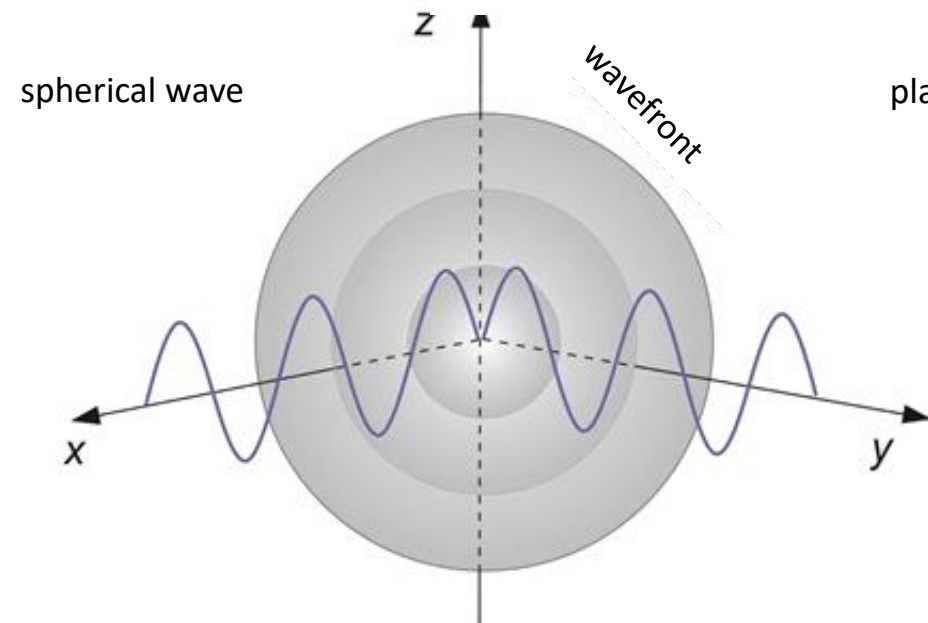
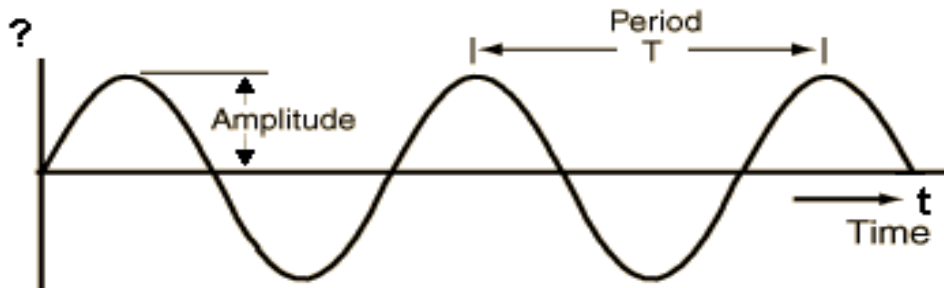
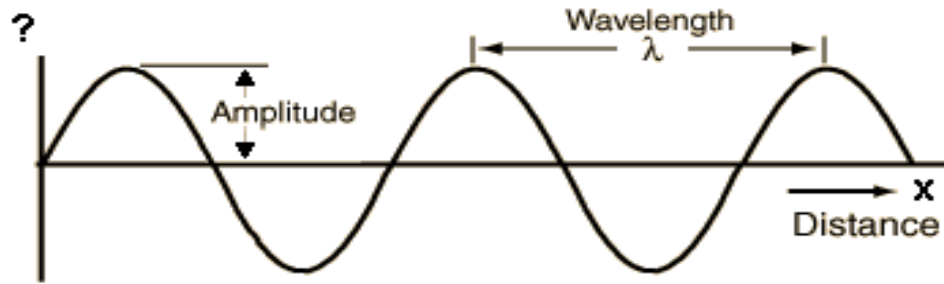


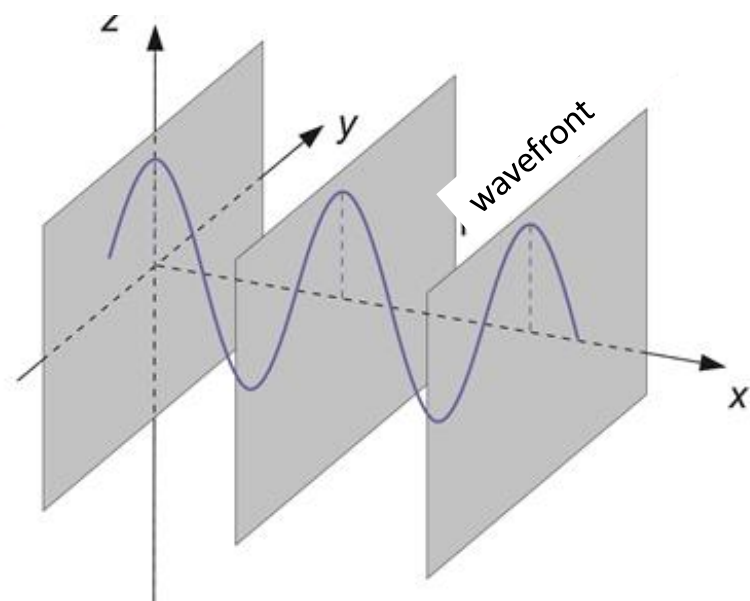
# Waves

Ádám Orosz

# Basics

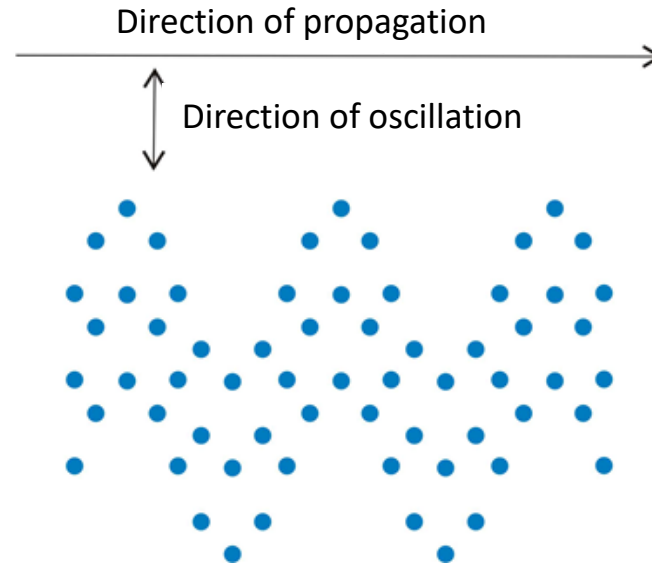


plane wave

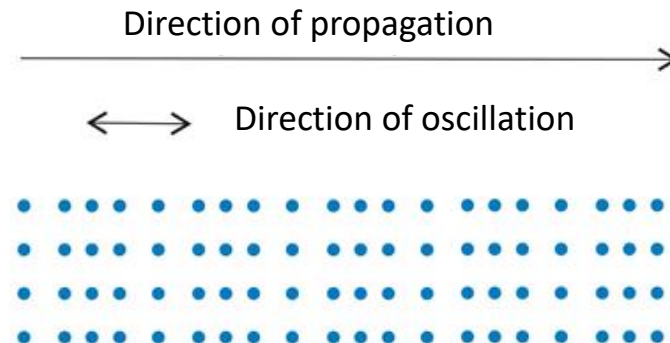


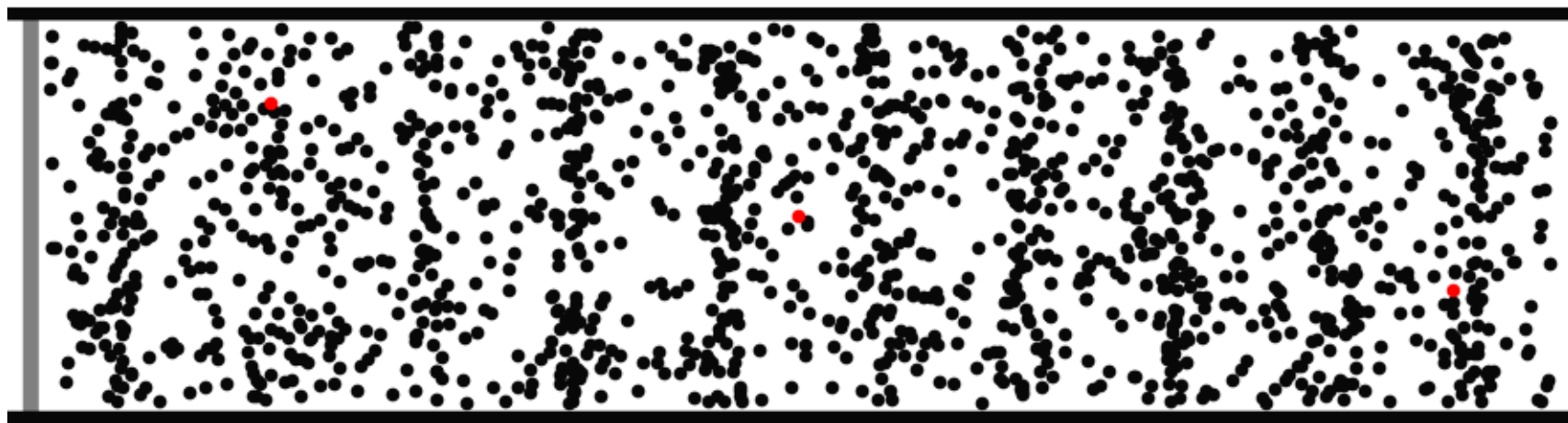
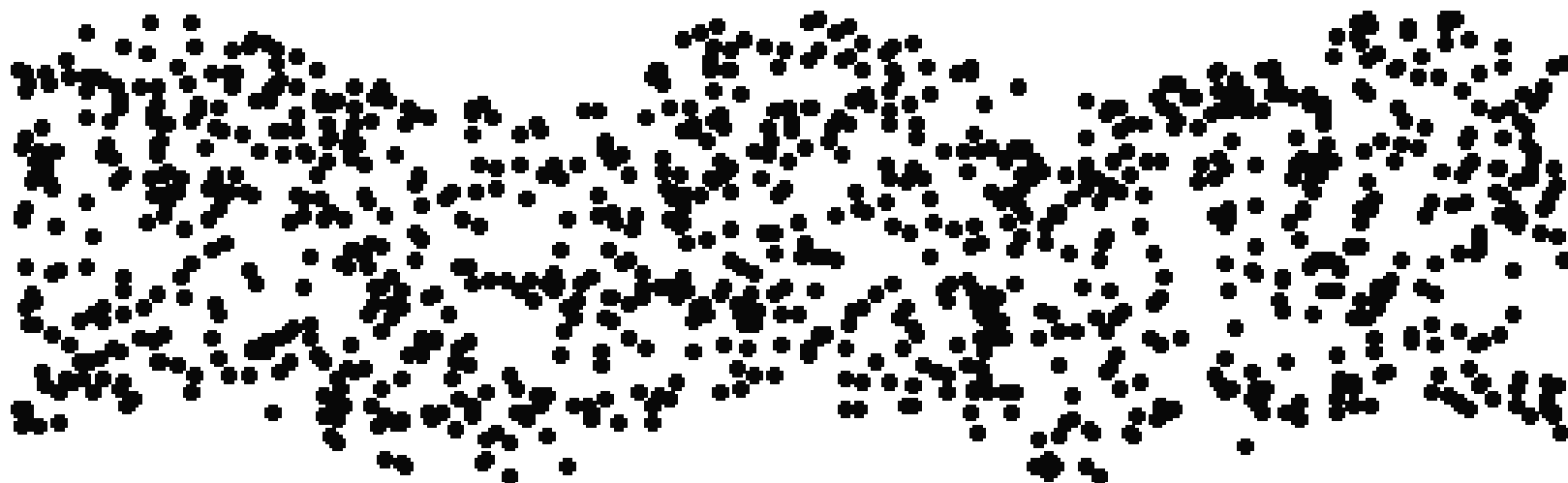
# Direction of propagation and oscillation

Transverse wave

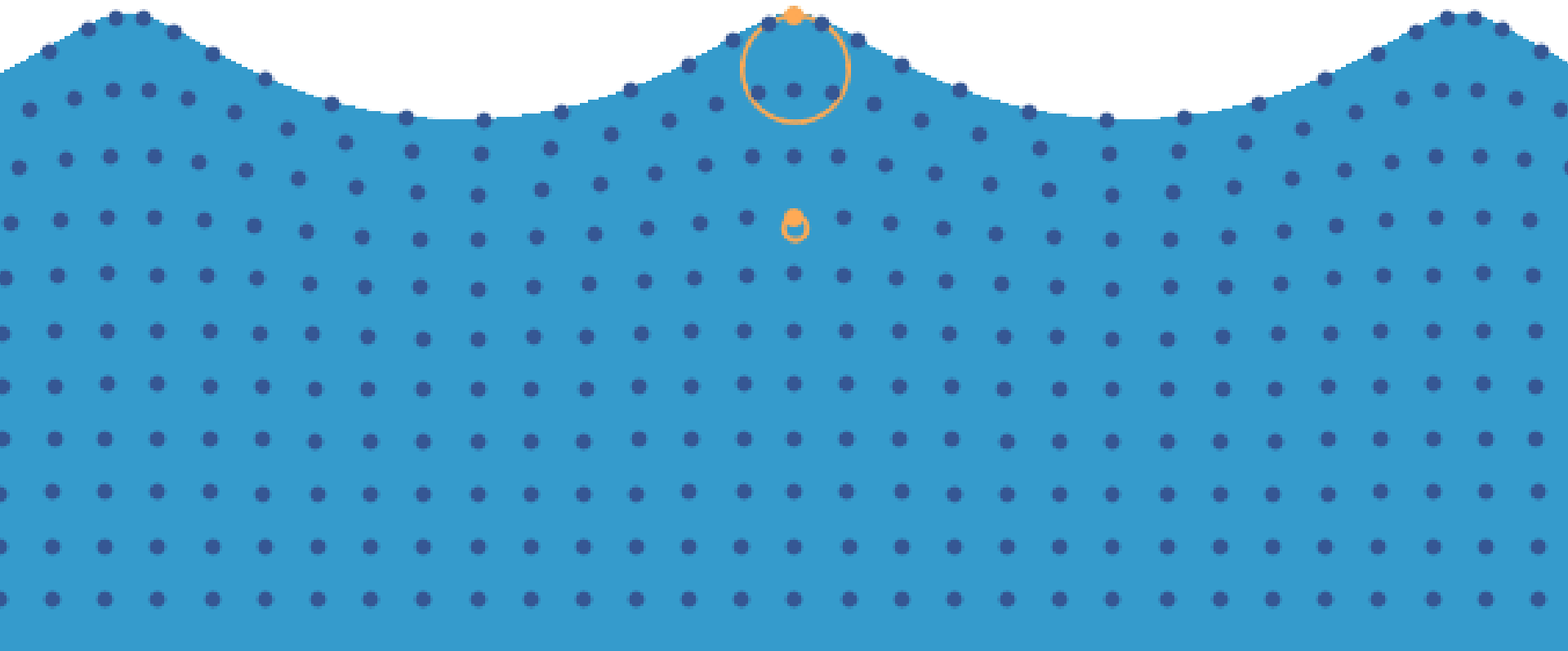


Longitudinal wave



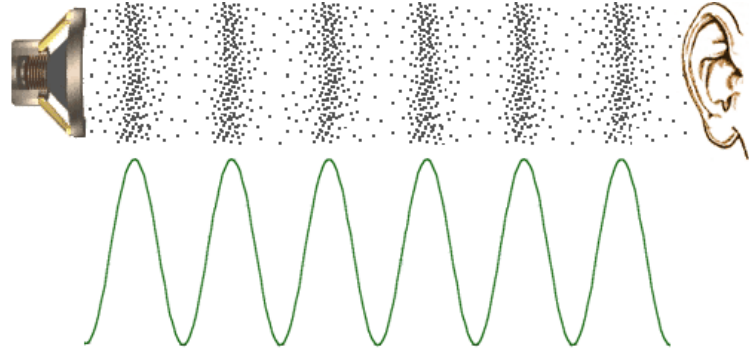


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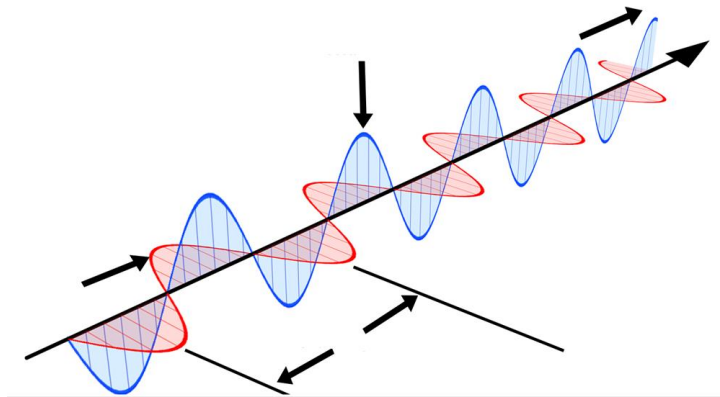


# Types of waves

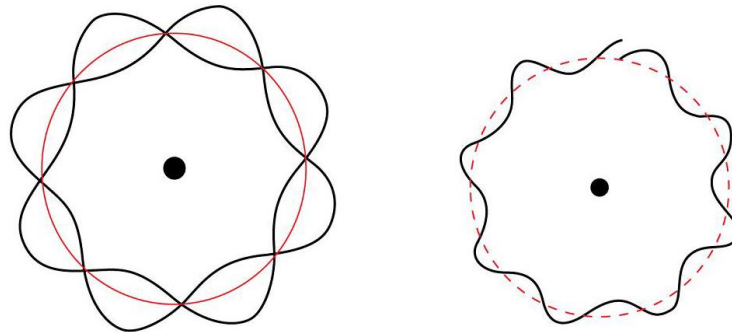
- mechanical



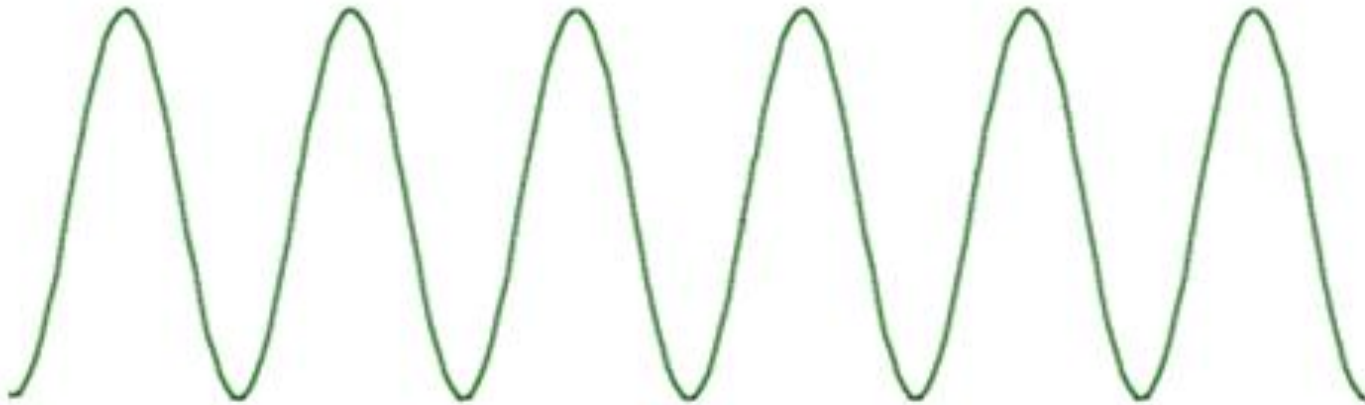
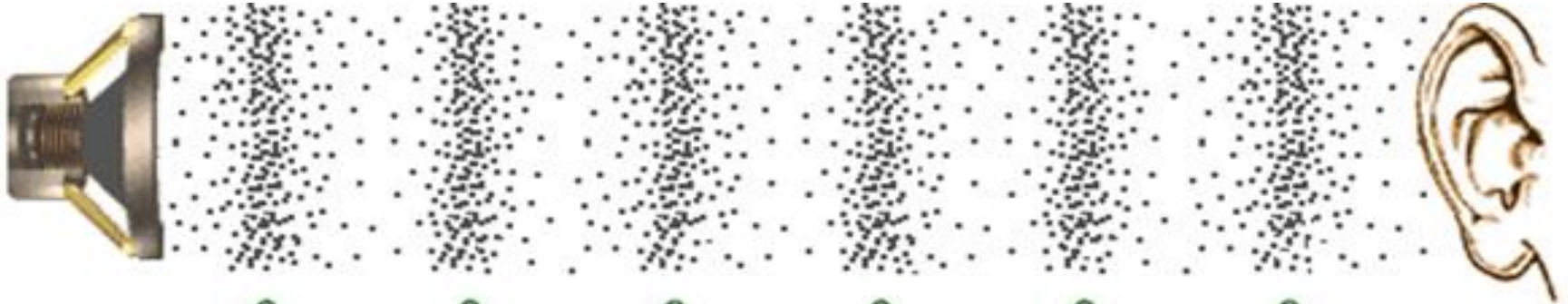
- electromagnetic



- matter

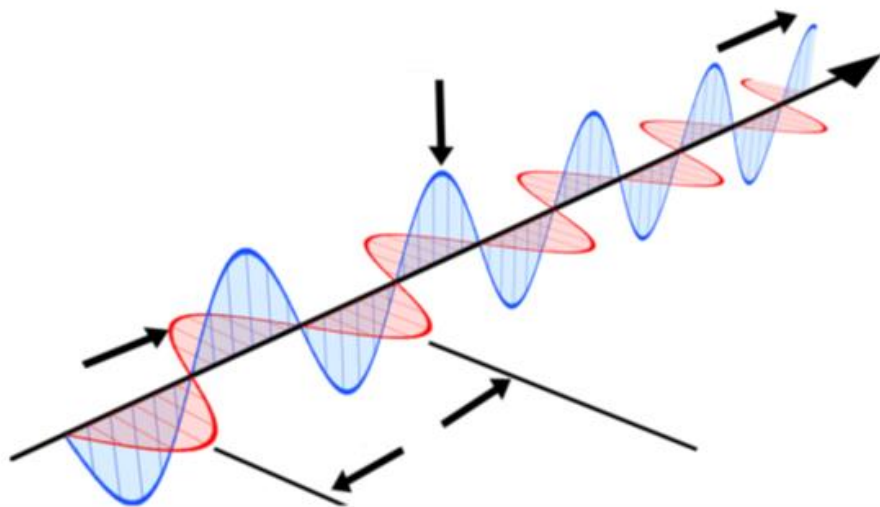


# Sound

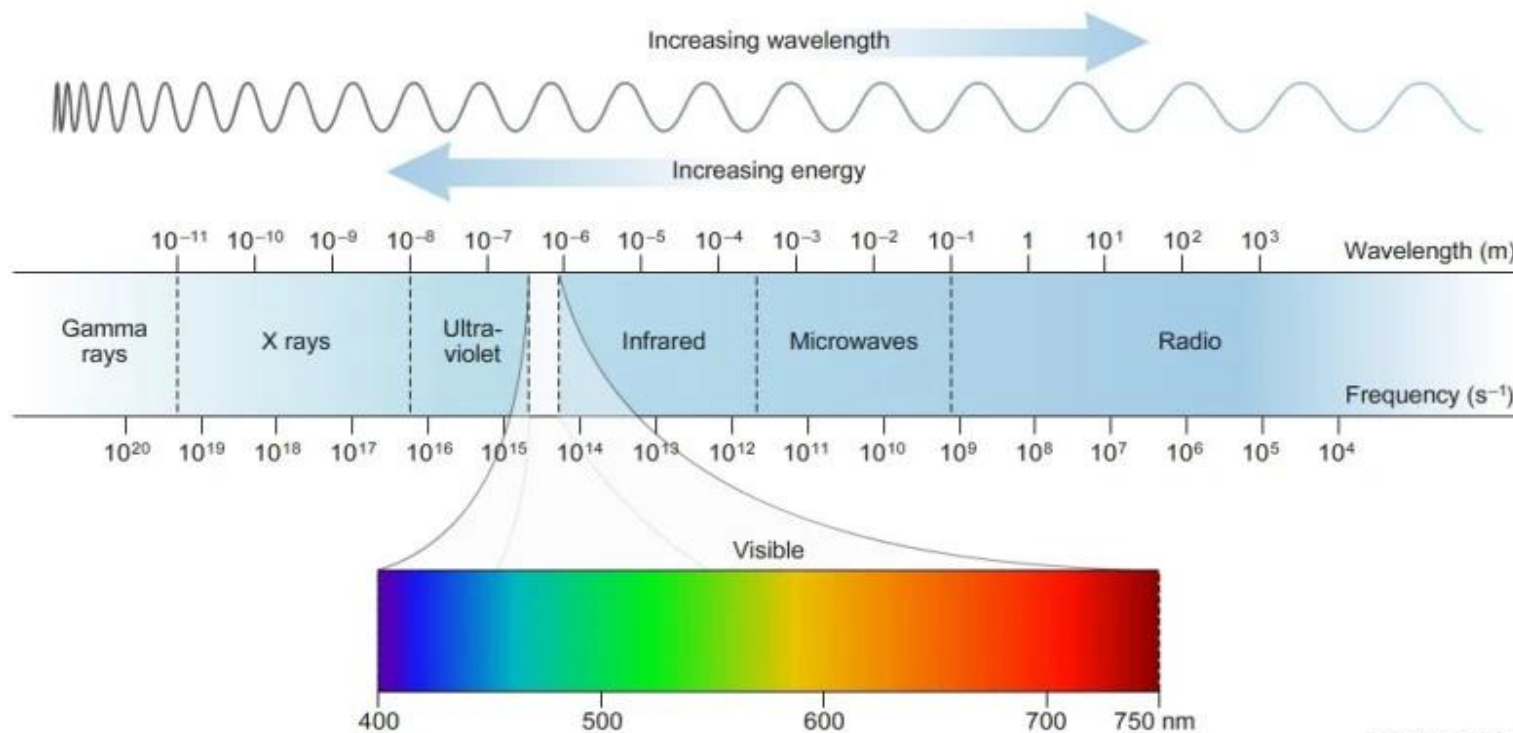


infrasound	audible sound	ultrasound	hypersound
$< 20 \text{ Hz}$	$20 - 20000 \text{ Hz}$	$20000 - 10^9 \text{ Hz}$	$10^9 \text{ Hz} <$
medium		$c_{\text{sound}} \text{ (m/s)}$	
air ( $0^\circ\text{C}$ , 101 kPa)		330	
water ( $20^\circ\text{C}$ )		1483	
muscle		1568	
iron		5950	

# Electromagnetic waves

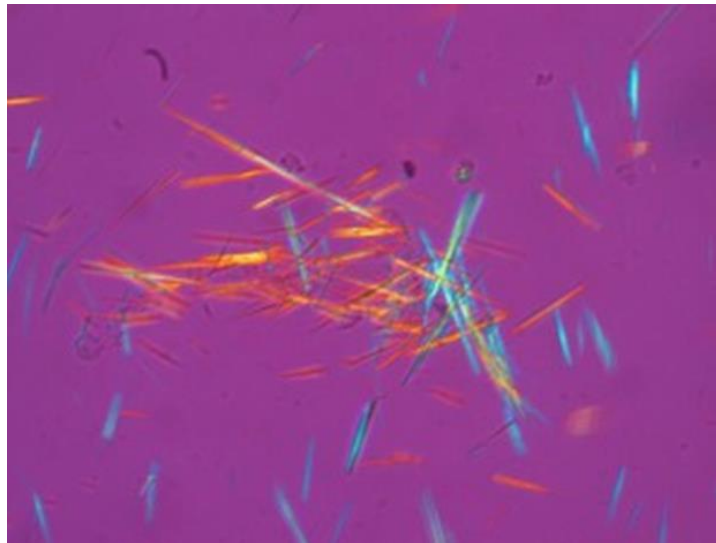
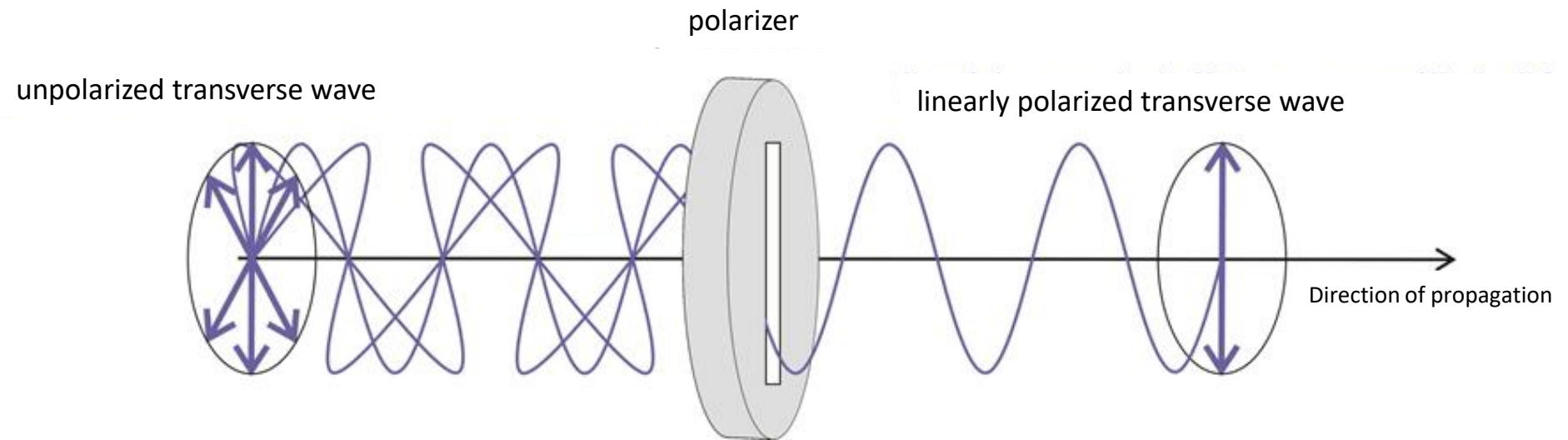


$$c = 299\,792\,458 \frac{m}{s} \approx 3 * 10^8 \frac{m}{s}$$

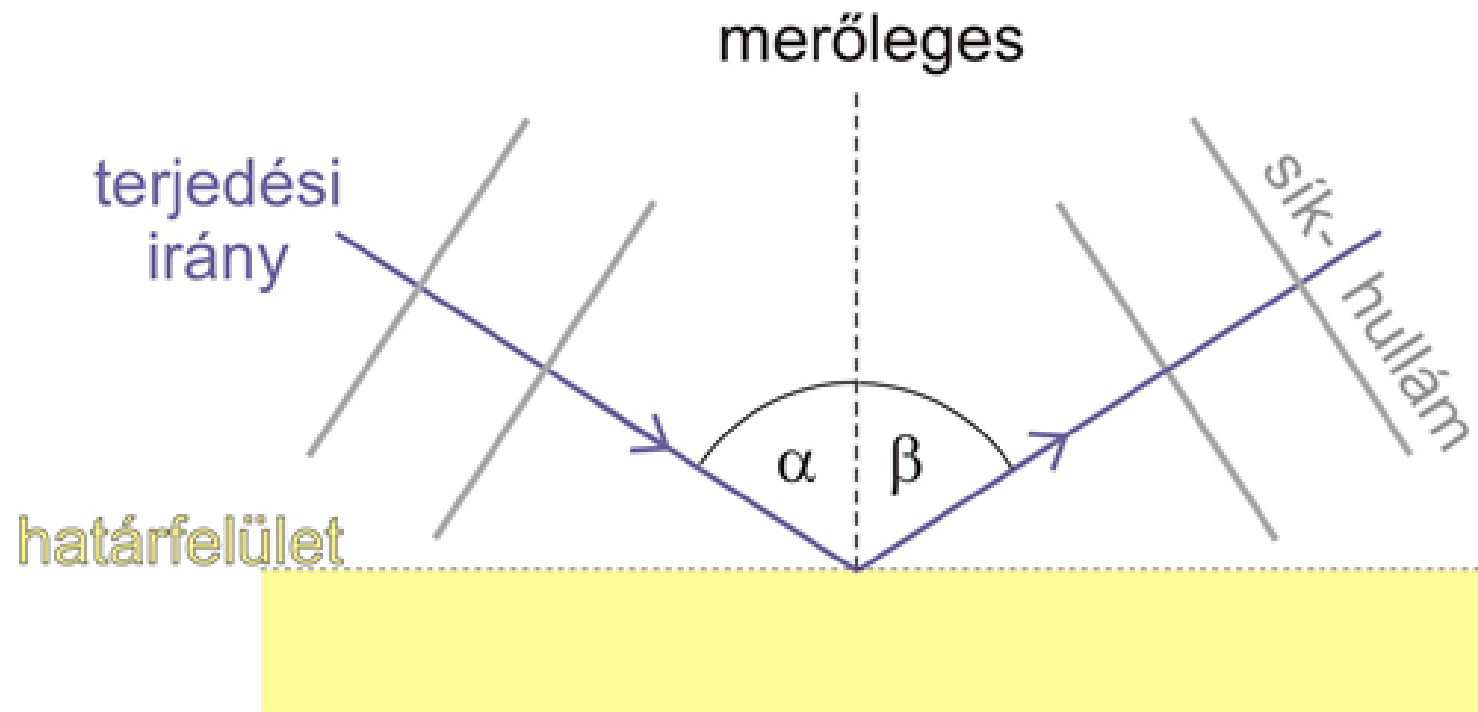




# Polarisation



# Reflection



$$\alpha = \beta$$

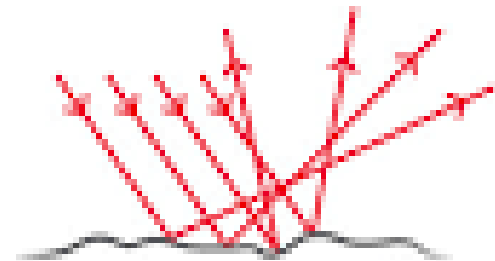
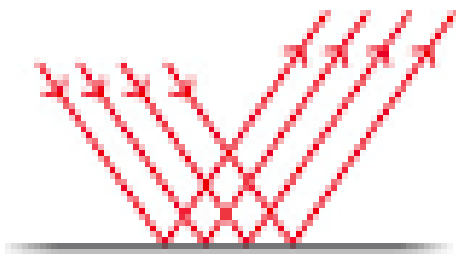
Specular reflection



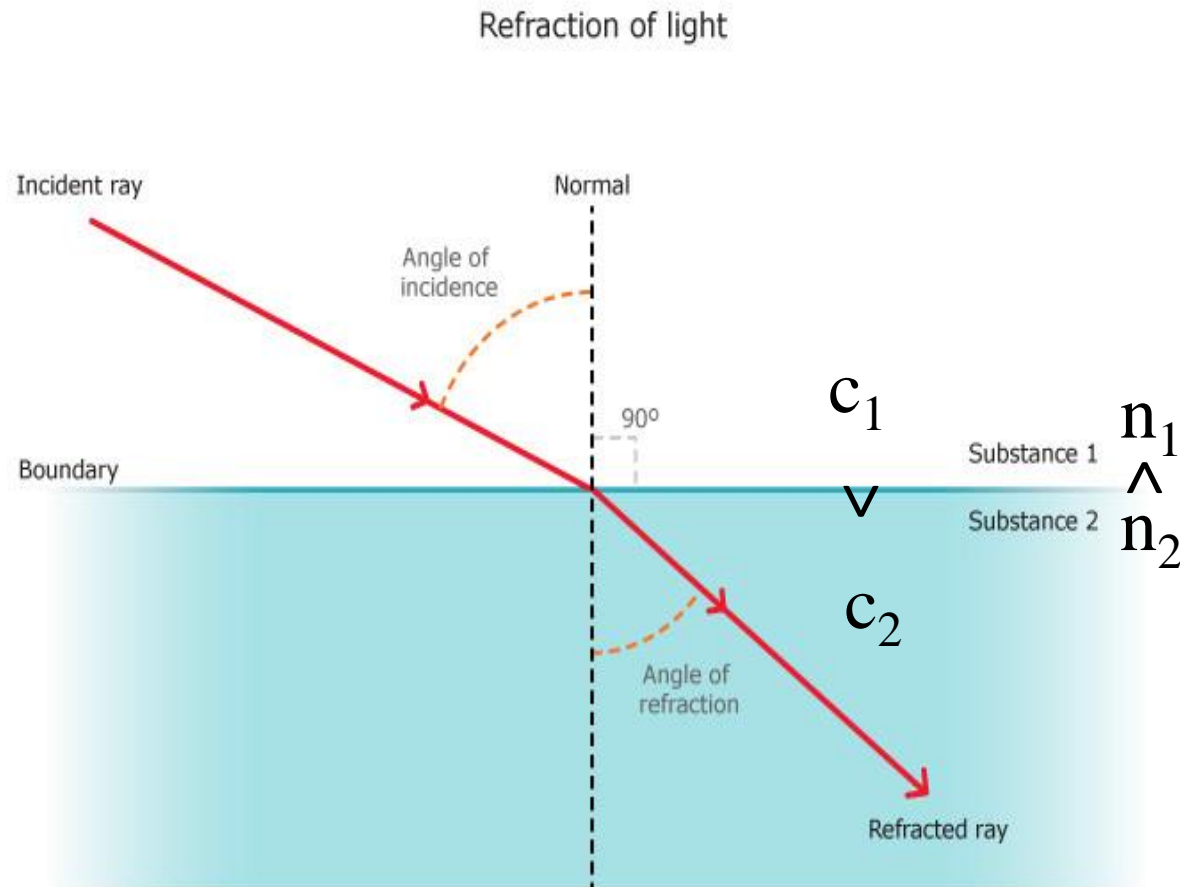
Diffuse reflection



Carol Highsmith/LOC



# Refraction



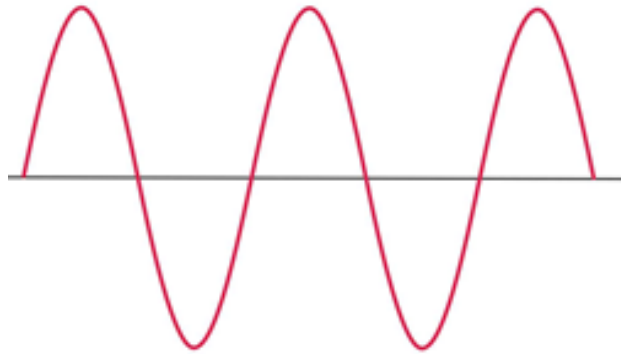
$$\frac{\sin \alpha}{\sin \beta} = \frac{c_1}{c_2} = \frac{n_2}{n_1}$$

# Wave phenomena - Interference

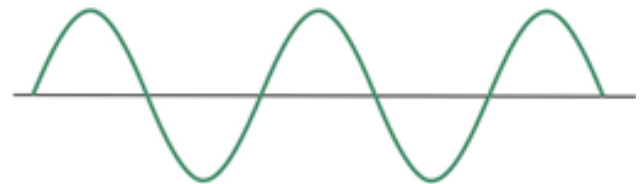
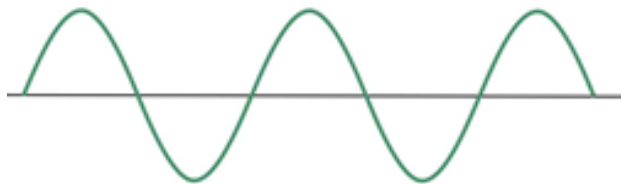
positive interference

negative interference

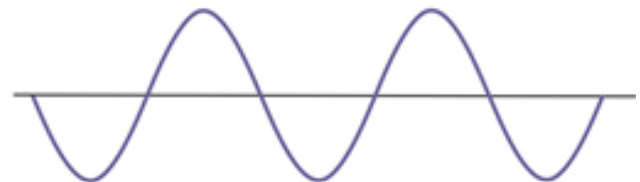
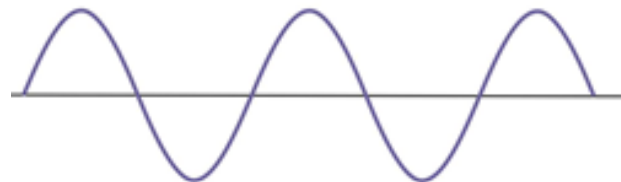
result



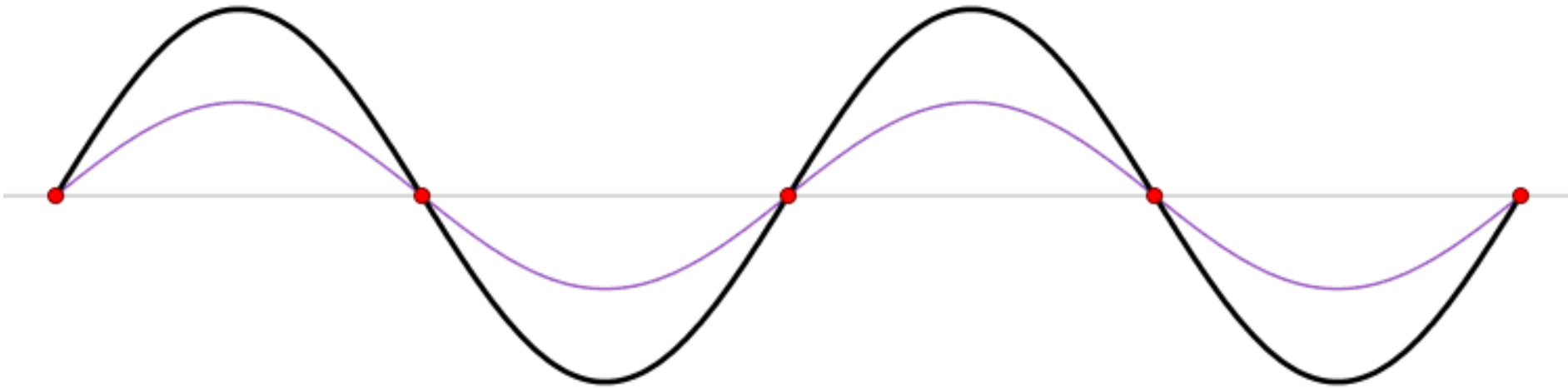
wave 1



wave 2

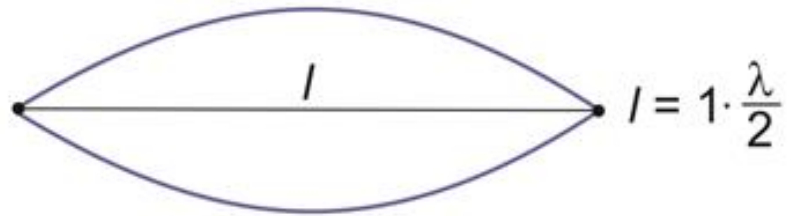


# Wave phenomena – Standing waves

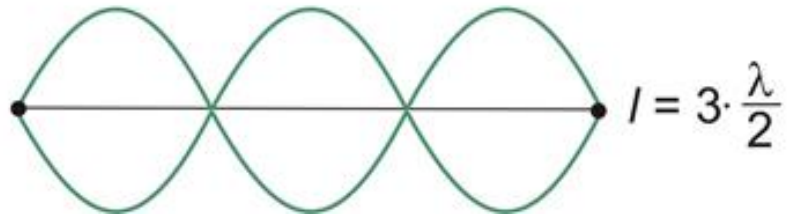
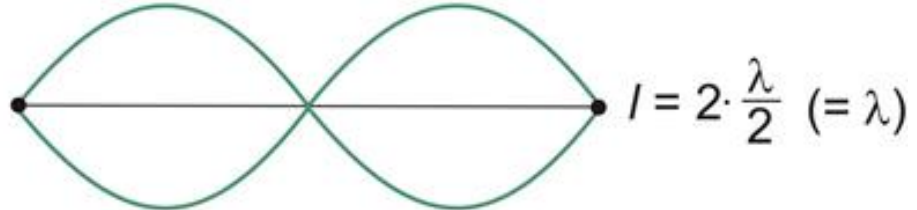


# Wave phenomena – Standing waves

Fundamental frequency

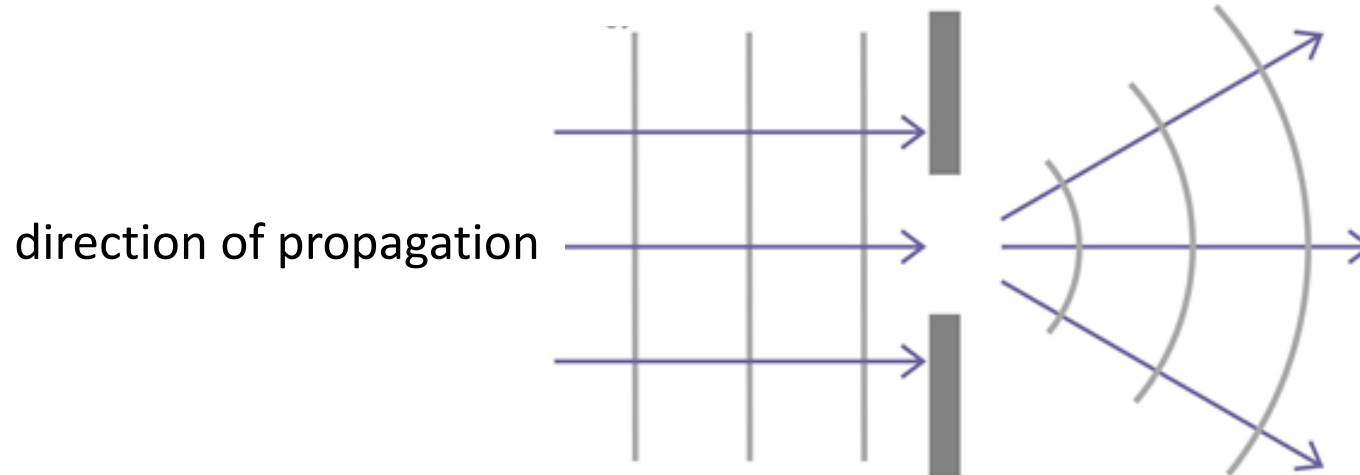
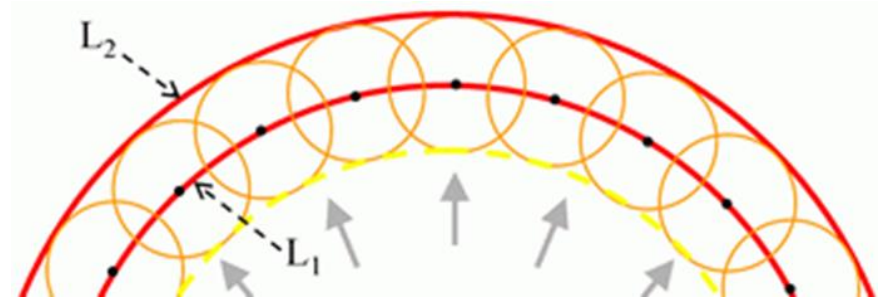


Higher harmonics (overtones)

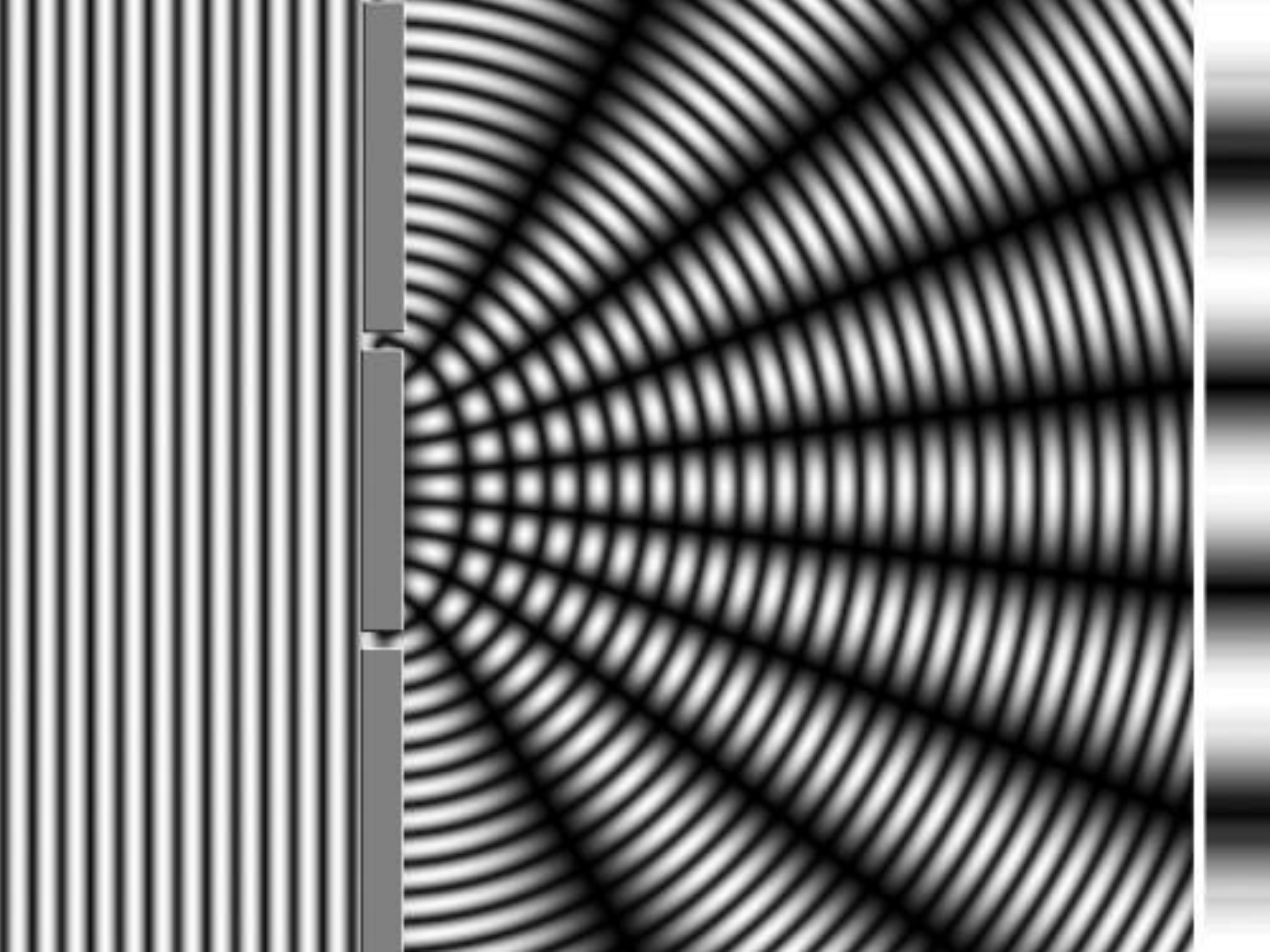


# Wave phenomena - Diffraction

- Huygens-Fresnel-principle
- Diffraction







# Problem 1.

Waves are propagating on the surface of water towards the shore with a velocity of 1.5 m/s. The distance between two neighboring crests is six meters. There is a piece of wood somewhere further in the water that turns up and disappears periodically as the water waves when you are looking at it from the shore. Calculate the time interval between two turn-ups. ?

$$c = 1,5 \frac{\text{m}}{\text{s}}$$

$$\lambda = 6 \text{ m}$$

$$c = \frac{\lambda}{T} \Rightarrow T = \frac{\lambda}{c} = \frac{6 \text{ m}}{1,5 \frac{\text{m}}{\text{s}}} = \underline{\underline{4 \text{ s}}}$$

## Problem 2.

A sound wave arrives from air (0°C) at the water surface (20°C). Angle of incidence is 10°. Calculate the angle of refraction!

$$c_{\text{air } 0^{\circ}\text{C}} = 330 \frac{\text{m}}{\text{s}}$$

$$\alpha = 10^{\circ}$$

$$c_{\text{water } 20^{\circ}\text{C}} = 1483 \frac{\text{m}}{\text{s}}$$

$$\sin \beta = \sin \alpha \cdot \frac{c_2}{c_1}$$

$$\underline{\underline{\beta = 51,3^{\circ}}}$$

# Thermodynamics

# Thermal motion, thermal energy

translation, rotation, vibration

# Temperature and its scales

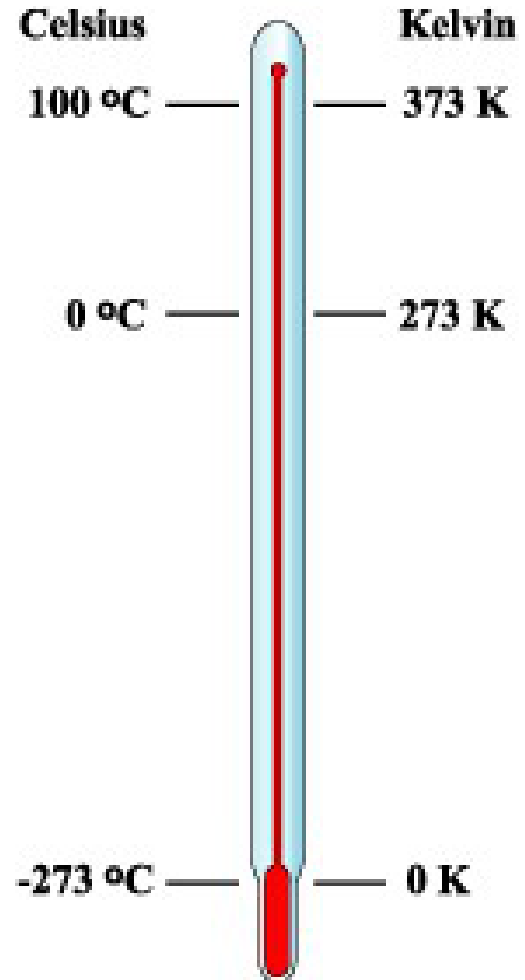
$$T_{\text{Celsius}} = T_{\text{Kelvin}} - 273$$
$$T_{\text{Kelvin}} = T_{\text{Celsius}} + 273$$

Temperature influences several properties:  
volume (hőtágulás)

color

electrical resistance

pressure of gases



# Specific heat capacity ( $c$ ) and specific latent heat ( $L$ )

$$Q = c \cdot m \cdot \Delta T$$

$$L = \frac{Q}{m}$$

# Ideal gas

properties:

particles without V

elastic collisions

only translation

Description of its state:

$$pV = nRT$$

*or*

$$pV = NkT$$

$$k = 1,38 * 10^{-23} \text{ J/K}$$

$$R = 8,31 \text{ J/mol*K}$$

Simple conditions for state transitions: isobar, isotherm, isochor



# Problem

A metal gas container is left lying under the shining Sun. The initial pressure of the ideal gas inside is 50 bar. Its temperature increases as a result of the sunshine from 12 °C to 72 °C. What will be the final pressure?

$$p = 50 \text{ bar}$$

$$p \cdot V = n \cdot R \cdot T$$

$$72^\circ\text{C} \rightarrow 345$$

$$12^\circ\text{C} \rightarrow 285$$

$$121\%$$

$$50 \cdot 1,21 = 60,5 \text{ bar}$$

$$50 \cdot 0,21 \rightarrow 10,5$$

$$\underline{\underline{60,5 \text{ bar}}}$$