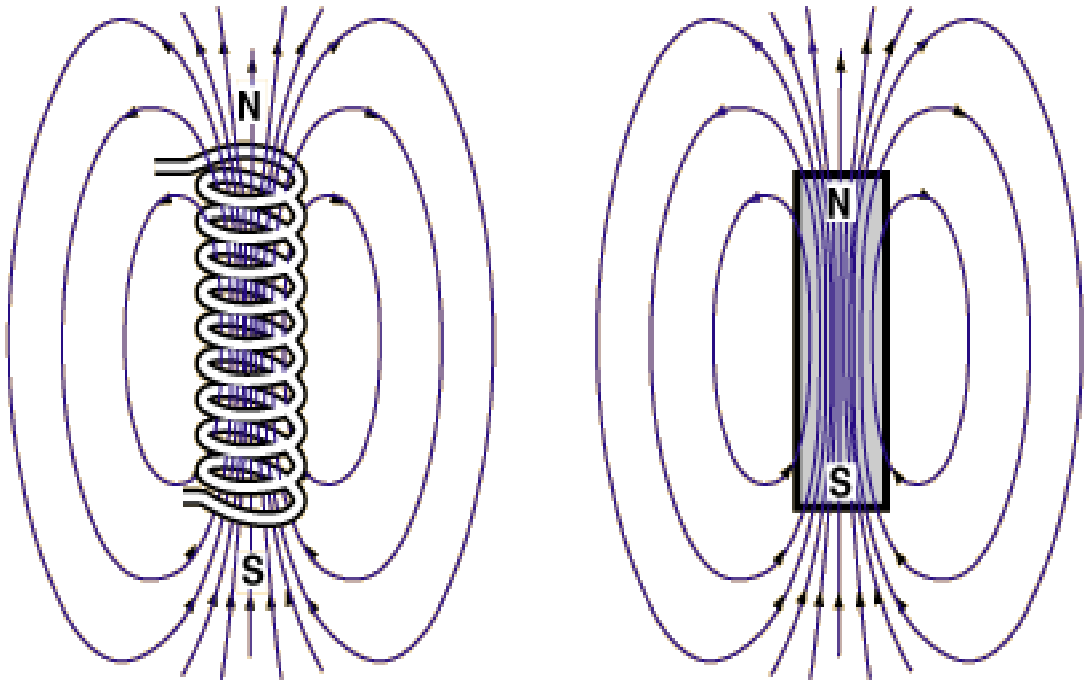
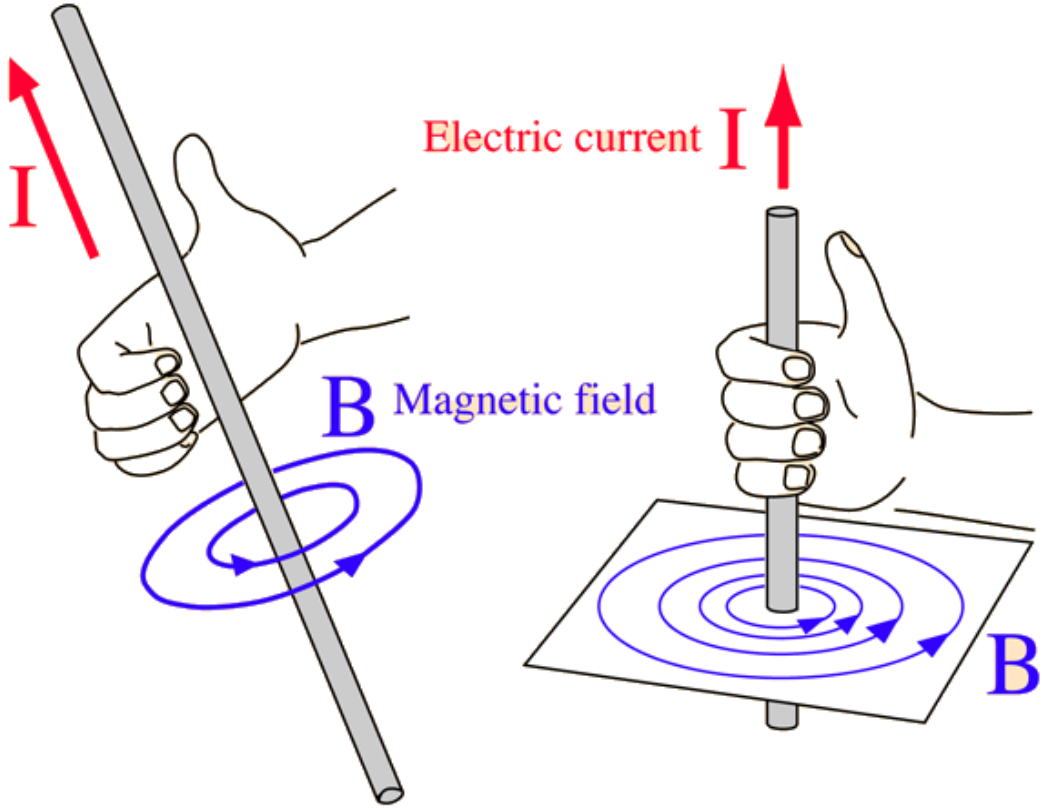
Source of magnetic field

1. Permanent Magnet



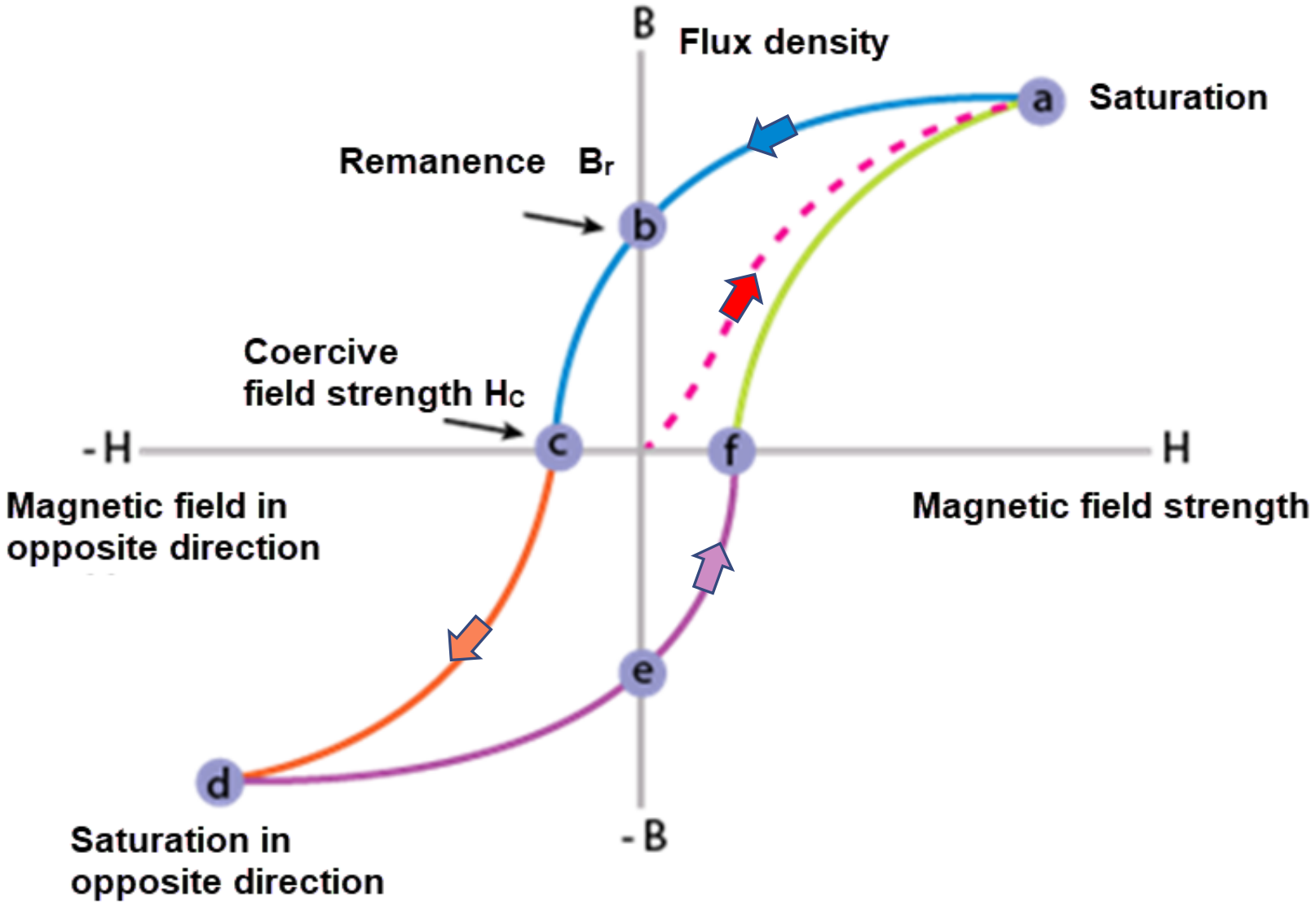
2. Current



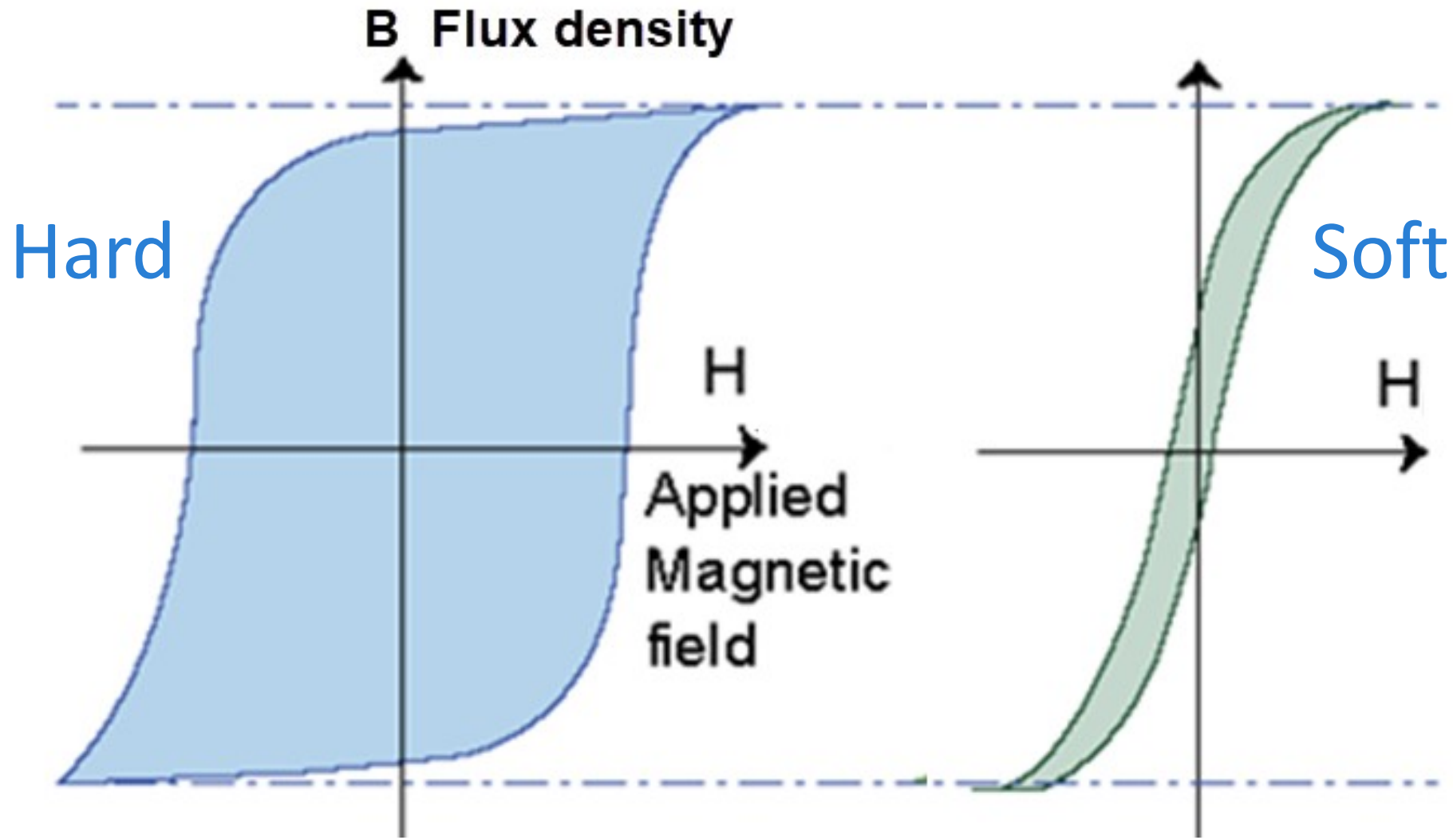
Material Magnetic Properties

Magnetic Permeability	Examples
Free Space: $\mu_r = 1$	
Paramagnetic: $\mu_r > 1$	Tungsten, Cesium, Aluminum, Magnesium, Sodium
Diamagnetic: $\mu_r < 1$	Bismuth, Mercury, Silver, Lead, Graphite, Copper, Water
Soft magnetic: B = f(H), $H_c \approx 10 \ldots 10^3$ A/m	Supermalloy (16Fe:79Ni:5Mo) Permalloy (Fe:4Ni) Elecrtic steel (96Fe:4Si)
Hard magnetic: B = f(H), $H_c \approx 10^4 \ldots 10^6$ A/m	Ferrite (Zn, Fe, Ni, O) Disk drive recording media (Cr, Co, Pt) Neodimium magnets (Nd, Fe, B) Samaruim Cobalt magnets ($SmCo_5$)

Typical hysteresis loop



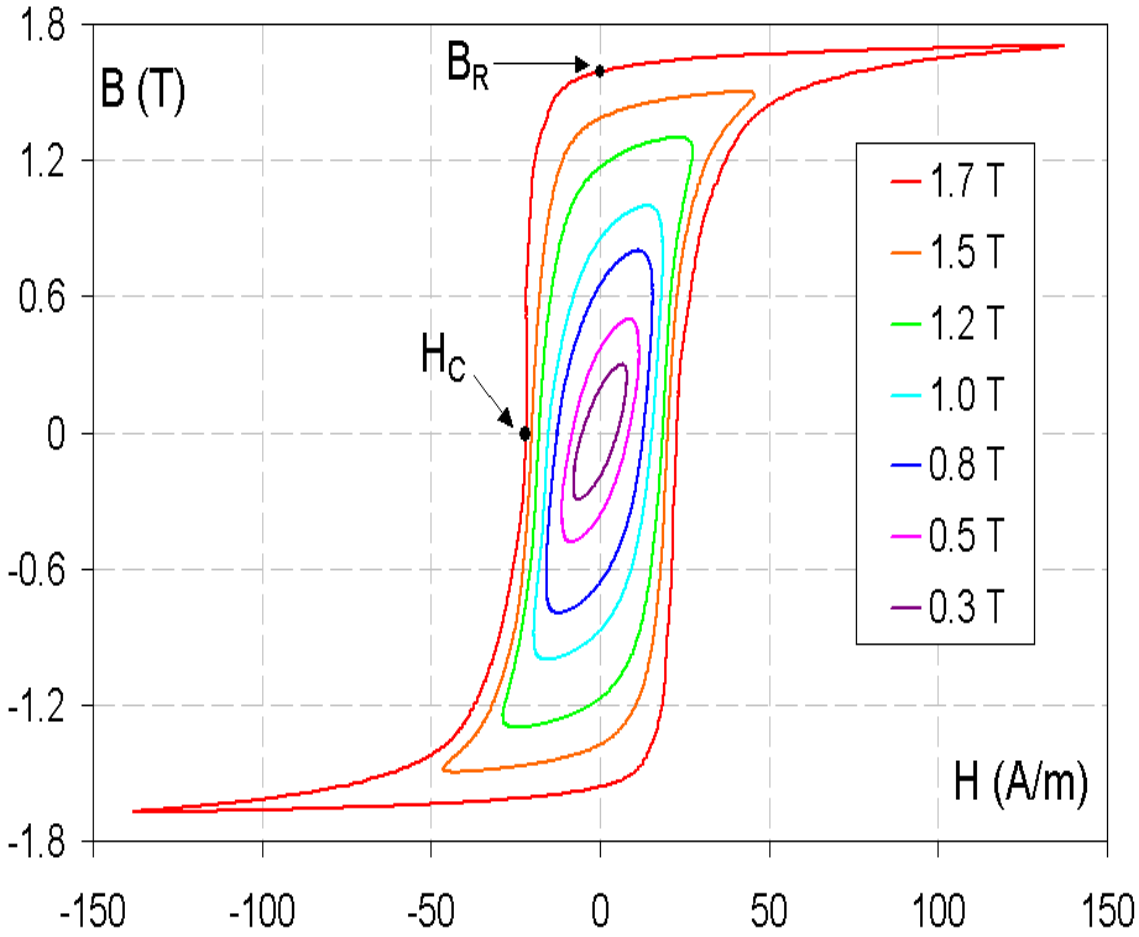
Hard and Soft Magnetic Materials



Magnetic properties of Hard Magnetics

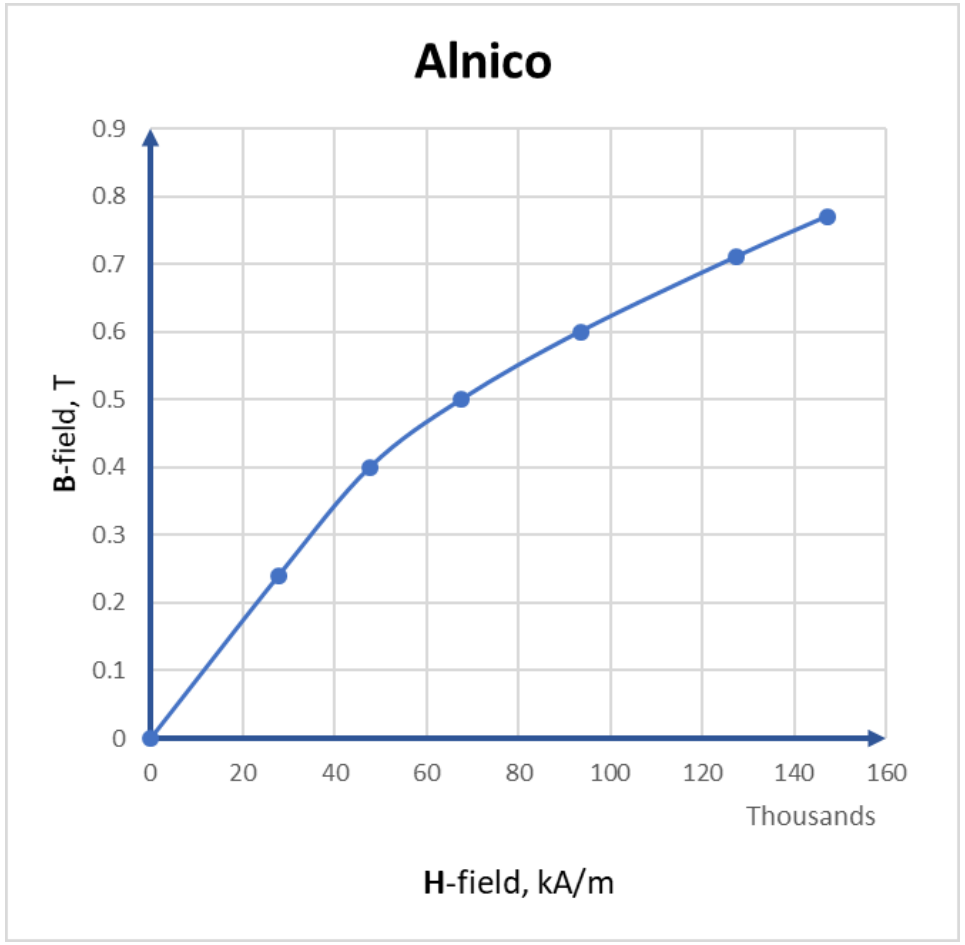
Definitions by IEC

Magnetic remanence B_r	Remanent magnetic flux density in a substance, when it departs from magnetic saturation by monotonic reduction to zero of the applied magnetic field strength
Coercive (magnetic) field strength H_c	Magnetic field strength to be applied to a magnetic substance to bring the magnetic flux density to zero. (any intersection with *H*-axis of the magnetization curve (for flux density, polarization or magnetization)

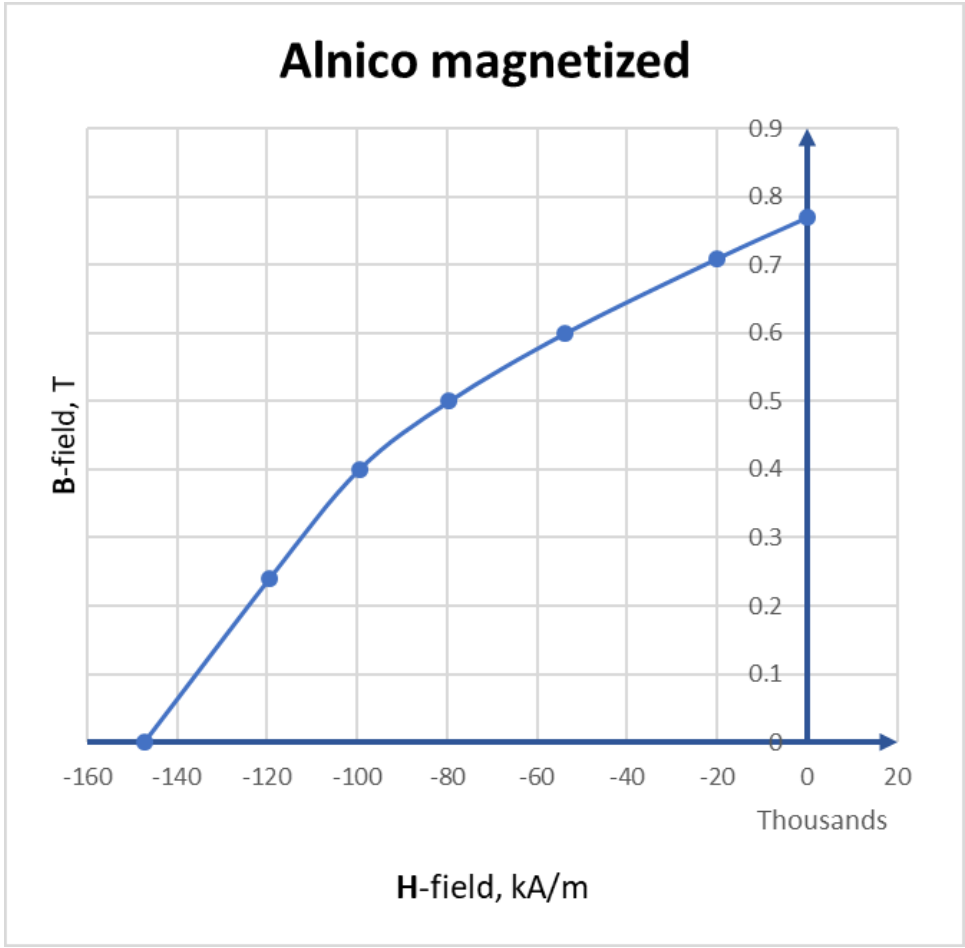


Material Magnetic Properties in QuickField

Non magnetized state (H_C=0) :
B=f(H)



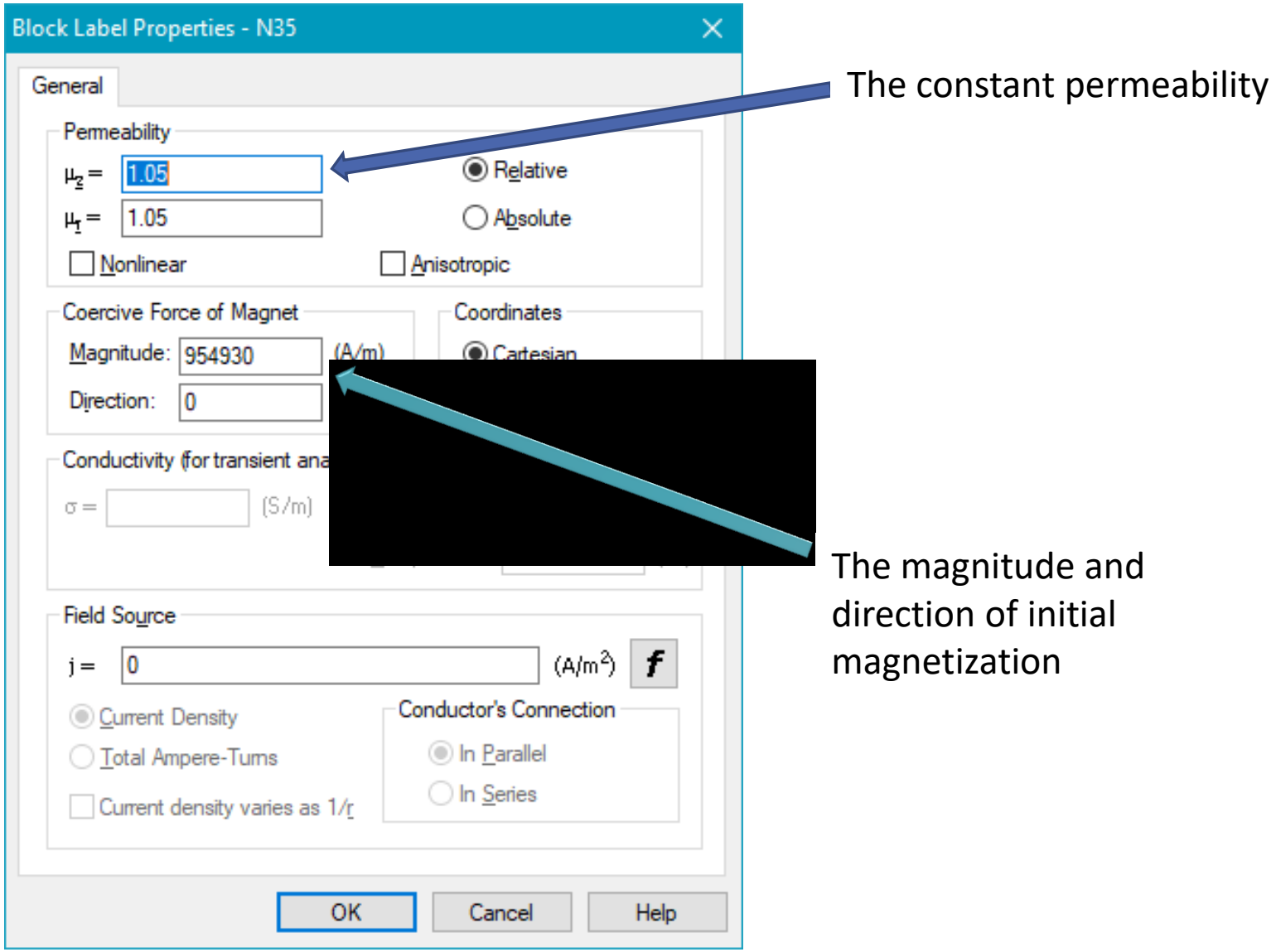
Magnetized up to maximum (H_C=147.3 kA/m)
B = f(H+M)



Material Magnetic Properties in QuickField

The modern magnets, both *Neodymium* and *Samarium-Cobalt*, are almost linear:

$$\mu_r = 1.05 = \text{const}$$

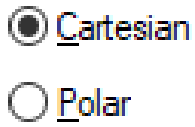


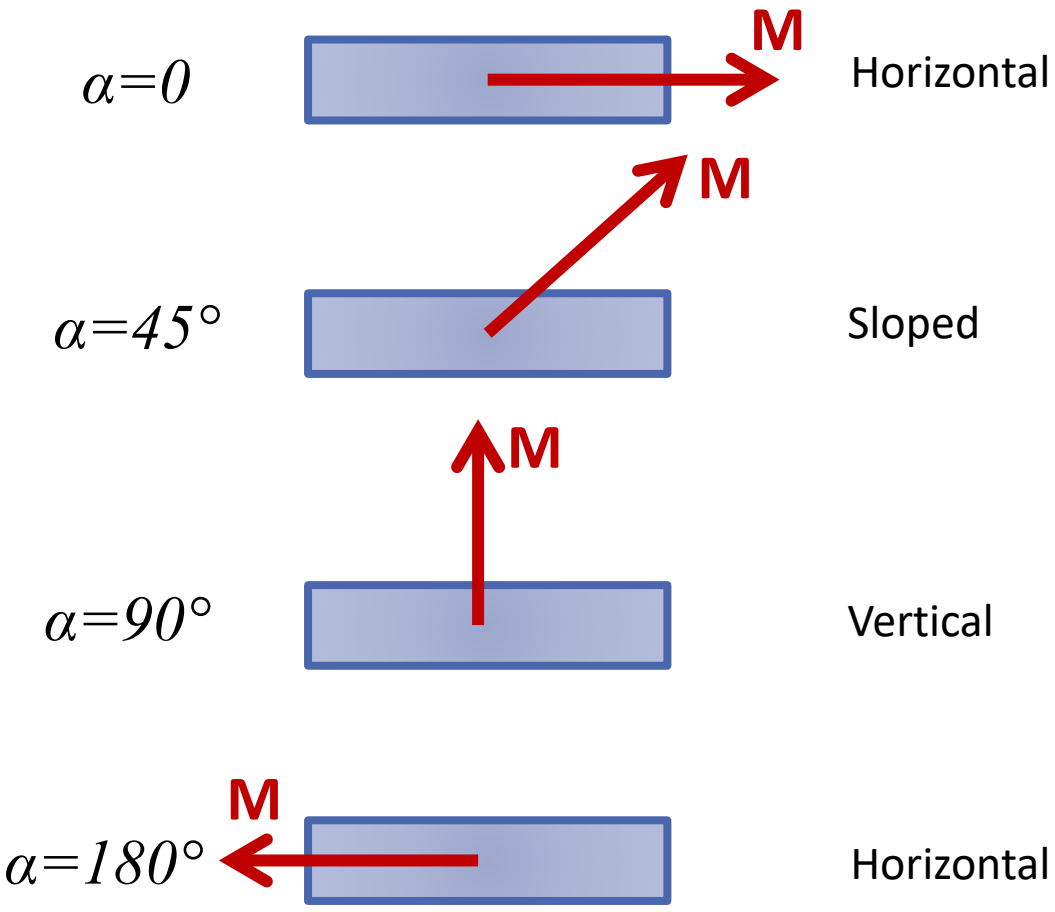
The constant permeability

The magnitude and direction of initial magnetization

Examples of Magnetization Direction

Cartesian





$\alpha=0$ Horizontal

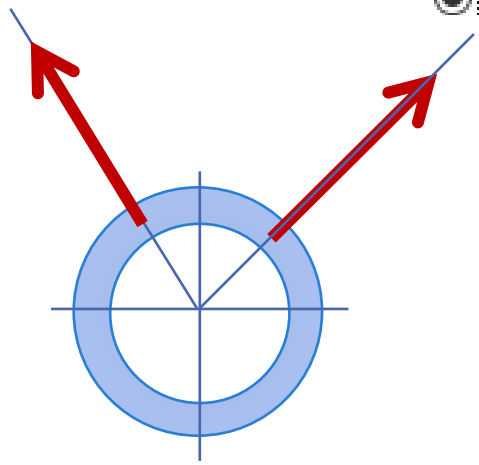
$\alpha=45°$ Sloped

$\alpha=90°$ Vertical

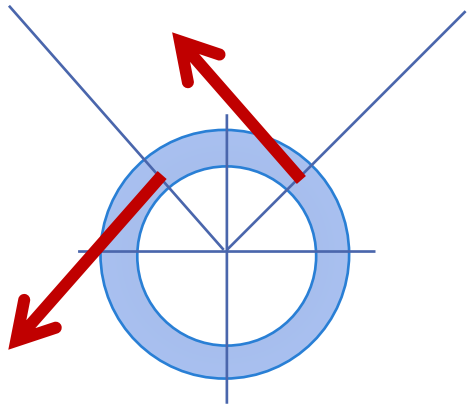
$\alpha=180°$ Horizontal

2.38125

Polar



$\alpha=0$ Radial

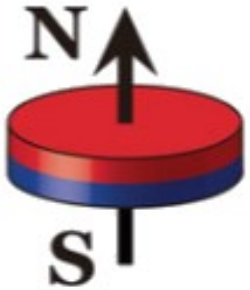


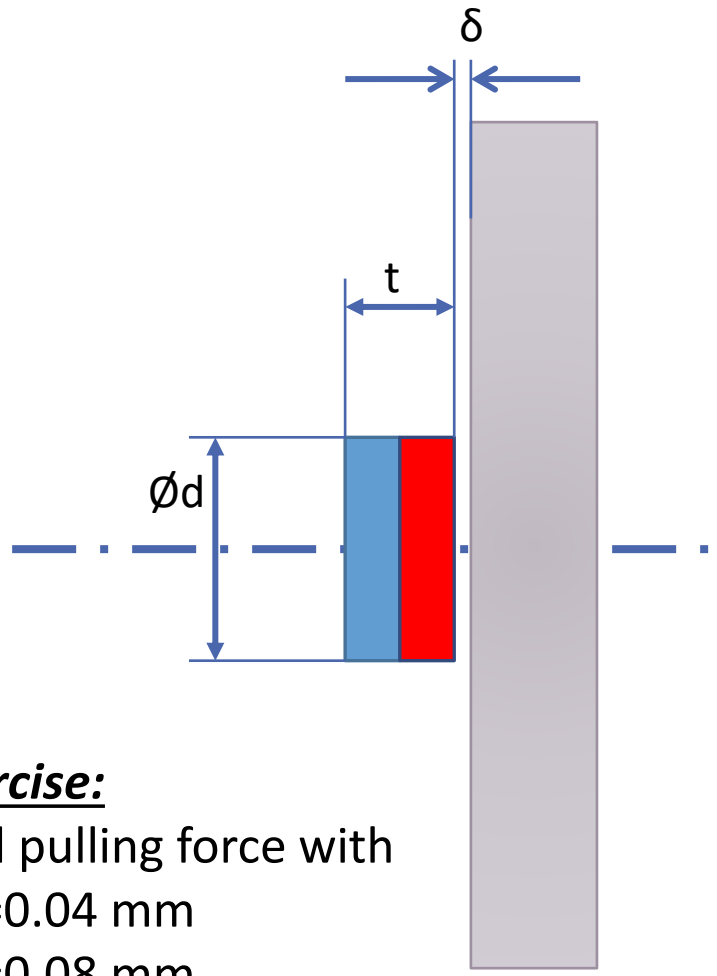
$\alpha=90°$ Tangential

Example: Pulling Force of Disc Magnet

Manufacturer's Data:

Neodymium Disc Magnet
N40 3/16"x1/32"
Gauss Rating: 12800 gauss
Pulling Force: 0.49 lbs
Price: 0.06 $





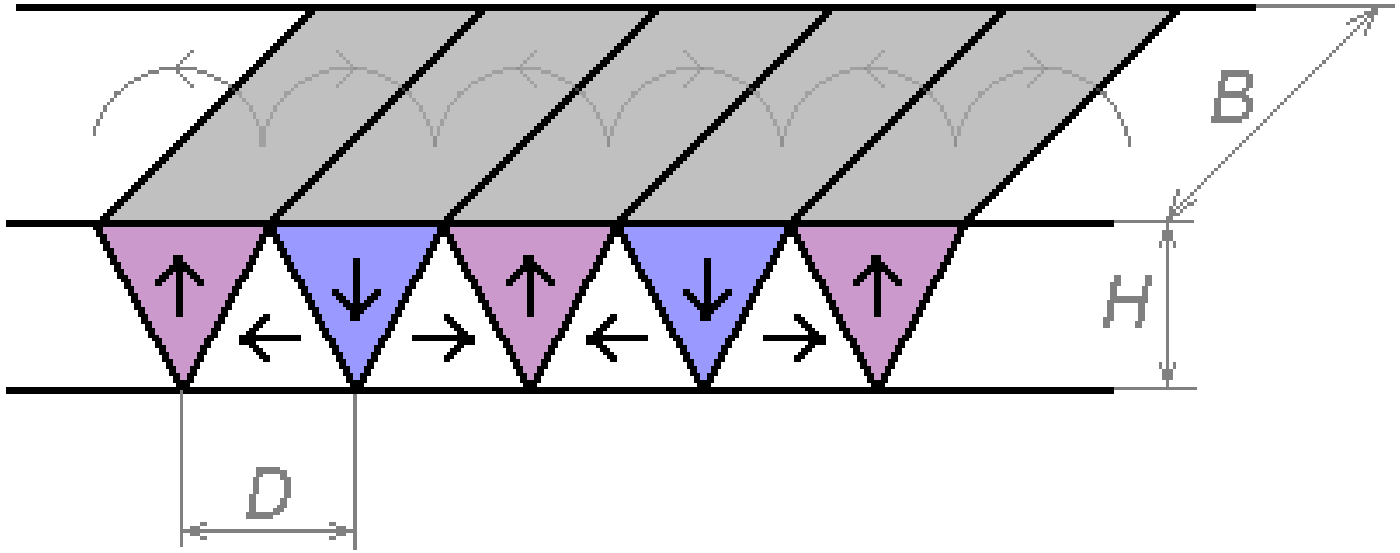
Exercise:

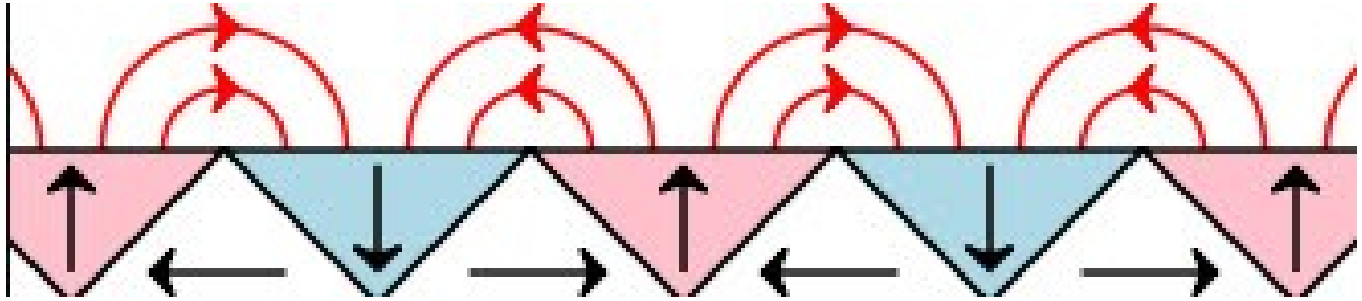
Find pulling force with
- δ=0.04 mm
- δ=0.08 mm
- δ=0.12 mm

Geometry	
d	4.7625 mm (R = 2.38125 mm)
t	0.7937 mm
δ	h/20 =0.04 mm
D	100 mm
Magnet	
μ_r	1.05
B_r	12800 Gs = 1.28 T
H_c	$B_r / (\mu_0\mu_r)$ = 970 kA/m
F	0.49 lbs = 1.8 N

One Side Magnet: The Halbach Array

Example 2: Refrigerator Magnet (Triangle Halbach Array)

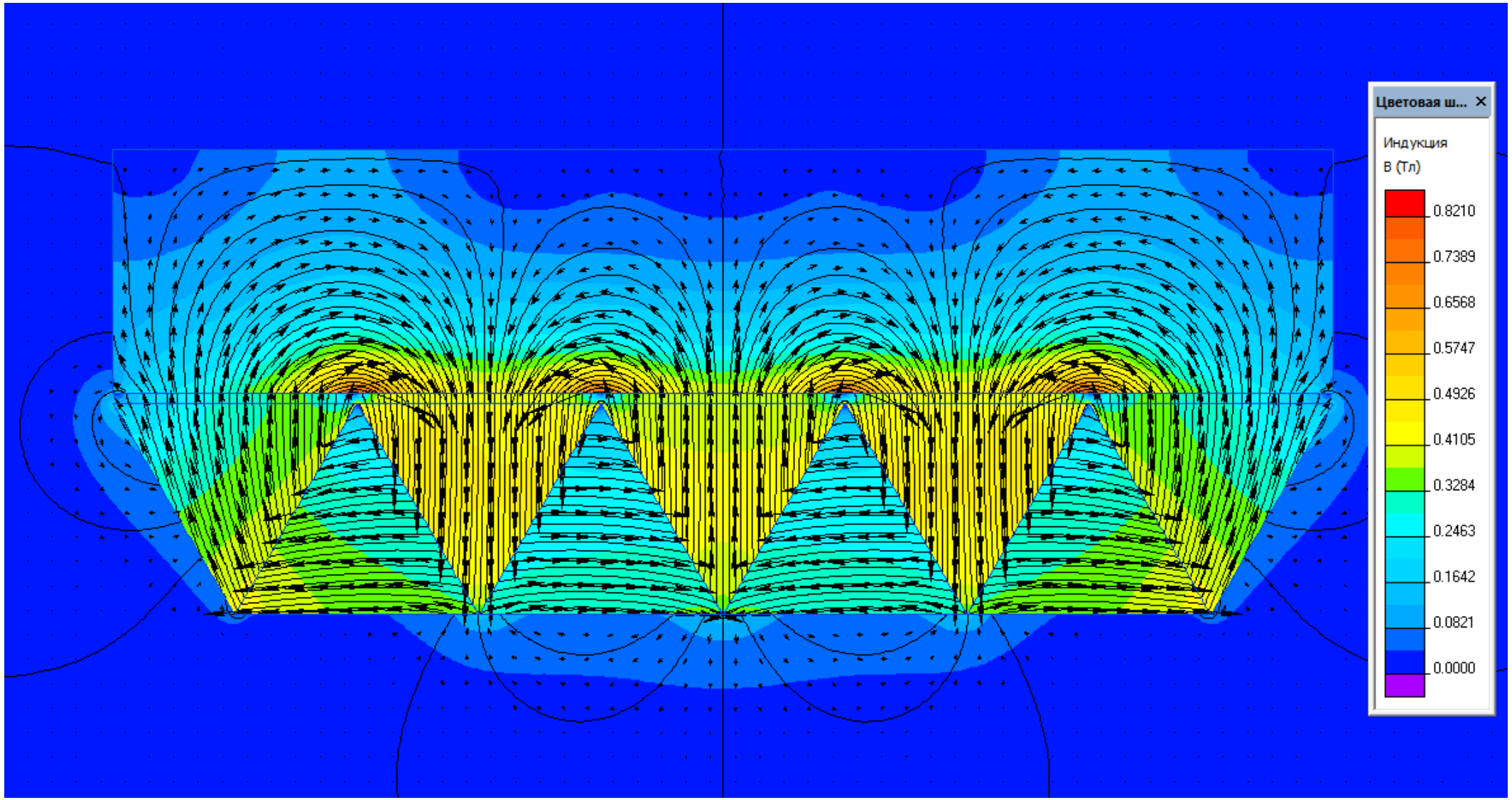




Given:
D = 1 mm,
H = 1 mm,
B = 20 mm,
Magnet material - N35,
Steel fridge door thickness 1 mm,
relative magnetic permeability 1000.

Coercive H_C=100 000 A/m

Refrigerator Magnet (Halbach Array)



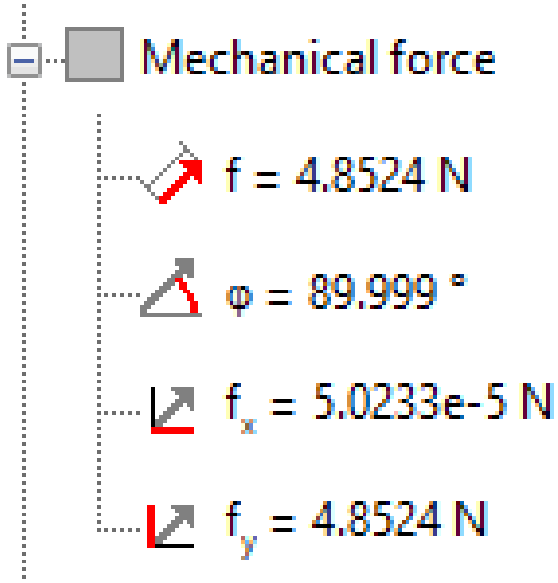
Comparing pulled force

Manufacturer Data

PART NO. & DESCRIPTION
E689 210mm x 145mm x 1.5mm - SUPER STRONG Anisotropic, Brown colour - 88g/cm2 Attractive Force
E691 500mm x 100mm x 0.8mm - Vehicle grade/brown colour - 44g/cm2 Attractive Force
ER30A 1000mm x 620mm x 0.8mm - Vehicle grade/brown colour - 44g/cm2 Attractive Force

QuickField Calculation

Film size = 2cm * 0.5cm = $1cm^2$



How to magnetize the fridge magnet?

How the magnetizer looks like?