

$$F = C_1rv + C_2r^2v^2 \quad F = \frac{mMG}{r^2} \quad \mathbf{F} = \frac{d\mathbf{p}}{dt} = m\mathbf{a} \quad dW = \mathbf{F} \cdot d\mathbf{r} \quad a_{cent} = \frac{v^2}{r} = \omega^2r$$

$$U = \frac{-mMG}{r} \quad U = mgh \quad U = \frac{1}{2}kx^2 \quad K = \frac{1}{2}mv^2 \quad K = \frac{1}{2}I\omega^2$$

$$E_{tot} = K + U = \frac{1}{2}mv^2 - \frac{mMG}{r} = \frac{-mMG}{2a} \quad \mathbf{L} = \mathbf{r} \times \mathbf{p} \quad I = \sum_i m_i r_i^2$$

$$m_1r_1 = m_2r_2 \quad v = \omega r \quad T^2 = \frac{4\pi^2(r_1 + r_2)^3}{G(m_1 + m_2)} \quad \omega = \frac{d\theta}{dt} \quad \omega = \sqrt{k/m}$$

$$\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F} = I\boldsymbol{\alpha} = \frac{d\mathbf{L}}{dt} \quad \alpha = \frac{d\omega}{dt} \quad T = \frac{2\pi}{\omega} \quad L = I\omega \quad \mathbf{I} = \int_0^{\Delta t} \mathbf{F} dt = \mathbf{p}_f - \mathbf{p}_i$$

$$\omega = \sqrt{g/l} \quad \omega_{pr} = \frac{\tau}{L_s} \quad T^2 = \frac{4\pi^2a^3}{GM}$$

Solid disk of mass M and radius R rotating about its cylindrical axis: $I = \frac{1}{2}MR^2$

Solid sphere of mass M and radius R rotating about an axis through its center: $I = \frac{2}{5}MR^2$

$$v_f - v_i = -u \ln\left(\frac{m_f}{m_i}\right) - gt \quad I = I_{cm} + Md^2 \quad I_z = I_x + I_y$$

$$f' = f \left(1 + \frac{v}{c} \cos \theta\right) \quad \lambda' = \lambda \left(1 - \frac{v}{c} \cos \theta\right) \quad \frac{dP}{dy} = -\rho g$$

$$PV = nRT \quad R = 8.31\text{J/K} \quad PV = NkT \quad k = 1.38 \times 10^{-23}\text{J/K} \quad N_A = 6.02 \times 10^{23}$$

$$\lambda = \frac{h}{p} \quad E = hf = \frac{hc}{\lambda} \quad \Delta L = \alpha L \Delta T \quad \Delta V = \beta V \Delta T$$

$$h = 6.6 \times 10^{-34} \text{ J} \cdot \text{sec} \quad \hbar = \frac{h}{2\pi} = 1.05 \times 10^{-34} \text{ J} \cdot \text{sec}$$

$$\frac{1}{2}\rho v_1^2 + \rho g y_1 + P_1 = \frac{1}{2}\rho v_2^2 + \rho g y_2 + P_2$$

Problem 1 (16 points)

A gunner fires a bullet of mass m with speed v_0 at an angle θ from the horizontal plane. Assume the bullet is fired from ground level. The gravitational acceleration is g . Ignore air drag. Express your answers in terms of m , g , v_0 , and θ .

- a. (4) When does the bullet reach its highest point?
- b. (4) How high is that above the ground?
- c. (4) With what speed will the bullet hit the ground?
- d. (4) What is the horizontal distance that the bullet has traveled when it hits the ground?

SOLUTIONS**Problem 1** 16 points

$$4 \text{ pts } \mathbf{a)} \quad v_y = v_0 \sin \theta - gt = 0 \rightarrow t = \frac{v_0 \sin \theta}{g}$$

$$4 \text{ pts } \mathbf{b)} \quad y = v_0 + (v_0 \sin \theta)t - \frac{1}{2}gt^2$$
$$y = 0 + (v_0 \sin \theta) \left(\frac{v_0 \sin \theta}{g} \right) - \frac{1}{2}g \left(\frac{v_0 \sin \theta}{g} \right)^2$$
$$\mathbf{y} = \frac{1}{2} \frac{v_0^2 \sin^2 \theta}{g}$$

$$4 \text{ pts } \mathbf{c)} \quad v_0$$

$$4 \text{ pts } \mathbf{d)} \quad x = v_0 + (v_0 \cos \theta)t \quad t = 2 \frac{v_0 \sin \theta}{g}$$
$$\mathbf{x} = \frac{2v_0^2 \sin \theta \cos \theta}{g}$$