PHYS 2325 Formula Sheet

Linear velocity and acceleration:

$\vec{v}(t) = \frac{d\vec{r}(t)}{dt}$

$\vec{v}_{avg} = \frac{\Delta\vec{r}}{\Delta t}$

$\vec{a}(t) = \frac{d\vec{v}(t)}{dt}$

$\vec{a}_{avg} = \frac{\Delta\vec{v}}{\Delta t}$

If $\vec{a}$ is constant:

$\vec{v}(t) = \vec{v}_0 + \vec{a}t$

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

$v^2 = v_0^2 + 2a(r - r_0)$

$\vec{r} = \vec{r}_0 + \frac{1}{2}(\vec{v} + \vec{v}_0)t$

Rotational velocity and acceleration:

$\vec{\omega} = \frac{d\vec{\theta}(t)}{dt}$

$\vec{\alpha} = \frac{d\vec{\omega}(t)}{dt}$

If $\vec{\alpha}$ is constant:

$\vec{\omega}(t) = \vec{\omega}_0 + \vec{\alpha}t$

$\vec{\theta}(t) = \vec{\theta}_0 + \vec{\omega}_0 t + \frac{1}{2}\vec{\alpha}t^2$

$\omega^2 = \omega_0^2 + 2\vec{\alpha}(\vec{\theta} - \vec{\theta}_0)$

$\vec{\theta} = \vec{\theta}_0 + \frac{1}{2}(\vec{\omega} + \vec{\omega}_0)t$

Relating linear and rotational motion:

$s = R\theta \qquad \vec{a}_{rad} = -\frac{v_{tan}^2}{R}\hat{R} = -\omega^2 R\hat{R}$

$v_{tan} = R\omega \qquad \vec{a}_{tot} = \vec{a}_{tan} + \vec{a}_{rad}$

$a_{tan} = R\alpha \qquad a_{tot} = \sqrt{a_{tan}^2 + a_{rad}^2}$

Relative velocity:

$\vec{v}_{A|C} = \vec{v}_{A|B} + \vec{v}_{B|C}$

Newton's Laws:

$\Sigma\vec{F} = 0$ (object in equilibrium)

$\Sigma\vec{F} = m\vec{a} = \frac{d\vec{p}}{dt}$

$\vec{F}_{A|B} = -\vec{F}_{B|A}$

Rotational analogs:

$\Sigma\vec{\tau} = 0$ (object in equilibrium)

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

$\vec{\tau}_{A|B} = -\vec{\tau}_{B|A}$

Forces:

$\vec{F}_{gravity} = \vec{w} = m\vec{g}$

$\vec{F}_{normal} = \vec{n}$

$\vec{F}_{friction} = \vec{f}$; $f_{static} \leq \mu_s n$; $f_{kinetic} = \mu_k n$

$\vec{F}_{spring} = -k\vec{x}$

Work and Energy:

$W = \int_{x1}^{x2} \vec{F}(x) \cdot d\vec{x}$

$W = \vec{F} \cdot \vec{x} = Fx\cos\theta$ (const. force)

$W_{net} = \Delta K$

$W = -\Delta U$ (work done by a conservative force)

$\vec{F} = -(\frac{\partial U}{\partial x}\hat{\imath} + \frac{\partial U}{\partial y}\hat{\jmath} + \frac{\partial U}{\partial z}\hat{k})$

$K = \frac{mv^2}{2}$ (linear motion)

$K = \frac{I\omega^2}{2}$ (rotational motion)

$U_{gravity} = mgh$

$U_{spring} = \frac{kx^2}{2}$

$W_{NC} = \Delta K + \Delta U$ (Conservation of M.E.)

$W = \Delta K + \Delta U + \Delta U_{int}$ (Conserv. of Energy)

Power:

$P_{avg} = \frac{W}{\Delta t}$; $P = \frac{dW}{dt}$;

$P = \vec{F} \cdot \vec{v}$ (constant force)

Impulse and Momentum:

$\vec{J} = \int_{t1}^{t2} \vec{F}(t) dt = \Delta\vec{p}$ (conservation of mom.)

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

$M = \sum_i m_i$

$\vec{r}_{cm} = \frac{1}{M} \sum_i m_i \vec{r}_i$

$\vec{v}_{cm} = \frac{1}{M} \sum_i m_i \vec{v}_i$

$\vec{p}_{tot} = \vec{p}_{cm} = M\vec{v}_{cm}$

Elastic collisions of a moving object A with a stationary object B:

$\vec{v}_{Af} = \frac{m_A - m_B}{m_A + m_B} \vec{v}_{Ai}$

$\vec{v}_{Bf} = \frac{2m_A}{m_A + m_B} \vec{v}_{Ai}$

Moment of inertia:

$I = \sum_i m_i r_i^2$ (point masses)

$I_{cm} = \frac{1}{2} MR^2$ (cylinder/disk, axis ⊥ to the face)

$I_{cm} = \frac{1}{12} ML^2$ (rod, axis ⊥ to the length)

$I_{cm} = \frac{2}{5} MR^2$ (sphere, axis through the center)

$I = I_{cm} + Md^2$ (parallel axis theorem)

Angular Momentum:

$\vec{L} = r \times \vec{p} = r \times m\vec{v} = rm\vec{v}_{tan}$ (point mass)

$\vec{L} = I\vec{\omega}$ (distributed masses)

Gravitation

$\vec{F} = G\frac{Mm}{r^2}\hat{r}$, $\vec{g} = G\frac{M}{r^2}\hat{r}$, $v_{esc} = \sqrt{\frac{2GM}{r}}$

$U = -G\frac{Mm}{r}$, $v_{orbit} = \sqrt{\frac{GM}{r_{orbit}}}$ (circular orbits)

Stress-Strain:

$\sigma_t = \frac{F_\perp}{A} = Y\frac{\Delta l}{l}$ (tensile/compressive)

$\sigma_B = \frac{F_\perp}{A} = B\frac{\Delta V}{V}$ (bulk)

$\sigma_s = \frac{F_\parallel}{A} = S\frac{\Delta x}{h}$ (sheer)

Fluids:

$P = \frac{F}{A} = P_0 + \rho g h$

$P_{abs} = P_{atm} + P_g$

$F_b = m_f g = \rho_f V_{in} g$

$Q = \frac{dV}{dt} = Av = const$ (incompressible)

$P + \rho g h + \frac{1}{2}\rho v^2 = const$ (Bernoulli's eq)

Simple Harmonic Motion:

$x(t) = A\cos(\omega t + \varphi)$

$v(t) = -\omega A \sin(\omega t + \varphi)$

$a(t) = -\omega^2 A\cos(\omega t + \varphi) = -\omega^2 x(t)$

$\omega = \sqrt{\frac{k}{m}} = 2\pi f = \frac{2\pi}{T}$

$k_{pendulum} = mg/l$

$k_{phys.\ pend.} = m^2 gh/I$

Waves:

$y(x,t) = A\cos(kx - \omega t)$

$k = \frac{2\pi}{\lambda}$; $\omega = \frac{2\pi}{T}$; $T = \frac{1}{f}$

$v = f\lambda = \frac{\lambda}{T} = \frac{\omega}{k}$

$v = \sqrt{T/\mu}$ (wave on a string, T= tension)

$f_o = f_s \frac{v \pm v_0}{v \mp v_s}$ (Doppler effect)

Standing waves:

$y(x,t) = 2A\sin(kx)\cos(\omega t)$

$f_n = nv/2L$ (on a string, n=integers)

$f_n = nv/2L$ (open pipe, n=integers)

$f_n = nv/4L$ (closed pipe, n=odd integers)

Mathematical relations:

$\vec{A} \cdot \vec{B} = |\vec{A}|\,|\vec{B}| \cos\theta$

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

$|\vec{A} \times \vec{B}| = |\vec{A}|\,|\vec{B}| \sin\theta$

for: $ax^2 + bx + c = 0$,

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Constants of Nature:

$g_{Earth} = 9.8$ m/s^2

$R_{Earth} = 6.37 \times 10^6$ m

$M_{Earth} = 5.98 \times 10^{24}$ kg

$R_{Earth}^{orbit} = 1.50 \times 10^{11}$ m = 1.0 AU

$M_{Sun} = 2.00 \times 10^{30}$ kg

$G = 6.67 \times 10^{-11}$ Nm^2/kg^2

$P_{atm} = 101.3 \times 10^3$ Pa

$\rho_{water} = 1.0 \times 10^3$ kg/m^3