



Total No. of Printed Pages – 8

AERTM
MECHANICAL ENGINEERING
PAPER – I
SUBJECT CODE : 08

Full Marks : 200

Time : 3 Hours

Instructions For Candidates :

Please read each of the following instructions carefully before attempting questions.

- (1) *Answers must be written in **ENGLISH** only.*
- (2) *The question paper contains a total of **8** questions in **TWO** Sections : Section-A and Section-B. (**FOUR** questions in each section)*
- (3) *Question No. 1 of Section 'A' and Question No. 5 of Section 'B' are **compulsory**.*
- (4) *Candidates have to attempt another **THREE** questions from remaining **SIX** questions choosing atleast **ONE** question from each section.*
- (5) *Assume suitable data if found necessary.*
- (6) *Wherever any assumption be made for answering a question, they must be clearly indicated.*
- (7) *Marks carried by a question / section is indicated against it.*
- (8) *Unless struck off, attempt of question shall be counted even if attempted partly.*
- (9) *Any page or portion of the page left blank in the Answer Booklet must be clearly struck off.*

SECTION – A

Marks

1. (a) Explain equations and figures with the performance briefly, how the heat pump differs from the refrigeration. Discuss the practical difficulties with the Carnot refrigeration cycle. 8
- (b) A 0.3 kg metal bar initially at 1200 k temperature is removed from an oven and quenched by immersing it in a closed tank containing 9 kg of water initially at a temperature of 300 k. Each substance can be modeled as incompressible. An appropriate constant specific heat value for the water is $C_w = 4.2 \text{ kJ/kg k}$ and for the metal is $C_m = 0.42 \text{ kJ/kg k}$. Heat transfer from the tank contents can be neglected. Determine. 8
 - (I) The final equilibrium temperature of the metal bar and water in Kelvin (K).
 - (II) The amount of entropy produced in kJ/k



- (c) Starting with an energy balance on a spherical shell volume element, derive the 1-D transient heat conduction equation for a sphere with constant thermal conductivity and without any heat generation. 8
- (d) What is the difference between fin effectiveness and the fin efficiency? Explain how the fins enhance the heat transfer from a surface? Also explain how the addition of fins may actually decrease heat transfer from a surface. 8
- (e) What are the methods used for increasing the efficiency of rankine cycle with the help of T-S diagram? 8

Atmospheric air at a flow rate of 3 kg/sec (on dry basis) enters a cooling and dehumidifying coil with an enthalpy of 85 kJ/kg of dry air having a humidity ratio of 90 gm/kg of dry air. The air leaves the coil with the enthalpy of 43 kJ/kg of dry air and a humidity ratio of 8 gm/kg of dry air. If the condensate water leaves the coil with an enthalpy of 67 kJ/kg, determine the required cooling capacity of the coil in kW.

2. (a) In a gas turbine engine turbine blades mounted to a rotating disc and are exposed to a gas steam i.e. at $T_a = 1200^\circ\text{C}$ and maintains a convection coefficient of $h = 250 \text{ W/m}^2 \text{ K}$ over the blade. The blades have a length of 50 mm and fabricated from Inconel having $K = 20 \text{ W/mK}$ (Thermal Conductivity), the blade profile has a uniform cross sectional area of $A_c = 6 \times 10^{-4} \text{ m}^2$ and a perimeter of $p = 110 \text{ mm}$. A blade cooling scheme is proposed which involves routing air through the supporting disc, is able to maintain the base of blade at a temperature of $T_b = 300^\circ\text{C}$. 10
- (I) If the maximum allowable blade temperature is 1050°C and the blade tip may be assumed to be adiabatic. Is the proposed cooling scheme is satisfactory.
- (II) For the proposed cooling scheme, what is the rate at which heat is transferred from each blade to coolant?
- (b) Consider a large plane wall of thickness $L = 0.4 \text{ m}$, thermal conductivity $k = 2.3 \text{ W/m}^\circ\text{C}$ and surface area $A = 20 \text{ m}^2$. The left side of the wall is maintained at a constant temperature of $T_1 = 80^\circ\text{C}$, while the right side losses heat by convection to the surrounding air at $T = 15^\circ\text{C}$ with a heat transfer coefficient of $h = 24 \text{ W/m}^2 \text{ }^\circ\text{C}$. Assuming Constant thermal conductivity and no heat generation in the wall : 10
- (I) Express the differential equation and the boundary condition for steady 1D-heat conduction through the wall.
- (II) Obtain a relation for the variation of temperature in the wall by solving the differential equation.
- (III) Evaluate the rate of heat transfer through the wall.



- (c) (i) Air at 20 °C and 1 atm flows over a flat plate at 35 m/s. The plate is 75 cm long and is maintained at 60 °C. Assuming unit depth in z-direction calculate the heat transfer from the plate. Where $\mu = 1.906 \times 10^{-5}$ kg/ms. Where, $Pr = 0.7$, $k = 0.02723$ W/m °C, $C_p = 1.007$ kJ/kg °C. 10
- (ii) Explain the effect of sub cooling and super heating in vapour compression refrigeration system with the help of T-S and P-H diagram. Explain the working of thermostatic expansion valve with the help of a schematic. 10
3. (a) Air flows through the supersonic nozzle. The pressure and temperature of air flowing through the supersonic nozzle are 7 kPa and 420 °C respectively. The nozzle exit diameter is adjusted such that the velocity of the air through nozzle is 700 m/s. 10
- Calculate :
- (I) The air exit temperature
- (II) Air mass flow rate
- (III) Nozzle exit diameter
- Assume on adiabatic quasi equilibrium flow.
- (b) 2.5 kg of air at 6 bar and 90 °C temperature expands adiabatically in a closed system until its volume is doubled and its temperature becomes equal to that of the surroundings. Which is 5 °C at 1 bar. For this process determine 10
- (I) Maximum work
- (II) Change in availability
- (III) Irreversibility
- (Take $C_v = 0.718$ kJ/kg k, $R = 0.287$ kJ/kg K are the properties of air)
- (c) (i) Explain the terms Pre-ignition, Detonation and Diesel knock. What is the effect of super charging on power output, mechanical efficiency and fuel consumption. 10
- (ii) Explain the working of nuclear power plant with neat sketch and list the various nuclear fuels ? 10



4. (a) Define a black body and shape factor. How do real bodies differ from black bodies. 10

A spherical tank of diameter $D = 2$ m is filled with liquid Nitrogen at 100 K is kept in an evacuated cubic enclosure whose sides are '3m' long. The emissivity of the spherical tank and the enclosure are $\epsilon = 0.1$ and $\epsilon = 0.8$, respectively. If the temperature of the cubic enclosure is measured as 240 K, determine the net rate of radiation heat transfer to the liquid Nitrogen.

- (b) A simple steam power plant operates between pressure of 10 kPa and 4 MPa with a maximum temperature of 400 °C. The power output from the steam turbine is 100 MW. A gas turbine provides the energy to the boiler; it accepts air at 100 kPa and 25 °C, and has a pressure ratio of 5 and maximum temperature of 850 °C. The exhaust gases exit from the boiler at 350 K. Draw the T-S diagram and determine the thermal efficiency of the combined Brayton-Rankine Cycle. 10

For given enthalpy values :

$h_2 = h_1 = 192$ kJ/kg. At 400 °C and 4 MPa we have $h_3 = 3214$ kJ/kg and $S_3 = 6.769$ kJ/kg K.

State 4 is located by noting that $S_4 = S_3$, $S_f = 0.6491$ kJ/kg K, $S_{fg} = 7.5019$ kJ/kg K

- (c) (i) Classify heat exchangers according construction and flow type and explain the characteristic of the same. 10
- (ii) Explain the working principle of turbo jet engine with suitable diagram. 10

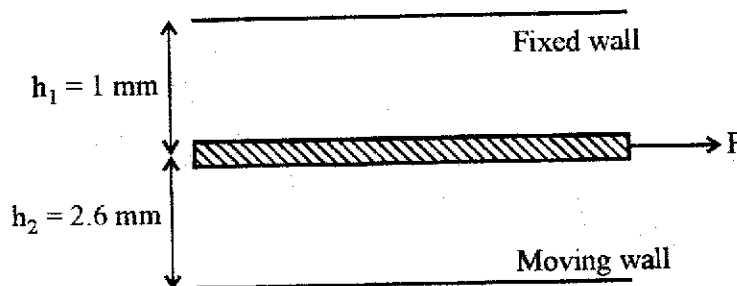
SECTION – B

5. (a) Two pipes each having length L . One of them has diameter of D and other d . If the pipes are arranged in parallel, the head loss is h for a discharge of Q m³/s. When the pipes are arranged in series the head lost is H for the same discharge. Find the ratio of H/h if $D = 2.25 d$. 8
- (b) (i) Define incompressible flow and incompressible fluid. Discuss whether the flow of a compressible fluid necessarily be treated as compressible ? 4
- (ii) If it is possible to describe turbulent flow by the equation $u = 5 + 0.5 \sin t$ then calculate $\rightarrow \bar{u}$ and $\bar{u}^2$. 4



- (c) A thin flat plate having its side as $20 \text{ cm} \times 20 \text{ cm}$ is pulled at 1 m/s horizontally through a 3.6 mm thick oil layer sandwiched between two plates. One stationary and another moving at constant velocity of 0.3 m/s . The dynamic viscosity of the oil is 0.027 Pa.S . Assuming the velocity in each layer to vary linearly. 8

- (I) Plot the velocity profile and find the location where the oil velocity is zero.
(II) Determine the force that needs to be applied on the plate to maintain this motion.



- (d) (i) What is priming ? Is priming needed in gear pump ? Justify your answer ? 4

- (ii) A flow field is defined by $u = 2y$ and $v = xy$. Derive expressions for acceleration components. Find the magnitude of the velocity and acceleration at the point $(2, 3)$. Specify units in terms of (L, T) 4

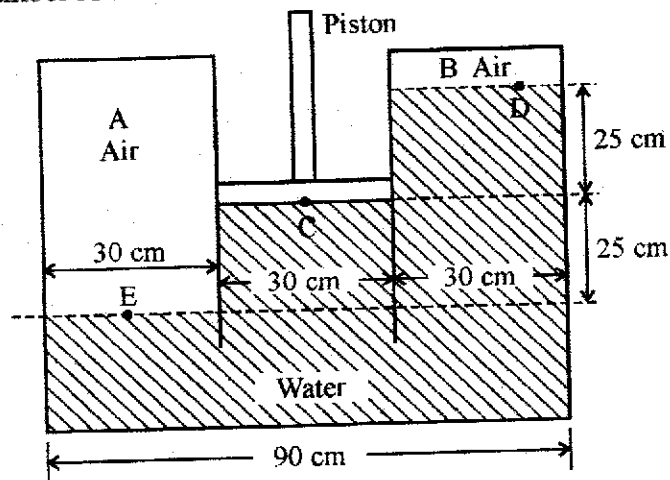
- (e) What do you mean by Froude model law ? Considering Froude as a criterion of dynamic similarity for a certain flow situation, find out the scale factors for velocity, time, discharge, acceleration, pressure, force, work and power in terms of scale factor for length (L) . 8

6. (a) With a neat sketch, explain stable, unstable and Neutral equilibrium ? Determine the position in which a solid cylindrical block of wood of diameter 4 m and 4 m height will float in water. Take specific gravity of wood as 0.6 . State whether the equilibrium is stable or unstable. 15



- (b) (i) Two chambers having same fluid at their base are separated by a piston whose weight is 25 N as shown in figure. Calculate gauge pressure in chamber A and B.

5



- (ii) Explain the separation of flow and name the methods used for controlling separation in a diffuser.
- (c) A rough pipe of diameter 0.1 m carries water at 20 °C at the rate of 50 l/s. If the average height of the roughness projection on pipe surface is 0.15 mm.

5

15

Determine

- (I) Friction
- (II) Shear stress at pipe surface
- (III) Shear velocity
- (IV) Maximum velocity

Take, kinematic viscosity = $1 \times 10^{-6} \text{ m}^2/\text{s}$ } For water at 20 °C
 mass density = 1000 kg/m^3

7. (a) In a BWR, type nuclear reactor, heat of nuclear fusion is transfer to water. In a reactor water comes out of the reactor as saturated vapour at 72 bar. The steam flows through a turbine and exhausts at 0.08 bar to condenser. The water leaves the condenser at 0.08 bar and 40 °C ($h = 176.5 \text{ kJ/kg}$). The liquid water is again pumped through the pump to the nuclear reactor. Isentropic efficiency of the turbine is 70%. The plant has a capacity of 750 MW. Calculate the mass flow rate of steam circulated and the rate of heat generation. Consider pump work is negligible.

20

at Pressure 0.08 bar

$$h_f = 173.9 \text{ kJ/kg}, h_{fg} = 2403.2 \text{ kJ/kg}, S_f = 0.5926 \text{ kJ/kg K}, S_{fg} = 7.637 \text{ kJ/kg K}$$

at 72 bar

$$h_g = 2770.9 \text{ kJ/kg}, S_g = 5.8019 \text{ kJ/kg K}.$$



- (b) At a location for hydraulic plant, head available (Net) was 335 m. The power availability with overall efficiency of 86% was 15500 kW. The unit is proposed to run at 500 rpm. Assume, $C_v = 0.98$, $k_u = 0.46$, blade velocity coefficient is 0.9. If the bucket outlet angle proposed is 165° . 10

Find out

- (I) Ratio of Jet diameter to the runner diameter if number of jet is 4.
- (II) Specific speed per jet.
- (III) Check the validity of hydraulic efficiency.
- (c) (i) Why should no moisture flow along with steam from the drum to super heater and why is no vapour bubble flows along with saturated water from the drum to the down comers ? 5
- (ii) Show the reheat and regenerative feed water heating cycle on T-S diagram. 5
8. (a) (i) A single acting 2-stage air compressor running at 300 rpm delivers air at 20 bars, while the intake condition of air are 0.98 bar and 305 K. The intermediate pressure is 5 bar and the clearance volume for low pressure compressor is 4% of its stroke volume. The compressor delivers $3 \text{ m}^3/\text{min}$ at 1 bar and 15°C . 15
- Estimate :
- (I) Power required to drive the compressor in kW.
- (II) Dimensions of low pressure cylinder if length of the cylinder equals to cylinder diameter.
- (III) Isothermal efficiency when the intercooling is perfect and the index $n = 1.3$ for compression and expansion.
- (ii) What is fanno flow ? Show that the upper and lower branches of fanno curve represent subsonic and supersonic flows respectively. 5
- (b) Explain with a neat sketch the fluid coupling and its area of application. 10
- (c) In a reciprocating pump the bore is 180 mm and the stroke is 280 mm. Water level is 5 m from the pump level. The suction pipe is 110 mm diameter and 9 m long. The atmospheric pressure head is 10.3 m water. Determine the maximum speed if the head at pipe suction should not be less than 2.5 m of head of water. If suction pipe diameter is increased to 125 mm and length reduced to 6 m, what will be the maximum speed ? 10

