AME 101 Fall 2016
Problem Set #1
Assigned: 9/2/2016
Due: 9/9/2016, 4:30 pm, in drop-off box in OHE 430N (back room of the OHE 430 suite of offices, where the Xerox machine is located)

<u>Problem #1 (10 points) (from a previous year's first midterm exam)</u>

Water has a heat capacity (also called specific heat) of $1.00\dfrac{calorie}{gram^{\circ}C}$. What is the heat capacity of water in units of $\dfrac{BTU}{lbm^{\circ}F}$?

<u>Problem #2 (15 points) (from a previous midterm)</u>

The friction factor (f) for flow of a fluid with density ρ (units mass/volume), velocity v, in a pipe of length L and inside diameter d, resulting in a pressure drop ΔP, is defined as

$$f \equiv \frac{\Delta P}{\dfrac{\rho v^2}{2}\dfrac{L}{d}}$$

(a) What are the units of the friction factor f ?
(b) For a fluid with density $\rho = 62.4$ lbm/ft^3, velocity v = 1 m/s, flowing in a pipe of length L = 20 ft and diameter d = 1 inch, resulting in a pressure drop $\Delta P = 17.39$ lbf/in^2, what is the friction factor f?

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

The power transmitted by a rotating shaft is given by

$$P = 2\pi N\tau$$

where P is the power, N is the number of revolutions per unit time and **τ** is the torque.

(a) Verify that the units are consistent, *i.e.*, show that the units on the left side of the equation are the same as on the right side of the equation.
(b) If N is in units of revolutions per minute (RPM) and **τ** in units of ft lbf, what conversion factor is needed to obtain P in units of horsepower? In other words, find ???? in the following relation

$$\text{Power (horsepower)} = \frac{\text{Torque (ft lbf)} \times \text{RPM (rev/min)}}{????}$$

Problem #4 (15 points)

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)) 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 3 you are most certain of.

Problem #5 (15 points)

The solar power transmitted to the ground at high noon at the equator is about 1000 Watts per square meter. How many square feet of solar collector area would be required to power your car, assuming a 100 horsepower electric motor and a conversion efficiency of solar power to motor shaft power of 15%?

Problem #6 (15 points)

You probably found that the solar collector area was prohibitive (which is why we're not driving around in solar powered cars.) So let's try batteries instead. Look up the specifications (volts, amp-hours and weight or mass) for any type of rechargeable battery.

(a) The energy delivered by the battery is volts x amp-hours. Compute this energy and convert to units of Joules.
(b) Divide by the mass of the battery and convert the result to units of Joules/kg. Compare this to the heating value of gasoline, about 4.3×10^7 J/kg. (This comparison shows you why most of us don't drive around in battery powered cars.)

Problem #7 (15 points)

One last try … how about compressed air? The energy (E) stored in a compressed gas of volume V_1 and pressure P_1 that can be extracted by expanding the gas to a lower pressure P_2 is

$$E = \frac{P_1 V_1}{\gamma - 1}\left[1 - \left(\frac{P_2}{P_1}\right)^{\gamma-1/\gamma}\right]$$

where γ is the *specific heat ratio* of the gas (dimensionless), whose value is about 1.4 for air.

(a) What volume (V_1) (in gallons) of air would be required to have the same energy content as one gallon of gasoline (1.25×10^8 Joules) if P_1 = 200 atmospheres and P_2 = 1 atmosphere?
(b) What would the mass of this air be? To determine this, recall that the ideal gas law can be written in the form $m = P_1V_1/RT_1$, where m is the mass of gas and $R = \Re/\mathcal{M}$ is the mass-based ideal gas constant ($\Re$ = universal gas constant, $\mathcal{M}$ = molecular mass) and T_1 = ambient temperature (say 70˚F).