PHY302L Useful Formulae

Electricity

Coulomb’s Law
\[ \mathbf{F}_{12} = k \frac{q_1 q_2}{r_{12}^2} \]

Electric Field of a point charge \( q \):
\[ \mathbf{E} = \frac{q}{\epsilon_0 |q|} \]

Electric field inside a conductor in electrostatic equilibrium:
\[ \mathbf{E} = 0 \]

Electric potential near a point charge:
\[ V = k \frac{q}{|q|} \]

Definition of capacitance:
\[ C = \frac{Q}{V} \]

Parallel plate capacitance:
\[ C = \epsilon_0 \frac{A}{d} \]

Energy stored in a capacitor:
\[ U = \frac{Q^2}{2} = \frac{CV^2}{2} = \frac{Q^2}{2C} \]

Resistance of a wire of length \( L \) and cross section \( A \):
\[ R = \rho \frac{L}{A} \]

Temperature dependence of Resistivity:
\[ \rho - \rho_0 = \rho_0 \alpha (T - T_0) \]

Electric power dissipation:
\[ P = IV = I^2R = V^2/R \]

Transient behavior in an RC circuit, discharging:
\[ Q(t) = Q_0 e^{-t/RC} \]

Magnetism

Magnetic Force on a moving charged particle
\[ \mathbf{F}_B = q \mathbf{v} \times \mathbf{B} \sin \theta \]

Magnetic Force on a current carrying wire
\[ \mathbf{F}_B = i \mathbf{L} \times \mathbf{B} \sin \theta \]

Magnetic dipole moment \( \mu = NA \)

Torque on a magnetic dipole:
\[ \tau = \mu \mathbf{B} \sin \theta \]

Uniform circular motion of a charged particle in a magnetic field, radius
\[ r = \frac{m \omega}{qB} \]

Uniform circular motion of a charged particle in a magnetic field, frequency
\[ \omega = 2\pi \nu = \frac{qB}{m} \]

Magnetic field of a long straight wire:
\[ B = \frac{\mu_0 I}{2\pi R} \]

Flux of the magnetic field:
\[ \Phi_B = BA \cos \theta \]

Faraday’s law of induction:
\[ E = -\frac{\Delta \Phi_B}{\Delta t} \]

Transformer equation:
\[ \frac{V_1}{V_p} = \frac{N_1}{N_P} \]
Wave equation relating speed, frequency and wavelength: $v = \lambda \nu$

Energy density in electromagnetic waves (peak):
$$u = \varepsilon_0 E^2 = \varepsilon_0 cEB = B^2 / \mu_0$$

Energy density in electromagnetic waves (average):
$$u = \frac{\varepsilon_0 E^2}{2} = \frac{\varepsilon_0 cEB}{2} = \frac{\mu_0}{2}$$

Power transported in electromagnetic waves (average):
$$S = \frac{\varepsilon_0 E^2}{2} = \frac{\varepsilon_0 cEB}{2} = \frac{\mu_0}{2}$$

Power dissipated in an electrical circuit:
$$P = I^2 R = \frac{V^2}{R} = VI$$

Optics

Index of refraction
$$n = \frac{c}{v}$$

Snell’s law of refraction
$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

Critical angle for total internal reflection
$$\sin \theta_c = \frac{n_2}{n_1}$$

Spherical mirror in air
$$\frac{1}{f} + \frac{1}{f} = \frac{1}{r} + \frac{1}{r} = \frac{1}{r}$$

Thin lens equation
$$\frac{1}{f} + \frac{1}{f} = \frac{1}{f}$$

Constructive interference in Young’s double slit
$$d \sin \theta = m \lambda$$

Einstein-Planck photon energy
$$E = h \nu$$

de Broglie wavelength
$$\lambda = \frac{h}{p}$$

Heisenberg uncertainty principle
$$\Delta p \Delta x \geq \hbar \quad \Delta E \Delta t \geq \hbar$$

Constants and Conversion factors:

Magnetic permeability, $\mu_0 = 1.26 \times 10^{-6}$ T·m/A

Coulomb’s law constant: $k_e = \frac{1}{4 \pi \varepsilon_0} = 8.89 \times 10^9$ N·m²/C²

$1 \text{ eV} = 1.602 \times 10^{-19}$ J

Proton mass, $m_p = 1.67 \times 10^{-27}$ kg

Electron mass, $m_e = 9.11 \times 10^{-31}$ kg

Electron charge, $e = 1.60 \times 10^{-19}$ C

Speed of light in vacuum, $c = 3.0 \times 10^8$ m/s