AME 101 Fall 2016
Lecture homework #2
Assigned: 9/16/2016
Due: 9/23/2016, 4:30 pm, in the drop box in OHE 430N (back room of the OHE 430 suite of offices, where the Xerox machine is located) (Note this is a different box than my personal mailbox in the same room).

FYI, some of you have been asking if is there a source of more examples and more problems for statics. A cheap text is the *Schaum's Outline Of Statics and Mechanics of Materials* (see http://www.mhprofessional.com/product.php?isbn=0070458960).

Problem #1 (20 points)

The Nusselt number (Nu) and Rayleigh number (Ra) for heat transfer between a vertical wall of height L at temperature $T_{surface}$ and a fluid at temperature T_{fluid} are defined by

$$Nu \equiv \frac{hL}{k_f}; Ra \equiv \frac{g\beta\left(T_{surface} - T_{fluid}\right)L^3}{\alpha\nu}$$

where h is the convective heat transfer coefficient (units W/m^2˚C), k_f is the thermal conductivity of the fluid (=0.0603 W/m˚C for water), g is the acceleration of gravity, β is the thermal expansion coefficient (=2.12 x 10^{-4}/˚C for water), α is the thermal diffusivity (=0.0014 cm^2/s for water) and ν is the fluid kinematic viscosity (0.010 cm^2/s for water).

(a) What are the units of Nu and Ra in the SI system?
(b) For a wall of height L = 2 ft submerged in water with $T_{surface}$ = 32˚C and T_{fluid} = 27˚C, what is the value of Ra?
(c) For certain conditions, Nu can be estimated by the expression $Nu = 0.10Ra^{1/3}$. For this configuration, using the value of Ra calculated in part (b), what is Nu and what is h?
(d) The formula for heat transfer rate ($\dot{Q}$, units of power, e.g. Watts) is

$$\dot{Q} = hA\left(T_{surface} - T_{fluid}\right)$$

where A is the wall area, i.e. height x width. For a wall of width 15 inches, what is the heat transfer rate $\dot{Q}$?

Problem #2 (15 points)

I calculated the power production from a new type of steam turbine as

$$Power = \left(\frac{v_{out}^2}{2} - \frac{v_{in}^2}{2}\right) + \dot{m}C_P\left(T_{out} + T_{in}\right) - \frac{\dot{m}}{\rho}\left(P_{out} - P_{in}\right) - \frac{\dot{m}}{\mu}\left(Nd\right)^2 + 1$$

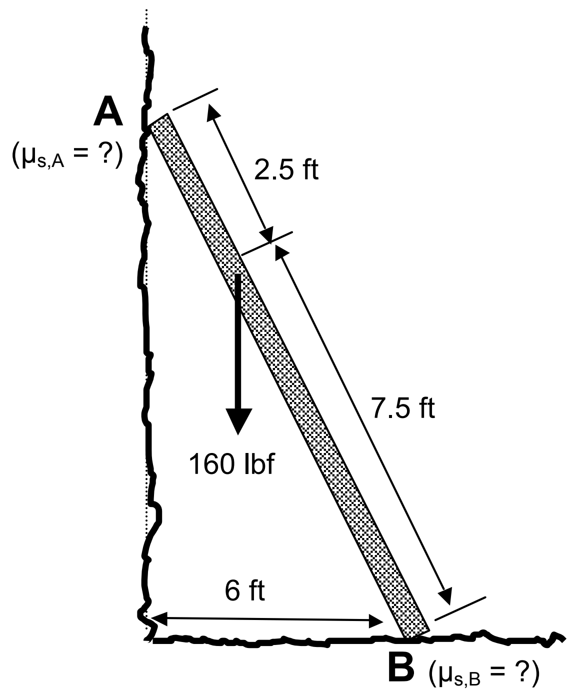
where T_{in}, P_{in} and v_{in} are the temperature, pressure and velocity of the steam going into the turbine, T_{out}, P_{out} and v_{out} are the temperature, pressure and velocity of the steam leaving the turbine, C_P is the heat capacity of the steam (units Joules/kg°C), $\dot{m}$ the mass flow rate of steam through the turbine (units kg/sec), ρ the steam density (kg/m^3), μ the coefficient of dynamic friction in the rotating shaft (not to be confused with viscosity which uses the same symbol), N the rotation rate of the shaft (units 1/sec) and d the shaft diameter.

Using "engineering scrutiny," what "obvious" mistakes can you find with this formula? There are at least 5, but list **only** the 3 of which you are most certain.

Problem #3 (25 points)

A 160 lbf individual stands 7.5 ft up a 10 foot long ladder whose base rests 6 ft away from the wall as shown in the figure. The ladder rests against a wall at point A and ground at point B. The coefficients of static friction (μ_s) will be different at points A and B for different parts of this problem. The ladder itself has negligible weight.

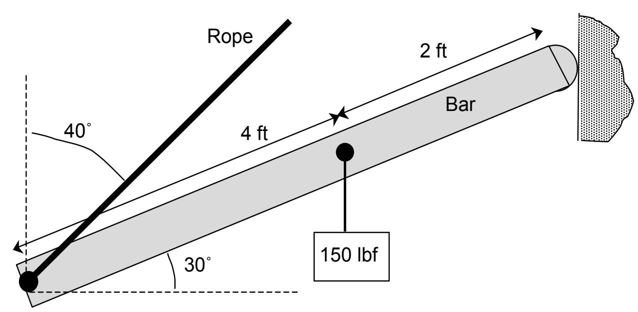
a) Draw all the forces acting on the ladder. How many unknown forces are there? List them.
b) For the case where there is friction at point B ($\mu_{s,B} \neq 0$), but no friction at point A ($\mu_{s,A} = 0$), write down a complete set of equations (i.e. as many equations as unknowns) needed to find the unknown forces.
c) For this case, solve these equations to find all the forces acting on the ladder.
d) For the case of part (c) ($\mu_{s,A} = 0$), what is the minimum coefficient of static friction at point B ($\mu_{s,B}$) required to prevent the ladder from sliding?
e) If the weight on the ladder were increased from 160 lbf to 320 lbf, would the minimum coefficient of static friction required at point B increase, decrease or remain the same? You don't have to re-solve the problem, just state your answer and explain why. **No credit without explanation**.



f) Suppose instead of having $\mu_{s,B} \neq 0$ and $\mu_{s,A} = 0$ as already analyzed, you had $\mu_{s,A} \neq 0$ and $\mu_{s,B} = 0$. Could you prevent the ladder from sliding in this case? Why or why not? **No credit without explanation.**

Problem #4 (15 points)

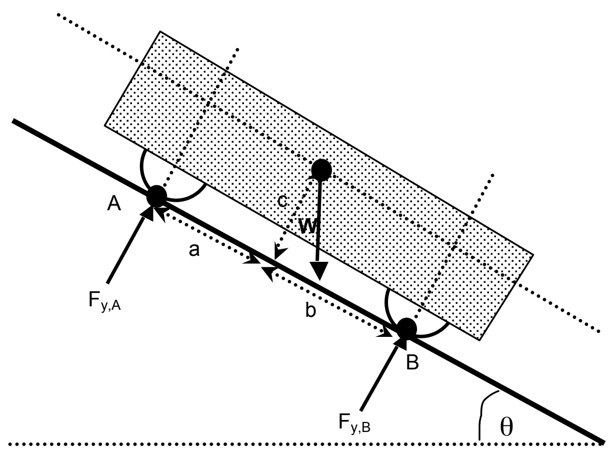
A 6 ft long bar of negligible weight has one end supported by a rope and the other end in contact with a vertical wall. There is friction at the contact point with the wall. A 150 lbf weight is hung on the bar as shown in the figure.



(a) Assuming that the friction is sufficient to keep the bar from sliding, what unknown forces are acting on the bar, and in what direction do they act?
(b) Write down all equations needed to solve for these 3 unknown forces (hint: you need 3 equations since there are 3 unknown forces!)
(c) Solve these equations to find the 3 unknown forces
(d) What is the minimum coefficient of friction required to prevent the bar from sliding?

Problem #5 (25 points)

Reanalyze the "car on a ramp" example in the lecture notes. Suppose that instead of either of the cases analyzed in class, the rear (downhill) wheels are locked and the front (uphill) wheels are free to spin. (There is no cable attached to the car.)



(a) In terms of a, b, c, θ and W, what coefficient of static friction μ_s would be required to keep the car from sliding down the ramp?
(b) What would the force parallel to the ramp at point B ($F_{x,B}$) be?
(c) Repeat part (a) and (b) if the configuration is reversed, that is, the front wheels are locked and the rear wheels are free to spin.