AEM 2011 Homework #3 (3.1, 3.2) Wednesday, February 1, 2023

Unless otherwise mentioned, these problems should be solvable using a basic calculator. Practice clear communication by showing all work (free body diagrams, algebra, etc). This will be required to receive full credit on any graded problems.

1. Force $\bar{F}$, which has a magnitude of 4 kN, acts along a line passing through points D and D'. The grid units are in m and counter-clockwise moments are positive. Determine the moment of the force about points A, and B using the definition of the moment: $M = F \cdot d_{\perp}$.

   (a) Find the length of the line segment from A to D (or any other point on the line of action of $\bar{F}$).

   - $d =$

   (b) Find the angle ($<= 90°$) between segment $\bar{AD}$ and the line of action of $\bar{F}$.

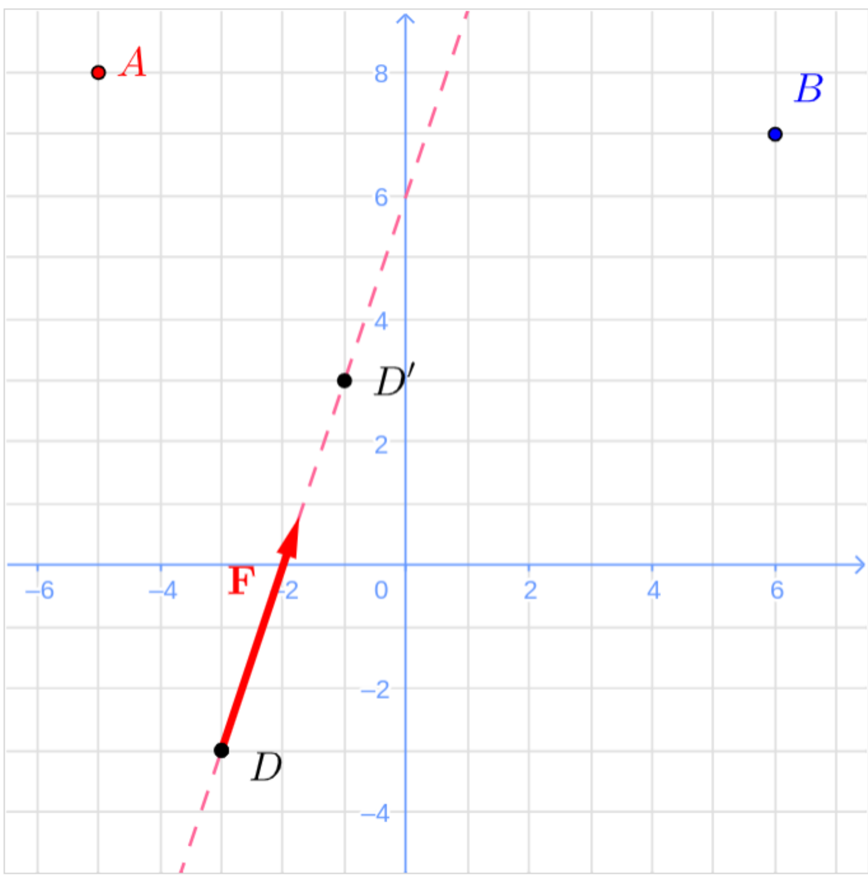
   - $\theta_A =$

   (c) Find the perpendicular distance between point A and the line of action of force $\bar{F}$.

   - $d_{\perp} =$

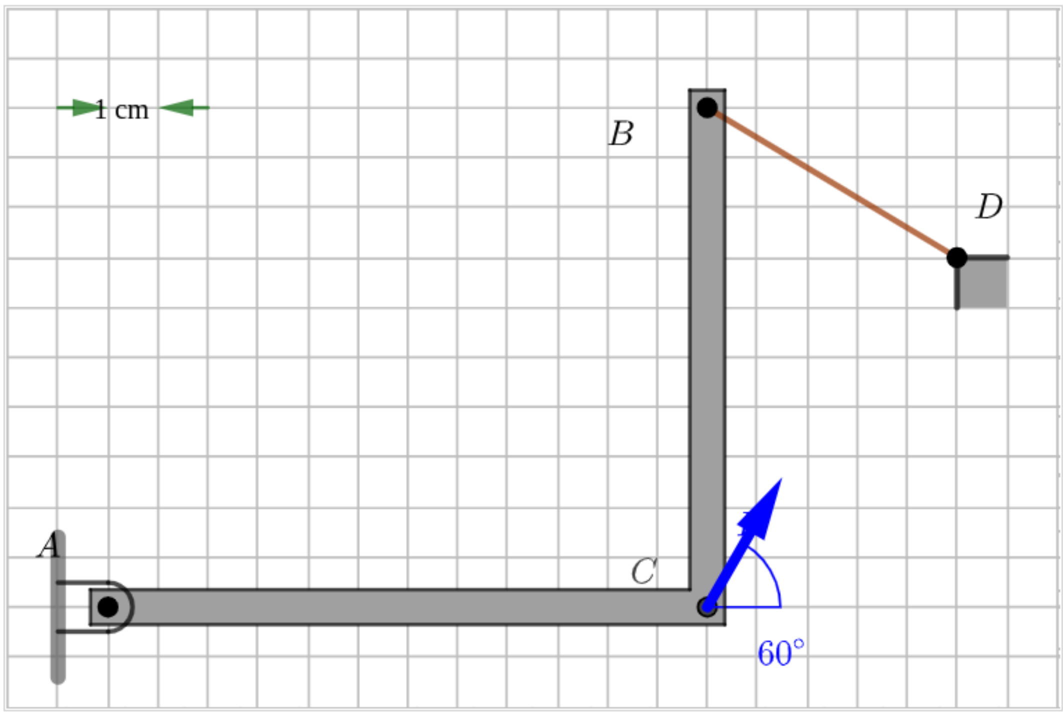
   (d) Use the definition of a moment to computer M_A.

   (e) In the same way, determine the moment of the force $\bar{F}$ about point B.

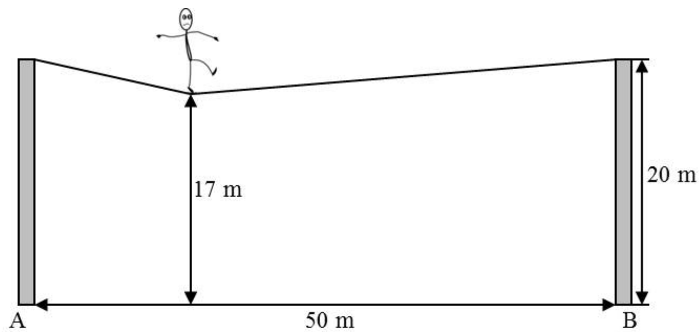


2. An L-shaped bracket is supported by a frictionless pin at A and a cable between points B and D. Determine the tension in the cable required for equilibrium when a $70N$ force $\bar{F}$ is applied to the bracket as shown at point C.

   Tip: Since the object is in equilibrium $\sum M_A = 0$ *implies that the opposing moments must have equal magnitudes.*



3. A 75 kilogram tightrope walker is attempting a walk across a 50 meter span 20 meters above the ground. When he is 20in the rope both ahead of and behind the walker, and the moments about points A and B (where the support posts meet the ground). Ignore the mass of the rope itself.



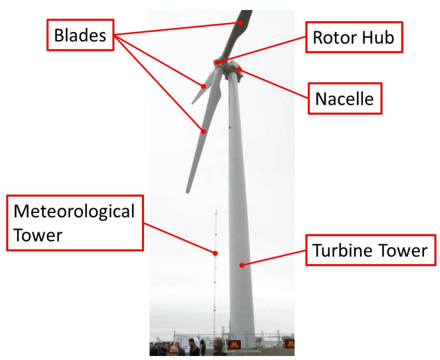
4. In HW2 you analyzed the cable tensions for a meteorological tower at the University of Minnesota Eolos Wind Research Field Station. The field station also has a 2.5MW Clipper Liberty Wind Turbine. The nacelle of this turbine is located at an elevation of 80m and the rotor radius is $R = 48m$. The power produced by a wind turbine is given by $P = \frac{1}{2}\rho A v^3 C_p (W)$ where $\rho = 1.225(kg/m^3)$ is the density of air, $A = \pi R^2$ is the circular area of the rotor plane (m^2), v is the wind speed (m/s) and C_p (unitless) is the efficiency of the wind turbine.

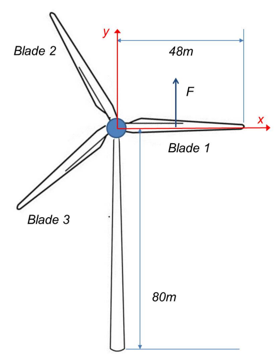
   (a) What is C_P if the turbine generates $P = 2.5MW$ of power when the wind speed is $v = 11m/sec$?

   (b) The diagram (right) shows a right-handed coordinate system attached to the rotor hub. The wind flowing past the blades causes a force to be distributed along each blade. For Blade 1 the effect is equivalent to a single force F acting vertically at mid span ($x = 24m$). Assume a similar force acts perpendicular to the other blades at midspan. What is the total moment about the center of the rotor hub, denoted M_{hub}, in terms of this force F?

   (c) The blades rotate at approximately $\omega = 1.6rad/s$ about the horizontal rotor axis (z-axis). The power captured by a wind turbine can also be calculated as $P = M_{hub}\omega$. What is the effective force F on each blade if the turbine is producing $2.5MW$ of power?

   (d) Suppose you plan to design a turbine to operate off-shore where the wind speed will be $v = 22m/sec$. Assume this new turbine has the same efficiency C_P (calculated in part A), rotational speed ω and radius R as the old turbine. You may also assume that the air density will remain the same. What is the power generated by this new off-shore turbine? What is the effective force on the blades of this new turbine? What is the impact on the design of the new turbine blades?





Left: Clipper Liberty Turbine, Right: Diagram of turbine rotor

5. Book problems:
   (a) 3.26
   (b) 3.37
   (c) 3.53
   (d) 3.60

   Additional Practice Problems: 3.2, 3.15, 3.31, 3.35, 3.41, 3.46

   The quiz problem will not be selected from these additional practice problems. However, these exercises contain important elements of the course and similar problems may appear on the exam.