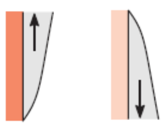
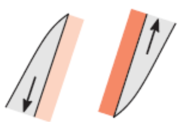
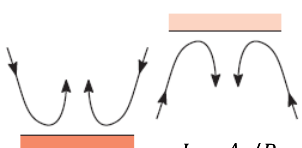
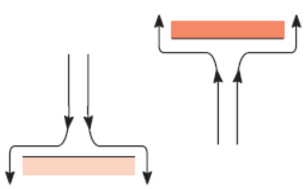
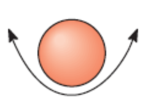
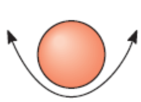
Chapter 4

Note: Equation numbers are from reference [1].

Table 1: External free convection

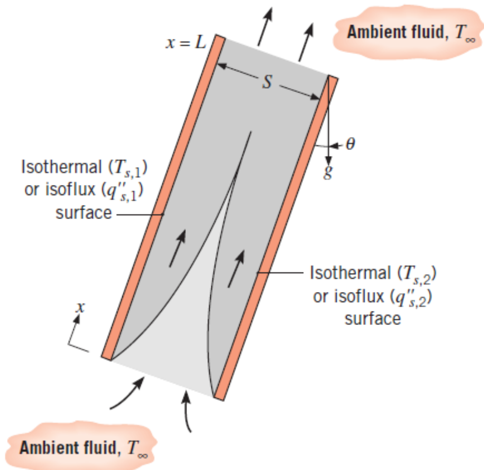
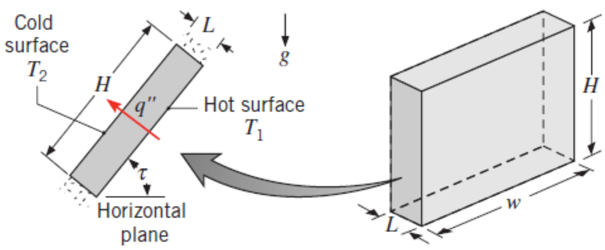
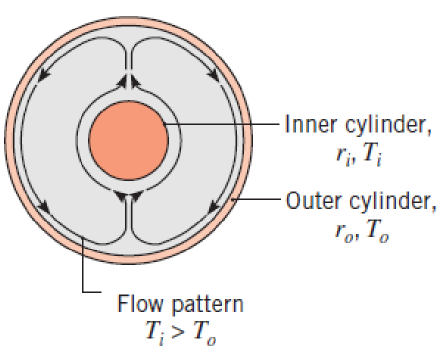
TABLE 9.2 Summary of free convection empirical correlations for immersed geometries

Geometry	Recommended Correlation	Restrictions
1. Vertical plates[a] 	Equation 9.24+C=0.59, n=1/4 Equation 9.24+C=0.1, n=1/3 or Equation 9.26 Equation 9.27	$10^4 < \mathrm{Ra}_L < 10^9$ $10^9 < \mathrm{Ra}_L < 10^{13}$ $\mathrm{Ra}_L \geq 10^9$ $\mathrm{Ra}_L < 10^9$
2. Inclined plates Cold surface up or hot surface down 	Equation 9.26 $g \rightarrow g \cos\theta$	$0 \leq \theta \lesssim 60°$
3. Horizontal plates (a) Hot surface up or cold surface down  $L = A_s/P$	Equation 9.30 Equation 9.31	$10^4 \lesssim Ra_L \lesssim 10^7, Pr \gtrsim 0.7$ $10^7 \lesssim Ra_L \lesssim 10^{11}$
(b) Cold surface up or hot surface down  $L = A_s/P$	Equation 9.32	$10^4 \lesssim Ra_L \lesssim 10^9, Pr \gtrsim 0.7$
4. Horizontal cylinder 	Equation 9.33+Table 9.1 or Equation 9.34	$Ra_D \lesssim 10^{12}$
5. Sphere 	Equation 9.35	$Ra_D \lesssim 10^{11}$ $Pr \gtrsim 0.7$

[a] The correlation may be applied to a vertical cylinder if $(D/L) \gtrsim (35/Gr_L^{1/4})$. $\mathrm{Ra}_{L,cr} = 10^9$

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

Table 2: Internal free convection

Geometry	**Recommended Correlation**	**Restrictions**
1-parallel plate channels [a] 	**Vertical** (9.45),(9.37),(9.38) Table 9.3 1st and 3rd rows (9.46),(9.41),(9.42) Table 9.3 2nd and 4th rows **Inclined** (9.47)	Constant Temperature Constant flux Constant Temperature $0 \lesssim \theta \lesssim 45°$ $Ra_S(S/L) > 200$ fluid: water
2-Rectangular cavities ($W/L \gg 1$) [b]  $L_e = L$	(9.48) **Horizontal ($\tau = 0$)** (9.49) **Vertical ($\tau = 90$)** (9.50)-(9.53) **Inclined** $\tau^* \rightarrow$ Table 9.4 (9.54),(9.55) (9.56),(9.57)	 ($\mathrm{Ra}_{L,cr} = 3 \times 10^5, \mathrm{Ra}_{L,cr2} = 1708$) $3 \times 10^5 \lesssim Ra_L \lesssim 7 \times 10^9$ ($Ra_{L,cr2} = 1000$) See each correlation ($Ra_{L,cr2} = 1708/\cos\tau$) $\tau \leq \tau^*$ $\tau > \tau^*$
3-Concentric cylinders and spheres [b] 	 **Cylinders** (9.58)-(9.60) $L_e = L_c$ **Spheres** (9.61)-(9.63) $L_e = L_s$	($Ra_{L,cr2} = 100$) $0.7 \lesssim Pr \lesssim 6000$ $Ra_c \lesssim 10^7$ $k_{\mathrm{eff}}/k \geq 1$ $0.7 \lesssim Pr \lesssim 4000$ $Ra_s \lesssim 10^4$ $k_{\mathrm{eff}}/k \geq 1$

a $T_f = (T_s(x = L) + T_f)/2$

b $T_f = \frac{T_1+T_2}{2}$, $\mathrm{Ra}_L = \frac{g\beta(T_1-T_2)L_e^3}{\alpha\nu}$, and $\mathrm{Ra}_{L,cr2}$ indicates the transition from conduction to free convection.