

**ENGT 320 Applied Thermal Systems**  
**Quiz 3 Formula Sheet**

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$$m = \rho V$$

$$\dot{V} = \frac{V}{t}$$

$$q = mc_p \Delta T$$

$$q = -kA \frac{dT}{dt}$$

$$q = hA (T_s - T_{\infty})$$

$$q = \varepsilon \sigma A (T_s^4 - T_{sur}^4)$$

$$\sigma = 5.67 \times 10^{-8} \frac{W}{m^2 K^4}$$

$$\Delta E_{sys} = \Sigma E_{in} - \Sigma E_{out}$$

$$\frac{dE_{sys}}{dt} = \Sigma \dot{E}_{in} - \Sigma \dot{E}_{out}$$

$$q'' = \frac{q}{A}$$

$$\hat{q}'' = -k_x \frac{\partial T}{\partial x} \hat{i} - k_y \frac{\partial T}{\partial y} \hat{j} - k_z \frac{\partial T}{\partial z} \hat{k}$$

$$k = \frac{9\gamma-5}{4} \frac{c_v}{\pi d^2} \sqrt{\frac{M_w k_B T}{N_A \pi}}$$

$$k_B = 1.381 \times 10^{-23} \frac{J}{K}$$

$$N_A = 6.022 \times 10^{23}$$

$$\alpha = \frac{k}{\rho c_p}$$

$$q_{x+dx} = q_x + \frac{\partial q_x}{\partial x} dx$$

$$q_{y+dy} = q_y + \frac{\partial q_y}{\partial y} dy$$

$$q_{z+dz} = q_z + \frac{\partial q_z}{\partial z} dz$$

$$\frac{\partial}{\partial x} \left( k \frac{\partial T}{\partial x} \right) + \frac{\partial}{\partial y} \left( k \frac{\partial T}{\partial y} \right) + \frac{\partial}{\partial z} \left( k \frac{\partial T}{\partial z} \right) + \dot{q} = \rho c_p \frac{\partial T}{\partial t}$$

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} + \frac{\dot{q}}{k} = \frac{1}{\alpha} \frac{\partial T}{\partial t}$$

$$\frac{\partial}{\partial x} \left( k \frac{\partial T}{\partial x} \right) + \frac{\partial}{\partial y} \left( k \frac{\partial T}{\partial y} \right) + \frac{\partial}{\partial z} \left( k \frac{\partial T}{\partial z} \right) + \dot{q} = 0$$

$$\frac{\partial}{\partial x} \left( k \frac{\partial T}{\partial x} \right) + \dot{q} = \rho c_p \frac{\partial T}{\partial t}$$

$$\frac{\partial}{\partial y} \left( k \frac{\partial T}{\partial y} \right) + \dot{q} = \rho c_p \frac{\partial T}{\partial t}$$

$$\frac{\partial}{\partial z} \left( k \frac{\partial T}{\partial z} \right) + \dot{q} = \rho c_p \frac{\partial T}{\partial t}$$

$$\frac{1}{r} \frac{\partial}{\partial r} \left( kr \frac{\partial T}{\partial r} \right) + \frac{1}{r^2} \frac{\partial}{\partial \phi} \left( k \frac{\partial T}{\partial \phi} \right) +$$

$$\frac{\partial}{\partial z} \left( k \frac{\partial T}{\partial z} \right) + \dot{q} = \rho c_p \frac{\partial T}{\partial t}$$

$$\frac{1}{r} \frac{\partial}{\partial r} \left( r \frac{\partial T}{\partial r} \right) + \frac{1}{r^2} \frac{\partial^2 T}{\partial \phi^2} + \frac{\partial^2 T}{\partial z^2} + \frac{\dot{q}}{k} = \frac{1}{\alpha} \frac{\partial T}{\partial t}$$

$$\frac{1}{r} \frac{\partial}{\partial r} \left( kr \frac{\partial T}{\partial r} \right) + \frac{1}{r^2} \frac{\partial}{\partial \phi} \left( k \frac{\partial T}{\partial \phi} \right) + \frac{\partial}{\partial z} \left( k \frac{\partial T}{\partial z} \right) + \dot{q} = 0$$

$$\frac{1}{r} \frac{\partial}{\partial r} \left( kr \frac{\partial T}{\partial r} \right) + \dot{q} = \rho c_p \frac{\partial T}{\partial t}$$

$$\frac{1}{r^2} \frac{\partial}{\partial \phi} \left( k \frac{\partial T}{\partial \phi} \right) + \dot{q} = \rho c_p \frac{\partial T}{\partial t}$$

$$\frac{\partial}{\partial z} \left( k \frac{\partial T}{\partial z} \right) + \dot{q} = \rho c_p \frac{\partial T}{\partial t}$$

$$\frac{1}{r^2} \frac{\partial}{\partial r} \left( kr^2 \frac{\partial T}{\partial r} \right) + \frac{1}{r^2 \sin^2 \theta} \frac{\partial}{\partial \phi} \left( k \frac{\partial T}{\partial \phi} \right) + \frac{1}{r^2 \sin \theta} \frac{\partial}{\partial \theta} \left( k \sin \theta \frac{\partial T}{\partial \theta} \right) + \dot{q} = \rho c_p \frac{\partial T}{\partial t}$$

$$\frac{1}{r^2} \frac{\partial}{\partial r} \left( r^2 \frac{\partial T}{\partial r} \right) + \frac{1}{r^2 \sin^2 \theta} \frac{\partial^2 T}{\partial \phi^2} +$$

$$\frac{1}{r^2 \sin \theta} \frac{\partial}{\partial \theta} \left( \sin \theta \frac{\partial T}{\partial \theta} \right) + \frac{\dot{q}}{k} = \frac{1}{\alpha} \frac{\partial T}{\partial t}$$

$$\frac{1}{r^2} \frac{\partial}{\partial r} \left( kr^2 \frac{\partial T}{\partial r} \right) + \frac{1}{r^2 \sin^2 \theta} \frac{\partial}{\partial \phi} \left( k \frac{\partial T}{\partial \phi} \right) + \frac{1}{r^2 \sin \theta} \frac{\partial}{\partial \theta} \left( k \sin \theta \frac{\partial T}{\partial \theta} \right) + \dot{q} = 0$$

$$\frac{1}{r^2} \frac{\partial}{\partial r} \left( kr^2 \frac{\partial T}{\partial r} \right) + \dot{q} = \rho c_p \frac{\partial T}{\partial t}$$

$$\frac{1}{r^2 \sin^2 \theta} \frac{\partial}{\partial \phi} \left( k \frac{\partial T}{\partial \phi} \right) + \dot{q} = \rho c_p \frac{\partial T}{\partial t}$$

$$\frac{1}{r^2 \sin \theta} \frac{\partial}{\partial \theta} \left( k \sin \theta \frac{\partial T}{\partial \theta} \right) + \dot{q} = \rho c_p \frac{\partial T}{\partial t}$$

$$T(0, t) = T_s$$

$$-k \frac{\partial T}{\partial x} \Big|_{x=0} = q_s''$$

$$\frac{\partial T}{\partial x} \Big|_{x=0} = 0$$

$$-k \frac{\partial T}{\partial x} \Big|_{x=0} = h(T_{\infty} - T(0, t))$$

$$\Delta U = N(V^- - V^+)$$

$$q = \frac{\Delta U}{\Delta t} = \frac{N}{\Delta t} \Delta V$$

$$q = -IV = \frac{-V^2}{R} = -I^2 R$$

$$R = \frac{\rho L}{A} = \frac{L}{\sigma A}$$

$$S_{AB} = S_B - S_A = \frac{-\Delta V}{\Delta T}$$

$$C_1 = \frac{T_{s,2} - T_{s,1}}{L}$$

$$C_2 = T_{s,1}$$

$$T(x) = (T_{s,2} - T_{s,1}) \frac{x}{L} + T_{s,1}$$

$$q = \frac{kA}{L} (T_{s,1} - T_{s,2})$$

$$R_{t,cond} = \frac{T_{s,1} - T_{s,2}}{q} = \frac{L}{kA}$$

$$R = \frac{V}{I}$$

$$R_{t,conv} = \frac{T_s - T_{\infty}}{q} = \frac{1}{hA}$$

$$R_{t,rad} = \frac{T_s - T_{sur}}{q} = \frac{1}{h_r A}$$

$$h_r = \varepsilon \sigma (T_s + T_{sur}) (T_s^2 + T_{sur}^2)$$

$$q = U A \Delta T$$

$$U = \frac{1}{R_{tot} A}$$

$$R_{tot} = \Sigma R_t = \frac{1}{U A}$$

$$R_{t,c}'' = \frac{T_A - T_B}{q''}$$

$$q = \frac{k_{eff} A}{L} (T_1 - T_2)$$

$$k_{eff,min} = \frac{1}{\frac{1-\varepsilon}{k_s} + \frac{\varepsilon}{k_f}}$$

$$k_{eff,max} = \varepsilon k_f + (1 - \varepsilon) k_s$$

$$R_{t,cond} = \frac{\ln \frac{r_2}{r_1}}{2\pi k L}$$

$$R_{t,conv} = \frac{1}{h 2\pi r L}$$

$$\frac{d^2 T}{dx^2} + \left( \frac{1}{A_c} \frac{dA_c}{dx} \right) \frac{dT}{dx} - \left( \frac{1}{A_c} \frac{h}{k} \frac{dA_s}{dx} \right) (T - T_{\infty}) = 0$$

$$A_s = Px$$

$$\frac{d^2 T}{dx^2} - \left( \frac{hP}{kA_c} \right) (T - T_{\infty})$$

$$\frac{d^2 \theta}{dx^2} - m^2 \theta = 0$$

$$\theta = T(x) - T_{\infty}$$

$$m^2 = \frac{hP}{kA_c}$$

$$P = 2w + 2t$$

$$A_c = wt$$

$$P = \pi D$$

$$A_c = \frac{\pi}{4} D^2$$

$$\theta(x) = C_1 e^{mx} + C_2 e^{-mx}$$

$$\theta_b = T_b - T_{\infty}$$

$$M = \sqrt{h P K A_c} \theta_b$$

$$\varepsilon_f = \frac{q_f}{h A_{c,b} \theta_b}$$

$$\varepsilon_f = \sqrt{\frac{kP}{h A_c}}$$

$$R_{t,f} = \frac{\theta_b}{q_f}$$

$$R_{t,b} = \frac{1}{h A_{c,b}}$$

$$\varepsilon_f = \frac{R_{t,b}}{R_{t,f}}$$

$$\eta_f = \frac{q_f}{q_{max}} = \frac{q_f}{h A_f \theta_b}$$

$$\eta_o = \frac{q_t}{q_{max}} = \frac{q_t}{h A_t \theta_b}$$

$$A_t = N A_f + A_b$$

$$q_t = N \eta_f h A_f \theta_b + h A_b \theta_b$$

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$$\eta_o = 1 - \frac{NA_f}{A_t} (1 - \eta_f)$$

$$R_{t,o} = \frac{\theta_b}{q_t} = \frac{1}{\eta_o h A_t}$$

$$\frac{\partial^2 T}{\partial x^2} \Big|_{m,n} \approx \frac{\frac{\partial T}{\partial x} \Big|_{m+\frac{1}{2},n} - \frac{\partial T}{\partial x} \Big|_{m-\frac{1}{2},n}}{\Delta x}$$

$$\frac{\partial T}{\partial x} \Big|_{m+\frac{1}{2},n} \approx \frac{T \Big|_{m+1,n} - T \Big|_{m,n}}{\Delta x}$$

$$\frac{\partial T}{\partial x} \Big|_{m-\frac{1}{2},n} \approx \frac{T \Big|_{m,n} - T \Big|_{m-1,n}}{\Delta x}$$

$$\frac{\partial^2 T}{\partial x^2} \Big|_{m,n} \approx \frac{T_{m+1,n} + T_{m-1,n} - 2T_{m,n}}{(\Delta x)^2}$$

$$\frac{\partial^2 T}{\partial y^2} \Big|_{m,n} \approx \frac{T_{m+1,n} + T_{m-1,n} - 2T_{m,n}}{(\Delta y)^2}$$

$$\sum_{i=1}^4 q_{(i) \rightarrow (m,n)} + \dot{q} (\Delta x \cdot \Delta y \cdot 1) = 0$$

$$q_{(m-1,n) \rightarrow (m,n)} =$$

$$k (\Delta y \cdot 1) \frac{T_{m-1,n} - T_{m,n}}{\Delta x}$$

$$q_{(m+1,n) \rightarrow (m,n)} =$$

$$k (\Delta y \cdot 1) \frac{T_{m+1,n} - T_{m,n}}{\Delta x}$$

$$q_{(m,n+1) \rightarrow (m,n)} =$$

$$k (\Delta x \cdot 1) \frac{T_{m,n+1} - T_{m,n}}{\Delta y}$$

$$q_{(m,n-1) \rightarrow (m,n)} =$$

$$k (\Delta x \cdot 1) \frac{T_{m,n-1} - T_{m,n}}{\Delta y}$$

$$T_{m,n+1} + T_{m,n-1} + T_{m+1,n} + T_{m-1,n} + \frac{\dot{q} \cdot 1 \cdot (\Delta x)^2}{k} - 4T_{m,n} = 0$$

$$A = \begin{bmatrix} AT = C \\ a_{11} & a_{12} & \cdots & a_{1N} \\ a_{21} & a_{22} & \cdots & a_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ a_{N1} & a_{N2} & \cdots & a_{NN} \end{bmatrix}$$

$$T = \begin{bmatrix} T_1 \\ T_2 \\ \vdots \\ T_N \end{bmatrix}$$

$$C = \begin{bmatrix} C_1 \\ C_2 \\ \vdots \\ C_N \end{bmatrix}$$

$$T = A^{-1}C$$

$$\frac{u(y)}{u_\infty} = 0.99$$

$$C_f = \frac{\tau_s}{\rho u_\infty^2 / 2}$$

$$\tau_s = \mu \frac{\partial u}{\partial y} \Big|_{y=0}$$

$$\frac{T_s - T(y)}{T_s - T_\infty} = 0.99$$

$$q_s'' = -k \frac{\partial T}{\partial y} \Big|_{y=0}$$

$$q_s'' = h (T_s - T_\infty)$$

$$h = \frac{-k \frac{\partial T}{\partial y} \Big|_{y=0}}{T_s - T_\infty}$$

$$q = \int_{A_s} q'' dA_s = (T_s - T_\infty) \int_{A_s} h dA_s$$

$$\bar{q}'' = \bar{h} (T_s - T_\infty)$$

$$\bar{q} = \bar{q}'' A_s = \bar{h} A_s (T_s - T_\infty)$$

$$\bar{h} = \frac{1}{A_s} \int_{A_s} h dA_s$$

$$\bar{h} = \frac{1}{L} \int_0^L h dx$$

$$Re_x = \frac{\rho u_\infty x}{\mu}$$

$$x^* = \frac{x}{L}$$

$$y^* = \frac{y}{L}$$

$$u^* = \frac{u}{V}$$

$$v^* = \frac{v}{V}$$

$$T^* = \frac{T - T_s}{T_\infty - T_s}$$

$$p^* = \frac{p - p_\infty}{\rho V^2 / 2}$$

$$u^* \frac{\partial u^*}{\partial x^*} + v^* \frac{\partial u^*}{\partial y^*} = -\frac{dp^*}{dx^*} + \frac{1}{Re_L} \frac{\partial^2 u^*}{\partial y^{*2}}$$

$$Re_L = \frac{VL}{\nu}$$

$$\nu = \frac{\mu}{\rho}$$

$$u^* \frac{\partial T^*}{\partial x^*} + v^* \frac{\partial T^*}{\partial y^*} = \frac{1}{Re_L Pr} \frac{\partial^2 T^*}{\partial y^{*2}}$$

$$Pr = \frac{\nu}{\alpha}$$

$$Nu = \frac{hL}{k} = \frac{\partial T^*}{\partial y^*} \Big|_{y^*=0}$$

$$\overline{Nu} = \frac{\bar{h}L}{k}$$

$$T_f = \frac{T_s + T_\infty}{2}$$

**Isothermal Flat Plate**

$$\frac{\delta}{\delta_t} \approx Pr^{1/3}$$

Laminar:

$$\delta = \frac{5}{\sqrt{\frac{u_\infty}{\nu x}}} = \frac{5x}{\sqrt{Re_x}}$$

$$C_{f,x} = \frac{\tau_{s,x}}{\frac{\rho u_\infty^2}{2}} = 0.664 Re_x^{-1/2}$$

$$Nu_x = \frac{h_x x}{k} = 0.332 Re_x^{1/2} Pr^{1/3}$$

$$(Pr \gtrsim 0.6)$$

$$\overline{C}_{f,x} = 1.328 Re_x^{-1/2}$$

$$\overline{Nu}_x = \frac{\bar{h}_x x}{k} = 0.664 Re_x^{1/2} Pr^{1/3}$$

$$(Pr \gtrsim 0.6)$$

Turbulent:

$$\delta = 0.37 x Re_x^{-1/2}$$

$$C_{f,x} = 0.0592 Re_x^{-1/5}$$

$$(Re_{x,c} \lesssim Re_x \lesssim 10^8)$$

$$Nu_x = 0.0296 Re_x^{4/5} Pr^{1/3}$$

$$(0.6 \lesssim Pr \lesssim 60)$$

$$A = 0.037 Re_{x,c}^{4/5} - 0.664 Re_{x,c}^{1/2}$$

$$\overline{C}_{f,L} = 0.074 Re_L^{-1/5} - \frac{2A}{Re_L}$$

$$(Re_{x,c} \lesssim Re_L \lesssim 10^8)$$

$$\overline{Nu}_L = \left( 0.037 Re_L^{4/5} - A \right) Pr^{1/3}$$

$$(0.6 \lesssim Pr \lesssim 60)$$

$$(Re_{x,c} \lesssim Re_L \lesssim 10^8)$$

$$Re_D = \frac{\rho V D}{\mu} = \frac{V D}{\nu}$$

$$C_D = \frac{F_D}{A_f \left( \frac{\rho V^2}{2} \right)}$$

**Cylinder**

$$\overline{Nu}_D = \frac{\bar{h} D}{k} = C Re_D^m Pr^{1/3}$$

$$(Pr \gtrsim 0.7)$$

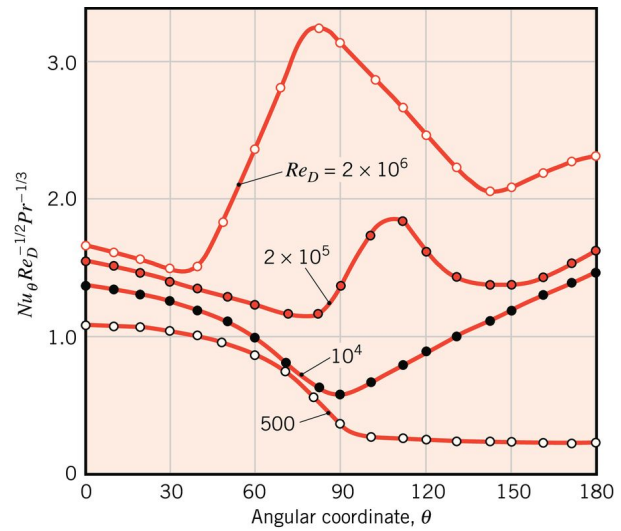
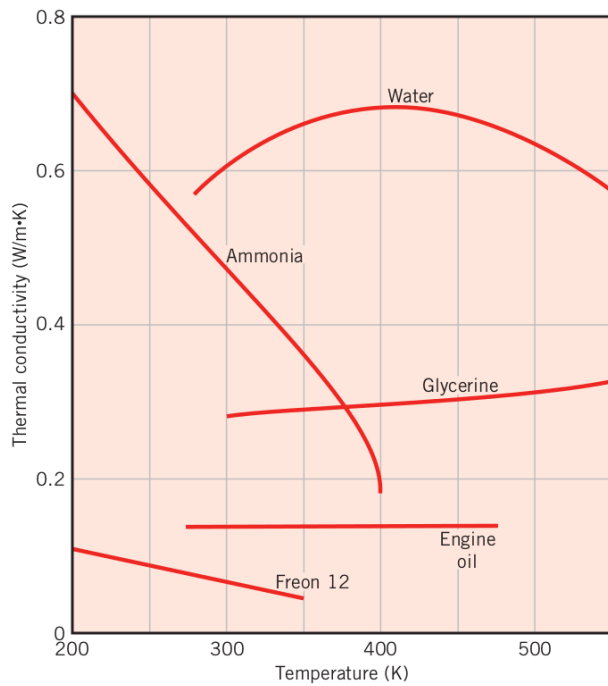
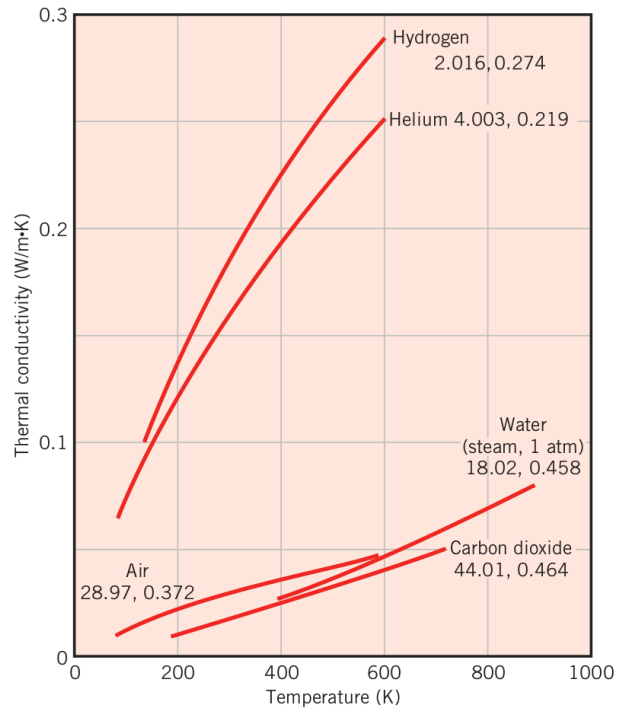
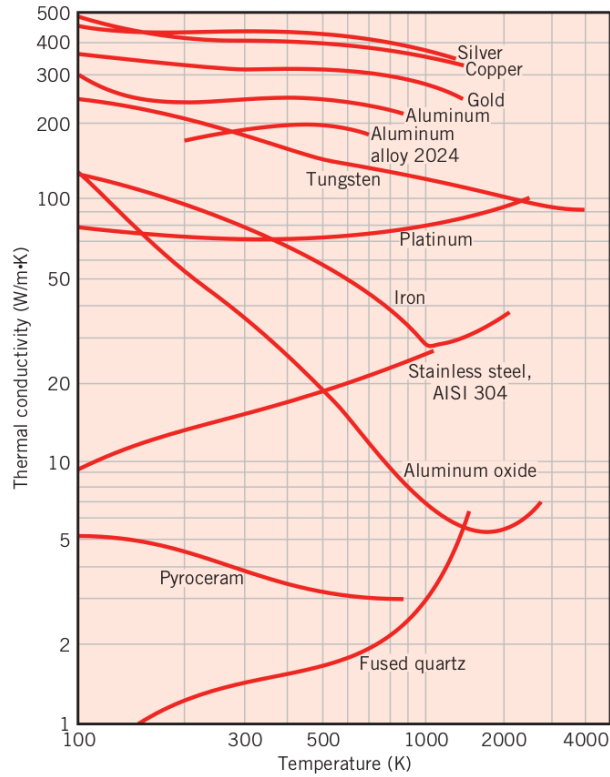
See Table 5

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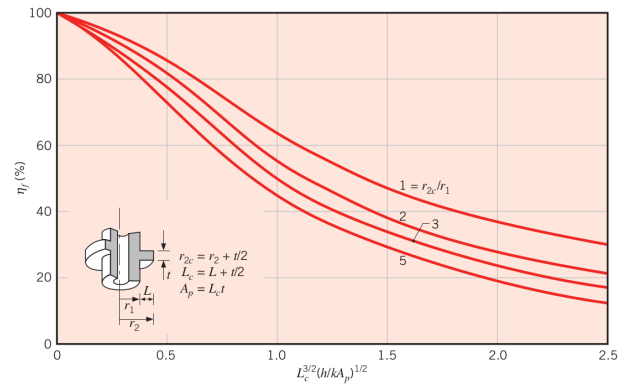
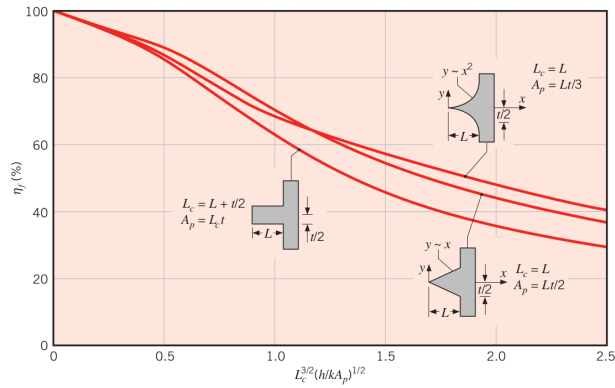
.....	$\Delta T_i = T_s - T_{m,i}$
<b><u>Various Geometries</u></b>	$q_{conv} = \bar{h} A_s \Delta T_{lm}$
$\overline{Nu}_D = \frac{\bar{h} D}{k} = C Re_D^m Pr^{1/3}$	.....
$(Pr \gtrsim 0.7)$	<b><u>Circular Tubes</u></b>
See Table 6	Fully dev. lam. w/ $q'' = \mathbb{C}$ :
.....	$Nu_D = 4.36$
.....	
<b><u>Sphere</u></b>	Fully dev. lam. w/ $T_s = \mathbb{C}$ :
$A_s = \pi D^2$	$Nu_D = 3.66$
$C_D = \frac{25}{Re_D}$	
$(Re_D \lesssim 0.5)$	Fully dev. turb. w/ small $\Delta T$ :
$\overline{Nu}_D = 2 +$	$Nu_D = 0.023 Re_D^{4/5} Pr^n$
$(0.4 Re_D^{1/2} + 0.06 Re_D^{2/3}) Pr^{0.4} \left( \frac{\mu}{\mu_s} \right)^{1/4}$	$n = 0.4, \quad T_s > T_m$
$(0.71 \lesssim Pr \lesssim 380)$	$n = 0.3, \quad T_s < T_m$
$(3.5 \lesssim Re_D \lesssim 7.6 \times 10^4)$	$(0.6 \lesssim Pr \lesssim 160)$
$\left( 1.0 \lesssim \frac{\mu}{\mu_s} \lesssim 3.2 \right)$	$(Re_D \gtrsim 10,000)$
.....	$(L/D \gtrsim 10)$
$m = \rho u_m A_c$	Fully dev. turb. w/ large $\Delta T$ :
$Re_D = \frac{\rho u_m D}{\mu} = \frac{u_m D}{\nu}$	$Nu_D = 0.027 Re_D^{4/5} Pr^{1/3} \left( \frac{\mu}{\mu_s} \right)^{0.14}$
$\left( \frac{x_{fd,t}}{D} \right) \approx 0.05 Re_D Pr$	$(0.7 \lesssim Pr \lesssim 16,700)$
$f = \frac{-\frac{dP}{dx} D}{\rho \frac{u_m^2}{2}}$	$(Re_D \gtrsim 10,000)$
$f = \frac{64}{Re_D}$	$(L/D \gtrsim 10)$
$\frac{1}{\sqrt{f}} = -2.0 \log \left[ \frac{e/D}{3.7} + \frac{2.51}{Re_D \sqrt{f}} \right]$	.....
$dq_{conv} = mc_p [(T_m + dT_m) - T_m] =$	<b><u>Noncircular Tubes</u></b>
$mc_p dT_m$	$D_h = \frac{4A_c}{P}$
$dq_{conv} = q_s'' P dx$	$Nu_D = \frac{h D_h}{k}$
$\frac{dT_m}{dx} = \frac{q_s'' P}{mc_p} = \frac{P}{mc_p} h (T_s - T_m)$	See Table 7
$T_m(x) = T_{m,i} + \frac{q_s'' P}{mc_p} x$	.....
$\Delta T = T_s - T_m$	
$\frac{dT_m}{dx} = -\frac{d(\Delta T)}{dx} = \frac{P}{mc_p} h \Delta T$	
$\frac{T_s - T_m(x)}{T_s - T_{m,i}} = e^{-\frac{Px}{mc_p} \bar{h}}$	
$\Delta T_{lm} = \frac{\Delta T_o - \Delta T_i}{\ln \left( \frac{\Delta T_o}{\Delta T_i} \right)}$	
$\Delta T_o = T_s - T_{m,o}$	

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# ENGT 320 Applied Thermal Systems

## Quiz 3 Formula Sheet



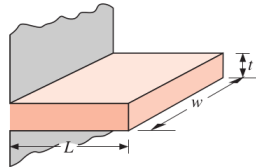
### Straight Fins

#### Rectangular

$$A_f = 2wL_c$$

$$L_c = L + (t/2)$$

$$A_p = tL$$

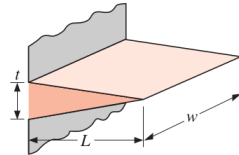


$$\eta_f = \frac{\tanh mL_c}{mL_c}$$

#### Triangular

$$A_f = 2w[L^2 + (t/2)^2]^{1/2}$$

$$A_p = (t/2)L$$



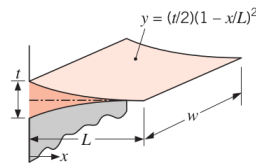
$$\eta_f = \frac{1}{mL} \frac{I_1(2mL)}{I_0(2mL)}$$

#### Parabolic

$$A_f = w[C_1 L + (L^2/t) \ln(t/L + C_1)]$$

$$C_1 = [1 + (t/L)^2]^{1/2}$$

$$A_p = (t/3)L$$



$$\eta_f = \frac{2}{[4(mL)^2 + 1]^{1/2} + 1}$$

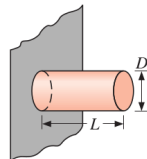
### Pin Fins

#### Rectangular

$$A_f = \pi D L_c$$

$$L_c = L + (D/4)$$

$$V = (\pi D^2/4)L$$

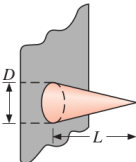


$$\eta_f = \frac{\tanh mL_c}{mL_c}$$

#### Triangular

$$A_f = \frac{\pi D}{2} [L^2 + (D/2)^2]^{1/2}$$

$$V = (\pi/12) D^2 L$$



$$\eta_f = \frac{2}{mL} \frac{I_2(2mL)}{I_1(2mL)}$$

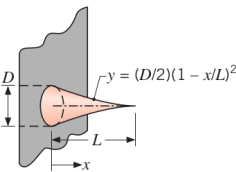
#### Parabolic

$$A_f = \frac{\pi L^3}{8D} \{C_3 C_4 - \frac{L}{2D} \ln [(2DC_4/L) + C_3]\}$$

$$C_3 = 1 + 2(D/L)^2$$

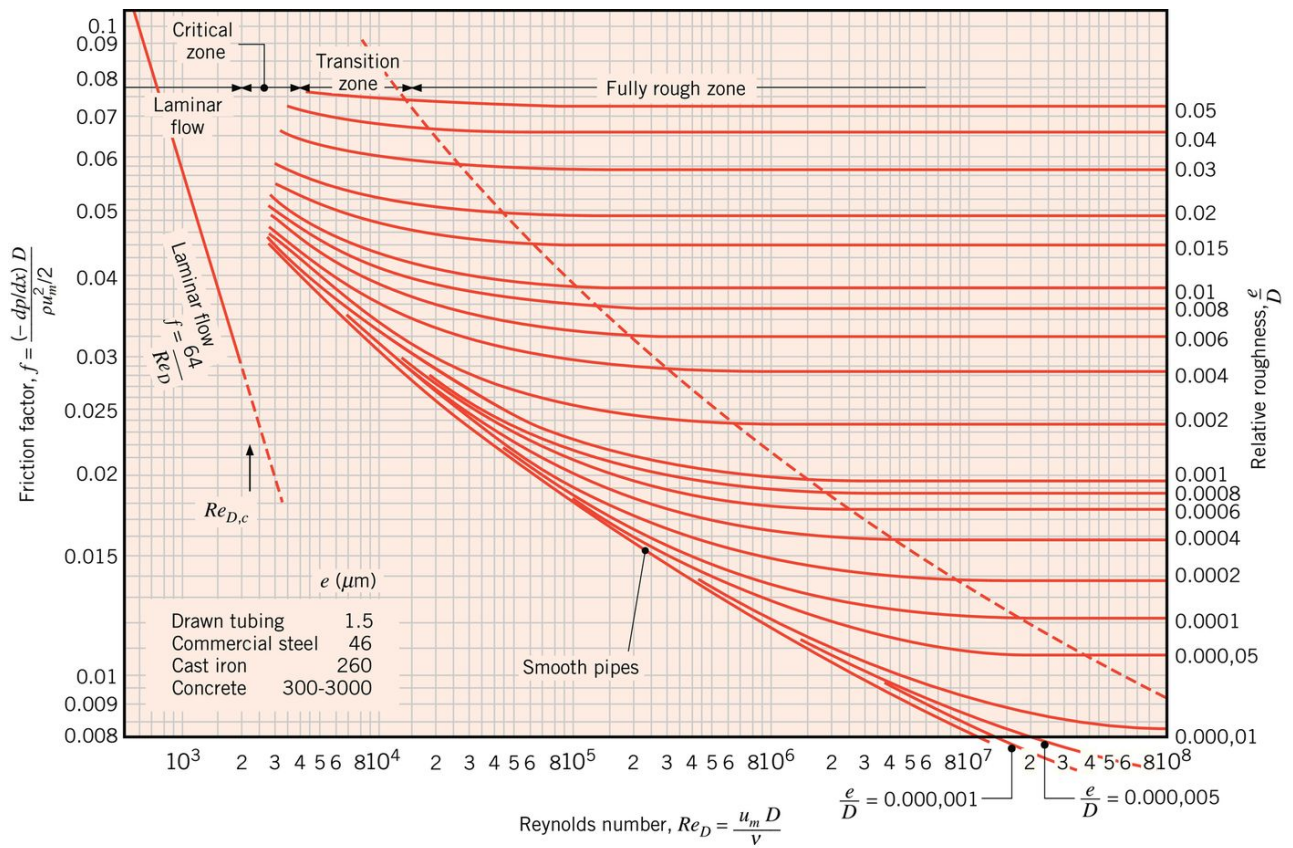
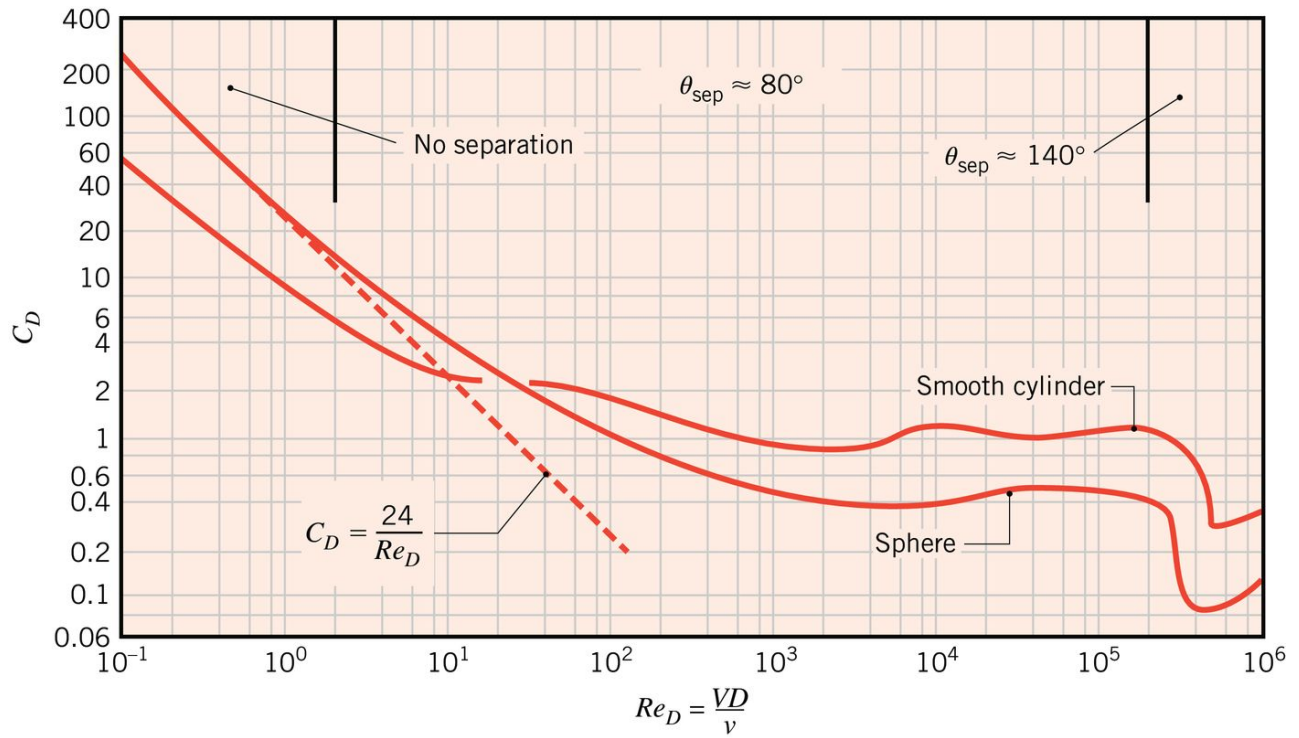
$$C_4 = [1 + (D/L)^2]^{1/2}$$

$$V = (\pi/20) D^2 L$$



$$\eta_f = \frac{2}{[4/9(mL)^2 + 1]^{1/2} + 1}$$

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Table 1: Contact Resistance for vacuum interfaces,  $R''_{t,c} \times 10^4 \left( \frac{m^2 K}{W} \right)$

Material	100 (kPa)	10,000 (kPa)
Stainless Steel	6-25	0.7-4.0
Copper	1-10	0.1-0.5
Magnesium	1.5-3.5	0.2-0.4
Aluminum	1.5-5.0	0.2-0.4

Table 2: Contact Resistance for aluminum ( $10\mu m$  surface roughness,  $10kPa$  contact pressure)

Interfacial Fluid	$R''_{t,c} \times 10^4 \left( \frac{m^2 K}{W} \right)$
Air	2.75
Helium	1.05
Hydrogen	0.720
Silicone Oil	0.525
Glycerine	0.265

Table 3: Fin Tip Conditions

Case	Tip Condition	Temperature Distribution $\frac{\theta}{\theta_b}$	Fin Heat Transfer Rate $q_f$
A	Convection	$\frac{\cosh m(L-x) + \left(\frac{h}{mk}\right) \sinh m(L-x)}{\cosh mL + \left(\frac{h}{mK}\right) \sinh mL}$	$M \frac{\sinh mL + \left(\frac{h}{mk}\right) \cosh mL}{\cosh mL + \left(\frac{h}{mk}\right) \sinh mL}$
B	Adiabatic	$\frac{\cosh m(L-x)}{\cosh mL}$	$M \tanh mL$
C	Constant Temperature	$\frac{\left(\frac{\theta_L}{\theta_b}\right) \sinh mx + \sinh m(L-x)}{\sinh mL}$	$M \frac{\cosh mL - \frac{\theta_L}{\theta_b}}{\sinh mL}$
D	Infinite Fin ( $L \rightarrow \infty$ )	$e^{-mx}$	$M$

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Table 4: Energy Balance Method Case Summary

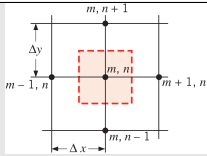
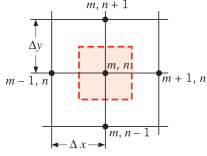
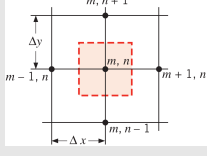
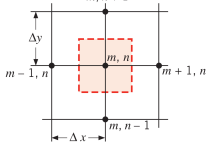
Case	Diagram	Equation
1		$T_{m,n+1} + T_{m,n-1} + T_{m+1,n} + T_{m-1,n} - 4T_{m,n} = 0$
2		$2(T_{m-1,n} - T_{m,n+1}) + (T_{m+1,n} + T_{m,n-1}) + 2\frac{h\Delta x}{k}T_{\infty} - 2\left(3 + \frac{h\Delta x}{k}\right)T_{m,n} = 0$
3		$(2T_{m-1,n} + T_{m,n+1} + T_{m,n-1}) + 2\frac{h\Delta x}{k}T_{\infty} - 2\left(2 + \frac{h\Delta x}{k}\right)T_{m,n} = 0$
4		$(T_{m,n-1} + T_{m-1,n}) + 2\frac{h\Delta x}{k}T_{\infty} - 2\left(1 + \frac{h\Delta x}{k}\right)T_{m,n} = 0$

Table 5: Cylinder In Cross Flow

$Re_D$	$C$	$m$
0.4 – 4	0.989	0.330
4 – 40	0.911	0.385
40 – 4000	0.683	0.466
4000 – 40,000	0.193	0.618
40,000 – 400,000	0.027	0.805



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Table 6: Various Geometries In Cross Flow



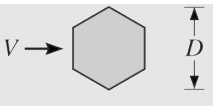
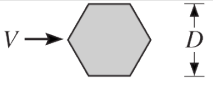





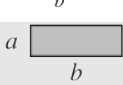
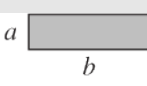
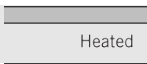


<i>Geometry</i>	$Re_D$	$C$	$m$
	6000 – 60,000	0.304	0.59
	5000 – 60,000	0.158	0.66
	5200 – 20,400 20,400 – 105,000	0.164 0.039	0.638 0.78
	4500 – 90,700	0.150	0.638
	10,000 – 50,000 7,000 – 80,000	0.667 0.191	0.500 0.667

Table 7: Noncircular Tubes

Cross Section	$\frac{b}{a}$	Uniform $q_s''$	Uniform $T_s$	$fRe_{D_h}$
		4.36	3.66	64
	1.0	3.61	2.98	57
	1.43	3.73	3.08	59
	2.0	4.12	3.39	62
	3.0	4.79	3.96	69
	4.0	5.33	4.44	73
	$\infty$	8.23	7.54	96
	$\infty$	5.39	4.86	96
		3.11	2.49	53