Equations

Velocity v

Kinematic viscosity ν

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

Conservation of Mass

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \frac{-1}{\rho}\frac{dp_\infty}{dx} + \nu\frac{\partial^2 u}{\partial y^2}$$

Momentum

$$\underbrace{u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}}_{\text{advection}} = \underbrace{\alpha\frac{\partial^2 T}{\partial y^2}}_{\text{y axis conduction}} + \underbrace{\frac{\nu}{c_p}\left(\frac{\partial u}{\partial y}\right)^2}_{\text{viscous dissipation}}$$

Energy

Normalized Boundary Layers

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

L characteristic length (flat plate)

$$u^* = \frac{u}{\bar{V}} \qquad v^* = \frac{v}{\bar{V}}$$

$\bar{V}$ free stream velocity

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

TABLE 6.1 The boundary layer equations and their *y*-direction boundary conditions in nondimensional form

Boundary Layer	Conservation Equation	Boundary Conditions: Wall	Boundary Conditions: Free Stream	Similarity Parameter(s)
Velocity	$u^*\frac{\partial u^*}{\partial x^*}+v^*\frac{\partial u^*}{\partial y^*}=-\frac{dp^*}{dx^*}+\frac{1}{Re_L}\frac{\partial^2 u^*}{\partial y^{*2}}$ (6.35)	$u^*(x^*,0)=0$	$u^*(x^*,\infty)=\frac{u_\infty(x^*)}{V}$ (6.38)	$Re_L=\frac{VL}{\nu}$ (6.41)
Thermal	$u^*\frac{\partial T^*}{\partial x^*}+v^*\frac{\partial T^*}{\partial y^*}=\frac{1}{Re_L\,Pr}\frac{\partial^2 T^*}{\partial y^{*2}}$ (6.36)	$T^*(x^*,0)=0$	$T^*(x^*,\infty)=1$ (6.39)	$Re_L,\ Pr=\frac{\nu}{\alpha}$ (6.42)
Concentration	$u^*\frac{\partial C_A^*}{\partial x^*}+v^*\frac{\partial C_A^*}{\partial y^*}=\frac{1}{Re_L\,Sc}\frac{\partial^2 C_A^*}{\partial y^{*2}}$ (6.37)	$C_A^*(x^*,0)=0$	$C_A^*(x^*,\infty)=1$ (6.40)	$Re_L,\ Sc=\frac{\nu}{D_{AB}}$ (6.43)

$$Pr=\frac{c_p\mu}{k}=\frac{\nu}{\alpha}$$ Prandtl number

Convection Similarity Parameters Re_L, Pr, and Sc

Nusselt Number

$$Nu = \frac{hL}{k_f} = \left.\frac{\partial T^*}{\partial y^*}\right|_{y^*=0}$$

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

$$Re_L = \frac{F_I}{F_s} = \frac{\rho \mathbb{V}^2/L}{\mu \mathbb{V}/L^2} = \frac{\rho \mathbb{V} L}{\mu}$$

F_I inertia forces

F_s viscous forces

$$Pr = \frac{\nu}{\alpha} \qquad \frac{\delta}{\delta_t} \approx Pr^n \qquad n > 0 \qquad n \text{ usually approximately } 1/3$$

gasses	$Pr \approx 1$	$\delta_t \approx \delta$
liquid metal	$Pr \ll 1$	$\delta_t \gg \delta$
oils	$Pr \gg 1$	$\delta_t \ll \delta$