

Mechanics Formulae for Physics Proficiency Exams

Motion, forces, work, energy and momentum.

$$v = dx/dt; \quad a = dv/dt; \quad v = v_0 + at; \quad x = x_0 + v_0t + at^2/2; \quad v^2 = v_0^2 + 2ad;$$

$$W = mg; \quad F = ma; \quad f = \mu N; \quad W = \mathbf{F} \cdot \mathbf{x}; \quad K = mv^2/2;$$

$$U_g = mgh; \quad U_s = kx^2/2; \quad F_x = -dU/dx; \quad x_{cm} = \sum m_i x_i / \sum m_i;$$

$$\mathbf{p} = m\mathbf{v}; \quad \mathbf{F} = d\mathbf{p}/dt;$$

Rotational motion.

$$\theta = s/r; \quad \omega = d\theta/dt; \quad \alpha = d\omega/dt; \quad a_c = v^2/r = \omega^2 r; \quad K = I\omega^2/2; \quad I = \sum m_i r_i^2; \quad I_{disc} = \frac{1}{2} MR^2;$$

$$\tau = I\alpha; \quad \boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}; \quad \mathbf{L} = m(\mathbf{r} \times \mathbf{v}); \quad L = I\omega; \quad \sum \mathbf{F} = 0; \quad \sum \boldsymbol{\tau} = 0;$$

Oscillators, gravity.

$$F = -kx; \quad E = \frac{1}{2}kx^2; \quad y = A \cos(\omega t + \phi); \quad \omega = 2\pi/T; \quad T = 1/f; \quad \omega = (k/m)^{1/2}; \quad T = 2\pi (\ell/g)^{1/2};$$

$$F = GM_1M_2/r^2; \quad U_g = -GMm/r; \quad K = GMm/2r;$$

$$T^2 = r^3 (4\pi^2)/(GM)$$

Fluids, waves, sound.

$$\rho = m/v; \quad p = F/A; \quad p = \rho gh; \quad p + 0.5 \rho v^2 + \rho gh = \text{const};$$

$$y = A \sin(kx - \omega t); \quad k = 2\pi/\lambda; \quad \omega = 2\pi/T; \quad v = \lambda f = \omega/k; \quad v = (\tau/\mu)^{1/2};$$

$$\beta = 10 \log(I/I_0) \text{ dB}; \quad f' = f (v+v_D)/(v+v_S);$$

Thermo, heat, kinetic theory.

$$T_F = 1.8 T_C + 32; \quad \Delta L/L = \alpha \Delta T; \quad Q = cm\Delta t; \quad Q = Lm; \quad \Delta E_{int} = Q_{in} - W_{done};$$

$$\Delta Q/\Delta t = kA \Delta T/L; \quad KE_{av} = 1.5 kT \text{ where } k = R/N_A = 1.38 \times 10^{-23} \text{ J/K};$$

Constants.

$$N_A = 6.02 \times 10^{23}; \quad R = 8.31 \text{ J/mol-K}, \quad G = 6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2, \quad g = 9.8 \text{ m/s}^2 = 32 \text{ ft/sec}^2$$

MISC.

$$\sin(2\theta) = 2 \sin(\theta) \cos(\theta)$$

$$\text{If } ax^2 + bx + c = 0 \text{ then } x = [-b \pm (b^2 - 4ac)^{1/2}] / [2a]$$

Electricity & Magnetism Formulae for Physics Proficiency Exams

Constants:

$$e = 1.6 \times 10^{-19} \text{ C} ; \quad k = 1/(4\pi\epsilon_0) = 9 \times 10^9 \text{ N m}^2/\text{C}^2$$

$$\epsilon_0 = 8.85 \times 10^{-12} \text{ F/m} ; \quad \mu_0 = 4 \pi \times 10^{-7} \text{ T m/A}$$

$$c = 3 \times 10^8 \text{ m/s} ; \quad 1 \text{ eV} = 1.6 \times 10^{-19} \text{ J} ; \quad m_e = 9.11 \times 10^{-31} \text{ kg}$$

Electric fields, resistance, circuits, capacitors:

$$F = kQ_1Q_2/r^2 ; \quad \mathbf{E} = \mathbf{F}/q ; \quad \Phi_E = \int \mathbf{E} \cdot \mathbf{A} = Q_{\text{encl}}/\epsilon_0 ; \quad \Delta V = -\mathbf{E} \cdot d\mathbf{r} ; \quad V = kq/r$$

$$-\mathbf{E} = \mathbf{i} \partial V/\partial x + \mathbf{j} \partial V/\partial y + \mathbf{k} \partial V/\partial z \quad i = V/R ; \quad R = \rho L/A ; \quad \rho - \rho_0 = \rho_0 \alpha \Delta T$$

$$P = iV ; \quad \text{Kirchhoff: } \sum_{\text{loop}} V = 0 ; \quad i_{\text{in}} = i_{\text{out}} ; \quad U = \sum kq_iq_j/r_{ij}$$

$$q = CV ; \quad C = \epsilon_0 A/d ; \quad U_c = \frac{1}{2} CV^2 ; \quad q = q_0 e^{-t/RC} \text{ or } q = q_f (1 - e^{-t/RC}) ; \quad \tau_c = RC;$$

$$R_{\text{series equiv}} = R_1 + R_2 + \dots \quad 1/R_{\text{parallel equiv}} = 1/R_1 + 1/R_2 + \dots$$

$$C_{\text{parallel equiv}} = C_1 + C_2 + \dots \quad 1/C_{\text{series equiv}} = 1/C_1 + 1/C_2 + \dots$$

Magnetic fields and electromagnetism:

$$\mathbf{F}_B = q\mathbf{v} \times \mathbf{B} ; \quad \mathbf{F}_B = i\mathbf{L} \times \mathbf{B} ; \quad qvB = mv^2/r$$

$$\text{Biot-Savart Law: } d\mathbf{B} = (\mu_0/4\pi)(i d\mathbf{s} \times \mathbf{r})/r^3$$

$$\epsilon = \oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt} - \frac{d}{dt}(\vec{B} \cdot d\vec{A}) ; \quad \oint \vec{B} \cdot d\vec{l} = \mu_0 \epsilon_0 \frac{d\Phi_E}{dt} + \mu_0 i$$

$$B_{\text{line}} = \mu_0 i/2\pi r ; \quad B_{\text{hoop}} = \mu_0 i/2r ; \quad B_{\text{solenoid}} = \mu_0 n i ;$$

$$\mathcal{E} = -L di/dt ; \quad L_{\text{sol}} = \mu_0 n^2 A ; \quad \tau_L = L/R ; \quad U_L = \frac{1}{2} Li^2 ; \quad \omega^2 = 1/LC$$

Optics:

$$n_1 \sin \theta_1 = n_2 \sin \theta_2 ; \quad 1/p + 1/i = 1/f = 2/r ; \quad 1/f = (n-1) [r_1^{-1} - r_2^{-1}] ; \quad \sin \theta = 1.22 \lambda/d$$

$$\vec{E} = E_{\text{max}} \sin(kx \pm \omega t) \hat{y} ; \quad k = 2\pi/\lambda ; \quad \omega = 2\pi f$$

$$c = (\epsilon_0 \mu_0)^{-1/2} ; \quad E_{\text{max}} = B_{\text{max}} c ; \quad \mathbf{S} = \mathbf{E} \times \mathbf{B}/\mu_0 ; \quad \Delta p = \Delta I/c$$

Math:

$$\text{The solutions to a quadratic equation: } ax^2 + bx + c = 0 \text{ are } x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\text{Surface Area of a Sphere is: } 4\pi r^2 ; \quad \text{Volume is } 4\pi r^3/3$$

Modern Physics Formulae for Physics Proficiency Exams

Special Relativity:

$$\beta = v/c; \gamma = (1 - \beta^2)^{-1/2}; \quad T = T_0\gamma; \quad L = L_0/\gamma$$

$$\text{Binomial Expansion: } \gamma = 1 + \beta^2/2 + 3\beta^4/8 + \dots$$

$$\text{Lorentz: } x' = \gamma(x - \beta ct); \quad y' = y; \quad z' = z; \quad ct' = \gamma(ct - \beta x)$$

$$\text{velocity transform: } v_x' = (v_x - u)/(1 - v_x u/c^2) \quad \text{Doppler: } v' = v [(1-\beta)/(1+\beta)]^{1/2}$$

$$\text{Kinematics: } E = \gamma mc^2; \quad pc = \beta\gamma mc^2; \quad E^2 = (pc)^2 + (mc^2)^2; \quad K = E - mc^2$$

Origins of Quantum Theory:

$$\text{Photoelectric effect: } K_{\max} = h\nu - \phi \quad ; \quad \text{de Broglie wavelength: } \lambda = h/p$$

$$\text{Blackbody radiation: } I = \sigma T^4; \quad \lambda_{\max} T = 2.898 \cdot 10^{-3} \text{ m K}$$

$$\text{Compton scattering: } \lambda' - \lambda = (hc/m_e c^2) (1 - \cos \theta)$$

$$\text{Electron diffraction: } n\lambda = d \sin \phi \quad \text{Heisenberg: } \Delta x \Delta p_x \sim h/2\pi; \quad \Delta E \Delta t \sim h/2\pi$$

$$\text{Schrödinger Equation: } -(\hbar^2/8\pi^2 m) d^2\psi/dx^2 + U\psi = E\psi \quad P(x)dx = |\psi(x)|^2 dx$$

$$\text{SHO: } E_n = (n + 1/2) (h/2\pi) \omega$$

$$\text{Rutherford Scattering: } N(\theta) = (nt/4r^2) (zZ/2K)^2 (e^2/4\pi\epsilon_0)^2 (\sin(\theta/2))^{-4}$$

$$\text{Hydrogen atom: } E_n = -13.6 \text{ eV} / n^2 \quad \lambda = (1/R) n_1^2 n_2^2 / (n_1^2 - n_2^2) \quad R = 1.097 \times 10^7 \text{ m}^{-1}$$

$$dV = r^2 \sin \theta dr d\theta d\phi; \quad P_{\text{orb}} = r^2 |R_{\text{orb}}|^2; \quad \text{orbital: } \mu_L = -(e/2m) \mathbf{L}; \quad \mu_{L,z} = -m_l \mu_B$$

$$\text{x-rays: } E_\alpha = 13.6 \text{ eV} (Z-1)^2 (3/4);$$

Statistics:

$$p(E)_{\text{MB}} \sim E^{1/2} / e^{E/kT}; \quad p(E)_{\text{BE}} \sim E^2 / (e^{E/kT} - 1);$$

$$p(E)_{\text{FD}} \sim E^{1/2} / \{\exp[(E-E_F)/kT] + 1\}; \quad E_F = (\hbar^2/2m) (3N/8\pi V)^{2/3}$$

Nuclear:

$$R = (1.2 \times 10^{-15} \text{ m}) A^{1/3}; \quad dN/dt = -\lambda N; \quad \lambda = 1/\tau = 0.693/t_{1/2}; \quad K_\alpha = (A-4)Q/A \quad R = \sigma N I_0 / S;$$

$$N(t) = (R/\lambda) (1 - e^{-\lambda t}); \quad \mathcal{A} = \lambda N; \quad (\text{for } x + X \rightarrow y + Y) \quad K_{\text{threshold}} = -Q (1 + m_x/m_X)$$

$$(\text{for } x + X \rightarrow A + B + C + \dots) \quad K_{\text{threshold}} = -Q (m_x + m_X + m_A + m_B + m_C + \dots) / (2m_X)$$

$$\text{Mössbauer Effect: recoil energy } K = E_\gamma^2 / (2Mc^2), \quad v \sim c\Delta E/E$$

Particle:

leptons e μ τ ; quarks [charge +2/3 u c t] [charge -1/3 d s b]

Constants:

$$hc = 1240 \text{ eV nm}; \quad m_e c^2 = 511,000 \text{ eV}; \quad \mu_B = eh/8\pi m = 9.274 \times 10^{-24} \text{ J/T}$$

$$h = 6.63 \cdot 10^{-34} \text{ J s} = 4.14 \cdot 10^{-15} \text{ eV s}; \quad k_{\text{Boltz}} = 8.617 \cdot 10^{-5} \text{ eV/K}; \quad e^2/4\pi\epsilon_0 = 1.440 \text{ eV nm}$$

$$1 \text{ u (or amu)} = 931.5 \text{ MeV}/c^2 \quad ; \quad m_e c^2 = 511000 \text{ eV}; \quad e = 1.6 \times 10^{-19} \text{ C}; \quad k = 1/(4\pi\epsilon_0)$$

$$= 9 \times 10^9 \text{ N m}^2/\text{C}^2; \quad \epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/(\text{N m}^2)$$

$$N_{\text{Avogad}} = 6.02 \times 10^{23}; \quad \mu_0 = 4\pi \times 10^{-7} \text{ T m/A}; \quad hc = 1240 \text{ eV nm};$$