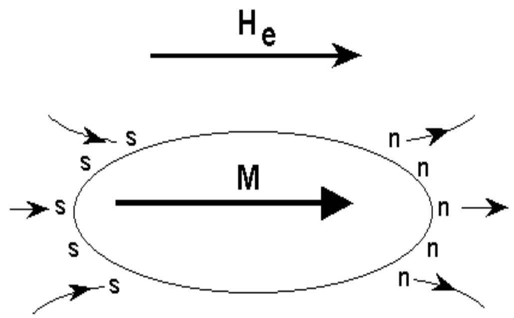
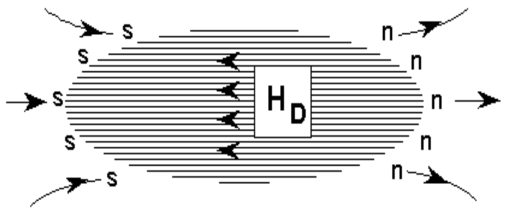
Demagnetizing factors and stray fields



Magnetization Produces Apparent Suface Pole Distribution



Demagnetizing Field Due to Apparent Surface Pole Distribution

$H=H_e+H_D$
$H_D=-NM$
N=demagnetizing factor

H_D in the opposite direction of H_e inside the sample, hence the name

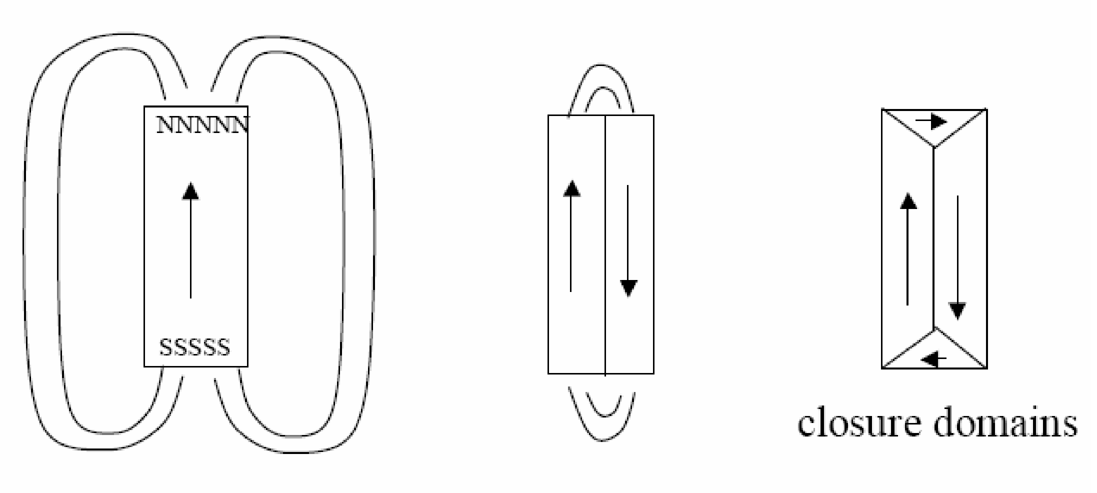
Furthermore

$$U_d = \frac{1}{2}\mu_0 \int_{allspace} H_d^2 dV$$

stray field of H_d increases the total energy

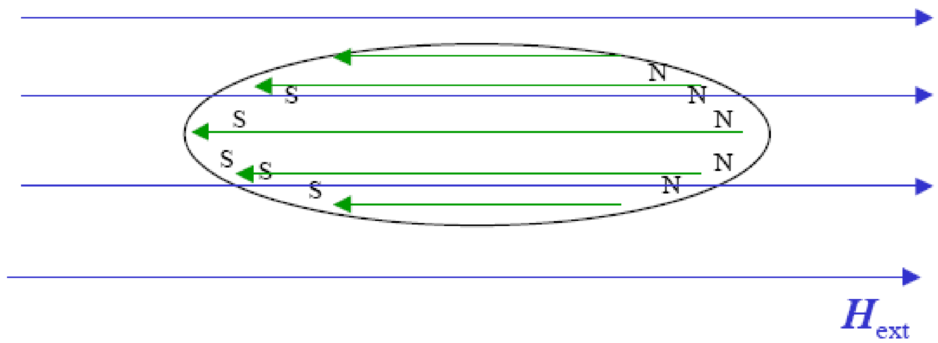
Stray fields and domains

$$U_d = \frac{1}{2}\mu_0 \int_{allspace} H_d{}^2 dV$$



Formation of domains reduces the stray fields outside the sample, hence reduces total energy

Shape anisotropy

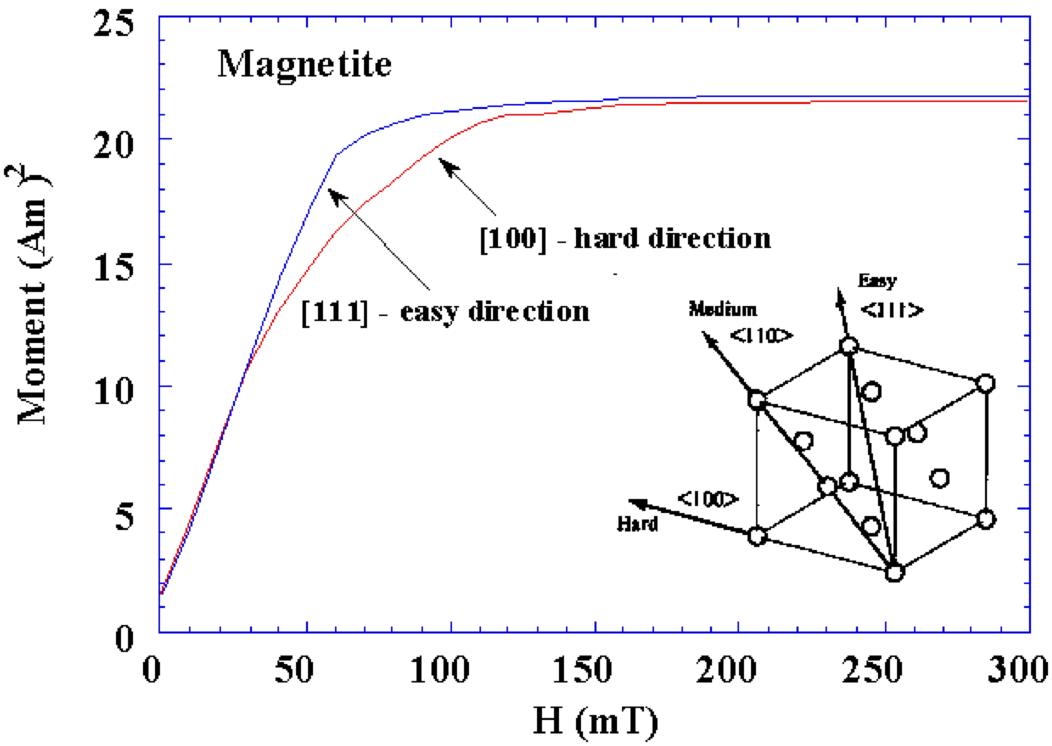


Easy axis along the long axis of an ellipse since H_d is minimal in this direction

Infinite plate

Magnetization in plane.
energetically unfavorable for a thin plate to have its magnetization lying perpendicular to its surface.

Crystalline anisotropy



Fe, FCC lattice
<111> is the easy axis

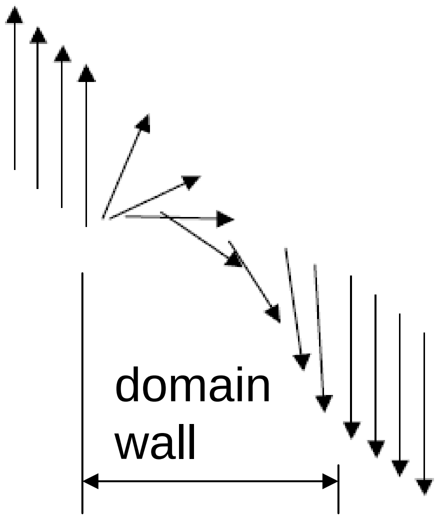
Because of band structure origins of FM, there can be certain crystallographic directions along which it's energetically favorable for ***M*** to lie.

$$u = K_1(\alpha^2\beta^2 + \beta^2\gamma^2 + \gamma^2\alpha^2) + K_2\alpha^2\beta^2\gamma^2$$

u, energy density due to crystalline anisotropy
α,β,γ, angles between M and the axis's

Domain walls

Boundary between two domains is called a *domain wall*.
• Because of the FM exchange interaction, it's very energetically costly for the direction of **M** to change very sharply.
• Result is that local magnetization spreads out the change over some distance = domain wall thickness.



Exchange energy:

$$E_{ex} = -JS_1 \cdot S_2 = -JS^2 \cos\varphi$$

favors "thick" walls (slow changes) to keep φ small

Anisotropy energy, favors "thin" walls to reduces spins not parallel with the easy axis

Competition between the two effects.
Typical thickness ~ 100 nm, comparable to the size of nanostructures

Domains and hysteresis

- Domains continuously rearrange themselves to minimize the total energy of the whole system.

- Metastable changes result in hysteresis

- Saturation achieved when all domains are aligned