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RECOGNISING ACHIEVEMENT

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OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS B (ADVANCING PHYSICS) 2863/01

Rise and Fall of the Clockwork Universe

Friday **21 JUNE 2002** Afternoon 1 hour 10 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 10 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name in the spaces above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces 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 round 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 values of standard physical constants are given in the Data, Formulae and Relationships Booklet. Any additional data required are given in the appropriate question.
- You will be awarded marks for the quality of written communication in Section B.
- You are advised to spend about 20 minutes on Section A and 50 minutes on Section B.

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

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

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Section A

1 Here is a list of units:

A $J\,m^{-2}$ **B** $N\,m^{-1}$ **C** $kg\,m\,s^{-2}$ **D** $N\,m^{-2}$

Which could be used as the unit of pressure?

Answer .....[1]

2 A laboratory has two samples of radioactive sources. The samples contain the same number of undecayed nuclei.

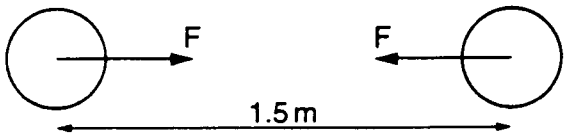
strontium-90	half-life 28 years
cobalt-60	half-life 5.3 years

The strontium-90 sample has a decay rate of 850 counts s^{-1}. Which of the following values is the best estimate for the decay rate of cobalt-60?

A 160 counts s^{-1} **B** 590 counts s^{-1} **C** 4500 counts s^{-1} **D** 24 000 counts s^{-1}

Answer .....[1]

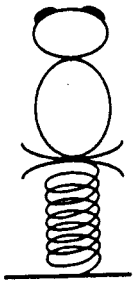
3 Two identical spheres are placed with their centres 1.5 m apart as shown. The mass of each sphere is 2.5 kg.



Show that the force of gravitational attraction between the spheres is 1.9×10^{-10} N.
($G = 6.67 \times 10^{-11}\ N\,m^2\,kg^{-2}$)

[2]

4 A novelty toy consists of a plastic frog mounted on a spring. The frog is pushed down and then released. This makes the frog jump into the air.



The stiffness constant of the spring is 220 N m^{-1}. The toy has a mass of 0.080 kg.

(a) Show that when the spring is compressed by 30 mm the energy stored in the spring is about 0.1 J.

[2]

(b) Calculate the maximum height the toy will reach when released, stating any assumption you make.

maximum height = ... m [3]

5 A central heating system contains 110 litres (110 kg) of water.

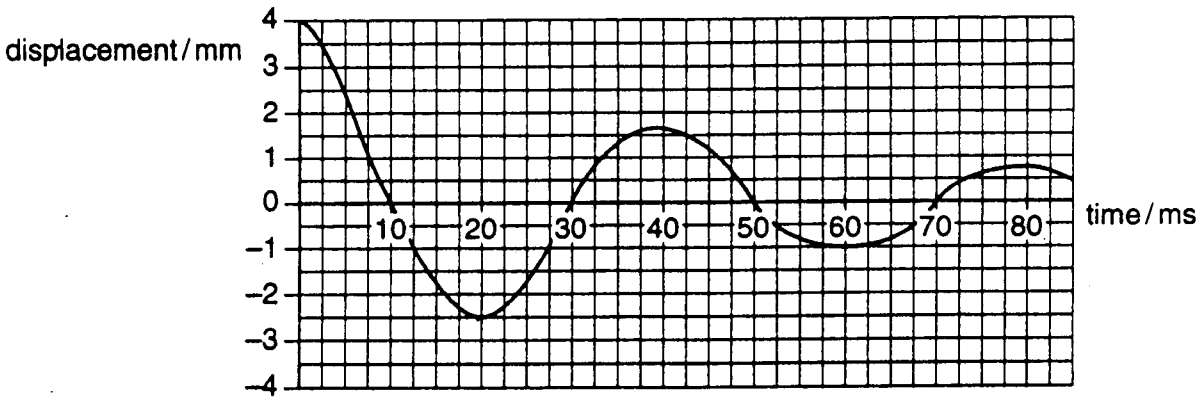
(a) Calculate the energy required to raise the temperature of all the water in the system from 10 °C to 40 °C. (specific thermal capacity of water = 4200 J kg^{-1} $°C^{-1}$)

energy required = ... J [2]

(b) The water is heated from 10 °C to 40 °C as it flows in a copper pipe above a gas flame. The water flows through the pipe at a rate of 5 kg per minute.
Calculate the rate of energy transfer to the water.

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

6 This is the displacement-time graph of a damped oscillator.



(a) Describe how the graph shows that the oscillation is damped.

[1]

(b) Which feature of the graph shows that the maximum velocity decreases from each oscillation to the next?

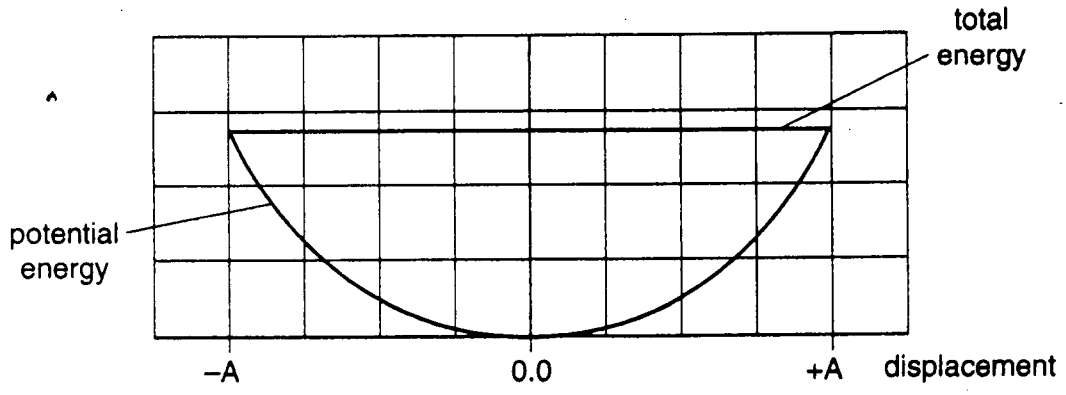
[2]

7 On the surface of the Earth the gravitational field strength, $g = 9.81\ \text{N kg}^{-1}$.

Explain what is meant by the term **'gravitational field strength'**.

[2]

8 The graph below shows how the total energy of an undamped oscillator varies with displacement. The graph also shows how the potential energy of the oscillator varies with displacement.



On the same axes draw a curve showing how the kinetic energy of the oscillator varies with displacement. [2]

[Turn over

Section B

Four marks in this section are awarded for quality of written communication.

9 This question is about using a capacitor to make a light flash on and off at regular intervals. A capacitor is connected in the circuit of Fig. 9.1.

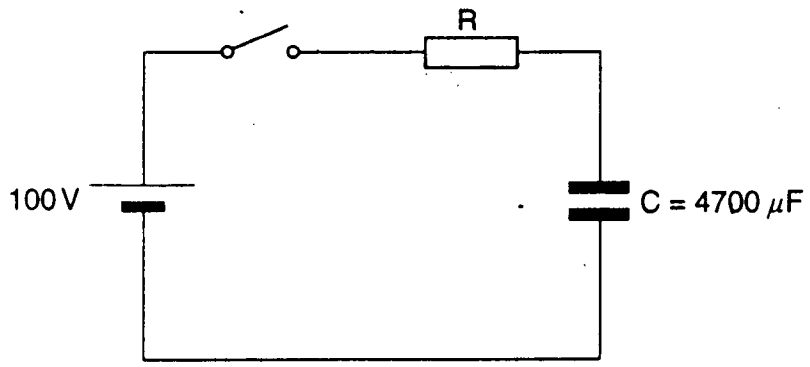


Fig. 9.1

The switch is closed and the capacitor is charged to a potential difference of 100 V.

(a) Calculate the charge on the capacitor.

charge = ... C [2]

(b) The time constant of the circuit is 0.70 s.

Calculate the value of the resistor, R.

resistance = ... Ω [2]

(c) The capacitor is discharged and a fluorescent lamp is connected into the circuit as shown in Fig. 9.2

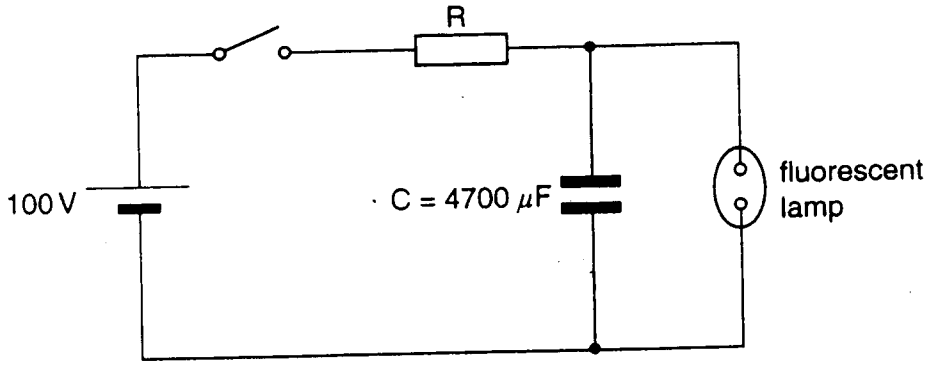


Fig. 9.2

The switch is closed and the capacitor begins to charge. When the p.d. across the capacitor reaches 72 V the lamp conducts. The capacitor discharges through the lamp which emits a flash of light.

(i) Show that the energy stored on the capacitor just before the discharge is about 12 J.

(ii) When the lamp flashes it transfers energy at an average rate of 150 W.

Show that the duration of the flash is about 0.08 s.

(iii) After the flash the lamp stops conducting and the capacitor begins to charge again. When the p.d. across the lamp reaches 72 V the process repeats.

Explain why the time interval between flashes is greater than the duration of the flash.

[6]

10 This question is about a new form of rocket engine called an Ion Drive that is used in the spacecraft Deep Space 1.
A stream of singly charged xenon ions enters the Ion Drive close to the anode. The ions are accelerated through a p.d. of 250 V and leave through a hole in the cathode as shown in Fig. 10.1.

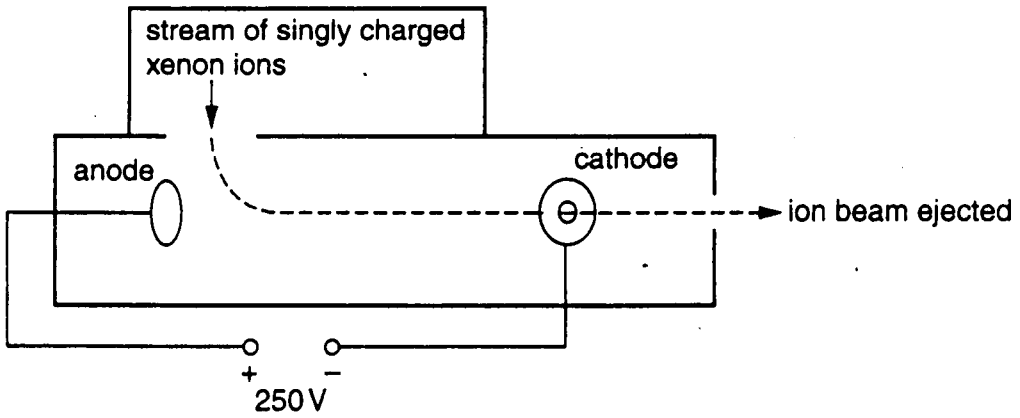


Fig. 10.1

(a) (i) Show that the kinetic energy gained by a single xenon ion is about 4×10^{-17} J when accelerated through a potential difference of 250 V.

(ii) The mass of a xenon ion is 2.2×10^{-25} kg. Show that the xenon ions leave the ion drive with a velocity of about 2×10^{4} m s^{-1}.

[3]

(b) (i) The drive ejects 2.9×10^{-6} kg of xenon each second. Show that the momentum gained by this amount of gas passing through the ion drive is about 0.06 kg m s^{-1}.

(ii) Explain why the force exerted on the spacecraft is about 0.06 N.

(iii) The spacecraft has a mass of 490 kg. Calculate the acceleration of the spacecraft.

acceleration = ... ms^{-2}

[5]

(c) Suggest and explain one possible effect of replacing the xenon ions with krypton ions, which have smaller mass but the same charge.

[2]

[Turn over

For Examiner's Use

11 This question is about gases under pressure.

One mole of helium gas is in a sealed container at 300 K and at a pressure of 2.0×10^5 Pa. The gas is slowly compressed to one third of its original volume without a temperature change. It behaves as an ideal gas.

(a) Calculate the new pressure of the gas.

pressure = ... Pa [2]

(b) Calculate the root mean square speed, c_{rms}, of the molecules at this temperature. (molar mass of helium = 4 g mol^{-1})

root mean square speed = ... m s^{-1} [2]

(c) Show that the root mean square speed goes up by a factor of $\sqrt{\frac{4}{3}}$ when the gas is heated to 400 K.

[2]

12 This question is about the expansion of the Universe.

(a) The speed of light is 3.0×10^8 m s^{-1}. Show that the distance light will travel through space in one year is about 10^{16} m.
(assume one year = 3.2×10^7 s)

[1]

(b) (i) During the past century it has been possible to observe galaxies which are receding from Earth.
One such galaxy is observed in the area of the sky known as Virgo. The distance to this galaxy is 10 000 million light years.
Explain why the galaxy is observed as it was 10 000 million years ago.

(ii) Show that the galaxy is about 1.0×10^{26} m from Earth.

[2]

(c) The light from the galaxy shows 'red-shift'. This is thought to be due to the expansion of space and is called 'cosmological red-shift'.

(i) Explain what is meant by 'red-shift'.

(ii) Explain how the expansion of space causes a cosmological red-shift.

(iii) The cosmological red-shift is greater for galaxies further away from the Earth. Describe how the model of an expanding universe explains this observation.

[6]

13 This question is about how the density of the air varies with height above the Earth's surface.

At sea level the density of the atmosphere is about 1.2 kg m^{-3}.

Consider nitrogen at a temperature of 300 K.

(a) Show that the average energy of a particle at this temperature is about 4.1×10^{-21} J.

[1]

(b) Show that the energy, E, required to lift a nitrogen molecule of mass 4.6×10^{-26} kg to a height 3000 m above sea level is about 1.4×10^{-21} J.

[1]

(c) Show that the Boltzmann factor, $e^{-E/kT}$, for the energy E found in part **(b)** at a temperature of 300 K is about 0.71.

[2]

Fig. 13.1 shows a graph of density of air against height above sea level. The atmospheric temperature is assumed to remain constant with height in this model.

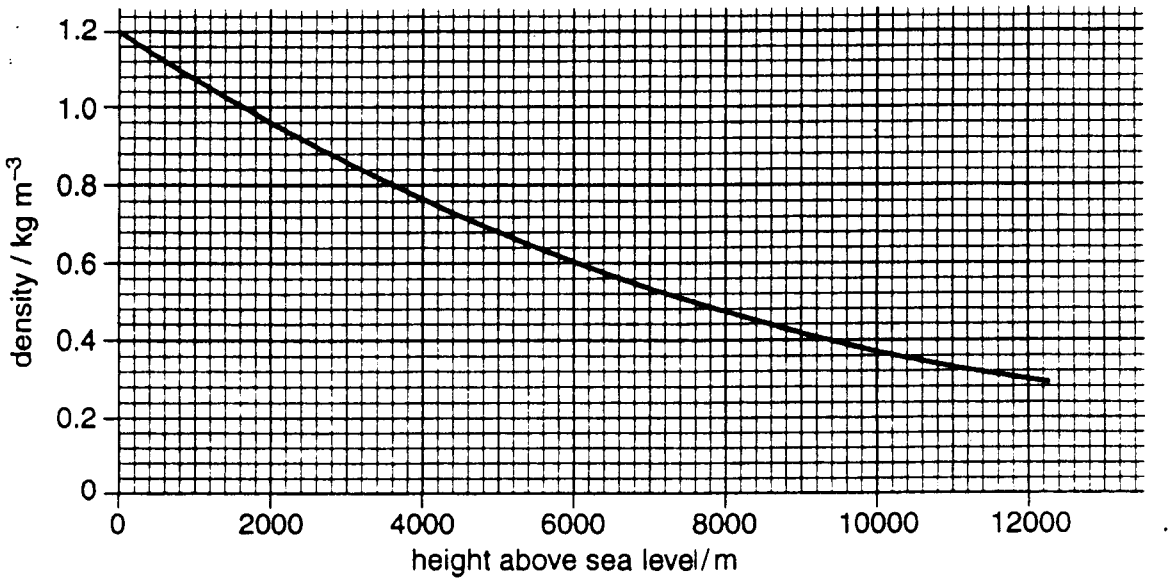


Fig. 13.1

(d) (i) The graph shows that density decreases with increasing height. Explain how the Boltzmann factor helps to account for this fact.

[2]

(ii) Propose and carry out a test to decide whether the density falls exponentially with height above sea level.

Proposed test:

Calculation:

Conclusion:

[3]

(e) In fact, atmospheric temperature decreases with height above sea level.
Explain why this makes the Boltzmann factor become smaller with height above sea level.

[2]

Quality of Written Communication [4]