

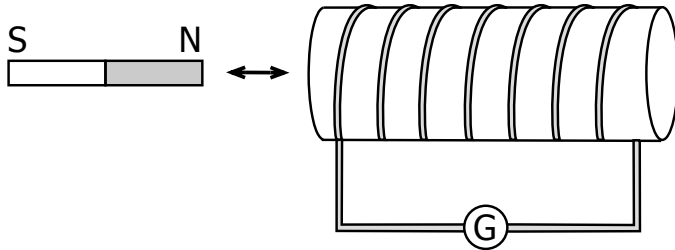
Lecture 29 – Faradays Law and Lenz Rule

Demo: Levitation of a cubic magnet

Jumping Ring

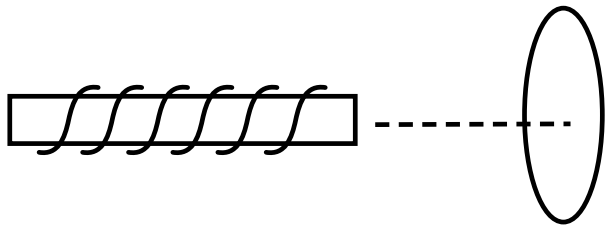
Falling magnet in a metal tube

Single faraday's law demo

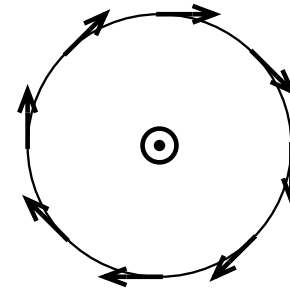


Flux ϕ_B through 1 loop: $\phi = BA$

Change of magnetic flux defined by the solenoid $\Rightarrow$ induced emf.



side view:



$\phi_B \odot, \uparrow$

Increasing outgoing magnetic flux: $\odot \Rightarrow$ CW E_{ind}

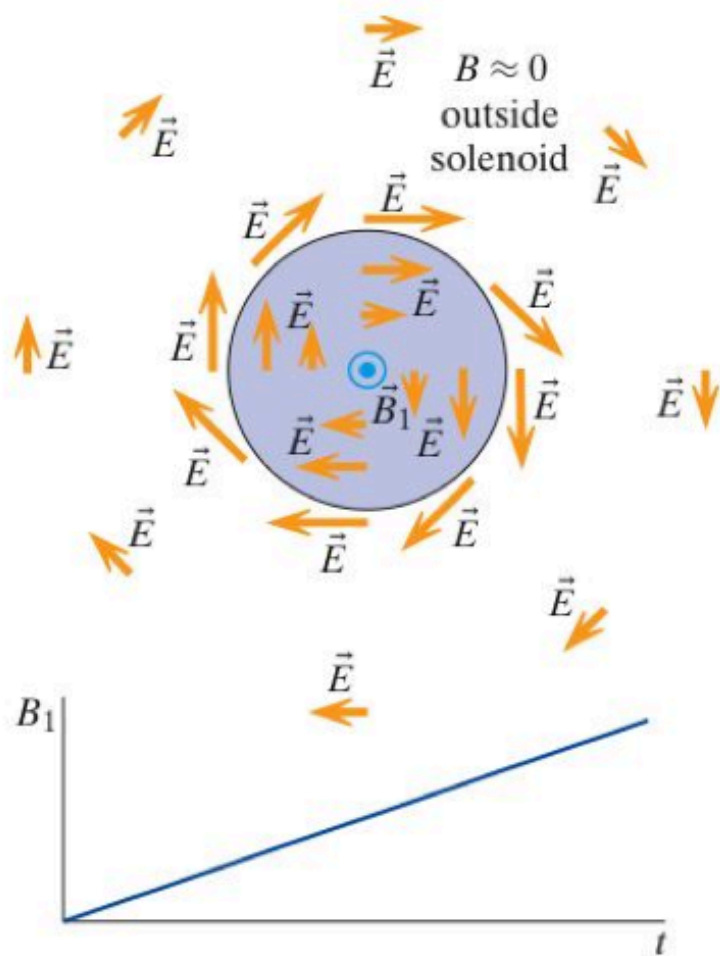


Figure 23.3 There is a curly electric field in the presence of a time-varying magnetic field (top). In this case B_1 is increasing with time (bottom).

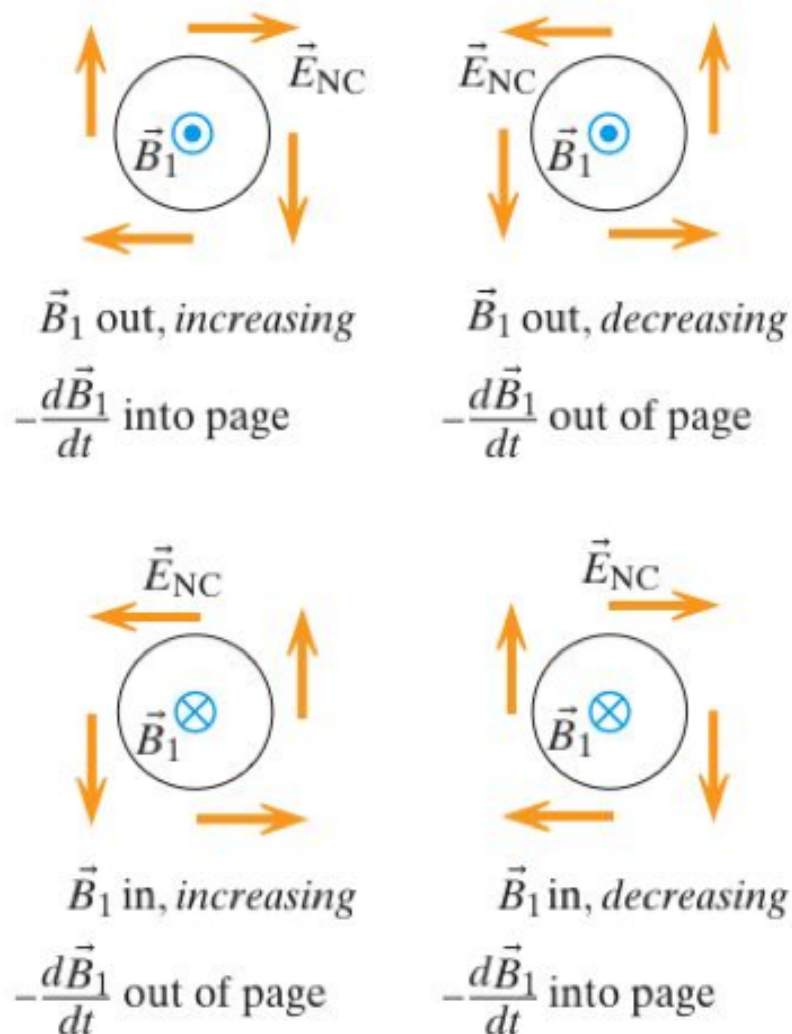


Figure 23.4 Four cases: magnetic field out or in, increasing or decreasing.

Faraday's Law: $\oint E \cdot dl = -\frac{d\phi_B}{dt}$

Direction: $\langle E_{ind} \rangle$: CW

$RHS : \left\langle -\frac{d\phi}{dt} \right\rangle = \langle -\Delta\phi \rangle = \text{"Opposite to the change"}$

Lenz Law: Current loop has magnetic inertia.

It has the tendency to maintain its flux state.

Initial: 10 lines out

Next: 12 lines out (2 lines in to maintain original 10 lines out status)

$\therefore I_{ind} \otimes E_{ind} \text{ CW}$

Lec29-5 Ampere's law application-I: Integration along a rectangular Amperian loop

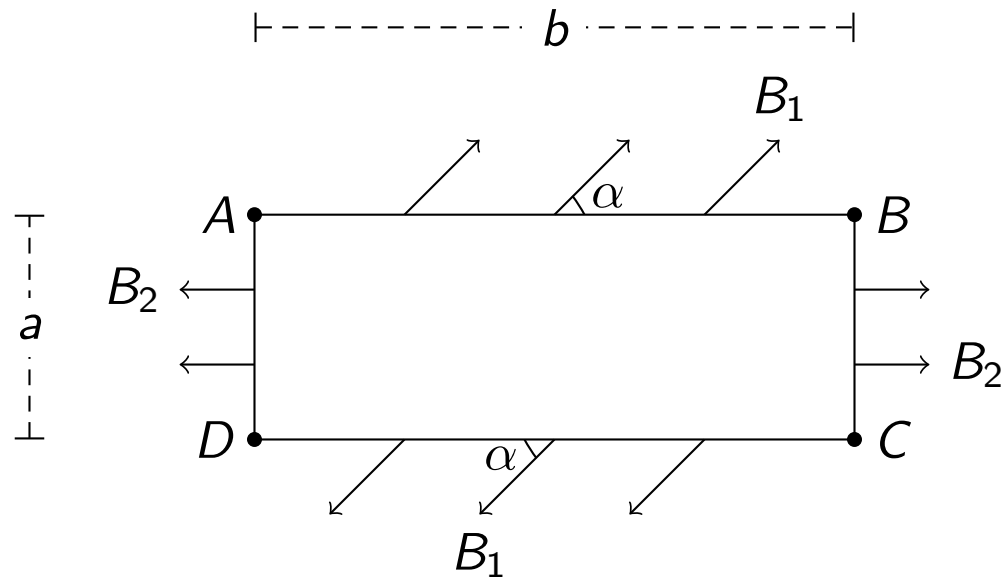


fig29.5

Given B field configuration as indicated. Find $\oint \mathbf{B} \cdot d\mathbf{\ell}$ along the rectangular Amperian loop ABCDA and the direction of the current encircled by the loop.

Choice	$\oint \mathbf{B} \cdot d\mathbf{\ell}$	Direction of current encircled
1	$2B_1 b \cos \alpha$	Into
2	$2B_1 b \cos \alpha + 2aB_2$	Into
3	$2B_1 b \cos \alpha$	Out
4	$2B_1 b \cos \alpha + 2aB_2$	Out

Lec29-6 Ampere's law application-II: A current sheet

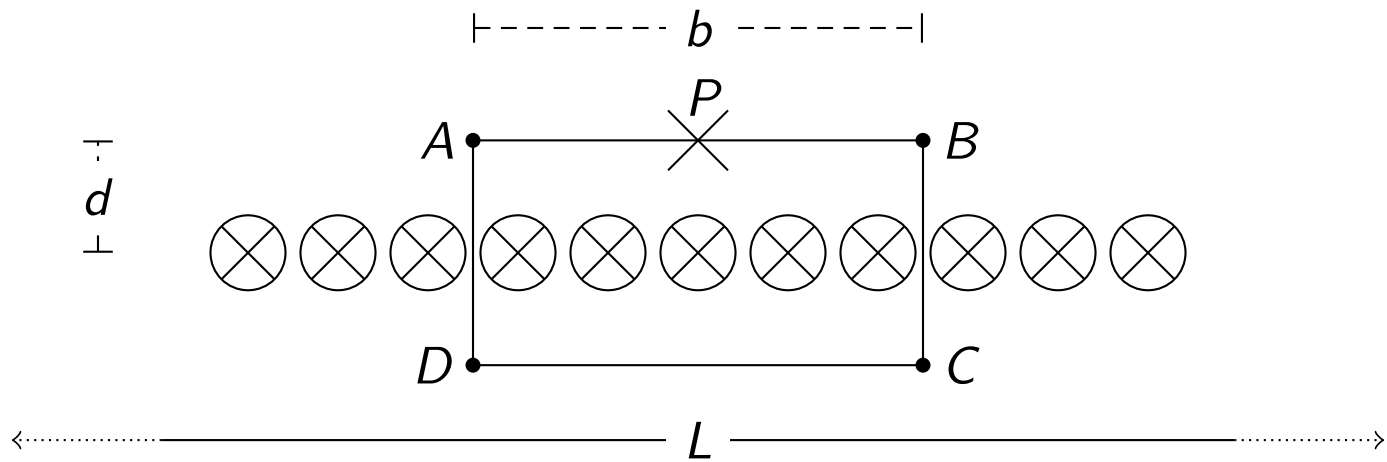


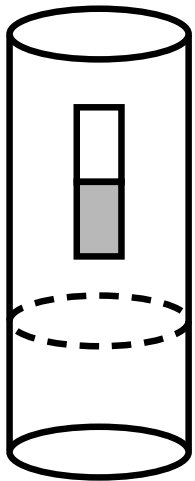
fig. 29.6a

fig29-6a shows a portion of a current sheet containing a large number N of densely packed wires, each carrying a current I into the page. The width of the sheet of the wires is L . We would like to determine B at the midpoint P of $\overline{AB}$ using Ampere's law on the loop $ABCD$ shown in the figure. Here we assume $b > d$, and $b \ll L/2$.

First we will look at the field pattern generated by the long wire-sheet near the midpoint P .

Application: Falling magnet in a metal tube

Demo: The falling magnet moves slowly



Do the current below the magnet

You will do the case where the loop is above the magnet.

The loop has magnetic inertia:

Now: 3 lines ↓

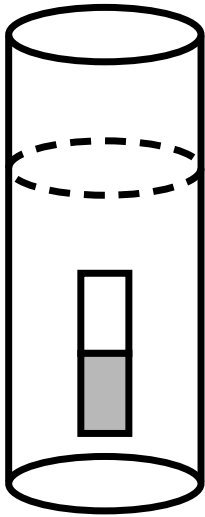
Next: 5 lines ↓

Loop generates B_{in} , 2 lines up to maintain original 3 lines.

$\therefore B_{in} \uparrow$ opposing the fall.

I_{ind} CCW. Or E_{ind} CCW pattern.

Now for the current loop above the magnet



Now: 3 lines ↓

Next: 1 line ↓

Loop generates B_{in} : ↓ 2 lines

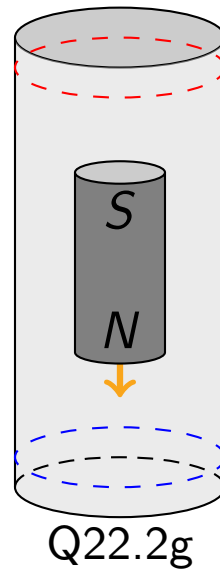
$\therefore B_{in}$ ↓

It affects the falling magnet:

$\therefore$ Loop below opposes its fall (by repulsion)

Loop above opposes its fall (by attraction)

$\therefore$ It takes the loop a longer time to fall.



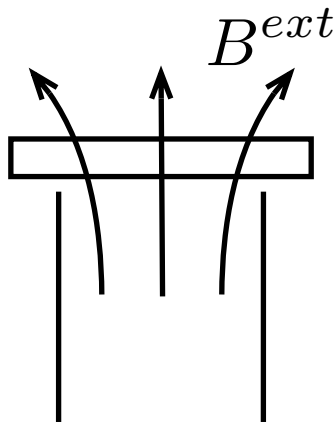
Choice	Direction of I_{ind} in the loop above the falling magnet, as viewed from above	Direction of the magnetic dipole moment in the loop below the falling magnet, as viewed from above
1	CW	Down
2	CW	Up
3	CCW	Down
4	CCW	Up

Jumping Ring Demo:

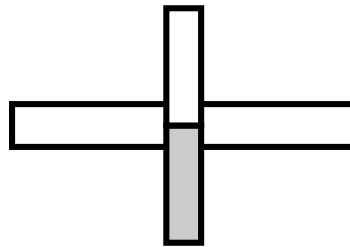
Show current loop as magnetic initial. Initial flux = 0

After we turn on B of the solenoid, the ring jumps away to maintain net flux state.

Understanding the force affecting the ring:

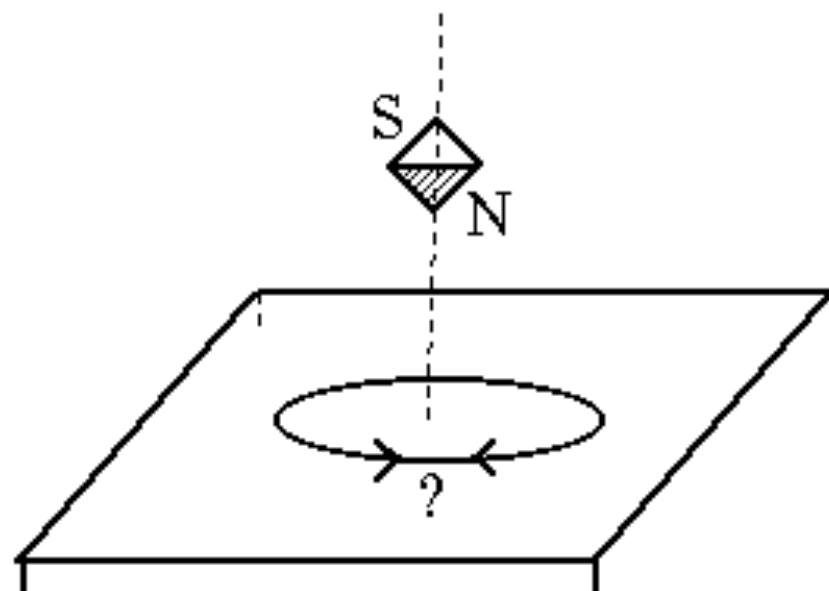


Induced Magnet



= stronger lifting force

31.3.1 Levitation of a magnet

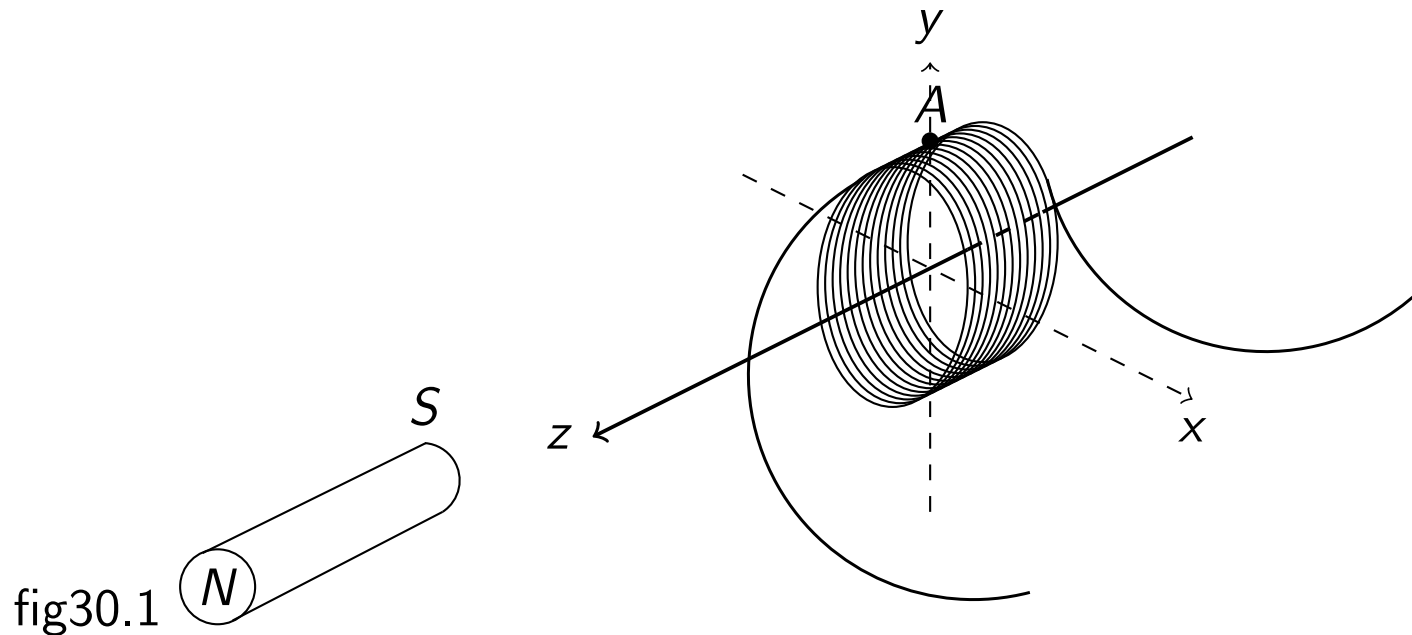


Consider levitation of magnet by a superconducting surface. The north pole is pointing downward. The direction of induced current as viewed from above is:

1	2	3
clockwise	0	counterclockwise

Hint: The loop of induced current should correspond to an equivalent induced dipole which repels the magnet.

Extra: If the polarity of suspending magnet is reversed, what is the direction of induced current? Will the magnet fall?



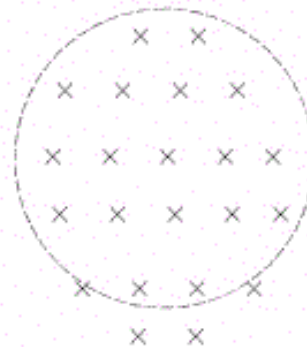
As the magnet is moved in the z direction, what is the...

Choice	direction of $-d\mathbf{B}/dt$ at the origin?	direction of induced current at A from Faraday's Law?
1	$\hat{z}$	$-\hat{x}$
2	$-\hat{z}$	$-\hat{x}$
3	$\hat{z}$	$\hat{x}$
4	$-\hat{z}$	$\hat{x}$

31.4.1 Varying flux & Induced emf



B_1 at t_1



B_2 at t_2

Given: $r=1\text{m}$. At $t_1=0\text{ sec}$, $B_1=1\text{T}$. At $t_2=2\text{ sec}$, $B_2=2\text{T}$.

Find: Induced emf ϵ_{ind} , in volts.

	1	2	3	4
ϵ_{ind} (in volts)	π	$\pi/2$	π	$\pi/2$
dir of ϵ_{ind}	clock-wise	clock-wise	counter-clockwise	counter-clockwise

Hint: $\epsilon_{\text{ind}} = \left| \frac{d\phi}{dt} \right| = \left| \frac{B_2 A - B_1 A}{t_2 - t_1} \right|$. Use Lenz law