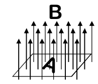
Faraday's Law

- Key to EVERYTHING in E+M
  - Generating electricity
  - Microphones, Speakers and Tape Decks
  - Amplifiers
  - Computer disks and card readers
  - Ground Fault Interrupters
- Changing B <u>creates</u> new E

Magnetic Flux

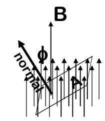
$$\Phi_B = BA\cos\theta$$

$$units:\ Tesla \cdot m^2 = Weber\ \ (Wb)$$



Uniform magnetic field, B, passes through a plane surface of area A.

Magnetic flux Φ = B A



Magnetic flux Φ = B A cos(ϕ)

ϕ is angle between normal and B

Note: The flux can be negative
(if field lines go thru loop in opposite direction)

Faraday's Law (EMF Magnitude)

Emf = Change in magnetic Flux/Time

$$\varepsilon = -\frac{\Delta\Phi}{\Delta t} = -\frac{\Phi_f - \Phi_i}{t_f - t_i}$$

Since Φ= B A cos(ϕ), 3 things can change Φ

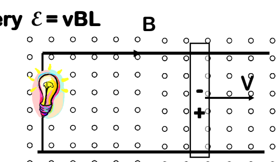
Lenz's Law (EMF Direction)

Emf <u>opposes change</u> in flux

- If flux **increases**:
  New EMF makes new field opposite to the original field (to oppose the increase)
- If flux **decreases**:
  New EMF makes new field in the same direction as the original field (to oppose the decrease)

Motional EMF circuit

Moving bar acts like battery $\mathcal{E}$ = vBL



- Magnitude of current

  I = $\mathcal{E}$/R= vBL/R

- Direction of Current

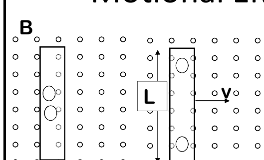
  Clockwise (+ charges go down thru bar, up thru bulb)

- Direction of force (F=ILB sin(θ)) on bar due to magnetic field

  To left, slows down

What changes if B points into page?

Motional EMF, Preflight 14.1



F = q v B sin(θ)

Which of the following statements is true?

- positive charge accumulates at the top of the bar, negative at the bottom
- since there is not a complete circuit, no charge accumulates at the bar's ends
- negative charge accumulates at the top of the bar, positive at the bottom

Preflight 14.2

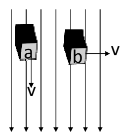
- Which bar has the larger motional emf?

$\mathcal{E}$ = v B L sin(θ)

θ is angle between v and B

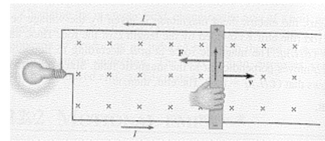
Case a:

Case b:



Preflight 14.4, 14.5

Suppose the magnetic field is reversed so that it now points OUT of the page instead of IN as shown in the figure.



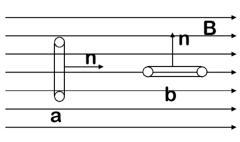
To keep the bar moving at the same speed, the force supplied by the hand will have to:

Increase   Stay the Same   Decrease

To keep the bar moving to the right, the hand will have to supply a force in the opposite direction:

True   False

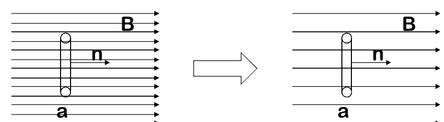
Preflight 14.7



Compare the flux through loops a and b.

1) $\Phi_a > \Phi_b$ 2) $\Phi_a < \Phi_b$

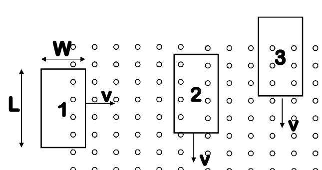
Preflight 14.9



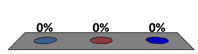
The magnetic field strength through the loop is cut in half (decreasing the flux). If you wanted to create a second magnetic field to oppose the change in flux, what would be its direction?

Left   Right

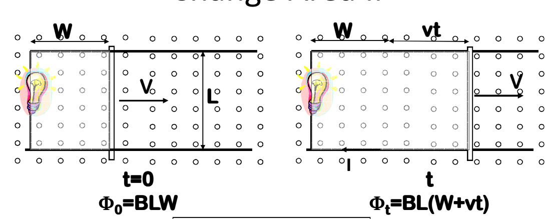
Which loop has the greatest induced EMF at the instant shown below?



1. Loop 1
2. Loop 2
3. Loop 3



Change Area II



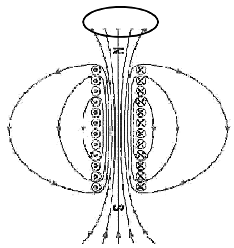
Φ = B A cos(ϕ)

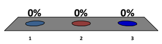
EMF Magnitude:

EMF Direction:

As current is increasing in the solenoid, what direction will current be induced in the ring?

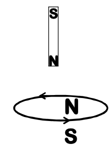
1. Same as solenoid
2. Opposite of solenoid
3. No current

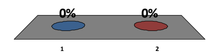




Which way is the magnet moving if it is inducing a current in the loop as shown?

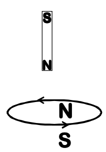
1. up
2. down

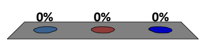




If the resistance in the wire is decreased, what will happen to the speed of the magnet's descent?

1. It will fall faster
2. It will fall slower
3. It will maintain the same speed



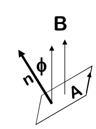


Change ϕ

Example

A flat coil of wire has $A=0.2\ m^2$ and $R=10\Omega$. At time t=0, it is oriented so the normal makes an angle $\phi_0=0$ w.r.t. a constant B field of 0.12 T. The loop is rotated to an angle of $\phi=30^o$ in 0.5 seconds. Calculate the induced EMF.

What direction is the current induced?



Magnetic Flux Examples

Example

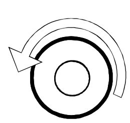
A conducting loop is inside a solenoid ($B=\mu_o nI$). What happens to the flux through the loop when you…

Increase area of solenoid?

Increase area of loop?

Increase current in solenoid?

Rotate loop slightly?



$\Phi \equiv B\ A\ \cos(\phi)$

Magnetic Flux II

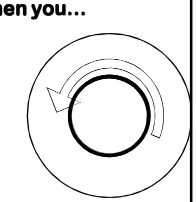
Example

A solenoid ($B=\mu_o nI$) is inside a conducting loop. What happens to the flux through the loop when you…

Increase area of solenoid

Increase area of loop

Increase current in solenoid



$\Phi \equiv B\ A\ \cos(\phi)$