Physics 50 Equation Sheet

$\vec{v} = \frac{\Delta \vec{r}}{\Delta t}$ $\vec{v} = \frac{d\vec{r}}{dt}$ $s = \frac{\ell}{t}$ $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$ Average Speed $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$ Average acceleration $\vec{a} = \frac{d\vec{v}}{dt} = \frac{d^2 \vec{r}}{dt^2}$ 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 $v^2 = v_o^2 + 2a(x - x_o)$ Velocity as function of position $x = x_o + \left(\frac{v_o + v}{2}\right)t$ Position as function of velocity and time $x = x_o + \left(\frac{v_o + v}{2}\right)t$ Radial (centripetal) acceleration $\vec{r} = \frac{\vec{v}}{r}$ Radial (centripetal) acceleration $\vec{r} = \vec{r}$ Newton's 2^{nd} Law $\vec{v} = mg$ Weight of a body $f_k = \mu_k N$ Kinetic friction force $f_s \leq \mu_s N$ Static frictional force $\vec{r} = -kx$ Spring force (Hooke's Law) $\vec{w} = \vec{r} = -kx$ Spring force (Hooke's Law) $\vec{w}_s = (1/2)kx_i^2 - (1/2)kx_f^2$ Work done by spring force $\vec{v}_{applied} - \vec{v}_s$ Work done by applied force $\vec{v}_{net} = \vec{v}_f - \vec{v}_i = \Delta K$ Work-Energy Theorem $\vec{v}_{net} = \frac{\Delta W}{\Delta t}$ Instantaneous power	$\Delta \vec{r} = \vec{r}_f - \vec{r}_i$	Displacement
$\overrightarrow{a} = \frac{\Delta \overrightarrow{v}}{\Delta t}$ $\overrightarrow{a} = \frac{d\overrightarrow{v}}{dt} = \frac{d^2\overrightarrow{r}}{dt^2}$ $v = v_o + at$ $Velocity as function of time x = x_o + v_o t + (1/2)at^2 Velocity as function of time v^2 = v_o^2 + 2a(x - x_o) Velocity as function of time v^2 = v_o^2 + 2a(x - x_o) Velocity as function of position x = x_o + \left(\frac{v_o + v}{2}\right)t velocity and time x = x_o + \left(\frac{v_o + v}{2}\right)t x = x_o + \left(\frac{v_o + v}{2}\right)t$	$\vec{v} = \frac{\Delta \vec{r}}{\Delta t}$	Average velocity
$\overrightarrow{a} = \frac{\Delta \overrightarrow{v}}{\Delta t}$ $\overrightarrow{a} = \frac{d\overrightarrow{v}}{dt} = \frac{d^2\overrightarrow{r}}{dt^2}$ $v = v_o + at$ $Velocity as function of time x = x_o + v_o t + (1/2)at^2 Velocity as function of time v^2 = v_o^2 + 2a(x - x_o) Velocity as function of time v^2 = v_o^2 + 2a(x - x_o) Velocity as function of position x = x_o + \left(\frac{v_o + v}{2}\right)t velocity and time x = x_o + \left(\frac{v_o + v}{2}\right)t x = x_o + \left(\frac{v_o + v}{2}\right)t$	$\vec{v} = \frac{d\vec{r}}{dt}$	Instantaneous velocity
$\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$ $\vec{a} = \frac{d\vec{v}}{dt} = \frac{d^2 \vec{r}}{dt^2}$ 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 $x = x_o + \left(\frac{v_o + v}{2}\right)t$ Position as function of velocity and time $x = x_o + \left(\frac{v_o + v}{2}\right)t$ Radial (centripetal) acceleration $x = x_o + \left(\frac{v_o + v}{2}\right)t$ Position as function of velocity and time $x = x_o + \left(\frac{v_o + v}{2}\right)t$ Radial (centripetal) acceleration $x = x_o + \left(\frac{v_o + v}{2}\right)t$ Newton's 2^{nd} Law $x = mg$ Weight of a body $x = x_o + v_o t + (1/2)at^2$ Kinetic friction force $x = x_o + \left(\frac{v_o + v}{2}\right)t$ Work done by constant force $x = x_o + \left(\frac{v_o + v}{2}\right)t$ Work done by spring force $x = x_o + \left(\frac{v_o + v}{2}\right)t$ Work done by spring force $x = x_o + \left(\frac{v_o + v}{2}\right)t$ Work done by applied force $x = x_o + \left(\frac{v_o + v}{2}\right)t$ Work done by applied force $x = x_o + \left(\frac{v_o + v}{2}\right)t$ Work done by applied force $x = x_o + \left(\frac{v_o + v}{2}\right)t$ Kinetic energy $x = x_o + \left(\frac{v_o + v}{2}\right)t$ Work-Energy Theorem $x = x_o + \left(\frac{v_o + v}{2}\right)t$ Average power	$s = \frac{\ell}{4}$	Average Speed
$\vec{a} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{r}}{dt^2}$ $v = v_o + at$ $v = v_o + at$ $v = v_o + at$ $v = v_o + v_o t + (1/2)at^2$ $v = v_o^2 + 2a(x - x_o)$ $v = $	$\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$	Average acceleration
$v = v_o + at$ $v = v_o + at$ $v = v_o + v_o t + (1/2)at^2$ $v = v_o^2 + 2a(x - x_o)$ $v = v_o^2 + 2a(x - x_o)$ $v = v_o + \left(\frac{v_o + v}{2}\right)t$ $v = v_o + v_o t + (1/2)at^2$ $v = v_o + v_o + (1/2)at^2$	$\vec{a} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{r}}{dt^2}$	Instataneous acceleration
$x = x_o + v_o t + (1/2)at^2$ 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 2^{nd} 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 $F_s = -kx$ 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 $P_{ave} = \frac{\Delta W}{\Delta t}$ Average power	$v = v_o + at$	
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$x = x_o + \left(\frac{v_o}{2}\right)t \qquad \text{velocity and time}$ $a_r = \frac{v^2}{r} \qquad \qquad \text{Radial (centripetal)}$ $acceleration$ $\sum \vec{F} = m\vec{a} \qquad \qquad \text{Newton's } 2^{\text{nd}} \text{ Law}$ $w = mg \qquad \qquad \text{Weight of a body}$ $f_k = \mu_k N \qquad \qquad \text{Kinetic friction force}$ $f_s \leq \mu_s N \qquad \qquad \text{Static frictional force}$ $W = \vec{F} \cdot s = Fs \cos \theta \qquad \qquad \text{Work done by constant force}$ $F_s = -kx \qquad \qquad \text{Spring force (Hooke's Law)}$ $W_s = (1/2)kx_i^2 - (1/2)kx_f^2 \qquad \text{Work done by spring force}$ $W_{applied} = W_s \qquad \qquad \text{Work done by applied force}$ $K = (1/2)mv^2 \qquad \qquad \text{Kinetic energy}$ $W_{net} = K_f - K_i = \Delta K \qquad \qquad \text{Work-Energy Theorem}$ $P_{ave} = \frac{\Delta W}{\Delta t} \qquad \qquad \text{Average power}$	$v^2 = v_o^2 + 2a(x - x_o)$	
$w = mg$ 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 $F_s = -kx$ 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 $P_{ave} = \frac{\Delta W}{\Delta t}$ Average power	$x = x_o + \left(\frac{v_o + v}{2}\right)t$	
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$f_{s} \leq \mu_{s}N$ Static frictional force $W = \vec{F} \bullet s = Fs \cos \theta$ Work done by 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 $W_{\text{applied}} = -W_{s}$ Work done by applied force $K = (1/2)mv^{2}$ Kinetic energy $W_{net} = K_{f} - K_{i} = \Delta K$ Work-Energy Theorem $P_{ave} = \frac{\Delta W}{\Delta t}$ Average power	$\overline{w} = mg$	Weight of a body
$\begin{aligned} f_s &\leq \mu_s N & \text{Static frictional force} \\ W &= \vec{F} \bullet s = Fs \cos \theta & \text{Work done by constant force} \\ F_s &= -kx & \text{Spring force (Hooke's Law)} \\ W_s &= (1/2)kx_i^2 - (1/2)kx_f^2 & \text{Work done by spring force} \\ W_{\text{applied}} &= -W_s & \text{Work done by applied force} \\ K &= (1/2)mv^2 & \text{Kinetic energy} \\ W_{net} &= K_f - K_i = \Delta K & \text{Work-Energy Theorem} \\ P_{ave} &= \frac{\Delta W}{\Delta t} & \text{Average power} \end{aligned}$	$f_k = \mu_k N$	Kinetic friction force
$W = \vec{F} \bullet s = Fs \cos \theta$ Work done by 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 $W_{\text{applied}} = -W_s$ Work done by applied force $K = (1/2)mv^2$ Kinetic energy $W_{net} = K_f - K_i = \Delta K$ Work-Energy Theorem $P_{ave} = \frac{\Delta W}{\Delta t}$ Average power		Static frictional force
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force $W_{\text{applied}} = -W_{\text{s}}$ Work done by applied force $K = (1/2)mv^2$ Kinetic energy $W_{net} = K_f - K_i = \Delta K$ Work-Energy Theorem $P_{ave} = \frac{\Delta W}{\Delta t}$ Average power	$F_s = -kx$	Spring force (Hooke's
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$P_{ave} = \frac{\Delta W}{\Delta t}$ Average power		Kinetic energy
$P_{ave} = \frac{\Delta W}{\Delta t}$ Average power	$W_{net} = K_f - K_i = \Delta K$	Work-Energy Theorem
$P = \frac{dW}{dW}$ Instantaneous power		Average power
dt	$P = \frac{dW}{dt}$	Instantaneous power
$P = \vec{F} \bullet \vec{v} = Fv \cos \theta \qquad \text{Instantaneous power}$	$P = \vec{F} \bullet \vec{v} = Fv \cos \theta$	Instantaneous power
$U_g = mgy$ Gravitational PE Function (constant g)		

$U_s = (1/2)kx^2$	Elastic PE Function
$E_{mech} = K + U$	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
$\sum \vec{F}_{ext} = \frac{d\vec{P}}{dt}$ $\vec{I} = \sum \vec{F}_{ext} (t_2 - t_1)$	Newton's 2 nd Law
$\vec{I} = \sum \vec{F}_{ext} (t_2 - t_1)$	Impulse due to a constant net force
$I = \vec{p}_2 - \vec{p}_1 = \Delta \vec{p}$	Impulse-Momentum Theorem
$v_{2f} - v_{1f} = -(v_{2i} - v_{1i})$	Relative velocities in an elastic collision
$s = r\theta$	Arc length
$\overline{\omega} = \frac{\Delta \theta}{\Delta t}$	Average Angular Speed
$\overline{\omega} = \frac{\Delta \theta}{\Delta t}$ $\omega = \frac{d\theta}{dt}$	Instantaneous Angular Speed
$\overline{\alpha} = \frac{\Delta \omega}{\Delta t}$	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
$I = \sum_{i} m_i r_i^2$	Moment of Inertia for System of Particles
$I_p = I_{cm} + Md^2$	Parallel-Axis Theorem
$K_{R} = \frac{1}{2}I\omega^{2}$ $\vec{\tau} = \vec{r} \times \vec{F}$ $\sum \tau_{ext} = I\alpha$	Rotational kinetic energy
$\vec{\tau} = \vec{r} \times \vec{F}$	Definition of Torque
$\sum \tau_{ext} = I\alpha$	Newton's 2 nd Law for Rotation

$W = \tau \Delta \theta$	Work Done by a constant Torque
$W = \frac{1}{2}I\omega_f^2 - \frac{1}{2}I\omega_i^2$	Work-Energy Theorem for Rotation
$\overline{P} = \frac{\Delta W}{\Delta t} = \tau \overline{\omega}$ $P = \tau \omega$	Average power delivered by Torque
$P = \tau \omega$	Instantaneous power delivered by Torque
$K = \frac{1}{2}MV_{cm}^2 + \frac{1}{2}I_{cm}\omega^2$	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
$\sum \vec{\tau}_{ext} = \frac{d\vec{L}}{dt}$ $F_g = \frac{Gm_1m_2}{r^2}$	Newton's 2 nd 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