AEM 2011 Final Exam Thursday, May 15

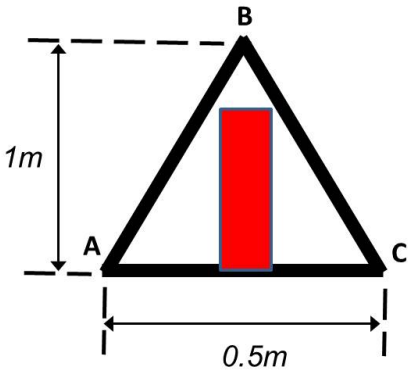
You may only use a simple calculator that does not communicate in any wireless manner. Pagers, cell phones, and all other communications devices must be turned off during the quiz. All work (free body diagrams, algebra, etc) is required to receive full credit.

1. The television at the front of the classroom hangs from a triangular mount as shown below (left). A simplified diagram is also shown as viewed from the side (right) where A,B,C are pin joints and the mount hangs by point B. Assume the television weighs $W = 1000$ N and the weight of the triangular mount is negligible. The television is located at the center of AC.

   (a) (4 points) Draw the free body diagram for the television.

   (b) (4 points) Draw the free body diagram for the triangular mount.

   (c) (7 points) Determine the forces in beams AB and BC required to maintain static equilibrium.



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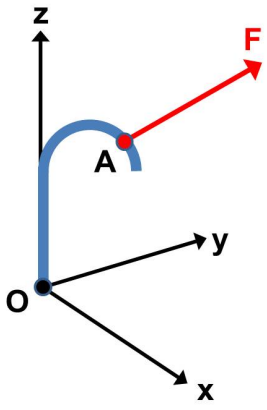
2. Prof. Seiler decides to pull on the faucet in the classroom as shown below (left). The simplified diagram (right) shows the faucet along with the force $\mathbf{F}$ applied by Prof. Seiler at point $\mathbf{A}$. The force is given by $\mathbf{F} = 20N\mathbf{i} + 25N\mathbf{j} + 15N\mathbf{k}$ and applied at $\mathbf{A} = 0.2m\mathbf{i} + 0.15m\mathbf{j} + 0.1m\mathbf{k}$.

   (a) (5 points) What is the moment caused by the force F about the point O?

   (b) (5 points) Assume the faucet is free to rotate about the z-axis at point O. Will the faucet remain in static equilibrium with the given force F applied at A?

   (c) (5 points) Next, assume the applied force has the form $\mathbf{F} = 20N\mathbf{i} + F_yN\mathbf{j} + F_zN\mathbf{k}$. What values of F_y and F_z yield static equilibrium if the faucet is free to rotate about the z-axis at point O?



3. The "Platonic Figure" (shown below left) is a stainless steel sculpture by Andrew Leicester. It is located between Keller Hall and the Mechanical Engineering building. For this problem, we'll consider only the body and arms of the sculpture as shown in the simple diagram below (right). The body and both arms are assumed to be hollow cones made with steel of thickness $t = 0.05ft$. The body has base centered at **O** with tip at $\mathbf{A} = -H_1\mathbf{k}$. The body has cone height $H_1 = 10ft$ and base radius of $R_1 = 10ft$. One arm has base centered at $\mathbf{B} = 4ft\mathbf{i} - 2ft\mathbf{k}$, cone tip at $\mathbf{C} = 11ft\mathbf{i} + 5ft\mathbf{k}$, and base radius of $R_2 = 1ft$. The other arm has base centered at $\mathbf{D} = -4ft\mathbf{i} - 2ft\mathbf{k}$, cone tip at $\mathbf{C} = -11ft\mathbf{i} + 5ft\mathbf{k}$, and base radius of $R_3 = 1ft$.

   You will need the following fact: The body (hollow cone) has approximate volume $V_1 = \pi t R_1(R_1 + \sqrt{R_1^2 + H_1^2})$. The center of gravity of the body is located at:

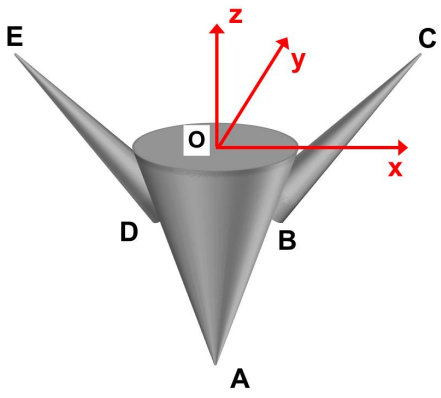
$$\bar{x}_1 = 0ft,\ \bar{y}_1 = 0ft,\ \text{ and } \bar{z}_1 = \frac{-H_1}{3\left(1 + \frac{R_1}{\sqrt{R_1^2+H_1^2}}\right)}$$

   (a) (5 points) What is the center of gravity $(\bar{x}_2, \bar{y}_2, \bar{z}_2)$ for the arm whose base is centered at **B**?

   (b) (5 points) What is the center of gravity $(\bar{x}_3, \bar{y}_3, \bar{z}_3$ for the arm whose base is centered at **D**?

   (c) (5 points) Calculate the center of gravity $(\bar{x}, \bar{y}, \bar{z})$ for the combined body and arms of the sculpture.

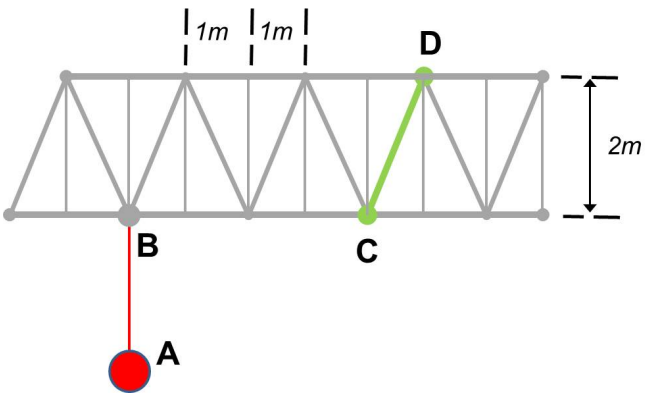
   (d) (5 points) Briefly describe how the combined center of gravity changes if you also include the legs.



4. Tower cranes such as the one shown below are being used for various construction projects on campus. The inset diagram shows the truss geometry for the end of the crane. Assume an object with weight of $80,000N$ hangs from a cable attached to the truss at point B. The length of the cable from A to B is $3m$.

   (a) (10 points) What is the force in member CD? Specify whether the force is in tension or compression.

   (b) (5 points) Assume the mass is lowered so that the length of the cable from A to B is $10m$. What is the force in member CD?

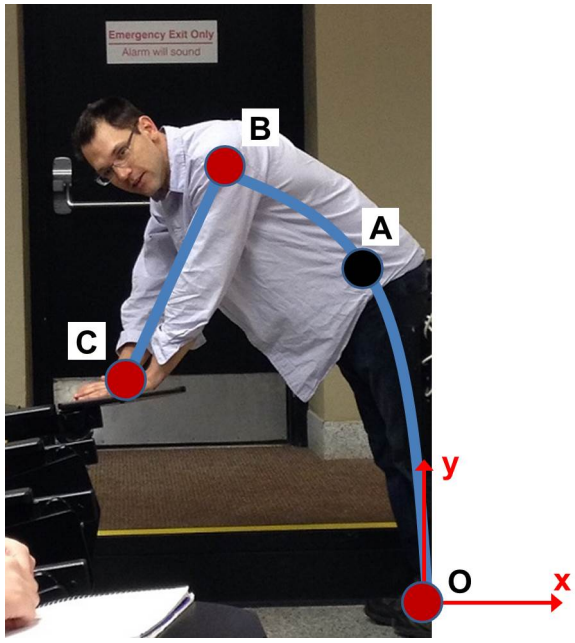


5. Professor Seiler leans against one of the classroom desks as shown in the figure below. Approximate Professor Seiler's legs and body as a rigid body OAB with weight of 750N acting at $\mathbf{A} = -0.2m\mathbf{i} + 1.2m\mathbf{j}$. Approximate his arms as a two-force member BC with $\mathbf{B} = -0.5m\mathbf{i} + 1.5m\mathbf{j}$ and $\mathbf{C} = -0.8m\mathbf{i} + 0.9m\mathbf{j}$. Finally, you may treat the contact between his feet and the ground as a hinge. In other words, the ground puts x and y reaction forces on Professor Seiler at $\mathbf{O}$ but no moments. ‘

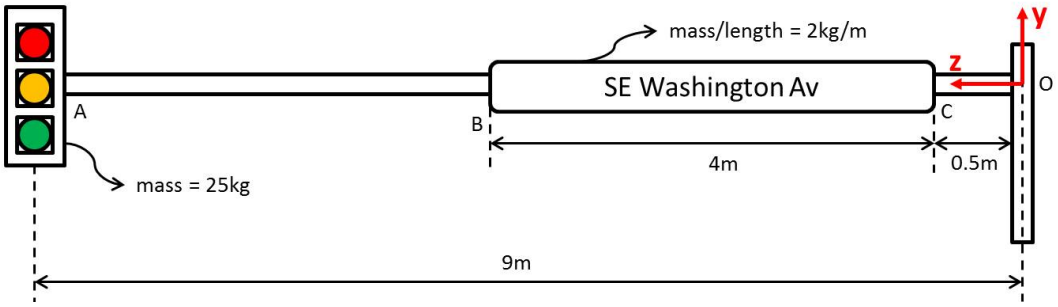
   (a) (5 points) What is the magnitude of the force in BC required to maintain equilibrium? Specify whether the force is in tension or compression.

   (b) (5 points) Let μ_S denote the coefficient of static friction between Professor Seiler's hand and the desk surface. What is the minimum value of μ_S required to maintain equilibrium? You may assume the desk surface is horizontal.

   (c) (5 points) Suppose Professor Seiler extends his arms slightly so that his hand now touches the table at $\mathbf{C} = -0.9m\mathbf{i} + 0.9m\mathbf{j}$ while the rest of his body remains fixed. Does the minimum value of μ_S required for static equilibrium increase, decrease, or stay the same (relative to the value computed in Part b)?



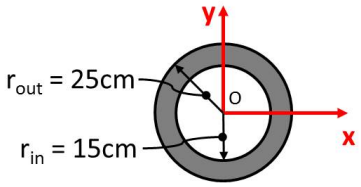
6. The figure below shows one of the traffic signals installed at the intersection of SE Washington Ave and SE Oak St. The traffic signal has a mass of $25kg$ and is attached to the horizontal beam at a single point A. The road sign "SE Washington Av" has a mass per unit length of $2kg/m$ and is attached to the horizontal beam between points B and C. The beam is cantilevered at its rightmost end (point O) which is also the origin of the coordinate system. It may be assumed that the horizontal beam is itself massless.



(a) (3 points) What are the reaction forces and moments at O required to support the beam?

(b) (5 points) Sketch the shear force $V(z)$ and bending moment $M(z)$ as a function of the beam position, z. You may neglect the beam cross-section dimensions in performing these calculations.

(c) (4 points) The horizontal beam has a hollow circular cross-section as shown in the figure below. The inner and outer radii of the cross-section are shown in the figure. What is the second moment of inertia of the beam cross-section about the x-axis?



(d) (4 points) What is the largest stress in compression and where does it occur on the beam?

(e) (4 points) Provide two reasons why a hollow circular tube is a good choice for the cross section of the beam.