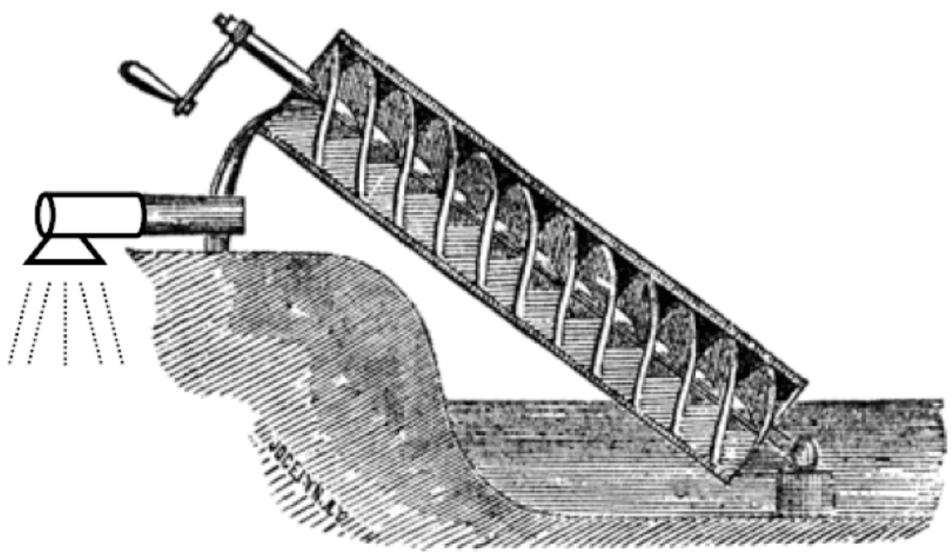
Physics 8, Fall 2019, Homework #9.

Due at start of class on Friday, November 8, 2019

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

(Chapter 12 problems)

1. Archimedes's screw, one of the first mechanical devices for lifting water, consists of a very large screw surrounded by a hollow, tight-fitting shaft (shown below). The bottom end of the device is placed in a pool of water. As the screw is turned, water is carried up along its ridges and comes out the top of the shaft and into a storage tank. As the handle is turned, work done by the torque exerted on the handle is converted to gravitational potential energy of the water-Earth system. Let's say you want to take a shower using this device. You figure your shower will consume 52 liters of water, and so you have to raise this amount to the storage tank 2.5 m above the pool, so it can fall down on you. When you turn the handle, you apply a torque of $12\ \mathrm{N \cdot m}$. How many times must you turn the handle? (Hint: work done by a torque τ is $W = \tau \Delta\theta$, with $\Delta\theta$ measured in radians.)

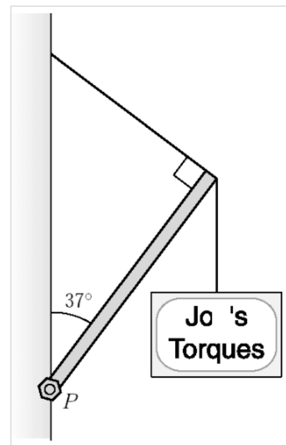


2*. A 37 kg child stands on the edge of a 410 kg playground merry-go-round that is turning at the rate of 1 revolution every 2.3 s. She then walks to the center of the platform. If radius of the platform is 1.6 m, what is the platform's rotational speed once the child arrives at the center? (Treat the merry-go-round as a solid cylinder. Think carefully about which conservation law to use. Also, be careful how you turn the given information into an initial value for rotational speed ω.)

3*. A horizontal 4.0 kg rod is 3.0 m long. It has a 10.0 kg block suspended from its left end and a 6.0 kg block suspended from its right end. (a) Find the magnitude and direction of the single extra force necessary to keep the rod in equilibrium. (b) At what distance from the left end of the rod must this force be applied?

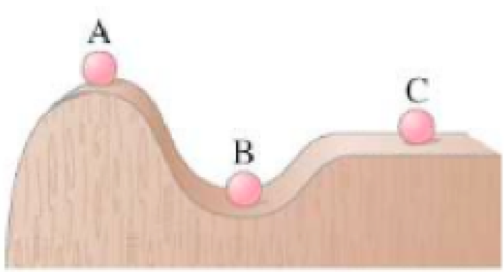
4*. A 16 kg ladder of length 6.0 m leans against a smooth wall and makes an angle of 51° with the ground. An 83 kg person starts to climb the ladder. If the coefficient of static friction between the ground and the ladder is 0.50, what distance along the ladder can he or she climb before the ladder starts to slip?

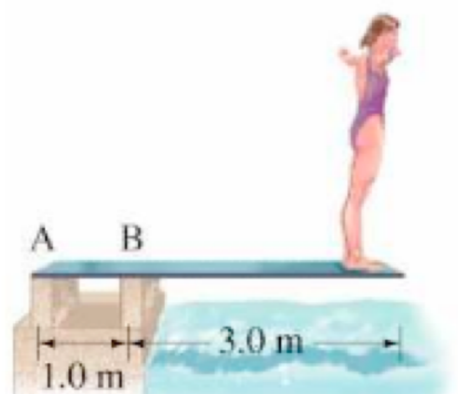
5*. You want to hang a 25 kg sign (shown at right) that advertises your new business. To do this, you attach a 6.0 kg beam of length 1.0 m to a wall at its base by a pivot P. You then attach a thin cable to the beam and to the wall in such a way that the cable and beam are perpendicular to each other. The beam makes an angle of 37° with the vertical. You hang the sign from the end of the beam to which the cable is attached. (a) What must be the minimum tensile strength of the cable (the amount of tension it can sustain) if it is not to snap? (b) Determine the horizontal and vertical components of the force the pivot exerts on the beam.



(Static-equilibrium problems: chapter G9, etc.)

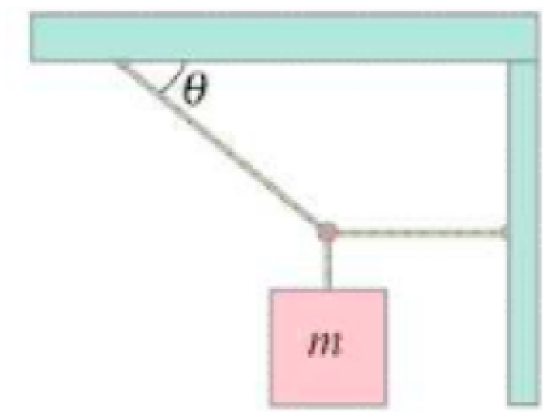
6. Name the type of equilibrium for each position of the ball in the figure below (left).

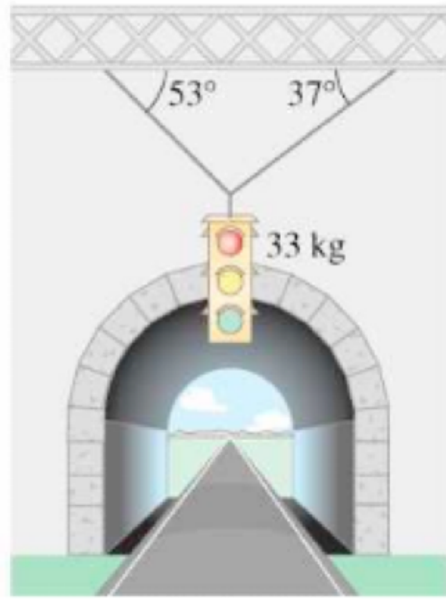




7. Calculate the forces (magnitudes and directions) F_A and F_B that the supports exert on the diving board in the figure above (right) when a 59 kg person stands at its tip. (a) Ignore the weight of the board. (b) Take into account the board's mass of 23 kg. Assume the board's CoM is at its center.

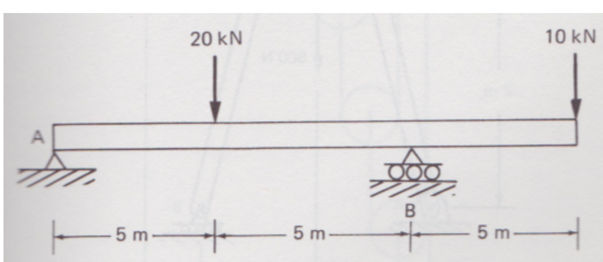
8*. Find the tension in the two cords shown in the figure below (left). Neglect the mass of the cords, and assume that the angle θ is 35° and the mass m is 105 kg.

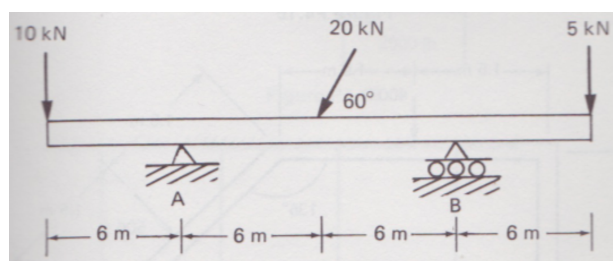




9. Find the tension in the two wires supporting the traffic light shown in the figure above (right).

10. Using the equations for static equilibrium, find the "reaction" forces exerted by the supports on the beam in the left figure below. (There are three forces: two vertical and one horizontal. You may find that one force equals zero.)



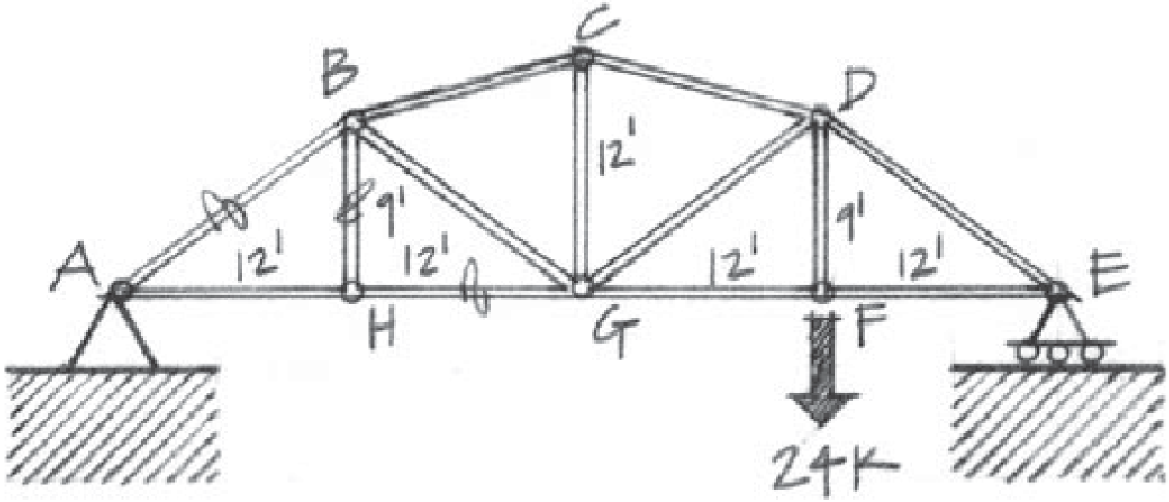


11*. Find the "reaction" forces exerted by the supports **A** and **B** on the beam in the right figure above. (There are three forces to find: two vertical and one horizontal.)

Remember **online response** at `positron.hep.upenn.edu/wja/jitt/?date=2019-11-08`

XC1*. Optional/extra-credit. A large steel bar of length $\ell = 1.0$ m is hinged at one end to a wall. A mechanic holds the far end so that the bar is parallel to the ground and places a penny on the bar right at the end she is holding. (a) What is the rotational acceleration of the bar at the instant after she lets go? (b) What is the magnitude of the downward linear acceleration of the far end of the bar at the instant after she lets go? (c) Does the penny remain in contact with the bar after the far end of the bar is released? (Hint: this idea is the basis for the so-called "faster than g" classroom demonstration that we may or may not do at some point.)

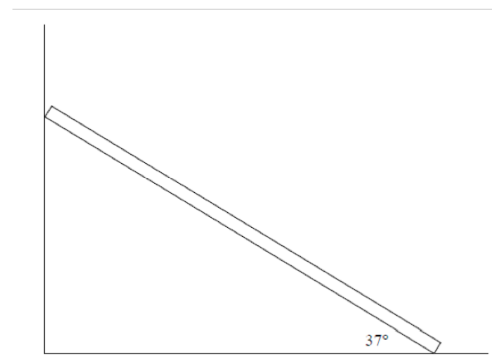
XC2*. Optional/extra-credit. Using the method of sections, solve for the forces in members AB, BH, and HG in the truss shown below. Indicate whether each of these members is in tension or in compression. Use only one section cut through the truss.



XC3*. Optional / extra-credit. Dragster drivers have to avoid supplying too much power to the vehicle because too much power causes the front end to rise in a "wheelie," compromising steering control. (a) Why does this happen? Your explanation should include an extended free-body diagram to indicate the relevant forces and torques. (b) What benefit would come from having front-wheel drive in a dragster? What penalty? (Normally a drag-race car would have rear-wheel drive.)

XC4*. Optional / extra-credit. Estimate the maximum torque that a bicyclist can deliver to the pedals. Assume that her inertia is 50 kg, that she is not wearing toe clips, and that she does not pull up very hard on the handlebars while she pushes down on the pedals. Also assume that the crank length (from axle to pedal) is 0.16 m.

XC5*. Optional / extra-credit. The top end of a 5.0 m board rests against a smooth wall (shown at right), and the bottom end makes an angle of 37° with the floor. If the board has an inertia of 10.0 kg, what are (a) the normal force exerted by the floor on the board and (b) the normal force exerted by the wall on the board?



XC6*. Optional/extra-credit. A small ball is put into a cone and made to move at constant speed v in a horizontal circle of constant radius r. (See figure below.) (a) What is the ball's centripetal acceleration? (b) What is its tangential acceleration? (c) What force can counteract the force of gravity so that the ball keeps moving in a horizontal circle? (d) Use these insights to determine the height h the ball is circling above the bottom of the cone. [Hint: This is equivalent to finding the angle the cone makes with its vertical axis.]