(6)

OCR RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS B (ADVANCING PHYSICS) **2863/01**

Rise and Fall of the Clockwork Universe

Monday **27 JANUARY 2003** Morning 1 hour 10 minutes

Additional materials:
Data, Formulae and Relationships Booklet
Electronic calculator

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 10 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 50 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	**21**	
B	**49**	
TOTAL	**70**	

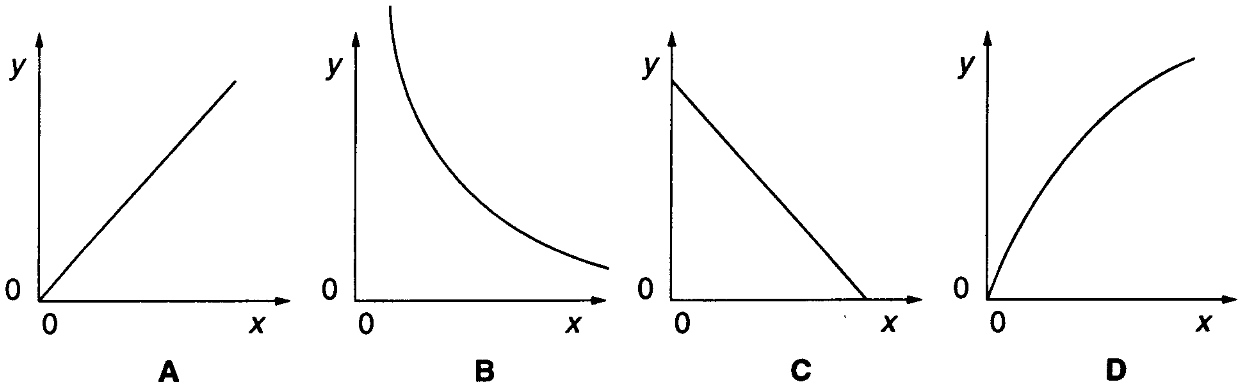
This question paper consists of 14 printed pages and 2 blank pages.

For Examiner's Use

Answer **all** the questions.

Section A

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



(a) Which graph shows the variation in **volume** (y) of a fixed mass of ideal gas at constant pressure with **absolute temperature** (x) ?

answer ....

(b) Which graph shows the variation in **pressure** (y) of a fixed mass of ideal gas at constant temperature with **volume** (x) ?

answer ....

[2]

2 The acceleration, a, of a body in simple harmonic motion is given by

$$a = -(2\pi f)^2 x$$

where f is frequency of the oscillation and x is the displacement.

Show that the right hand side of the equation has the units of acceleration.

[2]

For Examiner's Use

3 It has been suggested that drinking ice-cold water at 0 °C can help weight loss because the body uses stored energy in the form of fat to warm the water up to body temperature of 37 °C.

0.5 kg of fat stores about 1.6×10^8 J of energy.

(a) Calculate the mass of ice-cold water that a person would need to drink in order to lose 0.5 kg of fat.

specific thermal capacity, $c = 4200\ \mathrm{J\,kg^{-1}\,K^{-1}}$

mass = ...kg [2]

(b) Give a reason why it is not sensible to drink ice-cold water in order to lose weight.

[1]

4 A tennis ball of mass 0.11 kg travelling at $40\ \mathrm{m\,s^{-1}}$ hits a wall head on and bounces off, returning along the same path at $30\ \mathrm{m\,s^{-1}}$.

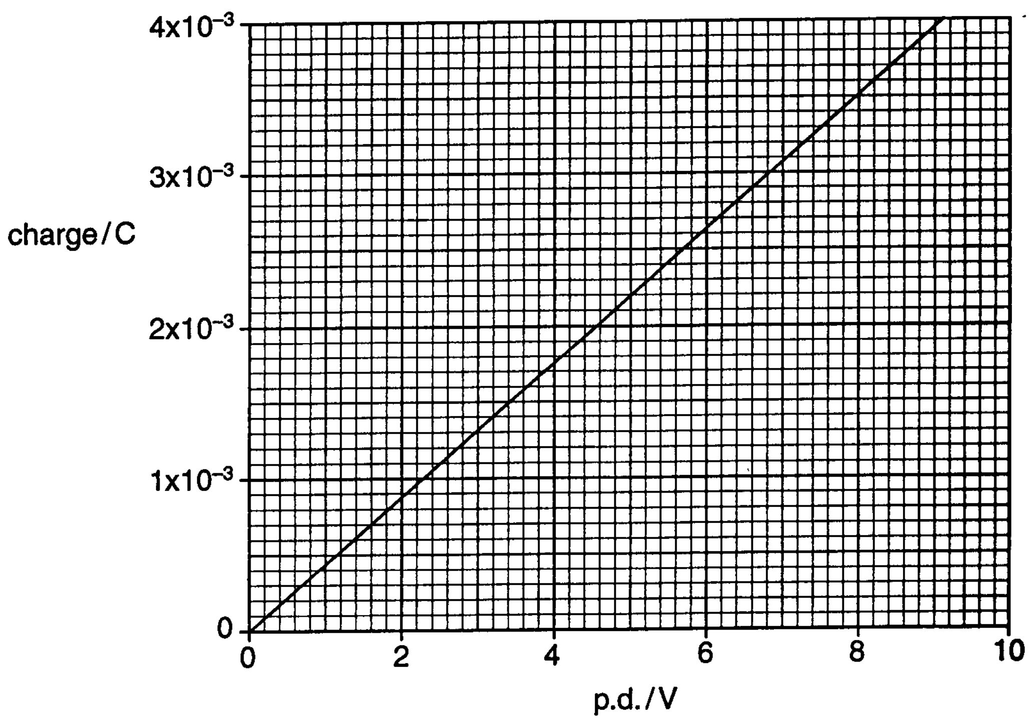
(a) Calculate the change in velocity of the ball.

change in velocity = ... $\mathrm{m\,s^{-1}}$

(b) Calculate the change in momentum of the ball. Include the unit in your answer.

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

5 The graph shows how the charge on a capacitor varies with p.d. across the capacitor.



Use the graph to find

(a) the energy stored by the capacitor when charged to a potential difference of 8 V

energy stored = ... J [2]

(b) the capacitance of the capacitor.

capacitance = ... F [2]

6 (a) Show that the particles of a gas at temperature 10 000 K will have an average kinetic energy of the order of 1 eV (1.6×10^{-19} J).

Boltzmann constant $k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$

[2]

(b) Explain why the particles of the gas will not all have a kinetic energy equal to the average value.

[2]

7 Fig. 7.1 shows a circuit diagram of a capacitor discharging through a resistor.

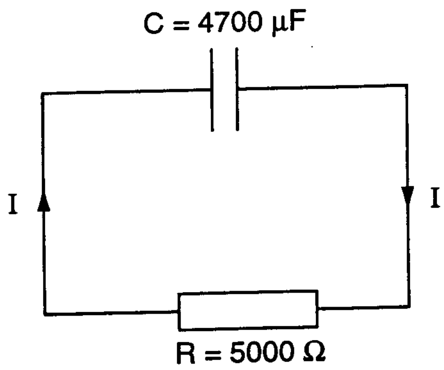


Fig. 7.1

A simple mathematical model of the discharge of the capacitor is shown in Fig. 7.2. It is assumed that the current I is constant over each small time interval, Δt . This process is repeated as shown.

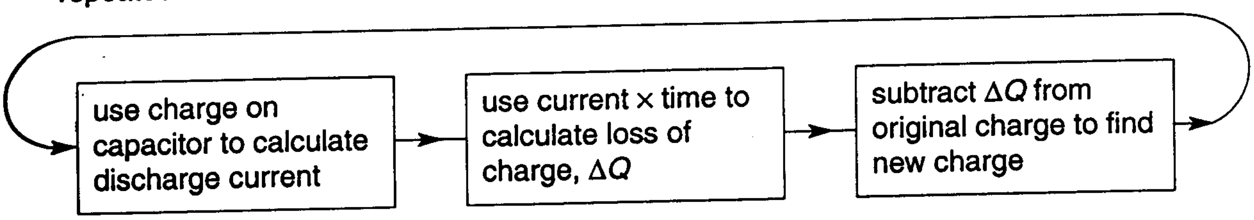


Fig. 7.2

Complete the table for the discharge of the 4700 μF capacitor. The small time interval used is $\Delta t = 2.0$ s.

Q	$I = \frac{V}{R} = \frac{Q}{RC}$	$\Delta Q = I\Delta t$	$Q_{new} = Q - \Delta Q$
5.64×10^{-2} C			5.16×10^{-2} C
5.16×10^{-2} C			

[3]

[Section A Total: 21]

[Turn over

For Examiner's Use

Section B

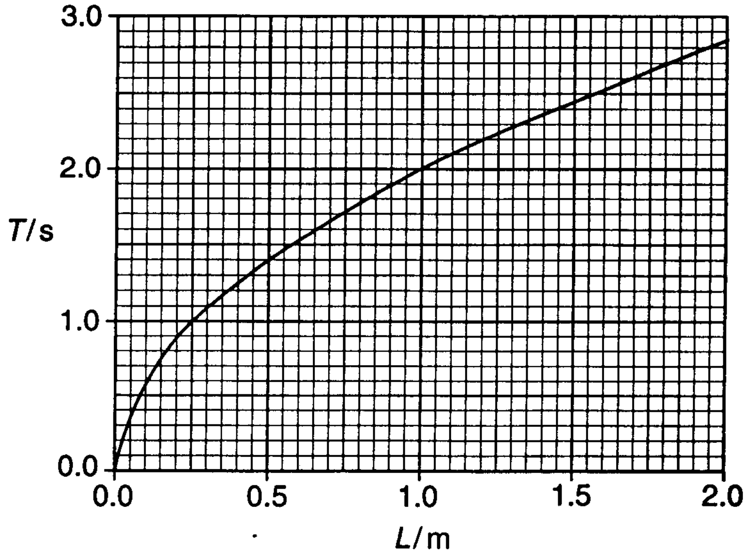
Up to four marks in this section will be awarded for the quality of written communication.

8 Accurate timekeeping became a practical possibility when Christiaan Huygens developed the pendulum clock. His design used the fact that the period of a pendulum is independent of its amplitude of swing for small angles.

(a) Explain what is meant by the **period** of a pendulum.

[1]

(b) The graph shows how the period T of a simple pendulum varies with length L.



Early clocks contained a pendulum with a time period of 2 seconds.

Use the graph to find the length of the pendulum that will give a time period **of 2 seconds.**

length of pendulum = ...m [1]

(c) The period of a pendulum, T, is proportional to $\sqrt{L}$.

(i) What graph could you draw to show that this is true?

[1]

(ii) State the property of your graph that would show that T is proportional to $\sqrt{L}$.

[2]

For Examiner's Use

(d) The amplitude of a pendulum will decrease every oscillation. Early clocks use a mass hanging on a rope to drive the mechanism. This gives the pendulum a push every oscillation which keeps the amplitude constant. The mass falls through a very small distance each oscillation and loses gravitational potential energy, transferring energy to the pendulum. When the mass has reached the bottom of its fall the clock is wound up by lifting the mass back up.

In one such clock a mass of 9 kg drops a distance of 1.2 m in a day. During this time the pendulum makes about 43 000 oscillations.

Assuming that all the energy from the falling mass is given to the pendulum show that about 2.5 mJ of energy is transferred to the pendulum each oscillation.

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

[3]

(e) The clocks are called 'long case clocks' and they stand about 2 metres high because of the length of the pendulum and the height through which the mass falls. Discuss the advantage in using

(i) a large drop height through which the mass can fall

[2]

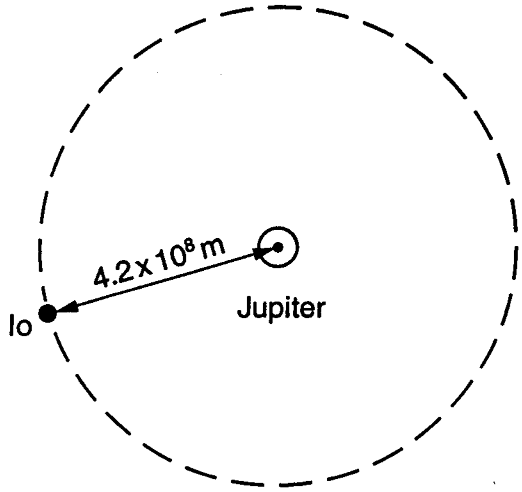
(ii) a long pendulum with a large, massive bob.

[2]

[Total: 12]

[Turn over

9 This question is about the planet Jupiter and one of the moons that orbits it, called Io.



Io orbits Jupiter at a speed, v, of $1.7 \times 10^4\,\mathrm{m\,s^{-1}}$ at an orbital radius, r, of $4.2 \times 10^8\,\mathrm{m}$.

(a) Show that Io takes approximately 43 hours to orbit Jupiter once.

[2]

(b) Io is held in its orbit by a centripetal force, $F = -\dfrac{mv^2}{r}$, where m is the mass of Io. This force is the gravitational attraction between Io and Jupiter.

(i) Show that $M = \dfrac{v^2 r}{G}$ where M is the mass of Jupiter.

(ii) Show that the mass of Jupiter is about 2.0×10^{27} kg.
$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$

[4]

For Examiner's Use

(c) Show that the gravitational potential at the top of Jupiter's atmosphere, 7.1×10^7 m from the centre of the planet, is about -2×10^9 J kg^{-1}.

Assume that Jupiter is a sphere.

[2]

(d) In July 1994, comet Shoemaker-Levy 9 crashed into Jupiter causing dramatic heating of the planet's atmosphere. During the approach to the planet, the comet broke up. One piece that struck the planet had a mass of about 4×10^{12} kg.

This fragment crossed the orbit of Io heading directly towards Jupiter with a velocity of 10 km s^{-1}.

(i) Show that the kinetic energy of the fragment at this moment is 2×10^{20} J.

[1]

(ii) Explain why the fragment will enter the atmosphere of Jupiter with a velocity greater than 10 km s^{-1}.

[2]

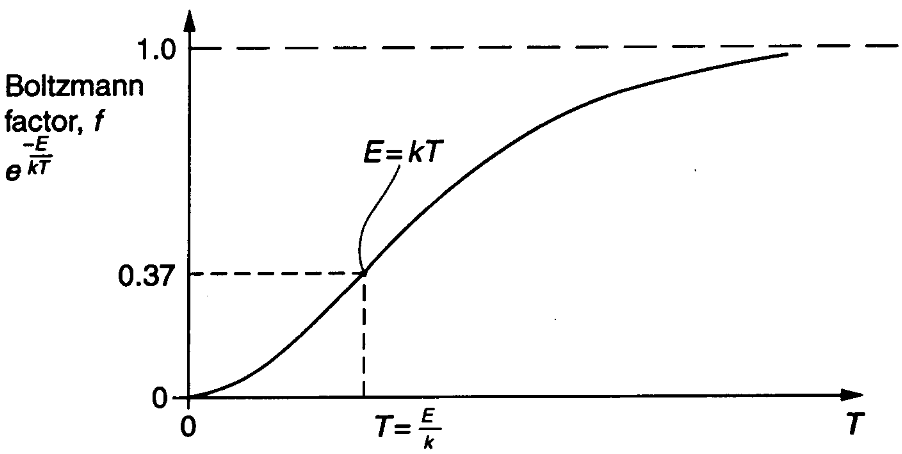
[Total: 11]

For Examiner's Use

10 The Boltzmann factor f is given as $f = e^{\frac{-E}{kT}}$. 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 = $1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
T is the Kelvin temperature

(a) The graph shows how the Boltzmann factor f varies with temperature.



Use $f = e^{\frac{-E}{kT}}$ to explain why, as shown in the graph

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

[1]

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

[1]

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

[1]

For Examiner's Use

(b) Some chemical reactions take place at a more rapid rate in the presence of an enzyme. The enzyme lowers the value of E, the energy needed for the reaction to take place. Enzymes speed up chemical reactions in the body.

The energy, E, required for a particular molecule to decompose is 1.3×10^{-19} J.

(i) Show that the Boltzmann factor f for this process taking place at body temperature, $T = 310$ K, is about 6×10^{-14}.

[2]

(ii) The presence of an enzyme lowers the value of E to 6.0×10^{-20} J.

Show that the Boltzmann factor f at 310 K is increased by a factor of more than a million in the presence of the enzyme.

[3]

(iii) Explain why this increase in the value of the Boltzmann factor f increases the rate at which a reaction will take place.

[2]

[Total: 10]

For Examiner's Use

11 This question is about calculating the age of stars using the radioactive decay of uranium-238.

A sample containing 1.0×10^{-6} kg of uranium-238 contains 2.5×10^{18} uranium-238 atoms.

The activity of the sample is 12 decays s^{-1}.

(a) **(i)** Show that the probability λ of any one atom of uranium-238 decaying in one second is about $5 \times 10^{-18} s^{-1}$.

[2]

(ii) Use the relationship, half life = $\frac{0.693}{\lambda}$, to find the half life of uranium-238 in years.

1 year = 3.2×10^7 s

[2]

(iii) Explain why it is not possible to predict the lifetime of one particular atom of uranium-238.

[1]

(b) Astronomers have observed the spectra of a very old nearby star to determine how much uranium-238 it contains. This is compared to the amount that is thought to have been present when the star was formed.

Recent observations suggest that the amount of uranium-238 in the star has fallen to one eighth of its original level.

(i) Use your answer to **(a)(ii)** to calculate the age of the star in years.

[2]

(ii) This technique, called **cosmochronometry** by its inventors, has given a value to the least possible age of the universe.

Explain why this method gives the least possible age of the universe.

[1]

(c) The Hubble Law, based on observation of cosmological red shifts, suggests that the universe is much older than the age of the stars measured by cosmochronometry.

The Hubble law suggests that the age of the universe is of the order $\frac{1}{H_0}$ where H_0 is the Hubble parameter.

Estimating the value of H_0 is an extremely important task. Until recently the values ranged from $1.6 \times 10^{-18}\,s^{-1}$ to $3.2 \times 10^{-18}\,s^{-1}$.

(i) Estimate the minimum and maximum age of the universe in years from the values of H_0.

minimum age = ... years maximum age = ... years [2]

(ii) Explain how data from cosmochronometry can be used to help astronomers choose between these values of H_0.

[2]

[Total: 12]

Quality of Written Communication [4]

[Section B Total: 49]