THIS IS A LEGACY SPECIFICATION

RECOGNISING ACHIEVEMENT

ADVANCED GCE

PHYSICS B (ADVANCING PHYSICS) 2863/01

Rise and Fall of the Clockwork Universe

Candidates answer on the Question Paper

OCR Supplied Materials:
- Data, Formulae and Relationships Booklet

Other Materials Required:
- Electronic calculator
- Ruler (cm/mm)

Friday 18 June 2010
Morning

Duration: 1 hour 15 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.
- Show clearly the working in all calculations and give answers to only a justifiable number of significant figures.

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 **70**.
- You are advised to spend about 20 minutes on Section A and 55 minutes on Section B.
- There are four marks 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 questions.
- 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 Fig.1.1 shows three possible paths, **A**, **B** and **C** of a spacecraft moving near the Earth but well above the atmosphere.

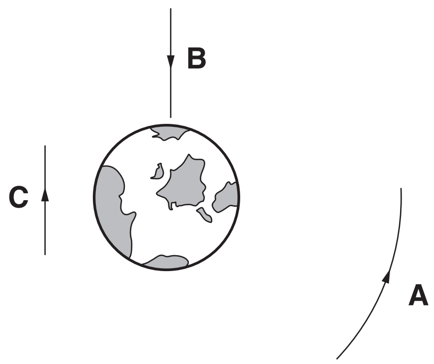

Fig. 1.1

(a) Which path follows a gravitational field line of the Earth?

answer .... **[1]**

(b) Which path follows a gravitational equipotential line of the Earth?

answer .... **[1]**

2 Here is a list of units.

J s   C s^{-1} s s^{-1}

Which of these is the unit of frequency ?

answer .... **[1]**

3 Three moles of nitrogen gas are at a pressure of 3.0×10^5 Pa and at a temperature of 300 K.

Calculate the volume of the gas under these conditions. Assume ideal gas behaviour.

State the equation you use in your calculation.

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

volume of gas = ... m^3 **[3]**

4 The Boltzmann factor f is given as $f = e^{-E/kT}$. It is a measure of the likelihood of a particle gaining sufficient energy for a physical process to occur.

E is the energy needed for the particular process to take place.
k is the Boltzmann constant.
T is the kelvin temperature.

Fig. 4.1 shows how the Boltzmann factor varies with temperature.

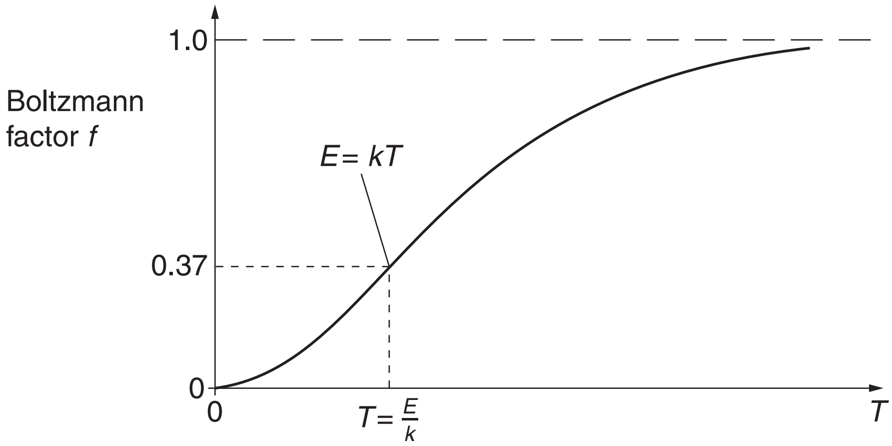

Fig. 4.1

Use $f = e^{-E/kT}$ to explain why, as shown in Fig. 4.1,

(a) the Boltzmann factor f is close to zero at low temperatures

[1]

(b) the Boltzmann factor f is less than 1 even at the highest temperatures

[1]

(c) the Boltzmann factor f is about 0.37 when $E = kT$.

[1]

5 A toy spider hangs from a long spring as shown in Fig. 5.1. The spider oscillates vertically with a time period of 2.6 s.

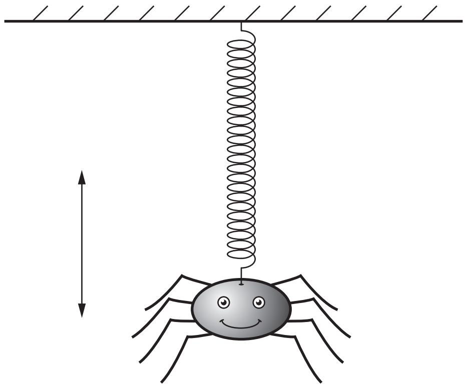

Fig. 5.1

(a) Calculate the frequency f of the oscillation.

f = …………………… Hz **[1]**

(b) The displacement x of the spider is given by the equation

$$x = A \sin (2 \pi f t)$$

where A = 0.18 m.

Calculate the displacement of the spider when t = 1.5 s.

x = …………………… m **[2]**

6 A mass of 0.70 kg of water is heated using a 1500 W heater.

Calculate the initial rate of change of temperature of the water.

specific thermal capacity of water = 4200 J kg^{-1} K^{-1}

initial rate of change of temperature of the water = ……………………K s^{-1} **[2]**

7 A sample of 1.0 g of uranium-238 contains 2.5×10^{21} nuclei. The graph in Fig. 7.1 shows how the natural logarithm ln N of the number N of uranium-238 nuclei changes with time.

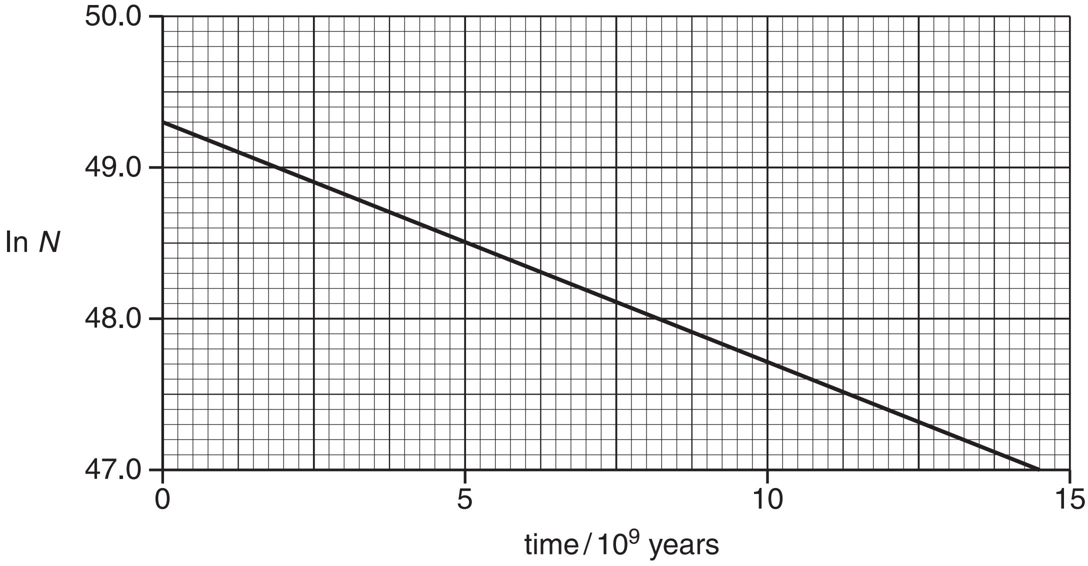

Fig. 7.1

(a) Explain what is meant by the half-life of uranium-238.

[1]

(b) Use information from the graph to calculate the half-life of uranium-238.

$\ln 2.5 \times 10^{21} = 49.3$

half life = …………………… years **[2]**

8 In a test laboratory, a car travelling at $12\,m\,s^{-1}$ strikes a wall head-on and comes to rest.

A crash test dummy of mass 78 kg is belted into the driver's seat of the car.

(a) Calculate the change of momentum of the dummy in the crash.

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

(b) In the crash, the dummy is brought to rest by the seat belt from the speed of $12\,m\,s^{-1}$ in a time of 0.13 s.

Show that the average force on the dummy is about nine times its weight.

$g = 9.8\,N\,kg^{-1}$

[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 measuring distances and velocities in the Universe.

Distances and velocities of planets and other objects within the Solar System can be measured by radar pulses from Earth reflected from distant objects.

(a) A radar pulse from Earth was aimed at an asteroid. The time interval between the pulse leaving the transmitter and the detection of the reflected pulse was 42.4 s.

Show that the distance to the asteroid at the time of measurement was about 6.4×10^9 m. State any assumptions you make.

$c = 3.00 \times 10^8 \, \text{m s}^{-1}$

[2]

(b) The measurement was repeated 780 s later. The time interval had reduced to 42.2 s.

Calculate the average velocity of approach of the asteroid between the two measurements. Show your method clearly.

average velocity = ... m s^{-1} **[3]**

(c) This radar-ranging method is impractical for measuring the distance or velocity of a star such as Sirius which lies about 7 light years from Earth.

Suggest **two** reasons why this is so.

[2]

(d) Distant galaxies are observed to be receding (moving away) from the Earth at high velocities. The velocity of recession of a galaxy in deep space is calculated from its red-shift.

Explain the meaning of the term *red-shift*.

[1]

(e) The distance d to a galaxy can be determined from its velocity of recession v using the relationship

$$v = H_0 d$$

where H_0 is the Hubble constant.

A galaxy is observed to be receding at a velocity of $9.0 \times 10^5\,\mathrm{m\,s^{-1}}$.

Calculate the distance to this galaxy.

$H_0 = 2.2 \times 10^{-18}\,\mathrm{s^{-1}}$

distance = …………………… m **[2]**

(f) The value of H_0 given above is often given in the alternative form $H_0 = 70\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$.

One megaparsec (Mpc) is an astronomical unit of distance equal to $3.1 \times 10^{22}\,\mathrm{m}$.

Show that the value $70\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ is approximately equivalent to $2.2 \times 10^{-18}\,\mathrm{s^{-1}}$.

[2]

[Total: 12]

10 This question is about capacitor discharge.

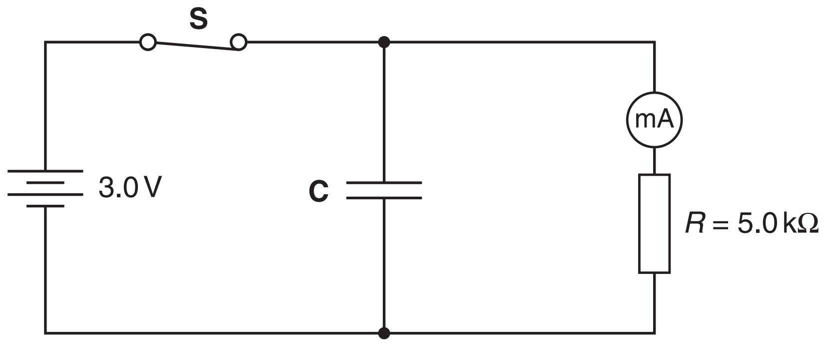

Fig. 10.1

The circuit is set up as shown in Fig. 10.1. Switch **S** is then opened and the capacitor discharges through the resistor. The variation of discharge current I with time t is shown in Fig. 10.2.

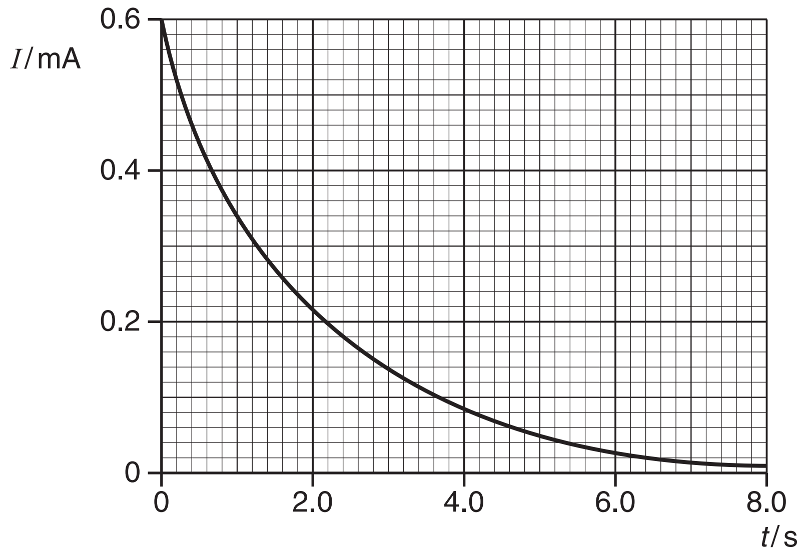

Fig. 10.2

(a) **(i)** Explain why the area under the curve represents the **initial** charge on the capacitor.

[2]

(ii) Show that the initial charge on the capacitor is about 1 mC.

[2]

(iii) Calculate the value of the capacitance used in the experiment.

value of capacitance = ... unit .... **[3]**

(b) Calculate the energy stored on the capacitor when the switch is closed.

energy stored = ... J **[2]**

(c) The experiment is repeated. The 5.0 kΩ resistor is replaced with a 10 kΩ resistor. No other changes are made to the circuit.

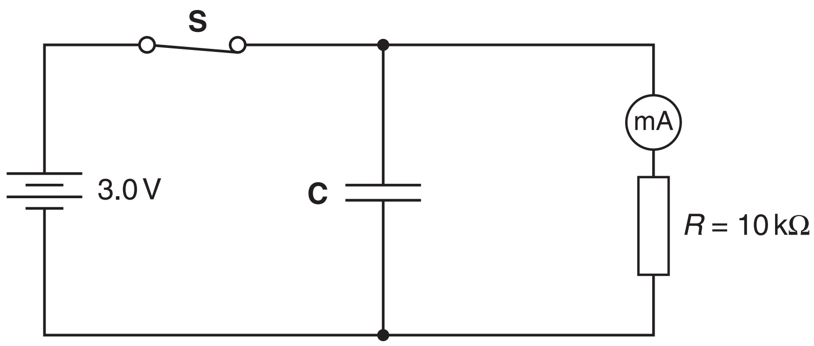

Fig. 10.3

Use the axes on Fig. 10.4 to sketch the graph of current against time for the circuit of Fig. 10.3.

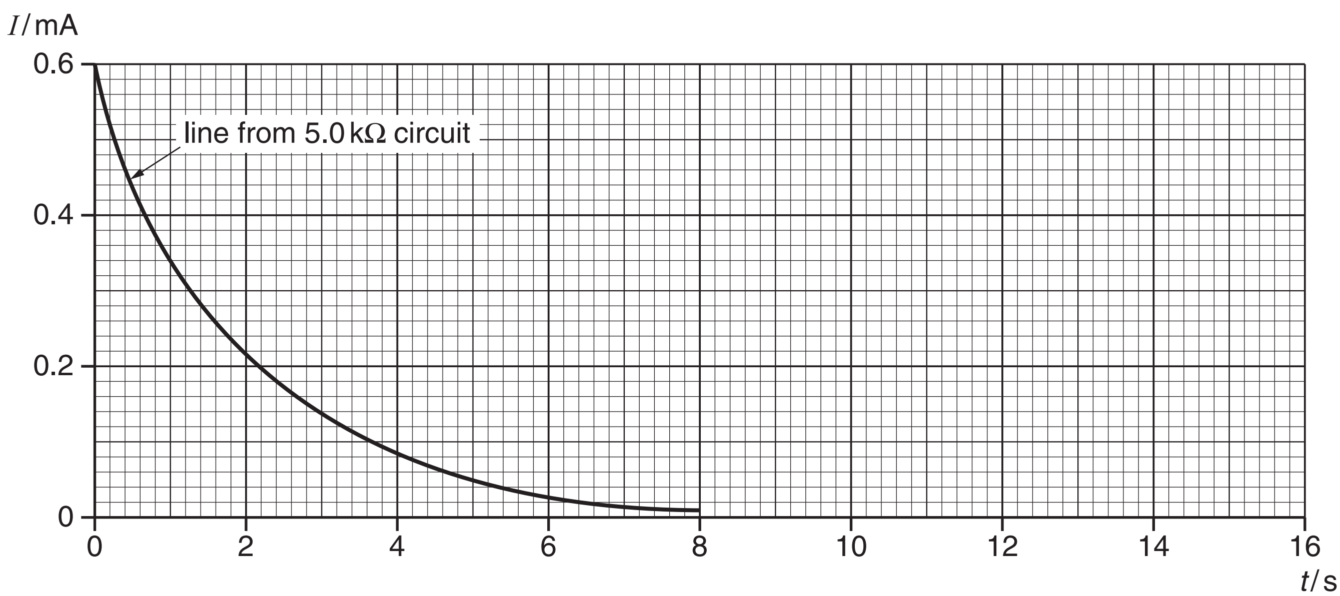

Fig. 10.4

[3]

[Total: 12]

11 This question is about the speed of bromine molecules at 20 °C.

Bromine is a brown gas. When a capsule of bromine is released into a tube containing air at 20 °C the brown gas slowly spreads up the tube.

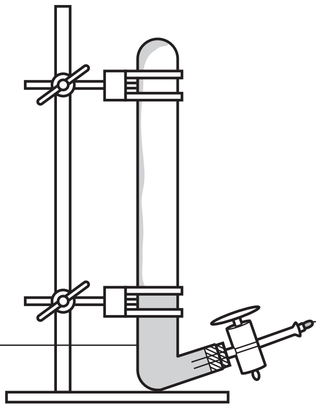

Fig. 11.1

(a) The average translational kinetic energy per molecule of a gas, $\frac{1}{2} m \overline{v^2}$, is related to the absolute temperature T by the relationship

$$\frac{1}{2} m \overline{v^2} = \frac{3kT}{2}$$

where k, the Boltzmann constant, is $1.4 \times 10^{-23}\,\text{J K}^{-1}$ and $\overline{v^2}$ is the mean square speed of the gas molecules.

(i) Show that the average translational kinetic energy of a bromine molecule at 20 °C is about 6×10^{-21} J.

[2]

(ii) Show that the root mean square speed $\sqrt{\overline{v^2}}$ of bromine molecules at 20 °C is about $200\,\text{m s}^{-1}$.

mass of bromine molecule $m = 2.7 \times 10^{-25}$ kg

[2]

(b) The bromine gas is observed to rise about 0.1 m up the tube in 470 s. This process is known as diffusion. The progress of the gas is slow because the bromine molecules collide with air molecules in the tube.

(i) Calculate the total distance covered in 470 s by a typical bromine molecule travelling at 200 m s^{-1}.

total distance = ... m **[1]**

(ii) The average distance between collisions is about 100 nm. Calculate the average number of collisions a bromine molecule makes as it travels 0.1 m up the tube. Give your answer to a suitable number of significant figures.

average number of collisions = ... **[2]**

(c) The experiment is repeated at the same temperature with the air in the tube at a lower pressure. Suggest and explain any change you would expect to the rate of diffusion.

[4]

[Total: 11]

12 This question is about a method of measuring the mass of the planet Saturn.

Saturn has a system of rings that orbit the planet. The rings are composed of pieces of ice and rock which orbit the planet.

(a) Consider a piece of rock of mass 2500 kg in a ring at a distance of 1.8×10^8 m from the centre of Saturn. The rock takes 21 hours to orbit the planet.

(i) Show that the speed of the rock is about 1.5×10^4 m s^{-1}.

[2]

(ii) Show that the magnitude of the centripetal force on the rock is about 3100 N.

Write down the equation you use to calculate your result.

[2]

(iii) The centripetal force is the force on the rock due to the gravitational attraction of Saturn.

Show that the mass of Saturn is about 6×10^{26} kg.

Write down the equation you use in your calculation.

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

[2]

(b) **(i)** Calculate the potential energy of the rock due to the gravitational field of Saturn.

potential energy = ... J **[2]**

(ii) Calculate the kinetic energy of the rock due to its speed in orbit.

kinetic energy = ... J **[1]**

(iii) Use your results to answers **(i)** and **(ii)** to explain why the rock will not fly out of the ring unless it gains energy from collisions with other rocks in the ring.

[2]

[Total: 11]

Quality of Written Communication [4]

[Section B Total: 50]

END OF QUESTION PAPER

PLEASE DO NOT WRITE ON THIS PAGE