Correlations for External Forced Convection

Geometry	Correlation	Conditions
Flat plate, laminar flow, constant wall temperature	$Nu_x = 0.332 Re_x^{\frac{1}{2}} Pr^{\frac{1}{3}}$ $\overline{Nu_L} = 0.664 Re_L^{\frac{1}{2}} Pr^{1/3}$ All the properties are evaluated at $T_f = (T_w + T_\infty)/2$	$Pr \geq 0.6$ $Re_x \leq 5 \times 10^5$
Flat plate, laminar flow, constant heat flux	$Nu_x = 0.453\, Re_x^{1/2} Pr^{1/3}$ $\overline{Nu_L} = 0.680\, Re_L^{1/2} Pr^{1/3}$ All the properties are evaluated at $T_f = (T_w + T_\infty)/2$	$Pr \geq 0.6$ $Re_x \leq 5 \times 10^5$
Flat plate, turbulent flow, constant wall temperature	$Nu_x = St\, Re_x\, Pr = 0.0296\, Re_x^{4/5} Pr^{1/3}$ All the properties are evaluated at $T_f = (T_w + T_\infty)/2$	$0.6 \leq Pr \leq 60$ $5 \times 10^5 \leq Re_x \leq 10^8$
Flat plate, turbulent flow, constant heat flux	$Nu_x = 0.0308\, Re_x^{4/5} Pr^{1/3}$ All the properties are evaluated at $T_f = (T_w + T_\infty)/2$	$5 \times 10^5 \leq Re_x \leq 10^8$ $0.6 \leq Pr \leq 60$
Cylinder in cross flow	$\overline{Nu_D} = \frac{\bar{h}D}{k} = C\, Re_D^m Pr^{1/3}$ *C* &*m* are from Table 1 All the properties are evaluated at $T_f = (T_w + T_\infty)/2$	$Pr \geq 0.7$ $0.4 \leq Re_D \leq 10^6$
Sphere	$Nu_D = \frac{\bar{h}D}{k} = 2 + (0.4\, \mathrm{Re}_P^{0.5} + 0.06\, \mathrm{Re}_P^{0.66}) \mathrm{Pr}^{0.4} \left(\frac{\mu}{\mu_s}\right)^{0.25}$ All the properties except μ_s are evaluated at T_∞ μ_s= Surface viscosity	$0.71 \leq \mathrm{Pr} \leq 380$ $3.5 \leq \mathrm{Re}_P \leq 7.6 * 10^{-4}$ $1.0 \leq \left(\frac{\mu}{\mu_s}\right) \leq 3.2$
Bank of Tubes	$Nu_D = 1.13 C_1 \mathrm{Re}_{D\max}{}^m \mathrm{Pr}^{0.33}$ All properties except μ_s are evaluated at $T_f = (T_w + T_\infty)/2$. C_1& m are in Table 2 For N<10, Nu is obtained by multiplying the Nu(N>10) by a correction factor as given in Table 3 $Re_{D\,max}$ is the Reynolds number at the location of maximum velocity. See text for details.	$N_c \geq 10$ $2000 \leq \mathrm{Re}_{D\max} \leq 40000$ $\mathrm{Pr} \geq 0.7$

Table 1

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

Table 2

Conguration	$Re_{D,\max}$	C_1	m
Aligned	10–10^2	0.80	0.40
Staggered	10–10^2	0.90	0.40
Aligned	10^2–10^3	Approximate as a single (isolated) cylinder	
Staggered	10^2–10^3		
Aligned $(S_T/S_L > 0.7)^a$	10^3–2×10^5	0.27	0.63
Staggered $(S_T/S_L < 2)$	10^3–2×10^5	$0.35(S_T/S_L)^{1/5}$	0.60
Staggered $(S_T/S_L > 2)$	10^3–2×10^5	0.40	0.60
Aligned	2×10^5–2×10^6	0.021	0.84
Staggered	2×10^5–2×10^6	0.022	0.84

[a]For $S_T/S_L < 0.7$, heat transfer is inefficient and aligned tubes should not be used.

Table 3

N_L	1	2	3	4	5	6	7	8	9
Aligned	0.64	0.80	0.87	0.90	0.92	0.94	0.96	0.98	0.99
Staggered	0.68	0.75	0.83	0.89	0.92	0.95	0.97	0.98	0.99