PHYSICS 4A EQUATION SHEET

$\Delta\vec{r} = \vec{r}_f - \vec{r}_i$	Displacement
$\vec{v} = \frac{\Delta\vec{r}}{\Delta t}$	Average velocity
$\vec{v} = \frac{d\vec{r}}{dt}$	Instantaneous velocity
$\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$	Average acceleration
$\vec{a} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{r}}{dt^2}$	Instataneous acceleration
$v = v_o + at$	Velocity as function of time
$x = x_o + v_o t + (1/2)at^2$	Position as function of time
$v^2 = v_o^2 + 2a(x - x_o)$	Velocity as function of position
$x = x_o + \left(\frac{v_o + v}{2}\right)t$	Position as function of velocity and time
$a_r = \frac{v^2}{r}$	Radial (centripetal) acceleration
$\sum \vec{F} = m\vec{a}$	Newton's 2nd Law
$w = mg$	Weight of a body
$f_k = \mu_k N$	Kinetic friction force
$f_s \le \mu_s N$	Static frictional force
$W = \vec{F} \bullet s = Fs\cos\theta$	Work done by constant force
$W = \int_1^2 \vec{F} \bullet d\vec{s}$	Work done by a non-constant force
$F_s = -kx$	Spring force (Hooke's Law)
$W_s = (1/2)kx_i^2 - (1/2)kx_f^2$	Work done by spring force
$W_{applied} = -W_s$	Work done by applied force
$K = (1/2)mv^2$	Kinetic energy
$W_{net} = K_f - K_i = \Delta K$	Work-Energy Theorem
$W_{net} = \int_1^2 \vec{F}_{net} \bullet d\vec{s} = \Delta K$	Work-Energy Theorem

$P_{ave} = \frac{W}{t}$	Average power
$P = \frac{dW}{dt}$	Instantaneous power
$P = \vec{F} \bullet \vec{v} = Fv\cos\theta$	Instantaneous power
$U_g = mgy$	Gravitational PE Function (constant g)
$U_s = (1/2)kx^2$	Elastic PE Function
$F(x) = -\frac{dU(x)}{dx}$	Force from PE function
$E_{mech} = K + U$	Total Mechanical Energy
$W_{nc} = \Delta K + \Delta U$	Work by non-conservative forces
$K_i + U_i = K_f + U_f$	Conservation of Mechanical Energy
$\vec{P} = M\vec{V}$	Linear Momentum
$\sum \vec{F}_{ext} = \frac{d\vec{P}}{dt}$	Newton's 2nd Law
$\vec{I} = \sum \vec{F}_{ext}(t_2 - t_1)$	Impulse due to a constant net force
$\vec{I} = \sum \vec{F}_{ext}(t_2 - t_1) = \vec{p}_2 - \vec{p}_1$	Impulse-Momentum Theorem
$\vec{I} = \int_{t_1}^{t_2} \sum \vec{F}_{ext} dt$	Impulse general definition
$v_{2f} - v_{1f} = -(v_{2i} - v_{1i})$	Relative velocities in an elastic collision
$\vec{r}_{cm} = \frac{\sum_i m_i \vec{r}_i}{M}$	Center of mass of a system of particles
$\vec{r}_{cm} = \frac{\int \vec{r}\,dm}{M}$	Center of mass of a continuous body
$\vec{P}_{sys} = M\vec{V}_{cm}$	Total Linear Momentum of a System
$\sum \vec{F}_{ext} = M\vec{a}_{cm} = \frac{d\vec{P}_{sys}}{dt}$	Newton's 2nd Law for a System
$M\frac{d\vec{v}}{dt} = \vec{v}_{rel}\frac{dM}{dt} + \sum \vec{F}_{ext}$	Rocket Equation

$M\frac{dv}{dt} = -v_{rel}\frac{dM}{dt} - Mg$	Rocket Equation where $\sum \vec{F}_{ext} = - Mg$
$s = r\theta$	Arc length
$\bar{\omega} = \frac{\Delta\theta}{\Delta t}$	Average Angular Speed
$\omega = \frac{d\theta}{dt}$	Instantaneous Angular Speed
$\bar{\alpha} = \frac{\Delta\omega}{\Delta t}$	Average angular acceleration
$\alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$	Instantaneous angular acceleration
$\theta = \theta_o + \omega_o t + \frac{1}{2}\alpha t^2$	Angular position as function of time
$\omega = \omega_o + \alpha t$	Angular speed as function of time
$\omega^2 = \omega_o^2 + 2\alpha(\theta - \theta_o)$	Angular speed as function of angular position
$\theta = \theta_o + \left(\frac{\omega_o + \omega}{2}\right)t$	Angular position as function of angular speed and time
$v_t = r\omega$	Tangential speed
$a_t = r\alpha$	Tangential acceleration
$a_r = \frac{v^2}{r} = r\omega^2$	Radial (centripetal) acceleration
$I = \sum m_i r_i^2$	Moment of Inertia for System of Particles
$I = \int r^2 dm$	Moment of Inertia for a Continuous Body
$I_p = I_{cm} + Md^2$	Parallel-Axis Theorem
$K_R = \frac{1}{2}I\omega^2$	Rotational kinetic energy
$\vec{\tau} = \vec{r} \times \vec{F}$	Definition of Torque
$\sum \tau = I\alpha$	Newton's 2nd Law for Rotation
$W = \int_{\theta_1}^{\theta_2} \tau d\theta$	Work Done by a Torque
$W = \frac{1}{2}I\omega_f^2 - \frac{1}{2}I\omega_i^2$	Work-Energy Theorem for Rotation
$\bar{P} = \frac{\Delta W}{\Delta t} = \tau\bar{\omega}$	Average power
$P = \tau\omega$	Instantaneous power

$K = \frac{1}{2}MV_{cm}^2 + \frac{1}{2}I_{cm}\omega^2$	Kinetic Energy = Translational KE + Rotational KE
$v_{cm} = R\omega$ $a_{cm} = R\alpha$	Condition for Rolling Without Slipping
$\vec{L} = \vec{r} \times \vec{p}$	Angular momentum
$\vec{L} = I\vec{\omega}$	Angular momentum for a rotating body about axis of symmetry
$\sum \vec{\tau}_{ext} = \frac{d\vec{L}}{dt}$	Newton's 2nd Law for rotation
$F_g = \frac{Gm_1m_2}{r^2}$	Newton's Law of Gravitation
$w_E = F_g = \frac{GmM_E}{R_E}$	Weight of a body at surface of earth
$g = \frac{GM_E}{(R_E + h)^2}$	Acceleration of gravity
$U = -\frac{GMm}{r}$	Gravitational Potential Energy function
$v_{esc} = \sqrt{\frac{2GM}{R}}$	Escape Speed
$v = \sqrt{\frac{GM}{r}}$	Circular Orbit Speed
$T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$	Orbital Period
$E = -\frac{GMm}{2r} = \frac{1}{2}U$	Orbital Total Mechanical Energy