Principles of Physics I (PHY 111)
Equation Sheet

$$v = \frac{dx}{dt} \qquad a = \frac{dv}{dt} = \frac{d^2x}{dt^2}$$

$$\frac{d}{dt}(Ct^n) = nCt^{n-1} \qquad \frac{dC}{dt} = 0$$

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

$$v^2 = v_0^2 + 2a(x - x_0) \qquad \bar{v} = \frac{v + v_0}{2}$$

$$V_x = V\cos\theta \qquad V_y = V\sin\theta$$

$$V = \sqrt{V_x^2 + V_y^2} \qquad \tan\theta = \frac{V_y}{V_x}$$

$$\vec{\mathbf{v}} = \frac{d\vec{\mathbf{r}}}{dt} \qquad \vec{\mathbf{a}} = \frac{d\vec{\mathbf{v}}}{dt} = \frac{d^2\vec{\mathbf{r}}}{dt^2}$$

$$v_x = v_{x0} + a_x t \qquad v_y = v_{y0} + a_y t$$

$$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2 \qquad y = y_0 + v_{y0}t + \frac{1}{2}a_y t^2$$

$$v_x^2 = v_{x0}^2 + 2a_x(x - x_0) \qquad v_y^2 = v_{y0}^2 + 2a_y(y - y_0)$$

$$\vec{\mathbf{v}} = \vec{\mathbf{v}}_0 + \vec{\mathbf{a}}t \qquad \vec{\mathbf{r}} = \vec{\mathbf{r}}_0 + \vec{\mathbf{v}}_0 t + \frac{1}{2}\vec{\mathbf{a}}t^2$$

$$\vec{\mathbf{V}} = V_x\hat{\mathbf{i}} + V_y\hat{\mathbf{j}} + V_z\hat{\mathbf{k}} \qquad \vec{\mathbf{v}}_{\text{BS}} = \vec{\mathbf{v}}_{\text{BW}} + \vec{\mathbf{v}}_{\text{WS}}$$

$$\Sigma\vec{\mathbf{F}} = m\vec{\mathbf{a}} \qquad \vec{\mathbf{F}}_{\text{AB}} = -\vec{\mathbf{F}}_{\text{BA}}$$

$$\vec{\mathbf{F}}_{\text{G}} = m\vec{\mathbf{g}}$$

$$F_{\text{fr}} = \mu_{\text{k}}F_{\text{N}} \qquad F_{\text{fr}} \leq \mu_{\text{s}}F_{\text{N}}$$

$$a_{\text{R}} = \frac{v^2}{r}$$

$$T = \frac{1}{f} \qquad v = \frac{2\pi r}{T}$$

$$F = G\frac{m_1 m_2}{r^2} \qquad \vec{\mathbf{F}}_{12} = -G\frac{m_1 m_2}{r_{21}^2}\hat{\mathbf{r}}_{21}$$

$$W = Fd\cos\theta = \vec{\mathbf{F}}\cdot\vec{\mathbf{d}} \qquad W = \int_{\mathrm{a}}^{\mathrm{b}} \vec{\mathbf{F}}\cdot d\vec{\mathbf{l}} = \int_{\mathrm{a}}^{\mathrm{b}} F\cos\theta dl$$

$$\vec{\mathbf{A}}\cdot\vec{\mathbf{B}} = AB\cos\theta \qquad \vec{\mathbf{A}}\cdot\vec{\mathbf{B}} = A_xB_x + A_yB_y + A_zB_z$$

$$F_{\mathrm{S}} = -kx$$

$$K = \frac{1}{2}mv^2 \qquad W_{\mathrm{net}} = \Delta K = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$$

$$U_{\mathrm{grav}} = mgy \qquad U_{\mathrm{el}} = \frac{1}{2}kx^2$$

$$\Delta U = U_2 - U_1 = -\int_1^2 \vec{\mathbf{F}}\cdot d\vec{\mathbf{l}} \qquad F = -\frac{dU(x)}{dx}$$

$$E = K + U$$

$$U(r) = -\frac{GmM_{\mathrm{E}}}{r}$$

$$P = \frac{dW}{dt} = \frac{dE}{dt} \qquad P = \vec{\mathbf{F}}\cdot\vec{\mathbf{v}}$$

$$\vec{\mathbf{p}} = m\vec{\mathbf{v}} \qquad \Sigma\vec{\mathbf{F}} = \frac{d\vec{\mathbf{p}}}{dt}$$

$$\vec{\mathbf{J}} = \int \vec{\mathbf{F}}\,dt \qquad \Delta\vec{\mathbf{p}} = \vec{\mathbf{p}}_{\mathrm{f}} - \vec{\mathbf{p}}_{\mathrm{i}} = \int_{t_{\mathrm{i}}}^{t_{\mathrm{f}}} \vec{\mathbf{F}}\,dt = \vec{\mathbf{J}}$$

$$\vec{\mathbf{p}}_{\mathrm{A}} + \vec{\mathbf{p}}_{\mathrm{B}} = \vec{\mathbf{p}}'_{\mathrm{A}} + \vec{\mathbf{p}}'_{\mathrm{B}} \qquad \frac{1}{2}m_{\mathrm{A}}v_{\mathrm{A}}^2 + \frac{1}{2}m_{\mathrm{B}}v_{\mathrm{B}}^2 = \frac{1}{2}m_{\mathrm{A}}v_{\mathrm{A}}'^2 + \frac{1}{2}m_{\mathrm{B}}v_{\mathrm{B}}'^2$$

$$x_{\mathrm{CM}} = \frac{\Sigma m_i x_i}{M} \qquad x_{\mathrm{CM}} = \frac{1}{M}\int x\,dm$$

$$y_{\mathrm{CM}} = \frac{\Sigma m_i y_i}{M} \qquad y_{\mathrm{CM}} = \frac{1}{M}\int y\,dm$$

$$z_{\mathrm{CM}} = \frac{\Sigma m_i z_i}{M} \qquad z_{\mathrm{CM}} = \frac{1}{M}\int z\,dm$$

$$M\vec{\mathbf{a}}_{\mathrm{CM}} = \Sigma\vec{\mathbf{F}}_{\mathrm{ext}} \qquad \frac{d\vec{\mathbf{P}}}{dt} = \Sigma\vec{\mathbf{F}}_{\mathrm{ext}}$$

$$e = \frac{v'_{\mathrm{A}} - v'_{\mathrm{B}}}{v_{\mathrm{B}} - v_{\mathrm{A}}}$$

$$\omega = \frac{d\theta}{dt} \qquad \alpha = \frac{d\omega}{dt}$$

$$v = R\omega \qquad a_{\text{tan}} = R\alpha$$

$$a_{\text{R}} = \omega^2 R$$

$$\omega = 2\pi f \qquad T = 1/f$$

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

$$\omega^2 = \omega_0^2 + 2\alpha\theta \qquad \bar{\omega} = \frac{\omega + \omega_0}{2}$$

$$\tau = R_\perp F = RF_\perp = RF\sin\theta \qquad \Sigma\tau = I\alpha$$

$$I = \sum m_i R_i^2 \qquad I = \int R^2\, dm$$

$$I = I_{\text{CM}} + Mh^2 \qquad I_z = I_x + I_y$$

$$K = \frac{1}{2}I\omega^2 \qquad K_{\text{tot}} = \frac{1}{2}Mv_{\text{CM}}^2 + \frac{1}{2}I_{\text{CM}}\omega^2$$

Object	Location of axis	Moment of inertia
Thin hoop	Through center	MR_0^2
Solid cylinder	Through center	$\frac{1}{2}MR_0^2$
Uniform sphere	Through center	$\frac{2}{5}MR_0^2$
Long uniform rod	Through center	$\frac{1}{12}Ml^2$
Long uniform rod	Through end	$\frac{1}{3}Ml^2$

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

$$\vec{\tau} = \vec{\mathbf{r}} \times \vec{\mathbf{F}} \qquad \vec{\mathbf{L}} = \vec{\mathbf{r}} \times \vec{\mathbf{p}}$$

$$P + \rho g h + \frac{1}{2}\rho v^2 = \text{ constant}$$

$$x = x_0\cos(\omega t + \delta) \qquad v = -\omega x_0 \sin(\omega t + \delta)$$

$$a = -\omega^2 x_0 \cos(\omega t + \delta) \qquad \omega = \sqrt{\frac{k}{m}}$$

$$\omega = 2\pi f = \frac{2\pi}{T}$$

$g = 9.81 \text{ m/s}^2$
$G = 6.6742 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2$

2π rad = 360°
1 km = 0.6214 mi
1 h = 3600 s
1 y = 3.156×10^7 s
1 atm = 101.3 kPa

Earth mass	5.97×10^{24} kg
Moon mass	7.35×10^{22} kg
Sun mass	1.99×10^{30} kg
Earth radius (mean)	6.371×10^{6} m
Moon radius (mean)	1.74×10^{6} m
Sun radius (mean)	6.96×10^{8} m
Earth-Moon distance (mean)	3.84×10^{8} m
Earth-Sun distance (mean)	1.50×10^{11} m