DEVIL PHYSICS

THE BADDEST CLASS ON CAMPUS

IB PHYSICS

TSOKOS LSN 11-2 TRANSMISSION OF POWER

Essential Idea:

- Generation and transmission of alternating current (ac) electricity has transformed the world.

Nature Of Science:

- Bias: In the late 19th century Edison was a proponent of direct current electrical energy transmission while Westinghouse and Tesla favoured alternating current transmission. The so called “battle of currents” had a significant impact on today’s society.

International-Mindedness:

- The ability to maintain a reliable power grid has been the aim of all governments since the widespread use of electricity started.

Theory Of Knowledge:

- There is continued debate of the effect of electromagnetic waves on the health of humans, especially children.
- Is it justifiable to make use of scientific advances even if we do not know what their long-term consequences may be?

Understandings:

- Alternating current (ac) generators
- Average power and root mean square (rms) values of current and voltage
- Transformers
- Diode bridges
- Half-wave and full-wave rectification

Applications And Skills:

- Explaining the operation of a basic ac generator, including the effect of changing the generator frequency
- Solving problems involving the average power in an ac circuit
- Solving problems involving step-up and step-down transformers

Applications And Skills:

- Describing the use of transformers in ac electrical power distribution
- Investigating a diode bridge rectification circuit experimentally
- Qualitatively describing the effect of adding a capacitor to a diode bridge rectification circuit

Guidance:

- Calculations will be restricted to ideal transformers but students should be aware of some of the reasons why real transformers are not ideal (for example: flux leakage, joule heating, eddy current heating, magnetic hysteresis)
- Proof of the relationship between the peak and rms values will not be expected

Data Booklet Reference:

- $I_{rms} = \frac{I_0}{\sqrt{2}}$

- $V_{rms} = \frac{V_0}{\sqrt{2}}$

- $R = \frac{V_0}{I_0} = \frac{V_{rms}}{I_{rms}}$

- $P_{max} = I_0 V_0$

- $\bar{P} = \frac{1}{2} I_0 V_0$

- $\frac{\varepsilon_p}{\varepsilon_s} = \frac{N_p}{N_s} = \frac{I_s}{I_p}$

Aims:

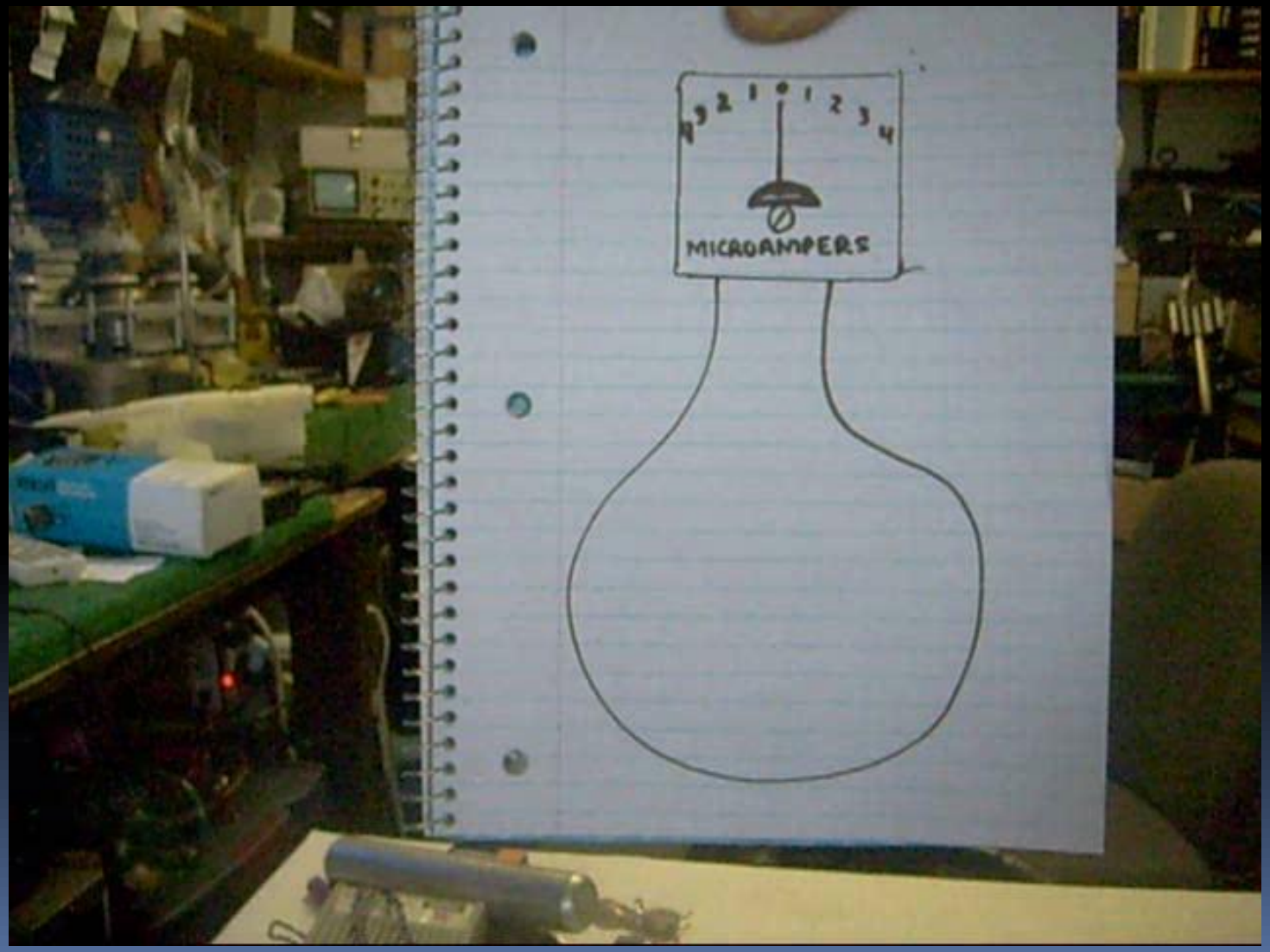
- Aim 6: experiments could include (but are not limited to): construction of a basic ac generator; investigation of variation of input and output coils on a transformer; observing Wheatstone and Wien bridge circuits
- Aim 7: construction and observation of the adjustments made in very large electricity distribution systems are best carried out using computer-modelling software and websites

Aims:

- Aim 9: power transmission is modelled using perfectly efficient systems but no such system truly exists. Although the model is imperfect, it renders the maximum power transmission. Recognition of, and accounting for, the differences between the “perfect” system and the practical system is one of the main functions of professional scientists

Introductory Video

Understanding AC and DC Generators



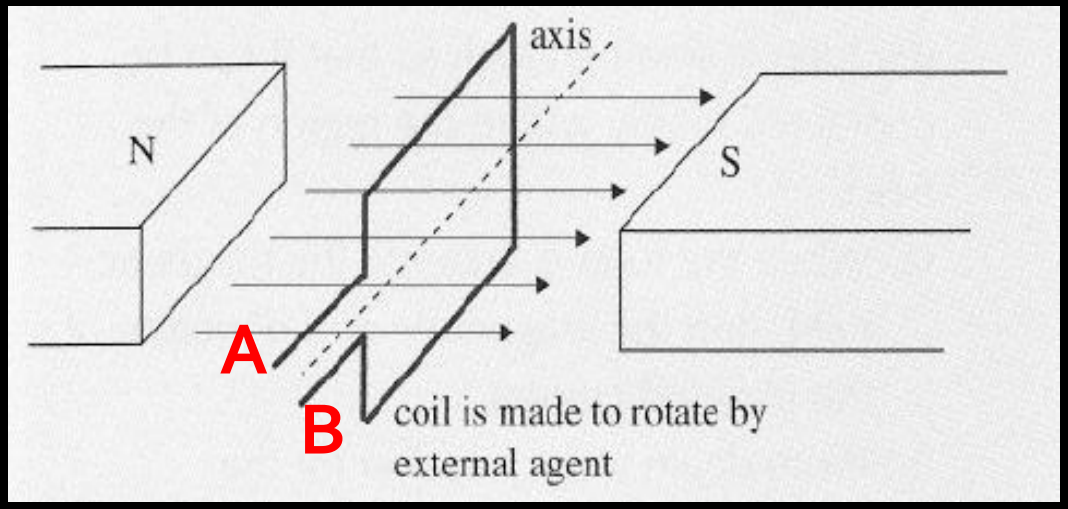
Alternating Current

- Alternating Current (AC) is universally accepted for electrical power production and distribution
- AC generator is an electrical motor in reverse
  - Instead of an electrical current passed through a magnetic field to produce a force,
  - A coil is made to move in relation to a magnetic field to produce a current

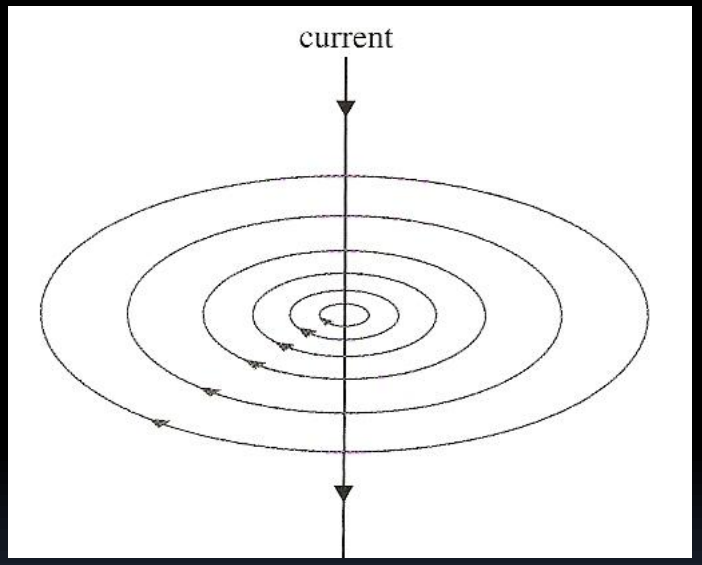
AC Generator

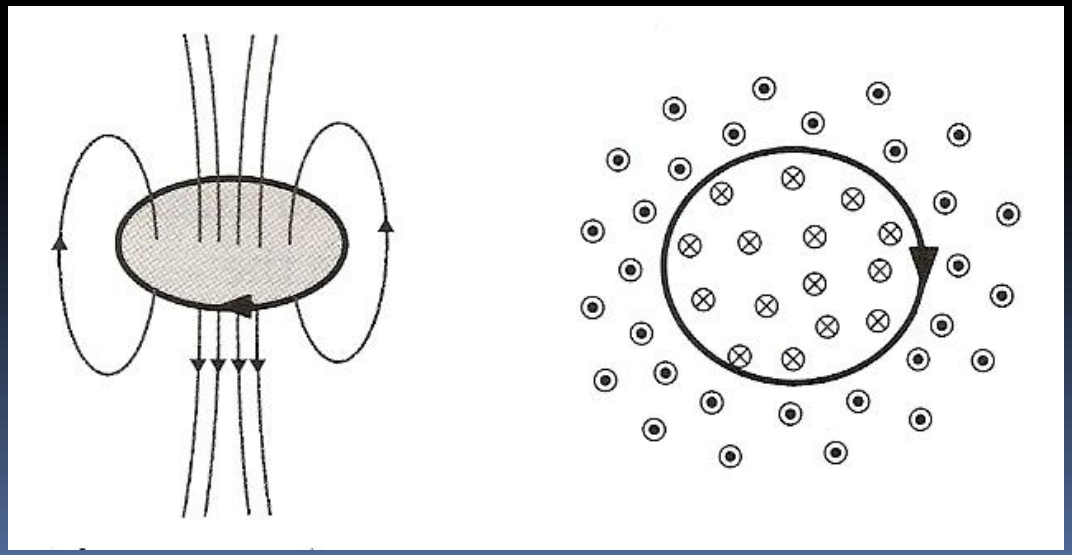
- Lsn 11-1
  - Electrical currents are generated when a loop of wire moves in relation to a magnetic field
  - Back and forth movement of a magnet through a loop of wire generated a current that alternated in the direction of its flow
    - Magnitude varied between positive and negative maxima in a sinusoidal fashion

AC Generator



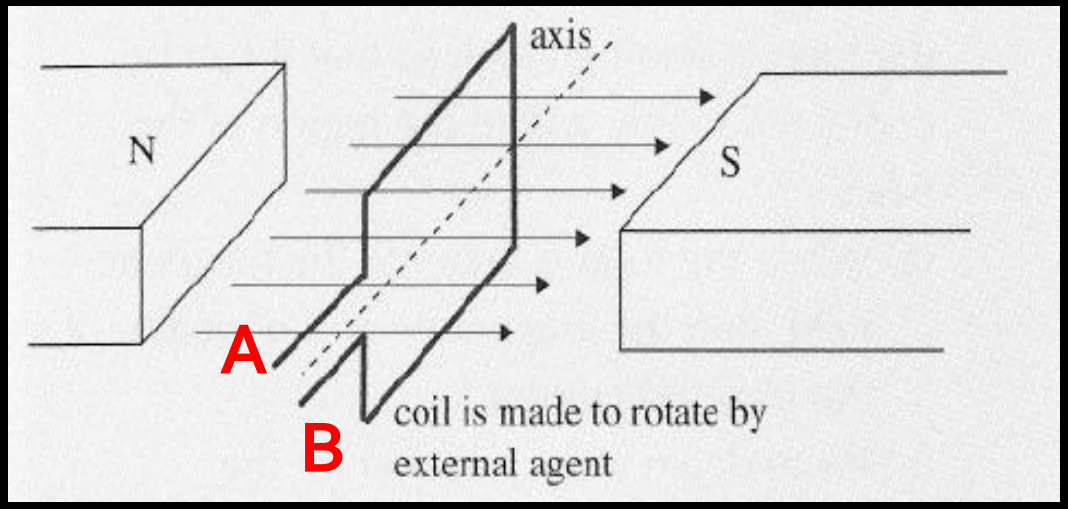
Lenz's Law



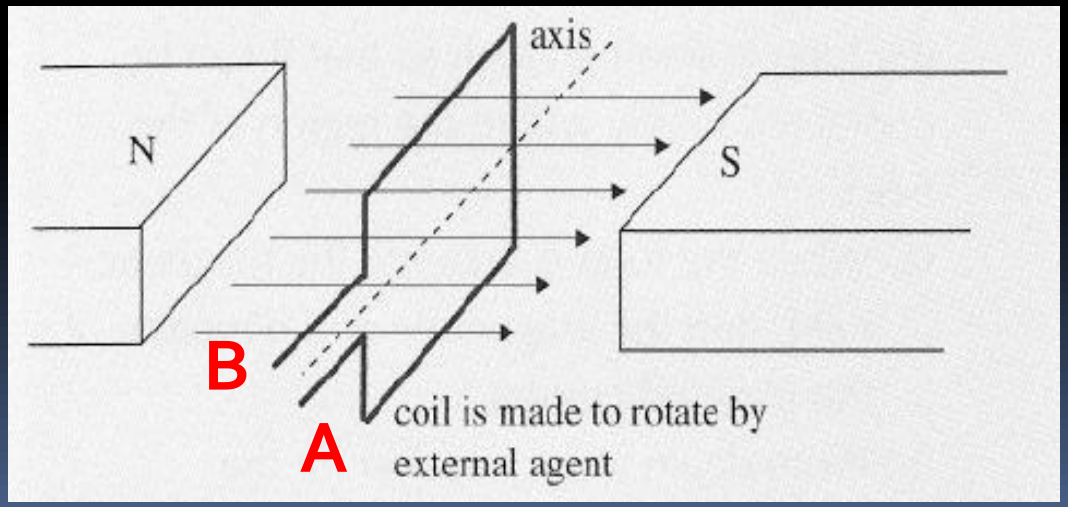


Faraday's Law

AC Generator



Current flow is from A to B



Current flow is from B to A

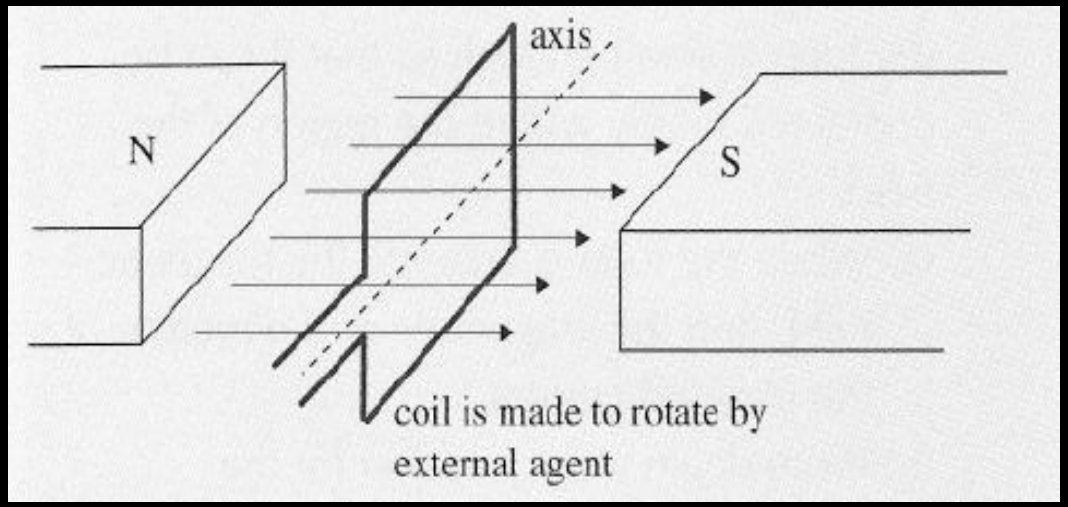
AC Generator

- Lsn 11-1
  - Equation for flux linkage is given as,

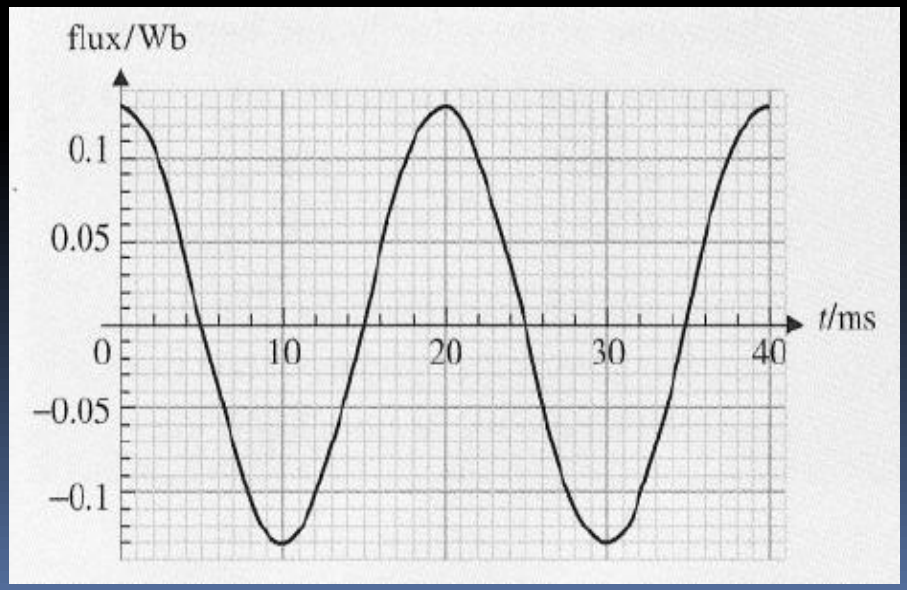
$$\phi = NBA\cos\theta$$

    - where θ is the angle between the magnetic field and the normal to the coil
    - and N is the number of turns in the coil

AC Generator



$$\phi = NBA\cos\theta$$



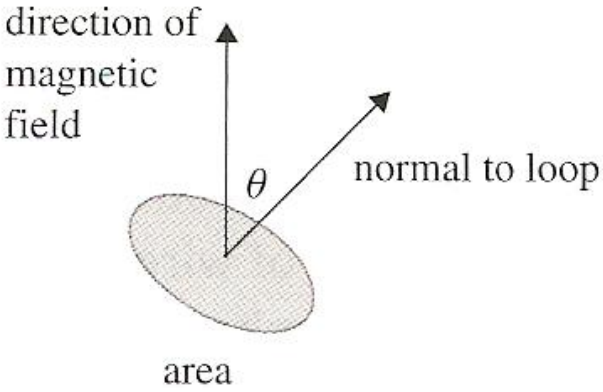
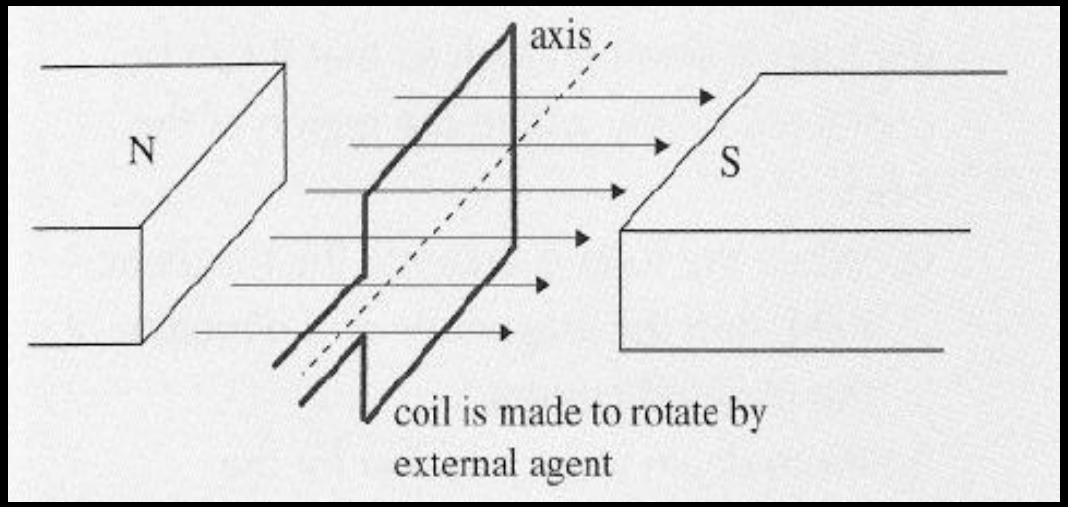


Figure 7.3.

AC Generator

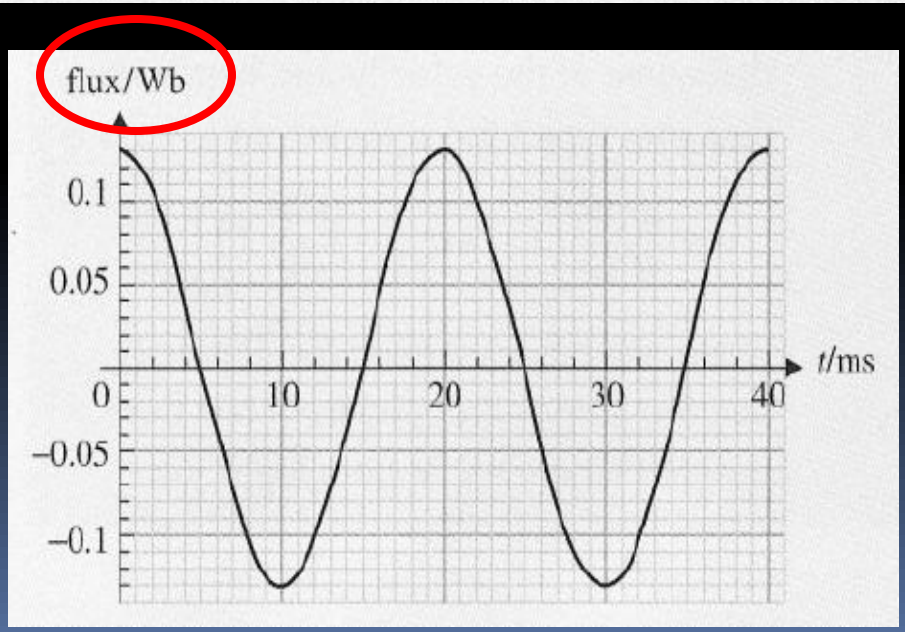


$$\phi = NBA\cos\theta$$

$$\omega = \frac{\Delta\theta}{\Delta t}$$

$$\theta = \omega t$$

$$\phi = NBA\cos(\omega t)$$



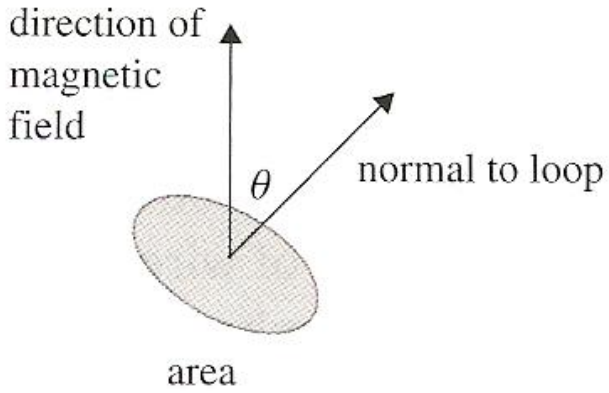
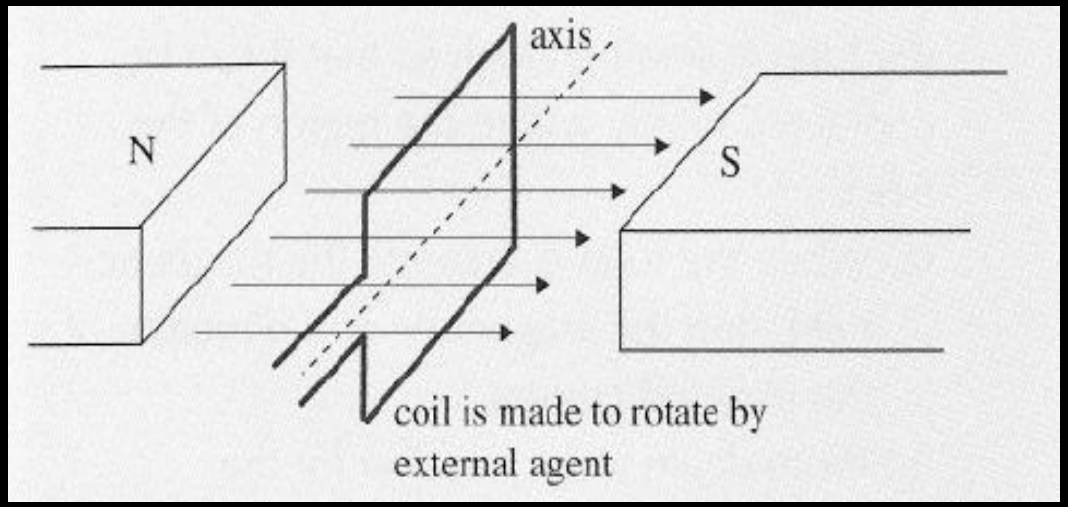


Figure 7.3.

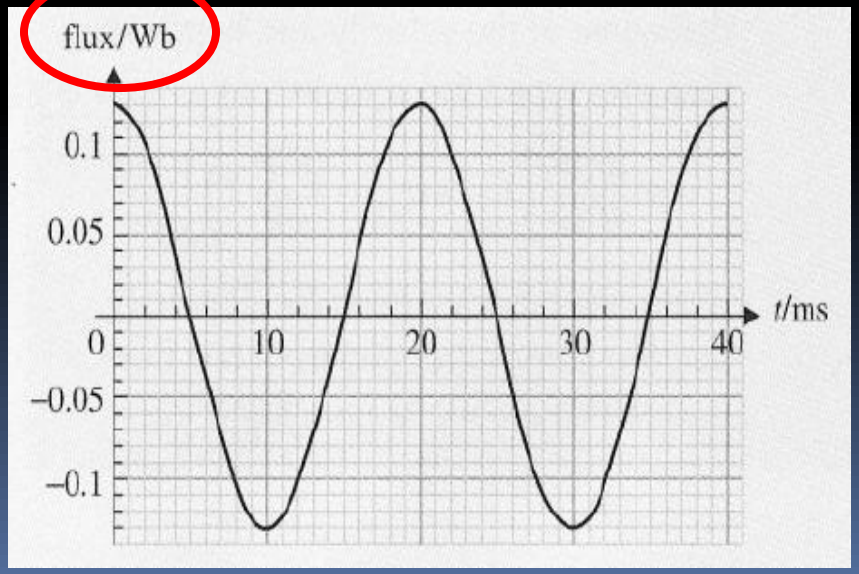
AC Generator

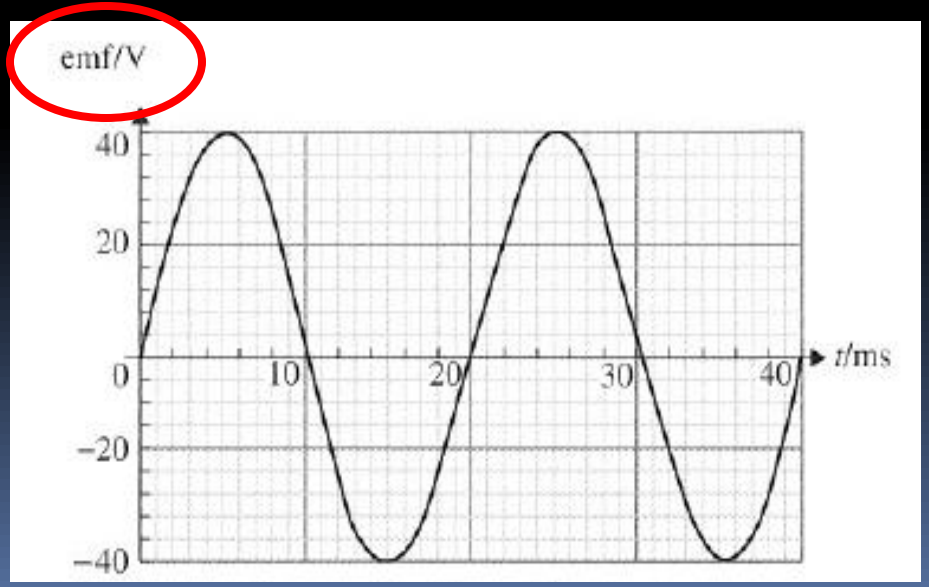


$$\phi = NBA\cos(\omega t)$$

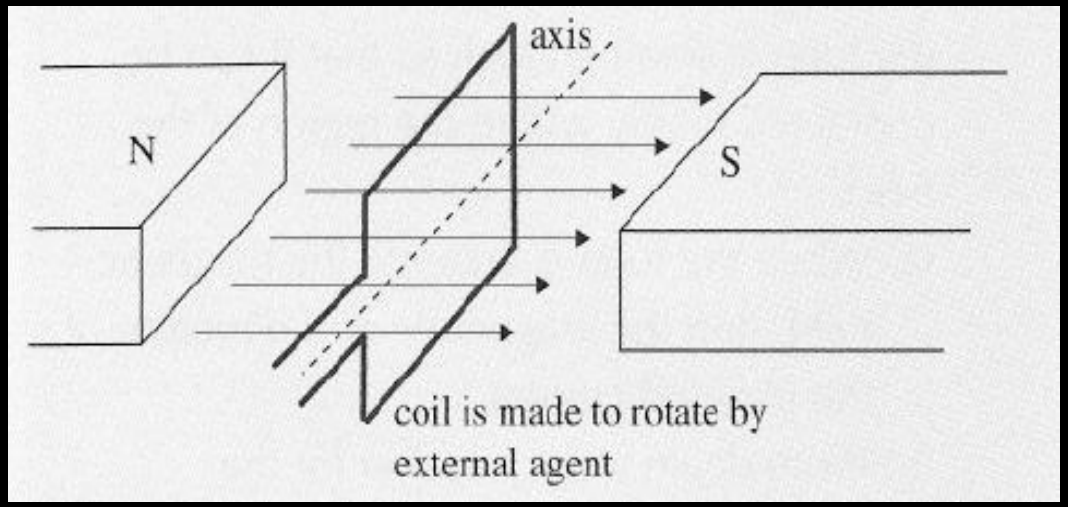
$$\varepsilon = -\frac{d\phi}{dt}$$

$$\varepsilon = \omega NBA\sin(\omega t)$$



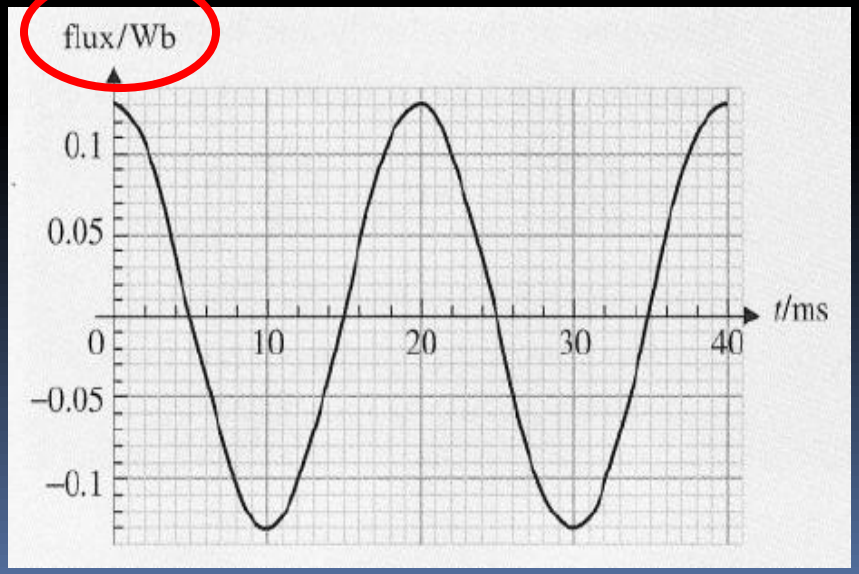


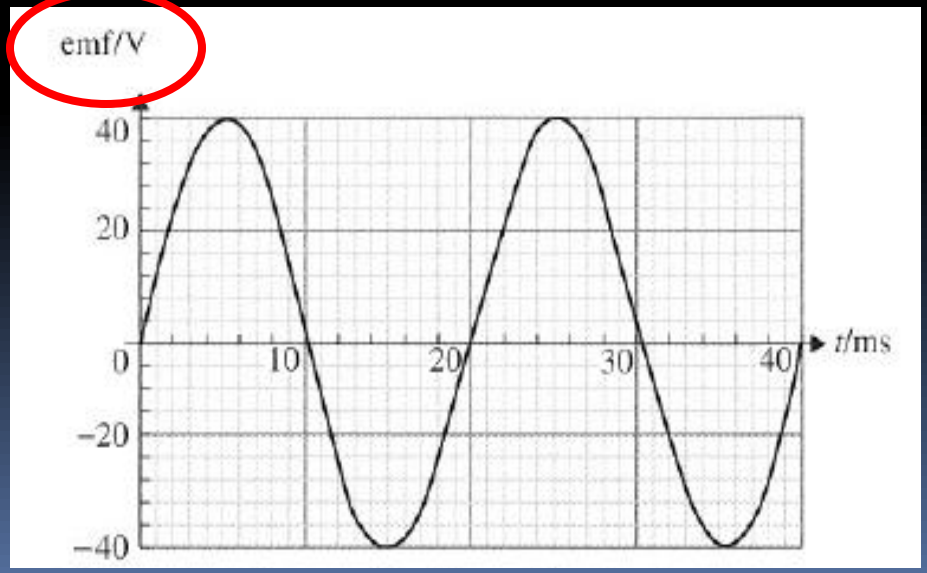
AC Generator



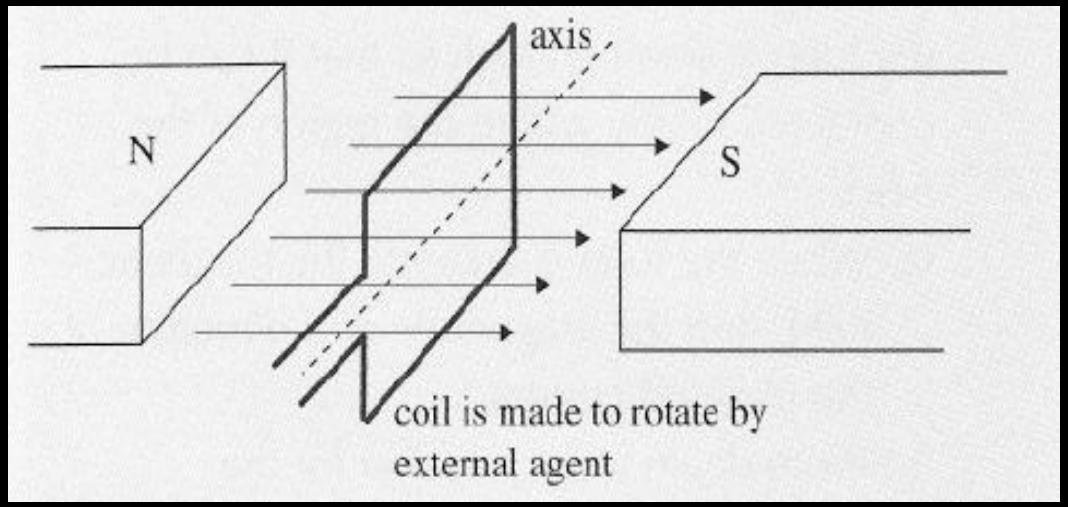
$$\varepsilon_0 = \omega NBA\sin(\omega t)$$

$$\omega = 2\pi f = \_\_?\_\_$$





AC Generator

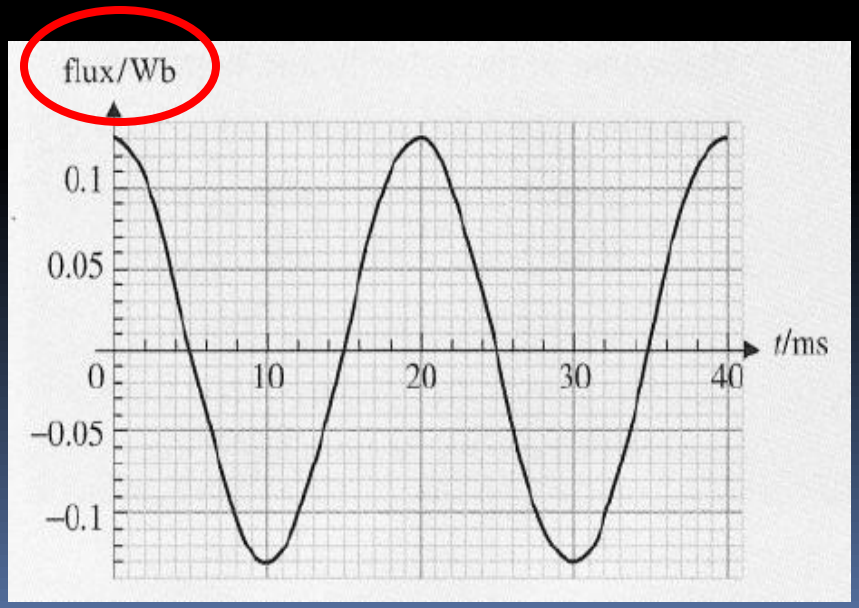


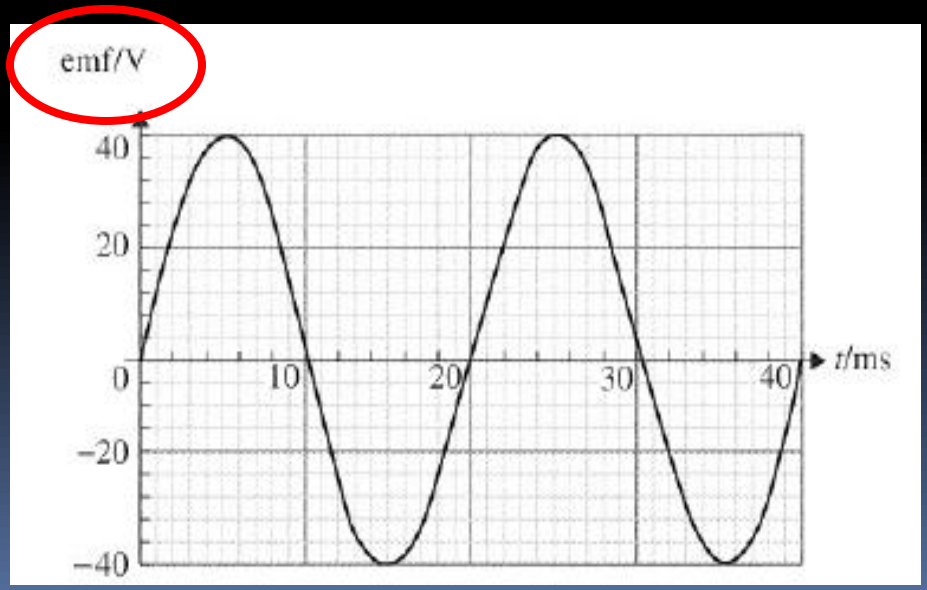
$$\varepsilon_0 = \omega NBA\sin(\omega t)$$

$$\omega = 2\pi f$$

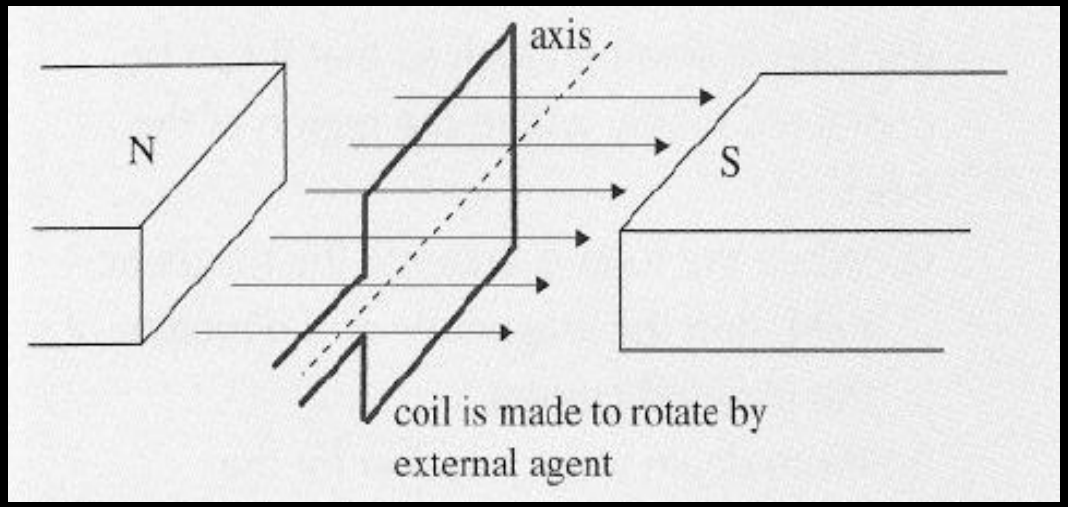
$$\omega = 2\pi\left(\frac{1}{20s}\right)x10^{-3}$$

$$\omega = 314.6s^{-1}$$

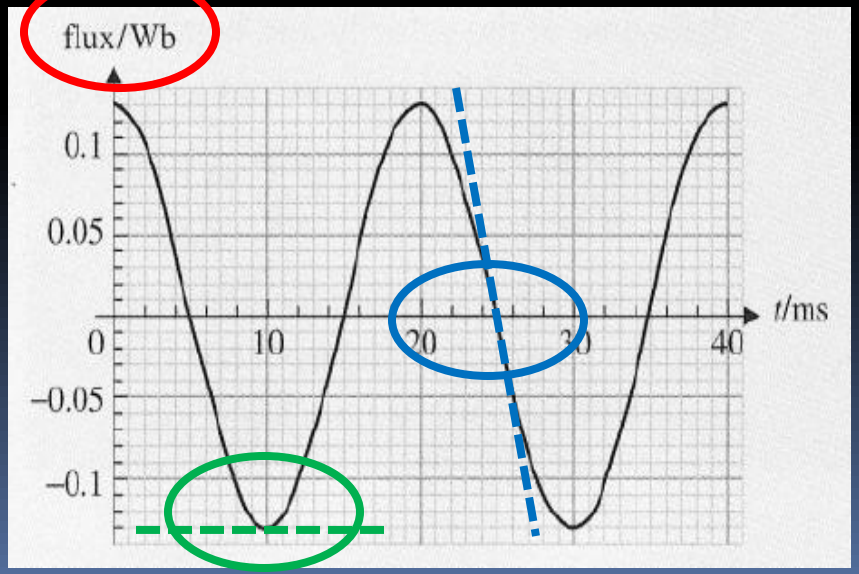


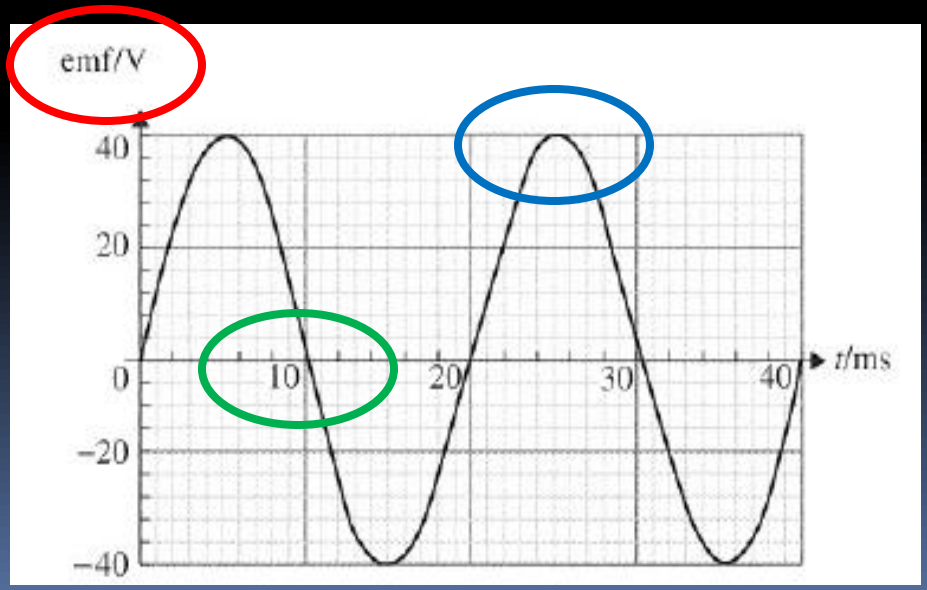


AC Generator



- Emf is zero when flux is max
- Emf is max when flux is zero
- ***Emf based on rate of change of flux***





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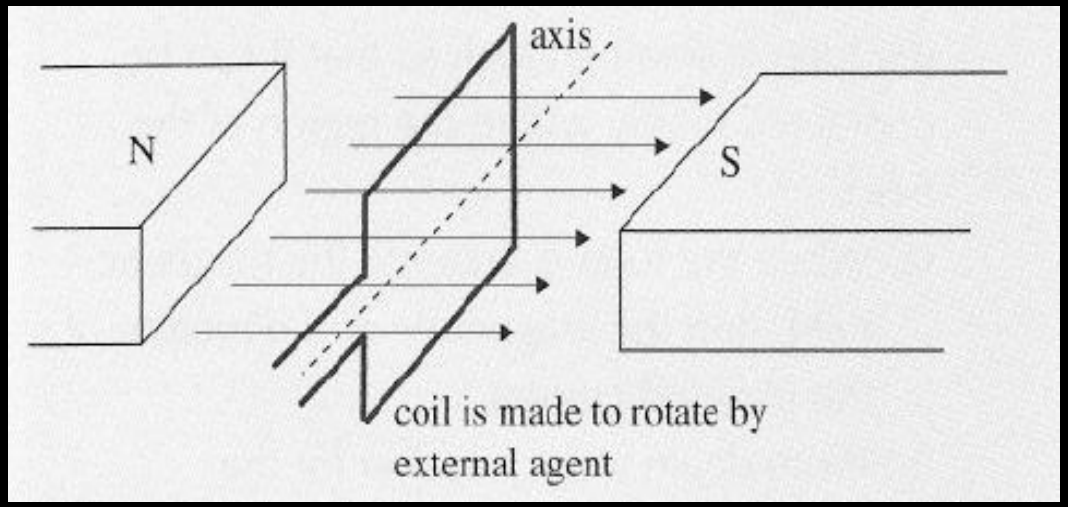
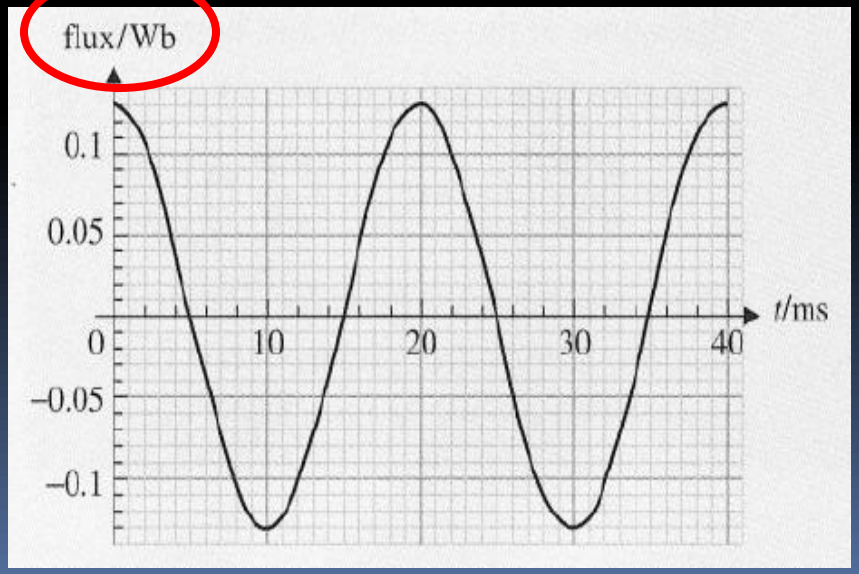
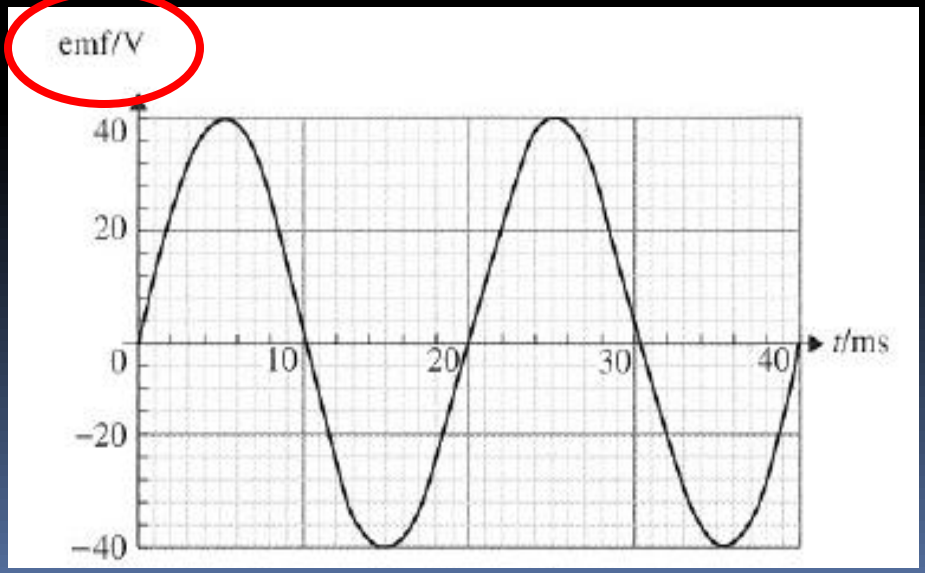
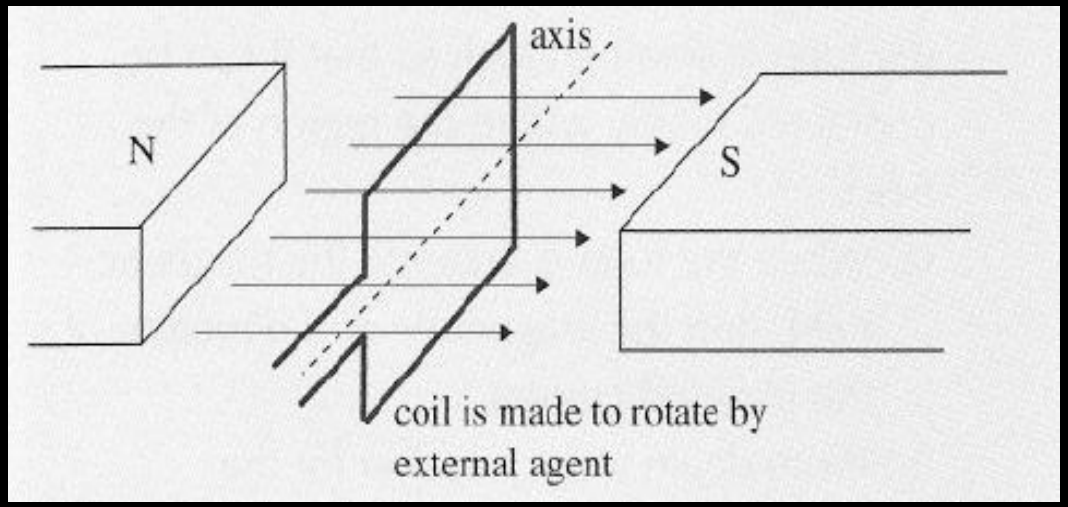


- Positive and negative voltage
- Refers to current flow
- Alternating current (AC)

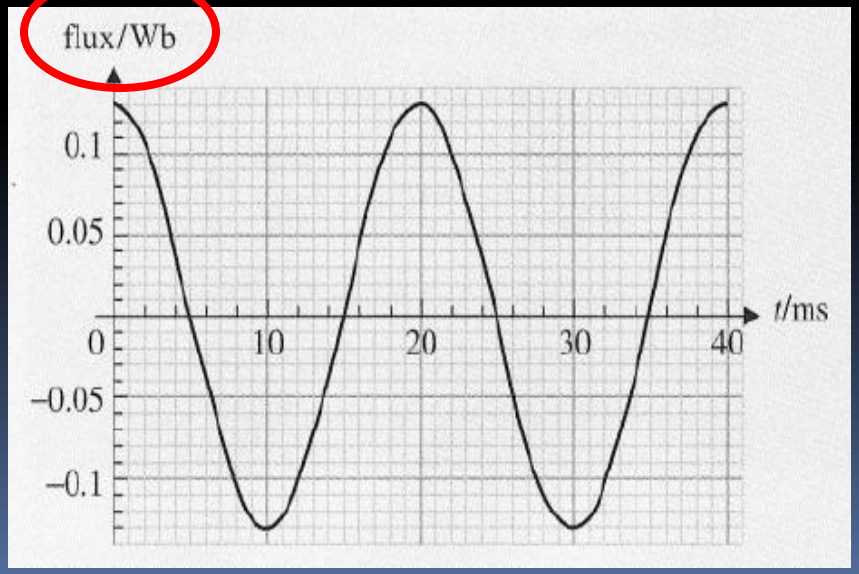


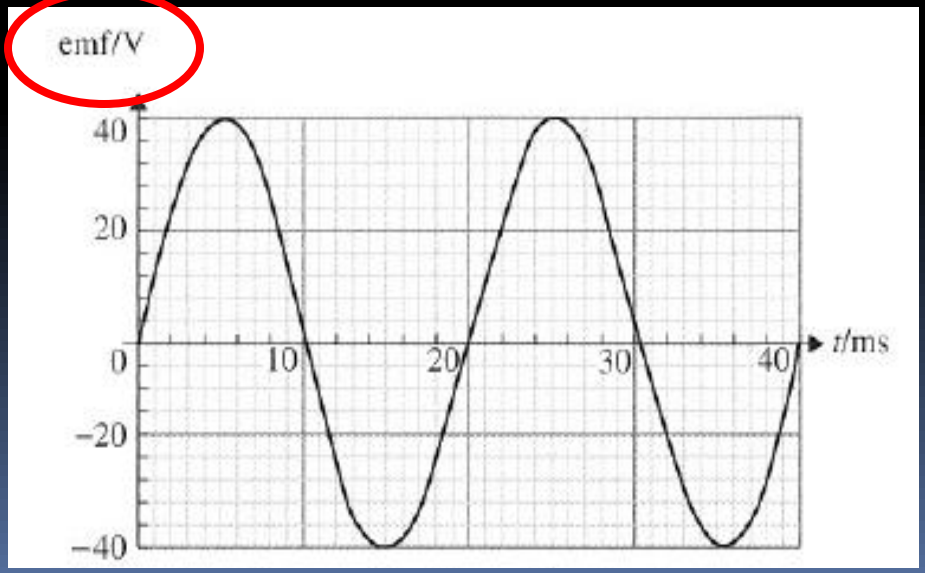


AC Generator



- DC current – electrons drift in one direction
- AC current – electrons oscillate with same freq as voltage





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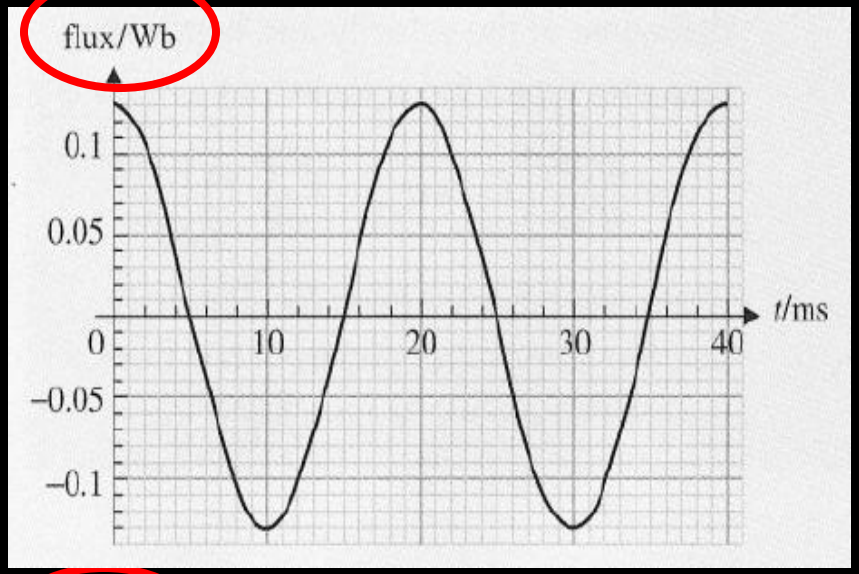
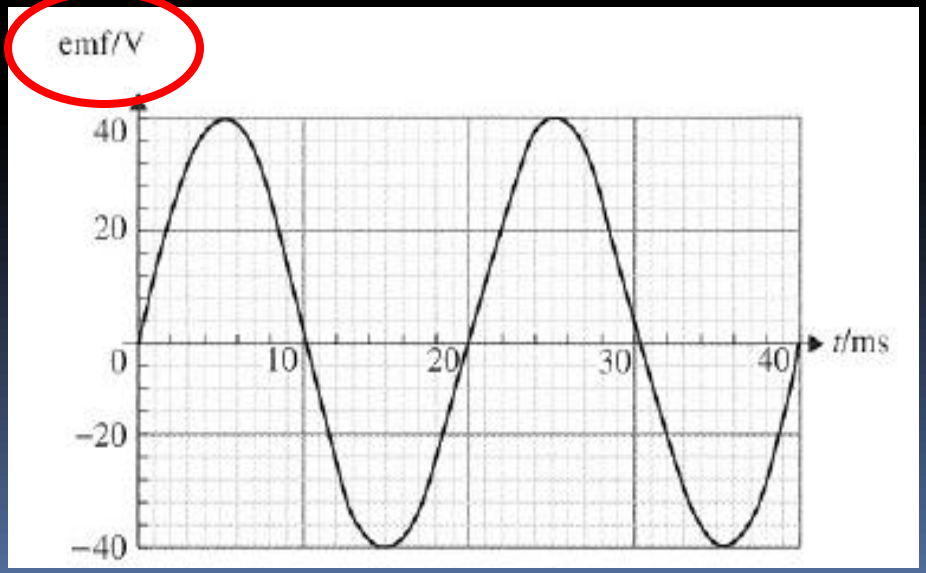
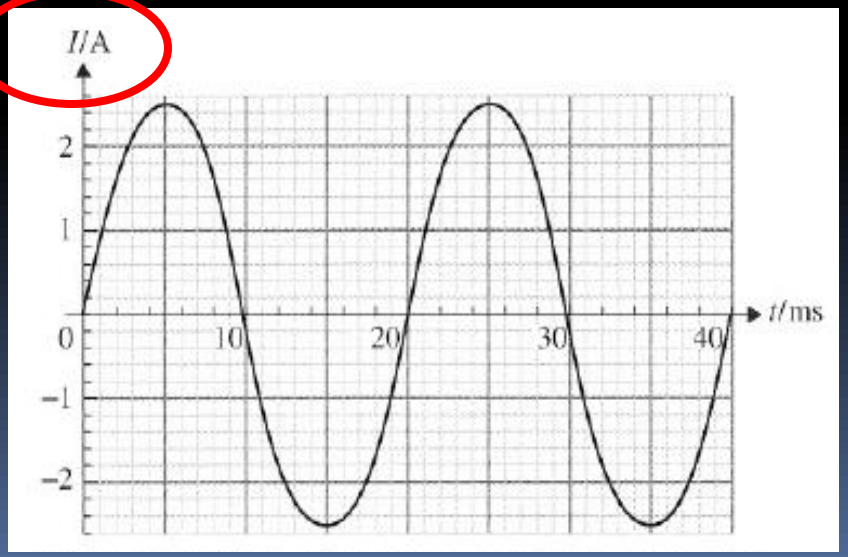


$$\varepsilon = \omega NBA\sin(\omega t)$$

$$\varepsilon_0 = \omega NBA$$

$$\varepsilon = \varepsilon_0 \sin(\omega t)$$





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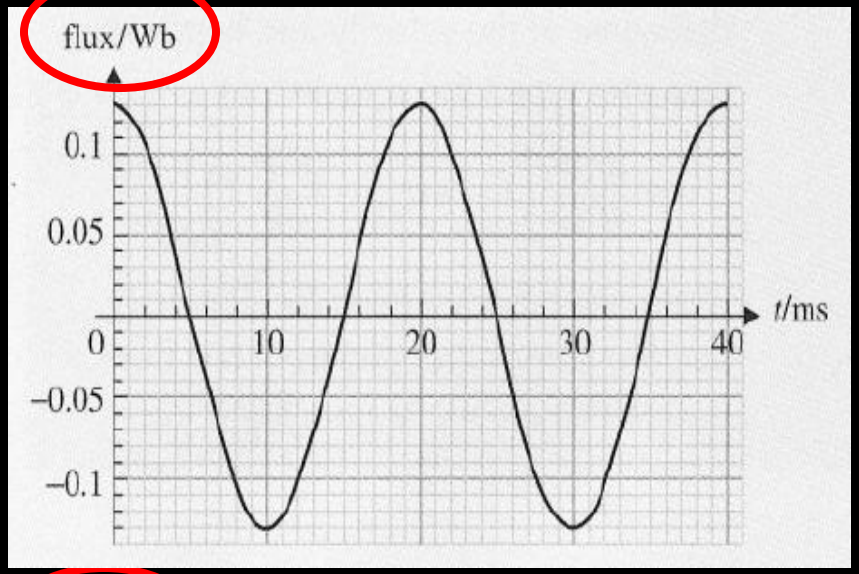


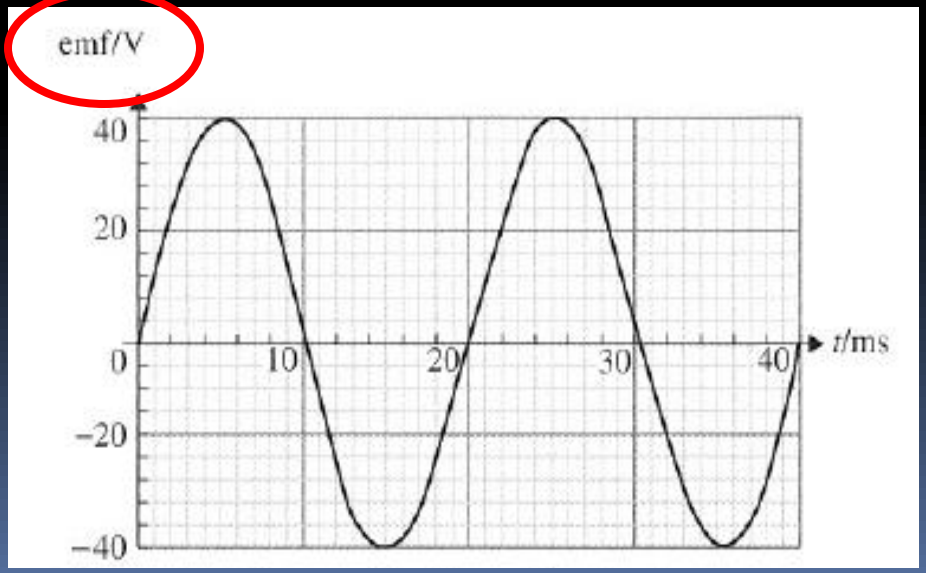
$$\varepsilon = \varepsilon_0 \sin(\omega t)$$

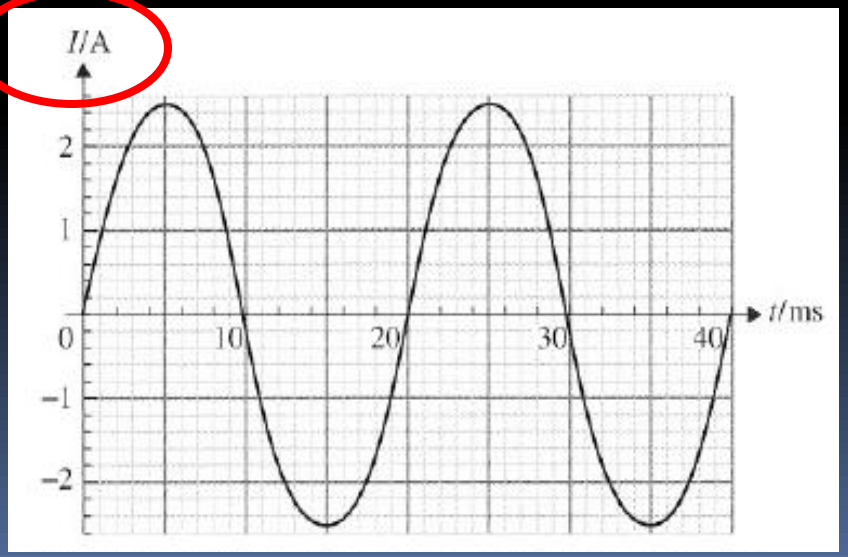
$$I = \frac{\varepsilon}{R}$$

$$I = \frac{\varepsilon_0 \sin(\omega t)}{R}$$

$$I_0 = \frac{\varepsilon_0}{R}$$

$$I = I_0 \sin(\omega t)$$





Power in AC Circuits

- Power is a function of current and voltage (emf)
- Not constant in time
- Peak power obtained at peak current and peak voltage

$$P_{\max} = \varepsilon_0 I_0$$

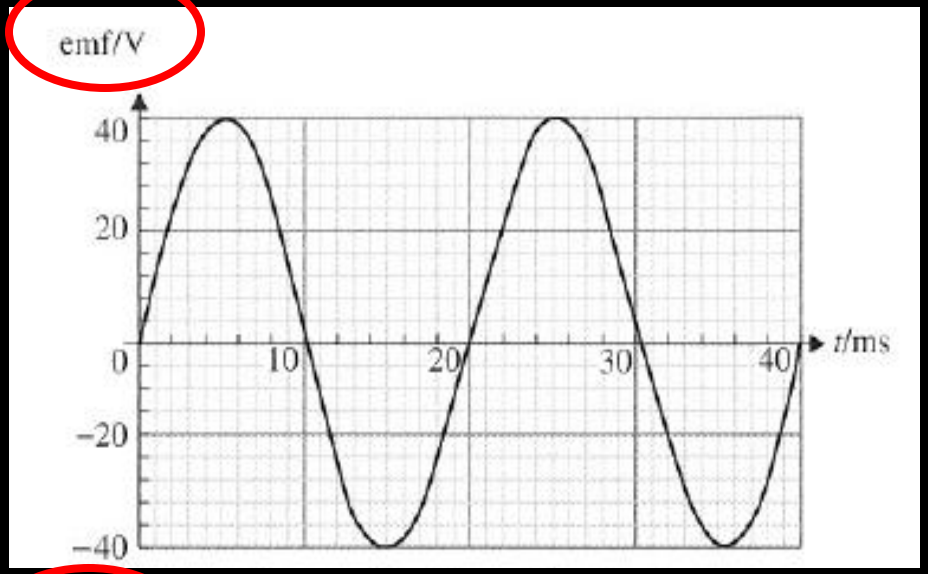
$$\varepsilon = \varepsilon_0 \sin(\omega t)$$

$$I = I_0 \sin(\omega t)$$

$$P = \varepsilon I$$

$$P = \varepsilon_0 I_0 \sin^2(\omega t)$$

Power in AC Circuits

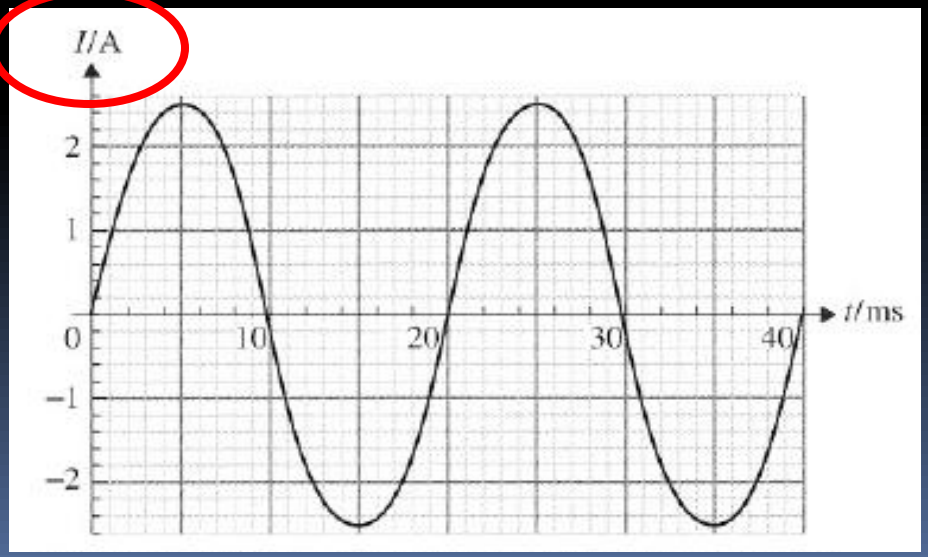


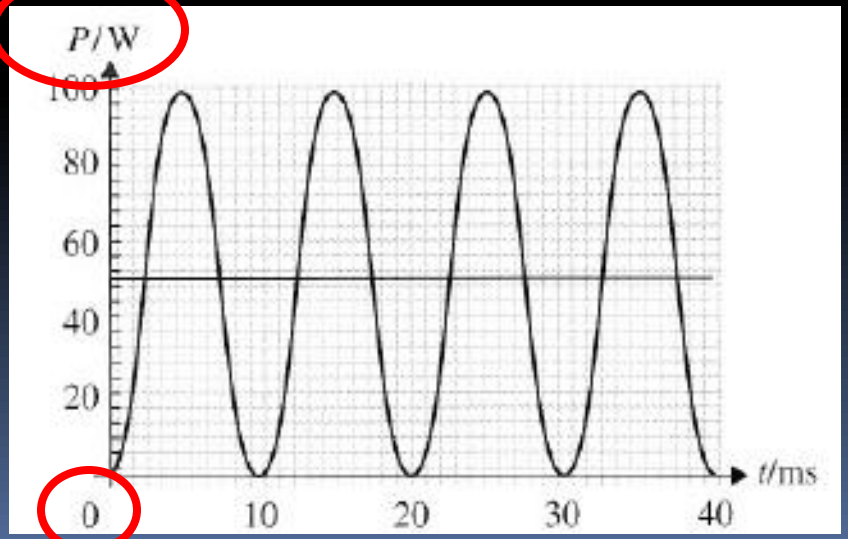
$$\varepsilon = \varepsilon_0 \sin(\omega t)$$

$$I = I_0 \sin(\omega t)$$

$$P = \varepsilon I$$

$$P = \varepsilon_0 I_0 \sin^2(\omega t)$$





Power in AC Circuits

- Power in terms of the parameters of the rotating coil

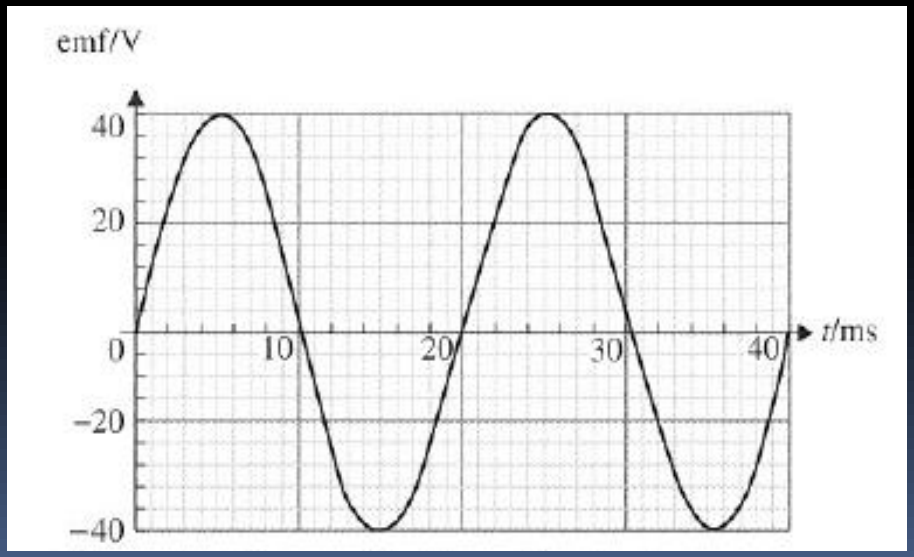
$$P = \varepsilon I$$

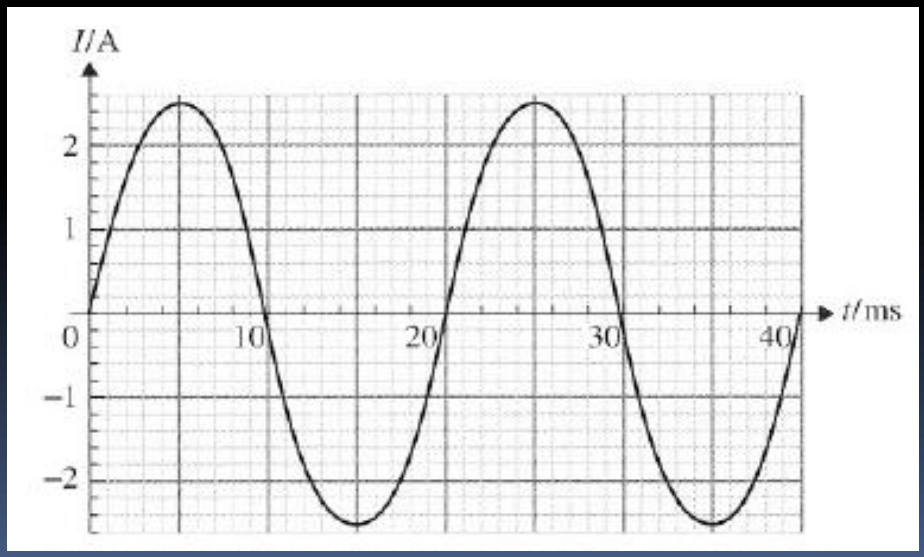
$$P = NBA\sin(\omega t)x\frac{\omega NBA\sin(\omega t)}{R}$$

$$P = \frac{(\omega NBA)^2}{R}\sin^2(\omega t)$$

Root Mean Square (rms)

- Since current and voltage alternate between positive and negative maximums, average current and voltage are always zero
- *How do you find a power rating?*





Root Mean Square (rms)

- Since current and voltage alternate between positive and negative maximums, average current and voltage are always zero
- Root Mean Square
  - Square the values (result always positive)
  - Find the average of the squares
  - Take the square root of the average
- Root – Mean – Square
  - Take square root of the mean of the squares

Root Mean Square (rms)

- Review derivations on page 449 (I'm too tired)

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

$$\varepsilon_{rms} = \frac{\varepsilon_0}{\sqrt{2}}$$

$$\langle P \rangle = \varepsilon_{rms} I_{rms} = \frac{\varepsilon_0}{\sqrt{2}} \frac{I_0}{\sqrt{2}} = \frac{\varepsilon_0 I_0}{2}$$

$$\langle P \rangle = R I_{rms}^2 = \frac{\varepsilon_{rms}^2}{R}$$

Slip-Ring Commutator

- Wires of the loop are attached to separate rings that rotate with the loop
- Separate brushes are pressed against each ring to pick up current

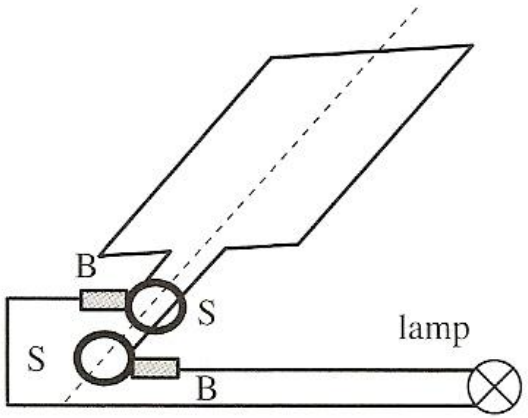


Figure 8.6 The slip-ring connection of the rotating coil to the outside circuit.

Back-emf in the DC Motor

- Magnetic field generates a force on a current-carrying loop of wire
- Since the current generates its own magnetic field, this field also creates an emf in the direction opposite to the current (Lenz's Law)
- The back-emf is at its peak when the motor initially starts to turn, but decreases as rotation increases
- That's why your lights dim when the refrigerator kicks on

Transformers

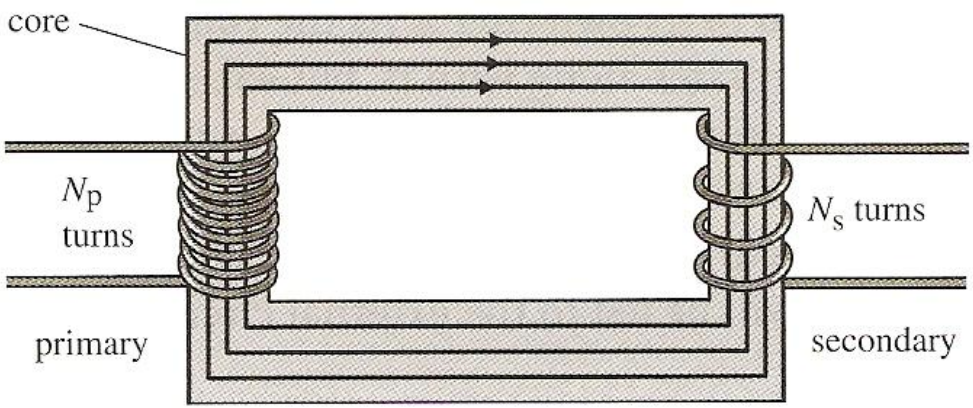


Figure 8.7 The changing flux in the secondary coil produces an emf in that coil.

$$V = N\frac{\Delta\phi}{\Delta t}$$

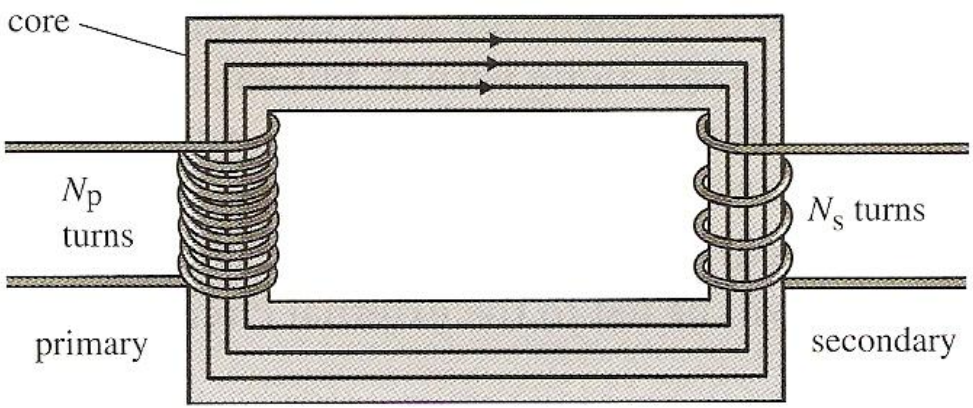
$$\frac{V}{N} = \frac{\Delta\phi}{\Delta t}$$

$$\frac{V_p}{N_p} = \frac{V_s}{N_s}$$

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

- Current in the primary coil generates a magnetic field
- This field is carried to the secondary coil by the iron core
- It then generates an emf/current in the secondary coil
- How?

Transformers



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- Current in the primary coil generates a magnetic field
- This field is carried to the secondary coil by the iron core
- It then generates an emf/current in the secondary coil
- How? -- *AC Current!*

Transformers

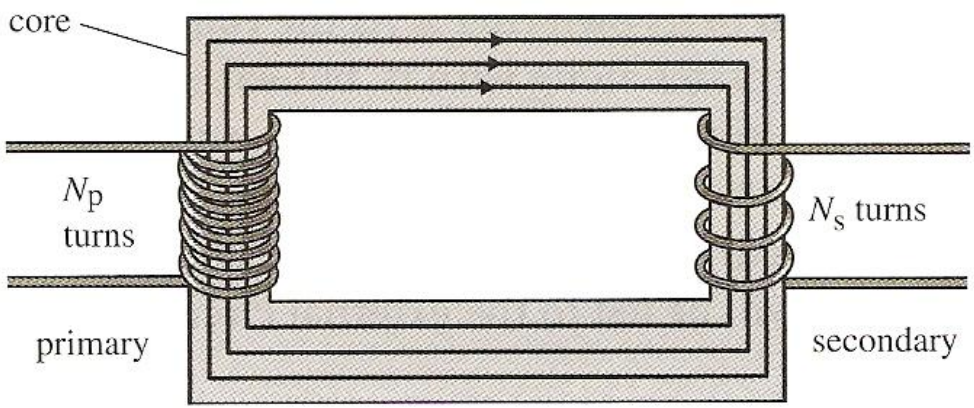


Figure 8.7 The changing flux in the secondary coil produces an emf in that coil.

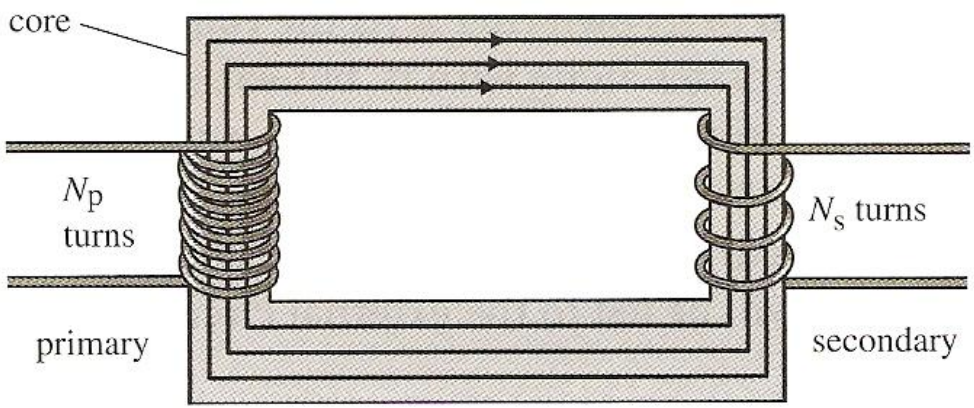
$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

$$V_p I_p = V_s I_s$$

$$\frac{V_p}{V_s} = \frac{I_s}{I_p}$$

$$\frac{N_p}{N_s} = \frac{I_s}{I_p}$$

Transformers



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Transformers and Power Transmission

- Power Demand

$$P = VI$$

- Power Loss

$$P_{loss} = RI^2$$

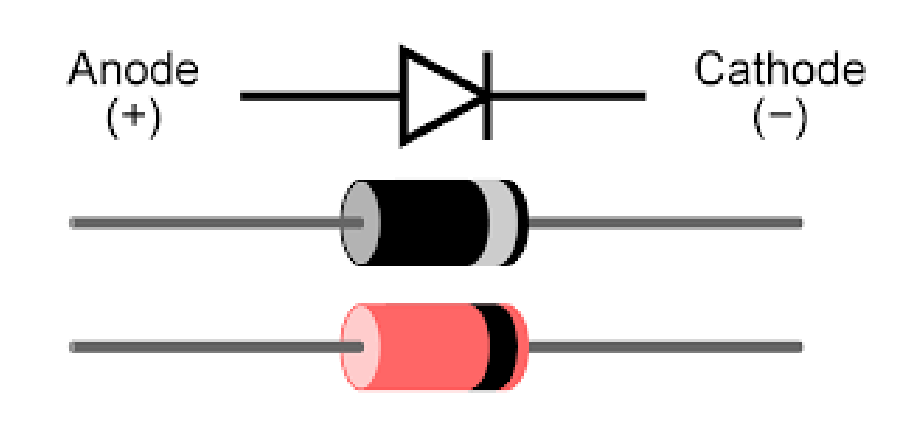
- To minimize loss, minimize current
- To minimize current, maximize voltage

Transformers and Power Transmission

- To minimize loss, minimize current
- To minimize current, maximize voltage
- High tension power lines can carry up to 200,000 volts
- [Almost] everything you plug into an outlet is rated at 110 volts
- Houston, we have a problem
  - Answer: Transformers! (and not the robot kind)

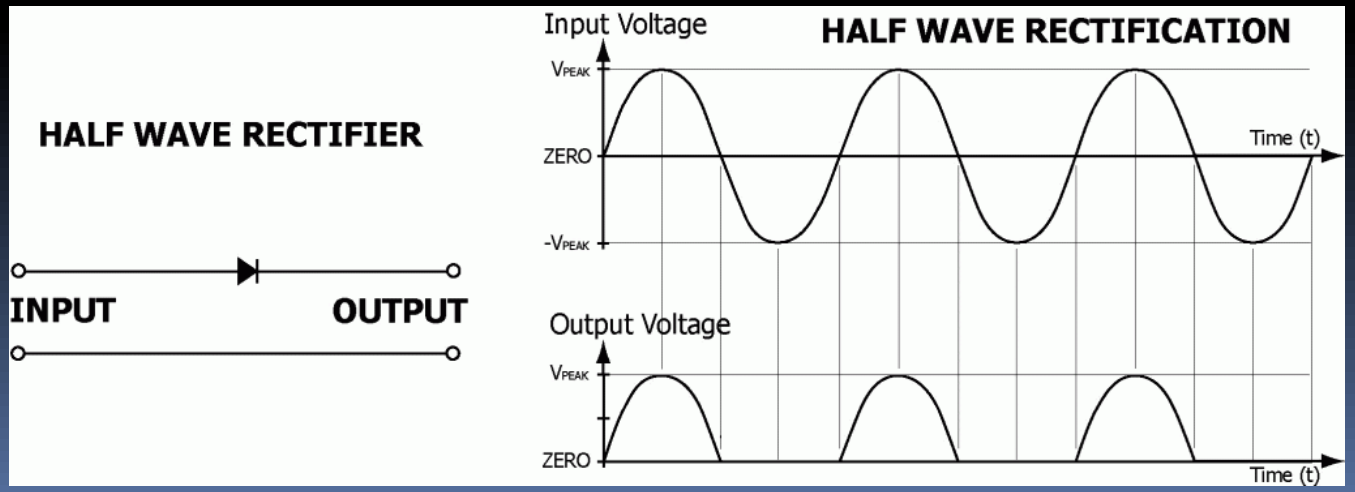
Diode Bridges and Rectification

- Suppose you need to convert ac current into dc current
- One method is to use a diode
- A diode only allows current to pass through it in one direction



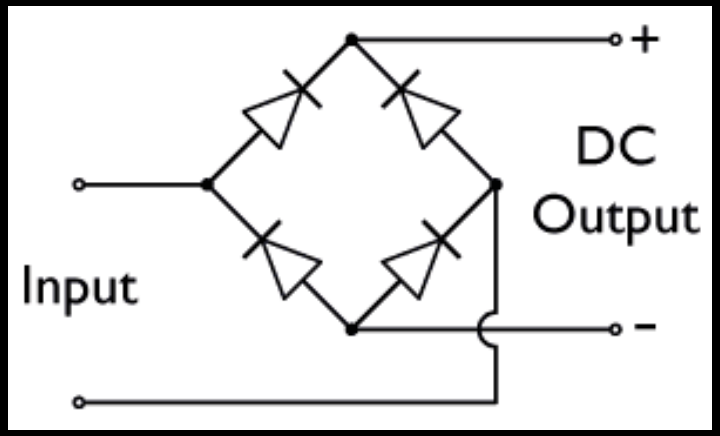
Diode Bridges and Rectification

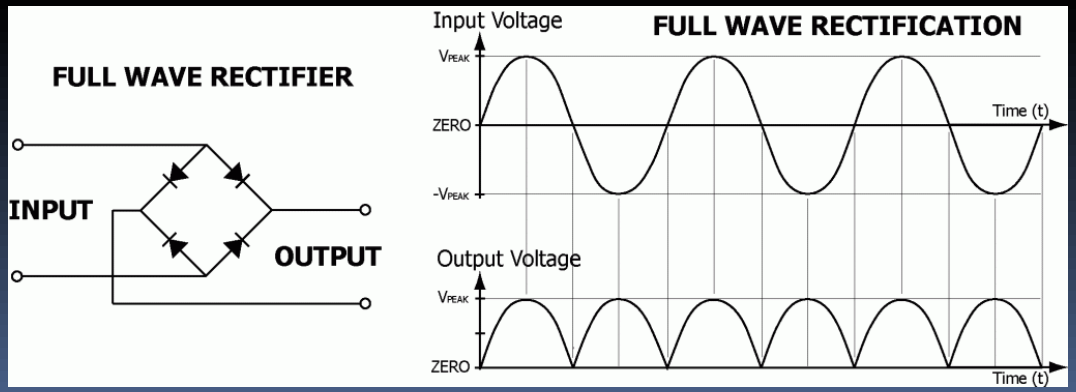
- This is called half-wave rectification because the negative current is not allowed to flow
- The disadvantage to this is you lose half of your power to the output device



Diode Bridges and Rectification

- A diode bridge can create full-wave rectification by capturing current in both directions





Diode Bridges and Rectification

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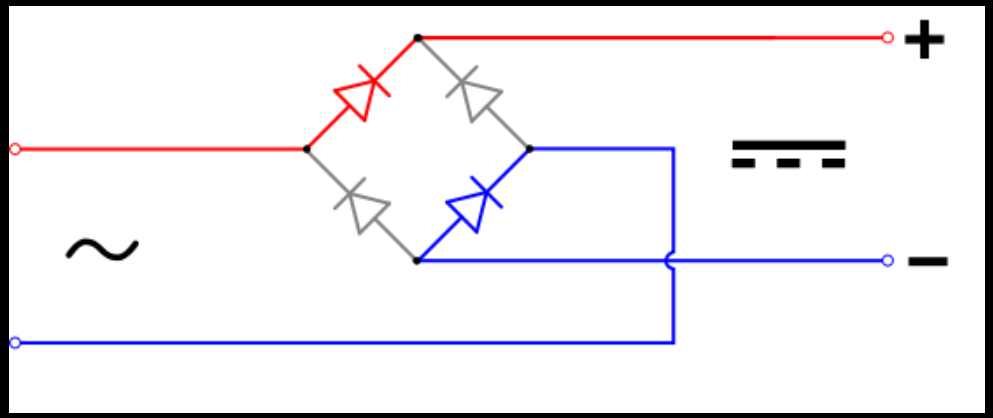
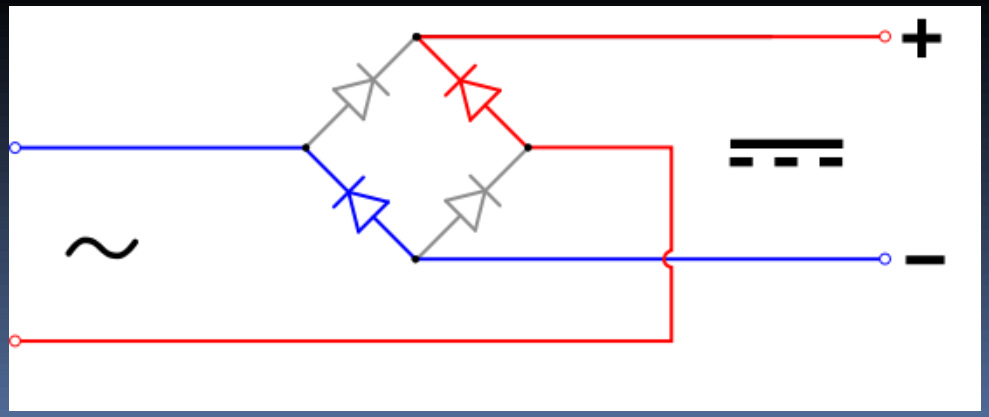


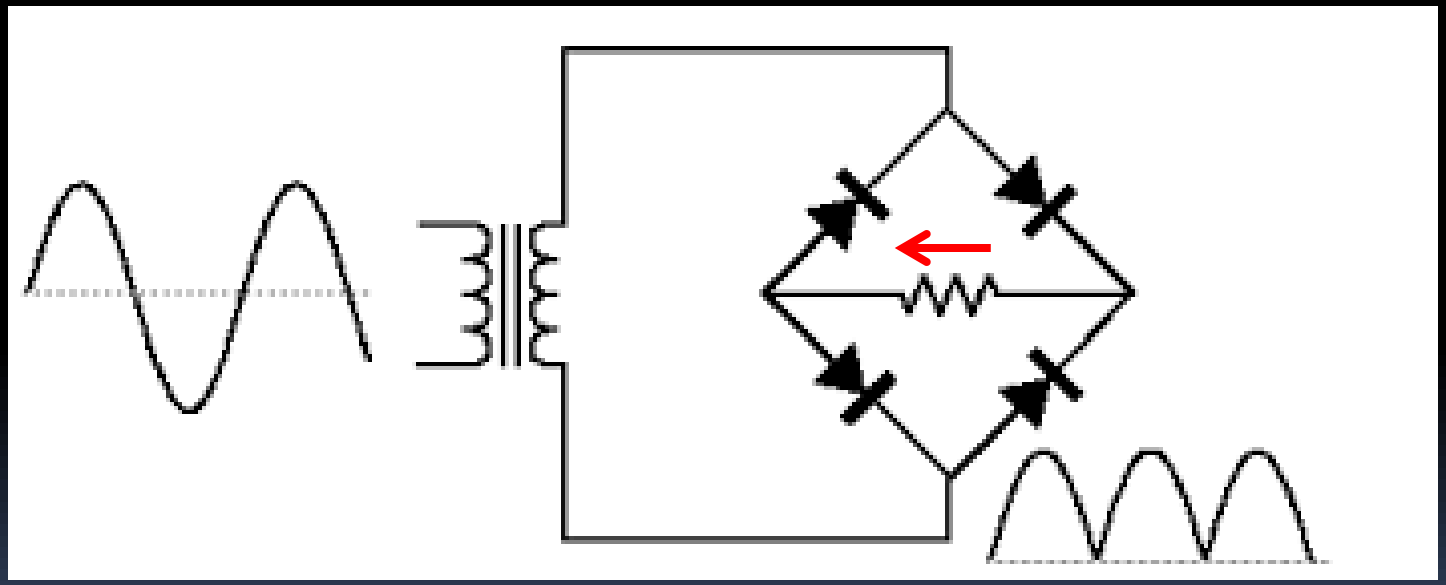


Diode Bridges and Rectification

- https://upload.wikimedia.org/wikipedia/commons/3/34/Diodebridge-eng.gif

Diode Bridges and Rectification

- Alternate depiction



Data Booklet Reference:

- $I_{rms} = \frac{I_0}{\sqrt{2}}$

- $V_{rms} = \frac{V_0}{\sqrt{2}}$

- $R = \frac{V_0}{I_0} = \frac{V_{rms}}{I_{rms}}$

- $P_{max} = I_0 V_0$

- $\bar{P} = \frac{1}{2} I_0 V_0$

- $\frac{\varepsilon_p}{\varepsilon_s} = \frac{N_p}{N_s} = \frac{I_s}{I_p}$

Applications And Skills:

- Explaining the operation of a basic ac generator, including the effect of changing the generator frequency
- Solving problems involving the average power in an ac circuit
- Solving problems involving step-up and step-down transformers

Applications And Skills:

- Describing the use of transformers in ac electrical power distribution
- Investigating a diode bridge rectification circuit experimentally
- Qualitatively describing the effect of adding a capacitor to a diode bridge rectification circuit

Understandings:

- Alternating current (ac) generators
- Average power and root mean square (rms) values of current and voltage
- Transformers
- Diode bridges
- Half-wave and full-wave rectification

Essential Idea:

- Generation and transmission of alternating current (ac) electricity has transformed the world.

QUESTIONS

Homework

#14-21