Indian Maritime University

(A Cent3ral University, Govt of India)

Supplementary Examinations – March/April 2025

Programme Name: B Tech (Marine Engineering)

Semester: V

Subject Code: UG11T4509

Subject Name: HEAT TRANSFER AND MARINE HEAT EXCHANGERS

Date: 22.04.2025	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. The thermal conductivity of a damp brick is higher than that of dry brick, because
(a) the thermal conductivity of air is less than that of water.
(b) the heat transfer takes place in damp bricks by convection due to capillary motion of water within the porous material.
(c) both (a) and (b)
(d) none of the above

2. In natural convection heat transfer, the Nusselt number is a function of
(a) Re and Pr
(b) Re and Gr
(c) Gr and Pr
(d) Gr and Bi

3. When one of the fluid is condensing the best flow arrangement is
(a) counter flow
(b) parallel flow
(c) cross flow
(d) all are equal.

4. For buoyancy-induced fluid flow and heat transfer, this dimensionless number is significant

(a) Reynolds number
(b) Prandtl number
(c) Grashof number
(d) Nusselt number

5. The relation $\nabla^2 T = 0$ is referred to as
(a) Fourier heat conduction equation
(b) Laplace equation
(c) Poisson equation
(d) Euler equation

6. The fin effectiveness is enhanced by
(a) the choice of a material of high thermal conductivity.
(b) increasing the ratio of the perimeter to the cross-sectional area of the fin.
(c) the low value of heat transfer coefficient.
(d) all of the above.

7. The characteristic length for computing Grashof number in the case of a horizontal cylinder is
(a) the length of the cylinder
(b) the diameter of the cylinder
(c) the perimeter of the cylinder
(d) the radius of the cylinder

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

9. Most solids are ________ to radiation
(a) highly absorptive
(b) highly transmittive
(c) opaque
(d) highly reflective

10. The value of the maximum monochromatic emissive power of a black body, $(E_{b\lambda})_{max}$ shifts with increasing temperature towards
(a) the shorter wavelengths
(b) the longer wavelengths
(c) the same wavelength
(d) none of the above

Section B

Five Questions of 02 Marks each

11. What is the physical mechanism of heat conduction in a solid, a liquid, and a gas?
12. Differentiate natural and forced convection.
13. Define fouling and discuss its effect on the performance of heat exchangers.
14. Define efficiency for a fin. Write the mathematical equation for the efficiency of an infinitely long fin.
15. Define Grashoff number and Prandtl number.

Section C

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

16. Draw the TEMA standard heat exchanger with channel and removable cover, one object pass, and outside packed floating head (AEP) and mention the various parts.

17. A composite wall consists of three layers of thicknesses 300 mm, 200mm and 100 mm with thermal conductivities 1.5, 3.5 and K_3 W/mK, respectively. The inside surface is exposed to gases at 1200°C with convection heat transfer coefficient as 30 W/m^{2}K. The temperature of air on the other side of the wall is 30°C with convective heat transfer coefficient 10 W/m^{2}K. If the temperature at the outside surface of the wall is 180°C, calculate the temperature at other surface of the wall, the rate of heat transfer, and the overall heat transfer coefficient. (4+3+3=10 Marks)

18. Discuss the physical mechanism of natural convection with the help of a sketch.

19. 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.

20. A long rod 12 mm square section made of low carbon steel protrudes into air at 35°C from a furnace wall at 200°C. The convective heat transfer coefficient is estimated at 22W/m^{2}K. The conductivity of the material is 51.9 W/mK. Determine the location from the wall at which the temperature will be 60°C. Also calculate the temperature at 80 mm from base. (5 + 5 Marks)

21. Air at 20°C, at a pressure of 1 bar is flowing over a flat plate at a velocity of 3 m/s. if the plate maintained at 60°C, calculate the heat transfer per unit width of the plate. Assuming the length of the plate along the flow of air is 2 m.

22. Briefly discuss the (a) velocity boundary layer and (b) thermal boundary layer. (5 +5 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.