THIS IS A LEGACY SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

PHYSICS A

Forces, Fields and Energy

2824

Candidates answer on the question paper

OCR Supplied Materials:
None

Other Materials Required:
- Electronic calculator

Monday 18 January 2010
Afternoon

Duration: 1 hour 30 minutes

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **90**.
- 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.
- This document consists of **20** pages. Any blank pages are indicated.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	**13**	
2	**12**	
3	**14**	
4	**13**	
5	**10**	
6	**12**	
7	**16**	
TOTAL	**90**	

Turn over

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,	$p = \frac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$
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,	$= 10 \lg\left(\dfrac{I}{I_0}\right)$

Answer **all** the questions.

1 **(a)** Fig. 1.1 shows a ball of mass 0.050 kg resting on the strings of a tennis racket held horizontally.

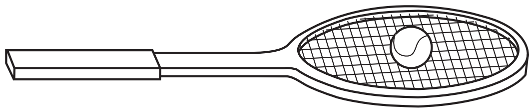

Fig. 1.1

(i) Draw and label arrows to represent the **two** forces acting on the ball. **[2]**

(ii) Calculate the difference in magnitude between the two forces on the ball when the racket is accelerated upwards at $2.0\,m\,s^{-2}$.

force = ... N **[2]**

(b) The ball is dropped from rest at a point 0.80 m above the racket head. The racket is fixed rigidly. Assume that the ball makes an elastic collision with the strings and that any effects of air resistance are negligible.
Calculate

(i) the speed of the ball just before impact

speed = ... $m\,s^{-1}$ **[2]**

(ii) the momentum of the ball just before impact

momentum = ... $kg\,m\,s^{-1}$ **[1]**

(iii) the change in momentum of the ball during the impact

momentum change = ... $kg\,m\,s^{-1}$ **[1]**

(iv) the average force during the impact for a contact time of 0.050 s.

force = ... N **[1]**

(c) The two forces you have drawn in **(a)(i)** are not a pair of forces as required by Newton's third law of motion. However each of these forces does have a corresponding equal and opposite force to satisfy Newton's third law. Describe these equal and opposite forces and state the objects on which they act.

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.... **[4]**

[Total: 13]

2 Fig. 2.1 shows a graph of the variation of the gravitational field strength g of the Earth with distance r from its centre.

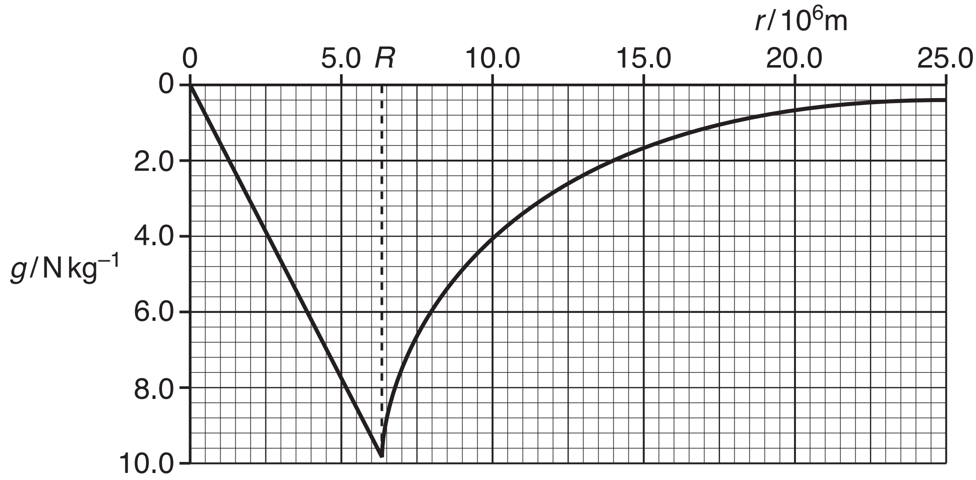

Fig. 2.1

(a) (i) Define the gravitational field strength at a point.

....

.... **[1]**

(ii) Write down an algebraic expression for the gravitational field strength g at the surface of the Earth in terms of the mass M and the radius R of the Earth and the universal gravitational constant G.

[1]

(iii) Use data from Fig. 2.1 and the value of G to show that the mass of the Earth is 6.0×10^{24} kg.

[2]

(iv) State which feature of the graph in Fig. 2.1 indicates that the gravitational field strength at a point below the surface of the Earth, assumed to be of uniform density, is directly proportional to the distance from the centre of the Earth.

....

.... **[1]**

(v) Calculate the **two** distances from the centre of the Earth at which $g = 0.098\,\mathrm{N\,kg^{-1}}$.
Explain how you arrived at your answers.

distance 1 = ... m

....

....

.... **[2]**

distance 2 = ... m

....

....

.... **[2]**

(b) A spacecraft on a journey from the Earth to the Moon has no resultant gravitational pull from the Earth and the Moon when it has travelled to a point 0.9 of the distance between their centres. Calculate the mass of the Moon, using the value for the mass of the Earth in **(a)(iii)**.

mass = ... kg **[3]**

[Total: 12]

Turn over

3 Fig. 3.1 shows two parallel metal plates which act as a capacitor supported above a bench on an insulating rod which passes through the centre of each plate.

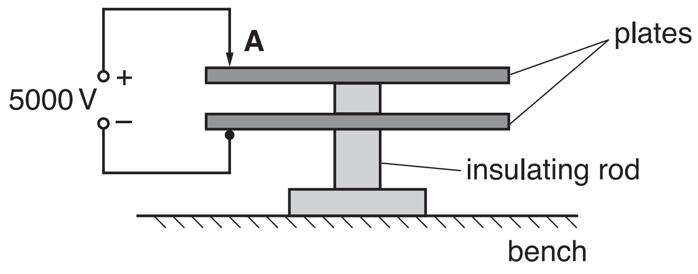

Fig. 3.1

(a) The capacitor is charged by touching the upper plate momentarily with a wire **A** connected to the positive terminal of a 5000 V power supply. The capacitance C of the plates is 1.2×10^{-11} F. Calculate the charge Q_o on the plates. Give a suitable unit for your answer.

Q_o = ... unit .... **[3]**

(b) The charge on the plates leaks away slowly through the insulating rod, which has an effective resistance R of $1.2 \times 10^{15}\,\Omega$.

(i) Show that the time constant for the plates to discharge through the rod is about 1.5×10^{4} s.

[1]

(ii) Show that the initial value of the leakage current is about 4×10^{-12} A.

[1]

(iii) Suppose that the plates continue to discharge at the constant rate calculated in **(ii).** Show that the charge Q_o would leak away in a time equal to the time constant.

[2]

(iv) Using the equation for the charge Q at time t

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

show that, in practice, the plates only lose about 2/3 of their charge in a time equal to one time constant.

[2]

(c) The plates are recharged to 5000 V by touching the upper plate momentarily with wire **A**. Switch **S** is then closed so that the plates are connected in parallel to an uncharged capacitor of capacitance 1.2×10^{-8} F and a voltmeter as shown in Fig. 3.2.

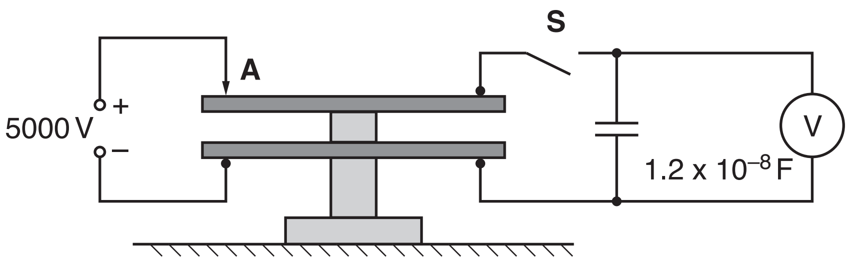

Fig. 3.2

(i) The charged and the uncharged capacitor act as two capacitors in parallel. The total charge Q_0 is shared instantly between the two capacitors. Explain why the charge left on the plates is $Q_0/1000$.

....

....

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....

....

.... **[3]**

(ii) Hence or otherwise calculate the initial reading V on the voltmeter.

V = ... V **[2]**

[Total: 14]

4 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. 4.1.

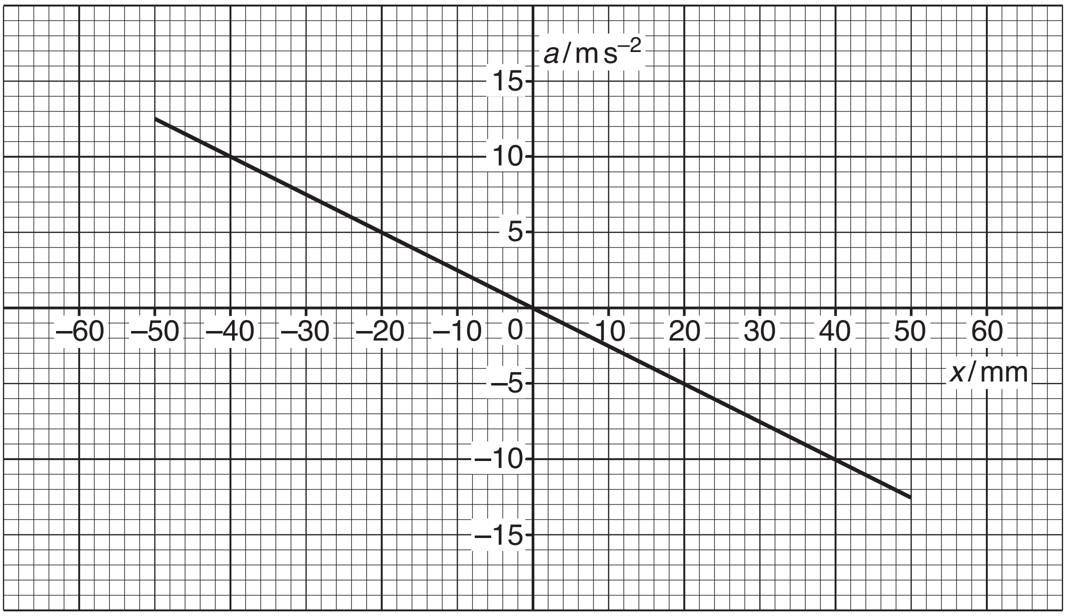

Fig. 4.1

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

....

....

.... **[2]**

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

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....

.... **[2]**

(b) Use data from the graph

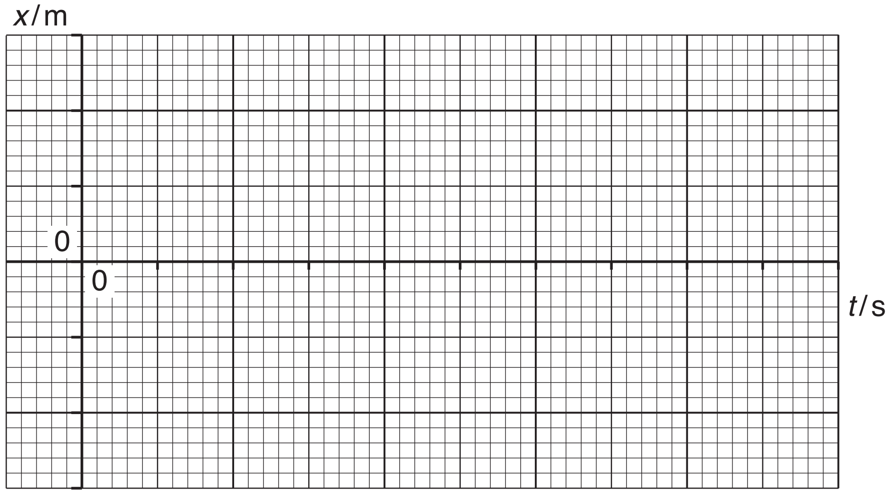
(i) to find the amplitude of the motion

amplitude = ... m **[1]**

(ii) to show that the period of oscillation is about 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. 4.2 of the displacement of the mass until $t = 1.0$ s. Add scales to both axes.



[3]

Fig. 4.2

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

displacement .... m

time .... s **[2]**

[Total: 13]

5 This question is about forcing a liquid metal, such as molten sodium, through a tube using a magnetic field.

The liquid metal is in a tube of square cross-section, side of length w, made of electrically insulating material. Two electrodes, shaded on Fig. 5.1, are mounted on opposite sides of the tube and a magnetic field of flux density B fills the region between the electrodes. An electric current I passes across the tube between the electrodes, perpendicular to the magnetic field. The interaction between the current and the field provides the force to move the liquid.

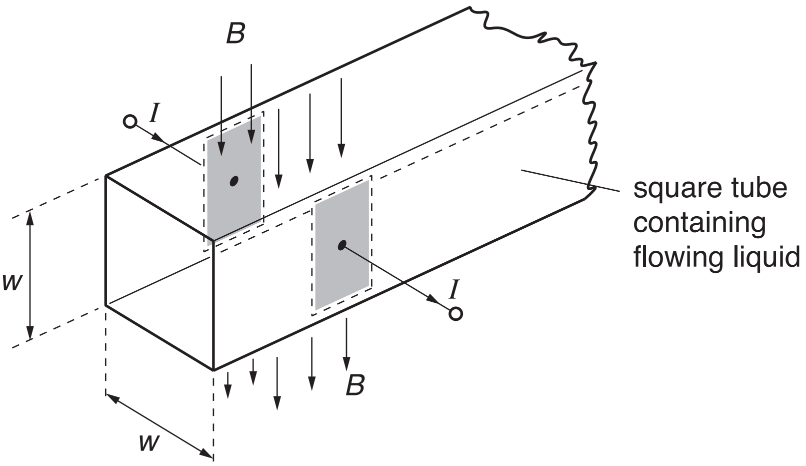


Fig. 5.1

(a) **(i)** Draw on Fig. 5.1 an arrow labelled **F** to indicate the direction of the force on the liquid metal. State the rule that enables you to determine the direction.

....

.... **[2]**

(ii) State a relationship for the force F in terms of the current I, the magnetic field B and the width w of the tube.

.... **[1]**

(iii) Data for this device are shown below.

$B = 0.15\,\text{T}$
$I = 800\,\text{A}$
$w = 25\,\text{mm}$

Calculate the force on the metal in the tube.

force = ... N **[2]**

(b) To monitor the speed of flow of the liquid metal, a similar arrangement of electrodes and magnetic field is set up further down the tube. See Fig. 5.2. A voltmeter is connected across the electrodes instead of a power supply.

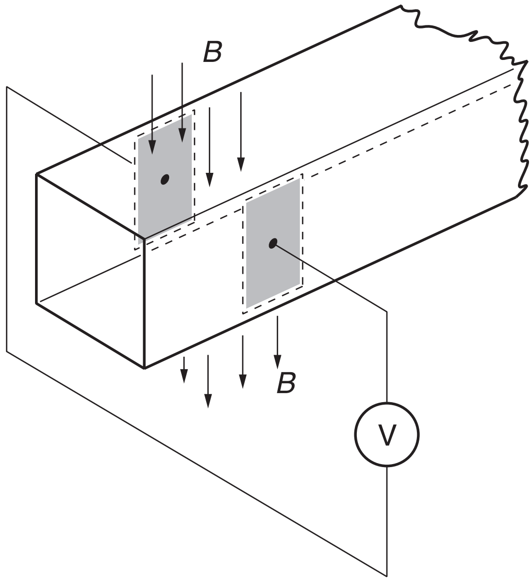


Fig. 5.2

(i) Explain, using the law of electromagnetic induction, why the voltmeter will register a reading which is proportional to the mean speed of flow of the metal.

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.... **[3]**

(ii) State how and explain why the voltmeter reading changes when the magnetic flux density across the tube is doubled.

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.... **[2]**

[Total: 10]

6 **(a)** The radioactive nuclide ${}^{238}_{92}U$ decays by alpha-particle emission. The newly formed nuclide X is also unstable and decays by a different radioactive emission to a third nuclide Y. Y then decays to become another isotope of uranium, ${}^{234}_{92}U$.

(i) Explain the meaning of the term *isotope*.

....

.... **[1]**

(ii) Write down suitable symbols in the form ${}^{238}_{92}U$ for

an α-particle ....

a β-particle. .... **[2]**

(iii) Show how ${}^{238}_{92}U$ can become the isotope ${}^{234}_{92}U$ after three decays.

[3]

(b) **(i)** The radioactive decay law can be written in the form

$$N = N_o e^{-\lambda t}.$$

Explain the meaning of each of the following

N ....

N_o ....

the decay constant λ ....

....

.... **[3]**

(ii) The uranium isotope ${}^{235}_{92}U$ was present at the formation of the Earth. Since then the nuclei of this isotope have been decaying according to the decay law.
Calculate the fraction *f* of the original quantity of ${}^{235}_{92}U$ which remains on the Earth today.

half-life of ${}^{235}_{92}U = 7.1 \times 10^8$ y
age of the Earth = 4.6×10^9 y

f = ... **[3]**

[Total: 12]

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

(a) Explain what is meant by *internal energy*. Hence suggest how the internal energy of a **real** gas differs from that of an **ideal** gas.

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.... **[4]**

(b) Describe the changes which occur to the *internal energy* and the *state of matter* as a **real** gas is cooled towards absolute zero. Include in your answer, where appropriate, a description of the changes on the molecular scale.

.... **[8]**

Quality of Written Communication **[4]**

[Total: 16]

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