BANGKOK UNIVERSITY
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Open Courses

INTRODUCTION TO OPTICS

Lecture 1: Introduction

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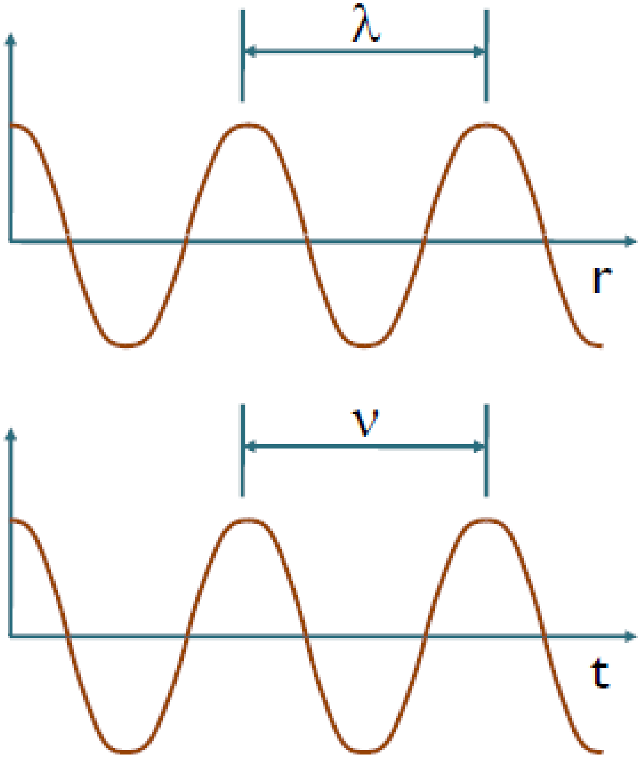
Introduction

- Light can be described as:
  - Particles (called photons) that carry energy from one place to the other. That is how we feel the heat of the sun.
  - A wave (Electromagnetic wave) that propagates from one place to another. That is how we see a light from far distances.

Light as a wave

- As a wave, light oscillates in space with a certain period, λ.
- λ is referred to as the wavelength.
- Lights also oscillates in time with a certain frequency, ν



Light as a wave

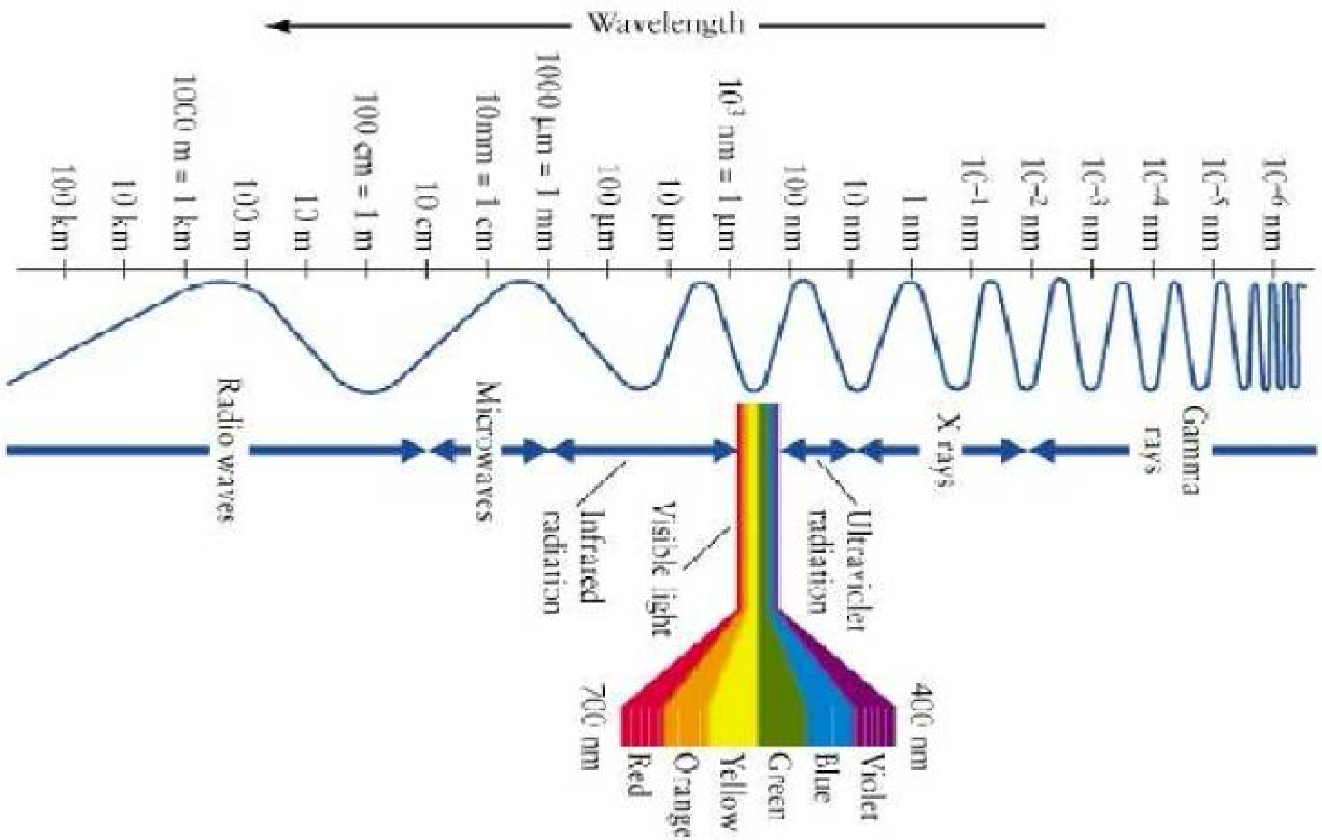
- The wavelength of a light wave and its frequency are linked through the speed of light.

$$\nu = c / \lambda$$

- The frequency of light defines its **color**

Color	Frequency (Hz)	Wavelength in vacuum (nm)
Red	4.615×10^{14}	650
Orange	5.084×10^{14}	590
Yellow	5.263×10^{14}	570
Green	5.882×10^{14}	510
Blue	6.315×10^{14}	475
Violet	7.500×10^{14}	400

Light and color



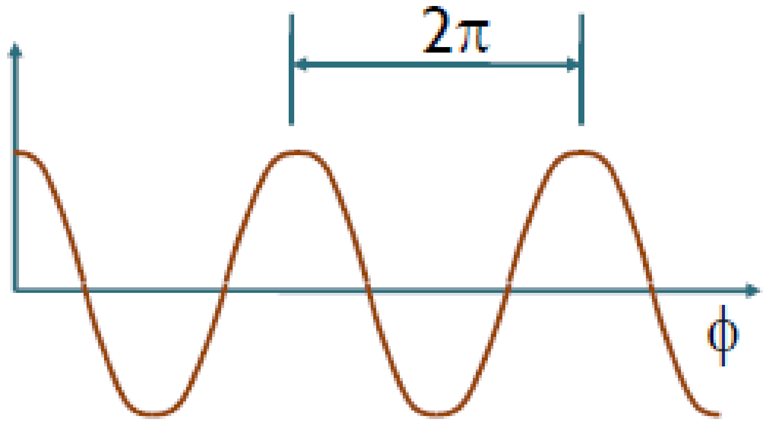
http://eosweb.larc.nasa.gov/EDDOCS/Wavelengths_for_Colors.html#blue

Light and color

- Our eyes are sensitive to light with wavelength in the range between 400-700 nm (violet - red)
- This is referred to as “**visible light**.”
- Wavelengths higher than red are referred to as “**Infra-red**” or in short IR.
- Wavelengths shorter than Violet are referred to
- “**ultra-violet**” or in short UV.

Phase of the light wave

- Light oscillation (in time and space) changes the phase of the wave.
- Oscillation in space is propagation.
- When light travels a distance r over a time t, it gains a phase φ.



$$\phi = 2\pi\nu t - \frac{2\pi r}{\lambda}$$

$$\omega = 2\pi\nu \text{ and } k = \frac{2\pi}{\lambda}$$

$$\phi = \omega t - kr$$

Phase of the light wave

- The term k is referred to as the wave-number, or the number of changes of the phase by 2π over a unit distance.

- The term ω is referred to as the angular frequency, or the number of changes of the phase by 2π over a unit time.

$$\omega = 2\pi\nu \ \text{ and } \ k = \frac{2\pi}{\lambda}$$

Exercise 1

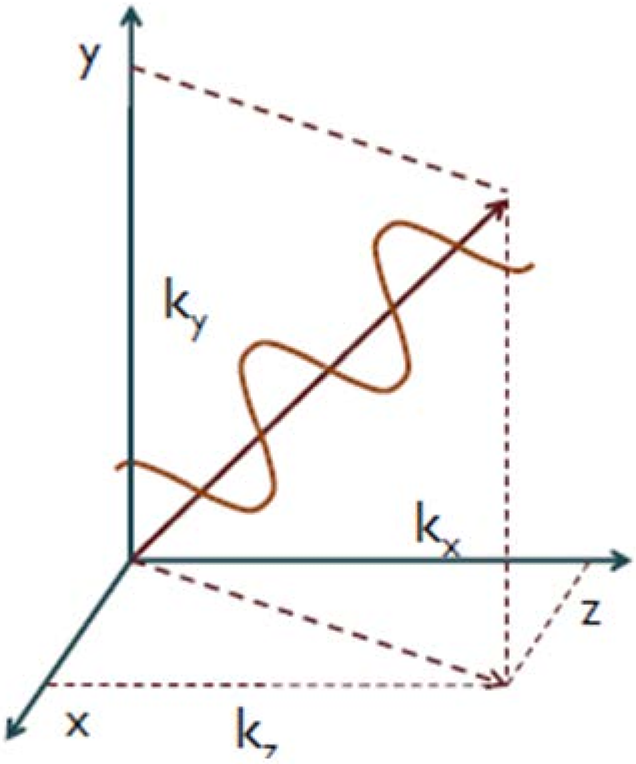
- Write the colors in the table above in terms of angular frequencies and wave-numbers.

- What is the distance needed to make a blue light gain a phase of 800π

The wave-number

- K is the number of 2π changes of the phase per unit length along the direction of propagation.

- To include the direction of propagation, wave-vector is introduced



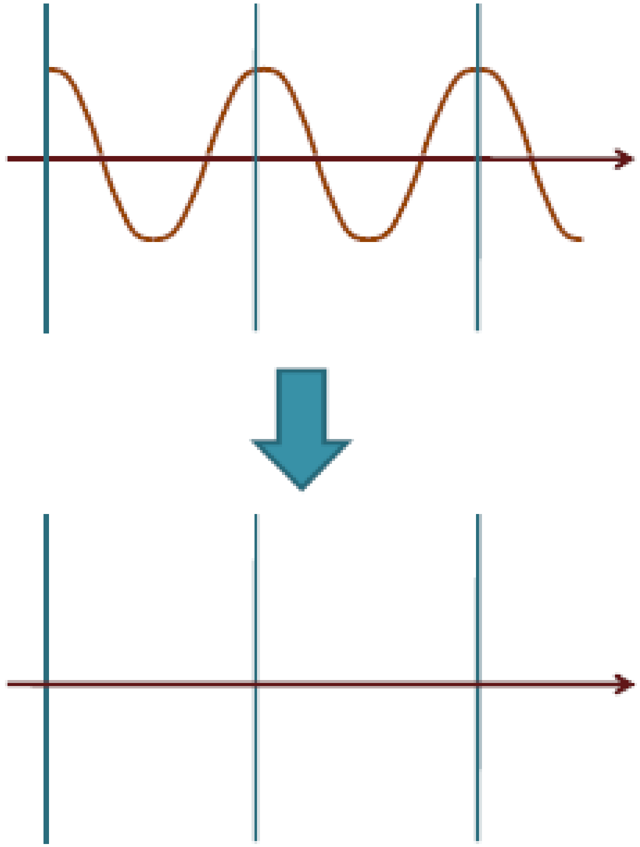
$$\vec{k} = k\hat{a}_r \quad \text{, where } \hat{a}_r = (a_x, a_y, a_z) \text{ and } |\hat{a}_r| = 1$$

$$k_x = ka_x \quad k_y = ka_y \quad k_z = ka_z \text{ and } k = \frac{2\pi}{\lambda}$$

Wave representation

- When representing a wave, lines at the locations of the peaks are drawn normal to
- the direction of propagation.

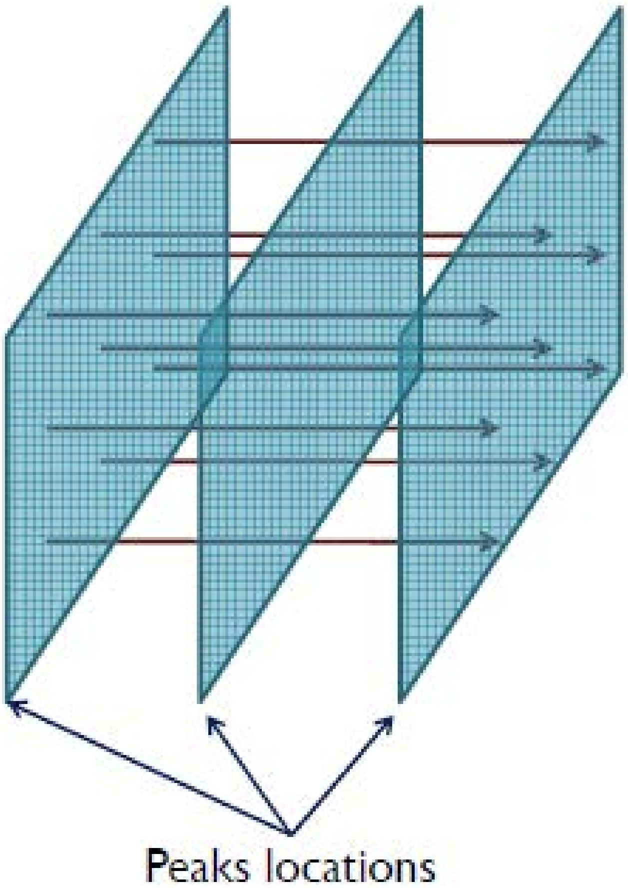
- The space between the lines correspond to 2π phase change.



Plane wave

- If the peak locations across the space are aligned in planes, the wave is referred to as “**plane-wave**.”

- For plane-wave, the surface of equal phase is a plane.



Plane wave

- The phase of the wave changes uniformly in a plane normal to the direction of propagation.

- The phase can be written as

$$\phi = \omega t - \vec{k}.\vec{r}$$

- As the wave amplitude has a sinusoidal nature, a plane wave can be generally written as

$$E(r,t) = A\exp\left[j\left(\omega t - \vec{k}.\vec{r}\right)\right]$$

- A is the amplitude and E is the electric field.

Exercise 2

- Write the phase of a green light plane wave propagating in the x-y plane with an angle 30º to the x axis.

- Write the equation for a violet light plane wave with an amplitude 0.9 (V/m) and angles of 45º to the x-z plane and 60o to the y axis

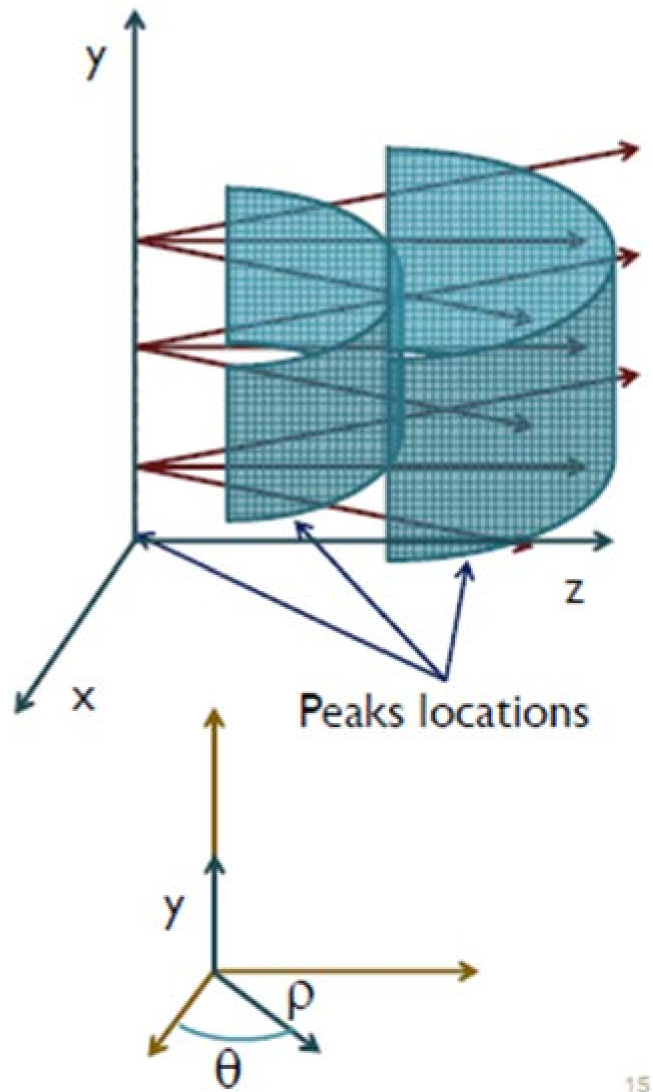
Cylindrical wave

- If the surfaces of constant phase are cylinders, then the wave is referred to as "**Cylindrical wave**."

- The phase in this case is written as

$$\phi = \omega t - \sqrt{k_x^2 + k_z^2}\,\rho - k_y y$$

$$\rho = \sqrt{x^2 + z^2}$$



Cylindrical wave

- The cylindrical wave function can be approximately written as

$$E_{cyl}(r,t) \approx \frac{A}{\sqrt{\rho}} \exp\left[j\left(\omega t - \sqrt{k_x^2 + k_z^2}\,\rho\right)\right] \exp\left[-jk_z z\right]$$

- This solution is an approximation of the Hankle
- function for large values of ρ.

Spherical wave

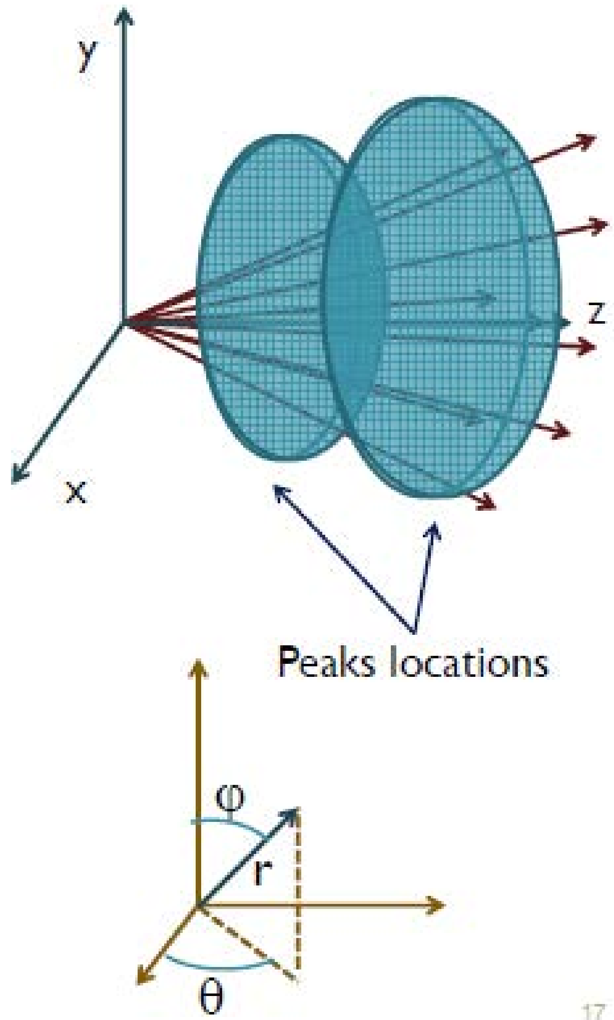
- When the surfaces of equal phases are spheres, the wave is referred to as "**spherical-wave**."

- The phase in this case is written as

$$\phi = \omega t - \sqrt{k_x^2 + k_y^2 + k_z^2}\, r$$

$$r = \sqrt{x^2 + y^2 + z^2}$$

or in short $\phi = \omega t - kr$



Spherical wave

- Spherical wave represents light emitting from a very small source (point-source.)

- The wave function can be written as

- $$E_{sph}(r,t) = \frac{A}{r}\exp[j(\omega t - kr)]$$

- For a point source located at location r_o

$$E_{sph}(r,t) = \frac{A}{r}\exp[j(\omega t - k(r - r_o))]$$

Exercise 3

- Write the wave function of red light cylindrical Wave

- Write the wave function of a yellow light spherical wave

Exercise 4

- For the following spherical wave, what is the light color and where is the point source located?

$$E_{sph}(r,t) = \frac{A}{r}\exp\left[j\left(3.19\times10^{15}t - 1.065\times10^{7}r - 21.3\right)\right]$$