MASSACHUSETTS INSTITUTE OF TECHNOLOGY  
Department of Physics  

8.01 Physics  
Fall Term 2013  

Exam 3: Equation Summary

Newton’s Second Law: Force, Mass, Acceleration:  
\[ \vec{F} = m \vec{a} \]

Newton’s Third Law:  
\[ \vec{F}_{1,2} = -\vec{F}_{2,1} \]

Center of Mass:  
\[
\vec{r}_{\text{cm}} = \frac{1}{m_{\text{total}}} \sum_{i=1}^{N} m_i \vec{r}_i \rightarrow \frac{1}{m_{\text{total}}} \int dm \vec{r} ;
\]

Velocity of Center of Mass:  
\[
\vec{v}_{\text{cm}} = \frac{1}{m_{\text{total}}} \sum_{i=1}^{N} m_i \vec{v}_i \rightarrow \frac{1}{m_{\text{total}}} \int dm \vec{v} ;
\]

Momentum:  
\[
\vec{p} = m \vec{v} , \quad \vec{p}_{\text{sys}} = \sum_{i=1}^{N} m_i \vec{v}_i ,
\]

Newton’s Second Law  
\[ \vec{r}_{\text{ext}} = \frac{d \vec{p}_{\text{sys}}}{dt} \]

Impulse:  
\[ \vec{I} = \int_{t=0}^{t=\infty} \vec{F}(t) dt = \Delta \vec{p} \]

Kinetic Energy:  
\[ K = \frac{1}{2} m v^2 ; \quad \Delta K \equiv \frac{1}{2} m v_f^2 - \frac{1}{2} m v_0^2 \]

Work- Kinetic Energy:  
\[ W = \int_A^B \vec{F} \cdot d\vec{r} \quad W = \Delta K \]

Potential Energy:  
\[ \Delta U \equiv U(B) - U(A) \equiv -W_c = -\int_A^B \vec{F} \cdot d\vec{r} \]

Potential Energy Functions with Zero Points:  

Constant Gravity:  
\[ U(y) = mg y \quad \text{with} \quad U(y_0 = 0) = 0 . \]

Inverse Square Gravity:  
\[ U_{\text{gravity}}(r) = -\frac{G m_1 m_2}{r} \quad \text{with} \quad U_{\text{gravity}}(r_0 = \infty) = 0 . \]

Springs:  
\[ U_{\text{spring}}(x) = \frac{1}{2} k x^2 \quad \text{with} \quad U_{\text{spring}}(x = 0) = 0 . \]

Work- Mechanical Energy:  
\[ W_{\text{nc}} = \Delta K + \Delta U_{\text{total}} = \Delta E_{\text{mech}} = \left( K_f + U_f^{\text{total}} \right) - \left( K_0 + U_0^{\text{total}} \right) \]
**Moment of Inertia:**
\[ I_p = \int_{\text{body}} dm(r_L)^2 \]

Moment of inertia of uniform disk of mass \( M \) and radius \( R \) about axis passing through center of mass perpendicular to plane of disk: \((1/2)MR^2\)

Moment of inertia of uniform disk of mass \( M \) and radius \( R \) about axis passing through center of mass parallel to plane of disk: \((1/4)MR^2\)

Moment of inertia of uniform rod of mass \( M \) and length \( L \) about axis passing through center of mass perpendicular to rod: \((1/12)ML^2\)

Parallel Axis Theorem:
\[ I_p = md^2 + I_{cm} \]

Torque about a point \( S \):
\[ \vec{\tau}_S = \vec{r}_{S,f} \times \vec{F} \]

Angular Momentum (point particle) about a point \( S \):
\[ \vec{L}_S = \vec{r}_S \times m\vec{v} \]

AngularImpulse:
\[ \int_{t_i}^{t_f} \vec{r}_S^{\text{ext}} dt = \vec{L}_{S,f} - \vec{L}_{S,i} \]

**Fixed Axis Rotation (about z-axis):**

AngularVelocity:
\[ \vec{\omega} = \omega_z \hat{k} \]

AngularAcceleration:
\[ \vec{\alpha} = \alpha_z \hat{k} \]

Angular Momentum for fixed axis rotation (symmetric body):
\[ \vec{L}_z = I_z \omega_z \hat{k} \]

Torque and Angular momentum about point \( S \):
\[ \vec{\tau}_S^{\text{ext}} = \frac{d\vec{L}_S^{\text{sys}}}{dt} \]

Rotational Kinetic Energy about fixed point \( S \):
\[ K^\text{rot}_S = \frac{1}{2} I_z \omega^2 \]