

MECHANICAL ENGINEERING (Paper II)

Time Allowed : Three Hours	Maximum Marks : 300
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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)
 - (a) Distinguish between biogas, producer gas, and liquefied petroleum gas (LPG) and compressed natural gas (CNG). Discuss the feasibility of each one of them for use in motor vehicles explaining why you do not consider any of them fit for use in present-day vehicles if you so consider. **20**
 - (b) Explain why the exhaust effluent from the tail pipe of a diesel vehicle is black in colour with an obnoxious odour, while it is not so with that from petrol driven vehicles. Which of these exhaust effluent is likely to have higher concentration of oxides of nitrogen and why? **20**
 - (c) What is meant by free expansion process and how does it differ from throttling process? One kilogram of a gas having pressure P and temperature T is enclosed in an insulated box of volume V_1 . It is allowed to expand freely till its volume increases to $V_2 = 2V_1$. Show the process on P - V and T - S diagrams and determine Q , ΔV , W and ΔS for the free expansion process. Comment on the results. **20**
 - (d) A Carnot Engine is working between temperature limits of T_1 and T_2 . Its efficiency can be increased either by increasing the source temperature T_1 or by decreasing the sink temperature T_2 . Determine which is more effective. What are the practical limitations of each of the above methods? **20**
2.
 - (a) 'Knocking in SI Engines is due to auto ignition of the "end charge" while knocking in CI Engines is due to autoignition of the "first charge". Discuss this statement and tabulate the effect of engine operating and design parameters on the knock intensity in SI and CI engines, giving reasons for the effects indicated by you. **30**
 - (b) What do you understand by the term 'dopes' used in IC Engine practice? Name at least two organic and two metallic dopes. Explain how addition of very small amount of metallic dopes per liter of gasoline completely suppresses knocking in SI engines. What additives are used to increase the cetane rating of diesel oil? **30**
3.
 - (a) Explain what is meant by Higher and Lower Calorific Value of a fuel. Describe with the help of a neat sketch the principle and working of an apparatus used for determining the calorific value of a gaseous fuel. **20**
 - (b) The following data related to a test trial of a single-cylinder four-stroke gas engine (i) Cylinder dia. 24 cm. stroke length 48 cm. (ii) Compression ratio = 5.9 (iii) Net brake load applied at brake wheel

having an effective circumference of 3.86 m is 1260 N at average speed of 227 r.p.m. (iv) Number of explosions/minute = 77. (v) Gas used/mt at 771 mm of mercury and 15°C = 0.217 cum (vi) Lower calorific value of gas at NTP 49350 kJ/m³. (vii) Mean effective pressure from indicator card = 7.5 bar (viii) Weight of Jacket cooling water/mt = 11 kg (ix) Temperature rise of cooling water = 34.2 °C (x) Specific heat of water = 4.2 kJ/kg °C. Estimate (i) mechanical efficiency, (ii) indicated thermal efficiency and (iii) efficiency ratio, and draw a heat balance sheet for the engine assuming that exhaust gases carry away 24% of heat. **40**

4. (a) A 200 kg iron block initially at 300 °C is allowed to cool in atmosphere at 30°C. Determine the reversible work and irreversibility for the cooling process. If this iron block is used to maintain a temperature of 30 ° within an enclosure having outside surrounding temperature of 10 °C, determine the maximum amount of heat that can be supplied to the enclosure space as the iron block cools from 300 °C to 30 °C. For iron $C_p = 0.45 \text{ kJ/kg } ^\circ\text{C}$. **30**
- (b) (i) Describe with a neat sketch, the working of a centrifugal compressor. How do pressure and velocity changes take place in impeller and diffuser? (ii) Compare the relative merits and demerits of reciprocating, axial and centrifugal compressors. (iii) Sketch axial compressor velocity diagrams for a stage. Show that total head pressure rise is given by

$$\frac{P_{0_2}}{P_{0_1}} = \left[1 + \eta \frac{u(C_{2w} - C_{1w})}{C_p T_{0_1}} \right]^{\frac{\gamma}{\gamma-1}}$$

[?] The notations have the usual meaning. **30**

SECTION 'B'

5. Answer any three of the following parts. (Answer to each part should not exceed 200 words)
- (a) Define the terms: capacity ratio, effectiveness and number of transfer units. Derive an expression for effectiveness for a parallel flow concentric heat exchanger in terms of capacity ratio and number of transfer units. **20**
- (b) What are the harmful environmental effects of conventional refrigerants? Name any one eco-friendly refrigerant which is being commercially used and discuss its important characteristics **20**
- (c) With reference to air-conditioning practice, explain the difference between human comforts and industrial air-conditioning pointing out the various parameters in each of these applications. Give suitable examples. Sketch and discuss a comfort chart. **20**
- (d) Explain the essential distinguishing and relative merits and demerits of Boiling Reactor and Pressurized Water Reactor used in nuclear power plants. How is nuclear waste disposed off? **20**
6. (a) A mixture of air and water vapour at 1.01325 bar, 16°C has dew point of 5°C. Calculate the relative humidity and specific humidity. **20**
- (b) A refrigerating plant of 10 kW capacities operates in the quasideal vapour compression cycle. The refrigerant is R 134 a. The saturation temperatures in the evaporator and condenser are respectively -20°C and 40°C. The plant includes a heat exchanger in which the saturated liquid leaving the condenser is subcooled to 30°C by the saturated vapour leaving the evaporator. The subcooled liquid is then throttled to -20 °C before entering the evaporator and the vapour leaving the heat exchanger is compressed isentropically to the condenser pressure. Sketch the schematic diagram and the cycle on p-h and T-s diagrams, numbering the important point. Calculate the mass flow rate of the refrigerant and power to be supplied to the compressor. The mechanical efficiency of the compressor may be assumed 80%. The compressor used by the plant is a single-stage single-acting reciprocating compressor having stroke-diameter ratio of 1.2 and a speed of 240 rev/min. Assuming

compressor volumetric efficiency to be 80% determine the diameter and stroke of the compressor. Properties of refrigerant may be obtained from table below: **35**

t (°C)	P_s (bar)	v_g (m^3/kg)	Enthalpy kJ/kg Liquid	Enthalpy kJ/kg Vapour	Entropy kJ/kg-K Liquid	Entropy kJ/kg-K Vapour	Specific heat kJ/kg-K Liquid	Specific heat kJ/kg-K Vapour
-20	1.3268	0.1474	173.82	386.66	0.9009	1.7417	1.282	0.805
40	10.165	0.0199	256.35	419.58	1.1905 [?]	1.7115	1.5	1.12

- (c) A central air-conditioning plant is to be installed at Delhi for cooling an office building during the summer season. Give a layout of the plant and explain the various processes on a skeleton psychrometric chart. **15**

7. (a) In a concentric tube heat exchanger, cold water is heated by the heat released by the steam condensation. The water enters the tube at 10°C and leaves at 50°C. The steam pressure is maintained at 1.01325 bar (atmospheric). If the length of the tube is increased to 3 times, what would be the outlet temperature of water? Assume overall heat transfer coefficient remains constant for both the cases. Specific heat for water may be assumed to be 4187 kJ/kg-K, **15**

- (b) A thin rod of length l has its two ends connected to two reservoirs at temperatures t_1 and t_2 respectively. The rod has the perimeter P and its cross-sectional area A . The rod loses heat to the environment at temperature, t_∞ . The convection coefficient of heat transfer between the rod and the environment is h . Assuming the thermal conductivity of the material of the rod to be constant k , derive an expression for (i) the temperature distribution in the rod and (ii) the heat transfer from the rod to the environment. **15**

- (c) The total emissivity of clean chromium as a function of temperature T K is approximately given as $\varepsilon = 0.38 \left(1 - \frac{263}{T} \right)$. Obtain an expression for the absorptivity of solar radiation as a function of surface temperature. The intensity of solar radiation at earth's surface may be calculated from the following data: Diameter of sun 1.39×10^6 km Surface temperature of sun = 600 K. Distance between sun and earth = 149×10^6 km Assume sun to behave as a black body **30**

8. (a) Explain the terms forced draft, induced draft and balanced draft, and discuss their relative merits and demerits. What is the role of a chimney in a boiler? Why no chimney is provided in a locomotive boiler? **20**

- (b) An oil fired boiler uses 52 kg/hr of oil having a higher calorific value of 44900 kJ/kg and composition/kg C = 0.847, H_2 = 0.13, S = 0.0125 and generates 635 kg of steam/hr at 10.5 bar pressure from feed water supplied at 338 K. The flue gases having dry gas analysis/unit volume O_2 = 0.043, CO_2 = 0.124, N_2 = 0.833 and specific heat 1.005 kJ/kg-K, leave the boiler at 635 K. The pressure and temperature of steam after throttling in a throttling calorimeter is 1.15 bar and 398 K respectively. Taking the partial pressure of steam in flue gases as 0.07 bar and the specific heat of superheated steam = 2.1 kJ/kg-K determine – (i) the equivalent evaporation / kg of fuel; (ii) boiler efficiency. Draw up a complete heat balance sheet. Take boiler room temperature = 234 K. **40**
