OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE **2863/01**

PHYSICS B (ADVANCING PHYSICS)

Rise and Fall of the Clockwork Universe

MONDAY 21 JANUARY 2008 Morning

Time: 1 hour 15 minutes

Candidates answer on the question paper

Additional materials: Data, Formulae and Relationships Booklet
Electronic calculator

CUP/T28318

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.
- Do **not** write outside the box bordering each page.
- 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

- 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.
- The total number of marks for this paper is **70**.
- Four marks are available 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 **18** printed pages and **2** blank pages.

Answer **all** the questions.

Section A

1 Here is a list of units:

J **N m** **J s^{-1}** **s^{-1}** **s**

Choose from the list above to complete the sentences below.

Energy can have the unit ……… or the unit ……..

The radioactive-decay constant λ has the unit ………..

[3]

2 Distant galaxies are observed to be receding from Earth at velocities approximately proportional to the distance from Earth. This relationship is shown in Fig. 2.1. Each point represents a galaxy.

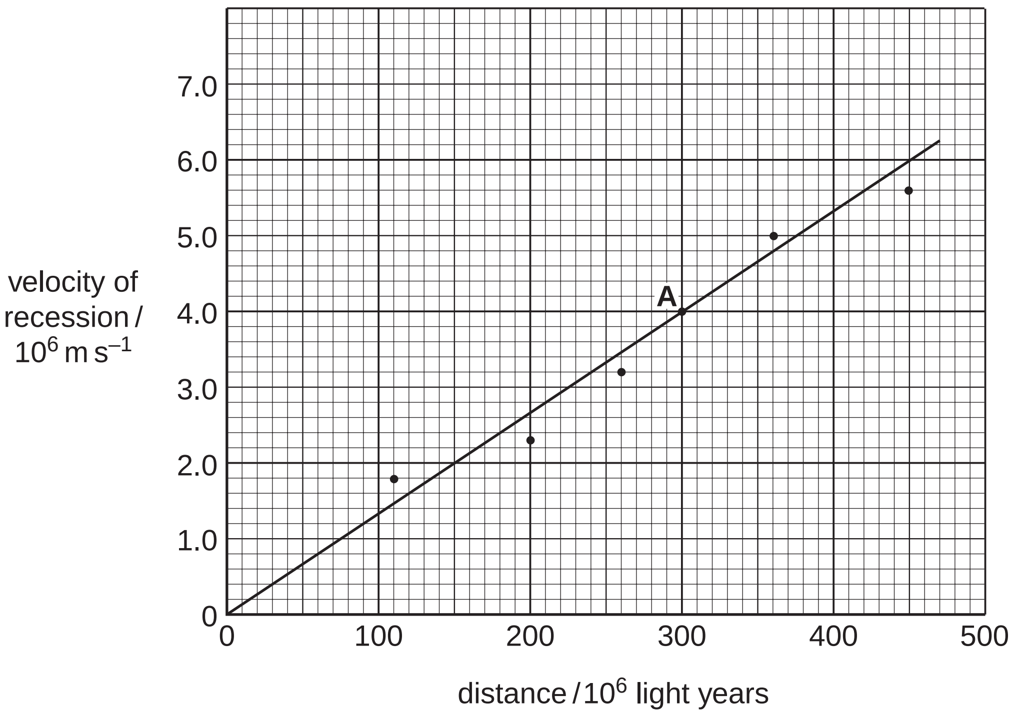

Fig. 2.1

(a) State the observational evidence that allows the velocities of distant galaxies to be calculated.

[1]

(b) Show that the galaxy represented by point **A** is about 3×10^{24} m from Earth.

1 light year = 9.6×10^{15} m

[1]

3 Radon-220 is a radioactive gas with a half-life of 52 seconds.
A sample of the gas is measured to have an activity of 1500 counts s^{-1}.

Calculate the activity 260 seconds later.

activity = …………………….. counts s^{-1} [2]

4 An amusement park ride spins brave customers so fast that they are 'held' to the sides of a vertical wall.

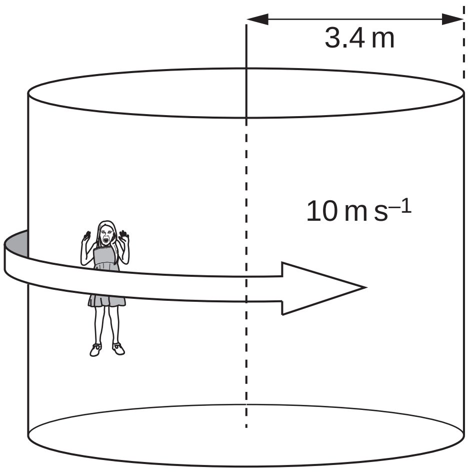

Fig. 4.1

A girl of mass 60 kg is spun around at a speed of $10\,\mathrm{m\,s^{-1}}$ in a circular drum of radius 3.4 m.

(a) Show that the centripetal force on the girl is more than 1700 N. State the equation you use in your calculation.

[3]

(b) Calculate the ratio $\dfrac{\text{centripetal force on the girl}}{\text{weight of the girl}}$.

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

ratio = ……………………………….. [2]

5 A filament lamp uses a tungsten filament of mass 1.3×10^{-4} kg.

It takes 0.7 seconds to heat up the filament so that it is shining at full brightness. During this time 40 J are transferred to the filament.

Estimate the temperature rise of the hot filament.

specific thermal capacity of tungsten = $130\,\text{J kg}^{-1}\,\text{K}^{-1}$

temperature rise of hot filament = ... K [2]

6 Here are some data about a room:

volume = $50\,\text{m}^3$
temperature = 300 K
pressure of air = $1.0 \times 10^5\,\text{N m}^{-2}$

Use the data to estimate the amount of air (in mol) in the room, assuming that the air behaves like an ideal gas. State the equation you use in your estimate.

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

amount of air in the room = ... mol [3]

7 A marimba is a musical instrument. The musician produces musical notes by striking the wooden blocks.

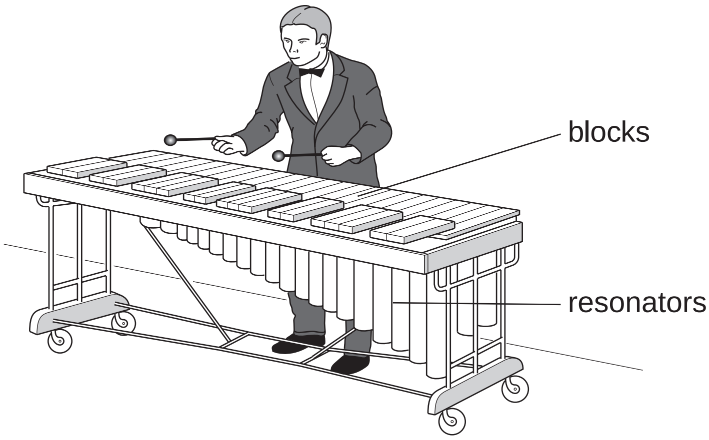

Fig. 7.1

This sound is amplified by hollow resonating tubes underneath the blocks. Each note played produces resonance in the tube beneath it.

(a) Explain what is meant by the term *resonance*.

[2]

(b) Explain why the presence of the resonator also reduces the time for which the note is heard.

[2]

[Section A Total: 21]

Section B

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

8 This question is about the escape velocity from the Earth and the atmosphere of the Earth.

The gravitational potential energy of a mass m on the surface of a planet of mass M is given by the equation

$$\text{gravitational potential energy} = -\frac{GMm}{r}$$

where r is the radius of the planet and G is the gravitational constant.

(a) (i) Explain why the minimum kinetic energy required for a body of mass m to escape from the surface of a planet and not fall back is equal to $+ GMm/r$.

[1]

(ii) Suggest why this gives the minimum energy required.

[1]

(iii) Hence show that the minimum velocity v_{esc} required to escape from the planet is given by

$v_{esc} = \sqrt{(2GM/r)}$.

[2]

(iv) Use the equation for gravitational field strength g at the surface of the planet to show that

$v_{esc} = \sqrt{(2gr)}$.

[2]

(v) Calculate v_{esc} for Earth.

$r = 6.4 \times 10^6\,\text{m}$
$g = 9.8\,\text{N kg}^{-1}$

v_{esc} = …………………… m s^{-1} [1]

(b) A particle in the atmosphere of the Earth has a kinetic energy of about 4×10^{-21} J when the temperature of the atmosphere is 300 K.

(i) Calculate the velocity of a nitrogen molecule with energy 4×10^{-21} J.

mass of nitrogen molecule = 5×10^{-26} kg

velocity = ……………………………….. m s^{-1} [2]

(ii) Use your answer to **(i)** to explain why the Earth retains nitrogen in its atmosphere.

[1]

(c) The energy required for a hydrogen molecule to escape from near the surface of the Earth is about 2×10^{-19} J.

The probability of a molecule having sufficient energy to escape from the Earth is given approximately by the Boltzmann factor for this process.

(i) Complete the table in Fig. 8.1 by calculating the value of the Boltzmann factor for hydrogen.

gas	energy E needed to escape / J	typical energy kT at 300 K / J	Boltzmann factor
hydrogen	2.0×10^{-19}	4×10^{-21}	
nitrogen	3.0×10^{-18}	4×10^{-21}	1×10^{-330}

Fig. 8.1

[1]

(ii) Use information from the table to help explain why the Earth has lost almost all of its atmospheric hydrogen over many millions of years.

[2]

(d) In the distant future it is likely that the Sun will expand and cause the Earth's temperature to rise dramatically.

Suggest and explain one effect this will have on the atmosphere.

[2]

[Total: 15]

[Turn over

9 This question is about using compressed air to accelerate a toy vehicle.

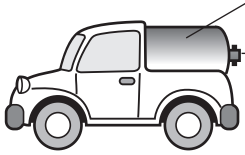

Fig. 9.1

The air tank initially contains 0.60 g of air at room temperature and a pressure of 1.0×10^5 Pa. More air is pumped into the tank until the pressure, at room temperature, is 6.0×10^5 Pa.

(a) Show that there is about 4 g of air in the tank when the pressure is 6.0×10^5 Pa.

[1]

(b) The valve is opened and air is released. In the first second after opening 0.90 g of air leaves the tank at a velocity of $12\,\text{m}\,\text{s}^{-1}$.

(i) Calculate the momentum of the air leaving the tank in the first second.

momentum = ... $\text{kg}\,\text{m}\,\text{s}^{-1}$ [1]

(ii) Explain why the magnitude of the average force exerted on the toy car during the first second is numerically equal to the answer to **(b)(i)**.

[1]

(iii) Calculate the initial acceleration of the toy car.

mass of car and air = 0.080 kg

acceleration = ... $\text{m}\,\text{s}^{-2}$ [1]

(c) The acceleration of the toy car does not remain constant as the air is expelled.

Suggest and explain two reasons why the acceleration of the vehicle changes.

reason 1

reason 2

[4]

(d) Describe and explain the effect on the initial acceleration of the vehicle if the original mass of compressed air in the tank was cooled to a lower temperature before the car was started.

[2]

[Total: 10]

10 This question is about the motion of a piston in a car engine.

Here are some data about the motion of the piston.

frequency f = 50 Hz
amplitude A = 0.050 m

The motion of the piston is represented in Fig. 10.1 where x is the displacement at time t of the piston from the mean position.

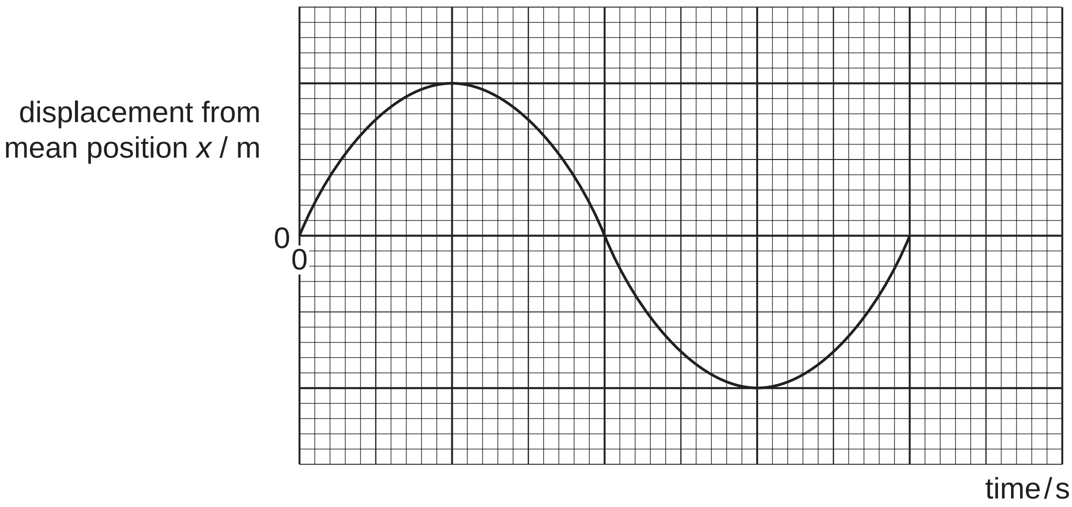

Fig. 10.1

(a) Complete the graph by adding numerical values to the axes.

[2]

(b) The equation of motion of the piston represented in Fig. 10.1 is

$$x = A \sin(2\pi f t)$$

where t is the time elapsed since the beginning of the motion.

Calculate the displacement of the piston at t = 0.013 s.

displacement = ……………………………….. m [2]

(c) The velocity of the piston v is given by the equation $v = 2\pi f A(\cos 2\pi ft)$.

(i) Explain how the equation shows that the maximum velocity of the piston is given by

maximum velocity = $2\pi f A$.

[1]

(ii) Calculate the maximum velocity of the piston.

maximum velocity = ……………………………….. $m\,s^{-1}$ [1]

(iii) State the feature of the graph in Fig. 10.1 that could be used to obtain a value for the maximum velocity of the piston.

[1]

(d) **(i)** Mark on Fig. 10.1 a point at which the acceleration of the piston is at a maximum. Label this point **X**. [1]

(ii) Calculate the maximum acceleration of the piston.

acceleration = ……………………………….. $m\,s^{-2}$ [2]

[Total: 10]

11 This question is about capacitor discharge in the circuit shown in Fig. 11.1.

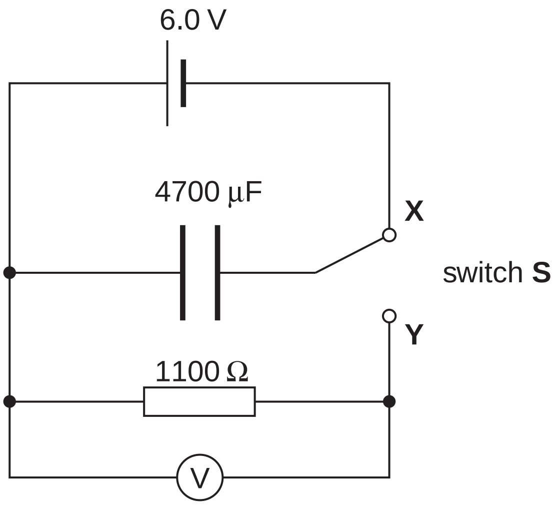

Fig. 11.1

The switch **S** is moved from **X** to **Y**. The capacitor discharges through the 1100 Ω resistor. Fig. 11.2 shows the graph of p.d. against time.

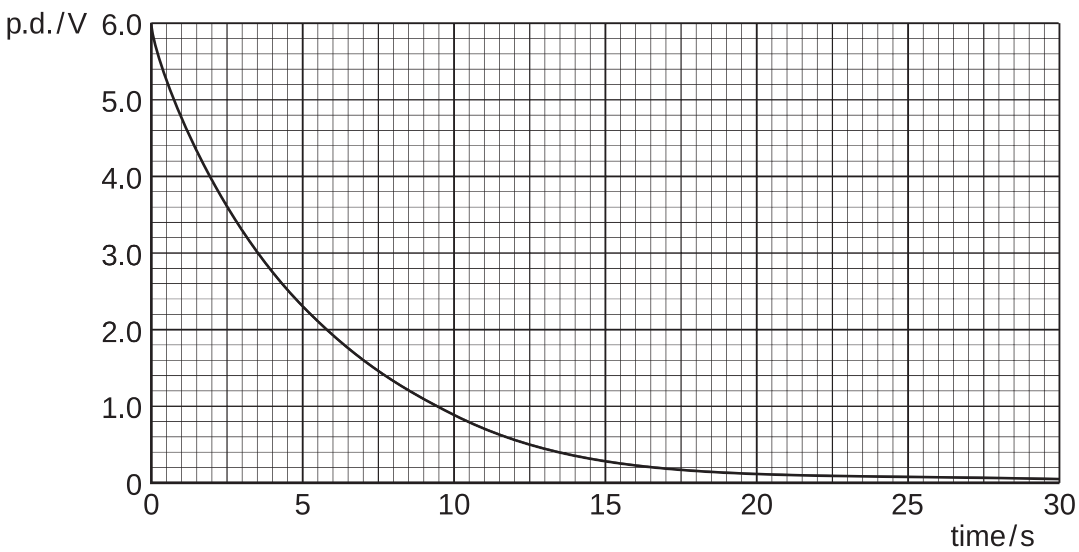

Fig. 11.2

(a) Use information from the diagram and the graph to show that

(i) the initial charge on the capacitor is about 0.03 C

[1]

(ii) the initial rate of discharge is about 5 mA

[1]

(iii) the time constant of the circuit is about 5 s.

[1]

(b) Explain why the rate of fall of voltage is proportional to the rate of fall of charge and hence proportional to the current in the circuit.

[2]

[Turn over

(c) A series of models of the discharge are considered.

(i) In the simplest model the current is assumed to remain constant at its initial value throughout the discharge. Show that this model predicts that the capacitor would fully discharge in time *RC*.

[2]

(ii) A better model calculates the change of charge ΔQ in successive time intervals Δt using the equation $\Delta Q = -\frac{Q}{RC}\Delta t$.

Fig. 11.3 shows the graph produced when Δt is set at 4.0 s.

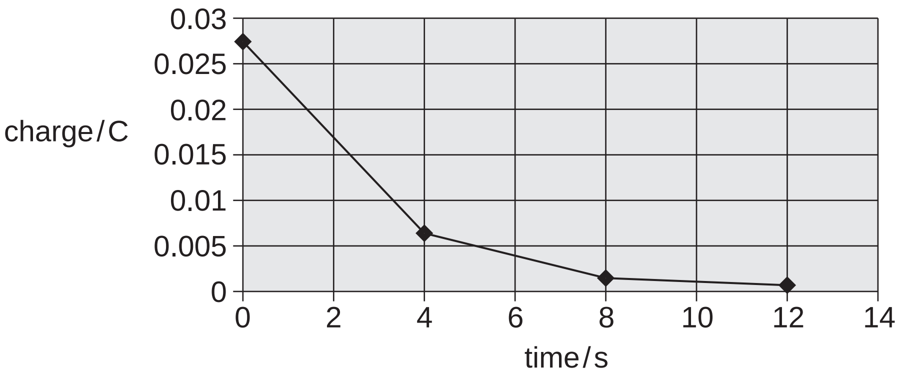

Fig. 11.3

To improve the model Δt is reduced to 2.0 s. This graph gives the charge remaining at 2.0 s as 0.017 C. Use this value to show that the loss of charge during the next two seconds will be about 6.5×10^{-3} C.

[1]

(iii) Draw a line on the graph in Fig. 11.3 to represent the loss of charge from the capacitor between 2.0 s and 4.0 s.

[1]

(iv) Explain why reducing the time interval Δt leads to a more accurate model of the discharge.

[1]

[Total: 10]

Quality of Written Communication: [4]

[Section B Total: 49]

END OF QUESTION PAPER

BLANK PAGE

BLANK PAGE