Please Do Not Write on This Sheet

Physics Formula Sheet

Chapter 1: Introduction: The Nature of Science and Physics

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$
$$Radius\ of\ Earth = 6.38 \times 10^6\ m$$
$$Mass\ of\ Earth = 5.98 \times 10^{24}\ kg$$
$$c = 3.00 \times 10^8\ m/s$$
$$G = 6.673 \times 10^{-11} \frac{Nm^2}{kg^2}$$
$$N_A = 6.02 \times 10^{23}$$
$$k = 1.38 \times 10^{-23} J/K$$
$$R = 8.31\ {}^{J}/_{mol \cdot K}$$
$$\sigma = 5.67 \times 10^{-8} W/(m^2 \cdot K)$$
$$k = 8.99 \times 10^9\ N \cdot m^2/C^2$$
$$q_e = -1.60 \times 10^{-19}\ C$$
$$\epsilon_0 = 8.85 \times 10^{-12} C^2/(N \cdot m^2)$$
$$\mu_0 = 4\pi \times 10^{-7}\ T \cdot m/A$$
$$h = 6.63 \times 10^{-34}\ J \cdot s$$
$$m_e = 9.11 \times 10^{-31}\ kg$$
$$m_p = 1.6726 \times 10^{-27}\ kg$$
$$m_n = 1.6749 \times 10^{-27}\ kg$$
$$amu = 1.6605 \times 10^{-27}\ kg$$
$$Density\ of\ water = 1000 \frac{kg}{m^3}$$

Chapter 2: Kinematics

$$\Delta x = x_f - x_0$$
$$\Delta t = t_f - t_0$$
$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_0}{t_f - t_0}$$
$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_0}{t_f - t_0}$$
$$x = x_0 + \bar{v}t$$
$$\bar{v} = \frac{v_0 + v}{2}$$
$$v = v_0 + at$$
$$x = x_0 + v_0 t + \frac{1}{2}at^2$$
$$v^2 = v_0^2 + 2a(x - x_0)$$
$$g = 9.80 \frac{m}{s^2}$$

Chapter 3: Two-Dimensional Kinematics

$$A_x = A\cos\theta$$
$$A_y = A\sin\theta$$
$$R_x = A_x + B_x$$
$$R_y = A_y + B_y$$
$$R = \sqrt{R_x^2 + R_y^2}$$
$$\theta = tan^{-1}\frac{R_y}{R_x}$$
$$h = \frac{v_{0y}^2}{2g}$$
$$R = \frac{v_0^2 \sin 2\theta_0}{g}$$
$$v_x = v\cos\theta$$
$$v_y = v\sin\theta$$
$$v = \sqrt{v_x^2 + v_y^2}$$
$$\theta = tan^{-1}\frac{v_y}{v_x}$$

Chapter 4: Dynamics: Forces and Newton's Laws of Motion

$$F_{net} = ma$$
$$w = mg$$

Chapter 5: Further Applications of Newton's Laws: Friction, Drag, and Elasticity

$$f_s \le \mu_s N$$
$$f_k = \mu_k N$$
$$F_D = \frac{1}{2}C\rho A v^2$$
$$F_s = 6\pi\eta r v$$
$$F = k\Delta x$$
$$\Delta L = \frac{1F}{YA}L_0$$
$$stress = \frac{F}{A}$$
$$strain = \frac{\Delta L}{L_0}$$
$$stress = Y \times strain$$
$$\Delta x = \frac{1F}{SA}L_0$$
$$\Delta V = \frac{1F}{BA}V_0$$

Chapter 6: Uniform Circular Motion and Gravitation

$$\Delta\theta = \frac{\Delta s}{r}$$
$$2\pi\ rad = 360° = 1\ revolution$$
$$\omega = \frac{\Delta\theta}{\Delta t}$$
$$v = r\omega$$
$$a_C = \frac{v^2}{r}$$
$$a_C = r\omega^2$$
$$F_C = ma_C$$
$$F_C = \frac{mv^2}{r}$$
$$\tan\theta = \frac{v^2}{rg}$$
$$F_C = mr\omega^2$$
$$F = G\frac{mM}{r^2}$$
$$g = \frac{GM}{r^2}$$
$$\frac{T_1^2}{T_2^2} = \frac{r_1^3}{r_2^3}$$
$$T^2 = \frac{4\pi^2}{GM}r^3$$
$$\frac{r^3}{T^2} = \frac{G}{4\pi^2}M$$

Chapter 7: Work, Energy, and Energy Resources

$$W = fd\cos\theta$$
$$KE = \frac{1}{2}mv^2$$
$$W_{net} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_0^2$$
$$PE_g = mgh$$
$$PE_s = \frac{1}{2}kx^2$$
$$KE_0 + PE_0 = KE_f + PE_f$$
$$KE_0 + PE_0 + W_{nc} = KE_f + PE_f$$
$$Eff = \frac{W_{out}}{E_{in}}$$
$$P = \frac{W}{t}$$

Chapter 8: Linear Momentum and Collisions

$$p = mv$$
$$\Delta p = F_{net}\Delta t$$
$$p_0 = p_f$$
$$m_1 v_{01} + m_2 v_{02} = m_1 v_{f1} + m_2 v_{f2}$$

$$\frac{1}{2}m_1v_{01}^2 + \frac{1}{2}m_2v_{02}^2 = \frac{1}{2}m_1v_{f1}^2 + \frac{1}{2}m_2v_{f2}^2$$

$$m_1v_1 = m_1v_1' \cos\theta_1 + m_2v_2' \cos\theta_2$$

$$0 = m_1v_1' \sin\theta_1 + m_2v_2' \sin\theta_2$$

$$\frac{1}{2}mv_1^2 = \frac{1}{2}mv_1'^2 + \frac{1}{2}mv_2'^2 + mv_1'v_2' \cos(\theta_1 - \theta_2)$$

$$a = \frac{v_e}{m}\frac{\Delta m}{\Delta t} - g$$

$$v_{cm} = \frac{v_1m_1 + v_2m_2}{m_1 + m_2}$$

Chapter 9: Statics and Torque

$$\tau = rF\sin\theta$$

$$r_\perp = r\sin\theta$$

$$MA = \frac{F_o}{F_i} = \frac{l_i}{l_o}$$

$$l_iF_i = l_oF_o$$

Chapter 10: Rotational Motion and Angular Momentum

$$\omega = \frac{\Delta\theta}{\Delta t}$$

$$v = r\omega$$

$$\alpha = \frac{\Delta\omega}{\Delta t}$$

$$a_t = \frac{\Delta v}{\Delta t}$$

$$a_t = r\alpha$$

$$\theta = \overline{\omega}t$$

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

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

$$\omega^2 = \omega_0^2 + 2\alpha\theta$$

$$\overline{\omega} = \frac{\omega_0 + \omega}{2}$$

$$net\ \tau = I\alpha$$

Hoop about cylinder axis: $I = MR^2$

Hoop about any diameter: $I = \frac{MR^2}{2}$

Ring: $I = \frac{M}{2}(R_1^2 + R_2^2)$

Solid cylinder (or disk) about cylinder axis: $I = \frac{MR^2}{2}$

Solid cylinder (or disk) about central diameter: $I = \frac{MR^2}{4} + \frac{M\ell^2}{12}$

Thin rod about axis through center $\perp$ to length: $I = \frac{M\ell^2}{12}$

Thin rod about axis through one end $\perp$ to length: $I = \frac{M\ell^2}{3}$

Solid sphere: $I = \frac{2MR^2}{5}$

Thin spherical shell: $I = \frac{2MR^2}{3}$

Slab about $\perp$ axis through center:

$$I = \frac{M(a^2+b^2)}{12}$$

$$net\ W = (net\ \tau)\theta$$

$$KE_{rot} = \frac{1}{2}I\omega^2$$

$$L = I\omega$$

$$net\ \tau = \frac{\Delta L}{\Delta t}$$

Chapter 11: Fluid Statics

$$\rho = \frac{m}{V}$$

$$P = \frac{F}{A}$$

$$P_{atm} = 1.01 \times 10^5\ Pa$$

$$P = \rho gh$$

$$P_2 = P_1 + \rho gh$$

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$F_B = w_{fl}$$

$$Fraction\ submerged = \frac{\rho_{obj}}{\rho_{fl}}$$

$$specific\ gravity = \frac{\overline{\rho}}{\rho_w}$$

$$\gamma = \frac{F}{L}$$

$$P = \frac{4\gamma}{r}$$

$$h = \frac{2\gamma\cos\theta}{\rho gr}$$

Chapter 12: Fluid Dynamics and Its Biological Medical Applications

$$Q = \frac{V}{t}$$

$$Q = A\overline{v}$$

$$A_1\overline{v}_1 = A_2\overline{v}_2$$

$$n_1A_1\overline{v}_1 = n_2A_2\overline{v}_2$$

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho gh_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho gh_2$$

$$\left(\Delta P + \Delta\frac{1}{2}\rho v^2 + \Delta\rho gh\right)Q = power$$

$$v_1 = \sqrt{2gh}$$

$$\eta = \frac{FL}{vA}$$

$$Q = \frac{P_2 - P_1}{R}$$

$$R = \frac{8\eta l}{\pi r^4}$$

$$Q = \frac{(P_2 - P_1)\pi r^4}{8\eta l}$$

$$N_R = \frac{2\rho vr}{\eta}$$

$$N_R' = \frac{\rho vL}{\eta}$$

$$x_{rms} = \sqrt{2Dt}$$

Chapter 13: Temperature, Kinetic Theory, and the Gas Laws

$$T(°F) = \frac{9}{5}T(°C) + 32$$

$$T(K) = T(°C) + 273.15$$

$$\Delta L = \alpha L\Delta T$$

$$\Delta A = 2\alpha A\Delta T$$

$$\Delta V = \beta V\Delta T$$

$$\beta \approx 3\alpha$$

$$PV = NkT$$

$$k = 1.38 \times 10^{-23}\ J/K$$

$$N_A = 6.02 \times 10^{23}\ mol^{-1}$$

$$PV = nRT$$

$$R = 8.31\frac{J}{mol \cdot K}$$

$$PV = \frac{1}{3}Nm\overline{v}^2$$

$$KE = \frac{1}{2}m\overline{v}^2 = \frac{3}{2}kT$$

$$v_{rms} = \sqrt{\frac{3kT}{m}}$$

$$\%\ relative\ humidity = \frac{vapor\ density}{saturation\ vapor\ denasity} \times 100\%$$

Chapter 14: Heat and Heat Transfer Methods

$$1.000\ kcal = 4186\ J$$
$$Q = mc\Delta T$$
$$Q = mL_f$$
$$Q = mL_v$$
$$\frac{Q}{t} = \frac{kA(T_2 - T_1)}{d}$$
$$\frac{Q}{t} = \sigma e A T^4$$
$$\sigma = 5.67 \times 10^{-8} \frac{J}{s \cdot m^2 \cdot K^4}$$
$$\frac{Q_{net}}{t} = \sigma e A (T_2^4 - T_1^4)$$

Chapter 15: Thermodynamics

$$U = \frac{3}{2} NkT$$
$$\Delta U = Q - W$$
$$W = P\Delta V\ (isobaric\ process)$$
$$\Delta U = Q - P\Delta V$$
$$W = 0\ (isochoric\ process)$$
$$\Delta U = Q$$
$$Q = W\ (isothermal\ process)$$
$$\Delta U = 0$$
$$Q = 0\ (adiabatic\ process)$$
$$\Delta U = -W$$
$$Eff = \frac{W}{Q_h}$$
$$Eff = 1 - \frac{Q_c}{Q_h}\ (cyclical\ process)$$
$$Eff_C = 1 - \frac{T_c}{T_h}$$
$$COP_{hp} = \frac{Q_h}{W}$$
$$COP_{ref} = COP_{hp} - 1 = \frac{Q_c}{W}$$
$$EER = \frac{Q_c/t_1}{Q_h/t_2}$$
$$\Delta S = \frac{Q}{T}$$
$$\Delta S_{tot} = \frac{Q_h}{T_h} + \frac{Q_c}{T_c} = 0$$
$$W_{unavail} = \Delta S \cdot T_0$$
$$S = k \ln W$$
$$k = 1.38 \times 10^{-23}\ J/K$$

Chapter 16: Oscillatory Motion and Waves

$$f = \frac{1}{T}$$
$$v = \frac{\lambda}{T} = f\lambda$$
$$F = -kx$$
$$PE_{el} = \frac{1}{2} kx^2$$
$$T = 2\pi \sqrt{\frac{m}{k}}$$
$$f = \frac{1}{2\pi} \sqrt{\frac{k}{m}}$$
$$x(t) = X \cos\left(\frac{2\pi t}{T}\right)$$
$$v(t) = -v_{max} \sin\left(\frac{2\pi t}{T}\right)$$
$$v_{max} = \frac{2\pi X}{T} = X\sqrt{\frac{k}{m}}$$
$$a(t) = -\frac{kX}{m} \cos\left(\frac{2\pi t}{T}\right)$$
$$v_{string} = \sqrt{\frac{F}{m/L}}$$
$$v_w = \left(331 \frac{m}{s}\right) \sqrt{\frac{T}{273\ K}}$$
$$I = \frac{P}{A}$$
$$A_{sphere} = 4\pi r^2$$
$$I = \frac{(\Delta p)^2}{2\rho v_w}$$

Chapter 17: Physics of Hearing

$$\beta = (10\ dB) \log\left(\frac{I}{I_0}\right)$$
$$f_o = f_s \left(\frac{v_w \pm v_o}{v_w \mp v_s}\right)$$
$$f_B = |f_1 - f_2|$$
$$f_n = n\left(\frac{v_w}{2L}\right)$$
$$f_n = n\left(\frac{v_w}{4L}\right)$$
$$Z = \rho v$$
$$a = \frac{(Z_2 - Z_1)^2}{(Z_1 + Z_2)^2}$$

Chapter 18: Electric Charge and Electric Field

$$|q_e| = 1.60 \times 10^{-19}\ C$$
$$F = k\frac{|q_1 q_2|}{r^2}$$
$$E = F/q$$
$$E = k\frac{|Q|}{r^2}$$

Chapter 19: Electric Potential and Electric Energy

$$V = \frac{PE}{q}$$
$$\Delta PE = q\Delta V$$
$$W = qV_{AB}$$
$$E = \frac{V_{AB}}{d}$$
$$E = -\frac{\Delta V}{\Delta s}$$
$$V = \frac{kQ}{r}$$
$$C = \frac{Q}{V}$$
$$C = \epsilon_0 \frac{A}{d}$$
$$\epsilon_0 = 8.85 \times 10^{-12} \frac{F}{m}$$
$$C = \kappa \epsilon_0 \frac{A}{d}$$
$$E_{cap} = \frac{QV}{2} = \frac{CV^2}{2} = \frac{Q^2}{2C}$$

Chapter 20: Electric Current, Resistance, and Ohm's Law

$$I = \frac{\Delta Q}{\Delta t}$$
$$I = nqAv_d$$
$$V = IR$$
$$R = \frac{\rho L}{A}$$
$$\rho = \rho_0(1 + \alpha\Delta T)$$
$$R = R_0(1 + \alpha\Delta T)$$
$$P = IV = \frac{V^2}{R} = I^2 R$$
$$P_{ave} = \frac{1}{2} I_0 V_0$$
$$I_{rms} = \frac{I_0}{\sqrt{2}}$$
$$V_{rms} = \frac{V_0}{\sqrt{2}}$$

Chapter 21: Circuits, Bioelectricity, and DC Instruments

$$R_S = R_1 + R_2 + R_3 + \cdots$$
$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$
$$V = emf - Ir$$
$$V = emf\left(1 - e^{-\frac{t}{RC}}\right)$$
$$\tau = RC$$
$$V = V_0 e^{-\frac{t}{RC}}$$

Chapter 22: Magnetism

$$F = qvB \sin\theta$$
$$r = \frac{mv}{qB}$$
$$\epsilon = Blv$$
$$F = ILB \sin\theta$$
$$\tau = NIAB \sin\theta$$
$$B = \frac{\mu_0 I}{2\pi r}$$
$$B = \frac{\mu_0 I}{2R}$$
$$B = \mu_0 nI$$
$$\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi r}$$

Chapter 23: Electromagnetic Induction, AC Circuits, and Electrical Technologies

$$\Phi = BA \cos\theta$$
$$emf = -N\frac{\Delta\Phi}{\Delta t}$$
$$emf = vBL$$
$$emf = NAB\omega \sin\omega t$$
$$\frac{V_S}{V_P} = \frac{N_S}{N_P} = \frac{I_P}{I_S}$$
$$emf_1 = -M\frac{\Delta I_2}{\Delta t}$$
$$emf = -L\frac{\Delta I}{\Delta t}$$
$$L = N\frac{\Delta\Phi}{\Delta I}$$
$$L = \frac{\mu_0 N^2 A}{\ell}$$
$$E_{ind} = \frac{1}{2}LI^2$$
$$I = I_0\left(1 - e^{-\frac{t}{\tau}}\right)$$
$$\tau = \frac{L}{R}$$
$$I = I_0 e^{-\frac{t}{\tau}}$$
$$I = \frac{V}{X_L}$$
$$X_L = 2\pi f L$$
$$I = \frac{V}{X_C}$$
$$X_C = \frac{1}{2\pi f C}$$
$$I_0 = \frac{V_0}{Z} \text{ or } I_{rms} = \frac{V_{rms}}{Z}$$
$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$
$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$
$$\cos\phi = \frac{R}{Z}$$
$$P_{ave} = I_{rms}V_{rms}\cos\phi$$

Chapter 24: Electromagnetic Waves

$$c = \frac{1}{\sqrt{\mu_0\epsilon_0}}$$
$$\frac{E}{B} = c$$
$$c = f\lambda$$
$$I_{ave} = \frac{c\epsilon_0 E_0^2}{2}$$
$$I_{ave} = \frac{cB_0^2}{2\mu_0}$$
$$I_{abe} = \frac{E_0 B_0}{2\mu_0}$$

Chapter 25: Geometric Optics

$$\theta_i = \theta_r$$
$$n = \frac{c}{v}$$
$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$
$$\theta_c = \sin^{-1}\frac{n_2}{n_1}$$
$$P = \frac{1}{f}$$
$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$
$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$
$$f = \frac{R}{2}$$

Chapter 26: Vision and Optical Instruments

$$P = \frac{1}{d_o} + \frac{1}{d_i}$$
$$m = m_o m_e$$
$$NA = n \sin\alpha$$
$$f/\# = \frac{f}{D} \approx \frac{1}{2NA}$$
$$d_i = f_o$$
$$M = \frac{f_o}{f_e}$$

Chapter 27: Wave Optics

$$\lambda_n = \frac{\lambda}{n}$$
$$\sin\theta = m\frac{\lambda}{d}$$
$$\sin\theta = \left(m + \frac{1}{2}\right)\frac{\lambda}{d}$$
$$\sin\theta = m\frac{\lambda}{W}$$
$$\theta = 1.22\frac{\lambda}{D}$$
$$2t = \frac{\lambda_n}{2}$$
$$2t = \lambda_n$$
$$I = \tfrac{1}{2} I_0$$
$$I = I_0 \cos^2\theta$$
$$\tan\theta_b = \frac{n_2}{n_1}$$

Chapter 28: Special Relativity

$$\Delta t = \frac{\Delta t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$
$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$
$$L = L_0\sqrt{1 - \frac{v^2}{c^2}}$$
$$v_{LG} = \frac{v_{LT} + v_{TG}}{1 + \frac{v_{LT}v_{TG}}{c^2}}$$
$$\lambda_{obs} = \lambda_s\sqrt{\frac{1 + \frac{u}{c}}{1 - \frac{u}{c}}}$$
$$f_{obs} = f_s\sqrt{\frac{1 - \frac{u}{c}}{1 + \frac{u}{c}}}$$
$$p = \frac{mv}{\sqrt{1 - \frac{v^2}{c^2}}}$$
$$E = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}}$$
$$E_0 = mc^2$$
$$KE_{rel} = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}} - mc^2$$
$$E^2 = (pc)^2 + (mc^2)^2$$