Optics

Optics equations

Electromagnetic spectrum, Light, UV, IR, equations that describe photons and electrons.

Fundamental equation of E.M. waves $f\lambda = c$ in vacuum and $f\lambda = \frac{c}{n}$ in a medium

Energy of one photon: $E_{photon} = hf = \frac{hc}{\lambda} = \hbar\omega$

Momentum of one photon: $p_{photon} = \frac{hf}{c} = \frac{h}{\lambda}$

Fresnel TE mode

$$\boxed{\frac{E_r}{E_i} = \frac{n_i \cos\theta_i - n_t \cos\theta_t}{n_i \cos\theta_i + n_t \cos\theta_t}} \quad \text{and} \quad \boxed{\frac{E_t}{E_i} = \frac{2n_i \cos\theta_i}{n_i \cos\theta_i + n_t \cos\theta_t}}$$

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Consequence of Fresnel equations relevant to interference:

When light is reflected by an interface between low and high index of refraction the electric field reflected is inverted (equivalent to a delay of half a wavelength).
On the other hand when light is reflected by an interface between high and low index of refraction the electric field reflected is in phase (zero delay).

Geometrical Optics

Mirrors and lenses: $"power" = \frac{1}{f} = \frac{1}{do} + \frac{1}{di}$ and $Magnification = -\frac{di}{do} = \frac{hi}{ho}$

Lens maker's equation $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$ with positive radii if convex

Spherical Mirrors $f = \pm\frac{R}{2}$ (positive for concave)

Optical Instruments

Angle-Magnification $= \frac{f_{objective}}{f_{eye-piece}}$

When combining lenses the image of the first lens is the object for the second lens

Stefan-Boltzmann radiation law $\frac{Power}{Area} = \sigma T^4$ where $\sigma = 5.67 \times 10^{-8} \frac{W}{m^2 K^4}$

Population of atomic levels $\frac{P_2}{P_1} = \exp\left(-\frac{E_2 - E_1}{k_B T}\right)$

Selection Rules:

$j = 0 \quad to \quad j = 0$ is never allowed

For dipole transitions

$\Delta\ell = \pm 1$ and $\Delta m = \pm 1 \quad or \quad 0$

Interference

Single slit: $w \sin\theta = n\lambda$ dark fringe except for n=0
Double slit: $d \sin\theta = n\lambda$ bright fringe for n integer
Circular aperture: $D \sin\theta = 1.22\lambda$ first dark circular fringe

Electric polarization reverses when the interface goes from low n to large n
Reversing the electric field is equivalent to a phase delay of π or $\lambda/2$

Fiber Optics
Snell's equation $n_i \sin\theta_i = n_t \sin\theta_t$
Total internal reflection critical angle $n_1 \sin\theta_{critical} = n_2 \sin 90^\circ$

Polarization
Malus law $\frac{I_{after}}{I_{before}} = \cos^2\theta$

Wien's law $\lambda_{MAX} T = 2.897 \times 10^{-3} mK$ (meter kelvin, not millikelvin)