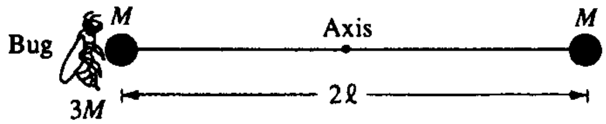
1. In the laboratory, you are asked to determine the mass of a meter stick without using a scale of any kind. In addition to the meter stick, you may use any or all of the following equipment:

- a set of known masses,
- four weight hangers,
- tape
- a fulcrum upon which the meter stick can be mounted and pivoted
- string
- stopwatch

a) Briefly list the steps in your procedure that will lead you to the mass of the meter stick. Include definitions of any parameters that you will measure.

b) Indicate which pieces of equipment will be used.

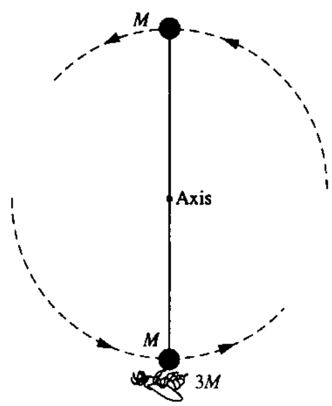
c) Show the calculations you would perform to find the mass of the meter stick.

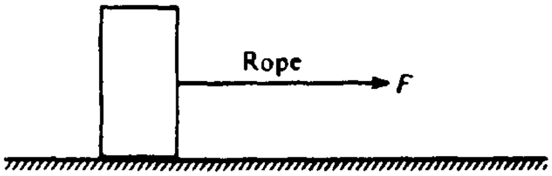


2. Two identical spheres, each of mass M and negligible radius, are fastened to opposite ends of a rod of negligible mass and length $2l$. This system is initially at rest with the rod horizontal, as shown above, and is free to rotate about a frictionless, horizontal axis through the center of the rod and perpendicular to the plane of the page. A bug, of mass 3M, lands gently on the sphere on the left. Assume that the size of the bug is small compared to the length of the rod. Express your answers to all parts of the question in terms of M, l, and physical constants.

a. Determine the torque about the axis immediately after the bug lands on the sphere.

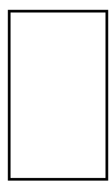
b. Determine the angular acceleration of the rod-spheres-bug system immediately after the bug lands.



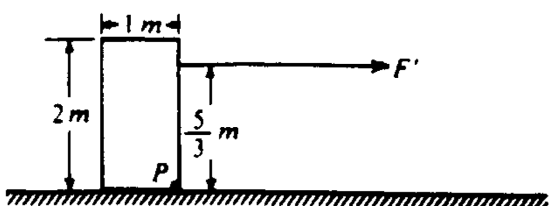


3. A box of uniform density weighing 100 Newtons moves in a straight line with constant speed along a horizontal surface. The coefficient of sliding friction is 0.4 and a rope exerts a force F in the direction of motion as shown above.

a. On the diagram below, draw and identify all the forces on the box.

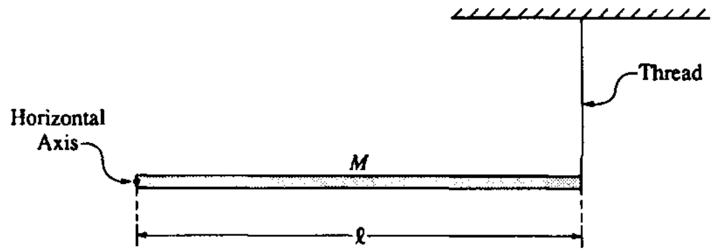


b. Calculate the force F exerted by the rope that keeps the box moving with constant speed.



c. A horizontal force F', applied at a height 5/3 meters above the surface as shown in the diagram above, is just sufficient to cause the box to begin to tip forward about an axis through point P. The box is 1 meter wide and 2 meters high. Calculate the force F'.

d. Does this value of F' increase or decrease if the box is made wider? Explain.



4. A long, uniform rod of mass M and length l is supported at the left end by a horizontal axis into the page and perpendicular to the rod, as shown above. The right end is connected to the ceiling by a thin vertical thread so that the rod is horizontal. The moment of inertia of the rod about the axis at the end of the rod is $Ml^2/3$. Express the answers to all parts of this question in terms of M, l, and g.

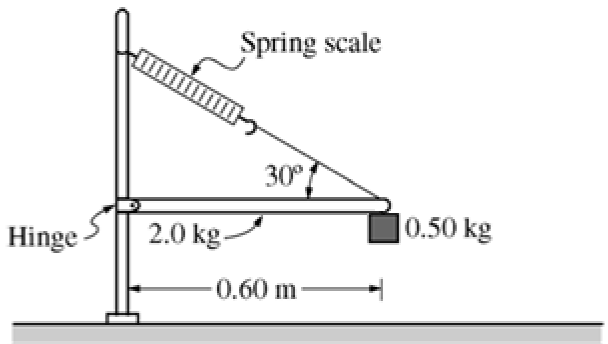
a. Determine the magnitude and direction of the force exerted on the rod by the axis.

The thread is then burned by a match. For the time immediately after the thread breaks, determine each of the following:

b. The angular acceleration of the rod about the axis

c. The translational acceleration of the center of mass of the rod

d. The force exerted on the end of the rod by the axis



5. The horizontal uniform rod shown above has length 0.60 m and mass 2.0 kg. The left end of the rod is attached to a vertical support by a frictionless hinge that allows the rod to swing up or down. The right end of the rod is supported by a cord that makes an angle of 30° with the rod. A spring scale of negligible mass measures the tension in the cord. A 0.50 kg block is also glued to the right end of the rod.

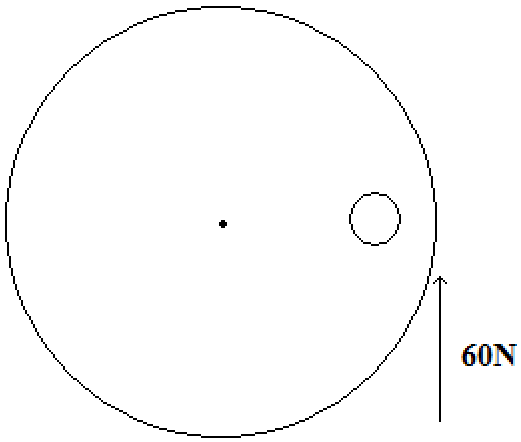
a. On the diagram below, draw and label vectors to represent all the forces acting on the rod. Show each force vector originating at its point of application.

b. Calculate the reading on the spring scale.

The rotational inertia of a rod about its center is $\frac{1}{12}ML^2$, where M is the mass of the rod and L is its length.

c. Calculate the rotational inertia of the rod-block system about the hinge.

d. If the cord that supports the rod is cut near the end of the rod, calculate the initial angular acceleration of the rod-block system about the hinge.



6. A merry-go-round ($I = \frac{1}{2}MR^2$) has a mass of 100kg and a radius of 2.4m. Sitting 2.0m from the center of the merry-go-round is a boy with a mass of 35kg. A girl then pushes on the merry-go-round counter-clockwise with a tangential force of 60N.

a. What is the rotational inertia of the merry-go-round and boy?

b. What is the angular acceleration caused by the pushing of the girl?

c. If the merry-go-round begins at rest, how many radians will it turn in ten seconds?

d. How many rotations is this?