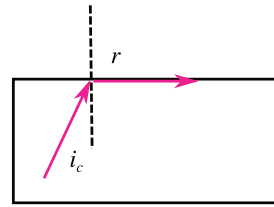
47 Calculating Critical Angles ♡



The conditions for total internal reflection are that the light

- must be attempting to leave a material into air, or more generally
  - crossing from a higher to lower refractive index material
  - this means that the light crosses a boundary where it speeds up
- and the angle of incidence must be above the critical angle (i_c).

If the angle of incidence were exactly critical, then the angle of refraction would be a right angle.

So $i = i_c$ and $r = 90°$. Remember, $\sin(90°) = 1$
Snell's Law for light leaving a material into air is

$$\sin(r) = n\sin(i)$$

In this case $\sin(90°) = n\sin(i_c)$. So $\sin(i_c) = \frac{1}{n}$ and $i_c = \sin^{-1}\left(\frac{1}{n}\right)$.

The refractive index $n = \frac{1}{\sin(i_c)}$.

Data:

$$\text{refractive index of glass} = 1.50$$
$$\text{refractive index of water} = 1.34$$

47.1 Calculate the critical angle for light leaving glass into air.

47.2 Calculate the critical angle for light leaving water into air.

47.3 The critical angle for light leaving diamond into air is 24°. Calculate the refractive index (n) for diamond.

Where light goes from one material (refractive index n_1) to another (n_2), we use the more general form of Snell's Law.

$$\begin{aligned} n_1 \sin(i) &= n_2 \sin(r) \\ n_1 \sin(i_c) &= n_2 \sin(90^\circ) = n_2 \\ \Rightarrow \sin(i_c) &= \frac{n_2}{n_1} \end{aligned}$$

47.4 The critical angle for light leaving a particular type of glass is 38.4°. What is its refractive index?

47.5 What is the critical angle for light passing from glass to water?

47.6 The inner section (core) of an optic fibre has a refractive index of 1.52 and the critical angle for light leaving the core into the cladding is 43.7°. What is the refractive index of the outer section (cladding) that is keeping the light inside the core?

47.7 In entering a transparent material from the air, the wavelength of a laser's light decreases from 600 nm to 451 nm. Calculate the refractive index of the material. *[Hint: when a wave passes from one material to another, the frequency doesn't change. The effect of the speed change on the wavelength can be worked out from speed $=$ frequency $\times$ wavelength]*

47.8 A tube of glass of refractive index 1.65 is surrounded by glass of refractive index 1.51. Calculate the critical angle for light travelling along the tube and incident on the boundary between the glasses.

47.9 A thin ray of monochromatic light enters a block of pure ice at an angle of 42.0° to the normal from the air and the refracted angle in the ice is 30.7°. Calculate the critical angle for ice.