OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE UNIT

PHYSICS B (ADVANCING PHYSICS) 2863/01

Rise and Fall of the Clockwork Universe

Wednesday 21 January 2009
Morning

Duration: 1 hour 15 minutes

Candidates answer on the question paper

OCR Supplied Materials:
- Data, Formulae and Relationships Booklet

Other Materials Required:
- Electronic calculator

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.
- Show clearly the working in all calculations, and give answers to only a justifiable number of significant figures.

INFORMATION FOR CANDIDATES

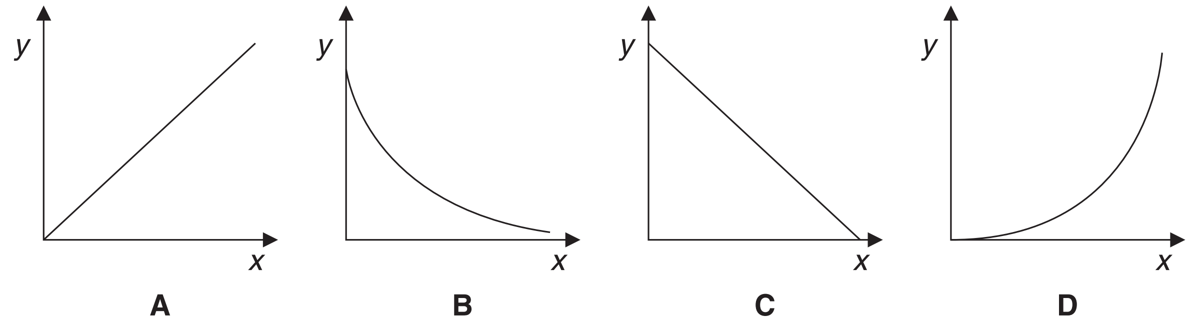
- You are advised to spend about 20 minutes on Section A and 55 minutes on Section B.
- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **70**.
- Four marks are available for the quality of written communication in Section B.
- The values of standard physical constants are given in the Data, Formulae and Relationships Booklet. Any additional data required are given in the appropriate question.
- This document consists of **16** pages. Any blank pages are indicated.

FOR EXAMINER'S USE		
Section	**Max.**	**Mark**
A	**20**	
B	**50**	
TOTAL	**70**	

Answer **all** the questions.

Section A

1 Study the graphs **A**, **B**, **C** and **D**.



(a) Which graph shows the variation of the **charge** on a capacitor (y) against **potential difference** (x)?

answer ....

(b) Which graph shows the variation of the **logarithm of charge** (y) against **time** (x) for a capacitor discharging through a resistor?

answer ....
[2]

2 Fig. 2.1 shows how the displacement of a simple harmonic oscillator varies with time.

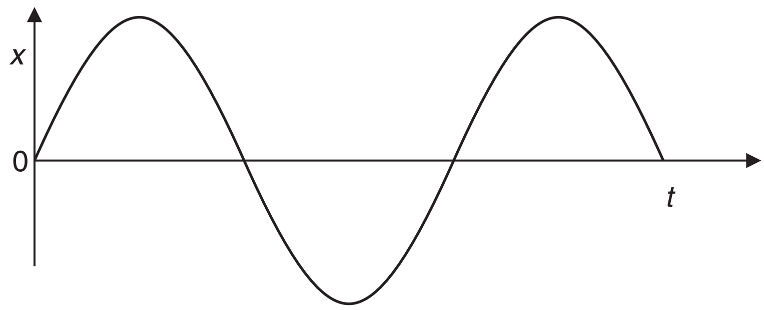


Fig. 2.1

(a) Mark on the graph a point where the velocity of the oscillator is at a maximum. Label this point **V**. **[1]**

(b) Mark on the graph a point where the acceleration of the oscillator is at a maximum. Label this point **A**. **[1]**

3 In the circuit in Fig. 3.1 the capacitor is charged to a potential difference of 4.5 V.

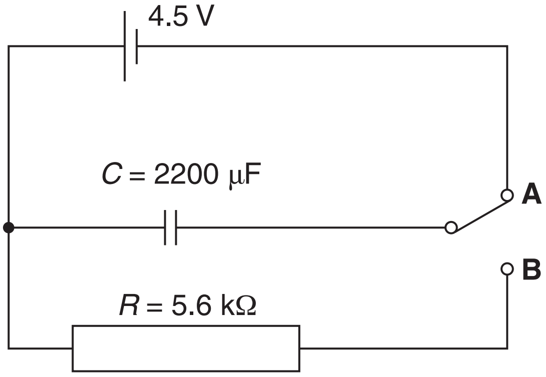


Fig. 3.1

When the switch is moved from **A** to **B** the capacitor discharges through the resistor.

(a) Which of the following values gives the best estimate of the value of RC in this circuit?

0.4 s   12 s   400 s   12 000 s

the best estimate is .... **[1]**

(b) Show that the value of the initial discharge current is about 0.8 mA.

[1]

(c) Calculate the current in the discharge circuit after the switch has been closed for RC seconds.

current = ... mA **[2]**

4 The behaviour of an ideal gas is described by the equation

$$pV = \frac{1}{3} Nm\overline{c^2}.$$

(a) State how the pressure of a fixed volume of the gas will change when the speed of each particle doubles.

[1]

(b) The particles in the gas have a range of speeds. Explain why they do not all have the same speed.

[2]

5 A satellite orbits at a distance of 4.2×10^7 m from the centre of the Earth.

Calculate the gravitational force on the satellite. State the equation you use.

mass of Earth = 6.0×10^{24} kg
mass of satellite = 600 kg
$G = 6.7 \times 10^{-11}$ N m^2 kg^{-2}

force = ...N **[3]**

6 A squash ball of mass 0.024 kg hits the wall of the court with velocity $+25\,\mathrm{m\,s^{-1}}$. It rebounds with a velocity of $-8\,\mathrm{m\,s^{-1}}$.

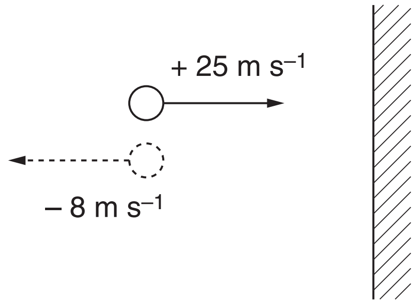


Fig. 6.1

Calculate the change of momentum of the squash ball.

change of momentum = ... $\mathrm{kg\,m\,s^{-1}}$ **[2]**

7 Asteroids are lumps of rocky material. Some are the size of mountains or even larger. Occasionally these asteroids pass near to the Earth.

The distance to an asteroid can be found by measuring the time for a radar pulse to travel to the asteroid and back. In one measurement the delay between the transmission of the pulse and receiving the reflected pulse was 53 seconds.

(a) Show that the asteroid was at a distance of about $8 \times 10^9\,\mathrm{m}$.
$c = 3.0 \times 10^8\,\mathrm{m\,s^{-1}}$

[1]

(b) Suggest one factor that makes an accurate measurement of this distance difficult.

[1]

8 4.5 mol of an ideal gas is at a pressure of 1.5×10^5 Pa and has a volume of 4.2×10^{-2} m^3.

Calculate the temperature of the gas.

$R = 8.3\,\mathrm{J\,K^{-1}\,mol^{-1}}$

temperature = ... K **[2]**

[Section A Total: 20]

Section B

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

9 This question is about the dwarf planet, Pluto.

Fig. 9.1 shows the variation of gravitational field strength g with distance r from the centre of the planet.

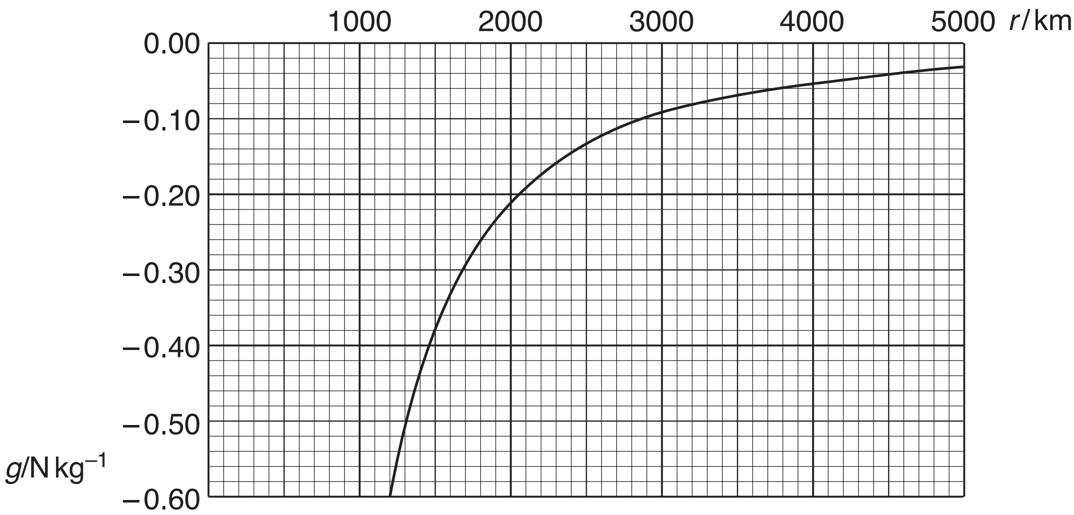


Fig. 9.1

(a) Use data from the graph to show that the field strength is given by the equation

$$g = -\frac{\text{constant}}{r^2}.$$

Show your working clearly.

[2]

(b) The mass M of a spherical planet of radius R and uniform density ρ is given by

$$M = \frac{4}{3}\pi R^3 \rho.$$

(i) Using the equation for the gravitational field strength at the surface of the planet show that

$$g = -\frac{4}{3}G\pi R\rho.$$

[1]

(ii) Pluto has a radius of 1.2×10^6 m. Use data from the graph to calculate the average density ρ of the material forming Pluto.

$G = 6.7 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$

density ρ = ... $\mathrm{kg\,m^{-3}}$ **[3]**

(iii) Calculate the mass of Pluto.

mass = ... kg **[2]**

(c) Pluto's orbit is highly elliptical. Its greatest distance from the Sun is 7.4×10^{12} m.

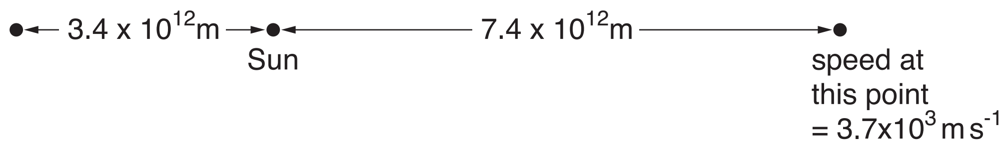
(i) Show that the gravitational potential at this distance from the Sun is about -2×10^{7} J kg^{-1}.

mass of Sun $= 2 \times 10^{30}$ kg

[1]

(ii) At the greatest distance from the Sun Pluto travels at a speed of 3.7×10^{3} m s^{-1}.

At its closest approach, Pluto is about 3.4×10^{12} m from the Sun.



not to scale

Fig. 9.2

By considering changes between potential energy and kinetic energy describe how you could use information from the question to calculate the speed of Pluto at closest approach. **Do not make the calculation**.

[4]

[Total: 13]

10 This question is about how radioactive carbon-14 has been used to estimate the date of construction of an ancient stone circle.

(a) Living matter has 4.0×10^{10} atoms of carbon-14 in every gram of carbon giving an activity of about 0.16 counts s^{-1}.

(i) Use this information to calculate the decay constant λ of carbon-14.

λ = ... s^{-1} **[2]**

(ii) Show that the half-life of carbon-14 is about 5500 years.
1 year = 3.2×10^7 s

[2]

(b) (i) Draw a graph on Fig. 10.1 to show how the number *N* of carbon-14 atoms per gram of carbon varies over time. **[2]**

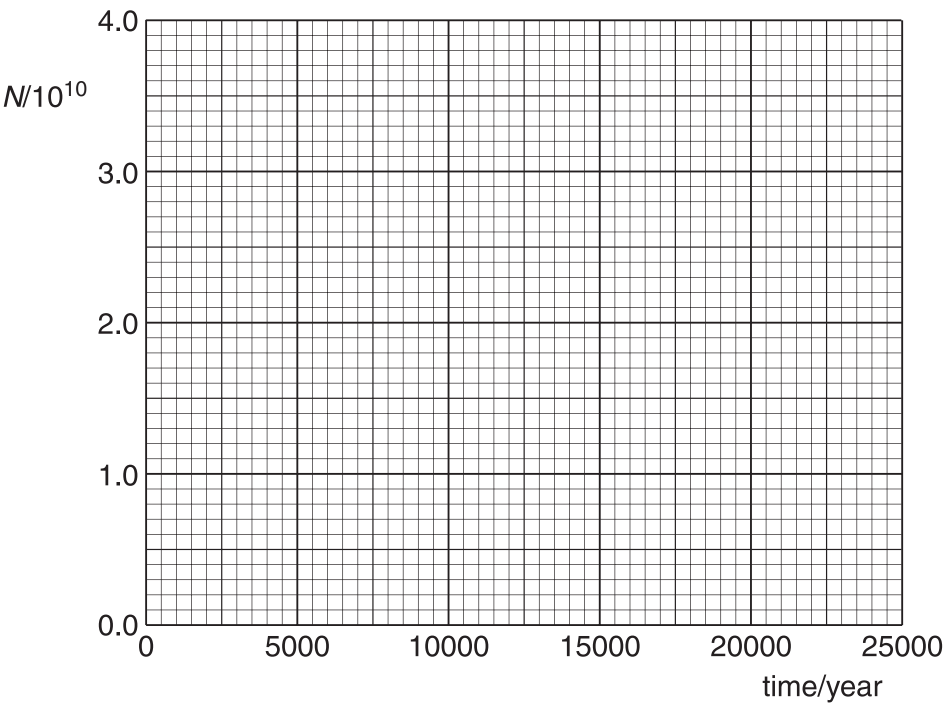


Fig. 10.1

(ii) A fragment of deer horn was found at the base of one of the large stones. It is assumed that the horn was buried when the stone was laid in place and that the horn had 4.0×10^{10} atoms of carbon-14 per gram of carbon at the time of burial.

The number of carbon-14 atoms per gram of carbon in samples from the horn varied between 2.1×10^{10} and 2.3×10^{10} .

Use the graph to estimate the age of the sample. State the uncertainty in your estimate.

age = ... uncertainty ± .... years **[2]**

(c) Carbon dating is used to date samples of organic material of up to 50,000 years old.

(i) State how many half-lives of carbon-14 represent a time interval of 50,000 years.

[1]

(ii) Calculate the activity of one gram of carbon in a sample of organic matter remaining after 50,000 years.

Assume the original activity per gram was 0.16 counts s^{-1}.

activity per gram = ... counts s^{-1} **[1]**

(iii) Suggest why this method of carbon dating is not suitable for determining the age of objects older than 50,000 years.

[1]

(d) It is very important to make sure that the ancient organic matter is not contaminated with modern organic matter.

Explain how contamination with modern matter can affect the calculated age of the sample and suggest whether younger or older samples will be more sensitive to the effects of contamination.

[3]

[Total: 14]

11 This question is about a helicopter hovering in the air.

Here are some data you may find useful:

mass of helicopter and crew = 5 300 kg
radius of rotor blades, $r = 9.9$ m
density of air near sea level, $\rho_{air} = 1.2$ kg m^{-3}
gravitational field strength, $g = 9.8$ N kg^{-1}

(a) Show that the force exerted by the blades to keep the helicopter hovering at a fixed height is about 52 kN.

[1]

(b) The helicopter hovers by accelerating air vertically downwards.

Explain why the magnitude of the rate of change of momentum of the air passing the rotor blades must be about 5.2×10^4 kg m s^{-1}.

[1]

(c) Fig. 11.1 shows the volume of air that passes the rotor blades in one second. It is assumed that the air is accelerated from rest to a vertical velocity v as it passes the rotor blades.

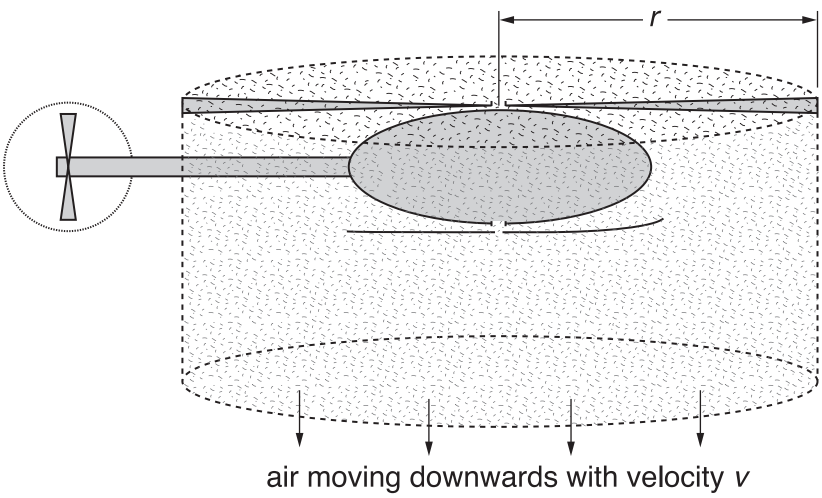


Fig. 11.1

(i) Show that the mass of air passing the blades in one second is $v\pi r^2 \rho$.

[1]

(ii) Show that the force F exerted on the air is given by:

$$F = v^2 \pi r^2 \rho$$

[1]

(iii) Calculate the velocity of the air from the blades when the helicopter is hovering.

velocity = ... $m s^{-1}$ **[2]**

(d) This helicopter can fly to a maximum height of 3000 m. At this height the density of air is about $0.90\,kg\,m^{-3}$.

(i) Show that, for a constant force,

$$v \propto \frac{1}{\sqrt{\rho}}.$$

[1]

(ii) Hence calculate the velocity of the air passing the blades when the helicopter is hovering at a height of 3000 m.

[2]

(iii) Suggest and explain a reason why there is a maximum height at which the helicopter can hover.

[2]

[Total: 11]

12 This question is about electrons gaining sufficient energy to escape from the surface of a metal when the metal is heated.

(a) (i) Show that an electron in a metal at a temperature of 295 K has an energy of about 4×10^{-21} J.

Boltzmann constant, $k = 1.4 \times 10^{-23}\ \text{J K}^{-1}$

[1]

(ii) It takes about 2×10^{-19} J to remove an electron from the surface of a sample of platinum. Use the energy value of 4×10^{-21} J to show that the Boltzmann factor for this process at 295 K is of the order of 10^{-22} .

[1]

(b) The electrons from a heated platinum surface are collected and form a current.

Fig. 12.1 shows how this current I from a metal surface varies with temperature T.

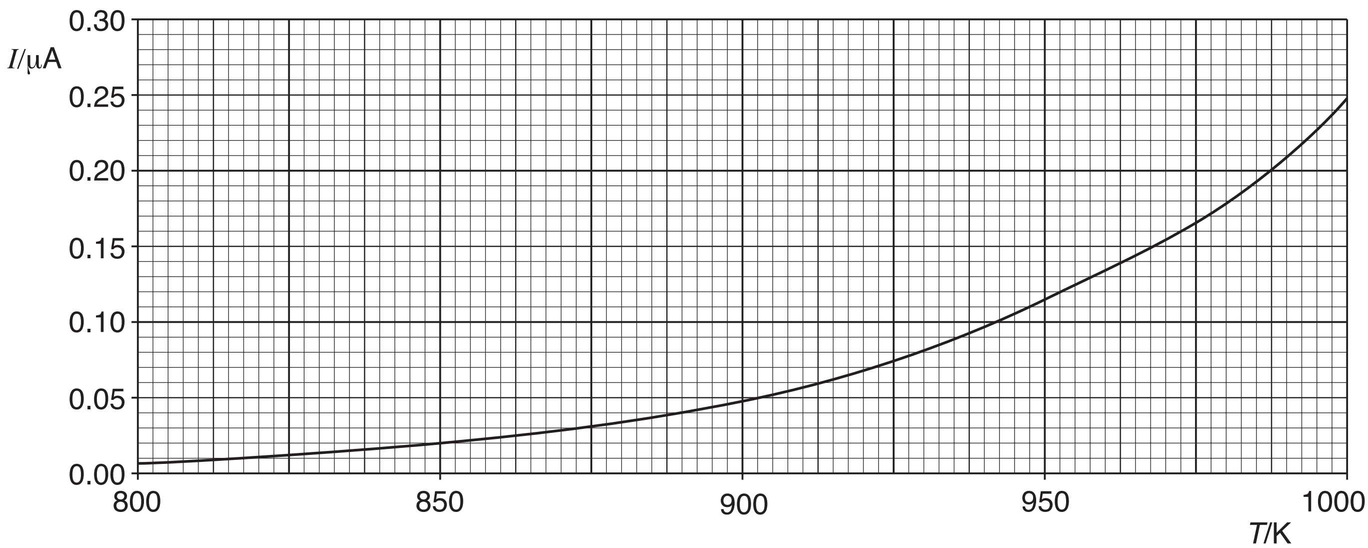


Fig. 12.1

Show that a current of 0.10 μA represents approximately 6×10^{11} electrons leaving the surface of the metal each second.

electronic charge, $e = -1.6 \times 10^{-19}$ C

[1]

(c) It is suggested that the current doubles for every 50 K rise in temperature.

Use data from the graph to test this suggestion.

[2]

Question 12 continues on next page

(d) The Boltzmann factor for the process approximately doubles for each 50 K rise in temperature over the range of results shown on the graph.

Explain why doubling the Boltzmann factor leads to a doubling of the current from the surface of the metal.

[3]

[Total: 8]

Quality of Written Communication: [4]

[Section B Total: 50]

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