

Physics

Higher level · Predicted paper · November 2026

Paper 2

2 hours 30 minutes

Instructions to candidates

- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Write your answers in the spaces provided.
- A calculator is required for this paper.
- A clean copy of the physics data booklet is required for this paper.

9 structured questions [90 marks].

Answers must be written within the answer boxes provided.

The maximum mark for this paper is **[90 marks]**.

1. A probe is designed to collect rock samples from the surface of Mars and to return them to Earth.

The following data are given:

$$\text{Mass of Mars} = 6.4 \times 10^{23} \text{ kg}$$

$$\text{Radius of Mars } R = 3.4 \times 10^6 \text{ m}$$

- (a) Calculate the gravitational field strength at the surface of Mars. [1]

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- (b) Calculate the escape speed from the surface of Mars. [2]

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diagram not to scale

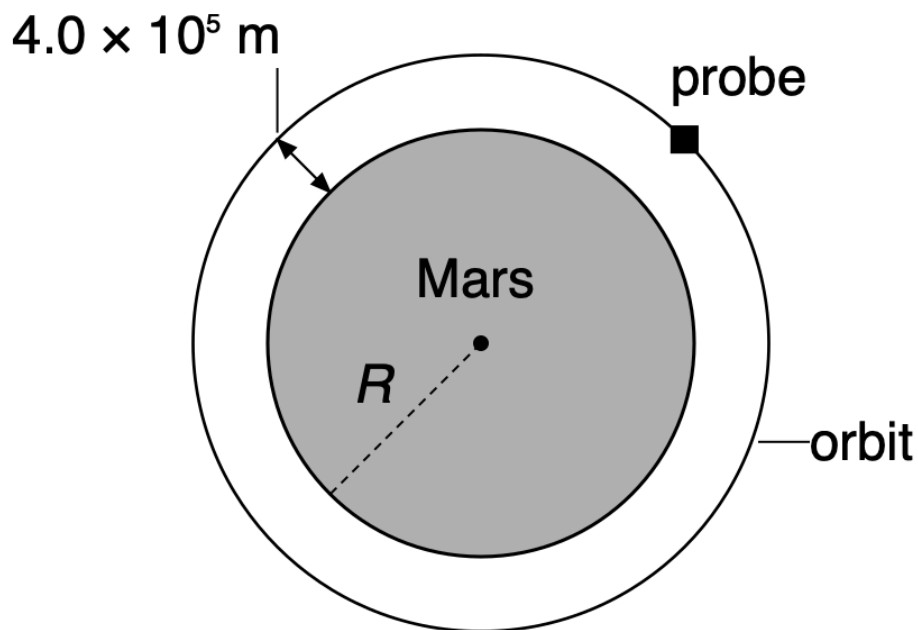


Figure 1

- (c) The probe leaves the surface of Mars and enters a circular orbit around Mars. The diagram shows the orbit.

Determine the orbital period of the probe.

[3]

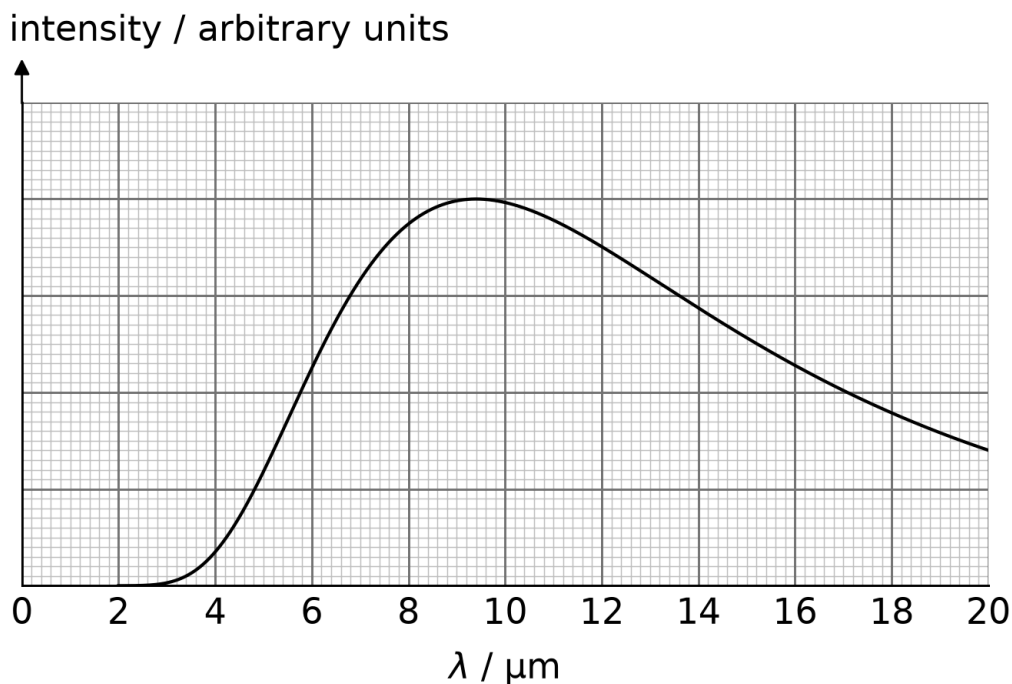
- (d) Outline why the total energy of the probe in this orbit is negative.

[1]

- (e) The engines of the probe are now fired. The probe moves to a circular orbit of larger radius. Explain why energy must be supplied to the probe to move it to the larger orbit, even though the kinetic energy of the probe in the larger orbit is smaller.

[1]

2. An infrared thermometer measures the temperature of the skin of a person's forehead. The thermometer is held close to the skin and points at it. The skin behaves as a black body. The graph shows the variation with wavelength λ of the intensity of the radiation emitted by the skin.



Graph 1

- (a) Determine the temperature of the skin. [2]

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- (b) Show that the power emitted per unit area by the skin is about 500 W m^{-2} . [2]

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- (c) The thermometer contains a sensor of area 2.0 mm^2 . The infrared radiation leaving the forehead can be modelled as a plane wave travelling towards the sensor.

Determine the power incident on the sensor.

[2]

- (d) The surface of the Earth also emits infrared radiation.

Explain how gases such as carbon dioxide in the atmosphere cause the mean temperature of the surface to be higher than it would be with no atmosphere.

[2]

3. Figure 2 shows the circuit of a frost alarm. A thermistor and a fixed resistor of resistance $3.0 \text{ k}\Omega$ are connected in series with a supply of emf 6.0 V . The supply has an internal resistance r . The dashed box in the diagram represents the supply. The potential difference across the fixed resistor is the input to an electronic switch. The switch draws negligible current from the circuit. The switch turns on a lamp in a separate circuit when the temperature of the thermistor falls to 0°C . Figure 2 shows the variation with temperature of the resistance of the thermistor.

diagram not to scale

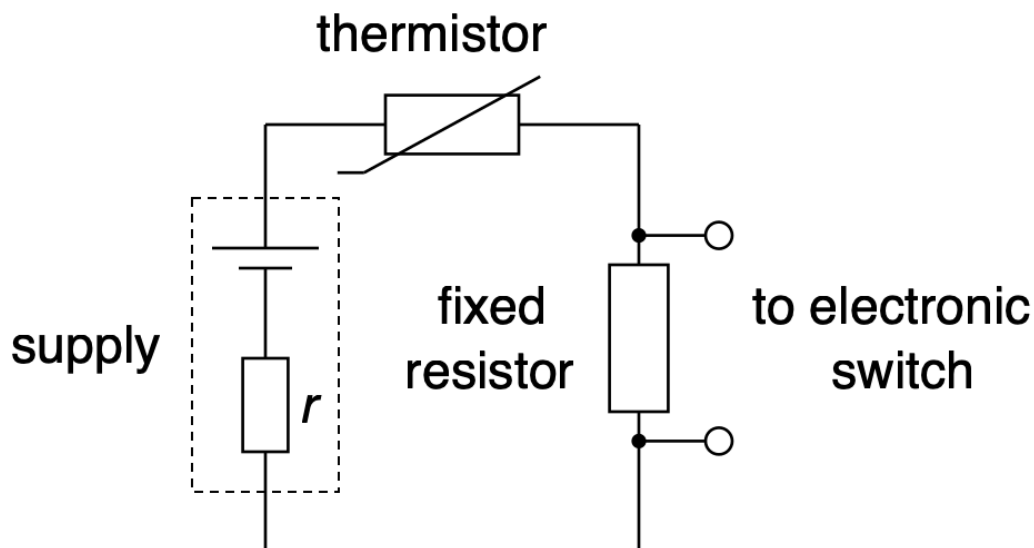
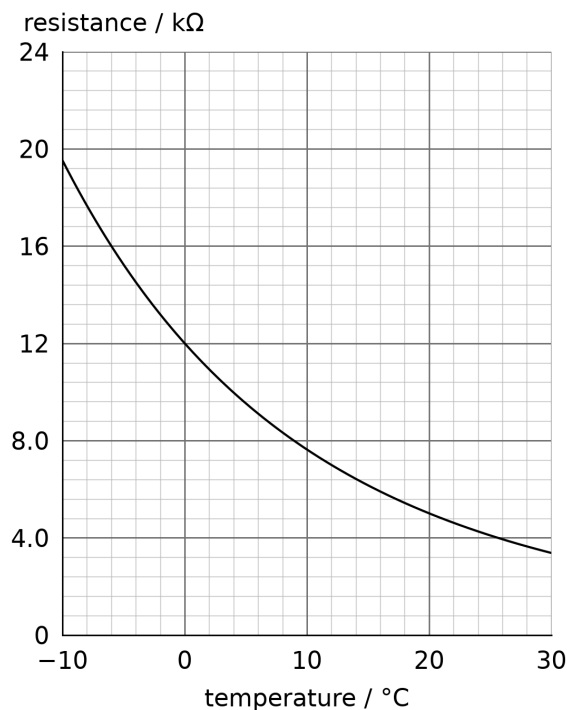


Figure 2



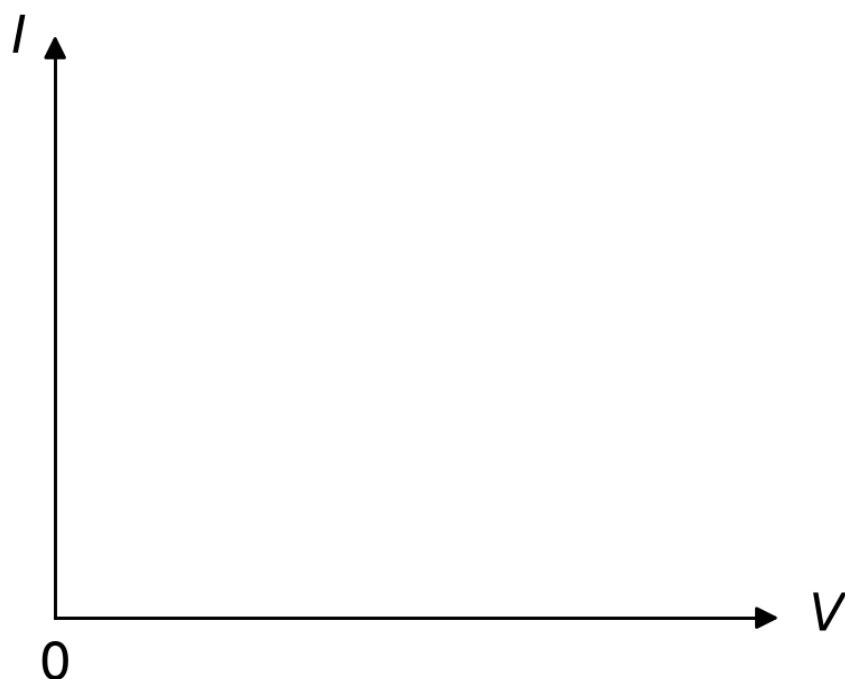
Graph 2

- (a) State the resistance of the thermistor at 0°C .

[1]

- (b) Calculate the potential difference across the fixed resistor at $0\text{ }^{\circ}\text{C}$. Assume that the internal resistance of the supply is zero. [2]

- (c) The internal resistance r of the supply is $2.0\text{ }\Omega$.
Explain why r has a negligible effect on the potential difference across the fixed resistor at $0\text{ }^{\circ}\text{C}$. [2]



Graph 3

- (d) The lamp in the separate circuit is a filament lamp. The potential difference V across the lamp is increased from zero and the current I in the lamp is measured.
Sketch on Figure 3 the variation with V of I . [1]

4. Light from a laser is incident normally on a double slit. The centres of the two slits are 0.21 mm apart. Each slit has a width of 0.042 mm. Bright fringes are observed on a screen at a distance of 2.5 m from the double slit. The diagram shows part of the fringe pattern and a millimetre scale.

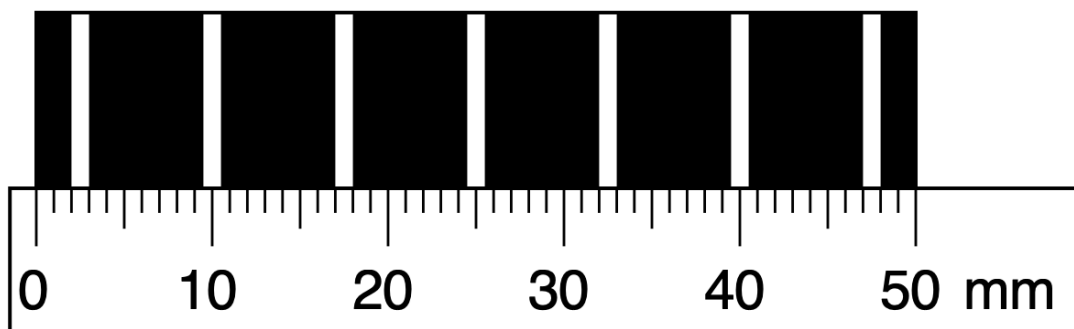


Figure 3

- (a) Show that the wavelength of the light emitted by the laser is about 630 nm. [2]

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- (b) (i) The double slit is replaced by a diffraction grating that has 300 lines per millimetre. Light from the same laser is incident normally on the grating. Show that the second-order maximum is formed at an angle of about 22° to the direction of the incident light. [2]

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- (b) (ii) Explain why the maxima produced by the grating are much sharper than the fringes produced by the double slit. [1]

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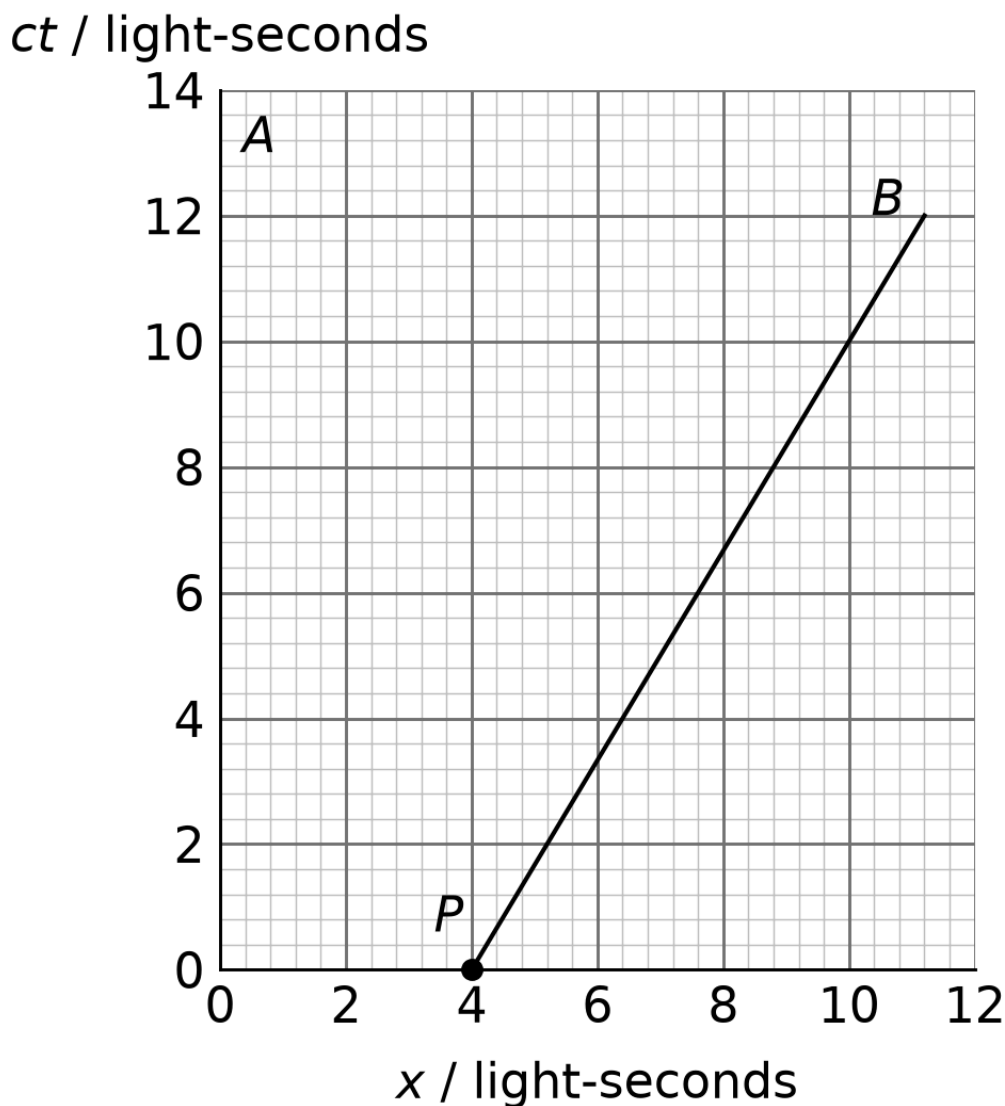
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- (c) The diffraction grating is replaced by the double slit. Beyond the region shown in the diagram, some bright fringes are absent from the pattern.

Determine the order of the first bright fringe that is absent.

[2]

5. Spacecraft A is at rest at $x = 0$ in the reference frame of the Earth. Spacecraft B moves in the positive x -direction at a constant speed of $0.60c$ relative to the Earth. At time $t = 0$, A emits a flash of light towards B. The spacetime diagram shows the world lines of A and B in the reference frame of the Earth. Event P on the world line of B is at $t = 0$.



Graph 4

- (a) Draw on the spacetime diagram the world line of the flash. [1]
- (b) Show that the flash reaches B at a time of about 10 s in the reference frame of the Earth. [2]

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- (c) A clock carried by B reads zero at event P.
Calculate the reading on this clock when the flash reaches B. [2]

- (d) State the speed of the flash relative to B according to Galilean relativity and according to special relativity. [1]

6. Positive ions of charge $+e$ move horizontally into the region between two parallel plates. The uniform electric field between the plates has a strength of $2.0 \times 10^4 \text{ V m}^{-1}$. A uniform magnetic field of strength 0.080 T is directed into the page. This magnetic field acts between the plates and in the whole region to the right of a vertical wall. There is no electric field to the right of the wall. Ions that pass undeflected between the plates enter the region to the right of the wall through a slit S. These ions move in a semicircle and strike a detector at D. The diagram shows the arrangement.

diagram not to scale

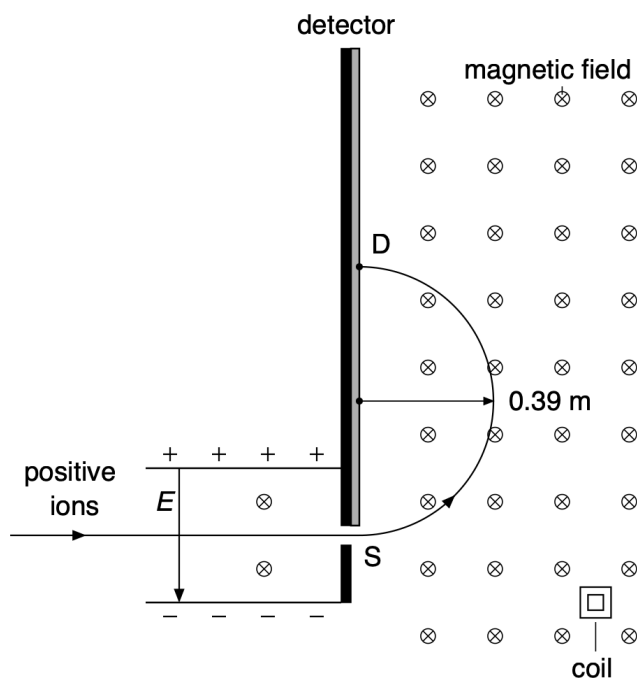


Figure 4

- (a) Show that the speed of an ion that passes undeflected between the plates is about $2.5 \times 10^5 \text{ m s}^{-1}$. [1]

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- (b) (i) Determine the mass of an ion that strikes the detector at D. [3]

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- (b) (ii) Another positive ion of charge $+e$ has a greater mass. This ion also passes undeflected between the plates.

Draw on the diagram the path of this ion to the right of the wall.

[1]

- (c) Explain why the magnetic force on an ion to the right of the wall changes the direction of motion of the ion but does not change its speed.

[2]

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- (d) (i) A small coil, shown in the diagram, is used to check the magnetic field to the right of the wall. The coil has 80 turns and an area of 2.5 cm^2 . The plane of the coil is perpendicular to the magnetic field. The coil is now removed from the magnetic field in a time of 0.40 s.

Calculate the average emf induced in the coil as it is removed from the magnetic field.

[2]

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- (d) (ii) Outline how the direction of the induced current in the coil is determined.

[1]

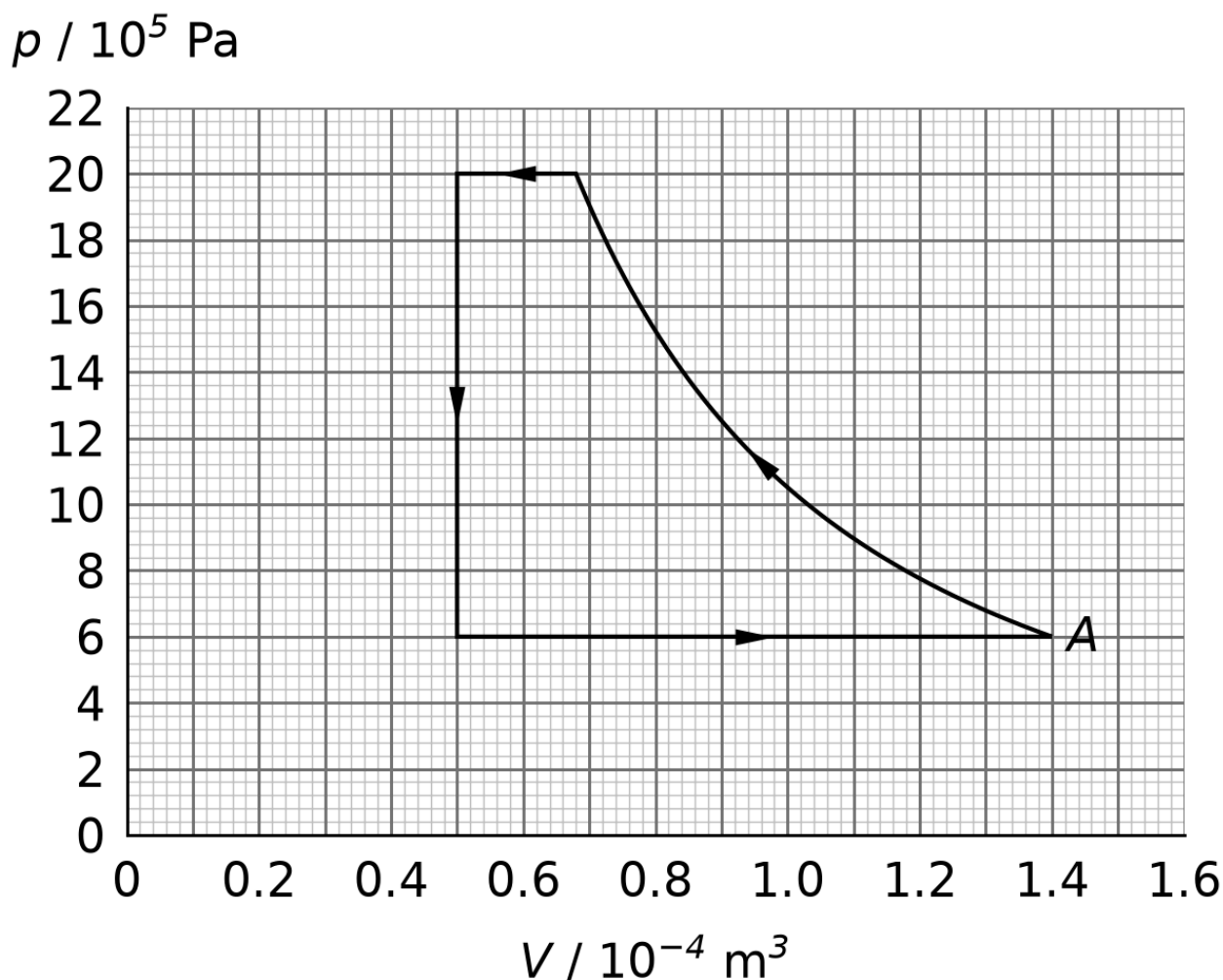
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7. In a model of a domestic heat pump, a fixed mass of an ideal monatomic gas is taken repeatedly around a cycle. The cycle starts at state A and consists of four processes in this order:
- an adiabatic compression
 - a cooling at constant pressure, during which the gas transfers thermal energy to the air inside a house
 - a drop in pressure at constant volume
 - a heating at constant pressure back to state A, during which the gas takes in thermal energy from the air outside the house.

The graph shows the variation of the pressure p of the gas with its volume V during the cycle.



Graph 5

- (a) Identify the process during which no thermal energy is transferred to or from the gas, by labelling it X on the graph.

[1]

- (b) The gas is taken around the cycle 50 times every second.
Determine the rate at which work is done on the gas. [2]

- (c) Explain why the entropy of the universe increases during each cycle, even though the gas returns to state A. [2]

8. A merry-go-round is a horizontal disc that rotates about a vertical axis through its centre. The moment of inertia of the merry-go-round about this axis is 180 kg m^2 . A child of mass 40 kg stands at the rim of the merry-go-round. The child can be treated as a point mass. The diagram shows a view from above of the merry-go-round.

diagram not to scale

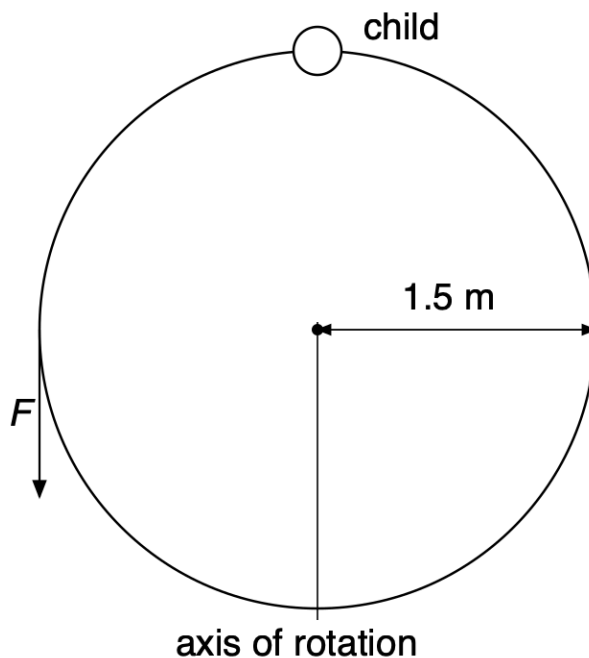


Figure 5

- (a) (i) The merry-go-round is initially at rest. An adult then pushes the rim with a force F of constant magnitude 60 N for 6.0 s . F is always tangential to the rim, as shown in the diagram.

Calculate the torque of F about the axis.

[1]

- (a) (ii) Show that the angular speed of the merry-go-round at the end of the push is about 2.0 rad s^{-1} .

[2]

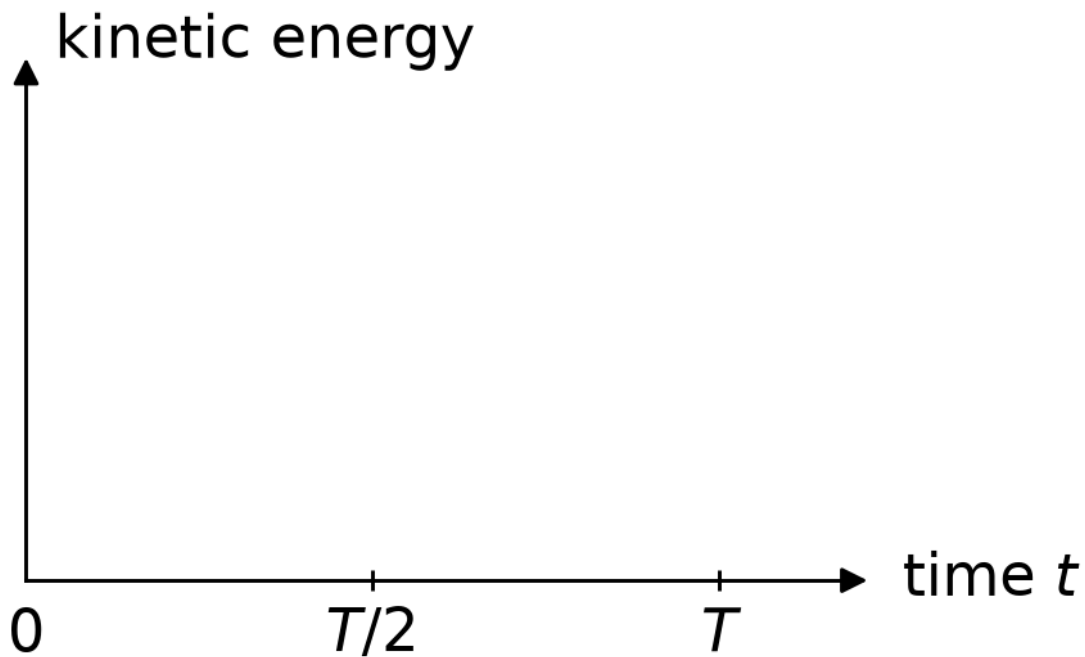
- (a) (iii) Determine the number of revolutions made by the merry-go-round during the push. **[2]**

- (b) (i) The adult now stops pushing. The child then moves from the rim to the centre of the merry-go-round.
Explain why the angular speed of the merry-go-round increases as the child moves towards the centre. **[2]**

- (b) (ii) Calculate the angular speed of the merry-go-round when the child is at the centre. **[2]**

- (b) (iii) Discuss whether the rotational kinetic energy of the merry-go-round and child is conserved as the child moves to the centre. **[2]**

- (c) (i) The child is now on a swing. The swing can be modelled as a simple pendulum of length 2.4 m. The swing oscillates with small amplitude.
Calculate the period of the swing. **[1]**



Graph 6

- (c) (ii) At time $t = 0$ the child is at maximum displacement.

Draw on the axes the variation with t of the kinetic energy of the child during one period of oscillation.

[2]

- (d) (i) On another occasion, the child moves through the lowest point of the swing with a speed of 1.8 m s^{-1} . An adult catches the child at the lowest point and brings the child to rest in 0.40 s . The masses of the seat and ropes are negligible. Assume that the adult exerts the only horizontal force on the child while the child is being stopped.

Calculate the magnitude of the average force exerted on the child by the adult.

[2]

- (d) (ii) Outline why this force is larger if the child is brought to rest in a shorter time.

[1]

- (d) (iii) Explain why, just before the child is caught, the tension in the ropes is greater than the weight of the child. **[2]**

- (e) Suggest one assumption made in (b)(ii) and how it affects the value calculated for the angular speed. **[1]**

9. A meteorite is a rock from space that has fallen to the Earth. The rock of one meteorite contains potassium-40 ($^{40}_{19}\text{K}$), which decays into argon-40 ($^{40}_{18}\text{Ar}$). The half-life of potassium-40 is 1.25×10^9 y. Assume that potassium-40 decays only into argon-40. Argon-40 is stable.

(a) (i) Show that the decay constant of potassium-40 is about $5.5 \times 10^{-10} \text{ y}^{-1}$. [1]

(a) (ii) A sample of the meteorite is analysed. The ratio (number of argon-40 atoms in the sample)/(number of potassium-40 atoms in the sample) is 2.4. The age of the meteorite is the time that has passed since its rock solidified.

Determine the age of the meteorite. [3]

(a) (iii) Outline one assumption on which your answer to (a)(ii) depends. [1]

(b) The meteorite was once part of an asteroid. The asteroid orbits the Sun in a circular orbit of radius 2.8 AU. The Earth orbits the Sun with an orbital radius of 1.0 AU and an orbital period of 1.0 y.

Calculate, in years, the orbital period of the asteroid. [2]

- (c) (i) Rocky bodies similar to the asteroid also orbit another star, X. The spectrum of the light received from X is continuous except for a number of narrow dark lines.

Explain why there are dark lines in the spectrum of X.

[2]

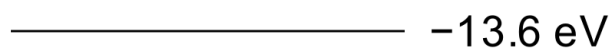
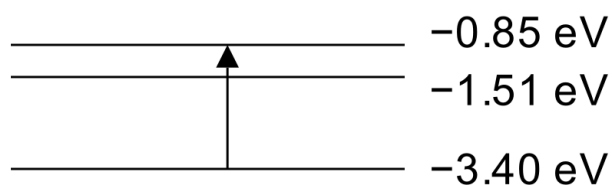
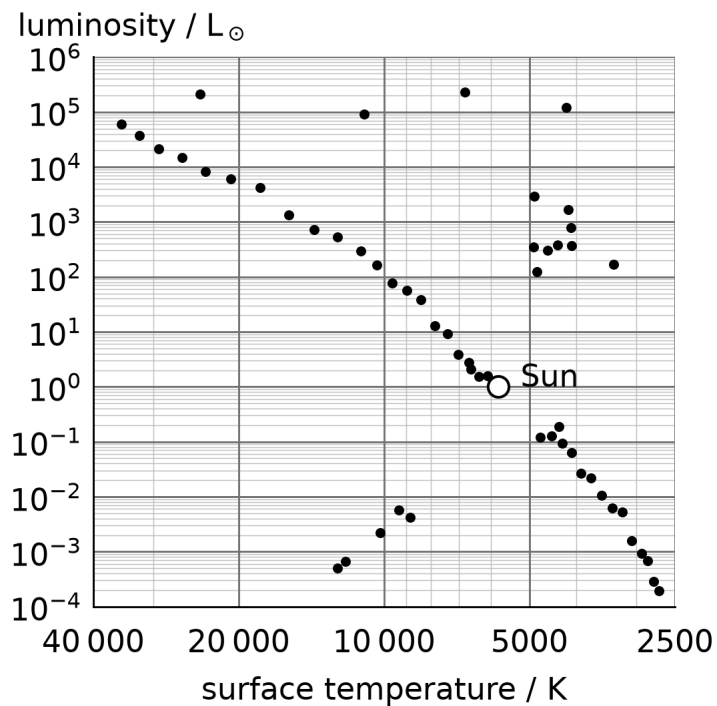


Figure 6

- (c) (ii) The diagram shows some of the energy levels of the hydrogen atom. One of the dark lines in the spectrum of X corresponds to the transition shown by the arrow.

Calculate the wavelength of this dark line.

[2]



Graph 7

- (d) (i) The luminosity of X is $0.40 L_{\odot}$, where $L_{\odot}$ is the luminosity of the Sun. The surface temperature of X is 5000 K. The Hertzsprung–Russell (HR) diagram shows the Sun and some other stars.

Identify on the HR diagram, with a cross labelled X, the position of star X.

[1]

- (d) (ii) The surface temperature of the Sun is 5800 K.

Show that the radius of X is about 0.85 times the radius of the Sun.

[2]

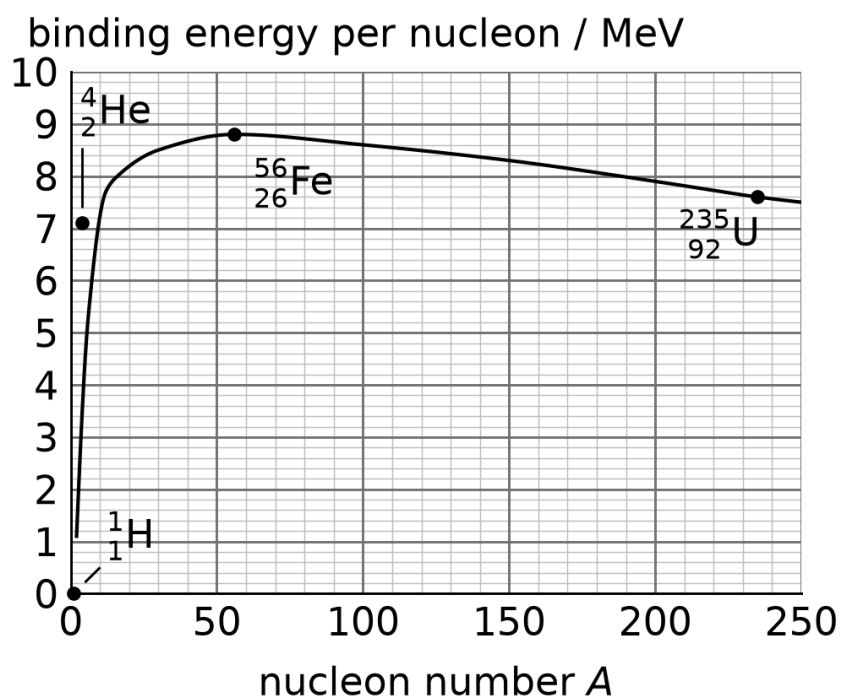
- (d) (iii) The mass of X is $0.77 M_{\odot}$, where $M_{\odot}$ is the mass of the Sun. The main-sequence lifetime of a star is proportional to M/L , where M is the mass of the star and L is its luminosity. The main-sequence lifetime of the Sun is 1.0×10^{10} y.

Estimate the main-sequence lifetime of X, stating one assumption you make.

[2]

- (d) (iv) Describe the evolution of X after it leaves the main sequence.

[2]



Graph 8

- (e) The graph shows the variation of binding energy per nucleon with nucleon number. Explain, with reference to the graph, why the fusion of hydrogen in the core of X releases energy but the fission of iron-56 would not release energy.

[2]

Want the mark scheme?

This paper is free to use and free to share. The full mark scheme for Paper 2 — with the marking points, the accepted alternatives and the examiner notes on what does *not* earn the mark — is at the link below, along with the mark schemes for the rest of the predicted set.

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