PhD, M. Sc Engg. (ME)/1st Sem, M Sc. TE (2 Yr) (TVE)/ 1st Sem 10.30 am-12.00 pm, Friday, 13 Oct, 2023

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)
ORGANISATION OF ISLAMIC COOPERATION (OIC)
DEPARTMENT OF MECHANICAL AND PRODUCTION ENGINEERING

MID Semester Examination
Course No.: ME 6145
Course Title: *Convective Heat Transfer*

Winter Semester: A.Y. 2022-2023
Time: 1.5 Hours
Full Marks: 75

There are **03 (Three)** Questions. Answer all of them. Marks in the margin indicate full marks. Do not write on this question paper. Symbols carry their usual meanings. Assume reasonable values for any missing data. Programmable calculators are not allowed.

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1. (a) The flow of oil in a journal bearing can be approximated as parallel flow between two large plates with one plate moving and the other stationary. Such flows are known as Couette flow **(Fig. 1)**. Consider two large isothermal plates separated by 2-mm-thick oil film. The upper plates move at a constant velocity of 12 m/s, while the lower plate is stationary. Both plates are maintained at 20°C. (*a*) Obtain relations for the velocity and temperature distributions in the oil. (*b*) Determine the maximum temperature in the oil and the heat flux from the oil to each plate. **[13]**

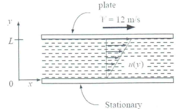

Figure 1

(b) A 5-cm-diameter shaft rotates at 4500 rpm in a 15-cmlong, 8-cm-outer-diameter cast iron bearing (k = 70 W/m °K) with a uniform clearance of 0.6 mm filled with lubricating oil (μ= 0.03 Ns/m^2 and k= 0.14 W/m.K) **(Fig. 2)**. The bearing is cooled externally by a liquid, and its outer surface is maintained at 40°C. Disregarding heat conduction through the shaft and assuming one-dimensional heat transfer, determine (*a*) the rate of heat transfer to the coolant, (*b*) the surface temperature of the shaft, and (*c*) the mechanical power wasted by the viscous dissipation in oil. **[12]**

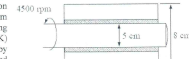

Figure 2

2. (a) A 25-cm-diameter stainless steel ball (k= 8055 kg/m^3, Cp= 480 J/kg. °C) is removed from the oven at a uniform temperature of 300°C **(Fig. 3)**. The ball is then subjected to the flow of air at 1 atm pressure and 25°C with a velocity of 3 m/s. The surface temperature of the ball eventually drops to 200°C. Determine the average convection heat transfer coefficient during this cooling process and estimate how long the process will take. **[13]**

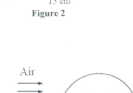

Figure 3

(b) Water at 15°C is to be heated to 65°C by passing it over a bundle of 4-m-long 1-cm-diameter resistance heater rods maintained at 90°C (**Fig. 4**). Water approaches the heater rod bundle in normal direction at a mean velocity of 0.8 m/s. The rods are arranged in-line with longitudinal and transverse pitches of $S_L = 4$ cm and $S_T = 3$ cm. Determine the number of tube rows N_L in the flow direction needed to achieve the indicated temperature rise. **[12]**

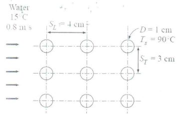

Figure 4

3. (a) Consider the flow of oil at 20°C in a 30-cm-diameter pipeline at an average velocity of 2 m/s (**Fig. 5**). A 200-m-long section of the pipeline passes through icy waters of a lake at 0°C. Measurements indicate that the surface temperature of the pipe is very nearly 0°C. Disregarding the thermal resistance of the pipe material, determine (*a*) the temperature of the oil when the pipe leaves the lake, (*b*) the rate of heat transfer from the oil, and (*c*) the pumping power required to overcome the pressure losses and to maintain the flow of the oil in the pipe. **[13]**

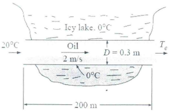

Figure 5

(b) Consider the flow of oil at 20°C in a 30-cm-diameter pipeline at an average velocity of 2 m/s (**Fig. 6**). A 200-m-long section of the pipeline passes through icy waters of a lake at 0°C. Measurements indicate that the surface temperature of the pipe is very nearly 0°C. Disregarding the thermal resistance of the pipe material, determine (*a*) the temperature of the oil when the pipe leaves the lake, (*b*) the rate of heat transfer from the oil, and (*c*) the pumping power required to overcome the pressure losses and to maintain the flow of the oil in the pipe. **[12]**

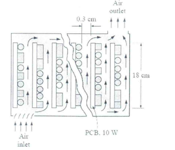

Figure 6

TABLE 7–2

Nusselt number correlations for cross flow over tube banks for N > 16 and 0.7 < Pr < 500 (from Zukauskas, Ref. 15, 1987)*

Arrangement	Range of Re_D	Correlation
In-line	0–100	$Nu_D = 0.9\,Re_D^{0.4}Pr^{0.36}(Pr/Pr_s)^{0.25}$
	100–1000	$Nu_D = 0.52\,Re_D^{0.5}Pr^{0.36}(Pr/Pr_s)^{0.25}$
	1000–2 × 10⁵	$Nu_D = 0.27\,Re_D^{0.63}Pr^{0.36}(Pr/Pr_s)^{0.25}$
	2 × 10⁵–2 × 10⁶	$Nu_D = 0.033\,Re_D^{0.8}Pr^{0.4}(Pr/Pr_s)^{0.25}$
Staggered	0–500	$Nu_D = 1.04\,Re_D^{0.4}Pr^{0.36}(Pr/Pr_s)^{0.25}$
	500–1000	$Nu_D = 0.71\,Re_D^{0.5}Pr^{0.36}(Pr/Pr_s)^{0.25}$
	1000–2 × 10⁵	$Nu_D = 0.35(S_T/S_L)^{0.2}\,Re_D^{0.6}Pr^{0.36}(Pr/Pr_s)^{0.25}$
	2 × 10⁵–2 × 10⁶	$Nu_D = 0.031(S_T/S_L)^{0.2}\,Re_D^{0.8}Pr^{0.36}(Pr/Pr_s)^{0.25}$