ME 306

Refrigeration Tutorial Sheet

Q1. A refrigerator uses refrigerant-134a as the working fluid and operates on an ideal vapor-compression refrigeration cycle between 0.14 and 0.8 MPa. If the mass flow rate of the refrigerant is 0.05 kg/s, determine:

(a) the rate of heat removal from the refrigerated space and the power input to the compressor.

(b) the rate of heat rejection to the environment, and

(c) the COP of the refrigerator.

Q2. A heat pump working on a reversed Carnot cycle is used to supply 80 kW of heat for maintaining the rooms of a building at 20◦C when the outside temperature is 0◦C. Determine (a) the COP of the system, (b) power consumed by the heat pump, and (c) heat absorbed from the atmosphere outside. Determine the power consumption if direct electric heating is used.

Q3. An ammonia ice plant operates on a simple saturation cycle at the following temperatures. Condensing temperature 40°C Evaporating temperature -15°C It produces 10 tons of ice per day at -5°C from water at 30°C. Determine:

i) Capacity of refrigeration plant.
ii) The mass flow rate of refrigerant.
iii) Isentropic discharge temperature.
iv) Compressor dimensions (bore and stroke) if its volumetric efficiency is assumed as 65%. The compressor is to run at 1400 rpm. Take the stroke/bore ratio (L/D) as 1.2.

Q4. In a vapor compression cycle saturated liquid refrigerant-22 leaving the condenser at 40°C is required to expand to an evaporator temperature of 0°C in a cold storage plant.

i) Determine the percentage saving in the net work of cycle per kg of refrigerant if an isentropic expander could be used in place of a throttling device.
ii) Also, determine the percentage increase in refrigerating effect per kg of refrigerant as a result of the use of an expander. Assume that compression is isentropic from the saturated vapour state at 0°C to the condenser pressure.

Q5. An ammonia refrigeration system operates between a saturated suction temperature of -20°C and a saturated discharge temperature of +40°C. Compare the COP of the cycle using wet compression to that of the cycle using dry compression. Assuming that vapour leaving the compressor is saturated in case of wet compression and the vapour entering the compressor is saturated in case of dry compression. The condenser exit is saturated liquid.

Q6. A standard vapour compression cycle using Freon 22 operates on a simple saturation cycle at the following conditions: Refrigeration capacity 15 TR Condensing temperature 40°C Evaporating temperature 5°C Calculate:

i) Refrigerant circulation rate in kg/s.

ii) Power required by the compressor in kW.

iii) Coefficient of performance.

iv) The volume flow rate of the refrigerant at compressor suction.

v) Compressor discharge temperature.

vi) Suction vapour volume and power consumption per ton of refrigeration.

Q7. An R134a simple vapor compression cycle refrigerator operates at 40°C condenser and −16°C evaporator temperatures. The ratio of horsepower to ton of refrigeration (HP/TR)? Properties of R134a are given below.

Tsat	Psat(mpa)	hf(kj/kg)	hg(kj/kg)	sf(kj/kgk)	sg((kj/kgk	cp(kj/kgk)
40	1.0166	256.41	419.43	1.1905	1.7111	1.145
16	0.15728	178.83	389.02	0.9205	1.7319	0.831

Q8. In a vapor-compression refrigeration cycle, ammonia exits the evaporator as saturated vapor at -22◦C. The refrigerant enters the condenser at 16 bar and 160◦C, and saturated liquid exits at 16 bar. There is no significant heat transfer between the compressor and its surroundings, and the refrigerant passes through the evaporator with a negligible change in pressure. If the refrigerating capacity is 150 kW, determine

(a) the mass flow rate of refrigerant, in kg/s,

(b) the power input to the compressor, in kW,

(c) the coefficient of performance and

(d) the isentropic compressor efficiency

Q9. A vapor compression cycle with R–134a has −10◦C as the evaporation temperature and +35◦C as the condensation temperature. Determine (a) all state points, (b) COP, (c) power consumption in kW/tonne. (d) Repeat the calculations for a low-temperature cycle with evaporator and condenser temperatures as −20◦C and +40◦C.

Q10. A refrigerator uses R-22 as the working fluid and operates on an ideal vapor compression refrigeration cycle. This system operates between 0.4 and 1.6 MPa respectively. (a) Determine COP of the system. (b) If the vapor is superheated by 6.56°C by useful superheating before entering the compressor, while keeping the other parameters unchanged, determine the new COP of the system. Provide comments on the result by making a comparison with (a).

Q11. A refrigerant R-134a vapour compression cycle includes a liquid - vapour regenerative heat exchanger in the system. The heat exchanger cools saturated liquid at 0.8 MPa coming out of the condenser with the help of saturated vapour coming out of the evaporator at 0.2 MPa. The inlet to the compressor is a superheated vapour at 0°C. The compression is isentropic. Find COP of the system with and without the heat exchanger.

Q12. Two stage R-22 based refrigeration cycle operating between -40°C and 40°C use flash chamber as intercooler. Capacity of cycle is 20TR. Find the total work input and compare it with the single stage refrigeration cycle. Comment on the usability of the flash intercooling system.

Q13. A two-stage refrigeration system is operating between the pressure limits of 8 bar and 1.4 bar. The working fluid is R-134a. The refrigerant leaves the condenser as a saturated liquid and is throttled to a flash chamber operating at 3.2 bar. The part of refrigerant evaporates during the flashing process and this vapour is mixed with the refrigerant leaving the low pressure compressor. The mixture is then compressed to the condenser pressure by the high pressure compressor. The liquid in the flash chamber is throttled to the evaporator pressure and cools the refrigerated space as it vaporises in the evaporator. Assuming the refrigerant leaves the evaporator as a saturated vapour and both compressions are isentropic, determine:

a) The fraction of refrigerant that evaporates as it is throttled to the flash chamber.

b) The amount of heat removed from the refrigerated space and the compressor work per unit mass of refrigerant flowing through the condenser.

c) The coefficient of performance.

Q14. The required refrigeration capacity of a vapour compression refrigeration system (with R- 22 as refrigerant) is 100 kW at -30°C evaporator temperature. Initially the system was single-stage with a single compressor compressing the refrigerant vapour from evaporator to a condenser operating at 1500 kPa pressure. Later the system was modified to a two- stage system. At the intermediate pressure of 600 kPa there is intercooling but no removal of flash gas. Find

a) Power requirement of the original single stage system.

b) Total power requirement of the two compressors in the revised two-stage system. Assume that the state of refrigerant at the exit of evaporator, condenser and intercooler is saturated, and the compression processes are isentropic.