RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A 2824

Forces, Fields and Energy

Thursday **16 JUNE 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	12	
2	12	
3	15	
4	10	
5	13	
6	12	
7	16	
TOTAL	90	

This question paper 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,	$= 10 \lg \left(\frac{I}{I_0}\right)$

For Examiner's Use

Answer **all** the questions.

1 This question is about kicking a football.

(a) Fig. 1.1 shows how the force F applied to a ball varies with time t whilst it is being kicked horizontally. The ball is initially at rest.

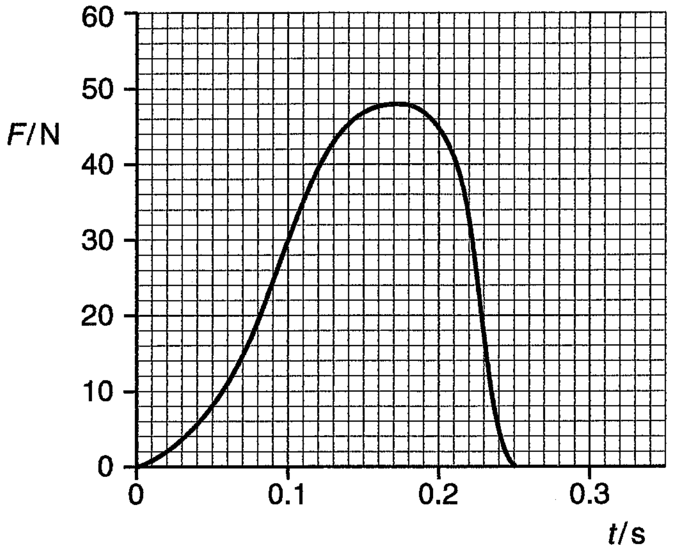

Fig. 1.1

(i) Use the graph to find

1 the maximum force applied to the ball

maximum force = ...N

2 the time the boot is in contact with the ball.

time = ...s [1]

(ii) The mean force multiplied by the time of contact is called the impulse delivered to the ball. Use the graph to estimate the impulse delivered to the ball.

impulse = ...N s [2]

For Examiner's Use

(b) The mass of the ball is 0.50 kg. Use your answers to **(a)** to calculate

(i) the maximum acceleration of the ball

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

(ii) the final speed of the ball

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

(iii) the kinetic energy of the ball after the kick.

kinetic energy = ...J [2]

(c) The ball hits a wall with a speed of 14 m s^{-1}. It rebounds from the wall along its initial path with a speed of 8.0 m s^{-1}. The impact lasts for 0.18 s. Calculate the mean force exerted by the ball on the wall.

force = ...N [3]

[Total: 12]

For Examiner's Use

2 **(a)** Define *gravitational field strength* at a point in a gravitational field.

....

....[1]

(b) The gravitational field strength at the surface of a planet of uniform density is $40\,N\,kg^{-1}$.

A satellite of mass 1500 kg is launched from the surface into a circular orbit around the planet at a height of 1.5×10^5 m with an orbital period of 4.5×10^3 s.

The radius of the planet is 2.0×10^7 m.

(i) Estimate the increase in potential energy of the satellite.

potential energy = ... J [2]

(ii) Suggest with a reason whether your estimate in **(i)** is likely to be larger or smaller than the true value.

....

....

....[1]

(iii) Calculate the kinetic energy of the satellite in orbit.

kinetic energy = ... J [4]

(c) Fig. 2.1 shows how the gravitational field strength g varies with distance r from the **centre** of the planet of radius 2.0×10^7 m.

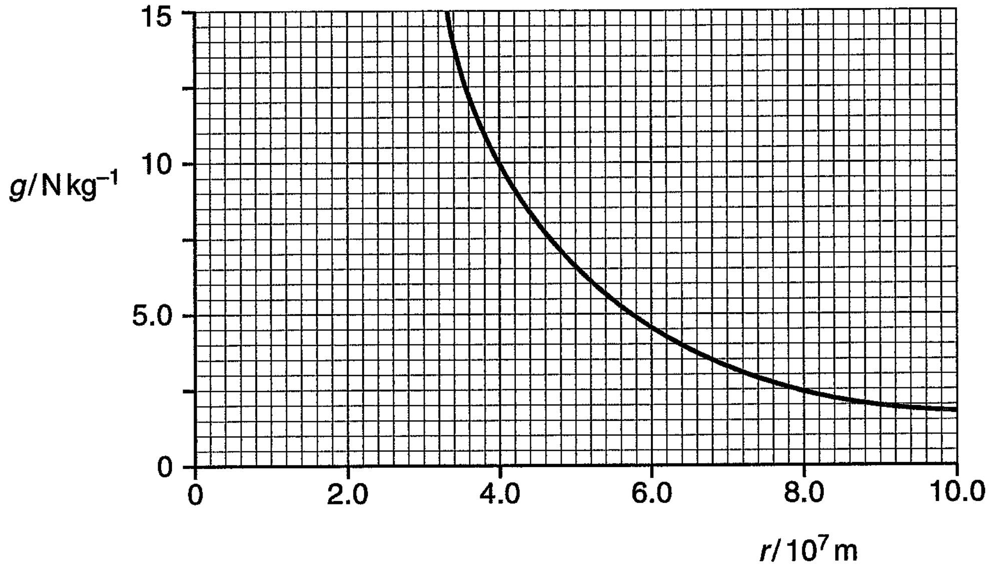

Fig. 2.1

(i) Use Fig. 2.1 to write down the value of g at a height of 4.0×10^7 m above the **surface**.

g = ...N kg^{-1} [1]

(ii) Write down an algebraic expression for g at a distance r from the centre of the planet. The planet can be treated as a point mass of magnitude M situated at its centre.

....[1]

(iii) The value of g at the surface is 40 N kg^{-1}. Use this information and your answer to **(ii)** to check, by a suitable calculation, your answer to **(i)**.

[2]

[Total: 12]

For Examiner's Use

3 (a) The equation of state of an ideal gas is $pV = nRT$. Explain why the temperature must be measured in kelvin.

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....

....

....

....[2]

(b) A meteorological balloon rises through the atmosphere until it expands to a volume of $1.0 \times 10^6\,\text{m}^3$, where the pressure is $1.0 \times 10^3\,\text{Pa}$. The temperature also falls from 17 °C to −43 °C.

The pressure of the atmosphere at the Earth's surface = $1.0 \times 10^5\,\text{Pa}$.

Show that the volume of the balloon at take off is about $1.3 \times 10^4\,\text{m}^3$.

[3]

(c) The balloon is filled with helium gas of molar mass $4.0 \times 10^{-3}\,\text{kg mol}^{-1}$ at 17 °C at a pressure of $1.0 \times 10^5\,\text{Pa}$. Calculate

(i) the number of moles of gas in the balloon

number of moles = ...[2]

(ii) the mass of gas in the balloon.

mass = ...kg [1]

(d) The internal energy of the helium gas is equal to the random kinetic energy of all of its molecules. When the balloon is filled at ground level at a temperature of 17 °C the internal energy is 1900 MJ. Estimate the internal energy of the helium when the balloon has risen to a height where the temperature is −43 °C.

internal energy = ...MJ [2]

(e) The upward force on the filled balloon at the Earth's surface is 1.3×10^5 N. The initial acceleration of the balloon as it is released is $27\,\text{m}\,\text{s}^{-2}$. The total mass of the filled balloon and its load is *M*.

(i) On Fig. 3.1 draw and label suitable arrows to represent the forces acting on the balloon immediately after lift off. [2]

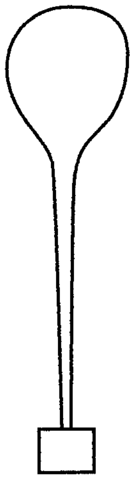

Fig. 3.1

(ii) Calculate the value of *M*.

M = ...kg [3]

[Total: 15]

[Turn over

For Examiner's Use

4 In nuclear fission, energy is released.

(a) Explain what is meant by *nuclear fission*.

....

....[1]

(b) In a possible fission reaction $^{235}_{92}U$ captures a neutron to become a compound nucleus before splitting into $^{141}_{56}Ba$ and $^{92}_{36}Kr$ releasing three neutrons.

Write down the nuclear reaction equation for this event.

....[2]

(c) The total mass of the compound nucleus $^{236}_{92}U$ before fission is 236.053 u. The total mass of the fission products is 235.867 u. Use these data to calculate the energy released in the fission process.

energy = ... J [3]

(d) Most of the energy released arises from the electrostatic repulsion of the two nuclei as they move apart. Use the information in **(b)** to show that the force F between the two nuclei at the instant after fission occurs is about 3000 N.
Assume the nuclei act as point charges a distance r apart of 1.3×10^{-14} m.

[4]

[Total: 10]

5 **(a)** Define *magnetic flux density.*

....

....

....[2]

(b) Fig. 5.1 shows an evacuated circular tube in which charged particles can be accelerated. A uniform magnetic field of flux density B acts in a direction perpendicular to the plane of the tube.
Protons move with a speed v along a circular path within the tube.

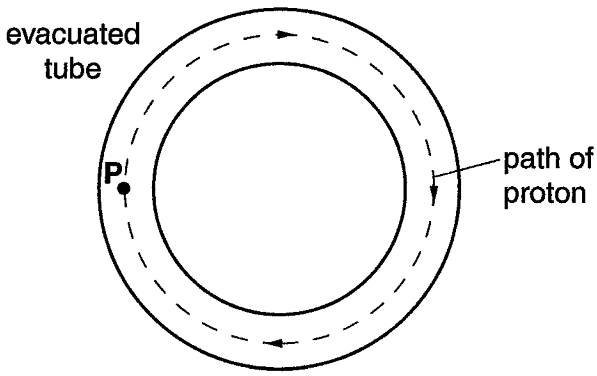

Fig. 5.1

(i) On Fig. 5.1 draw an arrow at **P** to indicate the direction of the force on the protons for them to move in a circle within the tube. [1]

(ii) State the direction of the magnetic field. Explain how you arrived at your answer.

....

....

....[2]

(iii) Write down an algebraic expression for the force F on a proton in terms of the magnetic field at point **P**.

....[1]

For Examiner's Use

(iv) Calculate the value of the flux density B needed to contain protons of speed $1.5 \times 10^7\,m\,s^{-1}$ within a tube of radius 60 m. Give a suitable unit for your answer.

B = ...unit.................. [5]

(v) State and explain what action must be taken to contain protons, injected at twice the speed ($2v$), within the tube.

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....[2]

[Total: 13]

For Examiner's Use

6 **(a)** Fig. 6.1 shows a toy consisting of a light plastic aeroplane suspended from a long spring.

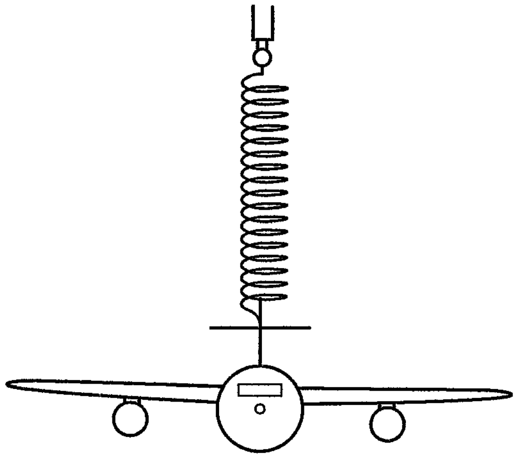

Fig. 6.1

(i) The aeroplane is pulled down 0.040 m and released. It undergoes a vertical harmonic oscillation with a period of 1.0 s. The oscillations are lightly damped. Sketch on the axes of Fig. 6.2 the displacement y of the aeroplane against time t from the moment of release. [3]

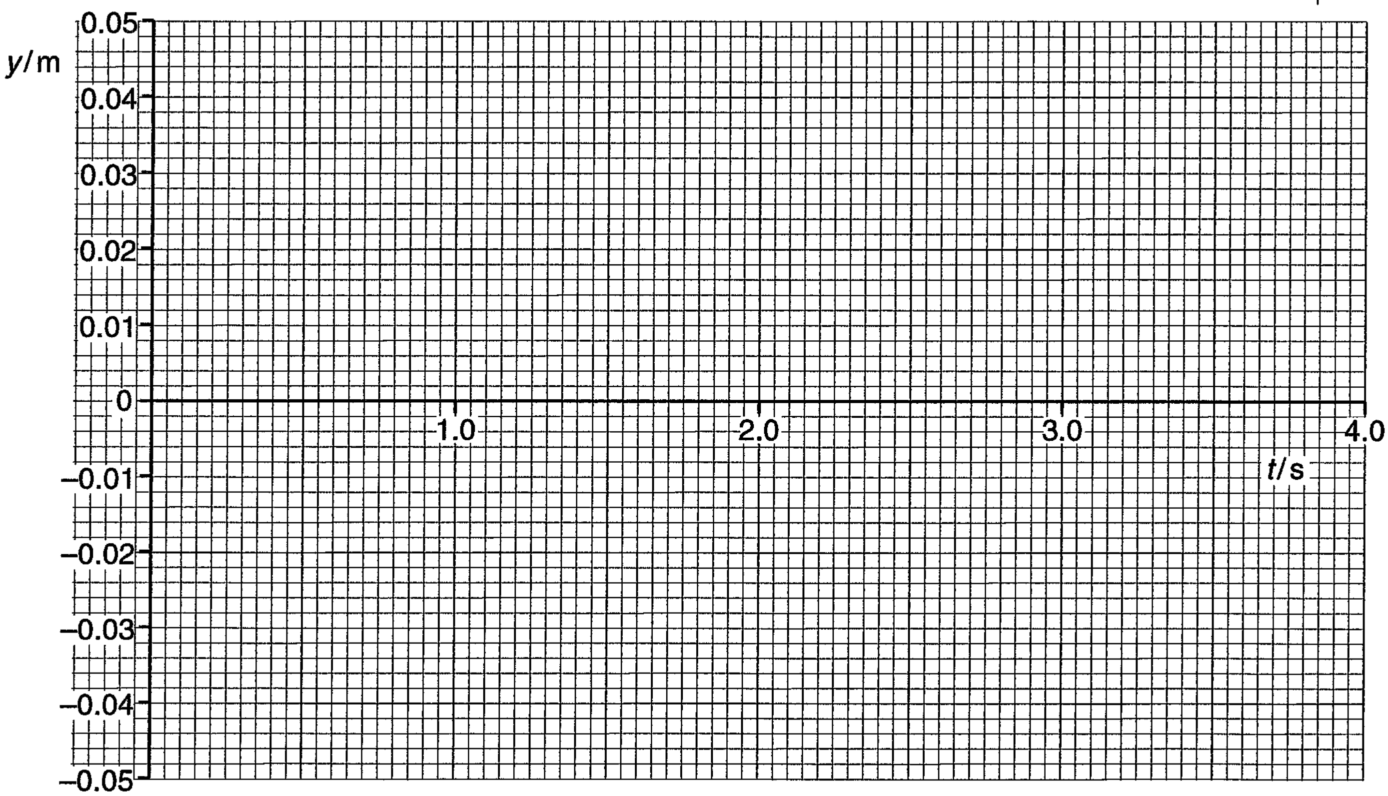

Fig. 6.2

For Examiner's Use

(ii) The aeroplane is replaced by a heavier model made of the same plastic having the same fuselage but larger wings. State and explain **two** changes which this substitution will make to the displacement against time graph that you have drawn on Fig. 6.2.

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....[4]

(b) The top end of the spring in Fig. 6.1 is then vibrated vertically with a small constant amplitude. The motion of the aeroplane changes as the frequency of oscillation of the top end of the spring is increased slowly from zero through resonance to 2.0 Hz.
Explain the conditions for resonance to occur and describe the changes in the motion of the aeroplane as the frequency changes from zero to 2.0 Hz.

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....[5]

[Total: 12]

For Examiner's Use

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

(a) State and compare the nature and properties of the three types of ionising radiations emitted by naturally occurring radioactive substances.

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....[6]

For Examiner's Use

(b) Describe experiments which would enable you to determine the **nature** and **energy** of the emissions from a sample of rock containing several radioactive nuclides. A space has been left for you to draw suitable diagram(s), if you wish to illustrate your answer.

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....[6]

Quality of Written Communication [4]

[Total: 16]

END OF QUESTION PAPER

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