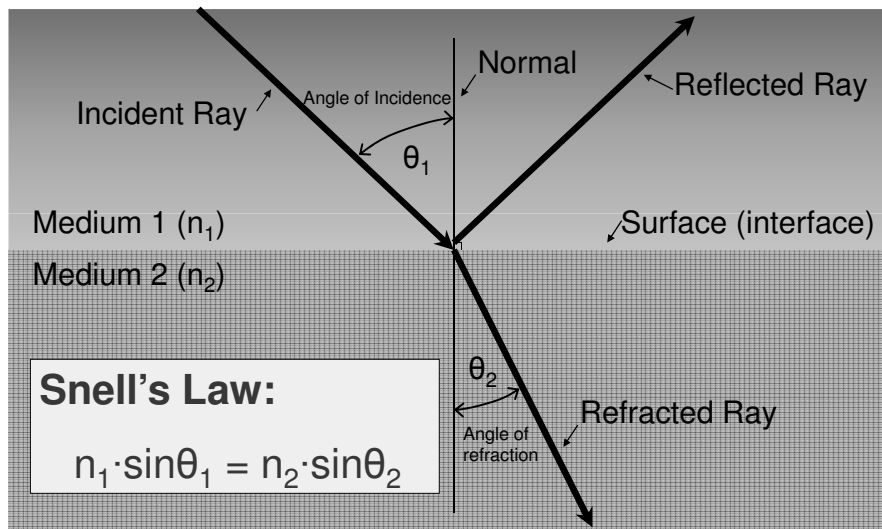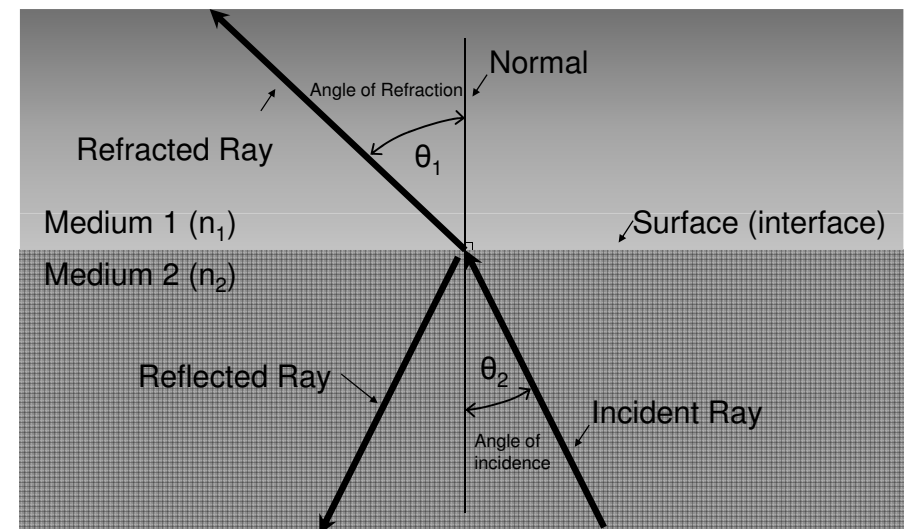# Total Internal Reflection

Objectives

- Measure indices of refraction for different media
- Describe the conditions under which total internal reflection occurs and determine the critical angle
- Explain and solve problems involving total internal reflection and critical angle
- Explain, using a diagram, total internal reflection in an optical device
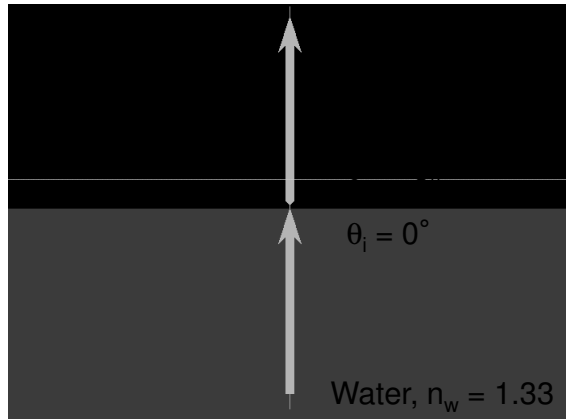- Analyze situations involving total internal reflections
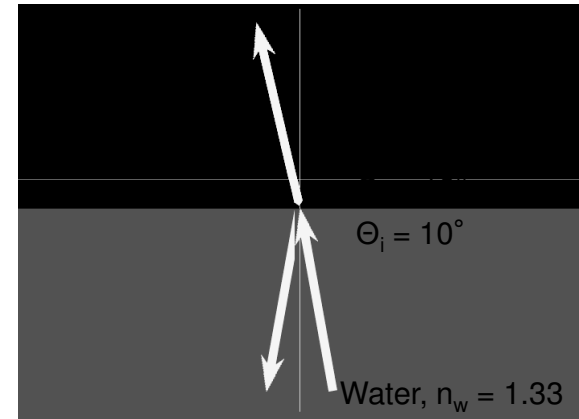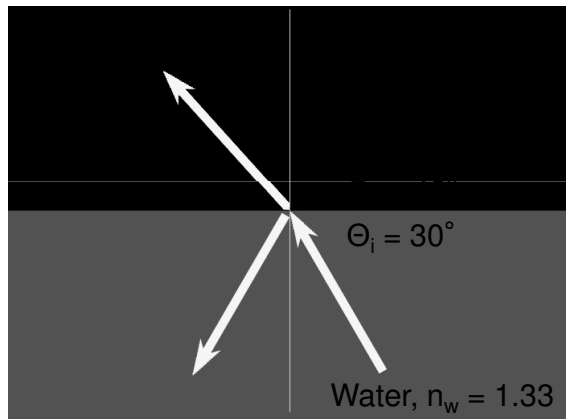
Review of Snell's Law

Incident Ray — Angle of Incidence — Normal — Reflected Ray

θ_1

Medium 1 (n_1) — Surface (interface)

Medium 2 (n_2)

θ_2 — Angle of refraction — Refracted Ray

Snell's Law:

$$n_1 \cdot \sin\theta_1 = n_2 \cdot \sin\theta_2$$

Snell's Law Works in the Other Direction
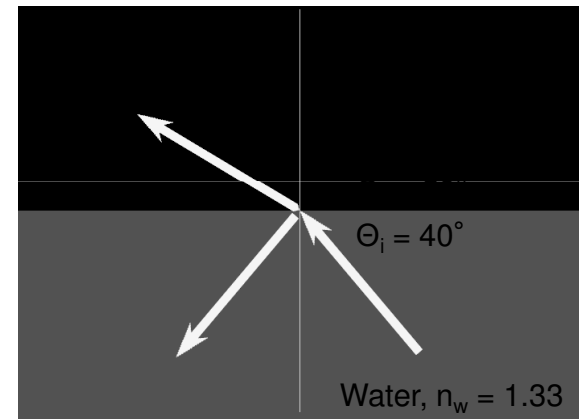
Refracted Ray — Angle of Refraction — Normal

θ_1

Medium 1 (n_1) — Surface (interface)

Medium 2 (n_2)

Reflected Ray — θ_2 — Incident Ray — Angle of incidence

What if $\theta_i = 0°$?

$\theta_i = 0°$

Water, $n_w = 1.33$

And if it increases?

$\Theta_i = 10°$

Water, $n_w = 1.33$

And if it increases?

$\Theta_i = 30°$

Water, $n_w = 1.33$

And if it increases?

$\Theta_i = 40°$

Water, $n_w = 1.33$

And if it increases?

$\Theta_i = 47°$

Water, $n_w = 1.33$

And if it increases?

$\Theta_i = 48°$

Water, $n_w = 1.33$

And if it increases?

$\Theta_i = 48°$

Water, $n_w = 1.33$

And if it increases?

Total Internal Reflection

$\Theta_i = 48.7536°$

Water, $n_w = 1.33$

Critical Angle

- Where did 48.7535° come from?

$\Theta_i = 48.7535°$

Water, $n_w = 1.33$
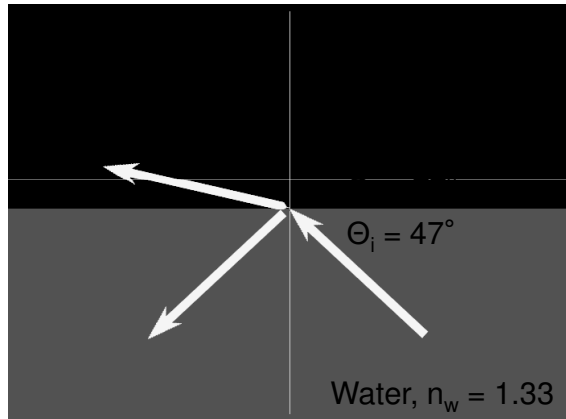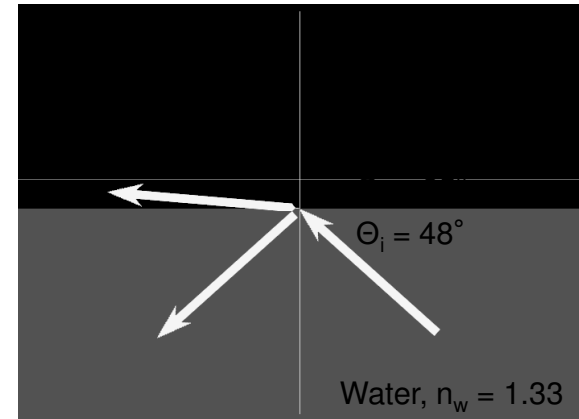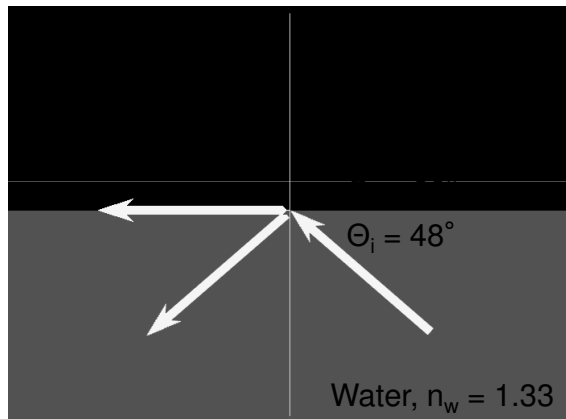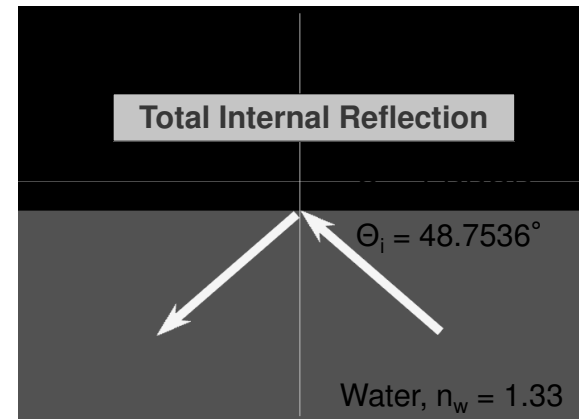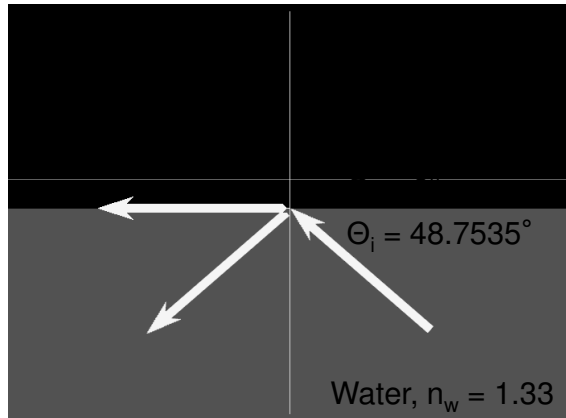
Critical Angle

- Where did 48.7535° come from?

$$n_i \sin \theta_i = n_r \sin \theta_r$$
$$\text{at critical angle } \theta_r = 90°$$
$$\text{but } \sin 90° = 1$$
$$\text{also } \sin \theta_i = \text{critical angle}$$
$$\text{therefore}$$
$$n_i \sin \theta_{crit} = 1 * n_r$$
$$\theta_{crit} = \sin^{-1}\left(n_r \big/ n_i \right)$$

$\Theta_i = 48.7°$

$n_w = 1.33$
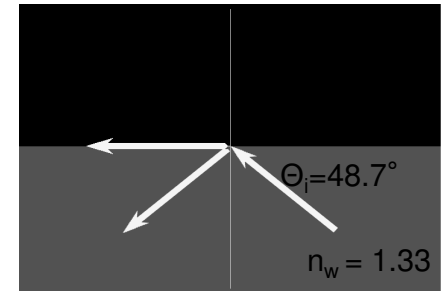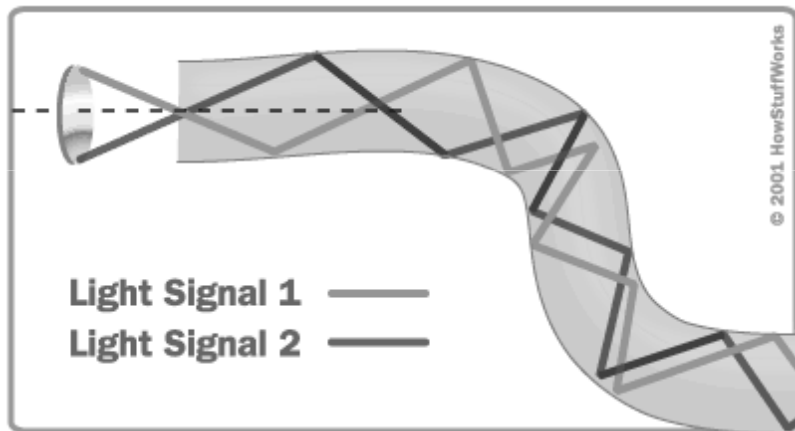
Poor fish can only see a little circle!
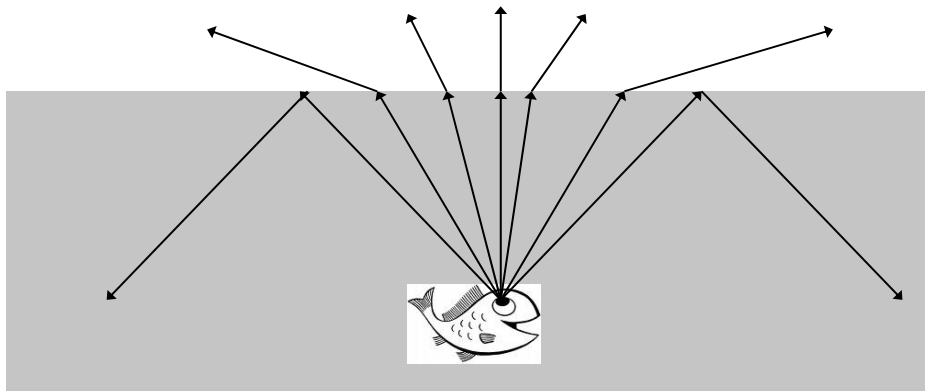
- The fish can only see a circle of sky!
- The circle is determined based on the θ_{CRIT} of water (49°)
- Beyond 49° fishy only sees the reflection of surroundings

Can we use this effect?

Yes! It is the basis of fibre optics.

Fibre Optics

Light Signal 1 ——
Light Signal 2 ——

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Summary

- $\sin\theta_1/\sin\theta_2$ is constant in a given medium
- Incident & Refracted rays are on opposite sides of the normal
- When light goes into a denser medium it bends towards the normal
- When light goes into a less dense medium it bends away from the normal
- Light doesn't refract when it enters at 90°
- $\theta_{CRIT} = \arcsin(n_2/n_1) = \sin^{-1}(n_2/n_1)$
- Total internal reflection occurs if:
  $$n_1 > n_2 \quad \text{and if} \quad \theta_1 > \theta_{CRIT}$$
- When $\theta_1 = \theta_{CRIT}$ then $\theta_2 = 90°$

Homework

Heath: p.482 #9, 13, 30, 32, 34, 36