SUPERVISOR'S USE ONLY

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

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.

Achievement

TOTAL 12

QUESTION ONE: LENSES

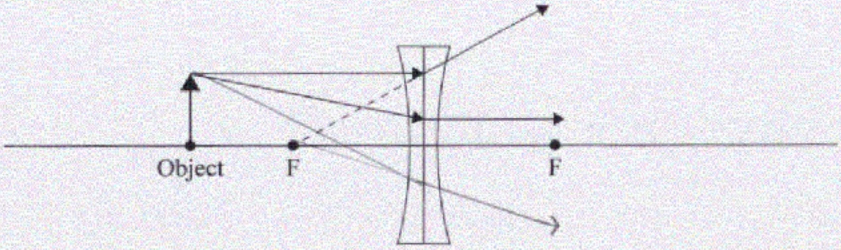
Data projectors in classrooms use a concave lens as part of their projection system.

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

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

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

Diagram is NOT to scale



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

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

$M = \frac{d_i}{d_o} = \frac{h_i}{h_o}$ focal length = 0.10m
$d_o = 0.15$m

we must find d_i

$\frac{1}{f} = \frac{1}{d_i}$ $\frac{1}{0.10} = \frac{1}{d_i}$ ~~1/~~ $10 = \frac{1}{d_i}$ $d_i \times 10 = 1$

$d_i = 1 \div 10$ $d_i = 0.10$m ✗

wrong equation! $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$ $\frac{1}{0.10} = \frac{1}{0.15} + \frac{1}{d_i}$ $10 = 6.67 + \frac{1}{d_i}$

$10 \times d_i = 6.67 \times d_i + 1$ $10d_i = 6.67d_i + 1$

$10d_i - 6.67d_i = 1$ $3.33d_i = 1$ $d_i = 1 \div 3.33$

$d_i = 0.3$m   Magnification $= \frac{d_i}{d_o} : \frac{0.3}{0.15} = 2$

∴ the magnification of the image is 2

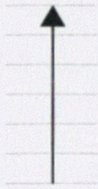
(ii) Fully describe the nature of the image formed.

No image is formed due to the light (represented through waves) being too scattered to intersect and result in an image.

(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.

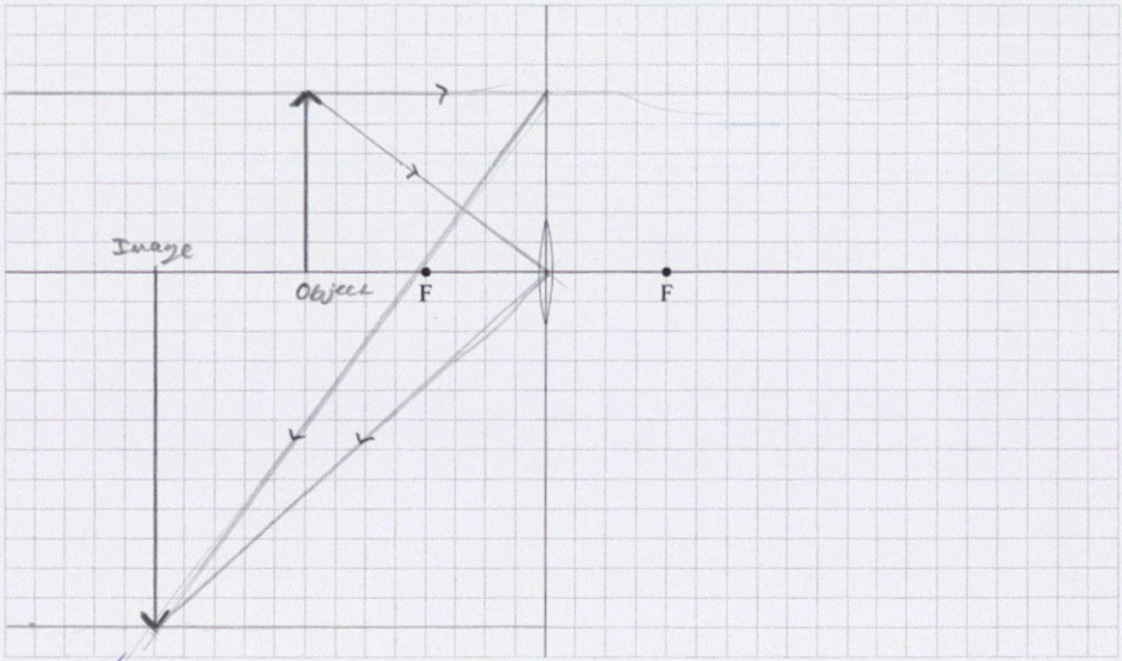
You must show any calculations you used to decide where to place the object.

Make the object 6 squares tall: 

1 square = 1 $m = \frac{d_i}{d_o} = \frac{h_i}{h_o}$ ~~find d_o~~ $m = 2$ because it's double

$h_o = 6$ $2 = \frac{h_i}{h_o = 6}$ $h_i = 12$ $h_o = 6$ $m = 2$

Real, ← this side



Real ✓

twice as large ✓

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

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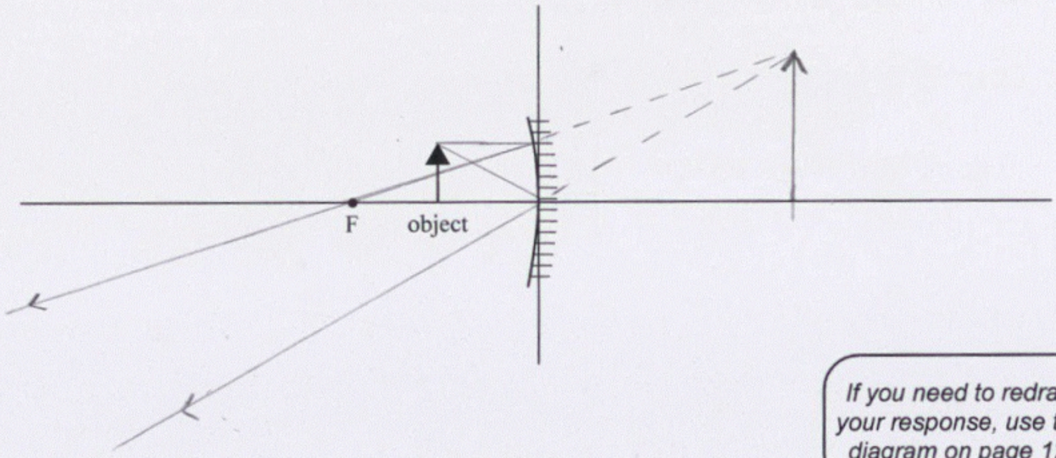
(d) An ultra-short-throw projector shortens the projection distance, and still produces high-quality images by using a concave mirror that reflects the light and focuses on the screen.

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

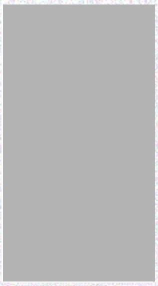


If you need to redraw your response, use the diagram on page 12.

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

The image formed by the mirror is: Virtual, magnified and upright.

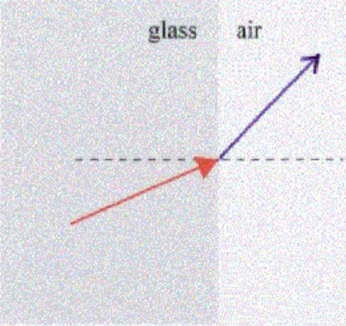
QUESTION TWO: REFRACTION



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

A double-glazed window has two glass panes with a refractive index of 1.5, separated by an air gap. Matiu 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.



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.

Refractive index refers to how much it slows and adjusts a ~~move~~ wave moving through a medium. When moving through air, light (example) light is unencumbered because air has a refractive index of 1, whereas glass is a denser medium, and ∴ has a refractive index of 1.5, which makes the light (waves) slower and travel away from the normal (dotted line).

(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.

Red laser $\lambda = 6.5 \times 10^{-7}$ m angle = 30° λ in glass = 4.64×10^{-7} M

$\frac{\lambda_2}{\lambda_1} = \frac{n_1}{n_2}$ $\frac{4.64 \times 10^{-7}}{6.5 \times 10^{-7}} = \frac{1}{n_2}$ $0.714 = \frac{1}{n_2}$

$0.714 n_2 = 1$ $n_2 = 1 \div 0.714$ $n_2 = 1.401$ (3dp)

we can now calculate angle of refraction.

$n_1 = 1$ (air) $n_2 = 1.401$ (glass) $\sin \theta_1 = 30°$ (incident)

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

$1 \times \sin 30° = 1.401 \times \sin \theta_2$

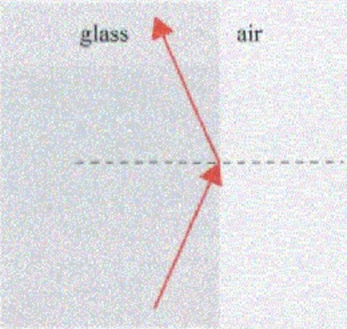
$\sin \theta_2 = \frac{1 \times \sin 30°}{1.401}$

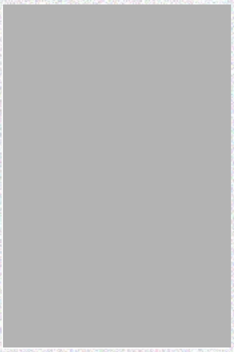
$\sin \theta_2 = 0.357$ (3dp)

$\sin \theta_2 = \sin^{-1} 0.357$

∴ angle of refraction is 20.909° (3dp)

(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.

diffraction

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

Calculations are not needed.

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

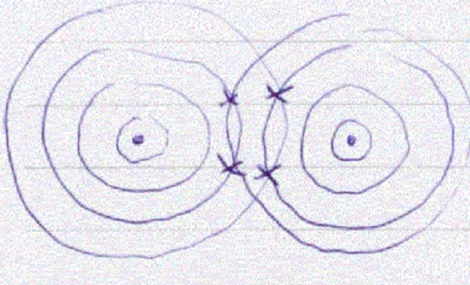
(a) What type of wave is an electromagnetic wave?

transverse

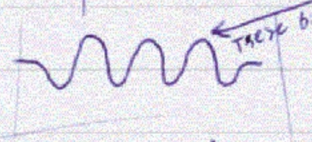
(b) Wi-Fi interference can be an issue in a populated school environment. This occurs when two or more Wi-Fi access points are using the same channel or frequency, causing interference and reducing the reliability of the Wi-Fi.

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.

This is due to the waves interacting with each other in a cool way when they make contact.



If we take this poorly drawn diagram as an example, the lines represent the peaks of their waves, when



these peaks come into contact, they essentially add together to create one larger wave, which is where the strong wifi comes from. As for the weaker sections? Similar but different.

Rather then peak on peak, weak spots occur when troth meets peak, and they add together, but less + more = nothing, resulting in a weak spot of wi-fi.

(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/

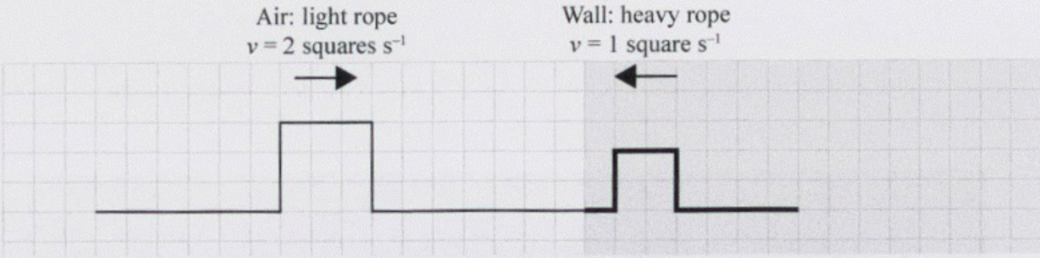
How many radio waves reach the Earth in 2 hours?

height = 550 km λ = 0.025 m

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.

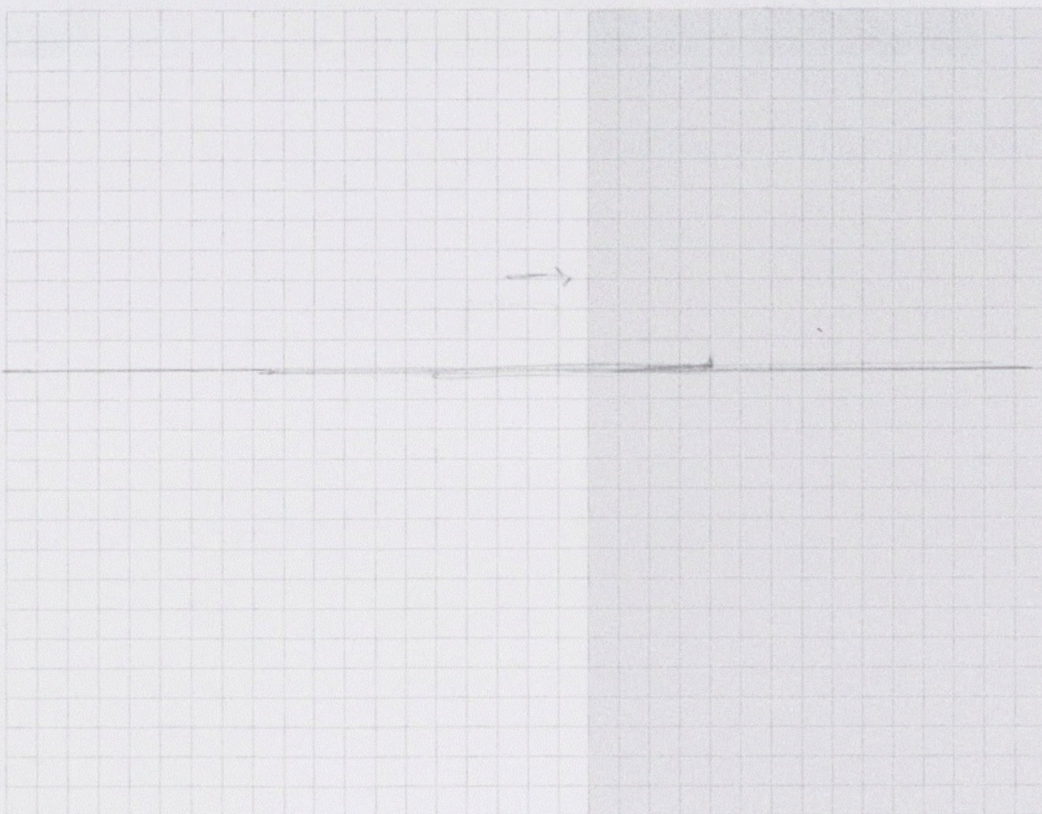
The diagram below models two pulses from two Wi-Fi points travelling towards each other. The speed in air is 2 squares per second, and the speed in the wall is 1 square per second.



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

Speed lessens when travelling through a denser medium. $V = f\lambda$ $f = \frac{v}{\lambda}$ according to this equation, ~~less speed means less frequency~~, meaning frequency will decrease when entering the wall (heavy rope)

(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.

Achievement

Subject: L2 Physics

Standard: 91170

Total score: 12

Q	Grade score	Marker commentary
One	A4	The correct image located for (a), incorrect *f* (should be –10 cm) giving d_i = 30 cm but image is incorrect for (b). Wrongly drawn diagram for (c) but states h_i = 12. Part (d) correct diagram and description.
Two	M5	Refracted ray correctly drawn for (a). In (b) slower speed but no qualitative answer. Full calculation with correct angle for (c). Part (d) names diffraction incorrectly and no conditions described.
Three	A3	Transverse wave correct for (a). Discusses interference in (b) with diagrams and links to signal strength but not path difference. Part (c) no real attempt. States that frequency changes in (d) and no diagram drawn.