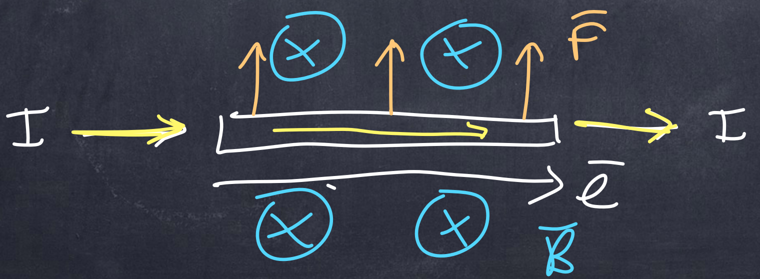
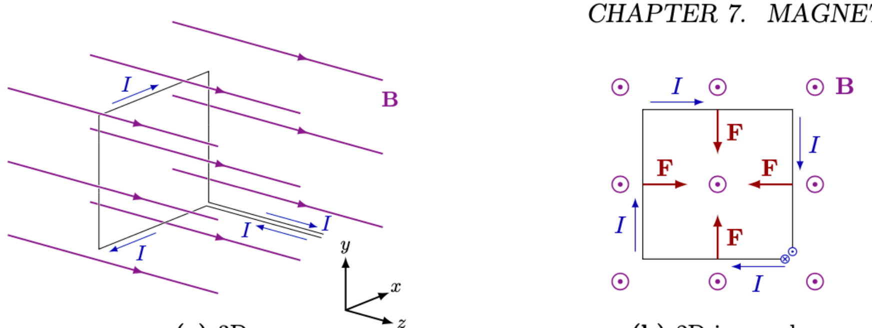
PHY117 HS2024

Week 10, Lecture 2
Nov. 20th, 2024
Prof. Ben Kilminster

yesterday:



$F = BI\ell$
↑ length of wire



(a) 3D. (b) 2D in xy plane.

Figure 7.9: Rectangular current loop in an external, uniform magnetic field $\mathbf{B} = B\hat{\mathbf{z}}$.

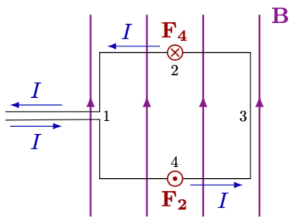
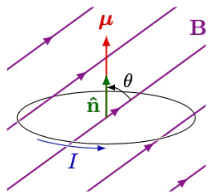
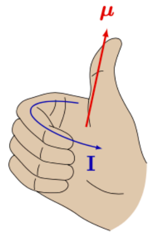


Figure 7.10: Rectangular current loop in an external magnetic field **B**.



(a) Magnetic moment of a current loop in a uniform magnetic field.



(b) Right-hand rule for the magnetic moment of a current loop.

Figure 7.11: Magnetic moment.

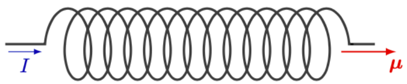
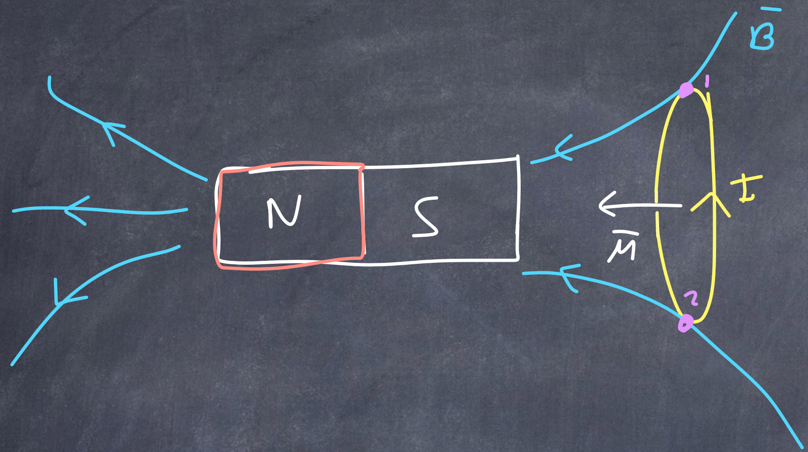
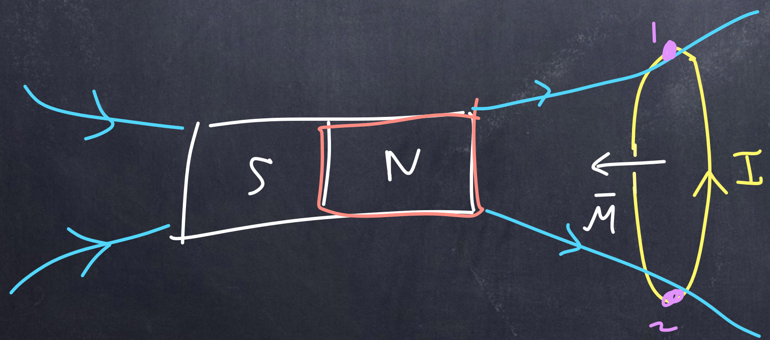
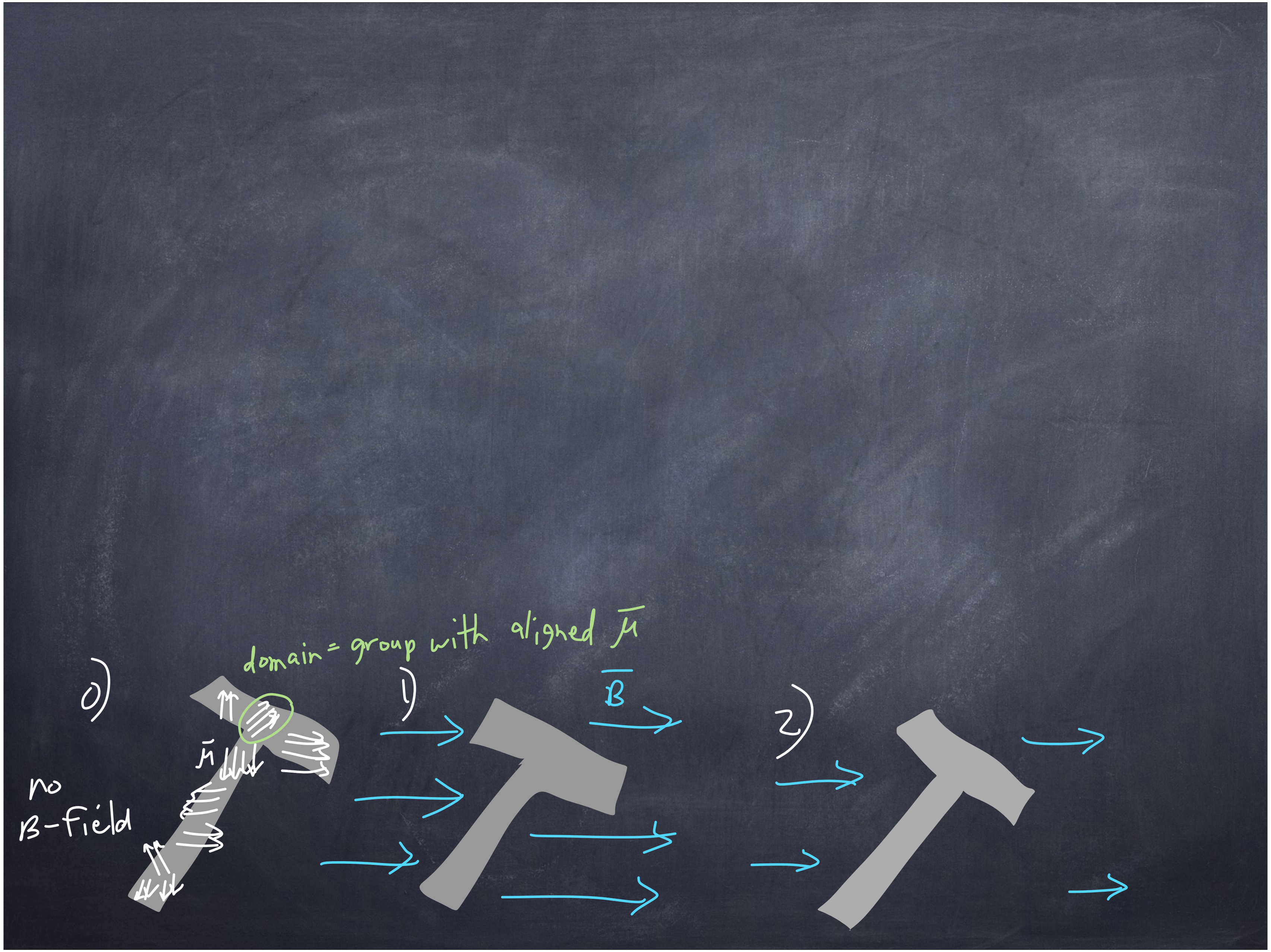


Figure 7.12: Magnetic moment of a solenoid with N windings.

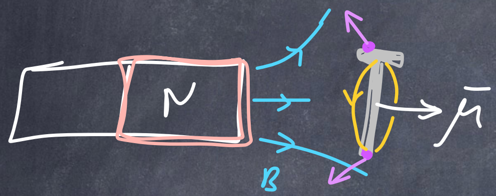
What if the magnetic field is non-uniform?

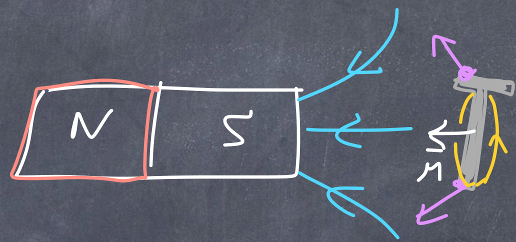


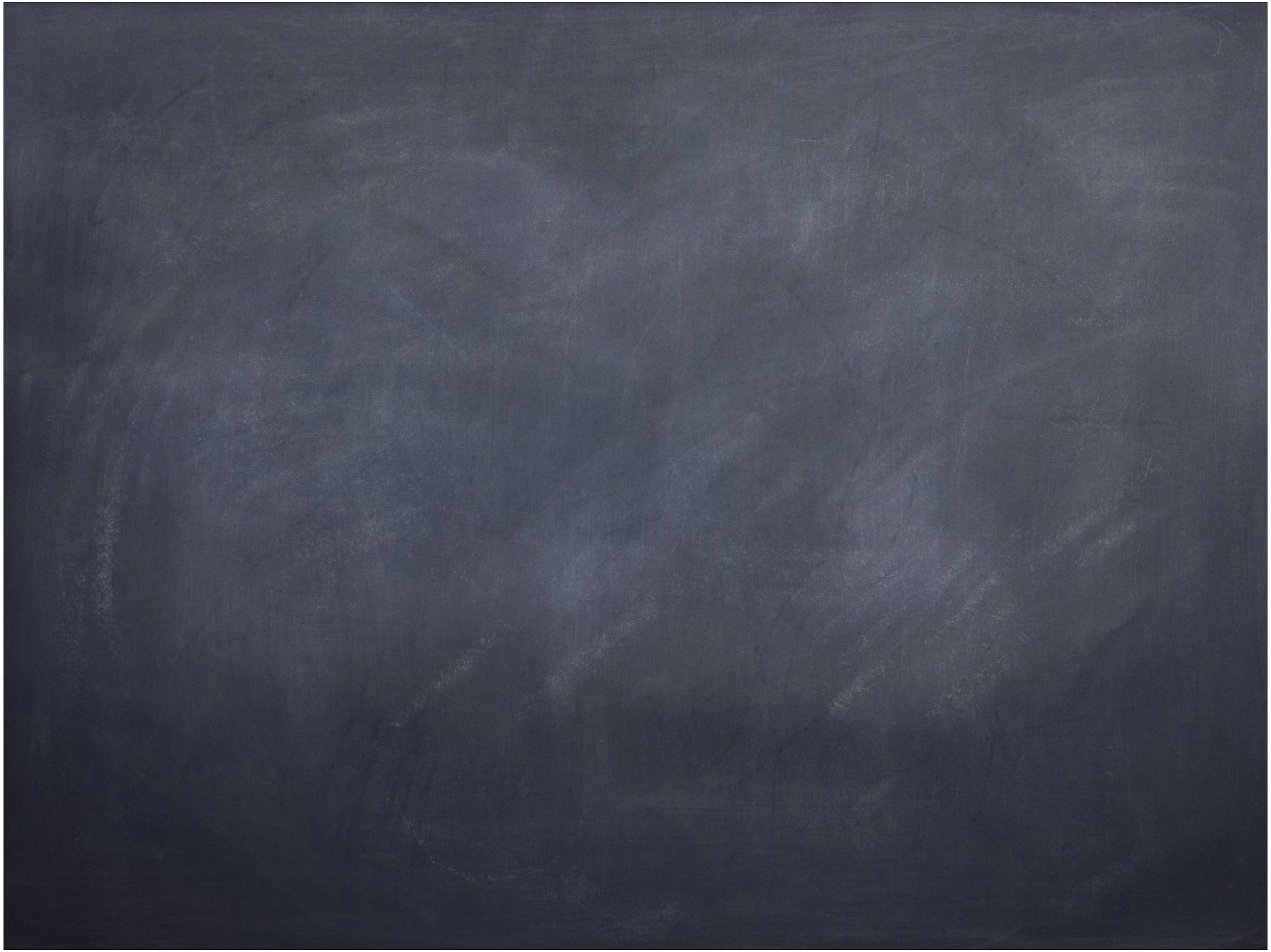


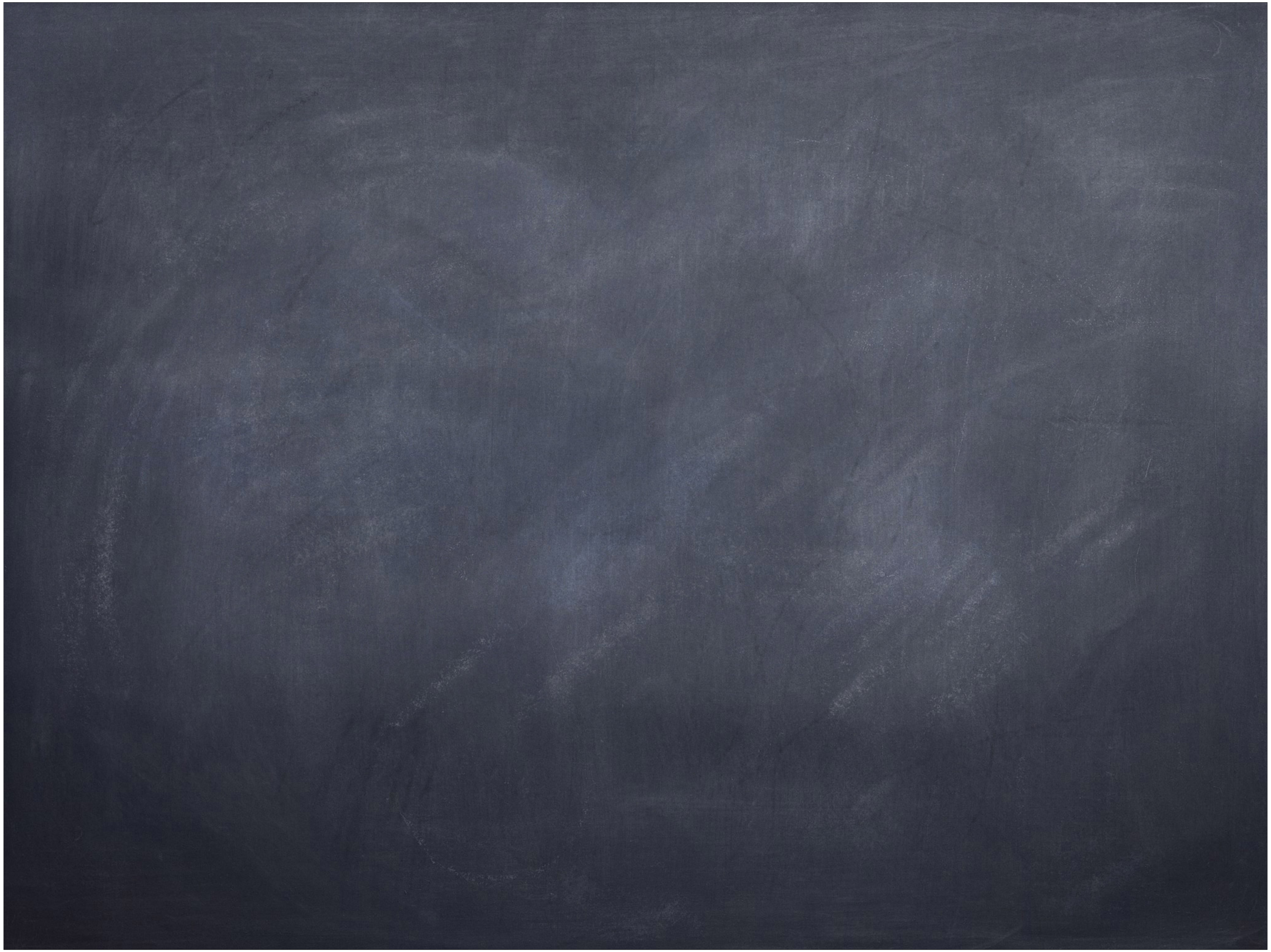

domain = group with aligned $\bar{\mu}$
0)
no
B-Field
$\bar{\mu}$
1)
$\bar{B}$
2)

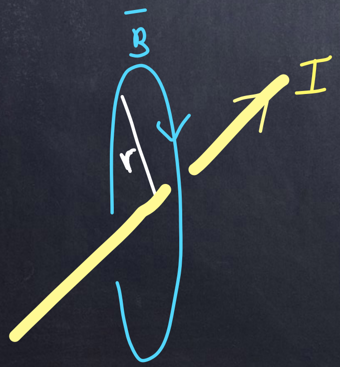
Why is nail attracted to N + S poles of magnet?

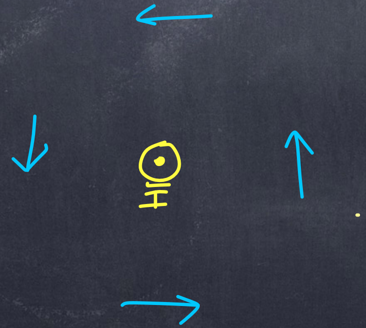


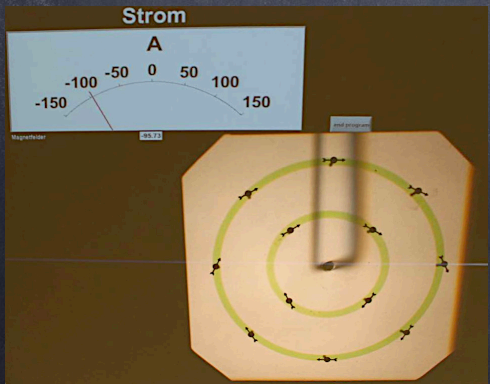







B
r
I


I


Strom
A
-150
-100
-50
0
50
100
150

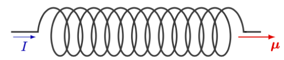
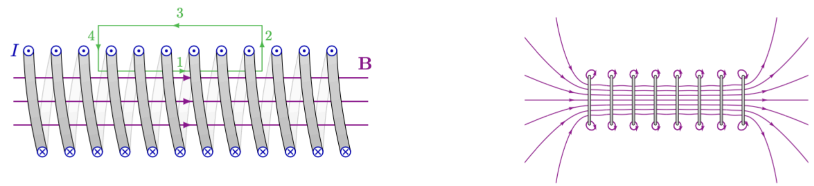


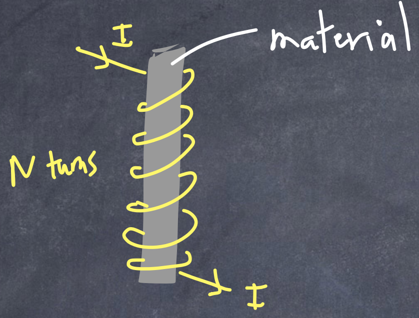
Figure 7.12: Magnetic moment of a solenoid with N windings.



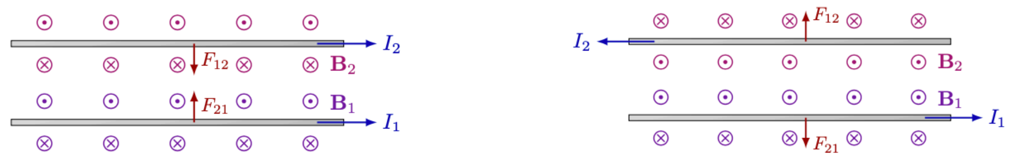
(a) Using Ampère's law on a rectangular loop. **(b)** Realistic field of a solenoid.

Figure 8.6: Magnetic field due to a solenoid.

If there is a material inside,

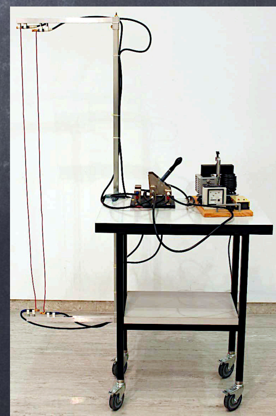


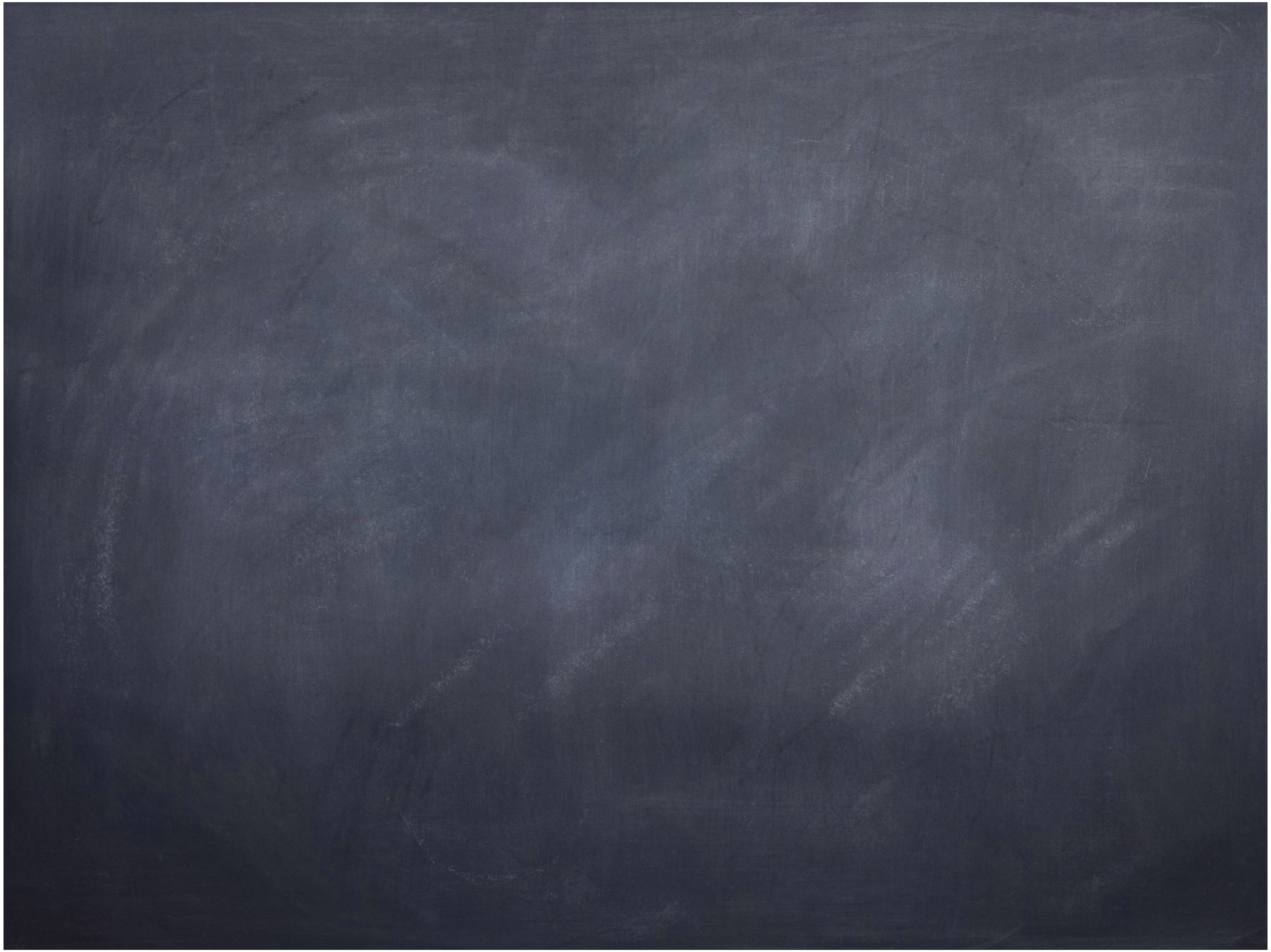
material	K $\left(\frac{\mu}{\mu_0}\right)$
air	1.000 000 37
water	0.99999 2
copper	0.999 994
pure iron (99.95%)	200 000
iron 99.8%	5000

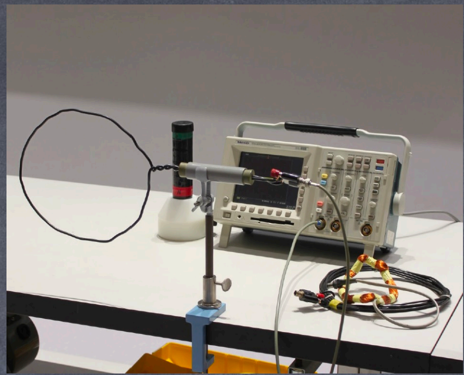


(a) Parallel current. **(b)** Anti-parallel current.

Figure 8.7: Magnetic force between current-carrying wires.

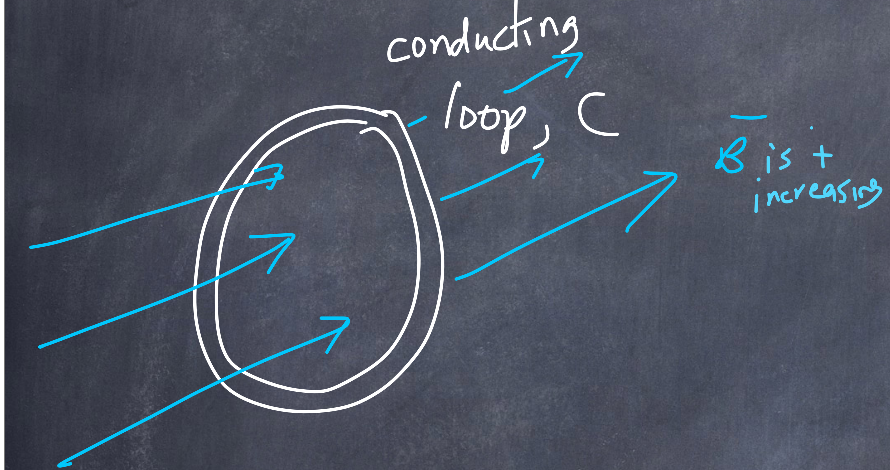


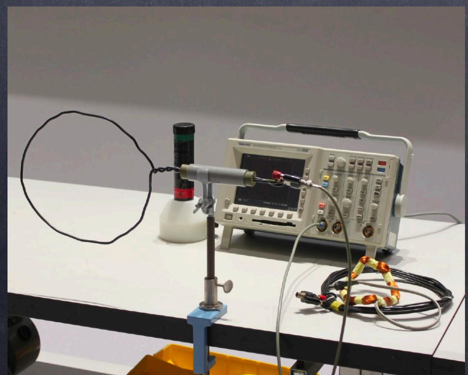


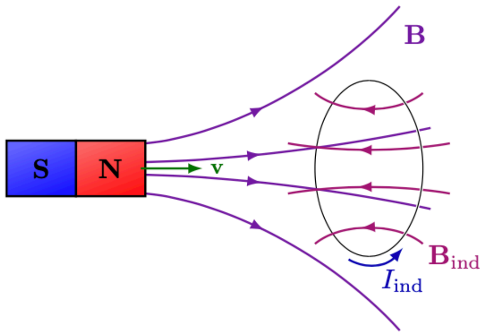


This means:

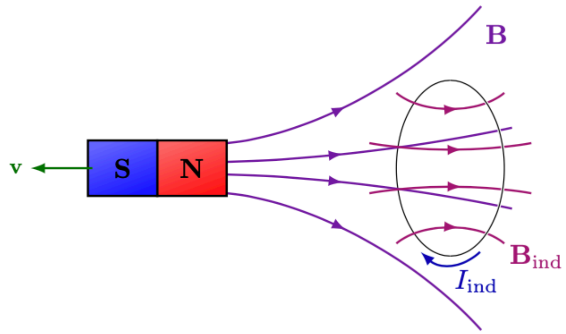
1) A moving magnet induces magnets in the opposite direction.





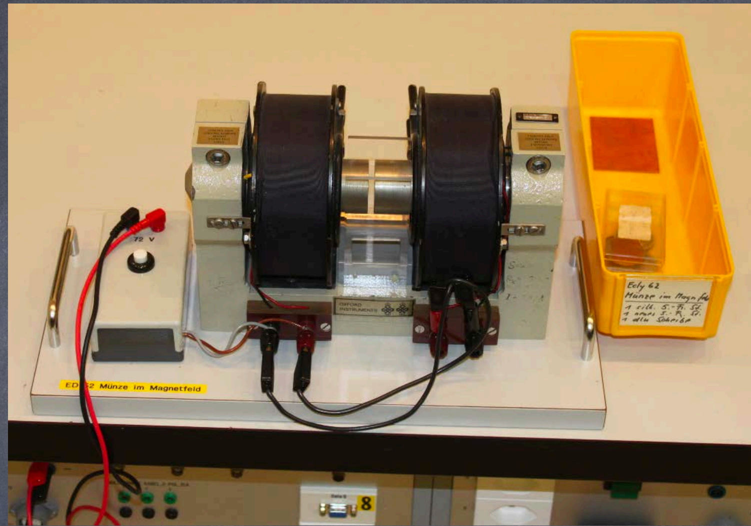


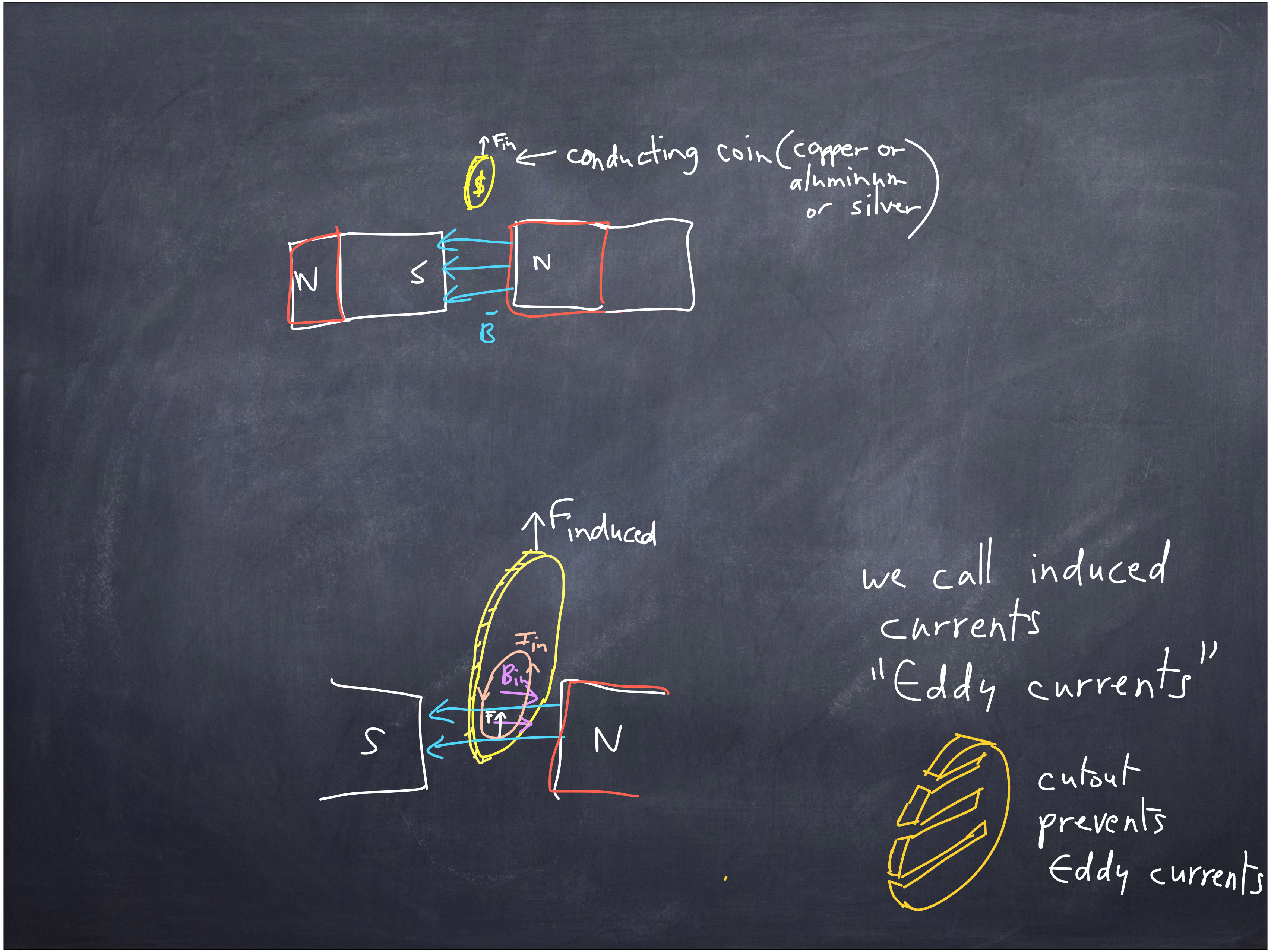
(a) Field moving toward the loop.



(b) Field moving away from the loop.

Figure 8.8: The magnetic field $\mathbf{B}$ of a moving bar magnet will induce a current I_{ind} in a conducting loop and therefore a magnetic field $\mathbf{B}_{\text{ind}}$.

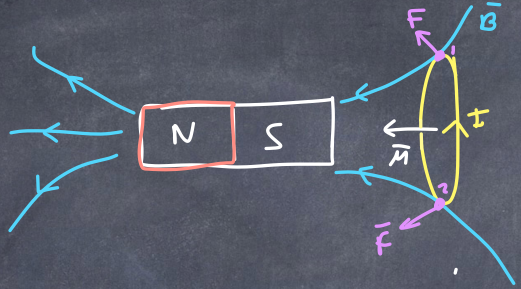

Münze im Magnetfeld



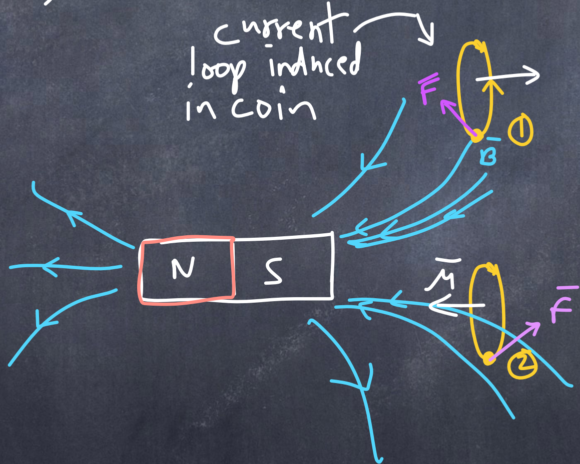
Fin
conducting coin (copper or aluminum or silver)
N
S
N
B
Finduced
Iin
Bin
F
S
N
we call induced currents "Eddy currents"
cutout prevents Eddy currents

Dropping coin

Remember:



In this case, the loop falls through the non-uniform field.



As it falls, the B-field gets bigger, so the induced current opposes the external B-field

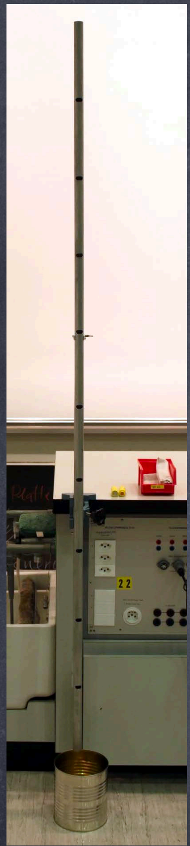
- ①: $\bar{V}$: ⊗ $\bar{B}$: ↙ $\bar{F}$ = ↖

Below, the induced magnetic field is in the same direction, resulting in an upward force

- ②: $\bar{V}$ = ⊙ $\bar{B}$ = ↖ : $\bar{F}$ = ↗

Force has up component in both cases

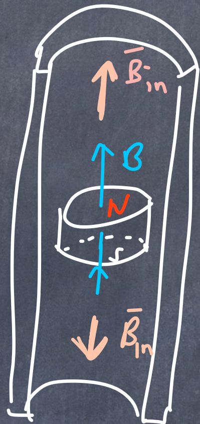
(keep in mind there are two magnets so horizontal force cancels out)

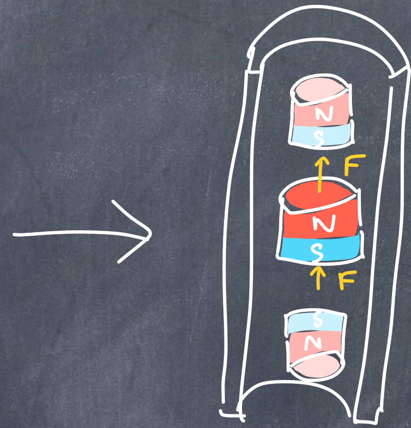


As magnet falls:

$\bar{B}$ decreases above magnet

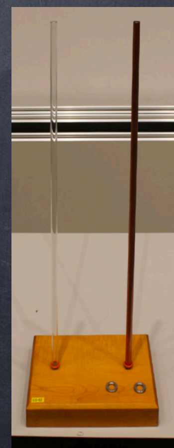
$\bar{B}_{in}$ is same direction as $\bar{B}$

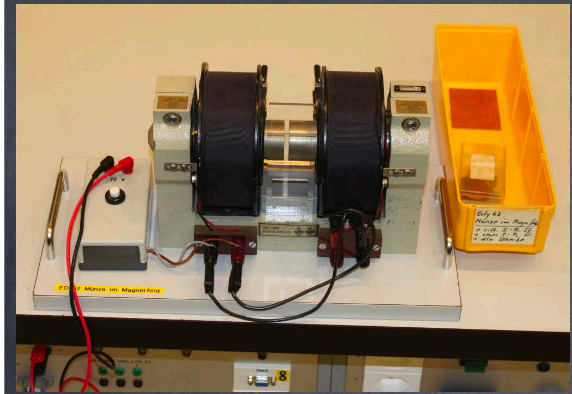




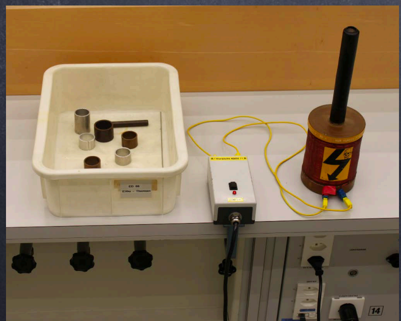
$\bar{B}$ increases below the magnet

$\bar{B}_{induced}$ opposite of $\bar{B}$





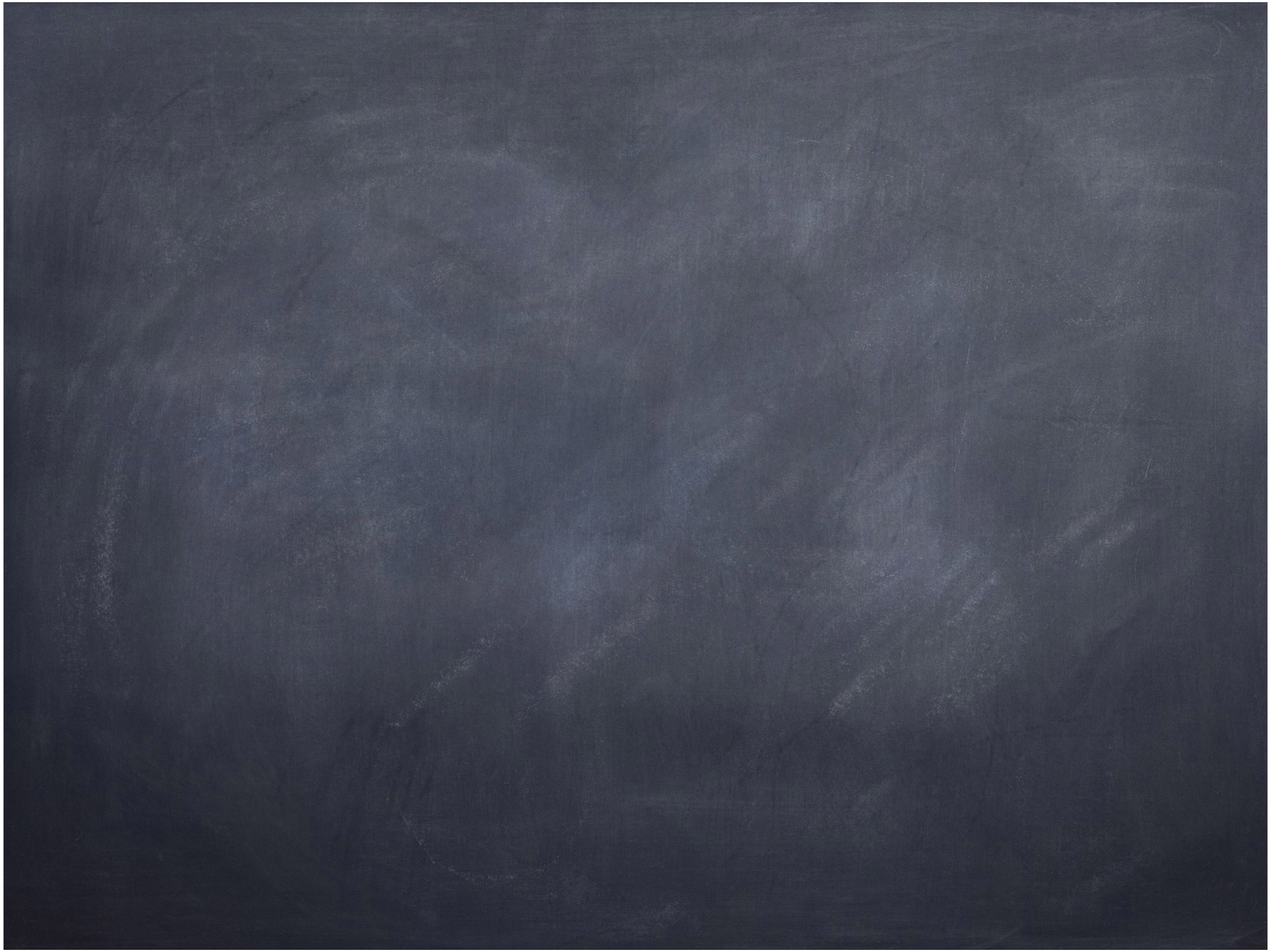
Dropping a conductor in a magnet



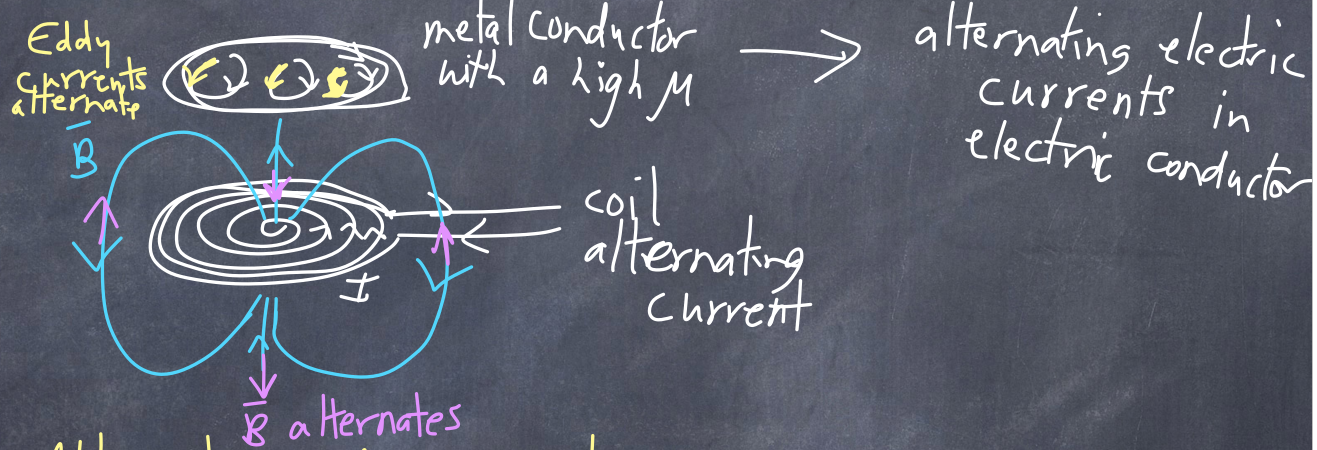
turning a conductor into an opposing magnet

cutout prevents Eddy currents

dropping magnet in a conductor

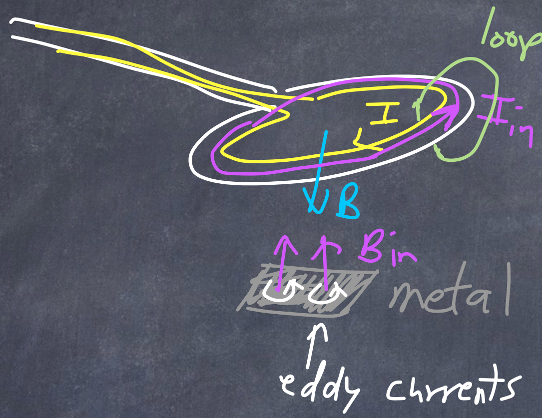


Induction stove uses Eddy currents:



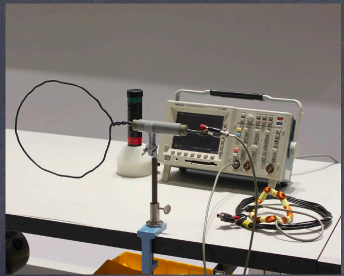
Alternating eddy currents generate heat in a conductor (Joule heating)

Metal detector uses Eddy currents



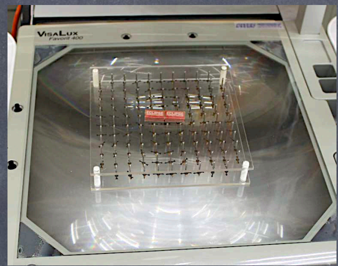
I_{in} is generated in metal in opposite direction, tends to decrease current in metal detector.

Metal detector searches for changes in its current caused by induced eddy currents.

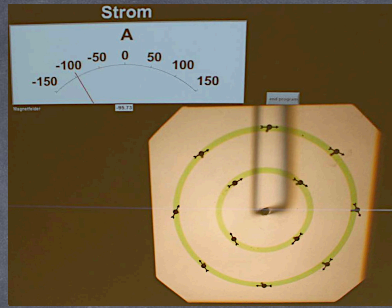


ED48

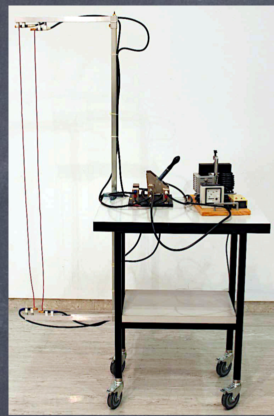
ED63



ED6

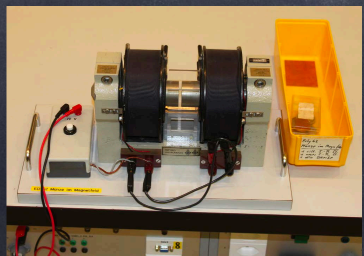


ED10

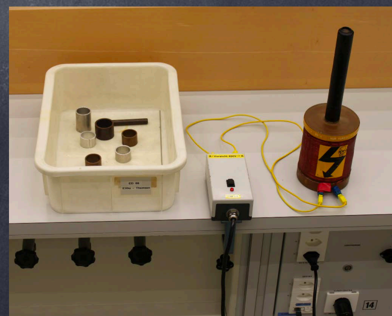


ED14

ED62



ED61



ED66