Energy in Waves - 2

Objective: Learning about different physical properties of waves and wave propagation.

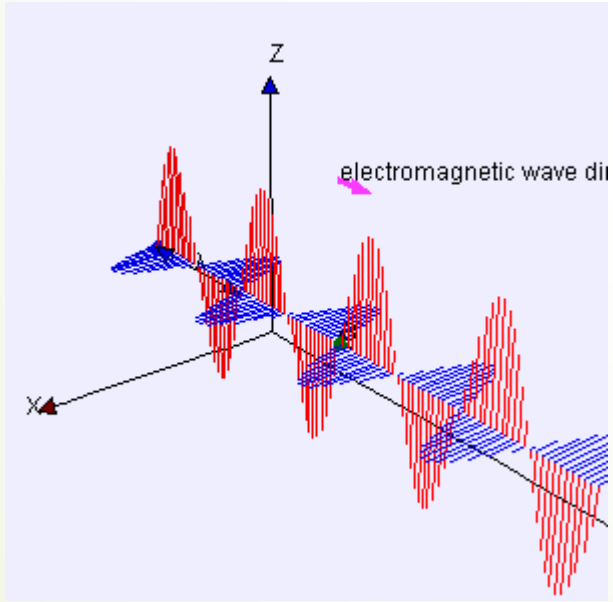
Key concepts:

- Heat and Thermal energy
- Temperature and Temperature Scales
- Laws of Thermodynamics
- Entropy
- Thermal expansion
- Heat transfer methods
- Change of Phase and Latent Heat

Electromagnetic waves

Electric and Magnetic Waves propagate together in *Electromagnetic waves* or *EM waves*.

- *EM waves* are transverse waves.
- All *EM waves* travel at 3 x 10^8 m/s in a vacuum.



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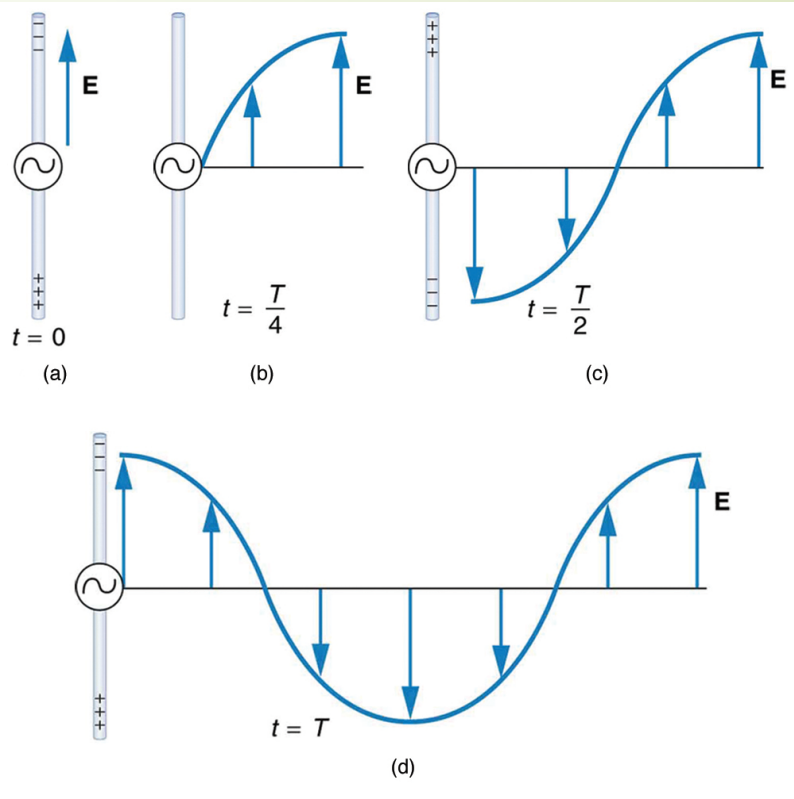
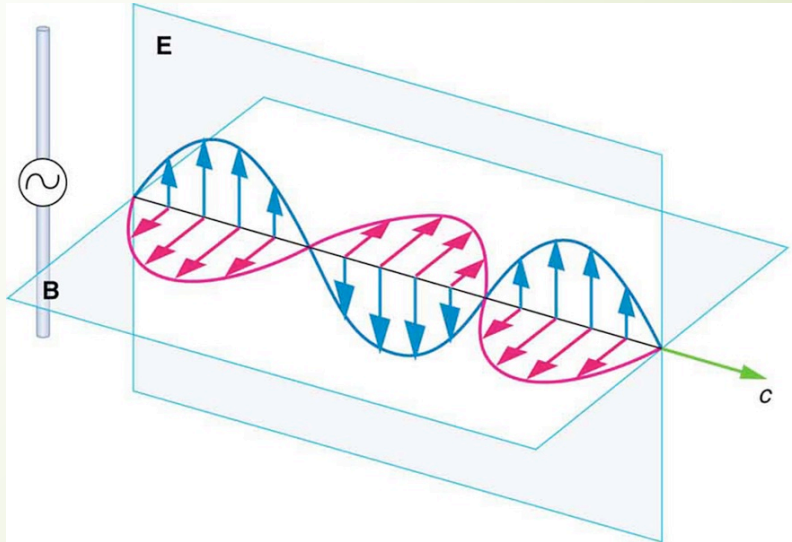
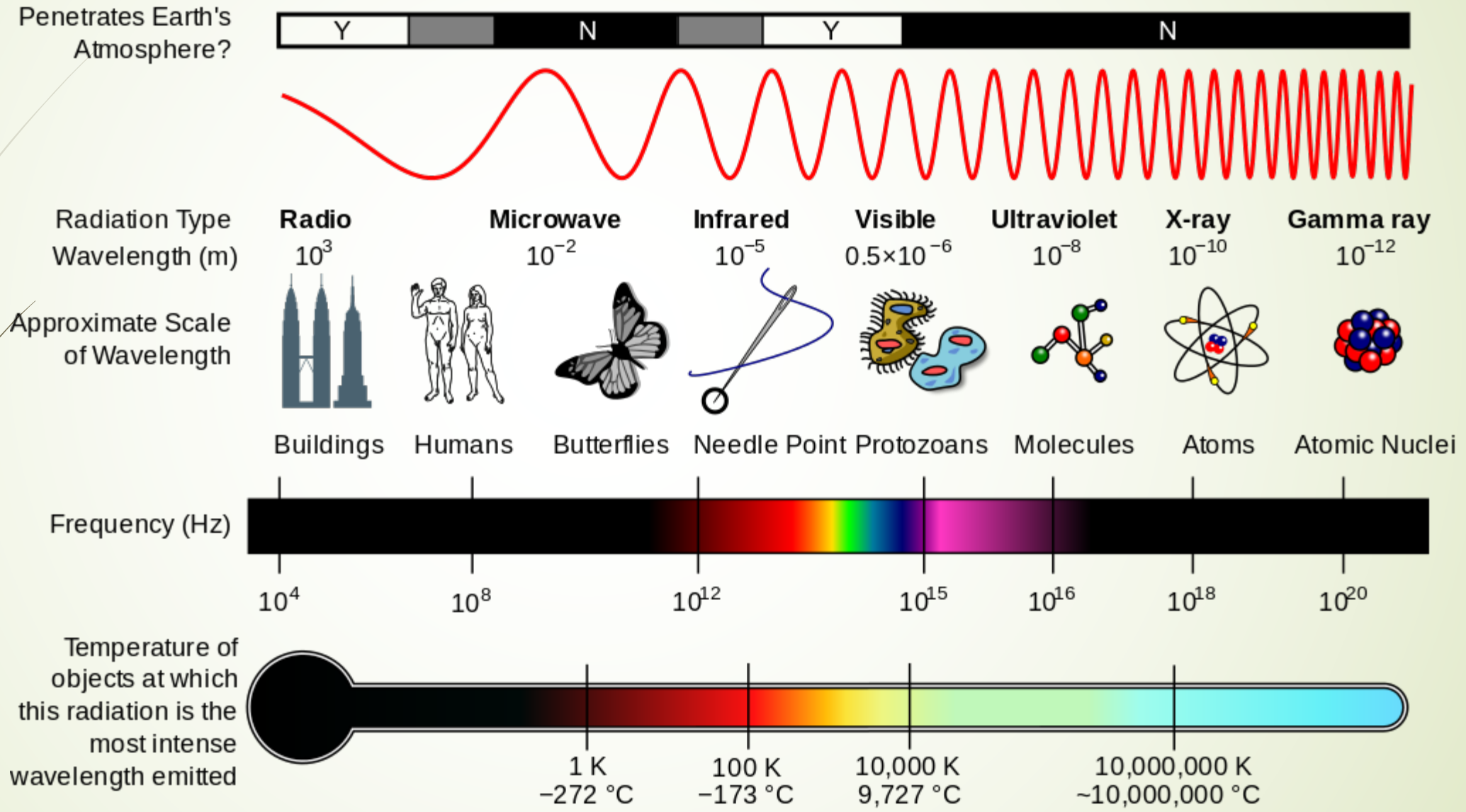




Electromagnetic Spectrum



Application of Electromagnetic waves

Type of EM wave	Production	Applications	Life sciences aspect	Issues
Radio and TV	Accelerating charges	Communications, Remote controls	MRI	Requires controls for band use
Microwaves	Accelerating charges and thermal agitation	Communications, Ovens, Radar	Deep heating	Cell phone use
Infrared	Thermal agitations and atomic/ molecular electron transitions	Thermal imaging, Heating	Absorbed by atmosphere	Greenhouse effect
Visible light	Thermal agitations and atomic/ molecular electron transitions	All pervasive	Photosynthesis, Human vision	
Ultraviolet	Thermal agitations and atomic/ molecular electron transitions	Sterilization, Cancer control	Vitamin D production	Ozone depletion, Cancer causing
X-rays	Inner atomic electron transitions and fast collisions	Medical, Security	Medical diagnosis, Cancer therapy	Cancer causing
Gamma rays	Nuclear decay	Nuclear medicine, Security	Medical diagnosis, Cancer therapy	Cancer causing, Radiation damage

Reflection

When light reflects from a smooth or rough surface, the incident and reflected rays make the same angle with the normal to the surface (figure (a) below):

For smooth surfaces, parallel rays all reflect at the same angle *(Law of Reflection)*

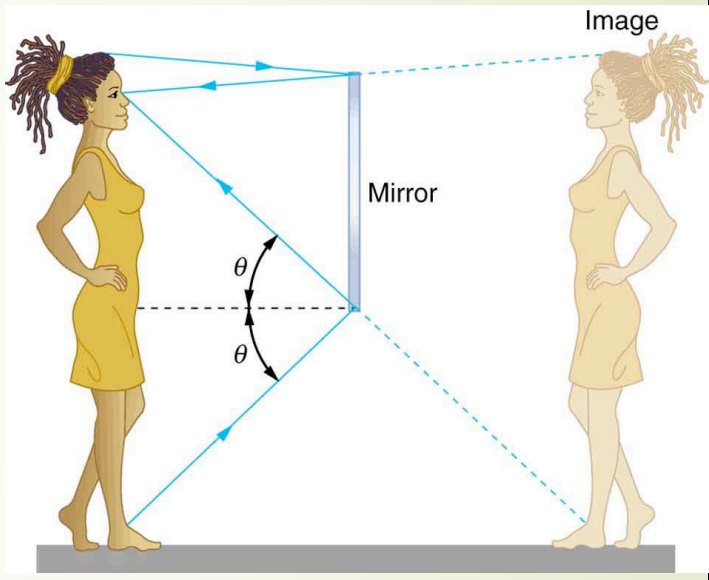
$$\theta_1' = \theta_1$$

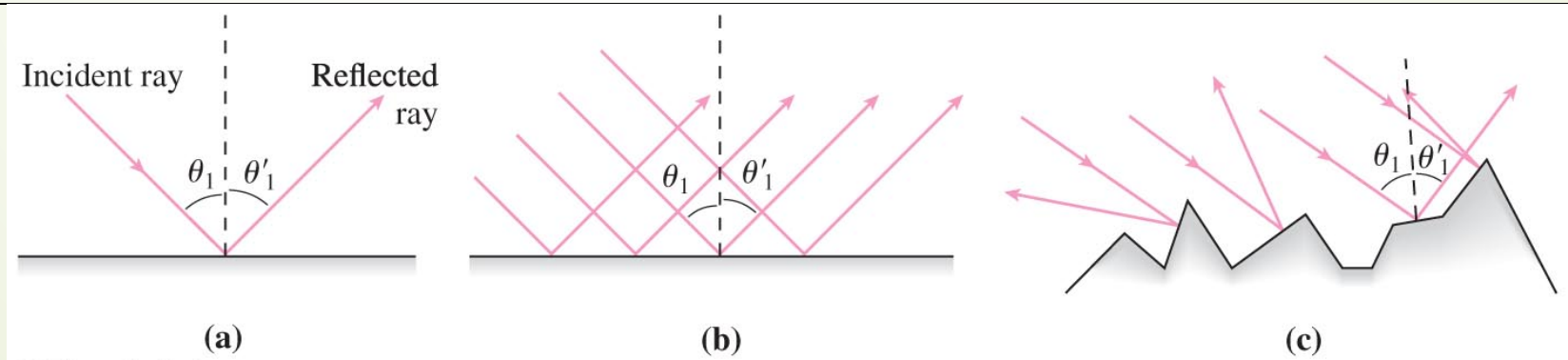
The surface then looks shiny and can form images.

- This is called *specular reflection* (figure (b) below).

For rough surfaces, parallel rays reflect at random angles.

- This is called *diffuse reflection* (figure (c) below).

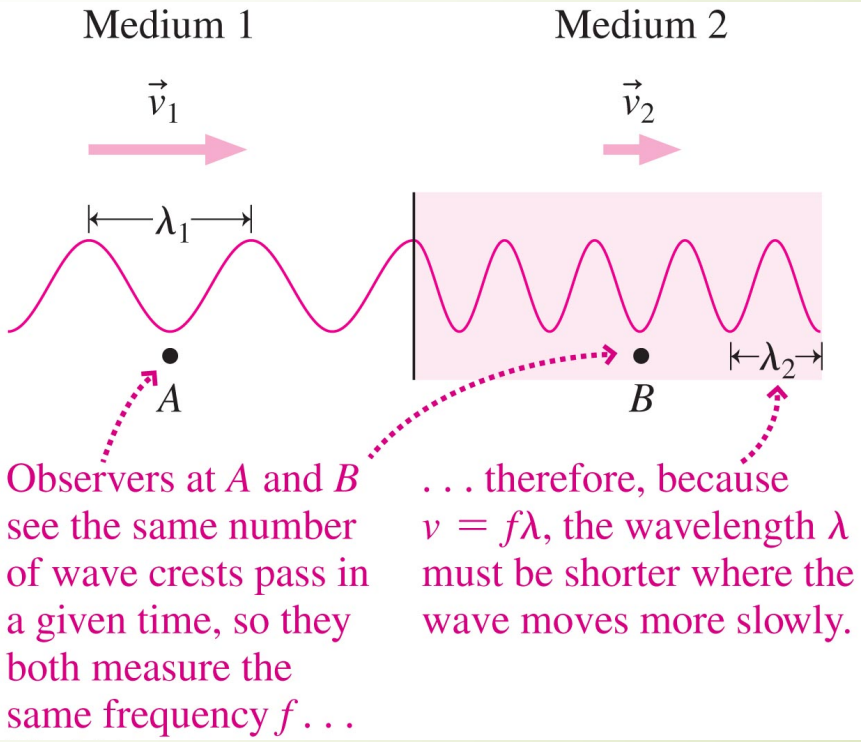




The Speed of EM wave (Light) in Matter

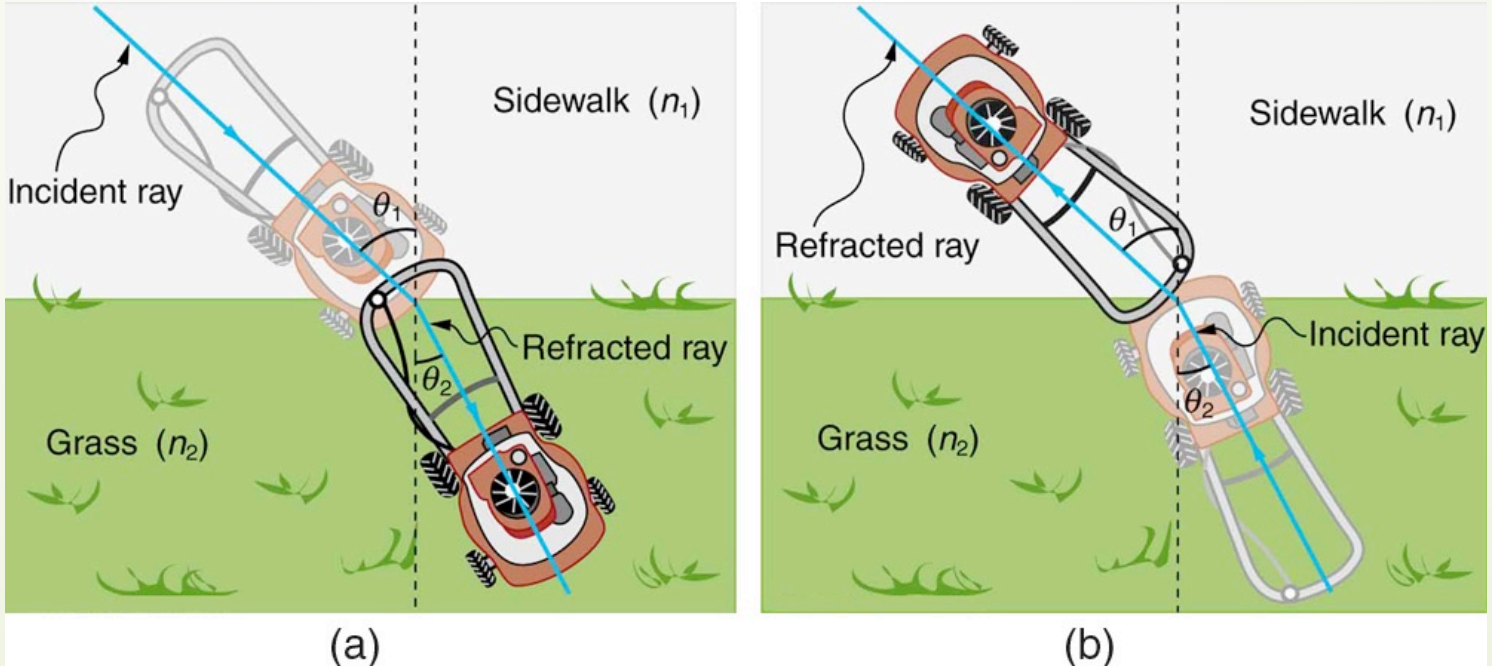
In matter, the speed of light is slower than in vacuum. The **index of refraction**, n, gives the unitless ratio of the speed of light in vacuum, c, and the speed of light in a material, v, given by the equation $n = \frac{c}{v}$.

medium	n
air at 0°C, 1 atm	1.000293
benzene	1.501
water	1.333
diamond	2.419



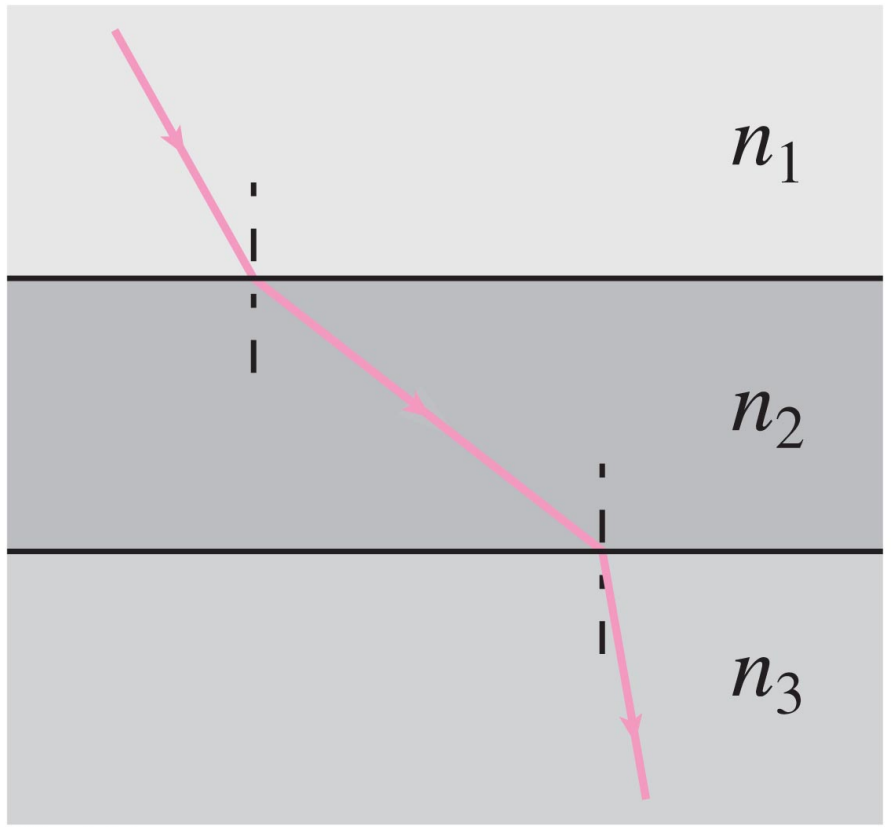
Refraction

- **Refraction** is the bending of light as it crosses the interface between two different transparent media.
- Refraction occurs because the wave speed differs in different media.
- For light, the **index of refraction**, $n = \frac{c}{v}$ describes the speed change.
- The speed of a wave in a medium is $v = \frac{c}{n}$.



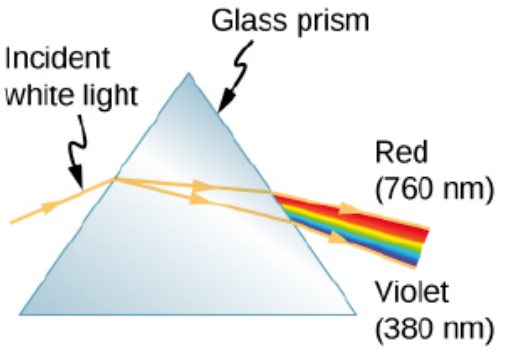
Concept Check!

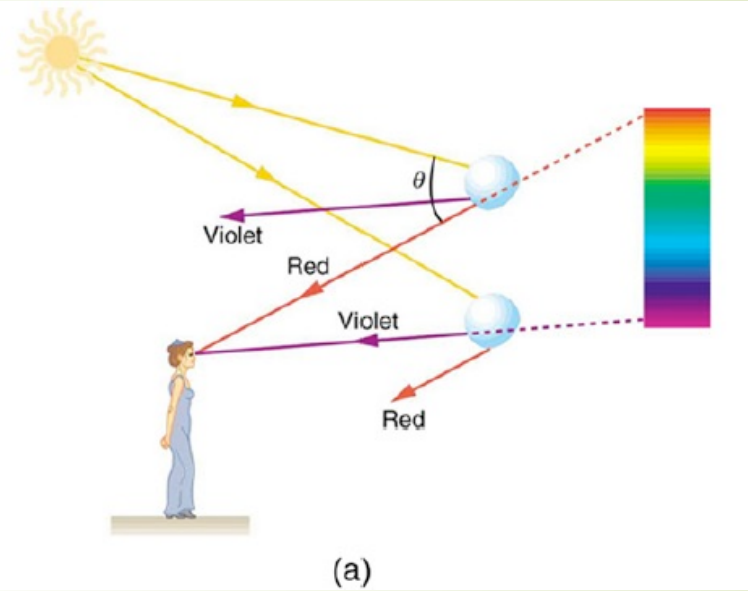
- The figure shows the path of a light ray through three different media. Rank the media according to their refractive indices, in decreasing order.



Dispersion

Dispersion: The refractive index depends on wavelength, and therefore refraction disperses the different wavelengths in slightly different directions. Dispersion is defined to be the spreading of white light into its full spectrum of wavelengths.





Medium	Red (660 nm)	Orange (610 nm)	Yellow (580 nm)
Water	1.331	1.332	1.333
Diamond	2.410	2.415	2.417
Glass, crown	1.512	1.514	1.518
Glass, flint	1.662	1.665	1.667
Polystyrene	1.488	1.490	1.492
Quartz, fused	1.455	1.456	1.458