THIS IS A LEGACY SPECIFICATION

ADVANCED GCE

PHYSICS A

2824

Forces, Fields and Energy

Candidates answer on the question paper

OCR Supplied Materials:
None

Other Materials Required:
- Electronic Calculator

Wednesday 21 January 2009
Morning

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	12	
2	12	
3	15	
4	15	
5	10	
6	11	
7	15	
TOTAL	90	

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,	$\mathrm{u} = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_{\mathrm{e}} = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_{\mathrm{p}} = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J K^{-1}\ mol^{-1}}$
the Avogadro constant,	$N_{\mathrm{A}} = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
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 This question is about hitting a tennis ball.

(a) A player serves a tennis ball of mass 60 g. Fig. 1.1 shows how the force F on the ball varies with the time t of impact between racket and ball. The ball is momentarily at rest before the impact.

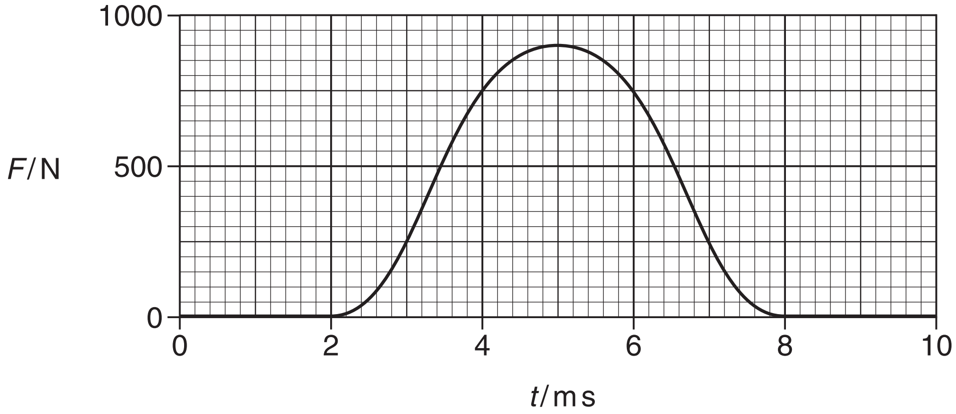

Fig. 1.1

(i) How can the momentum given to the ball be found from Fig. 1.1? Explain your answer.

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....

.... **[2]**

(ii) Use Fig. 1.1 to show that the momentum gained by the ball is about 2.7 N s. Make your reasoning clear.

[1]

(iii) Explain why the unit of momentum can be given either as N s or kg m s^{-1}.

....

....

.... **[1]**

(iv) Estimate

1 the speed v of the ball as it leaves the racket

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

2 the maximum acceleration a of the ball.

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

(b) The opponent manages to place his racket in the path of the ball, now travelling at $40\,m\,s^{-1}$, so that it is returned at $38\,m\,s^{-1}$ in the opposite direction. The contact time between ball and racket is 0.012 s. Calculate

(i) the change in momentum Δp of the ball

Δp = ... $kg\,m\,s^{-1}$ **[1]**

(ii) the change in kinetic energy ΔE of the ball

ΔE = ... J **[2]**

(iii) the mean force exerted by the ball on the racket.

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

[Total: 12]

2 A gas, which is to be treated as ideal, is trapped in a cylinder by a piston, which is free to move. See Fig. 2.1.

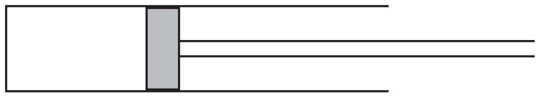

Fig. 2.1

(a) The equation of state of an ideal gas is $pV = nRT$.

State the meaning of each term in the equation.

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....

....

.... **[2]**

(b) The gas is heated suddenly from 27 °C to 627 °C.

(i) The pressure before heating is atmospheric pressure, p_0. Show that the pressure immediately after heating is $3p_0$. Assume that the piston has not had time to move.

[2]

(ii) The gas then pushes the piston out until the pressure of the gas returns to atmospheric pressure p_0. The volume V_0 of the gas has increased to $2.5\,V_0$. Calculate the final temperature of the gas in °C.

temperature = ... °C **[3]**

(c) (i) The original volume V_0 of gas trapped in the cylinder is $3.0 \times 10^{-5}\,\text{m}^3$. Atmospheric pressure p_0 is $1.0 \times 10^5\,\text{Pa}$. Show that the amount of gas is about $1 \times 10^{-3}\,\text{mol}$.

[2]

(ii) The molar mass M of the gas is $0.016\,\text{kg}\,\text{mol}^{-1}$. Calculate the mass m of gas present in the cylinder.

m = ... kg **[1]**

(iii) Calculate the increase in internal energy ΔU of the gas when it is heated suddenly as in **(b)(i)** from 27 °C to 627 °C.

Take the specific heat capacity of the gas to be $1300\,\text{J}\,\text{kg}^{-1}\,\text{K}^{-1}$.

ΔU = ... J **[2]**

[Total: 12]

3 **(a)** Fig. 3.1 shows a car of mass 800 kg travelling at a constant speed of $15\,\mathrm{m\,s^{-1}}$ around a bend on a level road following a curve of radius 30 m.

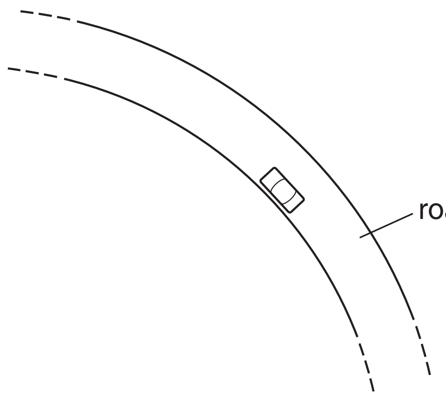

Fig. 3.1

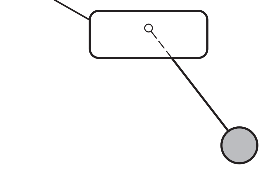

Fig. 3.2

(i) Draw an arrow on Fig. 3.1 to indicate the direction of the resultant horizontal force on the car at the position shown. **[1]**

(ii) Calculate the magnitude F of this force.

F = ... N **[3]**

(iii) A medallion hangs on a string from the shaft of the rear view mirror in the car.

Fig. 3.2 shows its position in the vertical plane, perpendicular to the direction of travel in Fig. 3.1.

1 Draw and label arrows on Fig. 3.2 to indicate the forces acting on the medallion. **[2]**

2 On another occasion the car travels around the bend at $25\,\mathrm{m\,s^{-1}}$. The angle of the string to the vertical is different. Explain how and why this is so. You may find it useful to sketch a vector diagram to aid your explanation.

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.... **[3]**

(b) Each wheel assembly of the car is mounted on a suspension spring. In a garage test, one wheel assembly is suspended off the ground by its spring with the damper disconnected. Fig. 3.3 shows a graph of the vertical motion of the wheel assembly against time when it is given a small displacement and released.

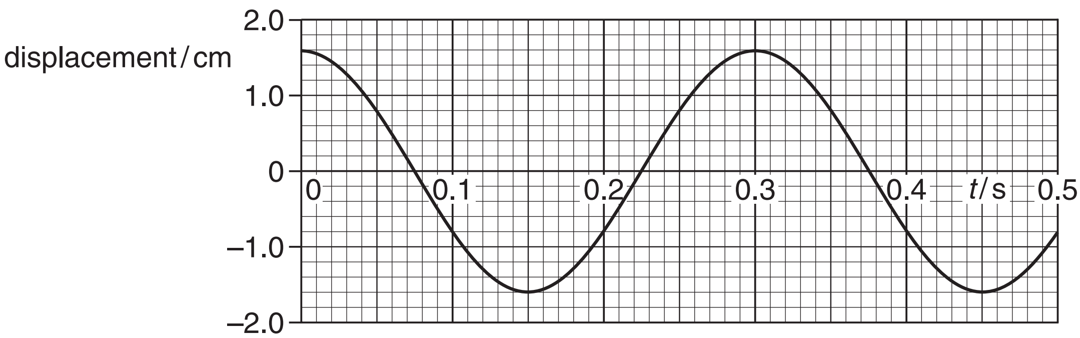

Fig. 3.3

(i) Use the graph to find the natural frequency f_0 of oscillation of the wheel.

f_0 = ... Hz **[2]**

(ii) When the car is travelling along a ridged concrete road at a speed of $20\,\mathrm{m\,s^{-1}}$ the driver notices that the car bounces significantly. The ridges in the road are equally spaced 6.2 m apart.

1 Calculate the frequency f of the bounce.

f = ... Hz **[1]**

2 State and explain the phenomenon which is occurring.

....

....

....

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.... **[3]**

[Total: 15]

4 This question is about changing the motion of a beam of electrons travelling in a vacuum.
Fig. 4.1 shows a simple device for accelerating or decelerating electrons. It consists of two parallel conducting plates, labelled **P** and **Q**, each with a hole at its centre.

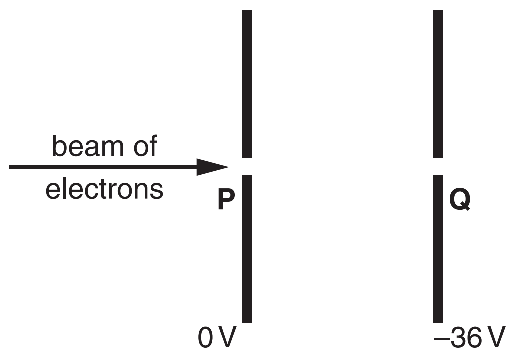

Fig. 4.1

(a) On Fig. 4.1 draw at least **six** arrowed lines to represent the electric field between the plates. **[2]**

(b) The electrons, all travelling at $4.0 \times 10^6\,\mathrm{m\,s^{-1}}$, pass through the holes in **P** and **Q**. The plates, a distance of 8.0 mm apart, are maintained at 0 V and –36 V as shown in Fig. 4.1.

Calculate

(i) the electric field strength E between the plates

E = ... $\mathrm{N\,C^{-1}}$ **[1]**

(ii) the magnitude F of the force on an electron when between the plates

F = ... N **[1]**

(iii) the loss of kinetic energy $\Delta\varepsilon$ of each electron between **P** and **Q**

$\Delta\varepsilon$ = ... J **[1]**

(iv) the decrease in velocity Δv of each electron between **P** and **Q**.

Δv = ... $\mathrm{m\,s^{-1}}$ **[3]**

(c) The plates are rotated through 90°. Fig. 4.2 shows the same beam of electrons, travelling at $4.0 \times 10^6\,\mathrm{m\,s^{-1}}$, entering the region between the plates, but now parallel to the plates. A uniform magnetic field is applied into the paper in the region between the plates.

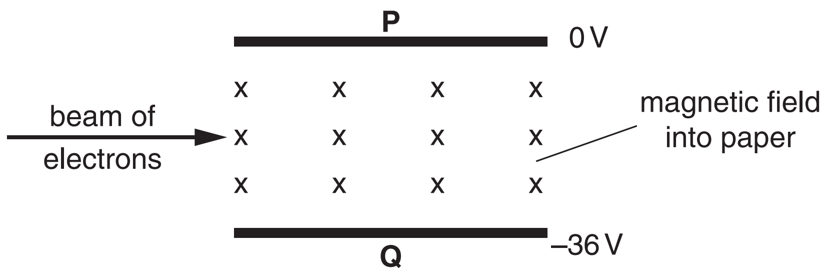

Fig. 4.2

(i) State the direction in which the force due to the magnetic field acts on the electrons as they enter the field.

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.... **[1]**

(ii) Explain why, by adjusting the strength of the magnetic field, the electrons can pass undeflected between the plates.

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.... **[2]**

(iii) Calculate the magnitude B of the magnetic field density needed for these electrons to pass undeflected between the plates. Give a unit with your answer.

B = ... unit .... **[4]**

[Total: 15]

5 Fig. 5.1 shows two capacitors of capacitance 150 μF and 300 μF connected in parallel to a 9.0 V d.c. supply. Fig. 5.2 shows them connected in series to the supply.

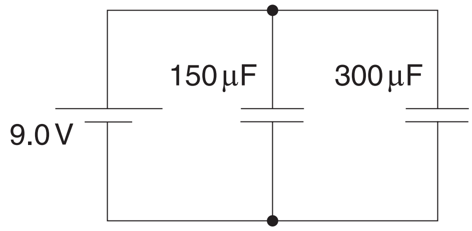

Fig. 5.1

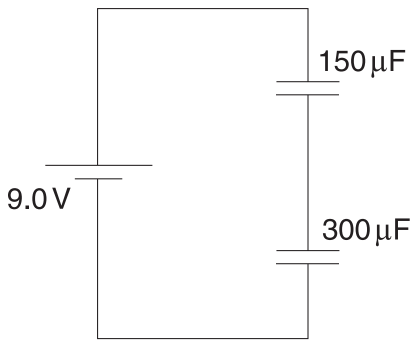

Fig. 5.2

(a) Determine the voltage *V* across the 300 μF capacitor in the circuit of

(i) Fig. 5.1

V = ... V **[1]**

(ii) Fig. 5.2.

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

(b) Calculate the charge *Q* in μC stored in the 150 μF capacitor in the circuit of

(i) Fig. 5.1

Q = ... μC **[2]**

(ii) Fig. 5.2.

Q = ... μC **[1]**

(c) Calculate the ratio *f* where

$$f = \frac{\text{the total energy stored in the capacitors in Fig. 5.1}}{\text{the total energy stored in the capacitors in Fig. 5.2}}.$$

f = ... **[4]**

[Total: 10]

6 **(a)** Define the terms *nuclide* and *nucleon*.

....

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.... **[2]**

(b) Fig. 6.1 shows a small region of the chart of nucleon number against proton number. A radioactive nuclide $^{212}_{83}Bi$ decays by either α or β-emission. The nucleon and proton numbers for this nuclide are plotted on the chart at the dot marked with the letter **X**.

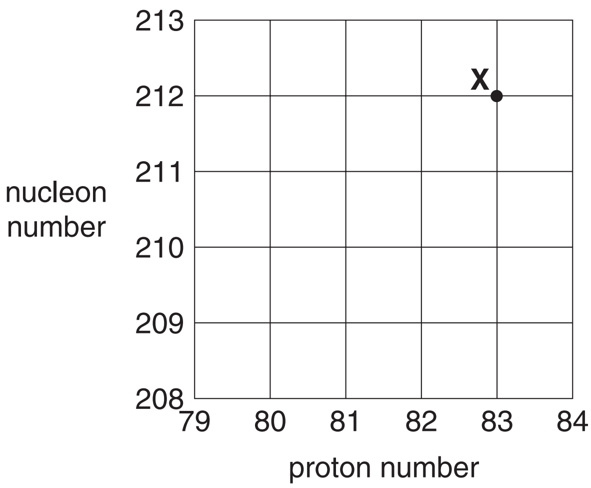

Fig. 6.1

(i) Mark with a dot and the letter **A** the position on the chart for the daughter nuclide created when $^{212}_{83}Bi$ emits an α-particle. **[2]**

(ii) Mark with a dot and the letter **B** the position on the chart for the daughter nuclide created when $^{212}_{83}Bi$ emits a β-particle. **[1]**

(iii) Explain why it is not possible to represent a γ-decay on this chart.

....

.... **[1]**

(c) (i) Complete the table below for the three types of ionising radiation.

radiation	range in air	range in a solid
α		0.2 mm paper
β		
γ	several km	

[2]

(ii) Describe briefly with the aid of a sketch an absorption experiment to distinguish between the three radiations listed in **(i)**.

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.... **[3]**

[Total: 11]

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

Many laws of physics can be described using mathematical functions and relationships and displayed graphically.

(a)

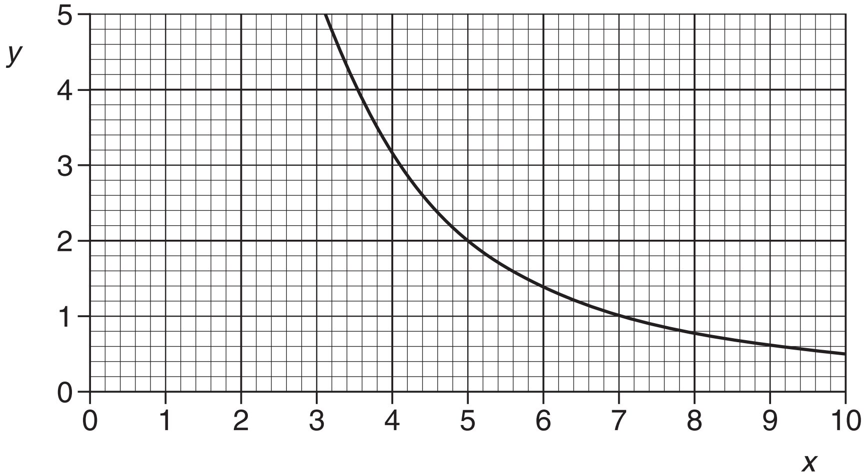

Fig. 7.1

Show that the graph of Fig. 7.1 displays an inverse square relationship between the variables *x* and *y*.
Choose one law of physics which follows an inverse square relationship. State the law in both word and mathematical forms. Indicate which physical quantities would be represented by *x* and *y* in Fig. 7.1.
Describe any physical conditions necessary for the law to be obeyed.

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.... **[6]**

(b)

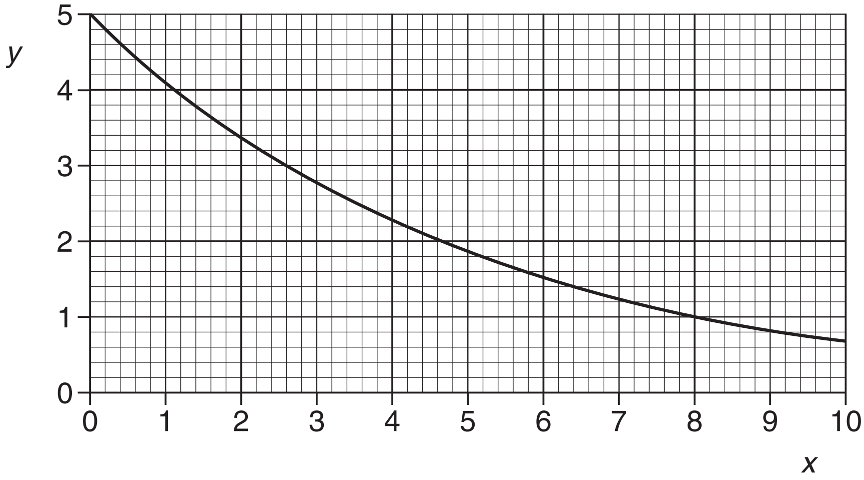

Fig. 7.2

Show that the graph of Fig. 7.2 displays an exponential relationship between the variables *x* and *y*.
Choose one law of physics which follows an exponential relationship.
State the law in both word and mathematical forms. Indicate which physical quantities would be represented by *x* and *y* in Fig. 7.2.

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.... **[5]**

Quality of Written Communication **[4]**

[Total: 15]

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