OCR RECOGNISING ACHIEVEMENT

ADVANCED GCE **2863/01**

PHYSICS B (ADVANCING PHYSICS)

Rise and Fall of the Clockwork Universe

WEDNESDAY 11 JUNE 2008 Morning

Time: 1 hour 15 minutes

Candidates answer on the question paper.
Additional materials: Data, Formulae and Relationships Booklet
Electronic calculator
Ruler (cm/mm)

CUP/T45495

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use blue or black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided.
- 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	**20**	
B	**50**	
TOTAL	**70**	

This document consists of **16** printed pages and **4** blank pages.

Section A

Answer **all** the questions.

1 Here is a list of units.

J $\quad$ J s^{-1} $\quad$ N kg^{-1} $\quad$ s^{-1} $\quad$ s

Choose from the list the unit for

(a) the time constant, $\tau = RC$

unit = ...

(b) the work done in stretching a spring

unit = ...

(c) the activity of a radioisotope.

unit = ...

[3]

2 An arrow is fired horizontally at a speed of 45 m s^{-1}.

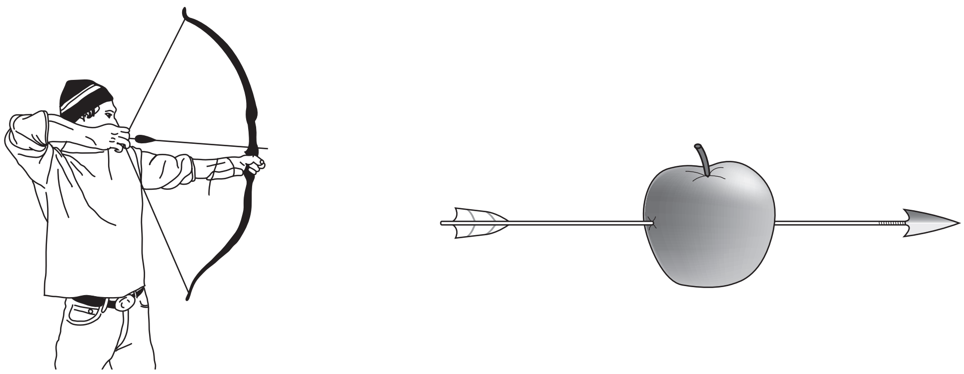


Fig. 2.1

(a) The momentum of the arrow is 3.5 kg m s^{-1} as it leaves the bow. Show that the mass of the arrow is about 0.08 kg.

[1]

(b) The arrow strikes an apple of mass 0.12 kg. The arrow embeds itself in the apple and the two objects move off together. Calculate the velocity of the arrow and apple.
Assume the arrow is moving horizontally with a speed of 45 m s^{-1} when it strikes the apple.

velocity of apple and arrow = ... m s^{-1} [1]

3 Here are some data about a capacitor

capacitance = 470 μF

p.d. across fully charged capacitor = 12 V.

(a) Show that the charge on the capacitor is about 5.6 mC.

[1]

The capacitor is discharged through a resistor. After three seconds the p.d. across the capacitor has fallen to 10 V.

(b) Show that a charge of about 0.9 mC passes through the resistor as the p.d. across the capacitor falls to 10 V.

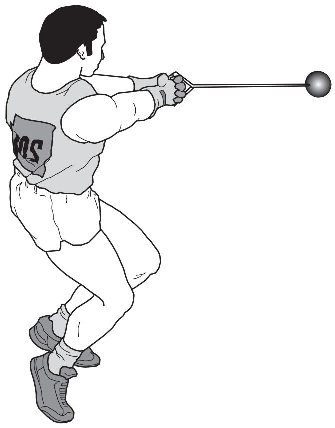
[2]

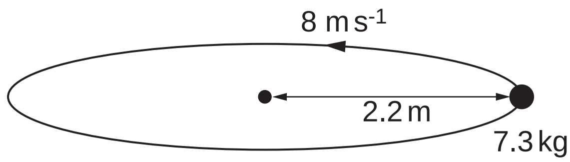
(c) The average current in the resistor as the p.d. across the capacitor falls from 12 V to 10 V is about 0.3 mA.

Explain why 0.3 mA is an **average** value.

[1]

4 A hammer thrower swings a mass of 7.3 kg in a circle around his body in 1.7 s. The mass is 2.2 m from the centre of the thrower's body.





(a) Show that the speed of the mass is about 8 m s^{-1}.

[1]

(b) Calculate the centripetal force on the mass.

centripetal force on the mass .... N [2]

5 Rooms can be warmed by 'storage heaters'. In one form of storage heater a large block of concrete is heated at night when electricity costs less. The concrete cools down during the day, releasing energy to the room.

150 kg of concrete are heated to 90 °C. During the day the concrete cools to 35 °C.

Calculate the energy released as the concrete cools.

specific thermal capacity of concrete = 3350 J kg^{-1} °C^{-1}

energy released = ... J [2]

6 An experiment is performed to measure the volume of water in a can at regular intervals as the water drains through a small hole. A graph of the results is shown in Fig. 6.1.

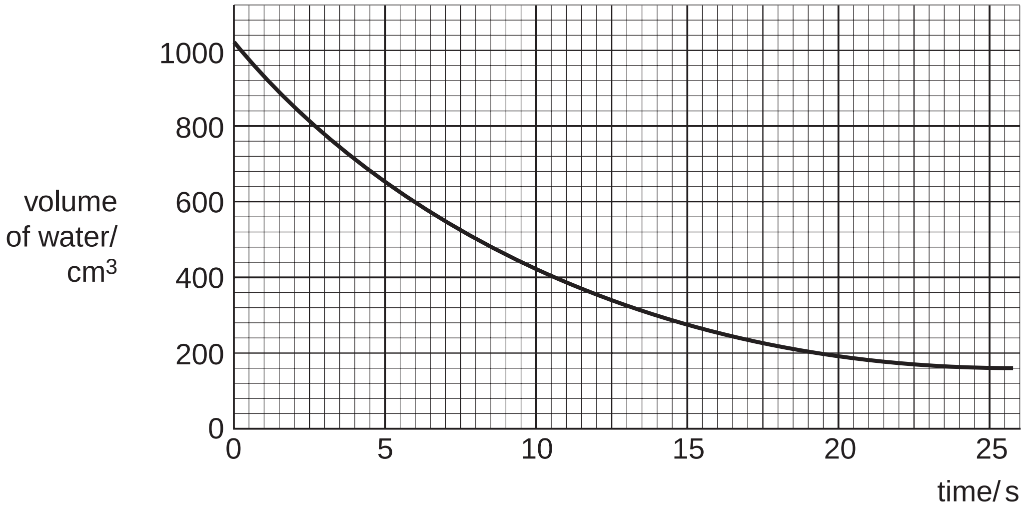


Fig. 6.1

The volume of water in the can is changing exponentially. The rate of change of volume, $\frac{\Delta V}{\Delta t}$, is given by the equation

$$\frac{\Delta V}{\Delta t} = -\phi V$$

where ϕ is a constant.

(a) Suggest one way to modify the can, hole or liquid to increase the value of ϕ.

[1]

(b) ϕ can by found from the graph using the relationship

$$\phi = \frac{\ln 2}{t_{1/2}}$$

where $t_{1/2}$ is the time for the volume of water in the can to reduce to half its original value. Use the graph to estimate a value for ϕ.

ϕ = ... unit .... [3]

7 The apparatus in Fig. 7.1 is used to investigate how the amplitude of oscillation of a metal strip varies as the frequency of the vibration generator is changed.

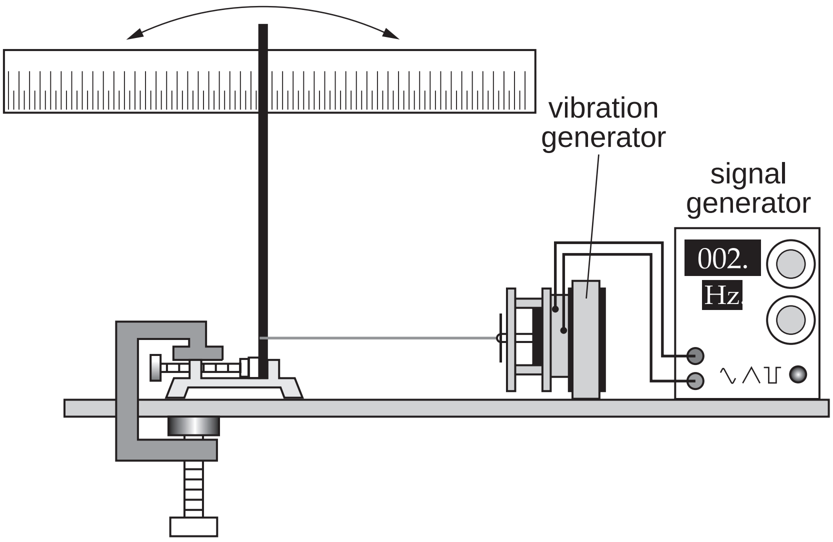


Fig. 7.1

Fig. 7.2 shows the graph obtained from the experiment.

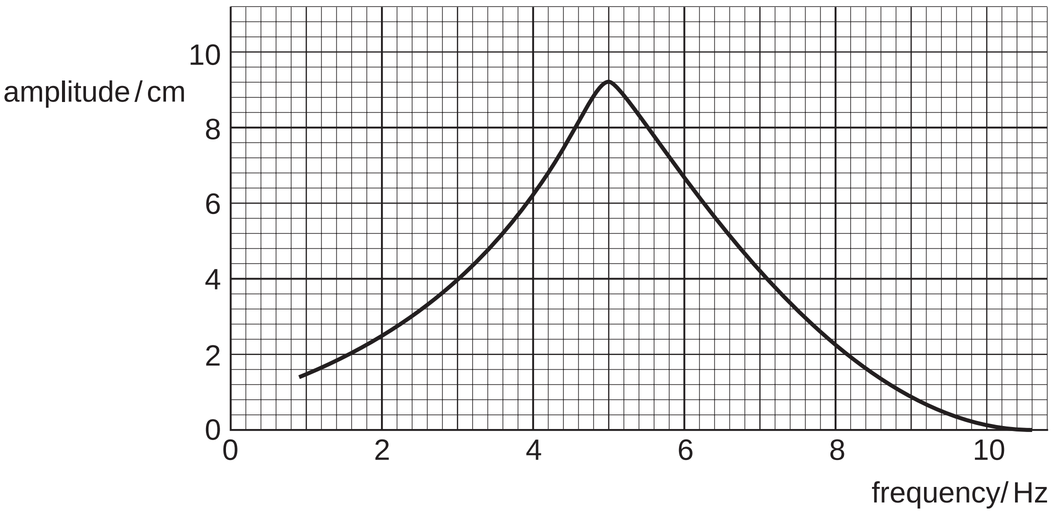


Fig. 7.2

(a) State the natural frequency of the metal strip.

natural frequency = ... Hz [1]

(b) Suggest how the curve would change if the experiment were repeated with a similar, but longer metal strip.

[1]

[Section A Total: 20]

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

Section B

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

8 This question is about a rocket used to take tourists to the 'edge of space' 100 km above the surface of the Earth.

A rocket carrying three people is taken to a height of about 10 km above the Earth's surface on the back of a second carrier craft. See Figs 8.1 and 8.2.

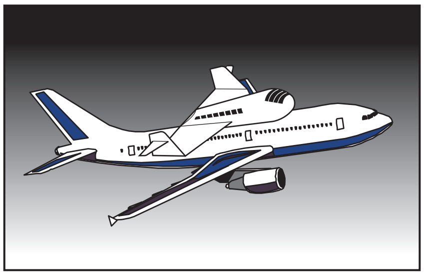


Fig. 8.1

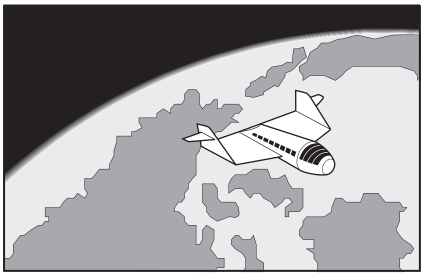


Fig. 8.2

At this height the air pressure is only 25% of that at the surface. The small rocket is released from the carrier craft and ignites its fuel.

(a) Suggest and explain an advantage of accelerating the rocket from a height at which air pressure is significantly reduced.

[2]

The rocket rises to a height of over 100 km above the Earth's surface.
Fig. 8.3 shows how the gravitational potential varies with height h near the Earth's surface.

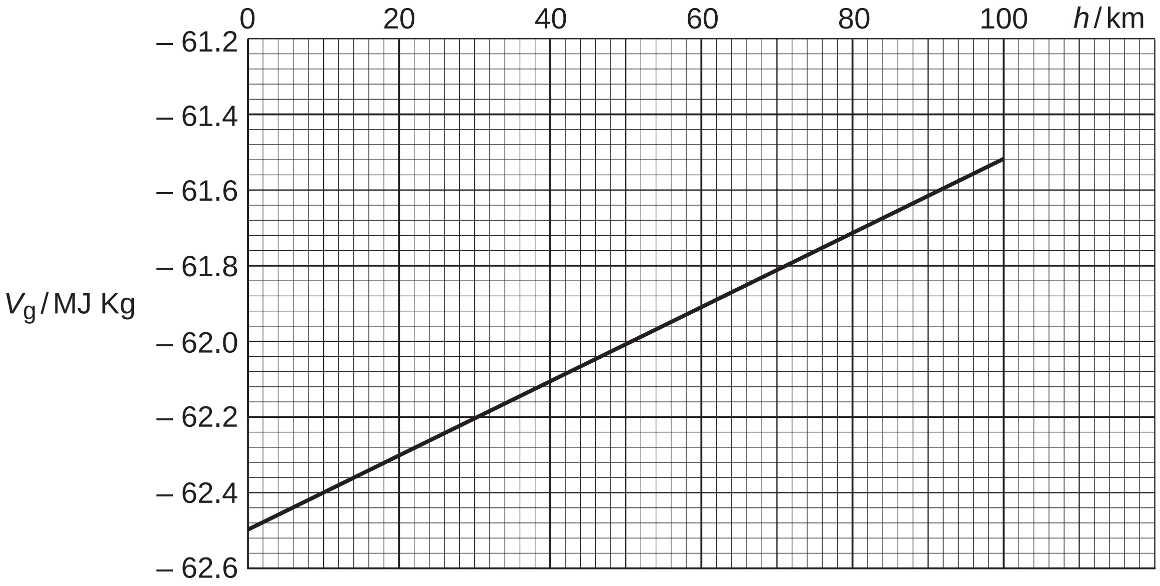


Fig. 8.3

(b) State how the graph shows that the gravitational field strength is approximately uniform over the range of the flight.

[1]

(c) Using the graph, or by calculation, show that the energy required to lift the craft from 10 km to the edge of space at 100 km above the Earth is about 3.3×10^9 J.

mass of craft = 3800 kg
average value of g over this height range = 9.7 N kg^{-1}

[2]

Question 8 continues on next page

(d) At one point the craft's engines provide a vertical thrust of 74 kN.

Calculate the value of the vertical acceleration at this point. Neglect the effect of any resistive forces.

mass of craft = 3800 kg
value of g at this height = 9.7 N kg^{-1}

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

(e) **(i)** When the engines stop firing the craft is travelling vertically (radially) away from Earth in the very thin atmosphere. Explain why the vertical velocity of the craft decreases even though there is practically zero air resistance.

[2]

(ii) During this period, when the craft is travelling without any thrust through a region of very low atmospheric pressure the space tourists are able to float around the small cabin and experience 'weightlessness'. However, when the atmosphere gets thicker as the craft descends the experience of apparent weightlessness disappears.

Explain the changing experience of the space tourists.

[4]

[Total: 13]

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

9 This question is about a simple harmonic oscillator.
The system is shown in Fig. 9.1.

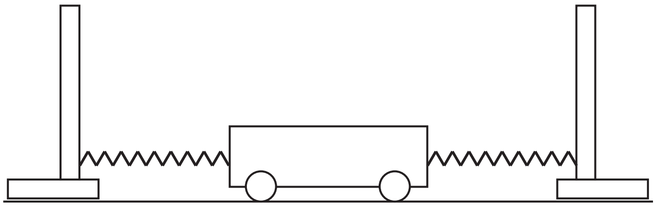


Fig. 9.1

The acceleration *a* of a mass *m* tethered between two springs is given by

$$a = -\frac{k\,s}{m}$$

where *k* is the stiffness constant of the system, and *s* is the displacement from the equilibrium position.

(a) State what the negative sign in the equation implies about the acceleration of the oscillator.

[1]

The equation giving the acceleration *a* of all simple harmonic oscillators is

$$a = -4\,\pi^2 f^2\ s$$

where *f* is the frequency of the oscillation and *s* is the displacement from the equilibrium position.

(b) Use the equations above to show that the frequency of the oscillation of the system in Fig. 9.1 to one significant figure is 0.8 Hz.

mass of oscillator m = 1.5 kg
stiffness constant of system k = 41 N m^{-1}
amplitude of oscillation A = 0.20 m

[3]

The graphs in Fig. 9.2 shows how the potential energy and kinetic energy of the system vary with time over one oscillation.

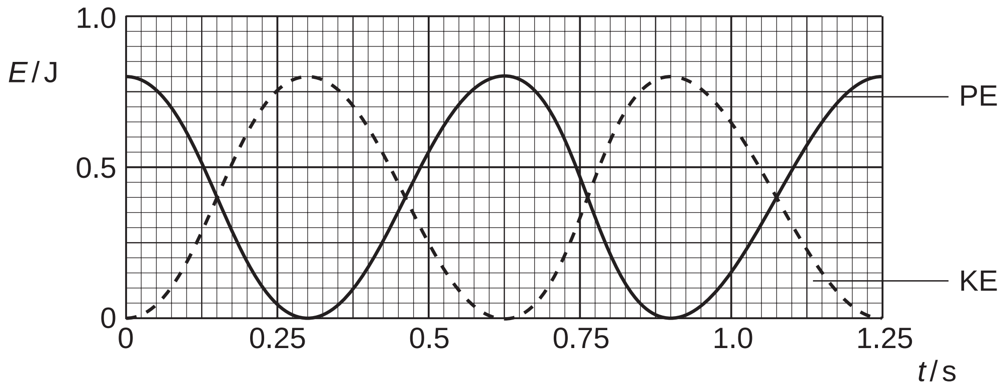


Fig. 9.2

(c) **(i)** State how the graphs show that the total energy of the system is about 0.8 J.

[1]

(ii) Verify this value by calculation, explaining your reasoning.

[2]

(d) The oscillation is stopped and the amplitude is changed from 0.20 m to 0.28 m. The mass is released and the oscillation begins at the new amplitude.

Explain why the increase of amplitude approximately doubles the total energy of the system.

[2]

Question 9 continues on next page

(e) Observations of a system like that pictured in Fig. 9.1 show that the oscillation can be **damped**.
Explain why the graphs in Fig. 9.2 suggest that the oscillator is **not** damped and suggest how the graphs for a damped oscillator would be different from Fig. 9.2.

[2]

[Total: 11]

10 This question is about collisions of molecules in a gas.

(a) Consider a sample of hydrogen gas at temperature 300 K and pressure 1.2×10^5 Pa. Assume that hydrogen behaves as an ideal gas.

(i) Show that 1 m^3 of gas will contain about 48 mol of gas under these conditions.
State the equation you use in your calculation.

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

[2]

(ii) Hence show that 1 m^3 of gas will contain about 2.9×10^{25} molecules under these conditions.
Avogadro constant, the number of particles per mole $N_A = 6.0 \times 10^{23}\,\mathrm{mol^{-1}}$

[1]

(b) Show that the root mean square speed of the hydrogen molecules under these conditions is about $2000\,\mathrm{m\,s^{-1}}$.

mass of hydrogen molecule = 3.3×10^{-27} kg
Boltzmann constant, $k = 1.4 \times 10^{-23}\,\mathrm{J\,K^{-1}}$

[2]

(c) Molecules in a gas make frequent collisions. A molecule in a gas can be modelled as a particle of cross sectional area A travelling through a gas of stationary point particles. Fig. 10.1 shows a molecule of effective cross sectional area A sweeping out a volume of Avt through a gas of point particles.

A = effective cross sectional area = $6.5 \times 10^{-19}\,\text{m}^2$
v = velocity of hydrogen molecule = $2000\,\text{m}\,\text{s}^{-1}$
t = time elapsed

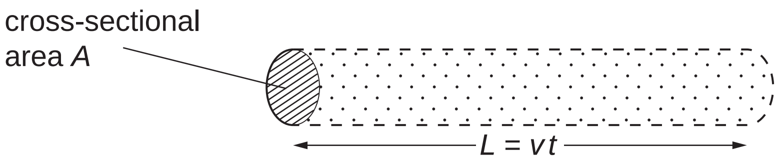


Fig. 10.1

Use the data above and the value from **(a) (ii)** to estimate the number of collisions a hydrogen molecule would make in one second.

number of collisions in one second = ... [2]

(d) The surface of the Sun contains ionised hydrogen **atoms** at a temperature of 6000 K and a pressure of about 7×10^2 Pa. The ionised atoms in the surface of the Sun make many collisions each second.

Suggest and explain two changes in the conditions of the gas in the Sun's surface that would change the rate of collision of hydrogen ions in the surface.

[4]

(e) Explain why a large number of collisions each second allows the atoms to become ionised even though the energy required for ionisation is about twenty five times the average energy of the atoms.

[2]

[Total: 13]

11 This question is about the expansion of the Universe and measurements of its age.

Distant galaxies are observed to show redshifts. The further away a galaxy is the greater the redshift that is observed.

(a) **(i)** State what is meant by the term ‘redshift’.

(ii) Use the concept of the expansion of space to explain

- the redshift of light from distant galaxies
- why light from more distant galaxies shows greater redshift.

[3]

(b) The Hubble Law states:

$v = H_0 d$

where v is the velocity of recession, d is the distance to the galaxy and H_0 is the Hubble constant.

Fig. 11.1 shows data for four galaxies.

distance/ m	velocity of recession / $km\,s^{-1}$	H_0 / s^{-1}
2.2×10^{24}	4000	1.8×10^{-18}
3.4×10^{24}	7500	
1.2×10^{24}	2600	
1.0×10^{24}	2200	

Fig. 11.1

Use the data to estimate a value for the Hubble constant H_0. Explain how you reached your value.

estimated value for H_0 = ... s^{-1}

Reasoning:

[3]

(c) $1/H_0$ gives an estimate of the time since all the galaxies were close together. This gives a lower limit on the age of the Universe.

(i) Use the value $H_0 = 2.2 \times 10^{-18}\,s^{-1}$ to estimate the time in years since the galaxies were close together.
1 year = 3.2×10^7 s.

time since galaxies were close together = ... years [2]

(ii) Suggest why this gives a **lower** limit for the age of the Universe.

[1]

[Total: 9]
Quality of Written Communication [4]
[Section B Total: 50]

END OF QUESTION PAPER

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE