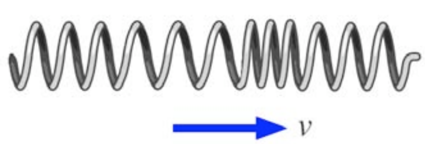
waves

the wave model

A traveling wave is an organized disturbance
propagating at a well-defined wave speed v.

• In transverse waves the particles of the medium move **perpendicular** to the direction of wave propagation.

• In longitudinal waves the particles of the medium move **parallel** to the direction of wave propagation.



A wave transfers **energy**, but no material or substance is transferred outward from the source.

demo

three types of waves

Three types of waves:

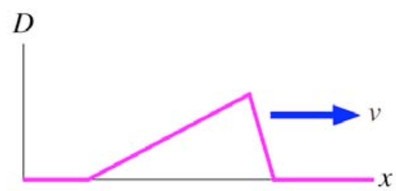
- Mechanical waves travel through a material medium such as water or air.
- Electromagnetic waves require no material medium and can travel through vacuum.
- Matter waves describe the wave-like characteristics of atomic-level particles.

For mechanical waves, the speed of the wave is a property of the medium. Speed ***does not*** depend on the size or shape of the wave.

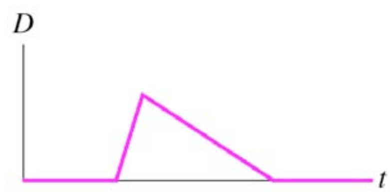
wave graphs

The displacement D of a wave is a function of both position (where) and time (when).

- A snapshot graph shows the wave's displacement as a function of position at a single instant of time.



- A history graph shows the wave's displacement as a function of time at a single point in space.



A wave traveling in the positive x-direction with speed v is a function of the form $D(x-vt)$
negative x-direction $D(x+vt)$

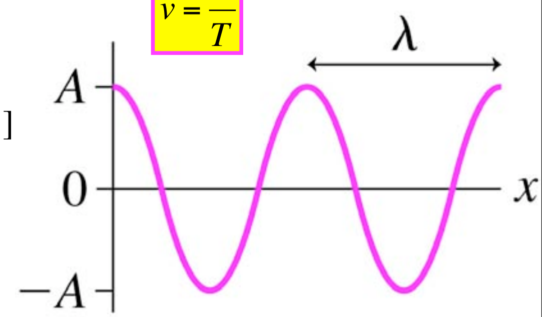
sinusoidal waves

Sinusoidal waves are periodic in both time (period T) and space (wavelength λ).

$$v = \frac{\lambda}{T}$$

$$D(x,t) = A\sin[2\pi(\frac{x}{\lambda} - \frac{t}{T}) + \phi_o]$$

$$D(x,t) = A\sin[kx - \omega t + \phi_o]$$



A = **amplitude**
$k = 2\pi/\lambda$ = **wave number**
$\omega = 2\pi f$ = **angular frequency**
ϕ_o = **phase constant** determined by the initial conditions.

wave speed

Spead of a (transverse, mechanical) wave on a string:

$$v = \sqrt{\frac{T_s}{\mu}} = \sqrt{\frac{T_s L}{m}}$$

$\mu = \frac{m}{L}$ = linear density of the string

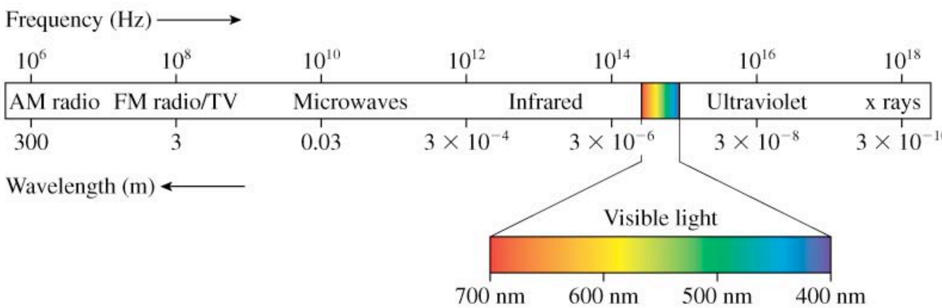
Speed of sound (longitudinal mechanical wave) in air at 20°C: $v = 343\frac{m}{s}$

Speed of light (transverse, electromagnetic wave) in vacuum: $c = 3x10^8\frac{m}{s}$

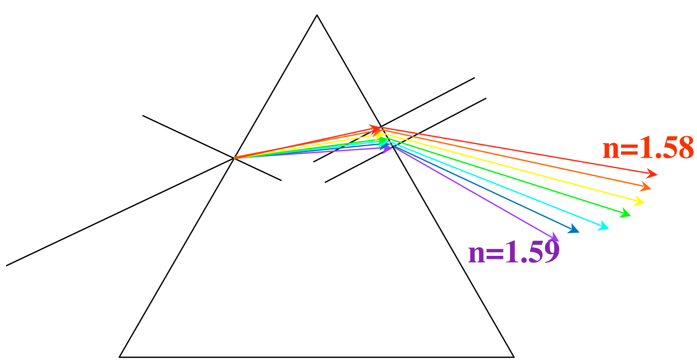
Speed of light (transverse, electromagnetic wave) in a medium: $v = \frac{c}{n}$

n = index of refraction of the medium

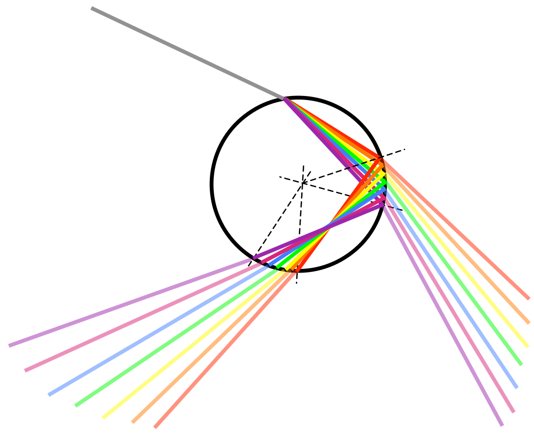
the electromagnetic spectrum



Different colors have different wavelengths

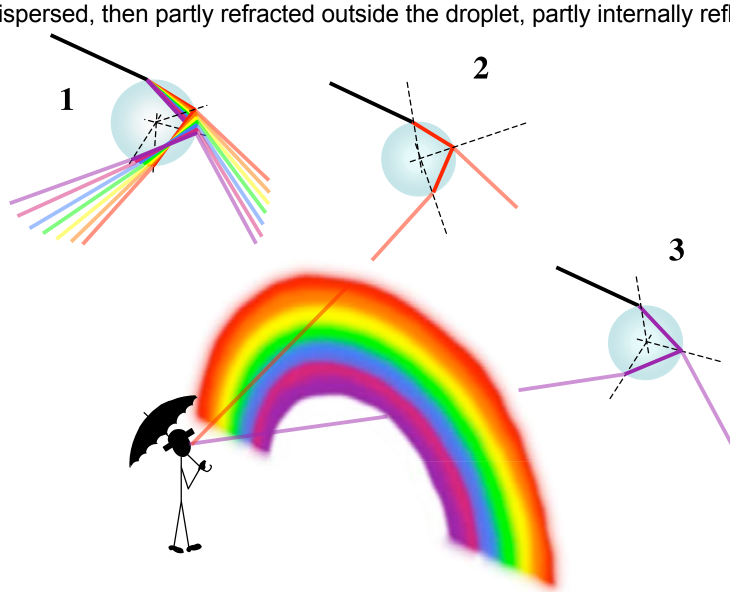


rainbow: refraction, dispersion, reflection, refraction



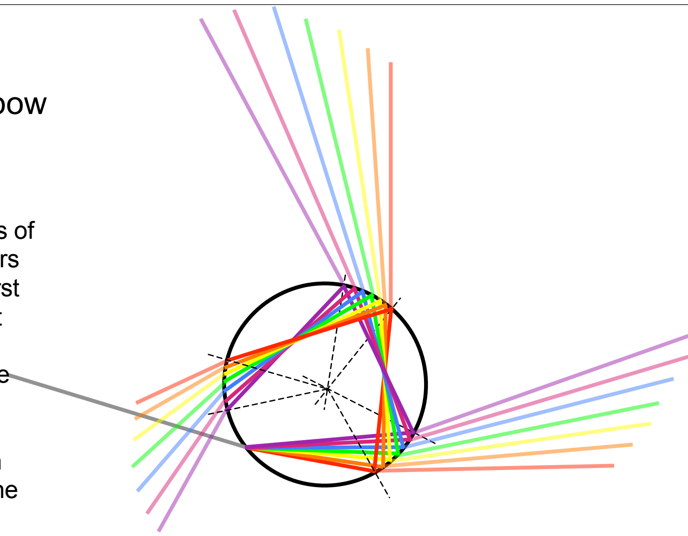
how the rainbow forms

Each water droplet, schematically represented by a sphere, is penetrated by white light, which is dispersed, then partly refracted outside the droplet, partly internally reflected



double rainbow

The first four refractions of dispersed rainbow colors are shown here. The first occurs when white light enters the droplet, the following ones when the dispersed colors are refracted outside the droplet. Each refraction is a less intense than the previous. This is why the second rainbow is always weaker than the first



Doppler effect

Occurs when a wave source and a detector are moving wrt each other:
the frequency detected *f* differs from the frequency emitted f_o

Sound source approaching observer

$$f_+ = \frac{f_o}{1 - \frac{v_s}{v}}$$

Observer approaching sound source

$$f_+ = (1 + \frac{v_o}{v}) f_o$$

Sound source moving away from observer

$$f_- = \frac{f_o}{1 + \frac{v_s}{v}}$$

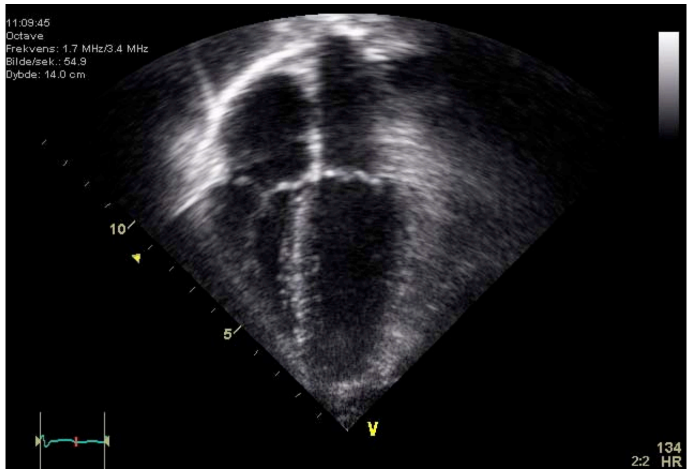
Observer moving away from sound source

$$f_- = (1 - \frac{v_o}{v}) f_o$$

demo doppler

Doppler effect

An echocardiogram uses only ultrasounds (mechanical waves, 1.7 - 4.4 MHz)



Doppler effect

An echocardiogram uses only ultrasounds (mechanical waves, 1.7 - 4.4 MHz)

Doppler ultrasound (colors), shows blood flow, its speed and direction.