

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 the following:

- (a) It is desired to maintain a room at temperature of 20°C when outside temperature is 30°C . The volume of this room is 300 m^3 . The pressure in the room and outside is 1 bar. (i) The air in the room is renewed completely in 1 hour. Calculate the mass of air that the air conditioning system pumps into the room. (ii) Compute maximum possible C.O.P. of this A/C system. (iii) When this A/C system is switched-off, the temperature inside the room reaches 21°C in 20 minutes. Calculate the amount of heat transferred from the surroundings to the room. (iv) Calculate power required by this system. 15
- (b) Air is contained in a piston-cylinder arrangement initially at 1.2 bar and 300 K with a volume of 0.12 m^3 . Energy as heat of 11.82 Joule is transferred to the air in a quasi-equilibrium constant pressure process to yield a final temperature of 370.2 K. The piston moves without friction. Taking $C_p = 1.005\text{ kJ/kg K}$ and $C_v = 0.72\text{ kJ/kg K}$, determine the availability change for the process. The reference environment is at 298 K and 1.0135 bar. 15
- (c) Sunlight of 1 kW/m^2 falls directly on a window which is a vertical sheet of plain glass. Sun is in southwest and 30° above horizon. Window points towards the south. Estimate the amount of solar energy that, (i) enters the building through the window, (ii) is reflected by the window. Given black body emissivity power table: 15

λT	$f(\lambda T)$
1900	0.05210
2000	0.06672
2100	0.08305
15000	0.96893
16000	0.97377
17000	0.97765

- (d) Draw rotor and stator blades and velocity diagrams for an axial flow compressor stage and derive the expression for energy transfer in terms of blade speed U , axial velocity C_a and blade angles. Discuss the effect of variation of axial velocity along blade height on energy transfer. How the influence is taken into account? 15

2. (a) An engine using 10 moles of diatomic ideal gas works on the reversible cycle having the following processes: (i) Adiabatic compression from 1 bar pressure and 300 K temperature to pressure of 9

times the initial value, (ii) Constant pressure transformation upto temperature of 1000 K, (iii) Adiabatic expansion upto 3 bars, (iv) Constant pressure transformation such that temperature of 1000 K is reached, (v) Adiabatic expansion, (vi) Constant pressure transformation upto the original state. For this engine, (a) Represent the cycle on a p-v diagram. (b) Calculate pressure, temperature and volume at salient points. (c) Calculate the efficiency of the engine summarising results in a tabular form. (d) Compare the efficiency of the engine operating on Carnot cycle between the same extreme temperatures. Give comments. **30**

- (b) Steam enters a nozzle operating at steady state at 40 bars, and 400°C and 10 m/s. Steam flows through this nozzle with negligible heat transfer and change in potential energy. Steam exits at 15 bars and 665 m/s. Mass flow rate is 2 kg/s. Compute exit area of the nozzle. Given data for steam at 15 bar: **20**

T(°C)	h(kJ/kg)	v(m ³ /kg)
250	2923.9	0.15201
300	3038.2	0.16971

and Enthalpy of steam at inlet 3214.5 kJ/kg.

- (c) What do you understand by governing of steam turbine? Explain the principle and working of throttle governing with the aid of a neat sketch. Compare the throttle governing with nozzle control governing with following aspects: (i) losses, (ii) use. Sketch the efficiency against load with throttle governing. **10**

3. (a) Water enters a tube of dia D and length L. Inlet and outlet temperatures are T_1 and T_2 respectively and wall temperature is T_0 . Convective heat transfer is h. (i) Derive the following expression for heat transfer:

$$Q = \frac{h \pi D L (T_1 - T_2)}{\ln \left(\frac{T_1 - T_0}{T_2 - T_0} \right)}$$

(ii) What is the significance of the logarithmic term in part (i) above? (iii) State assumptions used in part (i). **20**

- (b) Air is supplied to a convergent-divergent nozzle with a static temperature of 300 K, static pressure of 5 bar and a velocity of 150 m/s. The inlet area of the nozzle is 10 cm². A normal shock occurs at a section of the nozzle where flow Mach number is 2. The flow Mach number downstream of shock corresponding to Mach number 2 is 0.577. The flow Mach number at the exit of the nozzle is 0.4. Considering isentropic flow before and after shock and using isentropic flow relation for A/A^* and Mach number provided below, find: (i) throat area of the nozzle (ii) area of the nozzle where shock occurs (iii) exit area of the nozzle (iv) loss of stagnation pressure across shock. Sketch the variation of pressure and Mach number along the length of the nozzle: **30**

M	2	0.577	0.4
A/A^*	1.688	1.22	1.59

- (c) State the factors affecting the amount of draught produced in the boiler and discuss merits and demerits of induced draught system with reference to: (i) boiler efficiency, (ii) fan maintenance, (iii) power to drive the fan, (iv) leakages. **10**

4. (a) A steam power plant runs on an ideal reheat-regenerative Rankine cycle. Details are given in Figure. Steam at turbine inlet is at 150 bars and 600°C. Condensor pressure is 0.10 bar. Steam exiting the HPT is at 40 bars. This steam is split in two parts, y and x. Part x is reheated at the same pressure to 600°C and sent to LPT. Part y is condensed completely in CFWH and it is pumped to 150 bars before it mixes with the flow at same pressure. A fraction of steam, z, is extracted from LPT at 5

bars. Assume steam output of boiler as 1 kg/s for ease of computations. Determine: (i) fraction y (ii) fraction z (iii) thermal efficiency of the cycle. Given data is: $h_1=191.81$ kJ/kg $h_2=192.30$ kJ/kg $h_3=640.09$ kJ/kg $h_4=643.92$ kJ/kg $h_5=1087.4$ kJ/kg $h_6=1087.4$ kJ/kg $h_7=1101.2$ kJ/kg $h_8=1089.8$ kJ/kg $h_9=3155.0$ kJ/kg $h_{10}=3155.0$ kJ/kg $h_{11}=3674.9$ kJ/kg $h_{12}=3014.8$ kJ/kg $h_{13}=2335.7$ kJ/kg $w_{pump1}=0.49$ kJ/kg $w_{pump2}=3.83$ kJ/kg $w_{pump3}=13.77$ kJ/kg **30**

[Figure: Fig.: Schematic of steam power plant – Boiler B delivers steam (state ⑨) to the high pressure turbine HPT; the HPT exhaust (⑩) divides: one branch passes through the reheater R inside the boiler and goes (⑪) to the low pressure turbine LPT, the other branch goes down to the closed feedwater heater CFWH as heating steam; HPT and LPT are on a common shaft driving a generator; steam extracted from the LPT (⑫) goes to the open feedwater heater OFWH; the LPT exhaust (⑬) goes to the condensor C; condensate from C (①) is pumped by pump P1 (②) into the OFWH; the OFWH outlet (③) is pumped by P2 (④) through the tube coil of the CFWH, leaving as ⑤ to the mixing chamber MC; the condensed heating steam drained from the CFWH (⑥) is pumped by P3 (⑦) into the MC; the MC outlet (⑧) returns to the boiler B. Key: R – Reheater; B – Boiler; HPT – High pressure turbine; LPT – Low pressure turbine; C – Condensor; OFWH – Open feedwater heater; CFWH – Closed feedwater heater; MC – Mixing chamber; P1 – Pump 1; P2 – Pump 2; P3 – Pump 3]

- (b) Air flow is entering to a frictionless duct of 0.3 m diameter at a velocity of 580 m/s and a Mach number of 2. A 100 kJ/kg of heat is added to the flow and Mach number of 1.2 is attained. Determine (i) change in enthalpy of flow, (ii) change in kinetic energy of the flow, (iii) change in static pressure in terms of inlet pressure. Comment on result and show the process on T- ϕ diagram. **20**
- (c) (i) Mention the unique features of modern high pressure boiler and describe the operation of Lamont boiler with a sketch. (ii) Representing on h- ϕ diagram, explain supersaturated expansion of steam in a nozzle. Indicate Wilson line on diagram and state effects of supersaturation. **10**

SECTION 'B'

5. Answer the following:

- (a) A thermostatic expansion valve using R-134_a in the power assembly is designed to produce 10°C superheat at an evaporator temperature of 0°C. What will be the superheat that it will maintain when the evaporator temperature is –30°C? Given for R-134_a, the saturation pressure temperature data: **15**

Temp (°C)	–30	–25	–20	–15	–10
Pressure (bar)	.8438	1.065	1.327	1.64	2.006
Temp (°C)	–5	0	5	10	
Pressure (bar)	2.43	2.928	3.5	4.146	

- (b) Cold water bottles kept in a room often start condensing atmospheric moisture. What is the minimum temperature to which water bottle can be cooled without any dripping of moisture from its surface when kept in a room at 25°C DBT and 60% RH? If it is desired that a water bottle at 10°C should also not condense moisture on its surface, what should be the RH in the room, keeping the DBT the same? **15**
- (c) A Rankine cycle based power plant is designed with superheat and reheat: (i) Sketch T-s diagram. (ii) Explain the effect of lowering/raising condensor pressure. (iii) Explain the effect of lowering/raising boiler pressure. **15**
- (d) A taxicab is equipped with a flexible four cylinder S.I. engine running on a mixture of methanol and gasoline at an equivalence ratio of 0.95. How must the air-fuel ratio change as the fuel flow to the engine shifts from 10% methanol (M10) to 85% methanol (M85)? **15**

6. (a) What are the main pollutants emitted by petrol and diesel engine? Discuss their effect on human and biological life. **20**
- (b) What do you understand by catalytic converter? Explain the principle and the working of 3-way catalytic converter. **20**

- (c) Why do some thermostatic expansion valves have an 'external equalizer'? How does it improve its performance? **20**
7. (a) (i) Explain the phenomena of knocking in S.I. engine. Discuss the effects of following factors on the knocking tendency of S.I. engine: (1) Compression ratio (2) Spark timing (3) Engine speed (4) Air-Fuel Ratio. (ii) What are the functions of an additive? Discuss different type of additives and their effect on the properties of lubricating oil. How the lubricating oils are graded as per SAE? (iii) What are the important points that should be borne in mind when considering the new combustion chamber design? What are the different types of combustion chamber used in C.I. engine? Discuss them in detail with specific advantages and disadvantages and show $dp/d\theta$ for different combustion chambers. **30**
- (b) In a winter heating air-conditioning system 1 kg/s of ambient air at 7°C DBT, 80% RH is sensibly heated, then adiabatically saturated to a high humidity of RH = 90%, and then further sensibly heated to the desired outlet state of 25°C DBT and 50% RH. Determine the temperature of air at various state points and show all the processes on a psychrometric chart. Also determine the amount of moisture added per hour in the adiabatic saturator. **30**
8. (a) The following data relate to a boiler using induced draught system: Length of the duct carrying flue gases 150 m Mean size of the square duct 75 cm² Mean flue gas velocity in the duct 900 m/min Mean temperature of gases passing through duct 227°C Plenum pressure 15 cm of water Atmospheric pressure 75 cm of Hg Number of 90° bends 4 Number of 45° bends 4 Loss of draft in every 90° bend 0.1 cm of water Draft available from chimney 1.5 cm of water Fuel bed resistance for underfired stoker 10 cm of water Fan efficiency 60% Motor efficiency driving fan 92.5% Characteristic gas constant for gases 294 kJ/kg-K Friction factor, f , corresponding to round section duct 0.006 Assuming that a 45° bend equal one-half of 90° bend and that the resistance offered by square duct is 20% greater than a similar round duct, determine: (i) Draft to be produced due to friction in square cross-section duct in mm of water. (ii) Draft due to velocity head of flue gases in mm of water. (iii) Total draft for the boiler. (iv) Draft to be produced by induced fan. (v) Power required to drive fan. **30**
- (b) During a trial of a single cylinder, 4 stroke diesel engine the following observations were recorded: Bore = 340 mm Stroke = 440 mm rpm = 400 Area of indicator diagram = 465 mm² Length of diagram = 60 mm Spring constant = 0.6 bar/mm Load on hydraulic dynamometer = 950 N Dynamometer constant = 7460 Fuel used = 10.6 kg/h Calorific value of fuel (C_v) = 49500 kJ/kg Cooling water circulated = 25 kg/min Rise in temp. of cooling water = 25°C Mass analysis of fuel: Carbon = 84% Hydrogen = 15% Incombustible = 1% Volume analysis of exhaust gas: Carbon dioxide = 9% Oxygen = 10% Temp. of Exhaust gases = 400°C Sp. heat of exhaust gas = 1.05 kJ/kg °C Partial pressure of steam in exhaust gas = 0.030 bar Sp. heat of superheated steam = 2.1 kJ/kg °C Saturation temp. of steam at 0.030 bar = 24.1°C Draw up heat balance sheet on minute basis. **30**
