AME 101 Fall 2017
Problem Set #5
Assigned: 11/27/2017
Due: Tuesday 12/5/2017, 12:00 noon, in the drop box in OHE 430N (back room of the OHE 430 suite of offices, where the Xerox machine is located) or at the "Final Exam Review Party" on 12/5 (time to be discussed in class 11/28). **No late homework accepted.**

<u>Note:</u> 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.)

<u>Problem #1 (20 points total)</u>

Using the Control Mass form of the First Law of Thermodynamics I derived the following formula for the work output ($W_{1\text{-}2}$) of a new type of piston engine process in terms of the temperature after the process (T_2), the temperature before the process (T_1) and specific heat at constant pressure (C_P):

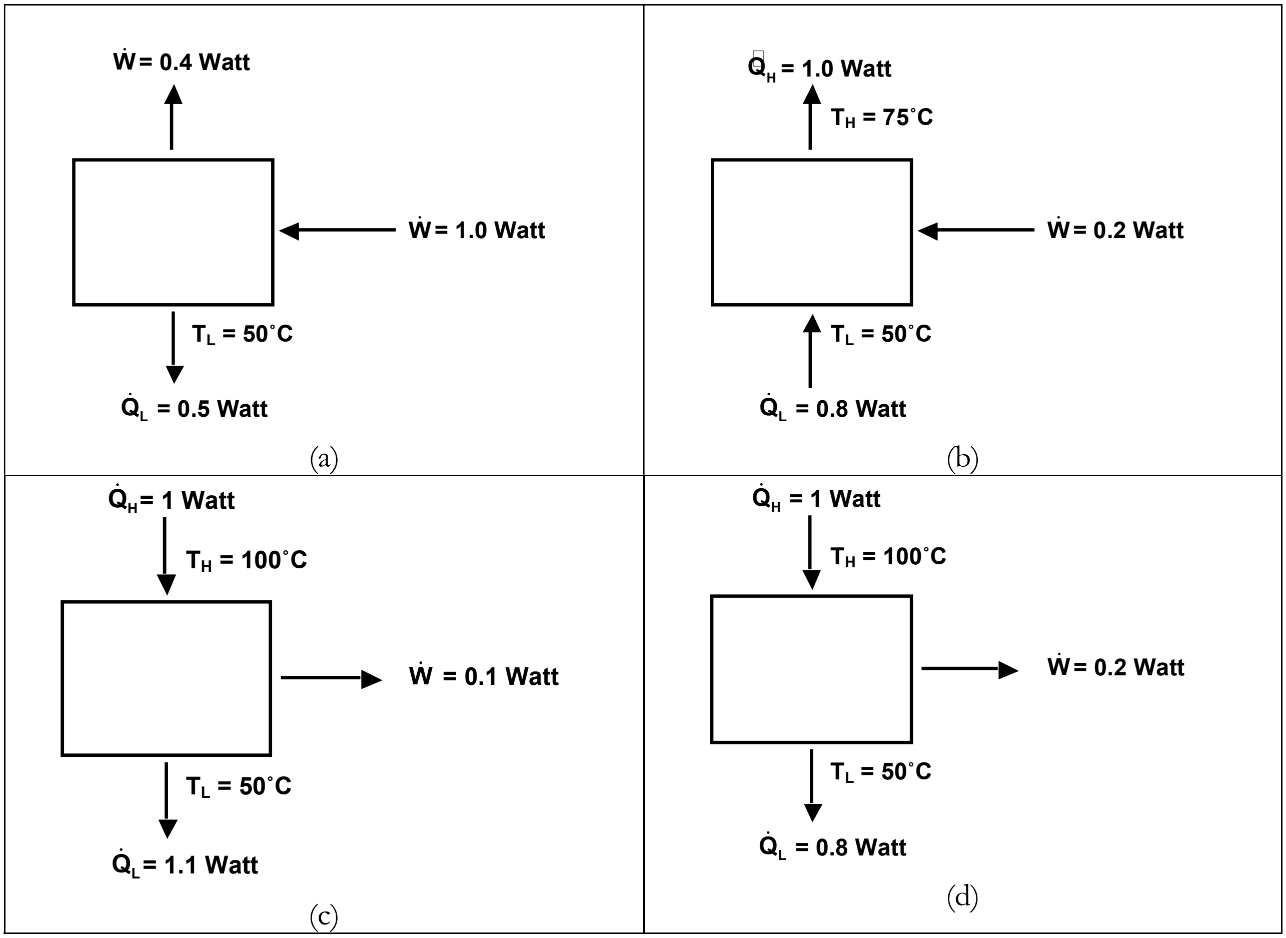
$$W_{1-2} = m\sqrt{2C_P(T_2 - T_1)}$$

(a) There are four mistakes in this equation, i.e. it's not possible to derive this result from the First Law of Thermodynamics. What are these 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
  (ii) No change in mass
  (iii) Control Mass does not change shape or volume

<u>Problem #2 (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 #3 (20 points)</u>

(a) A water heater uses 2 kg/hour of kerosene (heating value Q_R = 4.3 x 10^7 J/kg) as a heat source ($\dot{Q}$). Water enters the device at 25°C and leaves at 100°C with no change in velocity or elevation and no work extraction ($\dot{W}$). What is the mass flow rate ($\dot{m}$) of water? The process is steady-state, steady flow. The heat capacity (C_P) of water is 4184 J/kg°C.

(b) If the 100°C water in part (a) is used as the heat source for a steam engine, and waste heat is rejected to 25°C water, what is the <u>maximum possible</u> efficiency (η) and power ($\dot{W} = \eta \dot{Q}$) this engine could produce according to the 2nd Law of Thermodynamics?

(c) If the power produced in (b) is used to raise another stream of water by an elevation of change of 50 meters and increase its velocity from 5 m/s to 50 m/s, what is the mass flow rate of this stream? Assume no heat transfer and no change in water temperature.

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

The U.S.S. San Francisco is 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%?

Problem #5 (20 points)

Samantha (who we already know can be modeled as a cylinder 5 feet tall and 2 feet in diameter) is standing outside on a cold night. Her metabolic rate (heat production) is 100 Watts and all of her material properties (ρ, ν, μ, C_P, C_V, k, etc.) can be approximated as those of water.

(a) If Samantha loses this 100 Watts only by convection to the atmosphere (air) at 5°C, and the convective heat transfer coefficient h = 10 $W/m^2 °C$, what is her skin temperature? Assume that she's wearing a well-insulated hat and boots, so that only her curved cylindrical surface loses heat.
(b) If Samantha loses this 100 Watts only by radiation to the surroundings at 5°C, and her emissivity (ε) is 0.8, what is her skin temperature? Again assume that she's wearing a well-insulated hat and boots, so that only her curved cylindrical surface loses heat.
(c) If Samantha loses heat by both convection and radiation with the same h and ε as above, what is her skin temperature?
(d) Samantha takes off her boots and her bare feet (modeled as a 2 foot diameter circular disk) lose heat by conduction to the ground at 5°C. If she loses heat only via this heat conduction to the ground, what would the temperature of her head be?