$v\,dv = a_c\,ds$ constant acceleration $\qquad a_n = \frac{v^2}{r}$

$v = v_0 + a_c t$ constant acceleration

$s = s_0 + v_0 t + \frac{1}{2} a t^2$

$a_c (s - s_0) = \frac{1}{2}(v^2 - v_0^2) \qquad v^2 - v_0^2 = 2as$

Projectile Motion

$$\left.\begin{array}{l} a_x = 0 \\ v_x = v_{x_0} = \text{constant} \\ x = x_0 + v_{x_0} t \end{array}\right\} x\text{-axis}$$

$$\left.\begin{array}{l} a_y = -g \\ v_y = v_{y_0} - gt \\ y = y_0 + v_{y_0} t - \frac{1}{2} g t^2 \\ v_y^2 = v_{y_0}^2 - 2g(y - y_0) \end{array}\right\} y\text{-axis}$$

$v = \sqrt{\vec{v}_x^{\,2} + \vec{v}_y^{\,2}} \qquad G_c = 386 \ \frac{\text{lbm in}}{\text{lbf s}^2}$

$\theta = \tan^{-1} \frac{\vec{v}_y}{\vec{v}_x}$

For $y_0 = 0$

$t_{tot} = \frac{2u \sin\theta}{g}$

$x = \frac{u^2 \sin 2\theta}{g}$

$\dot{e}_t = \dot{\beta} e_n \qquad \rho$ = radius of curvature

$a = \frac{v^2}{\rho} e_n + \dot{v} e_t$

$a_n = \frac{v^2}{r} = v\dot{\theta}$

$a^2 = a_n^2 + a_t^2$

$\theta = \tan^{-1} \frac{a_n}{a_t}$

Polar coordinates

$v = \dot{r} e_r + r\dot{\theta} e_\theta \qquad v_r = \dot{r} \qquad a_r = \ddot{r} - r\dot{\theta}^2$

$a = (\ddot{r} - r\dot{\theta}^2) e_r + (r\ddot{\theta} + 2\dot{r}\dot{\theta}) e_\theta \qquad r\dot{\theta} = v_\theta \qquad a_\theta = r\ddot{\theta} + 2\dot{r}\dot{\theta}$

$a_\theta = \frac{1}{r}\frac{d}{dt}(r^2\dot{\theta})$

relative motion

$\vec{v}_A = \vec{v}_B + \vec{v}_{A/B}$

Law of sines: $\frac{a}{\sin A} = \frac{b}{\sin B}$

Law of cosines: $c^2 = a^2 + b^2 - 2ab\cos C \qquad w = \frac{1}{2} m (v_2^2 - v_1^2)$

$w = F \cdot s$

$\boxed{\text{Remember } a \text{ has } a_n \,\&\, a_t}$

$$\tfrac{1}{2}kx_1^2 + mgz_1 + \tfrac{1}{2}mv_1^2 = \tfrac{1}{2}kx_2^2 + mgz_2 + \tfrac{1}{2}mv_2^2$$

$$\Sigma F \Delta t = mv_2 - mv_1$$

$$I = \Sigma F \Delta t$$

$$M_A V_A + M_B V_B = M_A V_A' + M_B V_B' \quad \text{(conservation of momentum)}$$

$$e = \frac{V_B' - V_A'}{V_A - V_B} \quad \text{(coefficient of restitution)}$$

Collisions

1) y - momentum for A conserved
2) y - momentum for B conserved
3) x - momentum for both together conserved
4) coefficient of restitution equation

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

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

$$\alpha\, d\theta = \omega\, d\omega$$

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

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

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

$$\vec{V} = \vec{\omega} \times \vec{r}$$

$$\vec{a} = \vec{\alpha} \times \vec{r} + \vec{\omega} \times \vec{V}$$

$$\vec{a} = \alpha \vec{k} \times \vec{r} - \omega^2 \vec{r}$$

$\text{work} = (\text{Moment})(\Delta\theta)$

Work Energy

$\sum W = \sum \text{Energy}$ (Friction)

$(F)(s) = \sum \tfrac{1}{2}kx^2 + \sum \tfrac{1}{2}mv^2 + \sum mgz$

	normal	angular
K.E.	$\tfrac{1}{2}m(v_1^2 - v_0^2)$	$\tfrac{1}{2}\bar{I}(\omega_1^2 - \omega_0^2)$
		$\omega = \frac{v}{r}$

Conservation of Energy (No Friction)

$\sum\left(\tfrac{1}{2}kx^2 + \tfrac{1}{2}mv^2 + mgz\right) = 0$

$\tfrac{1}{2}kx_1^2 + \tfrac{1}{2}mv_1^2 + mgz_1 = \tfrac{1}{2}kx_2^2 + \tfrac{1}{2}mv_2^2 + mgz_2$

Impulse Momentum

$I = \sum F\,\Delta t$ $\quad \sum M_1 = \sum M_2$ $\quad m_1v_1 + I = m_2v_2$

Collisions

$m_Av_A + m_Bv_B = m_Av_A' + m_Bv_B'$ (conservation of momentum)

y-momentum of A conserved
y-momentum of B conserved
X-momentum for Both conserved
coefficient of restitution equation

$e = \frac{v_B' - v_A'}{v_A - v_B}$ (Coefficient of restitution)

Linkages

$\vec{v} = \vec{\omega} \times \vec{r}$

$\vec{a} = \vec{\alpha} \times \vec{r} - \omega^2\vec{r}$

$\vec{e} = \frac{x}{\sqrt{x^2+y^2}}\vec{i} + \frac{y}{\sqrt{x^2+y^2}}\vec{j}$

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

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

$\alpha\,d\theta = \omega\,d\omega$

$\omega = \omega_0 + \alpha t$

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

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

$\vec{a} = \vec{\alpha} \times \vec{r} + \vec{\omega} \times \vec{v}$

$\frac{\sum E_A}{\sum E_B} = E\,\%\text{ kept}$

e.g. $\frac{\tfrac{1}{2}m_1v_1'^2 + \tfrac{1}{2}m_2v_2'^2}{\tfrac{1}{2}m_1v_1^2 + \tfrac{1}{2}m_2v_2^2} \times 100$

$\sum M = \alpha\bar{I} + m\bar{a}d$

$I = \bar{I} + md^2$

$\bar{I} = mk^2$

$a = r\alpha - \omega^2 r$

$v = \omega r$