# LAMINAR NATURAL CONVECTION IN INCLINED ENCLOSURES BOUNDED BY A SOLID WALL

Course: CL CFD 613

(2020-21)

**Guide**


**Dr. R. Anandlakshmi**

**Submitted By**

**Rahul Meel** ( 170103051)

**Shivasish Biswal** ( 170103063)

**Ila Kulkarni** (204351012 )

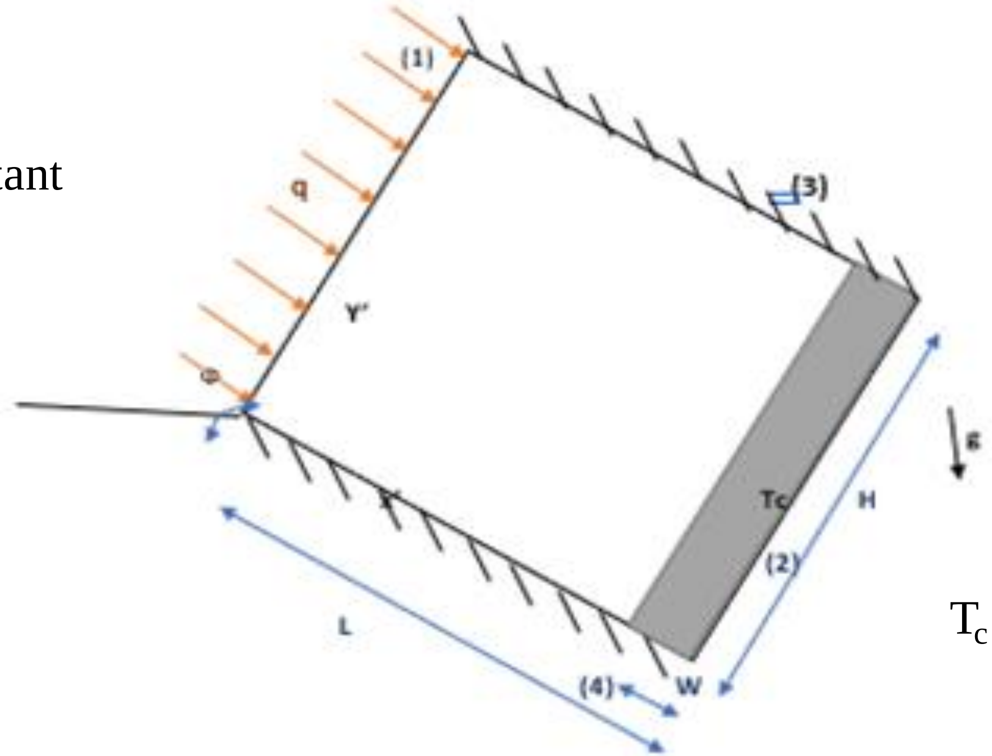
**Mahesh Mahajan** (204351007)

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी • Indian Institute of Technology Guwahati •

**Problem :** LAMINAR NATURAL CONVECTION IN INCLINED ENCLOSURES BOUNDED BY A SOLID WALL

$u' = v' = 0; \frac{\partial T}{\partial y'} = 0$

q = constant




$T_c$ = constant

# Assumptions :

- Fluid is non-absorbing ,perfect gas type fluid
- 2-D Steady flow
- Thermo physical properties are constant (K, Cp, μ)
- **Boussinesq Approximation**, density is constant
- The boundary conditions are the no-slip conditions of all the rigid wall surfaces,

# Governing Equations :

- **In terms of non-dimensional quantities** -

- $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$
- $\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + u\frac{\partial u}{\partial y} = -\frac{\partial p}{\partial x} + \tau \mathrm{Pr} \nabla^2 u + RaPr\theta \cos\varphi$
- $\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = -\frac{\partial p}{\partial y} + \tau \mathrm{Pr} \nabla^2 v + RaPr\theta \sin\varphi$
- $\frac{\partial \theta}{\partial t} + u\frac{\partial \theta}{\partial x} + v\frac{\partial \theta}{\partial y} = K_r \nabla^2 \theta$

# Why Solution is tricky ?

- Non- linear
- Source term, i.e., the pressure gradient has pressure which is a variable
- No explicit governing equation for calculating P.

# Model and methodology adopted

- Primitive Variable approach
- To avoid limitations of interpolation staggered grid concept is used

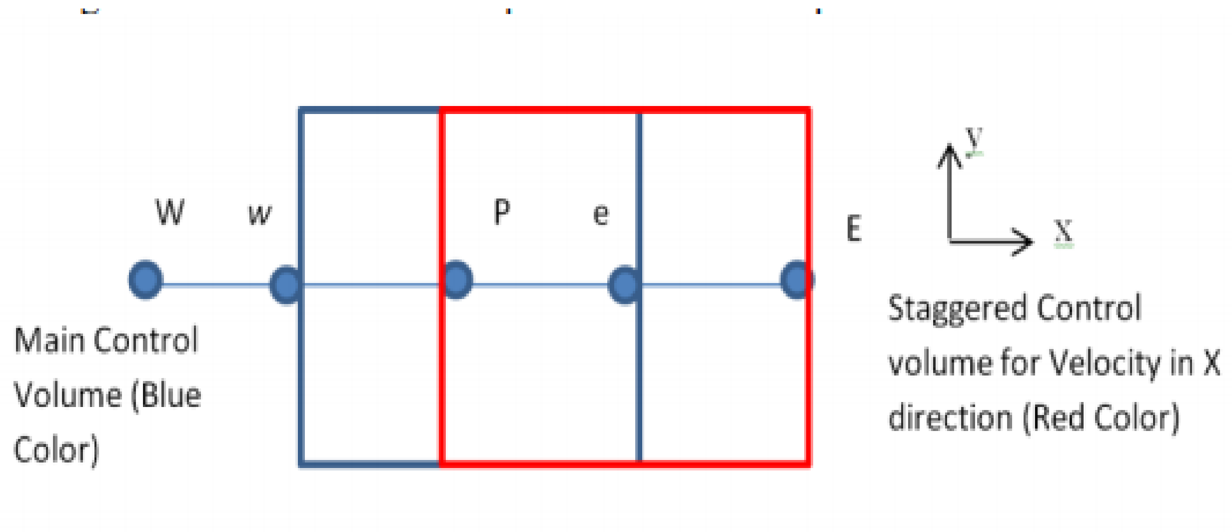
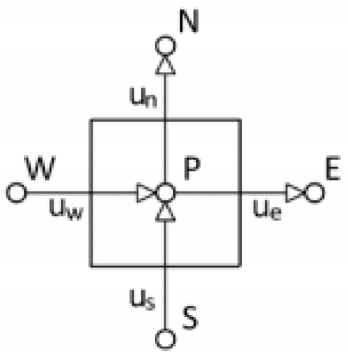



Fig. 2 Staggered and main Grid in X direction

# <u>Integrating x- momentum equation</u> :

$$\iiint \frac{du}{dt} dtdxdy + \iiint \frac{\partial u^2}{\partial x} dtdxdy + \iiint \frac{\partial uv}{\partial y} dtdxdy$$
$$= - \iiint \frac{\partial p}{\partial x} dtdxdy + \tau Pr \iiint \left( \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) dtdxdy + \iiint RaPr\theta \cos\varphi \, dtdxdy$$

Generalized discretized form of which is :




$$a_p u_P = a_e u_{E+} a_w u_{w+} a_n u_{N+} a_s u_S$$

- Pressure Using CDM –

$$\frac{\partial p}{\partial x}\Delta x\Delta y = (p_P - p_E)\Delta y$$

- Discretised x- momentum equation is

$$u^{n+1} = u^n - {\Delta t}/{\Delta x \Delta y}\,(a_p u_P - a_e u_{E+} a_w u_{w+} a_n u_{N+} a_s u_S)$$
$$+RaPr\left[{(\theta_e + \theta_p)}/{2}\right]\cos\varphi\Delta t - (p_P - p_E)\Delta t/\Delta x$$

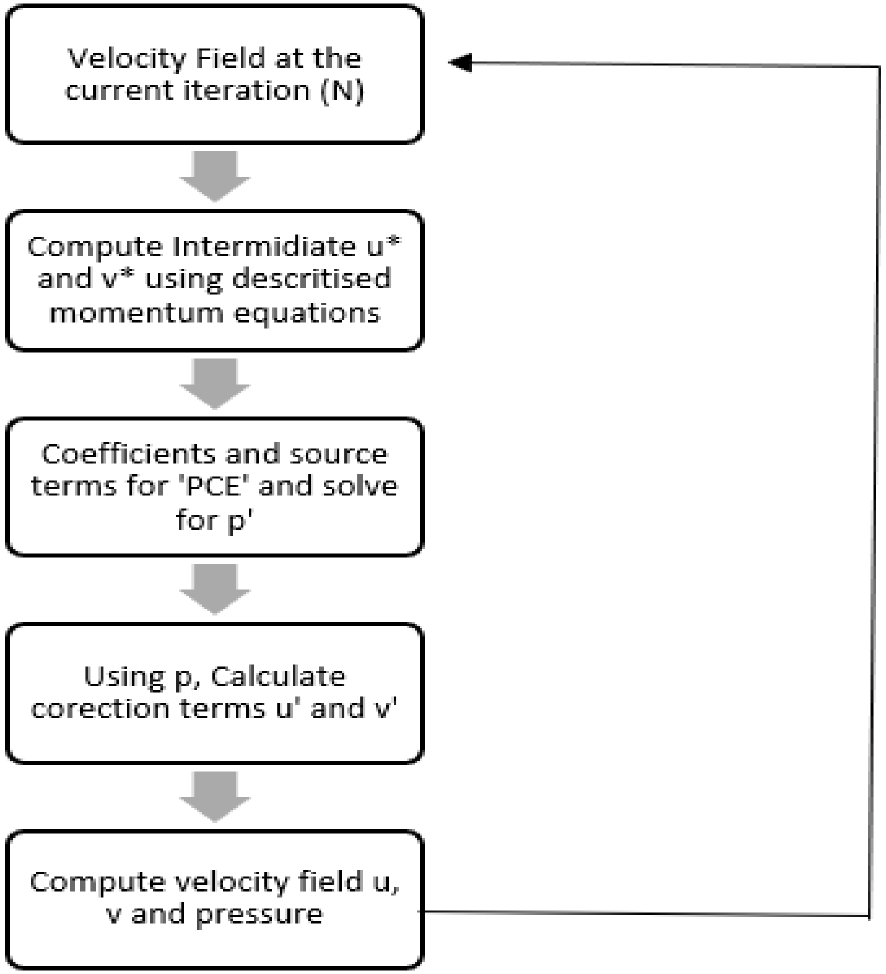
- Temperature transport equation

$$\theta^{n+1} = \theta^{n} - {}^{\Delta t}/_{\Delta x \Delta y}\left(a_p\theta_P - a_e\theta_{E+}a_w\theta_{w+}a_n\theta_{N+}a_s\theta_S\right)$$

- For solid region we have used FDM to solve for the temperatures

$$T_P = \frac{1}{4}\left[T_E + T_{W+}T_N + T_S\right]$$

# Iterative scheme : SIMPLE Algorithm



# Effect of inclination :

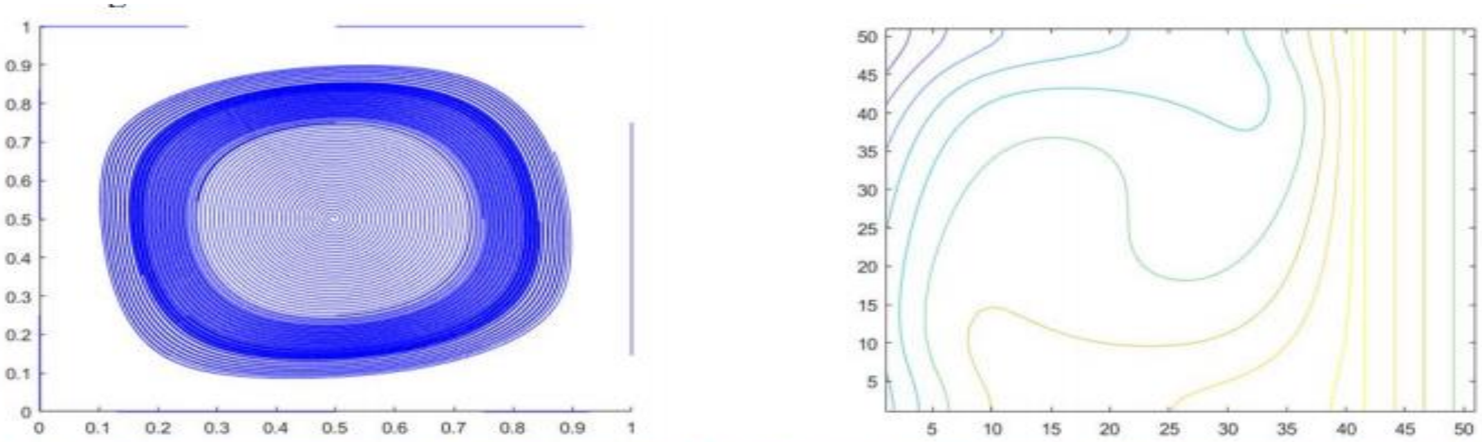


Fig. 6 Variation of Streamlines and Isotherm with 10^6 Rayleigh number and at 30-degree angle of inclination

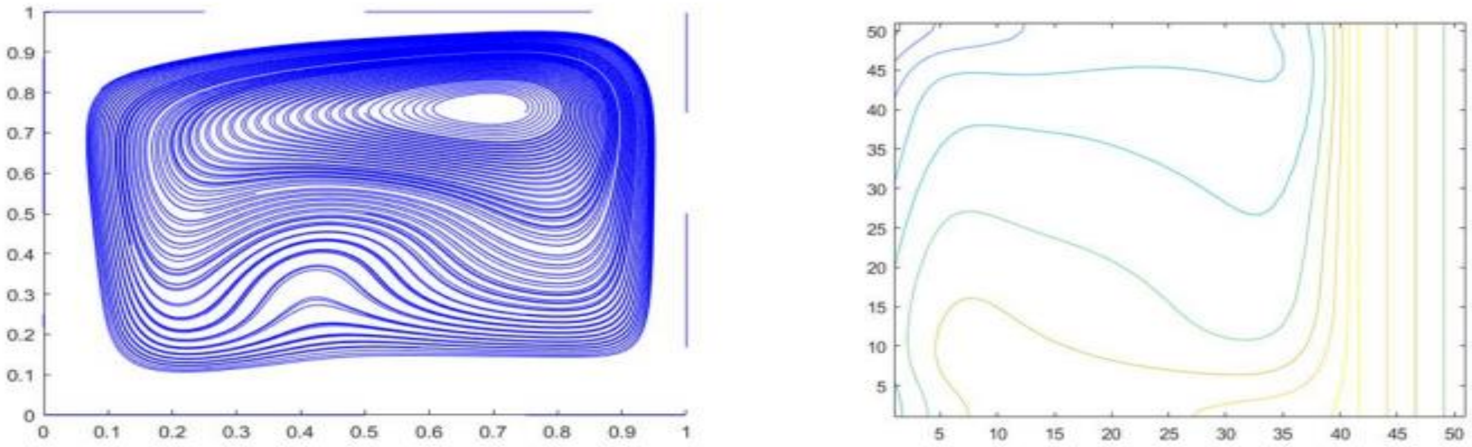


Fig. 7 Variation of Streamlines and Isotherm with 10^6 Rayleigh number and at 90-degree angle of inclination

# Effect of Rayleigh's Number

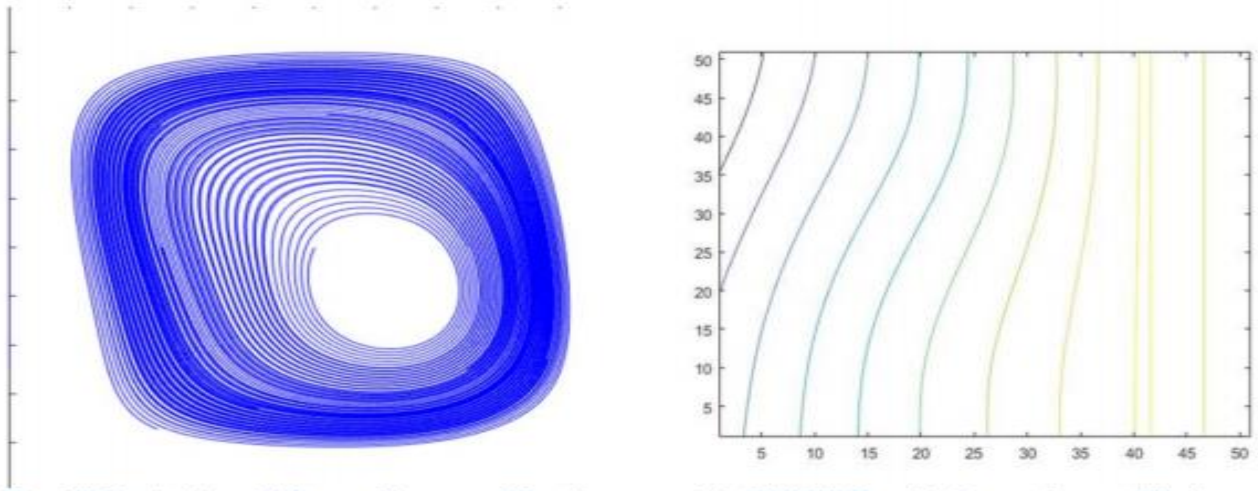



Fig. 10 Variation of Streamlines and Isotherms with 100000 Rayleigh number at 90 degree

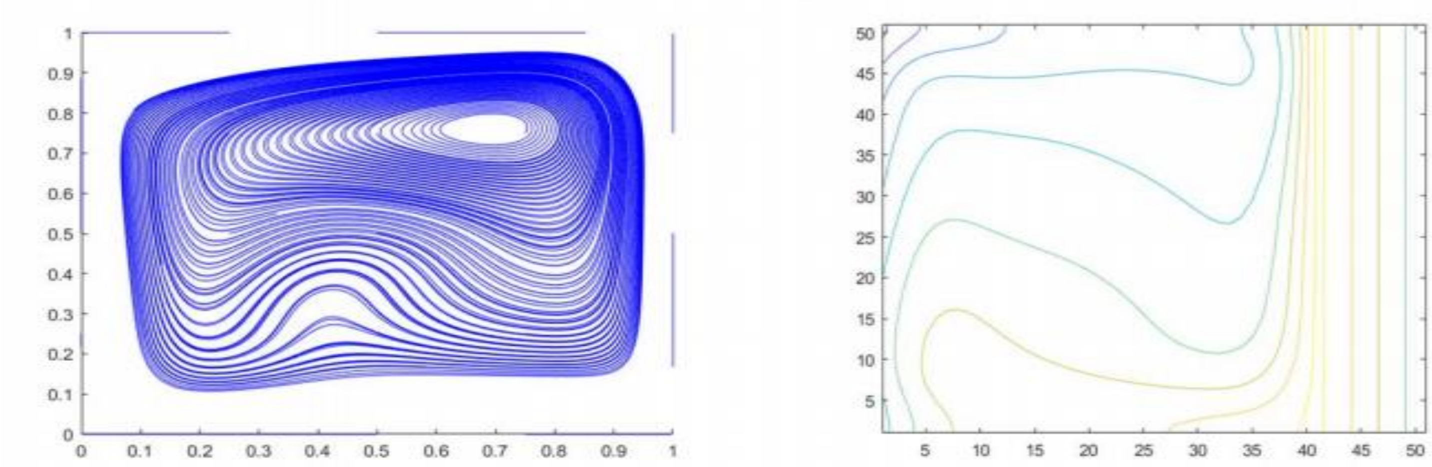



Fig. 11 Variation of Streamlines and Isotherms with 1000000 Rayleigh number at 90 degree

# To study the effect of conductivity

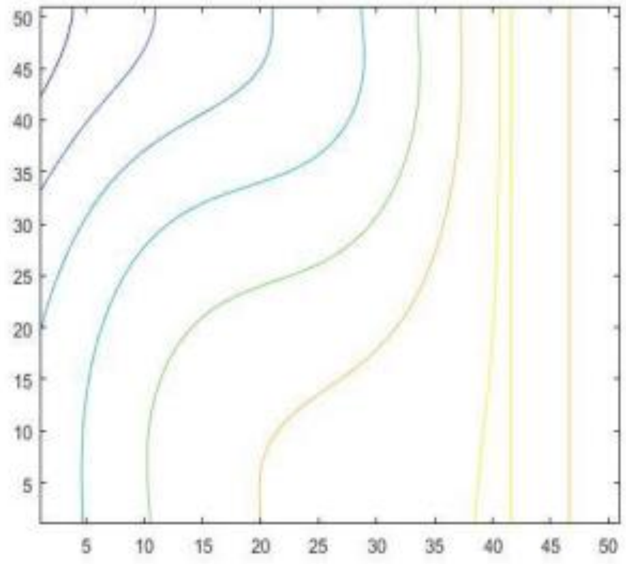



Fig. 12 Variation in isotherms with the conductivity ratio 1 at Ra=100000

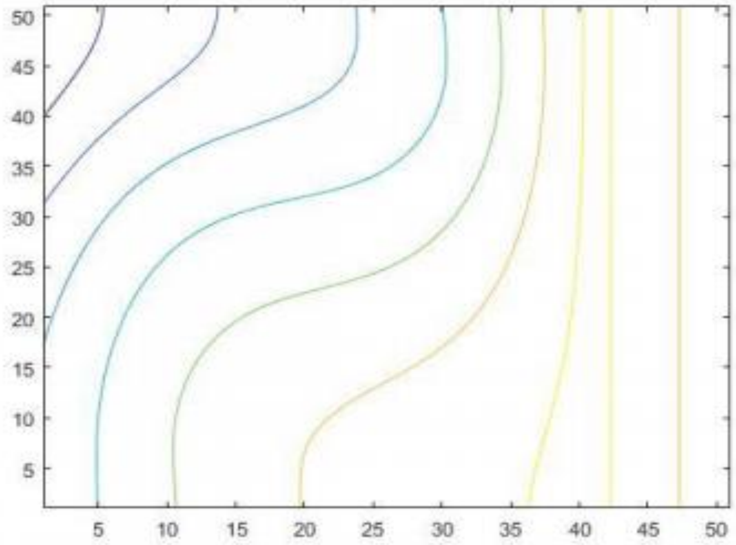



Fig. 13 Variation in the isotherms with conductivity ratio 10 at Ra=100000

# THANK YOU !