Ref. No Ex/ME/T/412/2019

B.E. MECHANICAL ENGINEERING FOURTH YEAR FIRST SEMESTER EXAMINATION, 2019

Refrigeration and Air-conditioning

Time: Three hours **Full Marks 100**

All parts of the same question must be answered together. Assume any unfurnished data suitably

Use of Thermodynamic Tables and Charts permitted

Group I

Answer any one question

Q:1.(a) Does the ideal vapor-compression refrigeration cycle involve any internal irreversibilities? Why is the throttling valve not replaced by an isentropic turbine in the ideal vapor-compression refrigeration cycle? 3

(b) In a reversed Carnot refrigerator system of 1 TR cooling capacity running on a perfect gas heat is absorbed at -10°C and rejected at 30°C. Find the states of all the points of the cycle, heat transfer and work done in all the processes, mass flow rate, volume flow rates, and the COP. The maximum pressure ratio is 5 and the pressure at inlet to the isentropic compressor is standard atmospheric pressure. Take $C_p = 1.005$ kJ/kgK and $\gamma = 1.4$. 12

Q:2(a) Explain the following terms (i) dew point temperature (ii) wet bulb temperature (iii) Evaporative cooling. 6

(b) When are the dry-bulb and dew-point temperatures identical? When are the adiabatic saturation and wet-bulb temperatures equivalent for atmospheric air? 4

(c) The dry-bulb temperature and the dew point temperature of moist air at standard atmospheric pressure are 21°C and 15°C respectively. Find the humidity ratio, the degree of saturation, the relative humidity, the specific enthalpy and the specific volume using the psychrometric chart. 5

Group II

Answer any three questions

Q:3 The condensing and evaporating pressures in a 10 TR refrigeration system are 11.82 bar and 1.64 bar respectively. The refrigerant enters the compressor at dry and saturated state and leaves the condenser subcooled by 10°C. The actual COP is 70% of its theoretical value. Determine the mass flow rate, theoretical and actual COPs and the compressor power for a single stage R22 saturation cycle. 16

Q:4 A two-stage compression refrigeration system operates with refrigerant-134a between the pressure limits of 1 and 0.14 MPa. The refrigerant leaves the condenser as a saturated liquid and is throttled to a flash chamber operating at 0.5 MPa. The refrigerant leaving the low-pressure compressor at 0.5 MPa is also routed to the flash chamber. The vapor in the flash chamber is then compressed to the condenser pressure by the high-pressure compressor, and the liquid is throttled to the evaporator pressure. Assuming the refrigerant leaves the evaporator as saturated vapor and both compressors are isentropic,

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determine (a) the fraction of the refrigerant that evaporates as it is throttled to the flash chamber, (b) the rate of heat removed from the refrigerated space for a mass flow rate of 0.25 kg/s through the condenser, and (c) the coefficient of performance. 16

Q:5 Determine the mass flow rate, heat rejection, compressor work, turbine work, COP and the volume flow rates at inlet to compressor and at outlet of turbine for a system of 1 TR cooling capacity. The working substance is air. If the isentropic compressor and turbine efficiencies are 0.8 and 0.85 respectively, then determine all the parameters. 16

Q:6 Refrigerant-134a enters the compressor of a refrigerator as superheated vapor at 0.14 MPa and -10°C at a rate of 0.05 kg/s and leaves at 0.8 MPa and 50°C. The refrigerant is cooled in the condenser to 26°C and 0.72 MPa and is throttled to 0.15 MPa. Disregarding any heat transfer and pressure drops in the connecting lines between the components, determine (a) the rate of heat removal from the refrigerated space and the power input to the compressor, (b) the isentropic efficiency of the compressor, and (c) the coefficient of performance of the refrigerator. 16

Q:7 The dry and the wet-bulb temperatures of atmospheric air at 1 atm (101.325 kPa) pressure are measured with a sling psychrometer and determined to be 25°C and 15°C, respectively. Determine (*a*) the specific humidity, (*b*) the relative humidity, and (*c*) the enthalpy of the air using the perfect gas relations. 16

Group III
Answer any one question

Q:8 Draw the schematic of ammonia-water or water-LiBr vapour absorption refrigeration system and explain its working principle. How is the coefficient of performance of an absorption refrigeration system defined? 10

Q:9 (a) Derive an expression for the maximum COP of a vapour absorption refrigeration system. 7

(b) How does a vapour absorption system differ from a vapour compression system? 3

Group IV
Answer any one question

Q:10 Catalog data for a six-cylinder refrigerant 22 compressor operating at 29 r/s indicate a refrigerating capacity of 96.4 kW and a power requirement of 28.9 kW at an evaporating temperature of 5°C and condensing temperature of 50°C. The performance data are based on 3°C liquid subcooling and 8°C superheating of the suction gas entering the compressor. The cylinder bore is 67 mm and the piston stroke is 57 mm. Compute (a) the clearance volumetric efficiency if the clearance volume is 4.8 percent, (b) the actual volumetric efficiency and (c) the compression efficiency. 15

Q:11 Show that the work required for single stage compression is more than that for two stage compression with intercooling up to saturated state for R22 between evaporator and condenser temperatures of −40°C and 40°C respectively. Consider intercooling temperature of -8 °C 15

Group V

Answer any one question

Q:12 Show a simple aircraft refrigeration cycle with ram compression on a T-s or p-h plane. Obtain the relation between different important state points in the cycle. 12

Q:13 An air-conditioning system is to take in outdoor air at 10°C and 30 percent relative humidity at a steady rate of 45 m^3/min and to condition it to 25°C and 60 percent relative humidity. The outdoor air is first heated to 22°C in the heating section and then humidified by the injection of hot steam in the humidifying section. Assuming the entire process takes place at a pressure of 100 kPa, determine (a) the rate of heat supply in the heating section and (b) the mass flow rate of the steam required in the humidifying section. 12