Physics 131-01 Final Exam

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

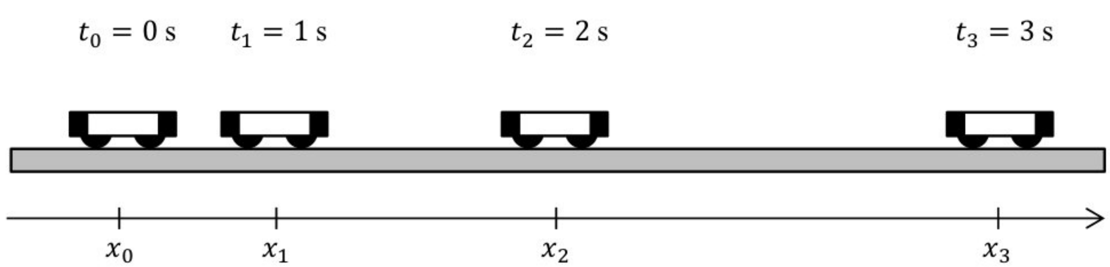
Name ______________________________ Signature ______________________________

Questions (4 pts. apiece) Answer in complete, well-written sentences WITHIN the spaces provided.

1. A paradox is defined in the Merriam-Webster online dictionary as 'an argument that apparently derives self-contradictory conclusions by valid deduction from acceptable premises'. What is paradoxical about the twin's paradox?

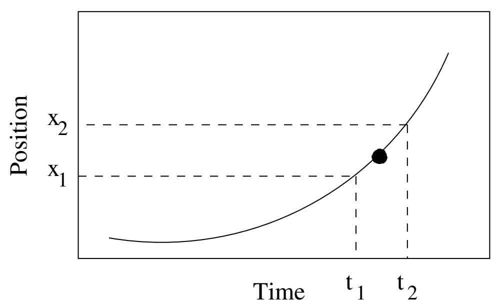
2. A spacecraft has the shape of a sphere when viewed from an inertial frame at rest with respect to the spacecraft. If it moves past an observer on Earth with a speed of $v = 0.5c$, what shape does the observer measure for the spacecraft? Explain. You don't have to be quantitative here - just discuss the shape of the craft.

3. 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?



4. You are sleeping at home over winter break and wake up to find the house is on fire and smoke is pouring into the partially open bedroom door. The room is so messy that you cannot get to the door. The only way to close the door is to throw either a blob of clay or a super ball at the door — there's not enough time to throw both. Assuming that the clay blob and the super ball have the same mass, which would you throw to close the door: the clay blob (which will stick to the door) or the super ball (which will bounce back with almost the same velocity it had before it collided with the door)? Give reasons for your choice, using any notions you already have or any new concepts developed in physics such as force, momentum, Newton's laws, etc. Remember, your life depends on it!

5. In the figure below, what is the equation to estimate the average slope of the curve at the highlighted point in terms of x_1, x_2, t_1, and t_2? How would you find the "exact" value of the slope at the point in the figure between t_1 and t_2?



6. Use Newton's law of universal gravitation to show that the magnitude of the acceleration due to gravity on an object of mass m at a height h above the surface of the earth 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.

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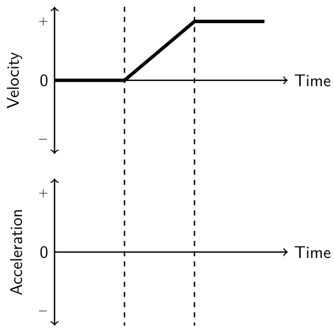
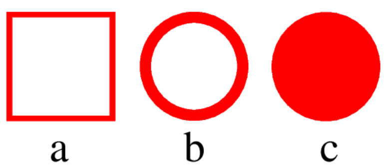
7. In the bottom panel of the figure below sketch the acceleration versus time graph that would match the velocity versus time plot that is shown in the top panel of the figure. State the reasoning behind your sketch.

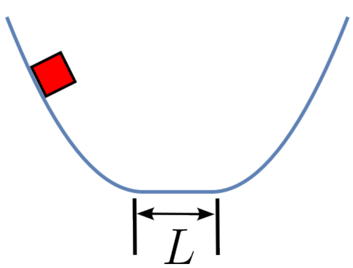


8. Three uniform solids with identical masses are shown below (a square ring, a disk, and a circular ring). Which one has the greatest rotational inertia about an axis through its center of mass and perpendicular to its cross section? Which one has the least? Explain.



9. A person riding a Ferris wheel at an amusement park moves through the positions at (a) the top, (b) the bottom, and (c) mid-height. Rank the three positions according to the magnitude of the net centripetal force on the person. Explain your reasoning.

10. In the figure below, a small block is released from rest on a track with an initial potential energy PE_i. The curved portions of the track are frictionless, but the horizontal portion of length L produces a frictional force f on the block. If $PE_i = 2.25\ fL$, then how many trips does the block make across the horizontal section? Explain. Where does the block come to a halt? In what direction was it moving before it stopped. Explain.



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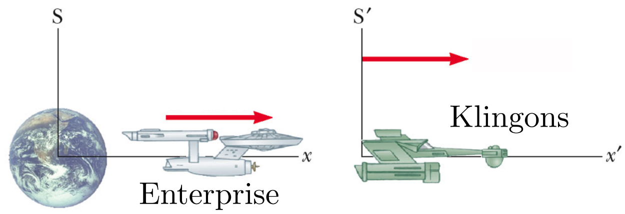
Problems. Clearly show all reasoning for full credit. Use a separate sheet for your work.

1. 7 pts. A Klingon spacecraft moves away from the Earth at a speed of $v_K = 0.7c$ (see figure) relative to the Earth. The starship Enterprise pursues the Klingons at a high speed. Observers on the Earth measure the Enterprise's speed to be $v_E = 0.85c$. With what speed is the Enterprise overtaking the Klingon ship as measured by the crew of the *Enterprise*?



2. 8 pts. Nerve impulses typically travel through the body at about $v_n = 150\ miles/hour$ or about $67\ m/s$. Imagine someone drops a brick from one meter above your big toe. You see this and immediately your brain starts the process of moving your big toe out of harm's way. Compare the time it takes for the brick to fall with the time it takes for the nerve signal to get from your brain to your toe and start moving it out of the way. Assume you are a height $h = 1.75\ m$ tall.

3. 10 pts. The astronauts orbiting the Earth in the figure are working on the International Space Station (ISS). The ISS is in a circular orbit a height $h = 420\ km$ above the Earth's surface, where the free-fall acceleration is $a = 8.56\ m/s^2$. Take the radius of the Earth as $R_E = 6400\ km$. Determine the speed of the satellite v_s and the time interval Δt required to complete one orbit around the Earth, which is the period of the satellite.

4. 10 pts. A crate of eggs is located in the middle of the flatbed of a pickup truck as the truck negotiates an unbanked curve in the road. The curve may be regarded as an arc of a circle of radius $r_c = 35.0\ m$. If the coefficient of static friction between crate and truck is $\mu = 0.6$, how fast can the truck be moving without the crate sliding?

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

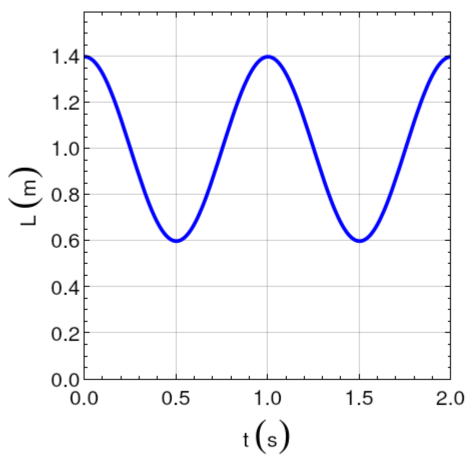
5. 12 pts. A proton (mass $m_p = 1\ u$) is shot at a speed of $v_p = 4.0 \times 10^7\ m/s$ toward a gold target. The nucleus of a gold atom (mass $m_g = 197\ u$) repels the proton and deflects it straight back toward the source with 90% of its initial speed. What is the recoil speed of the gold nucleus?

6. 13 pts. Astronauts in space cannot weigh themselves by standing on a bathroom scale. Instead, they use a large spring. An astronaut attaches one end of a large spring with spring constant $k = 600\ N/m$ to the wall of the space craft and the other end to a chair. She sets the spring/chair combination in motion and obtains a plot of the spring's length shown below. She then sits in the chair and a fellow astronaut pulls her away from the wall and releases her. The period of her oscillation is $T_a = 2.1\ s$.

   a) What is the period T_c of the spring/chair combination alone?

   b) What is the mass m_c of the spring/chair combination?

   c) What is the astronaut's mass m_a?



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Physics 131-1 Final Exam Equations and Constants

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

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

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

$$\vec{A} = A_x\hat{i} + A_y\hat{j} \quad \vec{A}+\vec{B} = (A_x+B_x)\hat{i} + (A_y+B_y)\hat{j} \quad \vec{A}\cdot\vec{B} = |\vec{A}||\vec{B}|\cos\theta = A_xB_x + A_yB_y$$

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

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

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

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

$$d_{Roche} = \left(\frac{12M}{\pi\rho}\right)^{1/3} \quad \rho = \frac{m}{V} \quad \vec{J} = \int_{t_1}^{t_2}\vec{F}dt = \Delta\vec{p}$$

$$\theta = \frac{s}{r} \quad \omega = \frac{v_\perp}{r} = \frac{d\theta}{dt} \quad \alpha = \frac{a_\perp}{r} = \frac{d\omega}{dt} \quad I = \sum m_i r_i^2 = I_{cm} + Md^2 \quad \vec{r}_{cm} = \frac{\sum m_i\vec{r}_i}{\sum m_i} \quad \vec{\tau} = rF\sin\phi\,\hat{\theta} = I\vec{\alpha}$$

$$\vec{\tau} = I\vec{\alpha} = \frac{d\vec{L}}{dt} \approx \frac{\vec{\Delta}L}{\Delta t} \quad \vec{L} = \sum I_i\vec{\omega}_i = \sum r_i m_i \vec{v}_{i\perp} \quad \vec{L}_i = \vec{L}_f \quad v_{cm} = r\omega \quad \theta = \frac{\alpha}{2}t^2 + \omega_i t + \theta_i \quad \omega = \alpha t + \omega_i$$

$$x(t) = A\cos(\omega t + \phi) \quad \omega^2 = \frac{k}{m} \quad T = \frac{2\pi}{\omega} = \frac{1}{f} \quad PE = \frac{1}{2}kx^2 \quad ME_s = \frac{1}{2}kA^2 \quad \sin\theta \approx \theta \quad \omega^2 = \frac{mg\ell}{I}$$

$$\Delta t = \frac{\Delta t'_p}{\sqrt{1-\frac{v^2}{c^2}}} \quad L' = L_p\sqrt{1-\frac{v^2}{c^2}} \quad u' = \frac{u-v}{1-\frac{uv}{c^2}} \quad u' = u - v \quad x' = \frac{x-vt}{\sqrt{1-v^2/c^2}} \quad x' = x - vt \quad y' = y$$

$$\frac{dA}{dt} = 0 \quad \frac{dt}{dt} = 1 \quad \frac{dt^2}{dt} = 2t \quad \frac{d}{d\theta}\cos\theta = -\sin\theta \quad \frac{d}{d\theta}\sin\theta = \cos\theta \quad \frac{df(x)}{du} = \frac{df(x)}{dx}\frac{dx}{du}$$

$$\int f(x)dx = \lim_{\Delta x\to 0}\sum f(x_i)\Delta x \quad \int dx = x + c \quad \int x dx = \frac{x^2}{2} + c \quad \left(1-\frac{v^2}{c^2}\right)^{\pm 1/2} \approx 1 \mp \frac{1}{2}\frac{v^2}{c^2}$$

$$\sin\theta = \frac{opp}{hyp} \quad \cos\theta = \frac{adj}{hyp} \quad \tan\theta = \frac{opp}{adj} \quad \cos(\theta - \frac{\pi}{2}) = \sin\theta \quad \sin(\theta + \frac{\pi}{2}) = \cos\theta \quad \cos^2\theta + \sin^2\theta = 1$$

$$x^2 + y^2 + z^2 = R^2 \quad V = \frac{4}{3}\pi r^3 \quad C = 2\pi r \quad Area = \pi r^2 \quad Area = \frac{1}{2}bh \quad Area = 4\pi r^2 \quad V = \pi r^2\, l$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

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 radius	$6.37 \times 10^6\ m$
Earth-Moon distance	$3.84 \times 10^8\ m$	Earth mass	$5.9742 \times 10^{24}\ kg$
Electron mass	$9.11 \times 10^{-31}\ kg$	Moon mass	$7.3477 \times 10^{22}\ kg$
1 newton	$0.2248\ lbs - force$	Moon radius	$1.74 \times 10^6\ m$
Solar radius	$6.96 \times 10^8\ m$	Solar mass	$1.99 \times 10^{30}\ kg$
Earth-Sun distance	$1.50 \times 10^{11}\ m$	1 u	$1.661 \times 10^{-27}\ kg$

Moments of Inertia