Useful data for physics students

Work and Energy

Work Done, $W = \int_{S_1}^{S_2} \mathbf{F} \cdot \mathrm{d}\,\mathbf{s}$

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

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

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

Instantaneous Power, $P = \frac{\mathrm{d}W}{\mathrm{d}t} = \mathbf{F} \cdot \mathbf{v}$

Potential Energy Function, $\Delta U = -W$

Gravitational Potential Energy, $U = U_0 + mgh$

Conservative Force, $F_x = -\frac{\mathrm{d}U}{\mathrm{d}x}$ and $\mathbf{F} = -\nabla U$

Motion in one dimension

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

Instantaneous velocity, $v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{\mathrm{d}x}{\mathrm{d}t}$

Constant Acceleration Equations,

$v = v_0 + at$

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

$x = x_0 + v_0 t + \frac{1}{2}at^2$

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

Instantaneous acceleration, $a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{\mathrm{d}v}{\mathrm{d}t}$

Newton's Law, $\mathbf{F} = ma = \frac{m\mathrm{d}v}{\mathrm{d}t}$

Thermal Properties of Matter

Ideal gas equation, $pV = nRT$

Total mass, $m = nM$

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

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

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

Molar heat capacities for ideal gases,

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

(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,

$T_F = \frac{9}{5}T_C + 32°$

$T_K = T_C + 273.15$

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

Linear change, $\Delta L = \alpha \Delta L_0 \Delta T$

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

Heat energy transferred, $Q = mc\Delta T$

Heat current (conduction),

$H = \frac{\mathrm{d}Q}{\mathrm{d}t} = kA\frac{T_H - T_L}{L}$

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

Useful data for physics students

Waves

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

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, $\mathrm{E} = hf = \frac{hc}{\lambda}$

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, $c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$

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, $I = \frac{1}{2}\omega BkA^2$

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

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),

$\mathbf{p} = m\mathbf{v}$ and $\sum \mathbf{F} = \frac{\mathrm{d}\mathbf{p}}{\mathrm{d}t}$

Impulse − momentum Theorem,

$\mathbf{J} = \int_{t_1}^{t_2} \mathbf{F}\,\mathrm{d}\,t = \mathbf{p}_2 - \mathbf{p}_1$

Useful data for physics students

Rotational Motion

Angular Velocity, $\omega = \lim_{\Delta t \to 0} \frac{\Delta\theta}{\Delta t} = \frac{\mathrm{d}\theta}{\mathrm{d}t}$

Angular Acceleration, $\alpha = \lim_{\Delta t \to 0} \frac{\Delta\omega}{\Delta t} = \frac{\mathrm{d}\omega}{\mathrm{d}t} = \frac{\mathrm{d}^2\theta}{\mathrm{d}t^2}$

Constant angular acceleration,

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

$\omega = \omega_0 + \alpha t$

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

Tangential Speed, $v = r\omega$

Tangential Acceleration, $a = r\alpha$

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

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

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

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

Torque

Torque, $\tau = Fl$

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

Total Torque, $\sum \tau = I\alpha$

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

Power, $P = \tau\omega$

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

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

and Total Torque, $\sum \tau = \frac{\mathrm{d}\mathbf{L}}{\mathrm{d}t}$

Quantum Mechanics

Schrödinger Equation,

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

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

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

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

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

Elasticity

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

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

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

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

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

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

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

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

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

Useful data for physics students

Electricity and Magnetism

Coulomb'sLaw, $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$

Electric Field, $\mathbf{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{\mathbf{r}}$

Dipole moment, $p = ql$

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

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

Gauss's Law, $\int \mathbf{E}\cdot d\mathbf{A} = \frac{\sum q_i}{\varepsilon_0} = \frac{Q_{encl}}{\varepsilon_0}$

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

Potential, $V = \frac{U}{q'} = \frac{1}{4\pi\varepsilon_0}\sum_i \frac{q_i}{r_i}$

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

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

Parallel plate capacitor, $C = \varepsilon_0 \frac{A}{d}$

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

Capacitors in parallel, $C = C_1 + C_2 + \cdots\cdots$

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

Energy density, $u = \frac{1}{2}\varepsilon_0 E^2$

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

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

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

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

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

Ohm's Law, $V = IR$

Terminal potential difference,

(source with internal resistance) $V = \varepsilon - Ir$

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

Resistors in series, $R = R_1 + R_2 \cdots\cdots$

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

Force on a charge in a magnetic field,

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

Force on a conductor in a magnetic field,

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

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

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

Faraday'sLaw: induced emf, $\varepsilon = -\frac{\mathrm{d}\phi_B}{\mathrm{d}t}$

Gravitation

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

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

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