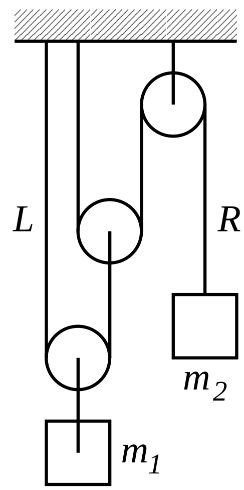
PHY 2060 Spring 2008 — Exam 2

DO NOT TURN THE PAGE UNTIL INSTRUCTED TO DO SO

Instructions: Attempt all ten questions, each of which carries a maximum of 10 points. Write your solution below each question, continuing on additional paper if necessary. Please try to write neatly!

You will receive credit only for knowledge and understanding that you demonstrate in your written solutions. It is in your best interest to write down something relevant for every question, even if you can't provide a complete answer. To maximize your score, you should briefly explain your reasoning and show all working. (This may benefit you even in the case of the multiple-choice Question 1.) Give all final algebraic answers in terms of variables defined in the problem, g (the acceleration due to gravity near the Earth's surface), and/or c (the speed of light). For numerical problems, take $g = 10\,\mathrm{m/s^2}$ and $c = 3.0 \times 10^8\,\mathrm{m/s}$.

1. Two masses, m_1 and m_2, are suspended from the ceiling using two ideal strings ("L" for left, and "R" for right) and three massless, frictionless pulleys. Consider the motion during a short period after the system is released from rest in the configuration shown in the diagram. Place a check to the left of any/all of the following statements that **must** be true:



   i. The tension in R will be twice the tension in L.

   ii. The system will remain at rest provided that $m_1 = 2m_2$.

   iii. The distance moved by m_1 will be four times the distance moved by m_2.

   iv. The tension in L will be $2m_1 g$.

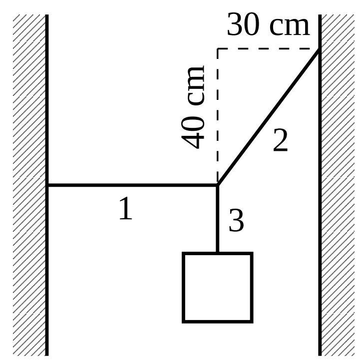
   v. The distance moved by m_2 will be four times the distance moved by m_1.

2. A car of mass 800 kg is traveling at velocity 20 m/s in the $+x$ direction when it undergoes a totally inelastic collision with a second car of mass 1,000 kg moving at 30 m/s. Find the cars' speed immediately after the collision, if before the collision the second car was moving along

   (a) the $-x$ direction;

   (b) the $+y$ direction.

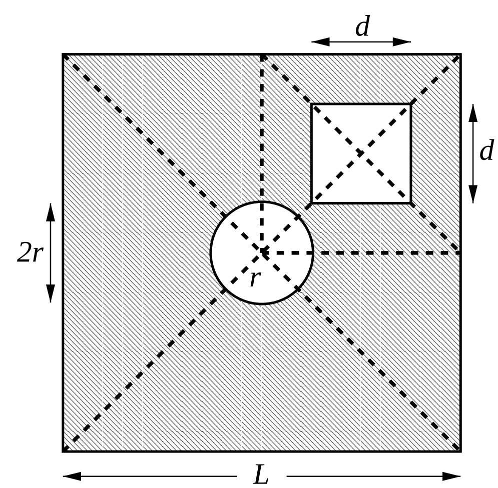
3. A 3.0-kg mass is suspended at rest using three ideal strings (labeled 1, 2, and 3 in the diagram) that meet at a knot. The other ends of strings 1 and 2 are attached to two rigid walls. Calculate the tensions T_1, T_2, and T_3 in the three strings.



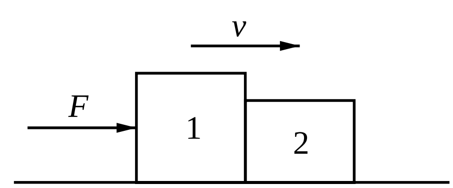
4. A bullet of mass 60 g is fired from a gun with an initial velocity of 150 m/s at an angle of 50° above the horizontal ground. During its flight, the bullet explodes into two fragments: one of mass 10 g, the other of mass 50 g. The internal forces acting on the fragments during the explosion are directed horizontally and within the vertical plane that contains the bullet's trajectory before the explosion. The lighter fragment eventually hits the ground 3.7 km from the gun. How far from the gun does the heavier fragment land? Neglect air resistance.

5. A plate of uniform thickness t and uniform density ρ has the shape of a a square of sides L containing two holes: one a circle of radius r centered on the middle of the square outer perimeter; the other a small square of sides d, centered three-quarters of the way along the diagonal leading from the plate's bottom left corner to its top right corner. (See the diagram.)

   Calculate the distance of the plate's center of mass from its bottom left corner.



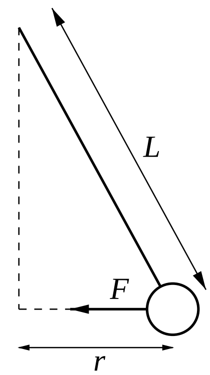
6. Two blocks ("1" and "2") are pushed in a straight line at a constant speed v across a horizontal surface. This is accomplished by applying an external force of magnitude F to block 1, while block 2 is pushed along in front of block 1, as shown in the diagram. Block j ($j = 1$ or 2) has mass m_j and its coefficient of kinetic friction with the surface is μ_j. Assume that $\mu_2 < \mu_1$.



   (a) What is the magnitude F of the applied force that sustains this motion?

   (b) The external force is now removed. Once the blocks have come to rest, how far apart will they be? (Remember that the blocks are in contact, i.e., at zero separation, during the whole time the force F is being applied.)

7. A variant of the conical pendulum consists of a small ball of mass m suspended on the end of an ideal string of length L. The upper end of the string is attached to a fixed support, and the pendulum is set in motion so that the ball travels in a horizontal circle of radius r at a uniform speed v. (The diagram shows a side view, where the instantaneous velocity of the ball is into the page.) Unlike the conventional conical pendulum, the ball experiences a third force in addition to its weight and the string tension, namely, a horizontal force of magnitude $F = kr$, where k is a constant. This force always points towards the center of the ball's circular path.

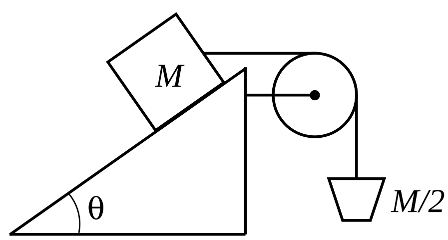


Find an expression for the speed v in terms of other quantities specified in the problem and g, the acceleration due to gravity. Neglect air resistance.

8. A plate of uniform thickness t and uniform density ρ has a shape in the xy plane satisfying $x > 0$, $y < 4 - x^2$, and $y > x^2 - 4$. Calculate the x and y components of the plate's center of mass position.

9. Four carts are spaced out as shown in the diagram along a straight track that permits the carts to move (without friction) in only one dimension. The carts have masses $m_2 = m_4 = m$ and $m_1 = m_3 = 3m$. Carts 1, 3, and 4 are initially stationary, while cart 2 is initially moving towards cart 3 at speed v. Find the final velocity of each cart, assuming that collisions involving cart 1 and/or cart 4 are totally inelastic, while collisions involving only carts 2 and 3 are elastic.

10. A block of mass M rests on an plane inclined at angle θ to the horizontal. The coefficient of static friction between the block and the slope is 0.3. An ideal string runs horizontally from the block and passes over a massless, frictionless pulley. A bucket, of mass $M/2$, is suspended from the other end of the string, as shown in the diagram.



Calculate the range of angles θ for which this system will remain in static equilibrium.