First Name--- Date:November 15, 2014-

Last Name--

Student ID Number------------------------------

Cankaya University

Faculty of Engineering

Mechanical Engineering Department

ME 313 Heat Transfer

Midterm Exam I

Closed Notes Closed Book

Fall 2014

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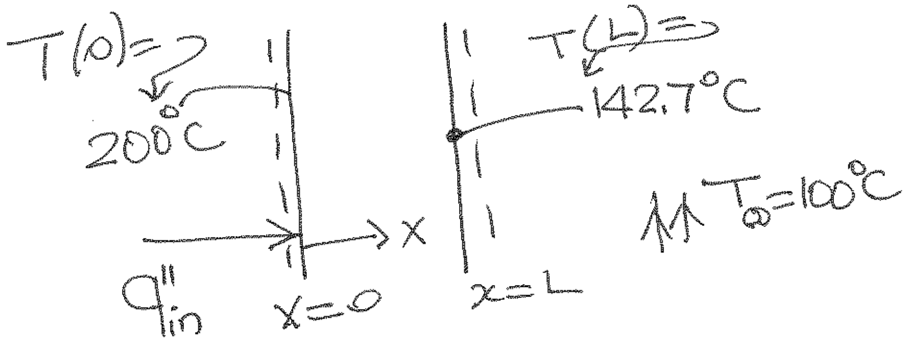
1) The temperature distribution across a wall 0.3 m thick at a certain instant of time is $T(x) = a + bx + cx^2$,where T is in degrees Celsius and x is in meters, a= 200 ^{0}C, b =-200 ^{0}C/ m, and c =30 ^{0}C/ m^2. The wall has a thermal conductivity of 1W/ m K.

(a) on a unit surface area basis, determine the rate of heat transfer into the wall on left face

(b) on a unit surface area basis, determine the rate of heat transfer out of the wall on right face

(c) the rate of change of energy stored by the wall.

(d) If the cold surface is exposed to a fluid at 100 ^{0}C, what is the convection coefficient $h(W/m^2.K)$?



$T = 200 - 200X + 30X^2$

L = 0.3 m

k = 1 W/mK

$q''_x = -k\frac{\partial T}{\partial x} = -(1)(-200+60X)$

a) $q''_{in} = q''_{x=0} = 200\,W/m^2$

b) $q''_{out} = q''_{x=L} = -(1)(-200+(60)(0.3)) = 182\,W/m^2$

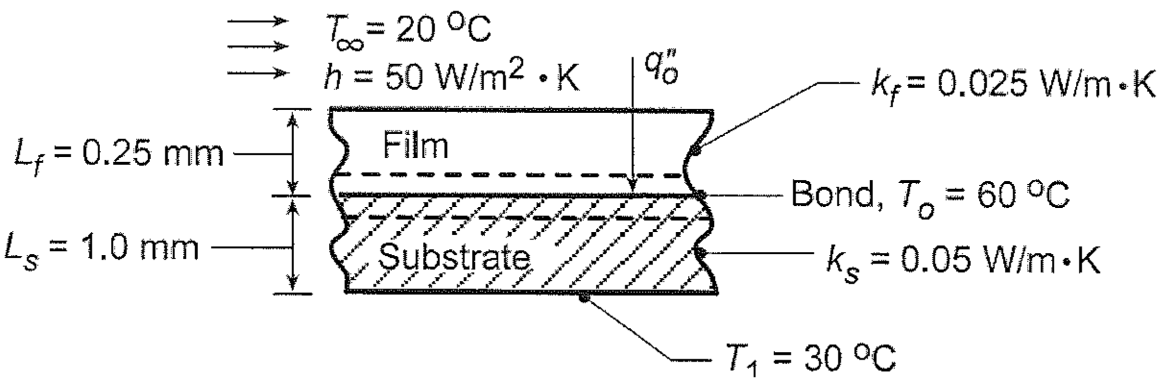
c) $E''_{in} - E''_{out} = E''_{st} \Rightarrow E''_{st} = 200-182 = 18\,W/m^2$

d) $q''_{out} = \bar{h}[T(L)-T_\infty]$

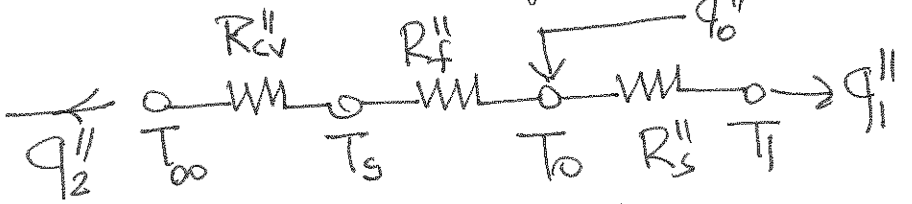
$T(0.3)=T(L)= 200-200(0.3)+30(0.3)^2 = 142.7^\circ C$

$\bar{h} = \frac{182}{142.7-100} = 4.3\,W/m^2K$

2) In a manufacturing process, a transparent film is being bonded to a substrate as shown in the sketch.



To cure the bond at a temperature T_0, a radiant source is used to provide a heat flux $q_0''\ (W/m^2)$, all of which is absorbed at the bonded surface. The back of the substrate is maintained at T_1 while the free surface of the film is exposed to air at T_∞ and a convection heat transfer coefficient h. Calculate the heat flux $q_0''\ (W/m^2)$ required to maintain the bonded surface at $T_0 = 60\,^0C$.



$$q_o'' = q_1'' + q_2'' \qquad q_o'' = \frac{T_o - T_\infty}{R_{cv}'' + R_f''} + \frac{T_o - T_1}{R_s''}$$

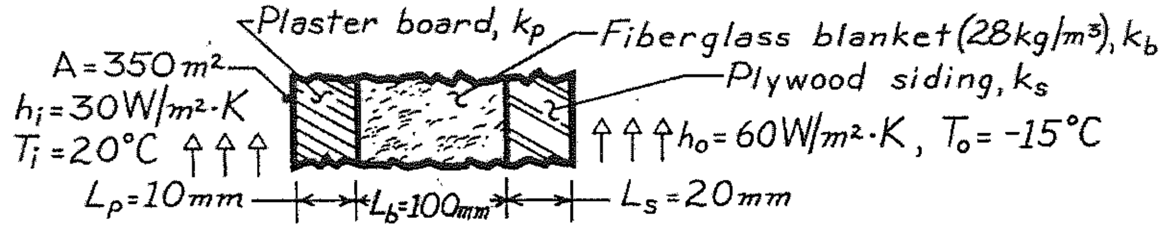
$$R_{cv}'' = \frac{1}{h} = \frac{1}{50} = 0.02 \quad m^2K/W$$

$$R_f'' = \frac{L_f}{K_f} = 0.00025/0.025 = 0.01\ m^2K/W$$

$$R_s'' = L/K = 0.001/0.05 = 0.02\ K/W$$

$$q_o'' = \frac{60-20}{0.02+0.01} + \frac{60-30}{0.02} = 2833\ W/m^2$$

3) A house has a composite wall of wood, fiberglass insulation, and plaster board, as indicated in the sketch. On a cold winter day, the convection heat transfer coefficients are $h_0 = 60\,W/m^2.K$ and $h_i = 60\,W/m^2.K$. The total wall surface area is 350 m2.



PROPERTIES: *Table A-3,* $\left(\bar{T} = (T_i + T_o)/2 = (20-15)^\circ C/2 = 2.5^\circ C \approx 300K\right)$: Fiberglass blanket, 28 kg/m^3, k_b = 0.038 W/m·K; Plywood siding, k_s = 0.12 W/m·K; Plasterboard, k_p = 0.17 W/m·K.

Determine the total heat flux through the wall.

$$q = \frac{\Delta T}{R_T} = \frac{T_i - T_o}{R_T}$$

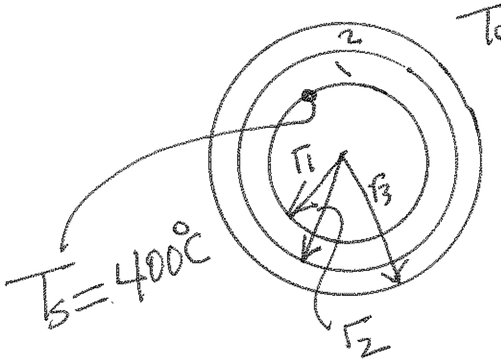
$$R_T = \frac{1}{Ah_i} + \frac{L_P}{AK_p} + \frac{L_b}{AK_b} + \frac{L_s}{AK_s} + \frac{1}{Ah_o}$$

$$= \frac{1}{(350)(30)} + \frac{0.01}{(0.17)(350)} + \frac{0.1}{(0.038)(350)} + \frac{0.02}{(350)(0.12)} + \frac{1}{(60)(350)}$$

$$= 831 \times 10^{-5}\ ^\circ C/W$$

$$q = \frac{20-(-15)}{831 \times 10^{-5}} = 4211\ W$$

4) A 5-cm diameter steel pipe is covered with a 1–cm layer of insulating material having $k = 22\,W/m.^0C$ followed by a 3-cm thick layer of another insulating material having $k = 0.06\,W/m.^0C$. The entire assembly is exposed to a convection surrounding condition of $h = 60\,W/m^2.^0C$ and $T_\infty = 15\ ^0C$. The outside surface temperature of the steel pipe is $400\ ^0C$. Calculate heat lost by the pipe-insulation assembly for a pipe length of 20 m.



$T_\infty = 15°C$

$h = 60\,W/m^2K$

$r_1 = 2.5\,cm$

$k_1 = 22\,W/mK$

$r_2 = 3.5\,cm$

$r_3 = 6.5\,cm$

$k_2 = 0.06\,W/m°C$

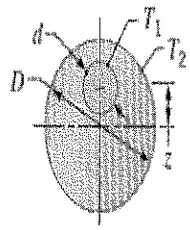
$$q = \frac{T_s - T_\infty}{\frac{\ln(r_2/r_1)}{2\pi k_1 L} + \frac{\ln(r_3/r_2)}{2\pi k_2 L} + \frac{1}{(2\pi r_3)(L)h}}$$

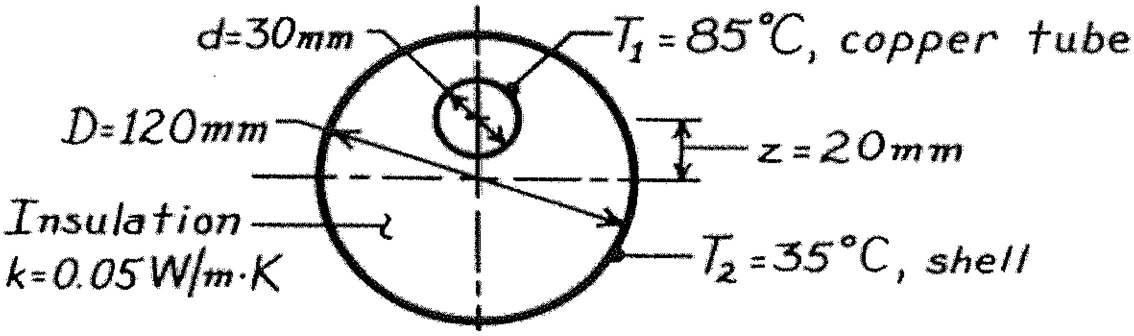
$$\frac{q}{L} = \frac{(400-15)}{\frac{\ln(3.5/2.5)}{(2)(\pi)(22)} + \frac{\ln(6.5/3.5)}{2)(\pi)(0.06)} + \frac{1}{(2\pi)(6.5)(60)}}$$

$$= \frac{385}{0.002434 + 1.64 + 0.000408}$$

$$= 385/1.6485 = 234.34\ W/m$$

5) Hot water at 85 °C flows through a thin- walled copper tube of 30- mm diameter. The tube is enclosed by an eccentric cylindrical shell that is maintained at 35 °C and has a diameter of 120 mm. The eccentricity, defined as the separation between the centers of the tube and shell, is 20 mm. The space between the tube and shell is filled with an insulating material having a thermal conductivity of 0.05 W/m K. Calculate the heat loss per unit length of the tube, and compare the result with the heat loss for a concentric arrangement.

Eccentric circular cylinder of length L in a cylinder of equal length		$D > d$ $L \gg D$	$\dfrac{2\pi L}{\cosh^{-1}\left(\dfrac{D^2 + d^2 - 4z^2}{2Dd}\right)}$



$$q = kS(T_1 - T_2) \qquad L = 1\,m$$

$$S = \frac{2\pi}{\cosh^{-1}\left[\dfrac{D^2 + 4d^2 - 4z^2}{2Dd}\right]} = \frac{2\pi}{\cosh^{-1}\left[\dfrac{120^2 + 30^2 - 4(20)^2}{2 \times 120 \times 30}\right]}$$

$$= \frac{2\pi}{\cosh^{-1}(1.903)} = 4.99 \approx 5$$

$$q = (0.05)(5)(85 - 35) = 12.5\ W$$

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Quiz # 4

Name :
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A 50 mm thick iron plate is initially at 225 °C. Both of its surfaces are suddenly exposed to an environment at 25 °C with a convection coefficient of 500 W/m^2K

i. Calculate the center temperature 2 minutes after the start of exposure.
ii. Calculate the temperature at the depth of 10 mm from the surface after 2 minutes of exposure
iii. Calculate the energy that is removed from the plate per square meter during this period.

$k=60\ W/mK$ $\rho=7850\ kg/m^3$ $c=460\ J/kgK$

$\alpha=1.6\times10^{-5}\ m^2/s$ $\bar{h}=500\ W/m^2K$

$2L=50\ mm$ $L=25mm=0.025m$

$T_i=225°C$ $T_\infty=25°C$ $t=2min=120s$

$Bi=\frac{hL}{k}=\frac{500)(0.025)}{60}=0.21>0.1$ Use charts

$\frac{1}{Bi}=\frac{1}{0.21}=4.8$

$Fo=\frac{\alpha t}{L^2}=\frac{(1.6\times10^{-5})(120)}{(0.025)^2}=3.07$

$\frac{\theta_o}{\theta_i}=\frac{T_o-T_\infty}{T_i-T_\infty}=0.58$

$T_o=0.58(225-25)+25=141°C$

b) At 10 mm from surface

$\frac{x}{L}=\frac{25-10}{25}=0.6$

$\frac{1}{Bi}=4.8$

$\frac{\theta}{\theta_o}=\frac{T-T_\infty}{T_o-T_\infty}=0.95$

$$T = 25 + 0.95(141 - 25) = 135.2\,°C$$

e)

$$\left.\begin{aligned} Bi &= 0.2 \\ Bi^2 Fo &= (0.21)^2(3.07) = 0.135 \end{aligned}\right] \frac{Q}{Q_i} = 0.45$$

$$Q_i = \rho c V (T_i - T_\infty)$$

$$= \rho c (A)(2L)(T_i - T_\infty)$$

$$= 7850)(460)(1\,m^2)(0.05)(225 - 25)$$

$$= 35.33 \times 10^3\ kJ/m^2$$

$$Q = (0.45)(35.33 \times 10^3) = 15.9 \times 10^3\ kJ/m^2$$