AME 101 Fall 2016
Problem Set #5
Assigned: 11/25/2016
Due: 12/2/2016, 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)

Note: Since your lowest homework grade will be dropped anyway, if you're satisfied with your other 4 scores, you can skip this assignment. (Though I recommend doing these problems anyway, you'll need to know the material for the final exam.)

Problem #1 (20 points)

Using the Control Volume form of First Law of Thermodynamics I derived the following formula for the power output ($\dot{W}$) of a new type of steady-flow engine in terms of the mass flow rate through the engine ($\dot{m}$), the temperature at the outlet of the engine (T_{out}), the temperature at the inlet of the engine (T_{in}) and the specific heat at constant volume (C_V):

$$\dot{W}_{1-2} = \dot{m}C_V(T_{out} - T_{in})$$

(a) There are two mistakes in this equation, *i.e.*, it's not possible to derive this result from the First Law of Thermodynamics. What are these two mistakes and how can the formula be corrected?
(b) Which of the following assumptions were required to obtain the above result, besides fixing the mistakes? **No credit for simple yes or no answers, you must state a reason for your answer.**

(i) No change in velocity between states 1 and 2
(ii) No change in pressure between states 1 and 2
(iii) No change in density between states 1 and 2
(iv) No heat transfer between states 1 and 2
(v) Working fluid has no viscosity

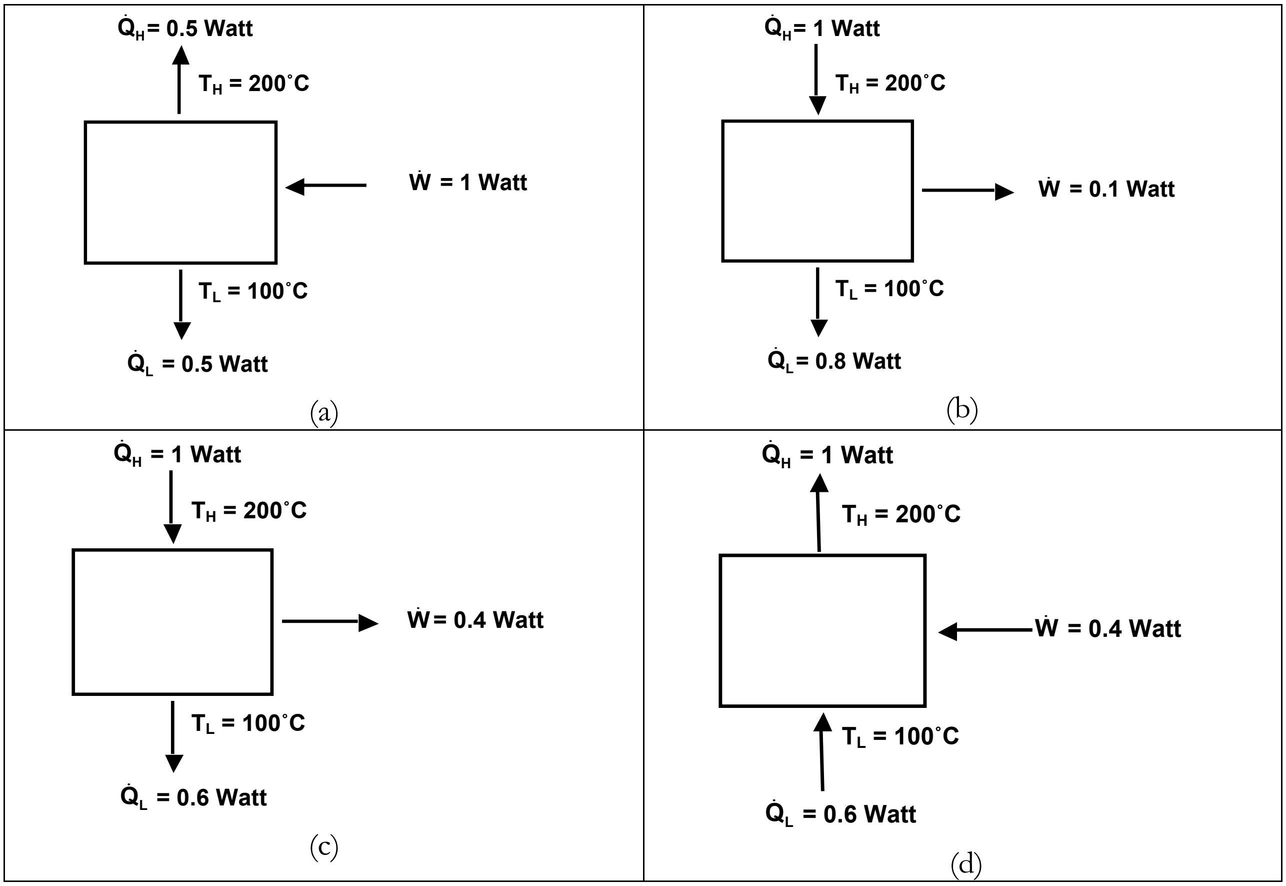
Problem #2 (20 points)

A 0.25 lbm **spherical** meteor of diameter 3 cm enters the earth's atmosphere at an elevation of 400,000 ft with a velocity of 30,000 mi/hr. The meteor's temperature is 200K. The specific heat at constant volume (C_v) of the meteor is 800 J/kg˚C.

(a) If the meteor has a temperature of 500˚C just before it hits the earth's surface ($z \approx 0$), what would its velocity be in ft/sec? Assume that there is no heat transfer to or from the atmosphere and no work done on or by the atmosphere (due to air drag) on the meteor.
(b) If instead you assumed that the meteor experienced air drag, what would its terminal velocity be in the lower atmosphere where the air properties are those given in Table 4?
(c) If just above the earth's surface ($z \approx 0$) the meteor had the terminal velocity determined in part (b) and had a temperature of 25˚C, how much work was done on or by the atmosphere? Is the work positive or negative? Again assume no heat transfer to or from the atmosphere.

<u>Problem #3 (20 points)</u>

Which of the devices (a) – (d) below are possible, which are impossible according to the First Law of Thermodynamics, and which are impossible according to the Second Law of Thermodynamics? Explain each in 1 or 2 sentences. **No credit without explanation!**



<u>Problem #4 (20 points)</u>

The U.S.S. San Francisco is a submarine with a top speed of 30 knots (34.5 mi/hr). The hull drag coefficient is 0.3 and the cross-section area can be approximated as a circle 32 feet in diameter.

(a) What force (in lbf) is required to move the ship at this speed?
(b) What power (in horsepower) is required to move the ship at this speed?
(c) If oil is used as fuel in a steam power plant, how many tons (1 ton = 2000 lbm) of oil per hour must be burned, assuming that the efficiency of the conversion of oil heating value to ship propulsive power is 20%? (Oil has essentially the same heating value as gasoline.)
(d) If U_{235} is used as fuel in a steam power plant (which is the actual case for this ship), how many pounds of U_{235} per hour must be fissioned, assuming that the efficiency of the conversion of U_{235} heating value to ship propulsive power is 20%?

<u>Problem #5 (20 points)</u>

An infrared lamp is used to keep the top surface of an 18" diameter ½" thick pizza at a temperature of 60°C.

(a) If the pizza loses heat only by conduction through the pizza to a 25°C plate on which the pizza lies, and the thermal conductivity of the pizza is 0.3 W/mK, what heating power (in Watts) must the infrared lamp supply?
(b) If the pizza loses heat only by radiation to the environment at 25°C, and the emissivity of the pizza is 0.8, what heating power (in Watts) must the infrared lamp supply?
(c) If the pizza loses heat only by convection to the atmosphere at 25°C, and the convective heat transfer coefficient h = 10 $W/m^2°C$, what heating power (in Watts) must the infrared lamp supply?