**Physics 1161: Lecture 12**

Induction - Faraday's Law

**Changing Magnetic Fields create Electric Fields**

- **Sections 23-1 -- 23-4**

## Faraday's Law

- Key to EVERYTHING in E+M
  - Generating electricity
  - Microphones, Speakers and MP3 Players
  - Amplifiers
  - Computer disks and card readers
  - Ground Fault Interrupters
- Changing B <u>creates</u> new E

## Magnetic Flux

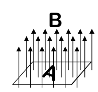
$$\Phi_B = BA\cos\theta$$

Faraday's Law for Coil of N Turns

Lenz's Law

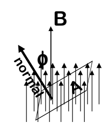
## Magnetic Flux

- Count number of field lines through loop.




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

**Magnetic flux $\Phi \equiv$ B A**




**Magnetic flux $\Phi \equiv$ B A cos($\phi$)**

**$\phi$ 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 $\Phi$= B A cos($\phi$), 3 things can change $\Phi$**

## Lenz's Law (EMF Direction)

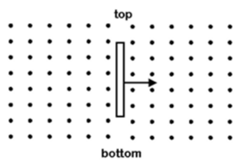
Emf <u>opposes change</u> in flux

- If flux **increases**:

- If flux **decreases**:

## *Checkpoint: Conducting Bar*

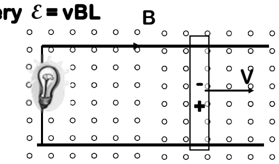
A conducting bar is moving to the right through a magnetic field which points OUT as shown in the diagram.




Which of the following statements is true?
1) positive charge accumulates at the top of the bar, negative at the bottom
2) since there is not a complete circuit, no charge accumulates at the bar's ends
3) negative charge accumulates at the top of the bar, positive at the bottom

## Motional EMF circuit

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

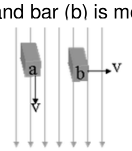



- Magnitude of current
- Direction of Current
- Direction of force (F=ILB sin(θ)) on bar due to magnetic field

**What changes if B points into page?**

## Checkpoint: Motional EMF

Two identical conducting bars (shown in end view) are moving through a vertical magnetic field. Bar (a) is moving vertically and bar (b) is moving horizontally.

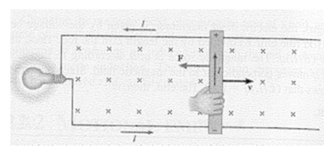



Which of the following statements is true?

1. A motional emf exist in the bar for case (a), but not (b).
2. A motional emf exist in the bar for case (b), but not (a).
3. A motional emf exist in the bar for both cases (a) and (b).
4. A motional emf exist in the bar for neither cases (a) nor (b).

## Checkpoint:
## Induced Current

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



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

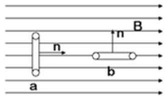
Increase Stay the Same Decrease

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

True False

## Checkpoint
## Loop in a Magnetic Field

**A rectangular loop of wire shown in edge view in the figure, is rotating in a magnetic field. (The circles represent the crossections of the wires coming out of and into the page, while the vertical lines correspond to the vertical sections of wire in the rectangle.) The sense of rotation is shown by the short arrows attached to the loop. The loop is shown in two different positions (a) and (b).**



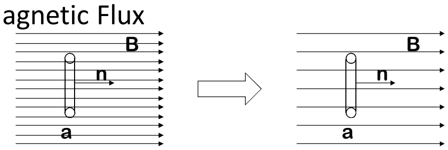

In which position does the loop have the largest flux?
1. Position A
2. Position B

## Lenz's Law (EMF Direction)

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

- If flux **increases**:
- If flux **decreases**:

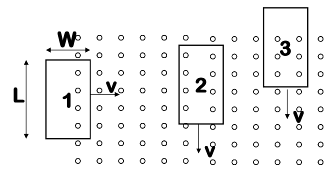
Checkpoint
Magnetic Flux




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?

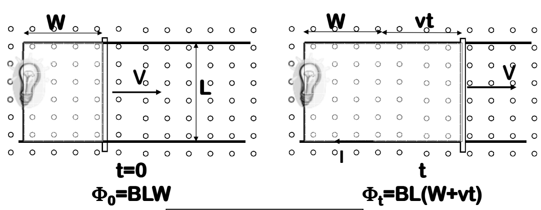
Left    Right

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




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

## Change Area II



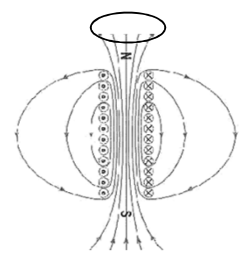

$\Phi = B\ A\ \cos(\phi)$

**EMF Magnitude:**

**EMF Direction:**

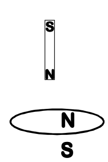
As current is increasing in the solenoid, what direction will current be induced in the ring?

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



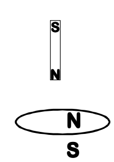

Which way is the magnet moving if it is inducing a current in the loop as shown?

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



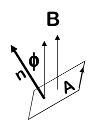
## Change $\phi$

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.

**$\Phi_i$ = B A cos(0)** **$\Phi_f$ = B A cos(30)**

**What direction is the current induced?**




## Magnetic Flux Examples

Example

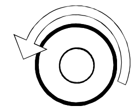
**A conducting loop is inside a solenoid ($B=\mu_o nI$). What happens to the flux through the loop when you…**

Increase area of solenoid?

Increase area of loop?

Increase current in solenoid?

Rotate loop slightly?



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

## Magnetic Flux II

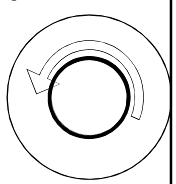
Example

**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 Increases

Increase area of loop No change

Increase current in solenoid Increases



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