Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Standard level
Paper 3

Friday 11 May 2018 (morning)

1 hour

Candidate session number

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[35 marks]**.

Section A	Questions
Answer all questions.	1 – 2

Section B	Questions
Answer all of the questions from one of the options.	
Option A — Relativity	3 – 5
Option B — Engineering physics	6 – 7
Option C — Imaging	8 – 10
Option D — Astrophysics	11 – 12

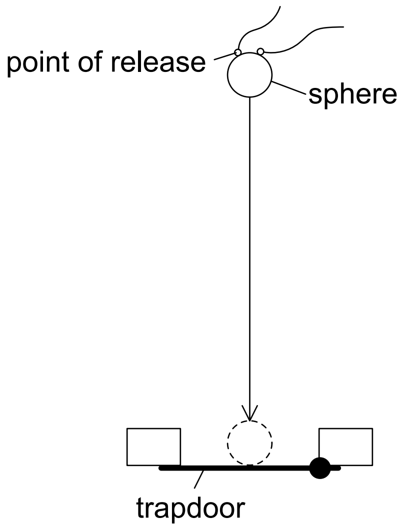
2218 – 6518

Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

1. To determine the acceleration due to gravity, a small metal sphere is dropped from rest and the time it takes to fall through a known distance and open a trapdoor is measured.

not to scale



The following data are available.

Diameter of metal sphere	$= 12.0 \pm 0.1$ mm
Distance between the point of release and the trapdoor	$= 654 \pm 2$ mm
Measured time for fall	$= 0.363 \pm 0.002$ s

(a) Determine the distance fallen, in m, by the centre of mass of the sphere including an estimate of the absolute uncertainty in your answer. [2]

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(Question 1 continued)

(b) Using the following equation

$$\text{acceleration due to gravity} = \frac{2 \times \text{distance fallen by centre of mass of sphere}}{(\text{measured time to fall})^2}$$

calculate, for these data, the acceleration due to gravity including an estimate of the absolute uncertainty in your answer. [4]

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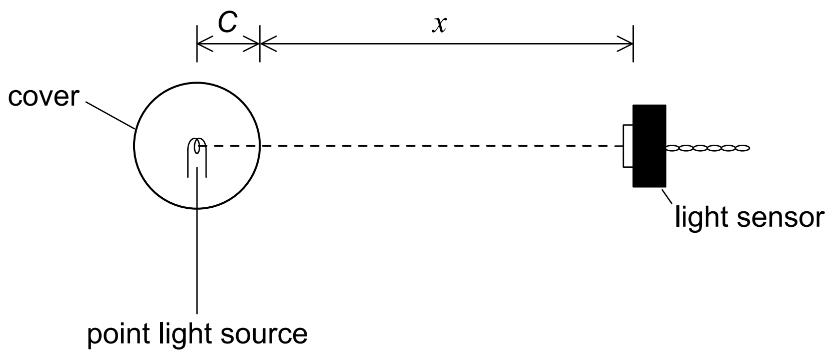
will not be marked.

2. A student carries out an experiment to determine the variation of intensity of the light with distance from a point light source. The light source is at the centre of a transparent spherical cover of radius C. The student measures the distance x from the surface of the cover to a sensor that measures the intensity I of the light.



The light source emits radiation with a constant power P and all of this radiation is transmitted through the cover. The relationship between I and x is given by

$$I = \frac{P}{4\pi(C + x)^2}$$

(a) This relationship can also be written as follows.

$$\frac{1}{\sqrt{I}} = Kx + KC$$

Show that $K = 2\sqrt{\frac{\pi}{P}}$. [1]

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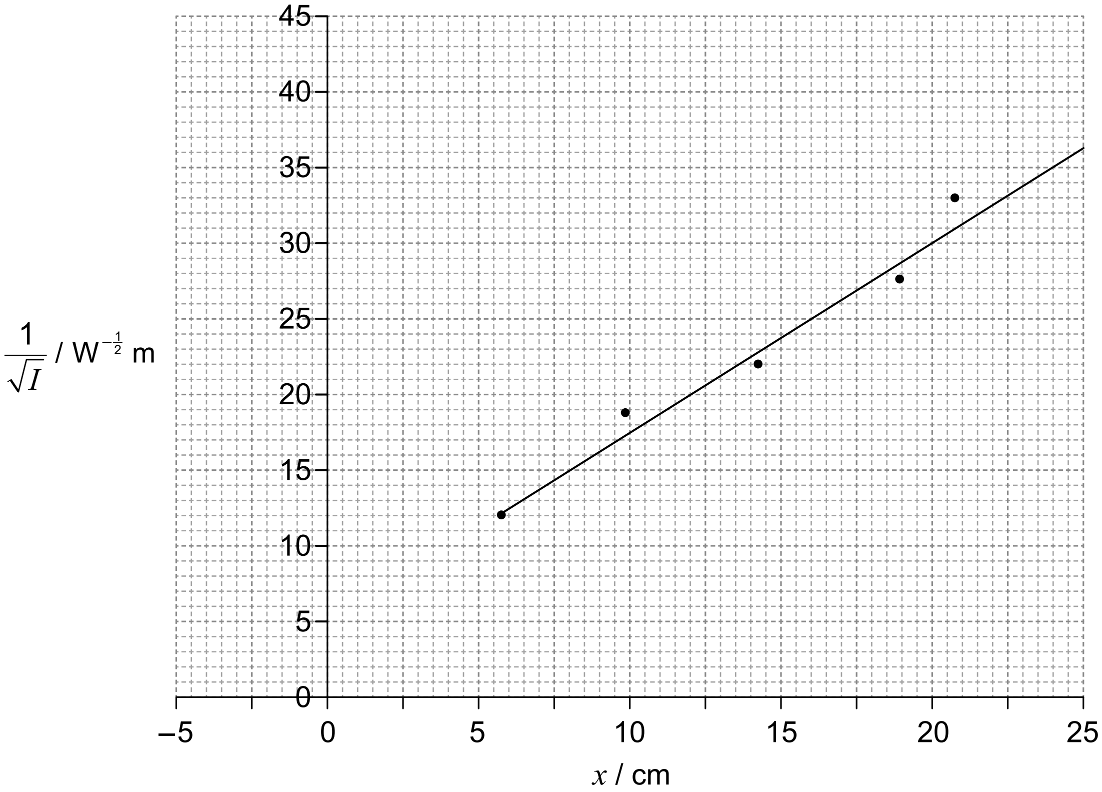
(Question 2 continued)

(b) The student obtains a set of data and uses this to plot a graph of the variation of $\frac{1}{\sqrt{I}}$ with x.



(i) Estimate *C*. [2]

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(Question 2 continued)

(ii) Determine P, to the correct number of significant figures including its unit. [4]

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(c) Explain the disadvantage that a graph of I versus $\frac{1}{x^2}$ has for the analysis in (b)(i) and (b)(ii). [2]

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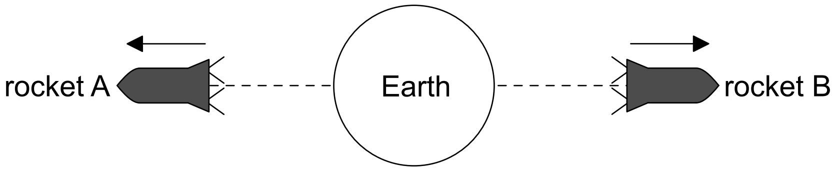
Section B

Answer **all** of the questions from **one** of the options. Answers must be written within the answer boxes provided.

Option A — Relativity

3. Rocket A and rocket B are travelling in opposite directions from the Earth along the same straight line.



In the reference frame of the Earth, the speed of rocket A is 0.75*c* and the speed of rocket B is 0.50*c*.

(a) Calculate, for the reference frame of rocket A, the speed of rocket B according to the

(i) Galilean transformation. [1]

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(ii) Lorentz transformation. [2]

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(b) Outline, with reference to special relativity, which of your calculations in (a) is more likely to be valid. [1]

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(Option A continues on the following page)

(Option A continued)

4. When a spaceship passes the Earth, an observer on the Earth and an observer on the spaceship both start clocks. The initial time on both clocks is 12 midnight. The spaceship is travelling at a constant velocity with $\gamma = 1.25$. A space station is stationary relative to the Earth and carries clocks that also read Earth time.

(a) Calculate the velocity of the spaceship relative to the Earth. [1]

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(b) The spaceship passes the space station 90 minutes later as measured by the spaceship clock. Determine, for the reference frame of the Earth, the distance between the Earth and the space station. [3]

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(c) As the spaceship passes the space station, the space station sends a radio signal back to the Earth. The reception of this signal at the Earth is event A. Determine the time on the Earth clock when event A occurs. [2]

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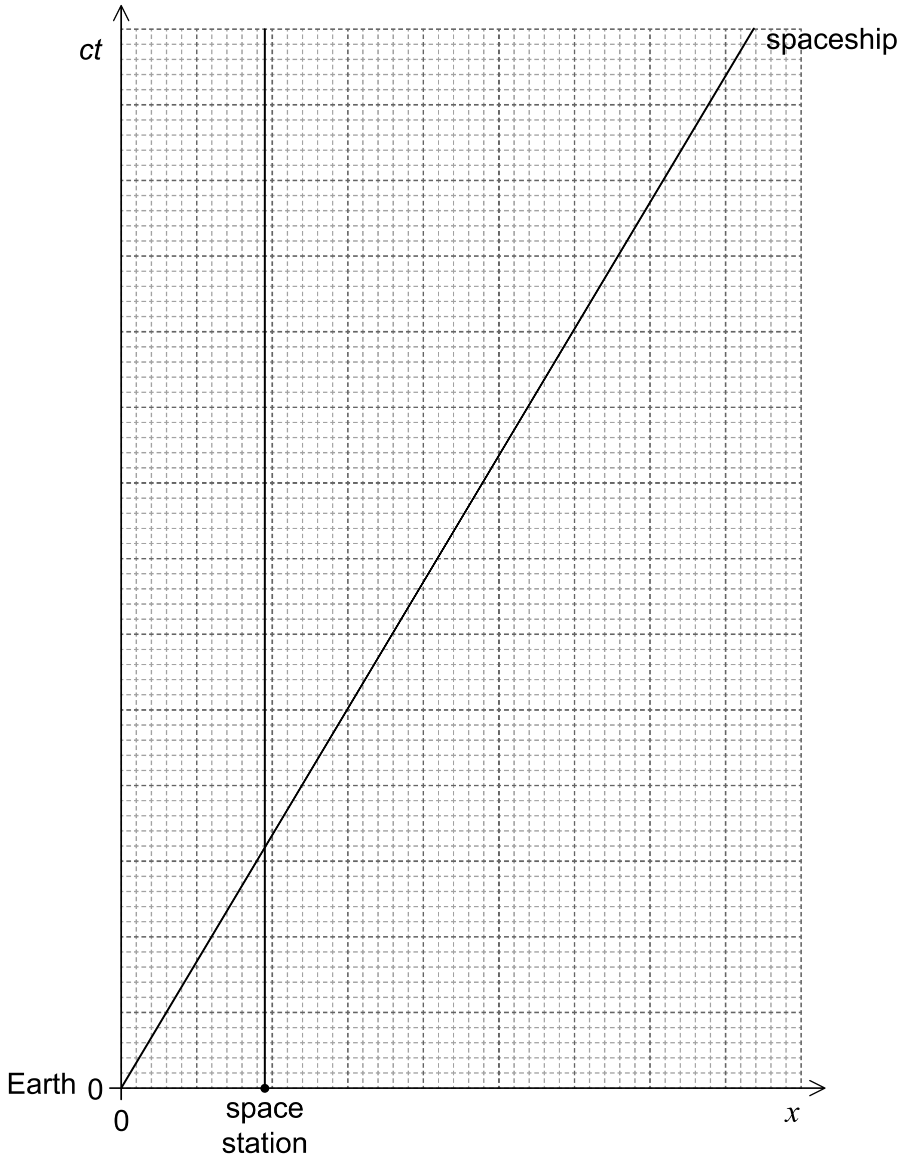
(Option A continues on the following page)

(Option A, question 4 continued)

(d) Some of the radio signal is reflected at the surface of the Earth and this reflected signal is later detected at the spaceship. The detection of this signal is event B. The spacetime diagram is shown for the Earth, showing the space station and the spaceship. Both axes are drawn to the same scale.



(Option A continues on the following page)

(Option A, question 4 continued)

(i) Construct event A and event B on the spacetime diagram. [3]

(ii) Estimate, using the spacetime diagram, the time at which event B occurs for the spaceship. [2]

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(Option A continues on page 13)

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will not be marked.

(Option A continued from page 11)

5. (a) Explain what is meant by the statement that the spacetime interval is an invariant quantity. [1]

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(b) Observer A detects the creation (event 1) and decay (event 2) of a nuclear particle. After creation, the particle moves at a constant speed relative to A. As measured by A, the distance between the events is 15 m and the time between the events is 9.0×10^{-8} s. Observer B moves with the particle.

For event 1 and event 2,

(i) calculate the spacetime interval. [1]

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(ii) determine the time between them according to observer B. [2]

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(c) Outline why the observed times are different for A and B. [1]

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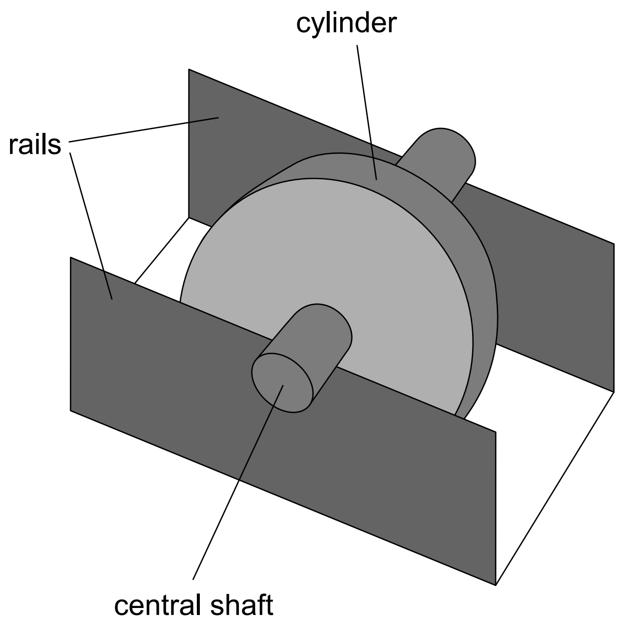
End of Option A

Option B — Engineering physics

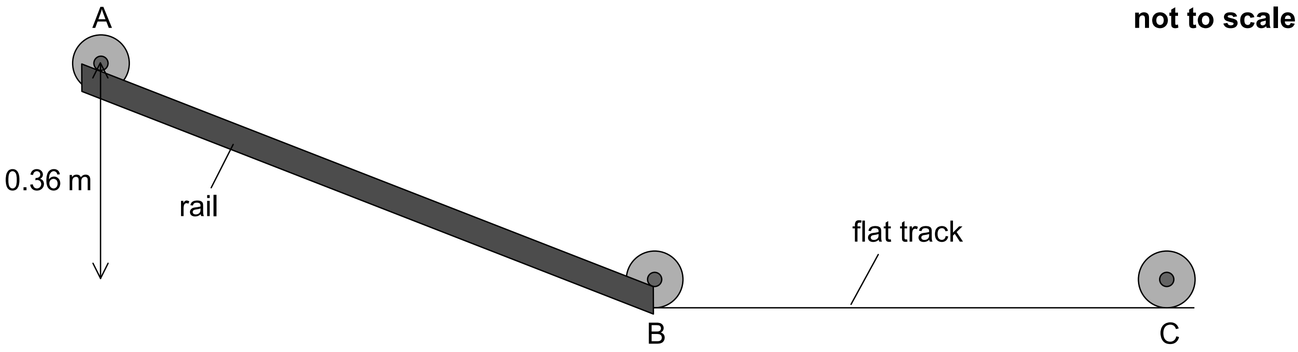
6. A wheel of mass 0.25 kg consists of a cylinder mounted on a central shaft. The shaft has a radius of 1.2 cm and the cylinder has a radius of 4.0 cm. The shaft rests on two rails with the cylinder able to spin freely between the rails.



(Option B continues on the following page)

(Option B, question 6 continued)

(a) The stationary wheel is released from rest and rolls down a slope with the shaft rolling on the rails without slipping from point A to point B.



(i) The moment of inertia of the wheel is 1.3×10^{-4} kg m^2. Outline what is meant by the moment of inertia. [1]

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(ii) In moving from point A to point B, the centre of mass of the wheel falls through a vertical distance of 0.36 m. Show that the translational speed of the wheel is about 1 m s^{-1} after its displacement. [3]

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(iii) Determine the angular velocity of the wheel at B. [1]

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(Option B continues on page 17)

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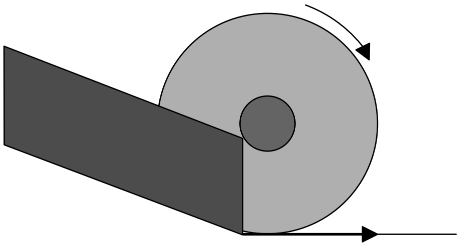
will not be marked.

(Option B, question 6 continued from page 15)

(b) The wheel leaves the rails at point B and travels along the flat track to point C. For a short time the wheel slips and a frictional force F exists on the edge of the wheel as shown.



Describe the effect of F on the

(i) linear speed of the wheel. [2]

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(ii) angular speed of the wheel. [2]

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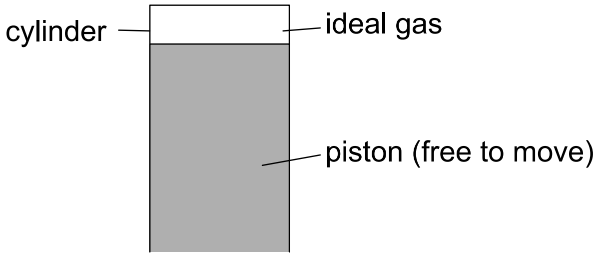
(Option B continues on the following page)

(Option B continued)

7. A cylinder is fitted with a piston. A fixed mass of an ideal gas fills the space above the piston.



The gas expands isobarically. The following data are available.

Amount of gas	= 243 mol
Initial volume of gas	= 47.1 m^3
Initial temperature of gas	= – 12.0 °C
Final temperature of gas	= + 19.0 °C
Initial pressure of gas	= 11.2 kPa

(a) Show that the final volume of the gas is about 53 m^3. [2]

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(b) Calculate, in J, the work done by the gas during this expansion. [2]

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(Option B continues on the following page)

(Option B, question 7 continued)

(c) Determine the thermal energy which enters the gas during this expansion. [3]

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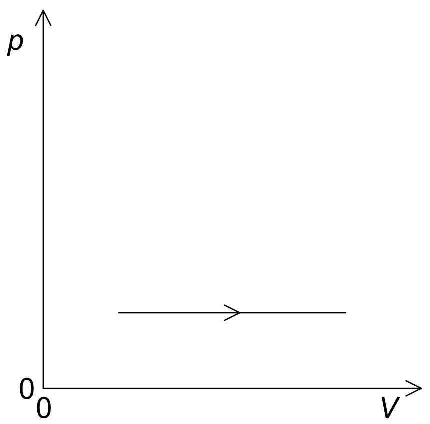
(d) The gas returns to its original state by an adiabatic compression followed by cooling at constant volume.

(i) Sketch, on the *pV* diagram, the complete cycle of changes for the gas, labelling the changes clearly. The expansion shown in (a) and (b) is drawn for you. [2]



(ii) Outline the change in entropy of the gas during the cooling at constant volume. [1]

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(e) There are various equivalent versions of the second law of thermodynamics. Outline the benefit gained by having alternative forms of a law. [1]

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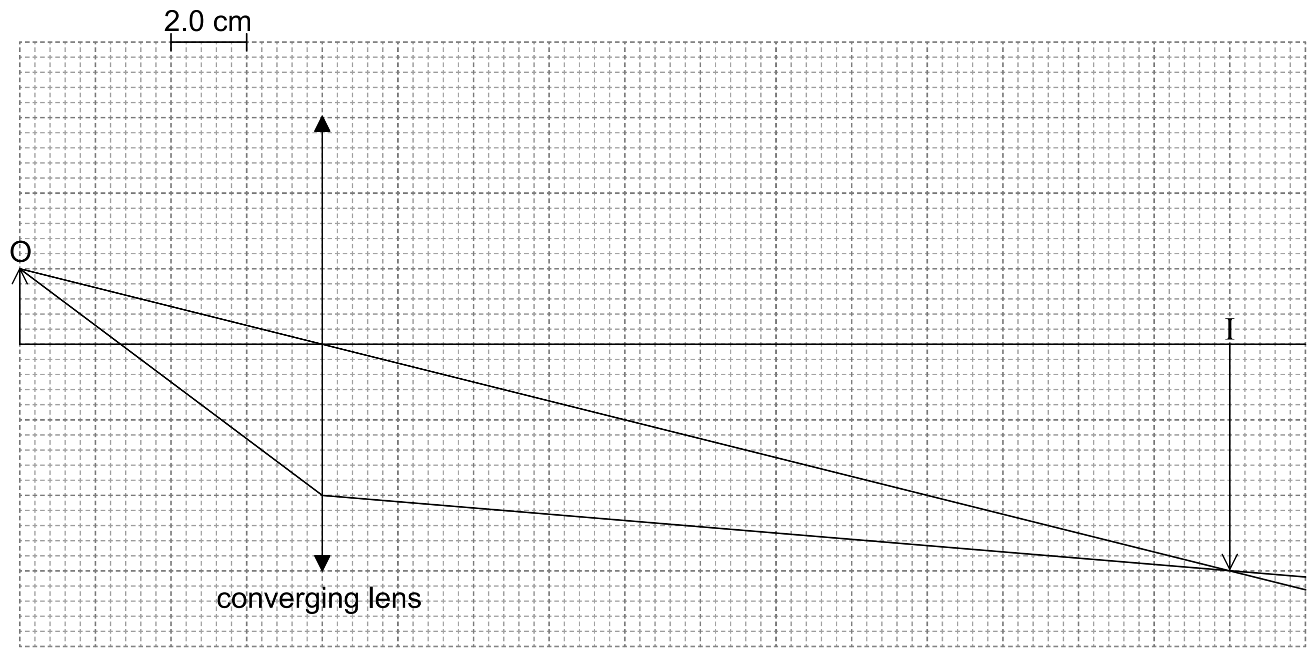
End of Option B

Option C — Imaging

8. A ray diagram for a converging lens is shown. The object is labelled O and the image is labelled I.



(a) Using the ray diagram,

(i) determine the focal length of the lens. [2]

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(ii) calculate the linear magnification. [1]

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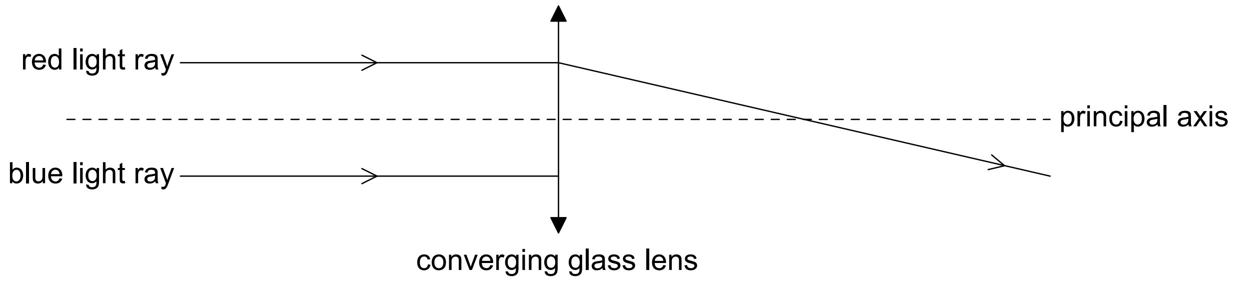
(Option C continues on the following page)

(Option C, question 8 continued)

(b) The diagram shows an incomplete ray diagram which consists of a red ray of light and a blue ray of light which are incident on a converging glass lens. In this glass lens the refractive index for blue light is greater than the refractive index for red light.



Using the diagram, outline the phenomenon of chromatic aberration. [2]

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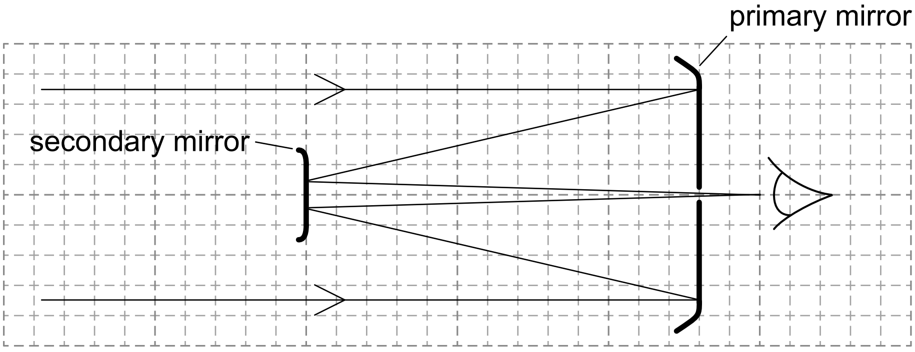
(Option C continues on the following page)

(Option C continued)

9. The diagram represents a simple optical astronomical reflecting telescope with the path of some light rays shown.



reflecting telescope

(a) Identify, with the letter X, the position of the focus of the primary mirror. [1]

(b) This arrangement using the secondary mirror is said to increase the focal length of the primary mirror. State why this is an advantage. [1]

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(c) Distinguish between this mounting and the Newtonian mounting. [2]

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(Option C continues on the following page)

(Option C, question 9 continued)

(d) A radio telescope also has a primary mirror. Identify **one** difference in the way radiation from this primary mirror is detected. [1]

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(Option C continues on the following page)

(Option C continued)

10. (a) An optic fibre of refractive index 1.4475 is surrounded by air. The critical angle for the core–air boundary interface is 44°. Suggest, with a calculation, why the use of cladding with refractive index 1.4444 improves the performance of the optic fibre. [3]

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(b) An optic fibre of length 185 km has an attenuation of 0.200 dB km^{-1}. The input power to the cable is 400.0 μW. The output power from the cable must not fall below 2.0 μW.

(i) Calculate the maximum attenuation allowed for the signal. [2]

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(ii) An amplifier can increase the power of the signal by 12 dB. Determine the minimum number of amplifiers required. [2]

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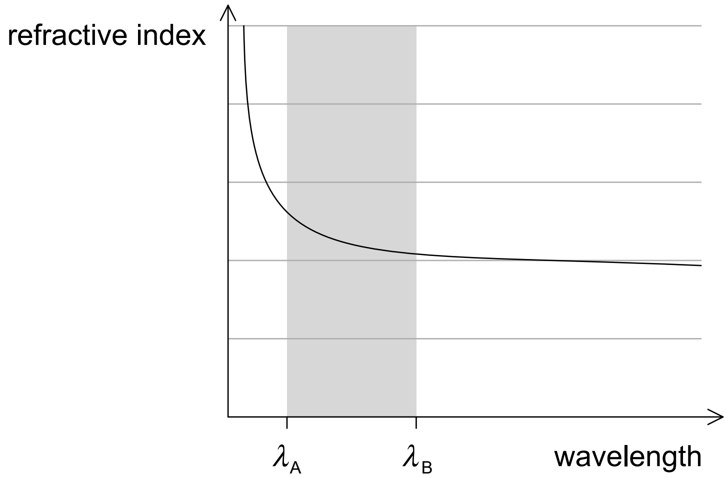
(Option C continues on the following page)

(Option C, question 10 continued)

(iii) The graph shows the variation with wavelength of the refractive index of the glass from which the optic fibre is made.



Two light rays enter the fibre at the same instant along the axes. Ray A has a wavelength of λ_A and ray B has a wavelength of λ_B. Discuss the effect that the difference in wavelength has on the rays as they pass along the fibre. [2]

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(c) In many places clad optic fibres are replacing copper cables. State **one** example of how fibre optic technology has impacted society. [1]

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End of Option C

Option D — Astrophysics

11. (a) Main sequence stars are in equilibrium under the action of forces. Outline how this equilibrium is achieved. [2]

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(b) A main sequence star P, is 1.3 times the mass of the Sun. Calculate the luminosity of P relative to the Sun. [1]

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(Option D continues on the following page)

(Option D, question 11 continued)

(c) The following data apply to the star Gacrux.

Radius $= 58.5 \times 10^{9}$ m
Temperature $= 3600$ K
Distance $= 88$ ly

(i) The luminosity of the Sun $L_{\odot}$ is 3.85×10^{26} W. Determine the luminosity of Gacrux relative to the Sun. [3]

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(ii) The distance to Gacrux can be determined using stellar parallax. Outline why this method is not suitable for all stars. [1]

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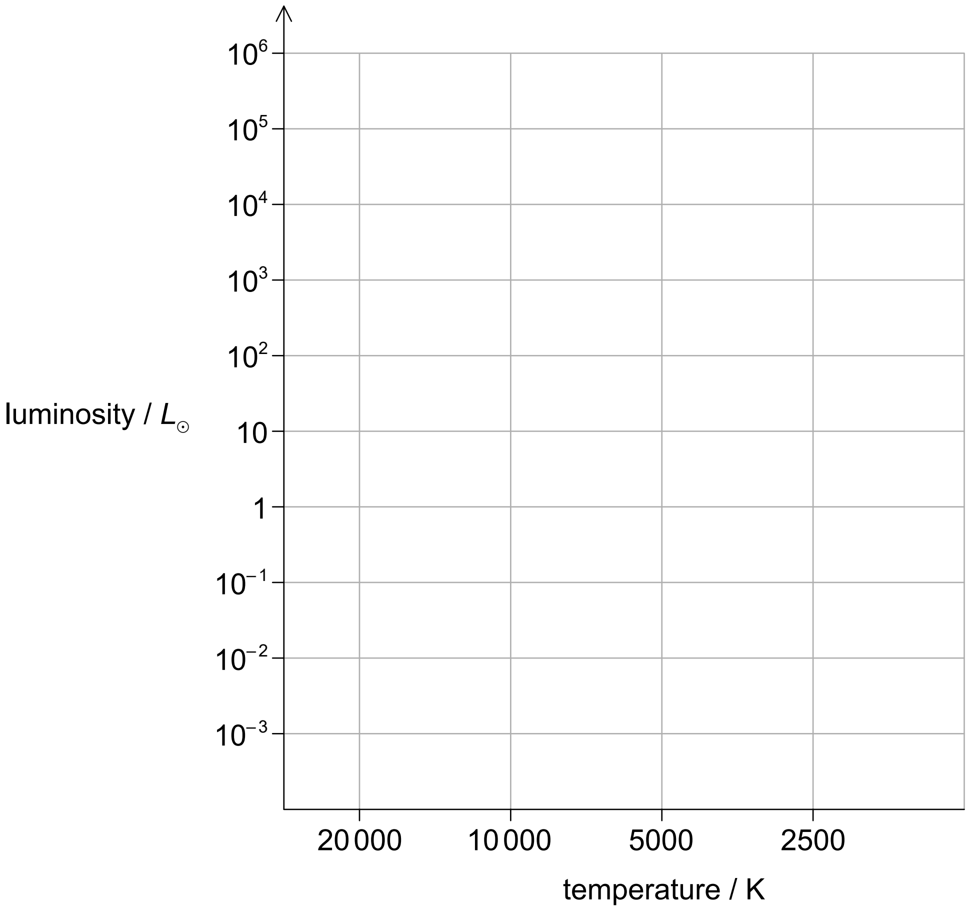
(Option D, question 11 continued)

(d) A Hertzsprung–Russell (HR) diagram is shown.



On the HR diagram,

(i) draw the main sequence. [1]

(ii) plot the position, using the letter P, of the main sequence star P you calculated in (b). [1]

(iii) plot the position, using the letter G, of Gacrux. [1]

(Option D continues on the following page)

(Option D, question 11 continued)

(e) Discuss, with reference to its change in mass, the evolution of star P from the main sequence until its final stable phase. [3]

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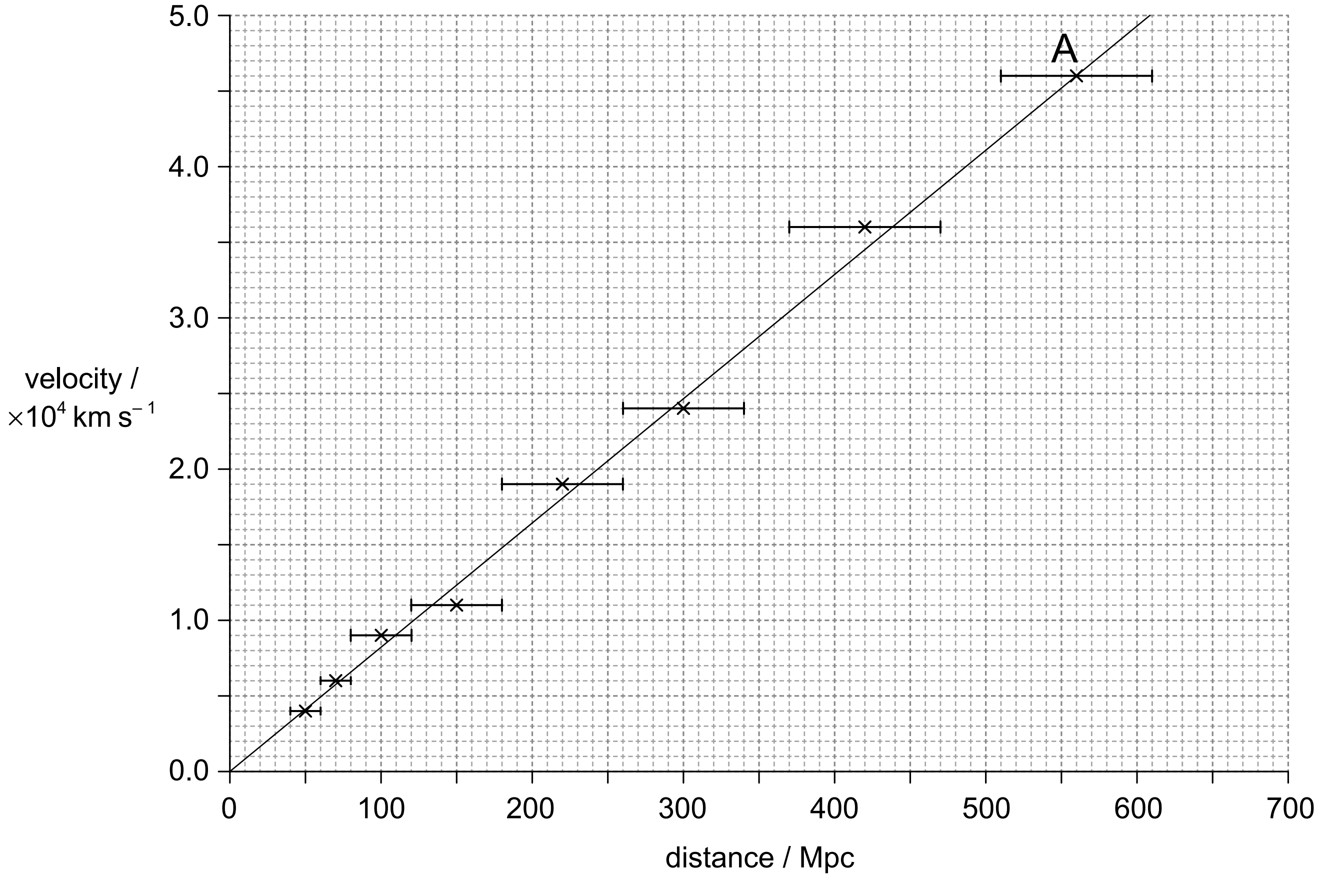
(Option D continues on the following page)

(Option D continued)

12. Data from distant galaxies are shown on the graph.



(a) Estimate, using the data, the age of the universe. Give your answer in seconds. [3]

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(Option D continues on the following page)

(Option D, question 12 continued)

(b) Identify the assumption that you made in your answer to (a). [1]

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(c) On the graph, one galaxy is labelled A. Determine the size of the universe, relative to its present size, when light from the galaxy labelled A was emitted. [3]

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End of Option D

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