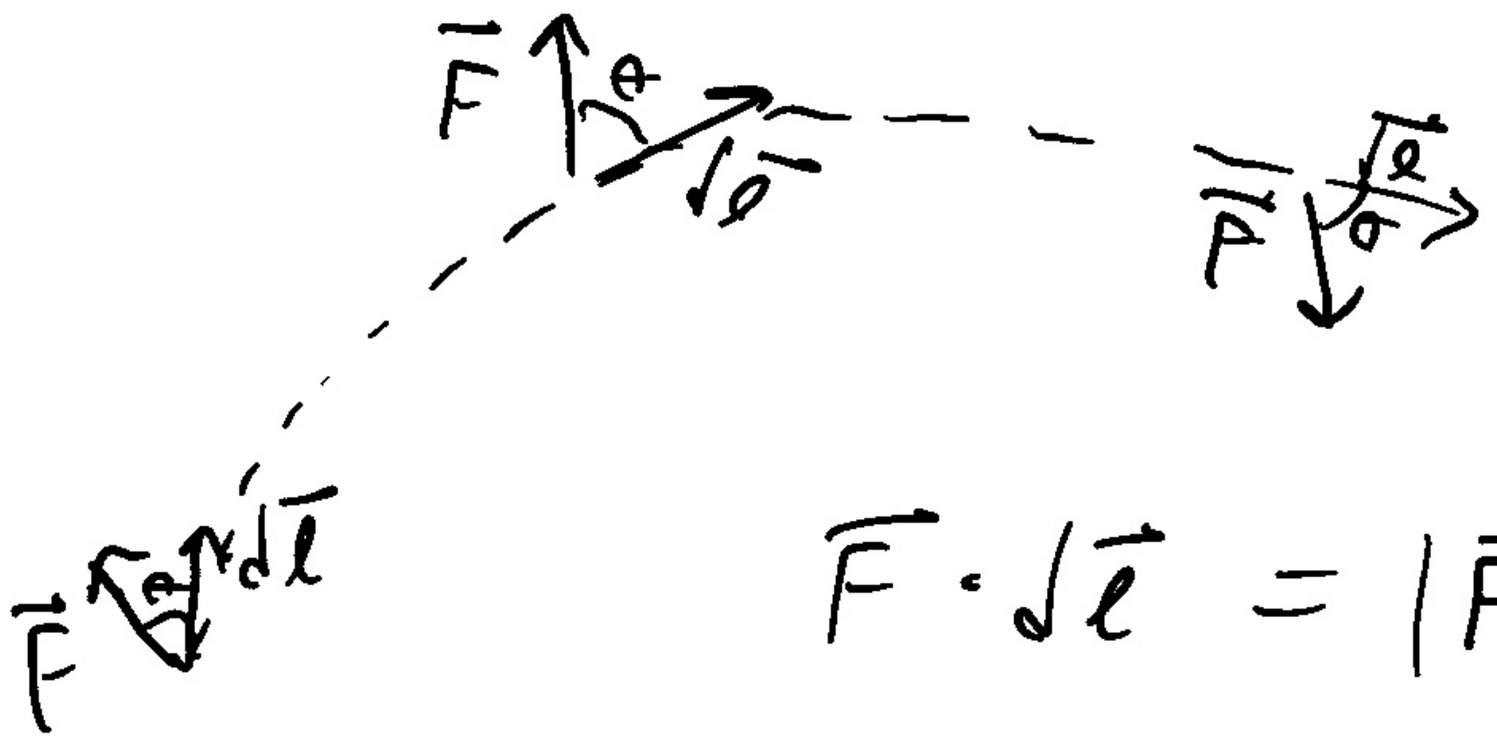
Review Math;

$\oint \vec{F} \cdot d\vec{\ell}$ Amount of $\vec{F}$ along path $\vec{\ell}$



$\vec{F} \cdot d\vec{\ell} = |\vec{F}||d\vec{\ell}| \cos\theta$

if $\vec{F} = -\nabla U$

then $\oint \vec{F} \cdot d\vec{\ell} = 0$

because $\int_a^b \nabla U \cdot d\vec{\ell} = -\int_a^b \vec{F} \cdot d\vec{\ell}$

$= U(b) - U(a) = \Delta U_{ab} = -W_{ab}$

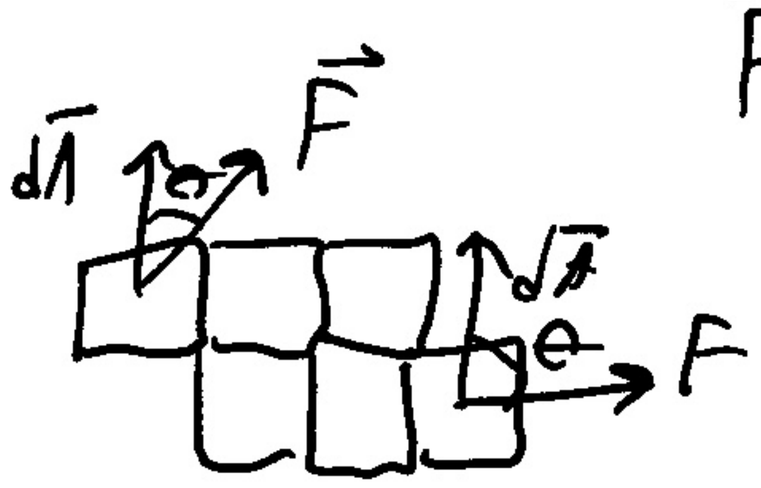
regardless of path

for non-potential fields

$\oint \vec{F} d\vec{\ell} \neq 0$ e.g. $\oint \vec{B} \cdot d\vec{\ell} = \mu_0 I_{enc}$

$\Phi = \oint \vec{F} \cdot d\vec{A}$ is a very different thing

$\vec{F} \cdot d\vec{A} = |\vec{F}||d\vec{A}| \cos\theta$



- Represents amount of $\vec{F}$ going across surface A

$\Phi_E = \oint \vec{E} \cdot d\vec{A}$
= # electric field lines through A

$\Phi_{E_{total}} = \oint \vec{E} \cdot d\vec{A} = q_{enc}/\varepsilon_0$

$\Phi_{B_{total}} = \oint \vec{B} \cdot d\vec{A} = 0$

Φ_B through a non-closed surface $\neq 0$ in general