Physics 221 – Test 4 – Fall 2010

One-page reminder sheet allowed. *Show all work – no credit given if work not shown!* Numerical calculations should be evaluated, suggesting that you ought to have a calculator.

1. Suppose that some type of particle obeys the dispersion relation $E = A - B\cos(Cp)$ where E is its energy, p is its momentum, and A, B, and C are constants. If this particle is placed in a one-dimensional box of size a, determine the allowed energies of the particle.

2. A stationary particle of mass m absorbs a photon of energy E, producing a single, moving particle. (Recall that a photon is massless. This is a relativistic problem.)

   (a) Compute the momentum and total energy of the new particle.

   (b) Compute the mass of the new particle.

   (c) Compute the velocity of the new particle.

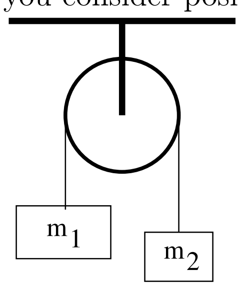
3. Atwood's machine: Two masses $m_1 > m_2$ are connected by a string which passes over a pully as shown below. Ignore the mass of the string and the moment of inertia of the pully.

   (a) Draw vectors showing the forces on each mass (including gravity).

   (b) Write down Newton's second law for each of the masses, including the appropriate forces.

   (c) Solve for the forces of the string on m_1 and m_2, using Newton's third law as appropriate.

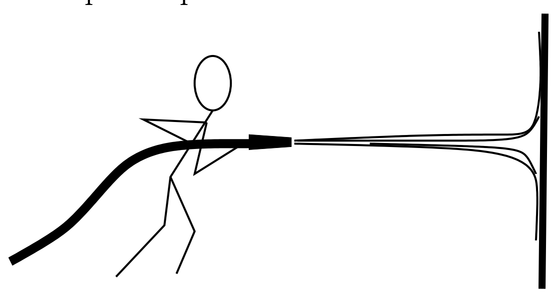
   (d) Solve for the acceleration of the masses, indicating which direction of movement you consider positive.



4. Suppose water comes out of a fire hose 3 cm in diameter at a speed of $V = 30$ m s^{-1}. The density of water is 1000 kg m^{-3}.

   (a) Compute the mass per unit time R flowing out of the fire hose.

   (b) Suppose that the fire hose is directed at a wall, which splashes water sideways as shown. Given R and V, compute the force that needs to be exerted on the wall to keep it in place.



5. The earth has mass $M = 5.98 \times 10^{24}$ kg and the moon's mass is $m = 7.36 \times 10^{22}$ kg. Their separation is $d = 3.82 \times 10^{8}$ m and the earth and moon move around each other once every 28 days.

   (a) Compute how far the center of mass of the earth-moon system is from the center of the earth and from the center of the moon.

   (b) Compute the speed of the earth and that of the moon in the center of mass reference frame.

   (c) Compute the ratio of the earth's to the moon's angular momentum in the reference frame of the center of mass. (Ignore the rotation of these bodies about their axes.)

   (d) Compute similarly the ratio of the earth's to the moon's kinetic energy. (Again, ignore rotation.)

6. You are keeping a cylinder of radius R and mass M from rolling under the influence of gravity down a ramp tilted at an angle θ by pulling on a rope wrapped around the cylinder as shown. Compute the force T you exert on the cylinder via the rope and the force F that the ramp exerts on the cylinder.