

Useful data for physics students

Work and Energy

$$\text{Work Done, } W = \int_{s_1}^{s_2} \mathbf{F} \cdot d\mathbf{s}$$

$$\text{Kinetic Energy, } K = \frac{1}{2}mv^2$$

$$\text{Work – Kinetic Energy, } W_T = \Delta K = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

$$\text{Average Power, } P_{av} = \frac{\Delta W}{\Delta t}$$

$$\text{Instantaneous Power, } P = \frac{dW}{dt} = \mathbf{F} \cdot \mathbf{v}$$

$$\text{Potential Energy Function, } \Delta U = -W$$

$$\text{Gravitational Potential Energy, } U = U_0 + mgh$$

$$\text{Conservative Force, } F_x = -\frac{dU}{dx} \text{ and } \mathbf{F} = -\nabla U$$

Motion in one dimension

$$\text{Average velocity, } v_{av} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$$

$$\text{Instantaneous velocity, } v = \lim_{\Delta t \rightarrow 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

Constant Acceleration Equations,

$$v = v_0 + at$$

$$x - x_0 = \frac{1}{2}(v_0 + v)t$$

$$x = x_0 + v_0t + \frac{1}{2}at^2$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

$$\text{Instantaneous acceleration, } a = \lim_{\Delta t \rightarrow 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$

$$\text{Newton's Law, } \mathbf{F} = ma = \frac{mdv}{dt}$$

Thermal Properties of Matter

$$\text{Ideal gas equation, } pV = nRT$$

$$\text{Total mass, } m = nM$$

$$\text{Molecular mass, } M = N_A m$$

$$\text{Kinetic energy (ideal gas), } K = \frac{3}{2}nRT = \frac{3}{2}N_A kT$$

$$\text{Root mean square speed, } v_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{M}}$$

Molar heat capacities for ideal gases,

$$\text{(monatomic) } C_V = \frac{3}{2}R$$

$$\text{(diatomic) } C_V = \frac{5}{2}R$$

Maxwell – Boltzmann Distribution,

$$f(v) = 4\pi \left(\frac{m}{2\pi kT} \right)^{\frac{3}{2}} v^2 e^{-mv^2/2kT}$$

Temperature and Heat

Temperature Scales,

$$T_F = \frac{9}{5}T_C + 32^\circ$$

$$T_K = T_C + 273.15$$

$$\text{For Gas – thermometer Scale, } \frac{T_2}{T_1} = \frac{p_2}{p_1}$$

$$\text{Linear change, } \Delta L = \alpha \Delta L_0 \Delta T$$

$$\text{Change in volume, } \Delta V = \beta V_0 \Delta T \quad \beta = 3\alpha$$

$$\text{Heat energy transferred, } Q = mc\Delta T$$

Heat current (conduction),

$$H = \frac{dQ}{dt} = kA \frac{T_H - T_L}{L}$$

$$\text{Heat current (radiation), } H = Ae\sigma T^4$$

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Waves

Speed, $v = f\lambda$ $k = \frac{2\pi}{\lambda}$ $\omega = 2\pi f$

Wave function for a sinusoidal wave,

$$y(x, t) = A \sin(\omega t - kx)$$

Wave Equation, $\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2} \frac{\partial^2 y}{\partial t^2}$

Energy of one photon, $E = hf = \frac{hc}{\lambda}$

Photoelectric Effect, $eV_0 = hf - \phi$

Emission of X-rays, $eV = hf_{max} = \frac{hc}{\lambda_{min}}$

Doppler Effect, $f_L = \frac{v \pm v_L}{v \pm v_S} f_S$

Electromagnetic wave speed, $c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$

Index of Refraction, $n = \frac{c}{v}$

Law of Refraction, $n_a \sin \theta_a = n_b \sin \theta_b$

Total Internal Reflection, $\sin \theta_{crit} = \frac{n_b}{n_a}$

Constructive Interference, $d \sin \theta = m\lambda$

Destructive Interference, $d \sin \theta = \left(m + \frac{1}{2}\right)\lambda$

Transverse wave in a string, $v = \sqrt{\frac{F}{\mu}}$

Longitudinal wave in a fluid, $v = \sqrt{\frac{B}{\rho}}$

Longitudinal wave in a rod, $v = \sqrt{\frac{Y}{\rho}}$

Intensity of a wave, $I = \frac{1}{2} \omega B k A^2$

Intensity level, $\beta = (10 \text{dB}) \log \frac{I}{I_0}$

Simple Harmonic Motion (SHM)

Angular Frequency, $\omega = 2\pi f = \frac{2\pi}{T}$

Acceleration, $a = \frac{F}{m} = -\frac{k}{m}x$

Conservation of energy, $E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \text{constant}$

Period, $T = 2\pi \sqrt{\frac{m}{k}}$

Period, $T = 2\pi \sqrt{\frac{L}{g}}$ (a simple pendulum)

Period, $T = 2\pi \sqrt{\frac{I}{mgd}}$ (a physical pendulum)

Momentum and Impulse

Momentum (particle),

$$\mathbf{p} = m\mathbf{v} \text{ and } \sum \mathbf{F} = \frac{d\mathbf{p}}{dt}$$

Impulse – momentum Theorem,

$$\mathbf{J} = \int_{t_1}^{t_2} \mathbf{F} dt = \mathbf{p}_2 - \mathbf{p}_1$$

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Rotational Motion

$$\text{Angular Velocity, } \omega = \lim_{\Delta t \rightarrow 0} \frac{\Delta \theta}{\Delta t} = \frac{d\theta}{dt}$$

$$\text{Angular Acceleration, } \alpha = \lim_{\Delta t \rightarrow 0} \frac{\Delta \omega}{\Delta t} = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$$

Constant angular acceleration,

$$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$$

$$\omega = \omega_0 + \alpha t$$

$$\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$$

$$\text{Tangential Speed, } v = r\omega$$

$$\text{Tangential Acceleration, } a = r\alpha$$

$$\text{Centripetal Acceleration, } a = \frac{v^2}{r} = r\omega^2$$

$$\text{Moment of Inertia (body), } I = \int r^2 dm$$

$$\text{Moment of Inertia (particles), } I = \sum_i m_i r_i^2$$

$$\text{Rotational Kinetic Energy, } K = \frac{1}{2}I\omega^2$$

Torque

$$\text{Torque, } \tau = Fl$$

$$\text{Vector Torque, } \boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$$

$$\text{Total Torque, } \sum \tau = I\alpha$$

$$\text{Work Done by Torque, } W = \tau(\theta_2 - \theta_1) = \tau\Delta\theta$$

$$\text{Power, } P = \tau\omega$$

$$\text{Angular Momentum (particle), } \mathbf{L} = \mathbf{r} \times \mathbf{p} = \mathbf{r} \times m\mathbf{v}$$

$$\text{Angular Momentum (rigid body), } L = I\omega$$

$$\text{and Total Torque, } \sum \tau = \frac{dL}{dt}$$

Quantum Mechanics

Schrödinger Equation,

$$-\frac{\hbar^2}{2m} \left(\frac{\partial^2 \Psi}{\partial x^2} + \frac{\partial^2 \Psi}{\partial y^2} + \frac{\partial^2 \Psi}{\partial z^2} \right) + U\Psi = E\Psi$$

$$\text{Uncertainty Principle, } \Delta x \Delta p_x \geq \frac{h}{4\pi}$$

$$\text{Fermi - Dirac Distribution, } f(E) = \frac{1}{e^{(E-E_F)/KT} + 1}$$

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

$$\text{Energy of a photon, } E = hf = \hbar\omega$$

Elasticity

$$\text{Stress} = \frac{F}{A}$$

$$\text{Strain} = \frac{\Delta l}{l_0}$$

$$\text{Pressure} = \frac{F}{A}$$

$$\text{Elastic Modulus} = \frac{\text{Stress}}{\text{Strain}}$$

$$\text{Young's modulus, } Y = \frac{\text{Tensile Stress}}{\text{Tensile Strain}} = \frac{l_0 F}{A \Delta l}$$

$$\text{Poisson's ratio } (\sigma), \frac{\Delta w}{w_0} = -\sigma \frac{\Delta l}{l_0}$$

$$\text{Bulk Modulus, } B = -\frac{\Delta p}{\Delta V/V_0}$$

$$\text{Compressibility, } k = \frac{1}{B} = -\frac{1}{V_0} \frac{\Delta V}{\Delta p}$$

$$\text{Shear Modulus, } S = \frac{\text{Shear Stress}}{\text{Shear Strain}} = \frac{F/A}{\phi}$$

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Electricity and Magnetism

$$\text{Coulomb's Law, } F = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2}$$

$$\text{Electric Field, } \mathbf{E} = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} \hat{\mathbf{r}}$$

$$\text{Dipole moment, } p = ql$$

$$\text{Vector torque, } \boldsymbol{\tau} = \mathbf{p} \times \mathbf{E}$$

$$\text{Potential Energy, } u = -\mathbf{p} \cdot \mathbf{E}$$

$$\text{Gauss's Law, } \int \mathbf{E} \cdot d\mathbf{A} = \frac{\sum q_i}{\epsilon_0} = \frac{Q_{\text{encl}}}{\epsilon_0}$$

$$\text{Potential Difference, } V_a - V_b = \int_a^b \mathbf{E} \cdot d\mathbf{l}$$

$$\text{Potential, } V = \frac{U}{q'} = \frac{1}{4\pi\epsilon_0} \sum_i \frac{q_i}{r_i}$$

$$\text{Electric Field, } \mathbf{E} = -\nabla V$$

$$\text{Capacitance, } C = \frac{Q}{V}$$

$$\text{Parallel plate capacitor, } C = \epsilon_0 \frac{A}{d}$$

$$\text{Capacitors in series, } \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$$

$$\text{Capacitors in parallel, } C = C_1 + C_2 + \dots$$

$$\text{Energy stored in a capacitor, } U = \frac{Q^2}{2C} = \frac{1}{2} CV^2 = \frac{1}{2} QV$$

$$\text{Energy density, } u = \frac{1}{2} \epsilon_0 E^2$$

$$\text{Energy density (in a dielectric), } u = \frac{1}{2} \epsilon E^2$$

$$\text{Current, } I = \frac{\Delta Q}{\Delta t} = nqAv_d$$

$$\text{Current Density, } \mathbf{J} = n_1 q_1 v_{d_1} + n_2 q_2 v_{d_2} + \dots$$

$$\text{Resistivity, } \rho = \frac{E}{J}$$

$$\text{Resistance, } R = \frac{\rho L}{A}$$

$$\text{Ohm's Law, } V = IR$$

Terminal potential difference,

$$\text{(source with internal resistance) } V = \mathcal{E} - Ir$$

$$\text{Power dissipated, } P = VI = I^2 R = \frac{V^2}{R}$$

$$\text{Resistors in series, } R = R_1 + R_2 + \dots$$

$$\text{Resistors in parallel, } \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

Force on a charge in a magnetic field,

$$\mathbf{F} = q\mathbf{v} \times \mathbf{B}$$

Force on a conductor in a magnetic field,

$$\mathbf{F} = I\mathbf{l} \times \mathbf{B}$$

$$\text{Energy Density, } u = \frac{B^2}{2\mu_0}$$

$$\text{Bohr Magneton, } \mu = \frac{e\hbar}{2m} = \frac{eh}{4\pi m}$$

$$\text{Faraday's Law: induced emf, } \mathcal{E} = -\frac{d\Phi_B}{dt}$$

Gravitation

$$\text{Newton's Law of Gravitation, } F_g = G \frac{m_1 m_2}{r^2}$$

$$\text{Acceleration due to gravity on Earth, } \mathbf{g} = \frac{GM_E}{R_E^2}$$

Physical Sciences Centre

Department of Chemistry, University of Hull, Hull HU6 7RX, Tel/Fax: 01482 465418,
psc@hull.ac.uk, www.heacademy.ac.uk/physsci