

**ENGINEERING THERMODYNAMICS
(MEC2103)**

Time Allotted : 2½ hrs

Full Marks : 60

Figures out of the right margin indicate full marks.

*Candidates are required to answer Group A and
any 4 (four) from Group B to E, taking one from each group.*

Candidates are required to give answer in their own words as far as practicable.

Group – A

1. Answer any twelve:

12 × 1 = 12

Choose the correct alternative for the following

- (i) Specific properties of the system
(a) are always extensive (b) are always intensive
(c) depend on a particular quantity of mass (d) can be any of these
- (ii) A PMM-1
(a) violates 1st law of thermodynamics
(b) violates 2nd law of thermodynamics
(c) violates 3rd law of thermodynamics
(d) does not violate any law
- (iii) The set of independent intensive properties that cannot be used to designate the state of a saturated liquid-vapour mixture is
(a) P and v (b) P and T (c) P and x (d) T and v
- (iv) Solids and liquids have
(a) one value of specific heat (b) two values of specific heats
(c) three values of specific heats (d) no particular value of specific heat
- (v) A pure substance must have homogeneous
(a) molecular structure (b) chemical composition
(c) phase (d) all of these
- (vi) A reversible refrigerator has COP of 9 with the freezer temperature of -3°C. The ambient temperature is
(a) 27°C (b) 30°C (c) 35°C (d) 37°C
- (vii) The value of $\oint Tds$ in a reversible cycle is equal to the
(a) net heat transfer which is more than the net work transfer
(b) net work transfer which is less than the net heat transfer
(c) net heat transfer which is equal to the net work transfer
(d) none of these

- (viii) If dry saturated steam is admitted to a steam turbine then after the isentropic expansion process at the exit of the turbine, it will be a
 (a) superheated steam (b) dry saturated steam
 (c) liquid condensate (d) wet steam
- (ix) Thermal efficiency of an air standard Diesel cycle depends only on
 (a) ratio of specific heats (b) cut off ratio
 (c) compression ratio (d) all of these
- (x) The ideal intermediate pressure for minimum work in a two stage compressor with intercooler is
 (a) $\sqrt{p_1 \cdot p_2}$ (b) $(p_1 + p_2)/2$
 (c) $(p_1 + p_2 + 2\sqrt{p_1 \cdot p_2})/4$ (d) $(p_1 + p_2 + \sqrt{p_1 \cdot p_2})/3$

Fill in the blanks with the correct word

- (xi) If X is a property, the value of $\oint dX =$
- (xii) A steady flow device that increases the pressure of a fluid at the expense of its kinetic energy is called _____
- (xiii) An ideal Rankine cycle is composed of two isentropics and two _____.
- (xiv) Zeroth law: Temperature::Second law: _____ .
- (xv) Heat transferred to an ideal gas in a rigid container is the change in the values of the property _____

Group - B

2. (a) A piston-cylinder device contains 1 kg of an ideal gas at 1 bar. The initial volume is 0.05 m^3 . Heat is supplied to the gas slowly in such a way that the gas expands in a quasi-static manner to 0.45 m^3 . During the expansion the pressure remains constant. Determine (i) the work done (ii) the change in internal energy (iii) the heat transfer to the gas. [[CO3](Apply/IOCQ)]
- (b) 1.5 kg of liquid having constant specific heat of $2.5 \text{ kJ/kg}^\circ\text{C}$ is stirred in a well-insulated tank causing the temperature to rise by 15°C . Apply the first law of thermodynamics and determine heat transfer, work transfer and change in internal energy with proper sign. [[CO3](Apply/IOCQ)]
- 7 + 5 = 12**
3. (a) A close system contains a fluid system which passes through a complete cycle consisting of four processes. The sum of all heat transfers during the cycle is -17000 kJ. Complete the following table showing the detailed calculations and compute the net work output during the cycle in kJ.

Process	Q (kJ)	W (kJ)	ΔE (kJ)
a - b	0	2170	?
b - c	21000	0	?
c - d	-2100	?	-36600
d - a	?	?	?

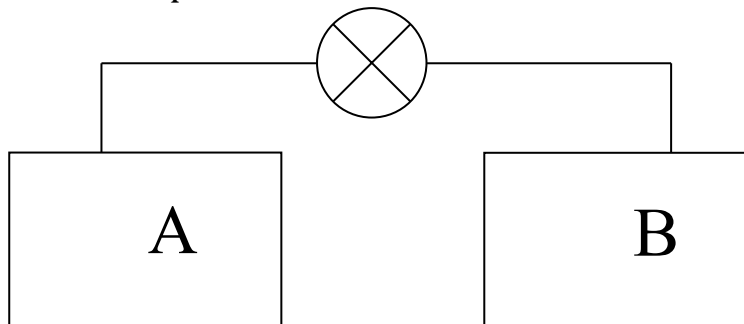
[[CO3](Apply/IOCQ)]

- (b) An elastic sphere initially has a diameter of 1 m and contains a gas at a pressure of 1 bar. Due to heat transfer, the diameter of the sphere increases to 1.1 m. During the heating process the gas pressure inside the cylinder is proportional to the sphere diameter. Calculate the work done by the gas. [[CO3](Analyse/HOCQ)]
5 + 7 = 12

Group - C

4. (a) Determine the state of steam, i.e., whether it is wet (with dryness fraction), dry or superheated (with degree of superheat), as the case may be in the following cases.
 (i) Steam at 10 bar with specific volume $0.175 \text{ m}^3/\text{kg}$
 (ii) Steam at 15 bar and 220°C . [[CO2](Understand/LOCQ)]
- (b) A spherical shell of 30 cm internal radius contains a mixture of saturated liquid and saturated vapour at 300°C . Calculate the mass of each if their volumes are equal. [[CO2](Understand/LOCQ)]
6 + 6 = 12

5. (a) Tank A has a volume 0.4 m^3 and contains steam at 200°C , 10% saturated liquid, 90% saturated vapour, by volume. An evacuated tank B is connected to tank A via a valve. The valve is now opened slowly and the tanks eventually come to same pressure which is found to be 4 bar. During the process, heat is transferred such that the final temperature remains 200°C . Find the volume of the tank B.



- [[CO3](Apply/IOCQ)]
- (b) Steam enters a turbine at 120 bar, 400°C . At the exit of the turbine, pressure is 1 bar and the entropy is 0.5 J/g.K greater than that at the inlet. The process is adiabatic and the changes in KE and PE may be neglected. Find the work done by the steam in kJ/kg. What is the mass flow rate required for a power output of 1000 kW? [[CO3](Apply/IOCQ)]
6 + 6 = 12

Group - D

6. (a) Write the Kelvin Planck and Clausius statements of second law of Thermodynamics. Show that the violation of one leads to the violation of the other. [[CO4](Analyse/IOCQ)]
- (b) A Carnot engine has an efficiency of 40%. If the engine is reversed, determine the COPs of the corresponding refrigerator and the heat pump. [[CO4](Apply/IOCQ)]
8 + 4 = 12

7. (a) A system undergoes a reversible cycle that involves heat transfer with three thermal reservoirs at temperature T_1 , T_2 and T_3 with corresponding heat transfer quantities Q_1 , Q_2 and Q_3 , all into the system without any net work output from it. Examine the validity of the following relation (regardless of the actual processes involved):

$$\frac{Q_1}{\frac{1}{T_2} - \frac{1}{T_3}} = \frac{Q_2}{\frac{1}{T_3} - \frac{1}{T_1}} = \frac{Q_3}{\frac{1}{T_1} - \frac{1}{T_2}} \quad [[CO6](Apply/IOCQ)]$$

- (b) A reversible heat engine absorbs heat from three thermal reservoirs at 1000 K, 800 K and 600 K. The engine delivers 10 kW of net work and rejects 400 kJ/min of heat to a sink at 300 K. The heat supplied by the reservoir at 1000 K is 60% of that supplied by the reservoir at 600 K. Make calculations for the quantities of heat supplied from each reservoir.

[[CO4](Apply/IOCQ)]

6 + 6 = 12

Group - E

8. (a) In a Rankine cycle, dry saturated steam at 100 bar is fed to the turbine where it expands adiabatically to a condenser pressure of 0.05 bar. What is the cycle efficiency? What is the steam rate? Assume all the processes as ideal. What is the efficiency of a Carnot cycle with temperatures corresponding to turbine entry and exit?

[[CO5](Analyse/IOCQ)]

- (b) Name and explain the four processes of an air standard Diesel cycle with the help of a $p - v$ diagram. What is cut off ratio and how does it affect the efficiency of a Diesel cycle?

[[CO2](Understand/LOCQ)]

6 + 6 = 12

9. (a) In a thermal power plant steam from boiler at 20 bar, 360°C is supplied to the turbine and expanded to 0.08 bar. The exhaust from the turbine is passed through a condenser which condenses it to saturated liquid water. The pump feeds back the water to the boiler. Assuming ideal processes, determine the following: (i) turbine work (ii) pump work (iii) cycle efficiency.

[[CO5](Analyse/IOCQ)]

- (b) A single cylinder reciprocating air compressor has a bore of 150 mm and stroke of 180 mm, and is driven at 1500 rpm. It is compressing CO_2 gas from a pressure of 120 kPa and a temperature of 20°C to a temperature of 215°C. Assuming polytropic compression with $n = 1.3$, no clearance and volumetric efficiency of 100 %, calculate (i) pressure ratio (ii) indicated power (iii) shaft power, with a mechanical efficiency of 80 % (iv) mass flow rate.

[[CO6](Evaluate/HOCQ)]

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	18.75	67.71	13.54