

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 parts (Answer to each part should not exceed 200 words) **20×3=60**

- (a) Using the concept of Second Law of Thermodynamics show that it is impossible to reach absolute zero temperature.
- (b) Using Maxwell's relations, show that for a pure substance,

$$T dS = C_p dT - T \alpha dP = C_v dT + T \frac{\beta}{K} dV = \frac{K C_v dP}{\beta} + \frac{C_p}{\beta} dV$$

where β is the coefficient of cubical expansion, K is coefficient of compressibility and C_p , C_v are specific heats at constant pressure and constant volume respectively.

- (c) Justify in brief, the following statements: (i) By advancing the spark timing, the possibility to knock in a S.I. engine increases. (ii) Willans line method for estimating frictional power can be used only in case of unthrottled engines. (iii) Exhaust hydrocarbon emissions increase with increase in surface to volume ratio of an engine. (iv) Carbon monoxide emissions are low for fuel lean mixtures.
- (d) An I.C. engine fuel has the following composition: $C=89\%$, $H_2=5\%$, $O_2=4\%$ and rest N_2 . Determine the chemically correct air-fuel ratio. If 40% excess air is supplied, find the percentage of dry products of combustion by volume.
2. (a) A reversible heat engine operating between thermal reservoir at 800°C and 30°C drives a reversible refrigerator which refrigerates a space at -15°C and delivers heat to a thermal reservoir at 30°C . The heat input to the heat engine is 1900 kJ and there is a net work output from the combined plant (heat engine and refrigerator) of 290 kJ. Determine the heat transfer to the 30°C thermal reservoir. **30**
- (b) 6 kg of air at 600 K and 5.0 bar is enclosed in a closed system. (i) Determine the availability of the system if the surrounding pressure and temperature are 10 bar and 300 K. (ii) If the air is cooled at constant pressure to the atmospheric condition, determine the availability and effectiveness. For air take, $C_p=1.005 \text{ kJ/kg K}$, $C_v=0.718 \text{ kJ/kg K}$ and $R=0.287 \text{ kJ/kg K}$. **30**
3. (a) A six-cylinder, 4-stroke petrol engine has a swept volume of 3.0 liters with a compression ratio of 9.5. Brake output torque is 205 N-m at 3600 r.p.m. Air enters at 85 N/m^2 and 60°C . The mechanical efficiency of the engine is 85% and air-fuel ratio is 15:1. The heating value of fuel is 44,000 kJ/kg and the combustion efficiency is 97%. Calculate: (i) Rate of fuel flow (ii) Brake thermal efficiency (iii) Indicated thermal efficiency (iv) Volumetric efficiency (v) Brake specific fuel consumption **30**

- (b)(i) Explain the various stages of combustion in a diesel engine. **15**
- (b)(ii) Discuss the effect of volatility of gasoline on engine starting, acceleration and vapour lock. **15**
4. (a) A 4-stroke petrol engine has a swept volume of 20 liters and is running at 4000 r.p.m. The volumetric efficiency at this speed is 0.75 and the air-fuel ratio is 14 : 1. The venturi throat diameter of the carburettor fitted to the engine is 30 mm. Estimate the air velocity at the throat if the discharge coefficient for air is 0.9. The ambient conditions are pressure = 1.0 bar, temperature = 20°C. Calculate the diameter of the fuel jet if the fuel density is 760 kg/m^3 . For air $C_p = 1.005 \text{ kJ/kg K}$ and $R = 287 \text{ J/kg K}$. Assume $C_d = 1.0$. **30**
- (b) Explain the necessary modifications that have to be made to convert a bus running on diesel fuel to Compressed Natural Gas (CNG). **20**
- (c) Discuss the advantages of using multi-point fuel injection system in place of conventional carburettor. **10**

SECTION 'B'

5. Answer any three of the following: **20×3=60**
- (a) Illustrate, with neat sketches, the temperature profile for hot and cold fluids as a function of the distance along the path for (i) parallel flow heat exchangers, (ii) counter flow heat exchangers, (iii) condenser and (iv) gas-heated boiler
- (b) Show that the COP of a cascade refrigeration system is $COP = \frac{COP_1 \times COP_2}{1 + COP_1 + COP_2}$ where COP_1 , and COP_2 and COP's of low temperature and high temperature side respectively.
- (c) An air compressor has eight stages of equal pressure ratio 1.35. The flow rate through the compressor and its overall efficiency are 50kg/s and 82 percent respectively. If the condition of air at entry are 1.0 bar and 40°C, determine: (i) the state of air at the compressor exit, (ii) polytropic or small stage efficiency, (iii) efficiency of each stage, (iv) power required to drive the compressor assuming overall efficiency of the drive as 90%. Take $C_p = 1.005 \text{ kJ/kg K}$ and $\gamma = 1.4$.
- (d) A central power station has annual factors as follows: Load factor = 0.6, Capacity factor = 0.4 and Use factor = 0.45. The power station has a maximum demand of 15 MW. Determine: (i) Annual energy production (ii) Reserve capacity over and above peak load (iii) Hours per year the plant is not in service.
6. (a) Two large parallel plates at $T_1 = 1000 \text{ K}$ and $T_2 = 750 \text{ K}$ have emissivities $\epsilon_1 = 0.5$ and $\epsilon_2 = 0.8$ respectively. A radiation shield having an emissivity of $\epsilon_{3,1} = 0.12$ on one side and an emissivity of $\epsilon_{3,2} = 0.08$ on the other side is placed between the plates. Calculate the heat transfer rate by radiation per square meter with and without radiation shield. Take $\sigma = 5.67 \times 10^{-8} \text{ W/m}^2 \text{ K}^4$. **30**
- (b) With usual notations, develop an expression for the efficiency of a fin of uniform cross-section when the heat loss from the tip is considered negligible. **30**
7. (a) An air conditioning plant is designed to maintain a room at a condition of 20° C dry bulb temperature and specific humidity 0.0079 kg/kg dry air when the outside condition is 30° C dry bulb temperature and 40% saturation. The corresponding heat gains are 18000W (sensible) and 3600W (latent). The supply air contains one-third outside air by mass and the supply temperature is to be 15° C dry bulb temperature. The plant consists of mixing chamber for fresh and re-circulated air, an air washer with chilled spray water with an efficiency of 80%, an after heater battery and a supply fan. Neglecting temperature changes in fan and ducting, calculate: (i) the mass flow rate of supply

air necessary; (ii) the specific humidity of the supply air; (iii) the cooling load on the washer; (iv) the heating load on the after heater. **40**

- (b) Explain the working principle of Electrostatic Precipitator (ESP). Discuss the factors which affect its efficiency. **20**

8. (a) A small compressor has the following data: Air flow rate = 1.5778 kg/s Pressure = 1.6 Rotational speed = 54,000 rpm Efficiency = 85% State of air at entry, $P_{0_1} = 1.008 \text{ bar}$; $T_{0_1} = 300 \text{ K}$ C_p for air = 1.009 kJ/kg K. (i) Calculate the power required to drive this compressor. (ii) A geometrically similar compressor of three times the size is constructed. Determine, for this compressor I. mass flow rate, II. Pressure ratio, III. speed and IV. the power required. Assume same entry conditions and efficiency for the two compressors and also assume kinematic and dynamic similarities between the two machines. **30**

- (b) Explain clearly what do you understand by Fanno flow. Show its plot on h-s diagram and give its characteristics. Air flows in an insulated duct with a Mach number of 0.2. The initial temperature and pressure are 290 K and 2.0 bar respectively. Determine: (i) the pressure and temperature at a section of the duct where the Mach number is 0.8. (ii) the distance between these two points if the duct diameter is 10 cm and friction factor is 0.004. (iii) what will be the maximum length of the duct to avoid choking? **30**

Use the following table

M	P/P^*	T/T^*	$4fL_{max}/D$
0.2	5.455	1.19	14.533
0.8	1.289	1.064	0.073
