

Kap. 27 Magnetisk felt og magnetiske krefter

Kortfatta målsetning:

- Forstå at magnetiske monopoler ikke fins, kun dipoler.
(mens elektriske monopoler fins, dvs. $+q$, $-q$)
- Lære at permanente magneter og elektromagneter har samme årsak:
-- ladninger i bevegelse.

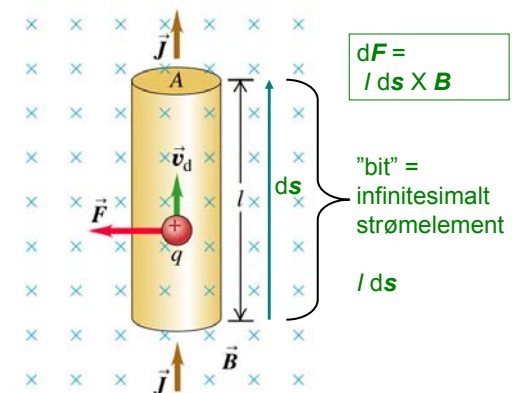
Kap. 27 Kjapp historie

- 1000 f.Kr.: Kompass brukt i Kina og i Mexico
800 f.Kr.: Magnetisk materiale i Magnesia i Hellas
Magnetitt: Fe_3O_4
1270: Nord- og sydpol
1600: Jordmagnetisme beskrives
1750: Magnetisk kraft prop. med $1/r^2$
1819-25: Vitenskapelig arbeid:
Hans Christian Ørsted, André Ampere, Jean Baptist Biot,
Felix Savart, Michael Faraday, Joseph Henry
1870: Systematisering av teorien v/James Clerk Maxwell.

Kap. 27 Magnetisme

- **Magnetostatikk** (ingen tidsvariasjon):
Kap 27. Magnetiske krefter
Kap 28: Magnetiske kilder
- **Elektrodynamikk**:
Kap 29-32:
Tidsvariasjon: Induksjon mm.

Kraft på ledningsbit

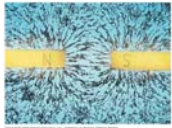


(Fig 27.25)

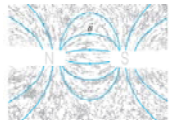
Kap. 27: Magnetisk felt og magnetiske krefter

- Forrige forelesning:**
- Lorentzkrafta = elektrisk kraft + magnetisk kraft:

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$
 (magnetisk flukstetthet \vec{B} defineres fra denne kraftvirkningen)
- Kraft på lederbit med lengde ds : $d\vec{F} = I ds \times \vec{B}$
- Magnetiske feltlinjer
- Magnetisk fluks: $\Phi_B = \iint \vec{B} \cdot d\vec{A}$

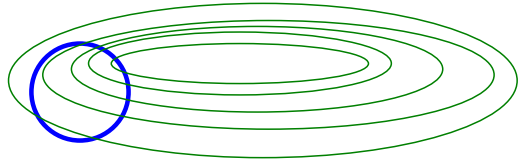


- Videre:**
- Gauss lov for \vec{B} -feltet
- Bevegelser av ladninger i \vec{B} og \vec{E} -felt, ved eksempler/anvendelser:
 - Hastighetsfilter
 - Thomsons e/m -eksperiment
 - Katodestrålerør
 - Massespektrometer
- Kraftmoment på strømsløyfe
- Magnetisk moment $\vec{\mu} = I \cdot \vec{A}$



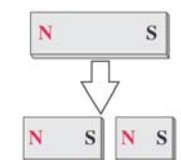
Gauss' lov for magnetfelt:

Nettofluks lukka flate = $\Phi_B = \int \vec{B} \cdot d\vec{A} = 0$

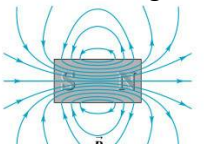


⇔ Feltlinjer er lukka kurver

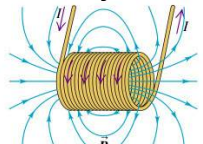
⇔ Magnetiske monopoler fins ikke:



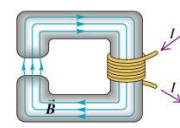
Alle magnetiske feltlinjer er lukka kurver:



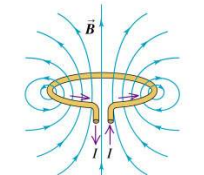
(a) Magnetic field lines through the center of a permanent magnet



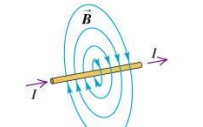
(b) Magnetic field lines through the center of a cylindrical current-carrying coil



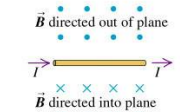
(c) Magnetic field lines through the center of an iron-core electromagnet



(d) Magnetic field lines in a plane containing the axis of a circular current-carrying loop



(e) Magnetic field lines in a plane perpendicular to a long, straight, current-carrying wire

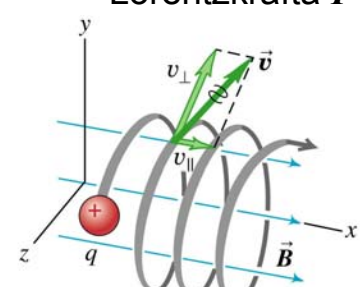


(f) Magnetic field lines in a plane containing a long, straight, current-carrying wire

\vec{B} directed out of plane

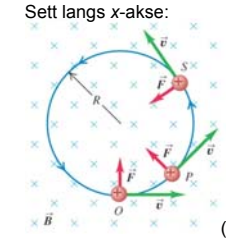
\vec{B} directed into plane

Heliksformet bane pga. Lorentzkrafta $\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$



(Fig 27.18)

Sett langs x-akse:



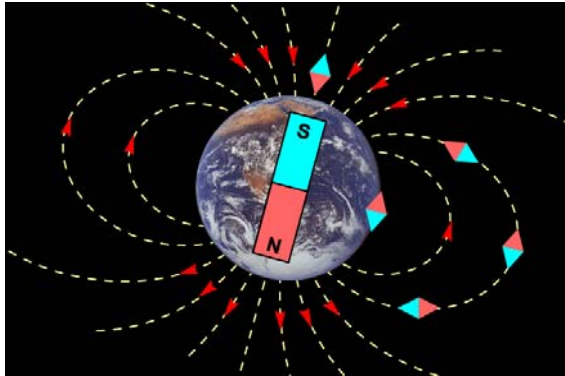
(Fig 27.17)

Syklusradius: $R = mv_{0z}/qB$ (27.11)

Syklusfrekvens: $\omega = qB_x/m$ (27.12)

Syklusperiode: $T = 2\pi/\omega$

Magnetfeltlinjer rundt jorda



<http://stargazers.gsfc.nasa.gov>

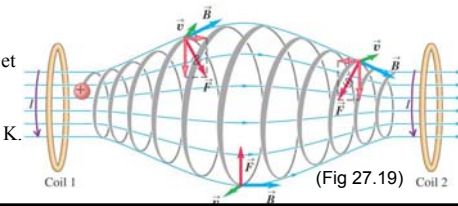
Nordlys i "van Allen strålingsbelter"



Tilsvaret

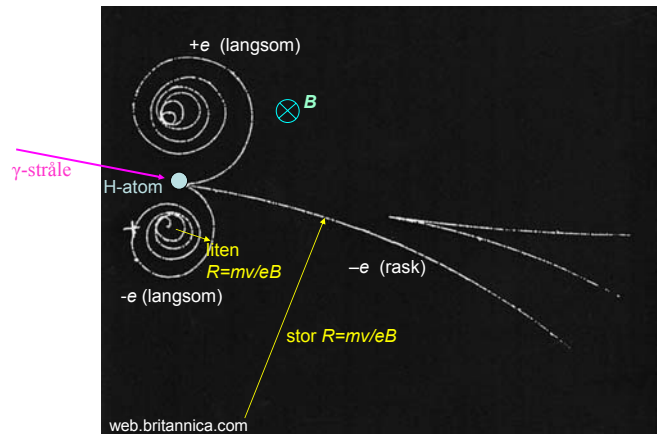
"Magnetisk flaske":

Ladde partikler kan fanges i et inhomogent magnetfelt. Kan oppnå plasmagass med temperaturer opp i ~ million K.



(Fig 27.19)

γ -stråle + H-atom \rightarrow elektron(rask)+elektron(langsom)+positron(langsom)

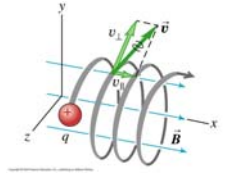


ESRF

(European Synchrotron Radiation Facility)
Grenoble, Frankrike. [LHC](#) : $R=4,3$ km



Heliksformet bane. Typiske tallstørrelser (Ex. 27.4)

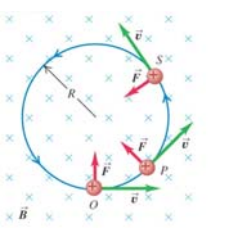


Oppgitte data:
 Proton: $B_x = 0,50 \text{ T}$
 $q = +e = 1,6 \cdot 10^{-19} \text{ C}$ $v_{0x} = 1,5 \cdot 10^6 \text{ m/s}$
 $m = 1,67 \cdot 10^{-27} \text{ kg}$ $v_{0z} = 2,0 \cdot 10^6 \text{ m/s}$

Finn:
 a) Syklotronradius R
 b) Syklotronfrekvens ω
 c) Heliksens stigning (Δx per omdreining)

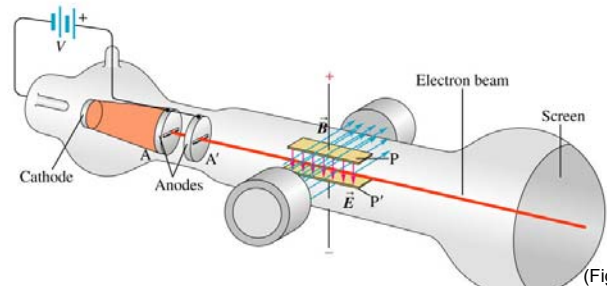
a) Syklotronradius (27.11): $R = mv_{0z}/qB_x = 4,2 \text{ mm}$
 b) Frekvens (27.12): $\omega = v_{0z}/R (= qB_x/m) = 4,8 \cdot 10^7 \text{ s}^{-1}$,
 dvs. periode $T = 2\pi/\omega = 1,3 \cdot 10^{-7} \text{ s}$
 c) $\Delta x = v_{0x}T = 20 \text{ mm}$ per periode T

Ellers:
 $F = |F| = qv_{0z}B_x = 1,6 \cdot 10^{-14} \text{ N}$
 Aksel = $a = F/m = 9,6 \cdot 10^{12} \text{ m/s}^2$



Thomsons e/m -eksperiment

Resultat: $e/m = 1,758820174 \cdot 10^{11} \text{ C/kg}$



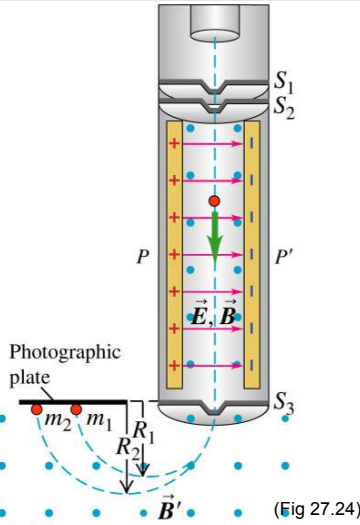
(Fig 27.23)

**Katodestrålerør (TV-rør) er svært likt:
Erstatt B -feltet med et horisontalt E -felt**

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Masse- spektrometer = hastighetsfilter + sirkelbaner for IONER

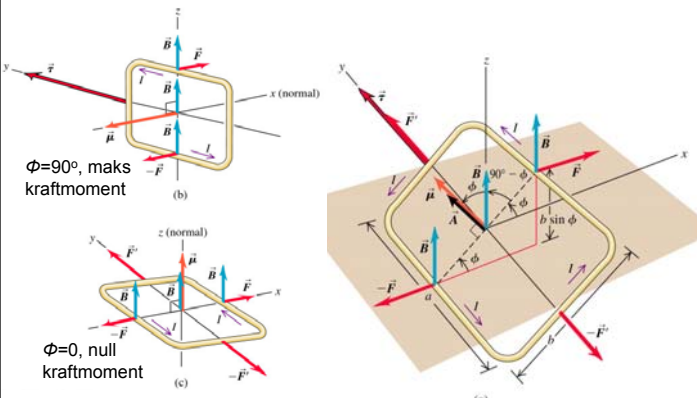
(Øving 9, opg. 3)



(Fig 27.24)

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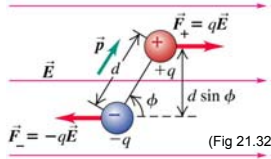
Kraftmoment på ledersløyfe



(Fig 27.31)

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Analogi mellom elektrisk dipol \mathbf{p} og magnetisk dipol $\boldsymbol{\mu}$



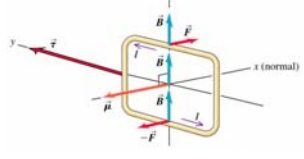
(Fig 21.32)

Kraft $F = qE$

Kraftmoment $\tau = \mathbf{p} \times \mathbf{E}$

Pot.energi $U = -\mathbf{p} \cdot \mathbf{E}$

\mathbf{p} søker seg paral. med \mathbf{E}
(lavest energi)



Kraft $F = I \mathbf{l} \times \mathbf{B}$

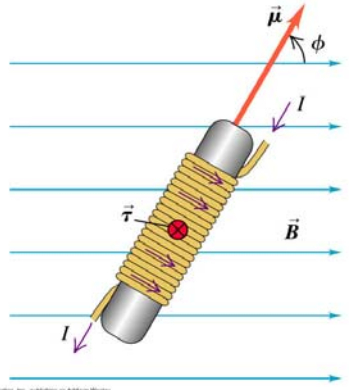
Kraftmoment $\tau = \boldsymbol{\mu} \times \mathbf{B}$

Pot.energi $U = -\boldsymbol{\mu} \cdot \mathbf{B}$

$\boldsymbol{\mu}$ søker seg paral. med \mathbf{B}
(lavest energi)

Ser dere at en magnetisk MONOPOL er utenkelig ?

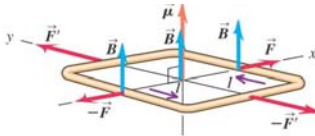
Solenoider med N viklinger: Hver vikling som éi sløyfe, totalt magnetisk moment: $\boldsymbol{\mu} = N I A$



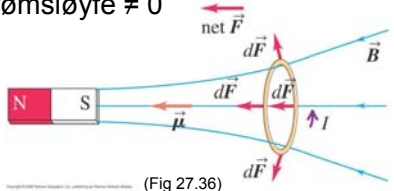
(Fig 27.34)

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Homogent magnetfelt: Nettokraft på strømsløyfe = 0 (Dreiemoment $\neq 0$)



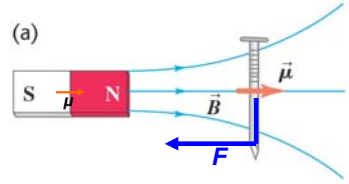
Inhomogent magnetfelt: Nettokraft på strømsløyfe $\neq 0$



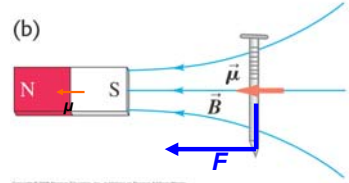
(Fig 27.36)

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Jern tiltrekkes både S-pol og N-pol. Feltet må være inhomogent.



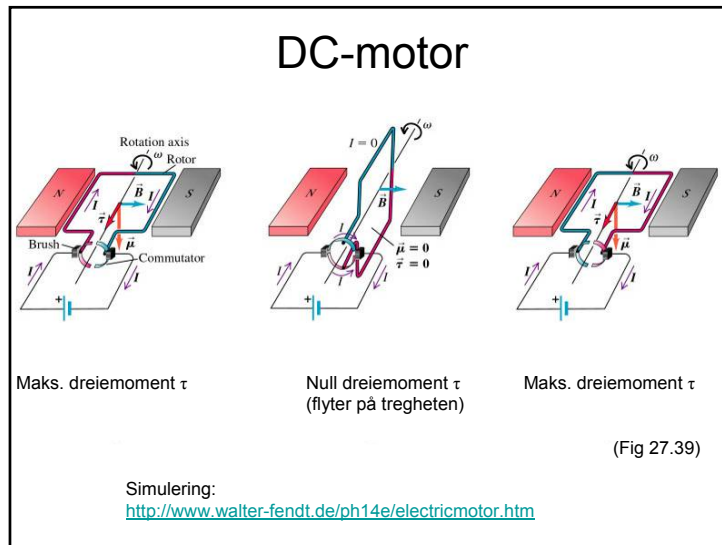
(a)



(b)

(Fig 27.38)

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Kap. 27: Oppsummering: Magnetisk felt og magnetiske krefter

- Lorentzkrafta = elektrisk kraft + magnetisk kraft:

$$\mathbf{F} = q\mathbf{E} + q\mathbf{v} \times \mathbf{B}$$
 (magnetflukstetthet \mathbf{B} defineres fra denne)
- Kraft på lederbit med lengde ds : $d\mathbf{F} = I ds \times \mathbf{B}$
- Magnetisk fluks: $\Phi_B = \iint \mathbf{B} \cdot d\mathbf{A}$
- Magnetisk kilde ("magnet") angis ved alternativt:
 - 1) **N/S-pol** (monopol - dvs. separat S eller N - fins ikke)
 - 2) **Feltlinjer**: Lukka kurver, fra N→S ytre og S→N indre.
 - 3) **Magnetisk moment μ** : Høyrehåndsregel, eller: i retning S→N.
- N strømsløyfer med areal A : $\mu = N I A$
- Kraftmoment på magnetisk moment i \mathbf{B} -felt, $\tau = \mu \times \mathbf{B}$, innretter momentet langs \mathbf{B} -feltet og momentet har potensiell energi: $U = -\mu \cdot \mathbf{B}$
- Jern tiltrekkes både S-pol og N-pol. \mathbf{B} -feltet må være inhomogent.
- Anvendelser:
 - Hastighetsfilter, Thomsons e/m-eksperiment, katodestrålerør, massespektrometer, syklotron, DC-motor, Hall-effekt.