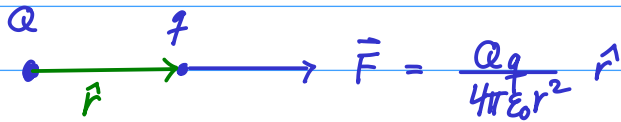


Elektromagnetisme - Fysikk-OL

Coulombs lov:

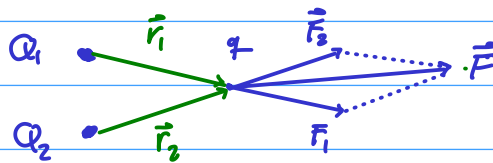


$$\vec{F} = \frac{Qq}{4\pi\epsilon_0 r^2} \hat{r}$$

Def. $\vec{E} = \frac{\vec{F}}{q}$.

$$\vec{E} = \frac{Q}{4\pi\epsilon_0 r^2} \hat{r}$$

Summere krefter:



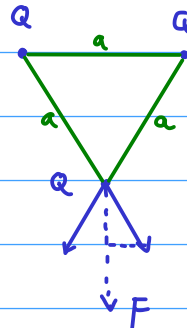
Dette gir superposjonsprinsippet for $\vec{E}$:

$$\vec{E} = \frac{Q_1 \hat{r}_1}{4\pi\epsilon_0 r_1^2} + \frac{Q_2 \hat{r}_2}{4\pi\epsilon_0 r_2^2} + \dots$$

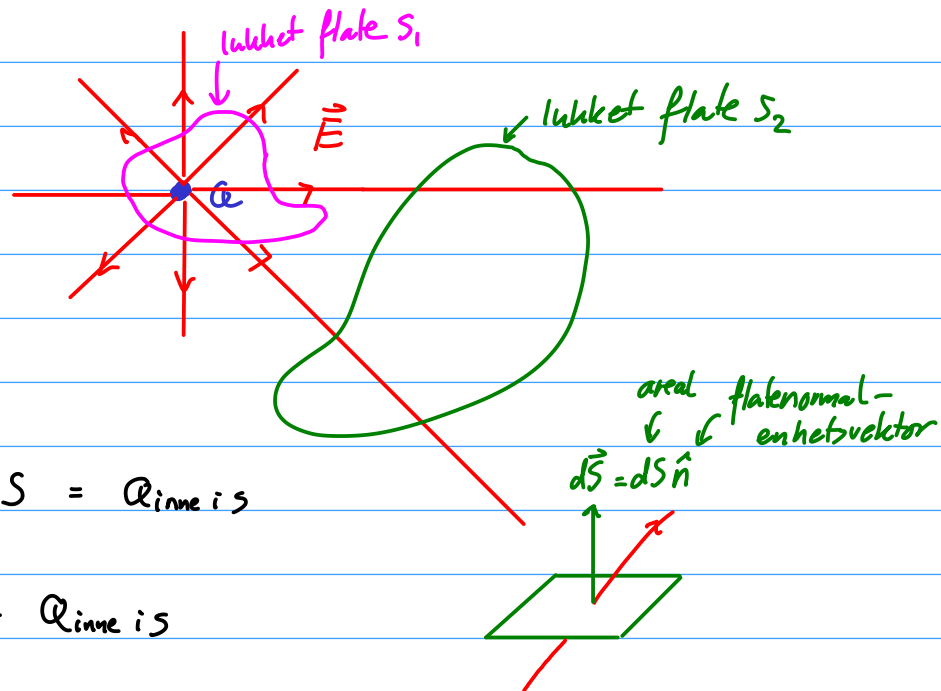
Eks: 3 like ladninger Q .
Finn kraften på en av dem.

$$\cos 30^\circ = \frac{F/2}{\frac{Q^2}{4\pi\epsilon_0 a^2}}$$

$$\frac{F}{2} = \frac{Q^2}{4\pi\epsilon_0 a^2} \cdot \frac{\sqrt{3}}{2} \Rightarrow F = \frac{\sqrt{3} Q^2}{4\pi\epsilon_0 a^2}$$



Gauss' lov



Gauss' lov: $\epsilon_0 \cdot \text{fluks ut av } S = Q_{\text{inne i } S}$

$$\epsilon_0 \oint_S \vec{E} \cdot d\vec{S} = Q_{\text{inne i } S}$$

Eks: Kule med jevnt fordelt ladning Q utover volumet. Finn $\vec{E}$ overalt.

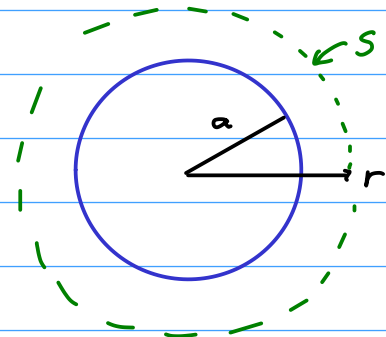
Se på obs.punkt $r > a$.

Symmetri $\Rightarrow \vec{E}$ er radielt rettet.

Fluks ut av $S = E \cdot 4\pi r^2$

$$\epsilon_0 4\pi r^2 E = Q$$

$$E = \frac{Q}{4\pi\epsilon_0 r^2} \quad (\text{som for pkt.ladn.})$$



Obs.pkt $r < a$ (inne i kula):

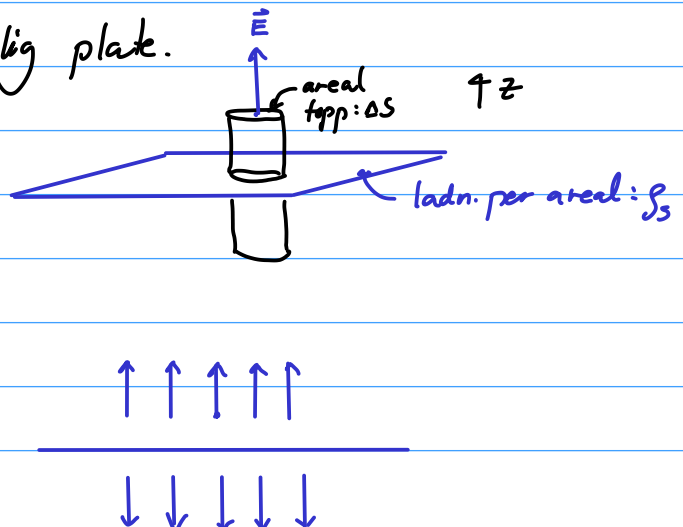
$$\epsilon_0 4\pi r^2 E = Q \frac{\frac{4}{3}\pi r^3}{\frac{4}{3}\pi a^3} \Rightarrow E = \frac{Qr}{4\pi\epsilon_0 a^3} \quad (\text{sjekk } r=0, r=a).$$

Eks: Finn E utenfor en ladd, uendelig plate.

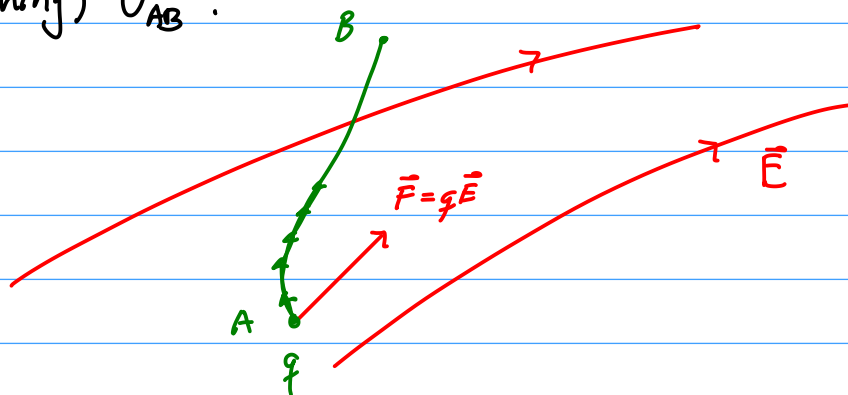
$$\epsilon_0 \text{ fluks} = \rho_s \Delta S$$

$$\underbrace{\epsilon_0 E \Delta S}_{\text{fluks topp}} + \underbrace{\epsilon_0 E \Delta S}_{\text{fluks bunn}} = \rho_s \Delta S$$

$$E = \frac{\rho_s}{2\epsilon_0}$$



Potensialforskjell (spenning) U_{AB} :

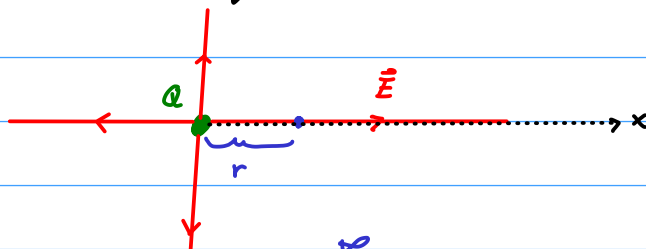


Arbeid utført av $q\vec{E}$ når q flyttes fra A til B:

$$W_{AB} = \int_A^B \vec{F} \cdot d\vec{l} = \int_{t_A}^{t_B} \vec{F}(t) \cdot \frac{d\vec{l}}{dt} dt = \int_A^B q\vec{E} \cdot d\vec{l}$$

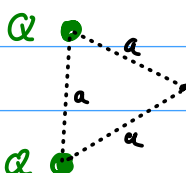
$$U_{AB} = \frac{W_{AB}}{q} = \int_A^B \vec{E} \cdot d\vec{l}$$

Eks: Punktladning. Finn potensialet i en avstand r , når ref. settes u langt unna.

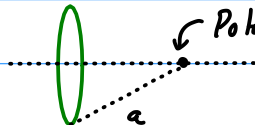


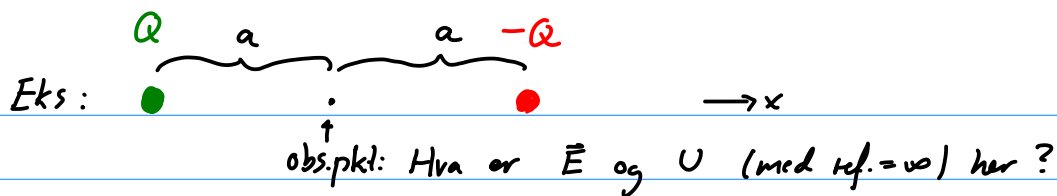
$$U(r) - U(\infty) = \int_r^\infty E(x) dx = \int_r^\infty \frac{Q}{4\pi\epsilon_0 x^2} dx = -\frac{Q}{4\pi\epsilon_0} \left[\frac{1}{x} \right]_r^\infty = \frac{Q}{4\pi\epsilon_0 r}$$

Potensial pga. en punktladning

Eks:  Potensial her? Bruk ∞ som referanse.

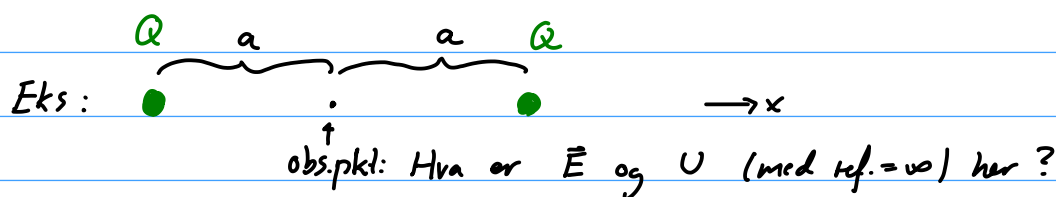
Svar: $U = \frac{Q}{4\pi\epsilon_0 a} + \frac{Q}{4\pi\epsilon_0 a} = \frac{2Q}{4\pi\epsilon_0 a}$

Eks:  Potensial her? Ringen har jevnt fordelt ladning, Q totalt.



Svar: $\vec{E} = 2 \frac{Q}{4\pi\epsilon_0 a^2} \hat{x}$ pga Coulombs lov

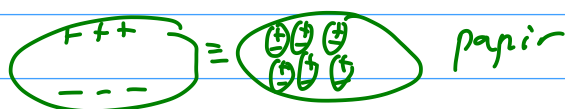
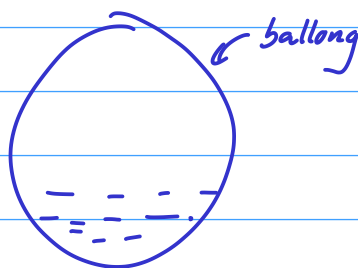
$U = \frac{Q}{4\pi\epsilon_0 a} + \frac{(-Q)}{4\pi\epsilon_0 a} = 0$ (husk at U ikke er en vektor!)



Svar: $\vec{E} = 0$

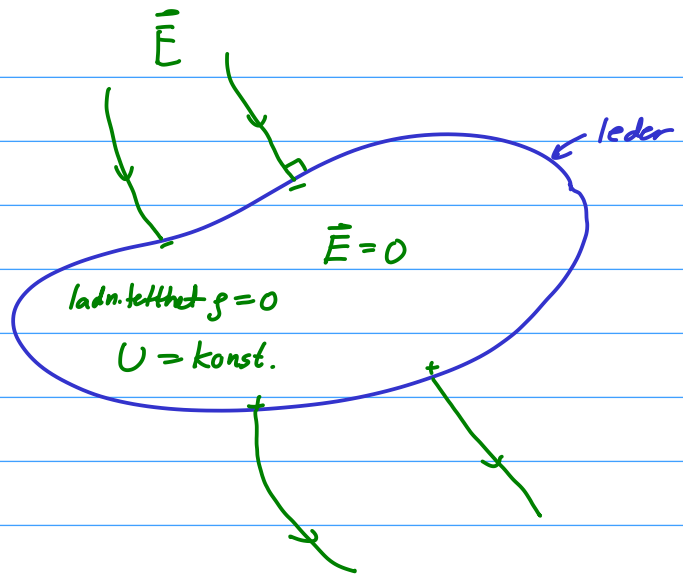
$U = \frac{Q}{4\pi\epsilon_0 a} + \frac{Q}{4\pi\epsilon_0 a} = \frac{2Q}{4\pi\epsilon_0 a}$

Dielektriske medier

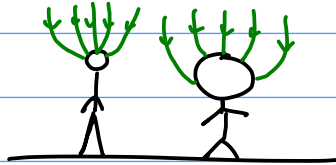


Ledere

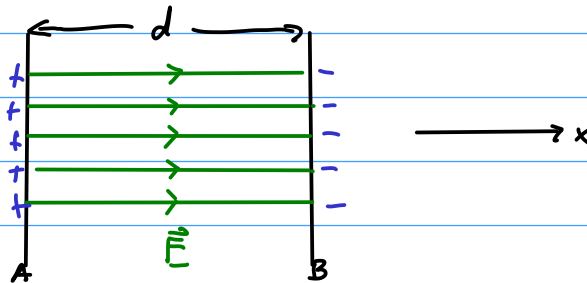
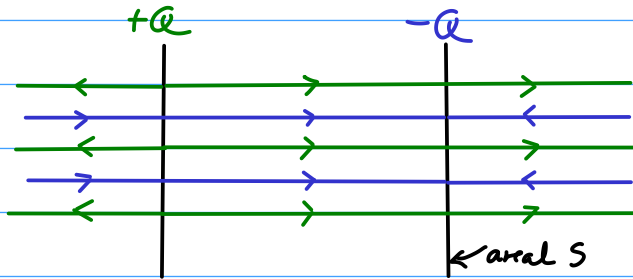
Anta statikk - alt har falt til ro.



Corona:



To plater:

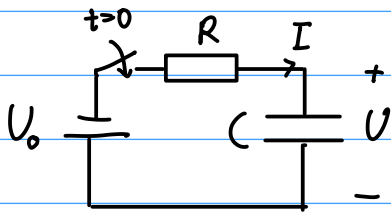


Potensialforskj. mellom platene : $U = \int_A^B E dx = Ed \Rightarrow E = \underline{\underline{\frac{U}{d}}}$

Samtidig har vi $E = \frac{\rho_s}{\epsilon_0} = \frac{Q/S}{\epsilon_0} \Rightarrow Q = \epsilon_0 S E$

Kapasitans : $C \stackrel{\text{def}}{=} \frac{Q}{U} = \frac{\epsilon_0 S E}{Ed} = \underline{\underline{\frac{\epsilon_0 S}{d}}}$

Kapasitans i krets



$$\begin{aligned}\text{Strøm } I &\stackrel{\text{def}}{=} \frac{dQ}{dt} = \frac{d}{dt}(CU) \\ &= C \frac{dU}{dt}\end{aligned}$$

Anta kondensator utladet ved $t=0$.

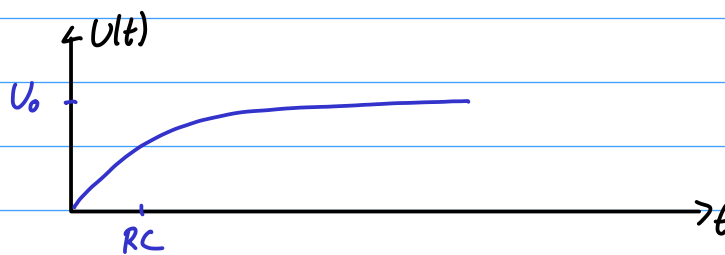
$$\text{For } t > 0 : I = C \frac{dU}{dt} = \frac{U_0 - U}{R} \Rightarrow \frac{dU}{dt} = -\frac{1}{RC}(U - U_0)$$

$$\Rightarrow \frac{d(U - U_0)}{dt} = -\frac{1}{RC}(U - U_0)$$

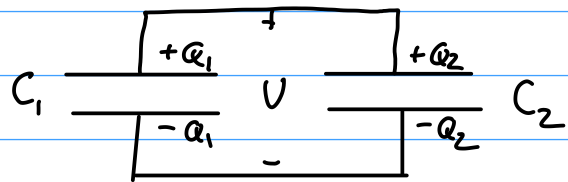
$$\Rightarrow U - U_0 = \text{konst} e^{-t/RC}$$

$$\text{Vet at } U(0) = 0 \Rightarrow \text{konst} = -U_0$$

$$\underline{U = U_0(1 - e^{-t/RC})}$$



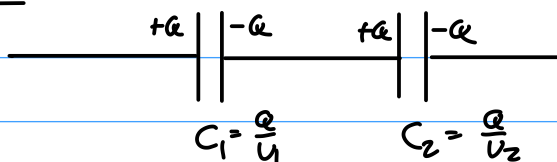
Parallellkobl. av kondensatorer



Felles U .

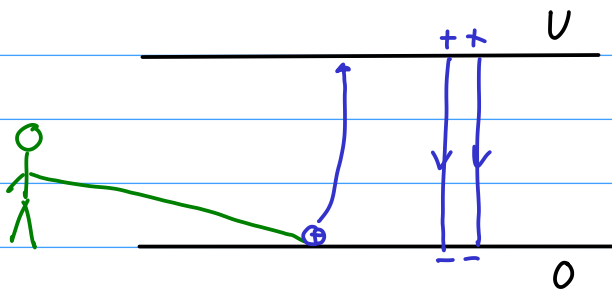
$$\begin{aligned}\text{Total } C &= \frac{Q_1 + Q_2}{U} = \frac{C_1 U + C_2 U}{U} = \underline{C_1 + C_2} \\ &\quad \uparrow \\ &\quad C_1 = \frac{Q_1}{U} \\ &\quad C_2 = \frac{Q_2}{U}\end{aligned}$$

Seriekobl.



$$\text{Total } C = \frac{Q}{U_1 + U_2} = \frac{Q}{\frac{Q}{C_1} + \frac{Q}{C_2}} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2}} \Rightarrow \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

Energi i en kondensator



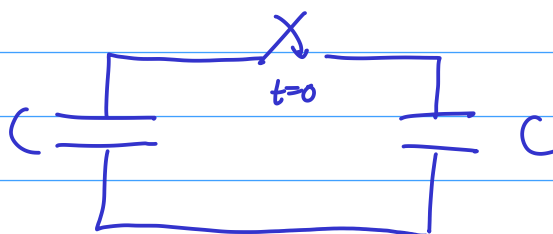
For å flytte dq opp kreves arbeidet:

$$dW = V dq$$

For å lade opp kond. til Q :

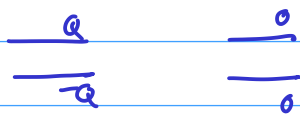
$$\begin{aligned} W &= \int_0^Q V(q) dq \\ &= \int_0^Q \frac{q}{C} dq = \frac{1}{2C} Q^2 \\ &\quad \uparrow V(q) = \frac{q}{C} \\ &= \frac{1}{2} C U^2 \end{aligned}$$

"Paradoks":



$$C = \frac{Q}{U}$$

For $t < 0$:



$$\text{Energi: } \frac{1}{2C} Q^2 + 0$$

For $t > 0$:



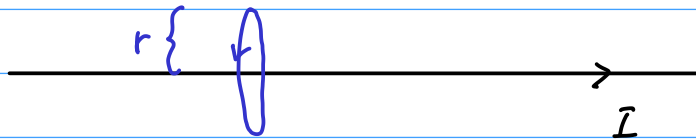
$$\text{Energi: } \frac{1}{2C} \left(\frac{Q}{2}\right)^2 + \frac{1}{2C} \left(\frac{Q}{2}\right)^2$$

Halvparten borte??

Magnetiske felt

Hva produserer $\vec{B}$ -felt? Svar: Strømmer

Ampères lov: $\frac{1}{\mu_0} \oint \vec{B} \cdot d\vec{l} = I_{\text{gjennom integrasjonskurven}}$

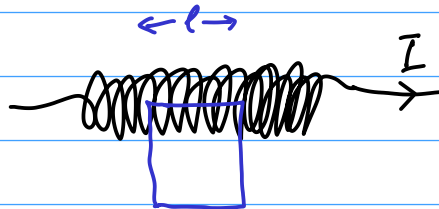


Symmetri $\Rightarrow \vec{B}$ i samme retn. som integrasjonsløypa
 B konst. på kurven.

$$\frac{1}{\mu_0} B 2\pi r = I$$

$$B = \frac{\mu_0 I}{2\pi r}$$

(strøm gir B -felt,
ikke spenning)



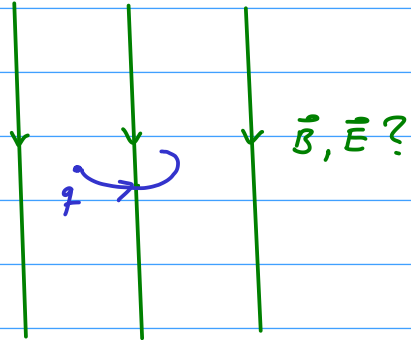
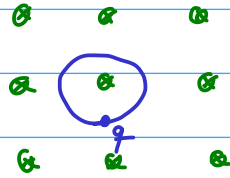
N vinkl. på lengden l .

$$\frac{1}{\mu_0} B l = N I$$

$$B = \frac{\mu_0 N I}{l}$$

Lorentz-krafta

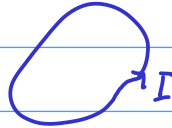
$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$



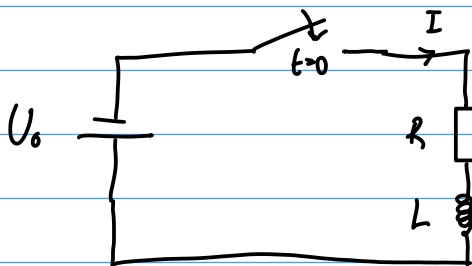
Elektrodynamikk

Faradays lov: $\text{ems} = - \frac{d\Phi}{dt}$, $\Phi = \text{fluks av } \vec{B}$
 $= \int_S \vec{B} \cdot d\vec{S}$

Induktans: $L \stackrel{\text{def}}{=} \frac{\Phi}{I}$



Krets:

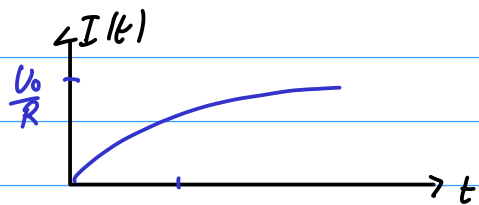


$$U_0 + \text{ems} = RI$$

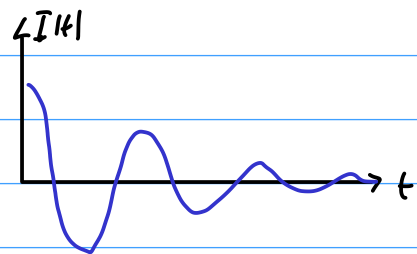
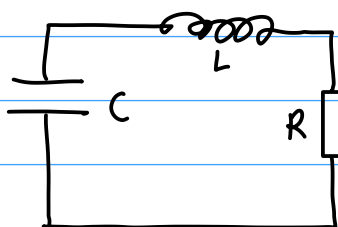
$$U_0 - \frac{d\Phi}{dt} = RI$$

$$U_0 - L \frac{dI}{dt} = RI$$

$$U_0 = RI + L \frac{dI}{dt}$$



RLC-krets:



Resonansfrekvens $(2\pi f_0)^2 = \frac{1}{LC}$

Mer elektrodynamikk Maxwells ligninger $\Rightarrow$ Elmag.-bølger!