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2.00AJ / 16.00AJ Exploring Sea, Space, & Earth: Fundamentals of Engineering Design
Spring 2009

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NAME: _____

Lab Section: W or F (circle one)

2.00AJ/16.00AJ FUNdaMENTALS of Engineering Design: Explore Space, Sea, and Earth

Pre-“test” Technical Questions

Homework #1

Due THURSDAY February 5, 2009

This exercise is an *individual, closed book* exercise designed to generally assess your knowledge at the beginning of this course. This will NOT be marked for a grade, however completion of the exercise will be noted. You may find that you do not understand some of the questions or that others are very basic – *this is intentional, do not worry*. Try to complete this exercise without stopping and make a note of the time you spent working on it. You can make your marks directly on this paper.

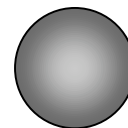
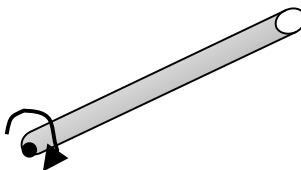
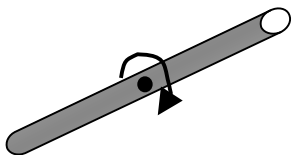
Approximate time to complete exercises: _____ minutes (to the nearest 5 minutes)

- 1) Given a function $f(x)$, expand $f(x)$ using Taylor Series Expansion (to third order):

- 2) Given a continuously differentiable scalar function $f(x,y)$ define its vector gradient. What does this mean qualitatively?

- 3) Given a continuously differentiable vector function $\mathbf{v}(x,y)$ define its divergence. What does this mean qualitatively?

- 4) Give an equation for the moment of inertial for the following objects (label your chosen variables):



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- 5) You throw a 1.5 kg ball up into the air. At its highest point, the ball's
- velocity and acceleration are zero.
 - velocity is non-zero but its acceleration is zero.
 - acceleration is non-zero but velocity is zero.
 - velocity and acceleration are both non-zero.
- 6) A person is trapped in an elevator that is accelerating upward. The upward normal force N on the person exerted by the elevator floor on the person is
- larger than
 - identical to
 - smaller than
- the downward weight W of the person?
- 7) Rain falls vertically into an open cart rolling along a straight horizontal track with negligible friction. As a result of the accumulating water, then speed of the cart
- increases
 - does not change
 - decreases.
- 8) You've just driven around a curve on a narrow one-way street at 25 mph when you notice a car identical to yours coming straight towards you at 25 mph. You only have two options: hitting the oncoming car head-on or swerving into a massive concrete wall, also head-on. In the split second before impact, you decide to
- hit the other car
 - hit the wall
 - hit either one—it makes no difference.

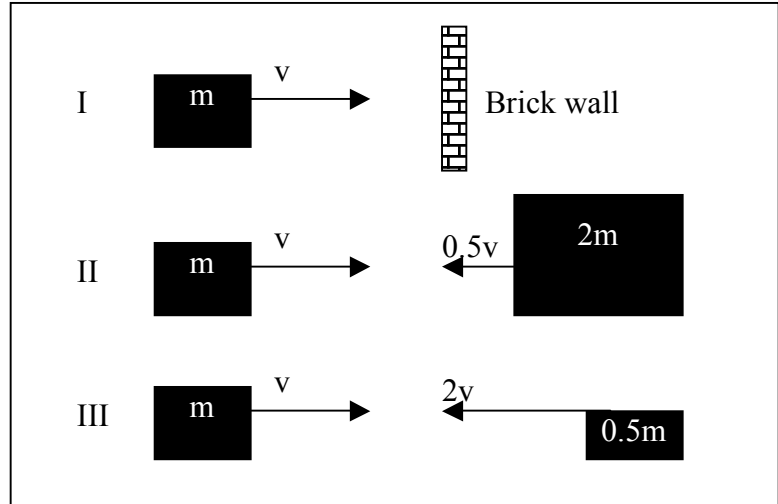
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- 9) A large 1 kg weight is suspended from the ceiling by a linear spring. In static equilibrium, the weight is hanging about 1 meter above the floor. The weight is then pulled down until it is positioned right above two fresh eggs (~1mm above the eggs). When the weight is released it is pulled upwards by the spring and then falls back down under the influence of gravity. On the way down it
- reverses direction of travel well above the eggs
 - reverses direction precisely as it reaches the eggs
 - makes a mess and crashes into the eggs

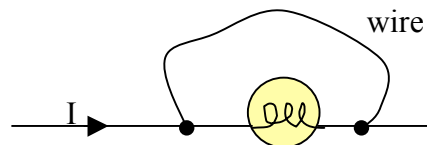
- 10) If all three of these collisions shown below are totally inelastic, which causes the most damage?

- I
- II
- III
- I, II
- I, III
- II, III
- All three



- 11) A charge flows through a light bulb. If a wire is connected across the light bulb as shown, then

- all the charge continues to flow through the bulb
- half the charge flows through the bulb, the other half through the wire
- all the charge flows through the wire
- none of the above occur.



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- 12) Two identical beakers are filled half full. One has oil in it and one has water. A plastic sphere placed in the beaker of water floats half submerged, however the same sphere placed in the beaker of oil sinks to the bottom. If the sphere is floating half-submerged in the beaker of water, and the oil is carefully poured on top of the water, so that it does not mix,
- the sphere descends lower into the water.
 - the sphere stays in the same position.
 - the sphere rises up higher out of the water.

- 13) A hollow, air-filled, thin-walled steel sphere is tethered to the bottom of the ocean, draw a well-labeled Force body diagram for the sphere and estimate the tension in the cable based on the sphere's outer diameter.

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- 14) You are required to lift a VERY heavy object ~100 kg from the floor to 20 feet off the ground. There is a very strong I-Beam fixed to the ceiling that can be used to attach anything you need to. If you have no electricity, but an abundance of all sizes of mechanical levers, gears, pulleys, rope, chain, nuts and bolts (and several ladders) at hand, SKETCH a potential device to help you lift the object with your bare hands (you can use any combination of mechanical widgets). Explain how/why this might work (use force diagrams, math, physics, etc). Can you estimate the force required to lift the object?

(continued on back...)

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15) You are asked to design a new rover to explore an icy moon, with uneven terrain, in space. You are uncertain whether the entire planet will be solid ice, so you must plan to be able to operate in regions where the ice may have melted into water or slush. Sketch a quick design concept, label novel features of your vehicle, and describe briefly how your vehicle will transition from ice to water. What instrumentation, video or diagnostic equipment, and or communication would you like to have on board? How would the vehicle be powered? Consider what would happen to your vehicle if the ice were thin and your vehicle broke through the ice. Also consider that water might freeze on your vehicle causing critical systems to fail if not properly protected. Remember, this is space we're talking about – it's really expensive to get there and failure might mean no second chance to explore this really cool planet!