Homework #5 - due Tuesday, 10/27 by 4:00 pm
bonus problems - due Thursday, October 29 by 4:00 pm

Readings for this homework assignment and upcoming lectures

- Read Chapter 5. Gas Turbines and Jet Engines (Weston Textbook)
- Review lecture notes:
  - Part 8. Brayton Cycle
- Review Thermodynamics textbook

Homework Submission

- For this assignment, the 4200-portion of 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). If you use EES for this assignment, then print a copy of the code and solution and include with the homework.
- MEEM 5290 problems are always to be worked and submitted individually.
- Bonus problems are always to be worked and submitted individually.
- At the end of each problem, rank your confidence in the answer from 1 to 5; 5 being very confident and 1 being ‘a guess’.
- PLEASE include the course number (MEEM4200, MEEM5290) in the subject line of any email correspondence.
Homework #5 - due Tuesday, 10/27 by 4:00 pm

1. What four processes make up the simple ideal Brayton cycle?

2. Weston 5.12

3. Compare the optimum pressure ratios and corresponding efficiencies of three ideal Brayton cycles using air, helium, and carbon dioxide as working fluids. The minimum and maximum temperatures are 10°C and 1115°C, respectively. Use a constant specific heats at low temperatures.

4. The idea of using gas turbines to power automobiles was conceived in the 1930s, and considerable research was done in the 1940s and 1950s to develop automotive gas turbines by major automobile manufacturers such as the Chrysler and Ford corporations in the United States and Rover in the United Kingdom. The world’s first gas-turbine powered automobile, the 200-hp Rover Jet 1, was built in 1950 in the United Kingdom. This was followed by the production of the Plymouth Sport Coupe by Chrysler in 1954 under the leadership of G. J. Huebner. Several hundred gas turbine-powered Plymouth cars were built in the early 1960s for demonstration purposes and were loaned to a select group of people to gather field experience. The users had no complaints other than slow acceleration. But the cars were never mass-produced because of the high production (especially material) costs and the failure to satisfy the provisions of the 1966 Clean Air Act.

A gas-turbine-powered Plymouth car built in 1960 had a turbine inlet temperature of 1700°F, a pressure ratio of 4, and a regenerator effectiveness of 0.9. Using isentropic efficiencies of 0.80 for both the compressor and the turbine, determine the thermal efficiency of this car. Also, determine the mass flow rate of air for a net power output of 95 hp. Assume the ambient air to be at 540°F and 14.5 psia.

5. An open Brayton-cycle engine operates with a compressor-pressure ratio of 5.0 and inlet temperature of 20°C, and a turbine-inlet temperature of 975°C. The engine drives an electric generator that produces 25 MWe with a generator efficiency of 90 percent. For the following systems, find the thermal efficiency, the specific work, and the air-mass-flow rate, if the compressor and turbine efficiencies are 80 percent.

(a) A simple Brayton cycle.

(b) A regenerative Brayton cycle with a regenerator effectiveness of 80 percent.

(c) A Brayton cycle using two stages of compression with intercooling to 20°C.

(d) A Brayton cycle that employs both the regenerator of (b) and the intercooler of (c).
6. A helium gas turbine cycle has compressor and turbine isentropic efficiencies of 0.8 and 0.9 and pressure ratios of 2.5 and 2.4, respectively. The compressor has one stage of intercooling and the turbine one stage of reheat. The cycle has a regenerator with 85 percent effectiveness. The cycle minimum and maximum temperatures are 100 and 2000 °F, respectively. Calculate

(a) all temperatures around the cycle, in degrees F, and draw the cycle diagram on a T-s plot,

(b) the cycle power for a helium mass flow rate of 200 lbm/s,

(c) the actual cycle efficiency,

(d) the actual cycle efficiency without regeneration,

(e) the ideal cycle efficiency without regeneration,

(f) the ideal cycle efficiency with regeneration with an effectiveness of 1,

(g) the Carnot efficiency for this maximum and minimum temperatures.

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7. Weston 5.19

8. An open-cycle regenerative gas-turbine power plant receives air at 94 kPa and 20 °C. The air is compressed to 550 kPa, heated to 425 °C in the regenerator, and then reaches a maximum temperature of 870 °C in the combustion chamber. Assuming an air-standard cycle, compute the thermal efficiency and the regenerator effectiveness if the mechanical efficiency of the compressor and turbine are 82 and 87 percent, respectively.

9. Weston 5.24

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10. An air-standard Brayton cycle operates with a compressor pressure ratio of 6.0. The actual expansion and compression efficiencies of the gas processes are 0.88 and 0.82, respectively, and the maximum and minimum temperatures are 800 °C and 16 °C, respectively. Compute the compression work, the expansion work, the ratio of compression to expansion work (the back-work ratio), and the actual and theoretical thermal efficiencies. If the power output of the installation is 8 MW, determine the air mass flow rate, kg/min.

11. In 1903, Aegidius Elling of Norway designed and built an 11-hp gas turbine that used steam injection between the combustion chamber and the turbine to cool the combustion gases to a safe temperature for the materials available at the time. Currently there are several gas-turbine power plants that use steam injection to augment power and improve thermal efficiency. For example, the thermal efficiency of the General Electric LM5000 gas turbine is reported to increase from 35.8% in simple-cycle operation to 43% when steam injection is used. Explain why steam injection increases the power output and the efficiency of gas turbines. Also, explain how you would obtain the steam.