Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Higher level
Paper 2

3 May 2023

Zone A morning | **Zone B** afternoon | **Zone C** morning

Candidate session number

2 hours 15 minutes

Instructions to candidates

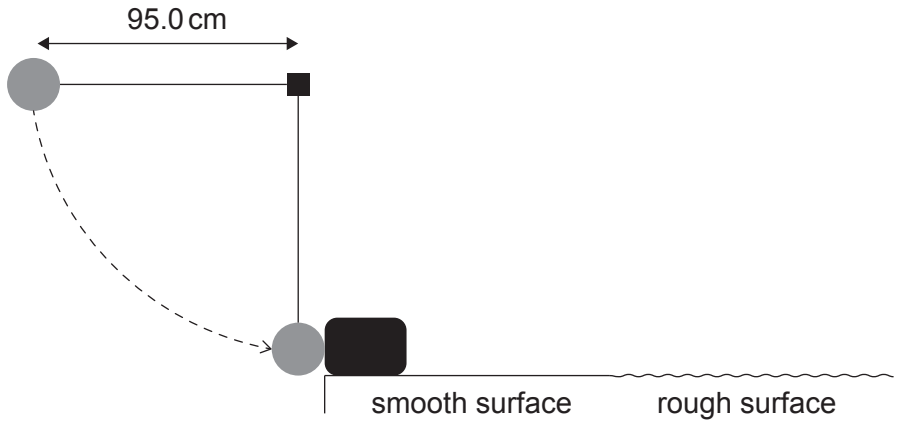
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[90 marks]**.

2223 – 6508

27 pages

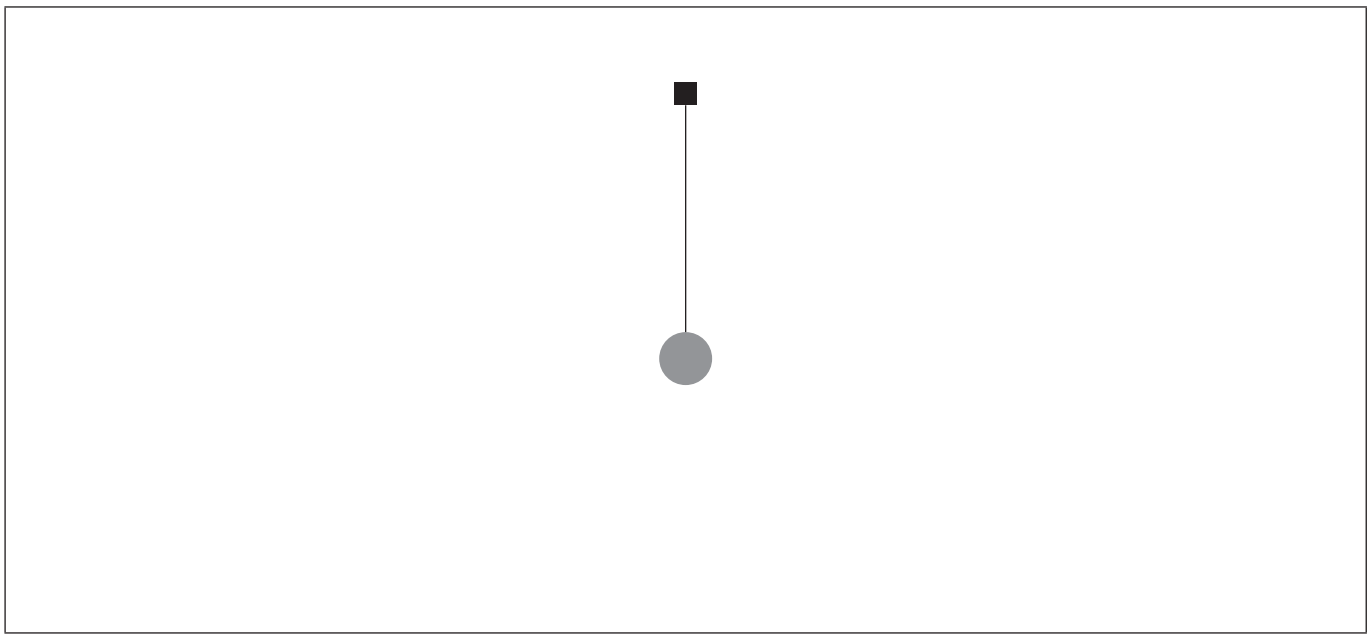
Answer **all** questions. Answers must be written within the answer boxes provided.

1. A ball of mass 0.800 kg is attached to a string. The distance to the centre of the mass of the ball from the point of support is 95.0 cm. The ball is released from rest when the string is horizontal. When the string becomes vertical the ball collides with a block of mass 2.40 kg that is at rest on a horizontal surface.



(a) Just before the collision of the ball with the block,

(i) draw a free-body diagram for the ball. [2]



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(Question 1 continued)

(ii) show that the speed of the ball is about $4.3\,m\,s^{-1}$. [1]

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(iii) determine the tension in the string. [2]

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will not be marked.

(Question 1 continued)

(b) After the collision, the ball rebounds and the block moves with speed $2.16\,m\,s^{-1}$.

(i) Show that the collision is elastic. [4]

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(ii) Calculate the maximum height risen by the centre of the ball. [2]

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(c) The coefficient of dynamic friction between the block and the rough surface is 0.400.

Estimate the distance travelled by the block on the rough surface until it stops. [3]

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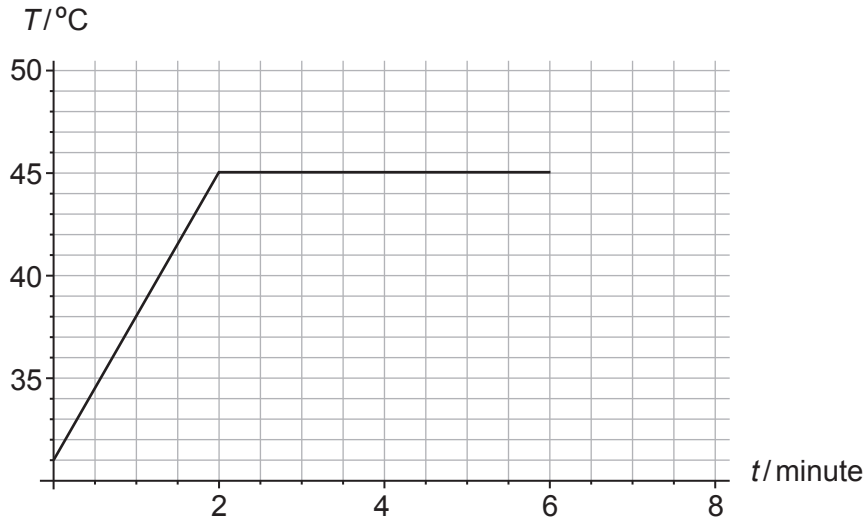
2. A solid piece of chocolate of mass 82 g is placed in a pan over fire. Thermal energy is transferred to the chocolate at a constant rate. The graph shows the variation with time *t*, of the temperature *T* of the chocolate. At 6.0 minutes all the chocolate has melted.



The specific heat capacity of solid chocolate is $1.6 \times 10^3\,J\,kg^{-1}\,K^{-1}$.

(a) Show that the average rate at which thermal energy is transferred into the chocolate is about 15 W. [3]

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(b) Estimate the specific latent heat of fusion of chocolate. [2]

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(Question 2 continued)

(c) Compare the internal energy of the chocolate at $t = 2$ minutes with that at $t = 6$ minutes. [2]

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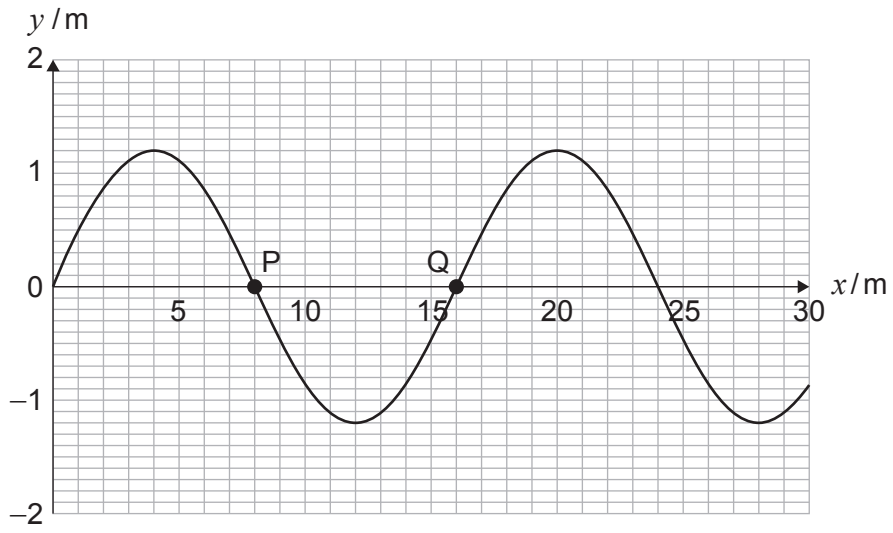
3. (a) A transverse water wave travels to the right. The diagram shows the shape of the surface of the water at time $t = 0$. P and Q show two corks floating on the surface.



(i) State what is meant by a transverse wave. [1]

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(ii) The frequency of the wave is 0.50 Hz. Calculate the speed of the wave. [1]

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(iii) Plot on the diagram the position of P at time $t = 0.50$ s. [1]

(iv) Show that the phase difference between the oscillations of the two corks is π radians. [1]

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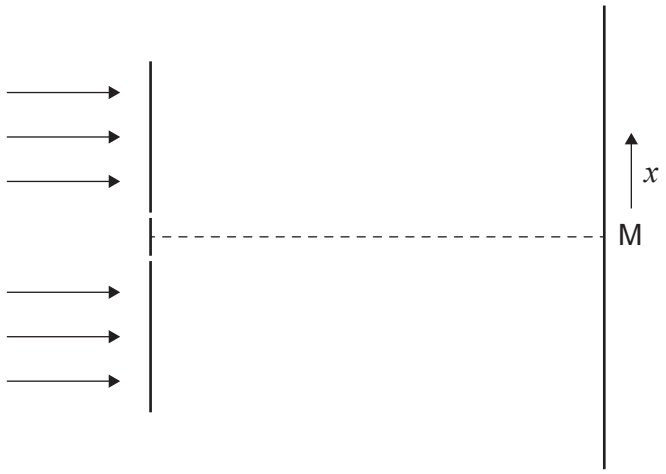
(Question 3 continued)

(b) Monochromatic light is incident on two very narrow slits. The light that passes through the slits is observed on a screen. M is directly opposite the midpoint of the slits. x represents the displacement from M in the direction shown.



A student argues that what will be observed on the screen will be a total of two bright spots opposite the slits. Explain why the student's argument is incorrect. [2]

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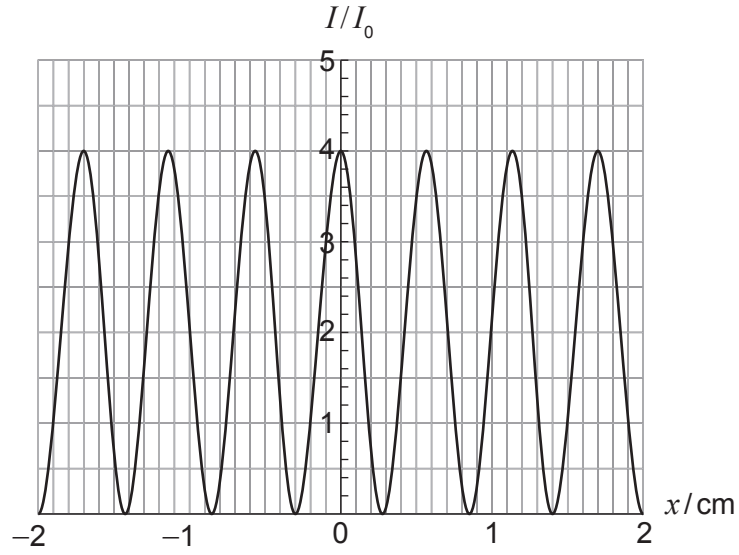
(Question 3 continued)

(c) The graph shows the actual variation with displacement x from M of the intensity of the light on the screen. I_0 is the intensity of light at the screen from one slit only.



(i) Explain why the intensity of light at $x = 0$ is $4I_0$. [2]

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(ii) The slits are separated by a distance of 0.18 mm and the distance to the screen is 2.2 m. Determine, in m, the wavelength of light. [2]

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(Question 3 continued)

(iii) The two slits are replaced by many slits of the same separation. State **one** feature of the intensity pattern that will remain the same and **one** that will change. [2]

Stays the same:. . . . . .

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Changes:. . . . . .

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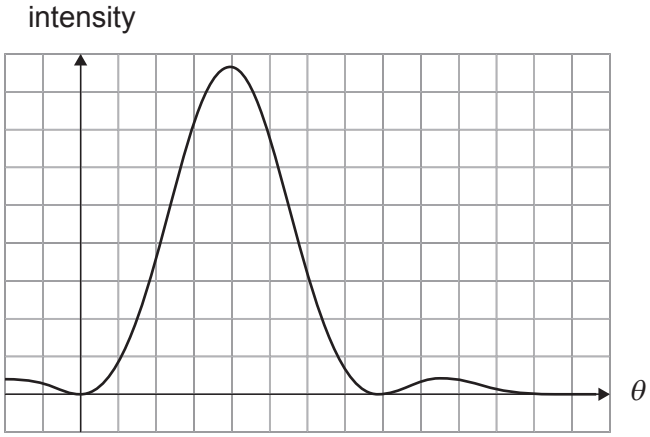
(d) (i) Two sources are viewed though a single slit. The graph shows the diffraction pattern of one source.



Sketch, on the axes, the diffraction pattern of the second source when the images of the two sources are just resolved according to the Rayleigh criterion. [1]

(ii) Centaurus A is a galaxy a distance of 1.1×10^{23} m away. A radio telescope of diameter 300 m operating at a wavelength of 3.2 cm is used to observe the galaxy. Determine the minimum size of the radio emitting region of the galaxy that can be resolved by this telescope. [2]

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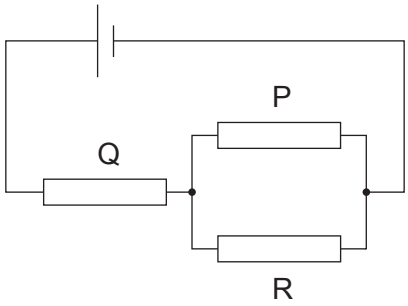
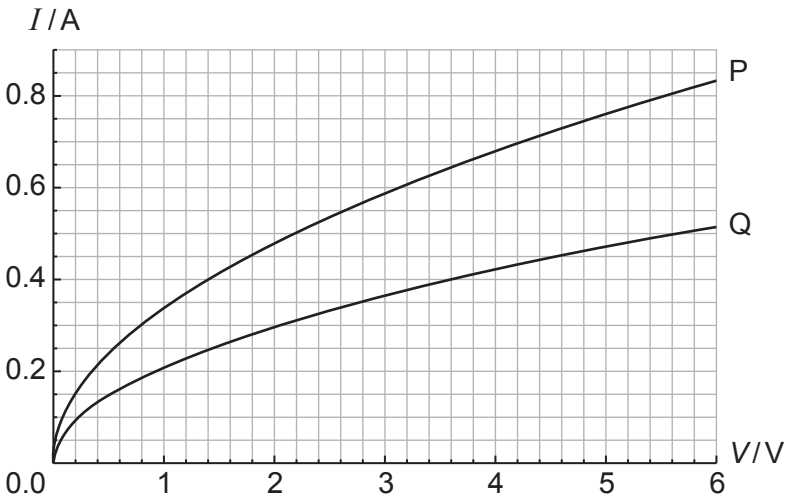
4. (a) A cell of negligible internal resistance and electromotive force (emf) 6.0 V is connected to three resistors R, P and Q.



R is an ohmic resistor. The I-V characteristics of P and Q are shown in the graph.



The current in P is 0.40 A.

(i) Show that the current in Q is 0.45 A. [3]

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(Question 4 continued)

(ii) Calculate the resistance of R. [2]

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(iii) Calculate the total power dissipated in the circuit. [1]

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(b) Resistor P is removed. Suggest, without any calculations, the effect of this on the resistance of Q. [2]

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5. (a) Identify with ticks [✓] in the table, the forces that can act on electrons and the forces that can act on quarks. [2]

	Weak nuclear	Strong nuclear
Electrons		
Quarks		

(b) The following data is available for atomic masses for the fusion reaction

$^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$:

$^{2}_{1}\mathrm{H}$	2.0141 u
$^{3}_{1}\mathrm{H}$	3.0160 u
$^{4}_{2}\mathrm{He}$	4.0026 u

(i) Show that the energy released is about 18 MeV. [2]

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(ii) Estimate the specific energy of hydrogen by finding the energy produced when 0.4 kg of $^{2}_{1}\mathrm{H}$ and 0.6 kg of $^{3}_{1}\mathrm{H}$ undergo fusion. [2]

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(Question 5 continued)

(c) It is hoped that nuclear fusion can be used for commercial production of energy.

Outline

(i) **two** difficulties of energy production by nuclear fusion. [2]

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(ii) **one** advantage of energy production by nuclear fusion compared to nuclear fission. [1]

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will not be marked.

(Question 5 continued)

(d) Tritium (${}^{3}_{1}\mathrm{H}$) is unstable and decays into an isotope of helium (He) by beta minus decay with a half-life of 12.3 years.

(i) State the nucleon number of the He isotope that ${}^{3}_{1}\mathrm{H}$ decays into. [1]

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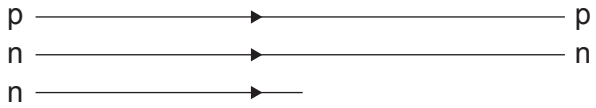
(ii) The following diagram is an incomplete Feynman diagram describing the beta minus decay of ${}^{3}_{1}\mathrm{H}$ into He. Complete the diagram and label all the missing particles. [3]



(iii) Estimate the fraction of tritium remaining after one year. [2]

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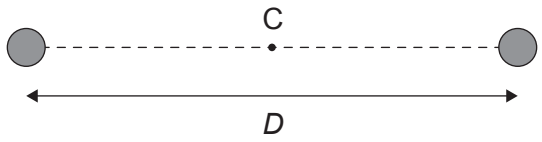
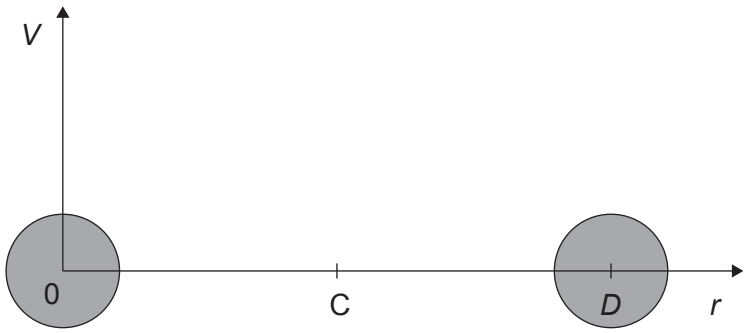
6. (a) The centres of two identical fixed conducting spheres each of charge $+Q$ are separated by a distance D. C is the midpoint of the line joining the centres of the spheres.



(i) Sketch, on the axes, how the electric potential V due to the two charges varies with the distance r from the centre of the left charge. No numbers are required. Your graph should extend from r = 0 to r = D. [3]



(ii) Calculate the work done to bring a small charge q from infinity to point C.
Data given:

$Q = 2.0 \times 10^{-3}\,\text{C}$,

$q = 4.0 \times 10^{-9}\,\text{C}$

$D = 1.2\,\text{m}$ [2]

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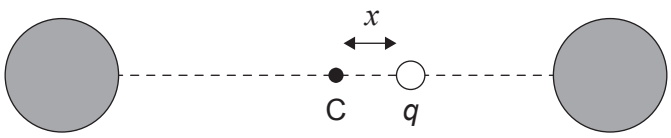
(Question 6 continued)

(b) The small positive charge q is placed a distance x to the right of C. The distance x is very small compared to D.



(i) The magnitude of the net force on q is given by $\frac{32kQq}{D^3}x$. Explain why the charge q will execute simple harmonic oscillations about C. [2]

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(ii) The mass of the charge q is 0.025 kg.

Calculate the angular frequency of the oscillations using the data in (a)(ii) and the expression in (b)(i). [2]

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(Question 6 continued)

(c) The charges Q are replaced by neutral masses M and the charge q by a neutral mass m. The mass m is displaced away from C by a small distance x and released. Discuss whether the motion of m will be the same as that of q. [2]

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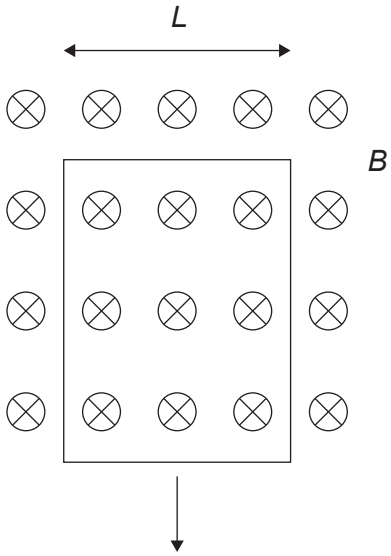
7. A vertical rectangular loop of conducting wire is dropped in a region of horizontal magnetic field. The diagram shows the loop as it leaves the region of the magnetic field.



(a) Explain, by reference to Faraday's law of electromagnetic induction, why there is an electromotive force (emf) induced in the loop as it leaves the region of magnetic field. [2]

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(Question 7 continued)

(b) Just before the loop is about to completely exit the region of magnetic field, the loop moves with constant terminal speed v.

The following data is available:

Mass of loop	$m = 4.0\,\text{g}$
Resistance of loop	$R = 25\,\text{m}\Omega$
Width of loop	$L = 15\,\text{cm}$
Magnetic flux density	$B = 0.80\,\text{T}$

Determine, in $\text{m}\,\text{s}^{-1}$ the terminal speed v. [4]

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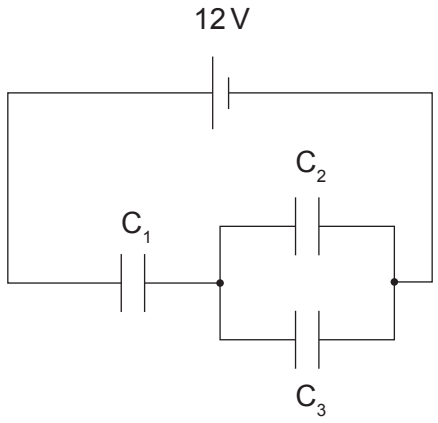
(Question 7 continued)

(c) Three capacitors $C_1 = 3.0\,\mu F$, $C_2 = 2.0\,\mu F$ and $C_3 = 4.0\,\mu F$ are connected to a cell of emf 12 V and negligible internal resistance. The capacitors are initially uncharged.



Calculate

(i) the total capacitance of the circuit. [2]

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(ii) the total energy stored in the three capacitors. [1]

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(Question 7 continued)

(iii) the charge on C_2. [3]

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8. (a) Photons of wavelength 468 nm are incident on a metallic surface. The maximum kinetic energy of the emitted electrons is 1.8 eV.

Calculate

(i) the work function of the surface, in eV. [2]

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(ii) the longest wavelength of a photon that will eject an electron from this surface. [2]

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(b) (i) In an experiment, alpha particles of initial kinetic energy 5.9 MeV are directed at stationary nuclei of lead ($^{207}_{82}Pb$). Show that the distance of closest approach is about 4×10^{-14} m. [2]

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(This question continues on the following page)

(Question 8 continued)

(ii) The radius of a nucleus of $^{207}_{82}Pb$ is 7.1×10^{-15} m. Suggest why there will be no deviations from Rutherford scattering in the experiment in (b)(i). [2]

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References:

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