2.611 / 2.612 Ship Power and Propulsion
Problem Set #6, Due December 5, 2006

1. Describe the advantages and disadvantages of using a Gas Turbine vs. a Diesel Engine.

2. Draw a T-S diagram for an inter-cooled regenerative Brayton Cycle. Label the points and explain, in words, each portion of the cycle. Mark on your diagram the area where heat is transferred into the system and where it leaves the system.

3. A simple closed-cycle Brayton engine operates with air as the working fluid. The conditions at the design point are as follows:
   - compressor inlet temperature, $T_1 = 25$ °C (300 K)
   - compressor pressure ratio, $p_2/p_1 = 11$
   - compressor isentropic efficiency, $\eta_c = 85\%$
   - turbine inlet temperature, $T_3 = 1425$°C (1698 K)
   - turbine isentropic efficiency, $\eta_t = 92\%$
   - pressure loss, $\Delta p/p = 6\%$
   - mass flow rate of air through engine = 60 kg/s

Determine:
   a. T_2 & T_4 using ideal gas properties
   b. the ratio of compressor power/turbine power
   c. the net power of the Brayton Cycle, (kW)
   d. the heat transfer rate (kW) (between T3 – T4)
   e. the thermal efficiency of the cycle
Assume that air is an ideal gas with constant specific heats ($c_p = 1.00$ kJ/kg K, $\gamma = 1.4$).

4. A design engineer recommends adding a regenerator with an efficiency of 90% to the Brayton engine in Question #3. Use the design conditions from #3, Determine:

   a. the heat transfer rate (kW)
   b. the thermal efficiency of the cycle
   c. Draw the T-S, Diagram highlighting the range which the heat transfer takes place.

5. An intercooled recuperative gas turbine has the following design conditions:

Compressor inlet temperature, $T_1=T_3$ 310K
Compressor pressure ratio, $p_2/p_1=p_4/p_3$ 5
Turbine inlet temperature, T_6 1350K
Pressure Loss, $\Delta p/p$ 10%
Compressor polytropic efficiency, η_{pc} 85%
Turbine polytropic efficiency, η_{pt} 90%
Regenerator effectiveness, $\varepsilon=(T_5-T_4)/(T_7-T_4)$ 0.85
Combustion efficiency, η_{comb} 92%

Determine:
a. the fuel/air ratio, m_f/m_a
b. the specific power in kW/kg per sec (i.e. net power/mass flow rate of air)
c. the specific fuel consumption in kg of fuel per kW hour
d. Calculate the required cross sectional area for the inlet duct if the inlet duct velocity is 25 m/s for the turbine. Assume that the ambient air outside the ship is at 1 bar and 298K

Assume that the working fluids are air ($\gamma_a = 1.4$ and $c_{pa} = 1.005$ kJ/kg K) for the compressor and the combustion products ($\gamma_p = 1.33$ and $c_{pp} = 1.130$ kJ/kg K) for the turbine. The fuel for the combustor is at 25° C and the heating value (LHV) is 43,000 kJ/kg.

6. A simple cycle 18 MW gas turbine has a maximum turbine entry temperature of 1100°C and a max pressure after the compressor of 2.2MPa. The maximum pressure in the combustion chamber is 500kPa. Pressure at the intake and temperature is 110kPa and 30° C. Additionally, a recuperator with an effectiveness of 85% has been installed. Using an isentropic index of 1.4 throughout the turbine determine:

a. power required for compression and polytropic efficiency of the compression process.
b. power delivered during expansion and polytropic efficiency of the expansion process
c. amount of heat released in combustion chamber and fuel mass flow.
d. brake power and over all efficiency

- Assume gas constant = 0.287 kJ/kgK
- Specific heat at constant pressure = 1.0 kJ/kgK
- LHV of fuel = 430000 kJ/kg
- $n_c = 1.4$ (irreversible loss for compression)
- $n_T = 1.33$ (irreversible loss for expansion)

Hint: Use the example in chapter 8 and figure 8.8 of the text.

7.   A DC motor with a speed of 180 rpm, current of 10 amps, resistance of 2 ohms
      has 400 volts applied. Determine the magnetic flux and torque.

              Assume K_e=5 and K_m=30

8.   The rotor of a certain 25 hp, 6 pole, 60Hz induction motor has an equivalent
      resistance and reactance per phase is 0.1 Ω and 0.5 Ω respectively. The blocked
      rotor voltage/phase is 150 V. If the rotor is turning at 1164 rpm, determine:

              a. synchronous speed
              b. slip
              c. rotor impedance
              d. rotor current
              e. rotor current is changing the shaft load resulted in 1.25% slip
              f. speed for condition in e.