Homework #3 - due Tuesday, September 29 by 4:00 pm
bonus problems - due Thursday, October 1 by 4:00 pm

Readings for this homework assignment and upcoming lectures

1. Read Chapter 1 of Textbook (Weston)
2. Read Chapter 2 of Textbook (Weston)
3. Review lecture notes:
   - Part 5. The Rise of Heat Engines
   - Part 6. Review of Engineering Thermodynamics
4. Review Thermodynamics textbook as needed
5. Review Chapter 1. Power Plant Technology, El-Wakil as needed

Homework Submission

For this assignment, the homework is to be worked as a group assignment and submitted as a group in class or by dropping off at my office (room 831).

PLEASE include the course number (MEEM4200) in the subject line of any email correspondence.

MEEM 5290 problems are always to be worked and submitted individually.

Bonus problems are always to be worked and submitted individually.
Homework #3 - due Tuesday, September 29 by 4:00 pm

1. A new inert gas appears to be well-suited for converting thermal energy from the exhaust heat of an engine manifold into mechanical energy via an Erickson engine. In order to design the cycle you need to determine the specific heats, the ideal gas constant and the entropy (all as a function of temperature) of this gas. The gas can be assumed to behave as an ideal gas. Design a simple experiment which will, with accompanying analysis, provide the necessary property data.

2. A 10-m$^2$ rigid tank contains steam at 30 bar and 400 °C. It is left to cool down until its pressure drops to 5 bar. Find (a) the final condition of the steam and (b) the heat transfer in kilojoules.

3. Air at 800 kPa and 27 °C enters a steady-flow nozzle with a very low velocity and leaves at 100 kPa. If the air undergoes an adiabatic expansion process through the nozzle, what is the maximum velocity of the air at the nozzle exit, in m/s?

4. As a new engineer, you are given the task of determining the mechanical efficiency of a pump driven by an electric motor. The test setup has an inlet and outlet diameter of 8 cm and 12 cm, respectively. The test fluid is an oil having a density of 800 kg/m$^3$. At a flow rate of 0.10 m$^3$/s, the pressure rise across the pump is 400 kPa and the motor (90% efficient) draws 35 kW of electric power. Is the instrumentation sufficient to determine the mechanical efficiency of the pump? If so, what is the mechanical efficiency of the pump? If not, what additional information is required?

5. Liquid ammonia at 87 °F and 250 psia is throttled to 100 psia into a flash tank. The flow rate into the flash tank is 100 lbm/hr. Ammonia vapor is drawn off of the top of the flash tank and liquid ammonia is discharged at the bottom. Determine the temperature [°F] in the tank and the mass and volume flow rates [lbm/hr, ft$^3$/hr] of the two exit streams. (good problem to use EES)

6. Air expands from 10 bar and 1000 °C to 1 bar and 500 °C in an insulated turbine. Calculate (a) the isentropic turbine efficiency, (b) the change in entropy during expansion, in kJ/kg K, (c) the specific work output of the turbine, in kJ/kg, and (d) the polytropic exponent.

   Assume a constant specific heat of 1.005 kJ/kg K.

7. $10^6$ lbm/hr of steam at 250 psia and 1000 °F expands in a turbine to 1 psia. The turbine has isentropic and mechanical efficiencies of 0.90 and 0.95, respectively. The turbine drives an electric generator that has an efficiency of 0.96. What is the output power of the generator, in MW$_e$?

8. Weston 1.24

9. An Ocean Thermal Energy Conversion (OTEC) power plant built in Hawaii in 1987 was designed to operate between the temperature limits of 86 °F at the ocean surface and 41 °F at a depth of 2100 ft. About 13300 gallons per minute (gpm) of cold seawater was to be pumped from deep ocean through a 40-in-diameter pipe to serve as the cooling medium or heat sink. If the cooling water experiences a temperature rise of 6 °F and the thermal efficiency is 2.5%, determine the amount of power generated. The density of seawater is approximately 64 lbm/ft$^3$. 

10. An ideal gas cycle is composed of four processes with air as the working fluid:
   1-2: Isentropic compression from 100 kPa and 27°C to 1 MPa.
   2-3: Isobaric heat addition of 2800 kJ/kg.
   3-4: Isochoric heat rejection to 100 kPa.
   4-1: Isobaric heat rejection to state (1).

   (a) Show the cycle on a $P-v$ and $T-s$ diagram.
   (b) Calculate the maximum temperature in the cycle.
   (c) Calculate the thermal efficiency.

   Assume the specific heats are constant at the room temperature value.

11. Weston 1.30

12. An ideal gas that has a constant specific heat of $c_p = 0.26 \text{ Btu/(lbm} \degree \text{R})$ undergoes an expansion process in a steady-flow machine with a mass flow rate of 100 lbm/h. The machine is water-cooled. The water mass flow rate is 10 lbm/h. During the process the gas temperature drops from 200 to 100°F and the water temperature rises from 70 to 100°F. Ignoring changes in potential and kinetic energies for the gas, calculate the work of the gas in Btus per hour and watts. [$c_p$ for water = 1 Btu/lbm $\degree$R]

**bonus problems – Thursday, October 1 by 4:00 pm**

13. Air at 140°F and 100 psia is confined in an uninsulated 10 ft$^3$ vessel. A propeller is driven inside the vessel by a 50-W electric motor. After a period of 1 hour the air temperature dropped to 100°F. Find the heat transfer in Btu per hour.

14. An inventor claims to have built an engine that operates on a cycle, receives 1000 kJ at 500°C, produces work, and rejects 350 kJ at 50°C. Is this claim valid? Why or Why not?

15. A 1.2 kW compressor moves R134a through a residential heat pump at a rate of 0.018 kg/s. The refrigerant enters the heat pump condenser at 800 kPa and 35°C and exits at 800 kPa as saturated liquid. Determine (a) the COP of the heat pump, and (b) the rate of heat absorption from the outside air.

16. Consider an office room that is being cooled adequately by a 12,000 Btu/h window air conditioner. It has been decided to convert this room into a computer room. Several computers, terminals, and printers with a total rated power of 3.5 kW will be installed. The facility has several 4000 Btu/hr air conditioners in storage that can be installed to meet the additional cooling requirements. Assuming a usage factor of 0.4 (i.e., only 40% of the rated power will be consumed at any given time) and additional occupancy of four people, each generating heat at a rate of 100 W, determine how many of these air conditioners need to be installed in the room.

17. A long roll of 2-m-wide and 0.5-cm-thick manganese steel plate ($\rho = 7854 \text{ kg/m}^3$ and $c_p$ = 0.434 kJ/kg°C) coming off a furnace at 820°C is to be quenched in an oil bath at 45°C to a temperature of 51.1°C. If the metal sheet is moving at a steady velocity of 10 m/min, determine the required rate of heat removal from the oil to keep its temperature constant at 45°C.