Physics 1161: Lecture 13

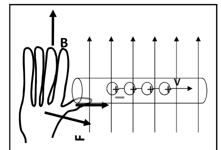
Generators & Motors

- **Textbook Sections 23-6 – 23-9**

http://www.walter-fendt.de/ph14e/electricmotor.htm
http://www.walter-fendt.de/ph14e/generator_e.htm

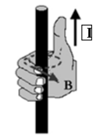
Review: Two uses of RHR's

- Force on moving charge in Magnetic field
  – Thumb: v (or I)
  – Fingers: B
  – Palm: F on + charge



Palm: out of page.

- Magnetic field produced by moving charges
  – Thumb: I (or v for + charges)
  – Fingers: curl along B field

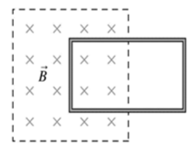


Review: Induction

- Lenz's Law
  – If the magnetic flux (Φ_B) through a loop changes, an EMF will be created in the loop to oppose the change in flux
  – EMF ⟹ current (V=IR) ⟹ additional B-field.
    - Flux decreasing => B-field in same direction as original
    - Flux increasing => B-field in opposite direction of original
- Faraday's Law
  – Magnitude of induced EMF given by:

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

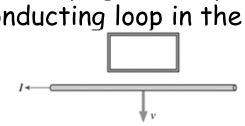
A conducting loop is halfway into a magnetic field. Suppose the magnetic field begins to increase rapidly in strength.



Which of the following statements is true?

1. The loop is pushed upward, toward the top of the page.
2. The loop is pushed downward, toward the bottom of the page.
3. The loop is pulled to the left, into the magnetic field.
4. The loop is pushed to the right, out of the magnetic field.
5. The tension in the wires increases but the loop does not move.

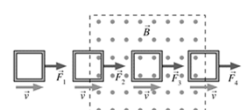
A current-carrying wire is pulled away from a conducting loop in the direction shown.



As the wire is moving, is there a cw current around the loop, a ccw current or no current?

1. There is a clockwise current around the loop.
2. There is a counterclockwise current around the loop.
3. There is no current around the loop.

A square loop of copper wire is pulled through a region of magnetic field as shown in the figure.

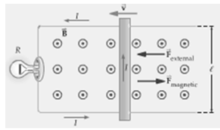


Rank in order, from strongest to weakest, the pulling forces, F_1, F_2, F_3, and F_4 that must be applied to keep the loop moving at constant speed.

1. $F_2 = F_4 > F_1 = F_3$
2. $F_3 > F_2 = F_4 > F_1$
3. $F_3 > F_4 > F_2 > F_1$
4. $F_4 > F_2 > F_1 = F_3$
5. $F_4 > F_3 > F_2 > F_1$

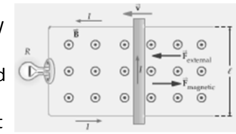
Motional emf

The lightbulb in the circuit has a resistance of 12 Ω and consumes 5.0 W of power; the rod is 1.25 m long and moves to the left with a constant speed of 3.1 m/s. What is the strength of the magnetic field?



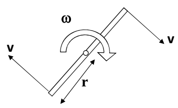
Motional emf

The lightbulb in the circuit has a resistance of 12 Ω and consumes 5.0 W of power; the rod is 1.25 m long and moves to the left with a constant speed of 3.1 m/s. What external force is required to maintain the rod's constant speed?



Review: Rotation Variables
v, ω, *f*, T

- Velocity (v):
  - How fast a point moves.
  - Units: usually m/s
- Angular Frequency (ω):
  - How fast something rotates.
  - Units: radians / sec
- Frequency (*f*):
  - How fast something rotates.
  - Units: rotations / sec = Hz
- Period (T):
  - How much time one full rotation takes.
  - Units: usually seconds



Generators and EMF

EMF is voltage!

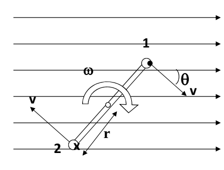
$\varepsilon_{side\ 1} = v\,B\,L\,\sin(\theta)$

$v = \omega r$

$\varepsilon_{side\ 1} = \omega r\,B\,L\,\sin(\theta)$

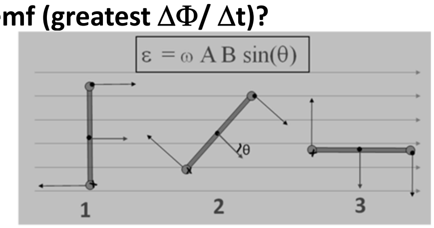
$\varepsilon_{side\ 2} = \omega r\,B\,L\,\sin(\theta)$

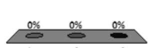
$\varepsilon_{loop} = \varepsilon_{side\ 1} + \varepsilon_{side\ 2}$



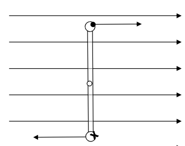
At which time does the loop have the greatest emf (greatest ΔΦ/ Δt)?

1. 1
2. 2
3. 3



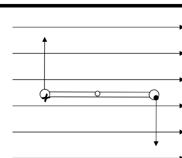


Comparison:
Flux vs. *EMF*



Flux is maximum
- Most lines thru loop

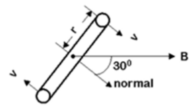
EMF is minimum
- Just before: lines enter from left
- Just after: lines enter from left
- No change!



Flux is minimum
- Zero lines thru loop

EMF is maximum
- Just before: lines enter from top.
- Just after: lines enter from bottom.
- Big change!

Checkpoint
Rotating Loop



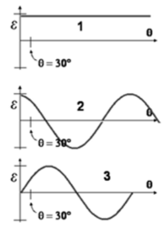
Flux is _________ at moment shown.

- **Increasing**
- **decreasing**
- **not changing**

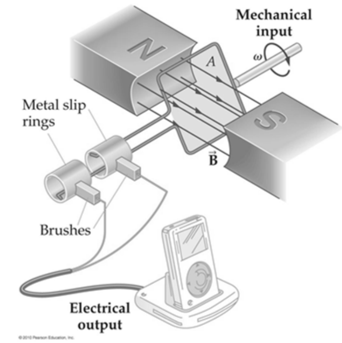
When θ=30°, the EMF around the loop is:

- **increasing**
- **decreasing**
- **not changing**

Which of the following graphs is the correct graph of EMF vs. angle for the loop shown above?



Generator



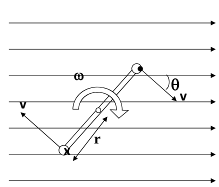
Generators and Torque

$\varepsilon = \omega A B \sin(\theta)$

Voltage!

Connect loop to resistance R use I=V/R:

$I = \omega A B \sin(\theta) / R$



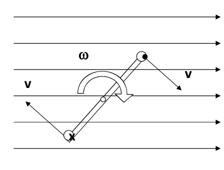
Example

Generator

A generator consists of a square coil of wire with 40 turns, each side is 0.2 meters long, and it is spinning with angular velocity ω = 2.5 radians/second in a uniform magnetic field B=0.15 T. Determine the direction of the induced current at instant shown. Calculate the maximum emf and torque if the resistive load is 4Ω.

$\varepsilon = NAB\,\omega \sin(\theta)$ **Units?**

$\tau = NIAB \sin(\theta)$ **Units?**



Motor

An electric motor is exactly the opposite of a generator – it uses the torque on a current loop to create mechanical energy.