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91170



Draw a cross through the box (☒) if you have NOT written in this booklet

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Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 2 Physics 2025

91170 Demonstrate understanding of waves

Credits: Four

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of waves.	Demonstrate in-depth understanding of waves.	Demonstrate comprehensive understanding of waves.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

Make sure that you have Resource Sheet L2-PHYSR.

Show ALL working.

In your answers use clear numerical working, words, and/or diagrams as required.

Numerical answers should be given with an appropriate SI unit.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–16 in the correct order and that none of these pages is blank.

Do not write in the margins (✂/✂/✂). This area will be cut off when the booklet is marked.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Excellence

TOTAL 24

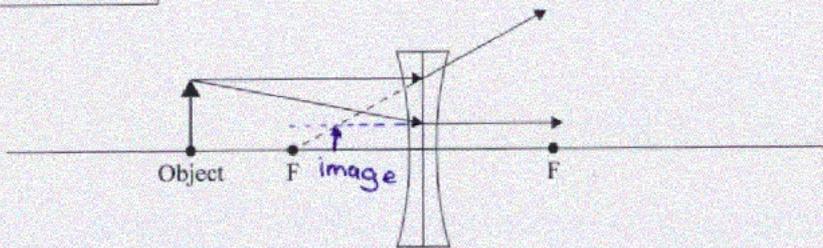
QUESTION ONE: LENSES

Data projectors in classrooms use a concave lens as part of their projection system.

One such projector has an object which is 15 cm from a concave lens with focal length 10 cm.

- (a) Draw and label the image in the diagram below.

Diagram is
NOT to scale



Source: <https://sitech.co.nz/products/projectors-screens/data-projectors/epson-eb-w06-data-projector>

If you
need to
redraw your
response,
use the
diagram on
page 11.

- (b) (i) Calculate the magnification of the image.

$$\frac{1}{-10} = \frac{1}{15} + \frac{1}{d_i}$$

$$\frac{1}{d_i} = -\frac{1}{6} \quad d_i = -6$$

$$m = \frac{16}{15} = -0.4$$

- (ii) Fully describe the nature of the image formed.

The image formed is
virtual, upright and diminished.

- (c) In another projector, a convex lens is used, and a real image twice as big as the object is formed.

Complete a ray diagram on the grid below to show how the real image that is twice as big as the object is formed.

You must show any calculations you used to decide where to place the object.

Make the object 6 squares tall:



$$\frac{1}{4} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$m = 2$$

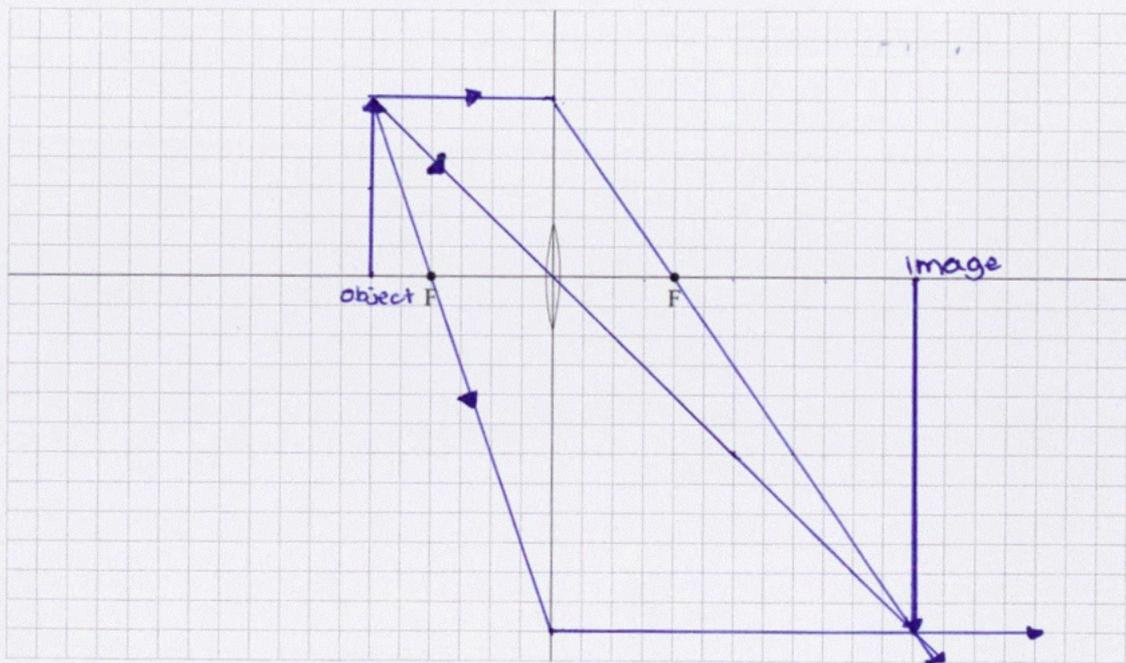
$$\frac{d_i}{d_o} = 2$$

$$d_i = 2d_o$$

$$\frac{1}{4} = \frac{1}{d_o} + \frac{1}{2d_o}$$

$$\frac{1}{4} = \frac{3}{2d_o}$$

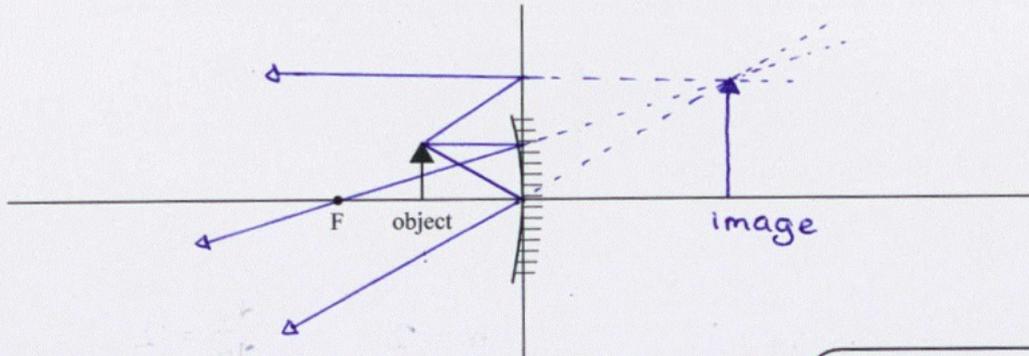
$$d_o = 6$$



If you need to redraw your response, use the diagram on page 11.

(d) An ultra-short-throw projector shortens the projection distance, and still produces high-quality images by using a concave mirror that reflects the light and focuses on the screen.

(i) Complete the ray diagram below to find and draw the image.



If you need to redraw your response, use the diagram on page 12.

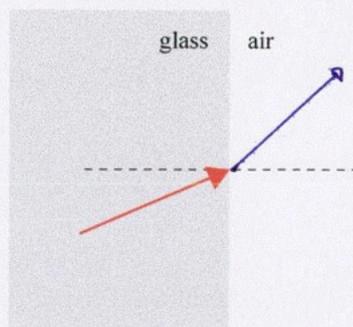
(ii) Describe the nature of the image formed by the concave mirror.

The image formed is upright, enlarged and virtual.

QUESTION TWO: REFRACTION

A double-glazed window has two glass panes with a refractive index of 1.5, separated by an air gap. Maiti notices that a red laser shone through the window does not travel straight through.

- (a) On the diagram below, show the path of the ray of light as it crosses from one glass pane to the air.



Source: <https://hestiadc.com/windows-101-window-frame-materials-and-glass-options/>

If you need to redraw your response, use the diagram on page 12.

- (b) Explain what a refractive index of 1.5 means, in terms of the speed of light in the glass.

The glass has a refractive index of 1.5 so light travels $\frac{2}{3}$ as fast in glass than in air, so will travel at $2 \times 10^8 \text{ ms}^{-1}$. $\frac{n_1}{n_2} = \frac{v_2}{v_1}$
 Glass is more optically dense than air so it has a higher refractive index and so light travels slower in glass than air.

- (c) Red laser with wavelength 6.50×10^{-7} m enters a **different** window at an incident angle of 30° . The wavelength of the red light in the glass is 4.64×10^{-7} m.

Calculate the angle of refraction as the red laser passes from air ($n = 1.0$) into the glass.

$$\frac{n_1}{n_2} = \frac{\lambda_2}{\lambda_1} \quad n_1 = \frac{6.5 \times 10^{-7}}{4.64 \times 10^{-7}}$$

$$n_1 = 1.40$$

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

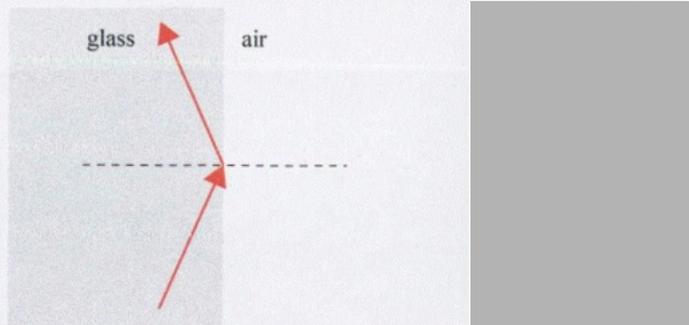
$$1 \sin 30^\circ = 1.4 \sin \theta_2$$

$$\sin \theta_2 = 0.357$$

$$\theta_2 = 20.92^\circ$$

$$21^\circ$$

- (d) Matiu notices that if he keeps increasing the angle, the ray of light bounces off the inner surface of the glass, as shown in the diagram below, and none enters the air.



Source: https://en.m.wikipedia.org/wiki/File:TIR_in_PMMA.jpg

- (i) Name the phenomenon that is occurring.

total internal reflection

- (ii) Describe the conditions needed for this phenomenon to occur.

Calculations are not needed.

For total internal reflection to occur, light must hit a boundary with a less optically dense medium, and it must hit ~~in~~ the boundary at an angle ~~greater~~ of incidence greater than the critical angle, which is the angle of incidence that results in an angle of refraction of 90° . If this happens, then no light will be refraction^{ed} out of the medium, and all of the light will be reflected inside it.

QUESTION THREE: WAVES

Wireless internet connections (Wi-Fi) work by sending information as electromagnetic waves through the air.



Source: <https://www.linkedin.com/pulse/how-choose-right-ai-ml-use-cases-obtain-benefits-approach-dharra>

- (a) What type of wave is an electromagnetic wave?

a transverse wave.

- (b) Wi-Fi interference can be an issue in a populated school environment. This occurs when two or more Wi-Fi access points are using the same channel or frequency, causing interference and reducing the reliability of the Wi-Fi.

Explain how having two Wi-Fi access points emitting waves of the same frequency can cause both spots of strong Wi-Fi signal and spots of weak Wi-Fi signal.

When two Wi-Fi access points are emitting the same frequency, the waves will spread out and interfere with each other. ~~Some spots~~ Each ^{wave will} ~~location~~ need to travel a different distance to reach a location. When waves from both Wi-Fi access points arrive in phase, and their path difference, the difference in distance travelled, is a product of a whole wavelength, then the waves will constructively interfere, and the amplitudes add together to create a

strong signal. When the waves arrive 180° out of phase and path difference $= (n - \frac{1}{2})\lambda$, then they will destructively interfere and cancel out, creating a weak or no signal. This means there will be both spots of strong and weak wifi.

- (c) Internet satellites orbit the Earth at a height of 550 km. The wavelength of the radio wave is 0.025 m.



Source: <https://researchoutreach.org/articles/satellite-internet-technology-double-edged-sword/>

How many radio waves reach the Earth in 2 hours?

$$v = 3 \times 10^8 \text{ m s}^{-1} \quad \lambda = 0.025 \text{ m}$$

$$v = \lambda f$$

$$3 \times 10^8 = 0.025 \times f$$

$$f = 1.2 \times 10^{10} \text{ Hz}$$

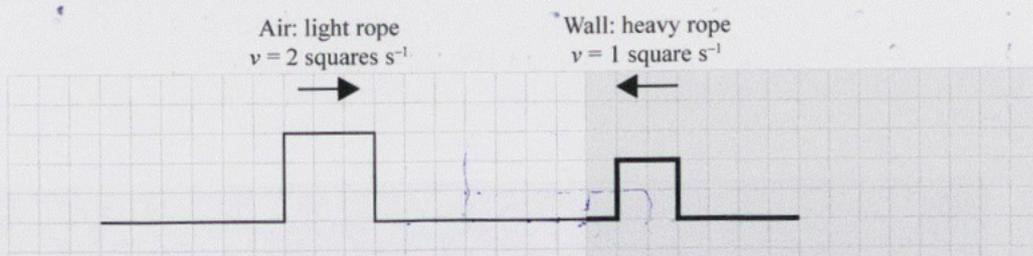
$$1.2 \times 10^{10} \times 7200 \text{ s} = 8.64 \times 10^{13}$$

8.64×10^{13} full wavelengths reach earth in a 2 hour time period.

Question Three continues on the following page.

- (d) When Wi-Fi signals pass through walls, they slow down. The boundary between wall and air can be modelled by ropes of different densities joined together.

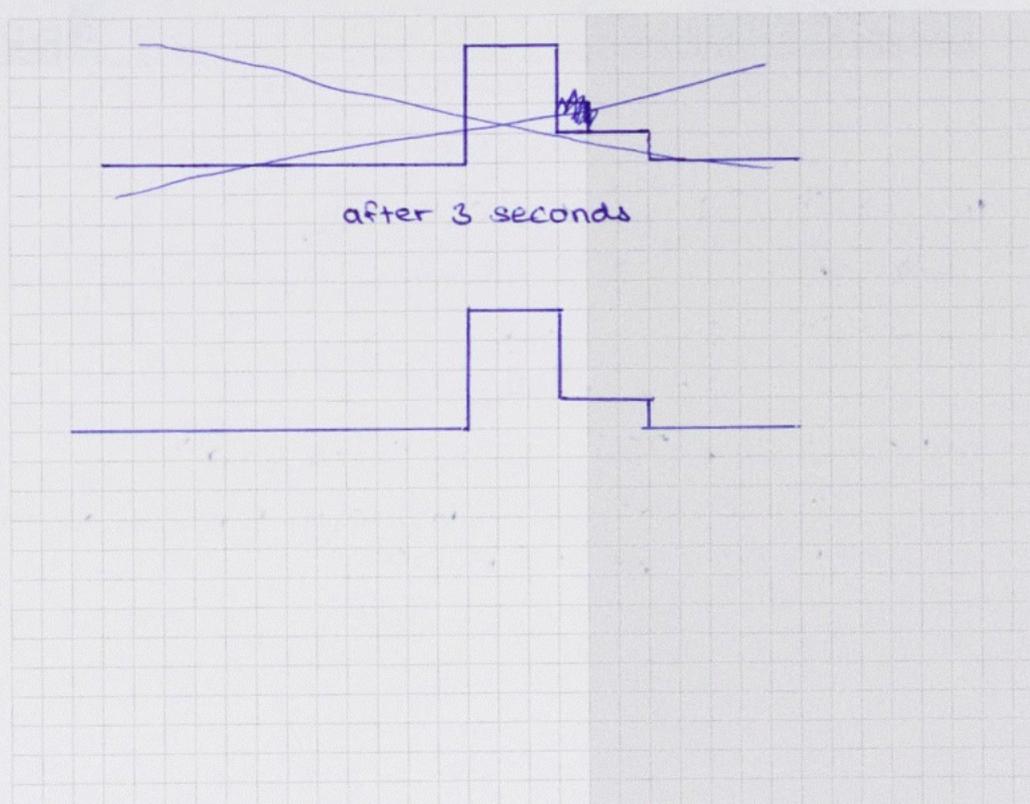
The diagram below models two pulses from two Wi-Fi points travelling towards each other. The speed in air is 2 squares per second, and the speed in the wall is 1 square per second.



- (i) Describe how the frequency of the Wi-Fi signal changes as it moves from air to wall.

When the Wi-Fi signal moves from air to wall it slows down, but the frequency stays the same as the same number of wavelengths pass in a second.

- (ii) Assuming any pulse is half the height of the original after it transmits and reflects with the boundary, draw the result of the two pulses' interactions after 3 seconds.



If you need to redraw your response,
use the diagram on page 13.

Excellence

Subject: L2 Physics

Standard: 91170

Total score: 24

Q	Grade score	Marker commentary
One	E8	All parts correct and both steps in the calculation for (b) using $f = -10$ cm. Both ray diagrams well drawn with arrows on rays, as well as the calculation in (c), and all image properties stated and correct in (d).
Two	E8	Apart from using optical density instead of refractive index in (d) (they are not the same) everything else, including calculations and a thorough understanding of what a refractive index of 1.5 means for the speed of light in glass, was well done.
Three	E8	Answered completely: transverse wave in (a), fully discusses interference in (b) and links signal strength to path difference. Correct frequency and number of waves calculated in (c). States that frequency remains unchanged in (d) and drew the correct pulse diagram after 3 seconds.