

Monday 20 June 2016 – Morning

A2 GCE PHYSICS B (ADVANCING PHYSICS)

G494/01 Rise and Fall of the Clockwork Universe

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)

Duration: 1 hour 15 minutes



Candidate
forename

Candidate
surname

Centre number

Candidate number

INSTRUCTIONS TO CANDIDATES

- Write your name, centre number and candidate number in the boxes above. 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 page at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the bar codes.

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 are advised to spend about 20 minutes on Section A and 55 minutes on 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.
-  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.
- This document consists of **16** pages. Any blank pages are indicated.

Answer **all** the questions.

SECTION A

- 1 Here is a list of units.

N s

N kg⁻¹

kg m s⁻¹

kg m s⁻²

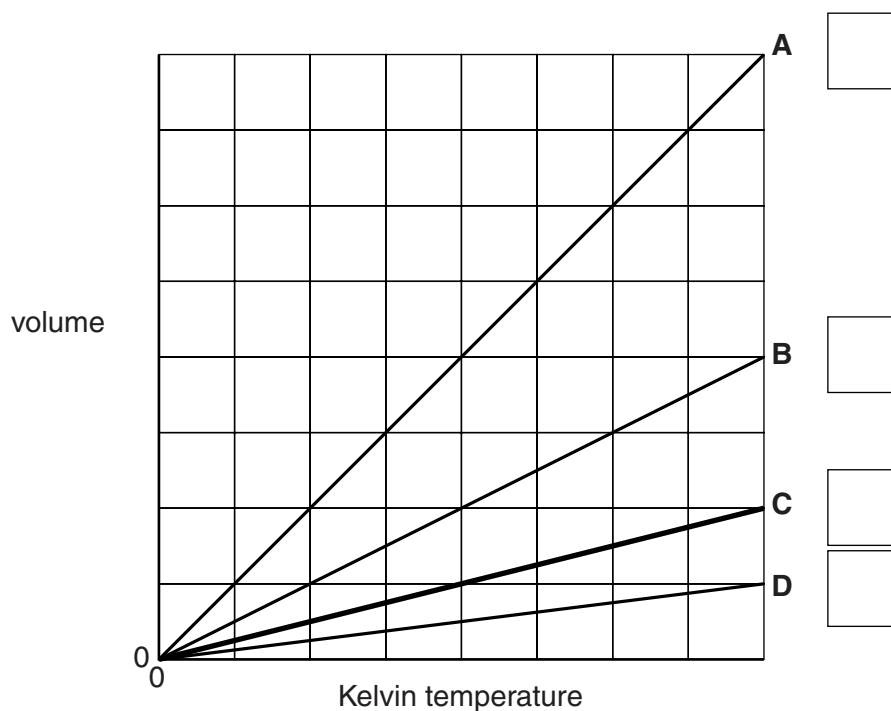
- (a) Which is the correct unit for gravitational field strength?

..... [1]

- (b) Which **two** units are the same?

..... and [1]

- 2 The line labelled **C** on the graph shows the expansion of an ideal gas at constant pressure.



Tick the box next to the line that would be produced by **both** doubling the mass of gas **and** halving the pressure at the same time. [1]

- 3 In a simple model of a solid the energy of its particles is quantised. The bar chart of Fig. 3.1 shows the number of particles in the energy levels above the lowest one at a particular temperature.

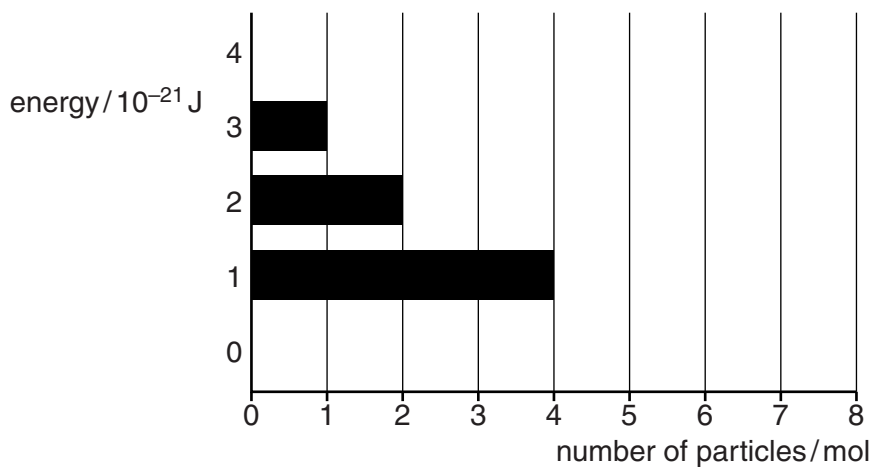


Fig. 3.1

Here is a list of values.

0.5 1 2 4 6 8

- (a) The ratio of the number of particles in adjacent energy levels is given by the Boltzmann factor. Which value is the Boltzmann factor for the solid?

Boltzmann factor = ... [1]

- (b) The bar chart does **not** show the number of particles with zero energy. Which value is the number of particles with no energy?

number of particles = ... mol [1]

- 4 A student measures the volume V of a fixed mass of air for different values of temperature T and pressure p . The results are shown in the table.

T / K	V / ml	p / kPa	
283	5.5	100	
270	2.2	230	
373	6.0	120	

The student decides that the data are consistent with air obeying the ideal gas equation

$$pV = NkT.$$

Is this conclusion correct, given the precision of the data in the table?
Justify your answer with calculations.

[3]

- 5 A block of mass 0.12 kg is supported by a spring as shown in Fig. 5.1. When displaced vertically from equilibrium and released it makes 5 complete oscillations in 3.0 s .

Calculate the force constant of the spring.
Assume that the motion is simple harmonic.

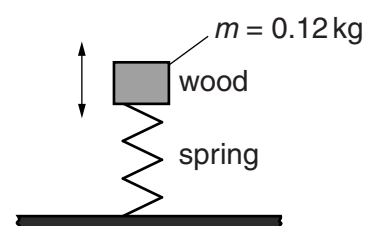


Fig. 5.1

force constant = ... N m^{-1} [3]

- 6 The top graph of Fig. 6.1 shows how the velocity of an object in simple harmonic motion varies with time.
Complete the other two graphs to show how the acceleration and displacement of the object vary with time over the same time interval.

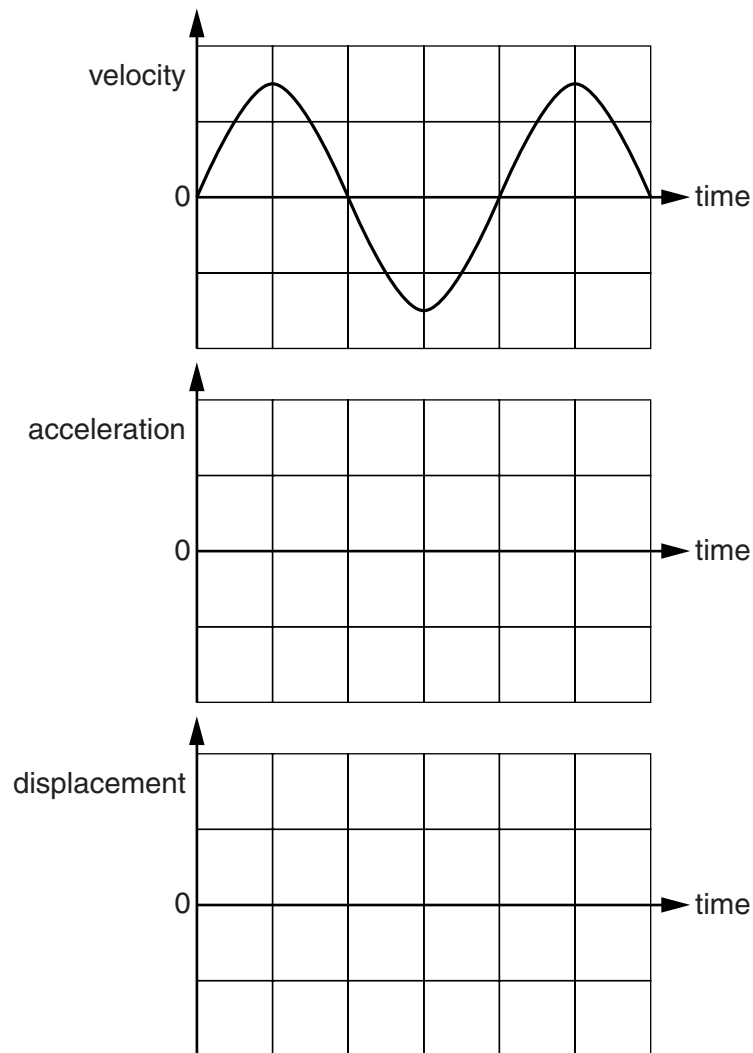


Fig. 6.1

[2]

- 7 The idea that the Universe started with a big bang almost 14 billion years ago is now a widely accepted theory.
Explain how the red shift of distant galaxies provides evidence for this theory.

[2]

- 8 The graph of Fig. 8.1 shows a time-distance graph of an unstable particle as it passes through a laboratory.

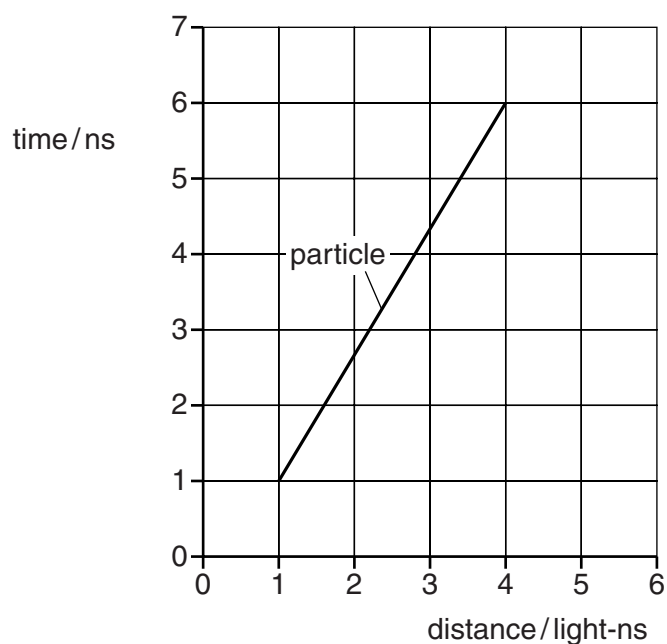


Fig. 8.1

The particle is produced at time 1.00 ns, measured by a clock in the laboratory.
The particle decays at time 6.0 ns, giving it a life time of 5.0 ns.

- (a) Show that the speed of the particle through the laboratory is about $2 \times 10^8 \text{ m s}^{-1}$.
 $c = 3.0 \times 10^8 \text{ m s}^{-1}$

[1]

- (b) Calculate the relativistic factor γ , and determine the life time of this particle if it had been at rest in the laboratory.

life time = ... ns [2]

- 9 A student sets up the circuit shown in Fig. 9.1 with an old capacitor.

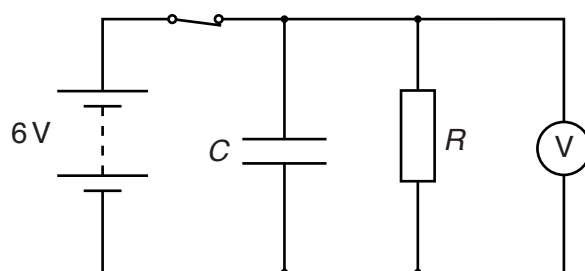


Fig. 9.1

The p.d. across the capacitor in the circuit is measured after the switch has been opened. The results are shown in the graph of Fig. 9.2.

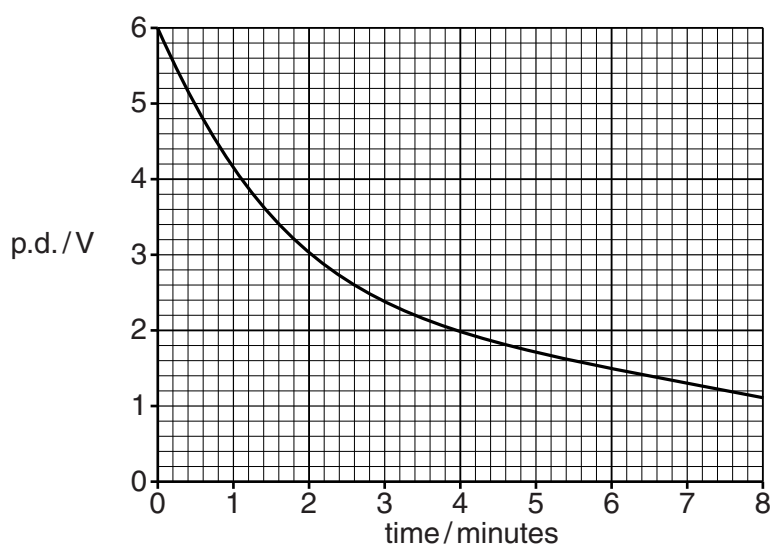


Fig. 9.2

The student expects the graph to show exponential decay, but it does not. Use data from the graph to show that the graph does **not** show exponential decay.

[2]

SECTION B

10 This question is about the planet Jupiter and its satellite Io.

(a) The mean radius r of the orbit of Io is $4.2 \times 10^8 \text{ m}$ and its orbital period T is 43 hours.

(i) Show that Io's mean orbital speed v is about 20 km s^{-1} .

[2]

(ii) By considering the centripetal force on Io from Jupiter, show that the mass of Jupiter M is given by

$$M = \frac{rv^2}{G}.$$

[2]

(iii) Calculate the mass of Jupiter.

$$G = 6.7 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$$

mass = ... kg [1]

- (b) Io's orbit is actually an ellipse, shown exaggerated in Fig. 10.1.

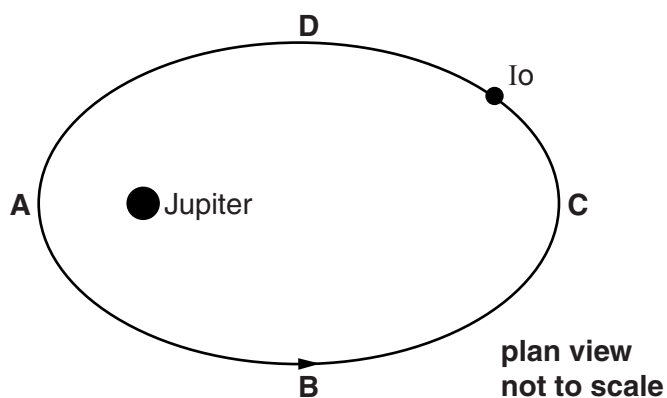


Fig. 10.1

- (i) Draw an arrow on Fig. 10.1 to show the direction of the gravitational force on Io from Jupiter. [1]
- (ii) On Fig. 10.2, sketch a graph to show how the speed of Io changes in one orbit around Jupiter.

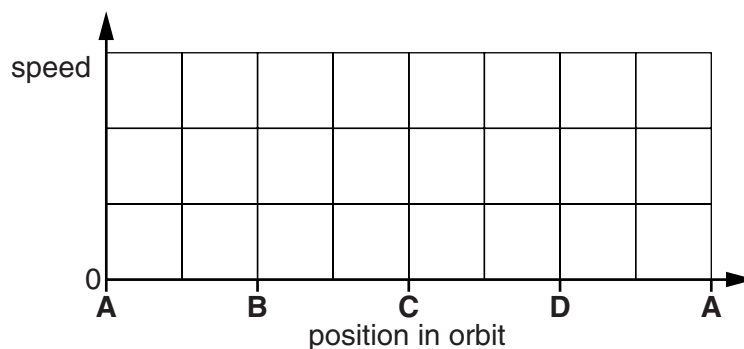


Fig. 10.2

- (iii) Explain why the speed changes in this way.

[1]

[2]

- 11 This question is about the scarcity of helium atoms in the Earth's atmosphere.

Party balloons are often inflated with helium gas. This gas eventually finds its way into the atmosphere. The Earth's gravitational field prevents the atmosphere from escaping into space.

- (a) Explain why the kinetic energy E_k of an atom of mass m which is just able to leave a planet's gravitational field is given by the expression

$$E_k = \frac{GMm}{R}$$

where M is the mass of the planet and R is its radius.

[2]

- (b) Show that the minimum energy of a helium atom which **can** escape the Earth's gravitational field is about 4×10^{-19} J.

molar mass of helium = 4.0×10^{-3} kg

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

mass of Earth = 6.0×10^{24} kg

radius of Earth = 6.4×10^6 m

$G = 6.7 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$

[2]

(c) The average temperature at the surface of the Earth is 15°C .

(i) Estimate the average energy of a helium atom in the Earth's atmosphere.

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

average energy = ... J [2]

(ii) Explain why energies of helium atoms at a given height and temperature in the Earth's atmosphere have a wide range of values.



Your answer should clearly link the variations in the energy of the helium atoms to the behaviour of particles in the atmosphere.

[3]

(iii) A student suggests that helium atoms in the atmosphere eventually escape into space.

Use the Boltzmann factor $e^{-\frac{\epsilon}{kT}}$ to discuss this idea.

[3]

12 This question is about measuring the air pressure inside a vacuum cleaner hose.

A vacuum cleaner reduces the pressure in its inlet hose to below atmospheric pressure. This reduction in pressure is about 20 kPa.

(a) To test this, a student sets up the experiment shown in Fig. 12.1.

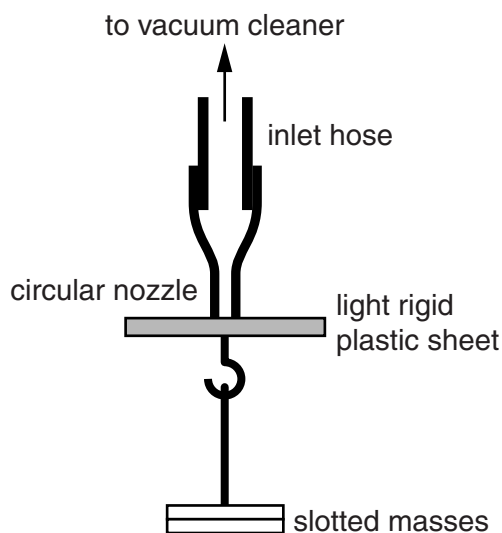


Fig. 12.1

When the vacuum cleaner is turned on, a number of slotted 100g masses can be hung from the plastic sheet.

- (i)** Explain, in terms of the behaviour of the air particles on each side of the sheet, how this difference in pressure holds the sheet in place.



Your answer should clearly link the forces on the sheet to the motion of the air particles on each side of it.

[3]

- (ii) The student finds that only two 100g masses can be hung from the plastic sheet before it is pulled from the nozzle.

Calculate the pressure of the air in the hose.

nozzle diameter = 12 mm

atmospheric pressure = 100 kPa

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

pressure = ... Pa [3]

- (b) The student proposes to improve the precision of the measurement by removing the nozzle on the end of the inlet hose, as shown in Fig. 12.2.

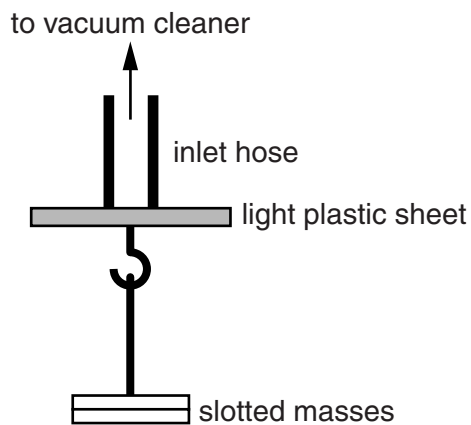


Fig. 12.2

This increases the diameter of the hose touching the sheet to 30 mm. This reduces the uncertainty in the measurement of the maximum mass supported by the light plastic sheet. Calculate what effect this has on the precision of the measurement of the pressure in the vacuum hose.

[3]

- 13** This question is about an experiment to measure the speed of an air rifle pellet. A student fires the rifle horizontally at a piece of Blu-tack suspended by a cord to form a pendulum, as shown in Fig. 13.1.

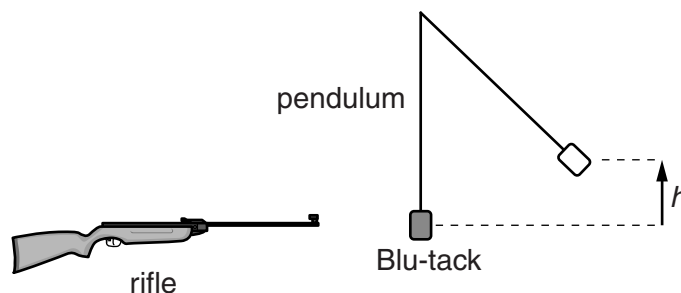


Fig. 13.1

The pellet becomes embedded in the Blu-tack which swings to the right, rising to a maximum height h of 0.23 m above its initial position.

- (a)** Show that the kinetic energy of the Blu-tack and pellet, immediately after pellet impact, is about 0.2 J, stating clearly the assumptions that you have made.
 mass of Blu-tack = 8.0×10^{-2} kg
 mass of pellet = 1.0×10^{-3} kg
 $g = 9.8 \text{ N kg}^{-1}$

[3]

- (b)** Use momentum conservation and the answer to **(a)** to calculate the speed u of the pellet immediately before its impact with the Blu-tack.

$u = \dots\dots\dots \text{ ms}^{-1}$ **[3]**

(c) The student claims that kinetic energy is **not** conserved in the collision between the pellet and the Blu-tack.

(i) Show that the results of the experiment support the student's claim.

[2]

(ii) Describe where the missing energy has gone.

[2]

END OF QUESTION PAPER

[illegible]

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