ME313 Heat Transfer Formula Sheet
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Chap 1

$$\dot{Q} = \dot{m} c_p \Delta T$$

$$\dot{Q}_{\text{cond}} = -kA\frac{dT}{dx}$$

$$\dot{Q}_{\text{convection}} = hA_s (T_s - T_\infty)$$

$$\dot{Q}_{\text{rad}} = \varepsilon\sigma A_s (T_s^4 - T_{\text{surr}}^4)$$

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

S.S. conduction

$$\frac{\partial^2 T}{\partial x^2} + \frac{\dot{e}_{\text{gen}}}{k} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$$

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right) + \frac{\dot{e}_{\text{gen}}}{k} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$$

$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial T}{\partial r}\right) + \frac{\dot{e}_{\text{gen}}}{k} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$$

Electrical Analogy

$$\dot{Q} = \frac{T_{\infty 1} - T_{\infty 2}}{R_{\text{total}}}$$

Conduction resistance (plane wall): $R_{\text{wall}} = \dfrac{L}{kA}$

Conduction resistance (cylinder): $R_{\text{cyl}} = \dfrac{\ln(r_2/r_1)}{2\pi Lk}$

Conduction resistance (sphere): $R_{\text{sph}} = \dfrac{r_2 - r_1}{4\pi r_1 r_2 k}$

Convection resistance: $R_{\text{conv}} = \dfrac{1}{hA}$

Lumped Analysis

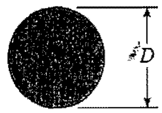
$$\frac{T(t) - T_\infty}{T_i - T_\infty} = e^{-bt} \qquad b = \frac{hA_s}{\rho c_p V} = \frac{h}{\rho c_p L_c} \qquad \text{Bi} = \frac{hL_c}{k} < 0.1$$

General

$$\text{Re} = \frac{\rho V_{\text{avg}} D}{\mu} = \frac{V_{\text{avg}} D}{\nu} \qquad \text{Gr}_L = \frac{g\beta(T_s - T_\infty)L_c^3}{\nu^2} \qquad \text{Ra}_L = \text{Gr}_L \text{Pr} = \frac{g\beta(T_s - T_\infty)L_c^3}{\nu^2}\text{Pr} \qquad \text{Nu} = \frac{hL}{k}$$

Forced Convection

Empirical correlations for the average Nusselt number for forced convection over circular and noncircular cylinders in cross flow (from Zukauskas, 1972 and Jakob, 1949)

Cross-section of the cylinder	Fluid	Range of Re	Nusselt number
Circle 	Gas or liquid	0.4–4	$\text{Nu} = 0.989\text{Re}^{0.330}\,\text{Pr}^{1/3}$
		4–40	$\text{Nu} = 0.911\text{Re}^{0.385}\,\text{Pr}^{1/3}$
		40–4000	$\text{Nu} = 0.683\text{Re}^{0.466}\,\text{Pr}^{1/3}$
		4000–40,000	$\text{Nu} = 0.193\text{Re}^{0.618}\,\text{Pr}^{1/3}$
		40,000–400,000	$\text{Nu} = 0.027\text{Re}^{0.805}\,\text{Pr}^{1/3}$

The average Nusselt number relations for flow over a flat plate are:

Laminar: $\text{Nu} = \dfrac{hL}{k} = 0.664\,\text{Re}_L^{0.5}\,\text{Pr}^{1/3}$, $\quad \text{Pr} > 0.6$, $\text{Re}_L < 5 \times 10^5$

Turbulent:

$\text{Nu} = \dfrac{hL}{k} = 0.037\,\text{Re}_L^{0.8}\,\text{Pr}^{1/3}$, $\quad 0.6 \le \text{Pr} \le 60$, $5 \times 10^5 \le \text{Re}_L \le 10^7$

Internal flow/Convection

$$\Delta T_{\text{lm}} = \frac{(T_s - T_e) - (T_s - T_i)}{\ln[(T_s - T_e)/(T_s - T_i)]} = \frac{\Delta T_e - \Delta T_i}{\ln(\Delta T_e/\Delta T_i)}$$

$$T_e = T_s - (T_s - T_i)\exp\left(-\frac{A_s h}{\dot{m} c_p}\right)$$

Internal flow/convection

For *fully developed turbulent flow with smooth surfaces,*

$$f = (0.790 \ln \text{Re} - 1.64)^{-2} \qquad 10^4 < \text{Re} < 10^6$$

$$\text{Nu} = 0.125 f\, \text{Re}\, \text{Pr}^{1/3}$$

$$\text{Nu} = 0.023\,\text{Re}^{0.8}\,\text{Pr}^{1/3} \begin{pmatrix} 0.7 \le \text{Pr} \le 160 \\ \text{Re} > 10{,}000 \end{pmatrix}$$

$\text{Nu} = 0.023\,\text{Re}^{0.8}\,\text{Pr}^n$ with $n = 0.4$ for *heating* and 0.3 for *cooling* of fluid

Radiation

$$(\lambda T)_{\text{max power}} = 2897.8\ \mu\text{m·K}$$

$$\dot{Q}_{1\to 2} = A_1 F_{1\to 2}\sigma(T_1^4 - T_2^4)$$

$$\dot{Q}_{12} = \frac{\sigma(T_1^4 - T_2^4)}{\dfrac{1-\varepsilon_1}{A_1\varepsilon_1} + \dfrac{1}{A_1 F_{12}} + \dfrac{1-\varepsilon_2}{A_2\varepsilon_2}}$$

$$\alpha + \rho + \tau = 1$$

$$A_i F_{i\to j} = A_j F_{j\to i}$$

Air Table

Properties of air at 1 atm pressure

Temp. T, °C	Density ρ, kg/m³	Specific Heat c_p, J/kg · K	Thermal Conductivity k, W/m · K	Thermal Diffusivity α, m²/s²	Dynamic Viscosity μ, kg/m · s	Kinematic Viscosity ν, m²/s	Prandtl Number Pr
−10	1.341	1006	0.02288	1.696×10^{-5}	1.680×10^{-5}	1.252×10^{-5}	0.7387
0	1.292	1006	0.02364	1.818×10^{-5}	1.729×10^{-5}	1.338×10^{-5}	0.7362
5	1.269	1006	0.02401	1.880×10^{-5}	1.754×10^{-5}	1.382×10^{-5}	0.7350
10	1.246	1006	0.02439	1.944×10^{-5}	1.778×10^{-5}	1.426×10^{-5}	0.7336
15	1.225	1007	0.02476	2.009×10^{-5}	1.802×10^{-5}	1.470×10^{-5}	0.7323
20	1.204	1007	0.02514	2.074×10^{-5}	1.825×10^{-5}	1.516×10^{-5}	0.7309
25	1.184	1007	0.02551	2.141×10^{-5}	1.849×10^{-5}	1.562×10^{-5}	0.7296
30	1.164	1007	0.02588	2.208×10^{-5}	1.872×10^{-5}	1.608×10^{-5}	0.7282
[illegible]	1.145	1007	0.02625	2.277×10^{-5}	1.895×10^{-5}	1.655×10^{-5}	0.7268
[illegible]	[illegible]	[illegible]	[illegible]	2.346×10^{-5}	1.918×10^{-5}	1.702×10^{-5}	[illegible]