THIS IS A LEGACY SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

PHYSICS B (ADVANCING PHYSICS) 2863/01

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)

Wednesday 10 June 2009
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, however additional paper may be used if necessary.
- 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 **70**.
- You are advised to spend about 20 minutes on Section A and 55 minutes on Section B.
- There are four marks for the quality of written communication in 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.
- This document consists of **20** pages. Any blank pages are indicated.

FOR EXAMINER'S USE		
Section	**Max.**	**Mark**
A	**20**	
B	**50**	
TOTAL	**70**	

Turn over

Section A

Answer **all** the questions.

1 Sirius is the brightest star visible in the night sky from Britain. It is about 1.1×10^{17} m from Earth.

Calculate the distance to Sirius in light years.

$c = 3.0 \times 10^{8}\,\mathrm{m\,s^{-1}}$

1 year = 3.2×10^{7} s

distance = ………………….. light years **[2]**

2 A student takes readings of the temperature of water in a beaker as it cools. She calculates from measurements that the initial rate of fall of temperature is 1.5 °C per minute.

Data: specific thermal capacity of water = $4200\,\mathrm{J\,kg^{-1}\,°C^{-1}}$

mass of water = 0.27 kg

(a) Which of the values below is the nearest to the initial rate of transfer of energy from the water?

A 3 W **B** 30 W **C** 300 W **D** 3000 W

The nearest value is ……………… **[1]**

(b) Here are two statements about the experiment:

The original rate of fall of temperature was 1.5 °C per minute.
After one minute the temperature had fallen by 1.2 °C.

Explain how both statements can be correct.

[1]

3 A hot solid can be represented by an energy level diagram as shown below. The atoms of a solid are assumed to occupy energy levels zero, E, $2E$, $3E$ or $4E$. Fig. 3.1 shows the relative number of atoms with different energies in the solid at temperature T.

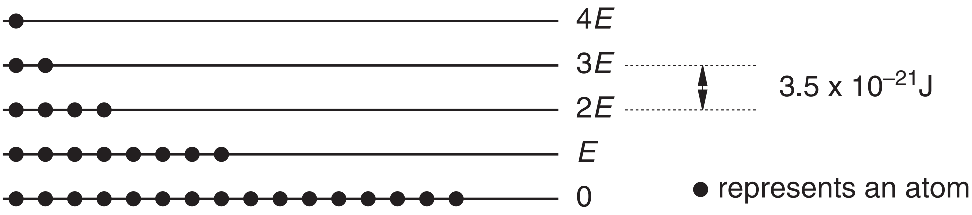

Fig. 3.1

(a) The Boltzmann factor for the solid is 0.5. State the feature of Fig. 3.1 that shows this to be the case.

[1]

(b) The energy levels shown are separated by an energy $E = 3.5 \times 10^{-21}$ J.
Show that for this solid a temperature of 360 K gives a Boltzmann factor of about 0.5.

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

[2]

4 Here are some data about a volume of helium gas:

temperature	= 300 K
volume	= 4.1×10^{-3} m^3
pressure	= 1.1×10^{-2} Pa

Calculate the number of helium atoms in the volume of gas. State the equation you use in your calculation.

Avogadro constant, number of particles mol^{-1} = 6.0×10^{23} mol^{-1}
R, molar gas constant = 8.3 J mol^{-1} K^{-1}

number of helium atoms = ... **[3]**

5 Sketch a graph on the axes of Fig. 5.1 showing how the volume of a fixed mass of an ideal gas at constant temperature varies with the pressure of the gas.

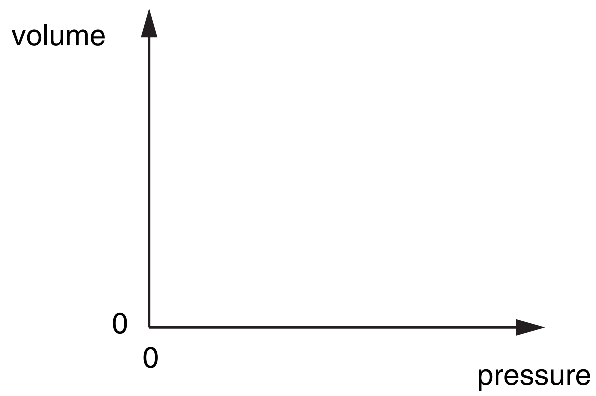

Fig. 5.1

[2]

6 Distant galaxies are observed to be moving away (receding) from the Earth at high velocities.

(a) State the observation that indicates that distant galaxies are receding from the Earth.

[1]

(b) If the velocity of recession v of a distant galaxy is known, its distance from Earth can be determined using the relationship

$$v = H_0 d$$

where H_0 is the Hubble constant.

A galaxy, X, is at a distance of 4.5×10^{20} km and is observed to be receding at a velocity of about $1000\,\text{km s}^{-1}$.

Another galaxy, Y, is observed to recede at a velocity of about $800\,\text{km s}^{-1}$.

Calculate the distance to galaxy Y.

distance to galaxy Y = …………………………… km **[2]**

7 A sample of uranium-238 contains 6×10^{19} nuclei. The sample has an activity of 300 decays per second. Calculate the decay constant λ of the uranium isotope.

decay constant = ……………………….. s^{-1} **[2]**

8 Fig. 8.1 shows a pinball machine. Fig. 8.2 shows a simplified view of the firing mechanism of the steel ball. The spring is compressed and then released, accelerating the steel ball which then enters the pinball track.

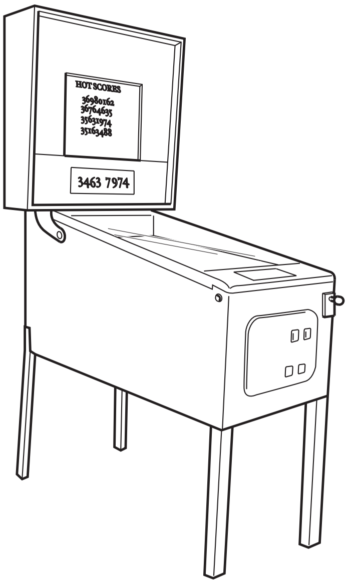

Fig. 8.1

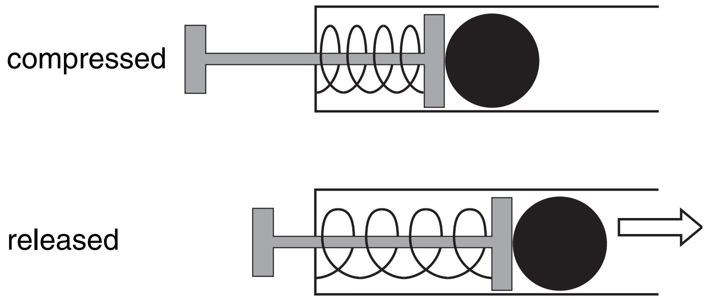

Fig. 8.2

The spring is compressed by 0.078 m. The stiffness constant of the spring is 140 N m^{-1}.

(a) Show that the energy stored in the spring is about 0.4 J.

[1]

(b) Sixty per cent of the stored energy in the spring is transferred to the kinetic energy of the steel ball.

Calculate the speed at which the steel ball leaves the spring.
mass of steel ball = 0.015 kg

velocity of ball = ……………………………….. m s^{-1} **[2]**

[Section A Total: 20]

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Section B

In this section, four marks are available for the quality of written communication.

9 This question is about a simple pendulum.
A pendulum has length L and oscillates through a small angle as shown in Fig. 9.1.

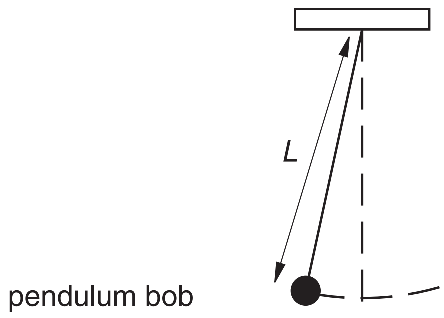

Fig. 9.1

Fig. 9.2 shows the displacement-time graph of the oscillation.

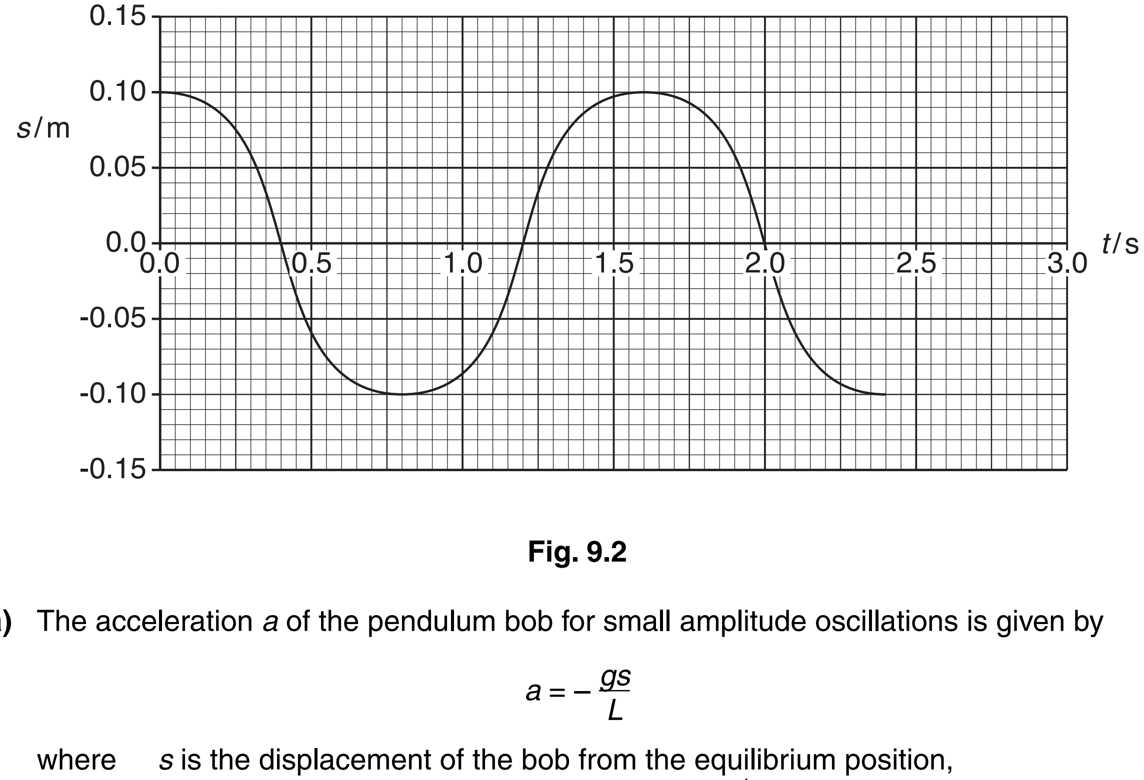

Fig. 9.2

(a) The acceleration a of the pendulum bob for small amplitude oscillations is given by

$$a = -\frac{gs}{L}$$

where s is the displacement of the bob from the equilibrium position,
g is the gravitational field strength = 9.8 N kg^{-1},
L is the length of the pendulum string = 0.60 m.

(i) Mark a point on the graph where maximum horizontal acceleration of the bob occurs. Label this point 'M'. **[1]**

(ii) Calculate the maximum acceleration of the bob.

maximum acceleration = ... $m\,s^{-2}$ **[2]**

(iii) Explain how the equation given for the acceleration of the bob shows that the pendulum oscillates with simple harmonic motion. Give a different example of an oscillator and explain whether or not it shows simple harmonic oscillation.

[4]

(b) The periodic time of a pendulum is given by the equation

$$T = 2\pi\sqrt{\frac{L}{g}}.$$

Use this equation and data from Fig. 9.2 to confirm that the length L of the pendulum is about 0.6 m.

[2]

Question 9 continues on next page

Turn over

(c) The oscillation of the pendulum is stopped. The oscillation is started again with **half** its original amplitude. Complete the table showing how the maximum velocity, maximum acceleration and the energy of the oscillation will change when the amplitude of the oscillation is halved. You have already calculated the maximum acceleration of the bob for the original amplitude in **(a) (ii)**.

	original	**new**
amplitude/m	0.10	0.05
maximum acceleration of bob/m s^{-2}		
maximum velocity of bob/m s^{-1}	0.39 m s^{-1}	
total energy of oscillation/J	3.8 x 10^{-3}	

[3]

[Total: 12]

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10 This question is about the physics of hitting a ball.
In the game of croquet a stationary ball of mass 0.5 kg is struck with a mallet as shown in Fig. 10.1. The force exerted on the ball by the mallet during contact when struck by the player is shown in Fig 10.2.

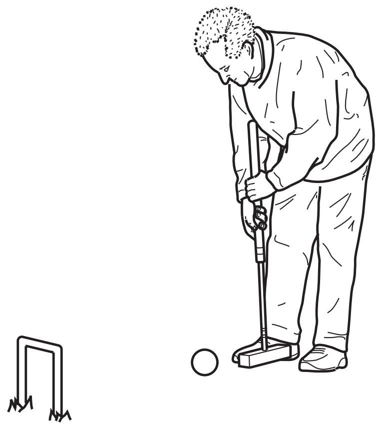


Fig. 10.1

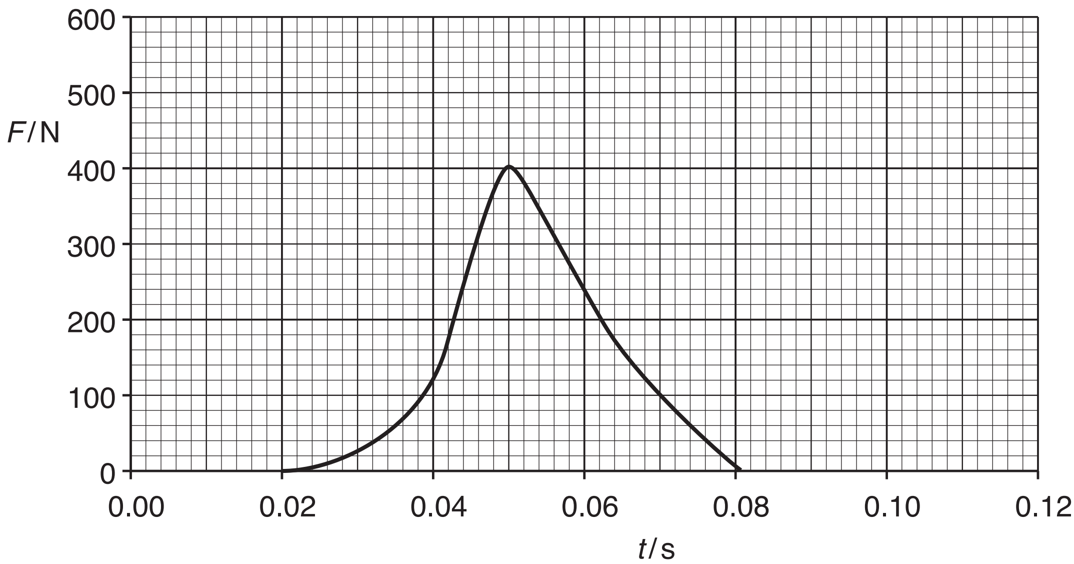


Fig. 10.2

(a) (i) State the feature of the graph that indicates the impulse given to the ball.

feature .... **[1]**

(ii) Use information from the graph to estimate the impulse given to the ball. Show your working clearly.

impulse = ……………………….. N s **[2]**

(b) The impulse given to the ball is the same quantity as the change of momentum of the ball.

(i) Show that the units of impulse, N s, are equivalent to the units of momentum, kg m s^{-1}.

[2]

(ii) Use your answer to **(a) (ii)** to calculate the velocity of the ball as it leaves the mallet.
mass of ball = 0.5 kg.

velocity of ball = …………………….. m s^{-1} **[2]**

(c) A ball of mass M makes a direct hit with an identical stationary ball as shown in Fig. 10.3.

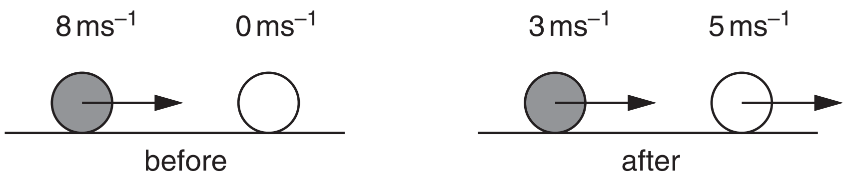


Fig. 10.3

Show that momentum has been conserved in the collision but kinetic energy has not. Suggest a reason why kinetic energy has not been conserved.

[4]

[Total: 11]

11 A student is experimenting with capacitors. He has two capacitors available, one of capacitance 1000 μF and one of unknown value. He connects the circuit shown in Fig 11.1 and closes the switch **S**.

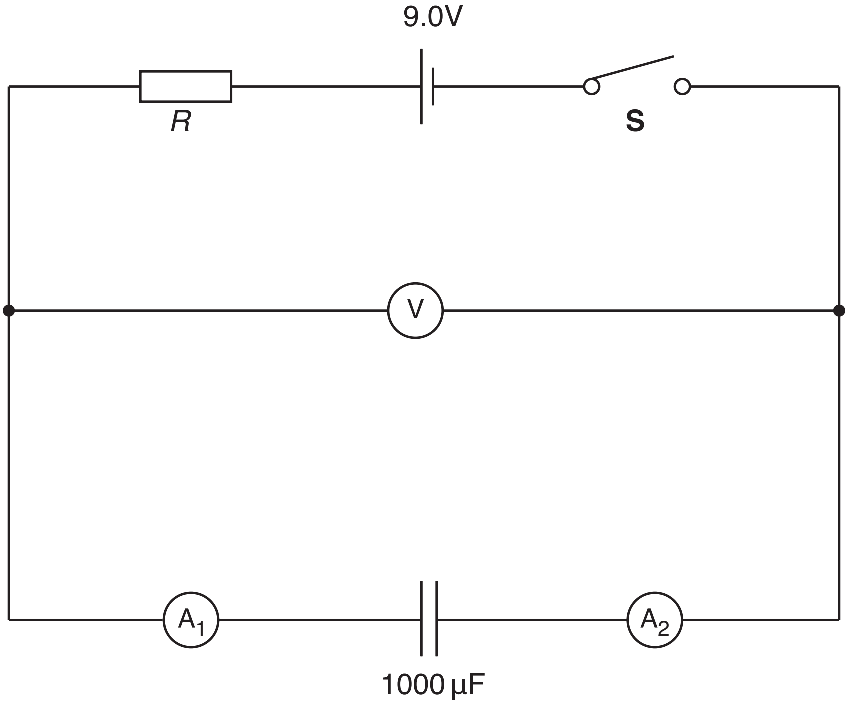


Fig. 11.1

(a) **(i)** State the current in ammeter A_1 when the current in ammeter A_2 is + 0.5 mA.

sign and magnitude of current = ………………….. mA **[1]**

(ii) Calculate the charge on the 1000 μF capacitor when the potential difference across the capacitor is 9.0 V.

charge = …………… C **[2]**

(b) The switch **S** is now opened again. The high-resistance voltmeter reading remains at 9.0V. The student connects the uncharged capacitor of unknown value in parallel with the charged 1000 μF capacitor.

(i) Draw on Fig. 11.1 to show the second capacitor connected in the circuit. **[1]**

When the second capacitor has been connected the student notices that the voltmeter reading has dropped to half its previous value.

(ii) Deduce the capacitance of the second capacitor explaining your reasoning carefully.

Reasoning:

capacitance = ………………….. μF **[2]**

(c) The student now connects the 1000 μF capacitor into the circuit shown in Fig. 11.2. Switch **S** is closed briefly and then opened again.

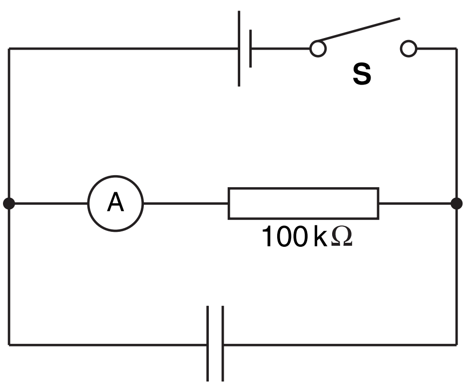


Fig. 11.2

(i) Show that when the switch is opened the initial current in the resistor is 9×10^{-5} A.

[1]

(ii) Show that the current in the resistor falls to less than 3.5×10^{-5} A after the switch has been opened for 100 s.

[2]

[Total: 9]

12 This question is about an attempt to send a space probe into orbit around a comet. This enables the mass of the comet to be estimated.
Fig. 12.1 shows the orbit of comet 67P around the Sun.

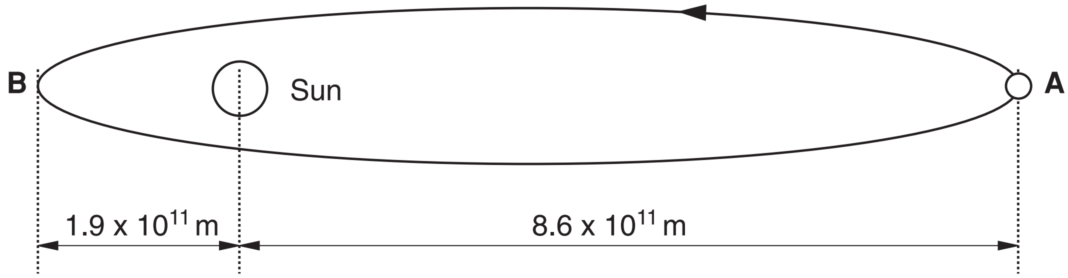


Fig. 12.1

At point **A** on the orbit the **gravitational potential** of the comet in the Sun's gravitational field is $-1.6 \times 10^8\,\mathrm{J\,kg^{-1}}$. As the comet approaches the Sun it loses potential energy.

(a) **(i)** Explain what is meant by the term *gravitational potential.*

[2]

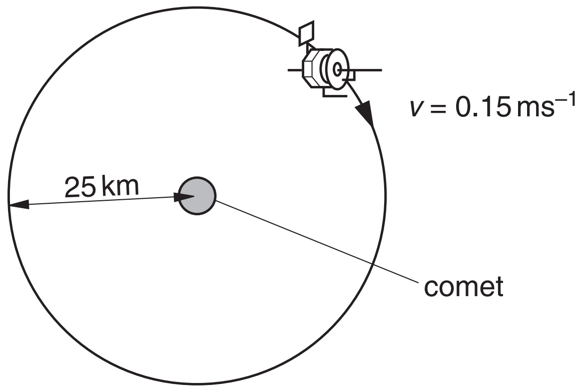
(ii) Calculate the gravitational potential of the comet at **B**.
mass of the Sun = 2.0×10^{30} kg
$G = 6.7 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$

gravitational potential = ... $\mathrm{J\,kg^{-1}}$ **[2]**

(iii) Estimate how much kinetic energy per kg the comet gained as it travelled from **A** to **B**. Explain your reasoning.

kinetic energy per kg = ... $\mathrm{J\,kg^{-1}}$ **[2]**

(b) Fig. 12.2 shows the comet with a space probe of mass 2900 kg in a circular orbit around the comet. The probe is orbiting at a speed of $0.15\,m\,s^{-1}$. The orbital radius is 25 km.



not to scale

Fig. 12.2

(i) Draw an arrow on the diagram showing the direction of the force keeping the probe in orbit. **[1]**

(ii) Use the information from Fig. 12.2 to calculate this force on the probe.

centripetal force = …………….N **[3]**

(iii) Write down an expression for the gravitational force acting between the probe and the comet.

[1]

(iv) Use your answers to **(ii)** and **(iii)** to calculate the mass of the comet.

mass of comet = …………………….. kg **[3]**

[Total: 14]
Quality of Written Communication **[4]**
[Section B Total: 50]

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