

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) **20×3=60**
 - (a) A reversible heat engine absorbs heat energy from a stream of hot gases whose temperature is falling linearly from T_1 to T_2 . The engine rejects heat to a constant temperature sink at T_0 . Assuming that any reversible cycle can be considered to be equivalent to an infinite number of Carnot cycles, prove that the maximum efficiency attainable for this heat engine is
$$1 - \frac{T_0}{T_1 - T_2} \ln \frac{T_1}{T_2}$$
 - (b) A rigid insulated tank of 3 m^3 volume is divided into 2 compartments. One compartment of volume 1 m^3 contains an ideal gas at 0.1 MPa and 300 K while the second compartment of volume 2 m^3 contains the same gas at 1 MPa and 1000 K. If the partition between the two compartments is ruptured, calculate the final temperature and pressure of the gas.
 - (c) The actual amount of air supplied per kg of a fuel can be ascertained from the measured composition by volume of combustion products. Describe an apparatus to do the needful.
 - (d) Discuss why a carburettor is being replaced by an injection system in S.I. engine these days.
2.
 - (a) A mass of air initially at 760 KPa and 250°C occupies 0.026 m^3 . The air is expanded at constant pressure to 0.07 m^3 . A polytropic process with $n=1.52$ is then carried out followed by an isothermal process and the cycle is thus completed, Assuming all the processes to be reversible, (i) show all the processes on pV and Ts planes (ii) compute the heat received and rejected in the cycle (iii) calculate the efficiency of the cycle. **30**
 - (b) Define availability. Explain the difference between useful work and the maximum useful work done in the context of availability of a closed system. Heat flows through a wall at the rate of $3 \times 10^5 \text{ kJ/h}$. The temperature of the two faces of the wall is 327°C and 207°C. If the surroundings are at 270°C, what is the loss in available energy? **30**
3.
 - (a) The exhaust gas analysis of an engine using Octane (C_8H_{18}) as fuel gives equal volumes of CO_2 and unused O_2 . Compute the actual and stoichiometric air-fuel ratios. For equivalence ratio of 1, calculate (i) the volume of mixture per kg of fuel at pressure of 100 kPa and temperature 70°C (ii) the volume of the products of combustion per kg of fuel when the temperature of products of combustion is 127°C at pressure 1 bar. **40**

- (b) Explain Cetane rating of a fuel. Discuss its importance for the selection of fuels. Justify the range of Cetane numbers of commercial diesel fuels. **20**
4. (a) Define scavenging efficiency, trapping efficiency and scavenge factor in two-stroke I.C. engines. Develop a relationship between them. **20**
- (b) A 4-stroke petrol engine of 2 liters capacity is to develop maximum power at 4000 rpm. The volumetric efficiency at this speed is 0.75 and the air-fuel ratio is 14 : 1. The venturi throat diameter is 28mm. The coefficient of discharge of venturi is 0.85 and that for fuel jet is 0.65. Calculate (i) the air velocity at the throat and (ii) the diameter of the fuel jet. The specific gravity of petrol is 0.76. Atmospheric pressure and temperature are 1 bar and 17°C respectively. **40**

SECTION 'B'

5. Answer any THREE of the following parts (Answer to each part should not exceed 200 words) **20×3=60**
- (a) Show the following processes on the psychrometric chart: (i) Heating and humidification (ii) Cooling and dehumidification (iii) Cooling and humidification (iv) Heating and dehumidification (v) Adiabatic saturation
- (b) Heat is transferred along the axis of a truncated conical cylinder of length l , radius r_1 at the shorter end and radius r_2 at the bigger end. The circumference of the cylinder is completely insulated. Develop an expression to calculate heat transfer along the axis of the cylinder. Assume no variation of conductivity with temperature.
- (c) A thermal power plant of 200 MW capacity has the maximum load of 160 MW and its annual load factor is 0.65. The coal consumption is [?] kg per kWh of energy generated and the cost of coal is Rs. 800 per ton. Other annual running expenses are Rs. 200×10^6 . Calculate (i) the annual revenue earned if the energy is sold at Rs. 1.5 per kWh and (ii) the capacity factor of the plant.
- (d) A forced draught fan discharges 1200 m^3 of air per minute through the outlet of 2 m^2 area and maintains a steady pressure of 110 mm of water. The temperature of air is 27°C. Calculate the power of the motor to drive the fan if the efficiency of the fan is 85%. Take the density of air at 27°C as 1.25 kg/m^3 [?].
6. (a) A spherical thermocouple of 2.5 mm diameter is used to measure the temperature of air flowing in a pipe. Initially both the thermocouple and the air are at a temperature of 30°C. The air is heated to a temperature of 235°C and maintained at this temperature. Find the time required for the thermocouple to reach 200°C. Also find out the time constant of the thermocouple and comment on the suitability of this thermocouple to measure unsteady state temperature. For thermocouple material take density = 9000 kg/m^3 , specific heat 0.4 kJ/kg K and thermal conductivity = 30 W/m K . Convective heat transfer coefficient between thermocouple surface and the air is $120 \text{ W/m}^2 \text{ K}$. **30**
- (b) Air at 30°C flows over a horizontal plate heated to 70°C at a speed of 3 m/s. Calculate the convective heat transfer coefficient and the rate of heat transfer between the plate and the air. The length of the plate is 2 m and width 1 m. Nusselt number is given by: $Nu = 0.664 Re^{1/2} Pr^{1/3}$. The properties of air at 50°C are $\nu = 17.95 \times 10^{-6} \text{ m}^2/\text{s}$, $K = 0.0283 \text{ W/m K}$, $\rho = 1.093 \text{ kg/m}^3$, $C_p = 1.005 \text{ kJ/kg K}$. **30**
7. (a) A vapour compression refrigerator works between pressure limits of 10 bar and 3 bar. The working fluid is dry at the end of compression and there is no undercooling before the expansion valve. If refrigerant flow rate is 10 kg/min, determine (i) COP and (ii) the capacity of the refrigerant. Table for properties of the refrigerant is as under **30**

Pressure bar	Saturation temperature °C	Liquid heat kJ/kg	Latent heat kJ/kg	Liquid entropy kJ/kg K
10	25	298.90	1166.94	1.1242
3	-10	135.37	1297.68	0.5443

- (b) Discuss the difference between natural circulation, forced circulation and once-through boilers. Explain, with the help of a sketch, the working of a La Mont boiler. **30**

8. (a) Steam expands in a steam turbine isentropically from inlet to exhaust having an enthalpy drop = 1200 kJ/kg. Assuming ideal conditions, determine the mean diameter of the wheel if the turbine were of (i) single impulse stage, (ii) single 50% reaction stage, (iii) one two-row Curtis stage and (iv) ten 50% reaction stages. Take the nozzle angle as 18° and blade speed as 4000 rpm. **30**
- (b) An axial flow compressor of 50% reaction blading has isentropic efficiency of 82%. It draws air at 17°C and compresses in the pressure ratio of 4 : 1. The mean blade speed and flow velocity are constant throughout the compressor. The inlet and outlet angles of blades are 15° and 45° respectively (angles measured from axial direction). Blade speed = 180 m/s and work input factor = 0.84. Calculate (i) flow velocity and (ii) number of stages. **30**

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