For steady flow $\frac{\partial f}{\partial t} = 0$

$$\Rightarrow \rho\left(\frac{u_r}{r} + \frac{\partial u_r}{\partial r}\right) + \rho \cdot \frac{\partial u_\theta}{\partial \theta} \cdot \frac{1}{r} = 0$$

$$\Rightarrow \frac{u_r}{r} + \frac{\partial u_r}{\partial r} + \frac{1}{r} \cdot \frac{\partial u_\theta}{\partial \theta} = 0$$

$$\Rightarrow u_r + r \cdot \frac{\partial u_r}{\partial r} + \frac{\partial u_\theta}{\partial \theta} = 0$$

$$\Rightarrow \boxed{\frac{\partial}{\partial r}(r \cdot u_r) + \frac{\partial (u_\theta)}{\partial \theta} = 0}$$

$$\left[\frac{\partial (r u_r)}{\partial \theta} = u_r + \frac{\partial u_r}{\partial r} \cdot r\right]$$

This is the continuity eqn in polar co-ordinate in two dimn flow

* <u>Velocity Potential function</u> :– It is defined as the scalar function of space and time such that its ~~gives the~~ -ve derivative of w.r.t ~~time~~ any direction gives the velocity in that direction. It is denoted by ϕ. $\phi = f(x, y, z)$

$$u = -\frac{\partial \phi}{\partial x}$$

$$v = -\frac{\partial \phi}{\partial y}$$

$$w = -\frac{\partial \phi}{\partial z}$$

For Polar co-ordinates

$$u_r = \frac{\partial \phi}{\partial r}$$

$$u_\theta = \frac{1}{r} \cdot \frac{\partial \phi}{\partial \theta}$$

Laplace Eqn for steady flow

$$\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} + \frac{\partial^2 \phi}{\partial z^2} = 0$$