WAVES: REFRACTION QUESTIONS

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.

\[
\begin{align*}
\text{v}_{\text{light in air}} &= 3.00 \times 10^8 \text{ m s}^{-1} \\
\eta_{\text{air}} &= 1.00 \\
\eta_{\text{juice}} &= 1.34
\end{align*}
\]

(a) Define ‘refraction’.

(b) The diagram shows the cross-section of the glass, looking down from above, with the juice inside. For the purpose of this question, you can assume the glass itself is very thin and has negligible effect on the path of the light rays.

(i) Complete the diagram, clearly showing the refraction of the light ray as it enters the juice.

(ii) Calculate the angle of refraction.

(d) The green laser used in this experiment has a frequency \(5.60 \times 10^{14}\) Hz in air.

(i) By first calculating the wavelength of the laser in air, calculate the wavelength of the light rays in the juice.

(ii) Explain why the wavelength of the green laser in juice is different from its wavelength in air.

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.

(a) Show that the refractive index for plastic is 1.43.
Water (2016;2)

Tim looked at the pond in the garden and noticed a pattern in the water caused by the wind. The diagram below shows a simplified pattern of the water waves being refracted as the depth of the water in the pond changes. Refraction occurs at the boundary between the two depths of the pond. The incident waves are on the left of the boundary.

(a) Draw an arrow to mark on the diagram the direction of the incident wave as it reaches point X. Draw an arrow to mark on the diagram the direction of the refracted wave after it leaves point X.

(b) (i) Which property of a wave does not change when it is refracted?

(ii) The wavelength of the wave gets smaller as it enters medium B. Explain what this tells you about the speed of the wave in medium B.

(c) If the wavelength of the wave in medium A is 0.300 m, and the speed of the wave in medium A is 3.30 m s\(^{-1}\), calculate the wave speed in medium B if the wavelength of the waves in medium B is 0.200 m.

Washing the car (2016;3)

Ana is washing her car and notices that she can see drops of water on the windscreen, even though both the glass and the water drops are transparent.

(a) Why is Ana able to distinguish between the glass and the water?

Ana tries to sketch a drawing of a large bead of water on the windscreen to help her understand what is happening. Use the information below to answer part (b).

Refractive index of air = 1.00
Refractive index of water = 1.33
Refractive index of glass = 1.52
Angle of incidence at air-water interface = 32°.

(b) If the air-water interface and the water-glass interface are roughly parallel, calculate the angle of refraction in the glass (as labelled).
**Lenses and refraction (2015;2)**

(b) Tom goes to a pool. He shines a red laser into the pool. He notices that even though the light ray bends, its colour does not change. Explain why the colour of the laser remains the same.

(c) Tom shines the red laser at an angle of 40° to the surface of the water in the pool, as shown in the diagram below.

\[
\text{Refractive index of air} = 1.00 \\
\text{Refractive index of water} = 1.33
\]

Calculate the angle of refraction.

(d) There is a coin at the bottom of the pool. Tom looks at the coin from above and sees an image of the coin, as shown in the diagram.

Write a comprehensive explanation for why the rays bend, and how the image of the coin at the bottom of the pool is formed when Tom looks at it from above.

**Ropes and a mirage (2015;3)**

(a) Tom drives down the motorway on a hot sunny day. He notices a mirage ahead of him. A mirage is the image of the sky that has been reflected by the road. The air just above the surface of the road is hotter than the layers of air above it. Hot air is less optically dense than cold air. Write a comprehensive explanation for why Tom sees a mirage.

**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.

(c) A beam of red light passes from the air into the water. Calculate the wavelength and the frequency of the light beam as it travels through the water (The speed of light in air is \(3.0 \times 10^8\) m s\(^{-1}\). The wavelength of red light in air is \(6.5 \times 10^{-7}\) m).
WATCHING THE WAVES (2014;3)

Moana watches the waves travel from deep to shallow water. In shallow water, the waves travel more slowly, compared to in deep water. Complete the diagram showing the wave fronts and the wave direction in the shallow water.

(a) At school, Moana investigates waves in springs. She connects a light spring to a heavy spring and ties the heavy spring to the leg of a bench. Moana sends a single pulse along the light spring, as shown in the diagram. (Waves travel faster in a light spring than in a heavy spring.)

The diagram below shows the pulse after it has moved into the heavy spring.

On the same diagram, draw the pulse reflected in the light spring showing:
- the phase of the pulse
- the distance travelled by the pulse.

Give reasons for your answer.

Frankie goes to the optician (2013;2)

The diagram is a simplified anatomy of the eye. Light enters through the transparent cornea and passes through the pupil to enter the lens. The position of the lens is fixed. However, the shape, and hence the focal length, of the lens can change in order for us to be able to see objects that are far away (distant), as well as objects that are near (close). The lens focuses the light onto the retina, where an image of the object is formed.

Frankie goes to the optician for an eye examination. The optician shines a ray of light into his cornea (at the front of his eye), as shown.

(a) State the size of the angle of incidence.
At the swimming pool (2013;3)

Jess and Rima are at the local pool. They notice that there is a shallow region at the edge of the pool. Waves travel through the deep water and change direction as they slow down moving into the shallow water.

(a) On the diagram, draw waves that have entered the shallow water. Also draw an arrow showing the new wave direction.

(b) State what happens to the frequency and wavelength of the waves when they enter the shallow water.

Refraction (2012;2)

(d) A ray of light is shone through a rectangular block of glass at an angle of 56° to the surface of the glass, as shown in the diagram. Refractive index of air = 1.0 Refractive index of glass = 1.5.

The glass block is 10.0 cm long and 8.0 cm wide. Calculate the distance the ray of light travels through the glass before emerging into the air.

Refraction (2012;3)

(b) Draw the refracted wave fronts with labelled arrows showing the following:

- direction of travel of the incident wave fronts
- direction of travel of the refracted (transmitted) wave fronts

The magnifying glass (2011;2)

Laura uses a lens as a “magnifying glass” to view a magnified image.

(f) Laura knows that her eye contains the same-shaped lens. The refractive index of this lens is 1.41 and the refractive index of the fluid around it is 1.34. Light travels through the lens at a speed of $2.1 \times 10^8$ m s$^{-1}$. Calculate the speed of light in the fluid. Write your answer to the correct number of significant figures
Refraction and lenses (2011;1)

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

(d) Calculate the angle of refraction at the first interface.

Refraction (2010;3)

Jane puts a glass block on top of a coin in a trough. She then pours water over this. The diagram below shows the situation.

The arrow represents a ray of light travelling from the coin through the glass.
The refractive index of glass is 1.55
The refractive index of water is 1.33
The refractive index of air is 1.00

(a) Complete the diagram to show what happens to the ray of light as it enters the water and then travels into the air.
(b) (i) Use calculations to determine whether the ray of light will enter the air when the angle of incidence of the ray of light at the glass-water interface is 48.7°.
(ii) Explain your answer to (i).

Refraction (2009;2)

When Bianca is sailing her boat out of the harbour, she notices that the apparent depth of the water is different from the real depth. The two arrows indicate two rays of light travelling from the bottom of the harbour towards the surface of the water.

(a) Complete the diagram to show where the bottom of the harbour appears to be. Use your diagram to explain why Bianca observes that the harbour depth appears to be different from what it really is.
(b) State what happens to the frequency and speed of the light as it leaves the water.
(c) One light ray is incident on the water/air interface as shown.

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

Calculate the angle of refraction. Give your answer to the correct number of significant figures.
Bianca notices that there is a shallow triangular reef near her boat. There is deep water all around the reef. The water waves travel at a speed of 1.6 m s$^{-1}$ in deep water and 1.2 m s$^{-1}$ in shallow water. The waves have a wavelength of 45 cm in deep water.

(a) Show that the wavelength of the waves in shallow water is 34 cm.

(c) On the diagram, show what happens to the waves as they travel through the shallow water and then into deep water. Make sure you make it clear (use labels if necessary) what has changed and what has stayed the same.

(d) The wavelength changes as the waves go from shallow water to deep water. The waves have a wavelength of 0.45 m in deep water. The waves have a wavelength of 0.34 m in shallow water. Refer to the diagram and calculate the angle of refraction when the waves go from shallow water to deep water.

Petra and Callum notice that the wavelength changes as the waves approach the beach through shallower water.

(a) Explain how the wavelength of the wave changes as it passes into the shallow region.

(b) The waves travel at 4.0 m s$^{-1}$, and the crests are 5.0 m apart. Calculate the time taken for one wave to pass a point.

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) Calculate the angle of refraction of the laser beam in the turpentine, when the laser beam passes from the glass into the turpentine. Give your answer to the correct number of significant figures. (*NB2S editor’s Note: It has been assumed that you remember that the refractive index of air = 1.00*)
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.

Plastic has a refractive index of 1.60. Glass has a refractive index of 1.50.

(a) State the meaning of the term "refractive index".

A ray of light enters the plastic lens as shown.

(b) Calculate the size of the angle of incidence.

(c) Calculate the size of the angle of refraction.

At the harbour (2007;2)

Further out to sea, Maria sees water waves travelling through shallow water above a reef and then into deep water, as shown in the diagram below (The water waves travel more slowly in shallow water).

(b) On the diagram, draw the wavefronts in the deep water, and an arrow showing the direction the refracted waves are travelling.

(c) Use the information provided below to calculate the angle of refraction in deep water.

\[
\text{Speed of waves in shallow water} = 0.25 \text{ ms}^{-1} \\
\text{Speed of waves in deep water} = 0.35 \text{ ms}^{-1} \\
\text{Angle of incidence in shallow water} = 35^\circ
\]

Light (2006;2)

Roy and Sally noticed a puddle of water with oil floating on top. The diagram shows a ray of light travelling from air as it meets the air-oil interface.

(c) Complete the path of the ray of light in the diagram to show what happens to the ray as it enters the oil, and then the water.

(d) The ray of light meets the air-oil interface at an angle of incidence of 40°. Calculate the angle of refraction when the ray goes into the water.

Roy and Sally visited a pet shop to buy a fish in a tank.

(e) On the diagram draw appropriate rays to locate the image of the fish if Roy was looking at it from above.
**Question Two (2005;2)**

Robbie and Amy decide to practise their underwater swimming. They are both wearing swimming goggles.

(a) The diagram shows a ray of light entering the transparent plastic goggles. Continue the ray showing how it bends as it enters the plastic, and then as it enters the air. (The plastic is optically denser than water.)

(b) The ray of light deviates (or changes direction) through an angle of 4.0° as it enters the plastic. The refractive index of plastic is 1.5. Calculate the refractive index of the water.

(c) State the meaning of the term "absolute refractive index".

**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.

(a) Clearly mark the angle of incidence for the ray from flint glass to crown glass in the diagram.

Use the information below to answer the questions (b) and (c).

- Refractive index of crown glass = 1.52
- Refractive index of flint glass = 1.66
- Speed of light in crown glass = 1.974 x 10⁸ ms⁻¹
- Angle of incidence in flint glass = 19.8°

(b) Show that the angle of refraction in the crown glass is 21.7°.

(c) Calculate the speed of light in flint glass.