MAE 423 HEAT AND MASS TRANSFER
EXAM 1 - SPRING 2013

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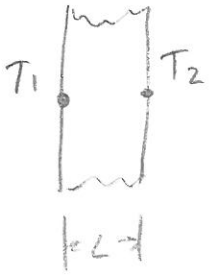
Name: AnswerKey

You are allowed one sheet of notes.

1. A planar wall has a temperature of 800° C on one side and 50° C on the other side. If the wall is 10 cm thick, and has a thermal conductance of 0.5 W/(mK), how much heat is transmitted through the wall per unit area (per m^2)?

Given:



$T_1 = 800°C$

$T_2 = 50°C$

$L = 10\,cm = 0.10\,m$

$k = 0.5\ \frac{W}{mK}$

10

Find: q/A

Solution: $q = kA\frac{T_1 - T_2}{L}$

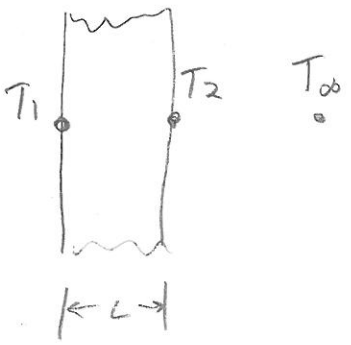
$= 0.5A\frac{800-50}{0.10}$

$= 3750A\ W$

$$\frac{q}{A} = 3750\ \frac{W}{m^2}$$

2. A planar wall has a temperature of 800° C on one side and is exposed to air at 20° on the other side. If the wall is 10 cm thick, and has a thermal conductance of 0.5 W/(mK), and the convection coefficient for the exposed side is 15 W/(m^{2}K), (i) how much heat is transmitted through the wall per unit area (per m^2), and (ii) what is the temperature of the exposed side of the wall?

Given:



$T_1 = 800°C$

$T_\infty = 20°C$

$L = 0.1\ m$

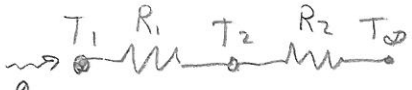
$k = 0.5\ \frac{W}{mK}$

$\bar{h}_c = 15\ \frac{W}{m^2K}$

10

Find: $\frac{q}{A}$, T_2

Solution:



$$R_1 = \frac{L}{kA} = \frac{0.1}{0.5A} = \frac{0.2}{A}$$

$$R_2 = \frac{1}{\bar{h}_c A} = \frac{1}{15A} = \frac{0.06667}{A}$$

$$q = \frac{T_1 - T_\infty}{R_1 + R_2} = \frac{800 - 20}{\frac{0.2}{A} + \frac{0.06667}{A}} = 2925A$$

$$\boxed{\frac{q}{A} = 2925\ \frac{W}{m^2}}$$

$$\left(\frac{q}{A}\right) = +k\frac{T_1 - T_2}{L}$$

$$2925 = +0.5\frac{(800 - T_2)}{0.1}$$

$$\boxed{T_2 = 215°C}$$

3. A planar wall has a temperature of 800° C on one side and is exposed to air and room surfaces at 20° on the other side. If the wall is 10 cm thick and has a thermal conductance of 0.5 W/(mK), and the exposed surface has an emissivity of 0.8 and convection coefficient of 15 W/(m^{2}K), (i) how much heat is transmitted through the wall per unit area (per m^2), and (ii) what is the temperature of the exposed side of the wall?

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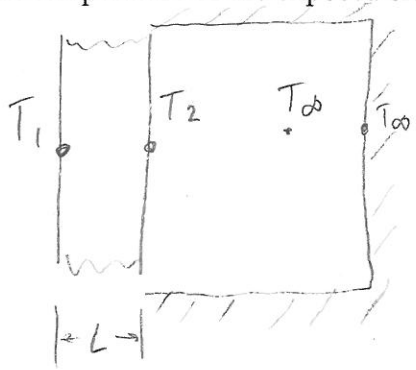
Given:



$T_1 = 800°C$

$T_\infty = 20°C = 293.15\ K$

$L = 0.1\ m$

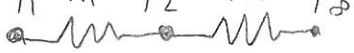
$k = 0.5\ \frac{W}{mK}$

$\epsilon = 0.8$

$\bar{h}_c = 15\ \frac{W}{m^2K}$

Find: $\frac{q}{A}$, T_2

Solution:



$R_1 = \frac{L}{kA} = \frac{0.1}{0.5A} = \frac{0.2}{A}$

$R_2 = \frac{1}{\bar{h}A}$

$= \frac{1}{26.491A}$

$q = \frac{T_1 - T_\infty}{R_1 + R_2} = \frac{800 - 20}{\frac{0.2}{A} + \frac{1}{26.491A}}$

$\frac{q}{A} = 3281\ \frac{W}{m^2}$

$\left(\frac{q}{A}\right) = k\frac{T_1 - T_2}{L}$

$3281 = 0.5\ \frac{800 - T_2}{0.1}$

$T_2 = 144°C$

$T_{2\,guess} = 215°C = 488.15K$

$\bar{h} = \bar{h}_c + \bar{h}_r = \bar{h}_c + \epsilon\sigma\frac{T_2^4 - T_\infty^4}{T_2 - T_\infty}$

$= 15 + 0.8 \times 5.67 \times 10^{-8}\ \frac{488.15^4 - 293.15^4}{488.15 - 293.15}$

$= 15 + 11.491\ \frac{W}{m^2K}$

$= 26.491\ \frac{W}{m^2K}$

4. A cylindrical wall has a temperature of 800° C on the inside and is exposed to air and room surfaces at 20° on the outside. If the wall has an inside radius of 0.25 m, thickness of 10 cm, height of 0.5 m, and thermal conductance of 0.5 W/(mK), and the exposed outside surface has an emissivity of 0.8 and convection coefficient of 15 W/(m^{2}K), (i) how much heat is transmitted through the wall, and (ii) what is the temperature of the exposed outside of the wall?

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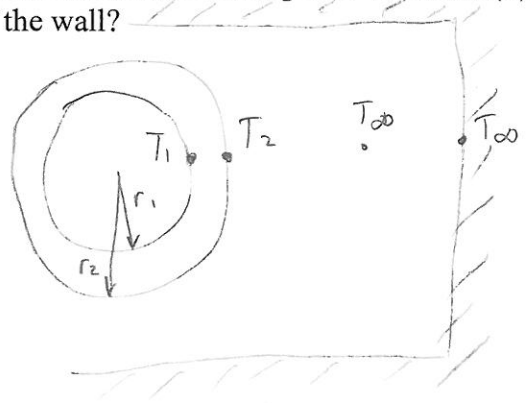
Given



$T_1 = 800°C$

$T_\infty = 20°C = 293.15 K$

$r_1 = 0.25 m$

$r_2 = 0.25 + 0.1 = 0.35 m$

$L = 0.5 m$

$k = 0.5 \frac{W}{mK}$

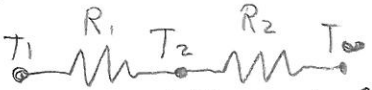
$\epsilon = 0.8$

$\bar{h}_c = 15 \frac{W}{m^2 K}$

Find : q , T_2

$T_{2\,guess} = 144°C = 417.0 K$

Solution:



$$R_1 = \frac{\ln \frac{r_2}{r_1}}{k 2\pi L} = \frac{\ln \frac{0.35}{0.25}}{0.5(2\pi \cdot 0.5)} = 0.2142 \frac{K}{W} \quad (= 0.2355 \frac{K m^2}{W})$$

$$R_2 = \frac{1}{\bar{h} A}$$

$$= \frac{1}{23.37 \times (2\pi \cdot 0.35 \cdot 0.5)}$$

$$= 0.0389 \frac{K}{W}$$

$$\bar{h} = \bar{h}_c + \bar{h}_r = \bar{h}_c + \epsilon \sigma \frac{T_2^4 - T_\infty^4}{T_2 - T_\infty}$$

$$= 15 + 0.8 \times 5.67 \times 10^{-8} \frac{417.0^4 - 293.15^4}{417.0 - 293.15}$$

$$= 15 + 8.370$$

$$= 23.370 \frac{W}{m^2 K}$$

$R_{2c} = \frac{1}{15} = 0.0667 \frac{K m^2}{W}$

$R_{2r} = \frac{1}{8.370} = 0.1195 \frac{K m^2}{W}$

$= \frac{1}{9.20} = 0.1087 \frac{K}{W}$

$$q = \frac{T_1 - T_\infty}{R_1 + R_2} = \frac{800 - 20}{0.2142 + 0.0389} = 3082 W$$

$q = 1198 W$

$$q = \frac{T_1 - T_2}{R_1}$$

$$3082 = \frac{800 - T_2}{0.2142}$$

$T_2 = 139.8°C$