Physics 8, fall 2011, final exam. **Name:** ______________________________

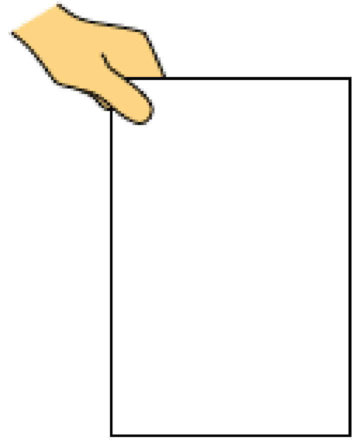
Please show your work on these sheets. Put a box around your final answer for each question.

1. (13 minutes, 10%) The spacecraft in the movie 2001: A Space Odyssey has a rotating cylinder to create the illusion of gravity, inside of which the crew walks and exercises.

(a) If the radius of the cylinder is about three times a crew member's height, what should the rate of revolution of the cylinder be in order to replicate Earth's gravity?

(b) For a person standing in this cylinder, how much do the gravitational acceleration at the top of her head and the gravitational acceleration at her feet differ?

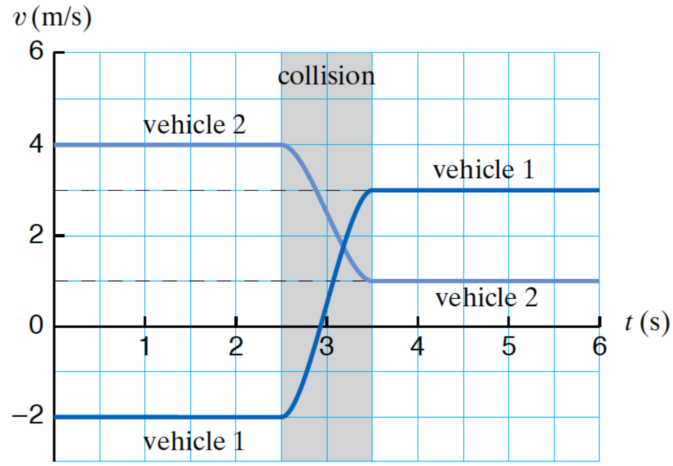
2. (6 minutes, 5%) You are holding a sheet of paper at rest between your thumb and index finger as shown at right. The sheet has a mass of 0.005 kg and its dimensions are 0.20 m by 0.30 m.



(a) Is the earth (via gravity) exerting a torque on the sheet about the top-left corner? If so, what is the magnitude of this torque?

(b) Are you exerting a torque on the sheet about the top-left corner? If so, what is the magnitude of this torque?

3. (16 minutes, 15%) The graph at right shows the velocities of two vehicles traveling along the same straight line. Around 3 s the two vehicles collide. The mass m_1 of vehicle 1 is 1200 kg.



(a) Determine the mass m_2 of vehicle 2. Explain how you determined your answer.

(b) Is the collision between the vehicles elastic, inelastic, or totally inelastic? Explain how you determined your answer. If the collision is elastic, describe the motion of the two vehicles. If it is inelastic, determine how much energy is dissipated in the collision.

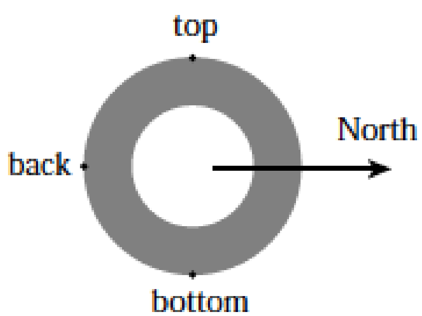
(c) Determine the magnitude of the average force exerted by vehicle 1 on vehicle 2 during the collision and the magnitude of the average force exerted by vehicle 2 on vehicle 1 during the collision.

4. (9 minutes, 5%) A 2.0 kg ball is suspended from a spring, stretching the spring by 0.50 m from its relaxed length. The ball is then pulled down an additional 0.20 m from its equilibrium position and then released. How long after being released does the ball pass its equilibrium position?

5. (22 minutes, 15%) A car with wheels of 0.60 m diameter travels North at 10 m/s.

(a) What are the magnitude and direction of the angular velocity of the wheels? How long does it take for a wheel to complete one rotation?

(b) In the reference frame of the Earth, what are the magnitude and direction of the velocity at the following points on the wheel? (i) at the top of the wheel? (ii) at the bottom of the wheel? (iii) at the back of the wheel?



(c) If the wheel is a uniform cylinder of mass 20 kg, what is the total kinetic energy of all four wheels?

6. (6 minutes, 5%) You have been hired to check the technical correctness of an upcoming made-for-TV murder mystery. The mystery takes place in the space shuttle. In one scene, an astronaut's safety line is sabotaged while she is on a space walk, so she is no longer connected to the space shuttle. She checks and finds that her thruster pack has also been damaged and no longer works. She is 200 meters from the shuttle and moving with it. That is, she is not moving with respect to the shuttle. There she is drifting in space with only 4 minutes of air remaining. To get back to the shuttle, she decides to unstrap her 10 kg tool kit and throw it away with all her strength, so that it has a speed of 8 m/s. According to the script, she makes it back to the shuttle before running out of air. Is this correct? Her mass, including space suit (but without the tool kit) is 80 kg.

7. (19 minutes, 15%) A janitor is pushing an 11 kg trashcan across a level floor at constant speed. The coefficient of friction between can and floor is 0.10.

(a) If he is pushing horizontally, what is the magnitude of the force he is exerting against the can?

(b) If he pushes not horizontally but rather at an angle of 30° down from the horizontal, what must the magnitude of his pushing force be to keep the can moving at constant speed?

(c) What is the magnitude of the normal force between the trashcan and the floor in part (a)? And in part (b)?

8. (13 minutes, 10%) A satellite that is always over the same spot on the earth is called "geostationary." Geostationary orbits are located above the equator and have an orbital period of 24 hours. How far above the center of the earth is a geostationary orbit? ($G = 6.67 \times 10^{-11}\ \frac{\text{N m}^2}{\text{kg}^2}$, and $M_{\text{earth}} = 6.0 \times 10^{24}$ kg. For checking that your answer makes sense, it may also help to know that $R_{\text{earth}} = 6.4 \times 10^6$ m.)

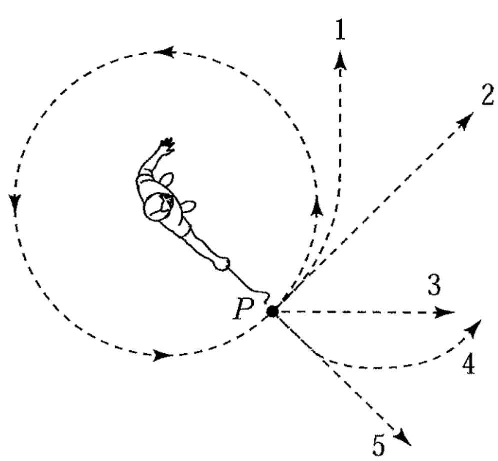
9. (6 minutes, 5%) Explain why, when a truck makes a sharp turn on an unbanked road (i.e. a perfectly horizontal road), the wheels on the inside of the turn tend to come off the ground. You may find it easier to explain with the help of a picture.

Conceptual questions: 10 minutes total, 15%

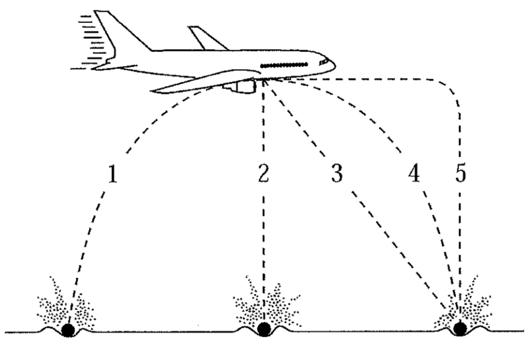
C1. Two metal balls are the same size but one weighs twice as much as the other. The balls roll off of a horizontal table at the same instant and with the same speed. In this situation

1. both balls hit the floor at approximately the same horizontal distance from the base of the table.
2. the heavier ball hits the floor at about half the horizontal distance from the base of the table as does the lighter ball.
3. the heavier ball hits the floor considerably closer to the base of the table than the lighter ball, but not necessarily half the horizontal distance.
4. the lighter ball hits the floor considerably closer to the base of the table than the heavier ball, but not necessarily at half the horizontal distance.

C2. A steel ball is attached to a string and is swung in a circular path in a horizontal plane as illustrated in the figure below. At point P, the string suddenly breaks near the ball. If these events are observed from directly above, which of the 1–5 paths below would the ball most closely follow after the string breaks?

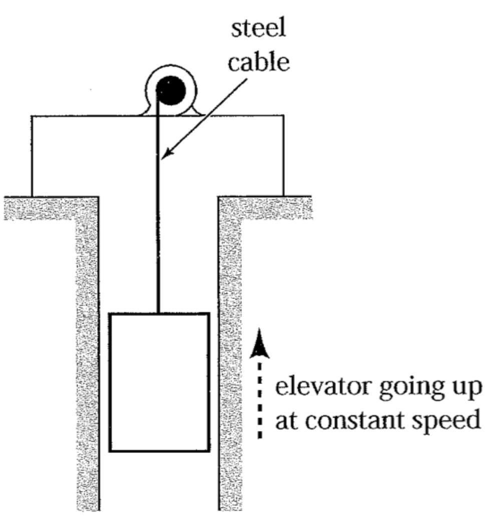


C3. A bowling ball accidentally falls out of the cargo bay of an airliner as it flies along in a horizontal direction. As observed by a person standing on the ground and viewing the plane as in the figure below, which of the paths 1–5 would the bowling ball most closely follow after leaving the airplane?



C4. An elevator is being lifted up an elevator shaft at a constant speed by a steel cable, as shown in the following figure. All frictional effects are negligible. In this situation, forces on the elevator are such that

1. the upward force by the cable is greater than the downward force of gravity.
2. the upward force by the cable is equal to the downward force of gravity.
3. the upward force by the cable is smaller than the downward force of gravity.
4. the upward force by the cable is greater than the sum of the downward force of gravity and a downward force due to the air.
5. none of the above. The elevator goes up because the cable is being shortened, not because an upward force is exerted on the elevator by the cable.



Possibly useful equations

$$f = \frac{1}{T} = \frac{\omega}{2\pi}$$

$$f_{\mathrm{spring}} = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \qquad f_{\mathrm{pendulum}} = \frac{1}{2\pi}\sqrt{\frac{g}{\ell}}$$

$$F = \frac{GMm}{r^2} \qquad G = 6.67 \times 10^{-11}\ \frac{\mathrm{N\ m^2}}{\mathrm{kg^2}}$$

$$\vec{F} = \frac{\mathrm{d}\vec{p}}{\mathrm{d}t} \qquad \vec{p} = m\vec{v}$$

$$F_c = \frac{mv^2}{r} \qquad F_c = m\omega^2 r \qquad v = \omega r$$

$$F^K = \mu^K F^N \qquad F^s \le \mu_s F^N$$

$$F_x^{\ \mathrm{spring}} = -k\ (x - x_0)$$

$$F_y^{\ \mathrm{grav}} = -mg \qquad g = 9.8\ \mathrm{m/s^2}$$

for a solid cylinder rotating about its axis, $I = \frac{1}{2}mr^2$

$$\vec{\tau} = \vec{r} \times \vec{F} \qquad \tau = rF\sin\theta = r_\perp F = rF_\perp$$

$$W = \int \vec{F}_{\mathrm{external}} \cdot \mathrm{d}\vec{x}$$

moving frames: let $\vec{v}$ be velocity in earth frame, and let $\vec{u}$ be velocity in inertial frame F that moves at velocity $\vec{V}^F$ with respect to the earth frame. Then

$$\vec{u} = \vec{v} - \vec{V}^F \qquad \vec{v} = \vec{u} + \vec{V}^F$$