Physics 8, Fall 2019, Homework #8.

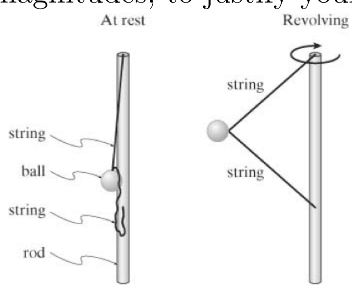
Due at start of class on Friday, November 1, 2019

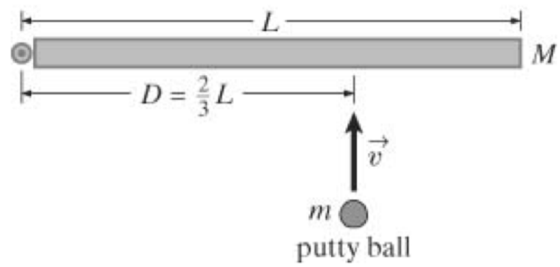
Problems marked with (*) must include your own drawing or graph representing the problem and at least one complete sentence describing your reasoning.

Remember **online response** at `positron.hep.upenn.edu/q008/?date=2019-11-01`

(Chapter 11 problems.)

1*. A ball is attached to a vertical rod by two strings of equal strength and equal length. (See figure, below left.) The strings are very light and do not stretch. The rod begins to rotate under the influence of a constant rotational acceleration. (a) Which string breaks first? (b) Draw a free-body diagram for the ball, indicating all forces and their relative magnitudes, to justify your answer to (a).





2*. An open door of inertia M and width L is at rest when it is struck by a thrown putty ball of inertia m that is moving at linear speed v at the instant it strikes the door. (See figure, above right.) The impact point is a distance $D = \frac{2}{3}L$ from the rotation axis through the hinges. The putty ball strikes at a right angle to the door face and sticks after it hits. What is the rotational speed of the door and putty? Do not ignore the inertia m. (Hint: angular momentum.)

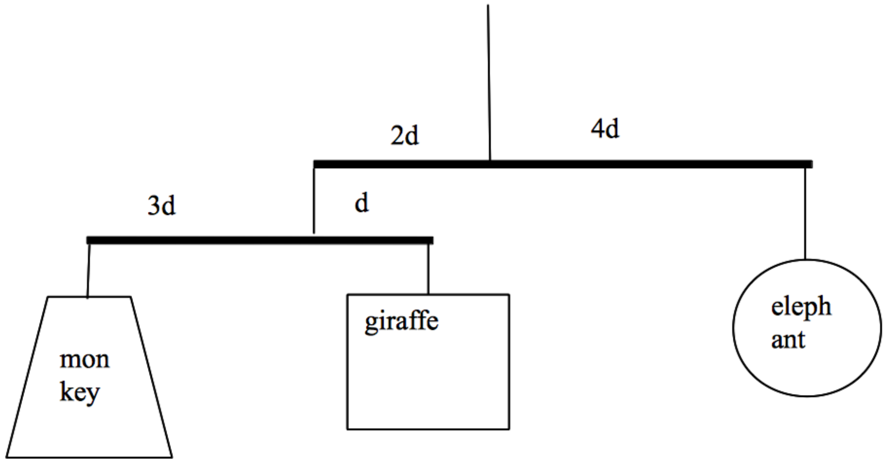
3*. Two skaters skate toward each other, each moving at 3.3 m/s. Their lines of motion are separated by a perpendicular distance of 1.5 m. Just as they pass each other (still 1.5 m apart), they link hands and spin about their common center of mass. What is the rotational speed of the couple about the center of mass? Treat each skater as a point particle, each with an inertia of 51 kg.

(Chapter 12 problems.)

4. When the wrench you are working with does not loosen a nut, you can sometimes succeed by slipping a length of pipe over the end of the wrench and pushing at the end of the pipe. Why does this work?

5. A baton-twirler tosses her spinning baton in the air. While the baton is in the air, is its linear momentum constant? Is its angular momentum constant? Explain.

6. In the mobile shown below, what are the inertias of the giraffe and of the elephant, if the monkey's inertia is 0.25 kg?



7*. Draw an extended free-body diagram for a stepladder resting on the floor, which you are standing on after having climbed halfway to the top.

8*. A seesaw consists of a 9.0 kg plastic plank balanced at its center on a very narrow support. A 38 kg child sits 1.0 m away from the center toward one end of the board, and a 19 kg child sits toward the opposite end so the see-saw is balanced. (a) What is the magnitude of the upward force exerted by the support? (Don't forget the factor $g = 9.8\ \mathrm{m/s^2}$.) (b) Where should the smaller child sit?

9*. Suppose a single force (that is not cancelled by any other forces) acts on an object. (a) Is it possible for this single force to change both the object's linear momentum and its angular momentum (about its CoM)? Explain. (b) Is it possible for this single force to change the object's linear momentum without changing its angular momentum (about its CoM)? Explain.

10*. A 55 kg box is suspended from the right end of a horizontal rod that has very small inertia. The left end of the rod is affixed to a wall by a pin. A wire connects the right end of the rod to the wall directly above the pin, making an angle of 30° with the rod. (a) Find the tension in the wire. (b) Determine the horizontal and vertical components of the reaction force that the pivot exerts on the rod. (c) Repeat parts (a) and (b) if the rod has an inertia of 25 kg.

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XC1*. Optional / extra-credit. 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 7.0 meters, what should the rate of revolution of the cylinder be in order to replicate Earth's gravity at this radius? (b) For a person, of height 1.7 meters, standing in this cylinder, how does the "gravitational" acceleration at the top of her head compare with the "gravitational" acceleration at her feet? (Might this be uncomfortable?)

XC2*. Optional/extra-credit. Your aunt owns an amusement park, and she wants you to add a circular loop to an exiting roller coaster ride to make it more fun. The first hill for the existing roller coaster is 38 m tall, and your aunt wants you to build right after this hill the tallest loop possible without having the cars fall out of the track or the passengers fall out of the cars. You think for a minute and realize what the minimum speed at the top of the loop has to be, and this gives you what you need to design the loop.

XC3*. Optional/extra-credit. (a) Calculate the rotational inertia of a flat sheet of plywood, of width w and height h, about an axis that passes through the center of the sheet and is perpendicular to the plane of the sheet. Since it's easy to look this answer up, you need to compute it using calculus and to show your work. (b) Calculate the rotational inertia of this same sheet about an axis that passes through the center of the sheet and is parallel to the long edge of the sheet. (c) Calculate the rotational inertia of this same sheet about an axis that passes through the center of the sheet and is parallel to the short edge of the sheet. (d) Verify that your answer for part (a) is the sum of your answers for parts (b) and (c).

XC4*. Optional/extra-credit. (a) Repeat problem 3, but let the two skaters have different masses: the first skater has inertia $m_1 = 45.0\,\text{kg}$ and the second skater has inertia $m_2 = 90.0\,\text{kg}$. (b) What is the center-of-mass velocity of the two-skater system after they link hands? (Assume, somewhat unrealistically, zero friction between the skaters and the ice. This should remind you of the two-male-moose problem from an earlier homework.)