

MECHANICAL ENGINEERING
(Paper II)

Time Allowed : Three Hours

Maximum Marks : 300

QUESTION PAPER SPECIFIC INSTRUCTIONS

(Please read each of the following instructions carefully before attempting questions)

There are EIGHT questions divided in two Sections.

Candidate has to attempt FIVE questions in all.

Question Nos. 1 and 5 are compulsory and out of the remaining, any THREE are to be attempted choosing at least ONE question from each Section.

The number of marks carried by a question/part is indicated against it.

Wherever any assumptions are made for answering a question, they must be clearly indicated.

Word limit in questions, wherever specified, should be adhered to.

SECTION 'A'

1. Answer any three of the following:

20×3=60

(a) Prove the following for an ideal gas:

$$dS = \frac{dV}{V} + C_v \frac{dP}{P}$$

Using this result show that for an ideal gas undergoing an isentropic change of state with constant specific heat $P V^\gamma = \text{constant}$.

(b) Give the Kelvin-Planck's and Clausius' statements of Second Law of Thermodynamics and show that violation of either statement implies violation of the other. A Carnot engine I operates between two reservoirs at temperatures of 2000 K and T K. Another Carnot engine II operates between the reservoirs at T K and 300 K. If both the engines have the same efficiency, determine the value of T.

(c) Explain the following: (i) Why is rich mixture used during idling? (ii) As the engine speed increases, the ignition timing should be advanced. (iii) S.I. engines are generally not supercharged. (iv) Two stroke cycle engines find wider applications either in small two-wheelers or in large marine propulsion engines.

(d) Determine the air-fuel ratio at 6000 m altitude in a carburettor adjusted to give an air-fuel ratio of 15:1 at sea level where air temperature is 27° C and pressure is 1.013 bar. The temperature of air decreases with altitude and is given by the expression $t = t_s - 0.0065 h$ where h is height in metres and t_s is the sea level temperature in °C. The air pressure decreases with altitude as per the relation

$$h = 19220 \log_e \left(\frac{1.013}{P} \right)$$

where P is in bar.

2. (a) A pressure vessel is connected, via a valve, to a gas main in which gas is maintained at a constant pressure and temperature of 1.4 MN/m^2 and 85° C respectively. The pressure vessel is initially evacuated. The valve is opened and a mass of 2.7 kg of gas passes into the pressure vessel. The valve is closed and the pressure and temperature of the gas in the pressure vessel are then 700 kN/m^2 and 60° C, respectively. Determine the heat transfer to or from the gas in the vessel. Determine the volume of gas before transfer. For the gas, take $C_p = 0.88 \text{ kJ/kg K}$, $C_v = 0.67 \text{ kJ/kg K}$. Neglect the velocity of the gas in the main.

30

- (b) A perfectly insulated chamber is divided in two parts by a diaphragm. 1.0 kg of oxygen is stored in one part while 7.0 kg of hydrogen is stored in another part. Both the gases are at the same temperature and pressure of 450 K and 1.0 bar respectively. They are mixed together by removing the diaphragm. Determine the loss in availability after mixing if the surrounding temperature is 290 K. The value of universal gas constant $R_0 = 8314 \text{ J/k g - mol - K}$. **30**
3. (a) The air flow to a four cylinder 4-stroke oil engine is measured by means of a 4.5 cm diameter orifice, having $C_d = 0.65$. During a test the following data was recorded: Bore = 10 cm, Stroke = 15 cm, Engine speed = 1000 RPM, Brake torque = 135 Nm, Fuel consumption = 5.0 kg/hour, $C V_{fuel} = 42600 \text{ k J/k g}$, Head across orifice = 6 cm of water, Ambient temperature and pressure are 300 K and 1.0 bar respectively. Calculate: (i) Brake thermal efficiency (ii) The brake mean effective pressure (iii) The volumetric efficiency Take $R = 287 \text{ J/kg K}$ for air. **30**
- (b) What are the different sources of emissions from an I.C. engine? Discuss the mechanism of formation of oxides of nitrogen and carbon monoxide. Explain various methods that can be used for the control of emissions of oxides of nitrogen. **30**
4. (a) An 8-cylinder, 4-stroke diesel engine has a power output of 368 kW at 800 RPM. The fuel consumption is 0.238 kg/kW-hr. The pressure in the cylinder at the beginning of injection is 35 bar and the maximum cylinder pressure is 60 bar. The injector is adjusted to operate at 210 bar and the maximum pressure in the injector is set at 600 bar. Calculate the orifice area required per injector if the injection takes place over 12° crank angle. Assume the coefficient of discharge for the injector = 0.6, specific gravity of fuel = 0.85 and the atmospheric pressure = 1.013 bar. Take the effective pressure difference to be the average pressure difference over the injection period. **30**
- (b) Describe the different phases of combustion in a S.I. engine. How should the following factors be changed to reduce the tendency of knock in a S.I. engine: (i) Compression ratio (ii) Distance of flame travel (iii) Inlet mixture temperature (iv) Turbulence Justify your answer with proper reasoning. **30**

SECTION 'B'

5. Answer any three of the following: **20×3=60**
- (a) In a double pipe counterflow heat exchanger, 10,000 kg/h of an oil, having a specific heat of 2095 J/kg K, is cooled from 80° C to 50° C by 8000 kg/h of water entering at 25° C . Determine the heat exchanger area for an overall heat transfer coefficient of $300 \text{ W/m}^2 \text{ K}$. Take C_p of water as 4180 J/kg K.
- (b) The air handling unit of an air conditioning plant supplies a total 4500 cubic metre/min of dry air which comprises 20 percent fresh air at 40° C DBT and 27° C WBT and 80 percent of recirculated air at 25° C DBT and 50% RH. The air leaves the cooling coil at 13° C saturated state. Determine the total cooling load and the room heat gain. Take specific volume of air entering the cooling coil as $0.869 \text{ m}^3/\text{kg da}$.

Condition	DBT $^\circ \text{C}$	WBT $^\circ \text{C}$	RH %	Sp. humidity g/wv/kg da	Enthalpy kJ/kg da
Outside	40	27	–	17.2	85.0
Inside	25	–	50	10.0	50.8
ADP	13	–	100	9.4	37.0

Note: ADP – Apparatus dew point wv – water vapour da – dry air.

- (c) Explain what do you understand by specific speed of a turbine. Highlight its importance. A centrifugal compressor develops a pressure ratio of 1.5 while running at 24,000 RPM and discharging 2.0 kg/s of air. The entry conditions are $P_1 = 1.0 \text{ bar}$ and $T_1 = 290 \text{ K}$. Determine the specific speed. Take $\gamma = 1.4$, $R = 287 \text{ J/kg K}$, $C_p = 1.005 \text{ k J/kg K}$.

- (d) A power plant of 210 MW installed capacity has the following particulars: Capital cost = Rs. 4 crores/MW installed Interest and depreciation = 12% Annual load factor = 60% Annual capacity factor = 54% Annual running charges = Rs. 400×10^6 Energy consumed by power plant auxiliaries = 6% Calculate: (i) The cost of power generation per kWh (ii) The reserve capacity

6. (a) A fluid at a temperature T_{∞_1} , with a heat transfer coefficient h_1 flows on one side of a slab at $x = 0$ and another fluid at a temperature T_{∞_2} with a heat transfer coefficient h_2 flows on the other side of the slab at $x = L$. Both the fluids flow in opposite directions. Develop an expression for the heat flow Q through an area 'A' of the slab. Calculate the heat transfer rate through an area of one square metre of the slab for the following data: $T_{\infty_1} = 150^\circ C$, $h_1 = 300 W/m^2 K$, $T_{\infty_2} = 50^\circ C$, $h_2 = 600 W/m^2 K$, thickness of slab = 5 cm and $K = 20 W/m K$. **30**

- (b) Define the term Nusselt number and explain its significance in the case of forced convection heat transfer. Atmospheric air at $T_\infty = 275 K$ and a free-stream velocity $u_\infty = 20 m/s$ flows over a flat plate $L = 1.5 m$ long that is maintained at a uniform temperature $T_w = 325 K$. (i) Calculate the average heat transfer coefficient h_m over the region where the boundary layer is laminar. (ii) Find the average heat transfer coefficient over the entire length $L = 1.5 m$ of the plate. (iii) Calculate the total heat transfer rate Q from the plate to the air over the length $L = 1.5 m$ and width $W = 1 m$. Assume transition occurs at $Re = 2 \times 10^5$. **30**

7. (a) A vapour compression refrigerator operates between the pressure limits of $462.47 kN/m^2$ and $1785.90 kN/m^2$. At entry to the compressor the refrigerant is dry saturated and after compression it has a temperature of $59^\circ C$. The compressor has a bore and stroke of 75 mm and runs at 8 rev/s with a volumetric efficiency of 80 percent. The temperature of the liquid refrigerant as it leaves the condenser is $32^\circ C$ and the specific heat capacity of the superheated vapour may be assumed constant. Determine: (i) The coefficient of performance of the refrigerator (ii) The mass flow of the refrigerant in kg/h. (iii) The cooling water required by the condenser in kg/h if the cooling water temperature rise is limited to $12^\circ C$. Take the specific heat capacity of water as $4.187 kJ/kg K$ and the specific heat of liquid refrigerant as $1.32 kJ/kg K$. The relevance properties of the refrigerant are given in the table below:

Pressure kN/m^2	Sat. temp. t_f $^\circ C$	Sp. enthalpy h_f	Sp. enthalpy h_g	Sp. vol. (m^3/kg) V_f	Sp. vol. (m^3/kg) V_g	Sp. entropy S_f	Sp. entropy S_g
462.47	-10	35.732	231.40	0.0008079	0.04573	0.1418	0.8614
1785.90	40	99.270	246.40	0.0009487	0.01105	0.3537	0.8093

- (b) (i) Discuss the factors to be considered in the selection of a site for a hydroelectric power plant. (ii) Differentiate between a cogeneration and a combined cycle power plant. **10+10**

8. (a) Air at a temperature of 300 K enters a ten-stage axial flow compression at the rate of 3.5 kg/s. The pressure ratio is 6.0 and the isentropic efficiency is 90%. The process is adiabatic and the compressor has symmetrical stages. The axial velocity of 120 m/s is uniform across the stages and the mean blade speed is 200 m/s. Assume that the temperature change is same in each stage. Determine the direction of the air at entry to and exit from the rotor and stator blades. Also find the power given to the air. For air, take $C_p = 1.005 kJ/kg$ and $\gamma = 1.4$. **15**

- (b) Sketch and explain the curves showing the variation of pressure ratio (or head) versus volume flow rate for the three types of blades generally used in centrifugal compressor. Indicate on each curve the stable range of operation. **30**
