**Vectors**

\[ \vec{A} = A_x \hat{x} + A_y \hat{y} \quad A = \sqrt{A_x^2 + A_y^2} \]

\[ \sin \theta = \frac{\text{opp}}{\text{hyp}}, \quad \cos \theta = \frac{\text{adj}}{\text{hyp}}, \quad \tan \theta = \frac{\text{opp}}{\text{adj}} \]

**Vector Addition**

\[ \vec{A} + \vec{B} = (A_x + B_x) \hat{x} + (A_y + B_y) \hat{y} \]

\[ \vec{v}_{AC} = \vec{v}_{AB} + \vec{v}_{BC} \text{ (Relative Motion)} \]

**General Definitions for Linear Motion**

Ave. speed = \( \frac{\text{distance}}{\text{time}} \)

\[ v_{x,avg} = \frac{\Delta x}{\Delta t} \quad (\text{motion along } x\text{-direction}) \]

\[ a_{x,avg} = \frac{\Delta v_x}{\Delta t} \quad (\text{motion along } x\text{-direction}) \]

\[ \vec{v} = \lim_{\Delta t \to 0} \frac{\Delta \vec{r}}{\Delta t}, \quad \vec{a} = \lim_{\Delta t \to 0} \frac{\Delta \vec{v}}{\Delta t} \]

\[ g = 9.8m/s^2 \quad (\text{on Earth’s surface}) \]

**Linear Motion at Constant Acceleration**

\[ v_x = v_{ox} + a_x t \]

\[ v_x^2 = v_{ox}^2 + 2a_x(x - x_o) \]

\[ x = x_o + v_{ox}t + \frac{1}{2}a_xt^2 \]

\[ x = x_o + \frac{1}{2}(v_x + v_{ox})t \]

**Quadratic Equation Solver**

\[ x = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A} \quad (A,B,C \text{ coefficients}) \]

**Equations Associated with Newton’s Laws**

\[ \sum \vec{F} = m\vec{a}, \quad w = mg, \]

\[ 0 \leq f_S \leq \mu_s N, \quad f_k = \mu_k N \]

\[ f_{\text{drag}} = \frac{1}{2}CPAv^2 \]

\[ F_{\text{spring}} = -k_{\text{spring}}x \quad (\text{deformation along } x\text{-direction}) \]

**Work, Energy, and Power Equations**

\[ W = Fs \cos \theta \quad (\text{for constant force}) \]

\[ KE = \frac{1}{2}mv^2 \quad (\text{for linear motion}) \]

\[ W_{\text{tot}} = \sum W, \quad W_{\text{tot}} = \Delta K, \quad W_{\text{cons}} = -\Delta U \]

\[ PE_{\text{gravity}} = mga \quad (\text{for constant } g\text{-acceleration}) \]

\[ PE_{\text{spring}} = \frac{1}{2}k_{\text{spring}}x^2 \quad (\text{for ideal spring along } x\text{-axis}) \]

\[ E_{\text{mech}} = PE + KE, \quad W_{\text{non cons}} = \Delta E_{\text{mech}} \]

\[ P_{\text{avg}} = \frac{w}{\Delta t}, \quad P = F v \cos \phi \quad (\text{for constant force}) \]

**Universal Gravitation**

\[ F = G \frac{m_1m_2}{r^2}, \quad g = G \frac{M}{r^2} \]

\[ G = 6.67 \times 10^{-11}N \cdot m^2/kg^2 \]

\[ M_{\text{Earth}} = 5.97 \times 10^{24}kg, \quad R_{\text{Earth}} = 6.38 \times 10^3km \]

\[ M_{\text{Sun}} = 1.99 \times 10^{30}kg \]

**Uniform Rotational Motion**

\[ \omega_{avg} = \frac{\Delta \theta}{\Delta t}, \quad \omega = \lim_{\Delta t \to 0} \frac{\Delta \theta}{\Delta t} \]

\[ s = r\theta, \quad v = r\omega \]

\[ a_c = \frac{v^2}{r}, \quad T = \frac{2\pi}{\omega} \]

**Equations Associated with Linear Momentum**

\[ \vec{p} = m\vec{v}, \quad \vec{p}_{\text{system}} = \sum \vec{p} \]

Impulse: \[ \vec{I} = \Delta \vec{p} = \vec{F}_{avg} \cdot \Delta t \]

**Rotational Motion and Torque**

\[ \tau = r F_{\tan} = r \perp F = r F \sin \theta \]

\[ \sum \vec{\tau} = I\vec{a}, \quad I = \sum_i m_i r_i^2 \]
<table>
<thead>
<tr>
<th>Rotational Motion at Constant Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a_{avg} = \frac{\Delta \omega}{\Delta t}, \quad \alpha = \lim_{\Delta t \to 0} \frac{\Delta \omega}{\Delta t} )</td>
</tr>
<tr>
<td>( \omega = \omega_o + \alpha t )</td>
</tr>
<tr>
<td>( \omega^2 = \omega_o^2 + 2\alpha(\theta - \theta_o) )</td>
</tr>
<tr>
<td>( \theta = \theta_o + \omega_o t + \frac{1}{2} \alpha t^2 )</td>
</tr>
<tr>
<td>( \theta = \theta_o + \frac{1}{2} \omega + \omega_o) t )</td>
</tr>
<tr>
<td>( a_{tan} = r \alpha, \quad a = \sqrt{a_{cp}^2 + a_{tan}^2} )</td>
</tr>
</tbody>
</table>

**Angular Momentum and Energy**

\( L = r m v_{tan} \)

\( \vec{L} = I \vec{\omega}, \quad \Delta \vec{L} = \vec{\tau}_{net} \Delta t \)

\( I_{particle} = mR^2, \quad I_{hoop} = mR^2 \)

\( I_{sphere} = \frac{2}{5} mR^2, \quad I_{disk} = \frac{1}{2} mR^2 \)

\( KE = \frac{1}{2} I \omega^2 \) (for rotational motion)

\( KE_{total} = \frac{1}{2} mn^2 + \frac{1}{2} I \omega^2 \)

**Fluids**

\( p = \frac{F}{A} \) (uniformly distributed perpendicular force)

\( p = p_{top} + \rho gh \)

\( \rho_{air} = 1.29 \text{ kg/m}^3, \quad \rho_{water} = 1000 \text{ kg/m}^3 \)

\( p_{atm} = 1.01 \times 10^5 \text{ Pa}, \quad p_{gauge} = p - p_{atm} \)

\( F_B = \rho_{fluid} V_{body} g \)

<table>
<thead>
<tr>
<th>Simple Harmonic Oscillations</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f = \frac{1}{T}, \quad \omega = 2\pi f = \frac{2\pi}{T} )</td>
</tr>
<tr>
<td>( x = A\cos(\omega t + \phi), \quad v = -A\sin(\omega t + \phi) )</td>
</tr>
<tr>
<td>( a = -A\omega^2 \cos(\omega t + \phi) )</td>
</tr>
</tbody>
</table>

\( \omega = \sqrt{\frac{k_{spring}}{m}} \), \( T = 2\pi \sqrt{\frac{m}{k_{spring}}} \) (ideal spring)

\( T = 2\pi \sqrt{\frac{l}{g}} \) (simple pendulum)

\( E_{SHO} = \frac{1}{2} k_{spring} A^2 \)

<table>
<thead>
<tr>
<th>Traveling Waves and Sound</th>
</tr>
</thead>
<tbody>
<tr>
<td>( v = \lambda f )</td>
</tr>
<tr>
<td>( v_{sound} = 343 \text{ m/s} ) (in calm air at 20C)</td>
</tr>
<tr>
<td>( v_{sound} = (331 \text{ m/s}) \sqrt{\frac{T}{273} K} )</td>
</tr>
<tr>
<td>( f_{perceived} = f \frac{v + v_{observer}}{v + v_{source}} )</td>
</tr>
<tr>
<td>( v_{transverse} = \sqrt{\frac{F}{\mu}}, \quad \mu = \frac{m}{l} ) (taut string)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wave Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I = \frac{P}{\Delta A} ) (at distance ( r ) from a point source)</td>
</tr>
<tr>
<td>( I = \frac{p}{4\pi r^2} )</td>
</tr>
<tr>
<td>( \beta(dB) = (10 \text{ dB}) \log \left( \frac{I}{I_0} \right) )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Standing Waves</th>
</tr>
</thead>
<tbody>
<tr>
<td>String: ( f_n = \frac{n}{2l} \sqrt{\frac{F}{\mu}}, \quad n=1,2,3,... )</td>
</tr>
<tr>
<td>Open pipe: ( f_n = \frac{nv}{2l}, \quad n=1,2,3,... )</td>
</tr>
<tr>
<td>Closed pipe: ( f_n = \frac{nv}{4l}, \quad n=1,3,5,... )</td>
</tr>
</tbody>
</table>