8.01L SUMMARY OF EQUATIONS

Note: Quantities shown in **bold** are vectors.

$\mathbf{v} = d\mathbf{r}/dt \quad \mathbf{a} = d\mathbf{v}/dt$

For *constant* acceleration **a**, if at $t = 0$ $\mathbf{r} = \mathbf{r}_0$ and $\mathbf{v} = \mathbf{v}_0$: $\mathbf{v} = \mathbf{v}_0 + \mathbf{a}t$, $\mathbf{r} = \mathbf{r}_0 + \mathbf{v}_0 t + \frac{1}{2}\mathbf{a}t^2$

Circular motion at constant speed $a = v^2/r = \omega^2 r$ (Centripetal acceleration, points towards center of circle, ω is angular speed in radians per second)

Adding relative velocities ("wrt" is short for "with respect to"): $\mathbf{v}_{A \text{ wrt } B} + \mathbf{v}_{B \text{ wrt } C} = \mathbf{v}_{A \text{ wrt } C}$

$\sum \mathbf{F} = 0 \Leftrightarrow \mathbf{a} = 0$ (Newton's first law)

$\mathbf{F} = m\mathbf{a}$ or $\mathbf{F} = d\mathbf{p}/dt$ (Newton's second law) $\mathbf{F}_{AB} = -\mathbf{F}_{BA}$ (Newton's third law)

$\mathbf{p} = m\mathbf{v}$ (momentum)

$\mathbf{J} = \int_{t_1}^{t_2} \mathbf{F}\, dt = \int_{t_1}^{t_2} \frac{d\mathbf{p}}{dt} dt = \mathbf{p}_2 - \mathbf{p}_1$ (impulse)

$\mathbf{r}_{cm} = \frac{\Sigma m_i \mathbf{r}_i}{\Sigma m_i}$ (position of center of mass)

$\mathbf{F} = -k\mathbf{x}$ (spring force) $f \le \mu N$ (Friction force relative to Normal force)

$\mathbf{F} = -\frac{GMm}{r^2}\hat{\mathbf{r}}$ (gravitational force between two particles)

$W = \int \mathbf{F} \cdot d\mathbf{r}$ (work done by force **F**)

$W_{other} = \Delta E = E_F - E_I \quad E = KE + PE$ (work-energy theorem)

$F_x = -\frac{dU}{dx}$ (force derived from potential energy)

Potential Energies: $U = \frac{1}{2}kx^2$ (spring force)

$U = \frac{-GMm}{r}$ (gravitational, general) $U = mgh$ (gravitational, near Earth)

$\omega = \sqrt{k/m} \quad x = A\cos(\omega t + \phi)$

$v = -A\omega\sin(\omega t + \phi) \quad T = 2\pi/\omega$

(Equations for Simple Harmonic Motion)

$P_2 + \rho g y_2 = P_1 + \rho g y_1$ (Pascal's Law: pressure versus height in a liquid with velocity = 0)

$P + \frac{1}{2}\rho v^2 + \rho g y = \text{constant}$ (Bernoulli's equation)

$A_2 v_2 = A_1 v_1$ (continuity equation)

$PV = NkT = nRT$ (ideal-gas law)

$\left\langle \frac{1}{2} m v^2 \right\rangle = \frac{3}{2}kT$ (definition of kinetic temperature)

$F_B = \rho_f V_f g$ (buoyancy force, f=fluid displaced)

Quantity	Translational	Rotational (about axis)
Velocity, acceleration	$\boldsymbol{v}$, $\boldsymbol{a}$	$\boldsymbol{\omega}$, $\boldsymbol{\alpha}$ ($v=R\omega$, $a = R\alpha$)
Mass	$M = \sum_i m_i$	$I = \sum_i m_i R_i^2$
Kinetic energy	$\frac{1}{2}Mv^2$	$\frac{1}{2}I\omega^2$
Net force	$\sum_i \mathbf{F}^{ext} = M\mathbf{a}_{cm}$	$\sum_i \tau^{ext} = I\alpha$
Momentum	$\mathbf{p} = m\mathbf{v}$	$\mathbf{L} = \mathbf{r}\times\mathbf{p}$ or $\mathbf{L}=\mathbf{I}\boldsymbol{\omega}$

$\boldsymbol{\tau} = \mathbf{r}\times\mathbf{F} = \frac{d\mathbf{L}}{dt} = \mathbf{I}\boldsymbol{\alpha}$ $|\tau| = rF\sin(\phi) = Fr_\perp$ (torque equations)

$\mathbf{L} = \mathbf{r}\times\mathbf{p}$ $|L| = mvr\sin(\phi)$ (angular momentum of point particle)

$\mathbf{L}=\mathbf{I}\boldsymbol{\omega}$ (angular momentum for solid object)

$I_1 = I_{c.m.} + Md^2$ (parallel axis theorum)

$I = \frac{1}{2}MR^2$ (cylinder around center) $I = \frac{2}{5}MR^2$ (solid sphere around center)

$I = \frac{1}{12}ML^2$ (rod around center) $I = \frac{1}{3}ML^2$ (rod around end)

$KE = \frac{1}{2}M_{Tot}v_{CM}^2 + \frac{1}{2}I_{CM}\omega^2$ (kinetic energy for object moving and rolling)

$KE = \frac{1}{2}I_{Pivot}\omega^2$ (kinetic energy for object rotating around a fixed pivot)

Physical Constants:

$g = 9.8$ m/s^2 Use the approximate value $g = 10$ m/s^2 where told to do so.

$G = 6.67\times10^{-11}$ N m^2/kg^2

$k = 1.38\times10^{-23}$ J/K R = 8.31 J/(mol. K)

$0° C = 273° K$

Density of water = 1,000 kg/m^3

Atmospheric pressure = 1.0×10^5 Pa

Conversion reminder:

π radians = 180^o

Lazy Physicist 's Favorite Angle: (to be used when calculators are not allowed):

36.9^o and 53.1^o are the angles of a 3-4-5 right triangle so:

$\sin(36.9°) = \cos(53.1°) = 0.60$ $\cos(36.9°) = \sin(53.1°) = 0.80$

$\tan(36.9°) = 0.75$ $\tan(53.1°) = 1.33$

Other (possibly) Useful Trig Functions:

$\cos(30°) = \sin(60°) = \sqrt{3}/2$ $\sin(30°) = \cos(60°) = 1/2$

$\cos(45°) = \sin(45°) = 1/\sqrt{2}$

Solution to a Quadratic Equation: If $ax^2 + bx + c = 0$ then $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$