Physics 131-01 Final Exam

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

Signature ______________________________

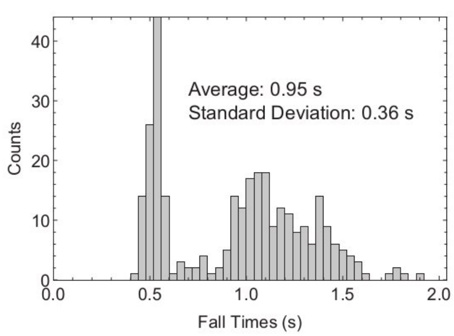
Questions (5 pts. apiece) Answer in complete, well-written sentences WITHIN the spaces provided.

1. Relativistic time dilation implies that moving clocks run more slowly when observed by someone in a different inertial frame. For the twins paradox what does this imply about the time interval the space-faring twin measures during her trip relative to the Earthbound twin?

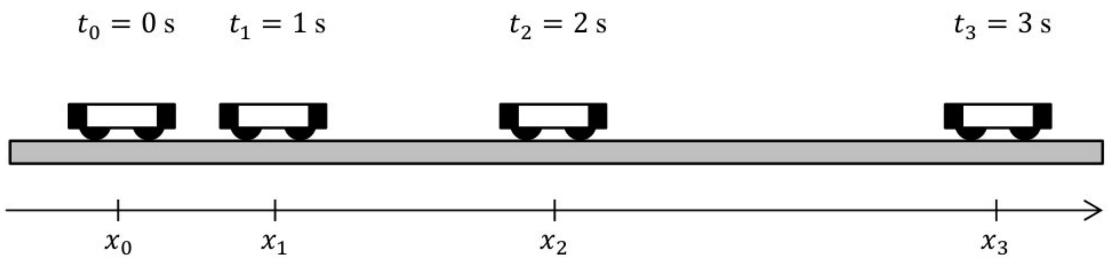
2. In the laboratory entitled *Galilean Relativity*, you measured the horizontal position of a projectile as a function of time from a stationary inertial frame and a moving one fixed to the projectile launcher. How did the two plots differ in appearance? Explain the difference.

3. What would you see in a mirror if you carried it in your hands and ran near the speed of light? Explain.

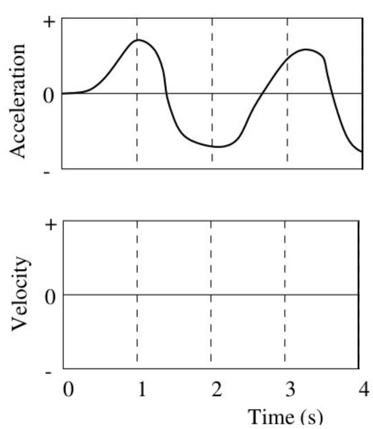
4. Consider the histogram shown below combining two sets of possible fall times of a projectile from different classes. The average and standard deviation are 0.95 ± 0.36 s. Do the average and standard deviation capture the full description of the data? Why or why not?



5. The diagram below shows the positions of a cart at equal time intervals. At each indicated time sketch and label a vector above the cart which might represent the velocity of the cart at that time while it is moving away from the motion detector and speeding up. Show below how you would find the approximate length and direction of the vector representing the change in velocity between the times 1.0 s and 2.0 s by creating a vector diagram using the vectors above. No quantitative calculations are needed. Based on the direction of the resultant vector and the direction of the positive x-axis, what is the sign of the acceleration?



6. Roughly sketch the velocity-time graph for the object in question 1 on the axes below, beginning with a negative velocity. Remember that acceleration is the derivative of velocity. Explain your reasoning.



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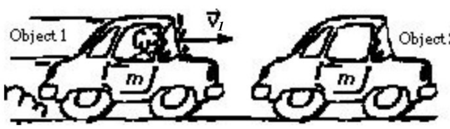
7. Use Newton's law of universal gravitation to show the magnitude of the acceleration due to gravity on an object of mass m at a height h above the surface of the Earth (radius R_e and mass M_e) is given by the following expression:

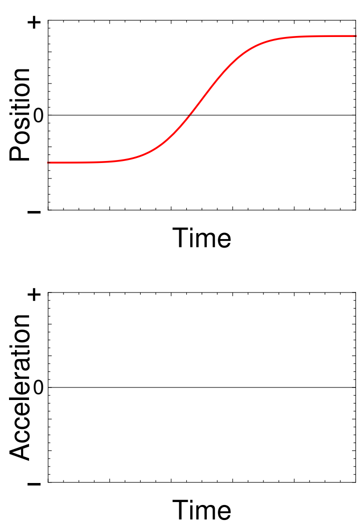
$$\frac{GM_e}{(R_e + h)^2}$$

Hint: Because of the spherical symmetry of the Earth you can treat the mass of the Earth as if it were all concentrated at a point at the Earth's center.

8. Suppose the masses of two objects are the same and that object 1 is moving toward object 2, but object 2 is at rest so $m_1 = m_2$ and $v_1 > v_2$. What are the relative magnitudes of the forces between object 1 and object 2 when they collide? Explain your reasoning.



9. In the bottom panel of the figure below sketch the acceleration versus time graph that would match the position versus time plot that is shown in the top panel of the figure. State the reasoning behind your sketch.



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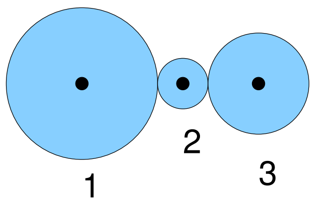
10. The figure below shows three gears that rotate together because of the friction between them so they turn without slipping. Gear 1 has radius $3R$, gear 2 has radius R, and gear 3 has radius $2R$. Gear 2 is forced to rotate by a motor. Rank the gears according to the angular speed of the gears with the greatest first. Explain your reasoning.



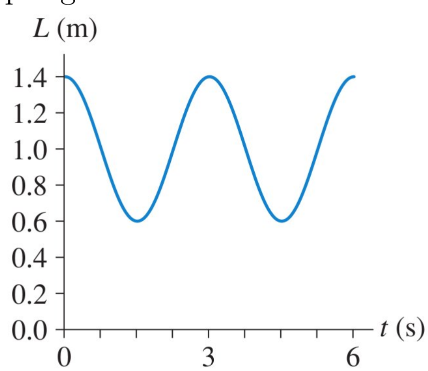
Problems. Clearly show all reasoning for full credit. Use a separate sheet for your work.

1. 8 pts. How fast must a rocket travel on a journey to and from a distant star so that the astronauts age 10 years while the Mission Control workers on earth age 120 years?

2. 8 pts. What is the rotational kinetic energy of the spinning Earth? Assume the Earth is a uniform sphere. Data for the Earth can be found on the equation sheet at the end of the exam. Ignore the effect of the Earth's orbit around the Sun.

3. 8 pts. On the Apollo 14 mission to the moon, astronaut Alan Shepard hit a golf ball with a 6 iron. The free-fall acceleration on the moon is 1/6 of its value on Earth. Suppose he hit the ball with a speed of $v_0 = 25\ m/s$ at an angle $\theta = 40°$ above the horizontal. Assume the Moon is largely flat where he hit it. How long was the ball in flight? Was this time longer or shorter than the flight on Earth? Explain.

4. 8 pts. Astronauts in space cannot weigh themselves by standing on a bathroom scale. Instead, they use a large spring. Suppose an astronaut attaches one end of a large spring to her belt and the other end to a hook on the wall of the space craft. A fellow astronaut then pulls her away from the wall and releases her. The spring's length as a function of time is shown in the figure. Ignore the mass of the belt and the spring. What is her mass m if the spring constant is $k = 220\ N/m$?



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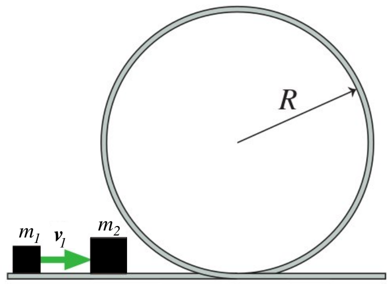
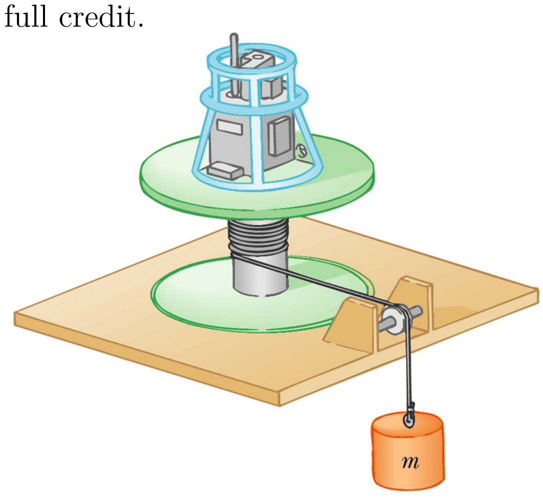
Problems (continued). Clearly show all work for full credit.

5. 9 pts. In the figure below, a block of mass m_1 slides along a frictionless track with speed v_1. It has a perfectly elastic collision (*i.e*, kinetic energy is conserved) with a stationary block of mass m_2 as shown below. The block of mass m_2 needs to reach a minimum velocity $v_2 = \sqrt{5Rg}$ after the collision to reach the top of the loop (R is the radius of the loop). What is the minimum value of v_1 that will give the block of mass m_2 the required velocity in terms of R, g, and the masses?



6. 9 pts. Measuring the moment of inertia of an irregularly-shaped object like the payload of a spacecraft can be done with a device like the one shown in the figure. A counterweight of mass m is suspended by a cord wound around a spool of radius r, forming part of a turntable supporting the object. The turntable can rotate without friction. When the counterweight is released from rest, it descends a distance h, acquiring a speed v. Show that the moment of inertia I of the rotating apparatus including the turntable is $mr^2(2gh/v^2 - 1)$. Clearly show all steps for full credit.



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Physics 131-1 Final Exam Sheet

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

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

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

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

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

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

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

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

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

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

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

$$\Delta t = \frac{\Delta t_p}{\sqrt{1-\frac{v^2}{c^2}}} \quad L = L_p\sqrt{1-\frac{v^2}{c^2}} \quad v_i' = \frac{v_i - v}{1-\frac{v_i'v}{c^2}} \quad v_i' = v_i - v \quad x' = x - vt \quad y' = y$$

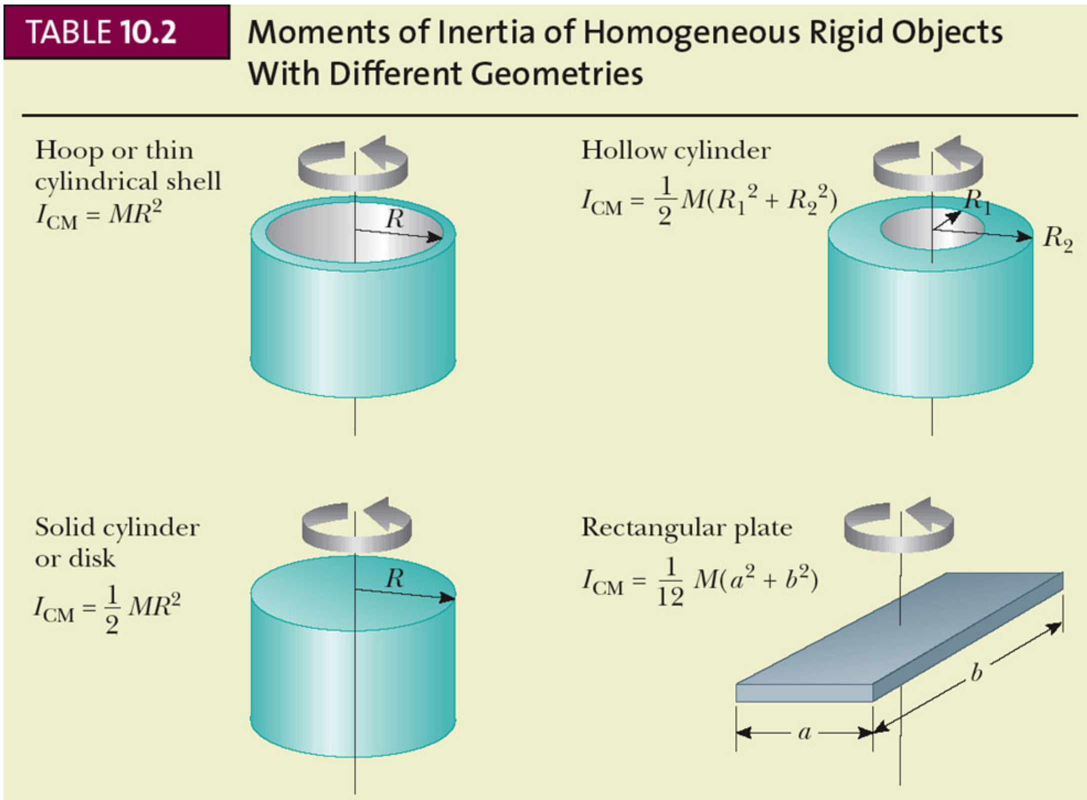
$$\vec{A} = A_x\hat{i} + A_y\hat{j} + A_z\hat{k} \quad \frac{dA}{dt} = 0 \quad \frac{dt}{dt} = 1 \quad \frac{dt^2}{dt} = 2t \quad \frac{d}{dt}\cos\theta = -\sin\theta \quad \frac{d}{dt}\sin\theta = \cos\theta$$

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

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

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

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-Sun distance	$1.50 \times 10^{11}\ m$	Earth's mass	$5.98 \times 10^{24}\ kg$
Earth-Moon distance	$3.84 \times 10^8\ m$	Electron mass	$9.11 \times 10^{-31}\ kg$



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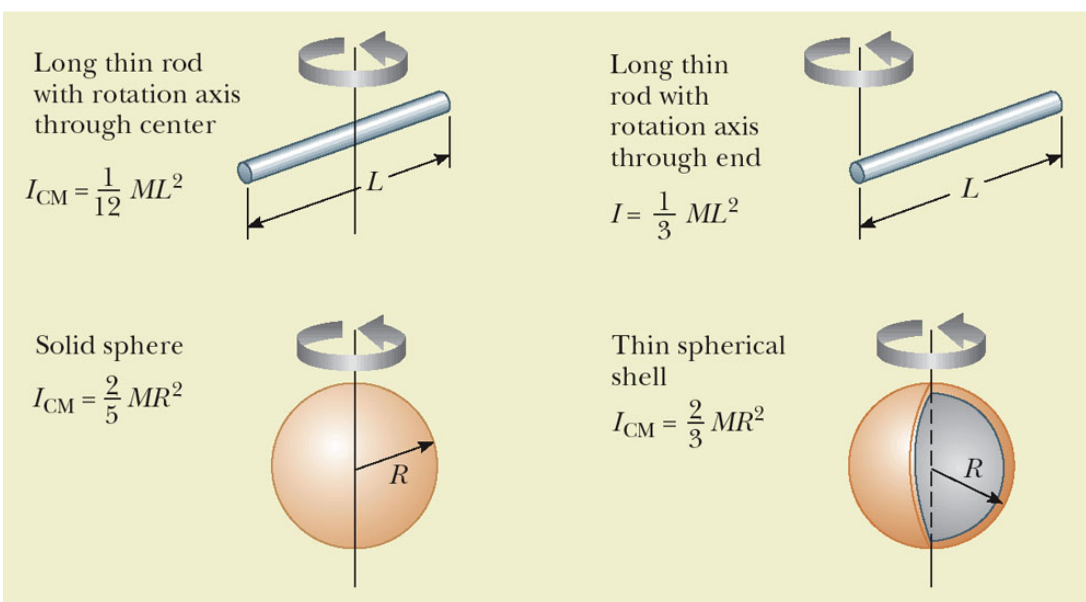

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