OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS B (ADVANCING PHYSICS) 2863/01

Rise and Fall of the Clockwork Universe

Tuesday **20 JANUARY 2004** Morning 1 hour 15 minutes

Candidates answer on the question paper.
Additional materials:
Data, Formulae and Relationships Booklet
Electronic calculator

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 15 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.
- 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.
- 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 question.

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

This question paper consists of 14 printed pages and 2 blank pages.

[Turn over

For Examiner's Use

Answer **all** the questions.

Section A

1 Here is a list of units.

J N $J\,kg^{-1}$ $N\,kg^{-1}$

From the list write down the correct unit for

(a) the energy stored in a stretched spring ....

(b) centripetal force. ....

[2]

2 A can of drinking chocolate contains a chemical heating pack that releases 3.5×10^4 J of energy into the drink when activated.

Calculate the final temperature of the drink assuming no energy is lost to the can or surroundings.

mass of drink = 0.21 kg
specific thermal capacity of drink = 4200 $J\,kg^{-1}\,K^{-1}$
initial temperature of drink = 20 °C.

final temperature of drink = ...°C [3]

3 **(a)** Here is an expression for the energy E stored on a capacitor

$$E = \tfrac{1}{2} Q V$$

where Q is the magnitude of the charge in coulombs on each plate of the capacitor and V is the p.d. in volts across the capacitor.

Show that this expression can be written as

$$E = \tfrac{1}{2} C V^2$$

where C is the capacitance in farads.

[2]

(b) Sketch a graph on the axes of Fig. 3.1 showing how the energy stored on a capacitor varies with the potential difference across the capacitor.

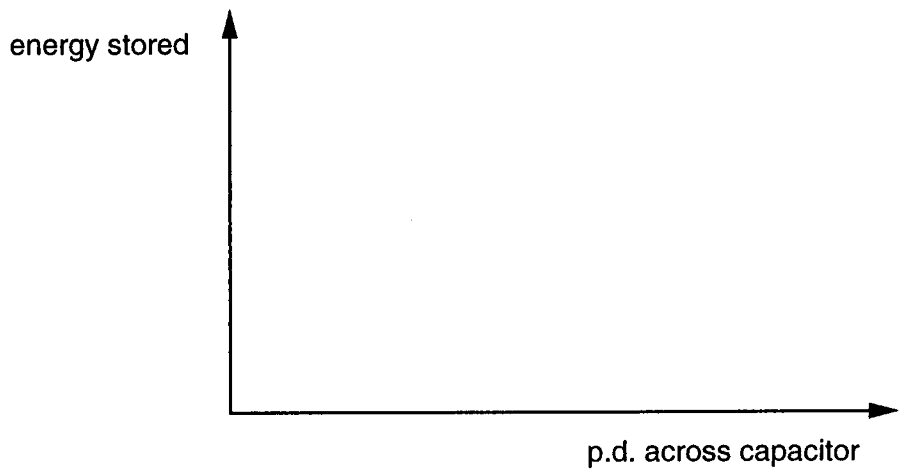

Fig. 3.1

[2]

4 Read the short passage and answer the questions below.

Most physicists accept the Hot Big Bang model of the origin of the Universe. Two pieces of evidence for this model are (i) the expansion of space and (ii) the microwave background radiation that is observed to be of almost equal intensity in all directions.

(a) State an observation that leads physicists to suggest that space is expanding.

[1]

(b) Explain why the second piece of evidence suggests that all the early Universe was at approximately the same temperature.

[2]

5 4.0 g of helium contains one mole (6.0×10^{23} atoms). The helium is at a pressure of 1.0×10^5 Pa and at a temperature of 300 K.

(a) Show that one mole of helium occupies a volume of about 0.025 m^3 under these conditions.

molar gas constant $R = 8.3\ J\ mol^{-1}\ K^{-1}$

[2]

(b) The gas is compressed to a volume of $0.020\,m^3$. The temperature of the gas is kept constant.

Calculate the new pressure of the gas.

pressure = ... Pa [2]

6 In the circuit in Fig. 6.1, the capacitor is charged to a potential difference of 6.0 V.

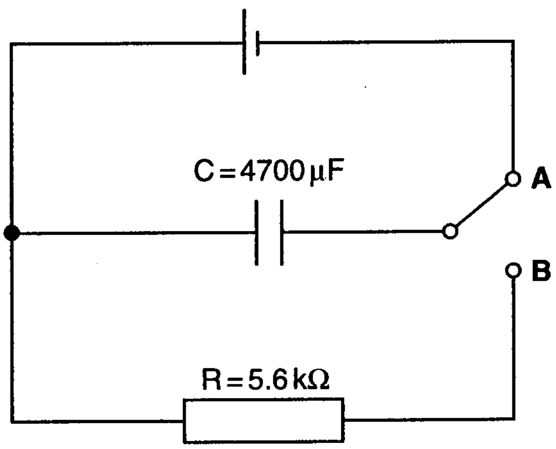

Fig. 6.1

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

(a) Show that the initial value of the discharge current is about 1 mA.

[2]

(b) The time constant *RC* of the discharge circuit is about 26 s.

Calculate the current in the discharge circuit after the switch has been closed for a time equal to *RC*.

current = ... mA [2]

[Section A Total: 20]

Section B

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

7 The variation in depth of water in a harbour can be modelled as a simple harmonic oscillation.

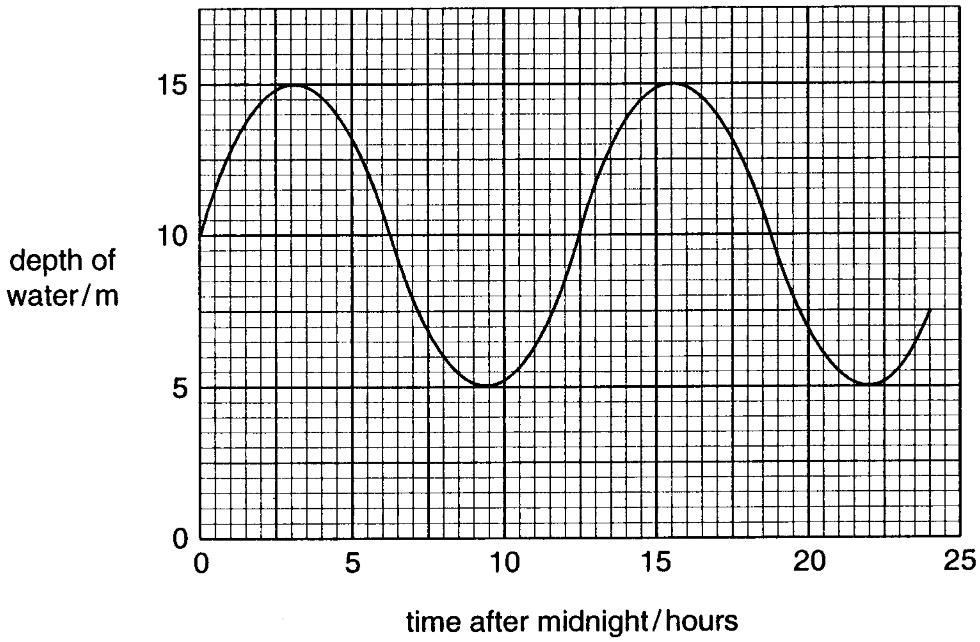

Fig. 7.1

Fig. 7.1 shows a graph produced from the model. It shows the variation of depth of water in a harbour with time over the period of one day (24 hours).

(a) Use the graph to find

(i) the maximum depth of the water in the harbour

maximum depth = ... m [1]

(ii) the amplitude A of the tidal motion

amplitude of motion = ... m [1]

(iii) the rate of change of depth in metres per hour (m hr^{-1}) at $t = 6$ hours where t = time after midnight in hours. Show your working.

rate of change of depth = ... m hr^{-1} [3]

(b) Use data from the graph to calculate the frequency f of the tidal motion in units of tides per hour.

frequency = ... tides per hour [3]

(c) A large boat needs at least 7 m of water to be able to enter the harbour. Use the graph to estimate the number of hours in the day (24 hours) that the boat could safely enter the harbour.
Show your method clearly.

[2]

(d) The equation for the depth of water d, in metres, in the harbour is

$$d = 10 + A \sin (2 \pi f t).$$

Use your answer to **(a)(ii)** and this equation to show that the lowest depth of water is 5 m.

[2]

[Total: 12]

8 This question is about the physics of ejection seats.

Ejection seats are designed to fire an aircraft pilot out of the plane at high velocity.

One type of ejection system uses an explosion to accelerate the seat upwards.

The seat was tested in a plane standing on the runway (Fig. 8.1a).

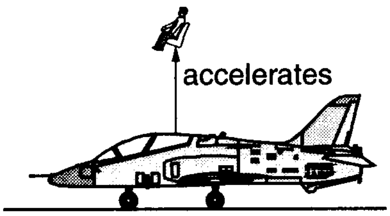

Fig. 8.1a

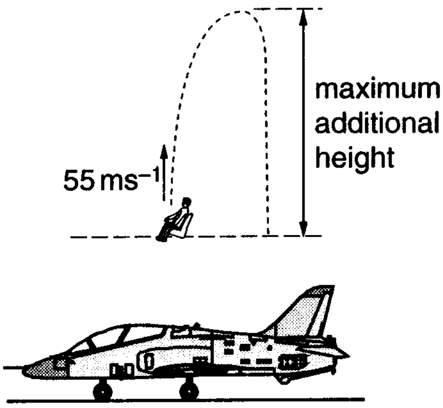

Fig. 8.1b

The combined mass of the seat and pilot is 280 kg. When ejection takes place, the mass accelerates to a vertical velocity of 55 m s^{-1}.

(a) **(i)** Calculate the change of momentum of the seat and pilot.

change of momentum = ... unit .... [3]

(ii) The change of momentum in **(i)** takes place in a time of 0.25 s.

Calculate the average force needed to give this change of momentum in 0.25 s.

force = ... N [2]

(iii) Suggest and explain how the body of the plane may move vertically during the ejection.

[2]

(b) 0.25 s after the ejection begins the seat and pilot have a maximum vertical velocity of $55\,m\,s^{-1}$.

Calculate the maximum additional height reached by the seat and pilot after maximum velocity is attained (see Fig. 8.1b).

Ignore air resistance.

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

height = ... [3]

(c) The height reached after the ejection is less than this simple calculation suggests because of air resistance.

Explain how the particles of air exert a decelerating force on the pilot.

[3]

[Total: 13]

9 Fig. 9.1 shows the apparatus used in an experiment to investigate the energy needed to evaporate water.

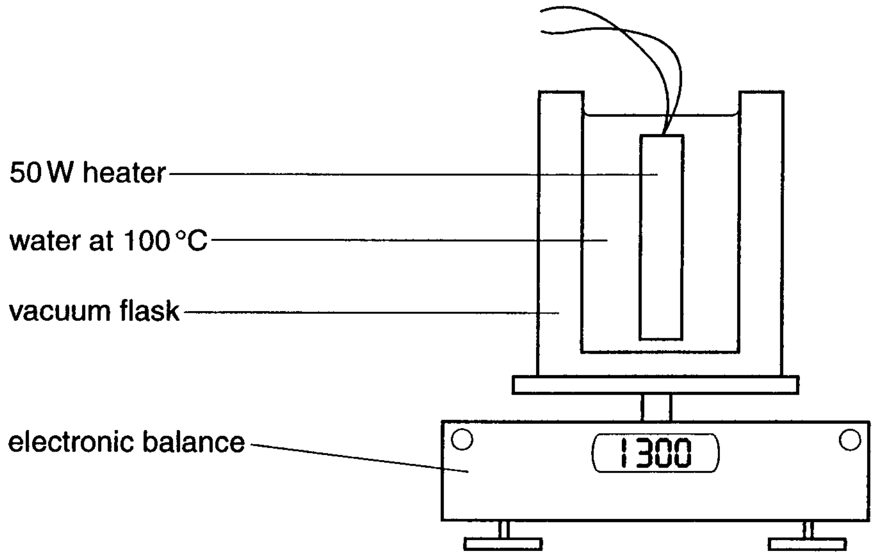

Fig. 9.1

(a) The 50 W heater keeps the water at boiling point for 250 seconds.

Show that the energy supplied to the water in this time is more than 12 kJ.

[1]

(b) In this time, the mass of the water in the flask decreases by 5.0 g.

Show that about 1.7×10^{23} molecules escape from the water.

18 g of water contains 6.0×10^{23} molecules.

[2]

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(c) Show that the energy E needed for a molecule to escape into the vapour is about 7.5×10^{-20} J.

[2]

(d) The average energy of a molecule at absolute temperature T is given approximately by

$$\text{average energy} \approx kT.$$

Use this expression to estimate the average energy of water molecules at 373 K.

$k = 1.4 \times 10^{-23}$ J K^{-1}

kT = ... J [1]

(e) **(i)** Calculate the value of the ratio of the average energy of a molecule at 373 K to the energy (7.5×10^{-20} J) required for a molecule to escape into a vapour.

$$\frac{\text{average energy of a molecule at 373 K}}{\text{energy required for molecule to escape into vapour}} = \text{....................}$$ [1]

(ii) Explain why some molecules escape into the vapour at 373 K.

[2]

[Total: 9]

[Turn over

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10 This question is about the gravitational field and potential near the Earth.

The gravitational potential V_{grav} due to the mass of an approximately spherical body is given by the expression

$$V_{grav} = \frac{-GM}{R}$$

where

M is the mass of the body
R is the distance from the centre of the body.

(a) (i) Show that the gravitational potential at the Earth's equator is about -6.25×10^{7} J kg^{-1}.

mass of Earth = 5.98×10^{24} kg
radius of Earth at the Equator = 6.38×10^{6} m
radius of Earth at the poles = 6.36×10^{6} m
gravitational constant $G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}

[2]

(ii) Show that the magnitude of the gravitational potential at one of the poles is about 1.003 times the magnitude at the equator.

[2]

(iii) Explain why gravitational potential is always negative.

[2]

For Examiner's Use

(b) State an equation which shows how the gravitational field strength *g* outside a uniform sphere of mass *M*, varies with distance *R* from the centre of the sphere.

[1]

(c) The strength of the gravitational field at the Earth's surface is not quite constant. There are local variations in field strength due to concentrations of dense material beneath the surface. The shape of the Earth also affects the field strength on the surface.

(i) Calculate the gravitational field strength at one of the Earth's poles.

gravitational field strength = ... unit .... [3]

(ii) The gravitational field strength at one of the poles is about 1.006 times the gravitational field strength at the equator.

The shape of the Earth changes the magnitude of the gravitational field strength by a factor of 1.006 but only changes the magnitude of the gravitational potential by a factor of 1.003.

Explain why these two factors are different.

[2]

[Total: 12]

Quality of Written Communication [4]

[Section B Total: 50]