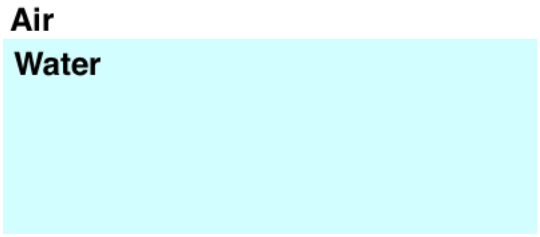
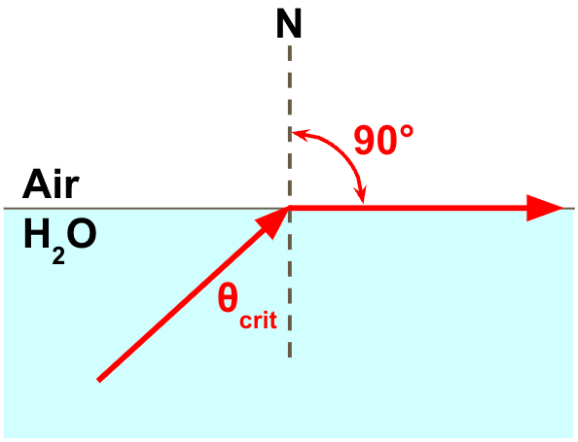
The Critical Angle
Lesson Notes

Learning Outcomes
- What is a critical angle?
- How is the critical angle calculated?

Total Internal Reflection
- **Total internal reflection** occurs when light traveling through a more dense medium approaches the boundary with a less dense medium at an angle of incidence that is greater than the *critical angle*.
- At angles of incidence less than or equal to the critical angle, light undergoes both reflection and refraction. But at angles of incidence greater than the critical angle, the incident light will only reflect.



What is a Critical Angle?
The **critical angle** is the angle of incidence that results in an angle of refraction of 90°.
The value of the critical angle depends upon the identity of the two materials on opposite sides of the boundary.
At the boundary, light either reflects and refracts (**R&R**) or light undergoes total internal reflection (**TIR**).
If $\theta_{incidence} < \theta_{critical}$: then R&R
If $\theta_{incidence} = \theta_{critical}$: then R&R (refracted ray on boundary)
If $\theta_{incidence} > \theta_{critical}$: then TIR (no refracted ray)



Critical Angle Derivation
When the angle of incidence is equal to the critical angle ($\theta_{critical}$), then the angle of refraction is 90°.

Snell's Law
$n_1 \cdot \sin\theta_1 = n_2 \cdot \sin\theta_2$

$$n_1 \cdot \sin\theta_{critical} = n_2 \cdot \sin 90° \qquad (n_1 > n_2)$$

$$\sin\theta_{critical} = n_2/n_1$$

$$\theta_{critical} = \sin^{-1}(n_2/n_1)$$

2nd sin^{-1} sin

Note that $n_1 > n_2$ since TIR occurs when light is traveling from the more dense to the less dense medium.

Example Calculations

Show solutions to the following problems:

1. Calculate the critical angle for the boundary between air (n=1.00) and water (n=1.33).

2. Calculate the critical angle for the boundary between air (n=1.00) and diamond (n=2.42).

3. Calculate the critical angle for the boundary between water (n=1.33) and glass (n=1.52).

TIR and the Sparkle of Diamonds

- Diamond has a very large index of refraction value.
- Thus, the air-diamond boundary has a very low critical angle of about 24°.
- Light entering the top face of a diamond will undergo several reflections before finally exiting the diamond. The multiple reflections give the diamond its sparkle … and that's Physics for Better Living.
- The actual cut of the diamond is important to insure that TIR occurs.