UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 8 Examination in Engineering: December 2016

Module Number: ME8301 **Module Name: Heat Transfer**

[Three Hours]

[Answer all questions, each question carries twelve marks]

Q1. a) Briefly explain the followings using the thermal resistance concept.

I) Thermal contact resistance.

II) Critical radius of insulation.

[2.0 Marks]

b) In Fig.Q1 (b), a 4 m high and 6 m wide wall consists of a long 18 cm × 30 cm cross section of horizontal bricks (k = 0.72 W/m.K) separated by 3 cm thick plaster layers (k = 0.22 W/m.K) .There are also 2 cm thick plaster layers on each side of the wall, and a 2 cm thick rigid foam (k = 0.026 W/m.K) on the inner side of the wall. The indoor and outdoor temperatures are 22 °C and -4 °C and the convection heat transfer coefficients on the inner and outer sides are h_1 = 10 W/m^2°C and h_2 = 20 W/m^2.K, respectively.

I) Determine the rate of heat transfer through the wall.

[5.0 Marks]

II) If the solid brick is replaced by a hollow brick repeat the calculation assuming that only stagnant air (k = 0.026 W/m.K) is inside the brick space and compare the results.

[5.0 Marks]

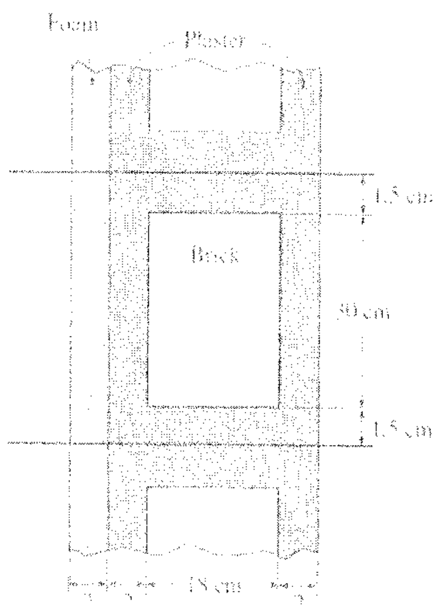


Fig.Q1 (b)

Q2. a) What is meant by the lump system analysis for transient conduction? Under which conditions is this concept validated?

[2.0 Marks]

b) Prove that the temperature for a lumped system is given by following equation,

$T(t) = T_\infty + (T_i - T_\infty).e^{-bt}$

Where,

$$b = \frac{h.A_s}{\rho.V.C_p}$$

[3.0 Marks]

c) In Fig.Q2 (c), Carbon steel balls (ρ = 7833 kg/m³ , k = 54 W/m.K and C_p = 0.465 kJ/kg.K) 8mm in diameter are annealed by heating them first to 900 °C in a furnace and then following them to cool slowly to 100 °C in ambient air at 35 °C. The average heat transfer coefficient is 75 W/m².K. Determine,

I) The time taken to the annealing process.

[3.0 Marks]

II) The heat transfer rate from the balls to the ambient air if 2500 balls are to be annealed per hour.

[4.0 Marks]

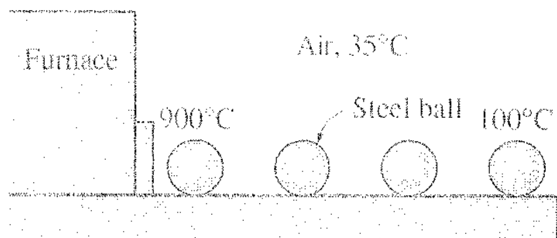


Fig.Q2(c)

Q3. a) In internal forced convection, describe the variation of the heat transfer coefficient in the region of entrance and fully developed flow regions with a suitable graph.

[3.0 Marks]

b) In internal forced convection for a constant surface temperature boundary by considering a differential fluid element, prove that exit temperature is given by the following equation with usual notations.

$T_e = T_s - (T_s - T_i).e^{-\frac{h.A_s}{\dot{m}.C_p}}$

[3.0 Marks]

c) Consider a flow of oil at 10 °C in a 40 cm diameter pipeline at an average velocity of 0.5 m/s. A 300 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,

I) The temperature of the oil when the pipe leaves the lake.

[1.0 Marks]

II) The rate of heat transfer from the oil.

[2.0 Marks]

III) The pumping power required to overcome the pressure losses and to maintain the flow oil in the pipe.

[3.0 Marks]

Use the Table Q3(c) for the equations and correlations for Internal forced convection.

Q4. a) Briefly describe the physical mechanism of natural convection.

[2.0 Marks]

b) What does the Grashof number represent? How does the Grashof number differ from Reynolds number?

[4.0 Marks]

c) A 10 m long section of a 6 cm diameter horizontal hot water pipe passes through a large room whose temperature is 20 °C. Temperature and the emissivity of the pipe are 60 °C and 0.8 respectively. Determine,

I) The rate of heat loss from the pipe.

[3.0 Marks]

II) Compare the heat transfer by natural convection and radiation.

[3.0 Marks]

Use the Table Q4 (c) for Nusslet number relations.

Q5. a) Describe the variation of the thermal radiation with the wavelength and temperature for a blackbody with the aid of a graph.

[2.0 Marks]

b) Briefly explain the two types of flow arrangements possible for double pipe heat exchangers.

[3.0 Marks]

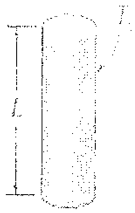
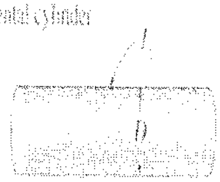
c) Steam in the condenser of a power plant is to be condensed at a temperature of 30 °C with cooling water from a nearby lake, which enters the tube of the condenser at 14 °C and leaves 22 °C. The surface area of the tubes is 45 m^2, and the overall heat transfer coefficient is 2100 $W/m^2.K$ .Determine the mass flow rate of the cooling water and the rate of condensation of the steam in the condenser. (C_p of cooling water = 4184 J/kg .K)

[7.0 Marks]

Table Q3: The equations and correlations for Internal forced convection

Description	Equation
Thermal Entry length for laminar and turbulent flow regimes	$L_{h,Laminar} \approx 0.05 Re\, D$ $L_{t,Laminar} \approx 0.05 Re\, Pr\, D = Pr\, L_{h,Laminar}$ $L_{h,turbulant} \approx L_{t,turbulent} \approx 10\, D$
Nusselt number for laminar flow	*Circular tube, laminar* ($\dot{q}_s = constant$): $Nu = \frac{hD}{k} = 4.36$ *Circular tube, laminar* ($T_s = constant$): $Nu = \frac{hD}{k} = 3.66$
Friction factor for laminar flow	$f = \frac{64\mu}{\rho D^o V_m} = \frac{64}{Re}$
Nusselt number for fully developed laminar flow with constant surface temperature	*Circular tube:* $Nu = 3.66 + \frac{0.065\,(D/L)\,Re\,Pr}{1 + 0.04[(D/L)\,Re\,Pr]^{2/3}}$ *Circular tube:* $Nu = 1.86 \left(\frac{Re\,\mathrm{Pr}\,D}{L}\right)^{1/3} \left(\frac{\mu_b}{\mu_s}\right)^{0.14}$ *Parallel plates:* $Nu = 7.54 + \frac{0.03\,(D_h/L)\,Re\,Pr}{1 + 0.016[(D_h/L)\,Re\,Pr]^{2/3}}$
Nusselt number for fully developed turbulent flow with smooth surfaces	$f = (0.79 \ln Re - 1.64)^{-2}$ $\quad 10^4 < Re < 10^6)$ $Nu = 0.125\, f\, Re\, Pr^{1/3}$ $Nu = 0.023\; Re^{0.8}\, Pr^{1/3}$ $\quad 0.7 < Pr < 160$, $Re > 10{,}000$

Table Q4: Empirical correlation for Nu for natural convection over surfaces

Geometry	Characteristic Length, Le	Range of Ra	Nusselt number
Vertical cylinder 	L		A Vertical cylinder can be treated as a vertical plate when, $D \geq \dfrac{35\,L}{Gr_L^{1/4}}$
Horizontal cylinder 	D	$Ra_D \leq 10^{12}$	$Nu = \left\{0.6 + \dfrac{0.378 Ra_D^{1/6}}{[1 + (0.559/Pr)^{9/16}]^{8/27}}\right\}^2$
Sphere 	D	$Ra_D \leq 10^{11}$ $(Pr \geq 0.7)$	$Nu = 2 + \dfrac{0.589 Ra_D^{1/4}}{[1 + (0.469/Pr)^{9/16}]^{4/9}}$