

Prefixes

a=10⁻¹⁸, f=10⁻¹⁵, p=10⁻¹², n=10⁻⁹, μ = 10⁻⁶, m=10⁻³, c=10⁻², k=10³, M=10⁶, G=10⁹, T=10¹², P=10¹⁵

Physical Constants

$k = 1/4\pi\epsilon_0 = 8.988 \text{ GNm}^2/\text{C}^2$ (Coulomb's Law)	$\epsilon_0 = 1/4\pi k = 8.854 \text{ pF/m}$ (permittivity of space)
$e = 1.602 \times 10^{-19} \text{ C}$ (proton charge)	$\mu_0 = 4\pi \times 10^{-7} \text{ T}\cdot\text{m/A}$ (permeability of space)
$m_e = 9.11 \times 10^{-31} \text{ kg}$ (electron mass)	$m_p = 1.67 \times 10^{-27} \text{ kg}$ (proton mass)
$c = 3.00 \times 10^8 \text{ m/s}$ (speed of light)	$c = 2.99792458 \times 10^8 \text{ m/s}$ (exact value in vacuum)
$h = 6.62607 \times 10^{-34} \text{ J}\cdot\text{s}$ (Planck's constant)	$\hbar = 1.05457 \times 10^{-34} \text{ J}\cdot\text{s}$ (Planck's constant/ 2π)
$\sigma = 5.67 \times 10^{-8} \text{ W}/(\text{m}^2\cdot\text{K}^4)$ (Stefan-Boltzmann const.)	$hc = 1239.84 \text{ eV}\cdot\text{nm}$ (photon energy constant)

Units

$N_A = 6.02 \times 10^{23}/\text{mole}$ (Avogadro's #)	1 u = 1 g/ N_A = $1.6605 \times 10^{-27} \text{ kg}$ (mass unit)
1.0 eV = $1.602 \times 10^{-19} \text{ J}$ (electron-volt)	1 V = 1 J/C = 1 volt = 1 joule/coulomb
1 F = 1 C/V = 1 farad = 1 C ² /J	1 H = 1 V·s/A = 1 henry = 1 J/A ²
1 A = 1 C/s = 1 ampere = 1 coulomb/second	1 Ω = 1 V/A = 1 ohm = 1 J·s/C ²
1 T = 1 N/A·m = 1 tesla = 1 newton/ampere·meter	1 G = 10 ⁻⁴ T = 1 gauss = 10 ⁻⁴ tesla

OpenStax Chapter 24 Equations - Electromagnetic Waves

Electromagnetic waves:

$$|\vec{E}|/|\vec{B}| = c = 1/\sqrt{\epsilon_0\mu_0}, \quad (\text{fields and speed}) \qquad f\lambda = c \quad (\text{wave equation})$$

Energy density, intensity, power:

$$\begin{aligned} u &= \epsilon_0 E^2 = \frac{B^2}{\mu_0} \quad (\text{instantaneous energy density}) & \bar{u} &= \frac{1}{2}\epsilon_0 E_0^2 = \frac{B_0^2}{2\mu_0} \quad (\text{average energy density}) \\ I &= \bar{u}c = \frac{1}{2}\epsilon_0 E_0^2 c \quad (\text{EM waves intensity}) & I &= P/A = P/(4\pi r^2) \quad (\text{intensity definition}) \end{aligned}$$

Approximate wavelengths λ for types of EM waves:

$$\begin{array}{ccccccc} 0 \text{ } (\gamma\text{-rays}) & 30 \text{ pm } (x\text{-rays}) & 3 \text{ nm } (\text{uv}) & 400 \text{ nm } (\text{visible}) & 700 \text{ nm } (\text{ir}) & 300 \text{ }\mu\text{m } (\mu\text{-waves}) & 3 \text{ cm } (\text{radio}) & \infty \\ \longrightarrow & \longrightarrow & \longrightarrow & \text{increasing wavelength} & \longrightarrow & \longrightarrow & \longrightarrow \end{array}$$

OpenStax Chapter 27 Equations - Wave Optics

Wave properties, interference:

$$\begin{aligned} \lambda_n &= \lambda_{\text{vacuum}}/n \quad (\text{wavelength in a medium}) & \Delta x &= d \sin \theta \quad (\text{path difference in double slits}) \\ d \sin \theta &= m\lambda \quad (\text{double slits bright fringes}) & d \sin \theta &= (m + 1/2)\lambda \quad (\text{double slits dark fringes}) \end{aligned}$$

Diffraction:

$$\begin{aligned} D \sin \theta &= m\lambda \quad (\text{single slit minima}) & y &= L \tan \theta \quad (\text{position on a screen}) \\ d \sin \theta &= m\lambda \quad (\text{diffraction grating maxima}) & d &= 1/(\text{lines per meter}). \end{aligned}$$

Rayleigh's Diffraction Limit:

$$\theta_{\min} = 1.22\lambda/D \quad (\text{resolution limit}) \qquad \theta = s/r \quad (\text{angular separation in radians})$$

Polarization:

$$I = I_0 \cos^2 \theta \quad (\text{transmission thru polarizer}) \qquad I = \frac{1}{2}I_0 \quad (\text{transmission of unpolarized light})$$

OpenStax Chapter 28 Equations - Special Relativity

Time dilation and length contraction:

$$\Delta t = \gamma \Delta t_0 = \Delta t_0 / \sqrt{1 - v^2/c^2}$$

$$\gamma = 1/\sqrt{1 - v^2/c^2} \quad (\text{relativistic factor})$$

$$L = L_0/\gamma = L_0 \sqrt{1 - v^2/c^2}$$

$$v/c = \sqrt{1 - 1/\gamma^2} \quad (\text{velocity})$$

Dynamics, mass, energy:

$$p = \gamma m_0 v \quad (\text{relativistic momentum})$$

$$E_0 = m_0 c^2 \quad (\text{rest energy})$$

$$\text{KE} = E - E_0 = (\gamma - 1)m_0 c^2 \quad (\text{kinetic energy})$$

$$m_{\text{rel}} = \gamma m_0 \quad (\text{relativistic mass})$$

$$E = \gamma m_0 c^2 = m_{\text{rel}} c^2 \quad (\text{relativistic energy})$$

$$E = E_0 + \text{KE} = \sqrt{p^2 c^2 + m^2 c^4} \quad (\text{relativistic energy})$$

OpenStax Chapter 29 Equations - Quanta and Quantum Waves

Blackbody radiation, photons, photo-electric effect:

$$\lambda_p T = 2.90 \text{ mm} \cdot \text{K} \quad (\text{Wien's Law})$$

$$E = n h f, \quad n = 1, 2, 3 \dots \quad (\text{quantized radiation energy})$$

$$E = h f = W_0 + \text{KE}_{\text{max}} \quad (\text{photo-electrons})$$

$$\text{KE}_{\text{max}} = e V_0 \quad (\text{stopping potential})$$

$$I = \sigma T^4 \quad (\text{intensity or power/area})$$

$$E = h c / \lambda = (1240 \text{ eV} \cdot \text{nm}) / \lambda \quad (\text{photons})$$

$$h c / \lambda_{\text{max}} = W_0 \quad (\text{work function})$$

$$v_{\text{max}} = \sqrt{2 \text{KE}_{\text{max}} / m} \quad (\text{max. speed})$$

Momentum, matter waves:

$$p = h / \lambda \quad (\text{quantum momentum})$$

$$\lambda = h / p \quad (\text{de Broglie wavelength})$$

$$\Delta \text{KE} + q \Delta V = 0 \quad (\text{acceleration thru potential})$$

$$\lambda' = \lambda + \frac{h}{m c} (1 - \cos \phi) \quad (\text{Compton effect})$$

$$\text{KE} = p^2 / 2m \quad (\text{kinetic energy, } v \ll c)$$

$$v = \sqrt{2 q \Delta V / m} \quad (\text{acceleration thru potential, } v \ll c)$$

Heisenberg Uncertainty Principle:

$$\Delta x \Delta p_x \approx h \quad (\text{approximate relation})$$

$$\Delta E \Delta t \approx h \quad (\text{approximate relation})$$

$$\Delta x \Delta p_x \geq \hbar / 2 \quad (\text{has the minimum uncertainty})$$

$$\Delta E \Delta t \geq \hbar / 2 \quad (\text{energy-time form})$$

$$\Delta E = \Delta m \cdot c^2 \quad (\text{Einstein's mass-energy equivalence})$$

$$h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s}$$

$$\hbar = \frac{h}{2\pi} = 1.05459 \times 10^{-34} \text{ J} \cdot \text{s}$$

← This has exact equality.