Physics 131 Spring 2006. Formulas you should memorize for Midterm #2 (of course, you must also know the formulas for Midterm #1.)

Angular Kinematics rotation angle θ (radians; rotation radius R):	$\theta \equiv s$(=arc length)$/R = \theta(t)$ (angular position)
angular velocity ω ; angular acceleration α	$\omega \equiv v_{tan}/R$; $\alpha \equiv a_{tan}/R$ ($_{tan}$ = tangential)
Circular motion (radius R) with **constant** α: circular motion – radial acceleration a_{rad}:	$\omega = \omega_0 + \alpha t$; $\theta = \theta_0 + \omega_0 t + ½\alpha t^2$; eliminating t: $\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$ $a_{rad} = a_c = v_T^2/R$ (radially inwards)
Center-of-Mass position of system (mass M)	$\mathbf{r}_{cm} \equiv \Sigma_i m_i \mathbf{r}_i / \Sigma_i m_i = \Sigma_i m_i \mathbf{r}_i / M$
Moment of Inertia I:	$I \equiv \Sigma m_i r_i^2 = \int r^2 dm$; $r_i(r)$ = distance between rotation axis and $m_i(dm)$
I for thin hollow cylinder, about the central symmetry axis	$I = MR^2$ More complicated formulas in table 9.2 do **NOT** need to be memorized. They will be given if needed.
Parallel-Axis Theorem	$I = I_{//,\mathbf{cm}} + Md^2$ (d=distance between the parallel axes)
Momentum **p**	$\mathbf{p} \equiv \Sigma_i m_i \mathbf{v}_i = M\mathbf{v}_{cm}$
Angular Momentum **L**	$\mathbf{L} \equiv \Sigma_i \mathbf{R}_i \times m_i \mathbf{v}_i$ (= $I\boldsymbol{\omega}$ for a rigid body rotating around the axis used when computing I)
Kinetic Energy K [J≡Nm]:	Moving axis: $K_{tot} \equiv ½\, m v_{cm}^2 + ½\, I_{cm}\omega_{cm}^2$
	Fixed axis A: $K_{rot,A} \equiv ½\, I_A \omega_A^2$
Forces [N≡kgm/s^2] **Torques** [Nm or J] and consequences:	$\Sigma_i \mathbf{F}_i = m\mathbf{a} = d\mathbf{p}/dt$; $\mathbf{F}_{A\text{ on }B} = -\mathbf{F}_{B\text{ on }A}$; $\Sigma_i \boldsymbol{\tau}_i = d\mathbf{L}/dt = I\boldsymbol{\alpha}$ In PHY131, rotations will always be in a fixed plane. The vectors **τ**, **ω**, etc. will therefore have a fixed direction perpendicular to the plane, and you do not need to worry about direction, just **sign**. Conventionally, counterclockwise is positive, but you may **specify** your own convention.

Force of **Gravity** between M and m, at center-to-center distance r	$\mathbf{F}_G = GMm/r^2$ (attractive! G=6.67×10^{-11} Nm^2/kg^2); near sea level: $\mathbf{F}_G = mg(-\mathbf{j})$ (downwards; g=9.80 m/s^2). Memorize 9.80, but not the numerical value 6.67×10^{-11} Nm^2/kg^2
Force of a **Spring** (spring constant k):	$\mathbf{F}_S = -k\mathbf{x}$ (opposes compression/stretch **x**)
Torque:	$\boldsymbol{\tau} \equiv \mathbf{R}\times\mathbf{F}$ ($\tau = RF\sin\theta_{\mathbf{R},\mathbf{F}}$; direction: right-hand rule)
Equilibrium & Collisions:	$\Sigma_i \mathbf{F}_i = d\mathbf{p}_{tot}/dt = 0$ and $\Sigma\boldsymbol{\tau}_i = d\mathbf{L}_{tot}/dt = 0 \Rightarrow \Delta\mathbf{p}_{tot} = \Delta\mathbf{L}_{tot} = 0$ *Elastic*: K is conserved; *Completely Inelastic*: objects stick together afterwards
Work done by a torque $\boldsymbol{\tau}_\mathbf{F}$ over a rotation by angle $\boldsymbol{\theta}$:	$W_\mathbf{F} \equiv \int \boldsymbol{\tau}_\mathbf{F} \cdot d\boldsymbol{\theta}$
Power P [W≡J/s]:	$P_\mathbf{F} \equiv dW_\mathbf{F}/dt = \mathbf{F}\cdot\mathbf{v}$ **or** $\boldsymbol{\tau}_\mathbf{F}\cdot\boldsymbol{\omega}$
Potential Energy U of **conservative** forces **F**	$U_F = -W_F$; e.g. $U_G = -GMm/r$, U_G (near earth)$=mgy$; $U_s = ½kx^2$
Harmonic oscillator $m\frac{d^2x}{dt^2} = -kx - b\frac{dx}{dt}$ The "circle of reference" is a picture where the oscillator displacement x is horizontal, while –v/ω is vertical. The oscillator is then "visualized" as a point on a circle of radius A, whose angular motion θ(t) is given by θ=ωt+φ, and x(t)=Acosθ.	$x(t)= A\cos(\omega t + \varphi)$ where $\omega = \sqrt{k/m}$ if the damping coefficient $b=0$. $\omega=2\pi f=2\pi/T$. $A = \sqrt{x_0^2 + (v_0/\omega)^2}$; $\phi = -\tan^{-1}(v_0/\omega x_0)$ when $b \neq 0$ the oscillations die exponentially as $e^{-\gamma t}$ where you do **not** need to memorize formulas like $\gamma = b/2m$ or the formula for the shifted resonant frequency.
Pendulum $I\frac{d^2\theta}{dt^2} = -MgL_{CM}\sin\theta \approx -MgL_{CM}\theta$ The small angle approximation is used in the second formula.	$\theta(t)=\Theta\cos(\omega t + \varphi)$ where $\omega = \sqrt{MgL_{CM}/I}$ for the general pendulum, which becomes $\omega = \sqrt{g/L}$ for the simple pendulum. These results depend on the angular amplitude Θ being small.