



**ADVANCED GCE**  
**PHYSICS B (ADVANCING PHYSICS)**  
 Rise and Fall of the Clockwork Universe

**G494**

Candidates answer on the Question Paper

**OCR Supplied Materials:**

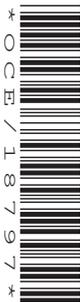
- Data, Formulae and Relationships Booklet

**Other Materials Required:**

- Electronic calculator
- Ruler (cm/mm)

**Tuesday 29 June 2010**  
**Afternoon**

**Duration: 1 hour 15 minutes**



Candidate Forename		Candidate Surname	
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Centre Number						Candidate Number				
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**INSTRUCTIONS TO CANDIDATES**

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use 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. Additional paper may be used if necessary but you must clearly show your Candidate Number, Centre Number and question number(s).
- 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 is given in brackets [ ] at the end of each question or part question.
- The total number of marks for this paper is **60**.
- 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.
- This document consists of **16** pages. Any blank pages are indicated.

Answer **all** the questions.

**Section A**

1 Here is a list of units.

$\text{J kg}^{-1} \text{K}^{-1}$

$\text{J kg}^{-1}$

$\text{J K}^{-1}$

$\text{N kg}^{-1}$

$\text{Ns}$

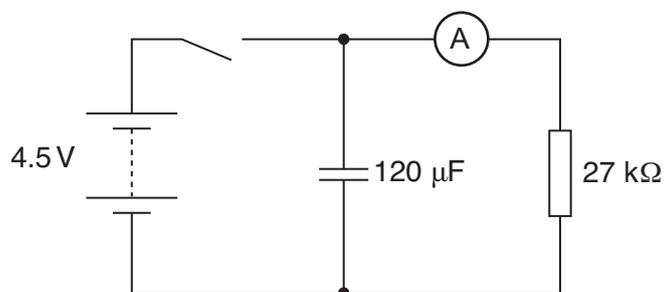
(a) Which one is a correct unit for gravitational field strength?

..... [1]

(b) Which one is a correct unit for specific thermal capacity?

..... [1]

2 The circuit of Fig. 2.1 contains a  $120 \mu\text{F}$  capacitor and a  $4.5\text{V}$  battery.



**Fig. 2.1**

(a) Calculate the energy stored in the capacitor when the switch is closed.

energy = ..... J [1]

(b) When the switch is opened the reading of the ammeter decreases with time. Explain why this happens.

[2]

3

3 An ideal gas obeys this equation.

$$pV = \frac{1}{3} Nm\overline{c^2}$$

(a) Use the equation to show that the density  $D$  of an ideal gas is given by the relationship:

$$D = \frac{3p}{\overline{c^2}}$$

[1]

(b) Use this information to calculate the typical speed of a gas particle in air.

$$p = 1.0 \times 10^5 \text{ Pa}$$
$$D = 1.2 \text{ kg m}^{-3}$$

speed = .....  $\text{ms}^{-1}$  [1]

(c) A gas particle takes a few minutes to travel about a metre through air.

Explain why it takes so long to cover this distance.

[2]

- 4 Strontium-90 is widely used as a source of beta particles.  
The activity of a strontium-90 source is  $1.6 \times 10^5 \text{ Bq}$ .

(a) Calculate the number of strontium-90 nuclei in the source.  
The decay constant of strontium-90 is  $7.6 \times 10^{-10} \text{ s}^{-1}$ .

number of nuclei = ..... [1]

(b) Calculate the activity of the source in fifty years time.

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

activity = ..... Bq [1]

- 5 The space shuttle is in a circular orbit above the Earth's atmosphere. In order to land on the surface of the Earth, the shuttle has to emit a short burst of high-speed gas. The gas is emitted in the **same** direction as the shuttle is travelling.

Here are some statements about the effect of this action on the space shuttle.

- A The shuttle's orbit remains circular as it descends.
- B The gravitational force on the shuttle decreases as it descends.
- C The momentum of the space shuttle decreases as the gas is emitted.
- D The gravitational potential energy of the shuttle decreases as it descends.
- E The kinetic energy of the space shuttle remains the same as the gas is emitted.

Which **two** of the statements are correct?

statements ..... and ..... [2]

6 The air in a car tyre has a volume of  $2.5 \times 10^{-2} \text{ m}^3$  and a pressure of  $4.8 \times 10^5 \text{ Pa}$  when it has a temperature of 280K.

(a) Show that the tyre holds about  $3 \times 10^{24}$  air particles.

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

[1]

(b) Use your answer to (a) to estimate the internal energy of the air in the tyre.

internal energy = ..... J [1]

7 The graph of Fig. 7.1 shows the relationship between the force  $F$  applied to a spring and its extension  $x$ .

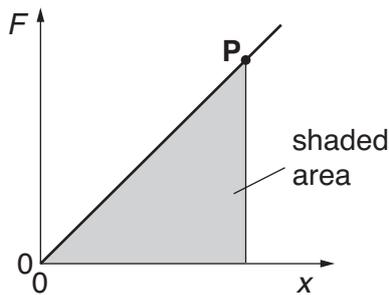


Fig. 7.1

Draw straight lines below to link each **quantity** at point **P** on the graph with its **calculation**.

**quantity**

energy stored in spring

force constant of spring

**calculation**

shaded area

gradient at **P**

reciprocal of gradient at **P**

[1]

- 8 Spacecraft use rockets to accelerate away from the ground during lift-off. The rockets eject large quantities of gas at high speed towards the ground.



Here are some statements about the spacecraft during lift-off from the Moon.

Put a tick (✓) in the boxes next to the **two** correct statements.

The total velocity of the spacecraft and rocket gases is always zero.

The weight of the spacecraft is less than the downwards force accelerating the rocket gases.

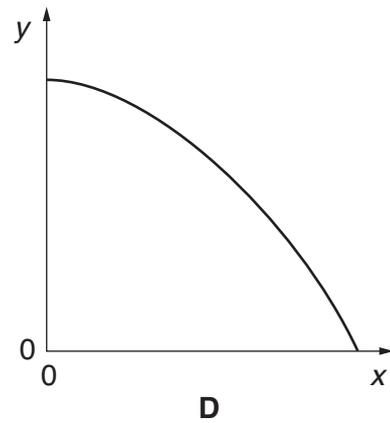
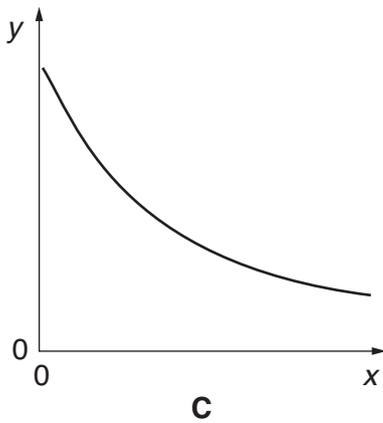
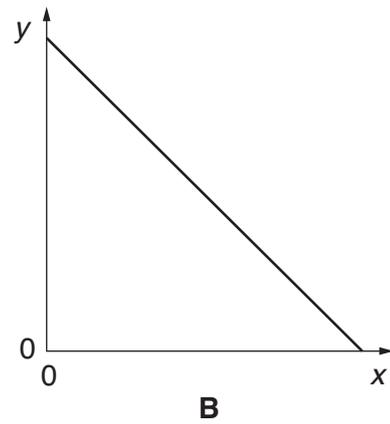
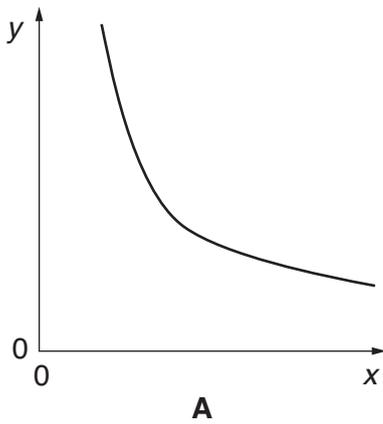
The kinetic energy of the rocket gases provides the upwards force on the spacecraft.

The rocket gases must hit the Moon for there to be an upwards force on the spacecraft.

The total momentum of the spacecraft and rocket gases remains constant as the gases are ejected.

[2]

9 The graphs show changes in the quantity  $y$  due to changes in the quantity  $x$ .



Complete the table with the letters **A**, **B**, **C** or **D**.

quantity $y$	quantity $x$	correct graph
volume of a fixed mass of ideal gas at constant temperature	pressure of the gas	
charge on a capacitor discharging through a resistor	time after the start of discharging	
gravitational potential energy of a ball falling freely to the ground	time after release of the ball	

[2]

[Section A Total: 20]

## Section B

**10** This question is about how atmospheric pressure changes with height above the ground.

- (a) Explain how the gas particles in the Earth's atmosphere are able to exert a downwards force on the ground.

Your answer should clearly link the force on the ground to the behaviour of the gas particles.



*You should use appropriate technical terms in your answer.*

[3]

- (b) A simple model of the Earth's atmosphere assumes that all parts of it have the same temperature  $T$ .

- (i) Use the ideal gas equation  $pV = NkT$  to show that the pressure of a gas at constant temperature is proportional to the number of particles per unit volume.

[1]

- (ii) By considering the energy required to move a gas particle of mass  $m$  to a height  $h$  above the ground, use the Boltzmann factor to justify the expression

$$p = p_0 e^{-\frac{mgh}{kT}}.$$

$p$  is the pressure at height  $h$

$p_0$  is the pressure at ground level

$g$  is the gravitational field strength

$T$  is the temperature of the air

[2]

- (iii) Atmospheric pressure is 100 kPa at ground level when the temperature is 290 K. Calculate the pressure at a height of 2.0 km, assuming the temperature remains constant.

$$m = 4.9 \times 10^{-26} \text{ kg}$$

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

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

pressure = ..... Pa [1]

- (c) The model of the Earth's atmosphere assumes that all parts of it have the same temperature  $T$ . Explain why the atmospheric pressure at a given height  $h$  increases when the temperature  $T$  is raised.

[2]

[Total: 9]

11 This question is about measuring the relative velocity of asteroids.

An asteroid is displaced from its orbit around the Sun and heads towards Earth.

(a) A concerned astronomer uses radar to measure the distance of the asteroid from the Earth. This is the method:

- a short radar pulse is emitted at time 0.00 s
- an echo from the asteroid is detected at 8.00 s.

(i) On the axes of Fig. 11.1, draw two straight lines to show the space-time worldline of the radar pulse.

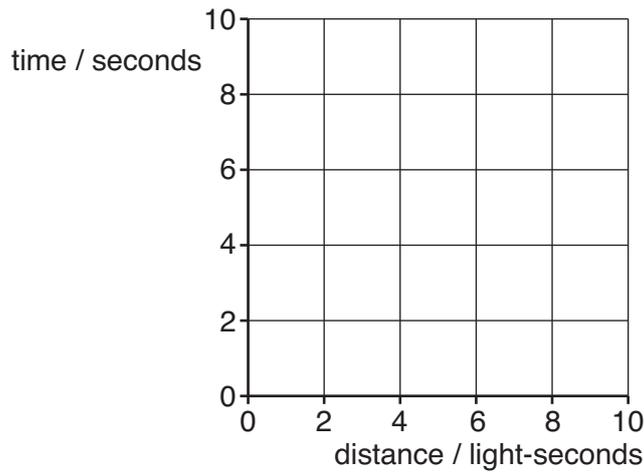


Fig. 11.1

[2]

(ii) Explain why the astronomer can assume that the radar pulse reflects off the asteroid at time 4.00 s.

[2]

(iii) Calculate the distance from the asteroid to the Earth at time 4.00 s.

$$c = 3.00 \times 10^8 \text{ m s}^{-1}$$

distance = ..... m [1]

(b) The astronomer sends out a second pulse at time 946.33s, receiving an echo at time 953.67s.

(i) Explain how the astronomer's data show that the asteroid is getting closer to the Earth.

[2]

(ii) Use the data to calculate the component of the velocity of the asteroid towards the Earth.

component velocity = .....  $\text{ms}^{-1}$  [2]

(c) Explain how the astronomer could use the wavelength of a **single** radar echo to confirm the measurement of the asteroid's component of velocity towards the Earth.

[2]

[Total: 11]

12 This question is about simple harmonic motion.

Fig. 12.1 shows a 10 kg mass suspended from a spring of force constant  $500 \text{ N m}^{-1}$ .

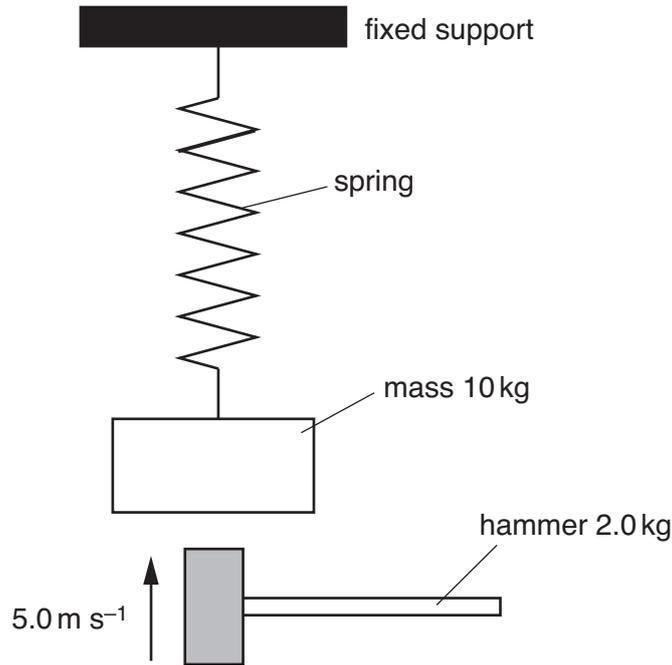


Fig. 12.1

(a) A hammer of mass 2.0 kg is used to set the mass into oscillation. The following observations are made:

- the hammer approaches the mass with an upwards velocity of  $5.0 \text{ m s}^{-1}$
- there is a sharp click as the hammer hits the mass
- the hammer leaves the mass with a downwards velocity of  $3.3 \text{ m s}^{-1}$

(i) Why does the second observation suggest that total kinetic energy is **not** conserved in the collision?

[1]

(ii) Use the observations to show that the collision gives the 10 kg mass an upwards velocity of about  $2 \text{ m s}^{-1}$ .

[3]

- (b) The graph of Fig. 12.2 shows the variation of velocity with time for the mass after it has been set in motion.

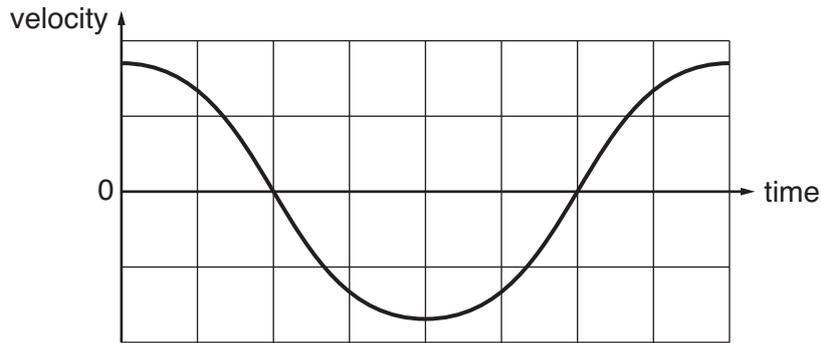


Fig. 12.2

Sketch a graph on Fig. 12.2 to show how the acceleration of the mass varies with time. [2]

- (c) The motion of the mass can be modelled by assuming that the acceleration  $a$  of the mass is given by the expression

$$a = - 50x$$

where  $x$  is the displacement of the mass from equilibrium.

- (i) The mass has a velocity of  $+0.85 \text{ m s}^{-1}$  when its displacement is  $+0.21 \text{ m}$ .

By calculating its average velocity, calculate the displacement  $0.05 \text{ s}$  later.

displacement = ..... m [4]

- (ii) Suggest how you could improve the accuracy of your calculation in (i).

[1]

[Total: 11]

13 This question is about the motion of Halley's comet.

Fig. 13.1 represents the highly elliptical path of Halley's comet in its 76 year orbit of the Sun.

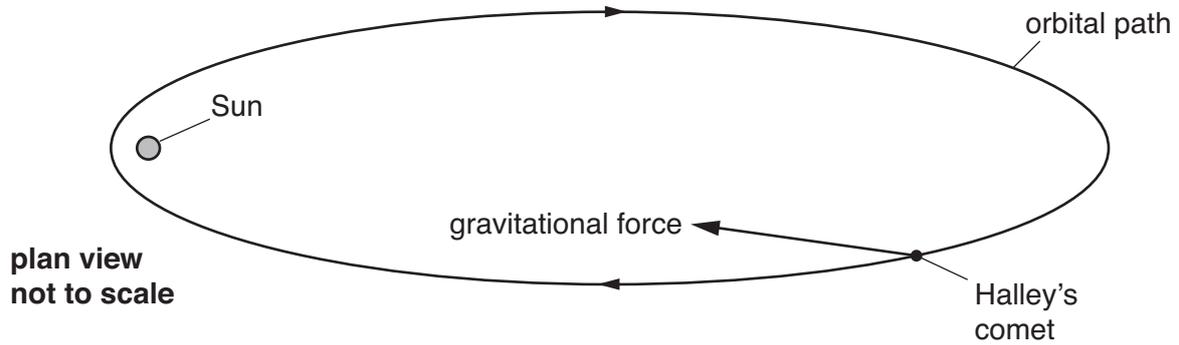


Fig. 13.1

(a) Fig. 13.1 shows the direction of the gravitational force on the comet.

(i) Draw an arrow on Fig. 13.1 to show the component of the gravitational force on the comet which changes its **speed**. Label it **A**. [1]

(ii) Draw an arrow on Fig. 13.1 to show the component of the gravitational force on the comet which changes its **direction**. Label it **C**. [1]

(b) At its closest approach to the Sun, the comet is moving at a speed of  $54.6 \text{ km s}^{-1}$ .

(i) Show that the **kinetic** energy per unit mass is about  $1.5 \text{ GJ kg}^{-1}$ .

[2]

- (ii) The distance from the Sun to the comet is  $8.82 \times 10^{10}$  m at its closest approach. Show that the **total** energy per unit mass is about  $-20 \text{ MJ kg}^{-1}$ .

$$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$$

$$M_s = 2.00 \times 10^{30} \text{ kg}$$

[2]

- (iii) When it is furthest from the Sun, the comet is  $5.3 \times 10^{12}$  m away from the Sun.

Calculate the speed of the comet at this distance.



*In your answer you should show your method clearly and completely.*

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

[Total: 9]

[Section B Total: 40]

**END OF QUESTION PAPER**

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