C = 3.00 \times 10^8 \text{ m/s in vacuum}

Distance equal to circumference of earth,

\[ \text{Time} = \frac{40,000 \text{ km}}{3 \times 10^5 \text{ km/s}} = 0.13 \text{ s} \]

In material, light travels slower by factor

\[ \frac{c}{v} = c/n \]

where \( n \) is index of refraction

<table>
<thead>
<tr>
<th>Medium</th>
<th>Index n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air (STP)</td>
<td>1.00029</td>
</tr>
<tr>
<td>Water (20°C)</td>
<td>1.33</td>
</tr>
<tr>
<td>Glass</td>
<td>1.52</td>
</tr>
<tr>
<td>Diamond</td>
<td>2.42</td>
</tr>
</tbody>
</table>
Ray optics

light travels in straight line (except for refraction, diffraction)

ex: reflection

For reflected ray, angle of incidence equals angle of reflection

Retraction at medium boundary

\[ n_1, \quad n_2 > n_1 \]

Snell's Law: \[ n_1 \sin \Theta_1 = n_2 \sin \Theta_2 \]
principle of minimum time

\[ \frac{n_1 l_1}{c} + \frac{n_2 l_2}{c} = \frac{\text{minimum}}{AB} \]

Q: Total internal reflection

\[ n_1 = \text{air} \]

\[ n_2 \]

\[ 1.33 \sin \theta_c = 1.00 \sin (90^\circ) = 1 \]

\[ \theta_c \text{ water} = \sin^{-1} \left( \frac{1}{1.33} \right) \approx 49^\circ \]

application - fiber optics
Thin lenses: concave lens.

- Central axis
- Image plane "in focus"
- Lens focal length
- Rays parallel to central axis are refracted through focal point
- Image is inverted on retina; brain compensates at pre-conscious level

Mirage:
- Warm air over cooler ground
- Portion of sky looks like water
polarization - light as transverse wave

I₀

randomly polarized light

Vertically polarized

Iₐ/2

polarized light

I = I₀ cos²θ

2nd polarizer

What is wave? (moving transverse function)?

Electric field
Diffraction

\[ \text{interference fringes} \]

\[ \text{shadow} \]

\[ \text{dark} \]

\[ \text{shadow of fine wire} \]

\[ \text{two slit interference diffraction pattern} \]

\[ \Delta(\text{path}) = s \sin \theta = s \theta \]

For \( \theta \ll \pi \), \( \sin \theta \approx \theta \)

Constructive: \( s \Theta_n = n \lambda \)

Destructive: \( s \Theta_n = (n + \frac{1}{2}) \lambda \)
3) Thin Films (Soap Bubbles)

\[ n_1 \quad n_2 \quad n_3 \]

At air-medium interface, 90° phase shift \( \Rightarrow \) inv. polar

No phase shift at medium-air interface

For \( L \ll \lambda \), interference is dark.

For \( L \approx \lambda \), different color will have constructive interference