Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Standard level
Paper 3

Monday 9 May 2016 (morning)

Candidate session number

1 hour

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 questions.
- Section B: answer all of the questions from one of the options.
- Write your answers in the 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]**.

Option	Questions
Option A — Relativity	3 – 6
Option B — Engineering physics	7 – 8
Option C — Imaging	9 – 11
Option D — Astrophysics	12 – 14

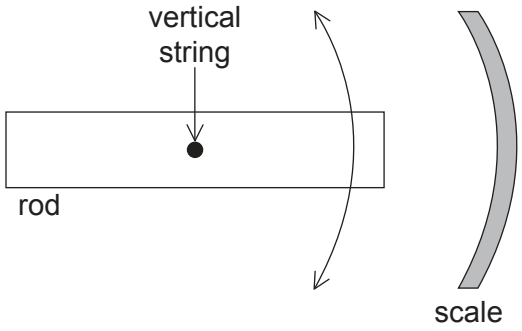
2216 – 6506

22 pages

Section A

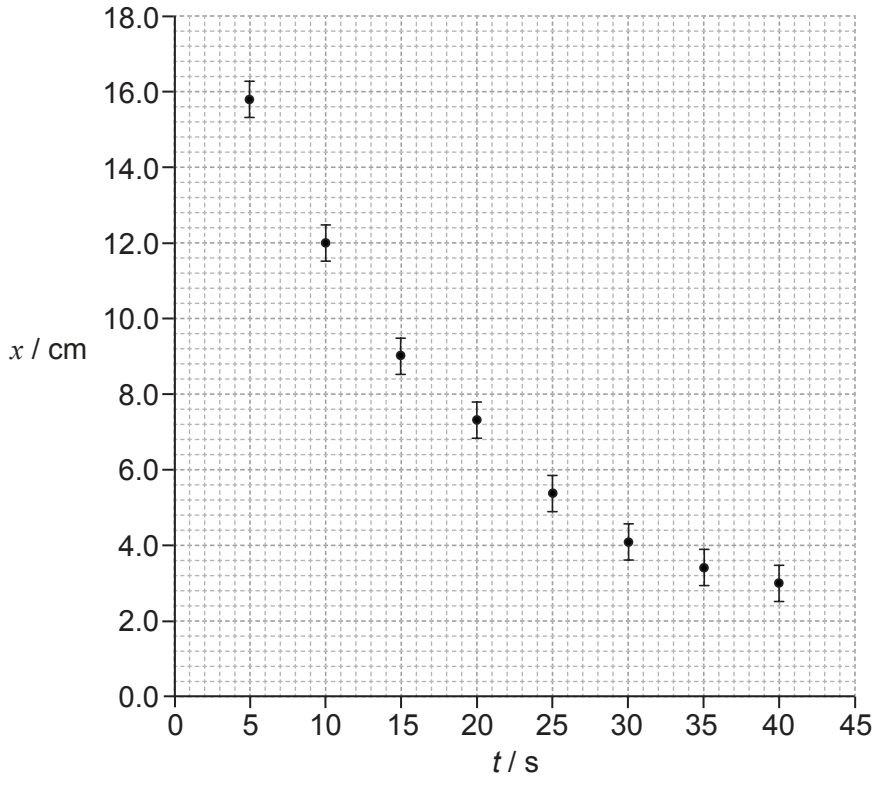
Answer **all** questions. Write your answers in the boxes provided.

1. A student investigates the oscillation of a horizontal rod hanging at the end of a vertical string. The diagram shows the view from above.



The student starts the rod oscillating and measures the largest displacement for each cycle of the oscillation on the scale and the time at which it occurs. The student begins to take measurements a few seconds after releasing the rod.

The graph shows the variation of displacement x with time t since the release of the rod. The uncertainty for t is negligible.



(a) On the graph above, draw the line of best fit for the data. [1]

(This question continues on the following page)

(Question 1 continued)

(b) Calculate the percentage uncertainty for the displacement when $t = 40\,\text{s}$. [2]

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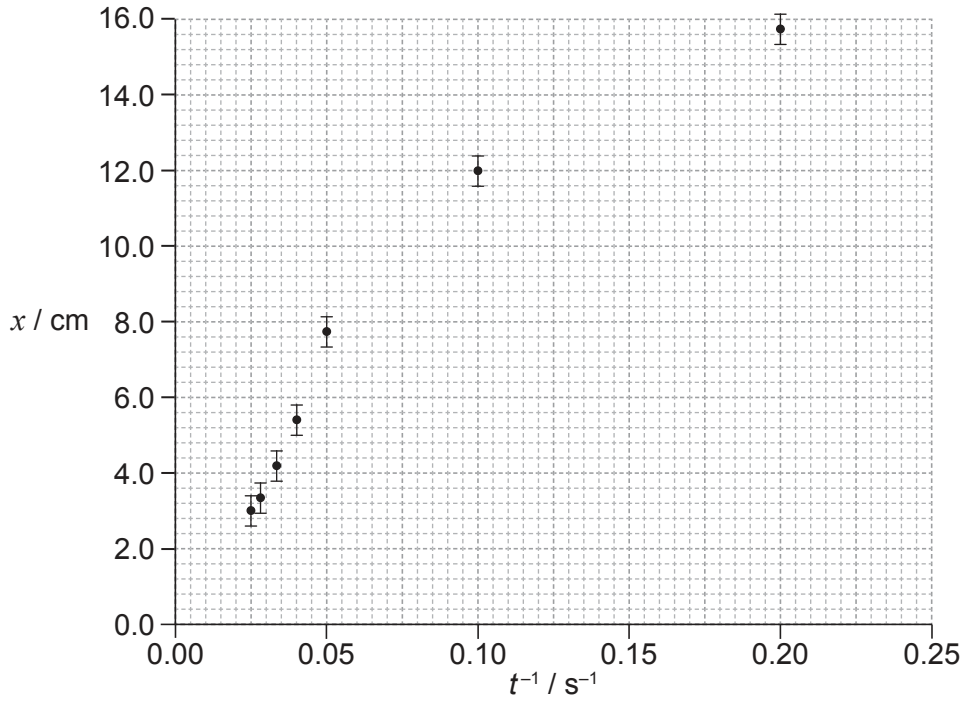
(c) The student hypothesizes that the relationship between x and t is $x = \frac{a}{t}$ where a is a constant.

To test the hypothesis x is plotted against $\frac{1}{t}$ as shown in the graph.



(i) The data point corresponding to $t = 15\,\text{s}$ has not been plotted. Plot this point on the graph above. [1]

(ii) Suggest the range of values of t for which the hypothesis may be assumed to be correct. [2]

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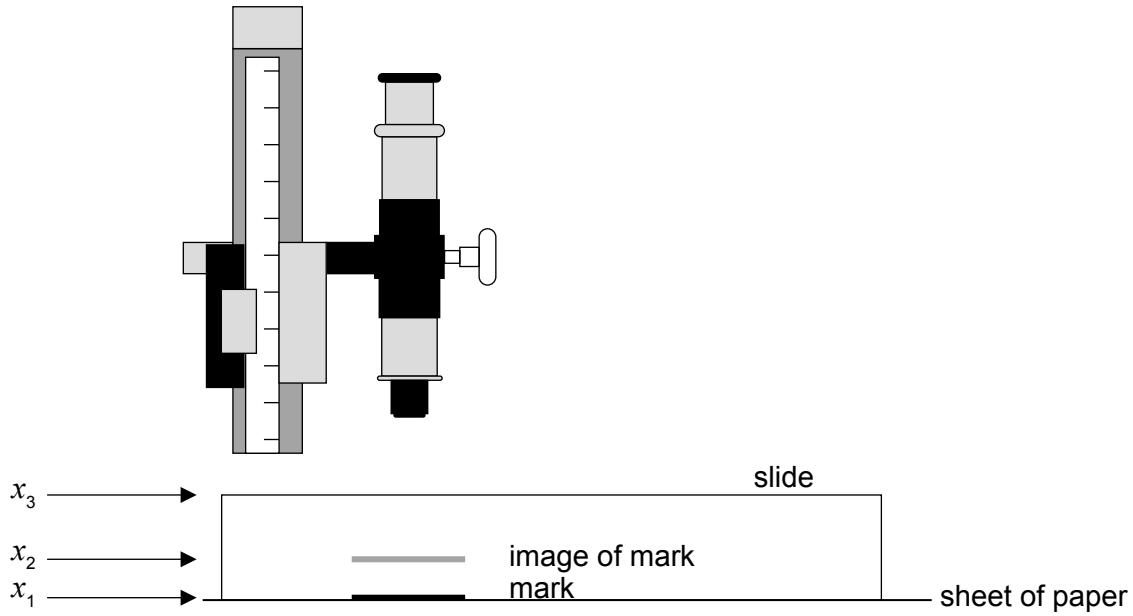
2. A student measures the refractive index of the glass of a microscope slide.

He uses a travelling microscope to determine the position x_1 of a mark on a sheet of paper. He then places the slide over the mark and finds the position x_2 of the image of the mark when viewed through the slide. Finally, he uses the microscope to determine the position x_3 of the top of the slide.



The table shows the average results of a large number of repeated measurements.

	Average position of mark / mm
x_1	0.20 ±0.02
x_2	0.59 ±0.02
x_3	1.35 ±0.02

(a) The refractive index of the glass from which the slide is made is given by

$$\frac{x_3 - x_1}{x_3 - x_2}.$$

Determine

(i) the refractive index of the glass to the correct number of significant figures, ignoring any uncertainty. [1]

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(This question continues on the following page)

(Question 2 continued)

(ii) the uncertainty of the value calculated in (a)(i). [3]

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(b) After the experiment, the student finds that the travelling microscope is badly adjusted so that the measurement of each position is too large by 0.05 mm.

(i) State the name of this type of error. [1]

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(ii) Outline the effect that the error in (b)(i) will have on the calculated value of the refractive index of the glass. [2]

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(This question continues on the following page)

(Question 2 continued)

(c) After correcting the adjustment of the travelling microscope, the student repeats the experiment using a glass block 10 times thicker than the original microscope slide. Explain the change, if any, to the calculated result for the refractive index and its uncertainty. [2]

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Section B

Answer **all** of the questions from **one** of the options. Write your answers in the boxes provided.

Option A — Relativity

3. One of the postulates of special relativity states that the laws of physics are the same in all inertial frames of reference.

(a) State what is meant by inertial in this context. [1]

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(b) An observer is travelling at velocity *v* towards a light source. Determine the value the observer would measure for the speed of light emitted by the source according to

(i) Maxwell's theory. [1]

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(ii) Galilean transformation. [1]

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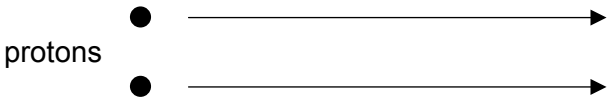
(Option A continues on the following page)

(Option A continued)

4. Two protons are moving with the same velocity in a particle accelerator.



Observer X is at rest relative to the accelerator. Observer Y is at rest relative to the protons.

Explain the nature of the force between the protons as observed by observer X **and** observer Y. [4]

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(Option A continues on the following page)

(Option A continued)

5. An electron is emitted from a nucleus with a speed of 0.975*c* as observed in a laboratory. The electron is detected at a distance of 0.800 m from the emitting nucleus as measured in the laboratory.

(a) For the reference frame of the electron, calculate the distance travelled by the detector. [2]

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(b) For the reference frame of the laboratory, calculate the time taken for the electron to reach the detector after its emission from the nucleus. [2]

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(c) For the reference frame of the electron, calculate the time between its emission at the nucleus and its detection. [2]

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(d) Outline why the answer to (c) represents a proper time interval. [1]

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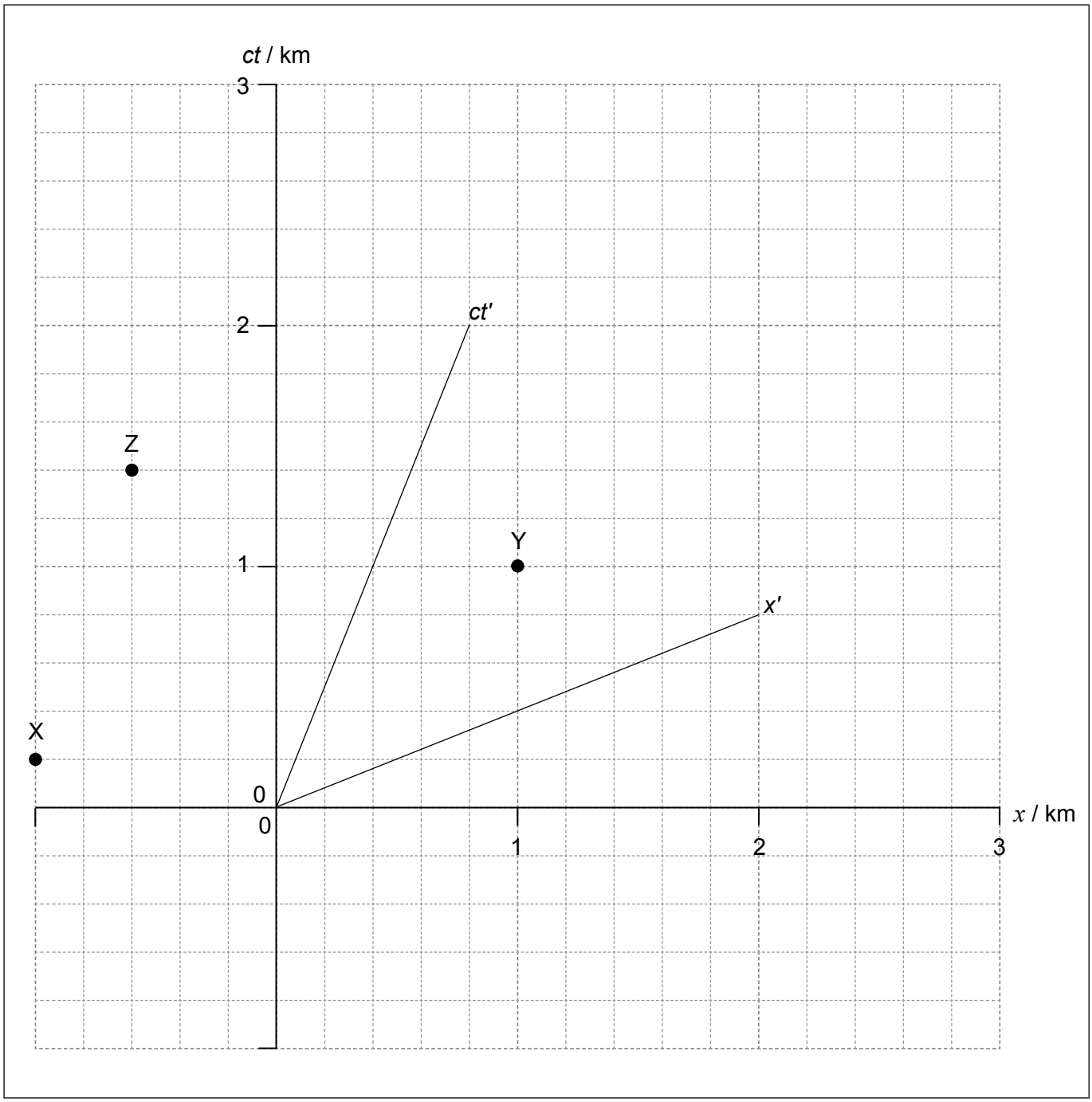
(Option A continues on the following page)

(Option A continued)

6. An observer on Earth watches a rocket A. The spacetime diagram shows part of the motion of A in the reference frame of the Earth observer. Three flashing light beacons, X, Y and Z, are used to guide rocket A. The flash events are shown on the spacetime diagram. The diagram shows the axes for the reference frames of Earth and of rocket A. The Earth observer is at the origin.



(Option A continues on the following page)

(Option A, question 6 continued)

(a) For the reference frame of the Earth observer, calculate the speed of rocket A in terms of the speed of light *c*. [2]

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(b) Using the graph opposite, deduce the order in which

(i) the beacons **flash** in the reference frame of rocket A. [2]

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(ii) the Earth observer **sees** the beacons flash. [2]

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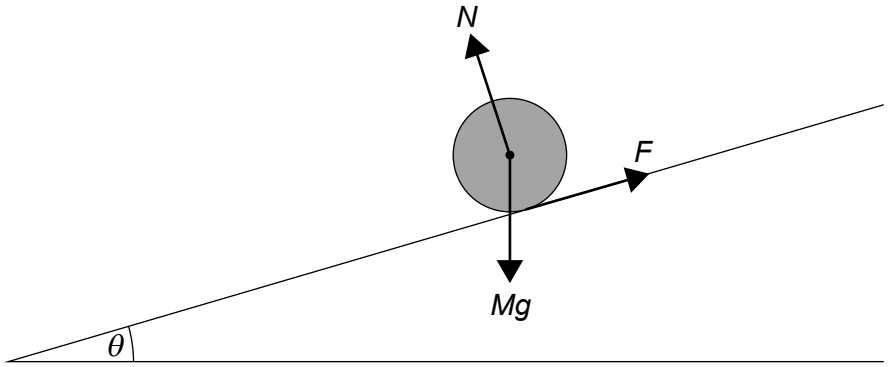
End of Option A

Option B — Engineering physics

7. A solid cylinder of mass *M* and radius *R* rolls without slipping down a uniform slope. The slope makes an angle θ to the horizontal.



The diagram shows the three forces acting on the cylinder. *N* is the normal reaction force and *F* is the frictional force between the cylinder and the slope.

(a) State why *F* is the only force providing a torque about the axis of the cylinder. [1]

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(b) (i) The moment of inertia of a cylinder about its axis is $I = \frac{1}{2}MR^2$. Show that, by applying Newton's laws of motion, the linear acceleration of the cylinder is $a = \frac{2}{3}g\sin\theta$. [4]

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(Option B continues on the following page)

(Option B, question 7 continued)

(ii) Calculate, for $\theta = 30°$, the time it takes for the solid cylinder to travel 1.5 m along the slope. The cylinder starts from rest. [2]

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(c) A block of ice is placed on the slope beside the solid cylinder and both are released at the same time. The block of ice is the same mass as the solid cylinder and slides without friction.

At any given point on the slope, the speed of the block of ice is greater than the speed of the solid cylinder. Outline why, using the answer to (b)(i). [1]

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(d) The solid cylinder is replaced by a hollow cylinder of the same mass and radius. Suggest how this change will affect, if at all, the acceleration in (b)(i). [2]

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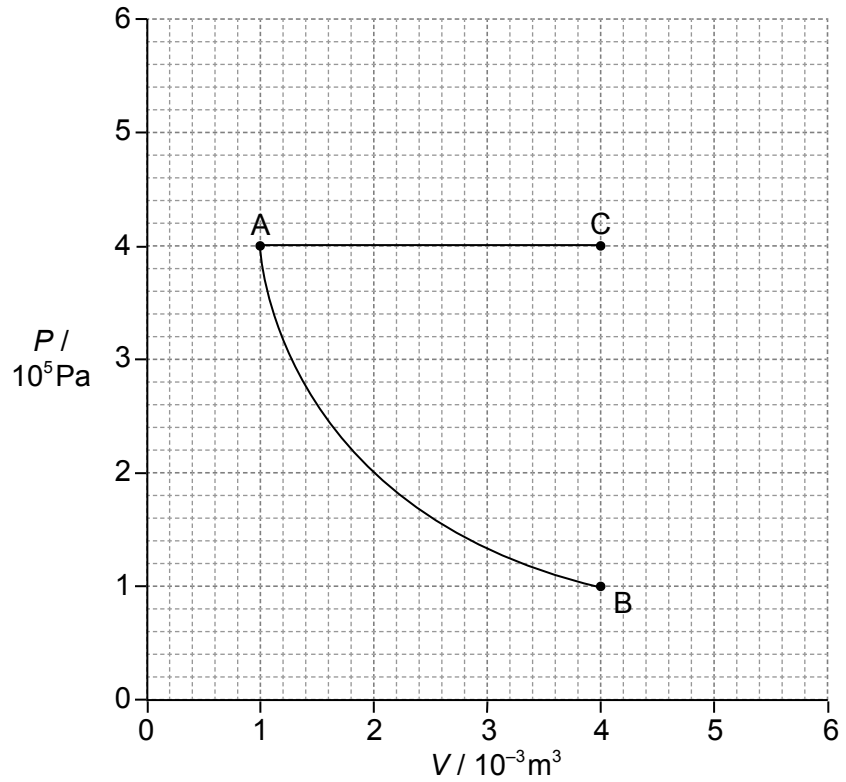
(Option B continues on the following page)

(Option B continued)

8. A fixed mass of an ideal monatomic gas undergoes an isothermal change from A to B as shown.



The temperature at A is 350 K. An identical mass of the same ideal monatomic gas undergoes an isobaric change from A to C.

(a) (i) Calculate the temperature at C. [1]

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(ii) Calculate the change in internal energy for AC. [2]

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(Option B continues on the following page)

(Option B, question 8 continued)

(iii) Determine the energy supplied to the gas during the change AC. [2]

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(iv) On the graph, draw a line to represent an adiabatic expansion from A to a state of volume $4.0 \times 10^{-3}\,m^3$ (point D). [1]

(b) (i) State the change in entropy of a gas for the adiabatic expansion from A to D. [1]

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(ii) Explain, with reference to the concept of disorder, why the entropy of the gas is greater at C than B. [3]

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End of Option B

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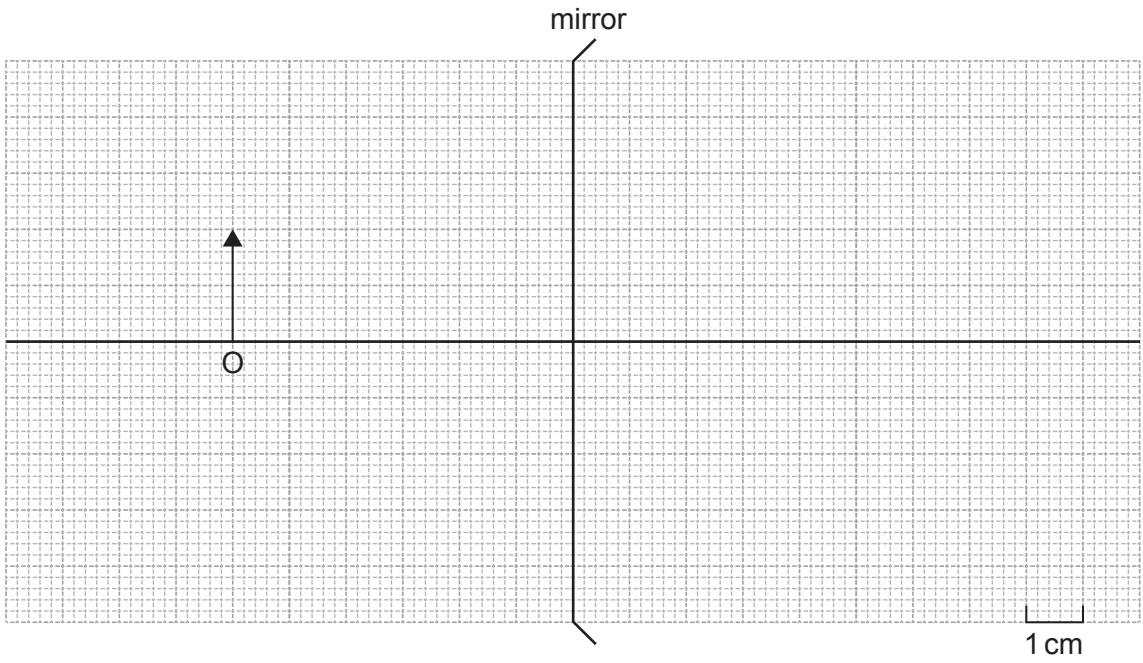
Option C — Imaging

9. The diagram shows a diverging mirror.



Object O has a height of 2.0 cm and is 6.0 cm from the mirror surface. The focal length of the mirror is 4.0 cm and the radius of curvature is 8.0 cm.

(a) Construct a ray diagram for object O. Label the image I. [3]

(b) Estimate the linear magnification of the image. [1]

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(c) Outline the advantage of parabolic mirrors over spherical mirrors. [3]

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(Option C continues on the following page)

(Option C continued)

10. An astronomical telescope is used in normal adjustment. The separation of the lenses in the telescope is 0.84 m. The objective lens has a focal length of 0.82 m.

(a) Calculate the magnification of this telescope. [2]

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(b) Outline why sign convention is necessary in optics. [1]

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(c) A student decides to reverse the positions of the same lenses without changing the separation to form an optical microscope in normal adjustment. The student's near point is 0.25 m from her eye.

(i) Show, using a calculation, that the image formed by the objective lens is about 0.19 m from the eyepiece. [2]

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(ii) Calculate the distance between the objective lens of the microscope and the object. [2]

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(Option C continues on the following page)

(Option C, question 10 continued)

(iii) Determine the overall magnification of the microscope. [2]

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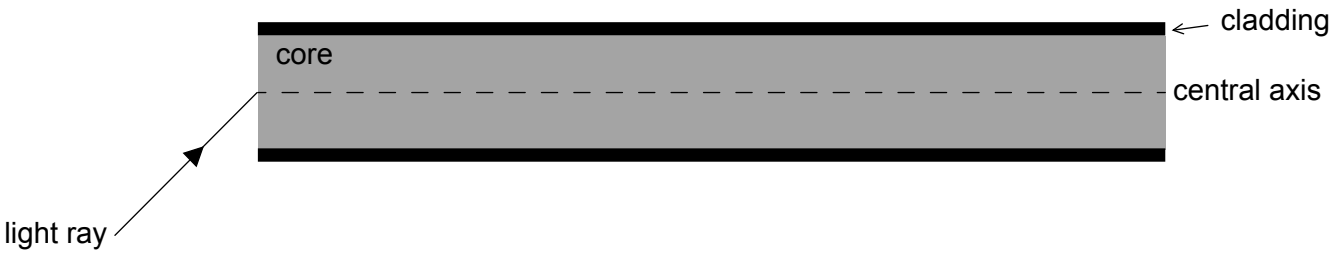
11. A ray of monochromatic light enters a graded-index optic fibre.



(a) Draw the path of the ray as it travels through the graded-index optic fibre. [1]

(b) Explain how the graded-index optic fibre reduces waveguide dispersion. [3]

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End of Option C

Option D — Astrophysics

12. (a) Describe **one** key characteristic of a nebula. [1]

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(b) Beta Centauri is a star in the southern skies with a parallax angle of 8.32×10^{-3} arc-seconds. Calculate, in metres, the distance of this star from Earth. [2]

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(c) Outline why astrophysicists use non-SI units for the measurement of astronomical distance. [1]

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13. Aldebaran is a red giant star with a peak wavelength of 740 nm and a mass of 1.7 solar masses.

(a) Show that the surface temperature of Aldebaran is about 4000 K. [2]

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(Option D continues on the following page)

(Option D, question 13 continued)

(b) The radius of Aldebaran is 3.1×10^{10} m. Determine the luminosity of Aldebaran. [2]

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(c) Outline how the light from Aldebaran gives evidence of its composition. [2]

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(d) Identify the element that is fusing in Aldebaran's core at this stage in its evolution. [1]

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(e) Predict the likely future evolution of Aldebaran. [3]

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(Option D continues on the following page)

(Option D continued)

14. (a) Light reaching Earth from quasar 3C273 has $z = 0.16$.

(i) Outline what is meant by z. [1]

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(ii) Calculate the ratio of the size of the universe when the light was emitted by the quasar to the present size of the universe. [1]

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(iii) Calculate the distance of 3C273 from Earth using $H_o = 68\,\text{km}\,\text{s}^{-1}\,\text{Mpc}^{-1}$. [2]

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(b) Explain how cosmic microwave background (CMB) radiation provides support for the Hot Big Bang model. [2]

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End of Option D

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