OCR RECOGNISING ACHIEVEMENT

ADVANCED GCE **2824**

PHYSICS A

Forces, Fields and Energy

WEDNESDAY 11 JUNE 2008 Morning

Time: 1 hour 30 minutes

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

CUP/T40056

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use blue or 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.

INFORMATION FOR CANDIDATES

- The number of marks for each question 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.

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

This document consists of **18** printed pages and **2** blank pages.

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

Answer **all** the questions.

1 This question is about the interactions between three identical perfectly elastic solid cubes.

(a) Fig. 1.1 shows three numbered cubes each of mass m placed in contact on a frictionless horizontal surface. A steady horizontal force P is applied to the end surface of cube **1**.

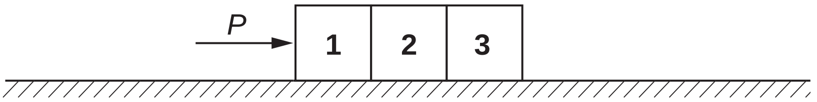

Fig. 1.1

(i) Show that the acceleration of cube **3** is $\frac{P}{3m}$.

[1]

(ii) Write down an expression for the resultant force F_3 on cube **3**.

F_3 = ...[1]

(iii) Write down expressions in terms of P for

the acceleration a_2 of cube **2**

a_2 = ...

the resultant force F_2 on cube **2**.

F_2 = ...[2]

(iv) Hence write down an expression for the magnitude of the force applied by

cube **3** on cube **2**, F_{32}

F_{32} = ...

cube **1** on cube **2**, F_{12}.

F_{12} = ...[2]

(b) Cube **3** is removed. Cube **1** is moved to the left and then projected towards the stationary cube **2** with speed u. Suppose that after collision cube **1** moves with speed v_1 and cube **2** moves with speed v_2. See Fig. 1.2.

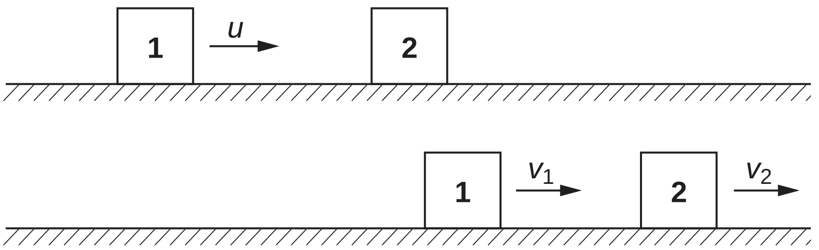

Fig. 1.2

(i) Write down equations for the conservation of momentum and of energy in the elastic collision in terms of m, u, v_1 and v_2.

equation 1 for momentum ....

equation 2 for energy ....[2]

(ii) Put the values $v_1 = 0$ and $v_2 = u$ into your equations in **(i)** to show that they are solutions.

[1]

(c) Cube **3** is replaced in its original position close to cube **2**. Cube **1** is moved to the left and projected towards cube **2** with speed u. See Fig. 1.3.

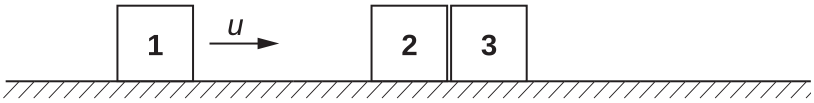

Fig. 1.3

(i) After the collision, cubes **1** and **2** remain at rest and cube **3** moves with speed u. Explain these observations.

....

....

....

....[2]

(ii) Cubes **2** and **3** are now glued together. Describe without calculation or explanation what happens in this situation when cube **1** is projected towards cube **2** as in Fig. 1.3.

....

....

....

....[2]

[Total: 13]

2 Fig. 2.1 shows a glider, tethered between two stretched springs, floating above a linear air track.

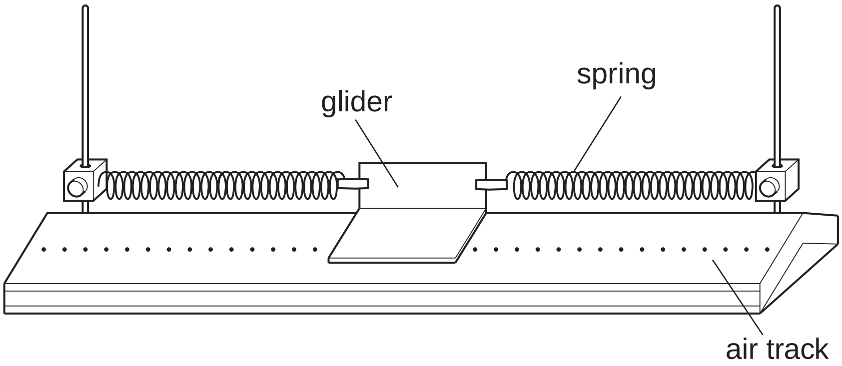

Fig. 2.1

The glider is pulled to one side and released. It oscillates in simple harmonic motion. The variation of the speed *v* of the glider with time *t* is shown in Fig. 2.2.

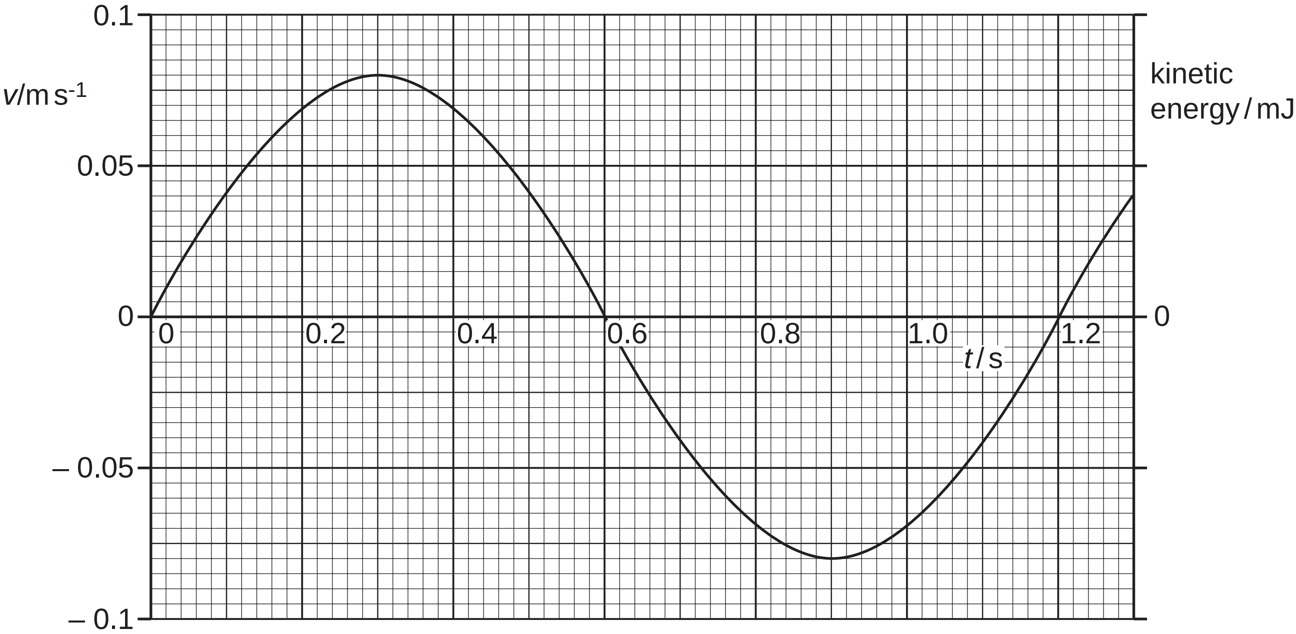

Fig. 2.2

(a) Calculate the frequency of the oscillation.

frequency = ... Hz [2]

(b) Use Fig. 2.2 to show that the maximum acceleration of the glider is about $0.4\,m\,s^{-2}$.

[2]

(c) Show that the maximum displacement of the glider from equilibrium is about 15 mm.

[3]

(d) When the glider was initially pulled to one side, the increase in elastic potential energy stored in the springs was 1.2 mJ.

(i) On Fig. 2.2 sketch a graph of the variation of the **kinetic** energy of the glider against time from the instant that it is released. Label the energy axis **on the right hand side** of the graph with a suitable scale. [3]

(ii) Calculate the mass of the glider.

mass = ... kg [2]

[Total: 12]

3 **(a)** Define *gravitational field strength, g*.

....

....[1]

(b) Explain why the acceleration due to gravity and the gravitational field strength at the Earth's surface have the same value.

....

....

....

....[2]

(c) A space probe, with its engines shut down, orbits Mars at a constant distance of 3500 km above the centre of the planet in a time of 110 minutes.

(i) Calculate the speed of the space probe.

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

(ii) Show that the mass of Mars is about 6×10^{23} kg.

[4]

(d) **(i)** Write down an algebraic expression for *g* at the surface of a planet in terms of its mass *M* and radius *R*.

[1]

(ii) The acceleration due to gravity at the surface of Mars is 3.7 m s^{-2}. Calculate the radius of Mars, in kilometres.

radius = ... km [2]

[Total: 12]

4 This question is about charging and discharging capacitors.

Fig. 4.1 shows a capacitor **C** in series with a centre-zero ammeter **A** and a two-way switch **S**. When the switch **S** is in position **1**, the capacitor is connected to a 12 V supply through a resistor **R**. The ammeter then shows the charging current in the circuit. To discharge the capacitor, the switch is moved to position **2**. The magnitude of the current through the ammeter **A** during the charge or discharge period is shown in Fig. 4.2.

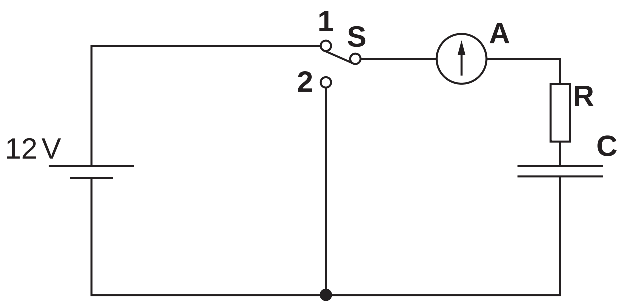

Fig. 4.1

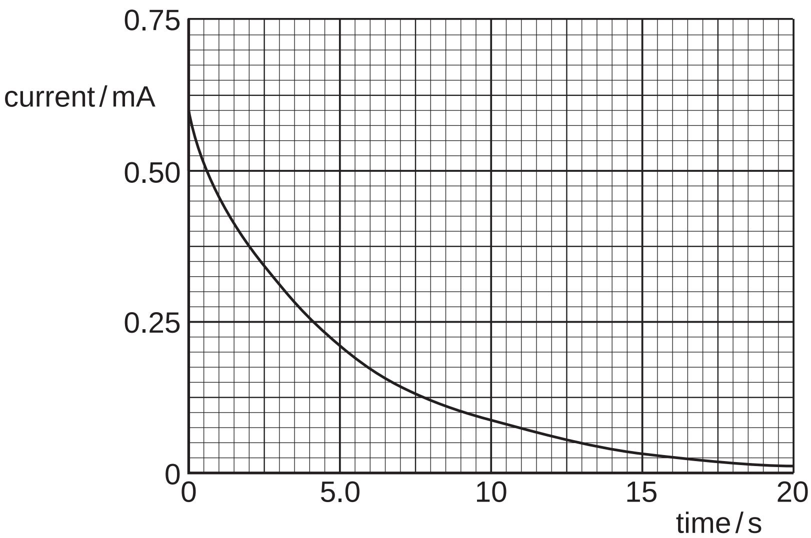

Fig. 4.2

(a) The following two statements about the charging and discharging processes are both true.
1 The variation with time of the magnitude of the current is the same in each case, as shown in Fig. 4.2.
2 The needle on the centre-zero ammeter is in a different position in each case.

Explain how both of these statements are correct.

....

....

....[2]

(b) The supply voltage is 12 V. Use data from Fig. 4.2 to show that the value of the resistor **R** is 20 kΩ.

[2]

(c) **(i)** The time constant of the circuit is 5.0 s. Explain how Fig. 4.2 shows this to be the case. You may find it useful to draw suitable lines on Fig. 4.2 to aid your explanation.

....

....

....[2]

(ii) Show that the capacitance of capacitor **C** is 250 μF.

[2]

(d) **(i)** Use the value of *C* to calculate the total charge stored on the capacitor.

charge = ... C [2]

(ii) It is suggested that the total charge stored on the capacitor is equal to the initial current, that is the current at $t = 0$ in Fig. 4.2, multiplied by the time constant. Verify that this is true.

[1]

(iii) Explain how else you could use Fig. 4.2 to find the charge calculated in **(i)**.

....

....[1]

[Total: 12]

5 A spark plug is the device in a petrol engine which ignites the fuel-air mixture, causing an explosion in the cylinder.

(a) A potential difference of 40 kV is needed across a gap of 0.60 mm to produce the spark which ignites the fuel vapour. Calculate the magnitude of the electric field strength in the spark gap just before the spark.

electric field strength = ... unit .... [3]

(b) The electrical supply in a motor car is 12 V. To achieve 40 kV, two coils are wound on the same iron core, shown schematically in Fig. 5.1. The secondary coil is in series with the spark gap. The primary coil is in series with the battery and a switch.

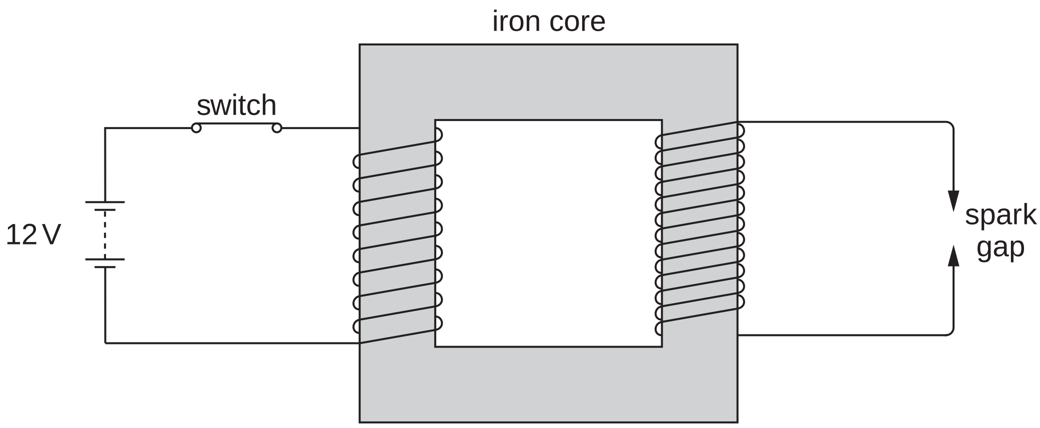

Fig. 5.1

(i) Draw on Fig. 5.1 the complete paths of **two** lines of magnetic flux linked with the current in the primary coil. [2]

(ii) The magnetic flux through both coils is the same but the magnetic flux linkage is not. Explain why.

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....[2]

(iii) Explain why a potential difference is produced across the spark gap as the switch is opened.

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....[1]

(iv) Explain how each of the following factors influences the size of the potential difference across the spark gap:

1 the rate of collapse of the magnetic flux

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....[2]

2 the ratio of the number of turns between the primary and secondary coils.

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....[2]

[Total: 12]

6 **(a)** In a short period at the end of the nineteenth century four radiations emitted by solid matter were discovered, namely α, β, γ and X-rays.

State and explain **two differences** between

(i) α and β-radiation

1. ....

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2. ....

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....[4]

(ii) γ and X-radiation.

1. ....

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2. ....

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....[4]

(b) Fig. 6.1 shows a gamma-ray detector placed 1.0 m from a pin-head source which emits uniformly in all directions. The detector registers a count of $40\,s^{-1}$. The background count is negligible.

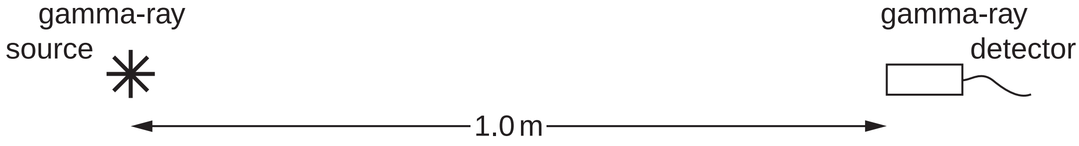

Fig. 6.1

(i) Use the inverse square law to explain why the count rate rises to $640\,s^{-1}$ when the detector is moved to 0.25 m from the source.

....

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....[2]

(ii) A thin lead sheet is now placed just in front of the source halving the count rate to $320\,s^{-1}$. The detector is moved from its position at 0.25 m towards the source until the count returns to $640\,s^{-1}$.

1 State the value of the count rate if the sheet is now removed.

count rate = ... s^{-1} [1]

2 Calculate the final distance of the detector from the source.

distance = ... m [2]

[Total: 13]

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

(a) There is no attraction between the molecules of an ideal gas. Use this information to explain why the internal energy of an ideal gas is proportional to its temperature. Hence explain how this relationship gives rise to the concept of an absolute zero of temperature.

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....[5]

(b) Fig. 7.1 represents how the temperature of a small mass of water changes when it is heated steadily from room temperature to above its boiling point in a large sealed container.

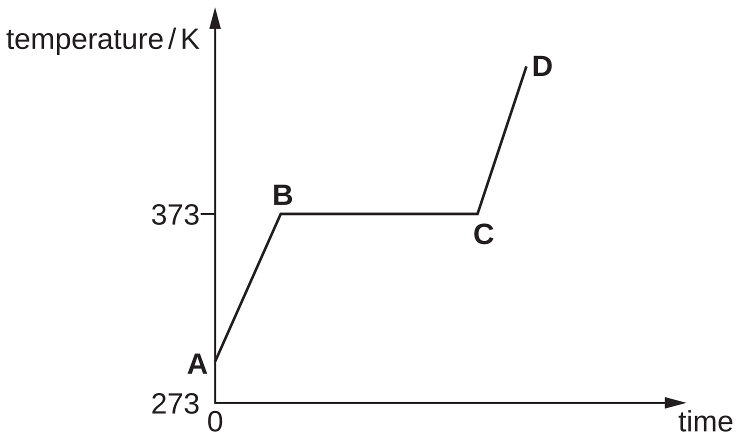

Fig. 7.1

Describe and explain the features of the graph in terms of the changes which occur to the separation and speed of the molecules and to their internal energy, that is, their potential and kinetic energies. Three distinct sections of the graph have been labelled to aid your description.

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....[7]

Quality of Written Communication [4]

[Total: 16]

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