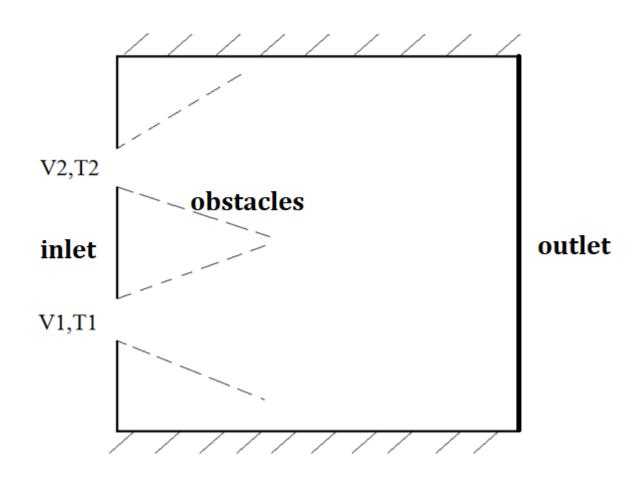
# Physical background



## Mathematical background

$$\frac{\partial U_{x}}{\partial x} + \frac{\partial U_{y}}{\partial y} = 0$$

$$\frac{\partial U_{x}}{\partial t} + U_{x} \frac{\partial U_{x}}{\partial x} + U_{y} \frac{\partial U_{x}}{\partial y} = -\frac{\partial p}{\partial x} - \frac{1}{\text{Re}} \left( \frac{\partial^{2} U_{x}}{\partial x^{2}} + \frac{\partial^{2} U_{x}}{\partial y^{2}} \right)$$

$$\frac{\partial U_{y}}{\partial t} + U_{x} \frac{\partial U_{y}}{\partial x} + U_{y} \frac{\partial U_{y}}{\partial y} = -\frac{\partial p}{\partial y} - \frac{1}{\text{Re}} \left( \frac{\partial^{2} U_{y}}{\partial x^{2}} + \frac{\partial^{2} U_{y}}{\partial y^{2}} \right) + \frac{Gr}{\text{Re}^{2}} \theta$$

$$\frac{\partial \theta}{\partial t} + U_{x} \frac{\partial \theta}{\partial x} + U_{y} \frac{\partial \theta}{\partial y} = \frac{1}{\text{Pr Re}} \left( \frac{\partial^{2} \theta}{\partial x^{2}} + \frac{\partial^{2} \theta}{\partial y^{2}} \right)$$

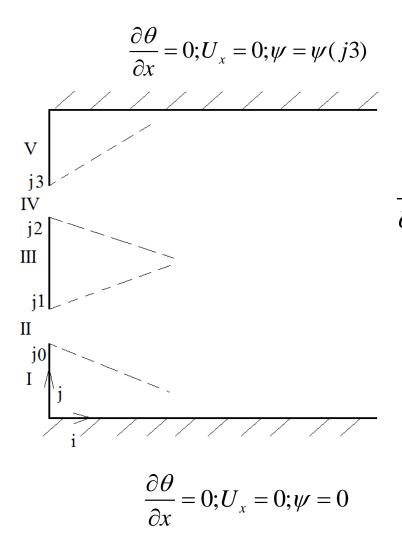
## Vorticity – Stream function formulation

$$U_{x} = \frac{\partial \psi}{\partial y}; U_{y} = -\frac{\partial \psi}{\partial x}$$

$$\Omega = \frac{\partial U_{x}}{\partial y} - \frac{\partial U_{y}}{\partial x} = \frac{\partial^{2} \psi}{\partial x^{2}} + \frac{\partial^{2} \psi}{\partial y^{2}}$$

$$\frac{\partial \Omega}{\partial t} + U_{x} \frac{\partial \Omega}{\partial x} + U_{y} \frac{\partial \Omega}{\partial y} = \frac{1}{\text{Re}} \left( \frac{\partial^{2} \Omega}{\partial x^{2}} - \frac{\partial^{2} \Omega}{\partial y^{2}} \right) + \frac{Gr}{\text{Re}^{2}} \frac{\partial \theta}{\partial x}$$

## **Boundary conditions**



$$I.U_{x} = 0; \theta = 0; \psi = 0$$

$$II.U_{x} = 0; \theta = 1; \psi = y - y_{0}$$

$$III.U_{x} = 0; \theta = 0; \psi = \psi(j1)$$

$$IV.U_{x} = 1; \theta = 0; \psi = y - y_{2} + \psi(j2)$$

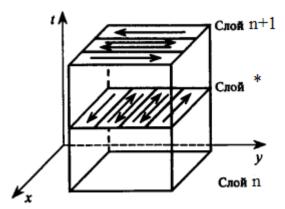
$$V.U_{x} = 0; \theta = 0; \psi = \psi(j3)$$

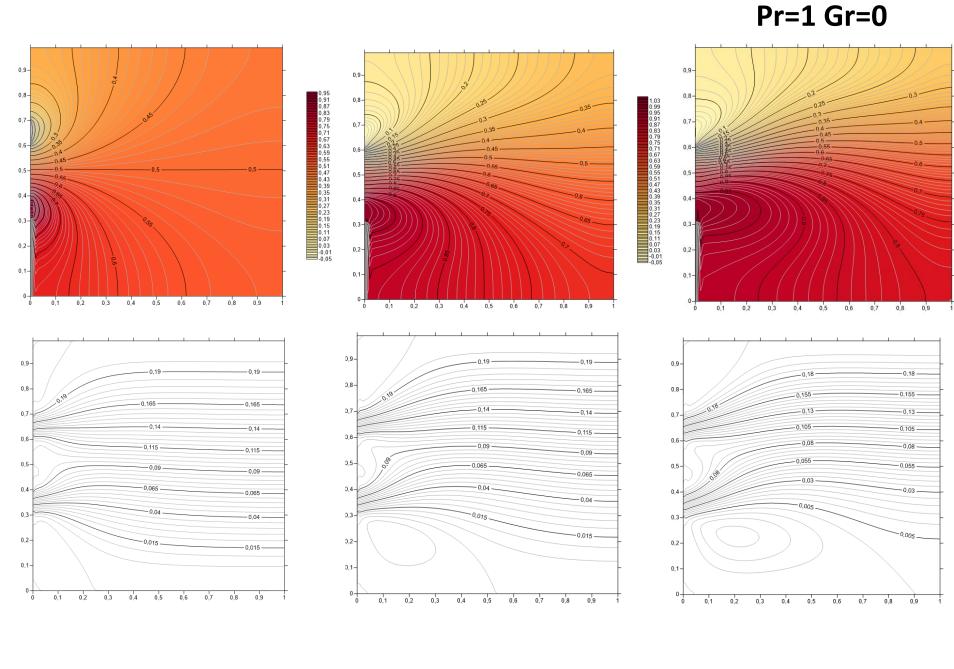
 $y = (j-1) \triangle y; y_n = (jn-1) \triangle y; n = 0,3$ 

### Local one-dimentional scheme

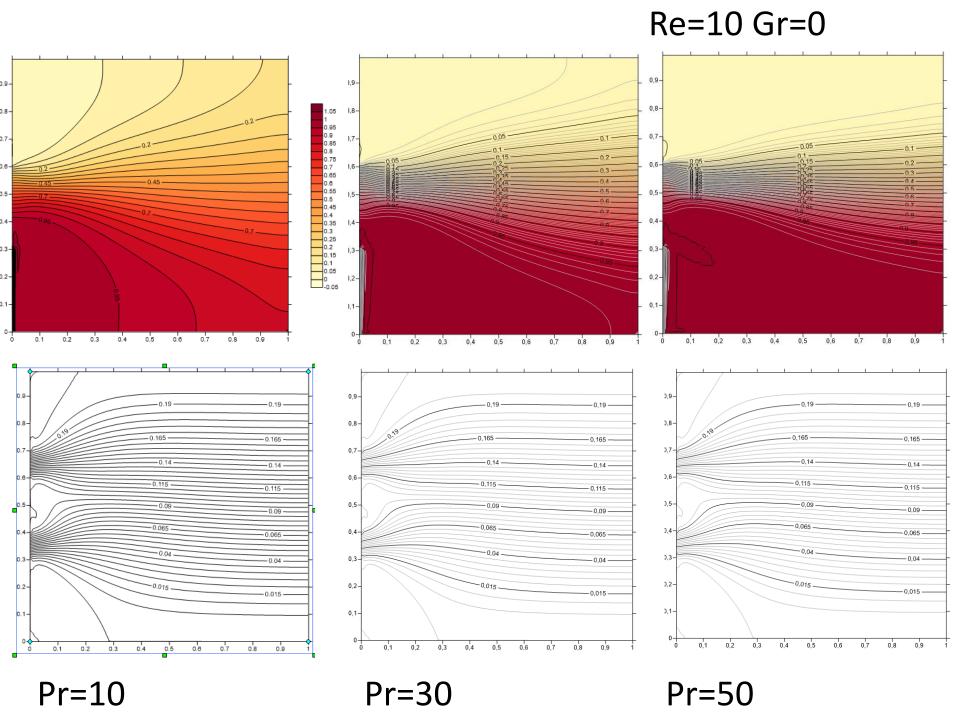
$$\frac{\theta_{ij}^* - \theta_{ij}^n}{\Delta \tau} + (U_x \frac{\partial \theta}{\partial x})_{ij}^* = \frac{1}{\text{Pr Re}} \left(\frac{\partial^2 \theta}{\partial x^2}\right)_{ij}^*$$

$$\frac{\theta_{ij}^{n+1} - \theta_{ij}^{*}}{\Delta \tau} + (U_{y} \frac{\partial \theta}{\partial x})_{ij}^{n+1} = \frac{1}{\text{Pr Re}} (\frac{\partial^{2} \theta}{\partial x^{2}})_{ij}^{n+1}$$



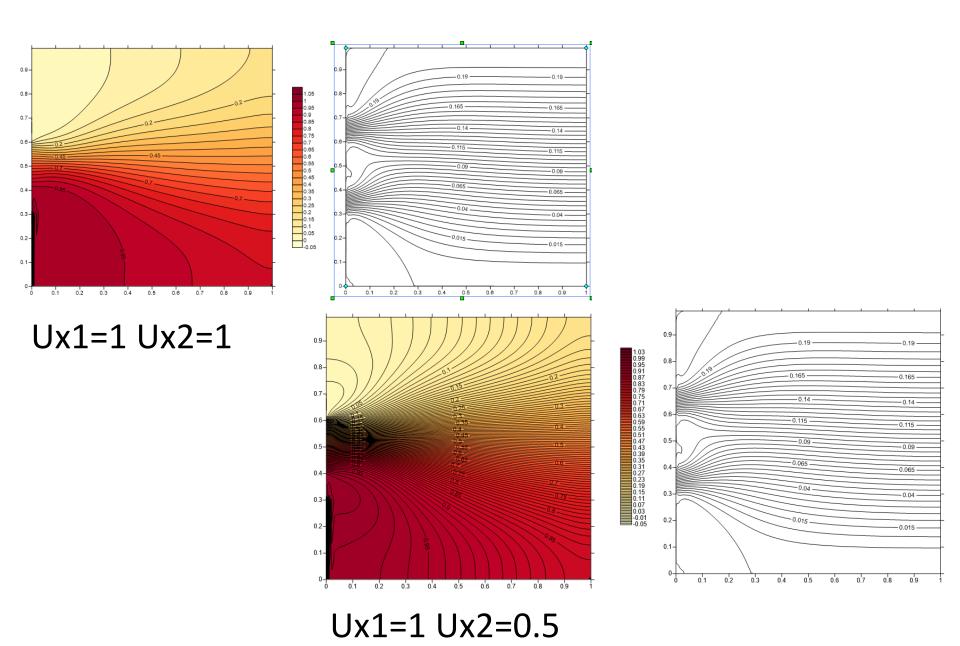


Re=1 Re=50 Re=80

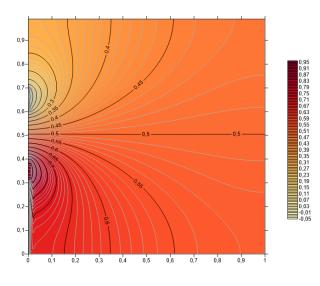


#### Re=1Pr=1 0,9-0,8-0.8 0.8-0,7-0.7-0.6 0.6 0.5-0.4-0,3-0.3-0,2-0.2-0.1 0,1-0.1 0.4 0.5 0,7 0.4 0,2 0,3 0,4 0,5 0,6 0,8 0.9 -0.19 -- 0,19 -0.8--0.165 --0.165 0,165 --0,165 - 0.165 --0.165 -- 0.14 --0.14 - 0,14 -- 0,14 --0.14 -- 0.14 --0.115 --0.115 -- 0,115 – 0.115 — - 0.115 --0.09 -- 0,09 --0.09 -0.09 --0,09 - 0.09 --0.065 --0,065 ---0.065 -- 0.065 -- 0,065 0.065 --0.04 --0,04 --0.04 -0,04 --0.04 0.2--0.015 --0.015 - 0,015 -- 0.015 -0.1 0.2 0.3 0.5 0.6 0.7 0.8 Gr=-100 Gr=0 Gr=100

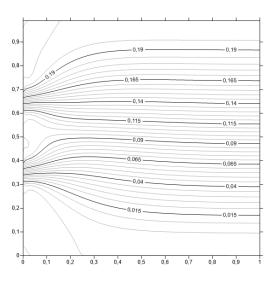
#### Re=10 Pr=10 Gr=0

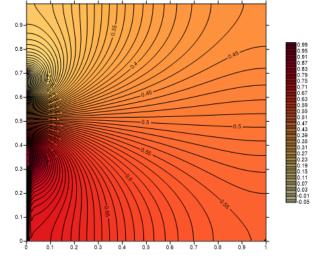


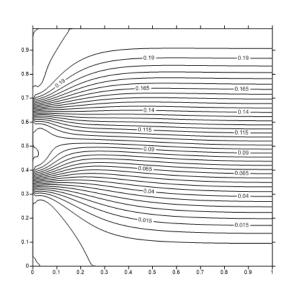
#### Re=1 Pr=10 Gr=0



Ux1=1 Ux2=1







Ux1=1 Ux2=0.5

#### Re=1 Pr=10 Gr=0

