22096508

International Baccalaureate®
Baccalauréat International
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**PHYSICS**
**HIGHER LEVEL**
**PAPER 2**

Tuesday 12 May 2009 (afternoon)

2 hours 15 minutes

Candidate session number

| 0 | 0 | | | | | | | |
|---|---|---|---|---|---|---|---|---|

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all of Section A in the spaces provided.
- Section B: answer two questions from Section B in the spaces provided.
- At the end of the examination, indicate the numbers of the questions answered in the candidate box on your cover sheet.

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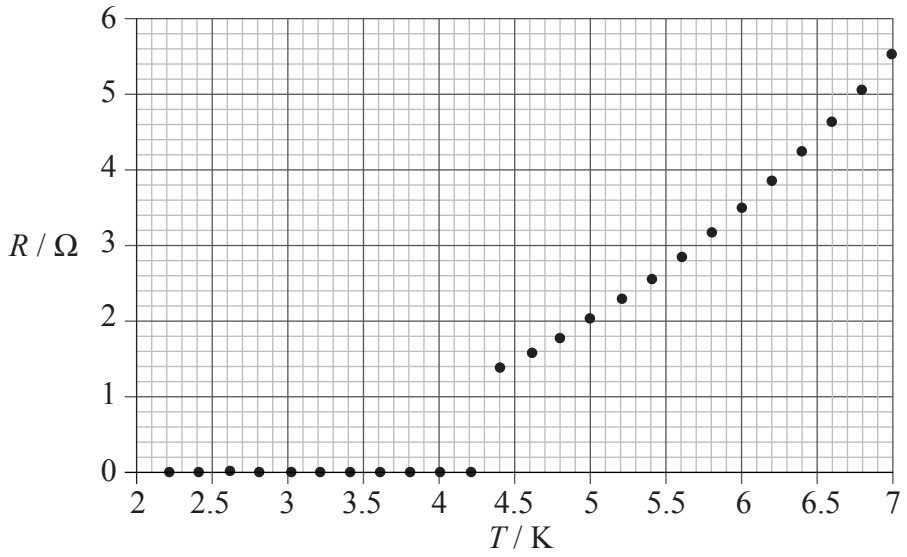
0130

## SECTION A

*Answer **all** the questions in the spaces provided.*

**A1.** This question is about electrical resistance of the metal mercury.

The resistance $R$ of a sample of mercury was measured as a function of the temperature $T$ of the sample. The sample was cooled and data points were taken at temperature intervals of 0.2 K. The uncertainties in $R$ and $T$ are too small to be shown on the graph.




The hypothesis is that resistance is proportional to absolute temperature for temperatures greater than 4.5 K.

(a) (i) Suggest whether the data supports the hypothesis. *[1]*

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(ii) Draw a line of best fit through the data. *[2]*

(b) State the value of $R$ for which the rate of change of resistance of the sample with temperature is least. *[1]*

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*(This question continues on the following page)*

*(Question A1 continued)*

(c) At a temperature $T_C$ the resistance suddenly becomes zero.

(i) Use the graph to determine the possible range of the temperature $T_C$. *[1]*

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(ii) State, to the correct number of significant figures, the value of $T_C$ and its uncertainty. *[2]*

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(iii) Outline how the temperature $T_C$ could be measured more precisely. *[1]*

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(d) Outline **two** reasons why you could not use the data to determine an accurate value for $R$ at room temperature. *[2]*

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**A2.** This question is about impulse.

(a) A net force of magnitude $F$ acts on a body. Define the *impulse* $I$ of the force. *[1]*

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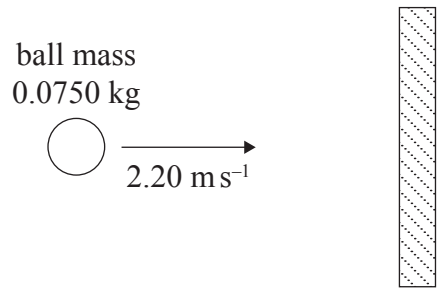
(b) A ball of mass 0.0750 kg is travelling horizontally with a speed of 2.20 $m\,s^{-1}$. It strikes a vertical wall and rebounds horizontally.




Due to the collision with the wall, 20 % of the ball's initial kinetic energy is dissipated.

(i) Show that the ball rebounds from the wall with a speed of 1.97 $m\,s^{-1}$. *[2]*

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(ii) Show that the impulse given to the ball by the wall is 0.313 N s. *[2]*

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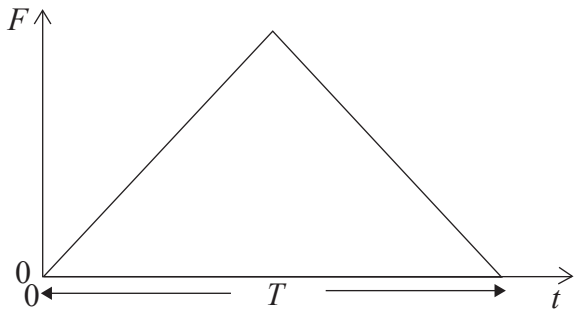
*(This question continues on the following page)*

*(Question A2 continued)*

(c) The ball strikes the wall at time $t = 0$ and leaves the wall at time $t = T$.

The sketch graph shows how the force $F$ that the wall exerts on the ball is assumed to vary with time $t$.




The time $T$ is measured electronically to equal 0.0894 s.

Use the impulse given in (b)(ii) to estimate the average value of $F$. *[4]*

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**A3.** This question is about internal energy, heat and ideal gases.

(a) The internal energy of a piece of copper is increased by heating.

(i) Explain what is meant, in this context, by internal energy and heating. *[3]*

Internal energy: . . . . . .

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Heating: . . . . . .

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(ii) The piece of copper has mass 0.25 kg. The increase in internal energy of the copper is $1.2 \times 10^3$ J and its increase in temperature is 20 K. Estimate the specific heat capacity of copper. *[2]*

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*(This question continues on the following page)*

*(Question A3 continued)*

(b) One mole of an ideal gas is heated at constant pressure. The increase in temperature of the gas is 30.0 K. The energy transferred to the gas is 623 J and the work done is 249 J.

Determine

(i) the change in internal energy of the gas. *[3]*

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(ii) the thermal capacity of the gas. *[2]*

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(c) Another mole of the same gas is heated at constant volume starting from the same state as that in (b). Suggest whether the thermal capacity in this case is equal to, greater than **or** less than the answer in b(ii). *[3]*

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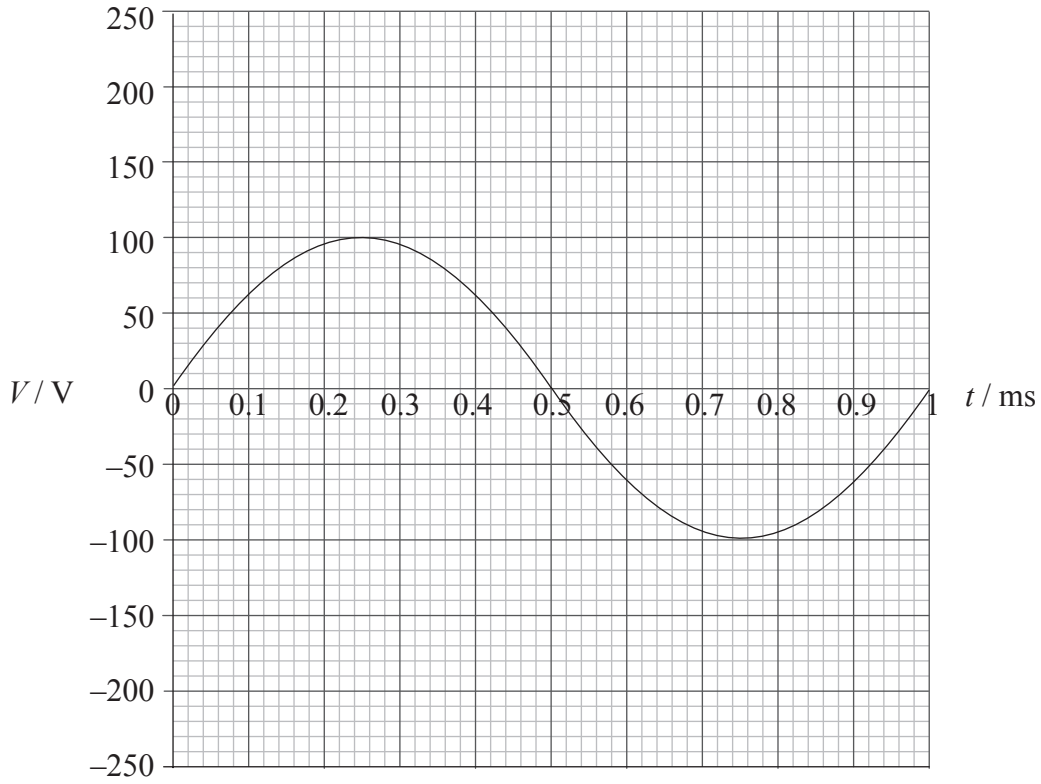
**A4.** This question is about alternating current.

(a) The graph shows the variation with time $t$ of the output voltage $V$ of an ac generator of negligible internal resistance.




A resistor of resistance 25 Ω is connected across the output of the generator.

Calculate

(i) the rms value of the current in the resistor. *[2]*

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(ii) the average power dissipated in the resistor. *[1]*

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*(This question continues on the following page)*

*(Question A4 continued)*

(iii) the power dissipated in the resistor at 0.40 ms. *[2]*

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(b) The frequency of rotation of the generator coil is now doubled. Sketch, using the axes in (a), the variation with $t$ of the new output voltage $V$. *[2]*

**A5.** This question is about energy transfers.

(a) Energy degradation takes place in the energy transformations which occur in the generation of electrical power. Explain what is meant in this context by energy degradation. *[2]*

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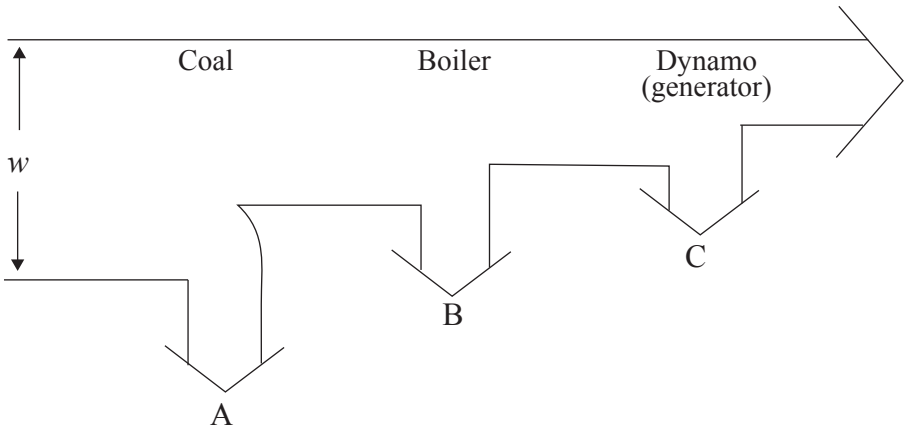
Some of the energy transformations that take place in a coal-fired power station are represented by the Sankey diagram below.




(b) (i) State what is represented by the width *w*. *[1]*

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(ii) At the three places marked A, B and C on the diagram, energy is degraded. Identify the process by which the energy is degraded in each of the places. *[3]*

A: . . . . . .

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B: . . . . . .

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C: . . . . . .

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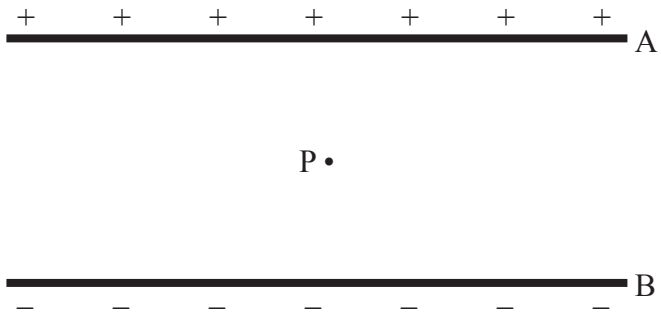
## SECTION B

*This section consists of four questions: B1, B2, B3 and B4. Answer **two** questions.*

**B1.** This question is in **two** parts. **Part 1** is about electric fields and electric circuits and **Part 2** is about atomic and nuclear spectra.

**Part 1** Electric fields and electric circuits

(a) Two parallel, charged metal plates A and B are in a vacuum.




At a particular instant an electron is at point P.

On the diagram, draw

(i) the electric field pattern due to the plates. *[3]*

(ii) an arrow to represent the direction of the force on the electron at P. *[1]*

(b) The acceleration of the electron at P is $8.8\times10^{14}\,\text{m s}^{-2}$. Determine the magnitude of the electric field strength at the point P. *[3]*

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(c) The electric potential energy of the electron changes by $1.9\times10^{-17}\,\text{J}$ as it moves from one plate to the other. Show that the potential difference between the plates is 120 V. *[1]*

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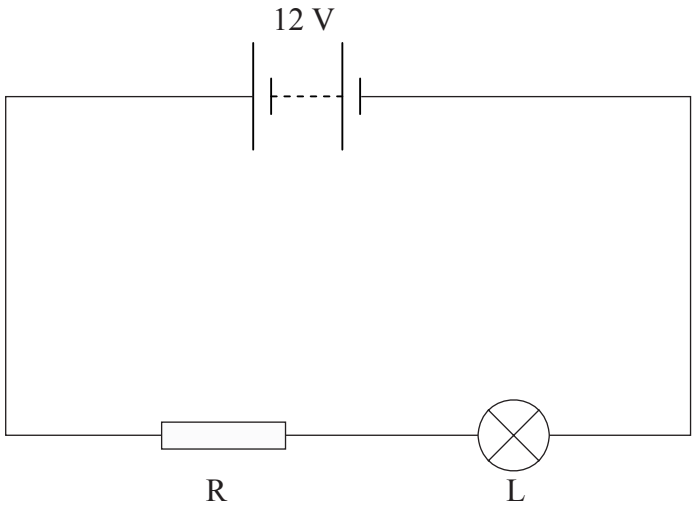
*(This question continues on the following page)*

*(Question B1, part 1 continued)*

(d) A resistor R and a filament lamp L are connected in series with a battery. The battery has an emf of 12 V and internal resistance 4.0 Ω. The potential difference across the filament of the lamp is 3.0 V and the current in the filament is 0.25 A.




(i) Calculate the total power supplied by the battery. *[1]*

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(ii) Calculate the power dissipated in the external circuit. *[2]*

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(iii) Determine the resistance of the resistor R. *[3]*

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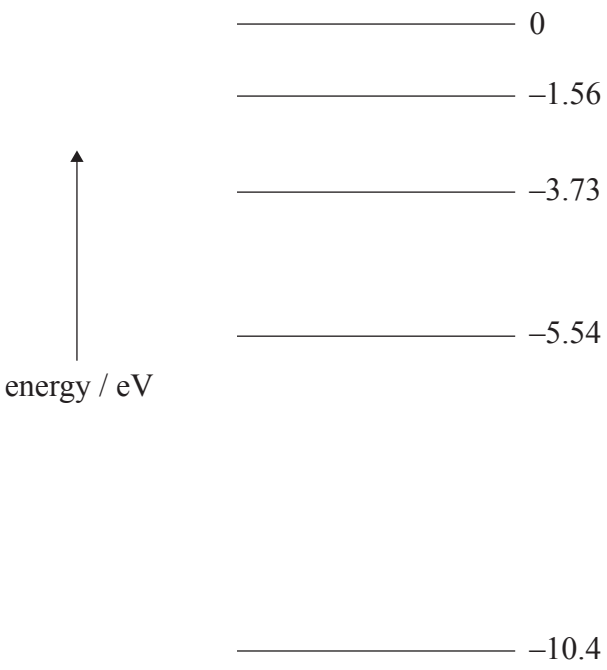
*(This question continues on the following page)*

*(Question B1 continued)*

**Part 2** Atomic and nuclear spectra

Atomic spectra

(a) The diagram represents some of the energy levels of the mercury atom.




Photons are emitted by electron transitions between the levels. On the diagram draw arrows to represent the transition, for those energy levels that gives rise to,

(i) the longest wavelength photon (label this L). *[1]*

(ii) the shortest wavelength photon (label this S). *[1]*

(b) Determine the wavelength associated with the arrow you have labelled S. *[3]*

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*(This question continues on the following page)*

*(Question B1, part 2 continued)*

Nuclear spectra

(c) A nucleus of the isotope bismuth-212 undergoes α-decay into a nucleus of an isotope of thallium. A γ-ray photon is also emitted.

Draw a labelled nuclear energy level diagram for this decay. *[2]*

(d) The activity of a freshly prepared sample of bismuth-212 is $2.80\times10^{13}$ Bq. After 80.0 minutes the activity is $1.13\times10^{13}$ Bq. Determine the half-life of bismuth-212. *[4]*

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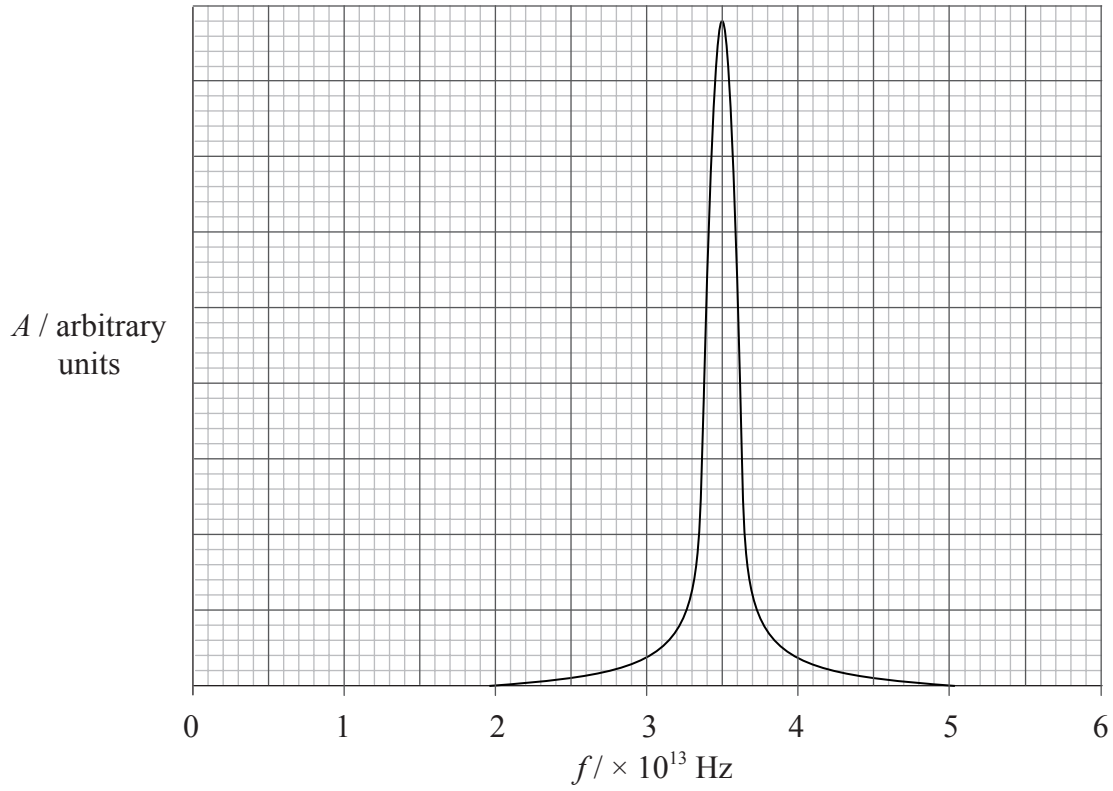
**B2.** This question is in **two** parts. **Part 1** is about the greenhouse effect and **Part 2** is about digital storage devices.

**Part 1** Greenhouse effect

(a) The graph shows part of the absorption spectrum of nitrogen oxide $(N_2O)$ in which the intensity of absorbed radiation $A$ is plotted against frequency $f$.




(i) State the region of the electromagnetic spectrum to which the resonant frequency of nitrogen oxide belongs. *[1]*

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(ii) Using your answer to (a)(i), explain why nitrogen oxide is classified as a greenhouse gas. *[2]*

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*(This question continues on the following page)*

*(Question B2, part 1 continued)*

(b) Define *emissivity* and *albedo*. *[3]*

Emissivity: . . . . . .

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Albedo: . . . . . .

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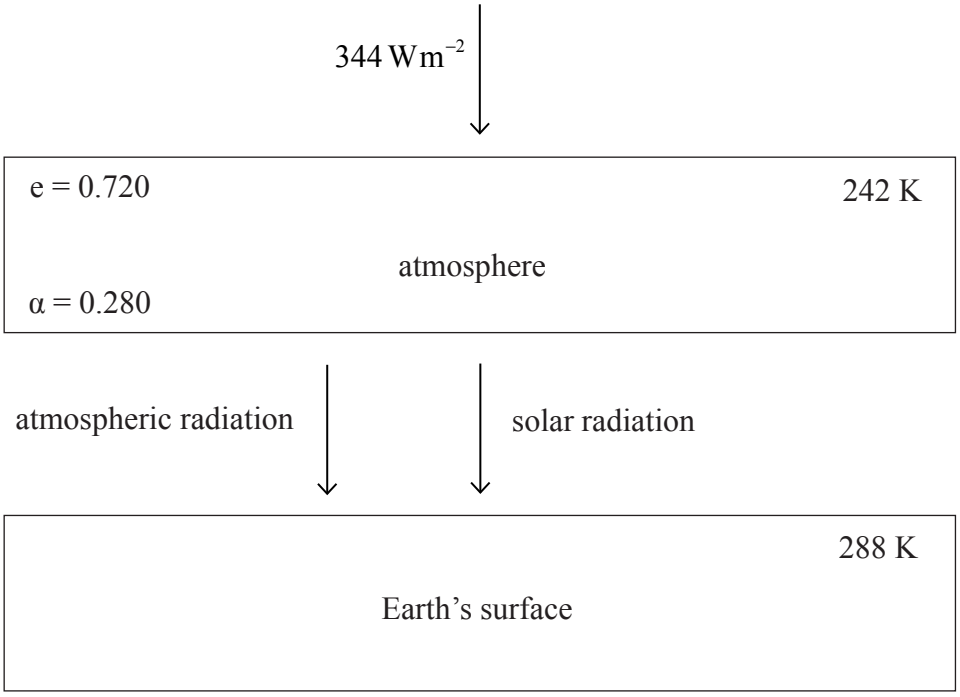
(c) The diagram shows a simple energy balance climate model in which the atmosphere and the surface of Earth are two bodies each at constant temperature. The surface of the Earth receives both solar radiation and radiation emitted from the atmosphere. Assume that the Earth's surface behaves as a black body.




The following data are available for this model.

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|---|---|
| average temperature of the atmosphere of Earth | = 242 K |
| emissivity, e of the atmosphere of Earth | = 0.720 |
| average albedo, α of the atmosphere of Earth | = 0.280 |
| solar intensity at top of atmosphere | = 344 W $m^{-2}$ |
| average temperature of the surface of Earth | = 288 K |

*(This question continues on the following page)*

*(Question B2, Part 1 (c) continued)*

Use the data to show that the

(i) power radiated per unit area of the atmosphere is 140 W $m^{-2}$. *[2]*

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(ii) solar power absorbed per unit area at the surface of the Earth is 248 W $m^{-2}$. *[1]*

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(d) It is hypothesized that, if the production of greenhouse gases were to stay at its present level then the temperature of the Earth's atmosphere would eventually rise by 6.0 K. Calculate the power per unit area that would then be

(i) radiated by the atmosphere. *[1]*

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(ii) absorbed by the Earth's surface. *[1]*

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(e) Estimate, using your answer to (d)(ii), the increase in temperature of Earth's surface. *[3]*

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*(This question continues on the following page)*

*(Question B2 continued)*

**Part 2** Digital storage devices

(a) (i) Convert the decimal number 25 to binary. *[2]*

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(ii) Outline **two** advantages of storing a text in digital form rather than in analogue form. *[2]*

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(b) State, with reference to their structure, why more data can be stored on a DVD than on a CD. *[1]*

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(c) Define the term *magnification* as it applies to a CCD. *[2]*

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(d) A digital camera is used to photograph a particular object. Two small marks on the object are separated by a distance of $2.0\times10^{-3}\,\text{m}$.

The camera has a magnification of $1.4\times10^{-2}$ and an image collection area of $4.0\times10^{-4}\,\text{m}^2$. Determine the minimum number of pixels that the CCD of a digital camera must have, in order that the images of the two marks on the object are just resolved. *[4]*

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**B3.** This question is in **two** parts. **Part 1** is about simple harmonic motion and waves and **Part 2** is about gravitational fields and potential.

**Part 1** Simple harmonic motion and waves

(a) A particle of mass $m$ that is attached to a light spring is executing simple harmonic motion in a **horizontal direction**.

State the condition relating to the net force acting on the particle that is necessary for it to execute simple harmonic motion. *[2]*

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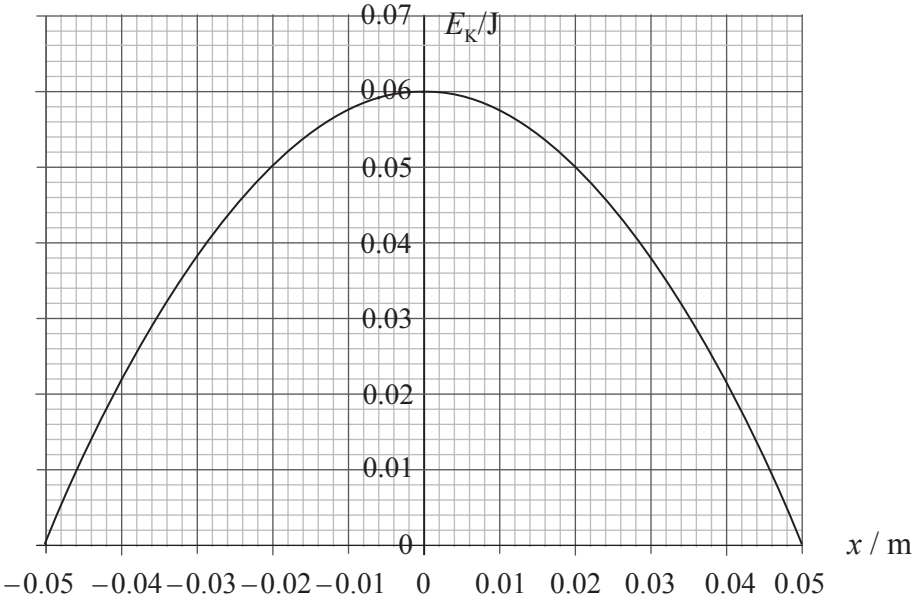
(b) The graph shows how the kinetic energy $E_K$ of the particle in (a) varies with the displacement $x$ of the particle from equilibrium.




(i) Using the axes above, sketch a graph to show how the potential energy of the particle varies with the displacement $x$. *[2]*

*(This question continues on the following page)*

*(Question B3, Part 1 (b) continued)*

(ii) The mass of the particle is 0.30 kg. Use data from the graph to show that the frequency $f$ of oscillation of the particle is 2.0 Hz. *[4]*

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(c) The particles of a medium $M_1$ through which a transverse wave is travelling, oscillate with the same frequency and amplitude as that of the particle in (b).

(i) Describe, with reference to the propagation of energy through the medium, what is meant by a transverse wave. *[2]*

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(ii) The speed of the wave is 0.80 $m\,s^{-1}$. Calculate the wavelength of the wave. *[1]*

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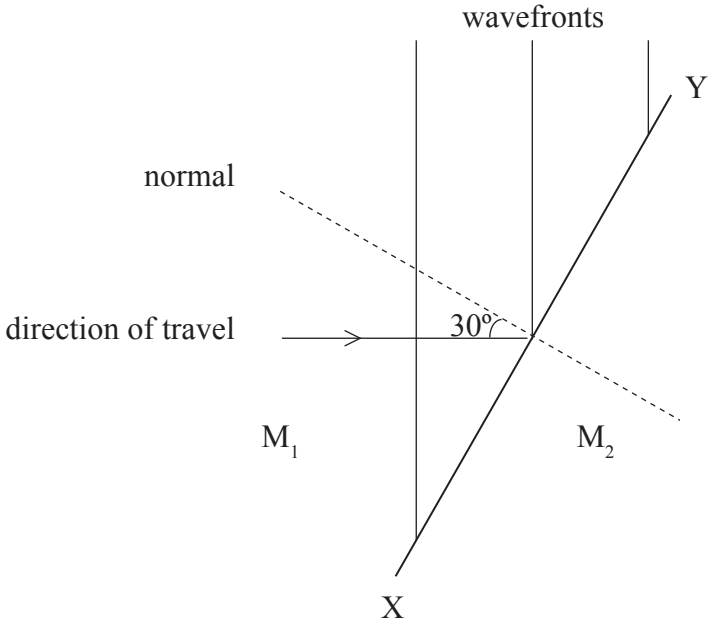
*(This question continues on the following page)*

*(Question B3, Part 1 continued)*

(d) The diagram shows wavefronts of the waves in (c) incident on a boundary XY between medium $M_1$ and another medium $M_2$.




The angle between the normal, and the direction of travel of the wavefronts is $30°$.

(i) The speed of the wave in $M_1$ is $0.80\,m\,s^{-1}$. The speed of the waves in $M_2$ is $1.2\,m\,s^{-1}$. Calculate the angle between the direction of travel of the wavefronts in $M_2$ and the normal. *[3]*

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(ii) On the diagram, sketch the wavefronts in $M_2$. *[1]*

*(This question continues on the following page)*

*(Question B3 continued)*

**Part 2** Gravitational fields and potential

(a) Define *gravitational field strength* and state how it is related to gravitational potential. *[3]*

Definition: . . . . . .
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Relationship: . . . . . .
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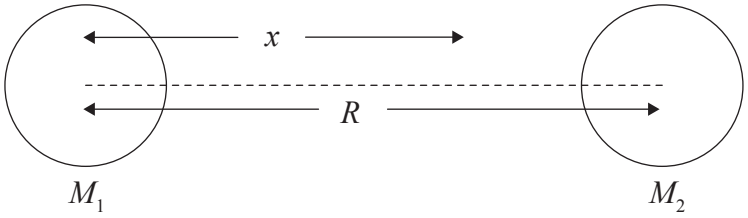
*(This question continues on the following page)*

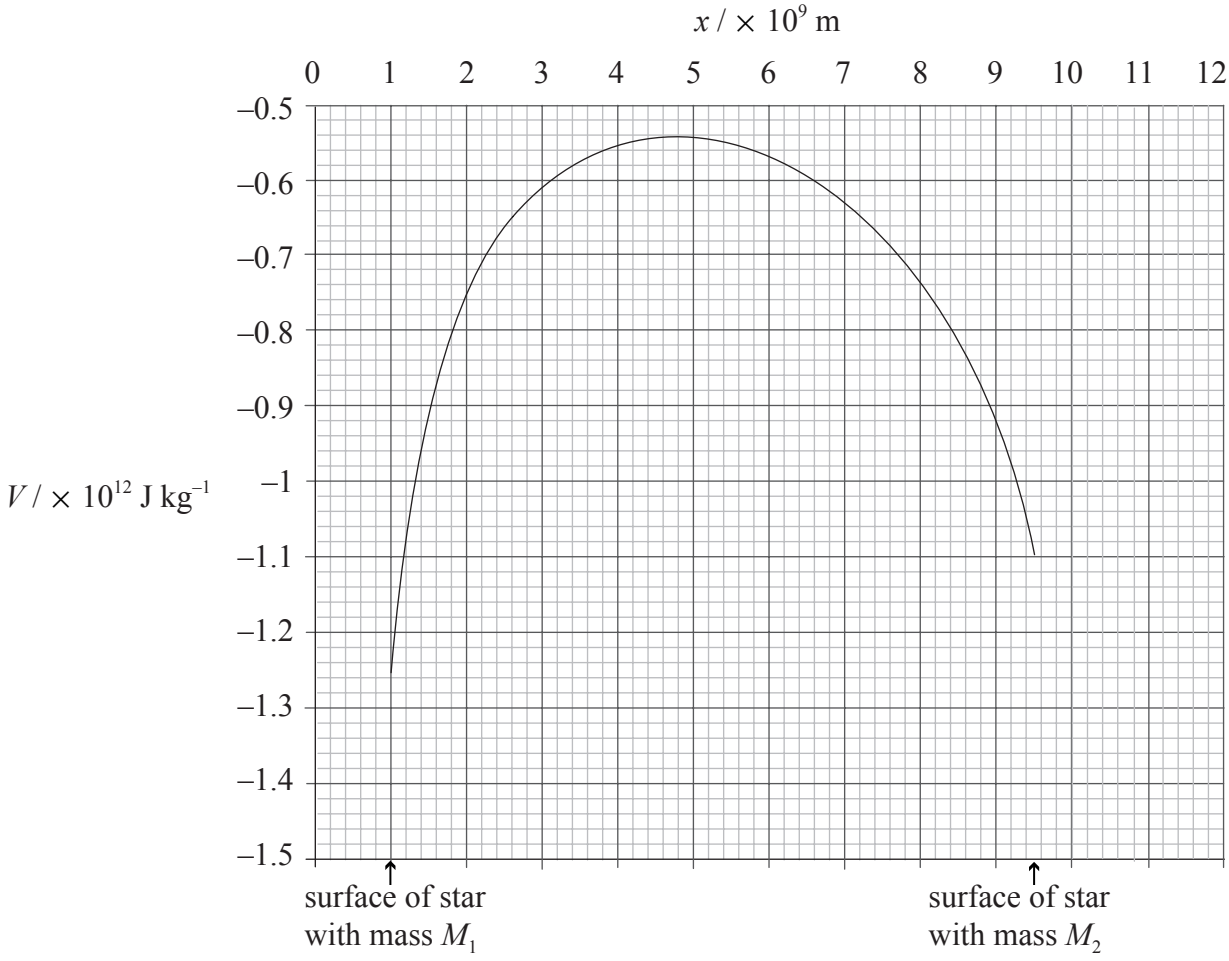
*(Question B3, part 2 continued)*

(b) A binary star system consists of two stars with masses $M_1$ and $M_2$ rotating about a common centre. The centres of the two stars are separated by a distance $R = 1.2\times10^{10}$ m.

The diagram is not to scale.




The total gravitational potential due to the stars at any point along a line joining their centres is $V$. The graph shows how $V$ varies with the distance $x$ from the centre of star $M_1$. (Values of the potential inside each star are not known.)

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*(Question B3, part 2 continued)*

A particle is launched with kinetic energy $E_K$ from the surface of star with mass $M_2$. The particle arrives at the surface of the star of mass $M_1$. Use the graph to

(i) explain whether the kinetic energy of the particle at the surface of $M_1$ is less than, equal to, **or** larger than $E_K$. *[2]*

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(ii) determine the distance $x$ at which the gravitational field strength due to the two stars is zero. *[2]*

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(iii) determine the ratio $\frac{M_1}{M_2}$. *[3]*

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**B4.** This question is in **two** parts. **Part 1** is about the decay of radium-226 and **Part 2** is about diffraction and resolution.

**Part 1** Decay of radium-226

(a) The nuclear reaction equation for the decay of radium-226 (Ra) may be written as

$$^{226}_{88}\text{Ra} = \text{Rn} + \alpha$$

(i) State the value of the proton number and neutron number of the isotope of radon (Rn). *[1]*

Proton number: . . . . . .

Neutron number: . . . . . .

(ii) Compare, with reference to the nuclear reaction in (a), the binding energy of Ra with that of Rn. *[2]*

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(b) The following data are available.

mass of Ra = 226.0254 u
mass of Rn = 222.0175 u
mass of α = 4.0026 u

Show that the energy released in the decay of a Ra nucleus is 4.94 MeV. *[2]*

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*(This question continues on the following page)*

*(Question B4, part 1 continued)*

(c) An α-particle of energy 4.94 MeV emitted in the decay of a Ra nucleus, travels a distance *d* in air before coming to rest.

(i) Show that the initial speed of the α-particle is $1.54\times10^{7}\,\text{m s}^{-1}$. *[3]*

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(ii) State the relationship between the magnitude of the average force *F* acting on the α-particle, the change in kinetic energy $\Delta E_{\text{K}}$ and the distance *d*. *[1]*

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(iii) Use your answer to (c)(ii) to calculate *F* given that $d = 4.20\times10^{-2}\,\text{m}$. *[2]*

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(iv) Estimate the time that it takes the α-particle to come to rest. *[4]*

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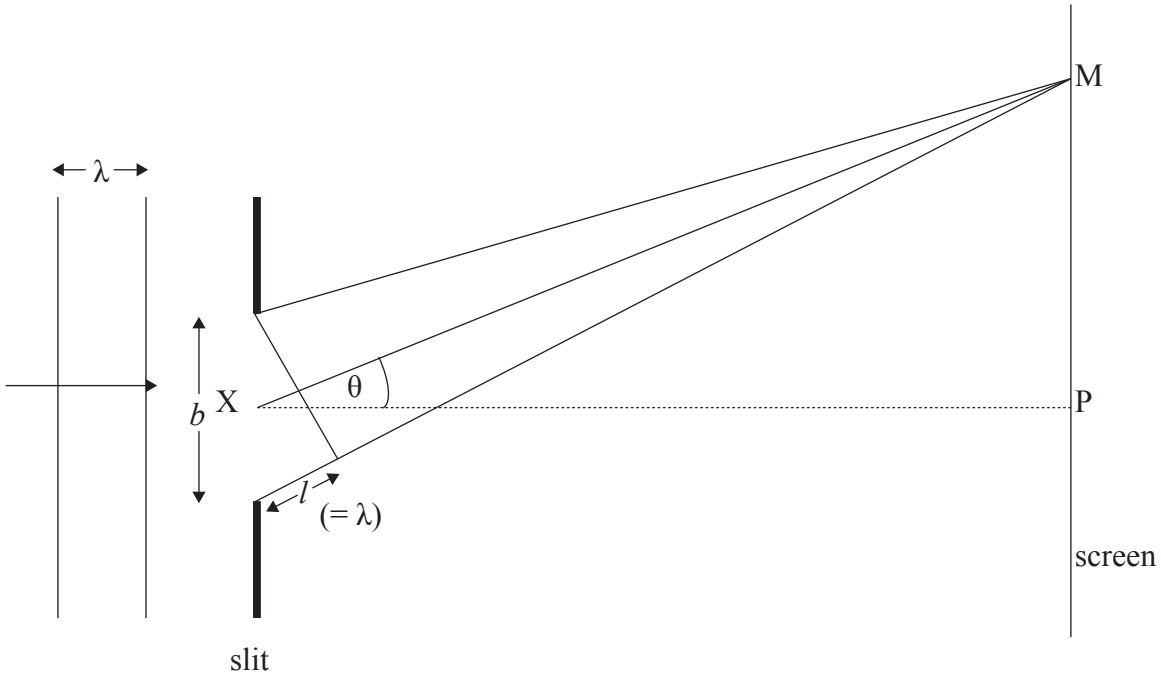
*(This question continues on the following page)*

*(Question B4 continued)*

**Part 2** Diffraction and resolution

(a) Plane wavefronts of monochromatic light of wavelength $\lambda$ are incident on a narrow slit. After passing through the slit they are incident on a screen placed a large distance from the slit.




The width of the slit is $b$ and the point X is at the centre of the slit. The point M on the screen is the position of the first minimum of the diffraction pattern formed on the screen. The path difference between light from the top edge of the slit and light from the bottom edge of the slit is $l$.

Use the diagram to explain why the distance $l$ is equal to $\lambda$. *[3]*

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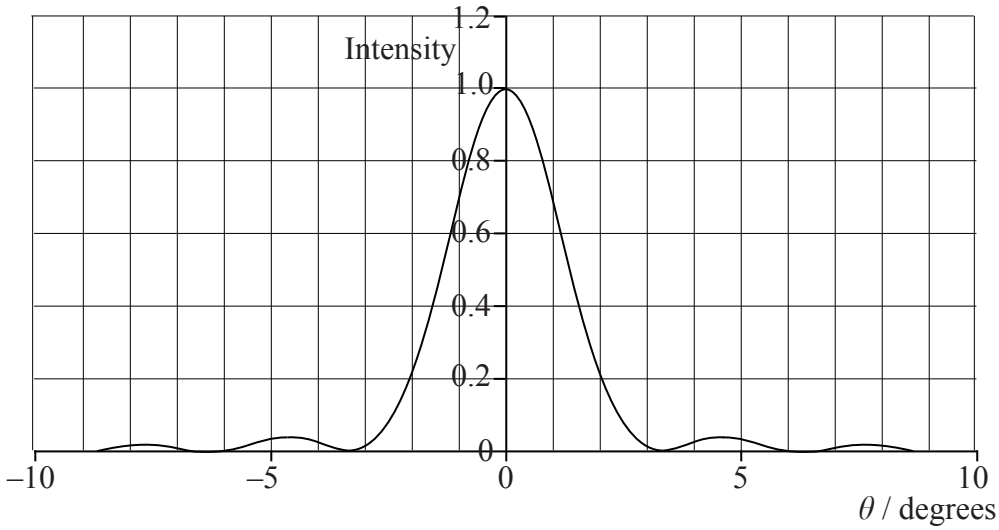
*(This question continues on the following page)*

*(Question B4, Part 2 continued)*

The wavefronts in (a) are from a monochromatic point source $S_1$. Diagram 1 is a sketch of how the intensity of the diffraction pattern formed by the single slit varies with angle $\theta$. The units on the vertical axis are arbitary.

**Diagram 1**




Another identical point source $S_2$ is placed close to $S_1$ as shown in diagram 2.

**Diagram 2**


(b) The diffraction patterns formed by each source are just resolved.

On **diagram 1** sketch the intensity distribution of the light from source $S_2$. *[2]*

*(This question continues on the following page)*

*(Question B4, part 2 continued)*

(c) Outline how the Rayleigh criterion affects the design of radio telescopes. *[2]*

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(d) The dish of the Arecibo radio telescope has a diameter of 300 m. Two distant radio sources are $2.0\times10^{12}$ m apart. The sources are $3.0\times10^{16}$ m from Earth and they emit radio waves of wavelength 21 cm. Determine whether the radio telescope can resolve these sources. *[3]*

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