ENGINEERING SERVICES EXAMINATION-(M)2017

ZLX–U–MCH

MECHANICAL ENGINEERING

PAPER—I

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 from each Section.

The number of marks carried by a question/part is indicated against it.

Attempts of questions shall be counted in sequential 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 QCA Booklet must be clearly struck off.

Wherever any assumptions are made for answering a question, they must be clearly indicated.

Diagrams/Figures, wherever required, shall be drawn in the space provided for answering the question itself.

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

Answers must be written in ENGLISH only.

SECTION—A

1. *(a)* A refrigerator machine uses R-12 as the working fluid. The temperature of R-12 in the evaporator coil is –5 °C, and the gas leaves the compressor as dry saturated at a temperature of 40 °C. The mean specific heat of liquid R-12 between the above temperatures is 0·963 kJ/kg K. The enthalpy of evaporation at 40 °C is 203·2 kJ/kg. Neglecting losses, find the COP. 12

(b) Compare the knocking phenomena in SI and CI engines. Explain clearly the factors which tend to prevent knock in SI engines in fact promote knock in CI engines. 12

(c) A laboratory wind tunnel has a test section that is 305 mm square. Boundary layer velocity profiles are measured at two cross-sections and displacement thicknesses are evaluated from the measured profiles. At section 1, where the free stream speed is $u_1 = 26$ m/s, the displacement thickness is $\delta_1^* = 1 \cdot 5$ mm. At section 2, the displacement thickness is $\delta_2^* = 2 \cdot 1$ mm. Calculate the change in static pressure between sections 1 and 2 as a fraction of the free stream dynamic pressure at section 1. 12

(d) A drying oven consists of a long semicircular duct of diameter $D = 1$ m as shown in Fig. 1 below. Materials are to be dried over the base of the oven while the wall is maintained at 1200 K. What is the drying rate per unit length of the oven if a water-coated layer of material is maintained at 325 K during the drying process? Blackbody behavior may be assumed for the water surface and the oven wall. 12

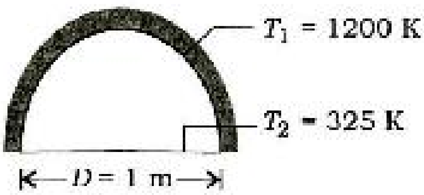


Fig. 1

(e) Explain the desirable properties of refrigerants. List all the possible alternative refrigerants to CFCs and HCFCs. 12

2. *(a)* In aircraft refrigerating unit using air cycle, 50 kg/min of air at 180 cm Hg gauge and 205 °C are bled off the air compressor serving the jet engine of an airplane. The bled air is passed through a heat exchanger leaving at 175 cm Hg gauge and 75 °C. At this point, it is expanded through a small cooling turbine to 20 cm Hg vacuum and –10 °C. The air exhausted out of the plane is at 25 °C. Assume $C_p = 1 \cdot 0$ kJ/kg K.

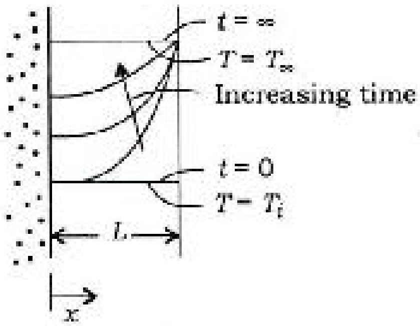
   (i) Find the cooling in ton (refrigeration).

(ii) If the compressor receives air at stagnation state of 2 cm Hg gauge and 50 °C and if the small air-cooling turbine output serves the centrifugal fan for passing coolant air through the heat exchanger, determine the input power for the refrigerant plant.

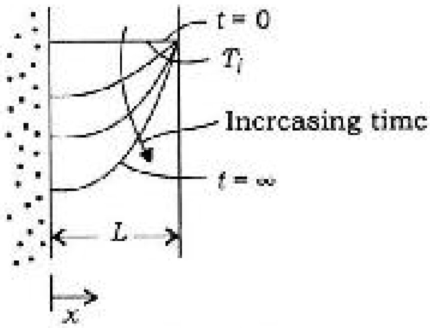
(iii) What is the COP based on input power to bled off air? 20

(b) The pressure in an automobile tire depends on the temperature of the air in the tire. When the air temperature is 25 °C, the pressure gauge reads 210 kPa. If the volume of the tire is 0·65 m^3, determine the pressure rise in the tire when the air temperature in the tire rises to 50 °C. Also determine the amount of air that must be bled off to restore pressure to its original value at this temperature. Assume atmospheric pressure to be 100 kPa and $R = 0 \cdot 287$ kJ/kg K. 20

(c) The temperature distributions within a series of one-dimensional plane walls at an initial time ($t = 0$), at steady state ($t = \infty$) and at several intermediate times are as shown in Fig. 2 below (Case–A and Case–B). For each case, write the appropriate form of diffusion equation. Also write the equations for the initial condition and the boundary condition that are applied at $x = 0$ and $x = L$. If the volumetric generation occurs, it is uniform throughout the wall. The properties are constant. 20



Case–A



Case–B

Fig. 2

3. (a) Determine the change of air-fuel ratio of an airplane engine carburetor when it takes off from sea level to a height of 5000 m. The carburetor is adjusted for 15:1 ratio at sea level, where the air temperature is 27 °C and pressure 1 bar.

Assume the variation of temperature of air with altitude as $t = t_s - 0 \cdot 0065h$, where h is in meter and t is in °C. The air pressure decreases with altitude as per the relation $h = 19200 \log_{10}(1/p)$, where p is in bar. Evaluate the variation of air-fuel ratio with respect to altitude in steps of 1000 m on the trend. Show the variation on a graph and discuss. 20

(b) Consider the laminar flow of a fluid layer falling down on a plane at an angle θ with the horizontal. If h is the thickness of the layer in the fully developed stage, then—

(i) show that the velocity distribution is $U = g\sin\theta(h^2 - y^2)/2\nu$, where ν is the kinematic viscosity (the x-axis points along the free surface and the y-axis points towards the plane);

(ii) develop the expression for volume flow rate per unit width;

(iii) develop the expression for frictional stress on the wall. 20

(c) Derive the Euler's equation for turbo-machines and show that for single-stage axial impulse turbine, work done can be represented as $W = \frac{1}{2}(V_1^2 - V_2^2)$, where V_1 and V_2 are absolute velocities at inlet and exit of rotor blades. 20

4. (a) Explain the working of electrostatic precipitator and discuss variation of its collection efficiency with operating parameters like collector area, migration velocity and mass flow rate. 20

(b) What are the three different types of fuel cell reactions? Give the hydrogen-oxygen, carbon-oxygen and methane-oxygen fuel cell reactions. 20

(c) Steam enters the condenser of a steam power plant at 20 kPa and a quality of 95% with a mass flow rate of 20000 kg/h. It is circulating the water through the tubes within the condenser. To prevent thermal pollution, the river is not allowed to experience a temperature rise above 10 °C. If the steam is to leave the condenser as saturated liquid at 20 kPa, determine the mass flow rate of the cooling water required.

Data from steam table : At 20 kPa, $h_f = 251 \cdot 4$ kJ/kg; $h_{fg} = 2358 \cdot 3$ kJ/kg; Specific heat of water = 4·18 kJ/kg °C. 20

SECTION—B

5. (a) A 30 kg iron block and a 20 kg copper block both initially at 80 °C are dropped into a large lake at 20 °C. Thermal equilibrium is established after a while as a result of heat transfer between the blocks and the lake water. Determine the total entropy change for this process. For copper and iron, specific heats are respectively 0·386 kJ/kg K and 0·46 kJ/kg K. 12

(b) The wind speed V_1 at a location is 4·472 m/s, the speed at turbine rotor is 60% of this value and the speed at the exit is 30% of V_1. The rotor diameter is 9 m, density = 1·293 kg/m^3. Calculate (i) the power available in the undisturbed wind at the turbine rotor, (ii) the power in the wind at outlet, (iii) the power developed by the turbine and (iv) the coefficient of performance. 12

(c) It has been seen that long blades are twisted along the height. With proper figure, explain reasons for twisting. 12

(d) Show all the heat losses taking place from flat plate solar collector with the help of a sketch. Using energy balance, develop performance equation and explain graphically also. 12

(e) Briefly discuss rubbing, pumping and auxiliary frictional losses in IC engines. 12

6. (a) Two identical vehicles are fitted with engines having the following specifications :

Engine 1 : Naturally aspirated, swept volume 3·6 liters, brake mean effective pressure 9 bar, speed 5000 r.p.m., compression ratio 8, efficiency ratio 0·5, mechanical efficiency 90% and mass 250 kg

Engine 2 : Swept volume 3·6 liters, brake mean effective pressure 12 bar, speed 5000 r.p.m., compression ratio 6, efficiency ratio 0·5, mechanical efficiency 90% and mass 260 kg

Identify the engines. If both the engines are supplied with just enough fuel for test run, determine the duration of the test run so that the specific mass is same for both the arrangements. Take the calorific value of the fuel as 43 MJ/kg. 20

(b) Steam at 175 bar and 550 °C expands to 0·1 bar in a steam turbine. The blade peripheral velocity is 250 m/s. The nozzle angles for impulse and reaction stages are 15° and 20° respectively. If all the stages are operated close to maximum efficiency, determine the number of stages for the following arrangements :

(Take saturated water entropy, enthalpy, entropy of evaporation and enthalpy of evaporation at 0·1 bar as 0·6493, 191·8, 7·5009 and 2392·8 respectively.)

(i) All reaction stages

(ii) First 2-row velocity compounding followed by 50% reaction stages 20

(c) A solar flux of 800 W/m^2 is incident on a flat plate solar collector used to heat water. The area of the collector is 4 m^2 and 90% of the solar radiation passes through the cover glass and is absorbed by the absorber plate as shown in Fig. 3. The remaining 10% is reflected away from the collector. Water flows through the tube passages on the back side of the absorber plate and is heated from an inlet temperature, T_i to an outlet temperature, T_o. The cover glass operating at a temperature of 30 °C has an emissivity of 0·94 and experiences radiation exchange with the sky at −10 °C. The convection coefficient between the cover glass and the ambient air at 25 °C is 10 W/m^2 K.

(i) Obtain an expression for the rate at which useful heat is collected per unit area of the collector, q''_u by performing an overall energy balance on the collector.

(ii) Determine the value of q''_u.

(iii) Calculate the temperature rise of the water, $T_o - T_i$, if the flow rate is 0·01 kg/s. Assume the specific heat of water to be 4179 J/kg K.

(iv) Calculate the collector efficiency. Note that the collector efficiency is defined as the ratio of the useful heat collected to the rate at which solar energy is incident on the collector.

Data : $\sigma = 5 \cdot 67 \times 10^{-8}$ W / m^2 K^4 20

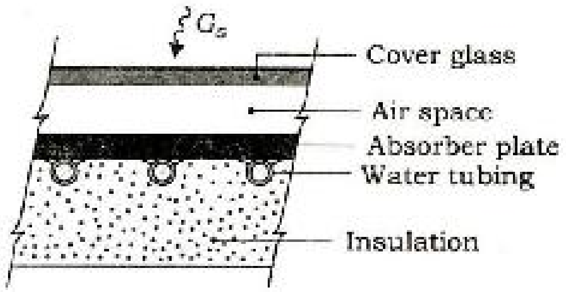


Fig. 3

7. *(a)* Air at 12 °C DBT and 70% RH is to be heated and dehumidified to 36·5 °C DBT and 21 °C WBT. The air is preheated sensibly before passing to the air washer in which water is recirculated. The RH of the air coming out of the air washer is 70%. This air is again reheated sensibly to obtain the final derived condition. Determine the *(i)* temperature to which the air should be preheated, *(ii)* total heating required, *(iii)* make-up water required in the air washer and *(iv)* humidifying efficiency of the air washer. 20

(b) The pump characteristic of a centrifugal pump with impeller diameter, $D = 200$ mm operating at 1170 r.p.m. is given by

$$H_1 = 7 \cdot 6 - 1 \cdot 95 \times 10^{-4} Q_1^2$$

where H is in m and Q is in m^3/h. For this pump operating at this speed ($N_1 = 1170$ r.p.m.), the best efficiency point corresponds to flow rate of 68 m^3/h and head equal to 6·7 m. You need to develop an equation at $N = 1750$ r.p.m. for the same pump expressed as

$$H_2 = H_{o2} - A_2 Q_2^2$$

Find out the value of H_{o2} and A_2. 20

(c) A tidal project has an installed capacity of 2176 MW in 64 units, each of 34 MW rated output. The head at rated output is 5·52 m. The embankment is 6·4 km long. Assume 93% efficiency for both turbine and generator. The generation works for 5 hours twice a day. Calculate *(i)* the quantity of water flowing through each turbine and the total flow out of the tidal basin, *(ii)* the surface area of the reservoir behind the embankment and the wash and *(iii)* the energy produced in TWh per year. 20

8. (a) A thermoelectric refrigerator is powered by a car battery and has a COP of 0·1. The refrigerator cools a $0 \cdot 35 \times 10^{-3}$ m^3 canned drink from 20 °C to 4 °C in 30 minutes. The properties of canned drink are same as that of water at room temperature, i.e., $\rho = 1000$ kg/m^3 and $C = 4 \cdot 18$ kJ/kg K. Neglecting the heat transfer through the walls of the refrigerator, determine the average electric power consumed by the thermoelectric refrigerator. 20

(b) Discuss the effect of regeneration in gas turbine cycle. Draw the cycle efficiency vs. pressure ratio curve and explain why efficiency drops with increase in pressure ratio. 20

(c) A thermal energy storage unit consists of a large rectangular channel which is well insulated on its outer surface and encloses alternating layers of the storage material and the flow passage as given below in Fig. 4. Each layer of the storage material is an aluminum slab of width 0·05 m which is at an initial temperature of 25 °C. Consider conditions for which the storage unit is charged by passing a hot gas through the passages with the gas temperature and the convection coefficient assumed to have constant values of $T_\infty = 600$ °C and $h = 100$ W / m^2 K throughout the channel.

(i) How long will it take to achieve 75% of the maximum possible energy storage?

(ii) What is the temperature of aluminum at this time? 20

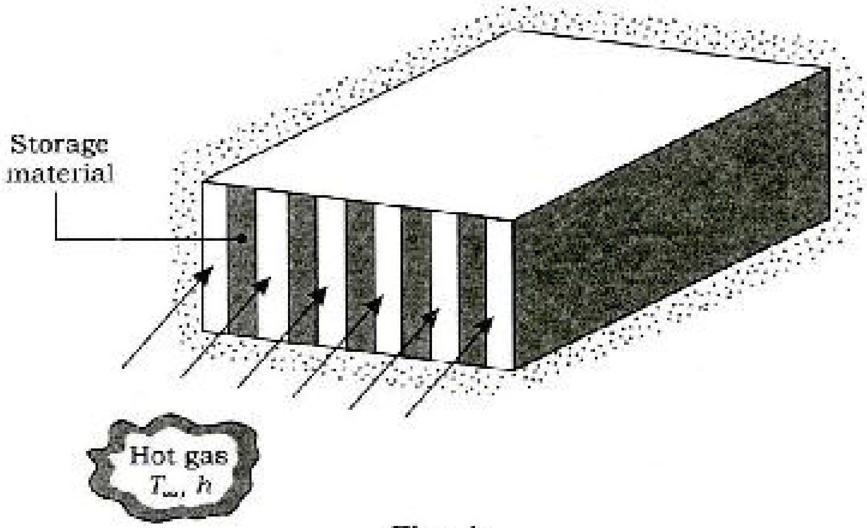


Fig. 4

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