Physics 12

Generators, Motors, and Transformers

Learning Targets:

I can:

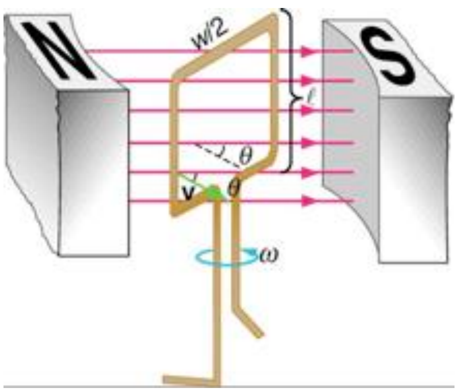
- ✓ Explain how DC motors and generators work
- ✓ Calculate the back EMF in produced by a DC motor
- ✓ Calculate changes in V, I, or N in circuits using transformers

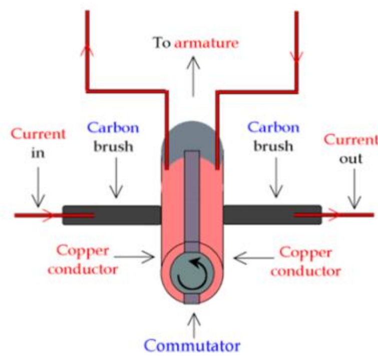
Generators and DC Motors

Electric generators work using similar principles to motors; however, generators __Make__ electrical energy from mechanical motion, while DC motors __Use__ electrical energy to produce motion.

A DC motor is an electronic device that __Converts__ electrical energy from a battery into mechanical energy by __Spinning__ an axel. The basic principle of a DC motor is that a current carrying wire is rotated by a __Magnetic__ field.

i.e.





A DC Motor requires a split-ring __Commutator__ to function. The split-ring commutator allows for a __Change__ in the direction of the __Current__ in the coil. If you didn't change the direction of the current in the coil, the coil would only turn until it found an equilibrium position. The geometry of the commutator makes certain that it keeps __Changing__.

Back EMF in D.C. Motors

A DC motor draws a __high__ current to start. Over time, this current slowly __decreases__ to a constant running current.

This is because, as the armature (coil) starts to turn, the magnetic __Flux__ through the coil __changes__. This changing magnetic flux generates an EMF which acts to __oppose__ the motion (Lenz's law). This EMF which opposes the motion is known as __Back EMF__ and is denoted with the symbol V_{back}. Back EMF is __proportional__ to the __RPM__ of the motor (speed of motor), so as the motor speeds up, V_{back} __Increases__ which reduces the current through the coil until a balance is reached where the speed remains constant. Therefore, the back EMF of the motor controls the __Speed__ of a motor. Without the back EMF the motor would accelerate indefinitely!

*** Note that If we increase the load on the motor, the rpm's decrease, therefore, the V_{back} decreases as well. When V_{back} decreases the current through the coil will increases. (too large of a load could increase the current so that it burns out the motor)***

Calculating Back EMF
Mathematically,

$$V_{back} = \epsilon - Ir$$

Where V_{back} represents the maximum back EMF, ϵ represents the terminal voltage of the source, I represents the current in the wire, and r represents the resistance in the wire.

Example:
120V motor draws 10A when it reaches full speed. If the armature has a resistance of 5.2 Ohms. Find back voltage at full speed. Find Current when motor stalled out.

Full Speed

$V_B = \varepsilon - Ir$

$= 120 - 10(5.2)$

$V_B = 68V$

Stalls

RPM = 0 $\quad V_{Back} = 0$

$V_B = \varepsilon - Ir$

$0 = \varepsilon - Ir$

$Ir = \varepsilon$

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

$I = \frac{120}{5.2}$

$I = 23.1A$

Example:
120v Motor Draws 3.5A at full speed. If it draws 15A when it is turned on what is:
a) The resistance of the armature
b) V_{back} at full speed.

a) Turning on

Rpm = 0 $\Rightarrow V_B = 0$

$0 = \varepsilon - Ir$

$Ir = \varepsilon$

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

$= \frac{120}{15}$

$r = 8\Omega$

Full speed $\Rightarrow V_B \neq 0$

$V_B = \varepsilon - Ir$

$= 120 - (3.5)(8\Omega)$

$V_B = 92V$

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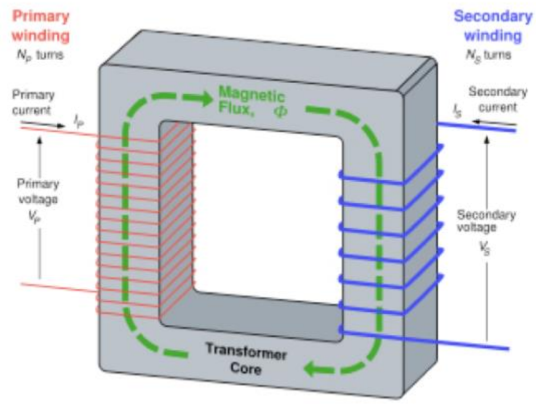
Power Transmission and Transformers

Power lines are often designed to carry a very high Voltage with a low current. This is to minimize power loss. This, however, is not practical as household appliances are designed to use low voltage circuits. To convert a power source from a high voltage to a low voltage you must use a Transformer.



Transformers use alternating current which means that the current direction is constantly Changing. This changing current produces a Changing magnetic field which, means Changing magnetic flux. A changing magnetic flux can be used to induce a current in a different wire.

*****This means DC current will not work*****

*** a transformer that increases the voltage in a circuit is known as a step Up transformer and a transformer that decreases the voltage in a circuit is known as a step down transformer.

→ ONLY WORKS WITH AC

Mathematically, the following relationship exists between the current, voltage, and number of coils in the primary and secondary circuit.

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

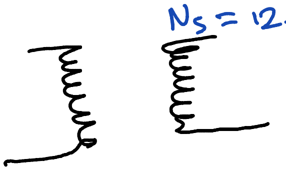
N = # coils

Where the subscript, ***p***, denotes the primary circuit, and the subscript, ***s***, denotes the secondary circuit.

Example:

A transformer has 7500 turns on its primary coil and 125 turns on it's secondary coil. The voltage across the primary coil is 7.2kv.

a) What is the voltage across the secondary?
b) If the current in the secondary is 36A, what is the current in the primary?
c) What type of transformer is it?



$N_s = 125$

$N_p = 7500$

$V_p = 7.2 \times 10^3 V$

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

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

$\frac{(125)(7.2 \times 10^3)}{7500} = V_s$

$120V = V_s$

b) $I_s = 36A$

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

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

$\frac{(125)(36)}{7500} = I_p$

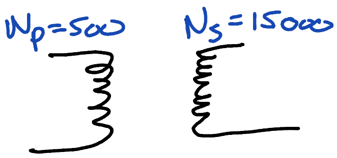
$0.6A = I_p$

c) $V_s < V_p$

$\Rightarrow$ Step down

Example:
A transformer has 500 turns on the primary coil and 15000 on the secondary coil.

a) If the primary side is connected to 120V, what is the secondary voltage?
b) If the secondary has a current of 3.0A, what current is in the primary?
c) What is the power input and output?



a) $V_p = 120$

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

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

$$\frac{(120)(15000)}{500} = V_s$$

$$\boxed{3600\ V = V_s}$$

b) $I_s = 3A$

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

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

$$\frac{(3)(15000)}{500} = I_p$$

$$\boxed{90A = I_p}$$

c)

$P_p = IV$

$= (90)(120)$

$= 10{,}800W$

$P_s = IV$

$= (3)(3600)$

$= 10{,}800W$

☆ This is for an IDEAL Transformer ☆