Find nondimensional form of x & y components of momentum equation:

From (1),

$$\rho\left(\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}\right) = -\frac{\partial P}{\partial x} + \mu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right)$$

The nondimensional variables,

$$\frac{\partial u}{\partial x} = \frac{U}{L}\frac{\partial \tilde{u}}{\partial \tilde{x}}$$

$$\frac{\partial^2 u}{\partial x^2} = \frac{U}{L}\frac{\partial}{\partial \tilde{x}}\left(\frac{\partial \tilde{u}}{\partial \tilde{x}}\right)\frac{\partial \tilde{x}}{\partial x} = \frac{U}{L^2}\frac{\partial^2 \tilde{u}}{\partial \tilde{x}^2}$$

$$\frac{\partial v}{\partial y} = \frac{U}{L}\frac{\partial \tilde{v}}{\partial \tilde{y}}$$

$$\frac{\partial^2 v}{\partial y^2} = \frac{U}{L^2}\frac{\partial^2 \tilde{v}}{\partial \tilde{y}^2}$$

** $\Delta f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$ in 2D

and $\tilde{\nabla} = \frac{1}{\partial \tilde{x}}\hat{i} + \frac{1}{\partial \tilde{y}}\hat{j}$ in 2D

Plug into (1),

$$\rho\left(\left(\frac{U}{1}\right)\left(\frac{U}{L}\right)\frac{\partial \tilde{u}}{\partial \tilde{t}} + (\tilde{u}U)\left(\frac{U}{L}\frac{\partial \tilde{u}}{\partial \tilde{x}}\right) + (\tilde{v}U)\left(\frac{U}{L}\frac{\partial \tilde{v}}{\partial \tilde{y}}\right)\right) = \frac{-\partial P}{\partial(\tilde{x}L)} + \mu\left(\frac{U}{L^2}\frac{\partial^2 \tilde{u}}{\partial \tilde{x}^2} + \frac{U}{L^2}\frac{\partial^2 \tilde{u}}{\partial \tilde{y}^2}\right)$$

$$\rho\frac{U^2}{L}\left(\frac{\partial \tilde{u}}{\partial t^2} + \tilde{u}\frac{\partial \tilde{u}}{\partial \tilde{x}} + \tilde{v}\frac{\partial \tilde{u}}{\partial \tilde{y}}\right) = \frac{-\rho U^2}{L}\frac{\partial \tilde{P}}{\partial \tilde{x}} + \mu\frac{U}{L^2}\left(\frac{\partial^2 \tilde{u}}{\partial \tilde{x}^2} + \frac{\partial^2 \tilde{u}}{\partial \tilde{y}^2}\right)$$