RECOGNISING ACHIEVEMENT

ADVANCED GCE UNIT **2863/01**

PHYSICS B (ADVANCING PHYSICS)

Rise and Fall of the Clockwork Universe

THURSDAY 14 JUNE 2007 Morning

Time: 1 hour 15 minutes

Additional materials:
Data, Formulae and Relationships Booklet
Electronic calculator
Ruler (cm/mm)

CUP/T23237

Candidate Name

Centre Number | | | | |

Candidate Number | | | |

INSTRUCTIONS TO CANDIDATES

- Write your name, Centre Number and Candidate Number in the boxes above.
- Answer **all** the questions.
- Use blue or black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Do **not** write in the bar code.
- Do **not** write outside the box bordering each page.
- WRITE YOUR ANSWER TO EACH QUESTION IN THE SPACE PROVIDED. ANSWERS WRITTEN ELSEWHERE WILL NOT BE MARKED.
- 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 for each question 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.
- 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 document consists of **15** printed pages and **1** blank page.

Section A

Answer **all** the questions.

1 Study the circuit in Fig. 1.1.

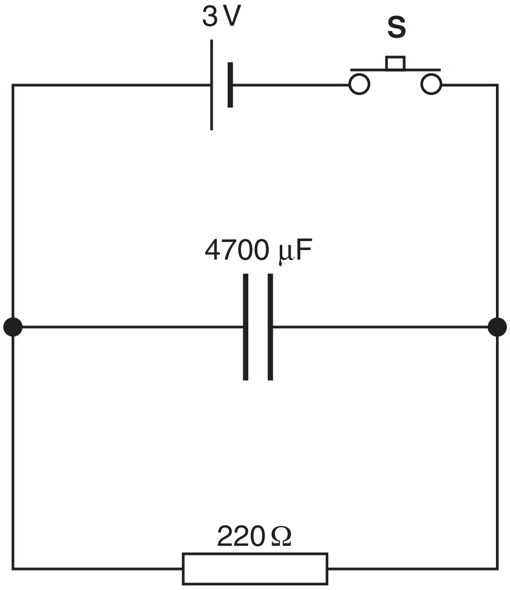


Fig. 1.1

The switch **S** is closed to charge the capacitor. When the switch is opened the capacitor discharges through the resistor.

Here is a list of values:

1.4×10^{-2} 2.1×10^{-2} 1.0 1.4 2.1

Choose from the list the value that is closest to

(a) the time constant τ of the circuit in seconds

value .... s

(b) the charge in coulombs on the capacitor when at a p.d. of 3.0 V

value C

(c) the energy stored on the capacitor in joules when at a p.d. of 3.0 V

value .... J

(d) the initial value of the current in ampere when the fully charged capacitor discharges through the resistor.

value .... A

[4]

2 Fig. 2.1 shows the variation in gravitational field strength near the Earth.

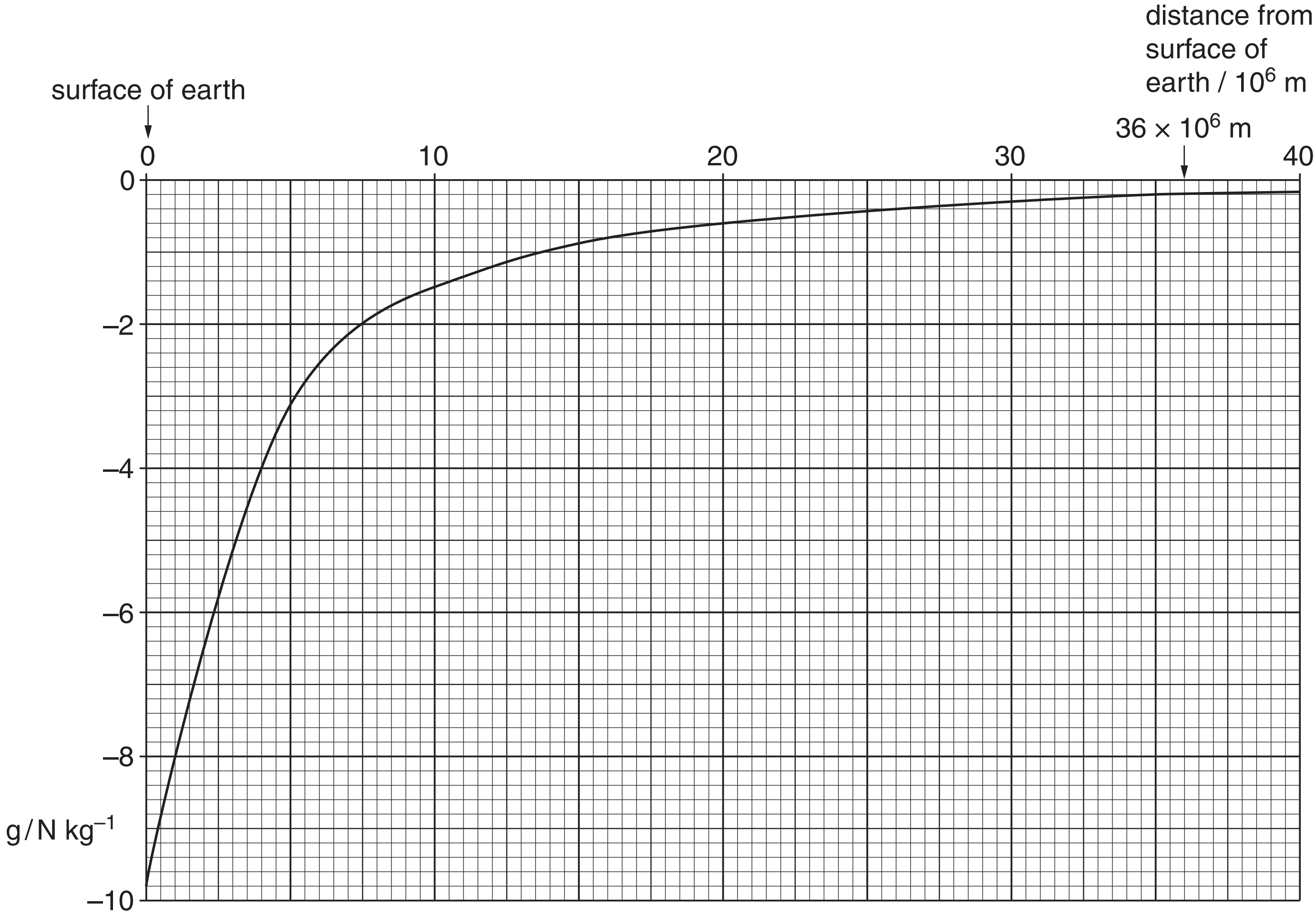


Fig. 2.1

Geostationary satellites orbit at a height of 36×10^6 m above the surface of the Earth.

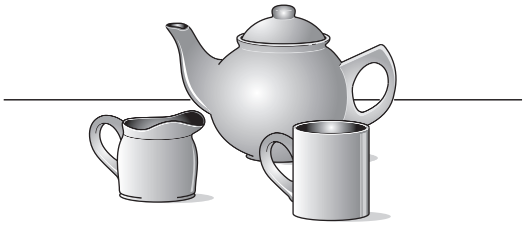
(a) Use the graph to show that the change in gravitational potential between the surface of the Earth and a height of 36×10^6 m is about 5×10^7 J kg^{-1}. Explain your method.

[3]

(b) Calculate the gravitational potential energy gained when a 900 kg satellite is raised from the surface of the Earth to a geostationary orbit.

energy = ... J [2]

3 0.18 kg of tea in a cup is at a temperature of 80 °C. When milk at 5 °C is added to the tea the temperature of the mixture becomes 70 °C. No energy is lost to the teacup or its surroundings during the change.



(a) Show that the energy of the hot tea decreases by about 7.6 kJ as its temperature falls to 70 °C.

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

[1]

(b) Calculate the mass of the milk added to the tea. Assume that all the energy used to warm the milk comes from the tea.

specific thermal capacity of milk = 4000 J kg^{-1} K^{-1}

mass of milk = ………………… kg [2]

4 The ratio E/kT can be used to consider whether iron atoms will evaporate from the surface of solid iron.

E is the energy required for an atom to leave the surface of iron,
T is the temperature in kelvin,
k is the Boltzmann constant = 1.4×10^{-23} J K^{-1}.

(a) State what is indicated by the energy kT.

[1]

(b) Iron does not evaporate when T = 300 K. Suggest what this fact indicates about the magnitude of the energy E.

[1]

5 On take-off an air-powered rocket ejects 7×10^{-3} kg of air at a velocity of 250 m s^{-1}.

(a) Calculate the momentum of the air leaving the rocket.

momentum = ………………… kg m s^{-1} [2]

(b) The air is ejected over 0.2 s. Calculate the average thrust on the rocket.

thrust = ………………… N [2]

6 Two moles of nitrogen gas are at a pressure of 4.0×10^5 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.

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

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

[Section A Total: 21]

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

Section B

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

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

Fig. 7.1

Saturn has a system of rings that orbit the planet. The rings are composed of pieces of ice and rock varying in diameter from about one centimetre to ten metres.

(a) Observations from Earth show that the wavelengths of the light from point **A** are stretched by a very small amount. The wavelengths of the light from point **B** are reduced by a very small amount. Suggest a reason for these observations.

[1]

(b) Consider a piece of rock of mass 3000 kg in a ring at a distance of 1.8×10^8 m from the centre of the planet. The rock orbits the planet at a speed of 1.5×10^4 m s^{-1}.

(i) Show that it takes the rock about 21 hours to orbit the planet at this distance.

[2]

(ii) Show that the centripetal force on the rock is about 3800 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]

(c) Show that the speed of a rock in a ring is given by

$$v = \sqrt{\frac{GM}{r}}$$

where M is the mass of Saturn and
r is the distance between the rock and the centre of Saturn.

[2]

(d) A rock at a distance of 1.8×10^8 m from the centre of Saturn orbits the planet at a speed of about 1.5×10^4 m s^{-1}.

Explain why a rock four times the distance from the centre of the planet orbits at half this speed.

[2]

[Total: 11]

8 This question is about an americium-241 radionuclide source used in a smoke detector.

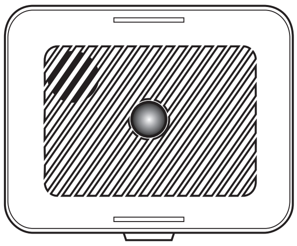


Fig. 8.1

Here are some data about the source:

activity of source = 3.3×10^4 Bq

decay constant, λ = $4.8 \times 10^{-11}\ s^{-1}$

(a) Show that the source initially contains about 7×10^{14} americium nuclei.

[2]

(b) Show that the half-life of the source is about 450 years.

1 year = 3.2×10^7 s

[3]

(c) The smoke detector works by detecting a decrease in the arrival of alpha particles from the americium when they are absorbed by the smoke. It is advised that the smoke detector is replaced after five years.

Use the equation $\Delta N = -\lambda N \Delta t$ with N taken as the original number of nuclei to show that about 5×10^{12} nuclei decay in the five years of use.

[2]

(d) Explain why

- it is reasonable to use the equation $\Delta N = -\lambda N \Delta t$ (as above) to estimate the number of nuclei decaying over a five year period
- the equation used in this way would **not** give an accurate answer for the number of nuclei decaying over a few hundred years.

[2]

(e) Explain why a decrease in activity of the sample is not likely to be the reason that the smoke detector should be replaced after five years. Suggest a more likely reason that the detector might need replacing.

[2]

[Total: 11]

9 This question is about the speed of bromine molecules at room temperature.

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

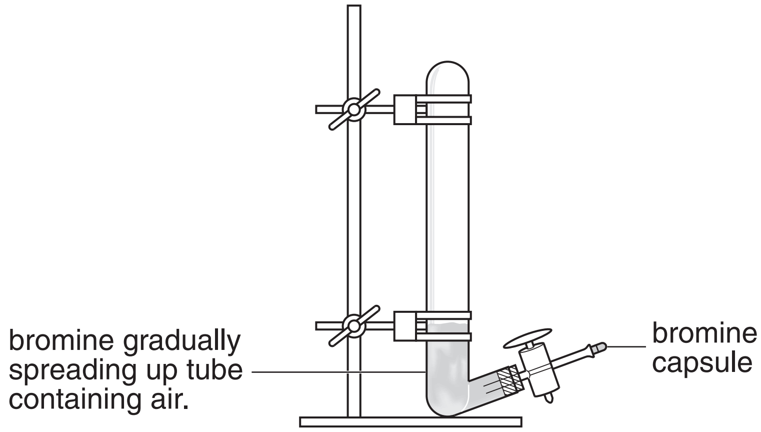


Fig. 9.1

(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

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

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

(i) Show that the average translational kinetic energy of a bromine molecule at 25 °C is about 6×10^{-21} J.

[2]

(ii) Show that the root mean square speed, $\sqrt{\overline{v^2}}$, of bromine molecules at 25 °C is about 200 m s^{-1}.

mass of bromine molecule = 2.7×10^{-25} kg

[2]

(b) The bromine gas is observed to rise about 0.1 m up the tube in 480 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 480 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) Suggest and explain any change you would expect to the rate of diffusion when the experiment is repeated at the same temperature with molecules of a lower mass than bromine.

suggested observation:

explanation:

[3]

[Total: 10]

10 This question is about investigating the physics of bungee jumping.

A student models a bungee jump by hanging a tennis ball of mass 0.12 kg from a single strand of elastic thread with unstretched length of 0.95 m as shown in Fig. 10.1.

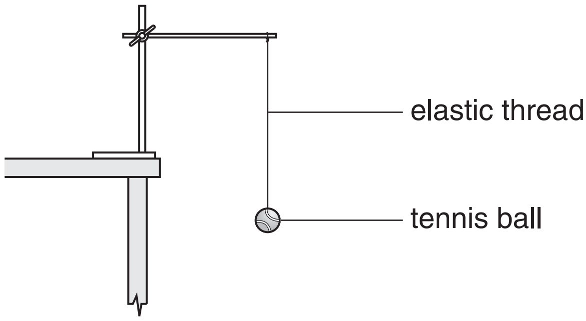


Fig. 10.1

(a) (i) Show that the weight of the ball is about 1.2 N.

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

[1]

(ii) The elastic thread has a stiffness constant of 3.1 N m^{-1}. Show that the elastic thread will stretch to a length of about 1.3 m when the ball is hanging from the end.

[2]

(iii) Explain why the resultant force on the tennis ball is zero when the thread is at this length.

[1]

(b) The ball is dropped from a position level with the top of the elastic thread as shown in Fig. 10.2.

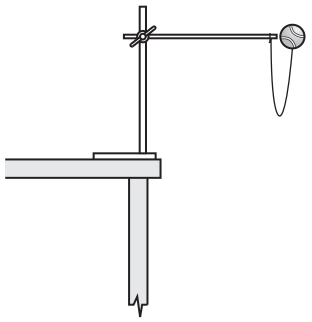


Fig. 10.2

Fig. 10.3 shows the graph of the resultant force on the ball as the distance fallen increases.

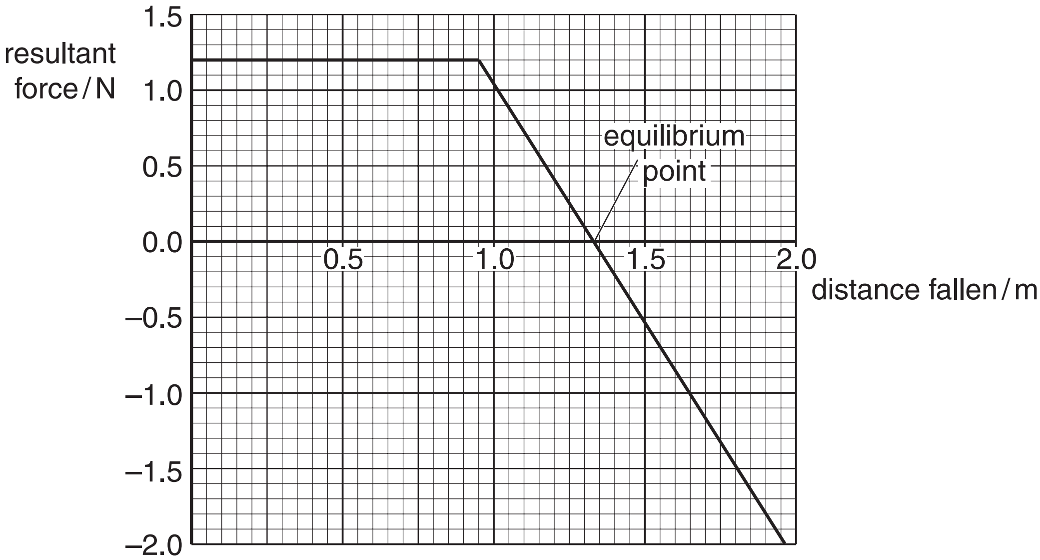


Fig. 10.3

Using the graph or by calculation show that

(i) the kinetic energy of the ball when it has fallen 0.95 m is about 1 J.

[1]

Question 10 is continued over the page.

(ii) the kinetic energy of the ball when it has fallen to the point of zero resultant force (equilibrium point) is about 1.3 J.

[2]

(c) The ball oscillates vertically. The amplitude decreases and after a number of oscillations the ball comes to rest at the equilibrium point.

(i) Explain how the graph shows that the motion could be described as simple harmonic for amplitudes less than about 0.4 m but cannot be simple harmonic for greater amplitudes.

[4]

(ii) Calculate the frequency of the small amplitude oscillations.

frequency = ………………… Hz [2]

[Total: 13]

Quality of Written Communication [4]

[Section B Total: 49]

END OF QUESTION PAPER