Prefixes

a=10^{-18}, f=10^{-15}, p=10^{-12}, n=10^{-9}, $\mu = 10^{-6}$, m=10^{-3}, c=10^{-2}, k=10^3, M=10^6, G=10^9, T=10^{12}, P=10^{15}

Physical Constants

$k = 1/4\pi\epsilon_0 = 8.988$ GNm^2/C^2 (Coulomb's Law)

$e = 1.602 \times 10^{-19}$ C (proton charge)

$m_e = 9.11 \times 10^{-31}$ kg (electron mass)

$c = 3.00 \times 10^8$ m/s (speed of light)

$\epsilon_0 = 1/4\pi k = 8.854$ pF/m (permittivity of space)

$\mu_0 = 4\pi \times 10^{-7}$ T·m/A (permeability of space)

$m_p = 1.67 \times 10^{-27}$ kg (proton mass)

$c = 2.99792458 \times 10^8$ m/s (exact value in vacuum)

Units

$N_A = 6.02 \times 10^{23}$/mole (Avogadro's #)

1.0 eV = 1.602×10^{-19} J (electron-volt)

1 F = 1 C/V = 1 farad = 1 C^2/J

1 A = 1 C/s = 1 ampere = 1 coulomb/second

1 T = 1 N/A·m = 1 tesla = 1 newton/ampere·meter

1 u = 1 g/N_A = 1.6605×10^{-27} kg (mass unit)

1 V = 1 J/C = 1 volt = 1 joule/coulomb

1 H = 1 V·s/A = 1 henry = 1 J/A^2

1 Ω = 1 V/A = 1 ohm = 1 J·s/C^2

1 G = 10^{-4} T = 1 gauss = 10^{-4} tesla

OpenStax Chapter 24 Equations - Electromagetic Waves

Electromagnetic waves:

$|\vec{E}|/|\vec{B}| = c = 1/\sqrt{\epsilon_0\mu_0}$, (fields and speed)

$\omega = 2\pi f = \frac{1}{\sqrt{LC}}$ (LC oscillator frequency)

$f\lambda = c$ (wave equation)

$x = ct$ (propagation in space)

Energy density, intensity, power:

$u = \epsilon_0 E^2 = \frac{B^2}{\mu_0}$ (instantaneous energy density)

$I = \overline{u}c = \frac{1}{2}\epsilon_0 E_0^2 c$ (EM waves intensity)

$\overline{u} = \frac{1}{2}\epsilon_0 E_0^2 = \frac{B_0^2}{2\mu_0}$ (average energy density)

$I = P/A = P/(4\pi r^2)$ (intensity definition)

Approximate wavelengths λ for types of EM waves:

0 (γ-rays) 30 pm (x-rays) 3 nm (uv) 400 nm (visible) 700 nm (ir) 300 μm (μ-waves) 3 cm (radio) ∞

$\longrightarrow$ $\longrightarrow$ $\longrightarrow$ increasing wavelength $\longrightarrow$ $\longrightarrow$ $\longrightarrow$

OpenStax Chapter 25 Equations - Geometrical Optics

Reflection, Mirrors:

$\theta_r = \theta_i$ (angle of reflection = angle of incidence)

$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ (mirror equation)

$d_i > 0 \Rightarrow$ real, light side.

$m > 0 \Rightarrow$ upright.

$|m| > 0 \Rightarrow$ magnified.

$f = r/2$ (focal length of spherical mirror)

$m = -d_i/d_o = h_i/h_o$ (linear magnification)

$d_i < 0 \Rightarrow$ virtual, dark side.

$m < 0 \Rightarrow$ inverted.

$|m| < 0 \Rightarrow$ diminished.

Refraction, Lenses:

$n = c/v$ (index of refraction)

$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ (lens equation)

$d_i > 0 \Rightarrow$ real image, light (opp.) side.

$m > 0 \Rightarrow$ upright.

$|m| > 1 \Rightarrow$ magnified.

$n_1 \sin\theta_1 = n_2 \sin\theta_2$ (Snell's Law)

$m = -d_i/d_o = h_i/h_o$ (linear magnification)

$d_i < 0 \Rightarrow$ virtual image, dark (same) side.

$m < 0 \Rightarrow$ inverted.

$|m| < 1 \Rightarrow$ diminished.

OpenStax Chapter 26 Equations - Optical Instruments & Vision

Angles in radians

$\theta = s/r$ angle = arc length / radius = separation / distance away.

Lens power

$P = 1/f$ (power in diopters, when f is in meters).

Cameras

f/D = f-number, or lens aperture

film exposure = exposure time / f-number.

$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ (lens equation)

$m = -d_i/d_o = h_i/h_o$ (linear magnification)

Vision correction

Far point FP = ∞. (good vision)

Near point = NP $\leq$ 25 cm. (good vision)

Nearsighted. Use lens to get FP=∞.

Farsighted. Use lens to get NP=25 cm.

Simple magnifier

$\theta = \frac{h_o}{\text{NP}}$ (angular size at NP, via bare eye)

$\theta' = \frac{h_o}{d_o}$ (angular size at d_o, thru magnifier)

$M = \frac{\theta'}{\theta} = \frac{\text{NP}}{d_o}$ (ang. Mag. viewed at any d_o)

$M = \frac{\theta'}{\theta} = \frac{\text{NP}}{f}$ (ang. Mag. viewed at $d_o = f$)

Microscopes

$\theta = \frac{h_o}{\text{NP}}$ (angular size of object at NP, via bare eye)

$m_o = \frac{h_i}{h_o} = \frac{-d_i}{d_o}$ (1^{st} image, linear magnification of objective lens)

$M_e = \frac{\theta'}{\theta} = \frac{\text{NP}}{d_o'}$ (angular magnification due to eyepiece lens)

$M = \frac{\theta_{\text{micro}}}{\theta} = m_o M_e$ (net angular magnification compared to bare eye)

Telescopes

$M = \frac{\theta'}{\theta} = -\frac{f_{\text{obj}}}{f_{\text{eye}}}$ (angular magnification compared to bare eye)