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OCR
RECOGNISING ACHIEVEMENT

**ADVANCED GCE**

# PHYSICS B (ADVANCING PHYSICS) G494

Rise and Fall of the Clockwork Universe

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 | |
|---|---|---|---|

| Centre Number | | | | | | Candidate Number | | | | |
|---|---|---|---|---|---|---|---|---|---|---|

**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.


DC (LEO/SW) 18797/10

Answer **all** the questions.

## Section A

**1** Here is a list of units.

**J kg$^{-1}$ K$^{-1}$**  **J kg$^{-1}$**  **J K$^{-1}$**  **N kg$^{-1}$**  **N s**

**(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 μF capacitor and a 4.5 V battery.

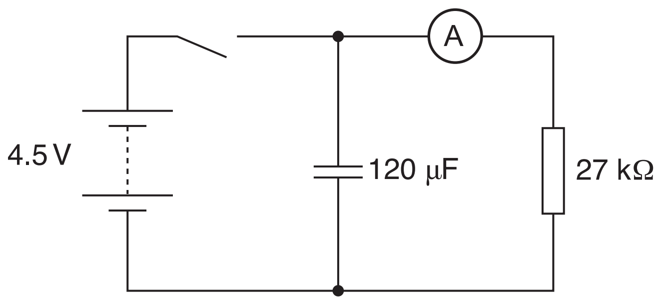



**Fig. 2.1**

**(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 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.

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

speed = ................................................ $\text{m s}^{-1}$ **[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 $1.6 \times 10^5$ Bq.

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

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

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

1 year = $3.2 \times 10^7$ 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 $2.5 \times 10^{-2}$ m$^3$ and a pressure of $4.8 \times 10^5$ Pa when it has a temperature of 280 K.

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

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

**[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 $x$.

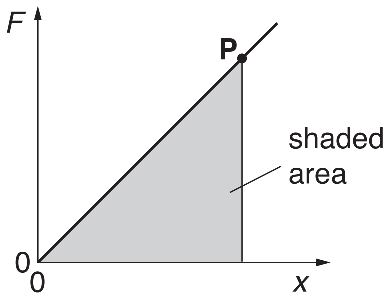



**Fig. 7.1**

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

| quantity | calculation |
|---|---|
| | shaded area |
| energy stored in spring | |
| | gradient at **P** |
| force constant of spring | |
| | 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. ☐

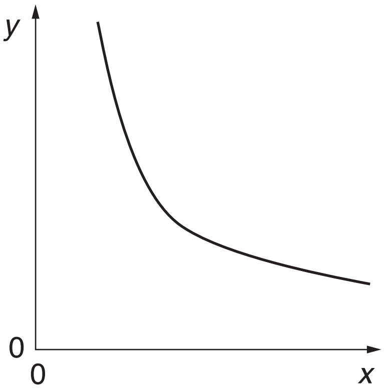
The kinetic energy of the rocket gases provides the upwards force on the spacecraft. ☐

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

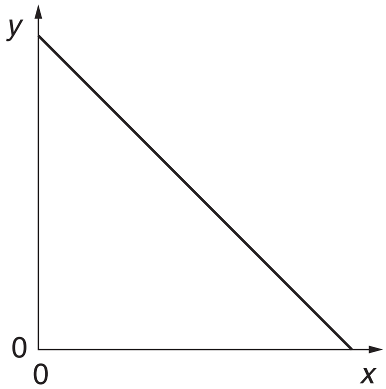
The total momentum of the spacecraft and rocket gases remains constant as the gases are ejected. ☐

**[2]**

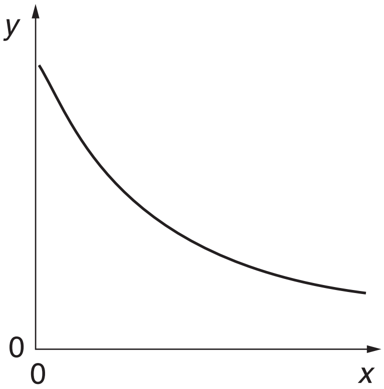
**9** The graphs show changes in the quantity *y* due to changes in the quantity *x*.



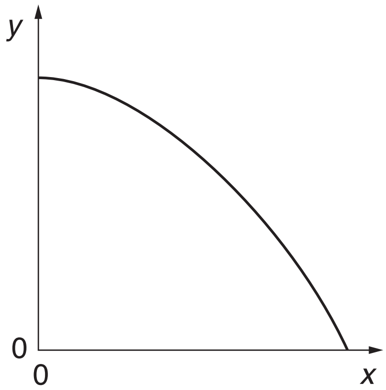

**A**




**B**




**C**




**D**

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.

$m = 4.9 \times 10^{-26}$ kg
$k = 1.4 \times 10^{-23}$ J K$^{-1}$
$g = 9.8$ 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.

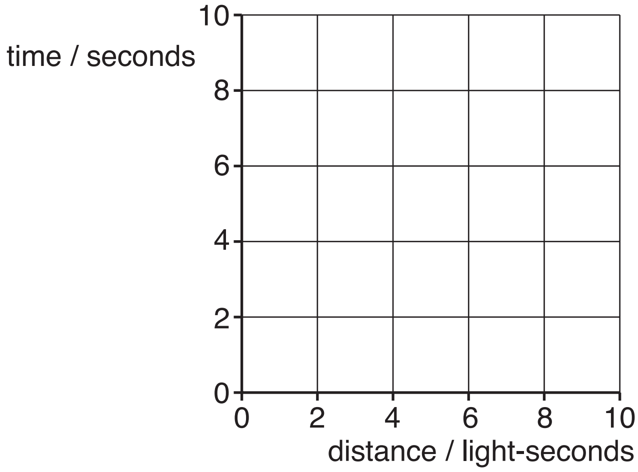



**Fig. 11.1**

**[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.

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

distance = .................................................... m **[1]**

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

**(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 = ............................................... $m\,s^{-1}$ **[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 N m$^{-1}$.

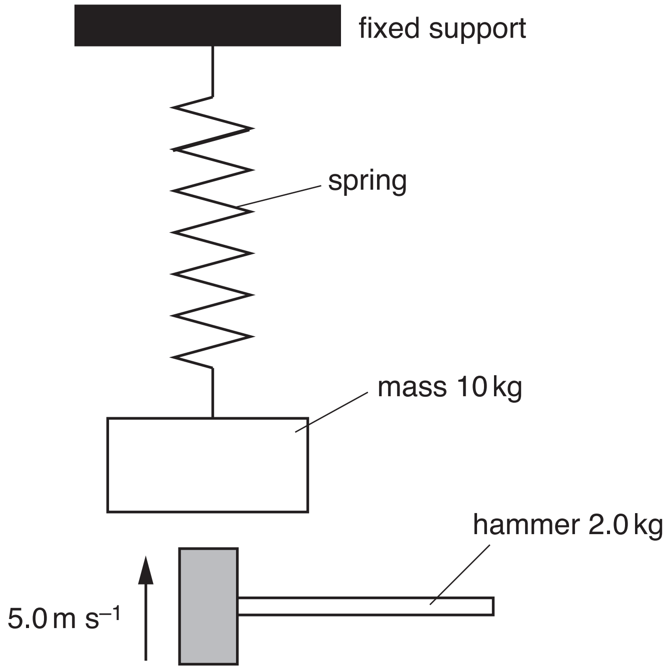



**Fig. 12.1**

**(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 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 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 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.

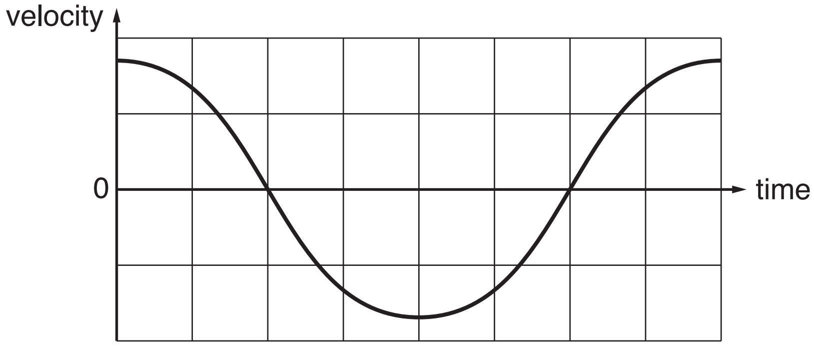



**Fig. 12.2**

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 m s$^{-1}$ when its displacement is +0.21 m.

By calculating its average velocity, calculate the displacement 0.05 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.

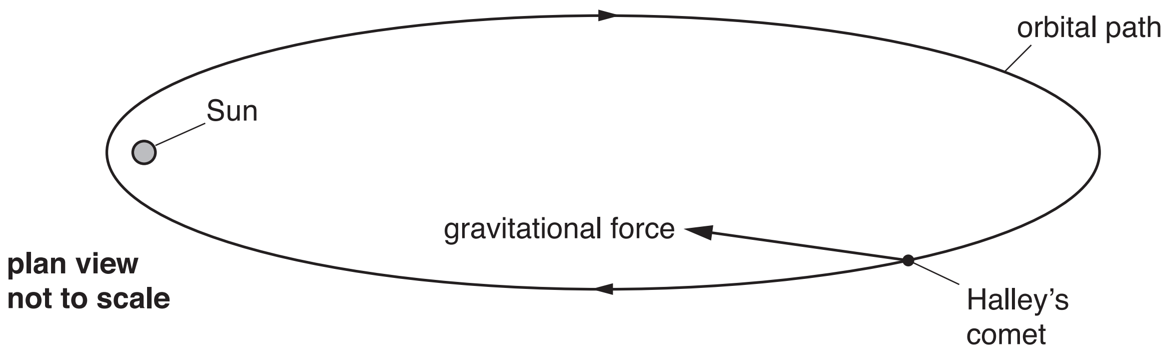



**Fig. 13.1**

**(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 $54.6\,\text{km}\,\text{s}^{-1}$.

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

**[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 MJ kg$^{-1}$.

$G = 6.67 \times 10^{-11}$ N m2 kg$^{-2}$
$M_s = 2.00 \times 10^{30}$ 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 = ................................................ m s$^{-1}$ **[3]**

**[Total: 9]**

**[Section B Total: 40]**

**END OF QUESTION PAPER**

**PLEASE DO NOT WRITE ON THIS PAGE**