

CANDIDATE
NAME

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Secondary 6

Physics

14/08/24
August 2024

Paper 4

1 hour

Candidates answer on the Question Paper.

Additional Materials: Calculator

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.

Write in dark blue or black pen.

You may use a soft pencil for any diagrams.

Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer all the questions.

The number of marks is given in brackets [] at the end of each question or part question.

The total of the marks for this paper is 40.

For Teacher's Use	
Question No	Marks
1	
2	
3	
4	
5	
Total	

Invigilator's Sign: _____

Invigilator's Signature: _____

1. (a) Two-point masses are isolated in space and are separated by a distance x .

State an expression relating the gravitational force F between the two masses to the magnitudes M and m of the masses. State the name of any other symbol used.

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.....
..... [1]

- (b) A spacecraft is to be put into a circular orbit about a spherical planet.

The planet may be considered to be isolated in space. The mass of the planet, assumed to be concentrated at its centre, is $7.5 \times 10^{23} \text{ kg}$. The radius of the planet is $3.4 \times 10^6 \text{ m}$.

- (i) The spacecraft is to orbit the planet at a height of $2.4 \times 10^5 \text{ m}$ above the surface of the planet. At this altitude, there is no atmosphere. Show that the speed of the spacecraft in its orbit is $3.7 \times 10^3 \text{ ms}^{-1}$.

[2]

- (ii) One possible path of the spacecraft as it approaches the planet is shown in **Fig.1**.

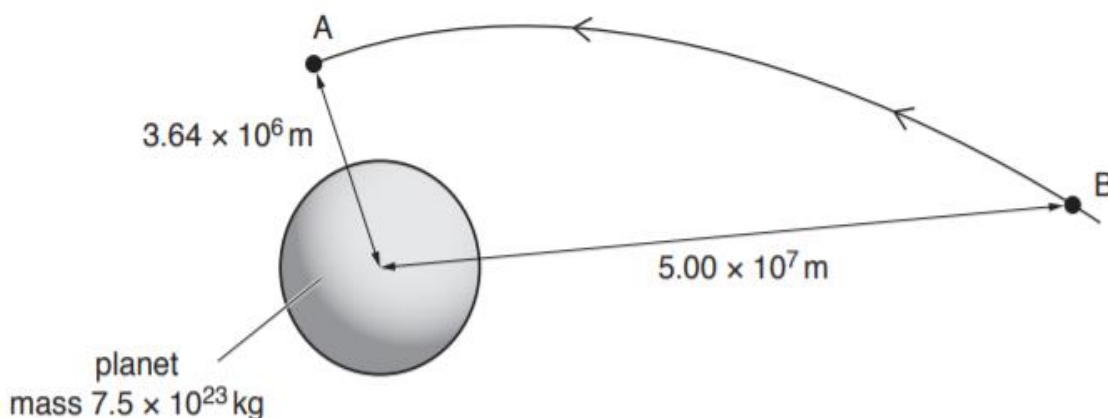


Fig.1 (not to scale)

The spacecraft enters the orbit at point A with speed $3.7 \times 10^3 \text{ ms}^{-1}$.

At point B, a distance of $5.00 \times 10^7 \text{ m}$ from the center of the planet, the spacecraft has a speed of $4.1 \times 10^3 \text{ ms}^{-1}$. The mass of the spacecraft is 650 kg .

For the spacecraft moving from point B to point A, show that the change in gravitational potential energy of the spacecraft is $8.3 \times 10^9 \text{ J}$.

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[3]

(c) By considering changes in gravitational potential energy and in kinetic energy of the spacecraft, determine whether the total energy of the spacecraft increases or decreases in moving from point B to point A. A numerical answer is not required.

.....

 [2]

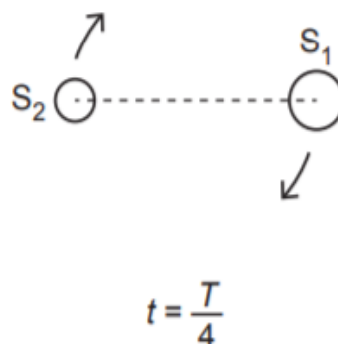
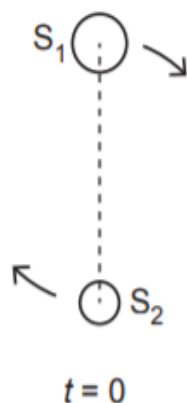
[Total: 8]

2. (a) State what is meant by a gravitational force.

.....
 [1]

(b) A binary star system consists of two stars S_1 and S_2 , each in a circular orbit.

The orbit of each star in the system has a period of rotation T .
 Observations of the binary star from Earth are represented in **Fig.1**.



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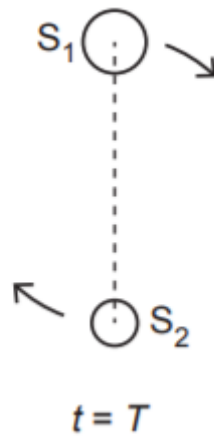
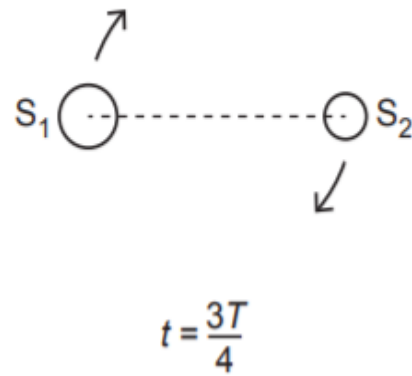
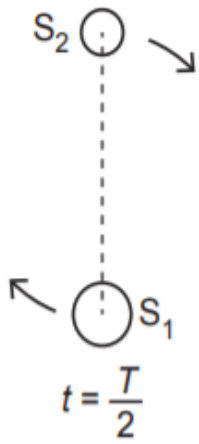


Fig.1 (not to scale)

Observed from Earth, the angular separation of the centers of S_1 and S_2 is 1.2×10^{-5} rad.

The distance of the binary star system from Earth is 1.5×10^{17} m.

Show that the separation d of the centers of S_1 and S_2 is 1.8×10^{12} m.

[1]

(c) The stars S_1 and S_2 rotate with the same angular velocity ω about a point P, as illustrated in Fig. 2.

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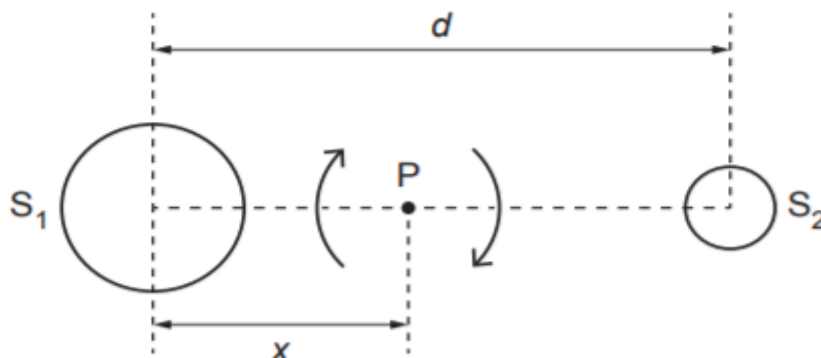


Fig.2 (not to scale)

Point P is at a distance x from the center of star S_1 .

The period of rotation of the stars is 44.2 years.

- (i) Calculate the angular velocity ω .

$$\omega = \dots\dots\dots \text{rads}^{-1} [2]$$

- (ii) By considering the forces acting on the two stars, show that the ratio of the masses of the stars is given by

$$\frac{\text{mass of } S_1}{\text{mass of } S_2} = \frac{d-x}{x}.$$

[2]

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- (iii) The mass M_1 of star S_1 is given by the expression

$$GM_1 = d^2 (d - x) \omega^2$$

where G is the gravitational constant.

The ratio in (ii) is found to be 1.5. Use data from (b) and your answer in (c)(i) to determine the mass M_1 .

$$M_1 = \dots\dots\dots \text{ kg [3]}$$

[Total: 9]

3. (a) Using a simple kinetic model of matter, describe the structure of a solid.

.....

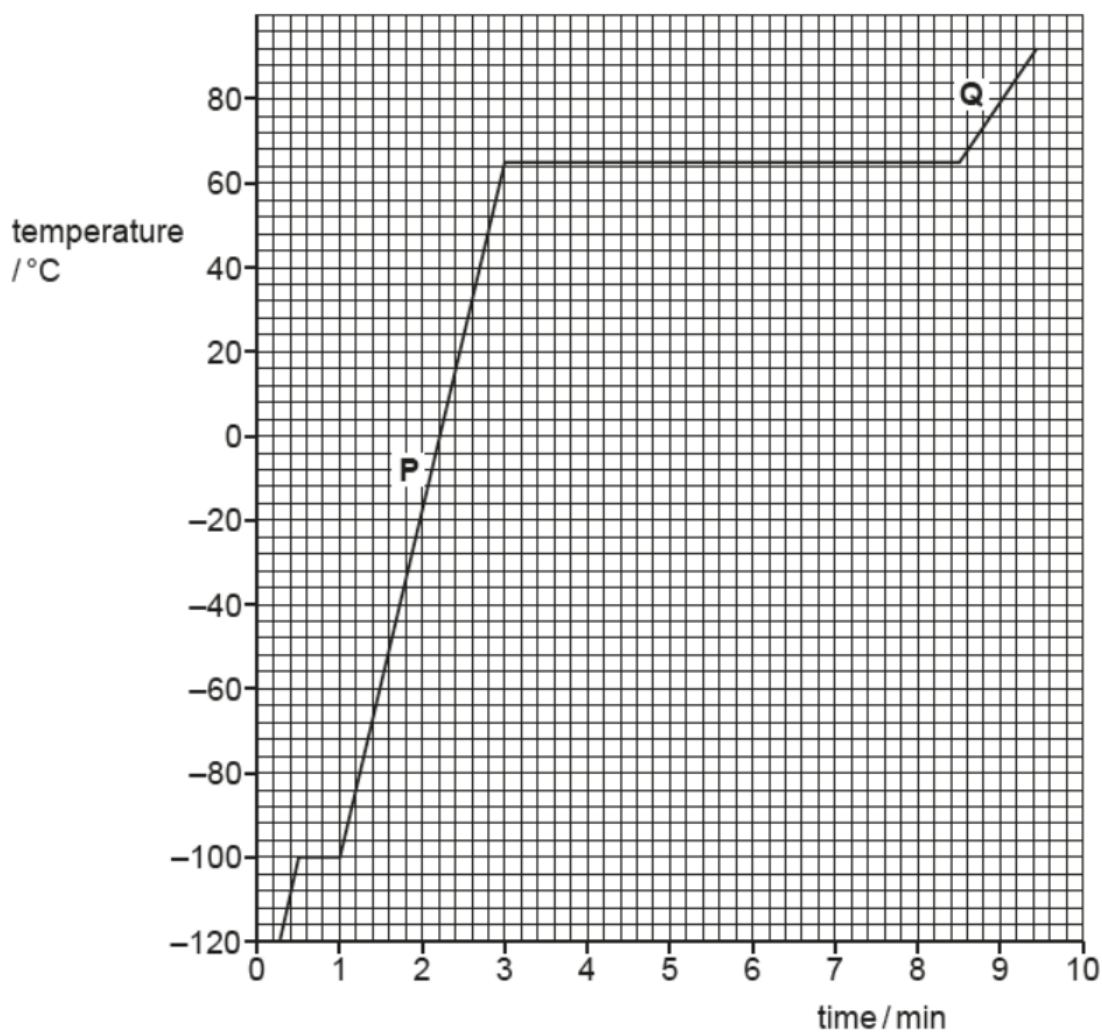
 [2]

- (b) The specific latent heat of vaporization is much greater than the specific latent heat of fusion for the same substance. Explain this, in terms of the spacing of molecules.

.....

 [1]

- (c) A heater supplies energy at a constant rate to 0.045 kg of a substance. The variation with time of the temperature of the substance is shown in Fig. 3.1. The substance is perfectly insulated from its surroundings



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Fig. 3.1

- (i) Determine the temperature at which the substance melts.

temperature = °C [1]

- (ii) The power of the heater is 150 W.

Use data from Fig. 3.1 to calculate, in kJ kg^{-1} , the specific latent heat of vaporization L of the substance.

$L = \dots\dots\dots \text{kJ kg}^{-1}$ [3]

- (iii) Suggest what can be deduced from the fact that section **Q** on the graph is less steep than section **P**.

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.....

..... [1]

[Total: 8]

4. (a) State Newton's law of gravitation.

.....

..... [1]

- (b) The astronomer Johannes Kepler showed that the period T of rotation of a planet about the Sun is related to its mean distance R from the centre of the Sun by the expression

$$\frac{R^3}{T^2} = k$$

where k is a constant.

Use Newton's law to show that, for planets in circular orbits about the Sun of mass M , the constant k is given by

$$k = \frac{GM}{4\pi^2}$$

where G is the gravitational constant.

Explain your working.

[3]

- (c) A satellite is in a circular orbit about Mars.

The radius of the orbit of the satellite is 4.38×10^6 m. The orbital period is 2.44 hours. Use the expressions in (b) to calculate a value for the mass of Mars.

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mass = kg [2]

[Total: 6]

5. (a) State what is meant by specific latent heat.

.....

 [2]

- (b) A student uses the apparatus illustrated in Fig.1 to determine a value for the specific latent heat of fusion of ice.

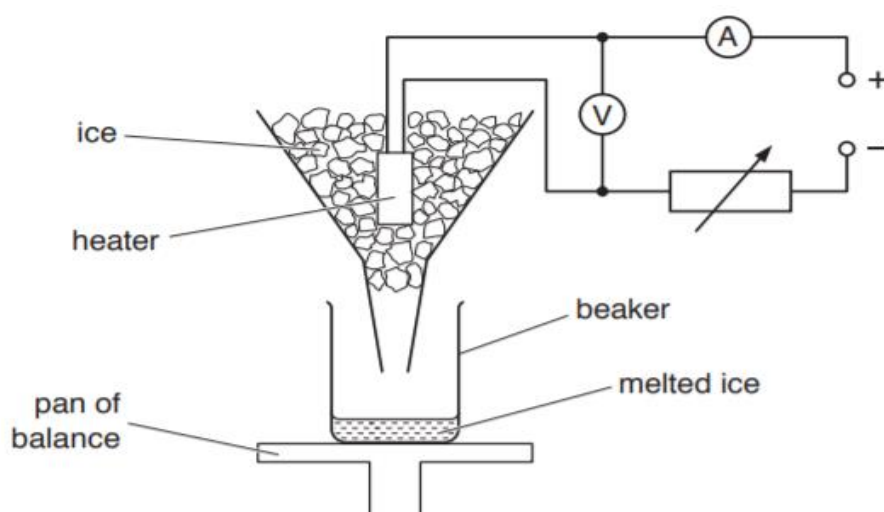


Fig.1

The balance reading measures the mass of the beaker and the melted ice (water) in the beaker.

The heater is switched on and pieces of ice at 0°C are added continuously to the funnel so that the heater is always surrounded by ice.

When water drips out of the funnel at a constant rate, the balance reading is noted at 2.0 minute intervals. After 10 minutes, the current in the heater is increased and the balance readings are taken for a further 12 minutes.

The variation with time of the balance reading is shown in **Fig.2**

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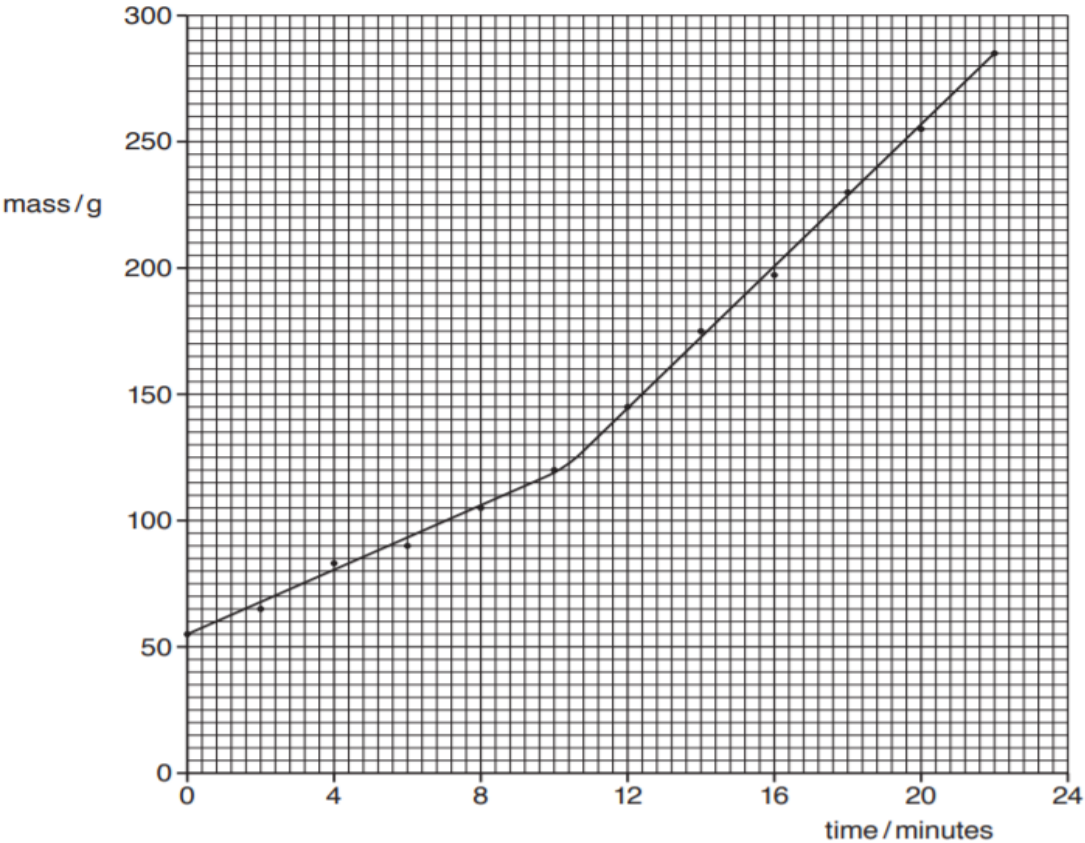


Fig.2

The readings of the ammeter and of the voltmeter are shown in Fig.3.

	ammeter reading /A	voltmeter reading /V
from time 0 to time 10 minutes	1.8	7.3
after time 10 minutes	3.6	15.1

Fig.3

- (i) From time 0 to time 10.0 minutes, 65g of ice is melted.

Use Fig.2 to determine the mass of ice melted from time 12.0 minutes to time 22.0 minutes.

mass = g [1]

- (ii) Explain why, although the power of the heater is changed, the rate at which thermal energy is transferred from the surroundings to the ice is constant.

.....

..... [1]

- (iii) Determine a value for the specific latent heat of fusion L of ice.

$$L = \text{..... Jg}^{-1} [3]$$

- (iv) Calculate the rate at which thermal energy is transferred from the surroundings to the ice.

$$\text{rate} = \text{..... W} [2]$$

[Total: 9]

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