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OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS B (ADVANCING PHYSICS)

Rise and Fall of the Clockwork Universe

2863/01

Thursday **17 JUNE 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, Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces on the question paper.
  DO NOT ANSWER IN PENCIL. **DO NOT** WRITE IN THE BARCODE. **DO NOT** WRITE IN THE GREY AREAS BETWEEN THE PAGES.
- 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.
- Four marks are available for the quality of written communication in Section B.
- The values of standard physical constants are give in the Data, Formulae and Relationship 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 16 printed pages.

[Turn over

Answer **all** the questions.

For Examiner's Use

Section A

1 Here is a list of energies.

10^{-15} J 10^{-18} J 10^{-21} J 10^{-24} J

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

Choose the value from the list that is the best approximation to

(a) the energy of a nitrogen molecule at room temperature, $T = 300$ K,

answer .... J

(b) the energy of a proton in the interior of a star at temperature, $T = 9 \times 10^6$ K.

answer .... J
[2]

2 Hydrogen atoms can emit ultraviolet light of wavelength 122 nm. A spectrum from a distant quasar shows that this light has been stretched to a wavelength of 440 nm. This is an example of cosmological redshift.

(a) Calculate the factor by which the Universe has expanded since the light was emitted by the quasar.

factor = ... [2]

(b) Explain why objects further from the Earth show a greater cosmological redshift.

[2]

For Examiner's Use

3 It is suggested that the height h of the foam on the top of a fizzy drink (see Fig. 3.1) decreases **exponentially** with time. The table shows data taken to test this assumption.

time / s	0	15	30	45	60
height of foam, h / cm	6.0	4.8	3.8	3.1	2.5

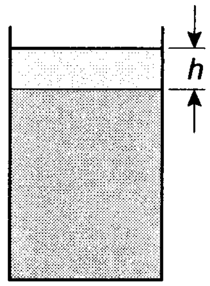

Fig. 3.1

(a) Use this data to test if the height of the foam decreases exponentially with time. State your conclusion.

[2]

(b) Give another physical example of an exponential decrease.

[1]

4 2.0 mol of an ideal gas is kept at a pressure of 1.5×10^5 Pa and a temperature of 310 K.

Calculate the volume occupied by the gas under these conditions.

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

volume = ... m^3 [2]

For Examiner's Use

5 A mass of 0.40 kg is hung from a spring. The spring extends by 22 mm. The extension of the spring is directly proportional to the force applied.

(a) Show that k, the stiffness constant of the spring, is about $180\,\mathrm{N\,m^{-1}}$.

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

[2]

(b) The mass is pulled down a small distance further and then released. This sets the mass oscillating.

Calculate the frequency of the oscillation.

frequency = ... Hz [3]

6 A circus clown fires a water gun that ejects water horizontally at a speed of $7.3\,\mathrm{m\,s^{-1}}$. The water leaves the gun at a rate of $2.7\,\mathrm{kg\,s^{-1}}$.

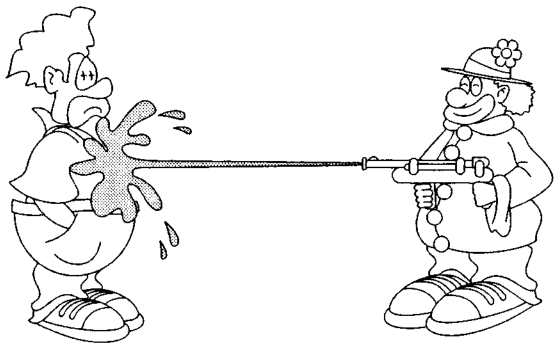

Fig. 6.1

(a) Show that the **rate of change of momentum** of the water on leaving the gun is about $20\,\mathrm{kg\,m\,s^{-2}}$.

[1]

For Examiner's Use

(b) Explain why the clown holding the gun experiences a **backward force** of about 20 N.

[2]

(c) The water strikes a second clown at the same velocity as it left the gun.

The water bounces off the clown.

Explain why this clown could experience a force **greater than** 20 N from the water jet.

[2]

[Section A Total: 21]

Section B

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

For Examiner's Use

7 This question is about using a capacitor to store energy.

People suffering from heart problems can be fitted with **implantable defibrillators** which can deliver an electric shock to 'kick start' the heart.

capacitance	200 μF
p.d. across fully charged capacitor	390 V
discharge time	10 ms

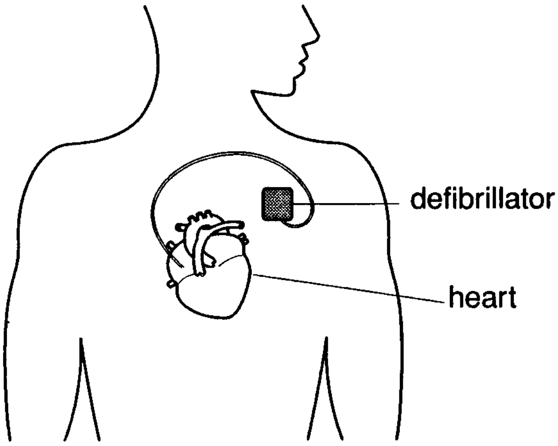

Fig. 7.1 defibrillator in position

This system uses capacitors to store energy.

The table shows some data about a capacitor used in an implantable defibrillator.

(a) **(i)** Calculate the energy stored in the fully charged capacitor.

energy .... J [2]

(ii) Calculate the average rate of energy transfer to the heart when the capacitor discharges.

average rate of energy transfer .... W [2]

For Examiner's Use

(iii) Explain why the value calculated in **(a)(ii)** is an **average** value.

[2]

(b) The discharge time of 10 ms corresponds to about five time constants (5 RC).

Calculate the resistance of the capacitor discharge circuit.

resistance = ... Ω [2]

(c) In fact, the energy required from the capacitor in this defibrillator is about twice as much as calculated in **(a)(i)**. One solution to this problem is to increase the p.d. across the capacitor.

Calculate the factor by which the p.d. must be increased to double the energy stored in the capacitor.

[2]

(d) To store the energy required, defibrillators actually use two capacitors, each at a p.d. of 390 V.

Suggest and explain **one** reason why this method is chosen rather than using one capacitor at a higher p.d.

[2]

[Total: 12]

For Examiner's Use

8 This question is about the vibrational testing of a satellite.

The vibrations simulate the shaking the satellite would undergo during launch. Assume the vibrations are simple harmonic.

(a) When a satellite of mass 10 000 kg oscillates at a frequency of 10 Hz, the amplitude of the oscillation is 35 mm.

(i) Explain what is meant by the term *amplitude*.

[2]

(ii) The maximum speed of the satellite during this oscillation is 2.2 m s^{-1}.

State the displacement of the satellite at which this maximum speed occurs.

displacement .... mm [1]

(iii) State the acceleration of the satellite at the instant that maximum speed occurs.

acceleration .... m s^{-2} [1]

(iv) Calculate the **maximum** acceleration of a satellite due to this oscillation.

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

For Examiner's Use

(v) Show that the satellite will experience accelerating forces far greater than its weight.

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

[2]

(b) The communications aerial on the satellite is observed to shake violently at one particular frequency. This is an example of resonance.

(i) Explain why the aerial behaves in this way.

[2]

(ii) Suggest and explain how the aerial could be modified in order to reduce the problem of resonance.

[2]

[Total: 12]

For Examiner's Use

9 This question is about heating soup with microwaves.

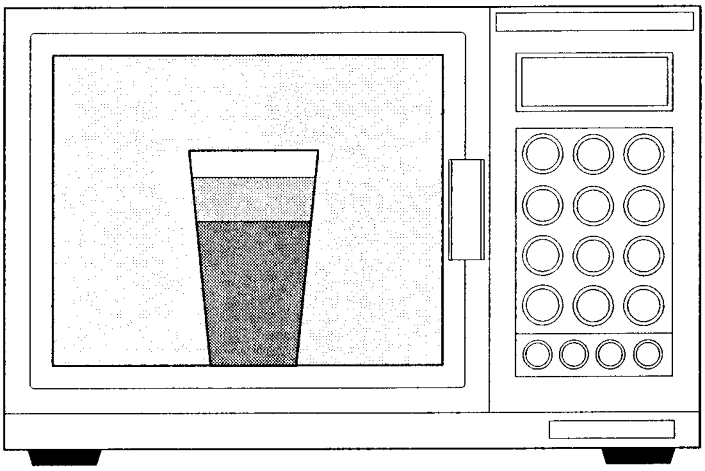

Fig. 9.1

(a) The microwave oven supplies energy to the soup at a rate of 600 W.

The soup, of mass 0.40 kg, has an initial temperature of 20 °C.

Show that after three minutes of heating the maximum temperature will be about 85 °C.

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

[3]

(b) Use ideas about the Boltzmann factor, $f = e^{-E/KT}$, to explain why increasing numbers of molecules evaporate from the soup as its temperature rises.

[2]

For Examiner's Use

(c) The soup container has a tight fitting lid on it.

(i) As the temperature rises, the **number** of molecules in the vapour increases. Explain why the growing number of molecules in the vapour increases the pressure of the vapour.

[2]

(ii) As the temperature rises, the average speed of the molecules in the vapour rises. Explain why this **also** increases the pressure of the vapour.

[2]

(iii) Explain why it is recommended that you do **not** use tight fitting lids on containers used in microwave cooking.

[1]

[Total: 10]

For Examiner's Use

10 This question is about the time it takes a planet to orbit once around the Sun. This is called the **orbital period** of the planet.

In this question the following symbols will be used.

orbital period T
mean radius of orbit R
mass of sun M_s
mass of planet M_p

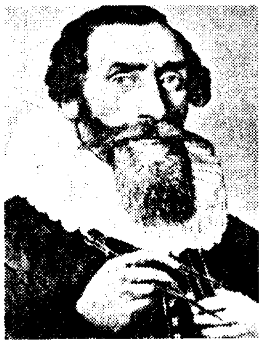

Fig.10.1

(a) In the seventeenth century Johannes Kepler (Fig. 10.1) suggested a relationship between the orbital period of a planet T and the radius of its orbit R. This relationship can be written as

$$T^2 \propto R^3.$$

Data for four of the planets are shown in Fig. 10.2.

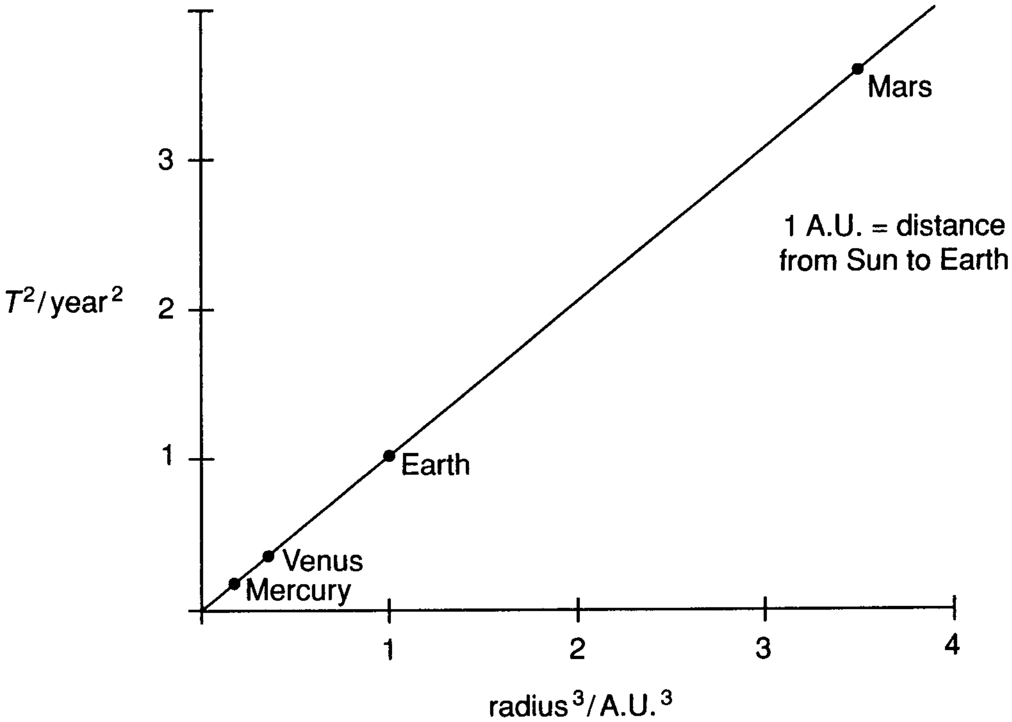

Fig. 10.2

State which features of the graph show that T^2 is proportional to R^3.

[2]

For Examiner's Use

(b) Isaac Newton (Fig. 10.3) developed a description of gravity that provided a mathematical backing for Kepler's work.

Fig. 10.3

(i) Suppose that a planet travels at speed v in a circular orbit of radius R. Using the equation for centripetal acceleration show that the centripetal force on the planet is given by the expression

$$F = \frac{M_p v^2}{R}.$$

[1]

(ii) Write down the equation that gives the magnitude of the gravitational force on a planet of mass M_p due to the Sun of mass M_s at distance R.

[1]

(iii) Hence show that

$$v^2 R = G M_s.$$

[1]

For Examiner's Use

(iv) For a circular orbit, the speed v is given by

$$v = \frac{2\pi R}{T}.$$

Use this and the result of **(b)(iii)** to show that Newton could predict Kepler's law in the form

$$\frac{(2\pi)^2 R^3}{G M_s} = T^2.$$

[2]

(v) Calculate the mass of the Sun M_s using the following data for the orbit of the planet.

$G = 6.7 \times 10^{-11}\,\text{N m}^2\,\text{kg}^{-2}$
$R = 1.5 \times 10^{11}\,\text{m}$
$T = 3.2 \times 10^{7}\,\text{s}$

mass of Sun = ... kg [2]

(c) The Sun loses mass at a rate of $6.2 \times 10^{11}\,\text{kg s}^{-1}$.

Suggest and explain how this mass loss might affect the orbit of the planet.

[2]

[Total: 11]

[Quality of Written Communication 4]

[Section B Total: 49]