Indian Maritime University

(A Central University, Govt of India)

March/April 2024 - Supplementary Examinations

Programme Name: B. Tech. (Marine Engineering)

Semester: 5th Semester

Subject Code: UG11T4509

Subject Name: HEAT TRANSFER AND MARINE HEAT EXCHANGERS

Date: 05.04.2024	Max Marks: 70
Duration: 03 Hrs	Pass Marks: 35

General Instructions

(i) All Sections (A, B & C) are to be attempted.
(ii) Options, if any, are specified in respective section.
(iii) Heat Transfer Data Handbook can be used.

Section A

Ten MCQs/Fill in the Blanks of 01 Mark each – Choose the correct answer as applicable.

1. Thermal contact resistance is a function of
a) surface roughness
b) the pressure holding the two surfaces in contact
c) the interface fluid and its temperature
d) all of the above

2. The relationship $(\text{Wavelength})_{max}$ T = constant, between the temperature of a black body and the wavelength at which maximum value of monochromatic emissive power occurs is known as

a) Planck's law
b) Kirchoff's law
c) Lambert's law
d) Wein's law

3. A composite wall consists of two layers of different materials having conductivities k_1 and k_2. For equal thickness of the two layers, the equivalent thermal conductivity of the slab will be

a) $k_1 + k_2$ b) $k_1 k_2$

c) $\dfrac{2k_1k_2}{k_1+k_2}$ d) $\dfrac{k_1+k_2}{k_1k_2}$

4. What does NTU indicate?
   a) Effectiveness of heat exchanger
   b) Efficiency of heat exchanger
   c) Size of heat exchanger
   d) Temperature drop in heat exchanger

5. For the fully developed laminar flow and heat transfer in a uniformly heated long circular tube, if the flow velocity is doubled and the tube diameter is halved, the heat transfer coefficient will be
   a) Double of the original value
   b) Half of the original value
   c) Same as before
   d) Four times of the original value

6. Gases have poor
   a) transmissivity
   b) absorptivity
   c) reflectivity
   d) emissivity

7. Which non-dimensional number relates the thermal boundary layer and hydrodynamic boundary layer?
   a) Prandtl Number
   b) Grashof Number
   c) Peclet Number
   d) Reynold Number

8. For calculation of heat transfer by natural convection from a horizontal cylinder, what is the characteristic length in Grashof number?
   a) Diameter of the cylinder
   b) Length of the cylinder
   c) Circumference of the base of the cylinder
   d) Half the circumference of the base of the cylinder

9. Forced convection dominates if
   a) $Gr/Re^2 << 1$
   b) $Gr/Re^2 >> 1$
   c) $Gr/Re^2 = 1$
   d) $Gr.Pr/Re^2 >> 1$

10. The fraction of radiative energy leaving one surface that strikes the other surface is called
    a) Radiative flux
    b) View factor

c) Reradiation flux
d) Emissive power of the first surface

Section B

Five Questions of 02 Marks each

11. Define the importance of critical radius of insulation.

12. How does fins / extended surfaces aids in the heat transfer?

13. Define Prandtl Number and Nusselt Number?

14. Differentiate the parallel flow and counterblow heat exchangers.

15. State the Kirchhoff's law of heat radiation?

Section C

Seven Questions of 10 Marks each of which any 05 questions to be answered.

16. Dry saturated steam at 10 bar enters a counter-flow heat exchanger at the rate of 15 kg/s and leaves at 280 ^{0}C. The entry of gas at 600 ^{0}C is with mass flow rate of 25 kg/s. If the condenser tubes are 35 mm diameter and 4 m long, make calculations for the heating surface area and the number of tubes required. Neglect the resistance offered by the metallic tubes. Take the following properties for steam and gas:

For steam: t_{sat} = 180 ^{0}C(at 10 bar), C_{ps} = 2.7 kJ/kg-K & h_s = 600W/m^2-^{0}C

For gas: C_{pg} = 1 kJ/kg-K & h_g = 250 W/m^2-^{0}C.

(10 marks)

17. Derive the general 1-Dimensional steady state heat conduction equation in cartesian coordinate system.

(10 marks)

18. Draw the TEMA standard heat exchanger with channel and removable cover and one object pass (AES) and mention the various parts. **(10 Marks)**

19. A steam main 80 mm inside diameter and 90 mm outside diameter is lagged with two successive layers of insulation. The layer in contact with the pipe is 40 mm asbestos and the asbestos layer is covered with 25 mm thick magnesia insulation. The surface coefficients for inside and outside surfaces are 227 W/m^2-K and 6.8 W/m^2-K respectively. If the steam temperature is 400 ^{0}C and the ambient temperature is 30 ^{0}C, calculate
a) the steady state loss of heat from steam for 60 m length of pipe.

b) the overall coefficient of heat transfer based on the inside and outside surfaces of the lagged steam main.

Thermal conductivity values of the pipe material, asbestos and magnesia insulation are 45 W/m-K, 0.14 W/m-K & 0.07 W/m-K respectively.

(7 + 3 marks)

20. A steel rod (k = 30 W/m-deg) 10 mm in diameter and 50 mm long protrudes from a wall which is maintained at 100 ^{0}C. the rod is insulated at its tip and is exposed to an environment with h = 50 W/m^2-deg and t_a = 30 ^{0}C. Estimate the following:

a) fin efficiency
b) temperature at the tip of fin
c) rate of heat dissipation

(4 + 3 + 3 marks)

21. 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, using the NTU-method determine the length of the heat exchanger required to achieve the desired heating. (C_p of water = 4.18 kJ/kg.K; C_p of geothermal water = 4.31 kJ/kg.K) **(10 marks)**

22. a) Explain briefly the extended surfaces or fins **(4 Marks)**

b) Derive an expression for LMTD in Parallel Flow Heat Exchangers. **(6 Marks)**

TABLE A-15

Properties of air at 1 atm pressure

Temp. T, °C	Density ρ, kg/m^3	Specific Heat c_p, J/kg · K	Thermal Conductivity k, W/m · K	Thermal Diffusivity α, m^2/s^2	Dynamic Viscosity μ, kg/m · s	Kinematic Viscosity ν, m^2/s	Prandtl Number Pr
−150	2.866	983	0.01171	4.158×10^{-6}	8.636×10^{-6}	3.013×10^{-6}	0.7246
−100	2.038	966	0.01582	8.036×10^{-6}	1.189×10^{-5}	5.837×10^{-6}	0.7263
−50	1.582	999	0.01979	1.252×10^{-5}	1.474×10^{-5}	9.319×10^{-6}	0.7440
−40	1.514	1002	0.02057	1.356×10^{-5}	1.527×10^{-5}	1.008×10^{-5}	0.7436
−30	1.451	1004	0.02134	1.465×10^{-5}	1.579×10^{-5}	1.087×10^{-5}	0.7425
−20	1.394	1005	0.02211	1.578×10^{-5}	1.630×10^{-5}	1.169×10^{-5}	0.7408
−10	1.341	1006	0.02288	1.696×10^{-5}	1.680×10^{-5}	1.252×10^{-5}	0.7387
0	1.292	1006	0.02364	1.818×10^{-5}	1.729×10^{-5}	1.338×10^{-5}	0.7362
5	1.269	1006	0.02401	1.880×10^{-5}	1.754×10^{-5}	1.382×10^{-5}	0.7350
10	1.246	1006	0.02439	1.944×10^{-5}	1.778×10^{-5}	1.426×10^{-5}	0.7336
15	1.225	1007	0.02476	2.009×10^{-5}	1.802×10^{-5}	1.470×10^{-5}	0.7323
20	1.204	1007	0.02514	2.074×10^{-5}	1.825×10^{-5}	1.516×10^{-5}	0.7309
25	1.184	1007	0.02551	2.141×10^{-5}	1.849×10^{-5}	1.562×10^{-5}	0.7296
30	1.164	1007	0.02588	2.208×10^{-5}	1.872×10^{-5}	1.608×10^{-5}	0.7282
35	1.145	1007	0.02625	2.277×10^{-5}	1.895×10^{-5}	1.655×10^{-5}	0.7268
40	1.127	1007	0.02662	2.346×10^{-5}	1.918×10^{-5}	1.702×10^{-5}	0.7255
45	1.109	1007	0.02699	2.416×10^{-5}	1.941×10^{-5}	1.750×10^{-5}	0.7241
50	1.092	1007	0.02735	2.487×10^{-5}	1.963×10^{-5}	1.798×10^{-5}	0.7228
60	1.059	1007	0.02808	2.632×10^{-5}	2.008×10^{-5}	1.896×10^{-5}	0.7202
70	1.028	1007	0.02881	2.780×10^{-5}	2.052×10^{-5}	1.995×10^{-5}	0.7177
80	0.9994	1008	0.02953	2.931×10^{-5}	2.096×10^{-5}	2.097×10^{-5}	0.7154
90	0.9718	1008	0.03024	3.086×10^{-5}	2.139×10^{-5}	2.201×10^{-5}	0.7132
100	0.9458	1009	0.03095	3.243×10^{-5}	2.181×10^{-5}	2.306×10^{-5}	0.7111
120	0.8977	1011	0.03235	3.565×10^{-5}	2.264×10^{-5}	2.522×10^{-5}	0.7073
140	0.8542	1013	0.03374	3.898×10^{-5}	2.345×10^{-5}	2.745×10^{-5}	0.7041
160	0.8148	1016	0.03511	4.241×10^{-5}	2.420×10^{-5}	2.975×10^{-5}	0.7014
180	0.7788	1019	0.03646	4.593×10^{-5}	2.504×10^{-5}	3.212×10^{-5}	0.6992
200	0.7459	1023	0.03779	4.954×10^{-5}	2.577×10^{-5}	3.455×10^{-5}	0.6974
250	0.6746	1033	0.04104	5.890×10^{-5}	2.760×10^{-5}	4.091×10^{-5}	0.6946
300	0.6158	1044	0.04418	6.871×10^{-5}	2.934×10^{-5}	4.765×10^{-5}	0.6935
350	0.5664	1056	0.04721	7.892×10^{-5}	3.101×10^{-5}	5.475×10^{-5}	0.6937
400	0.5243	1069	0.05015	8.951×10^{-5}	3.261×10^{-5}	6.219×10^{-5}	0.6948
450	0.4880	1081	0.05298	1.004×10^{-4}	3.415×10^{-5}	6.997×10^{-5}	0.6965
500	0.4565	1093	0.05572	1.117×10^{-4}	3.563×10^{-5}	7.806×10^{-5}	0.6986
600	0.4042	1115	0.06093	1.352×10^{-4}	3.846×10^{-5}	9.515×10^{-5}	0.7037
700	0.3627	1135	0.06581	1.598×10^{-4}	4.111×10^{-5}	1.133×10^{-4}	0.7092
800	0.3289	1153	0.07037	1.855×10^{-4}	4.362×10^{-5}	1.326×10^{-4}	0.7149
900	0.3008	1169	0.07465	2.122×10^{-4}	4.600×10^{-5}	1.529×10^{-4}	0.7206
1000	0.2772	1184	0.07868	2.398×10^{-4}	4.826×10^{-5}	1.741×10^{-4}	0.7260
1500	0.1990	1234	0.09599	3.908×10^{-4}	5.817×10^{-5}	2.922×10^{-4}	0.7478
2000	0.1553	1264	0.11113	5.664×10^{-4}	6.630×10^{-5}	4.270×10^{-4}	0.7539

Note: For ideal gases, the properties c_p, k, μ, and Pr are independent of pressure. The properties ρ, ν, and α at a pressure P (in atm) other than 1 atm are determined by multiplying the values of ρ at the given temperature by P and by dividing ν and α by P.

Source: Data generated from the EES software developed by S. A. Klein and F. L. Alvarado. Original sources: Keenan, Chao, Keyes, Gas Tables, Wiley, 198; and Thermophysical Properties of Matter. Vol. 3: Thermal Conductivity, Y. S. Touloukian, P. E. Liley, S. C. Saxena, Vol. 11: Viscosity, Y. S. Touloukian, S. C. Saxena, and P. Hestermans, IFI/Plenun, NY, 1970, ISBN 0-306067020-8.

For Q. 16. chart is reqd.

5/4/24.