

Chapter 12 Homework Answers

12.1 What is Refraction?

- 2 a) Refraction takes place because light travels at different speeds in different mediums. When a light wave hits a new medium at an angle (not along the normal), the front part of the wave changes speed while the far side side of the wave does not. This causes the light wave to bend as it enters a new medium.
- b) The light must hit the new medium at an angle. If light enters along the normal then NO refraction is seen. The 2 mediums must be different.
- c) Water is more optically dense than air so light will travel more slowly in water than air.
- 3 a) medium A is air and medium B is water. Light will travel more slowly in water and so will bend TOWARDS the medium when it goes from air → water.
- b) We don't know which way light is travelling. It doesn't matter though. Light is bending AWAY from normal as it goes from B → A (water to air) and light travels TOWARDS the normal as it travels from A → B (air to water)
- 4 a) Light bends AWAY from normal when it travels faster
- b) Light bends TOWARDS the normal when it slows down.
5. In Figure 11 we see reflection AND refraction.

12.4 The Index of Refraction

- 1a) The index of refraction refers to the ratio of speed of light in a medium compared to speed of light in a vacuum. Mathematically: $n = c/v$ (remember c = speed of light in vacuum and v = velocity or speed in the medium of interest)
- b) The index of refraction has no units (dimensionless) because it's m/s (speed) divided by m/s (speed) so the units cancel out.
2. $n = 3.0 \times 10^8 / 2.3 \times 10^8$ $n = 1.3$ The index of refraction of vinegar is 1.3
3. $n = 3.0 \times 10^8 / 1.69 \times 10^8$ $n = 1.8$ The index of refraction of sapphire is 1.8
4. a) $n = c/v$ so.... $v = c/n$ $n_{\text{quartz}} = 1.46$ $v = 3.0 \times 10^8 / 1.46 = 2.1 \times 10^8$ m/s
So light travels 2.1×10^8 m/s in quartz
- b) $v = c/n$ $n_{\text{diamond}} = 2.42$ $v = 3.0 \times 10^8 / 2.42 = 1.24 \times 10^8$ m/s
So light travels 1.24×10^8 m/s in diamond
5. 80% sugar has $n = 1.49$ $v = c/n$ $v = 3.0 \times 10^8 / 1.49 = 2.0 \times 10^8$ m/s
So light travels 2.0×10^8 m/s in 80% sugar solution
6. acetone $n = 1.36$ $v = c/n$ $v = 3.0 \times 10^8 / 1.36 = 2.2 \times 10^8$ m/s
So light travels 2.2×10^8 m/s in acetone
7. a) unknown substance - speed of light = 2.20×10^8 m/s $v = 2.20 \times 10^8$ m/s
 $n = c/v$ $n = 3.0 \times 10^8 / 2.20 \times 10^8$ 'n' of unknown substance = 1.36
- b) ethyl alcohol has $n = 1.36$. The unknown substance might be ethyl alcohol.
8. The fastest light (or anything really) can go is 3.0×10^8 . So there must be some incorrect math to get a speed greater than 3.0×10^8 . Faster than that is impossible.
9. You see more refraction (more bending) the greater the difference in the 'n' values. Diamond and glass are closer in 'n' values (2.42 and 1.5) than diamond and air (2.42 and 1.00) so there will be LESS refraction with the glass next to diamond. The angle of refraction will be greater than 56° .
10. Light travels at a slightly different speed in each medium. So every medium has a different 'n' value or different refractive index. This means the 'n' value or refractive index is unique for each substance. We can use this to identify a mystery substance.

12.5 Total Internal Reflection (T.I.R)

- 1 For T.I.R. to happen the light must #1. be travelling from high 'n' to low 'n' mediums. And #2 . the angle of incidence MUST be greater than the critical angle.
- 3 a) No T.I.R. b) Yes..T.I.R. c) Yes T.I.R. d) No T.I.R.
For Total Internal Reflection to occur, the angle of incidence must be greater than the crucial angle of 34.4°
- 4 Prisms reflect (internally) almost 100% of the light they receive whereas mirrors absorb some light (so 100% is not reflected). Also, the silvered back of the mirror can flake off (deteriorate) over time.
- 5 You will have more T.I.R. when the critical angle is small. The smaller the critical angle, the more angles are greater than it!! Ie; if the critical angle is 20° , then angle incident angle from 21° to 89° will T.I.R. But if critical angle is 70° , then only 71° to 89° will T.I.R. Draw a diagram and think about it!
- 7 **APPLICATION!!!** Take time to briefly describe 3 examples given in this section of textbook. What do we use this for in society???
- 8 T.I.R. would be possible in the ones in which the light is starting in the high 'n' and going to low 'n'. This means the light would be bending AWAY from normal as it leaves.
So...T.I.R. possible in (b) and (c)
No T.I.R. in (a) – since light is bending towards normal and thus moving INTO a higher 'n' – no T.I.R.
- 9 T.I.R. would occur in
(b) → in medium A (because this is the higher 'n' medium light starts in)
(c) → in medium A (because this is the higher 'n' medium light starts in)

12.7 Phenomena Related to Refraction

- 1 Apparent depth – is the depth an object APPEARS to be but isn't really. It is an illusion created by the refraction of light as it moves between water and air.
- 2 If I really want to scoop a fish out of water, I would need to aim BELOW where I see it. Refraction makes the fish appear to be HIGHER in the water than it really is. (You can use a diagram to explain here too – like on page 535)
- 3 Index of refraction decreases (gets lower) as air warms up. That means cold air has a higher index of refraction and light travels more slowly in cold air than warm air. (light speeds up as it travels through warm up)
- 4 The water mirage is really you seeing an image of the sky! (see page 537 for diagram)
- 5 If violet light refracts more, than the 'n' value or index of refraction is greater for violet light than red light.
- 6 Rainbows occur because of refraction (light refracts as it enters AND leaves the water droplet), dispersion (ROYGBIV refracts differently and thus white light separates into the rainbow colours) and T.I.R. (because light totally internally reflects inside the water droplet).
- 7 Different colours in white light (ROYGBIV) have different speeds in water and this allows for the colours to refract different amounts. This different amount of bending separates the colours. Separating the colours is what makes the rainbow. So...if the different colours didn't travel at different speeds in water, there would be NO rainbow. ☹ Good thing they do travel at different speeds! ☺