Physics 131-1 Test 3

I pledge that I have neither given nor received unauthorized assistance during the completion of this work.

Signature ________________________________

Questions (8 pts. apiece) Answer in complete, well-written sentences WITHIN the spaces provided.

1. If someone told you that the area of a circle was $A = r$, how could you refute them immediately?

2. Recall the laboratory entitled *Conservation of Angular Momentum* where you dropped a weight onto a rotating disk. The addition of the weight changes the moment of inertia of the system. What information do you need to measure to account for the change? Clearly describe each part of your answer.

3. Assume that an object is moving in a circle of constant radius, r. Using the general relationship between a length of arc, s, on a circle and the variables r and θ in radians take the derivative of s with respect to time to find the velocity of the object. Show how the magnitude of the linear velocity, v, is related to the magnitude of the angular velocity, ω.

4. Recall the laboratory entitled *Periodic Motion* where you studied the motion of a weight oscillating on a spring. When the mass has its maximum positive velocity, is its distance from the detector maximum, minimum, the equilibrium value, or some other value? Explain your answer using Newton's Laws and/or conservation of mechanical energy.

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5. For many years it was considered impossible by many to use rockets in space because the exhaust (*i.e.* the burnt fuel) propelled from the rocket had nothing to push against. On Jan. 13, 1920 the editorial page of the New York Times made the following statement about a proposal by Robert Goddard (now recognized as the father of American rocket science).

   > That Professor Goddard with his 'chair' in Clark College and the countenancing of the Smithsonian Institution, does not know the relation of action to reaction, and of the need to have something better than a vacuum against which to react - to say that would be absurd. Of course he only seems to lack the knowledge ladled out daily in high schools.

   Was the Times' correct and how might you respond?

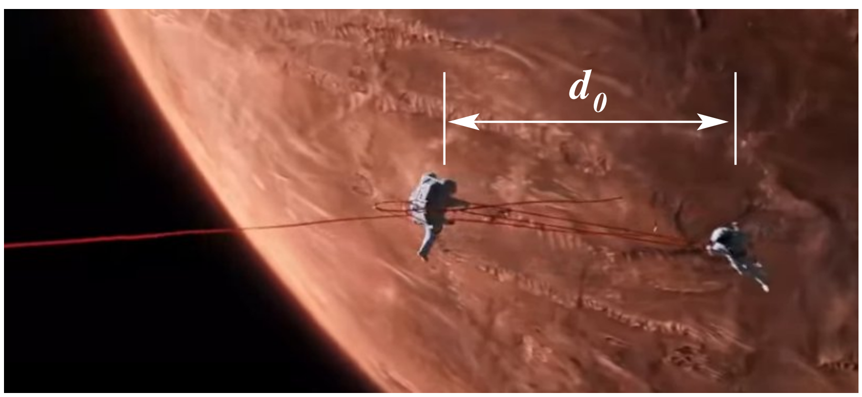
Problems. Clearly show all reasoning for full credit. Use a separate sheet to show your work.

1. 15 pts. An object in simple harmonic motion oscillates with a period of $T = 4.0\ s$, an amplitude of $A = 10\ cm$, and a phase $\phi = 0$. At $t = 0$, $x = 10.0\ cm$. How long does the object take to move from $x = 10.0\ cm$ to $x = 5.0\ cm$?

2. 20 pts. A package of mass m is released from rest at a warehouse loading dock and slides down a frictionless chute of height h_0 as shown in the figure to a waiting truck. Unfortunately, the truck driver went on a break without having removed the previous package of mass $3m$ from the bottom of the chute. Suppose the collision between the packages is perfectly elastic. To what final height h_1 does the package of mass m rebound? Your answer should in terms of m, g, h_0, and any other constants.

3. 25 pts. In the final rescue scene of the movie *The Martian* Commander Lewis and Mark Watney are spinning around each other on a tether of length d_0. They orbit the center-of-mass of the tether located at the midpoint. Commander Lewis pulls Watney toward her until she can grab him. Assume the masses of each astronaut are m (the commander is lighter, but she has a manned maneuvering unit attached to her spacesuit) and their initial tangential speed is $v_{\perp 0}$. Treat the astronauts as point particles as they orbit around one another. What is the astronauts' angular momentum in terms of d_0, m, and $v_{\perp 0}$? Commander Lewis pulls Watney toward her until she can reach him at a distance d_1. What is the tangential velocity $v_{\perp 1}$ when she grabs him in terms of d_0, d_1, m, and $v_{\perp 0}$? What is the change in the kinetic energy ΔKE of the astronauts? Use the following values to obtain a numerical value for ΔKE ONLY. Compare your result with the energy of a car going 55 mph - 3×10^5 J. Could she do it or is Hollywood violating the laws of physics?

$$\begin{array}{ll} m = 320\ kg & d_0 = 7\ m \\ v_{\perp 0} = 2\ m/s & d_1 = 0.5\ m \end{array}$$



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Physics 131-1 Exam Sheet, Test 3

$$\Delta\vec{r} = \vec{r}_{finish} - \vec{r}_{start} \quad \Delta\vec{v} = \vec{v}_{finish} - \vec{v}_{start}$$

$$\langle\vec{v}\rangle = \frac{\Delta\vec{r}}{\Delta t} \qquad \vec{v} = \frac{d\vec{r}}{dt} = \lim_{\Delta t\to 0}\frac{\Delta\vec{r}}{\Delta t} = \lim_{\Delta t\to 0}\frac{\vec{r}(t+\Delta t)-\vec{r}(t)}{\Delta t}$$

$$\langle\vec{a}\rangle = \frac{\Delta\vec{v}}{\Delta t} \qquad \vec{a} = \frac{d\vec{v}}{dt} = \lim_{\Delta t\to 0}\frac{\Delta\vec{v}}{\Delta t} = \lim_{\Delta t\to 0}\frac{\vec{v}(t+\Delta t)-\vec{v}(t)}{\Delta t}$$

$$x(t) = \frac{1}{2}at^2 + v_0 t + y_0 \quad v = at + v_0 \quad a = g \quad a_c = \frac{v^2}{r} \quad (\vec{v}\perp\vec{r} \quad \vec{v}\perp\vec{a}_c)$$

$$\vec{F}_{net} = \sum_i \vec{F}_i = m\vec{a} = \frac{d\vec{p}}{dt} \qquad \vec{F}_{AB} = -\vec{F}_{BA} \quad \vec{p} = \sum m_i\vec{v}_i \quad \vec{p}_i = \vec{p}_f$$

$$|\vec{F}_f| = \mu N \quad |\vec{F}_c| = m\frac{v^2}{r} \quad |\vec{F}_G| = \frac{Gm_1m_2}{r^2} \quad \vec{F}_s(x) = -kx\hat{i} \quad \vec{F}_g(y) = -mg\hat{j}$$

$$W = \int\vec{F}\cdot d\vec{s} = \int|\vec{F}|\,|\vec{ds}|\,\cos\theta = \Delta KE = -\Delta U \quad KE = \frac{1}{2}mv^2 \quad KE_i = KE_f \;\; elastic$$

$$KE_i + U_i = KE_f + U_f \quad KE = KE_{cm} + KE_{rot} \quad KE_{rot} = \frac{1}{2}I\omega^2 \quad U_s(x) = \frac{1}{2}kx^2 \quad U_g(y) = mgy$$

$$\theta = \frac{s}{r} \quad \omega = \frac{v_\perp}{r} = \frac{d\theta}{dt} \quad \alpha = \frac{a_\perp}{r} = \frac{d\omega}{dt} \quad I = \sum m_i r_i^2 = I_{cm} + Mh^2 \quad \vec{r}_{cm} = \frac{\sum m_i\vec{r}_i}{\sum m_i}$$

$$\vec{\tau} = rF\sin\phi\,\hat{\theta} = I\vec{\alpha} = \frac{d\vec{L}}{dt} \quad \vec{L} = \sum I_i\vec{\omega}_i \quad \vec{L}_i = \vec{L}_f \quad v_{cm} = r\omega$$

$$x(t) = A\cos(\omega t + \phi) \quad \omega^2 = \frac{k}{m} \quad T = \frac{2\pi}{\omega} = \frac{1}{f}$$

$$\vec{A} = A_x\hat{i} + A_y\hat{j} + A_z\hat{k} \;\; \frac{dA}{dt} = 0 \;\; \frac{dt}{dt} = 1 \;\; \frac{dt^2}{dt} = 2t \;\; \frac{d}{dt}\cos\theta = -\sin\theta \;\; \frac{d}{dt}\sin\theta = \cos\theta$$

$$\int f(x)dx = \lim_{\Delta x\to 0}\sum f(x_i)\Delta x \qquad \int dx = x + c \qquad \int xdx = \frac{x^2}{2} + c$$

$$\sin\theta = \frac{opp}{hyp} \quad \cos\theta = \frac{adj}{hyp} \quad \tan\theta = \frac{opp}{adj} \quad x^2 + y^2 + z^2 = R^2 \quad \rho = \frac{m}{V}$$

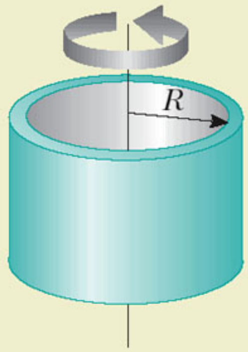
$$x = \frac{-b\pm\sqrt{b^2-4ac}}{2a} \quad C = 2\pi r \quad Area = \pi r^2 \quad Area = \frac{1}{2}bh \quad Area = 4\pi r^2$$

Speed of Light (c)	$2.9979\times 10^8\ m/s$	proton/neutron mass	$1.67\times 10^{-27}\ kg$
R	$8.31 J/K - mole$	g	$9.8\ m/s^2$
Gravitation constant	$6.67\times 10^{-11}\ N - m^2/kg^2$	Earth's radius	$6.37\times 10^6\ m$
Earth-Moon distance	$3.84\times 10^8\ m$	Electron mass	$9.11\times 10^{-31}\ kg$

TABLE 10.2 Moments of Inertia of Homogeneous Rigid Objects With Different Geometries

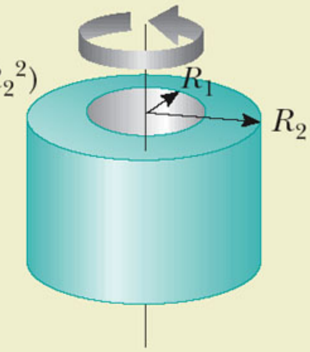
Hoop or thin cylindrical shell

$I_{CM} = MR^2$



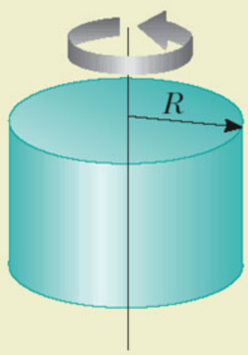
Hollow cylinder

$I_{CM} = \frac{1}{2}M(R_1^{\,2} + R_2^{\,2})$



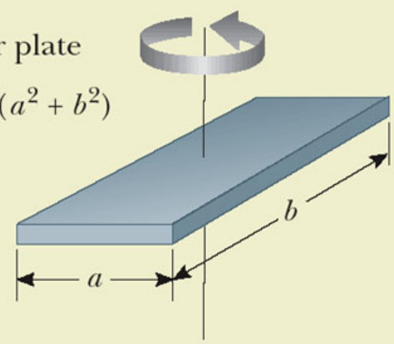
Solid cylinder or disk

$I_{CM} = \frac{1}{2}MR^2$



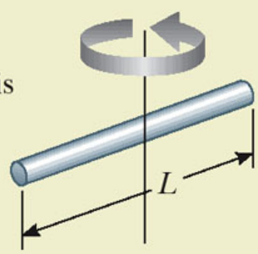
Rectangular plate

$I_{CM} = \frac{1}{12}M(a^2 + b^2)$



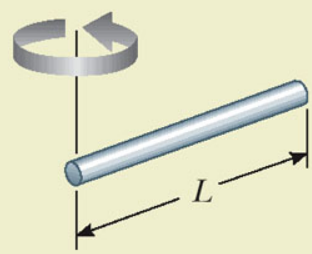
Long thin rod with rotation axis through center

$I_{CM} = \frac{1}{12}ML^2$



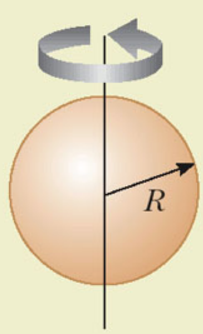
Long thin rod with rotation axis through end

$I = \frac{1}{3}ML^2$



Solid sphere

$I_{CM} = \frac{2}{5}MR^2$



Thin spherical shell

$I_{CM} = \frac{2}{3}MR^2$