Roll No.

Candidate should write his/her Roll No. here.

Total No. of Questions : **03**

No. of Printed Pages : **08**

M-SFS-II-2017 (11)

MECHANICAL ENGINEERING

(Optional Subject)

Second Paper

Time : **3** Hours]

[Total Marks : **200**

Instructions to the candidates :

1. This question paper consists of **three** questions and all questions are compulsory.

2. Marks for each question have been indicated on the right hand margin.

3. There is no internal choice in Question No. 01, remaining questions carry internal choice.

4. The first question is of very short-answer type consisting of **15** compulsory questions. Each one is to be answered in one or two lines. Question No. 02 is short answer type, word limit is **100**. Question No. 03 is long answer/Essay type, word limit is **300**.

5. Wherever word limit has been given, it must be followed to.

6. Question should be answered exactly in the order same as mentioned in the question paper. Answer to the various parts of the same question should be written together compulsorily and no answer of the other question should be inserted between them.

1. Give answer of the following questions in **one** or **two** lines : **$15 \times 4 = 60$**

(A) Under what conditions does the SFEE reduce to Euler's equation ?

(B) Explain the law of degradation of energy.

(C) Write four most important causes of irreversibility.

(D) What are stagnation temperature and pressure ?

(E) What is cavitation ? What is its effect ?

(F) Define the specific speed of hydraulic turbine and pump. What is its utility ?

(G) Define specific humidity and relative humidity of moist air.

(H) Explain what is meant by critical thickness of insulation.

(I) What is a Fouling factor ?

(J) What is an ignition delay period in CI engine ? How delay period is responsible for knocking in CI Engines ?

(K) Why compounding is done in impulse steam turbine ?

(L) Write the effect of pressure ratio on the isentropic efficiency of multistage compression and expansion process by giving reasons.

(M) What is a robot proximity sensor ?

(N) How tool coding system helps FMS ?

(O) What do you mean by work piece handling system ?

2. Write the answer of any **ten** questions from the following questions. Each answer should be limited upto **100** words : **$10 \times 8 = 80$**

(A) Which is more effective way to increase the efficiency of a Carnot engine : to increase higher temperature T_1, keeping T_2 constant; or to decrease lower temperature T_2, keeping T_1 constant ? **8**

(B) In an ideal gas turbine cycle with reheat, air at state (P_1, T_1) is compressed to rP_1 and heated to temperature T_3. The air is then expanded in a two stage turbine such that the pressure ratio is the same in each stage. The air is reheated between the turbine stages to the temperature T_3. Assuming that working fluid is a perfect gas having a ratio of specific heat equal to y and that the compression and both expansion are isentropic, show that the net output per kg of working fluid will be maximum when r is given by 8

$$r = \left(\frac{T_3}{T_1}\right)^{\frac{2}{3}\left(\frac{\gamma}{\gamma-1}\right)}$$

(C) In case of two-row Curtis stage having frictionless symmetrical blading with axial discharge, show that the three fourth of the total work is done by the steam jets on the first row of moving blades and one-fourth of total work is done on the second row. 8

(D) Calculate the decrease in available energy when 25 kg of water at 95 °C mixes with 35 kg of water at 35 °C, the pressure being taken as constant and the temperature of the surroundings being 15 °C. C_p for water = 4.18 kJ/kg-K. 8

(E) Calculate the entropy change of the universe as a result of the following processes : 8

(i) A copper block of 600 g mass and with C_p of 150 J/K at 100 °C is placed in a lake at 8 °C.,

(ii) The same block, at 8 °C, is dropped from a height of 100 m into the lake.

(F) The three jet Pelton wheel turbines are required to generate 10,000 MW, when the net head at the nozzle is 400 m. The exit blade angle is 165° and the reduction in relative velocity while passing through the bucket is 5% assuming that the total efficiency of the wheel is 80%, coefficient of nozzle velocity is 0.98, and speed ratio is 0.46. Find the following : 8

(i) The diameter of jet

(ii) Total flow in m^3/s

(iii) The force exerted by a single jet on the buckets.

(G) In a laminar boundary layer with a zero pressure gradient over a smooth flat plate is defined by

$u/V_s = \sin(\pi y/2\delta)$

determine the general expressions for

(i) boundary layer thickness $\delta = 4.795\, x/(Re_x)^{1/2}$ and

(ii) wall shear stress $\tau_0 = 0.328\, \rho V_0^2 / (Re_x)^{1/2}$ 8

(H) Find the power required to drive a centrifugal pump which delivers 40 litres of water per second and to a height of 20 m through a 150 mm diameter and 100 m long pipe. The overall efficiency of the pump is 70% and Darcy's f = 0.06 for the pipeline, assume inlet losses in suction pipe equal to 0.33 m. 8

(I) Air at 27 °C and 1 atm flows over a flat plate at a speed of 2 m/s. Assume that the plate is heated over its entire length to a temperature of 60 °C. Calculate the heat transferred in (i) the first 20 cm of the plate and (ii) the first 40 cm of the plate. Assume unit depth in the z direction. The properties at the film temperature are : kinematic viscosity = 17.36×10^{-6} m²/s, thermal conductivity = 0.02749 W/m K, $P_r = 0.7$, $C_p = 1.006$ kJ/kg K. 8

(J) A furnace wall consists of 125 mm wide refractory brick and 125 mm wide insulating firebrick separated by an air gap. The outside wall is covered with a 12 mm thickness of plaster. The inner surface of the wall is at 1100 °C and the room temperature is 25 °C. The heat transfer coefficient from the outside wall surface to the air in the room is 17 W/m² K, and the resistance to heat flow of the air gap is 0.16 K/W. The thermal conductivities of refractory brick, insulating firebrick and plaster are 1.6, 0.3 and 0.14 W/m K, respectively. Calculate : (i) The rate of heat loss per unit area of wall surface; (ii) The temperature at each interface throughout the wall; (iii) The temperature at the outside surface of the wall. 8

(K) What are the differences of knock in SI and CI engines ? **8**

(L) Describe the various stages involved with NC manufacturing. **8**

3. Write the answer of any **three** questions from the following questions. Each answer should be limited upto **300** words : **3 × 20 = 60**

(A) (i) A heat engine operates between maximum and minimum temperatures of 671 °C and 60 °C respectively, with an efficiency of 50% of the appropriate Carnot efficiency. It drives a heat pump which uses river water at 4.4 °C to heat a block of flats in which the temperature is to be maintained at 21.1 °C. Assuming that a temperature difference of 11.1 °C exist between the working fluid and the river water, on the other hand, and the required room temperature on the other, and assuming the heat pump to operate on the rivers Carnot cycle, but with a COP of 50% of the ideal COP, find the heat input in to engine per unit heat output from the heat pump. **10**

(ii) A vapour compression system operating at condenser temperature of 40 °C and an evaporator temperature of 0 °C develops 15 tons of refrigeration. For the refrigerant 134a, determine : **10**

(1) the discharge temperature and mass flow rate of the refrigerant circulated,

(2) the theoretical piston displacement of the compressor and piston displacement per ton of refrigeration (m^3/min).

(3) the theoretical horsepower of the compressor and horsepower per ton of refrigeration,

(4) the heat rejected in the condenser and

(5) actual cop of the cycle

Properties of R134a

Temperature (°C)	Sp. Vol. (m^3/kg) v_g	Sp. Enthalpy (kJ/kg) h_f	h_g	Entropy (kJ/kg-K) s_g	Sp. Heat (kJ/kg-K)
0	0.06931	–	398.6	1.7541	–
40	–	256.41	419.43	1.7111	1.145

(B) (i) A counter flow double-pipe heat exchanger is to heat water from 20 °C to 80 °C at a rate of 1.2 kg/s. The heating is to be accomplished by geothermal water available at 160 °C at a mass flow rate of 2 kg/s. The inner tube is thin-walled and has a diameter of 1.5 cm. If the overall heat transfer coefficient of the heat exchanger is 640 W/m^2 K, determine the length of the heat exchanger required to achieve the desired heating. Use LMTD method only. Take the specific heats of water and geothermal fluid to be 4.18 and 4.31 kJ/kg-K, respectively. Also determine effectiveness of the heat exchangers. **10**

(ii) Determine the specific work output, specific fuel consumption and cycle efficiency for a heat-exchange cycle having the following specifications : **10**

Compressor pressure ratio	4.0
Turbine inlet temperature	1100 K
Isentropic efficiency of compressor	0.85
Isentropic efficiency of turbine	0.87
Mechanical transmission efficiency	0.99
Combustion efficiency	0.98
Heat-exchanger effectiveness	0.80
Pressure losses :	
Combustion chamber pressure loss	2% comp. deliv.
Press	
Heat-exchanger air side	3% comp. deliv.
Press	
Heat-exchanger gas side	0.04 bar
Ambient conditions P_a, T_a	1 bar, 288 K
Calorific value of fuel	43100 kJ/kg

(specific heat ratio for air 1.4, specific heat ratio for gas 1.333, Specific heat for air 1.005 kJ/kg K, specific heat for gas 1.148 kJ/kg K)

(C) (i) Air at 7.8 bar & 180 °C expands through a convergent-divergent nozzle into a space at 1.03 bar. The flow rate of air is 3.6 kg/s. Assuming isentropic flow throughout and neglecting the inlet velocity. Calculate the throat and exit areas of the nozzle. **10**

(ii) Steam expands in a turbine from 40 bar, 500 °C (h = 3445.3 kJ/kg) to 0.10 bar (h = 2246.5 kJ/kg) isentropically. Assuming ideal conditions, determine the mean diameter of the wheel, if the turbine were of (i) single stage (ii) Single 50% reaction stage, (iii) Four pressure stage, (iv) One two row Curtis stage and (v) Four 50% reaction stages. Take the nozzle angle as 16° and N as 3000 rpm. **10**

(D) (i) Assuming the following velocity distribution in a circular pipe $u = U_{max}(1 - r/R)^{1/7}$, where U_{max} is the maximum velocity, calculate : **10**

(i) The ratio between the mean velocity and the maximum velocity,

(ii) The radius at which the actual velocity is equal to the mean velocity.

(ii) In a nuclear power plant heat is transferred in the reactor to liquid sodium. The liquid sodium is then pumped to a heat exchanger where heat is transferred to steam. The steam leaves this heat exchanger as saturated vapour at 55 bar (h = 2790 kJ/kg), and is then superheated in an external gas-fired super heater to 650 °C (h = 3780 kJ/kg). The steam then enters the turbine, which has one extraction point at 4 bar, where steam flows to an open feed water heater. The turbine efficiency is 75% and the condenser temperature is 40 °C. Determine the heat transfer in the reactor and in the super heater to produce a power output of 80 MW.

Isentropic heat drop in turbine before extraction = 840 kJ/kg and after extraction = 870 kJ/kg. **10**

Properties at saturated steam

$T_{sat.}$ °C	$P_{sat.}$ bar	Sp. Vol. (m^3/kg) v_f	Sp. Enthalpy (kJ/kg) h_f	h_g
40	0.07375	0.001008	176.5	2574.4
143.6	4	0.001084	604.7	2737.6