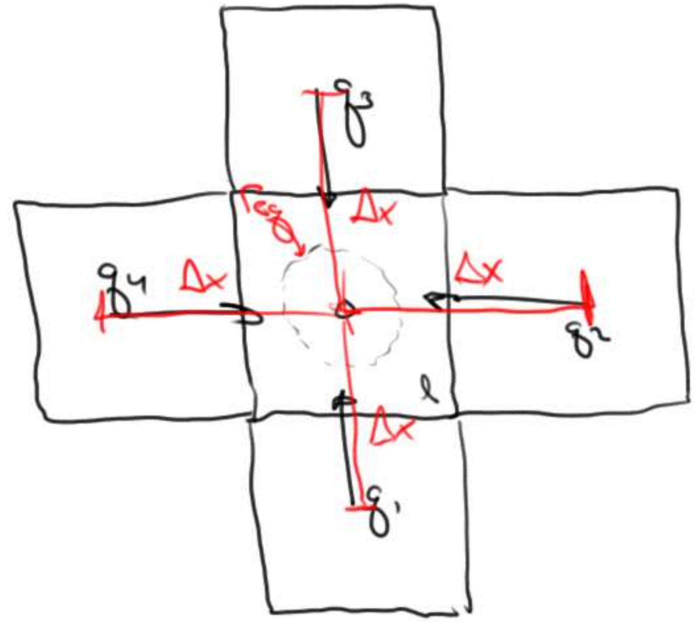
$$q_w + (q_1 + q_2 + q_3 + q_4) = 0$$



$$q_1 = \frac{kh\Delta x}{\mu B_w \Delta y}(P_1 - P_\ell)$$

$$q_2 = \frac{kh\Delta y}{\mu B_w \Delta x}(P_2 - P_\ell)$$

$$q_3 = \frac{kh\Delta x}{\mu B_w \Delta y}(P_3 - P_\ell)$$

$$q_4 = \frac{kh\Delta y}{\mu B_w \Delta x}(P_4 - P_\ell)$$

Block is square $\Delta x = \Delta y$

$$\rightarrow P(r) = P_\ell - \frac{q_w \mu B_w}{2\pi kh} \ln\left(\frac{r}{r_{eq}}\right)$$

$$P_4 = P_3 = P_2 = P_1 = \underbrace{P_\ell - \frac{q_w \mu B_w}{2\pi kh} \ln\left(\frac{\Delta x}{r_{eq}}\right)}$$

$$\underbrace{q_w = \frac{-kh}{\mu B_w}\left(P_1 + P_2 + P_3 + P_4 - 4P_\ell\right)}$$

$$q_w = \frac{-kh}{\mu B_w}\left[\cancel{4}\left(p_e - \frac{q_w \mu B_w}{2\pi k h}\ln\left(\frac{\Delta x}{r_{eq}}\right)\right) - \cancel{4 p_e}\right]$$

$$= \frac{-\cancel{kh}}{\cancel{\mu B_w}}\left[-\frac{4 q_w \mu \cancel{B_w}}{2\pi \cancel{kh}}\ln\left(\frac{\Delta x}{r_{eq}}\right)\right]$$

$$= \frac{2 q_w}{\pi}\ln\left(\frac{\Delta x}{r_{eq}}\right)$$

$$\frac{\pi}{2} = \ln\left(\frac{\Delta x}{r_{eq}}\right) \Rightarrow r_{eq} = \Delta x\, e^{-\pi/2} \simeq \underbrace{0.207 \Delta x}$$

"Peaceman correction"

$$p(r) = p_{ref} - \frac{q_w \mu B_w}{2\pi k h}\ln\left(\frac{r}{r_{ref}}\right)$$

$$p_e = p_{wf} - \frac{q_w \mu B_w}{2\pi k h}\ln\left(\frac{r_{eq}}{r_w}\right)$$

Productivity index

$$q_w = -J_e\,(p_e - p_{wf}) \qquad J = \frac{2\pi k h}{\mu B_w\left[\ln\left(\frac{r_{eq}}{r_w}\right) + s\right]}$$

$r_{eq} \cong 0.2\,\Delta x$

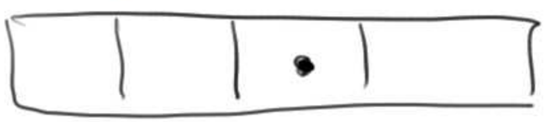
$$T\left(P_{l-1}^{n+1} - P_l^{n+1}\right) + T\left(P_{l+1}^{n+1} - P_l^{n+1}\right) = \frac{1}{\Delta t} B_l \left(P_l^{n+1} - P_l^{n}\right) - Q_l$$

$$Q_l = J_l^{w}\left(P_l^{n+1} - P_{wf}\right)$$

$$-T P_{l-1}^{n+1} + \left(2T + J_l^{w} + \frac{1}{\Delta t} B_l\right) P_l^{n+1} - T P_{l+1}^{n+1} = \frac{1}{\Delta t} B_l P_l^{n} + J_l P_{wf}$$

$$\boxed{\left(\vec{\vec{T}} + \vec{\vec{J}} + \frac{1}{\Delta t}\vec{\vec{B}}\right)\vec{P}^{\,n+1} = \frac{1}{\Delta t}\vec{\vec{B}}\,\vec{P}^{\,n} + \vec{Q}}$$

diagonal matrix



$$\vec{\vec{J}} = \begin{bmatrix} 0 & & & \\ & 0 & & \\ & & J_3 & \\ & & & 0 \end{bmatrix} \Rightarrow \vec{Q} = \begin{bmatrix} 0 \\ 0 \\ J P_{wf} \\ \\ \end{bmatrix}$$