WAVES: TOTAL INTERNAL REFLECTION QUESTIONS

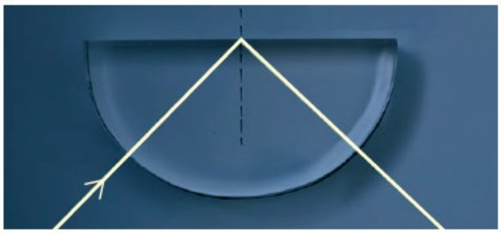
BEHAVIOUR OF LIGHT (2022;1)

Helen is investigating wave behaviour in the school physics laboratory.
Refractive index of glass = 1.52
Refractive index of air = 1.00

(c) Helen now uses a semi-circular block and alters the angle that the light hits the straight side, and she observes the following phenomenon:

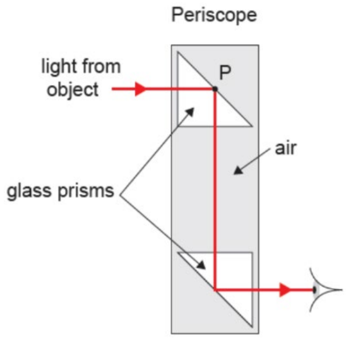
(i) Identify the physics phenomenon occurring at the straight boundary.

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



TRIP TO THE COAST (2021;1)

Fred and his younger sister Maiy walk along the harbour wall path to look at the view from the end. The sea wall is too high for Mary to see over, so Fred gives Mary a periscope to look over the wall. The periscope uses two glass prisms.

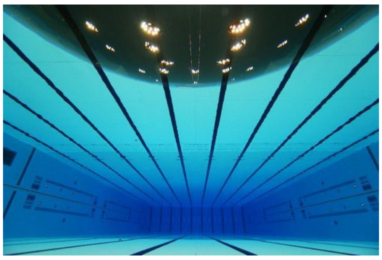


Refractive index of air: 1.00
Refractive index of glass: 1.52

(a) Name the physics phenomenon that is occurring at the glass/ air boundary at point P in the above diagram.

(b) Calculate the critical angle required for this phenomenon to take place in the periscope.

THE BOTTOM OF THE POOL (2020;2)



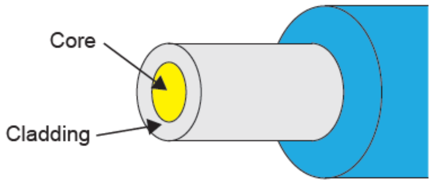
(d) Mia jumps into the deep end and looks up and sees the bottom of the pool reflected above her, as show.
Refractive index of air = 1.00.
Refractive index of water = 1.33

(i) Identify the phenomenon that is taking place in the photo.

(ii) Write a comprehensive explanation of how this phenomenon occurs. Include the conditions required, and a calculation of the critical angle.

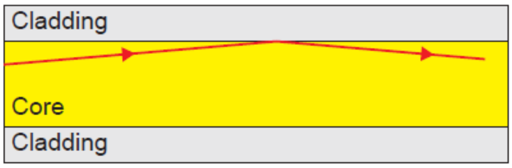
FIBRE OPTIC CABLES (2019;2)

Fibre optic networks are being installed throughout New Zealand to increase communication effectiveness and efficiency. An optical fibre consists of a core and cladding, as shown below. The initial stage requires a beam of infra-red waves to be sent into the fibre optic cable so it can be transmitted along great distances.



The diagram shows infra-red waves travelling from the air into the core:

As the beam moves through the optical fibre, it is continually rebounding off the walls of the core, as shown below. For this to occur, the cladding must have a lower refractive index than the core.



(c) Name the phenomenon that allows this process and give a comprehensive explanation why it is important that the cladding has a lower refractive index than the core.

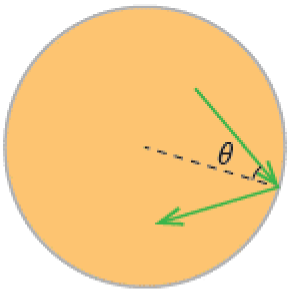
(d) The infra-red waves have a frequency of 3.53×10^{14} Hz.
The speed of light in air = 3.00×10^{8} m s^{-1}
The refractive index of the core = 1.45
By first determining the wavelength of the incident ray in air, calculate the wavelength of the ray once it has entered the core.

LASER IN THE JUICE (2018;2)

Sophie shines a green laser beam from air into a glass of juice. When she does, she notices that the light refracts.

v_{light} in air = 3.00×10^{8} m s^{-1}
n_{air} = 1.00
n_{juice} = 1.34

(c) When the light hits the side of the glass, as shown on the right, the rays "bounce" back inside.

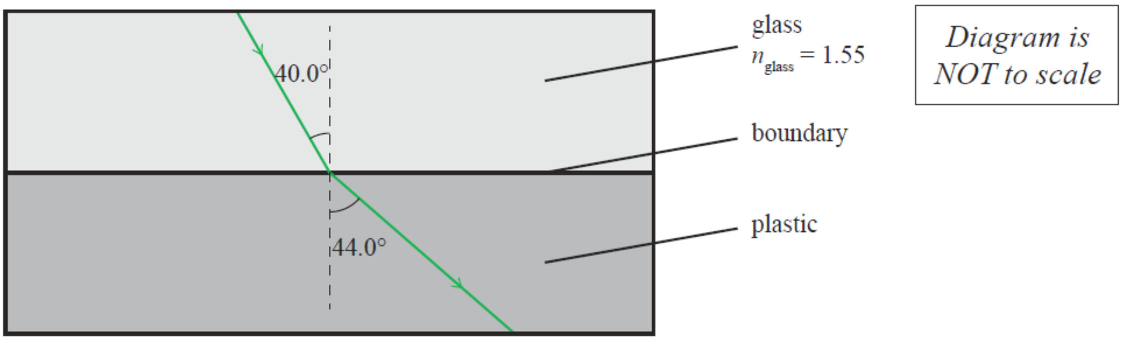


(i) Under what condition will the ray "bounce back", as shown in the diagram?

(ii) Calculate the minimum angle at which the light has to hit the side of the glass for this effect to occur.

Refraction and lenses (2017;2)

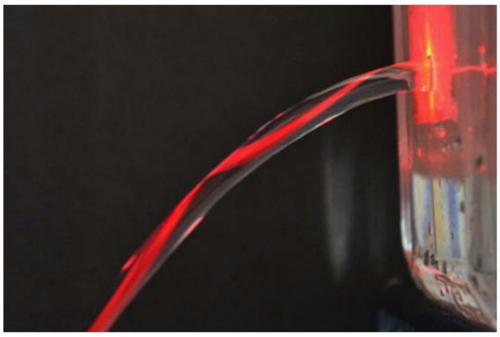
Sarah found two pairs of old reading glasses in her grandmother's drawer. One pair was quite heavy, made up of glass lenses and the other pair was quite light, made up of plastic lenses. Sarah has learned from her physics class that glass and plastic have different refractive indexes. To investigate further, she places a transparent glass and a transparent plastic rectangular block together and shines a green laser beam, as shown below.



(b) If the angle of incidence in glass becomes greater than the critical angle, then the light is totally internally reflected, and no refraction takes place. Calculate the critical angle for the glass-plastic boundary to 3 significant figures.

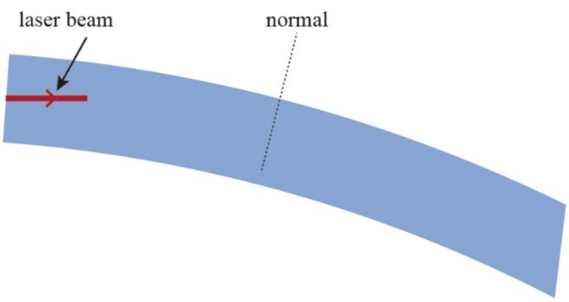
Washing the car (2016;3)

Ana experiments with a red laser, a perspex bottle, and a stream of water, to create total internal reflection.



(c) State two conditions necessary for total internal reflection to occur.

(d) (i) Complete the diagram to show the path of the laser beam in the stream of water. On your diagram, mark the angle of incidence. The normal has been drawn for you.



(ii) If the exact critical angle for red light is 48.70°, calculate the refractive index of water for red light, to 3 decimal places.

At the Beach (2014;2)

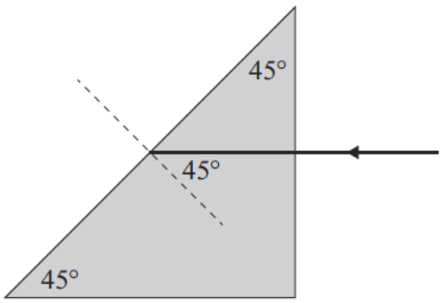
Moana is swimming under the water. She can see a fish, and she can also see an image of the fish caused by light reflecting at the water/ air interface.

(a) State the full name of the process by which Moana can see the image of the fish reflecting at the water/ air interface. Draw one ray on the above diagram to show this process.

(b) The critical angle at the water/ air interface is 47°. The refractive index of air is 1.0. Calculate the refractive index of the water.

Frankie goes to the optician (2013;2)

(d) The optician looks at the inside of Frankie's eye with an instrument that uses red light. This device contains a glass prism like the one shown in the diagram

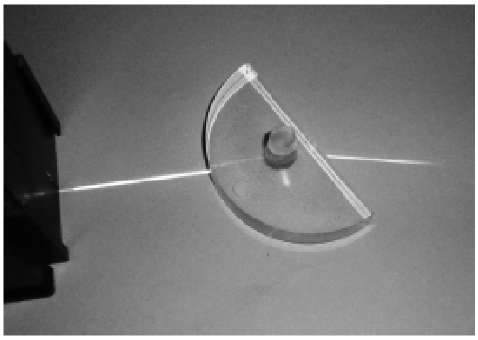


The speed of red light in air is 3.0×10^{8} *m* s^{-1}.
The speed of red light in the glass prism is 2.0×10^{8} *m* s^{-1}.
$n_{air} = 1.0$, $n_{glass} = 1.5$

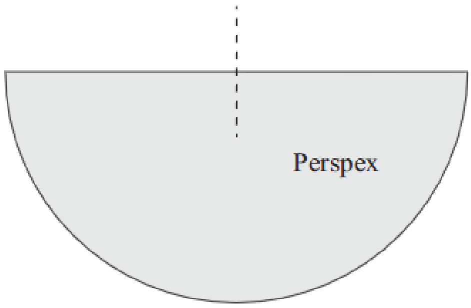
Explain what happens to a beam of red light that shines into the glass prism as shown in the diagram above. (You will need to carry out a calculation to answer this question.) Draw the path of the beam of red light to support your answer.

Refraction (2012;2)

One way to determine the critical angle of Perspex (acrylic glass) is to use a semi-circular Perspex block, through which a ray of light is passed and an angle measured.



(a) Complete the diagram below to show the path of a ray of light when used to determine the critical angle of Perspex. On your diagram **mark the critical angle**. The normal has been drawn for you.

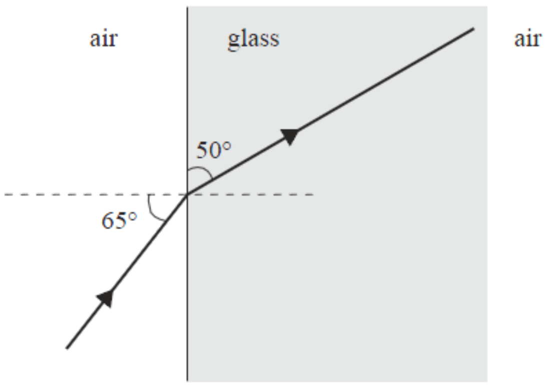


(b) State two conditions necessary for total internal reflection to occur.

(c) In the above experiment, the critical angle of Perspex was found to be 42°. Determine the refractive index of Perspex.

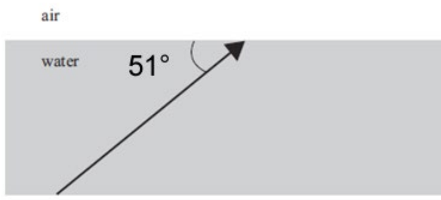
Refraction and lenses (2011;1)

Laura shines another ray of light into the lens, as shown in the diagram.



(e) Use the information in the diagram to calculate the **critical angle** for light incident from within the glass at the glass / air boundary. (The refractive index of air is 1.0.)

Refraction (2009;2)



The refractive index of water is 1.33.
The refractive index of air is 1.00.

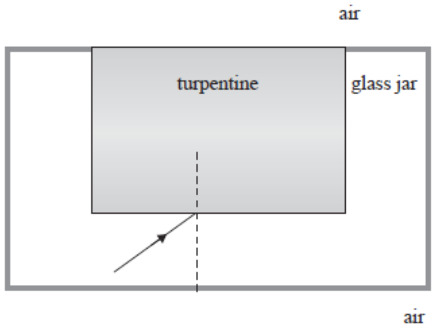
Use the $n_1 \sin\theta_1 = n_2 \sin\theta_2$ relationship to derive the formula for the critical angle at an interface.

Use the formula to show whether a ray that is incident on the water/air interface at an angle of incidence of 50° would be refracted into the air.

Refraction (2008;5)

Jane shone a laser beam through turpentine, which was in a glass jar.
The refractive index of turpentine is 1.472. The refractive index of glass is 1.67.

(a) The diagram shows the path of a laser beam hitting the glass-turpentine interface at an angle of incidence greater than the critical angle for glass-turpentine. Continue the ray until it passes into the air.



(b) Calculate the critical angle for the glass-turpentine interface.

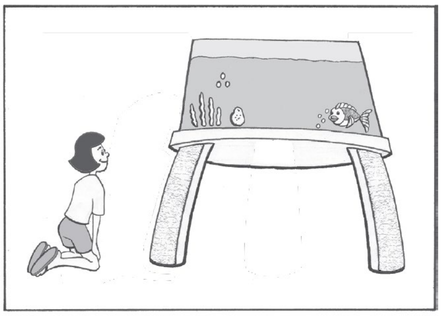
THE OPTICIAN (2007;1)

Pita is visiting the medical centre to get a new pair of glasses. He finds out that lenses can be made of either plastic or glass. (the refractive index of air is 1.00 and the refractive index of the plastic is 1.60).

Calculate the size of the critical angle at the plastic / air boundary.

LIGHT (2006;2)

Sally knelt down to take a closer look at the fish. While looking up at the surface of the water in the fish tank, she noticed that the surface of the water looked like a mirror and she could see the reflection of the fish in it.

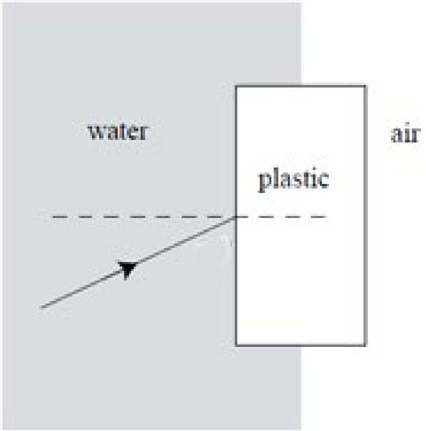


(f) Explain concisely, using physics principles, the conditions that are required for the rays of light from the fish to reflect off the water / air boundary (interface).

(g) Calculate the critical angle of the water / air interface. Express your answer to the correct number of significant figures (the refractive index of water is 1.33).
(*NB2S editor's Note: It is assumed that you remember that the refractive index of air = 1.00*)

QUESTION TWO (2005;2)

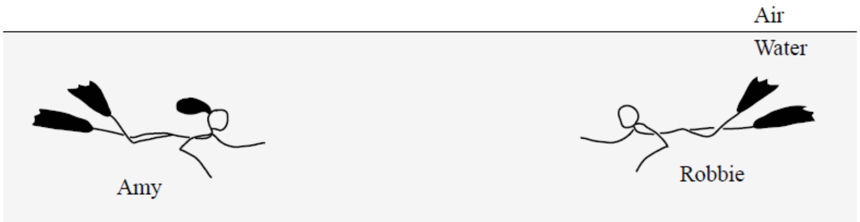
Robbie and Amy decide to practise their underwater swimming. They are both wearing swimming goggles. The diagram below shows a ray of light entering the transparent plastic goggles. The refractive index of plastic is 1.5. The refractive index of air is 1.00.



(d) State the meaning of the term "critical angle".

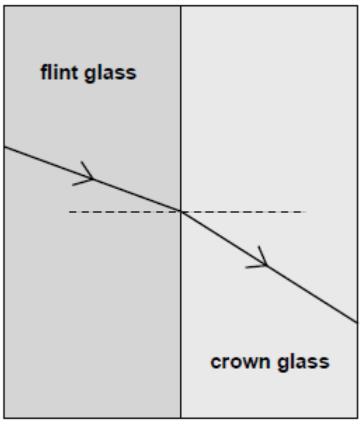
(e) Calculate the critical angle for the plastic/air interface.

(f) A short time later, Robbie and Amy are in the pool, swimming under water. Amy notices that when she looks forwards, she can see Robbie, but she can also see a reflected image of him. Draw TWO rays to show how Robbie's image is formed. Draw Robbie's reflected image in the correct place.



REFRACTION (2004;3)

Lee is a keen astronomer. He discovers that good telescope lenses are often made of two types of glass of different refractive index cemented together.
The diagram shows the path of a ray of light as it travels through two such pieces of glass.



Refractive index of crown glass	= 1.52
Refractive index of flint glass	= 1.66
Speed of light in crown glass	= 1.974×10^8 ms^{-1}
Angle of incidence in flint glass	= 19.8°

(a) Calculate the size of the critical angle for the flint glass/crown glass boundary.

(b) Give a detailed explanation of what is meant by the phrase 'the critical angle for the flint glass/crown glass boundary'.