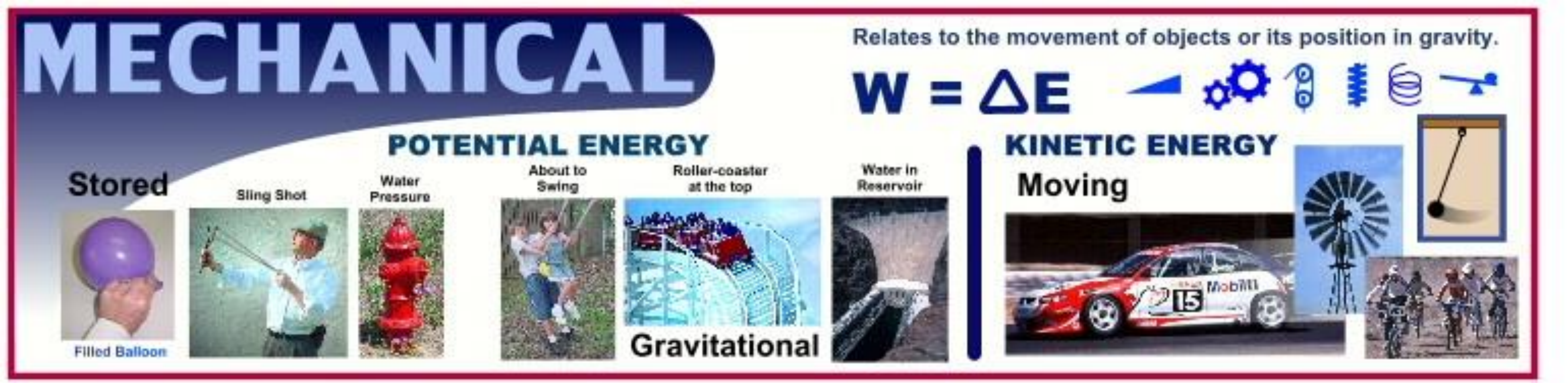
Electrical Machines

ENERGY CONVERSION

- Takes place between well known **pairs** of **forms of energy**

FORMS OF ENERGY



FORMS OF ENERGY

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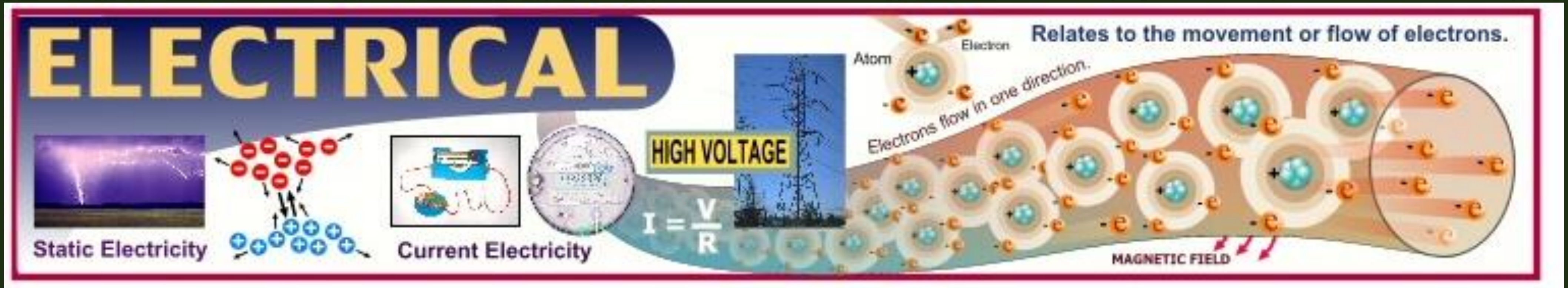

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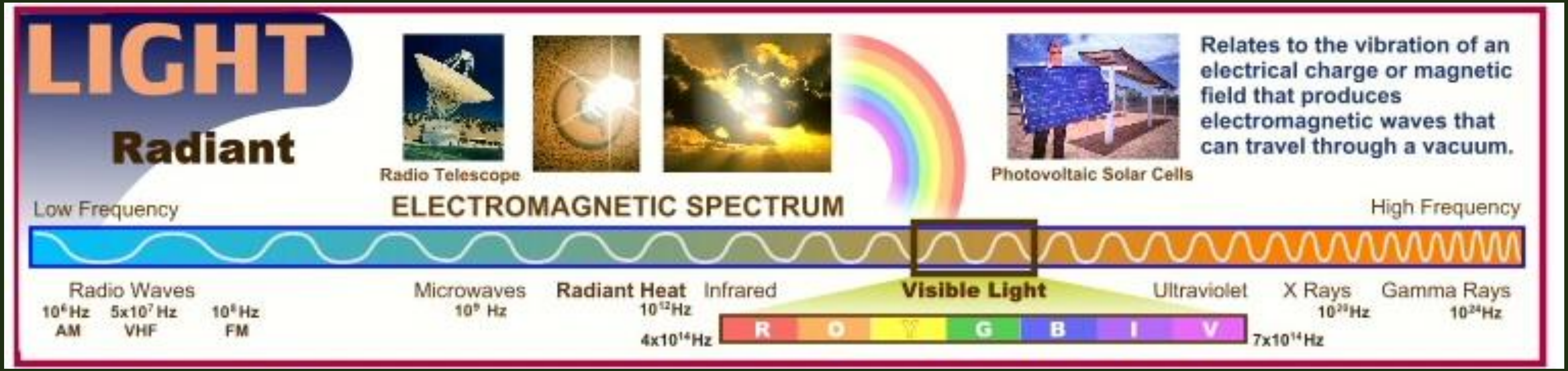
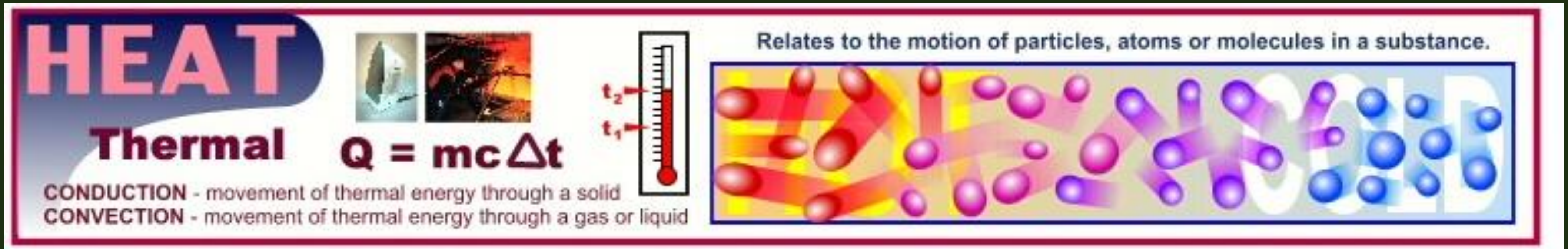
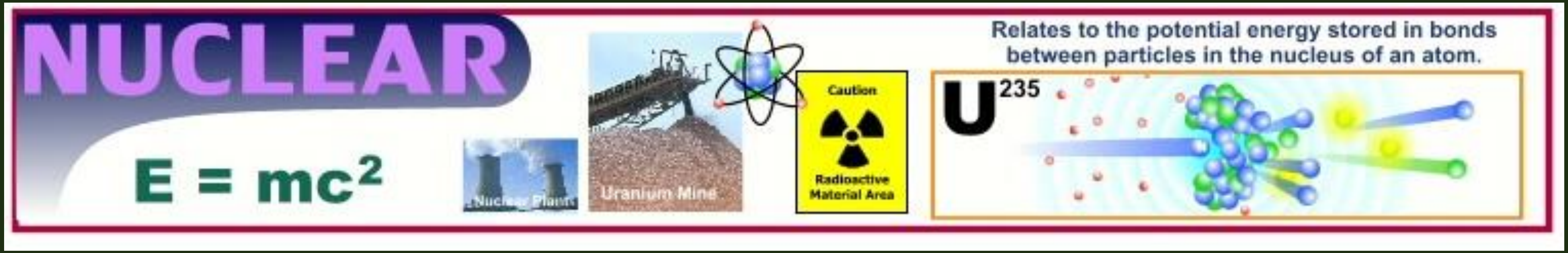


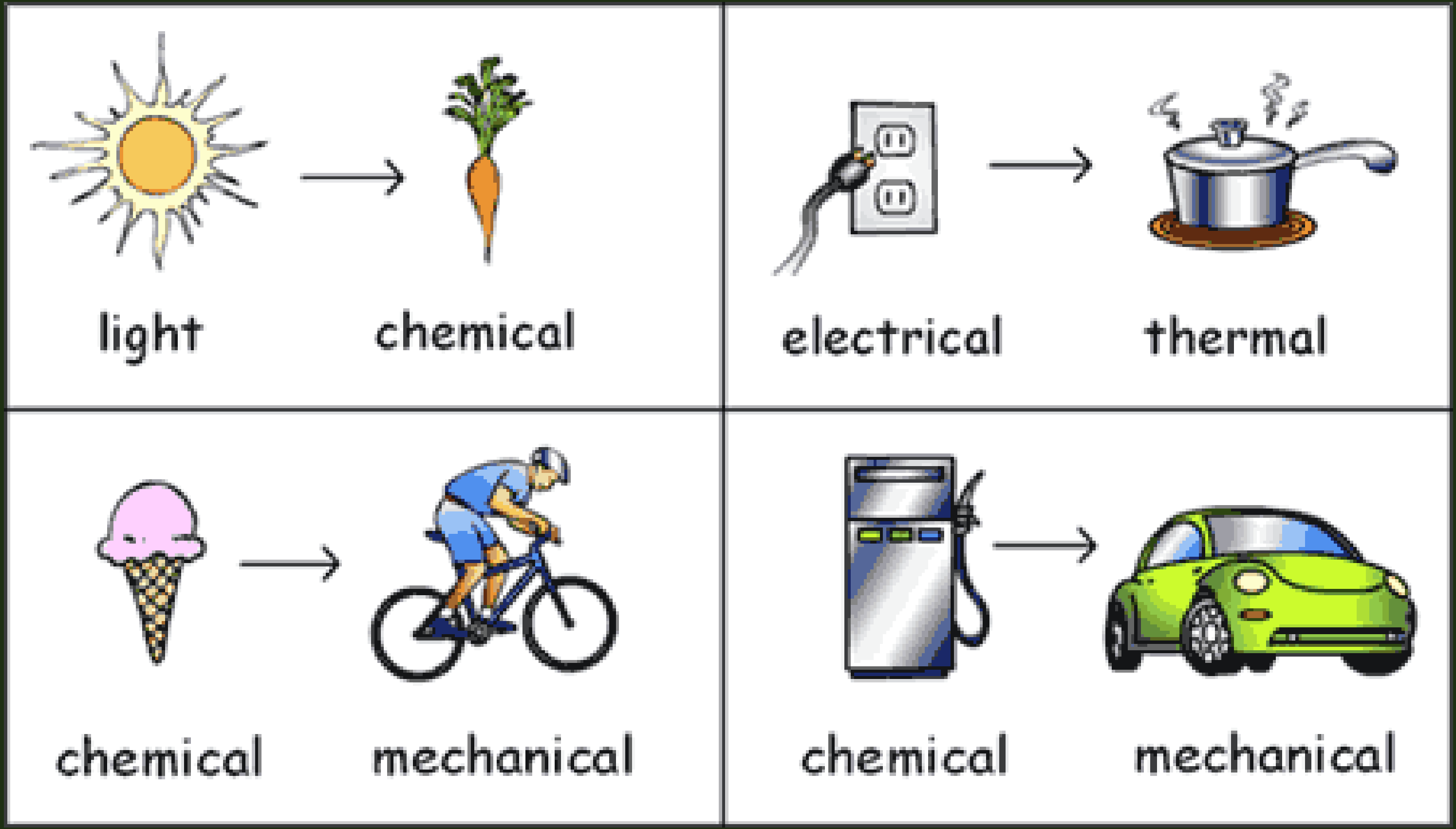
FORMS OF ENERGY



FORMS OF ENERGY



Energy Conversion



Energy Conversion Matrix

Energy Conversion Matrix

FROM ⇓ TO ⇒	Thermal	Mechanical	Acoustical	Chemical	Electrical & Magnetic	Electromagnetic Radiation	Nuclear	Elastic	Gravitational
Thermal	• Heat exchangers • Thermal conduction	• Steam turbine • Heat engines • Wind • Radiometer		• Endothermic reaction • "Cold packs"	• Thermo-electric effect • Thermionic emission	• Thermocouple • Incandescence	• Thermionic emission		• Convection • Hot air balloon • Popcorn
Mechanical	• Refrigerator • Heat pump • Brakes	• Gear box			• Wind turbine • Generator • Microphone	• X-ray tube		• Wishbone • Inflating a balloon	• Pendelum • B-ball pop fly
Chemical	• Furnace • Combustion • Exothermic reaction • "Hot packs"	• Combustion engines • Muscle action • Dynamite	• Chemical explosion	• Glycolysis • ADP to ATP • AMP to ADP	• Fuel cell • Chemical battery	• Bio-luminescence • Chemical lasers • Fireflies • Glowsticks		• Combustion expanding gas	• Rocket
Electrical & Magnetic	• Electric heater • Toaster	• Motor • Thunder		• Electrolysis • Electro-plating • Rechargeable batteries	• Transformer	• Lamp • LED • Radio broadcast		• Electrostriction • Magneto-striction	• Elevator
Electromagnetic Radiation	• Solar collector • Microwave oven	• Photoelectric effect		• Plants • Photography • Sunburn	• Solar cell	• Photo-luminescence			• Microwave popcorn
Nuclear	• Nuclear bomb • Fission reactor	• Nuclear bomb	• Nuclear bomb	• Nuclear bomb	• Nuclear bomb • Nuclear generator	• Nuclear bomb • Stars	• Nuclear bomb • Breeder reactor		• Nuclear propulsion
Elastic	• Compression of gas refrigerator	• Spring driven wristwatch • Bow & arrow			• Peizo-electric effect	• Peizo-luminescence		• Newton's cradle	• Trampoline • Toaster
Gravitational	• Contraction of a protostar	• Flowing water • Pendelum			• Hydropower		• Formation of a neutron star	• diving board	• One period of satellite orbit

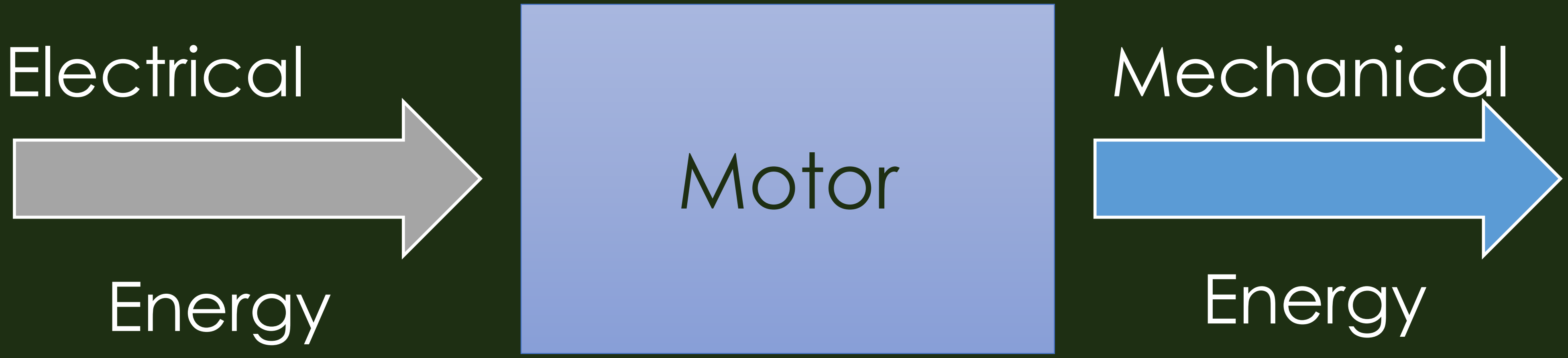
Machine

- a tool containing one or more parts that uses energy to perform an intended action.

Dynamo

- a rotating machine for converting mechanical energy into electrical energy, or the reverse process, electrical energy into mechanical energy.

Dynamo

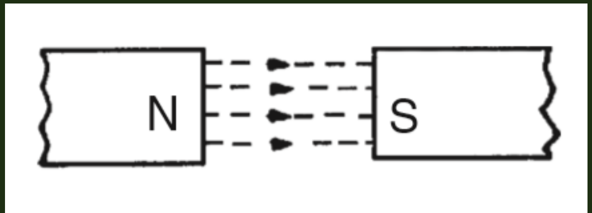


Construction and Operation of DC Generator

Faraday's Law of Electro Magnetic Induction

First Law:

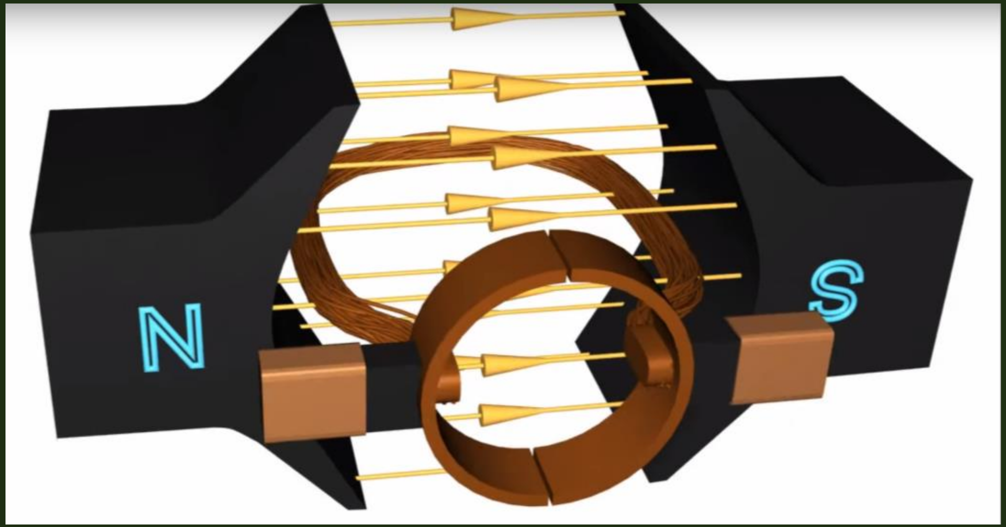
Whenever a conductor cuts magnetic flux an E.M.F is induced in that conductor.



Faraday’s Law of Electro Magnetic Induction

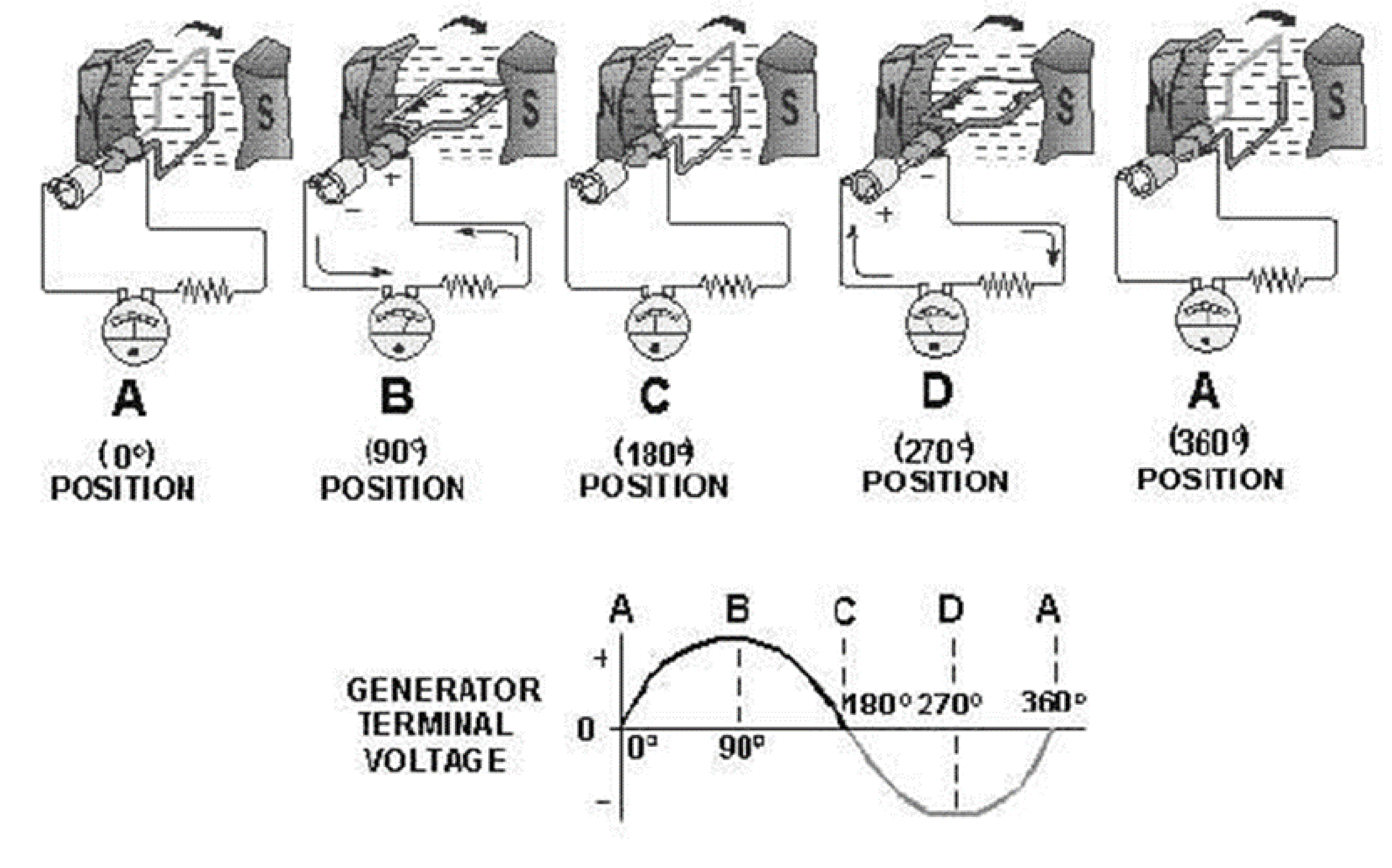
Second Law:

The magnitude of the induced e.m.f. is equal to the rate of change of flux linkage.

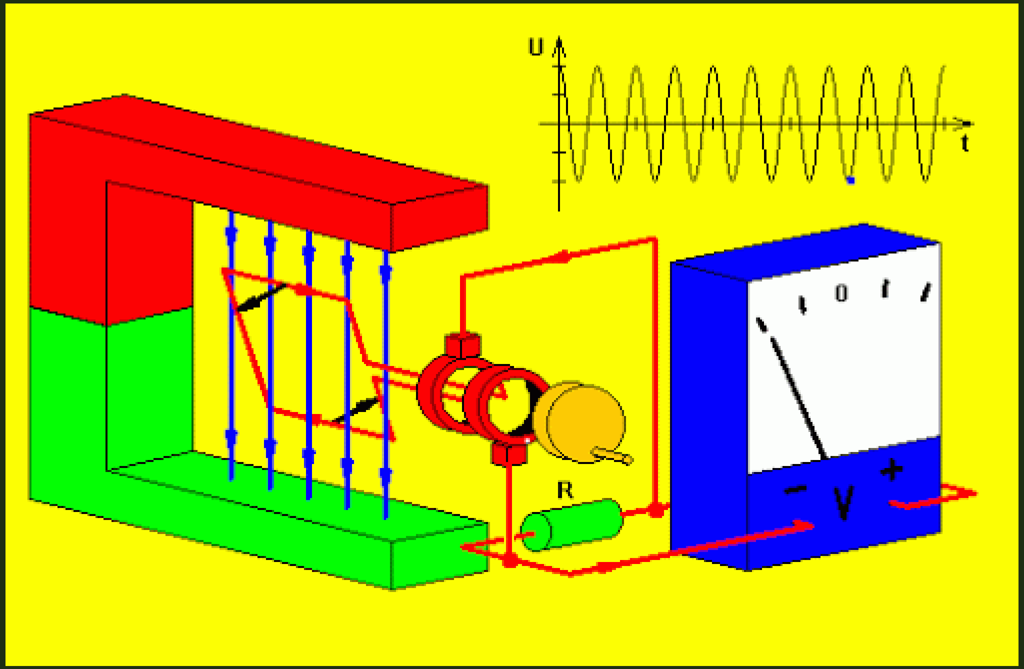


Faraday's Law of Electro Magnetic Induction

Generated EMF

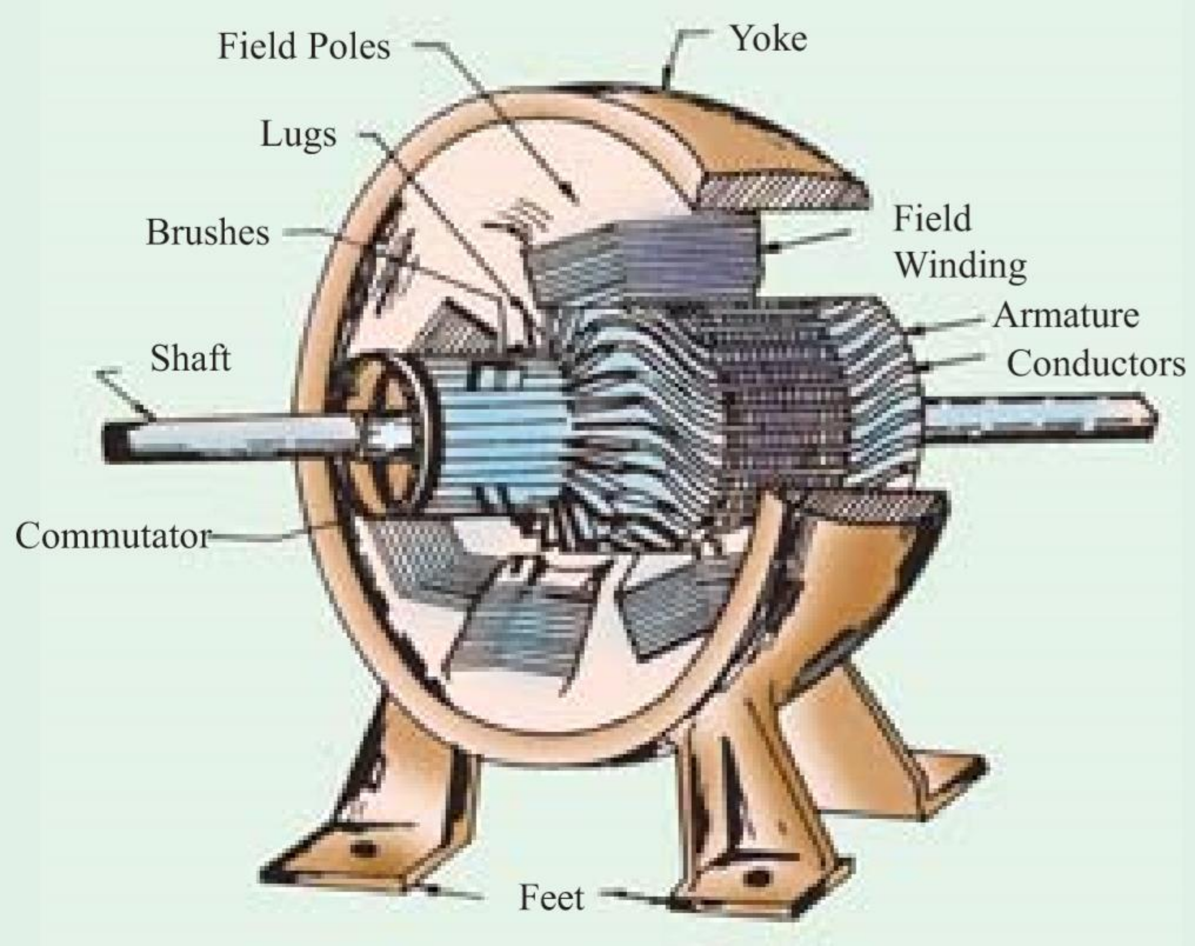


Electromechanical Energy Conversion



CONSTRUCTION OF DC GENERATOR

DC Generator



Two Major Parts of a Dynamo

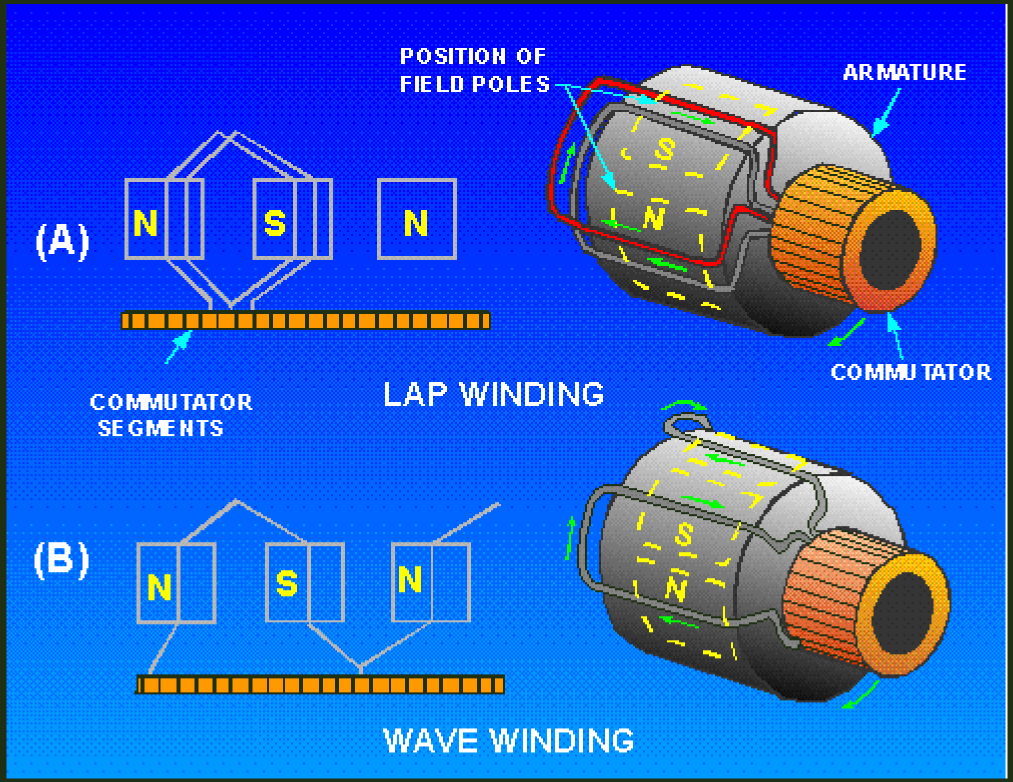
- Stator
  - That portion which is stationary
  - The most important part of which is the field winding

Two Major Parts of a Dynamo

- Rotor
  - That portion which rotates
  - The most important part of which is the armature winding

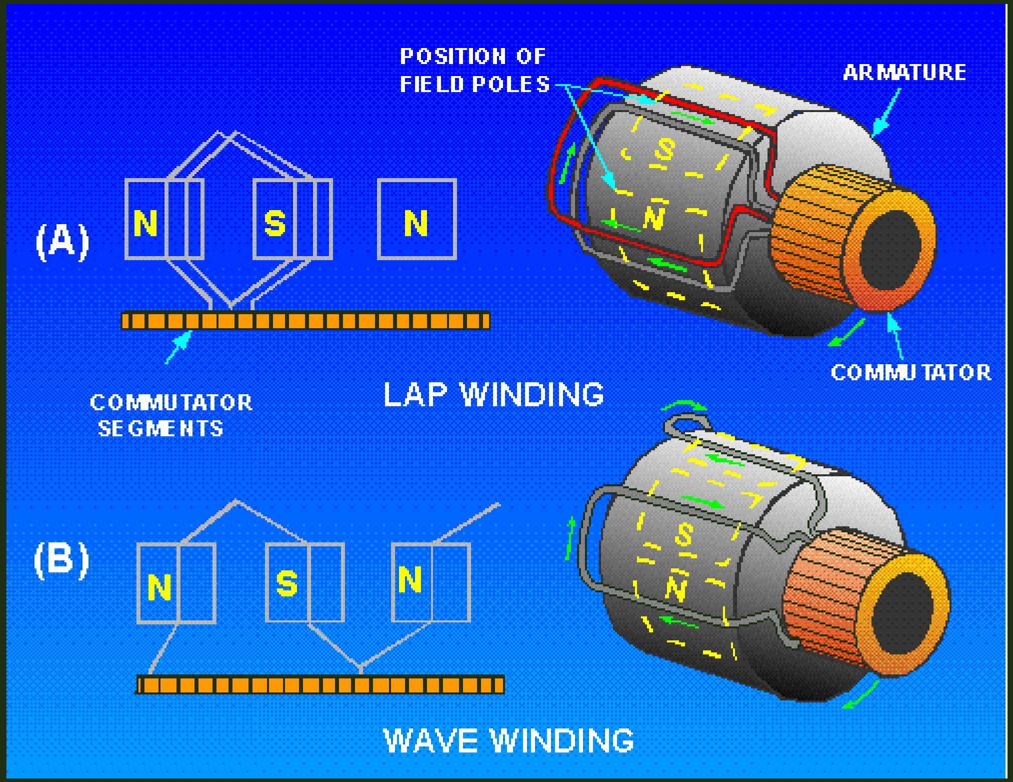
Types of Armature Windings

- Lap winding
  - It forms a loop as it expands around the armature core

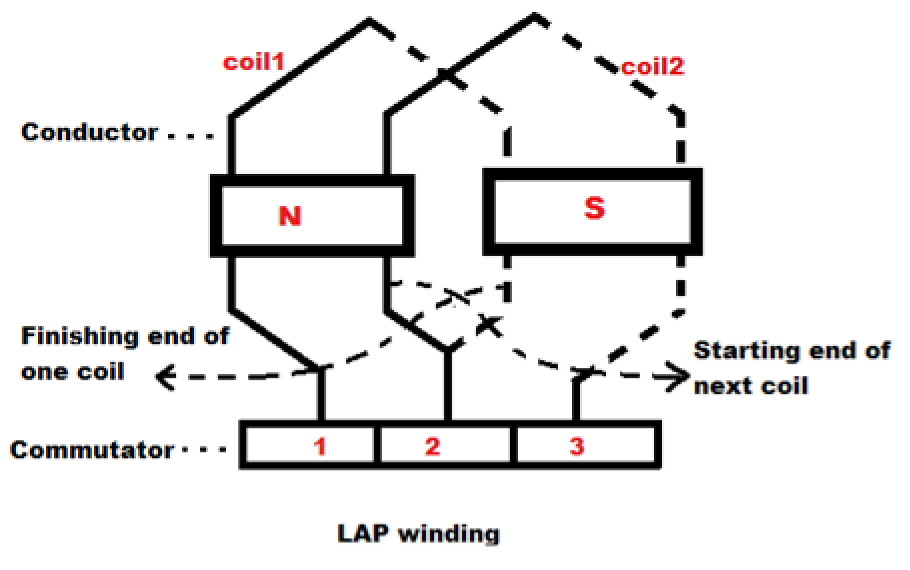


Types of Armature Windings

- Wave winding
  - It forms a wave as it expands around the armature core

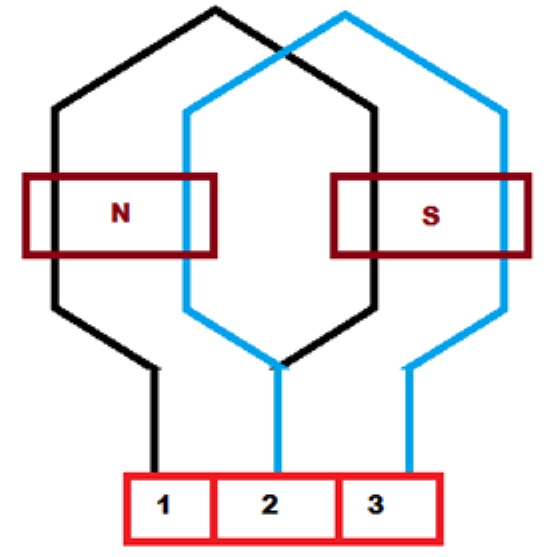


Lap Winding



- In this winding the finishing end of one coil is connected to one commutator segment and the starting end of the next coil situated under the same pole and connected with same commutator segment.

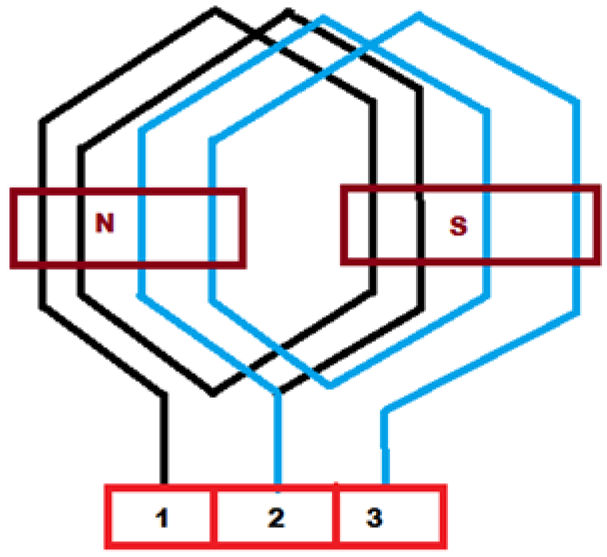
Lap Winding



Simplex lap winding

A winding in which the number of parallel path between the brushes is equal to the number of poles

Lap Winding



Duplex lap winding

Equations:

Number of parallel paths = multiplicity x Poles

$$a = mP$$

Where:

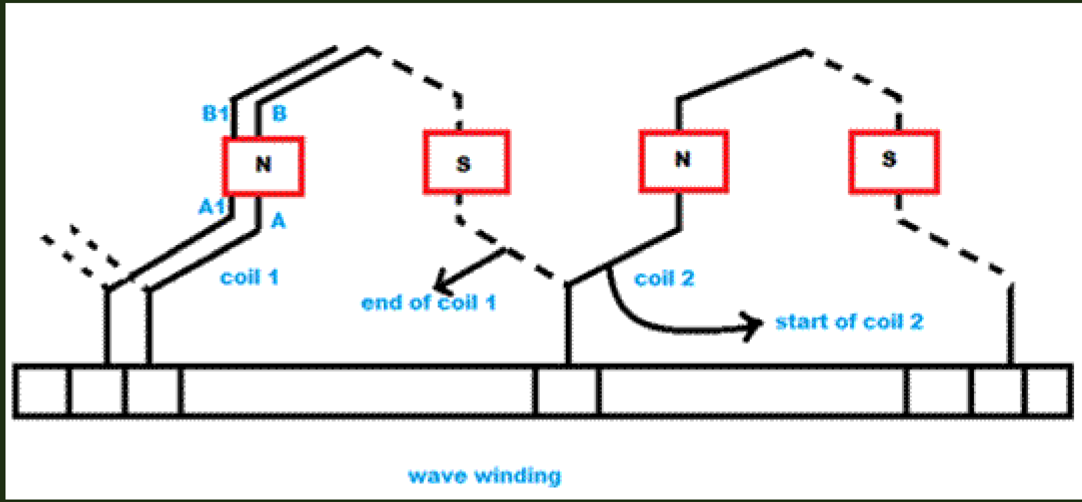
m = multiplicity factor

=1, for simplex winding

=2, for duplex winding… etc.

- A winding in which the number of parallel path between the brushes is twice the number of poles

Wave Winding



- two ends of each coil are connected to commutator segments separated by the distance between poles

Equations:

Number of parallel paths = multiplicity x 2

$$a = m2$$

Where:

m = multiplicity factor
=1, for simplex winding
=2, for duplex winding… etc.

Principle of Generator Action

- The principle of generator action requires

1. The presence of magnetic lines of force
2. Motion of conductors cutting the flux
3. Voltage is generated

Principle of Generator Action

- When a conductor moves at a constant speed across a uniformly dense magnetic field,

$\boxed{\text{1 volt is generated for every 100,000,000 } (10^8) \text{ lines cut per second}}$

Principle of Generator Action

If the flux density is not constant, the average generated voltage will be

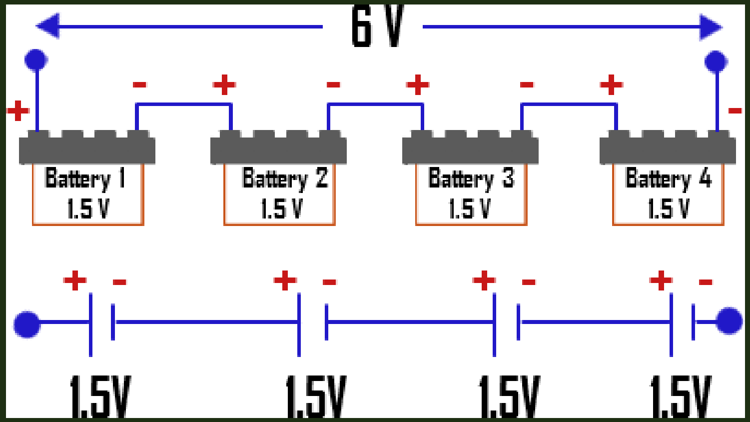
$$\boxed{E_{ave} = \frac{\emptyset}{t \times 10^8} \quad volts}$$

Where

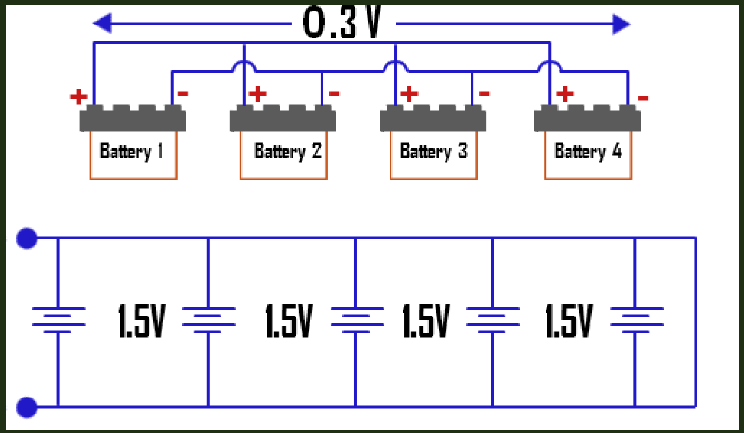
E_{ave}	Average generated voltage in a conductor	Volts
$\emptyset$	Total flux cut	Lines
t	time, during which cutting takes place	seconds

of Conductors vs # of Parallel Paths

- NOTE: the generated voltage is determined only by the "string of conductors joined in series and not by the number pf parallel paths through the current may pass.



- The situation existing in a generator with regards to voltage and current is analogous to dry-cell connections.



of Conductors vs # of Parallel Paths

Example: If voltage and current ratings of 1.5 volts and 5 amperes are assured per cell, determine the relative ratings of 120 cells connected when the number of parallel paths is a.) 2 b.) 4 c.) 6 d.) 8

The power rating is independent of the manner in which the cells or conductors are connected.

Problems

1. A four-pole DC generator has an armature winding containing a total of 648 conductors connected in two parallel paths. If the flux per pole is 0.321×10^6 maxwells and the speed of rotation of the armature is 1800 rpm, calculate the average generated voltage.

   Answer: 125 V

Problems

2. In Problem 1, calculate the rated current in each conductor if the power delivered by the armature is 5kW.

   Answer: 20 A

General Voltage Equation for DC Generator

$$\boxed{\bullet\, E_g = \frac{\emptyset \times P \times N \times Z}{a \times 60} \times 10^{-8} \qquad volts}$$

Where

E_g	Total **generated voltage**	Volts
$\emptyset$	**Flux per pole**	maxwells
P	**Number of poles**, an even number	Unitless
N	**Speed** of armature	rpm
Z	Total number of **armature conductors** effectively used to add to resulting voltage	Unitless
a	Number of armature **paths connected in parallel** (determined by the type of armature winding)	unitless

Problems

1. A four-pole generator, having wave-wound armature winding has 51 slots, each slot containing 20 conductors. What will be the voltage generated in the machine when driven at 1500 rpm assuming the flux per pole to be 7.0 mWb ?

- Answer: 357 V

Problems

2. An 8-pole d.c. generator has 500 armature conductors, and a useful flux of 0.05 Wb per pole. What will be the e.m.f. generated if it is lap-connected and runs at 1200 rpm ? What must be the speed at which it is to be driven to produce the same e.m.f. if it is wave-wound?

Answer: $E_g = 500V$, $N_{wave} = 300rpm$

Problems

3. The armature of a four-pole shunt generator is lap wound and generates 216 volts when running at 600 rpm. The armature has 144 slots, with six conductors per slot. If this armature is rewound, wave connected, find the emf generated at the same speed and flux per pole.

Answer: $E_g = 432V$