

Physics 120 Formula Sheet

General Definitions of Motion

$$\Delta \vec{r} = \langle \Delta x, \Delta y, \Delta z \rangle = \langle x_f - x_i, y_f - y_i, z_f - z_i \rangle$$

$$\vec{v} = \frac{\Delta \vec{r}}{\Delta t} = \left\langle \frac{\Delta x}{\Delta t}, \frac{\Delta y}{\Delta t}, \frac{\Delta z}{\Delta t} \right\rangle$$

$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t} = \left\langle \frac{\Delta v_x}{\Delta t}, \frac{\Delta v_y}{\Delta t}, \frac{\Delta v_z}{\Delta t} \right\rangle$$

$$d\vec{r} = \langle dx, dy, dz \rangle$$

$$\vec{v} = \langle v_x, v_y, v_z \rangle = \frac{d\vec{r}}{dt} = \left\langle \frac{dx}{dt}, \frac{dy}{dt}, \frac{dz}{dt} \right\rangle$$

$$\vec{a} = \langle a_x, a_y, a_z \rangle = \frac{d\vec{v}}{dt} = \left\langle \frac{dv_x}{dt}, \frac{dv_y}{dt}, \frac{dv_z}{dt} \right\rangle$$

Geometry

$$C = 2\pi r; \quad A_{\text{circle}} = \pi r^2; \quad A_{\text{rect}} = LW$$

$$A_{\text{triangle}} = \frac{1}{2}bh; \quad A_{\text{sphere}} = 4\pi r^2$$

$$V_{\text{sphere}} = \frac{4}{3}\pi r^3; \quad V_{\text{cyl}} = \pi r^2 h; \quad V_{\text{cone}} = \frac{1}{3}\pi r^2 h$$

Motion with constant acceleration

$$\vec{r}_f = \vec{r}_i + \vec{v}_i t + \frac{1}{2}\vec{a}t^2 \rightarrow \langle x_f, y_f, z_f \rangle = \langle x_i + v_{ix}t + \frac{1}{2}a_x t^2, y_i + v_{iy}t + \frac{1}{2}a_y t^2, z_i + v_{iz}t + \frac{1}{2}a_z t^2 \rangle$$

$$\vec{v}_f = \vec{v}_i + \vec{a}t \rightarrow \langle v_{fx}, v_{fy}, v_{fz} \rangle = \langle v_{ix} + a_x t, v_{iy} + a_y t, v_{iz} + a_z t \rangle$$

Forces/Momentum

$$\vec{p} = m\vec{v}$$

$$\vec{F}_{\text{net}} = \frac{d\vec{p}}{dt} = m\vec{a}$$

$$\vec{p}_f - \vec{p}_i = \int d\vec{p} = \int \vec{F}_{\text{net}} dt$$

$$\vec{J} = \int \vec{F}_{\text{net}} dt$$

$$\vec{F}_{\text{net}} = \vec{F}_{\parallel} + \vec{F}_{\perp} = \frac{d\vec{p}}{dt} \hat{p} + \vec{p} \frac{d\hat{p}}{dt} = m\vec{a}_{\parallel} + m\vec{a}_{\perp}$$

$$|\vec{F}_{\perp}| = m|\vec{a}_{\perp}| = m \frac{v^2}{r}$$

$$\vec{F}_G = G \frac{M_1 M_2}{r_{12}^2} \hat{r}_{12} \rightarrow |\vec{F}_G| = G \frac{M_1 M_2}{r_{12}^2}$$

$$\vec{F}_G = m\vec{g}; \quad \vec{g} = G \frac{M_{cb}}{(R_{cb} + h)^2} \hat{r}$$

$$|\vec{F}_{fr}| = \mu |\vec{F}_N|$$

$$\vec{F}_s = -k\Delta \vec{r}$$

Constants

$$g = 9.8 \frac{m}{s^2}; \quad G = 6.67 \times 10^{-11} \frac{Nm^2}{kg^2}$$

$$v_{\text{sound}} = 343 \frac{m}{s}; \quad v_{\text{light}} = c = 3 \times 10^8 \frac{m}{s}$$

$$N_A = 6.02 \times 10^{23}$$

Vectors

$$\vec{C} = \vec{A} + \vec{B} \rightarrow \langle C_x, C_y, C_z \rangle = \langle A_x + B_x, A_y + B_y, A_z + B_z \rangle + \langle C_x, C_y, C_z \rangle; \quad |\vec{C}| = \sqrt{C_x^2 + C_y^2 + C_z^2}$$

$$\vec{A} \cdot \vec{B} = |\vec{A}| |\vec{B}| \cos \theta = A_x B_x + A_y B_y + A_z B_z$$

$$\vec{A} \times \vec{B} = |\vec{A}| |\vec{B}| \sin \theta = \langle a_y b_z - b_y a_z, a_z b_x - b_z a_x, a_x b_y - b_x a_y \rangle$$

Work and Energy

$$W_T = \int dW_T = \int \vec{F} \cdot d\vec{r} = \Delta K_T = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = \frac{p_f^2}{2m} - \frac{p_i^2}{2m}$$

$$W_R = \int dW_R = \int \vec{\tau} \cdot d\vec{\theta} = \Delta K_R = \frac{1}{2}I\omega_f^2 - \frac{1}{2}I\omega_i^2 = \frac{L_f^2}{2I} - \frac{L_i^2}{2I}$$

$$W_{net} = W_T + W_R = \Delta E_{sys} = \begin{cases} 0 \\ W_{fr} \end{cases}$$

$$W_{net} = -\sum \Delta U = \Delta K_T + \Delta K_R$$

$$\Delta E_{sys} = \Delta K + \Delta U_g + \Delta U_s = \begin{cases} 0 \\ W_{fr} \end{cases}$$

$$U_g = mgy$$

$$U_s = \frac{1}{2}kx^2$$

Rotational Motion

$$s = r\theta \rightarrow ds = r d\theta$$

$$\frac{ds}{dt} = r \frac{d\theta}{dt} \rightarrow v = r\omega; \quad \omega = \frac{d\theta}{dt}$$

$$a = \frac{dv}{dt} = r \frac{d\omega}{dt} = r\alpha; \quad \alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$$

$$\theta_f = \theta_i + \omega_i t + \frac{1}{2}\alpha t^2$$

$$\omega_f = \omega_i + \alpha t$$

$$\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$$

Rotational Forces/Momentum

$$\vec{\tau} = \vec{r} \times \vec{F} = \frac{d\vec{L}}{dt} = I\vec{\alpha}$$

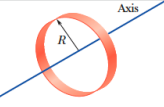
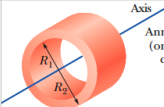
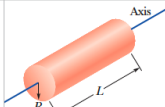
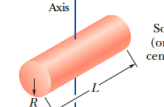
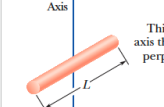
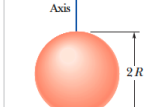
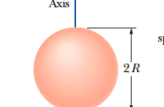
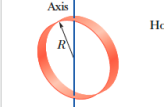
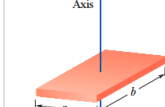
$$|\vec{\tau}| = rF \sin \theta = r_{\perp}F = rF_{\perp}$$

$$\vec{L} = I\vec{\omega}$$

$$I = \int r^2 dm$$

$$\vec{L}_f = \vec{L}_i + \int \vec{\tau}_{net} dt$$

Table 10-2 Some Rotational Inertias

 Hoop about central axis $I = MR^2$ (a)	 Annular cylinder (or ring) about central axis $I = \frac{1}{2}M(R_1^2 + R_2^2)$ (b)	 Solid cylinder (or disk) about central axis $I = \frac{1}{2}MR^2$ (c)
 Solid cylinder (or disk) about central diameter $I = \frac{1}{4}MR^2 + \frac{1}{12}ML^2$ (d)	 Thin rod about axis through center perpendicular to length $I = \frac{1}{12}ML^2$ (e)	 Solid sphere about any diameter $I = \frac{2}{5}MR^2$ (f)
 Thin spherical shell about any diameter $I = \frac{2}{3}MR^2$ (g)	 Hoop about any diameter $I = \frac{1}{2}MR^2$ (h)	 Slab about perpendicular axis through center $I = \frac{1}{12}M(a^2 + b^2)$ (i)

Some moments of inertia from Halliday, Resnick, & Walker, 10th edition.