Physics 200a Midterm 18 October 2006
70 minutes

I suggest you draw pictures, write neatly and go over the exam quickly before deciding the order in which to attack the problems.

I. A bullet of mass m moving at horizontal velocity v strikes and sticks to the rim of a wheel (a solid disc) of mass M, radius R, anchored at its center, initially at rest, but free to rotate. (Figure 1.) (i) Which of energy, momentum and angular momentum is conserved for the bullet+wheel system? Give a few words of explanation. (ii) Find ω_f the final angular velocity of the wheel. **10**

II. A wooden block of mass M and negligible width sits on frictionless table L meters from the edge. At $t = 0$ bullet of mass m and velocity v_1 penetrates it from the left and exits to the right with a speed v_2. (i) When will the block fly off the table? (ii) If the table has a height h how far from the edge of the table will it land? **10** (Neglect the loss of wood in block due to bullet penetrating it and the time it takes bullet to traverse block.)

III. Consider the force $\mathbf{F} = \mathbf{i}2xy^3 + \mathbf{j}3x^2y^2$. (i) Show that it is conservative. (ii) What is the corresponding potential energy $U(x,y)$? (iii) What is the work done by the force along a path $y = x^{123456789}$ joining $(0,0)$ to $(1,1)$? **10**

IV. (i) Why can't a body with total energy $E < 0$ in the gravitation field of the sun ever escape to infinity? (Ignore all other bodies.) **3**

(ii) I give you a spring of unknown force constant k, a meter stick, a clock, a $1kg$ mass and a block of wood at rest on a table. How will you find μ_s, the coefficient of static friction between the block and the table. Assume g is known. (Help yourself to my tool box with massless hooks, nails etc.) **7**

(iii) I give you two spheres of same mass M and radius R, one solid and one
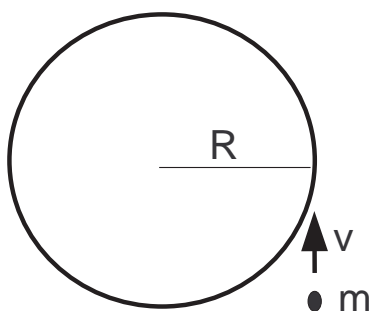

FIG. 1. Top view of bullet as it approaches disk.

hollow, and an incline on which they can roll without slipping. Explain how you will determine which is which. Provide a brief explanation displaying your understanding of the underlying ideas. **5**

V. A mass m tethered to a massless string is spinning in a *vertical circle*, keeping its total energy constant. Find $T_1 - T_2$, the difference in the (magnitude of) the tension between the top most and bottom-most points. **10**

VI. A horizontal rod of length L and mass M supports a mass m at one end. It is supported by pivot P on the wall at the left end and a cable at angle of θ at the other end as shown in Figure 2.
(i) Find T, the tension on the cable.
(ii) If the cable snaps, and rod swings down, with what angular velocity ω will it slam into the wall? **15**
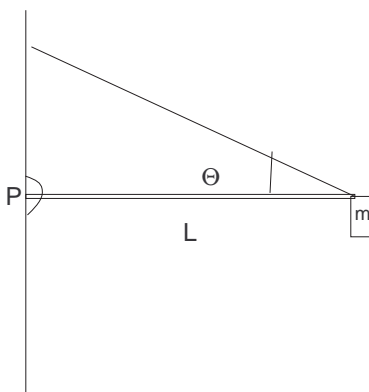
FIG. 2. The rod of length L is supported by pivot P and a string anchored to the wall.

Data Sheet

$$\mathbf{r} = \mathbf{r}_0 + \mathbf{v}_0 t + \frac{1}{2}\mathbf{a}t^2$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

$$F = \frac{GM_1 M_2}{r^2}$$

$$G = 6.6 \cdot 10^{-11} N \cdot m^2/kg^2$$

$$E = K + U$$

$$U = mgh \text{ near earth,}$$

$$U = -\frac{GM_1 M_2}{r}$$

$$U = \frac{1}{2}kx^2$$

$$M_E = 6 \cdot 10^{24} kg$$

$$E_2 - E_1 = W_{friction} \qquad \text{Law of Conservation of Energy}$$

$$W = \int_1^2 \mathbf{F} \cdot \mathbf{dr} \qquad (= U(1) - U(2) \text{ For conservative forces})$$

$$m_1 v_1 + m_2 v_2 = m_1 v_1' + m_2 v_2' \quad \text{momentum conservation}$$

$$\frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_2 v_2^2 = \frac{1}{2}m_1 v_1'^2 + \frac{1}{2}m_2 v_2'^2 \quad \text{conservation of kinetic energfy}$$

$$\theta = \theta_0 + \omega_o t + \frac{1}{2}\alpha t^2$$

$$\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$$

$$\tau = I\alpha \qquad \tau = Fr\sin\theta$$

$$\Delta W = \tau\delta\theta$$

$$I = \sum_i m_i r_i^2$$

$$I_{CM} = \frac{MR^2}{2} \text{ disk or cylinder} \qquad \frac{2MR^2}{5}\text{solid sphere} \qquad \frac{ML^2}{12} \text{ rod}$$

$$W = \int_{\mathbf{r_1}}^{\mathbf{r_2}} \mathbf{F} \cdot \mathbf{dr} \quad (= U(1) - U(2) \text{ if conservative}$$

$$L = I\omega \qquad K = \frac{1}{2}I\omega^2$$

$$I = I_{CM} + Md^2 \qquad \text{Parallel axis theorem for an axis a distance } d \text{ from CM}$$

$$E = K + V \qquad V = (1/2)kx^2 \qquad V = mgh \text{ near earth}$$