

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
A2 GCE
G494/01
PHYSICS B (ADVANCING PHYSICS)
Rise and Fall of the Clockwork Universe

WEDNESDAY 11 JUNE 2014: Afternoon
DURATION: 1 hour 15 minutes
plus your additional time allowance

MODIFIED ENLARGED

Candidate forename		Candidate surname	
-------------------------------	--	------------------------------	--

Centre number						Candidate number				
--------------------------	--	--	--	--	--	-----------------------------	--	--	--	--

Candidates answer on the Question Paper.

OCR SUPPLIED MATERIALS:

**Data, Formulae and Relationships Booklet
(sent with general stationery)**

OTHER MATERIALS REQUIRED:

**Electronic calculator
Ruler (cm/mm)**

READ INSTRUCTIONS OVERLEAF

INSTRUCTIONS TO CANDIDATES

Write your name, centre number and candidate number in the boxes on the first page. Please write clearly and in capital letters.

Use black ink. HB pencil may be used for graphs and diagrams only.

Answer ALL the questions.

Read each question carefully. Make sure you know what you have to do before starting your answer.

Write your answer to each question in the space provided. If additional space is required, you should use the lined pages at the end of this booklet. The question number(s) must be clearly shown.

INFORMATION FOR CANDIDATES

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 60.

You may use an electronic calculator.

You are advised to show all the steps in any calculations.



Where you see this icon you will be awarded marks for the quality of written communication in your answer.

This means for example, you should:

ensure that text is legible and that spelling, punctuation and grammar are accurate so that the meaning is clear

organise information clearly and coherently, using specialist vocabulary when appropriate.

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.

Any blank pages are indicated.

Answer ALL the questions.

SECTION A

1 Here is a list of units.

$$\text{kg m}^{-1} \text{s}^{-2}$$

$$\text{kg m s}^{-1}$$

$$\text{kg m}^2 \text{s}^{-1}$$

$$\text{kg m}^2 \text{s}^{-2}$$

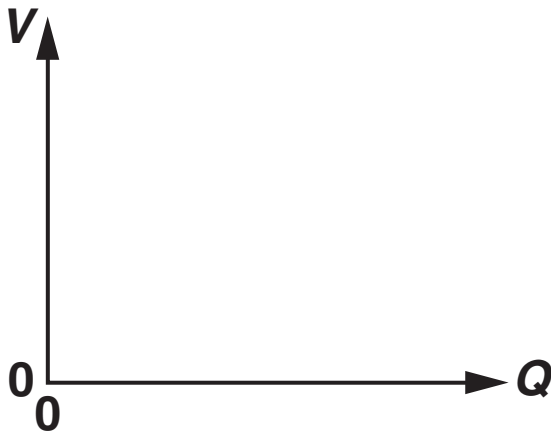
(a) Which ONE is a correct unit for momentum?

_____ [1]

(b) Which ONE is a correct unit for pressure?

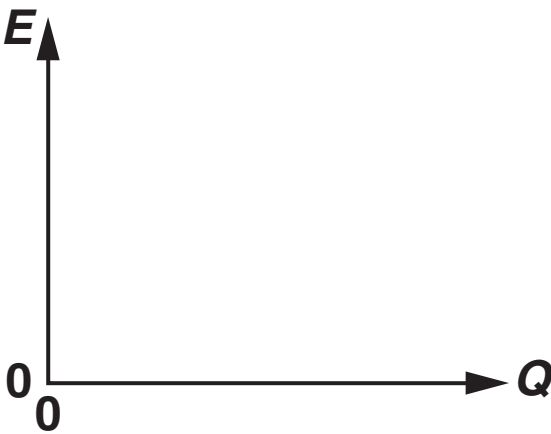
_____ [1]

- 2 (a) Sketch a graph on the axes below to show how the potential difference V across a capacitor varies with the charge Q on its plates.



[1]

- (b) Sketch a graph on the axes below to show how the energy E stored in the capacitor varies with the charge Q on its plates.



[1]

3 This question is about the behaviour of a mass suspended by a spring from a vibrating support.

(a) Describe the condition required for the mass-spring system to go into RESONANCE. [1]

(b) Damping is applied to the mass-spring system.

Describe and explain one effect of damping when the system goes into resonance. [2]

- 4 The atmosphere of Mars is mostly carbon dioxide at a mean temperature of -63°C .

Estimate the speed v of carbon dioxide molecules at this temperature.

mass of a carbon dioxide molecule = $7.3 \times 10^{-26} \text{ kg}$

$k = 1.4 \times 10^{-23} \text{ J K}^{-1}$

$v = \underline{\hspace{2cm}} \text{ m s}^{-1} [3]$

- 5 A student does an experiment to verify that momentum is conserved when a pair of trolleys on a track collide head-on.

Fig. 5.1 shows the trolleys on a level track approaching each other.

FIG. 5.1



Fig. 5.2 shows the situation AFTER the trolleys collide.

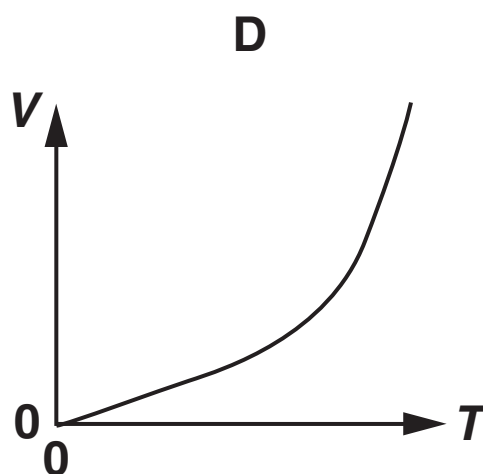
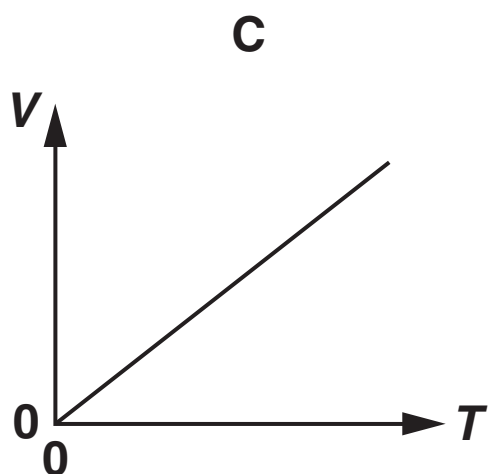
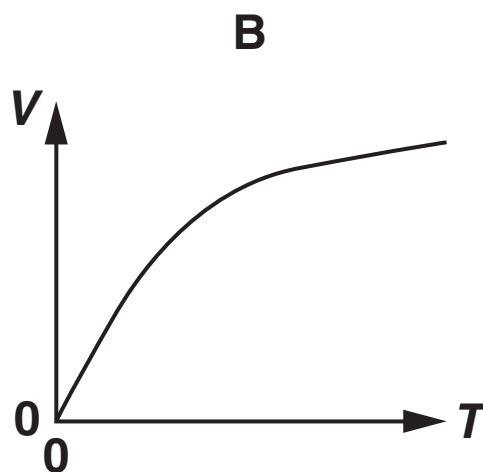
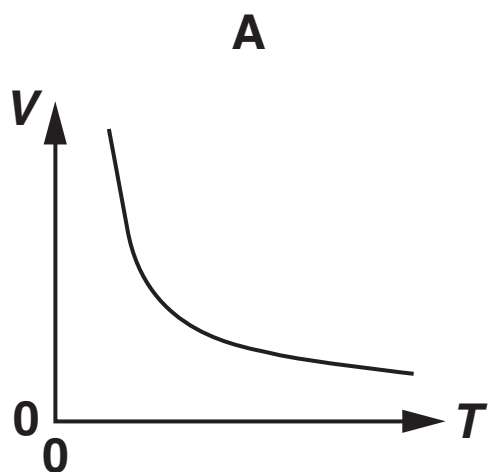
FIG. 5.2



Show that momentum is conserved in the collision.

[2]

- 6 Which one of these four graphs (A, B, C or D) shows how the volume V of a fixed mass of gas at a constant pressure changes with kelvin temperature T ?



answer _____ [1]

7 This question is about the random walk of a molecule through air.

(a) Explain why the molecule does a random walk. [2]

(b) A typical molecule in still air is displaced by a distance of 5 mm in a time of 1 s.

Explain why it will take 100 s for the molecule to be displaced by a distance of 50 mm. [2]

- 8 The recessional velocity of a distant galaxy is measured to be $3.5 \times 10^3 \text{ km s}^{-1}$.

Use the age of the Universe (14×10^9 years) to estimate the distance from Earth to this galaxy. State the assumption you have to make.

$$1 \text{ year} = 3.2 \times 10^7 \text{ s}$$

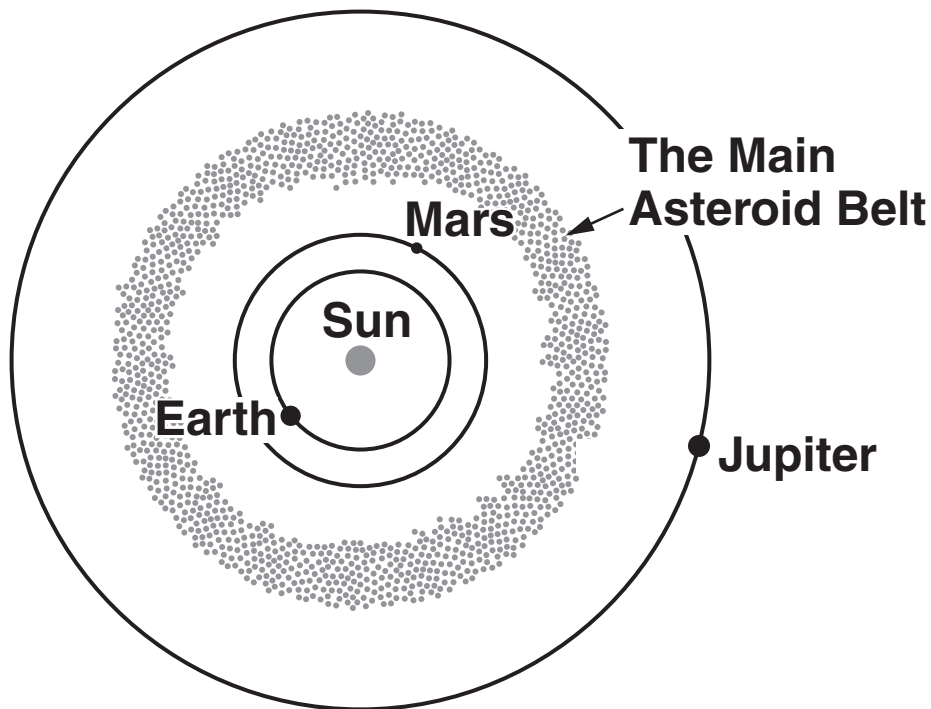
distance = _____ m [3]

[SECTION A TOTAL: 20]

SECTION B

- 9 The asteroid belt between Mars and Jupiter contains a large number of rocks in circular orbit around the Sun.

FIG. 9.1



- (a) Show that the speed v of an asteroid of mass m in a circular orbit of radius r around the Sun of mass M is given by

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

[2]

- (b) One particular asteroid in the asteroid belt is in a circular orbit of radius $3.6 \times 10^{11} \text{ m}$.
- (i) Show that it has a kinetic energy of about 10^{11} J .

$$\begin{aligned}\text{mass of asteroid} &= 500 \text{ kg} \\ \text{mass of Sun} &= 2.0 \times 10^{30} \text{ kg} \\ G &= 6.7 \times 10^{-11} \text{ Nm}^2 \text{ kg}^{-2}\end{aligned}$$

[2]

- (ii) It is believed that collisions between asteroids can put them into elliptical orbits which cross the Earth's orbit. These asteroids may then collide with the Earth, causing widespread damage.

If a collision changes the direction of motion of the asteroid in (i) WITHOUT changing its kinetic energy, calculate its speed v when it crosses the Earth's orbit.

radius of the Earth's orbit = $1.5 \times 10^{11} \text{ m}$

$v =$ _____ ms^{-1} [4]

- (c) Astronomers study many asteroids whose orbits approach the Earth's orbit.**

Explain how the distance from Earth to a nearby asteroid can be measured using radar.



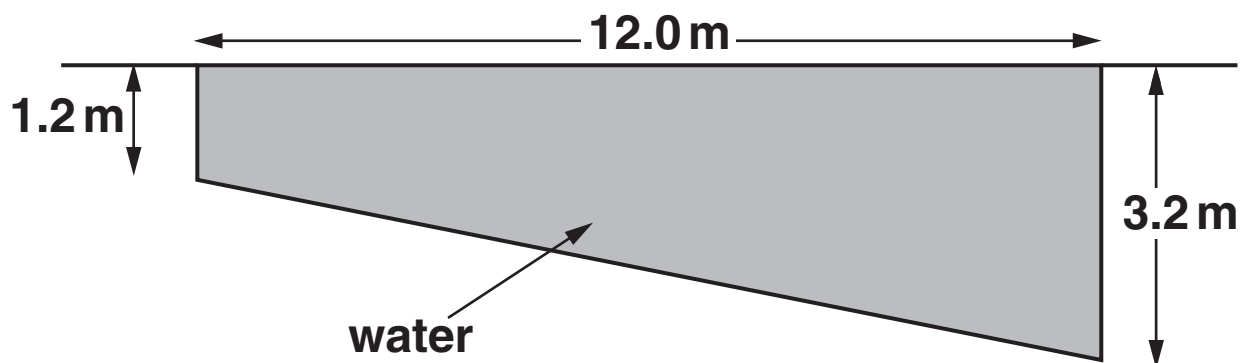
Your answer should state clearly the assumptions behind the method you describe.

[3]

[TOTAL: 11]

- 10 This question is about heating the water in a swimming pool which has the cross-sectional shape shown in Fig. 10.1.

FIG. 10.1



- (a) The pool has a constant width of 5.6 m.

Show that it contains about 1.5×10^5 kg of water.

density of water = $1.0 \times 10^3 \text{ kg m}^{-3}$

[2]

(b) A heater raises the temperature of the water in the pool from 10 °C to 30 °C.

Calculate the energy supplied to the heater.

State an assumption you have to make.

**specific thermal capacity of water =
 $4.2 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1}$**

energy = _____ J [2]

- (c) Evaporation is one way in which water in a swimming pool cools down.**

The Boltzmann factor can be used to model how the rate of evaporation varies with temperature.

- (i) The energy required to evaporate 1.0 kg of water is 2.3×10^6 J.**

Show that the energy required to remove ONE MOLECULE of water from the pool into the air above it is about 7×10^{-20} J.

molar mass of water = $1.8 \times 10^{-2} \text{ kg mol}^{-1}$

Avogadro constant = $6.0 \times 10^{23} \text{ mol}^{-1}$

[2]

- (ii) The rate of evaporation from the pool R is estimated by

$$R = Ce^{-\frac{\epsilon}{kT}}.$$

Explain how the Boltzmann factor $f = e^{-\frac{\epsilon}{kT}}$ can be used to justify this equation.



Your answer should clearly link the Boltzmann factor to the behaviour of the water molecules.

[3]

- (iii) The rate of evaporation from the pool is $7.2 \times 10^{-3} \text{ kg s}^{-1}$ when the temperature is $+30^\circ\text{C}$. Estimate the rate of evaporation at a temperature of $+10^\circ\text{C}$.

Show your working.

$$k = 1.4 \times 10^{-23} \text{ J K}^{-1}$$

rate of evaporation = _____ kg s^{-1} [2]

[Total: 11]

11 This question is about a measurement of the half-life of protactinium.

A fresh sample of protactinium was placed in a detector of radiation.

The count rate of the sample was measured at intervals of one minute for six minutes.

The activity A , the count rate corrected for background radiation, is given in the table.

time / minutes	0	1	2	3	4	5	6
activity A / Bq	943	523	287	161	79	61	20

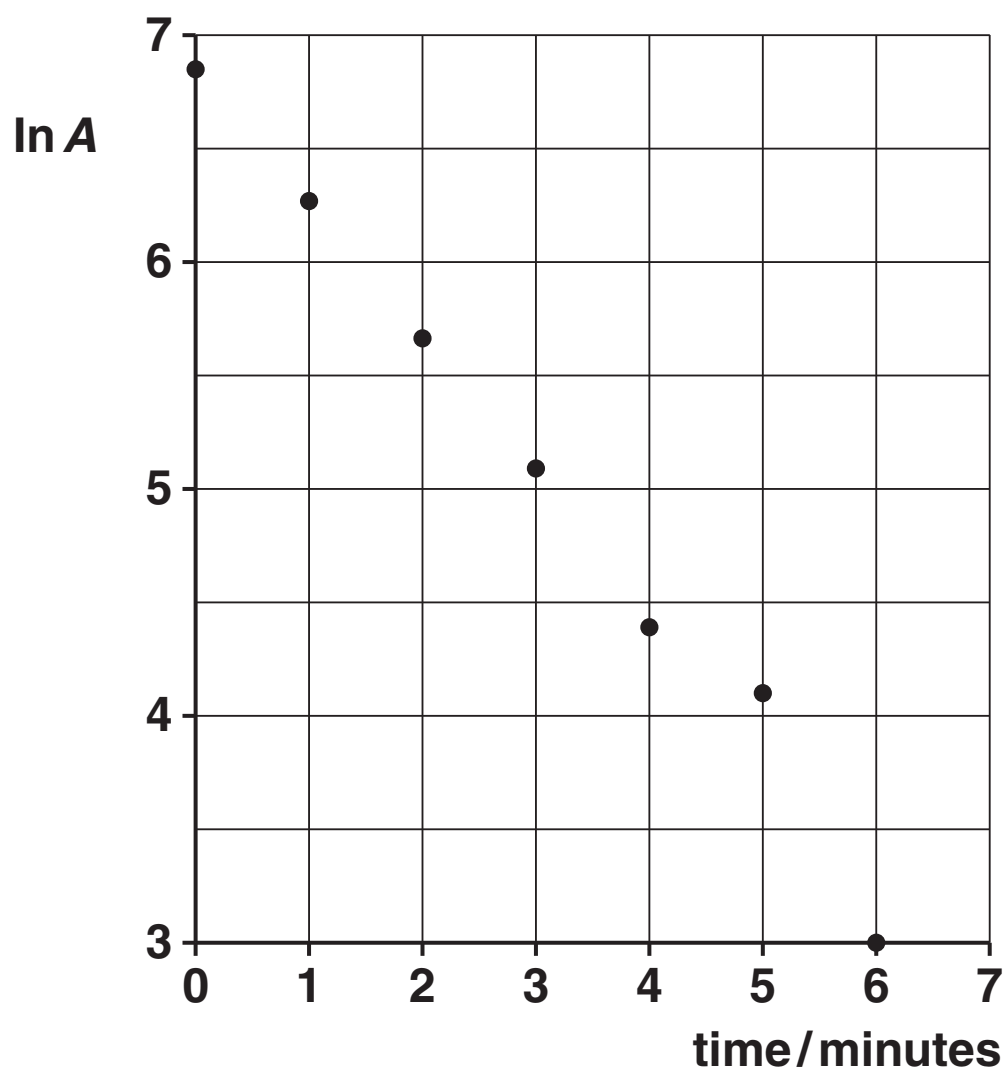
(a) Describe how the correction for background radiation is made. [2]

(b) Use the relationships $N = N_0 e^{-\lambda t}$ and $\frac{\Delta N}{\Delta t} = -\lambda N$ to show that the results of the experiment should obey the relationship $\ln A = C - \lambda t$, where C is a constant. [3]

BLANK PAGE

(c) The graph of Fig. 11.1 shows the variation of $\ln A$ with time.

FIG. 11.1



- (i) Use the graph opposite to determine a value for the half-life of protactinium.

half-life = _____ s [3]

- (ii) Give a reason why some of the points on the graph of Fig. 11.1 are not expected to lie close to a straight line.

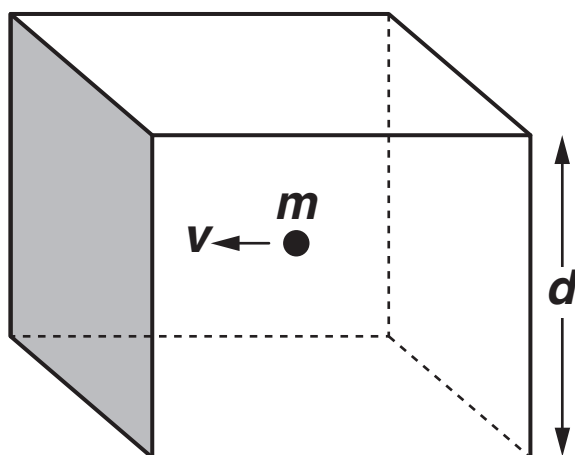
[1]

[TOTAL: 9]

12 This question is about a derivation of the relationship $PV = NkT$ for a gas from a simple model.

- (a) Fig. 12.1 shows one particle of mass m moving with speed v directly towards the left-hand face of a cubical box of side d . There are no other particles in the box.

FIG. 12.1



The rate at which the left-hand face gains momentum p from the particle in the box is given by

$$\frac{\Delta p}{\Delta t} = \frac{2mv}{\frac{2d}{v}}.$$

- (i) State what assumption has to be made about the motion of the particle for $\Delta p = 2mv$. [1]

(ii) Explain why $\Delta t = \frac{2d}{v}$.

[1]

(b) The box now contains N particles of the gas, all with the same speed and mass, so that it models a gas.

(i) Explain why the total force F on the left-hand face of the box is given by

$$F = \frac{N}{3} \times \frac{mv^2}{d}.$$

[3]

(ii) State another assumption made about the N particles in the box. [1]

- (c) The pressure P on the left-hand face of the box is then given by

$$P = \frac{F}{A} = \frac{Nmv^2}{3V}.$$

By making appropriate assumptions about the particles of a gas, this can be used to show that

$$P = \frac{NkT}{V}.$$

State the assumptions required and explain how they lead to the final equation. [3]

[TOTAL: 9]

[SECTION B TOTAL: 40]

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional answer space is required, you should use the following lined pages. The question number(s) must be clearly shown in the margins.



Copyright Information

OCR is committed to seeking permission to reproduce all third-party content that it uses in its assessment materials. OCR has attempted to identify and contact all copyright holders whose work is used in this paper. To avoid the issue of disclosure of answer-related information to candidates, all copyright acknowledgements are reproduced in the OCR Copyright Acknowledgements Booklet. This is produced for each series of examinations and is freely available to download from our public website (www.ocr.org.uk) after the live examination series.

If OCR has unwittingly failed to correctly acknowledge or clear any third-party content in this assessment material, OCR will be happy to correct its mistake at the earliest possible opportunity.

For queries or further information please contact the Copyright Team, First Floor, 9 Hills Road, Cambridge CB2 1GE.

OCR is part of the Cambridge Assessment Group; Cambridge Assessment is the brand name of University of Cambridge Local Examinations Syndicate (UCLES), which is itself a department of the University of Cambridge.

