Physics 8, Fall 2019, Homework #10.

Due at start of class on Friday, November 15, 2019

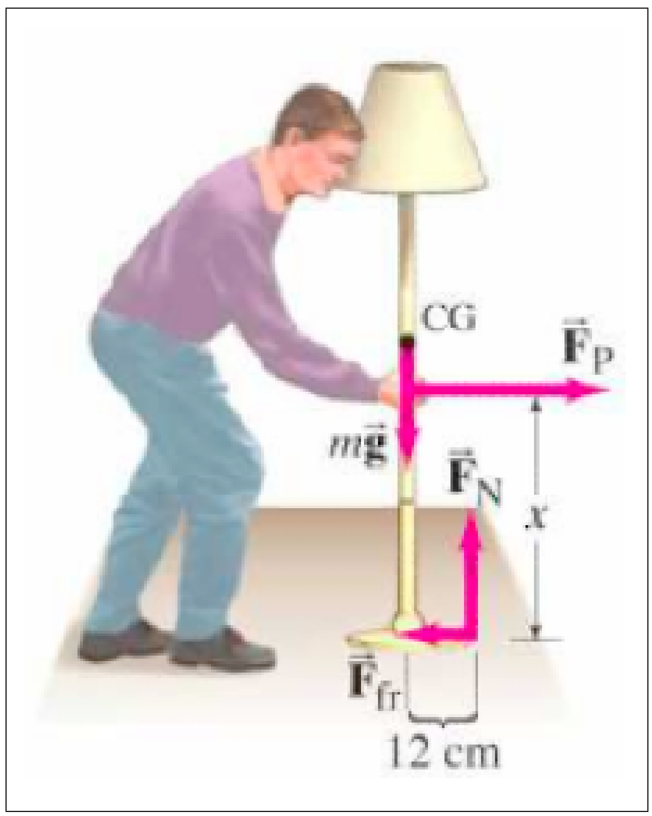
Problems marked with (*) must include your own drawing or graph representing the problem and at least one complete sentence describing your reasoning.

Remember **online response** at `positron.hep.upenn.edu/q008/?date=2019-11-15`

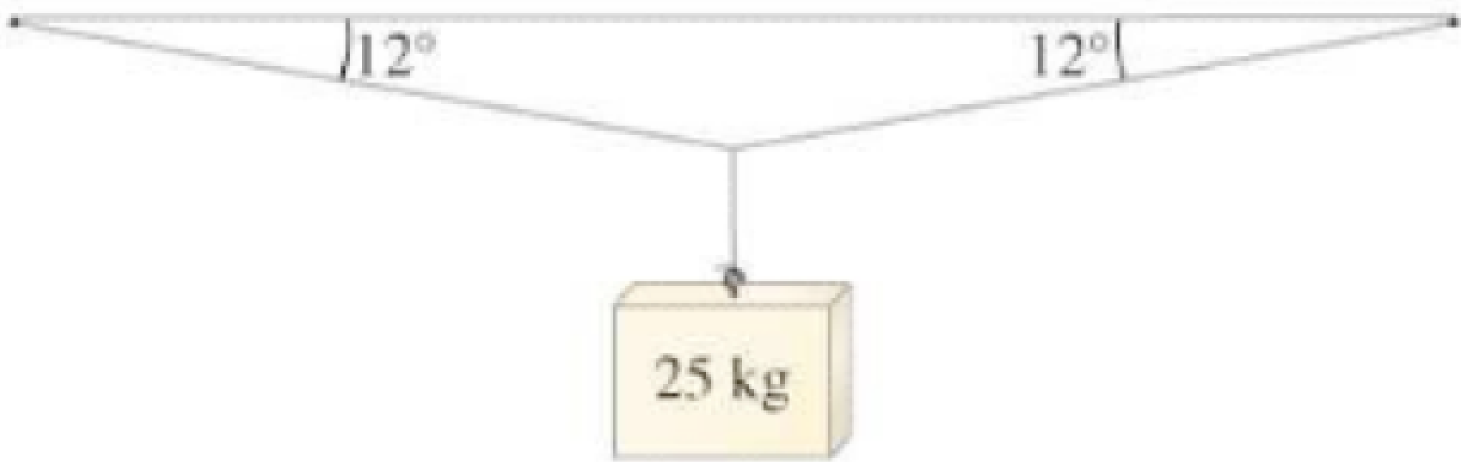
(Chapter "G9" problems)

1. An elevator of mass (including passengers, at full capacity) 1700 kg hangs on a steel cable (of circular cross-section). Suppose that the building code requires a safety factor of 10 for such a cable. (The weakest point of the cable should not break when loaded with 10 times the maximum specified load.) (a) What should be the smallest diameter of the required cable? The weight of the cable itself can be neglected. (b) What should be the smallest diameter of the cable if the elevator accelerates upward at $2.45\,\mathrm{m/s^2}$? Use $8.0 \times 10^8\,\mathrm{N/m^2}$ as the tensile strength of steel. Remember not to mix up radius, diameter, and cross-sectional area! The "safety factor of 10" in this problem means that the largest allowed stress in the cable is 1/10 of the quoted tensile strength.

2*. A person wants to push a lamp (mass 8.0 kg) across the floor. The coefficient of friction between the lamp and the floor is $\mu_k = 0.15$. Calculate the maximum height x above the floor at which the person can push the lamp so that the lamp slides at constant speed rather than tips. The base of the lamp is a circle of radius 0.12 m. The lamp's center of gravity is directly above the center of the circular base. [When the lamp is just sitting at rest on the floor, the normal force exerted by the floor on the lamp is a "distributed force" whose centroid is at the center of the lamp's base. But when you push the lamp across the floor by its pole, the centroid of the distributed normal force moves forward. When you push the lamp by a point so high up the pole that the lamp is on the cusp of tipping over, the normal force is concentrated at the front edge of the base of the lamp. So you want to consider the extreme case where the normal force is concentrated at the front of the base. Using the front of the base as a pivot, you need to make sure that the lamp will not pivot clockwise about the front of the base, i.e. is in equilibrium.]

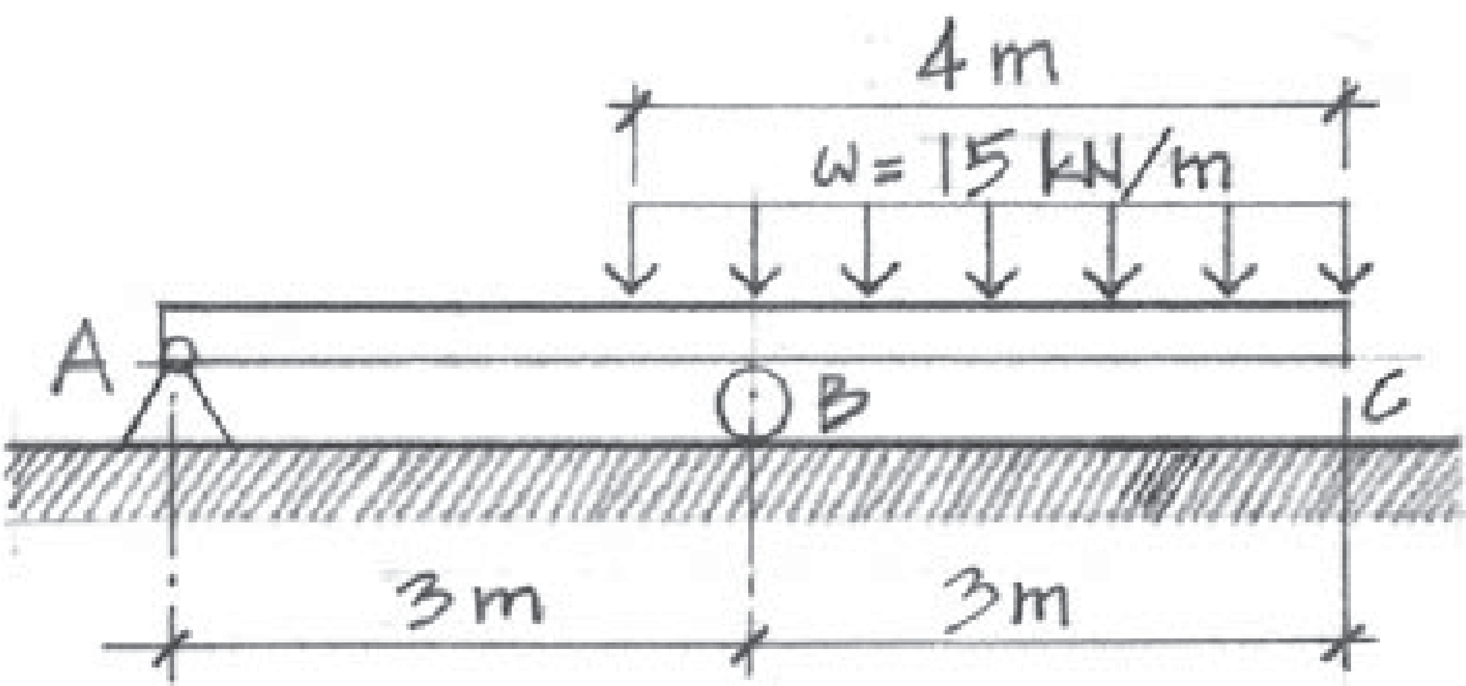


3*. When a mass of 25 kg is suspended from the middle of a fixed straight aluminum wire (which is initially horizontal), the wire sags to make an angle of 12° with the horizontal, as shown below. (a) What is the tension in each of two diagonal wire segments? (b) If the original length of each wire segment was 1.000 m when it was horizontal (before the 25 kg mass was attached), what is its length when it is diagonal? (c) What is the strain in the wire? (d) If Young's modulus for aluminum is $7.0 \times 10^{10}\,\mathrm{N/m^2}$, what is the stress in the diagonal wire segments? (e) If the wire has a circular cross-section, what is the wire radius? (You know the tension (force) and you know the tensile stress, so you can calculate the area, and hence the radius.)

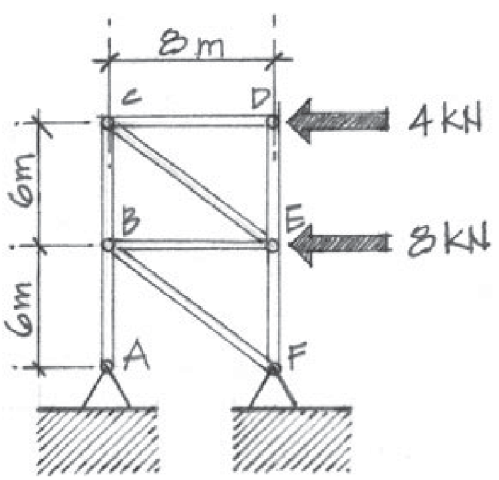


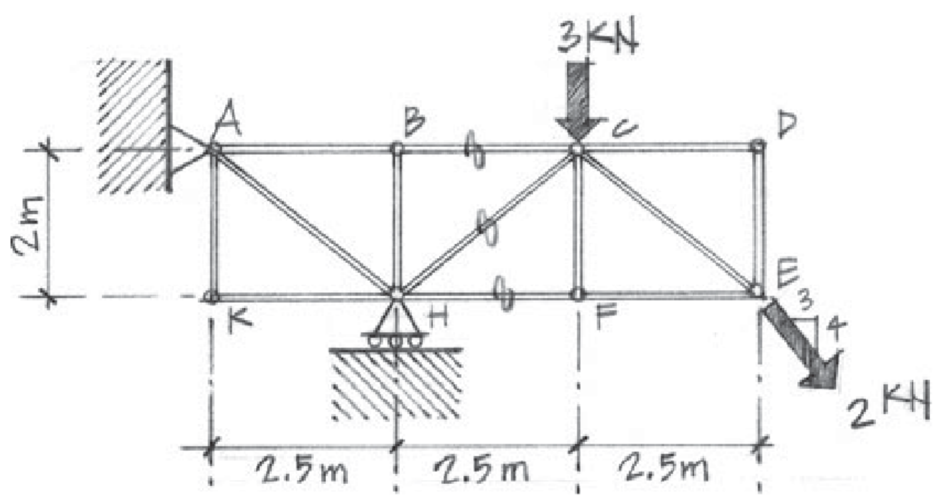
(Onouye/Kane Chapter 3 problems.)

4*. Solve for the support reactions at A and B (i.e. the forces exerted by the supports at A and B on the beam) in the figure below. To do this, you will need to convert the distributed load into an equivalent concentrated load.



5*. Using the method of joints, find the force in each member of the truss shown below (left). Summarize the results on a diagram that indicates both the magnitude of each force and whether each member is in tension or compression. [Hints: note that the reaction force at A must be parallel to bar AB, so the reaction force at A has only a vertical component. You can sum moments about F to find reaction force A_y. Then continue to use equilibrium for the truss as a whole to find reaction forces F_y and F_x. Then work at joint A to find T_{AB}. Then at joint F find T_{BF} then T_{EF}. Then at joint B find T_{BE} then T_{BC}. Then at joint C find T_{CE} then T_{CD}. Then at joint D find T_{DE}. As a check, I got $T_{CE} = 5\,\text{kN}$ and $T_{BC} = -3\,\text{kN}$.]

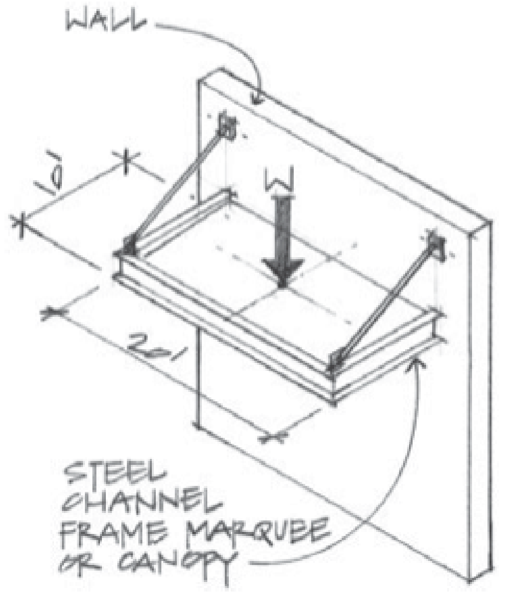


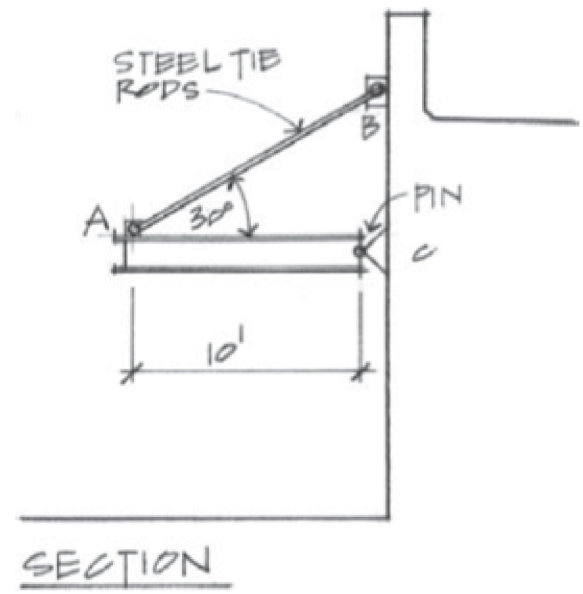


6*. Using the method of sections, solve for the forces in members BC, CH, and FH in the truss shown above (right). Indicate both the magnitudes of these forces and whether the member is in tension or compression. [**Warning:** the angle of the 2 kN diagonal load is different from the angle of bar CE.]

(Onouye/Kane Chapter 5 problem)

7. A 10 foot × 20 foot hotel marquee (shown below) hangs from two rods inclined at an angle of 30°. The dead load and snow load on the marquee add up to 110 pounds per square foot. Design the two rods out of A-36 steel that has an allowable tensile stress $F_t = 21000\,\text{psi}$ (psi = pounds per square inch). To solve this problem, you first need to convert the distributed load into an equivalent point load (in pounds), then analyze the two-dimensional problem shown in the section view. By symmetry, each tie rod supports half of the total load. Then you need to use static equilibrium to find the tension (measured in pounds) in one tie rod. Finally, use the allowable tensile stress to find the required diameter (in inches) of a tie rod. Be careful with factors of 2 in diameter vs. radius, with inches vs. feet, and that the total load is shared between two tie rods. This problem may leave you wondering why the US has not yet switched to the metric system.

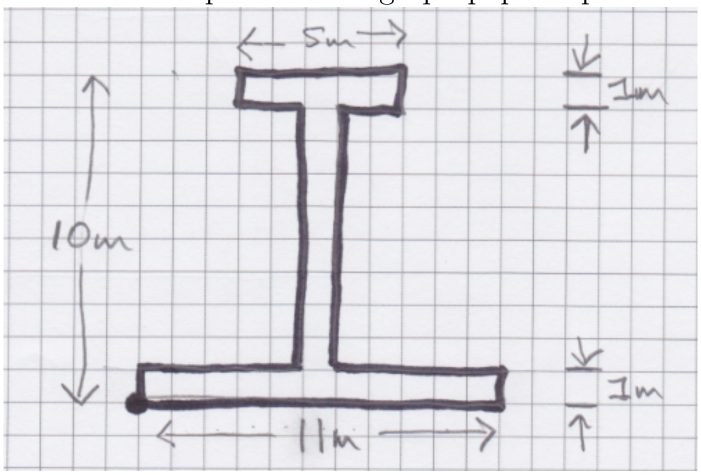


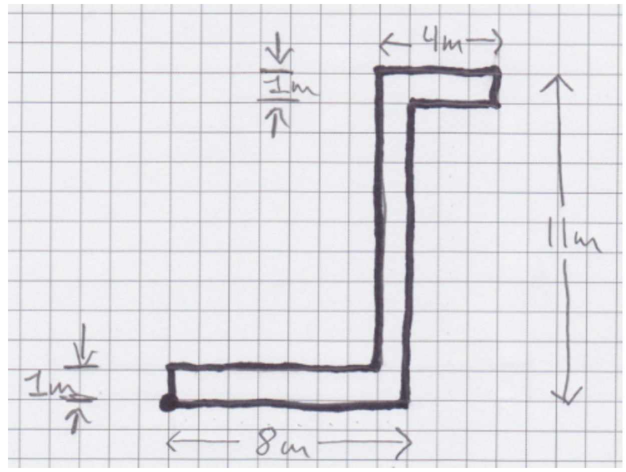


(Homework continues on next page.)

(Onouye/Kane Chapter 6 problems)

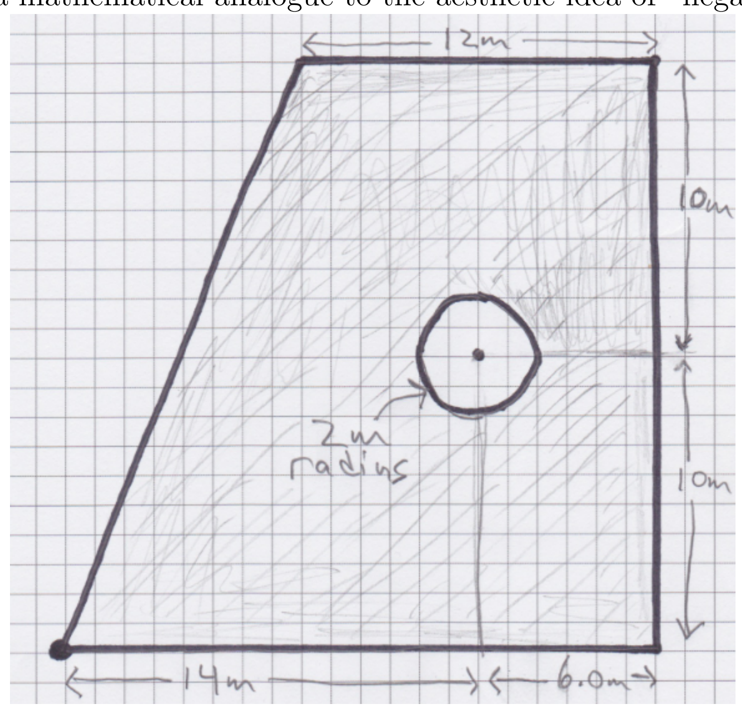
8*. Find the centroid of the enclosed area shown below (left). Take the bottom-left corner of the enclosed area (where the large dot is drawn) to be the origin $(0, 0)$ of the coordinate system. The side of each square on the graph paper represents 1.0 m.





9*. Find the centroid of the enclosed area shown above (right). Take the bottom-left corner of the enclosed area (where the large dot is drawn) to be the origin $(0, 0)$ of the coordinate system. The side of each square on the graph paper represents 1.0 m.

10. Find the centroid of the enclosed shaded area in the figure below (left). Take the origin of the coordinate system to be the lower-left corner of the trapezoid, indicated with the dark dot. A circle of radius 2.0 m is missing from the shaded area. The circle is centered at $x = 14$ m, $y = 10$ m. Hint: treat the circle as "negative area" when you do the weighted averages to find the centroid. This problem shows a mathematical analogue to the aesthetic idea of "negative space" in design!



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XC1*. Optional/extra-credit. (From O/K §5.4.) The steel rails of a continuous, straight railroad track are each 60 feet long and are laid with spaces between their ends of 0.25 inch at 70°F. (a) At what temperature will the rails touch end to end? (Use $\alpha = 6.5 \times 10^{-6}$ inch/inch/°F for steel's linear coefficient of thermal expansion, from Table 5.3.) (b) What compressive stress will be produced in the rails if the temperature rises to 150°F? (Use $E = 29 \times 10^{6}$ psi for the Young's modulus for steel.) [This problem may also leave you marveling that the US has not yet adopted the use of metric units.]