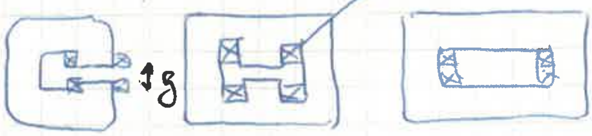
Start Here 15.11

-4- (L3)

3. Magnets

- dipole magnet



Fe : L
$B \leq 2T$
steele with a few carbon
small remanence
small coercivity
laminated to reduce Eddy currents

Coil : copper water cooled

"C"
asymmetric
open - easy access

"H"
symmetric
compact
highest B-homogeneity
for $\frac{\Delta B}{B} \sim 10^{-4}$
$\frac{\Delta g}{g(4cm)} \leq 4 \mu m$

Window frame
compact
less iron to achieve B than for H-magnet
+ large apertures possible
- complicated

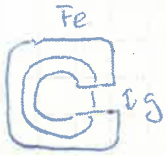
L3 10

g - gap

- Static magnetic field

$$\vec{\nabla} \times \vec{H} = 0 \qquad \vec{\nabla} \cdot \vec{B} = 0 \qquad (\vec{B} = \mu \vec{H})$$

field, flux, permeability



$$\oint H ds = H_0 g + H_{Fe} l_{Fe} = nI$$

n: number of wirings

$\mu_{Fe} \gg 1 \Rightarrow H_{Fe} \ll H_0$

$\Rightarrow H_0 \simeq nI/g \Rightarrow B = \mu_0 \frac{nI}{g}$ $\qquad \mu_0 = 4\pi\, 10^{-7} \frac{Tm}{A}$

Example: $nI = 50\,000 A$, $g = 4cm$ $\Rightarrow B \simeq 1{,}57\, T$

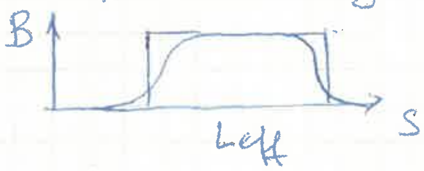
Problems

$B(H) \rightarrow$ saturation (complicated calculations)

hysteresis / remanence

$\Rightarrow$ reproducibility, stability

- Effective lenght



$$L_{eff} = \frac{1}{B_0} \int_{-\infty}^{\infty} B(s) ds$$

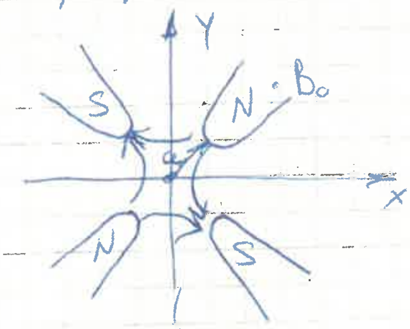
for dipole : $L_{eff} \simeq L_{Fe} + 1{,}3g$

continue with magnets after ionsources

-5- (L3)

- Quadrupole magnet

purpose - focusing / defocusing



center $= B_\theta = 0$

$\vec{B} = -\vec{\nabla}\phi$ $\quad \phi(x,y)$ - scalar potential

g - field gradient

$\Phi(x,y) = -gxy$

$g = \frac{\partial B_y}{\partial x} = \frac{\partial B_x}{\partial y} = \frac{B_0}{a} \approx 2\mu_0 \frac{nI}{a^2}$

a - aperture

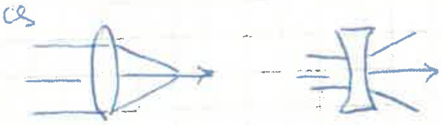
B_0 - flux at the pole tip

[Lorentz force $F = -e\vec{v} \times \vec{B}$

$F_x = -egcx$ focus $y=0$

$F_y = egcy$ defocus $x=0$] skip

like optics



$L_{eff} = L_{Fe} + a$

slide

- Sextupole magnet

6 - poles typicaly used to correct for aberration - chromaticity - slide

$L_{eff} = L_{Fe} + \frac{a}{2}$ mix x & y planes

- Multipole expansion → errors e.g. QP poles not exactly hyperbolic, mechanical errors etc

slide

- Superconducting magnets

s.c. $B \leq 10T$ $\qquad$ conventional $B \leq 2T$

$g \leq 100 T/m$ $\qquad$ $g \leq 20 T/m$

4. Ion Optics

1. Coordinate system

- various definition exist!

$\vec{s}$ - particle direction
$\vec{y}$ - upwards
$\vec{x}$ - bending plane
} Curvilinear system

Coordinate system is defined on the reference / nominal / sollbahn trajectory !

- metric $\boxed{r(s) = \vec{r}_0(s) + x(s)\vec{u}_x(s) + y(s)\vec{u}_y(s)}$

$$d\vec{r} = \vec{u}_x dx + \vec{u}_y dy + \vec{u}_s(1+hx)ds$$

$$h = \frac{1}{\rho_0} \quad \rho_0 \text{ - curvature of nominal trajectory}$$

$$h(s) = \frac{1}{\rho_0(s)} = \frac{q}{p_0} B_y(x=0, y=0, s) = \frac{q}{p_0} B_0(s)$$

q, p_0 - charge and momentum of reference particle

slide

- deviation of a particle in 3-dimensions

$\Delta x, \Delta y, \Delta z$ - in space
$\Delta p_x, \Delta p_y, \Delta p_z$ - in momentum
} 6 parameters

$\Delta p_x, \Delta p_y, \Delta p_z \ll p_0$

$$x' = \frac{dx}{ds} = \frac{\Delta p_x}{p_0}, \quad y' = \frac{dy}{ds} = \frac{\Delta p_y}{p_0}, \quad \ell = -v_0(t-t_0)$$

early particle $t<t_0$; $\ell>0$

$$\delta = \frac{p-p_0}{p_0}$$

$$\cancel{X(s)} \begin{pmatrix} x \\ x' \\ y \\ y' \\ \ell \\ \delta \end{pmatrix} = \begin{pmatrix} \text{radial orbit deviation} \\ \text{radial direction deviation} \\ \text{axial} \quad \text{''} \\ \text{axial} \quad \text{''} \\ \text{logitudinal} \ldots \\ \text{''} \quad \text{momentum deviation} \end{pmatrix}$$

Since $x, x', y, y', \ell, \delta$ are small $\Rightarrow$ mm, mrad, promil