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OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A 2824

Forces, Fields and Energy

Thursday **20 JANUARY 2005** Morning 1 hour 30 minutes

Candidates answer on the question paper.
Additional materials:
Electronic calculator

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces provided on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- You will be awarded marks for the quality of written communication where this is indicated in the question.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	13	
2	13	
3	12	
4	13	
5	12	
6	11	
7	16	
TOTAL	**90**	

This question paper consists of 18 printed pages and 2 blank pages.

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
refractive index,	$n = \dfrac{1}{\sin C}$
capacitors in series,	$\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
capacitor discharge,	$x = x_0 e^{-t/CR}$
pressure of an ideal gas,	$p = \frac{1}{3}\dfrac{Nm}{V}<c^2>$
radioactive decay,	$x = x_0 e^{-\lambda t}$
	$t_{\frac{1}{2}} = \dfrac{0.693}{\lambda}$
critical density of matter in the Universe,	$\rho_0 = \dfrac{3H_0^{\,2}}{8\pi G}$
relativity factor,	$= \sqrt{(1 - \dfrac{v^2}{c^2})}$
current,	$I = nAve$
nuclear radius,	$r = r_0 A^{1/3}$
sound intensity level,	$= 10 \lg \left(\dfrac{I}{I_0}\right)$

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For Examiner's Use

Answer **all** the questions.

1 A mass oscillates on the end of a spring in simple harmonic motion. The graph of the acceleration *a* of the mass against its displacement *x* from its equilibrium position is shown in Fig. 1.1.

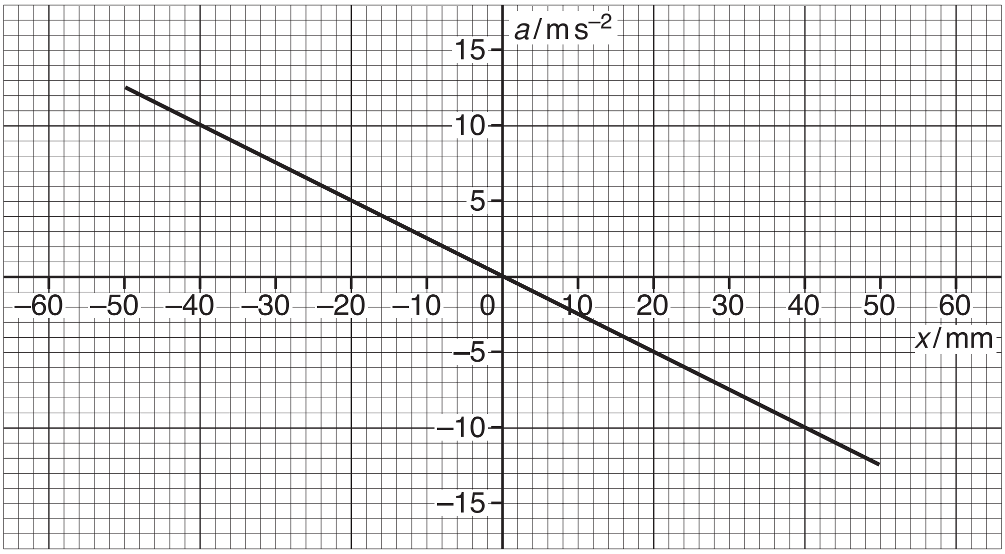

Fig. 1.1

(a) (i) Define *simple harmonic motion*.

....

....

....[2]

(ii) Explain how the graph shows that the object is oscillating in simple harmonic motion.

....

....

....[2]

(b) Use data from the graph

(i) to find the amplitude of the motion

amplitude = ... m [1]

(ii) to show that the period of oscillation is 0.4 s.

[3]

(c) **(i)** The mass is released at time $t = 0$ at displacement $x = 0.050$ m. Draw a graph on the axes of Fig. 1.2 of the displacement of the mass until $t = 1.0$ s. Add scales to both axes. [3]

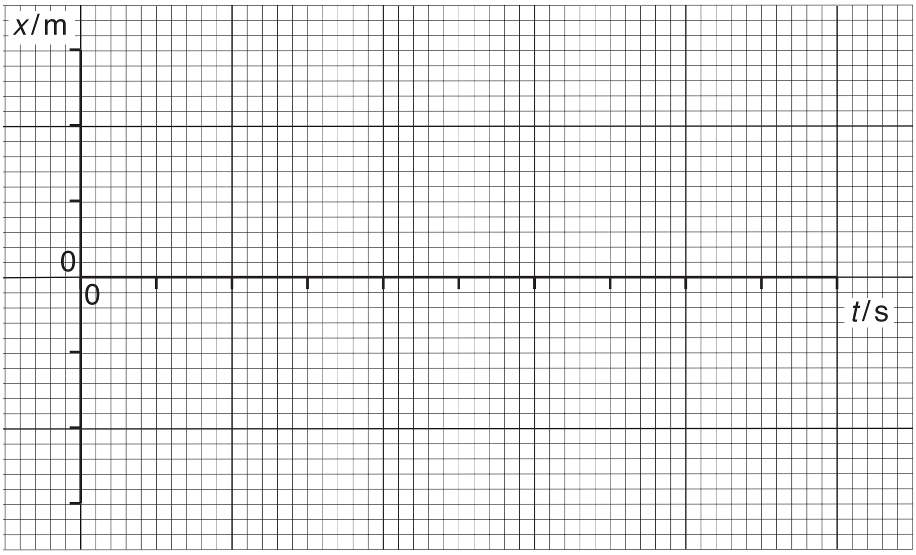

Fig. 1.2

(ii) State a displacement and time at which the system has maximum kinetic energy.

displacement .... m

time .... s [2]

[Total: 13]

2 This question is about the operation of an electrically operated shower.

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Details: An image of an electric shower

Fig. 2.1

(a) The water moves at constant speed through a pipe of cross-section $7.5 \times 10^{-5}\,\text{m}^2$ to a shower head. See Fig. 2.1. The maximum mass of water which flows per second is $0.090\,\text{kg s}^{-1}$.

(i) Show that the maximum speed of the water in the pipe is $1.2\,\text{m s}^{-1}$.

density of water = $1000\,\text{kg m}^{-3}$

[2]

(ii) The total cross-sectional area of the holes in the head is half that of the pipe. Calculate the maximum speed of the water as it leaves the shower head.

speed = ... m s^{-1} [1]

(iii) Calculate the magnitude of the force on the shower head.

force = ... N [3]

(iv) Draw on Fig. 2.1 the direction of the force in (iii) . [1]

For Examiner's Use

(b) The water enters the heater at a temperature of 15 °C. At the maximum flow rate of 0.090 kg s^{-1}, the water leaves the shower head at a temperature of 27 °C.

(i) Calculate the rate at which energy is transferred to the water. Give a suitable unit for your answer.

specific heat capacity of water = 4200 J kg^{-1} K^{-1}

rate of energy transfer = ... unit .... [4]

(ii) Suggest a reason why the power of the heater must be greater than your answer to **(b)(i)**.

....

....[1]

(iii) Calculate the maximum possible temperature of the water at the shower head when the flow rate is half of the maximum.

temperature = ...°C [1]

[Total: 13]

3 This question is about changing the motion of electrons using electric fields. Fig. 3.1 shows a horizontal beam of electrons moving in a vacuum. The electrons pass through a hole in the centre of a metal plate **A**. At **B** is a metal grid through which the electrons can pass. At **C** is a further metal sheet. The three vertical conductors are maintained at voltages of +600 V at **A**, 0 V at **B** and +1200 V at **C**. The distance from plate **A** to grid **B** is 40 mm.

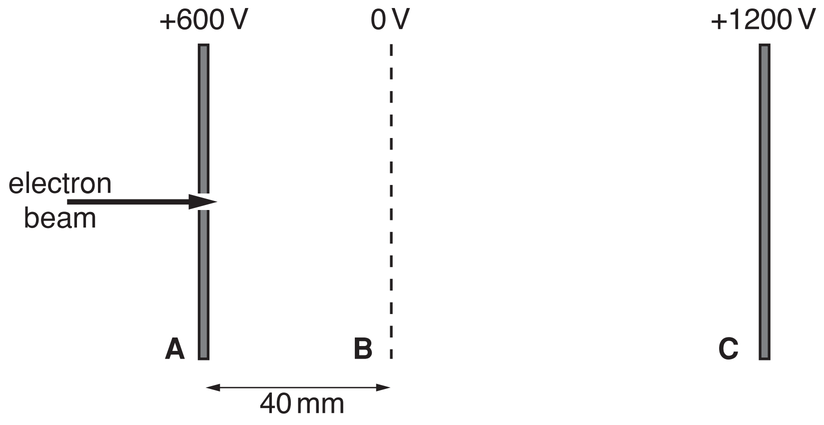

Fig. 3.1

(a) On Fig. 3.1 draw electric field lines to represent the fields in the regions between the three plates. [3]

(b) Show that the magnitude of the electric field strength between plate **A** and grid **B** is $1.5 \times 10^4\,\mathrm{V\,m^{-1}}$.

[2]

(c) Calculate the horizontal force on an electron after passing through the hole in **A**.

force = ... N [2]

(d) Show that the minimum speed that an electron in the beam must have at the hole in **A** to reach the grid at **B** is about $1.5 \times 10^7\,\mathrm{m\,s^{-1}}$.

[2]

(e) Calculate the speed of these electrons when they collide with sheet **C**.

speed = ... $m\,s^{-1}$ [1]

(f) Describe and explain the effect on the current detected at **C** when the voltage of the grid **B** is increased negatively.

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....[2]

[Total: 12]

For Examiner's Use

4 **(a)** Fig. 4.1 shows the graph of charge Q stored against potential difference V across a capacitor.

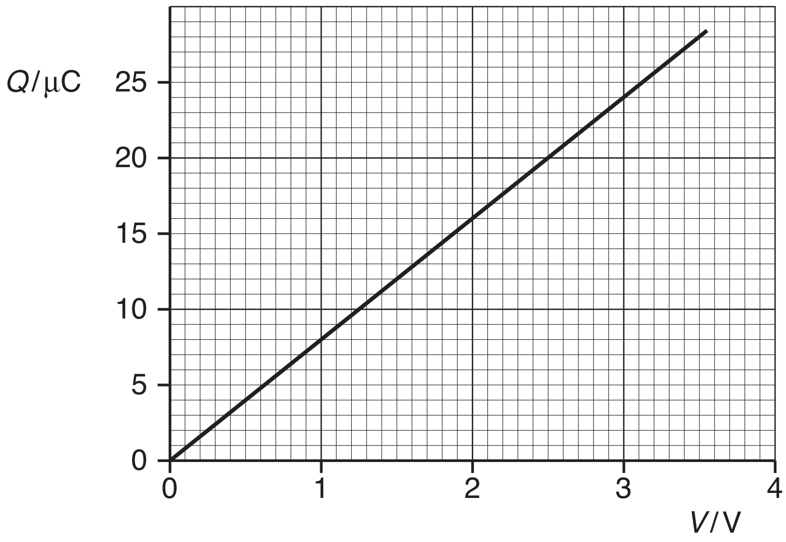

Fig. 4.1

(i) Use the graph to find the capacitance of the capacitor.

capacitance = ... μF [2]

(ii) Calculate the energy in the capacitor when it is charged to 3.0 V.

energy = ... μJ [2]

(iii) The capacitor is discharged through a resistor. The charge falls to 0.37 of its initial value in a time of 0.040 s. This is the time constant of the circuit. Calculate the resistance of the resistor.

resistance = ... Ω [2]

(iv) Explain why the discharge time of the capacitor is independent of the initial charge on the capacitor.

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....[2]

(b) You are provided with a number of identical capacitors, each of capacitance 3.0 μF. Three are connected in a series and parallel combination as shown in Fig. 4.2.

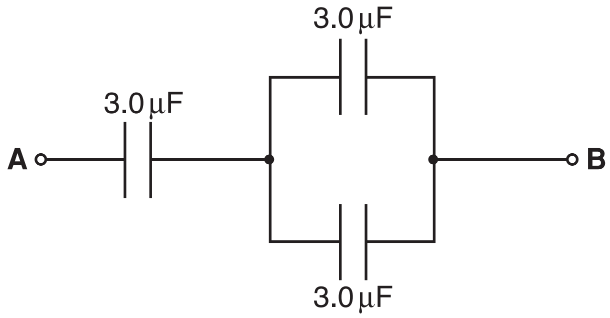

Fig. 4.2

(i) Show that the total capacitance between the terminals **A** and **B** is 2.0 μF.

[3]

(ii) Draw a diagram in the space below to show how you can produce a total capacitance of 2.0 μF using **six** 3.0 μF capacitors.

[2]

[Total: 13]

For Examiner's Use

5 The radioactive nuclide $^{42}_{19}K$ decays by emission of a beta-particle. Fig. 5.1 shows the apparatus used to measure the half life of the nuclide. A Geiger-Muller (GM) tube connected to a counter is placed a short distance in front of the potassium source and the count per minute is recorded once every hour.

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Details: An image of a potassium source and a GM tube connected to a counter

Fig. 5.1

(a) The activity of the potassium source is proportional to the count rate minus the background count rate, that is

activity = constant × (count rate – background count rate).

(i) Explain the meaning of the terms

activity . ...

.... [1]

background count rate ....

.... [1]

(ii) Suggest, with a reason, one of the factors which affect the value of the constant in the equation above.

....

....

....

....[2]

(b) (i) The radioactive decay law in terms of the count rate C corrected for background can be written in the form

$$C = C_o e^{-\lambda t}$$

where λ is the decay constant.
Show how the law can be written in the linear form

$$\ln C = -\lambda t + \ln C_o$$

[2]

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(ii) Fig. 5.2 shows the graph of ln C against time t for the beta-decay of potassium.

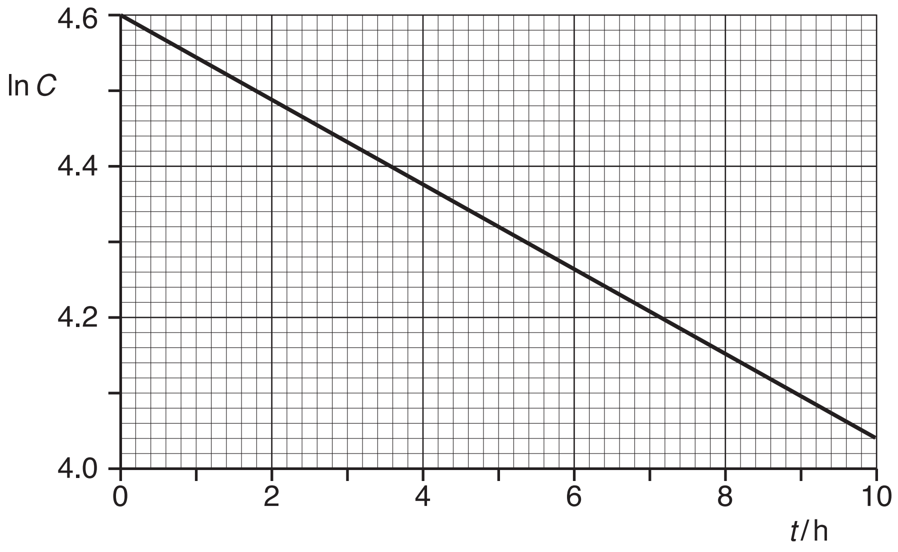

Fig. 5.2

Use data from the graph to estimate the half-life of the potassium nuclide.

half-life = …………………h [3]

(c) State **three** ways in which decay by emission of an α-particle differs from decay by emission of a β-particle.

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....[3]

[Total: 12]

[Turn over

For Examiner's Use

6 A single-turn square coil of side 0.050 m is placed in a magnetic field of flux density B of magnitude 0.026 T.

(a) The coil is placed in three different orientations to the field as shown in Fig. 6.1(a), (b) and (c).

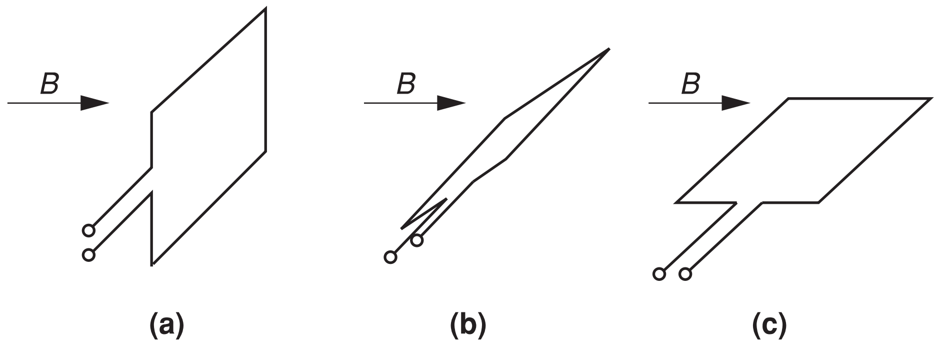

Fig. 6.1

In Fig. 6.1(a), the plane of the coil is perpendicular to the field. In (b), it is at 45° to the field and in (c), it is parallel to the field. Calculate the value, giving a suitable unit, of the magnetic flux linking the coil for the position shown in

(i) Fig. 6.1(a)

magnetic flux = …………..unit……… [3]

(ii) Fig. 6.1(b)

magnetic flux = …………..unit……… [1]

(iii) Fig. 6.1(c).

magnetic flux = …………..unit……… [1]

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(b) The coil is rotated in the magnetic field to generate an e.m.f. across its ends. The graph of the variation of e.m.f. with time is shown in Fig. 6.2.

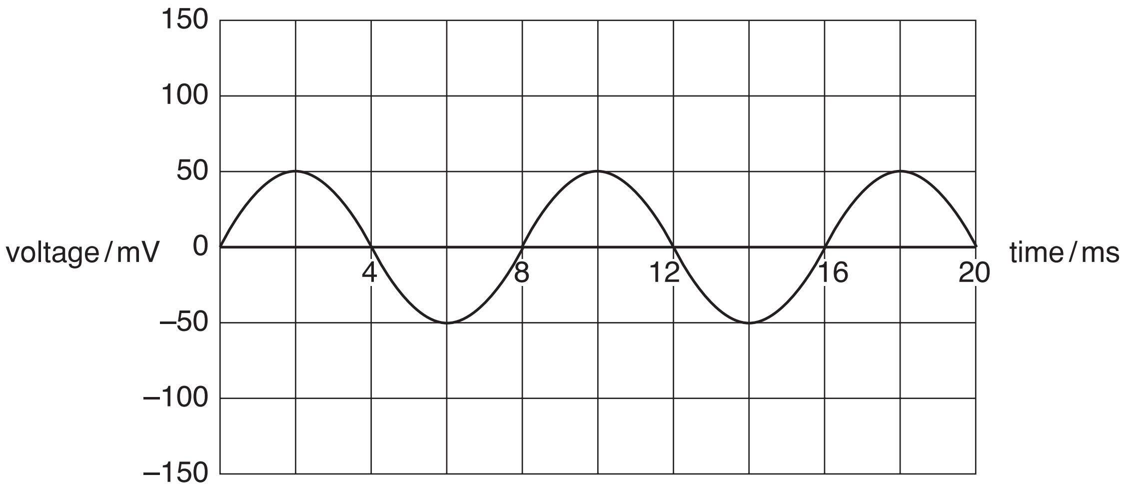

Fig. 6.2

(i) On Fig. 6.2 mark, with an **X**, a point on the graph at a time when the flux linking the coil is a maximum. [1]

(ii) Give your reasoning for your choice of position **X**.

....

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....

....

....[2]

(iii) The rate of rotation of the coil is doubled. On Fig. 6.2 draw a graph showing at least two cycles of the e.m.f. now generated across the ends of the coil. [3]

[Total: 11]

[Turn over

For Examiner's Use

7 In this question, four marks are available for the quality of written communication.

(a) Describe what conclusions can be drawn about the structure of the atom from Rutherford's experiment in which α-particles are scattered by gold nuclei. Explain how and why the experiment differs when high-speed electrons are fired at nuclei.

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....[7]

(b) A beam of low-energy electrons, incident on an atomic crystal or lattice, enables the spacing of the atoms to be determined. Explain the principles of such an experiment and how the atomic spacing is found.
How does the energy of the electrons in the beam determine the size of the particles that can be investigated?
A space has been left for you to draw suitable diagram(s), if you wish to illustrate your answer.

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Quality of Written Communication [4]

[Total: 16]

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