OCR
RECOGNISING ACHIEVEMENT

Thursday 20 June 2013 – Morning

A2 GCE PHYSICS B (ADVANCING PHYSICS)

G494/01 Rise and Fall of the Clockwork Universe

G412070613

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

G49401

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. Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- 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**.
- 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.

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

(a) Which **one** is a correct unit for gravitational potential?

answer .... **[1]**

(b) Which **one** is a correct unit for kinetic energy?

answer .... **[1]**

2 State carefully the meaning of the quantity λ in the radioactive decay expression $\Delta N = -\lambda N \Delta t$.

[2]

3 The distance of an asteroid from the Earth can be measured by firing a pulse of electromagnetic radiation at the asteroid and measuring how long it takes for the pulse to return to Earth.

One of the following assumptions is needed to calculate the distance.

Put a tick (✓) in the box next to the **one** necessary assumption.

The asteroid is not moving relative to the Earth.	☐
None of the radiation is absorbed by the asteroid.	☐
The outward and returning pulses travel for the same time.	☐
The outward and returning pulses have the same wavelength.	☐

[1]

4 A teacher attempts to use the apparatus shown in Fig. 4.1 to demonstrate that momentum is conserved in a collision.

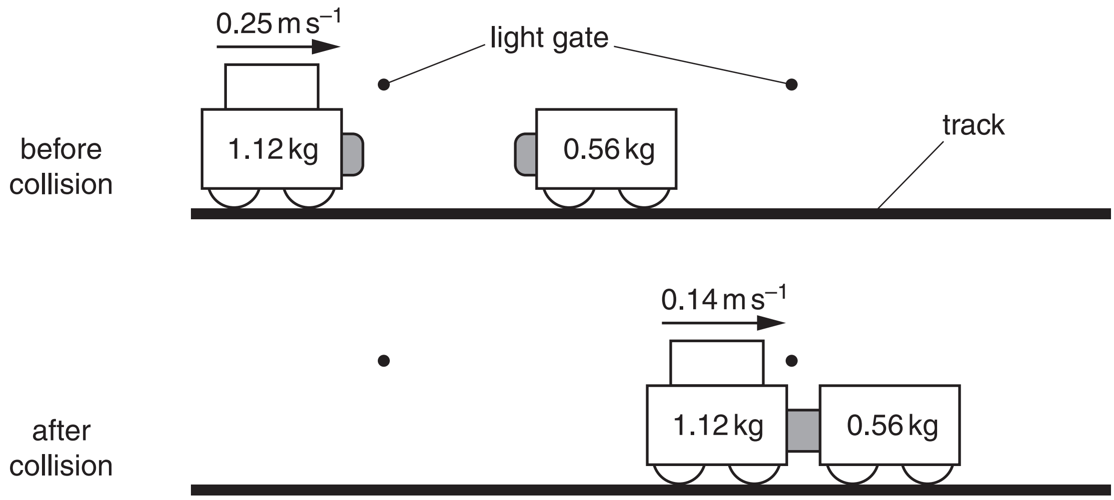


Fig. 4.1

The teacher launches a trolley along the track towards a stationary trolley.

The trolleys collide and stick together.

The speed of the launched trolley is measured before and after the collision using light gates.

(a) Use the data of Fig. 4.1 to show that the collision does **not** appear to conserve momentum.

[2]

(b) Suggest a reason for the discrepancy.

[1]

5 A student uses the circuit of Fig. 5.1 to measure the capacitance of the capacitor.

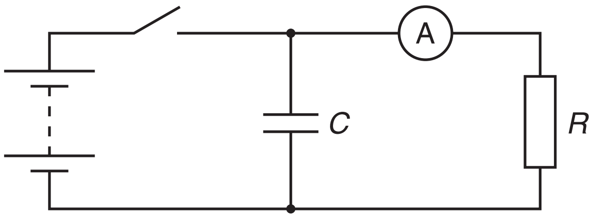


Fig. 5.1

The switch is closed to charge the capacitor to 3.0 V.

The switch is then opened at time $t = 0$.

The current in the resistor is recorded every ten seconds after the switch is opened.

The graph of Fig. 5.2 shows how the current changes with time.

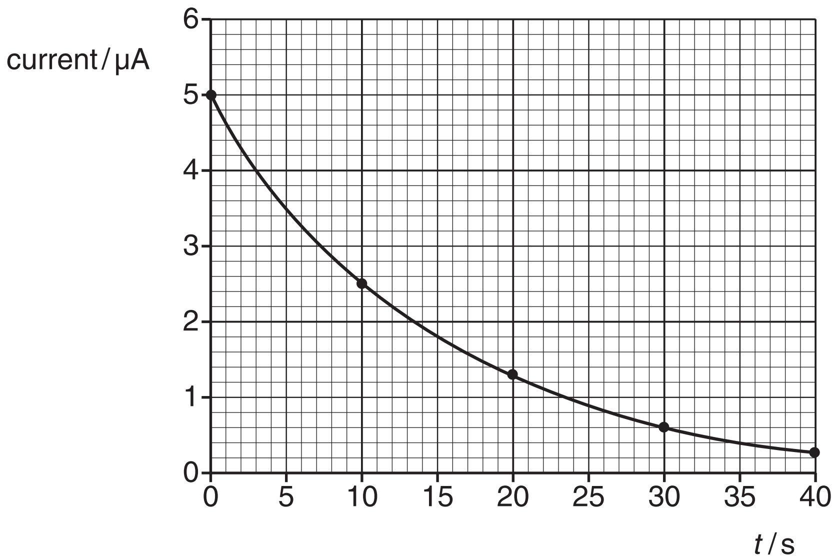


Fig. 5.2

(a) Use the current at $t = 0$ to show that the resistance R is 600 kΩ.

[1]

(b) By using the graph to find the time constant, calculate the capacitance C.

C = ... F **[2]**

6 Fig. 6.1 shows a mass on the end of a spring.

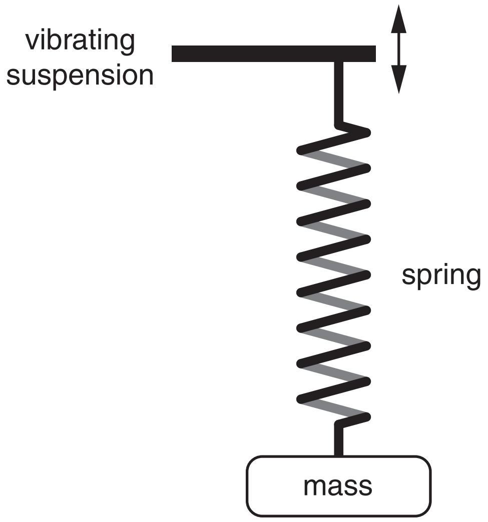


Fig. 6.1

The suspension vibrates vertically with a constant amplitude of 1.0 mm.

It is observed that when the frequency of the suspension is 3.0 Hz, the system goes into resonance, with the mass oscillating vertically with an amplitude of 5.0 mm.

Sketch a graph on the axes of Fig. 6.2 to show how the amplitude of the mass varies as the frequency of the suspension is slowly increased from 0.1 Hz to 8.0 Hz.

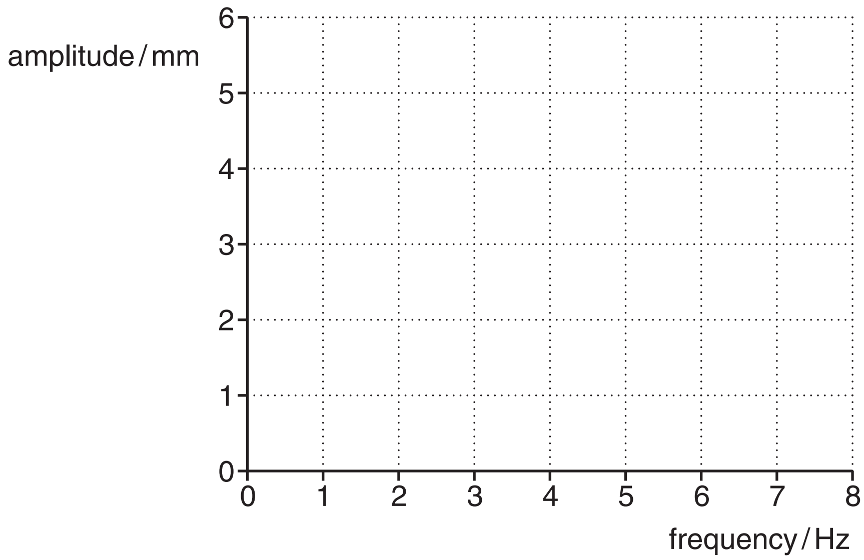


Fig. 6.2

[3]

7 The graph of Fig. 7.1 shows how the gravitational potential V changes as you move from the surface of a planet to the surface of its moon, where r is the distance from the centre of the planet.

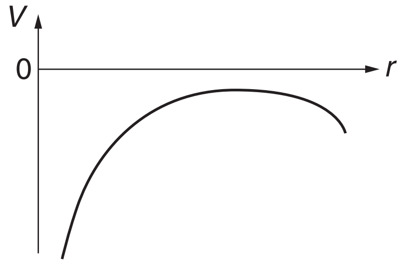


Fig. 7.1

Which of the graphs of Fig. 7.2 shows how the gravitational force F on you changes as you make the same journey?

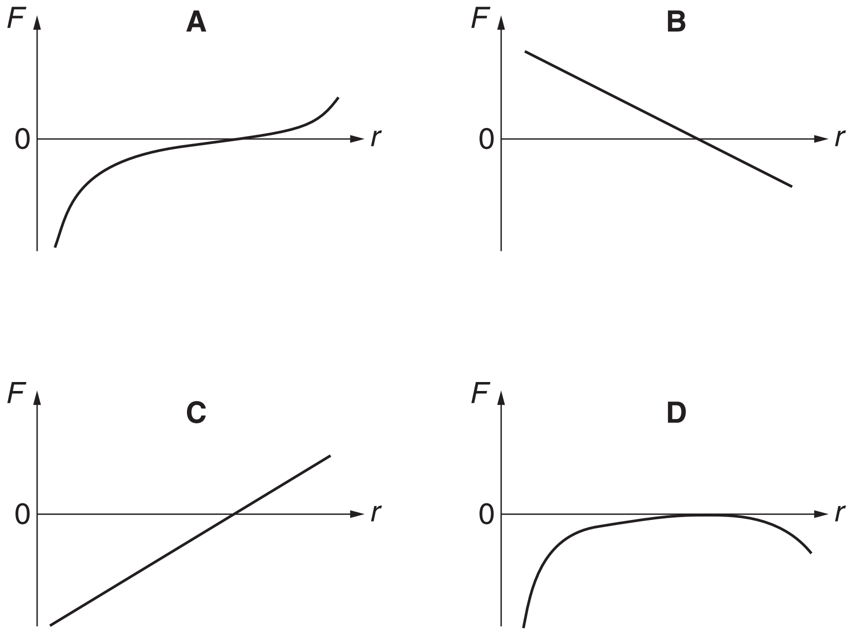


Fig. 7.2

answer .... **[1]**

8 In 2005 the Huygens probe landed on Titan, one of Saturn's moons.

It recorded an atmosphere of nitrogen at a temperature of 94 K.

Calculate the root mean square speed of a nitrogen molecule at this temperature.

mass of a nitrogen molecule = 4.7×10^{-26} kg

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

root mean square speed = ... m s^{-1} **[3]**

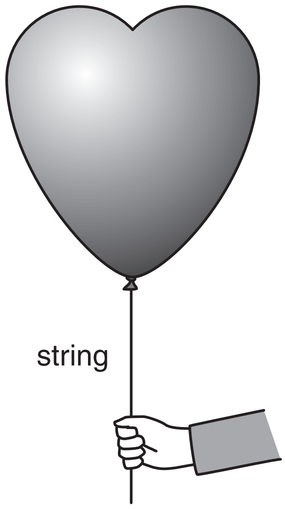
9 The idea that the Universe started with a hot big bang almost 14 billion years ago is now a widely accepted theory.

Explain how the cosmological background radiation provides evidence for this theory.

[2]

SECTION B

10 This question is about the use of helium to inflate party balloons.



(a) A balloon is fully inflated with helium gas at a temperature of 20 °C and a pressure of 1.1×10^5 Pa. The volume of the gas in the inflated balloon is $4.5 \times 10^{-3}\,\text{m}^3$.

(i) Calculate the number of helium particles in the balloon.

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

number = ... **[3]**

(ii) Calculate the mass of helium gas in the balloon.

molar mass of helium atoms = 4.0×10^{-3} kg mol^{-1}

Avogadro constant = 6.0×10^{23} mol^{-1}

mass = ... kg **[1]**

(b) Explain how the motion of the helium particles stops the balloon from collapsing.

Your answer should clearly link the motion of the particles to their effect on the balloon.

[3]

(c) A second identical balloon is filled with hydrogen gas.

The gas in each balloon has the same density, volume and temperature.

Calculate the pressure of the hydrogen gas. Explain your answer clearly.

molar mass of hydrogen molecules = $2.0 \times 10^{-3}\,\text{kg mol}^{-1}$

pressure = ... Pa **[3]**

[Total: 10]

11 This question is about the use of a pendulum to measure the strength of the Earth's gravitational field.

Fig. 11.1 shows a pendulum made from a mass suspended from a fixed point by a stiff wire.

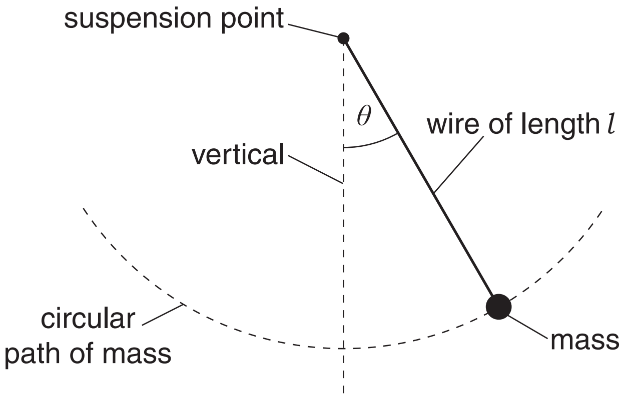


Fig. 11.1

When the mass is displaced from equilibrium by an angle θ and released, it performs oscillations, following the circular path shown. For small enough values of θ the period of the oscillations T is given by

$$T = 2\pi\sqrt{\frac{l}{g}}$$

where l is the length of the wire and g the gravitational field strength.

(a) Show that the length of the wire needs to be about 1 m if T is 2.0 s in a location where $g = 9.8\,\mathrm{N\,kg^{-1}}$.

[2]

(b) A measurement of g is made using the pendulum. The length of the wire is measured in the morning of a cold day. The timing of the oscillations is done later when it is warmer and the wire has increased in length.

Explain the effect this systematic error will have on the calculated value of g.

[2]

(c) Fig. 11.2 shows the two forces *T* and *W* which act on the mass.

T is the tension in the wire and *W* is the weight of the mass.

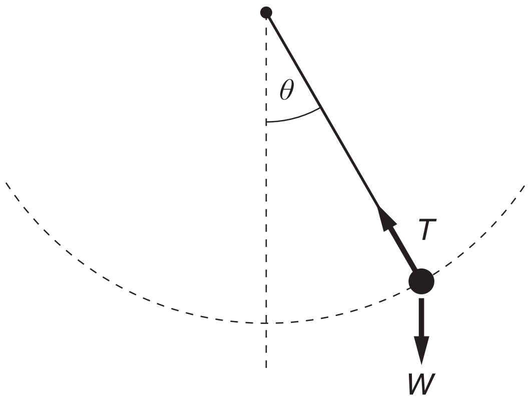


Fig. 11.2

The resultant force *F* on the mass is at right angles to the tension *T*.

Draw a vector triangle in the space above which shows that $F = W\sin\theta$.

[2]

(d) The graph of Fig. 11.3 shows how the value of *F* changes during two cycles of oscillation.

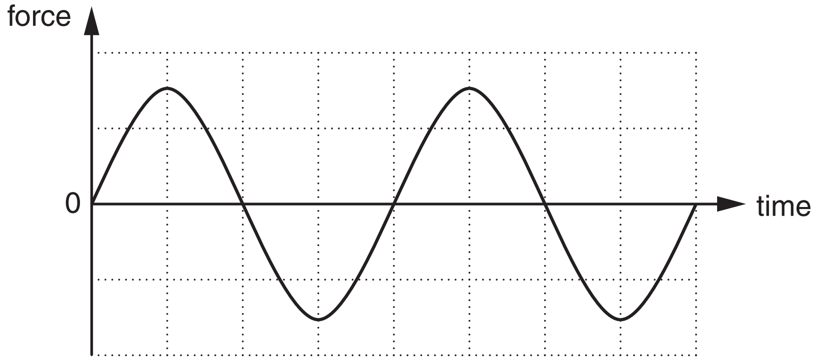


Fig. 11.3

Draw on Fig. 11.3 to show how the value of the velocity of the mass changes during this time.
[2]

[Total: 8]

12 Fig. 12.1 shows the circular orbit of a satellite **S** around a planet **P**.

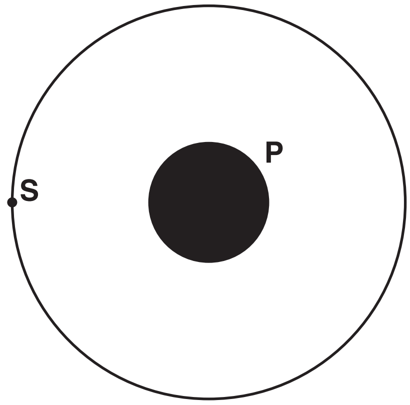


Fig. 12.1

(a) (i) Draw an arrow on Fig. 12.1 to show the direction of the planet's gravitational field at **S**. **[1]**

(ii) Explain why the force due to this gravitational field does not change the speed of the satellite.

[2]

(iii) By considering the centripetal force on the satellite, calculate its speed v.

mass of planet = 4.8×10^{23} kg

radius of orbit = 6.1×10^{6} m

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

v = ... m s^{-1} **[3]**

(iv) Calculate the gravitational potential energy of the satellite **S**.

mass of satellite = 5.7×10^3 kg

gravitational potential energy = ... J **[2]**

(b) Two satellites, $\mathbf{S_1}$ and $\mathbf{S_2}$, of the same mass are also in circular orbits around **P**.

The radius of orbit for $\mathbf{S_1}$ is twice the radius of orbit for $\mathbf{S_2}$. Compare the kinetic energy of the two satellites.

[3]

[Total: 11]

13 This question is about an ion thruster, a type of rocket for accelerating spacecraft.

The main details of an ion thruster are shown in Fig. 13.1.

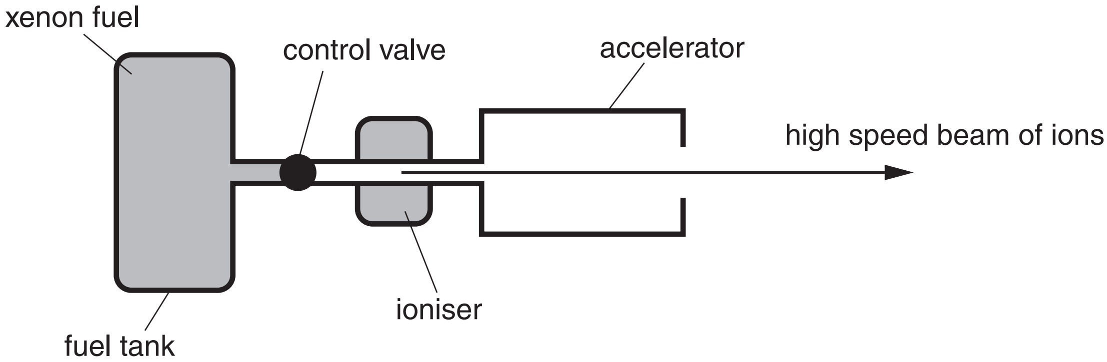


Fig. 13.1

The thruster operates as follows:

- xenon gas in the fuel tank passes into the ioniser
- the ioniser removes an electron from each xenon atom to make an ion
- the accelerator transfers kinetic energy to each ion
- the ions leave the thruster at high speed

(a) The ions enter the accelerator with negligible kinetic energy.

Each ion leaves with a kinetic energy of 4.0×10^{-16} J.

(i) Show that the momentum transferred to each ion by the accelerator is about 1×10^{-20} kg m s^{-1}.

mass of xenon ion = 2.2×10^{-25} kg

[3]

(ii) 3.6×10^{17} ions leave the accelerator every second.

Calculate the force on the ion thruster.

force = ... N **[1]**

(iii) The combined mass of the ion thruster and spacecraft is 860 kg.

Calculate the change in speed of the spacecraft when the thruster operates for a year. Neglect any change of mass of the spacecraft.

1 year = 3.2×10^7 s

change of speed = ... m s^{-1} **[2]**

(b) It has been suggested that the ioniser could simply be a tube heated to a high temperature.

(i) Explain why some of the gas in the tube would be ionised.

Your answer should clearly link the ionisation of the gas to its temperature.

[3]

(ii) The tube is heated to a temperature of 1400 K. The energy ε required to remove an electron from a xenon atom in the ioniser is 2.0×10^{-18} J. By calculating the value of the Boltzmann factor $f = e^{\frac{-\varepsilon}{kT}}$ for the gas in the tube at 1400 K comment on the feasibility of the suggested ioniser.

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

f = ... **[2]**

[Total: 11]

END OF QUESTION PAPER

PLEASE DO NOT WRITE ON THIS PAGE