OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A

2824

Forces, Fields and Energy

Friday **20 JUNE 2003** Afternoon 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	12	
2	13	
3	11	
4	11	
5	14	
6	13	
7	16	
TOTAL	90	

This question paper consists of 16 printed pages.

MML 2847 3/02 S33787/5

[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,	$n = \frac{1}{\sin C}$
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 **(a)** Show that the relationship between the mechanical power P of an object, its velocity v and the applied force F is given by

$$P = Fv.$$

Start from the definition of work, W.

[3]

(b) Fig. 1.1 shows how the force F produced by a railway locomotive varies with velocity v.

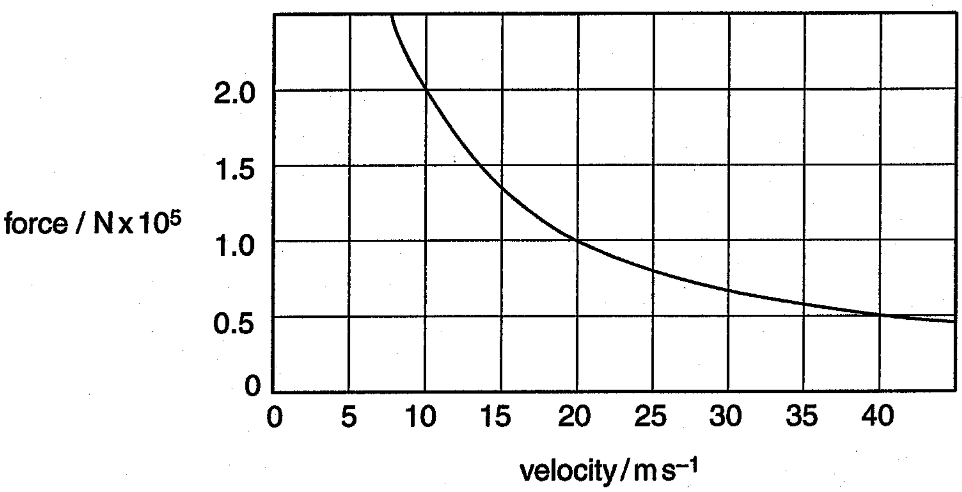

Fig. 1.1

Use data from Fig. 1.1 to

(i) calculate the power developed by the locomotive when it is travelling at $10\,\text{m}\,\text{s}^{-1}$

power = ... W [2]

(ii) show that the power developed by the locomotive is constant

[1]

(iii) calculate the force produced at a velocity of 5 m s^{-1}.

force = ... N [1]

(c) The locomotive in **(b)** pulls a train of total mass 3.0 x 10^5 kg against a constant frictional force of 5.0 x 10^4 N. Use Fig. 1.1 and the data above to calculate

(i) the acceleration of the train when travelling at 10 m s^{-1}

acceleration = ... m s^{-2} [3]

(ii) the maximum speed that the train can achieve on a level track.

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

[Total: 12]

2 Fig. 2.1 shows the path of an alpha particle (α-particle) $^{4}_{2}He$ being deflected through an angle of 30° as it passes a nucleus **N** in a thin gold foil.

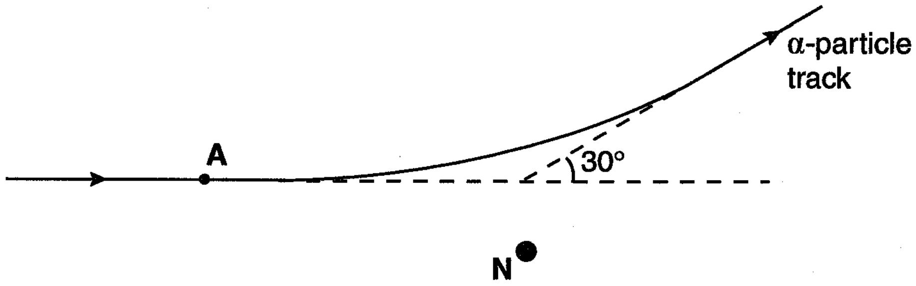

Fig. 2.1

(a) Draw on Fig. 2.1 arrows to represent

(i) the direction of the electrostatic force on the α-particle when it is at **A**

(ii) the direction of the maximum electrostatic force on the nucleus **N** during the passage of the α-particle.

[2]

(b) The incident α-particle has kinetic energy 8.0×10^{-13} J and mass 6.7×10^{-27} kg.

Show that

(i) its initial speed is $1.5 \times 10^{7}\,\mathrm{m\,s^{-1}}$

[2]

(ii) the magnitude of its initial momentum is $1.0 \times 10^{-19}\,\mathrm{kg\,m\,s^{-1}}$.

[1]

For Examiner's Use

(c) Imagine a proton moving initially along the same path as the α-particle with the same kinetic energy.

(i) Show that the initial momentum of the proton is 5.0×10^{-20} kg m s^{-1}.

[2]

(ii) The proton is deflected through about 15° as it passes the gold nucleus. State qualitatively, **two** ways in which the movement of the nucleus differs in this case from the movement caused by the α-particle.

1. ....

.... [1]

2. ....

.... [1]

(d) Calculate the magnitude of the electrostatic force between the proton at the point **A** and the gold nucleus $^{197}_{97}$Au. The distance **AN** is 7.5×10^{-13} m.

force = ... N [4]

[Total: 13]

For Examiner's Use

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

State the meaning of each term in the equation.

....

....

....

....

.... [2]

(b) The oven of a domestic cooker has a volume of $0.10\,m^3$. The pressure in the oven is 1.0×10^5 Pa (1 atmosphere).

(i) Calculate the mass of air in the oven at 27 °C.

molar mass of air = $0.030\,kg\,mol^{-1}$

mass = ... kg [3]

(ii) At constant atmospheric pressure, the density of the air at 227 °C is x times the density of the air at 27 °C. Calculate the value of x.

x = ... [3]

(iii) The average speed of the air molecules in a hot oven at 227 °C is greater than those in a cold oven at 27 °C.

1. Explain why.

....

....

.... [1]

2. Calculate the factor *f* by which the average speed is increased.

f = ... [2]

[Total: 11]

4 The faulty suspension system of a car is tested. The body of the stationary car is pushed down and released. Fig. 4.1 shows how the vertical displacement of the car varies with time after it has been released.

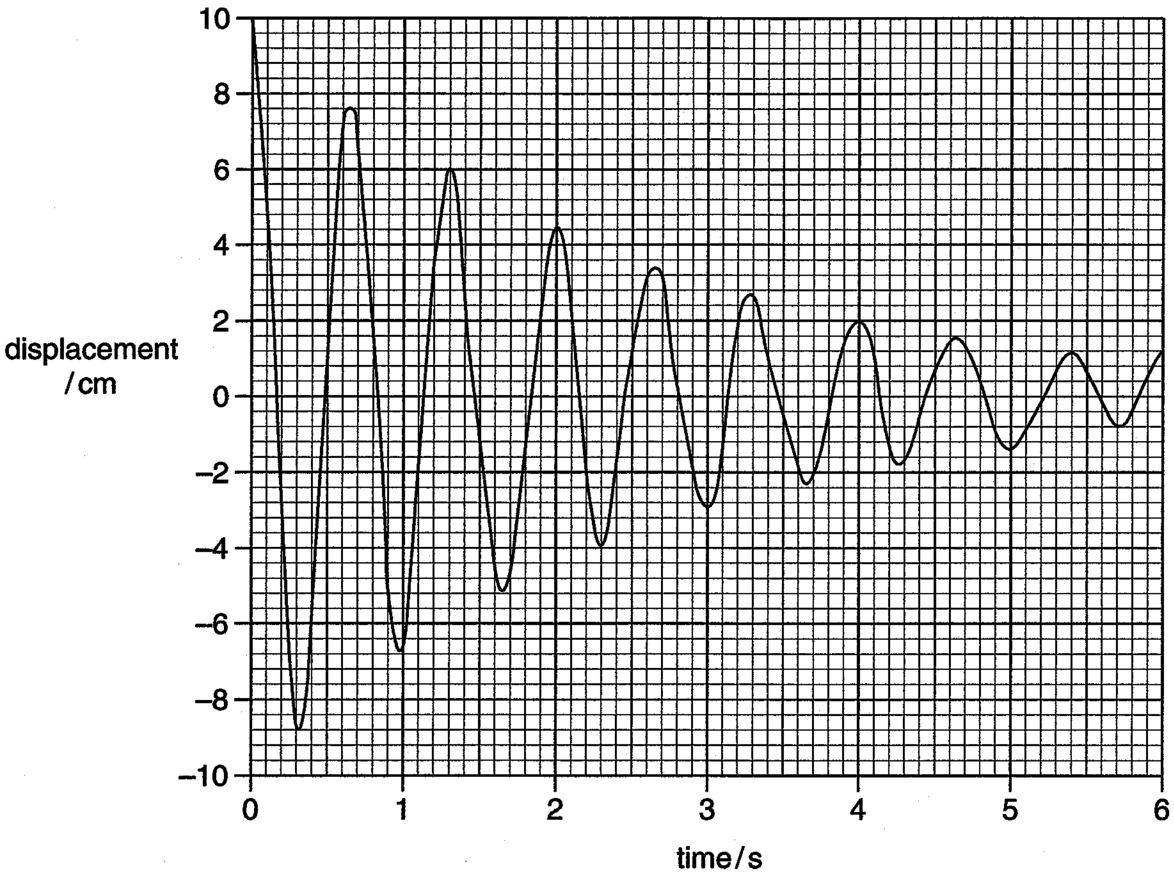

Fig. 4.1

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

....

....

.... [2]

(ii) State **two** features of Fig. 4.1 which indicate that the car body is oscillating in damped harmonic motion.

....

....

....

.... [2]

(b) Use data from Fig. 4.1 to calculate the frequency of oscillation of the car body.

frequency = ... Hz [2]

(c) To simulate the car being driven along a ridged road at different speeds, the stationary car is oscillated up and down in simple harmonic motion by a mechanical oscillator. The mechanical oscillator provides a movement of variable frequency and constant amplitude. Fig. 4.2 shows the graph of the vertical motion of the car body obtained from the test.

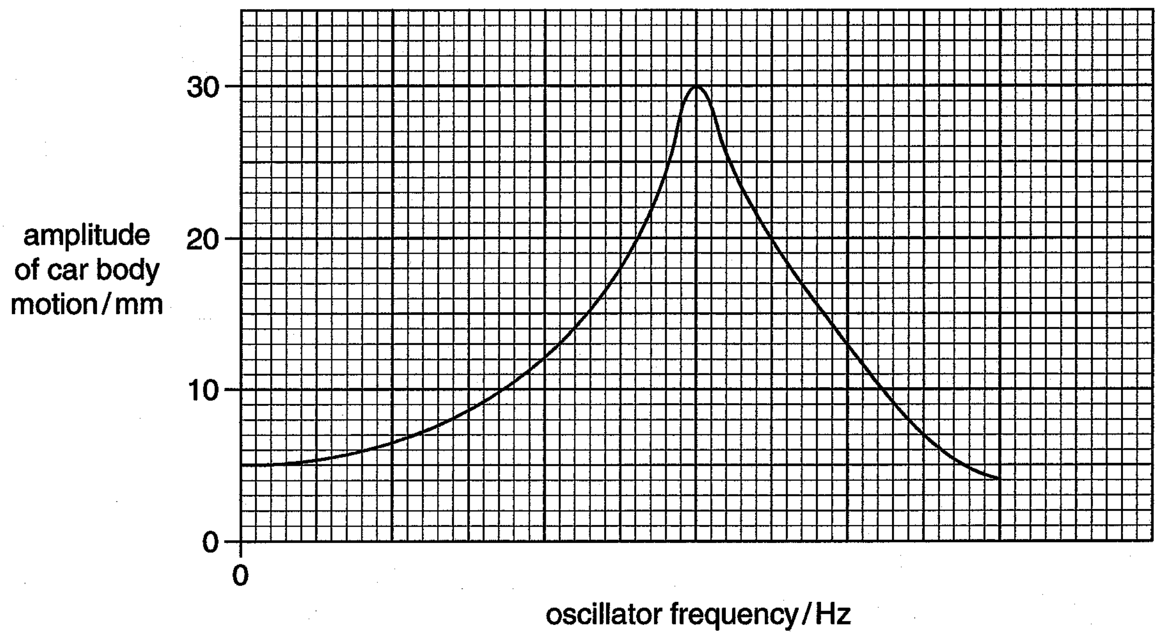

Fig. 4.2

(i) Use information from Fig. 4.2 to write down the amplitude of the motion of the mechanical oscillator.

amplitude = ... mm [1]

(ii) Using your answer to **(b)**, add the scale to the frequency axis of Fig. 4.2. [1]

(iii) New dampers are fitted to increase the damping of the car body. On Fig. 4.2 sketch the graph you would expect for greater damping. [3]

[Total: 11]

5 In a thunder cloud, thermally induced vertical winds separate out electrical charges. The base of the cloud acquires a negative charge while the centre of the cloud, 1.5 km above it, becomes positively charged. See Fig. 5.1. Lightning flashes occur inside the cloud on average every 25 s, discharging the cloud, which is then recharged by the wind. The typical charge at breakdown is 20 C when the electric field strength in the cloud is $3.0 \times 10^5\,V\,m^{-1}$.

Fig. 5.2 shows two cloud-sized uniformly-charged parallel plates 1.5 km apart, which can be imagined as a very simple model to simulate the electrical mechanism within a thundercloud.

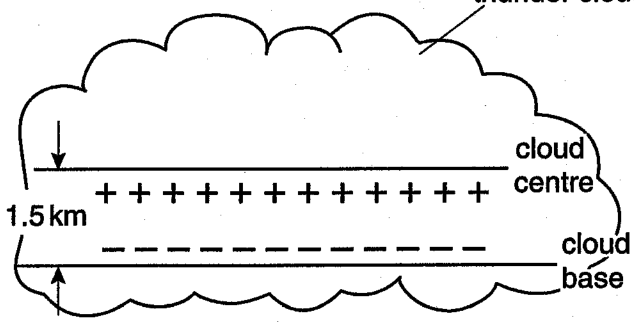

Fig. 5.1

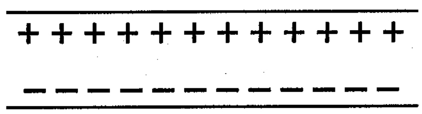

Fig. 5.2

(a) **(i)** On Fig. 5.2, draw arrows to represent the electric field between the plates. [2]

(ii) Show that the voltage between the plates at discharge is 450 MV.

[1]

(b) The theoretical circuit of Fig. 5.3 can be used to model the charging process in the thundercloud.

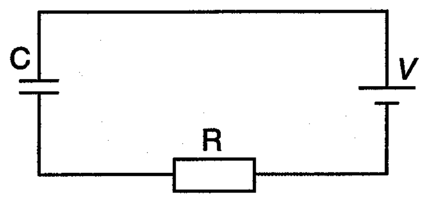

Fig. 5.3

Explain what part each component in the circuit plays so that the circuit models the charging of the cloud.

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.... [3]

(c) Use the data above to calculate for the theoretical circuit

(i) the mean current through the resistor R during charging

current = ... A [2]

(ii) the value of R, taking the initial current to be 5 times the mean current

resistance = ... Ω [2]

(iii) the value of C

capacitance = ... F [2]

(iv) the time constant of the circuit.

time constant = ... s [2]

[Total: 14]

[Turn over

For Examiner's Use

6 Fig. 6.1 shows the initial path of an electron observed in a nuclear particle detector. The electron has been created along with another particle, not shown here, in the detector at point **A**. There is a uniform magnetic field perpendicular to the plane of Fig. 6.1.

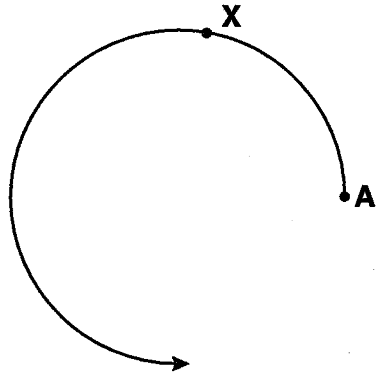

Fig. 6.1

(a) Explain how you can tell that there is a magnetic field in the particle detector.

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.... [2]

(b) **(i)** The speed of the electron at point **X** is $1.0 \times 10^8\,\mathrm{m\,s^{-1}}$. The radius of curvature of the electron path is 0.040 m. Calculate the magnitude of the force on the electron.

force = ... N [3]

(ii) Draw an arrow on Fig. 6.1 to indicate the direction of the force at **X**. [1]

(c) Calculate the magnitude of the magnetic flux density *B* in the detector. Give a suitable unit for your answer.

magnetic flux density = ... unit .... [4]

(d) An event called *pair-production* produced the electron at point **A** in the detector. A gamma ray photon was changed into two particles, the electron and a positron. The positron is a particle of the same mass but opposite charge to the electron. Calculate the energy a gamma ray photon must have in order to change into two particles each of mass equal to that of an electron.

energy = ... J [3]

[Total: 13]

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

(a) Define the term *activity* as used for a sample of radioactive material. Discuss physical factors which do and do not affect the activity of the sample.

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.... [6]

Question 7 continued over the page

[Turn over

For Examiner's Use

(b) Uranium can change into other nuclides by two processes, *radioactive decay* and *fission*. For these processes, describe **two** similarities and **two** differences between them.

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Quality of Written Communication [4]

[Total: 16]