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Navier - Stokes equation dimensionless form

$$\rho \left(\frac{\partial \vec{v}}{\partial t} + (\vec{v} \cdot \vec{\nabla}) \vec{v} \right) = - \vec{\nabla} p + \mu \nabla^2 \vec{v} + \vec{f} \qquad (*)$$

$$\frac{\partial}{\partial t} = \frac{U}{L} \frac{\partial}{\partial t^*}$$

$$\frac{\partial}{\partial x} = \frac{1}{L} \frac{\partial}{\partial x^*} \qquad (\text{similar for } x, y, z)$$

$$\vec{v} = U \vec{v}^*$$

(*) becomes

$$\frac{U^2}{L} \left(\frac{\partial \vec{v}^*}{\partial t^*} + (\vec{v}^* \cdot \vec{\nabla}^*) \vec{v}^* \right) = - \frac{1}{\rho L} \vec{\nabla}^* p + \frac{\mu \cdot U}{\rho L^2} \nabla^{*2} \vec{v}^* + \frac{\overset{\rho g \vec{e}_z}{\vec{f}}}{\rho}$$

$$\Rightarrow \left(\frac{\partial \vec{v}^*}{\partial t^*} + (\vec{v}^* \cdot \vec{\nabla}^*) \vec{v}^* \right) = - \vec{\nabla}^* p^* + Re^{-1} \nabla^{*2} \vec{v}^* + \frac{1}{Fr^2} \vec{e}_z^{\,*}$$

$$\frac{gL}{U^2}$$

with $p^* = \frac{p}{\rho U^2}$ $\qquad \frac{\rho L U}{\mu} = Re$

$$Fr = \frac{U}{\sqrt{gL}}$$