

Light - Refraction ①

A Phys. in

✓ light in air $3 \times 10^8 \text{ m/s}$

1 nm = $1 \times 10^{-9} \text{ m}$

$\mu_{\text{air/glass}} = 1.52$

$\mu_{\text{air/water}} = 1.33$

$\mu_{\text{air/octane}} = 1.40$

$\mu_{\text{air/diamond}} = 2.42$

$\mu_{\text{air/quartz}} = 1.46$

formulas

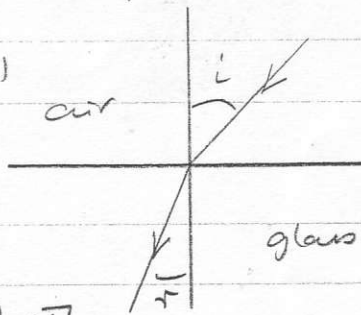
$$\mu = \frac{\sin i}{\sin r}$$

$$\mu = \frac{v}{c}$$

1. (a) $i = 45^\circ$ $r = ?$ (2)

(b) $r = 25^\circ$ $i = ?$ (2)

(c) What is the velocity of light in glass? (2) 6



2. It is said that fish and someone swimming underwater see a cone of light from above.

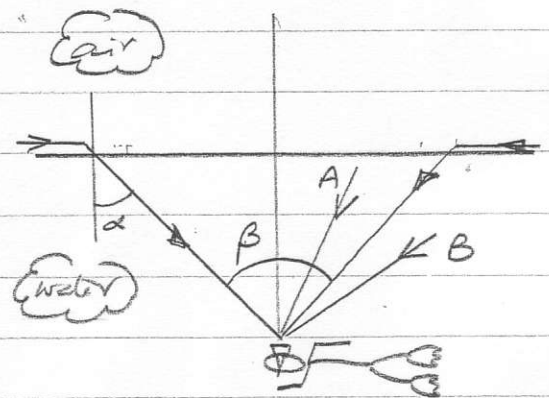
(a) Copy the diagram and show how rays A and B get to the swimmer. (2)

(b) Explain why the swimmer sees a cone of light. (3)

(c) Calculate angle α (2)

(d) What is angle β ? (1)

(e) What is the velocity of light in water? (2) 10

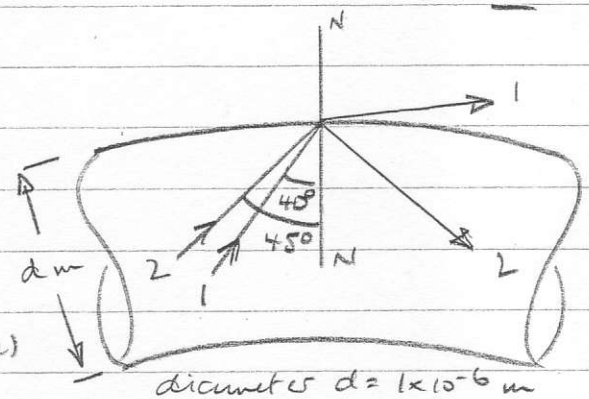


3. a) Calculate the critical angle for light in quartz (2)

(b) Explain why ray 1 emerges from glass, and ray 2 does not (2)

(c) Calculate the speed of light in quartz (2)

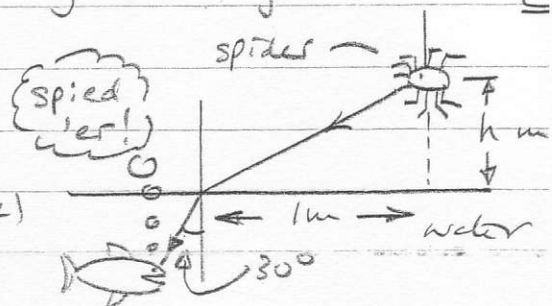
(d) Draw a diagram to show a light ray travelling down a straight fibre, internally reflected at the critical angle



(e) Calculate how far the ray moves forward between reflections. (2) (2)

(f) Calculate how far the ray travels in moving 1 m along the fibre. (2) 11

4. The diagram shows an Archer fish watching a spider.



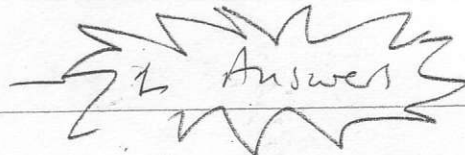
(a) What is height h m of spider above water? (4)

(b) How does the Archer fish catch its prey? (2) 6

8.98

11.98

Refraction



A Physics

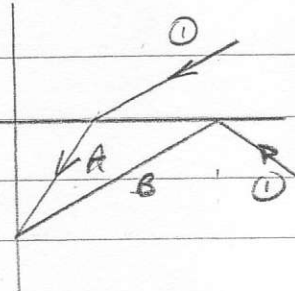
1. (a) $n_{\text{air}} = \frac{\sin i}{\sin r} = 1.52 \rightarrow \sin r = \frac{\sin i}{n} = 0.465 \rightarrow i = 27.7^\circ$ (2)

(b) $\sin i = n \sin r \rightarrow i = 39.96 = 40^\circ$ (2)

(c) $n = 1.52 = v_{\text{air}} / v_{\text{glass}} \rightarrow v_{\text{glass}} = 3 \times 10^8 / 1.52 = 1.97 \times 10^8 \text{ m/s}$ (2)

2. (a) A - refracted B - Totally Int. Reflected inside water. (2)

(b) All light rays from outside the water are refracted, so that the maximum angle to the vertical / normal they can have is β ($= \alpha$, critical angle). Outside angle β the rays are Totally Internally Reflected by the underside of the water (3)



(c) $\alpha = \text{critical angle } c. \quad n = 1.33 = \frac{\sin i}{\sin c} = \frac{\sin 90}{\sin c} \rightarrow c = 48.7^\circ$

(d) $\beta = 2 \times \alpha = 97.5^\circ$

(e) $n = 1.33 = v_{\text{air}} / v_{\text{water}} \rightarrow v_{\text{water}} = 3 \times 10^8 / 1.33 = 2.26 \times 10^8 \text{ m/s}$ (10)

3. (a) $n_{\text{quartz}} = \frac{\sin 90}{\sin c} \rightarrow c_{\text{quartz}} = 43.2^\circ$ (2)

(b) Ray 1 has angle i to normal less than c , so emerges, refracted. Ray 2 has $i > c$ so is totally internally reflected (2)

(c) $n_{\text{quartz}} = 1.46 = v_{\text{air}} / v_{\text{quartz}} \rightarrow v_{\text{quartz}} = 2.05 \times 10^8 \text{ m/s}$ (2)

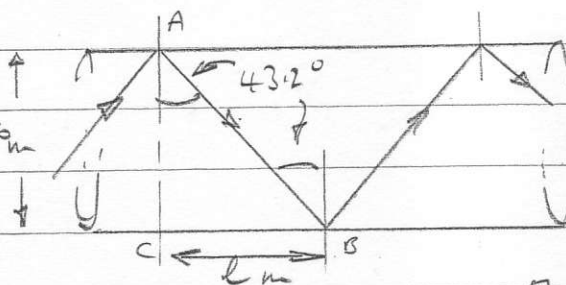
(d) - shows... - ray 1 into reflected (1)

- shows $c = 43.2^\circ$ (2)

(e) $\tan 43.2 = l/d \rightarrow l = 940 \times 10^{-9} \text{ m} \times 10^6$

l is the distance moved forward

between reflections. (2)



(f) Distance travelled by ray between reflections = $AB = 1 \times 10^{-6} / \cos 43.2 = 1.37 \times 10^{-6} \text{ m}$

so distance travelled by ray in glass / distance moved forward = $\frac{1.37 \times 10^{-6}}{940 \times 10^{-9}} = 1.46$

so to move 1 m forwards, the light must travel 1.46 m forwards (12)

2. (a) $n_{\text{water}} = 1.33 = \frac{\sin i}{\sin r} \rightarrow \sin i = 0.665 \rightarrow i = 41.7^\circ$ (12)

$\alpha = 90 - i = 48.3^\circ$

$\tan \alpha = h/l \rightarrow h = \tan \alpha = 1.12 \text{ m}$ (4)

(b) It shoots a jet of water at the spider, knocking it into the water, - it's aim takes into account the refraction of light! (2)

