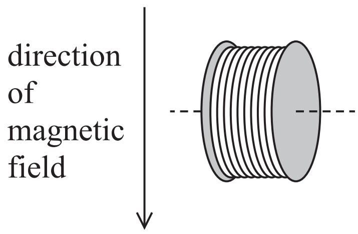
16 A search coil is used to investigate magnetic fields.

The search coil consists of a coil of thin copper wire connected to two output terminals, as shown.

A student placed the coil in a magnetic field with the axis parallel to the direction of the field, as shown.



The coil was rotated through 90° so the axis was perpendicular to the direction of the field, as shown.



As the coil was rotated, a potential difference (p.d.) was detected across the terminals.

(a) Explain why a p.d. was produced as the coil was rotated.

(2)

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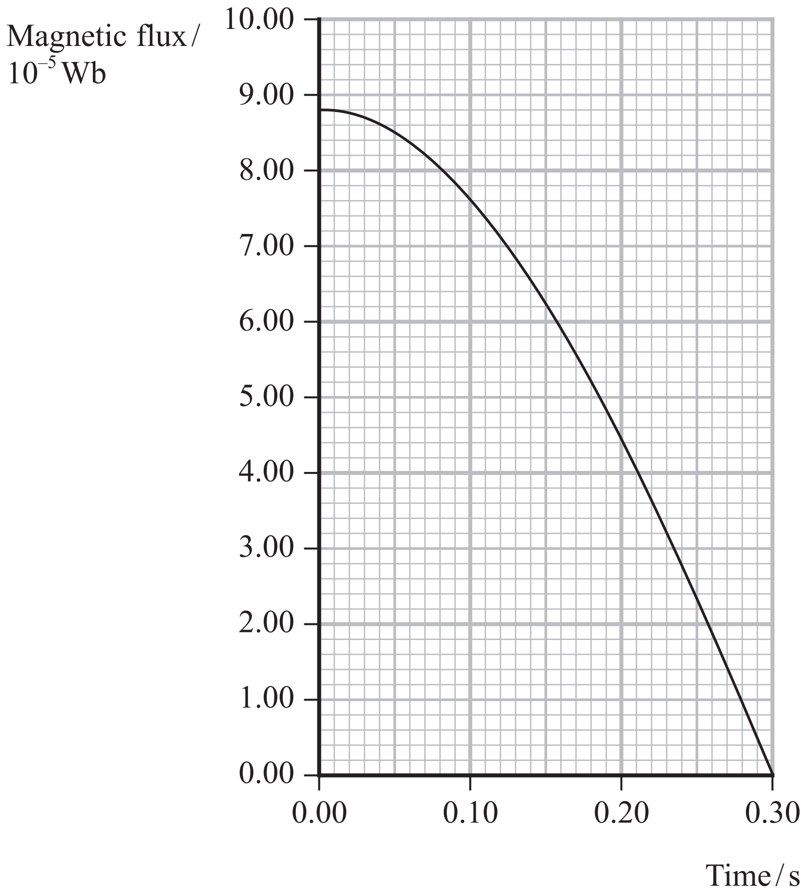
(b) Show that the initial value of magnetic flux in the coil is about 9×10^{-5} Wb.

diameter of coil = 25 mm
magnetic flux density = 0.18 T

(3)

(c) The graph shows the magnetic flux in the coil while the coil was being rotated.



Determine the maximum p.d. produced across the terminals.

number of turns on coil = 5000

(4)

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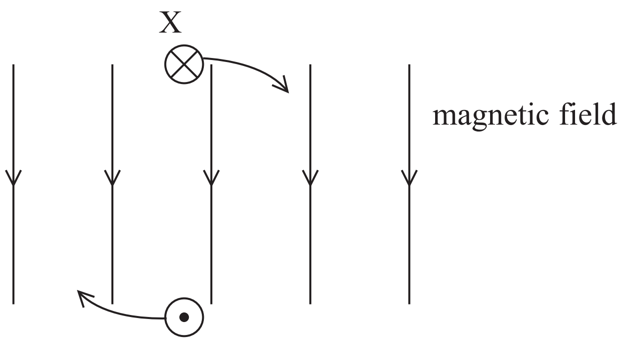
Maximum p.d. = ...

(d) The output terminals of the coil are connected together, while the coil is in the magnetic field. The diagram shows a cross-section through one turn of the coil. X is on one side of the coil.



The coil is rotated clockwise in the magnetic field, causing a current in the coil. The student states that the current at X is into the page.

Deduce whether the student's statement is correct.
You should refer to Lenz's law.

(4)

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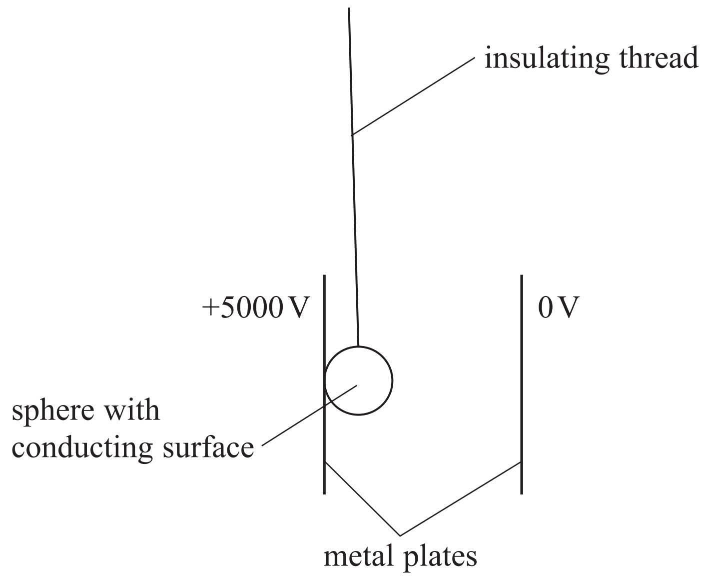
(Total for Question 16 = 13 marks)

17 A potential difference of 5000 V is applied across two vertical metal plates.

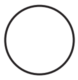
A sphere with a conducting surface is suspended by an insulating thread and touches the positively charged plate as shown.



The sphere becomes positively charged.

(a) Complete the diagram to show the electric field around a positively charged sphere.

(3)

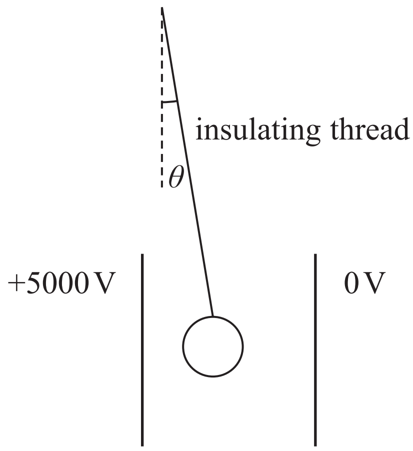


(b) (i) Show that the charge on the sphere is about 10 nC.

potential at surface of sphere = 5000 V
radius of sphere = 20 mm

(2)

(ii) The sphere moves away from the positive plate and comes to rest at an angle θ to the vertical.



Show that the horizontal force on the sphere is about 5×10^{-4} N.

distance between plates = 10.5 cm

(3)

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(iii) Show that θ is about 1°.

mass of sphere = 2.7 g

(3)

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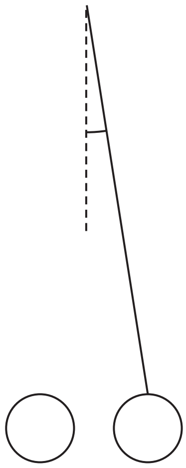
(c) A second identical charged sphere is held in a fixed position.

The first sphere, attached to the insulating thread, is placed near to the fixed sphere.

The spheres exert a repulsive force on each other.



fixed sphere

The force between the spheres is 5.0×10^{-4} N.

Calculate the distance between the centres of the spheres.

charge on each sphere = 12 nC

(3)

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Distance between centres of spheres = ...

(Total for Question 17 = 14 marks)

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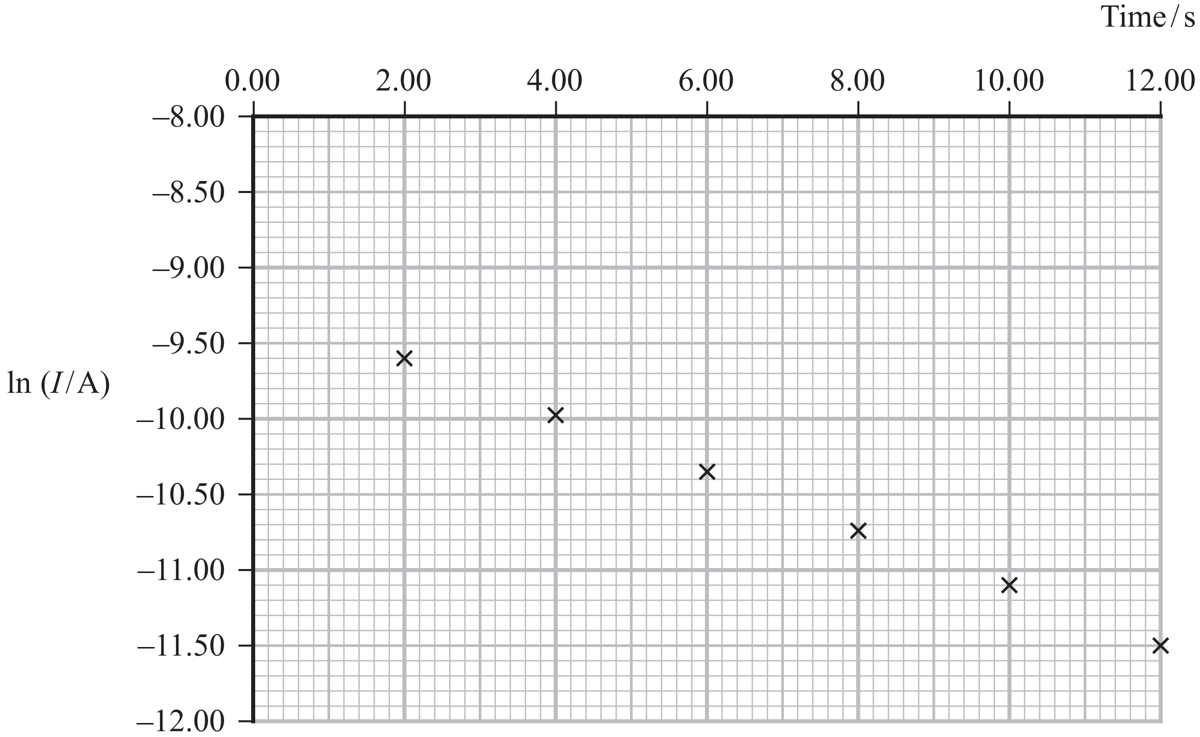
18 A student planned to use a capacitor in a timing circuit.

The capacitor was connected in series with a resistor to determine the capacitance of the capacitor.

The capacitor was charged while measuring the current I in the circuit.

The following graph was plotted.



(a) The value marked on the capacitor is 22 μF.

Show that this value is correct.

resistance of resistor = 240 kΩ

(4)

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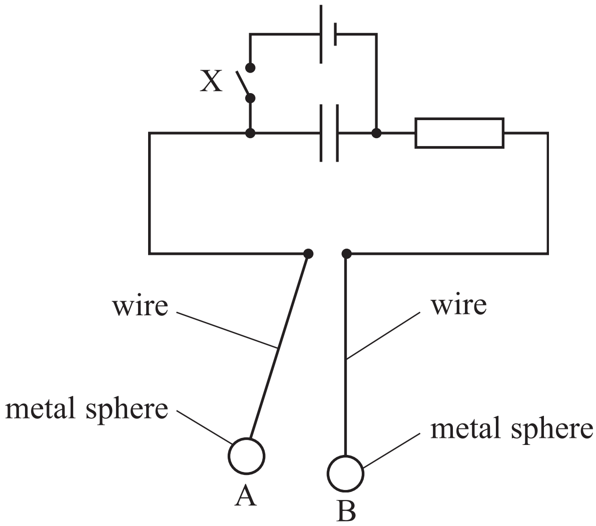
(b) The capacitor was used in a circuit to time a collision between two identical metal spheres.

The spheres were suspended from wires. The wires were connected to the circuit, as shown.



When the wires hang vertically the spheres are in contact and the discharging circuit is complete.

Switch X was closed to charge the capacitor. The switch was then opened and sphere A was released.

Sphere A collided with sphere B.

While the spheres were in contact, the capacitor partially discharged.

Sphere B moved to the right. The maximum height h of sphere B above its starting position was measured.

(i) Calculate the maximum speed of sphere B after the collision.

h = 1.1 cm
mass of sphere B = 28 g

(3)

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Maximum speed = ...

(ii) Calculate the time for which the spheres were in contact.

resistance in circuit = 49 Ω
potential difference across capacitor before collision = 6.18 V
potential difference across capacitor after collision = 5.43 V
capacitance of capacitor = 22 μF

(2)

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Time spheres in contact = ...

(iii) The student stated that the average force acting on sphere B cannot be more than the weight of sphere A.

Deduce whether this statement is correct.

mass of each sphere = 28 g

(4)

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(Total for Question 18 = 13 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

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

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

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

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

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	$Q = Q_0 e^{-t/RC}$

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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