

What is light?

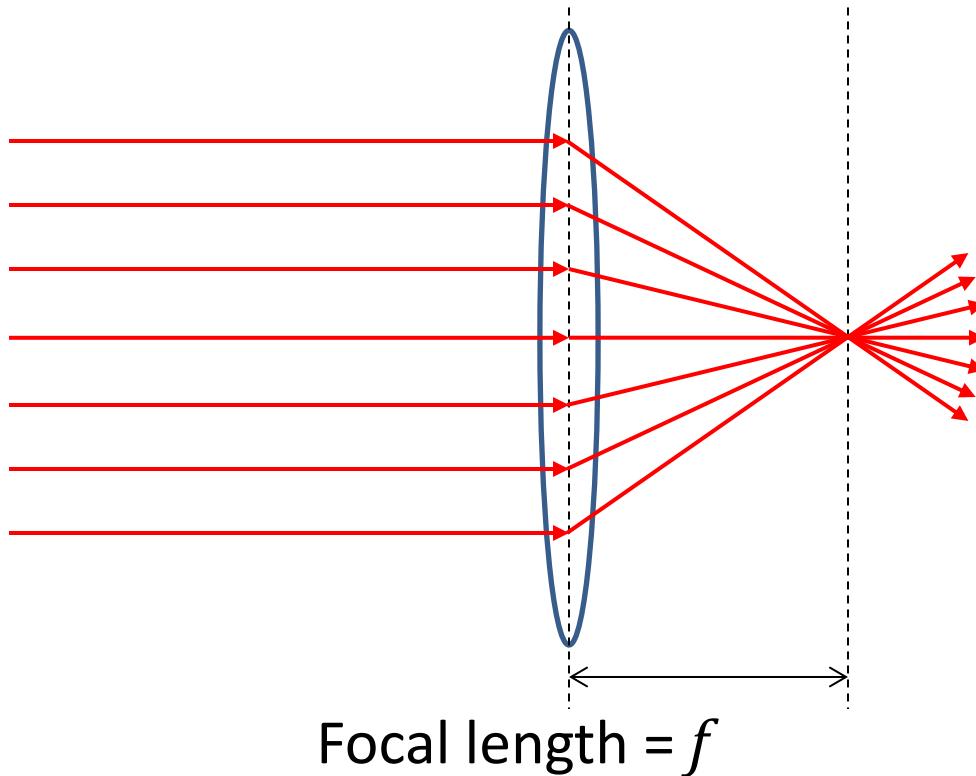
Bo Huang
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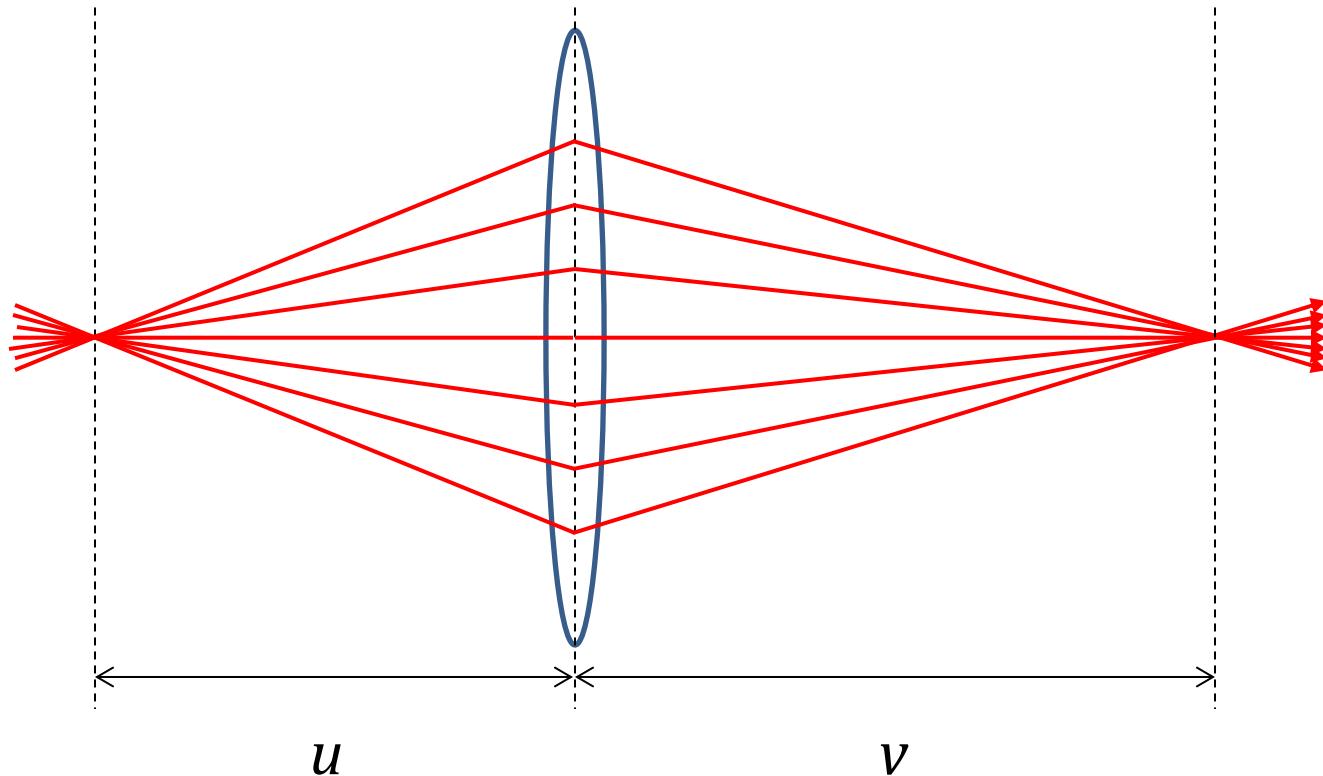
A photograph of a dense forest. Sunlight filters through the thick canopy of leaves, creating bright rays of light that illuminate patches of the ground and some of the tree trunks. The overall atmosphere is dark and幽静 (yōu jìng), with the light being the primary source of illumination.

Light as rays

A simple thin lens

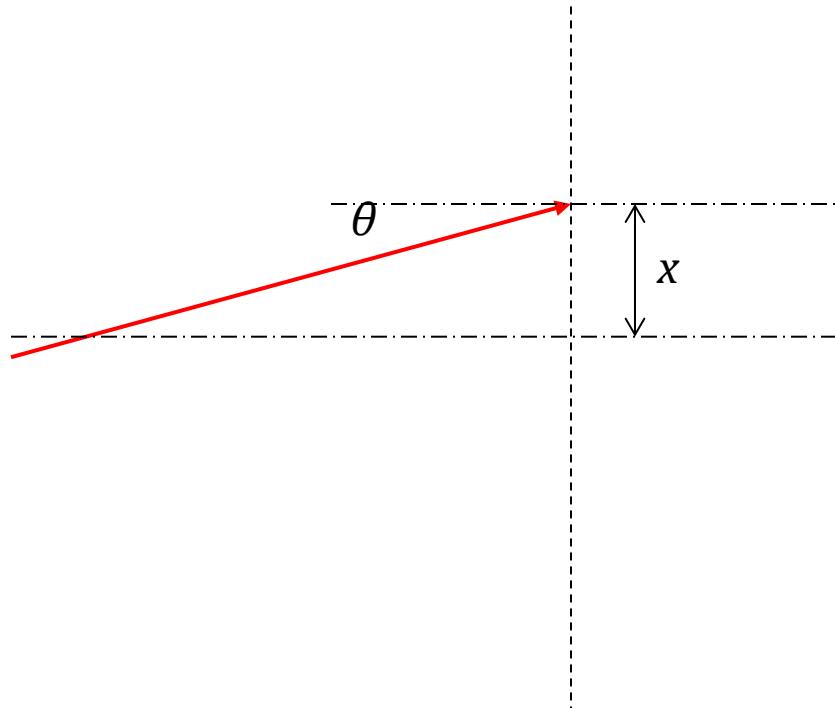


A simple thin lens

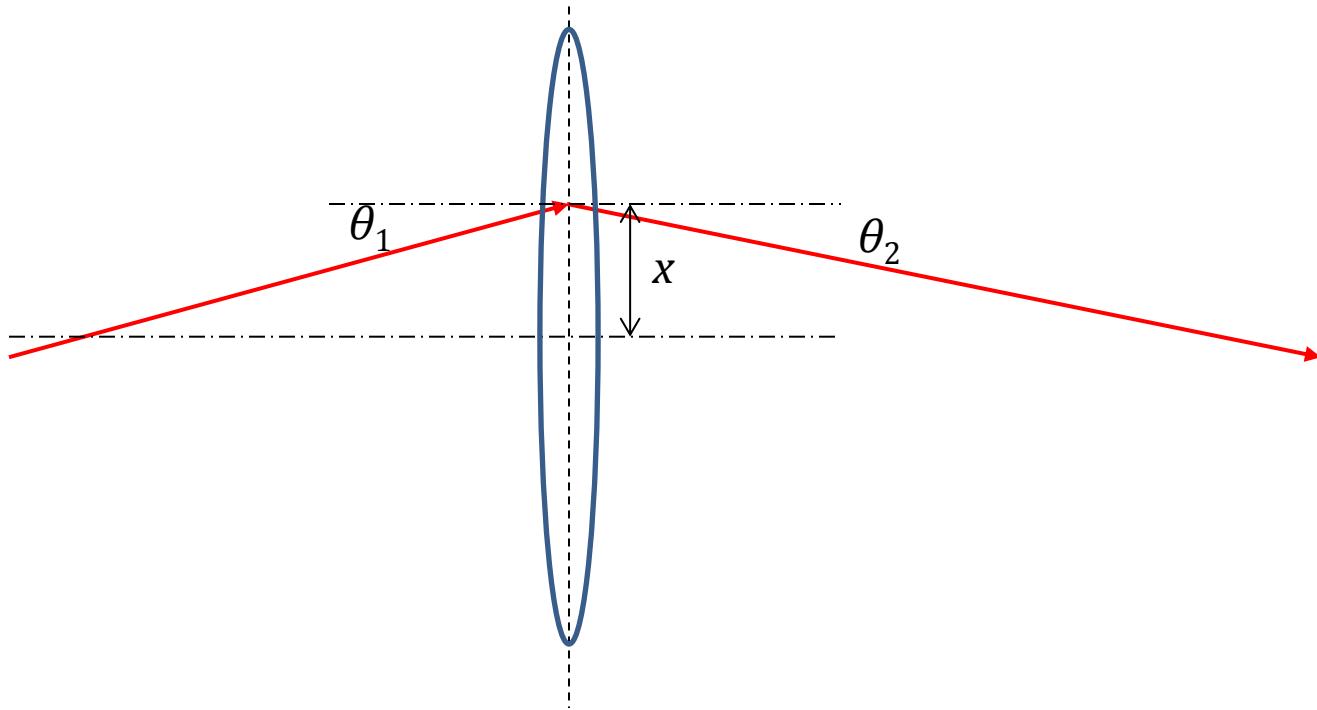


$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

Describing a light ray

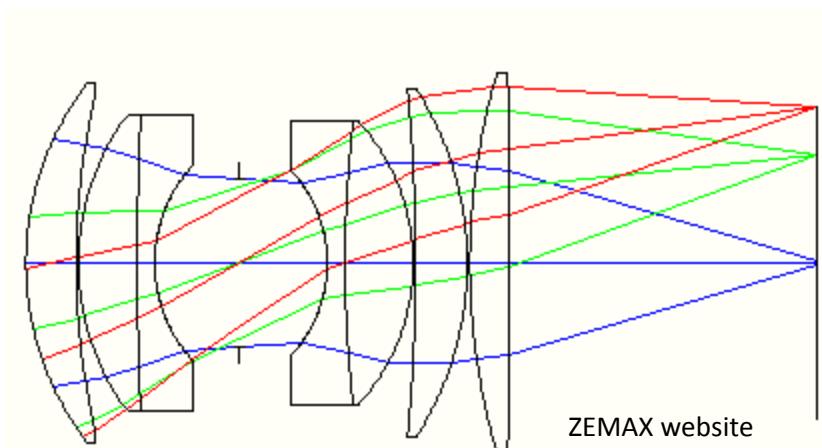


Describing a light ray



$$(x_1, \theta_1) \Rightarrow (x_2, \theta_2)$$

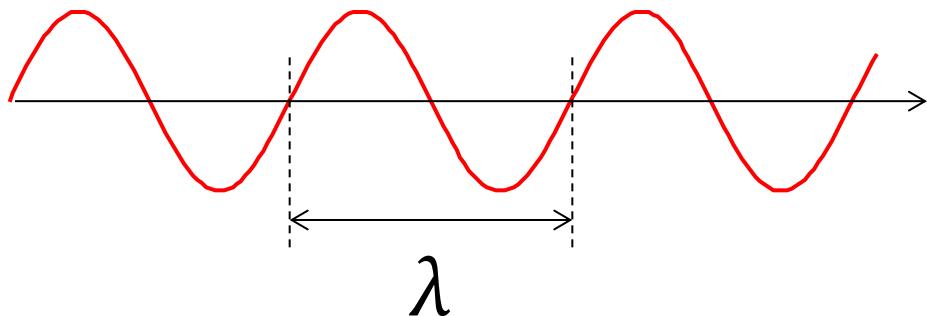
Geometric optics and ray tracing



A photograph of a large, white, cylindrical object, possibly a buoy or a piece of debris, floating in dark blue water. The object casts a prominent, distorted shadow on the water's surface directly beneath it. The shadow is highly textured and wavy, resembling the surface of the water itself. The lighting creates bright highlights on the top of the cylinder and the edges of the shadow, while the rest of the scene is in deep shadow.

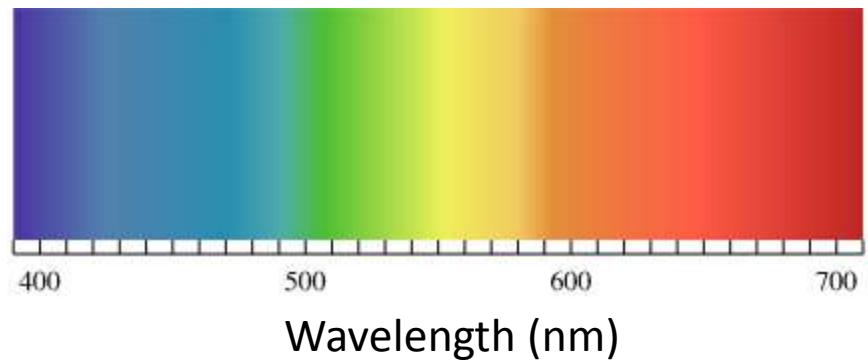
Light as waves

Wavelength and frequency

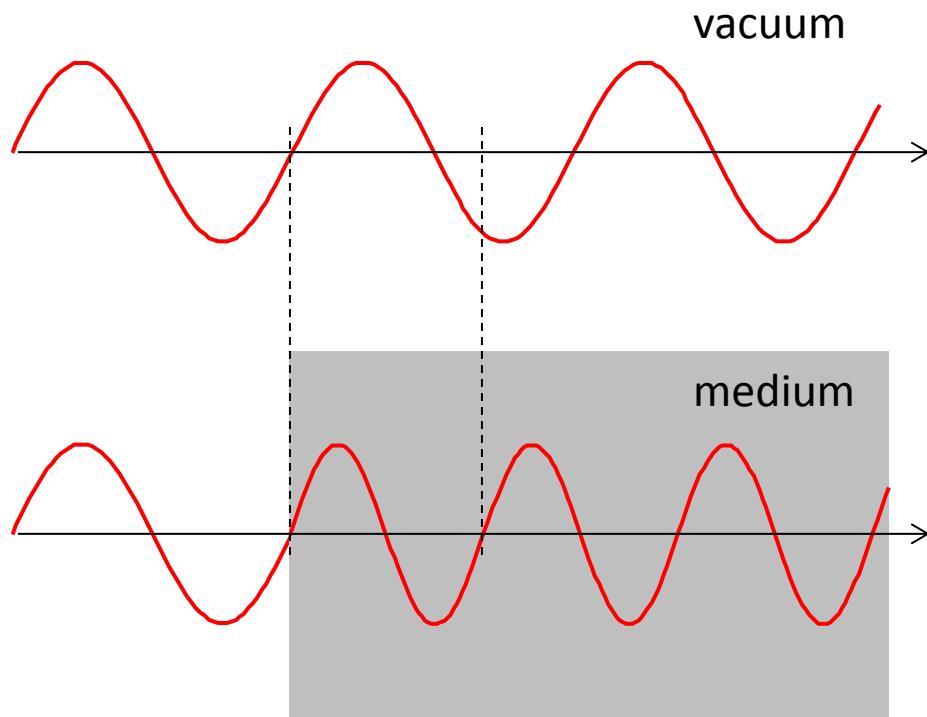


$$c = \lambda\nu$$

= 299,792,458 m/s in vacuum

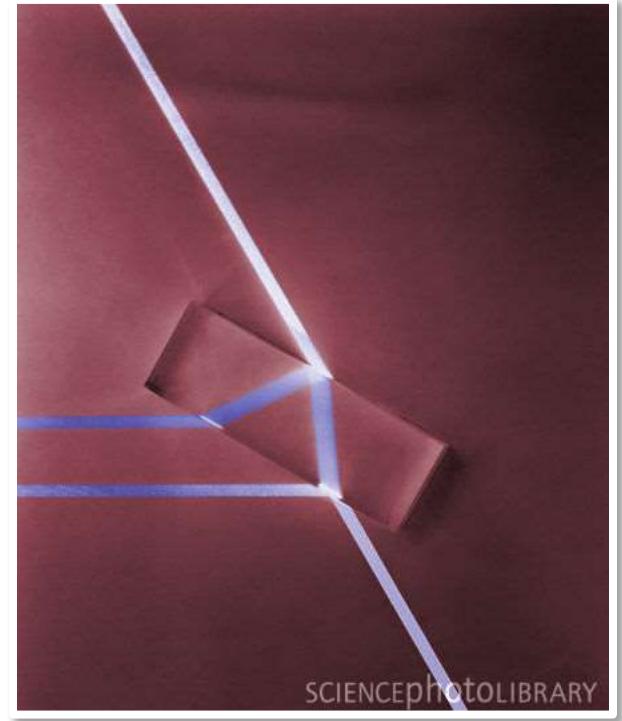
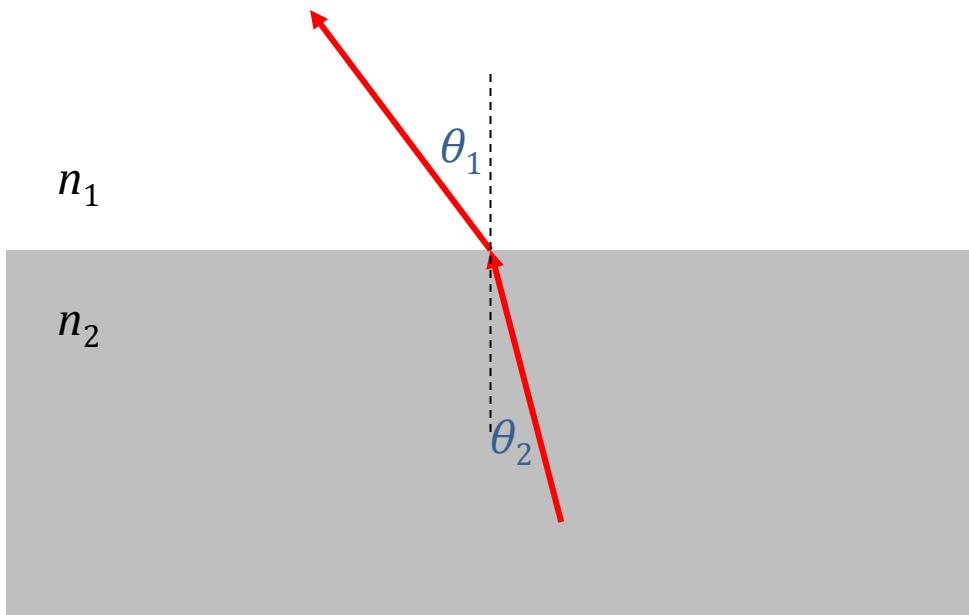


Refractive index



$$n = \frac{c}{\text{speed in medium}} = \frac{\lambda_{\text{vacuum}}}{\lambda_{\text{medium}}}$$

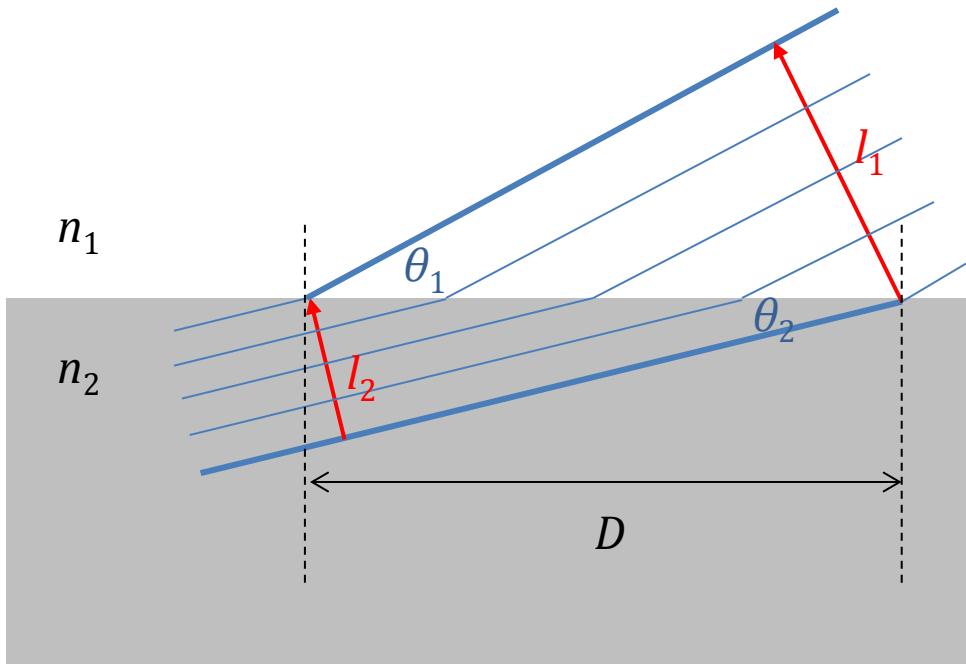
Refraction



Snell's law:

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

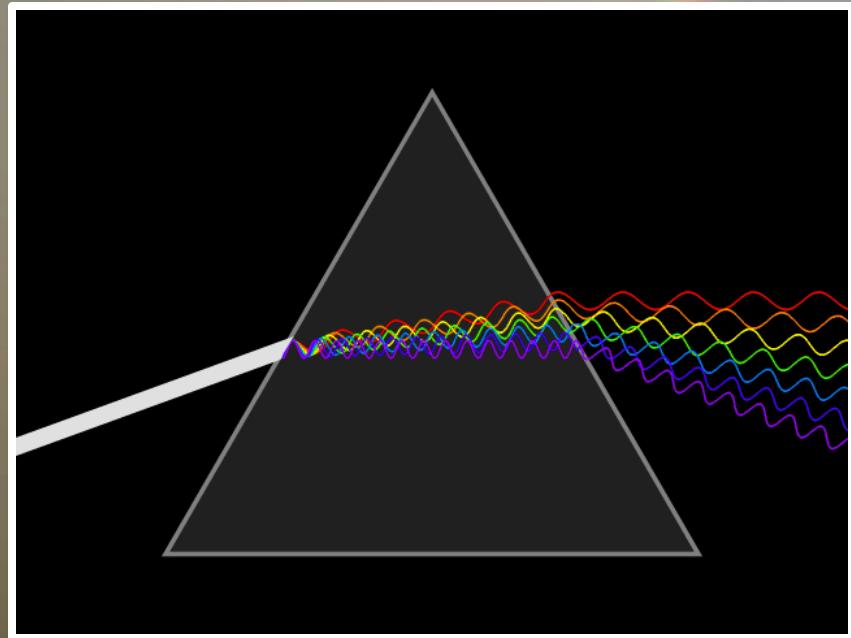
Explaining refraction



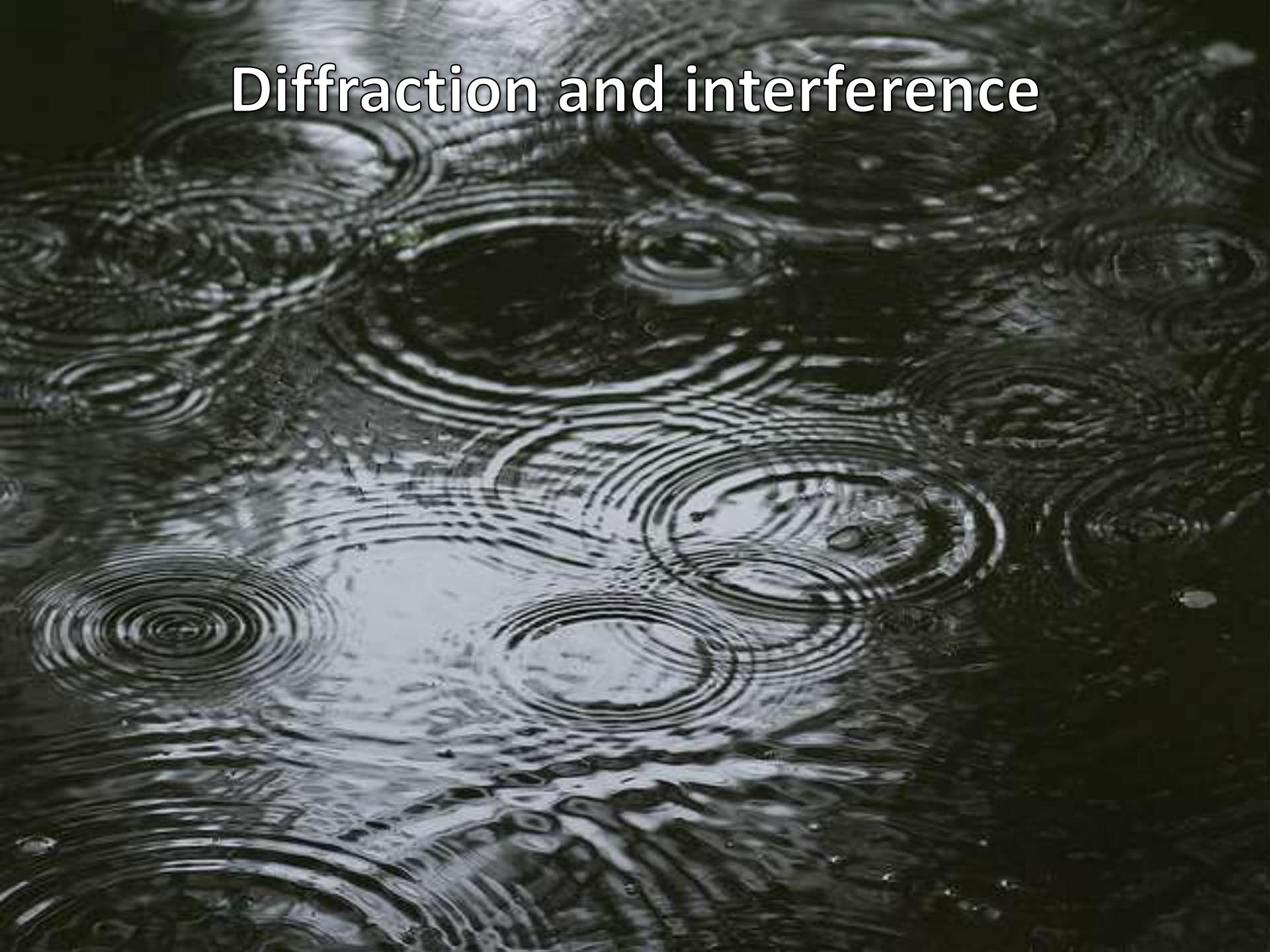
$$\Delta t = \frac{l_1}{c/n_1} = \frac{l_2}{c/n_2} \quad \Rightarrow \quad n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$l_1 = D \sin\theta_1 \quad l_2 = D \sin\theta_2$$

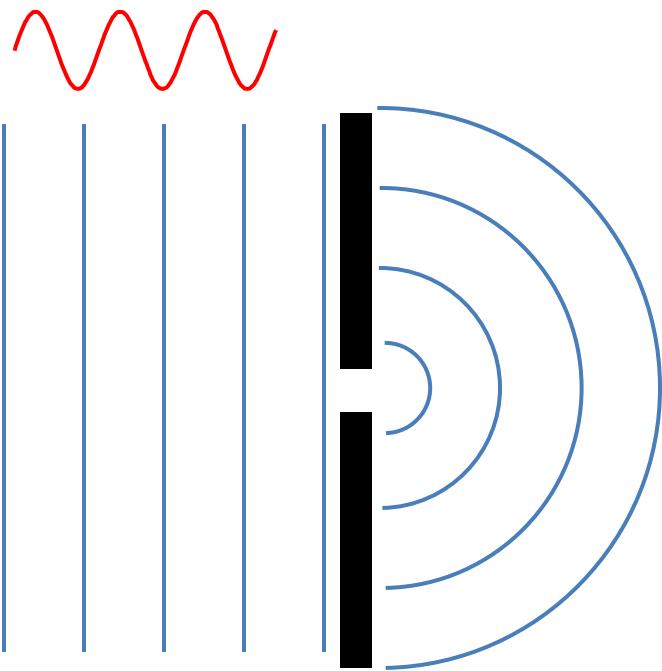
Dispersion



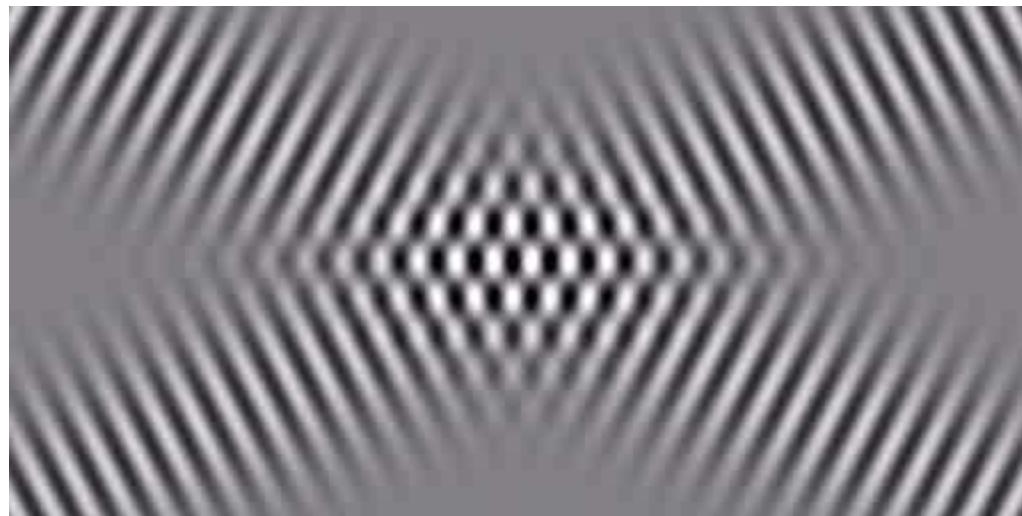
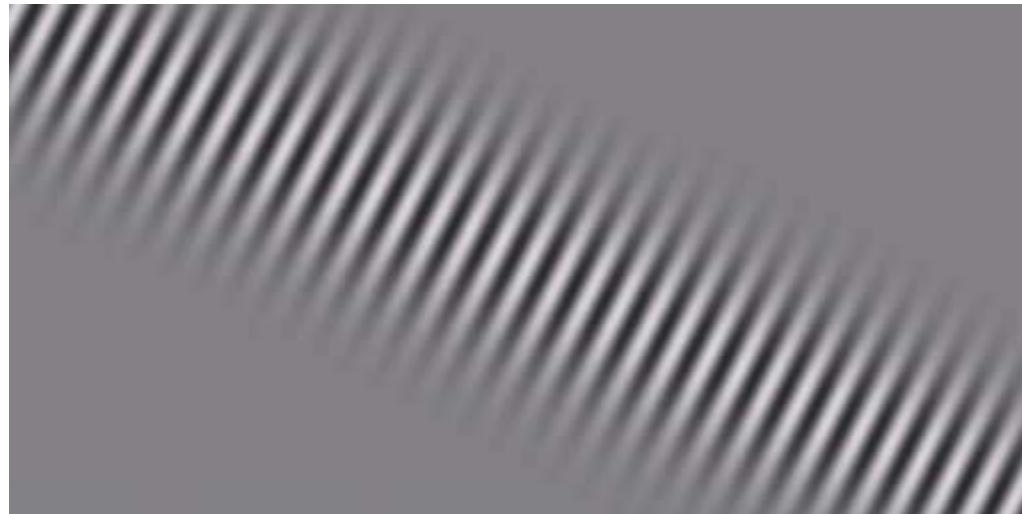
Diffraction and interference



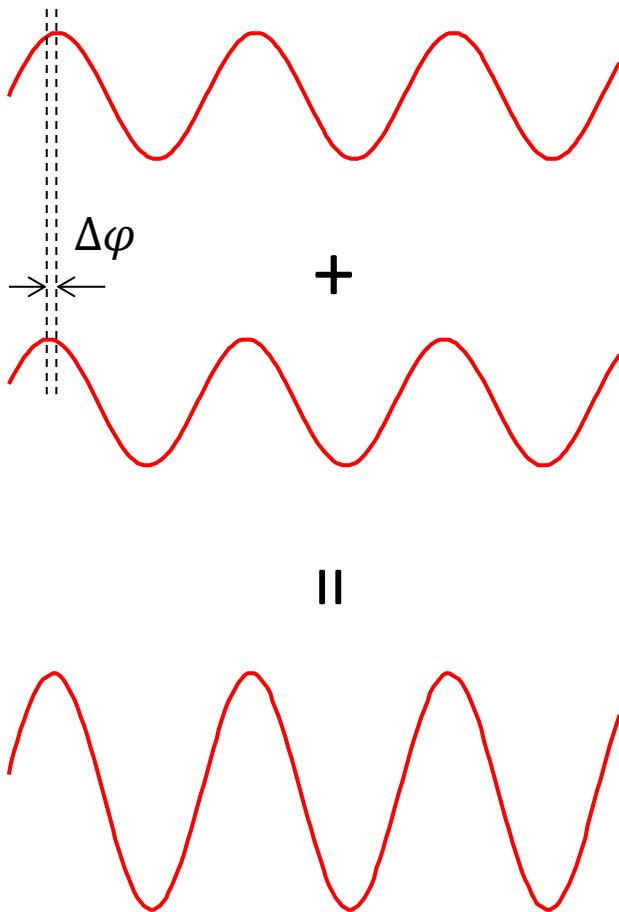
Diffraction



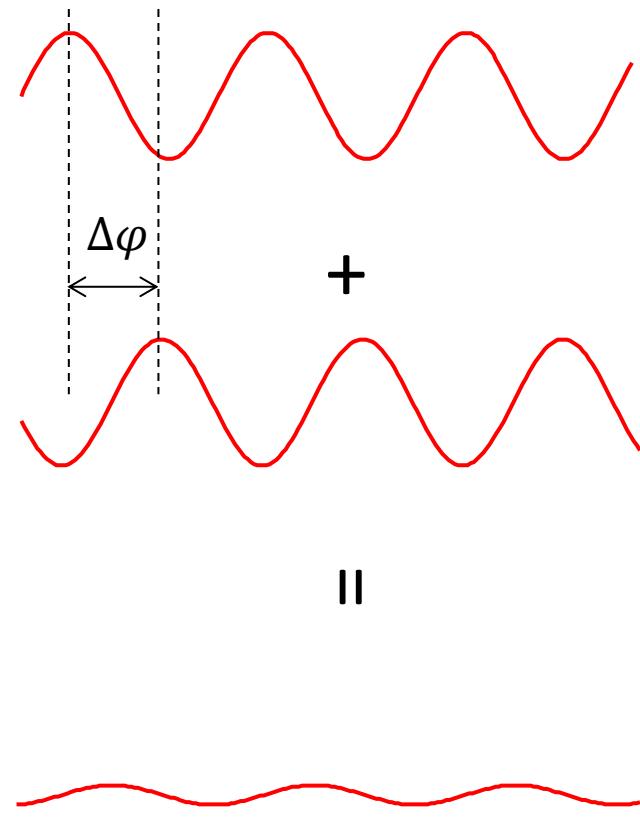
Interference



Interference

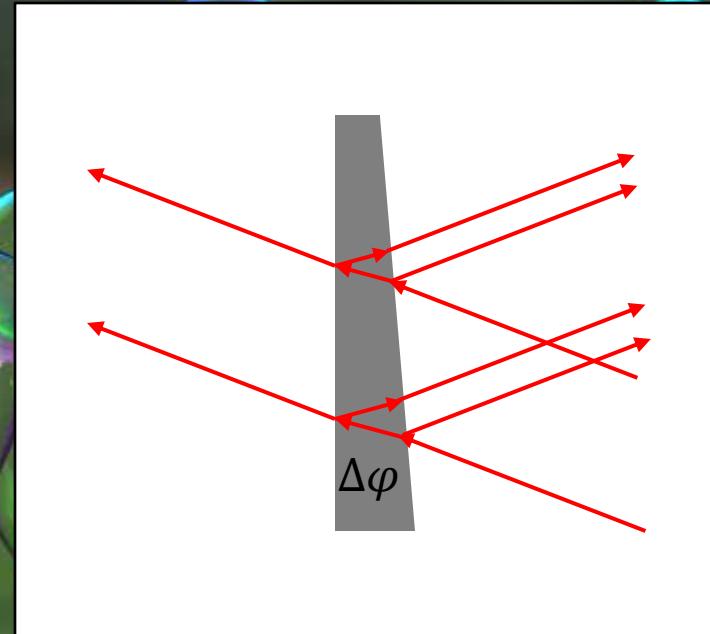
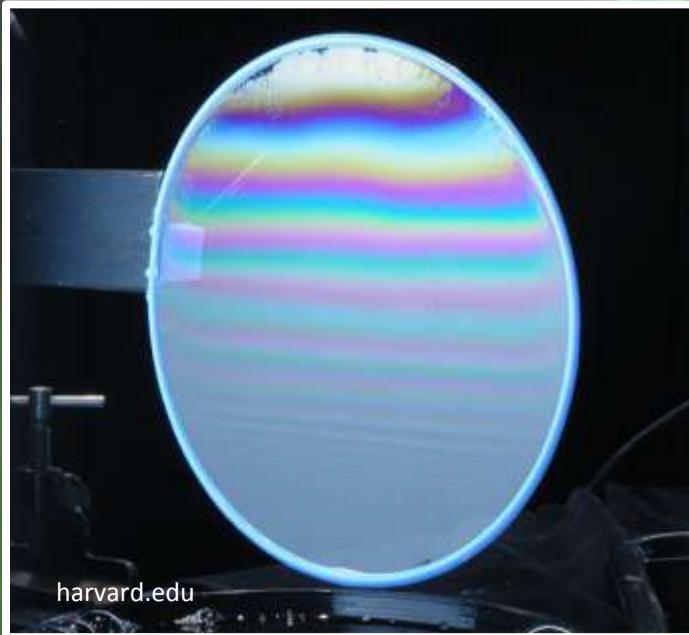


Constructive



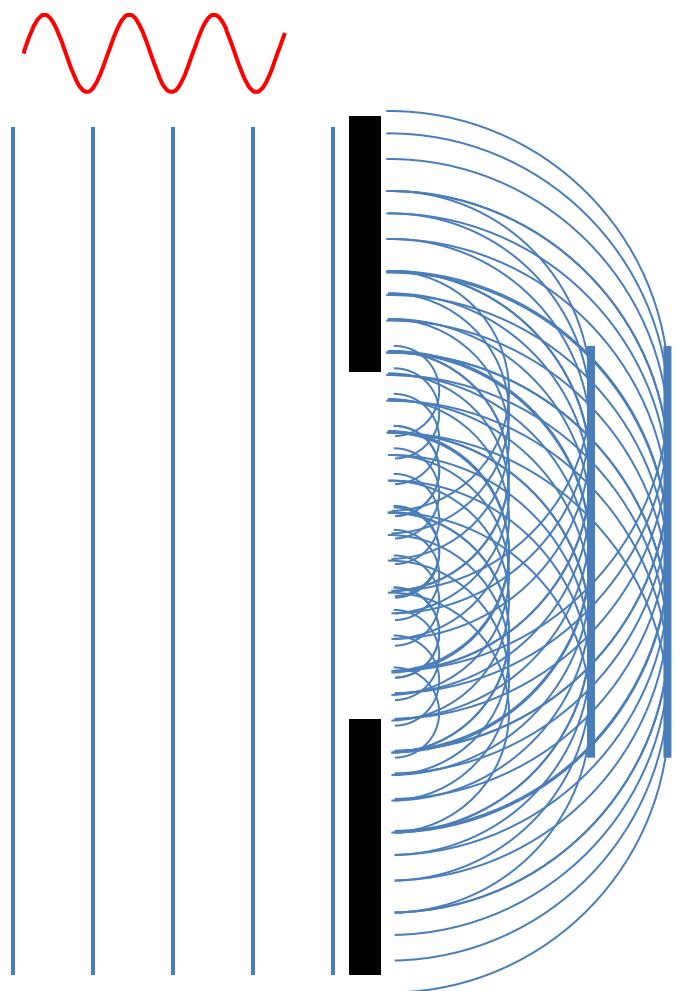
Destructive

Thin film interference

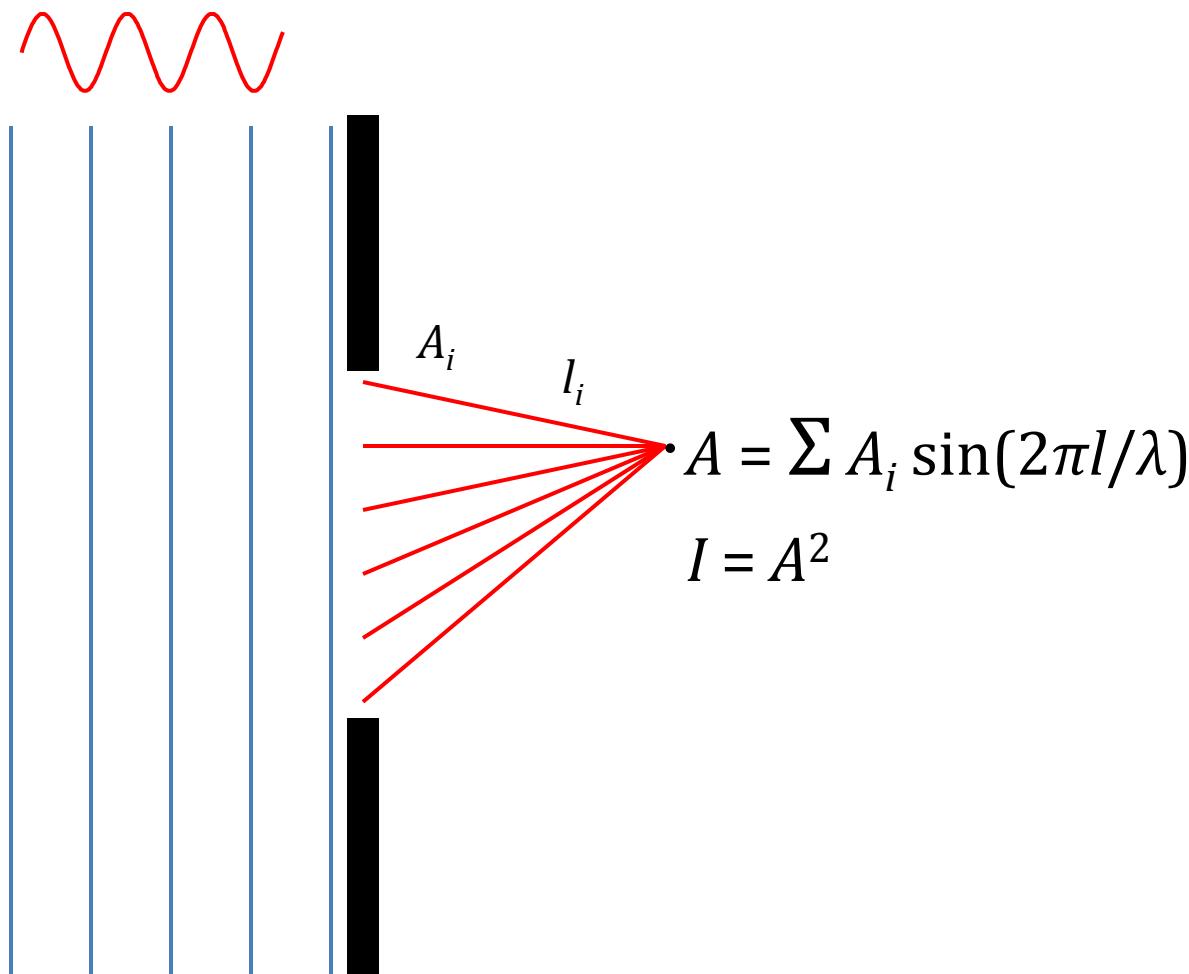


- Thickness
- Angle
- Wavelength

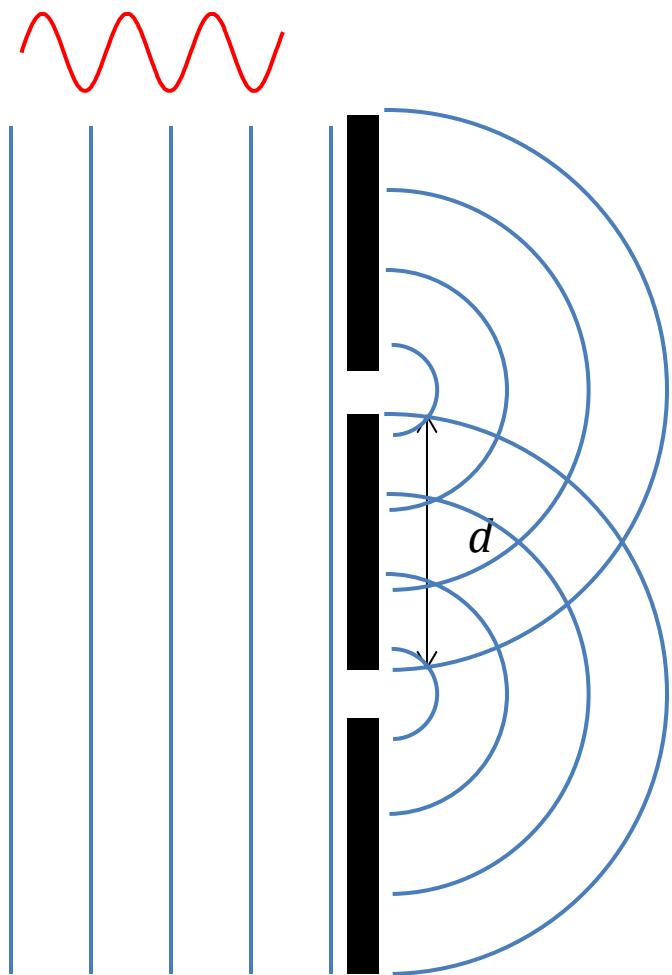
Light propagation = diffraction + interference



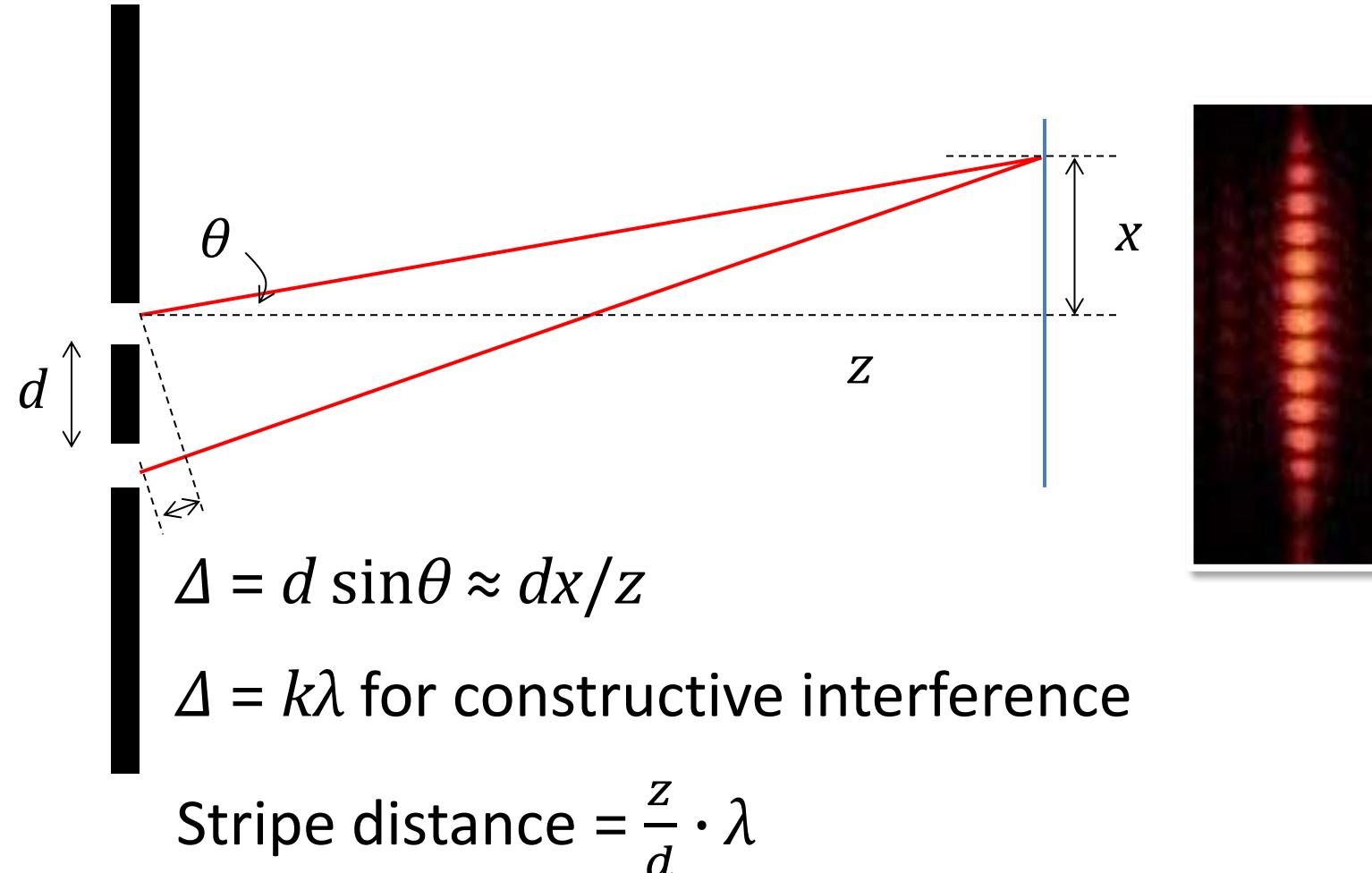
Light propagation = diffraction + interference



Double slit interference



Double slit interference



Light as electromagnetic waves

Maxwell's equations

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

Light as electromagnetic waves

Maxwell's equations

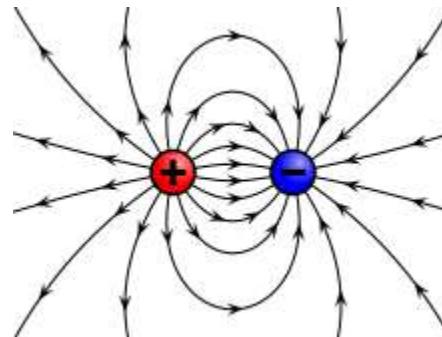
$$\nabla \cdot E = \frac{\rho}{\epsilon_0}$$

Charge density

Electric field

$$\nabla \times E = -\frac{\partial B}{\partial t}$$
$$\nabla \times B = \mu_0 J + \mu_0 \epsilon_0 \frac{\partial E}{\partial t}$$

Static electric field generated by charges



wikipedia

Light as electromagnetic waves

Maxwell's equations

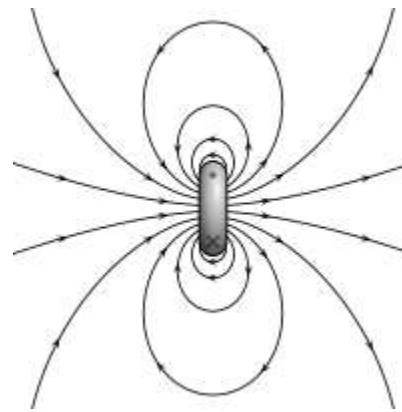
$$\nabla \cdot E = \frac{\rho}{\epsilon_0}$$

$$\nabla \cdot B = 0$$

Magnetic field

$$\nabla \times B = \mu_0 J + \mu_0 \epsilon_0 \frac{\partial E}{\partial t}$$

Magnetic force lines form closed circles.



wikipedia

Light as electromagnetic waves

Maxwell's equations

$$\nabla \cdot E = \frac{\rho}{\epsilon_0}$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times B = \mu_0 \epsilon_0 \frac{\partial E}{\partial t}$$

A changing magnetic field generates electric field

Rate of change

Light as electromagnetic waves

Maxwell's equations

$$\nabla \cdot E = \frac{\rho}{\epsilon_0}$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times B = \mu_0 J + \mu_0 \epsilon_0 \frac{\partial E}{\partial t}$$

Electric current

Electric current and changing electric field generate magnetic field

Light as electromagnetic waves

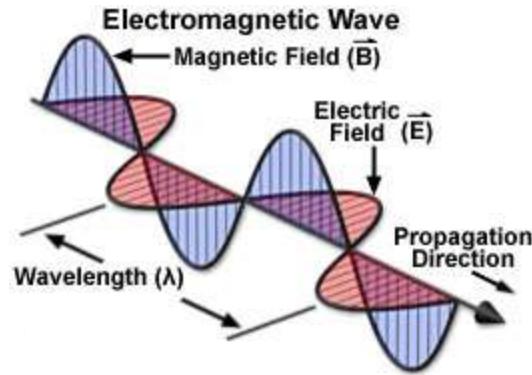
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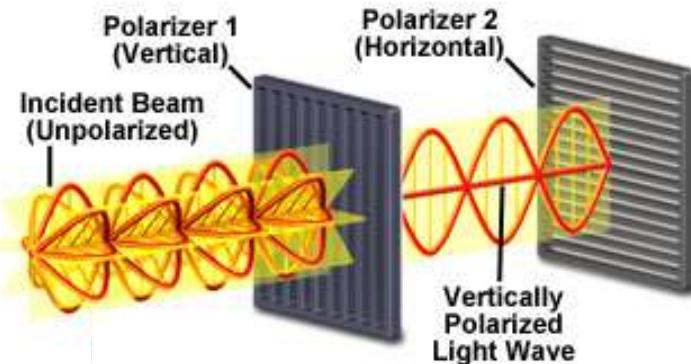


Michael Davidson

Speed of light = $1/\sqrt{\mu_0 \epsilon_0}$

Polarization

Polarization of Light Waves



Michael Davidson



wikipedia

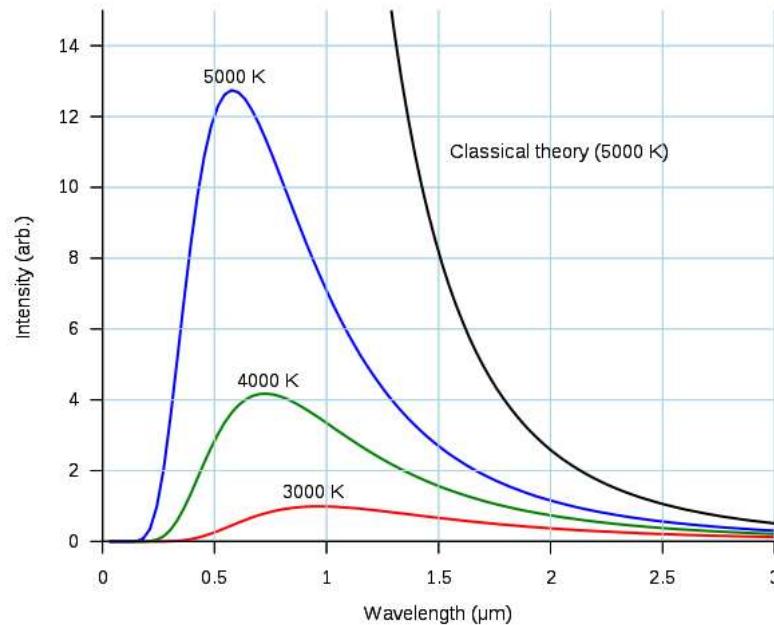
Light as particles



From blackbody emission

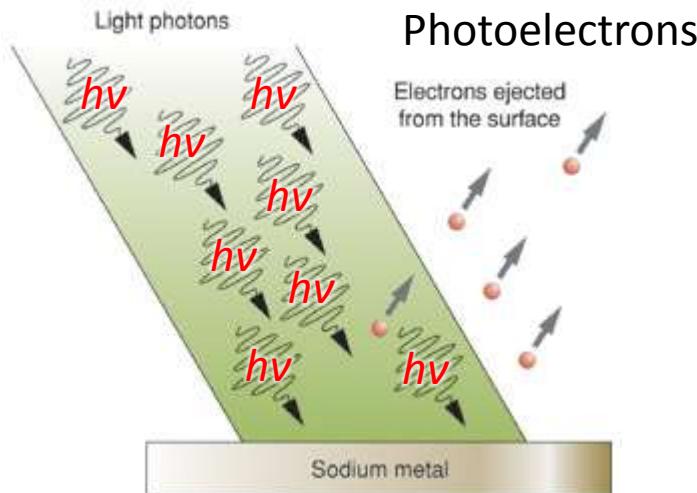


Max Planck



$$E = h\nu$$

Photoelectric effect



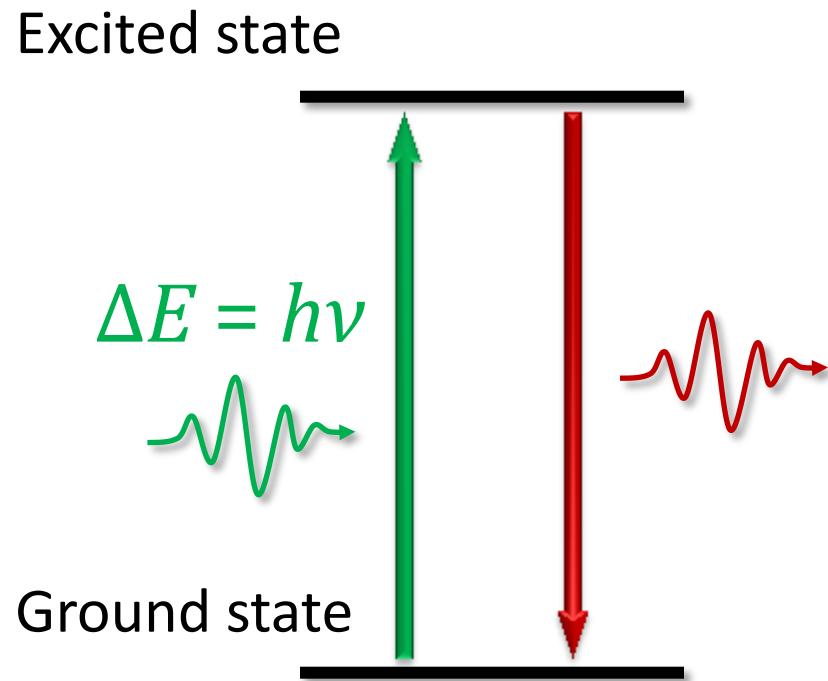
The Encyclopedia of Science

Albert Einstein



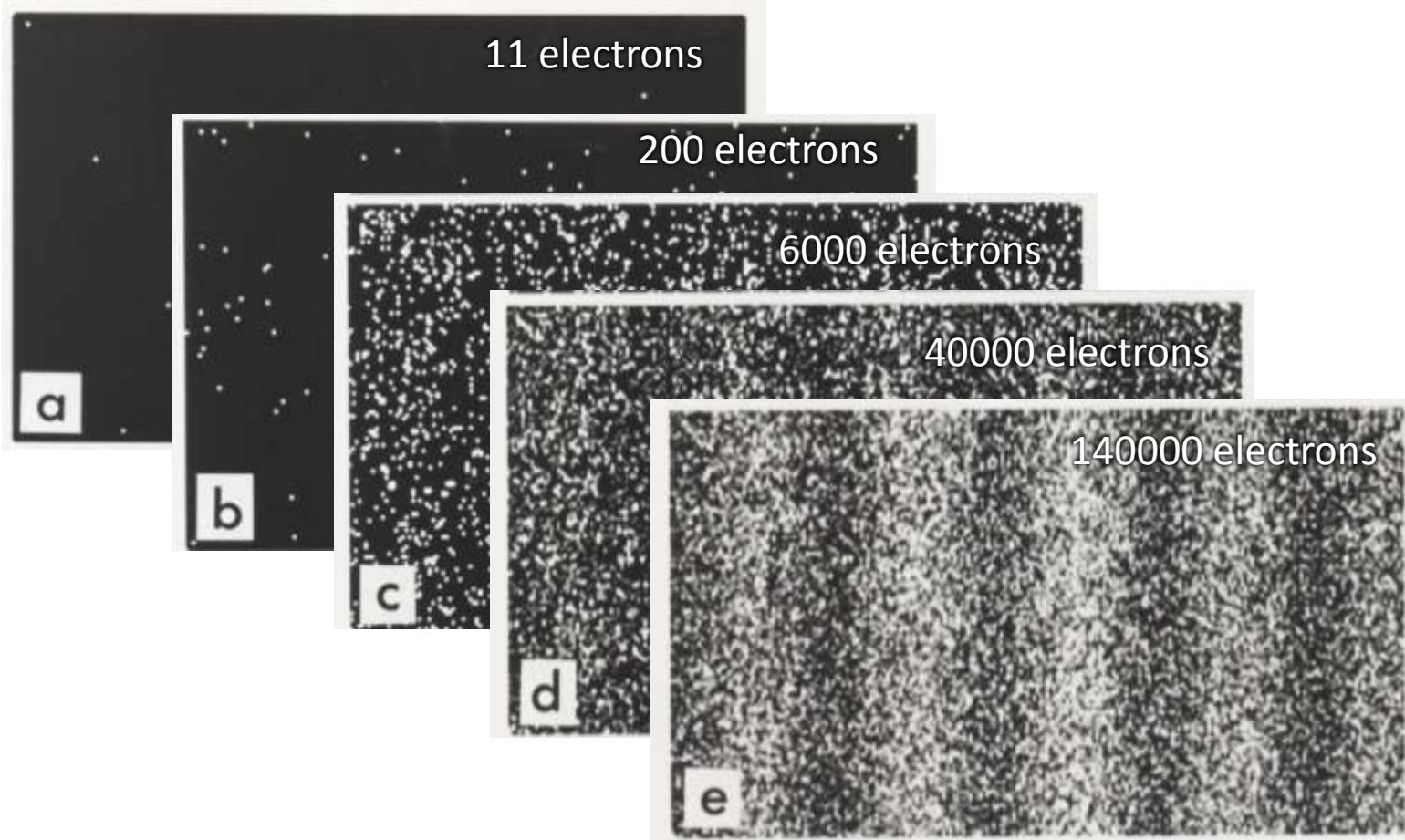
1 Einstein = 1 mole of photons

Photon: the quantized energy of light



Wave-particle duality

Double-slit experiment of electrons



What light really is?

A photograph of a dark night sky filled with numerous stars of varying brightness. The stars appear as small white points of light scattered across the dark blue to black gradient of the sky. In the lower portion of the image, the dark silhouettes of evergreen trees are visible, their pointed tops contrasting against the star-filled background.