MAE 101C

MAE101C: Final study sheet

Ch 6

$C = \nu\lambda$ — [Hz] — [μm]

speed of light, 3×10^8 m/s

Blackbody: absorbs all radiation falling upon it

Emission is diffuse: no preferred direction

Max emission

$\alpha + \rho = 1$

absorptivity — reflectivity

Stefan-Boltzmann law

$E_b = \sigma T^4$

$\sigma = 5.67\times10^{-8}\ W/m^2K^4$

ε: emmitance

$\varepsilon = 1$ for blackbody

radiosity — J = ~~incoming~~ outgoing radiation energy

G = incoming

reciprocal rule

$F_{21} = \frac{A_1}{A_2} F_{12}$

Shape factor

F_{12}: ~~radiation~~ fraction of energy leaving A_1 that is intercepted by A_2

$\dot{Q}_{12} = E_{b1} A_1 F_{12} - E_{b2} A_2 F_{21}$

Emmitance — ratio of radiant emmitance of object / " blackbody

absorbs all incident radiation

Absorptance: ratio of radiant flux absorbed / " received

gray surface

why $\alpha = \varepsilon$?

String rule pg 464

$J_1 = \varepsilon_1 \sigma T_1^4 + (1-\varepsilon_1)\left[F_{12} J_2 + F_{13} J_3\right]$

Refractory: $\dot{Q} = 0$

$\dot{Q} = 0 = J - G$

$J = G$

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String rule pg 464

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101C Notes

overall heat transfer coefficient

U? Problem 6
How to find?

Ch1

$q = -k\frac{dT}{dx}$

Thermal resistance: $R = \frac{L}{Ak}$ thermal conductivity $= \frac{U}{A} = \frac{1}{hA}$

air = low conductivity = high resistance

Lumped thermal capacity

valid if conductive $\gg$ convective

$Bi = \frac{\text{convective}}{\text{conductive}}$ If < 0.1, valid

$= \frac{\bar{h}_c L_{eff}}{k}$ $\sim V/A$

ρ: density
c: thermal capacity
h: heat transfer coeff

$\frac{T - T_e}{T_0 - T_e} = \exp\left(-\frac{t}{t_c}\right) \quad t_c = \frac{\rho V c}{\bar{h}_c A}$

conduction

$q = h_c \Delta T$

Equilibrium temp:

$M_1 C_1 (T_{0,1} - T_2) = M_2 C_2 (T_2 - T_{0,2})$

Radiative heat transfer b/w bodies

$Q_{12} = \varepsilon_1 A_1 \sigma (T_1^4 - T_2^4)$ $\quad \varepsilon_1 =$ emittance

$q = \sigma(T_1^4 - T_2^4)$

First Law

$\rho c V \frac{dT}{dt} = \dot{Q} + \dot{Q}_v$

$\dot{Q} = \dot{Q}_{in} - \dot{Q}_{out}$

$\rho V = \text{mass}$

σ = Stefan-Boltzman constant

Ch2

$q = -k\frac{dT}{dx}$

Fourier's law: $\dot{Q} = 4\pi r^2 \left(-k\frac{dT}{dr}\right)$ for shell

$\dot{Q}_v'''$ = volumetric thermal energy generation rate

$\dot{Q}_{loss} = \frac{T(r_0) - T_e}{R_{tot}}$

Energy balance $\longrightarrow$ governing equation $\longrightarrow$ Apply BCs

$\dot{Q}|_x - \dot{Q}|_{x+\Delta x} + \dot{Q}_v''' A \Delta X = 0$

Fins $\quad \beta = \sqrt{\frac{h_c P}{kA}} \quad P = \text{perimeter} \quad \dot{Q}_{fin} = h_c P L (T_B - T_e) \frac{\tanh(\beta L)}{\beta L}$

Prandtl number (Pr)

$$Pr = \frac{\nu}{\alpha} = \frac{\text{viscous diffusion rate}}{\text{thermal diffusion rate}}$$

Ch3 P6

$$\frac{T_A - T_i}{T_i - T_B} = \left(\frac{(k\rho c)_B}{(k\rho c)_A}\right)^{1/2}$$

$$\frac{310 - T_i}{T_i - 263} = \left(\frac{(0.1)(500)(2400)}{(990)(4180)(0.628)}\right)^{1/2}$$

$$310 - T_i = 0.2149\,(T_i - 263)$$

$$310 - T_i = 0.2149T_i - 56.5$$

$$1.2149T_i = 366.5$$

$$T_i = 301.671$$

$$T_i = 28.7^\circ$$

Ch3: conduction

$\theta = T - T_0$ to have fewer non-zero sides

$\theta_1(y, 1-x)$ 90°CCW

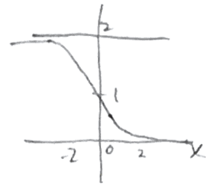
$\theta_2(1-y, x)$ 90° CW

Superposition: $\theta(x,y) = C_1\theta_1(x,y) + C_2\theta(x,y)$

Eq. (3.30) rotate to match Figure 3.7

$\dot{Q} = kS\Delta T$

shape factor [m]



$\text{erfc}(x) = \frac{2}{\sqrt{\pi}}\int_x^\infty e^{-t^2}dt$

$x = T_s - T_0$

$\theta = \frac{T - T_0}{T_s - T_0}$: dimensionless temp

α = thermal diffusivity

1. energy balance

$qA|_x - qA|_{x+\Delta x}$

$+Q'''$

$-\varepsilon A\sigma T^4$

$-h_c\Delta x\Delta T p$

Laplace's equation

$$\frac{\partial^2\theta}{\partial x^2} + \frac{\partial^2\theta}{\partial y^2} = 0$$

$$\theta(x,y) = X(x)\,Y(y)$$

$$X'' - \lambda^2 X = 0, \quad Y'' + \lambda^2 Y = 0$$

$$\theta = XY = (A_1 e^{\lambda x} + A_2 e^{-\lambda x})(B_1 \sin\lambda y + B_2 \cos\lambda y)$$

Convection problems: find equation and calculate Nu

Ch 4: convection

$Re = \frac{DV}{\nu}$ Turbulent flow: $Re_D \approx 2300$ in pipe, $Re_x \geq 50{,}000$ for flat plate

Nusselt number: $\frac{\text{convective}}{\text{conductive}}$ heat transfer, across fluid boundary

~~Bi: $\frac{\text{convective}}{\text{conductive}}$ $\frac{\text{outside}}{\text{inside}}$~~

solid body (Bi) vs. fluid (Nu)

If $Bi < 0.1$, conductive inside $\gg$ convective outside $Bi = \frac{hL}{k}$

Pipes: evaluate properties at average of temps