Displacement, Speed, Velocity, and Acceleration

$\Delta x = x_2 - x_1$ (similarly for Δy, etc.)

$\bar{v}_x = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}$ (similarly for $\bar{v}_y$, etc.)

$\bar{s} = \frac{\text{total distance}}{\Delta t}$

$s = \sqrt{v_x^2 + v_y^2}$

$\bar{a} = \frac{\Delta v}{\Delta t}$

Constant Acceleration

$x_f = x_i + v_{ix}\Delta t + \frac{1}{2}a_x \Delta t^2$

$v_{fx} = v_{ix} + a_x \Delta t$

$v_{fx}^2 = v_{ix}^2 + 2a_x(x_f - x_i)$

$x_f = x_i + \frac{1}{2}(v_{ix} + v_{fx})\Delta t$

Forces

Name an object or group of objects !!!!

$\Sigma F_x = ma_x, \quad \Sigma F_y = ma_y$

$W = mg$ (down)

$f_{s,\max} = \mu_s N$

$f_k = \mu_k N$

Vectors

$\vec{A} = A_x\hat{x} + A_y\hat{y} + A_z\hat{z}$

$A = |\vec{A}| = \sqrt{A_x^2 + A_y^2 + A_z^2}$

$\theta = \arctan\left(\frac{A_y}{A_x}\right)$

$A_x = A\cos\theta$

$A_y = A\sin\theta$

Projectile Motion

(assumes $+y$ is upwards)

$a_x = 0$

$a_y = -g$

$g = +9.8\,\frac{\text{m}}{\text{s}^2}$

$\tan\theta_0 = \frac{v_{0y}}{v_{0x}}$

$v_{0x} = |v_0|\cos\theta_0$

$v_{0y} = |v_0|\sin\theta_0$

$y = y_0 + (x - x_0)\left(\frac{v_{0y}}{v_{0x}}\right) - \frac{g(x - x_0)^2}{2v_{0x}^2}$

or

$y = y_0 + (x - x_0)\tan\theta_0 - \frac{g(x - x_0)^2}{2(v_0\cos\theta_0)^2}$

$R = \frac{v_0^2}{g}\sin(2\theta_0)$

(destination and source at same height)

Springs & SHM

$F = k\Delta L$

$PE_{elastic} = \frac{1}{2}k\Delta L^2$

$W_{spring} = -\frac{1}{2}k\left(x_f^2 - x_i^2\right)$

$\omega_{natural} = \sqrt{\frac{k}{m}}$

$x = x_{\max}\cos(\omega t)$

$v_{\max} = \omega x_{\max}$

$a_{\max} = \omega^2 x_{\max}$

Pendulum : $T = 2\pi\sqrt{\frac{L}{g}}$

Work, Energy, Power

$W_F = F \cdot \Delta x \cdot \cos\theta$ (note $\cos 180^\circ = -1$)

$\Sigma W = KE_f - KE_i$

$KE = \frac{1}{2}mv^2$

$\bar{P} = \frac{W}{\Delta t} = F \cdot v$

$PE_{2g} = mgy_2$ if $+y$ is upwards

$E = KE + PE_g$

$E_2 = E_1 + W_{1\to 2,\text{all but gravity}}$, so:

$KE_2 + PE_2 = KE_1 + PE_1 + W_{1\to 2,\text{all but gravity}}$

Gravity

$F = G\frac{m_1 m_2}{r^2}$

$G = 6.67\times 10^{-11}\,\frac{\text{Nm}^2}{\text{kg}^2}$

$T = 2\pi\sqrt{\frac{R^3}{GM}}$

Center of Mass

$x_{CM} = \frac{1}{m_{tot}}\Sigma m_i x_i$

Momentum & Impulse

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

$\Sigma\vec{F}\cdot\Delta t = \Delta\vec{p}$

$\Sigma\vec{F}_x \cdot \Delta t = m\left(v_{fx} - v_{ix}\right)$

$\vec{p}_f = \vec{p}_i$ if $\Sigma\vec{F} = 0$

$\vec{J} = \Sigma\vec{F}\cdot\Delta t$

1D Elastic Collisions

$v_{1f} = \frac{m_1 - m_2}{m_1 + m_2}v_{1i} + \frac{2m_2}{m_1 + m_2}v_{2i}$

$v_{2f} = \frac{2m_1}{m_1 + m_2}v_{1i} + \frac{m_2 - m_1}{m_1 + m_2}v_{2i}$

Fluids

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

$\rho_{\text{water}} = 1000$ kg/m^3

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

1 atm = 101300 Pa

$P_{\text{gauge}} = P_{\text{actual}} - P_{\text{atm}}$

$P_{\text{outlet}} = P_{\text{atm}}$

$P_{\text{bottom}} = P_{\text{top}} + \rho g(h_{\text{top}} - h_{\text{bottom}})$

$F_B = W_{\text{displaced fluid}} = \rho_{\text{fluid}} g V_{\text{sub}}$ (upwards)

$\dot{m} = \rho vA$, and $Q = vA$

$\dot{m}_{\text{gain}} = \dot{m}_{\text{in}} - \dot{m}_{\text{out}}$

$P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$

Circular Motion & Rotation

$|a_c| = \frac{v^2}{r} = r\omega^2$ towards the center of the circle

$|a_t| = r\alpha$

$T = \frac{2\pi r}{v} = \frac{2\pi}{\omega} = \frac{1}{f}$ (constant speed)

$s = r\Delta\theta$ (distance traveled, $\Delta\theta$ in radians)

$T = 2\pi\sqrt{\frac{R^3}{GM}}$ (orbits)

$\Delta\theta = \theta_f - \theta_i$

$\omega_{\text{average}} = \frac{\Delta\theta}{\Delta t}$

$\alpha_{\text{average}} = \frac{\Delta\omega}{\Delta t}$

$v = R\omega$ (on a rotating object)

$r_A\omega_A = r_B\omega_B$ (gears)

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

$W = \tau\Delta\theta$

$L = I\omega \qquad L_{particle} = mr_\perp v$

$\Sigma\tau\Delta t = \Delta L$

Rolling

$N = \frac{L}{2\pi R}$

$v_{\text{CM}} = R\omega$

$a_{\text{CM}} = R\alpha$

Torque

$\Sigma\tau = I\alpha$

$|\tau| = |R_\perp F|$

$I_{\text{particle}} = mr^2$

$I_{\text{parallel axis}} = I_{CM} + mh^2$

Constant Angular Acceleration

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

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

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

$\theta - \theta_0 = \frac{1}{2}(\omega + \omega_0)\Delta t$

Heat

$T > 0K$

$E_{\text{thermal}} = mcT$

$\Delta L = L_{\text{orig}}\alpha\,\Delta T$

$\Delta V = V_{\text{orig}}\beta\,\Delta T$

$\beta = 3\alpha$

$\dot{Q}_{\text{radiation}} = \frac{Q}{\Delta t} = e\sigma AT^4$

$\sigma = 5.67\times 10^{-8}\,\frac{\text{J}}{\text{sm}^2\text{K}^4}$

$\dot{Q}_{\text{conduction}} = \frac{Q}{\Delta t} = \frac{kA\,\Delta T}{L}$