VIT
Vellore Institute of Technology

# Final Assessment Test – November/December 2023

Course: BMEE203L - Engineering Thermodynamics

Class NBR(s): 1706 / 1707 / 1708 / 1709 / 1711 / 1879 Slot: **D1+TD1**

Time: **Three Hours** Max. Marks: **100**

**KEEPING MOBILE PHONE/SMART WATCH, EVEN IN 'OFF' POSITION, IS TREATED AS EXAM MALPRACTICE**

**General Instructions:**

- **Use of Steam Table, Mollier Chart, p-h Chart, and Compressibility Chart are permitted.**
- **Assume suitable data, if necessary.**

**Answer any FIVE Questions**

**(5 X 20 = 100 Marks)**

1. a) (i) Boyle's law states the pressure and volume of a system are inversely proportional to each other, by keeping the temperature fixed. List out the intensive and extensive properties of this system. **[2]**

(ii) The average body temperature of a person rises by 2°C during a strenuous exercise. What is the rise in his body temperature in °F during the exercise? **[2]**

(iii) Can there be any process where $\delta W = 0$? Justify with an example. **[2]**

(iv) You are holding 10 gm of solid ice in your hand. Give the direction of heat transfer by considering you as the system and ice as the system. **[2]**

(v) All the cyclic processes are not reversible. Justify. **[2]**

b) A classroom with 60 students is to be air-conditioned with a window air-conditioning unit of 5 kW cooling capacity. A student at rest may be assumed to dissipate heat at a rate of about 360 kJ/h. There are 10 tube lights and 5 ceiling fans in the classroom, each with a rating of 40 W and 60 W, respectively. The heat transfer rate to the classroom through the walls and the windows is estimated to be 15000 kJ/h. The room air is maintained at a constant temperature of 21°C.

(i) Write down the energy balance for the classroom. **[5]**

(ii) Determine the number of window air-conditioning units to be installed in the classroom. **[5]**

2. a) A mixture of saturated liquid water and dry saturated steam is kept inside a vessel of capacity 0.09 $m^3$ at a temperature of 200°C. The mass of the liquid water is found to be 10 kg.

(i) Represent the condition of the steam in the property diagram. **[1]**

Determine the following.

(ii) The volume of the liquid water. **[2]**

(iii) The mass of the steam. **[3]**

(iv) The enthalpy of the mixture. **[4]**

b) A spherical-shaped balloon of 12 cm diameter contains $H_2$ at 30°C and 1.2 bar. Determine the mass of $H_2$ in the balloon using the following models.

(i) Ideal gas. **[3]**

(ii) Compressibility factor chart, by considering **[4]**
Pc = 1.297 bar, Tc = 150 K.

(iii) Vander Wall's equation with the constants **[3]**
$a = 5.525 \frac{m^6 bar}{kgmol^2}$, $b = 0.03042 \frac{m^3}{kgmol}$

3\. a) 2 kg of air undergoes a cyclic process represented by a rectangle on a P-V diagram as shown in Figure below. The maximum and minimum pressures of the cycle are 6 bar and 1 bar respectively while the maximum and minimum volumes are 2.3 $m^3$ and 1.6 $m^3$ respectively. Determine the following.

(i) The magnitude of heat transfer for the process 1-2. **[2]**

(ii) Change in internal energy for the process 2-3. **[3]**

(iii) Show that for this cyclic process, the net heat transfer is the same as that of the network transfer. **[5]**

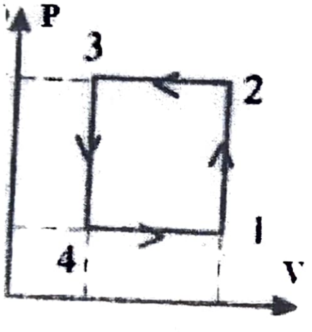


Figure: Cyclic Process

b) Air at a temperature of 20°C passes through a Heat exchanger at a velocity of 40 m/s where its temperature is raised to 820°C. It then enters a turbine with the same velocity of 40 m/s and expands till the temperature falls to 620°C. The airflow rate is 2.5 kg/s.

(i) Give a schematic diagram for the arrangement and make suitable assumptions for the analysis. **[2]**

Calculate the following.

(ii) Heat transfer rate to the air in the Heat exchanger. **[4]**

(iii) The power output from the turbine, assuming no heat loss. **[4]**

4\. a) A reversible air-conditioner (AC) removes 1000 kJ/s of heat from a room maintained at 25°C. The air-conditioner rejects the heat to the environment at 40°C. The air-conditioner is driven by a reversible heat engine which receives heat from a reservoir at 200°C and rejects the heat to the environment kept at the same temperature of 40°C.

(i) Give the schematic diagram for the arrangement. **[2]**

Determine the following.

(ii) Input power to the AC. **[3]**

(iii) Heat received by heat engine from the reservoir. **[3]**

(iv) Efficiency of the heat engine. **[2]**

b) 5 kg of water at 60°C is mixed with 7 kg of water at 20°C in an isolated system. The system is made isolated using an adiabatic wall.

(i) Calculate the entropy change of the whole system due to the mixing. **[6]**

(ii) Now the adiabatic walls are removed, which allows a heat transfer of 10 J to the surroundings at 25°C. Determine net entropy change for this condition. **[3]**

(iii) Check whether both cases execute reversible/ irreversible/impossible processes. **[1]**

5. a) A steam power plant operates on an ideal reheat Rankine cycle. Steam entering the boiler at 150 bar is superheated to 550°C before expanding in a high-pressure turbine. It is then reheated at a constant pressure of 40 bar to 550°C and expands in a low-pressure turbine to a condenser pressure of 0.1 bar.

(i) Represent the cycle in the T-s and h-s diagram. **[2]**

Determine the following.

(ii) Quality of steam at turbine (low-pressure) exhaust. **[3]**

(iii) Cycle efficiency. **[5]**

b) An engine with a 200 mm cylinder diameter and 300 mm stroke length works on a theoretical Diesel cycle. The compression ratio of the cycle is 15 and the working fluid is air. The initial pressure and temperature of air are 1 bar and 27°C respectively. The cut-off is 8% of the stroke. Assume all conditions to be ideal with constant specific heats.

(i) Represent the cycle in the p-v and T-s diagram. **[2]**

Determine the following.

(ii) Pressures and temperatures at all salient points. **[5]**

(iii) The air standard efficiency. **[3]**

6. The pressure and temperature of the mixture of 4 kg of $O_2$ and 6 kg of $N_2$ are 4 bar and 27°C respectively. For the mixture determine the following.

(i) The mole fraction of each component. **[4]**

(ii) The average molecular weight of the mixture. **[3]**

(iii) The specific gas constant of the mixture. **[3]**

(iv) The volume and density of the mixture. **[4]**

(v) The partial pressures and partial volumes. **[6]**

7\. a) Give the physical significance of Clausius's Clapeyron equation. Derive an expression for the slope of the P-T diagram of water using this equation. Prove the relation between saturation pressure and saturation temperature as $\ln P = A + B/T$; where A and B are constants. **[2+3+5]**

b) Give the function of different components of an ideal vapor power cycle. Explain its detailed working principle with a neat schematic diagram. Using the principle of steady flow energy balance, derive an expression for the cycle efficiency. Suggest suitable methods to improve the cycle efficiency. **[3+3+2+2]**

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