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# Physics

## Standard level

### Paper 3

Thursday 29 October 2020 (morning)

Candidate session number

1 hour

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#### 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 – 9
Option C — Imaging	10 – 13
Option D — Astrophysics	14 – 17



### Section A

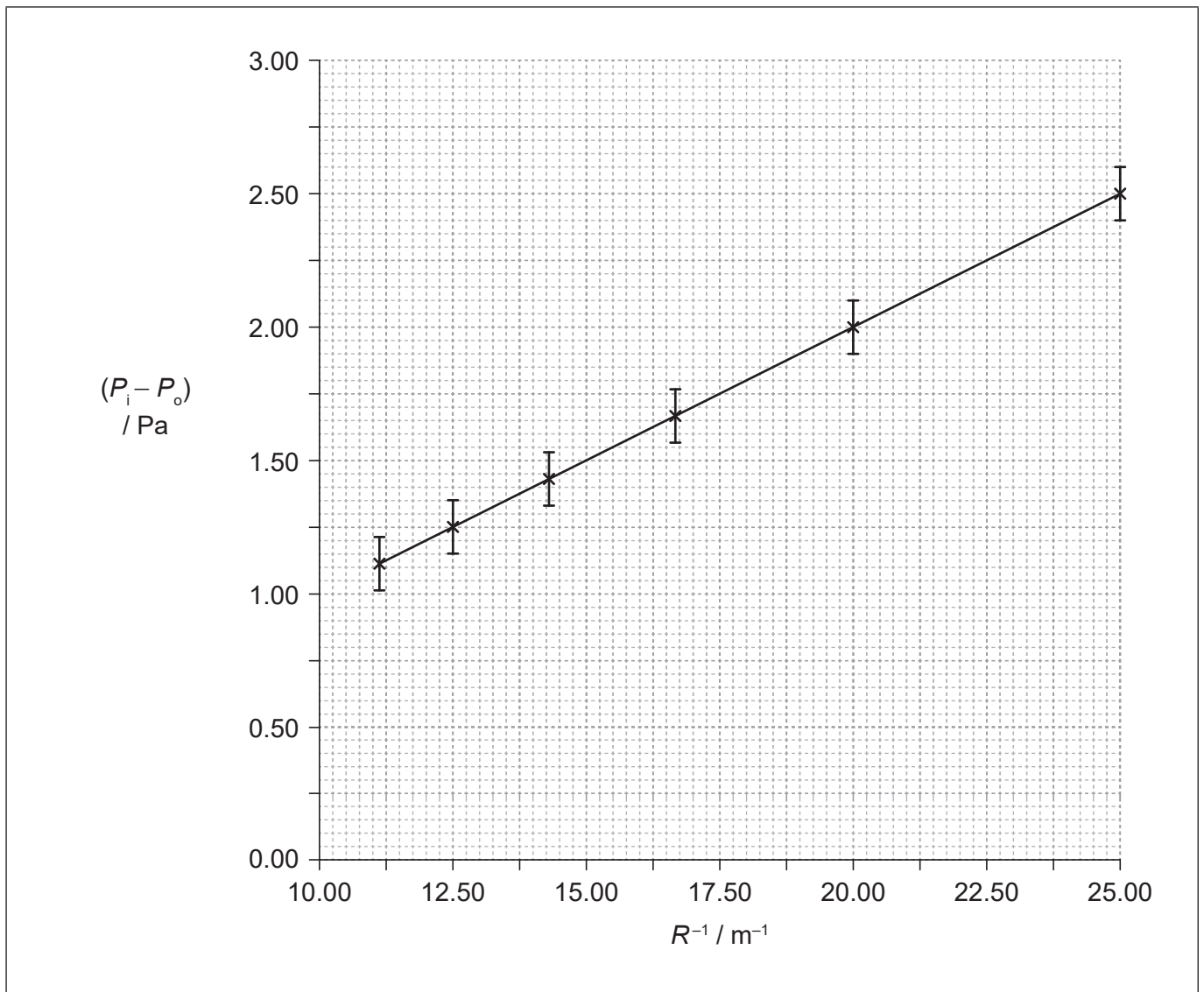
Answer **all** questions. Answers must be written within the answer boxes provided.

1. A spherical soap bubble is made of a thin film of soapy water. The bubble has an internal air pressure  $P_i$  and is formed in air of constant pressure  $P_o$ . The theoretical prediction for the variation of  $(P_i - P_o)$  is given by the equation

$$(P_i - P_o) = \frac{4\gamma}{R}$$

where  $\gamma$  is a constant for the thin film and  $R$  is the radius of the bubble.

Data for  $(P_i - P_o)$  and  $R$  were collected under controlled conditions and plotted as a graph showing the variation of  $(P_i - P_o)$  with  $\frac{1}{R}$ .



(This question continues on the following page)



**(Question 1 continued)**

(a) Suggest whether the data are consistent with the theoretical prediction. [2]

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(b) (i) Show that the value of  $\gamma$  is about 0.03. [2]

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(ii) Identify the fundamental units of  $\gamma$ . [1]

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(iii) In order to find the uncertainty for  $\gamma$ , a maximum gradient line would be drawn. On the graph, sketch the maximum gradient line for the data. [1]

(iv) The percentage uncertainty for  $\gamma$  is 15%. State  $\gamma$ , with its absolute uncertainty. [2]

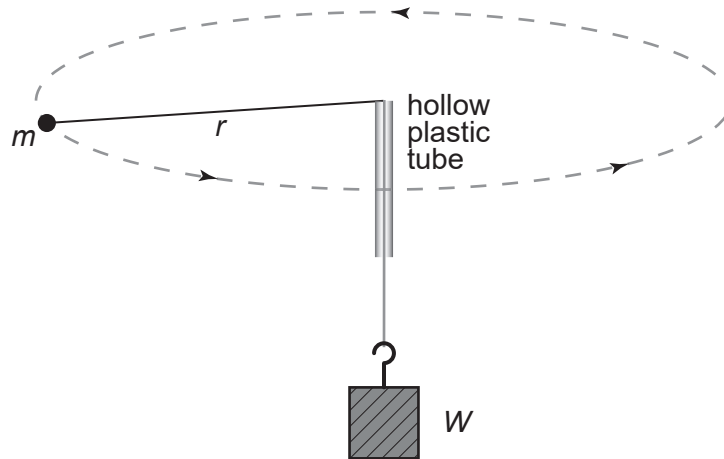
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(v) The expected value of  $\gamma$  is 0.027. Comment on your result. [1]

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2. A student studies the relationship between the centripetal force applied to an object undergoing circular motion and its period  $T$ . The object (mass  $m$ ) is attached by a light inextensible string, through a tube, to a weight  $W$  which hangs vertically. The string is free to move through the tube. A student swings the mass in a horizontal, circular path, adjusting the period  $T$  of the motion until the radius  $r$  is constant. The radius of the circle and the mass of the object are measured and remain constant for the entire experiment.



The student collects the measurements of  $T$  five times, for weight  $W$ . The weight is then doubled ( $2W$ ) and the data collection repeated. Then it is repeated with  $3W$  and  $4W$ . The results are expected to support the relationship

$$W = \frac{4\pi^2 mr}{T^2}$$

- (a) State why the experiment is repeated with different values of  $W$ . [1]

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In reality, there is friction in the system, so in this case  $W$  is less than the total centripetal force in the system. A suitable graph is plotted to determine the value of  $mr$  experimentally. The value of  $mr$  was also calculated directly from the measured values of  $m$  and  $r$ .

- (b) Predict from the equation whether the value of  $mr$  found experimentally will be larger, the same or smaller than the value of  $mr$  calculated directly. [2]

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(This question continues on the following page)



**(Question 2 continued)**

- (c) (i) The measurements of  $T$  were collected five times. Explain how repeated measurements of  $T$  reduced the random error in the final experimental value of  $mr$ . [2]

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- (ii) Outline why repeated measurements of  $T$  would not reduce any systematic error in  $T$ . [1]

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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. (a) Maxwell's equations led to the constancy of the speed of light. Identify what Maxwell's equations describe. [1]

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- (b) State a postulate that is the same for both special relativity and Galilean relativity. [1]

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- (c) Two parallel current-carrying wires have equal currents in the same direction. There is an attractive force between the wires.

- (i) Identify the nature of the attractive force recorded by an observer stationary with respect to the wires. [1]

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- (ii) A second observer moves at the drift velocity of the electron current in the wires. Discuss how this observer accounts for the force between the wires. [3]

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(Option A continues on the following page)

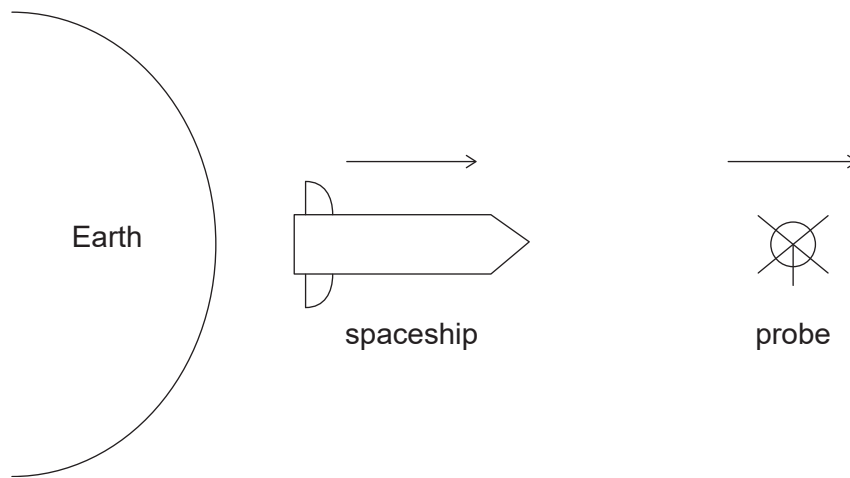


**(Option A continued)**

4. (a) The Lorentz transformations assume that the speed of light is constant. Outline what the Galilean transformations assume. [1]

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- (b) A spaceship is travelling at  $0.80c$ , away from Earth. It launches a probe away from Earth, at  $0.50c$  relative to the spaceship. An observer on the probe measures the length of the probe to be  $8.0\text{m}$ .



- (i) Deduce the length of the probe as measured by an observer in the spaceship. [2]

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- (ii) Explain which of the lengths is the proper length. [2]

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**(Option A continues on the following page)**





(Option A, question 4 continued)

(c) Calculate the speed of the probe in terms of  $c$ , relative to Earth.

[2]

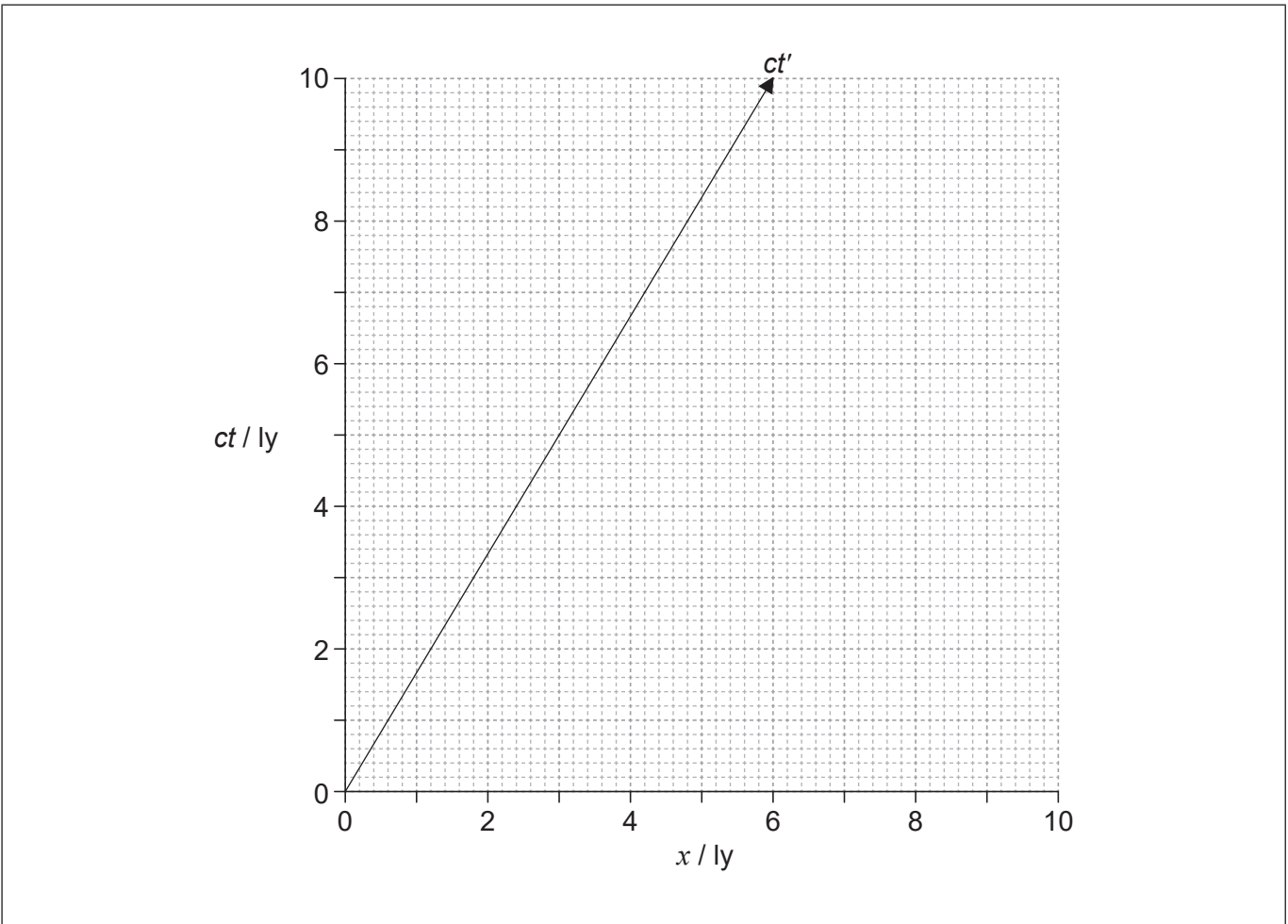
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5. The spacetime diagram is in the reference frame of an observer O on Earth. Observer O and spaceship A are at the origin of the spacetime diagram when time  $t = t' = 0$ . The worldline for spaceship A is shown.



(Option A continues on the following page)



**(Option A, question 5 continued)**

- (a) (i) Calculate in terms of  $c$  the velocity of spaceship A relative to observer O. [1]

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- (ii) Draw the  $x'$  axis for the reference frame of spaceship A. [1]

- (b) Event E is the emission of a flash of light. Observer O sees light from the flash when  $t = 9$  years and calculates that event E is 4 ly away, in the positive  $x$  direction.

- (i) Plot the event E on the spacetime diagram and label it E. [2]

- (ii) Determine the time, according to spaceship A, when light from event E was observed on spaceship A. [3]

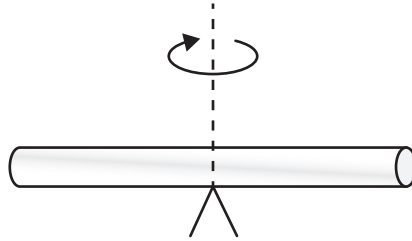
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**End of Option A**



**Option B — Engineering physics**

6. A bar rotates horizontally about its centre, reaching a maximum angular velocity in six complete rotations from rest. The bar has a constant angular acceleration of  $0.110 \text{ rad s}^{-2}$ . The moment of inertia of the bar about the axis of rotation is  $0.0216 \text{ kg m}^2$ .



- (a) Show that the final angular velocity of the bar is about  $3 \text{ rad s}^{-1}$ . [2]

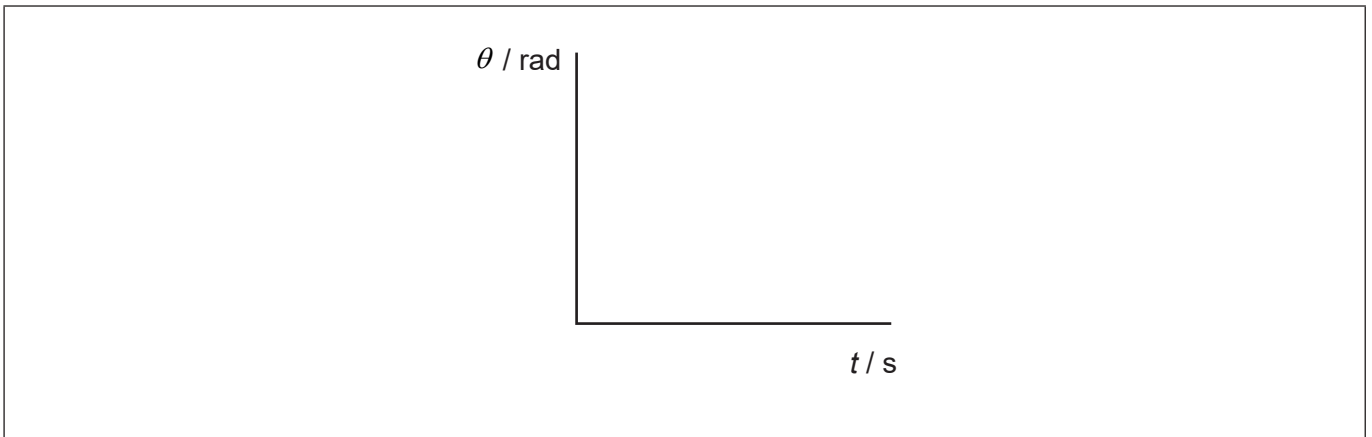
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- (b) Draw the variation with time  $t$  of the angular displacement  $\theta$  of the bar during the acceleration. [1]



- (c) Calculate the torque acting on the bar while it is accelerating. [1]

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(Option B continues on the following page)



**(Option B, question 6 continued)**

- (d) The torque is removed. The bar comes to rest in 30 complete rotations with constant angular deceleration. Determine the time taken for the bar to come to rest. [2]

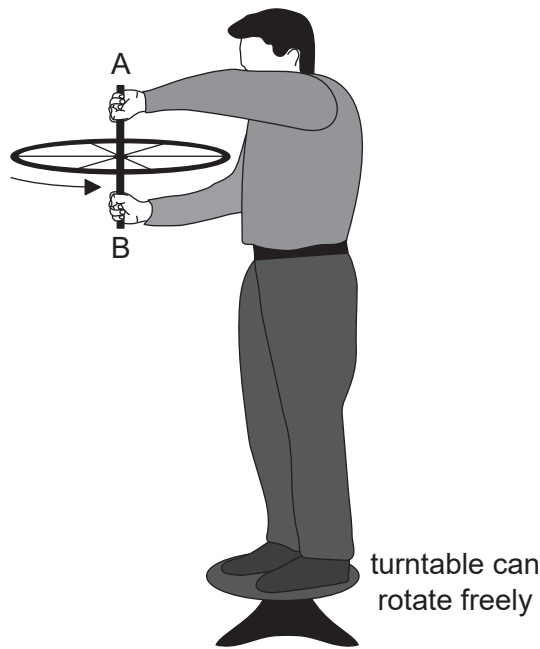
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**(Option B continues on the following page)**

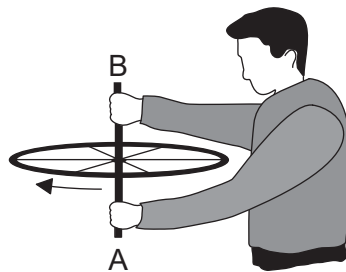


(Option B continued)

7. The first diagram shows a person standing on a turntable which can rotate freely. The person is stationary and holding a bicycle wheel. The wheel rotates anticlockwise when seen from above.



The wheel is flipped, as shown in the second diagram, so that it rotates clockwise when seen from above.



- (a) Explain the direction in which the person-turntable system starts to rotate. [3]

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(Option B continues on the following page)



**(Option B, question 7 continued)**

(b) Explain the changes to the rotational kinetic energy in the person-turntable system. [2]

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8. A solid sphere of radius  $r$  and mass  $m$  is released from rest and rolls down a slope, without slipping. The vertical height of the slope is  $h$ . The moment of inertia  $I$  of this sphere about an axis through its centre is  $\frac{2}{5}mr^2$ .



Show that the linear velocity  $v$  of the sphere as it leaves the slope is  $\sqrt{\frac{10gh}{7}}$ . [3]

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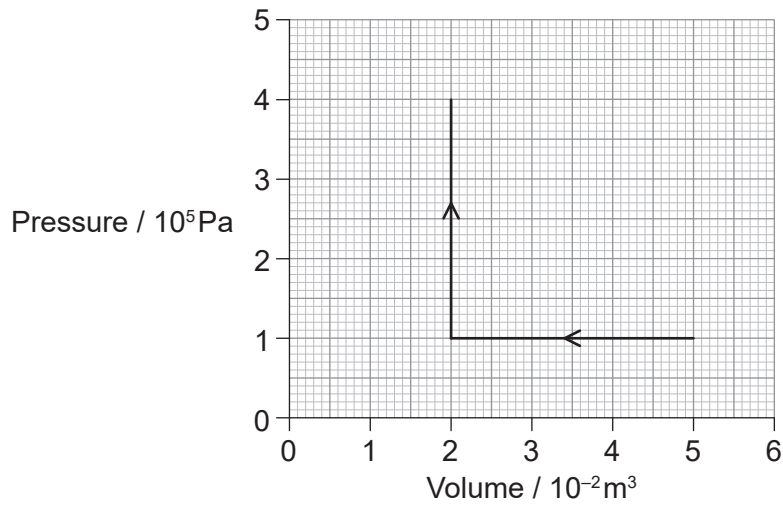
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**(Option B continues on the following page)**



(Option B continued)

9. The diagram represents an ideal, monatomic gas that first undergoes a compression, then an increase in pressure.



- (a) Calculate the work done during the

(i) compression.

[1]

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.....

(ii) increase in pressure.

[1]

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- (b) An adiabatic process then increases the volume of the gas to  $5.0 \times 10^{-2} \text{ m}^3$ .

(i) Calculate the pressure following this process.

[2]

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(Option B continues on the following page)



**(Option B, question 9 continued)**

(ii) Outline how an approximate adiabatic change can be achieved.

[2]

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**End of Option B**



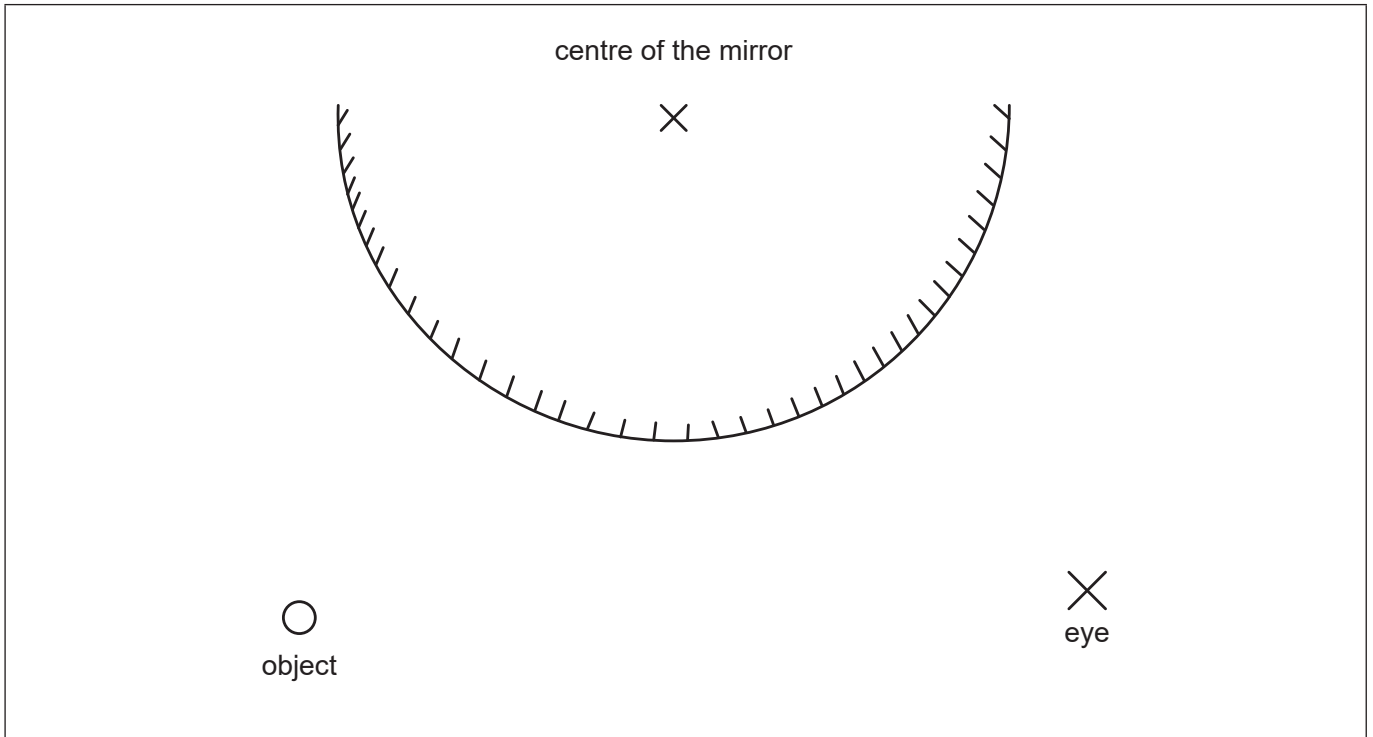
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**Turn over**



**Option C — Imaging**

**10.** The diagram represents a diverging mirror being used to view an object.



- (a) Construct a single ray showing one path of light between the eye, the mirror and the object, to view the object. [2]
- (b) The image observed is virtual. Outline the meaning of virtual image. [1]

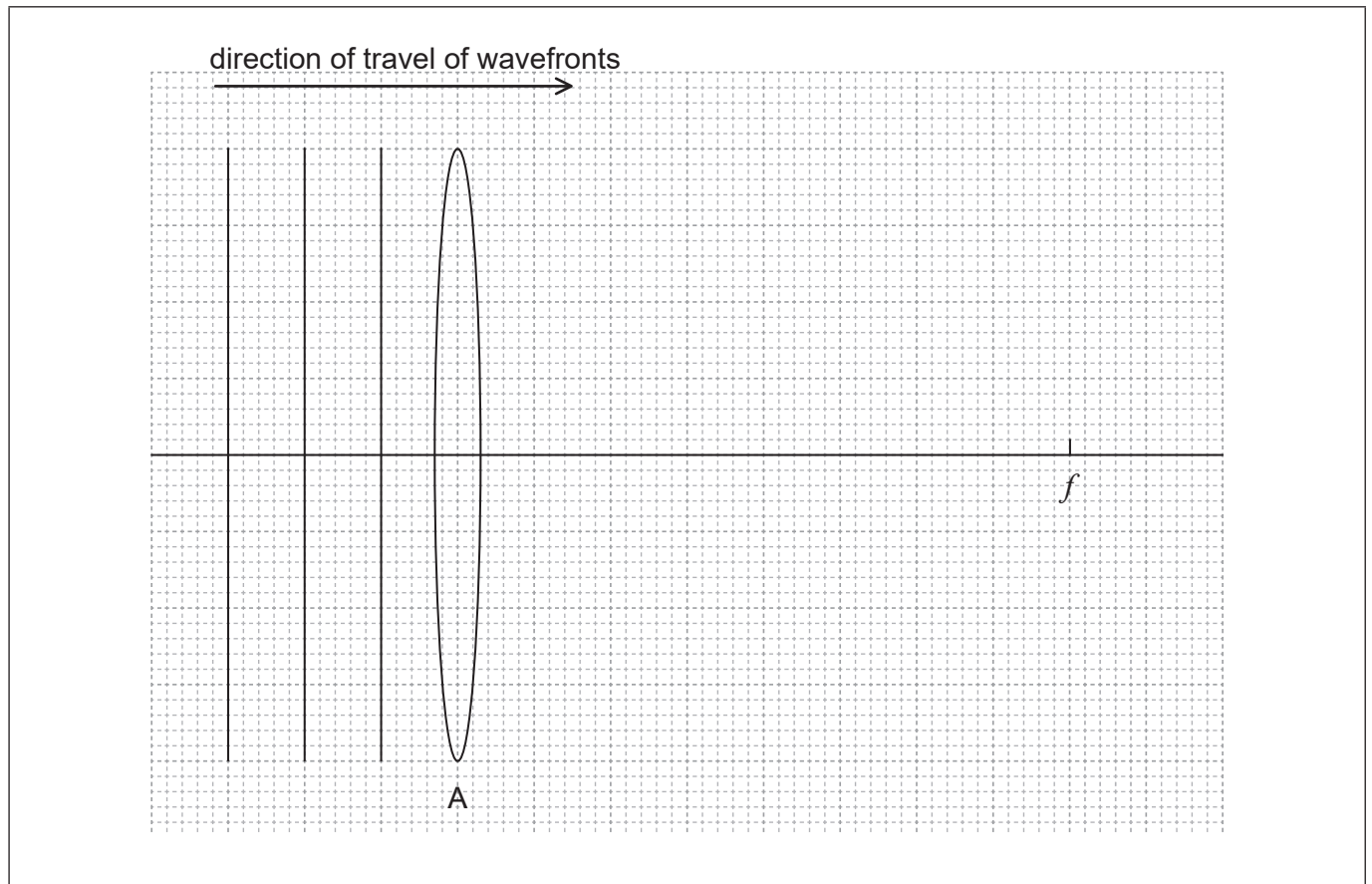
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**(Option C continues on the following page)**

(Option C continued)

11. A beam of monochromatic light from infinity is incident on a converging lens A. The diagram shows three wavefronts of the light and the focal point  $f$  of the lens.



- (a) Draw on the diagram the three wavefronts after they have passed through the lens. [2]
- (b) Lens A has a focal length of 4.00 cm. An object is placed 4.50 cm to the left of A. Show by calculation that a screen should be placed about 0.4 m from A to display a focused image. [2]

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(Option C continues on the following page)



**(Option C, question 11 continued)**

- (c) The screen is removed and the image is used as the object for a second diverging lens B, to form a final image. Lens B has a focal length of 2.00 cm and the final real image is 8.00 cm from the lens. Calculate the distance between lens A and lens B. [3]

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- (d) Calculate the total magnification of the object by the lens combination. [2]

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**(Option C continues on the following page)**

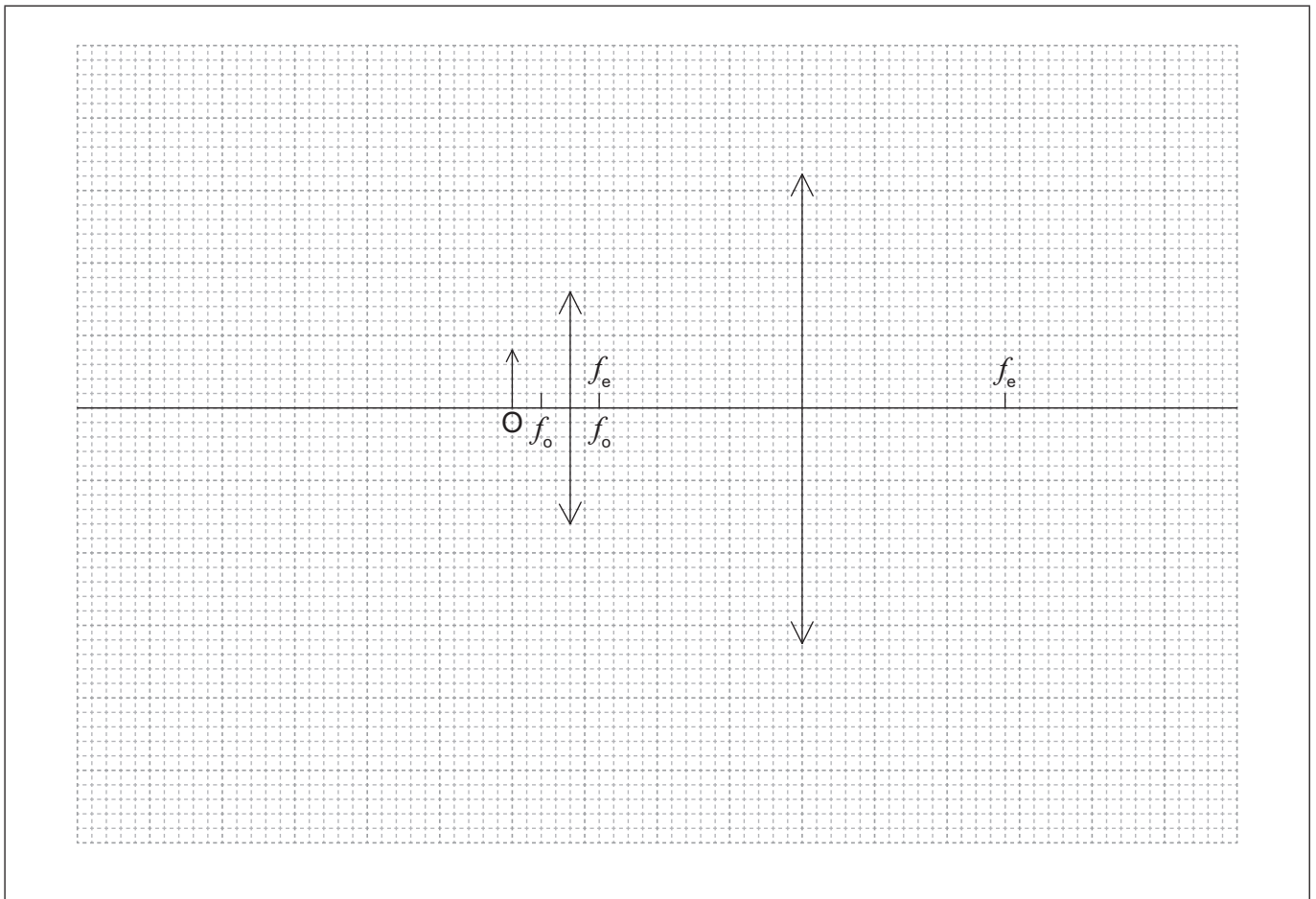


(Option C continued)

12. (a) Outline the meaning of normal adjustment for a compound microscope. [1]

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- (b) Sketch a ray diagram to find the position of the images for both lenses in the compound microscope at normal adjustment. The object is at O and the focal lengths of the objective and eyepiece lenses are shown. [4]



(Option C continues on the following page)



**(Option C continued)**

- 13.** A single pulse of light enters an optic fibre which contains small impurities that scatter the light. Explain the effect of these impurities on the pulse.

[3]

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**End of Option C**



**Option D — Astrophysics**

14. (a) The astronomical unit (AU) and light year (ly) are convenient measures of distance in astrophysics. Define each unit. [2]

AU: .....

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ly: .....

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- (b) An image of a comet is shown.



- (i) Comets develop a tail as they approach the Sun. Identify **one** other characteristic of comets. [1]

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- (ii) Identify **one** object visible in the image that is outside our Solar System. [1]

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(Option D continues on the following page)



**(Option D continued)**

15. (a) Show that the apparent brightness  $b \propto \frac{AT^4}{d^2}$ , where  $d$  is the distance of the object from Earth,  $T$  is the surface temperature of the object and  $A$  is the surface area of the object. [1]

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- (b) Two of the brightest objects in the night sky seen from Earth are the planet Venus and the star Sirius. Explain why the equation  $b \propto \frac{AT^4}{d^2}$  is applicable to Sirius but not to Venus. [2]

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16. (a) The light from a distant galaxy shows that  $z = 0.11$ .

Calculate the ratio  $\frac{\text{size of the universe when the light was emitted}}{\text{size of the universe at present}}$ . [1]

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- (b) Outline how Hubble's law is related to  $z$ . [1]

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**(Option D continues on the following page)**



(Option D continued)

17. The data for the star Eta Aquilae A are given in the table.

	Value
Mean luminosity	$2630 L_{\odot}$
Mass	$5.70 M_{\odot}$
Parallax angle	$2.36 \times 10^{-3}$ arcsec
Apparent brightness	$7.20 \times 10^{-10} \text{ W m}^{-2}$

$L_{\odot}$  is the luminosity of the Sun and  $M_{\odot}$  is the mass of the Sun.

(a) Show by calculation that Eta Aquilae A is not on the main sequence. [2]

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(b) Estimate, in pc, the distance to Eta Aquilae A

(i) using the parallax angle in the table. [1]

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(ii) using the luminosity in the table, given that  $L_{\odot} = 3.83 \times 10^{26} \text{ W}$ . [3]

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(Option D continues on the following page)





**(Option D, question 17 continued)**

(c) Suggest why your answers to (b)(i) and (b)(ii) are different. [2]

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(d) Eta Aquilae A is a Cepheid variable. Explain why the brightness of Eta Aquilae A varies. [3]

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**End of Option D**

**References:**

**Q2.** © International Baccalaureate Organization 2020.

**Q7.** © International Baccalaureate Organization 2020.

**Q14.** Comet P/Halley as taken March 8, 1986 by W. Liller, Easter Island, part of the International Halley Watch (IHW) Large Scale Phenomena Network.

