5.21 Derive the expression for specific work output and the efficiency of a simple cycle with intercooled and heat exchanger. Draw their trends as a function of pressure ratio.

5.22 Explain the important observations from the specific work output and efficiency variation as a function of pressure ratio for the above cycle.

5.23 Draw the schematic diagram of a simple cycle with intercooled and reheat and explain briefly the working principle. Draw also the p-V and T-s diagrams of the cycle.

5.24 Derive the expression for specific work output and the efficiency of a simple cycle with intercooled and reheat. Draw their trends as a function of pressure ratio.

5.25 Explain the important observations from the specific work output and efficiency variation as a function of pressure ratio for the above cycle.

5.26 Draw the schematic diagram of a simple cycle with intercooled, heat exchange and reheat and explain briefly the working principle. Draw also the p-V and T-s diagrams of the cycle.

5.27 Derive the expression for specific work output and the efficiency of a simple cycle with intercooled, heat exchange and reheat. Draw their trends as a function of pressure ratio.

5.28 Explain the important observations from the specific work output and efficiency variation as a function of pressure ratio for the above cycle.

5.29 By means of suitable graphs compare the specific work output of various cycles without heat exchanger.

5.30 With a T-s diagram briefly explain the Ericsson cycle.

Exercise

[Note: Take $\frac{\gamma-1}{\gamma} = 0.286$ and $C_p = 1.005$ kJ/kg K for all problems, unless stated otherwise.]

5.1 In a gas turbine plant, air enters the compressor at 1 bar and 27°C. The pressure ratio is 6. The temperature at turbine inlet is 1000 K. The mass flow rate of air is 10 kg/s. Determine

(i) power required to drive the compressor and the turbine power output,

(ii) the ratio of the turbine to compressor work,

(iii) net power developed by the plant, and

(iv) the thermal efficiency.

Ans: (i) 2018.14 kW; 4029.75 kW (ii) 1.997
(iii) 2011.61 kW (iv) 40.10%

5.2 A gas turbine is supplied with 60 kg/s of gas at 5 bar and 800°C and expands it isentropically to 1 bar. Take the mean specific heats of the gas at constant-pressure and constant-volume to be 1 kJ/kg K and 0.717 kJ/kg K respectively. Calculate the exhaust gas temperature and the power developed in MW.

Ans: (i) 680.44 K (ii) 23.55 MW

5.3 An open-cycle gas turbine receives air at 0.98 bar and 23°C. The air is compressed to 5.25 bar and reaches a maximum temperature of 650°C before entering into the turbine. The hot air expands back to 0.98 bar. Assuming air-standard cycle and for unit mass flow rate, compute the thermal efficiency of the plant if the compression and expansion processes are isentropic. What is the ratio of the work required to drive the compressor to the work developed by the turbine.

Ans: (i) 38.13% (ii) 0.5183

5.4 In a gas turbine plant the air enters the compressor at 1 bar and 300 K. The pressure ratio is 5. The temperature at the turbine inlet is 1200 K. The mass rate of flow is 12 kg/s.

Sketch the cycle on p-V and T-s planes and indicate the area representing the heat supply, heat rejection and net work of the cycle. Determine,

(i) compressor and turbine work,
(ii) net work developed,
(iii) the ratio of turbine work to compressor work, and
(iv) the thermal efficiency.

Ans: (i) 2116.53 kW; 5341.37 kW (ii) 3224.84 kW
(iii) 2.5236 (iv) 36.9%

5.5 In an air-standard cycle heat supply is at constant-volume and the heat rejection is at constant-pressure. The compression and expansion are isentropic and the air at the start of the compression is at 30°C and 1 bar. The pressure ratio is 6. The heat supply is 860 kJ/kg of air and air flow is 2.0 kg/s. Assume C_p = 1.005 kJ/kg K and C_v = 0.717 kJ/kg K. Calculate

(i) temperature at the end of each processes,
(ii) the power developed, and
(iii) the thermal efficiency.

Ans: (i) 505.82 K; 1705.26 K; 721.56 K
(ii) 1569.6 kW (iii) 91.25%

5.6 The inlet pressure and temperature before compression in a Joule cycle are 1 atm and 300 K respectively. What will be the *imep* of the cycle when the pressure ratio is 2.0 and peak temperature at the end of combustion is 2200 K.

Ans: 0.7218 bar

5.7 If an ideal regenerator is added to the above cycle, for the same temperature and pressure ranges as for the previous problem, calculate the work done and efficiency.

Ans: (i) 331.8 kJ/kg (ii) 83.4%

5.8 A simple ideal gas turbine works with a pressure ratio of 8. The compressor and turbine inlet temperatures are 300 K and 800 K respectively. If the volume flow rate is 250 m^3/s, compute the net power output and cycle efficiency.

Ans: (i) 33.557 MW (ii) 44.75%

5.9 A gas turbine power plant, working on an air-standard cycle, the heat supply is at constant-volume and heat rejection is at constant-pressure. The compression and expansion are isentropic. The atmospheric temperature and pressure are 27°C and 1 atm respectively. The pressure ratio is 9. The heat supply is 600 kJ/kg of air. For an air flow of 3 kg/s calculate, (i) temperature at the end of each process, (ii) the net power developed and (iii) the thermal efficiency. Draw the p-V and T-s diagrams.

Ans: (i) 562 K; 1398.8 K; 574.9 K
(ii) 1694.12 kW (iii) 94.1%

5.10 A turbine supplied with gas at 5.15 bar and 800°C and expands it isentropically to 1.03 bar. If the mean specific heat of the gas at constant-pressure and constant-volume are 1 kJ/kg K and 0.717 kJ/kg K respectively. The air inlet temperature to compressor is at 30°C. Calculate (i) the exhaust temperature and (ii)the power developed in kJ per kg of gas per minute.

Ans: (i) 680.4 K (ii) 13068 kJ/kg

5.11 An open-cycle gas turbine plant receives air at 1 bar and 23°C. The air is compressed to 5.5 bar and reaches a maximum temperature of 700°C in the cycle. The hot air expands back to 1 bar. Assuming air-standard cycle, compute thermal efficiency of the plant if the compression and expansion are isentropic. What is the ratio of work required to drive the compressor to the work developed by the turbine.

Ans: (i) 38.6% (ii) 0.495

5.12 In a gas turbine plant the air at 10°C and 1 bar is compressed to 4 bar with compressor efficiency of 100%. The air is heated in the regenerator having 100 per cent effectiveness and the combustion chamber till its temperature is raised to 700°C and has a pressure drop of 0.14 bar. Determine the thermal efficiency of the plant. *Ans:* (i) 55.9%

5.13 A gas turbine operating between pressure limits of 1.5 bar and 5.5 bar. The inlet air temperature of the compressor is 20°C and the air entering the turbine is at a temperature of 560°C. If the volume rate of air entering the compressor is 1600 m^3/min, determine the available power output for the cycle. Assume that the cycle operates under ideal conditions. *Ans:* (i) 6057.57 kW

5.14 In a regenerator gas turbine cycle, air enters the compressor at a temperature and pressure of 30°C and 1.5 bar and discharges at 220°C and 5.2 bar. After passing through the regenerator the air temperature is 395°C. The temperature of air entering and leaving the gas turbine are 900°C and 510°C. Assuming no pressure drop through the regenerator, determine (i) the output per kg of air, (ii) the efficiency of the cycle and (iii) the work required to drive the compressor.

Ans: (i) 201 kJ/kg (ii) 39.6% (iii) 190.95 kJ/kg

5.15 Compare the maximum work delivered by an aircraft gas turbine which works in the following two atmospheric conditions (two-stage compression with perfect intercooling, but without reheat and regeneration). Compressor pressure ratio is 4 and metallurgical temperature limit is 1000 K. At ambient conditions: pressure = 1 atm and temperature = 28°C and at 6000 m altitude : pressure = 0.5 atm and temperature = −25°C. Find the percentage change in Net work output, efficiency and exhaust temperature if the volume flow rate of air is 2.5 m^3/s.

Ans: (i) 32.11% decrease (ii) 1.34% increase (iii) Nil

5.16 A closed-cycle gas turbine (with reheat) power plant operates using helium as the working medium. The pressure ratio is 10. The maximum permitted temperature is 1000 K. Assuming the work output to be maximum, calculate the efficiency. If air is used instead of helium, calculate the efficiency and difference in heat added. Assume ideal Brayton cycle. Temperature at the inlet of compressor = 27°C, C_p of helium = 5.204 kJ/kg K and γ of helium = 1.67.

Ans: (i) 40.16%; 46.23% (ii) 2490.22 kJ/kg

5.17 A Brayton cycle operates with ideal air between 1 bar, 300 K and 5 bar, 1000 K. The air is compressed in two stages with perfect intercooling. Similarly in the turbine expansion occurs in two stages with perfect reheating. Calculate the optimum pressure in bar, net work output and the fraction of turbine output that has to be put back to compressor (W_C/W_T)

Ans: (i) 2.236 bar (ii) 257.3 kJ/kg (iii) 0.378

5.18 A gas turbine unit operates at a mass flow of 30 kg/s. Air enters the compressor at a pressure of 1 bar and temperature 15°C and is discharged from the compressor at a pressure of 10.5 bar. Combustion occurs at constant-pressure and results in a temperature rise of 420 K. If the flow leaves the turbine at a pressure of 1.2 bar, determine the net power output from the unit and also the thermal efficiency.

Ans: (i) 5388.74 kW (ii) 42.55%

5.19 An ideal open-cycle gas turbine plant using air operates on an overall pressure ratio of 4 and between the temperature limits of 300 K and 1000 K. Assuming constant specific heats, C_p = 1.005 kJ/kg K and