MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Physics
Experimental Study Group

Physics 8.012 **Fall Term 2010**

Momentum

$$\vec{\boldsymbol{p}} = m\vec{\boldsymbol{v}}, \quad \vec{\boldsymbol{F}}_{\text{ave}}\Delta t = \Delta\vec{\boldsymbol{p}}, \quad \vec{\boldsymbol{F}}^{\text{total}}_{\text{ext}} = \frac{d\vec{\boldsymbol{p}}^{\text{total}}}{dt}$$

Impulse

$$\vec{\boldsymbol{I}} \equiv \int_{t=0}^{t=t_f} \vec{\boldsymbol{F}}(t)\,dt = \Delta\vec{\boldsymbol{p}}$$

Work-Change in Mechanical Energy

$$W_{\text{nc}} = \Delta K^{\text{total}} + \Delta U^{\text{total}} = \Delta E_{\text{mech}}$$
$$E_{\text{mech}} = K^{\text{total}} + U^{\text{total}} = K^{\text{orbit}} + K^{\text{spin}} + U^{\text{total}}$$

Kinematics Circular Motion

$$\vec{\boldsymbol{v}} = \frac{dr}{dt}\hat{\boldsymbol{r}} + r\frac{d\theta}{dt}\hat{\boldsymbol{\theta}}$$
$$\vec{\boldsymbol{a}} = \left(\frac{d^2r}{dt^2} - r\left(\frac{d\theta}{dt}\right)^2\right)\hat{\boldsymbol{r}} + \left(2\frac{dr}{dt}\frac{d\theta}{dt} + r\frac{d^2\theta}{dt^2}\right)\hat{\boldsymbol{\theta}}$$

Kinematics

$$v_x(t) - v_{x,0} = \int_{t'=0}^{t'=t} a_x(t')\,dt'$$
$$x(t) - x_0 = \int_{t'=0}^{t'=t} v_x(t')\,dt'$$

Constant Acceleration

$$x_1(t) = (x_0)_1 + (v_{x,0})_1 t + \frac{1}{2}(a_x)_1 t^2$$
$$v_{x,1}(t) = (v_{x,0})_1 + (a_x)_1 t$$

Universal Law of Gravity

$$\vec{\boldsymbol{F}}_{1,2} = -G\frac{m_1 m_2}{r^2_{1,2}}\hat{\boldsymbol{r}}_{1,2}$$

Surface of earth

$$\vec{\boldsymbol{F}}_{\text{grav}} = m_{\text{grav}}\vec{\boldsymbol{g}}$$

Coulomb's Law

$$\vec{\boldsymbol{F}}_{1,2} = k_e\frac{q_1 q_2}{r^2_{1,2}}\hat{\boldsymbol{r}}_{1,2}$$

Contact force

$$\vec{\boldsymbol{F}}_{\text{contact}} = \vec{\boldsymbol{N}} + \vec{\boldsymbol{f}}$$

Static Friction

$$0 \le f_s \le f_{s,\text{max}} = \mu_s N$$

direction depends on applied forces

Kinetic Friction

$$f_k = \mu_k N \text{ opposes motion}$$

Hooke's Law

$$F = k|\Delta x|, \text{ restoring}$$

Center of Mass

$$\vec{\boldsymbol{R}}_{\text{cm}} = \sum_{i=1}^{i=N} m_i\vec{\boldsymbol{r}}_i \Big/ \sum_{i=1}^{i=N} m_i \longrightarrow \int_{\text{body}} dm\vec{\boldsymbol{r}} \Big/ \int_{\text{body}} dm$$

Velocity of Center of Mass

$$\vec{\boldsymbol{V}}_{\text{cm}} = \sum_{i=1}^{i=N} m_i\vec{\boldsymbol{v}}_i \Big/ \sum_{i=1}^{i=N} m_i \longrightarrow \int_{\text{body}} dm\vec{\boldsymbol{v}} \Big/ \int_{\text{body}} dm$$

Kinetic Energy

$$K = \frac{1}{2}mv^2; \quad \Delta K = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_0^2$$

Work

$$W = \int_{r_0}^{r_f} \vec{\boldsymbol{F}} \cdot d\vec{\boldsymbol{r}}$$

Work–Kinetic Energy

$$W^{\text{total}} = \Delta K$$

Power

$$P = \vec{\boldsymbol{F}} \cdot \vec{\boldsymbol{v}} = dK/dt$$

Potential Energy

$$\Delta U = -W_{\text{conservative}} = -\int_A^B \vec{\boldsymbol{F}}_c \cdot d\vec{\boldsymbol{r}}$$

Potential Energy Functions with Zero Points

Constant Gravity

$$U(y) = mgy; \qquad U(y_0 = 0) \equiv 0$$

Inverse Square Gravity

$$U_{\text{gravity}}(r) = -\frac{Gm_1 m_2}{r} \qquad U_{\text{gravity}}(r_0 = \infty) \equiv 0$$

Hooke's Law

$$U_{\text{spring}}(x) = \frac{1}{2}kx^2 \qquad U_{\text{spring}}(x = 0) \equiv 0$$