AME 101 Fall 2018
Lecture homework #2
Assigned: 9/13/2018
Due: 9/21/2018, 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). This is a very old book but the information is still current and relevant to this course. In addition to covering the material in Chapter 4 (Statics) it also covers the most of Chapter 5 (Materials and Stresses).

Problem #1 (15 points)

The "Thrust Specific Fuel Consumption" (TSFC) of an aircraft engine is defined as follows:

$$TSFC = \frac{\dot{m}_f Q_R}{F\,c}$$

where $\dot{m}_f$ is the fuel mass flow rate (units mass/time), Q_R is the fuel heating value (units energy/mass), F is the thrust (units of force) and c is the sound speed (units of velocity.)

(a) What are the units of TSFC in the SI system?
(b) Recalling that the formula for the mass-based gas constant (R) is $R = \Re/M$ where $\Re$ is the universal gas constant (=1.987 calorie/mole˚C) and M is the molecular mass, what is R in SI units for a gas with M = 0.06388 lbm/mole?
(c) Recalling that the formula for sound speed is $c = \sqrt{\gamma R T}$, where γ is the gas specific heat ratio and T is the temperature, what is c (in SI units) for a gas with γ = 1.35 and T = 25˚C?
(d) Using the value of c you just computed, if $\dot{m}_f$ = 4 lbm/s, Q_R = 4.4 x 10^7 J/kg, F = 51977 lbf, what is the value of TSFC in SI units?

Problem #2 (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 (=0.603 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 $T_{surface}$ = 88˚F and T_{fluid} = 80˚F, 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 L x width w. For a wall of width w = 15 inches, what is the heat transfer rate $\dot{Q}$?

<u>Problem #3 (15 points)</u>

I calculated the normal stress (σ, units force/area, i.e. same as pressure) acting on a telephone pole of height h and diameter d caused by a hurricane wind of speed v in air with drag coefficient C_D, density ρ and dynamic viscosity μ (units (mass)/(length * time), for example kg / (m s)) (don't confuse this μ with the coefficient of friction already discussed) with magnitude of gravitational acceleration g as follows:

$$\sigma = \frac{\rho v}{2C_D} - \rho g h + \sqrt{\frac{\rho^3 v^5 h}{\mu}}$$

Using "engineering scrutiny," what "obvious" mistakes can you find with this formula? There are at least 5, but list only the 4 you are most certain of.

<u>Problem #4 (25 points)</u>

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 the known parameters 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 are the normal forces at points A and B, i.e. what are $F_{y,A}$ and $F_{y,B}$?

(c) Repeat parts (a) and (b) if the configuration is reversed, that is, the front wheels are locked and the rear wheels are free to spin.

(d) What are the normal forces at points A and B, i.e. what are $F_{y,A}$ and $F_{y,B}$? Are they the same as in part (b) or different?

<u>Problem #5 (25 points)</u>

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 **on the figure at right** 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 (in units of lbf) acting on the ladder.
d) Based on your answer to 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 to prevent the ladder from sliding increase, decrease or remain the same? You don't have to re-solve the problem (but you can if you want), just state your answer and explain why. **No credit without explanation**.