OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE UNIT

2863/01

PHYSICS B (ADVANCING PHYSICS)

Rise and Fall of the Clockwork Universe

MONDAY 22 JANUARY 2007

Morning

Time: 1 hour 15 minutes

Additional materials:
Data, Formulae and Relationships Booklet
Electronic calculator

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 round 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.
- 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**	

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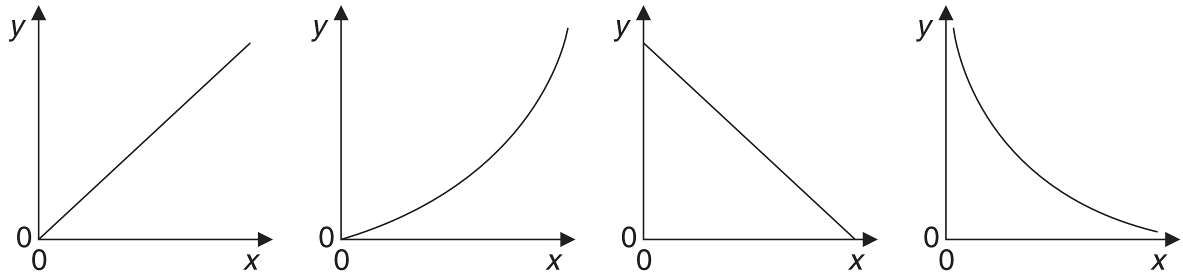
Answer **all** the questions.

Section A

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



A **B** **C** **D**

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

answer .... [1]

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

answer .... [1]

(c) Which graph shows the variation in **energy stored** (y) on a capacitor with **potential difference** (x) across the capacitor?

answer .... [1]

2 Fig. 2.1 shows a diagram of the region of space near the Earth.

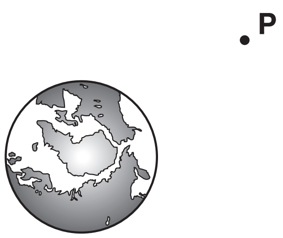


Fig. 2.1

(a) Draw an arrow through point **P** to show the direction of the gravitational field at that point. [1]

(b) Draw a line on Fig. 2.1 to show the shape of the equipotential which passes through point **P**. Label the line 'equipotential'. [1]

3 A cubical container is filled with helium gas.

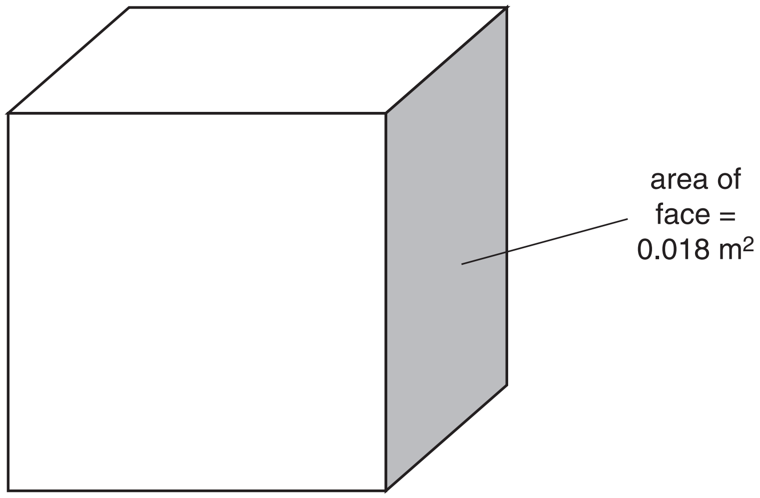


Fig. 3.1

When an atom of helium makes an elastic collision perpendicular to a face of the container it experiences a change of momentum of $5.4 \times 10^{-24}\,\mathrm{kg\,m\,s^{-1}}$.

(a) In one second there are the equivalent of 5.1×10^{24} collisions perpendicular to each face of the container. Calculate the force exerted by the gas on one face of the container.

force = ... N [2]

(b) Calculate the pressure exerted by the gas.

area of face of container = $0.018\,\mathrm{m^2}$

pressure = ... Pa [1]

4 Protoactinium decays with a decay constant λ of $9.7 \times 10^{-3}\,s^{-1}$.

(a) Show that the expected number of decays in one second in a sample of 10^4 protoactinium atoms is about $10^2\,s^{-1}$.

[1]

(b) A student suggests that all the protoactinium will have decayed after about 100 s and draws the graph in Fig. 4.1 to explain why.

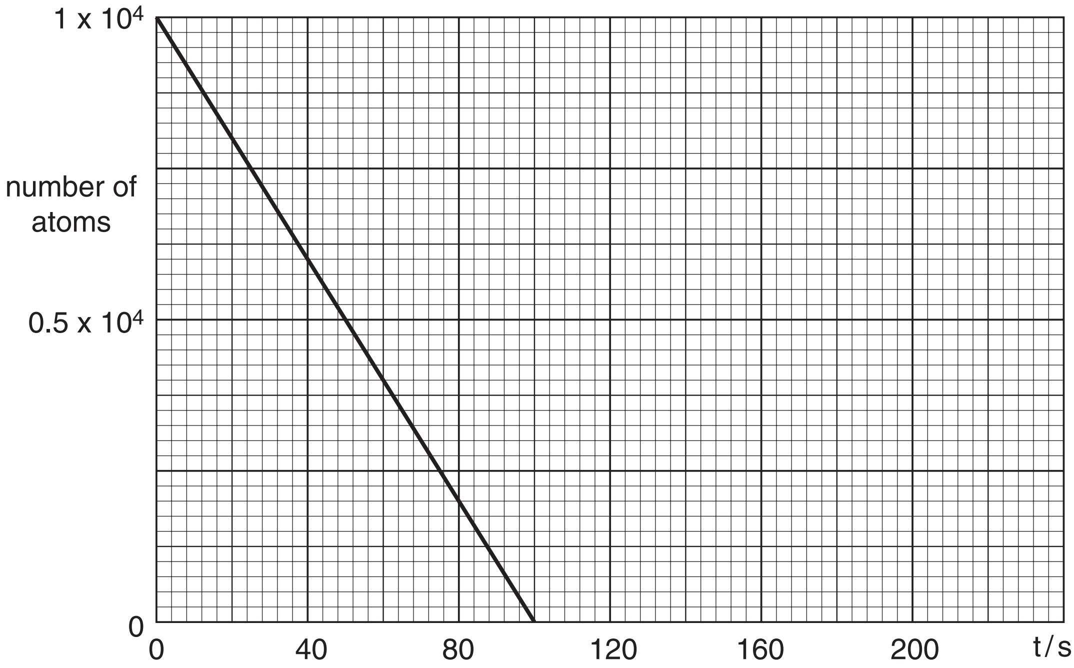


Fig. 4.1

(i) Sketch a more appropriate decay graph on Fig. 4.1. [2]

(ii) Explain why the student's reasoning is wrong.

[1]

5 A satellite of mass 650 kg orbits the Earth at a distance of 4.2×10^7 m from the centre of the Earth.

(a) Show that the magnitude of the gravitational force on the satellite is about 150 N. State the equation used in the calculation.

mass of Earth = 6.0×10^{24} kg
$G = 6.7 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$

[2]

(b) This value is the centripetal force acting on the 650 kg satellite.

Calculate the speed of the satellite in orbit.

speed = ... $\mathrm{m\,s^{-1}}$ [3]

6 A balloon contains a volume of $1.1 \times 10^{-3}\,\mathrm{m^3}$ of gas. The temperature of the gas is 298 K. The gas is at a pressure of 2.2×10^5 Pa. It behaves as an ideal gas.

Show that the balloon contains about 0.1 mol of gas. State the equation you use.

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

[2]

7 A capacitor stores a charge of 5.6 mC at a p.d. of 12 V.

Calculate the value of the capacitance.

capacitance = ... F [2]

[Section A Total: 21]

Section B

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

8 This question is about a possible explanation of the formation of craters on the Moon. It considers the effect of a 30 kg rock striking the surface of the Moon.

(a) In this part of the question ignore the effects of the Sun and the Earth.

(i) Show that the gravitational potential at the surface of the Moon is about $-3 \times 10^6\,\mathrm{J\,kg^{-1}}$.

mass of Moon = 7.4×10^{22} kg
radius of Moon = 1.7×10^6 m
$G = 6.7 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$

[1]

(ii) Show that the potential energy of a 30 kg rock at the surface of the Moon is about -9×10^7 J.

[1]

(iii) Explain, without further calculation, why the kinetic energy gained by the rock as it approaches the Moon from a great distance is about $+9 \times 10^7$ J.

[2]

(b) It has been suggested that the kinetic energy of the rock is transferred into sufficient internal energy to melt the rock.

(i) The rock needs to reach a temperature of about 1500 K to start melting.

Show that about 1.7×10^6 J are required to bring 1 kg of the rock to melting point.

original temperature of rock = 90 K
specific thermal capacity of rock = $1.2 \times 10^3\,\mathrm{J\,kg^{-1}\,K^{-1}}$

[1]

(ii) It requires an extra $4.8 \times 10^5\,J\,kg^{-1}$ to melt the rock completely.

Calculate whether the energy of the 30 kg rock as it strikes the surface is enough to raise it to 1500 K and then melt the rock.

[3]

(c) Images such as Fig. 8.1 suggest that not all the kinetic energy of rocks that hit the Moon's surface is transferred to internal energy.

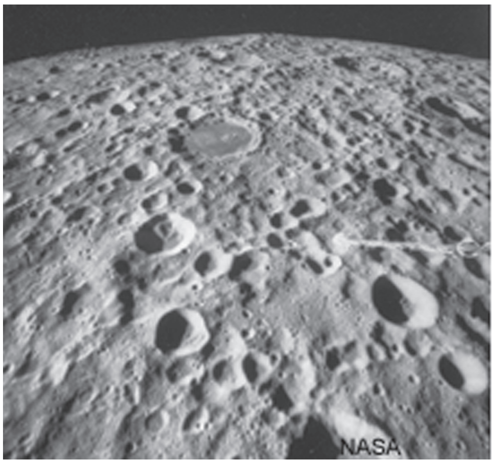


Fig. 8.1

Use Fig. 8.1 to suggest and explain one other effect of a large rock colliding with the Moon.

[2]

[Total: 10]

9 This question is about the oscillation of a mass between a pair of springs as shown in Fig. 9.1.

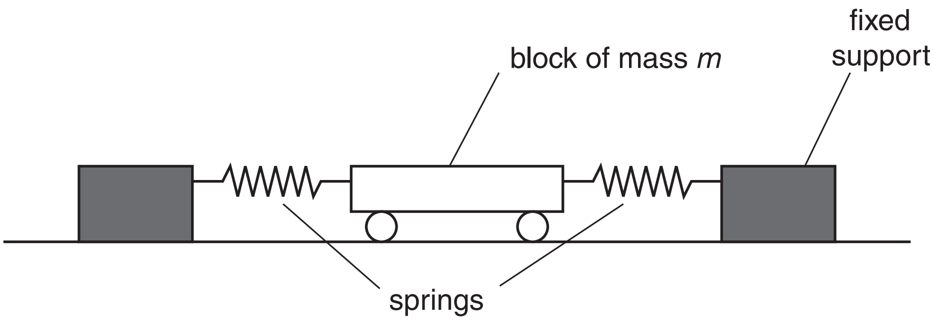


Fig. 9.1

(a) The system obeys Hooke's Law with a stiffness constant k.

The block is displaced a horizontal distance x and released.

(i) Show that the initial acceleration a of the mass m is given by

$$a = -\frac{kx}{m}.$$

[2]

(ii) Explain why the equation in **(i)** shows that the body will undergo simple harmonic motion.

[2]

(iii) The acceleration of the mass is also given by the equation

$$a = -4\pi^2 f^2 x.$$

Use this equation and the equation from **(i)** to show that

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}.$$

[1]

(b) Such a system is used as a **damper** to reduce the movement of tall buildings in earthquakes or high winds as shown in Fig. 9.2.

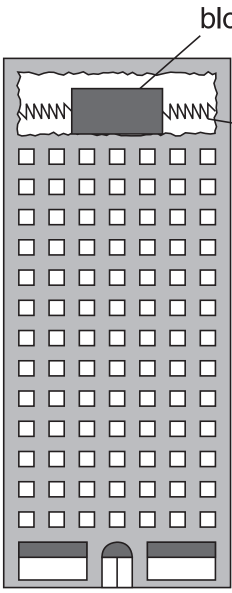


Fig. 9.2 **not to scale**

Here are some data for this damper system.

mass of block = 290 000 kg
stiffness constant of the system = $2.8 \times 10^6\,N\,m^{-1}$

The system is designed to reduce the oscillations of a building which has a natural frequency of 0.5 Hz.

(i) Show that the frequency of the mass oscillating between springs matches the natural frequency of the building.

[2]

(ii) A sudden movement of the building displaces the block 0.7 m from its equilibrium position relative to the building.

Show that the energy transferred to the oscillator is about 700 kJ.

[1]

(c) The oscillator is damped. It loses 50% of its **energy** on each oscillation.

(i) Show that the **amplitude** of the oscillator is reduced from 0.7 m to 0.5 m after one complete oscillation.

[2]

(ii) Calculate the number of oscillations it takes for the amplitude to fall to one eighth of its original value.

number of oscillations = ... [2]

(d) Suggest why dampers are more effective when placed near the top of the buildings.

[1]

[Total: 13]

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10 This question is about using the Boltzmann factor to explain why wet clothes dry more quickly on a hot day.

Fig. 10.1

(a) To evaporate 1.0 kg of water requires 2.3×10^6 J.

(i) Show that the energy E needed for a water molecule to escape into the vapour is about 6.9×10^{-20} J.

molar mass of water = 0.018 kg
Avogadro number, number of particles in one mole = $6.0 \times 10^{23}\,\text{mol}^{-1}$

[2]

(ii) The average energy kT of a particle at 283 K is about 3.9×10^{-21} J.

Calculate the ratio E/kT.

ratio = ... [1]

(b) (i) Calculate the Boltzmann factor, $f = e^{-E/kT}$ for the vaporisation of water at 283 K.

Boltzmann factor = ... [1]

(ii) Plot your calculated value for the Boltzmann factor on the graph in Fig. 10.2. [1]

(iii) Draw a suitable line through the data points on Fig. 10.2. [1]

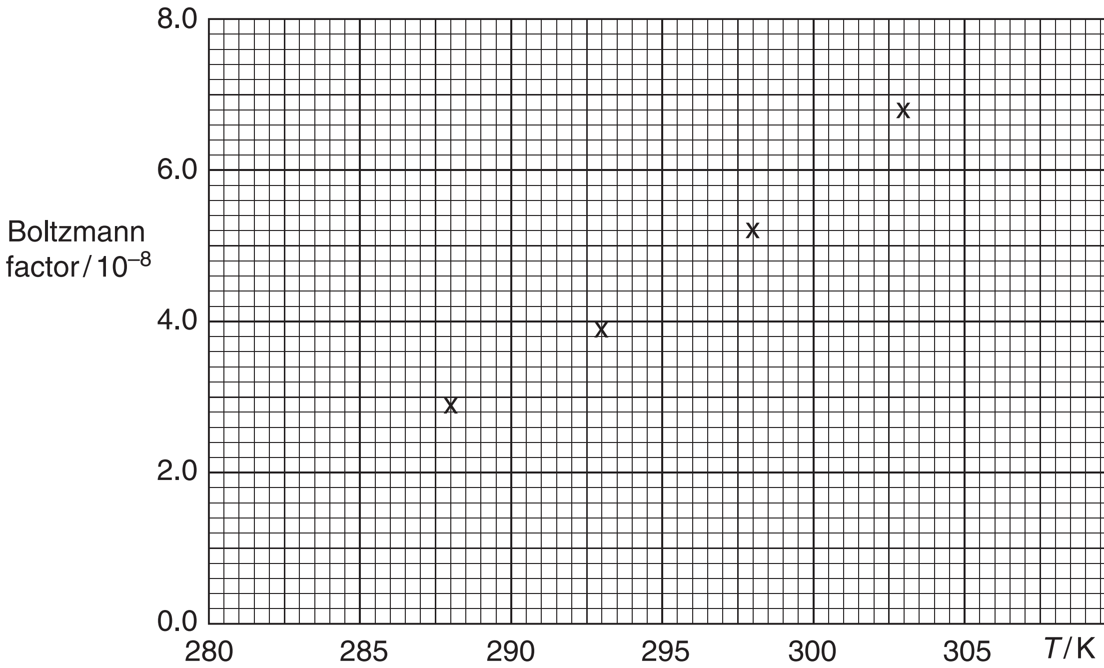

Fig. 10.2

(c) (i) Explain how the equation $f = e^{-E/kT}$ shows that the Boltzmann factor increases with temperature.

[2]

(ii) Explain why the rate of evaporation of water will increase when the Boltzmann factor increases.

[2]

(iii) It has been suggested that clothes will take about twice as long a time to dry at 293 K than they do at 303 K. Use data from the graph to explain whether this is a reasonable suggestion.

[2]

[Total: 12]

11 This question is about observations which suggest that space is expanding.

In 1929 Edwin Hubble (Fig. 11.1) suggested that distant galaxies were moving away (receding) from our own galaxy with velocities that are directly proportional to the distance to the galaxy. This is known as Hubble's law.

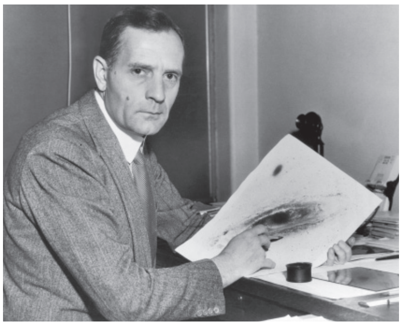

Fig. 11.1

Some data collected by Hubble are given in the table below.

galaxy	**distance to galaxy / light years**	**velocity of recession / m s^{-1}**
NGC 221	9.0×10^5	2.0×10^5
NGC 379	2.3×10^7	2.2×10^6
Gemini cluster	1.4×10^8	2.3×10^7

(a) Propose and carry out an arithmetical test to decide if velocity of recession is directly proportional to distance.

test proposed:

working:

conclusion:

[4]

Hubble's Law can be written in the form

velocity of recession = H_o × *distance from galaxy*

where H_o is the Hubble constant.

The accepted value of H_o in 2005 was $2.2 \times 10^{-18}\,s^{-1}$. This is considerably lower than Hubble's early results suggested.

(b) Use the data on the Gemini cluster given in the table to calculate a value for H_o. Show that this value is about eight times the modern value.

One light year is the distance light travels in one year.

1 year = $3.2 \times 10^{7}\,s$
velocity of light = $3.0 \times 10^{8}\,m\,s^{-1}$

[3]

The speed of recession of the galaxies is found from observations of *redshift*. It is thought that distant galaxies show *cosmological redshift* which gives evidence that the speed of recession is due to the expansion of the Universe.

(c) **(i)** State what is meant by the term *redshift*.

[1]

(ii) Explain why the expansion of space will cause light from more distant galaxies to show greater redshift.

[2]

[Total: 10]

Quality of Written Communication [4]

[Section B Total: 49]

END OF QUESTION PAPER

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