C–HENT–N–LFBIB

INDIAN FOREST SERVICE P (EXAM)-2014

MECHANICAL ENGINEERING

PAPER—II

Time Allowed : Three Hours	Maximum Marks : 200

QUESTION PAPER SPECIFIC INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions

There are EIGHT questions in all, out of which FIVE are to be attempted.

Question Nos. **1** and **5** are compulsory. Out of the remaining SIX questions, THREE are to be attempted selecting at least ONE question from each of the two Sections A and B.

Attempts of questions shall be counted in chronological order. Unless struck off, attempt of a question shall be counted even if attempted partly. Any page or portion of the page left blank in the Question-cum-Answer Booklet must be clearly struck off.

All questions carry equal marks. The number of marks carried by a question/part is indicated against it.

Answers must be written in ENGLISH only.

Unless otherwise mentioned, symbols and notations have their usual standard meanings.

Assume suitable data, if necessary and indicate the same clearly.

Neat sketches may be drawn, wherever required.

Newton may be converted to kgf using the equality 1 kilonewton (1 kN) = 100 kgf, if found necessary.

All answers should be in SI units.

Take : 1 kcal = 4·187 kJ and 1 kg/cm^2 = 0·98 bar

1 bar = 10^5 pascals

Universal gas constant = 8314·6 J/kmol-K

SECTION—A

1. Answer **all** of the following :

   (a) A balloon is filled with hydrogen. It has 1000 m^3 volume at temperature 300 K and pressure 100 kPa. Determine the payload that can be lifted with the balloon. 8

   (b) A two-stroke CI engine delivers a brake power of 368 kW, while 73·6 kW is used to overcome friction losses. It consumes 180 kg/hr of fuel at an air-fuel ratio of 20 : 1. The heating value of the fuel is 42000 kJ/kg. Calculate *(i)* indicated power, *(ii)* mechanical efficiency, *(iii)* air consumption, *(iv)* indicated thermal efficiency and *(v)* brake thermal efficiency. 8

   (c) Explain with *T-s* and *P-h* diagrams the effect of superheating and subcooling in vapour compression cycle of refrigeration. 8

   (d) Prove the Clapeyron equation $\left(\frac{dp}{dT}\right)_{\text{saturation}} = \frac{h_{fg}}{T \cdot v_{fg}}$, where the terms have their usual meanings. 8

   (e) What do you mean by effectiveness of heat exchangers? Derive the expression for effectiveness of parallel-flow heat exchanger. 8

2. *(a)* A circumferentially finned tube with inner diameter 3 cm, outer diameter 3·2 cm, having thermal conductivity 15 W/m-K is provided with 2 fins/cm. The outer diameter of circumferential fin is 4·5 cm and its thickness is 1 mm and is made of the same material as the tube.

   The finned tube is used to cool water, which flows inside the tube, by transferring heat to air which flows across the finned tube. Heat transfer coefficients on air and water side are 15 W/m^2-K and 500 W/m^2-K respectively. Effectiveness of fins is 0·65.

   Calculate the value of overall heat transfer coefficient for the finned tube based on inside surface area of the tube. 15

   (b) Three thinned-wall infinitely long hollow cylinders 1, 2 and 3, having radii 7·5 cm, 12·5 cm and 17·5 cm respectively, are arranged concentrically. The surface of the cylinder 1 is maintained at 727 °C, while the surface of cylinder 3 is maintained at 27 °C. Emissivities of all surfaces of the cylinders are 0·08.

   Calculate the steady-state temperature of cylinder 2, if there is high vacuum in the annular spaces between the cylinders. 15

   (c) What is Fick's law? On what factors does the rate of mass transfer depend in molecular diffusion? 10

3. *(a)* Discuss in brief various factors which affect the volumetric efficiency of an engine. 10

(b) A six-cylinder petrol engine develops 62 hp at 3000 RPM. The volumetric efficiency at NTP is 85%. The bore is equal to the stroke and thermal efficiency of 25% may be assumed. Calorific value of petrol is 10500 kcal/kg. Air-fuel ratio is to be 15 : 1. Calculate cylinder bore and stroke. 15

(c) A four-cylinder four-stroke petrol engine was subjected to a laboratory test and the following data were obtained :

Cylinder diameter = 64 mm

Stroke length = 90 mm

Fuel consumption = 7·5 litres/hr

RPM = 2400

Calorific value of fuel = 11400 kcal/kg

Specific gravity of fuel = 0·717

Brake drum diameter = 73·5 cm

Rope diameter = 2·5 cm

Load on brake drum running at one-third engine speed by belts, spring balances read 60 kg and 8 kg. Mechanical efficiency = 80%

Determine *(i)* brake thermal efficiency and *(ii)* indicated mean effective pressure. 15

4. *(a)* Which is the more effective way to increase the efficiency of a Carnot engine—to decrease T_1 keeping T_2 constant or to decrease T_2 keeping T_1 constant? 10

(b) The Joule-Kelvin coefficient μ_j is a measure of the temperature change during a throttling process. A similar measure of the temperature change produced by an isentropic change of pressure is provided by the coefficient μ_s, where $\mu_s = \left(\frac{\partial T}{\partial P}\right)_s$. Prove that $\mu_s - \mu_j = \frac{V}{C_p}$. 15

(c) In a steam power station, steam flows steadily through a 0·2 m diameter pipeline from the boiler to the turbine. At the boiler end, the steam conditions are found to be $p = 4$ MPa, $t = 400\,°C$, $h = 3213{\cdot}6$ kJ/kg and $v = 0{\cdot}073$ m^3/kg. At the turbine end, the conditions are found to be $p = 3{\cdot}5$ MPa, $t = 392$ °C, $h = 3202{\cdot}6$ kJ/kg and $v = 0{\cdot}084$ m^3/kg. There is a heat loss of 8·5 kJ/kg from the pipeline. Calculate the steam flow rate. 15

SECTION—B

5. Answer **all** of the following :

(a) What is the function of a thermostatic expansion valve used in vapour compression refrigeration systems? Discuss with the help of neat sketch the working of an internally equalized thermostatic expansion valve. How does it differ from an externally equalized thermostatic expansion valve? 8

(b) Air enters an insulated pipe at Mach number $(M) = 0{\cdot}4$ and leaves at $M = 0{\cdot}6$. What portion of the duct length in percentage is required for the flow to occur at $M = 0{\cdot}5$? Take Fanno line parameters as

M	$\frac{fL}{D}$
0·4	0·5770
0·5	0·2673
0·6	0·1227

8

(c) The moist air at 25 °C, total pressure of 100 kPa and 50% RH is compressed to 50 °C, total pressure of 300 kPa and then cooled at constant pressure. At what temperature will water begin to condense? Show the process on psychrometric chart. 8

(d) Why is there a need of governing of steam turbines? With the help of a simple sketch, discuss the working principle of hydromechanical speed-governing loop for steam turbine. 8

(e) With the help of a sketch, discuss the working principle of temperature control in steam boiler. 8

6. *(a)* A simple R-12 plant is to develop 5 tonnes of refrigeration. The condenser and evaporator temperatures are to be 40 °C and −10 °C respectively. Determine the following :

(i) Refrigerant flow rate

(ii) Volume flow rate handled by the compressor in m^3/s

(iii) Compressor discharge temperature if the enthalpy of refrigerant at compressor exit is 209·41 kJ/kg

(iv) Pressure ratio

(v) Heat rejected to the condenser in kW

(vi) Flash gas percentage after throttling

(vii) COP

(viii) Power required to drive the compressor

Saturated values of properties of R-12 :

Temperature (°C)	*Pressure* (bar)	*Sp. enthalpy (Saturated liquid)* h_f (kJ/kg)	*Sp. enthalpy (Saturated vapour)* h_g (kJ/kg)	*Sp. entropy* (kJ/kg-K)	*Volume* (m^3/kg)
−10	2·1912	—	183·19	0·7019	0·077
40	9·6066	74·59	203·981	—	—

Enthalpy values of vapour refrigerant at 9·6066 bars :

Temperature (°C)	*Sp. enthalpy* (kJ/kg)
40	203·981
50	210·950

20

(b) How does absorption refrigeration system differ from vapour compression system? 10

(c) What are the different types of compressors used in vapour compression plants? What are their limitations? 10

7. (a) The following data relate to a small gas axial turbine of a small turbojet unit :

Turbine inlet temperature, $T_{01} = 1100$ K

Turbine inlet pressure, $P_{01} = 4$ bars

Pressure ratio, (stage) $\dfrac{P_{01}}{P_{03}} = 1 \cdot 873$

Blade mean speed = 340 m/s

Mean radius of rotating blade ring = 0·216 m

Blade height = 0·0612 m

For gas, take $C_p = 1 \cdot 148$ kJ/kg/K and $\gamma = 1 \cdot 333$

Assuming isentropic efficiency of stage (total to total) as 0·9, flow coefficient as 0·8 and flow enters the jet nozzle without swirl from turbine, calculate *(i)* direction of absolute and relative velocity vector at entry and exit of rotor with axial direction and *(ii)* loading coefficient and degree of reaction. 20

(b) Mentioning the requirements of pulverized coal burners, explain the types of burners used for efficient utilization of different kinds of coal. 10

(c) In context of a power plant, explain the following : 10

(i) Load curve

(ii) Load duration curve

(iii) Load factor

(iv) Plant factor

(v) Reserve factor

8. *(a)* Explain the working principle of a supercritical boiler with the help of a diagram. What are the advantages of a supercritical boiler? 20

(b) What are the various locations of ID and FD fans for producing draught? Discuss them. 10

(c) Diesel plants are used as standby units in a grid system. Explain why. A power station supplies the following loads to consumers :

Time (hr)	0–6	6–9	9–12	12–16	16–20	20–22	22–24
Load (MW)	20	50	60	50	80	70	40

(i) Find the load factor of the plant.

(ii) What is the load factor of a standby plant of 30 MW capacity, if it takes up all the loads above 50 MW? 10

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