

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 (answers to each part should not exceed 200 words):
 - (a) Prove the validity or otherwise of the following statements
 - (a)(i) Availability is a function of state of the system and the medium and that irreversibility can be evaluated with the help of availability 10
 - (a)(ii) For a perfect gas the work done by a constant pressure expansion from any point on a given isothermal to another given isothermal is constant. 10
 - (b) Explain why:
 - (b)(i) Two stroke compression-ignition engines which are widely employed for marine applications and rail traction, are not used for surface transport applications. 10
 - (b)(ii) Gas turbines which have a near monopoly in air transport systems, are not used for surface transport applications. 10
 - (c) Explain why:
 - (c)(i) Lead free gasoline is not supplied to cars not fitted with catalytic convertors in India 10
 - (c)(ii) The exhaust from diesel engine powered vehicles is black in colour with an obnoxious odour while the exhaust coming from petrol engine operated vehicles is not so. 10
 - (d)
 - (d)(i) Explain briefly the Boundary layer Theory as propounded by Prandtl. 10
 - (d)(ii) Obtain an expression for the thickness of the boundary layer for laminar flow assuming the velocity distribution $u/U = 2(y/\delta) - (y/\delta)^2$ Where U = approach velocity of the stream, u = velocity of the stream in the boundary layer at a distance y from the boundary and δ = thickness of the boundary layer. 10
2.
 - (a) Discuss the advantages of fuel injection in SI engines over Carburation. How does mixture strength affect the concentration of carbon monoxide, hydrocarbons and oxides of nitrogen in SI engine exhaust? 20
 - (b) A single-cylinder 4-stroke gas engine with a hit and miss governing has 200 mm bore and 400 mm stroke. It recorded a gas consumption of 153 litre/min at 8.75 cm of water above atmospheric pressure, when barometer reading was 759mm of mercury, atmospheric and gas temperature was 17°C. The gas used had gross calorific value of 18200 kJ/m^3 and density 0.592 kg/m^3 both at N.T.P. hydrogen present in the gas was 12 per cent by mass, air consumed was 0.0242 kg/s , C_p for

dry exhaust gas was 1.05 kJ/kg K. The mean effective pressure of positive loop was 5.72 and of negative loop 0.274 bar in firing and 0.38 bar in missing strokes, the engine speed as 285 rpm; and explosions per minute 114. The brake torque was 330 Nm. Cooling water used was 9.2 kg per minute with its temperature raised by 20° C. Exhaust temperature was 400°C The total heat of steam at atmospheric pressure is 2676 kJ per kg and C for superheated steam 1.8 kJ/Kg K. Calculate the percentage of the indicated power used for pumping work and for mechanical friction and draw up an energy balance for the engine. **40**

3. (a) For a free vortex turbine blade with an impulse hub, show that the degree of reaction (R) at any radius (r) is related to hub radius (r_h) by the relation

$$R = 1 - (r_h/r)^2$$

15

- (b) Discuss compressor Stall on the basis of blade angle of attack. **10**
- (c) In a single stage turbine of free vortex design the inlet total head temperature and pressure are 1000° K and 3.8 kg/cm^2 . The static head efficiency is 88% and nozzle efficiency 96%. Outlet static pressure is 1.2 kgf/cm^2 and outlet velocity 280 m/sec. If there no outlet swirls and the turbine is designed for impulse conditions at the root radius, find the work output. Also find the nozzle angle and degree of reaction at the tip radius, if the radius ratio of turbine annulus at exit from nozzle is 1.4 Neglecting disc friction and tip leakage loss find nozzle angle and blade angle at root. Assume $C_p = 0.276$ and $\gamma = 1.333$. **35**

4. (a) Establish from first principles the Fanno equation and sketch. On T-s plane characteristic “Fanno Line” for a duct of constant cross-section. Mark the subsonic and supersonic parts and the sonic point. **20**
- (b) Show that in flow through a tube of constant cross- sectional area with heat addition, (i) the Mach number at the point of maximum temperature is equal to $1/\gamma$ [?] and (ii) the Mach number at the point of maximum entropy is equal to unity. **20**
- (c) Show that the Mach number behind a normal shock wave may be written in the form

$$M_y = \left(\frac{\gamma + 1}{2\gamma} \right) + \frac{P_1}{P_2} \left(\frac{\gamma - 1}{2\gamma} \right)^{1/2}$$

[?] where P_1 and P_2 are the pressure before and after the shock wave and γ is the ratio of calorie value. **20**

SECTION 'B'

5. Answer any three parts out of the following four parts of this compulsory question. Each part of the question must be answered briefly to the point, in not more than 200 words.
- (a)(i) Distinguish between nucleate boiling and film boiling and discuss a typical pool boiling curve. **10**
- (a)(ii) A drop of oil put on a hot plate dances over the plate before finally evaporating, why? **10**
- (b) With reference to the refrigeration and air-conditioning practice explain why
- (b)(i) ammonia which is a very good refrigerant, is not used in domestic vapour compression refrigerators. **10**
- (b)(ii) Hydrocarbons such as propane and butane are being tried as substitutes for freon refrigerants. **10**
- (c)(i) Explain with the help of suitable illustrations the phenomena of “Sonic Boom” and “Breaking of Sound Barrier”. **10**

- (c)(ii) Show by dimensional analysis that in forced convection $Nu = \phi[Re, Pr, U^2/C_p T]$ [?] when friction heating in the fluid cannot be neglected. **10**
- (d)(i) What is a deaerator, why and where it is used in a thermal power plant? **10**
- (d)(ii) With reference to an electrostatic Precipitator (ESP) explain the phenomena of Corona discharge and the effect of Sulphur present in fuel on ESP performance. **10**

6. (a) Explain how would you find whether a refrigerator is undercharged or overcharged. How would you detect leaking of refrigerant from a refrigerator? Name and describe any equipment/instrument available for this purpose. **20**

(b) A vapour compression ice plant has a twin-cylinder single-acting compressor with a bore and stroke of 90 cm and 70 cm respectively. It works between pressure limits 10.587 bar and 1.826 bar and has mean effective pressure of 334 kN per sq meter. It runs at 500 rev/min, temperature of refrigerant at entry and exit from condenser 65°C and 32°C respectively; rate of flow of cooling water 13 kg per minute with a rise of 8°C and produces at 27°C, 360 kg of ice in 8 hours from water; latent heat of ice is 335 kJ. Find (a) the theoretical coefficient of performance (b) the actual coefficient of performance and (c) the mass flow of refrigerant per minute. Draw up an energy balance of the plant. The relevant properties of the refrigerant used are: **40**

Pressure bar	Sat temp. C	Enthalpy kJ/kg K Liquid	Enthalpy kJ/kg K Vapour	Entropy kJ/kg K
10.587	44	78.679	204.544	0.6814
1.826	-15	22.23	180.973	0.7051

The average specific heat of liquid refrigerant is 1.256 and for superheated vapour it is 0.645 kJ/kg K.

7. (a) Distinguish between Black Body Radiation and Grey Body Radiation. Can the displacement law of radiation be applied to Grey Body Radiation? **15**
- (b) Define Planck's distribution Law and derive Stefan Boltzmann law from Planck's distribution equation. **15**
- (c) Show that where the heat transfer between two black surfaces is influenced by a third adjoining re-radiating surface in steady state the geometric factor will be given by

$$\dot{F}_{12} = F_{12} + \left[\frac{1}{\frac{A_1}{A_2} \frac{1}{F_2} \frac{1}{F_{13}}} \right]$$

[?] Where F, A have usual meaning and suffix 1, 2, 3 are for the three surfaces respectively. **30**

8. (a) The volumetric percentages of CO_2 , CO and O_2 in the dry flue gas from a boiler using fuel containing C per cent of carbon are X, Y and Z respectively. Show that the quantity of excess air R per kg of fuel burnt can be expressed in the form.

$$R = K \frac{CZ}{(X+Y)}$$

Determine the value of the numerical constant K. **20**

- (b) A boiler with economiser uses coal having the following gravimetric composition: C = 84% H_2 = 4.5% O_2 = 3.5%, Moisture = 1% Ash = 7%. The percentage volumetric composition of the flue gas when entering and leaving the economiser was found to be **40**

	CO_2	CO	O_2	N_2
Entering	8.28	0.42	11.40	79.90
Leaving	6.95	0.35	12.95	79.75

Determine per 100kg of fuel fired: (a) the mass of the flue gas (including moisture) entering the economiser; (b) the leakage of air into the economiser; (c) the loss of heat due to imperfect combustion. Calorific value of carbon when burnt to $C O_2$ is 8100 kcal/kg and when burnt to CO is 2430 kcal/kg. Air contains 23 per cent by weight of O_2 .

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