EECE-165
Basic Electrical Technology
References

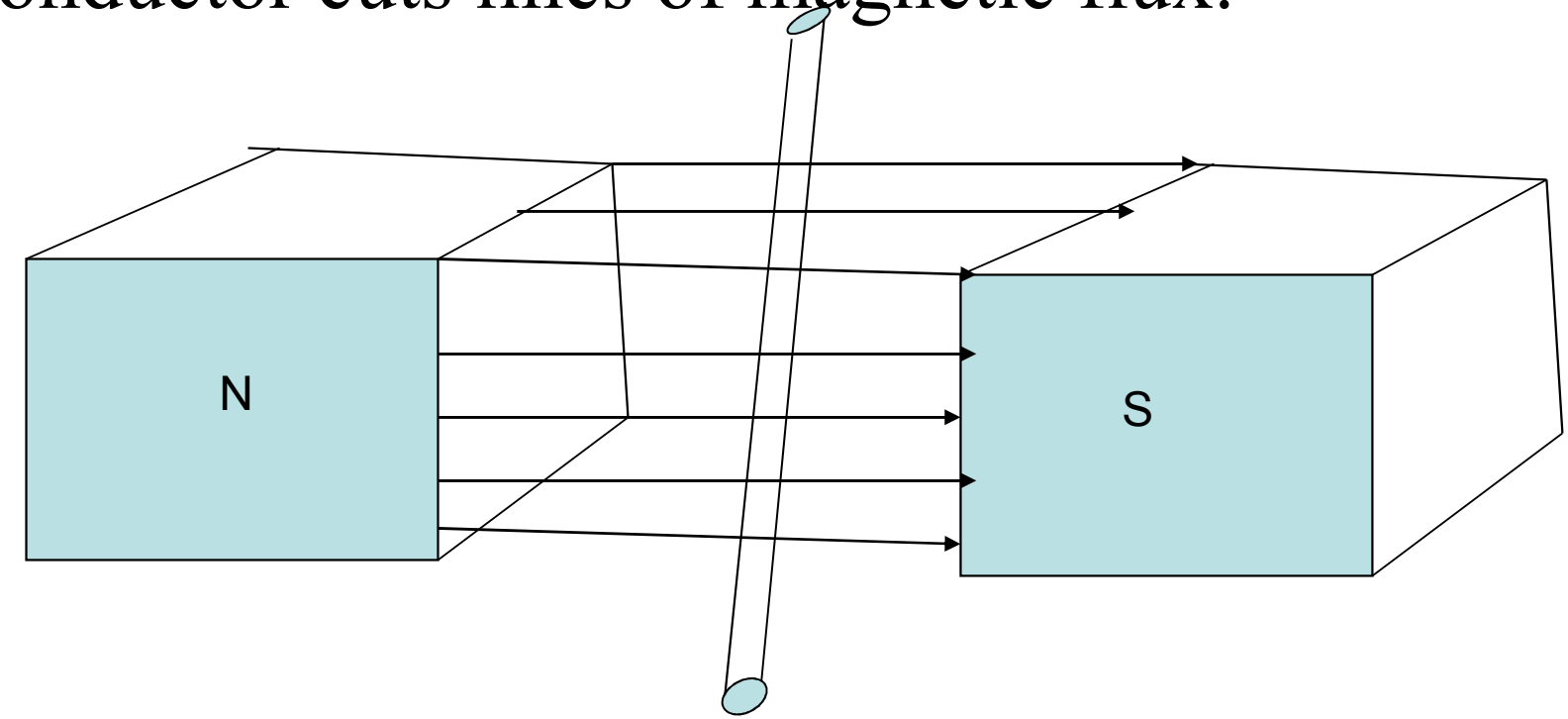
1. A textbook of Electrical Technology (Vol.II)
-B. L. Theraja
2. Electronic Devices & Circuit Theory-R.L. Boylstad

Introduction to Electrical Engineering

WELCOME TO THE LECTURE ON DC GENERATOR

Faraday's law of Electromagnetic Induction

- A voltage is induced in a conductor if the conductor cuts lines of magnetic flux.



Lenz's Law

- When a conductor is moved through a magnetic fields a voltage is induced in the conductor .If the circuit is closed, the induced voltage will cause a current flow. The magnetic field produced by the current will always oppose the motion of the conductor.

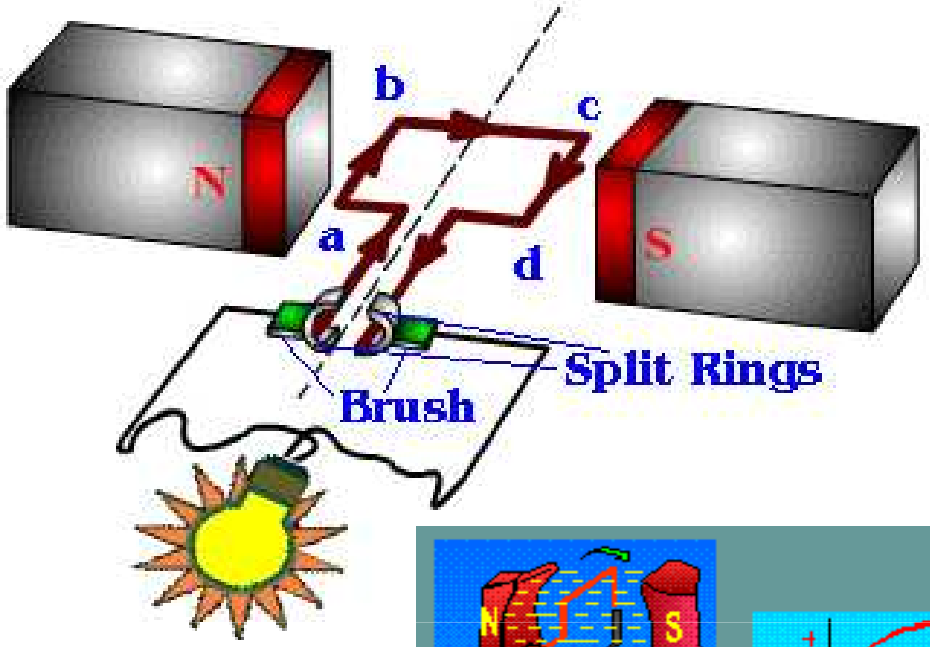
DC Generators

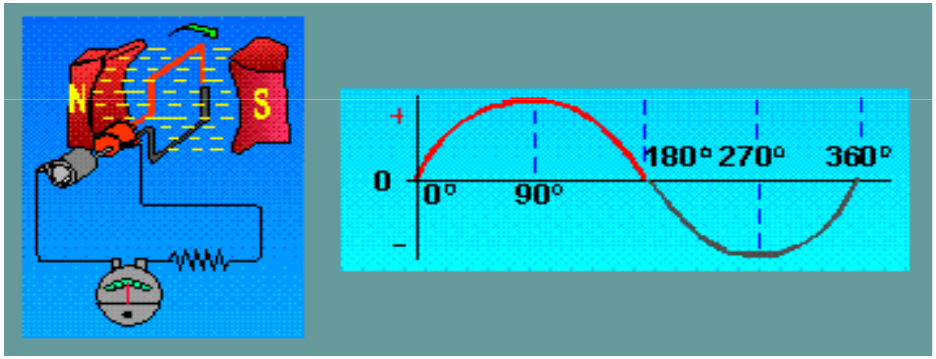
- **An electrical Generator is a machine which converts mechanical energy (or power) into electrical energy (or power).**
- **Principle :**

It is based on the principle of production of dynamically (or motionally) induced e.m.f (Electromotive Force). Whenever a conductor cuts magnetic flux, dynamically induced e.m.f. is produced in it according to Faraday's Laws of Electromagnetic Induction. This e.m.f. causes a current to flow if the conductor circuit is closed.

Hence, the basic essential parts of an electric generator are :

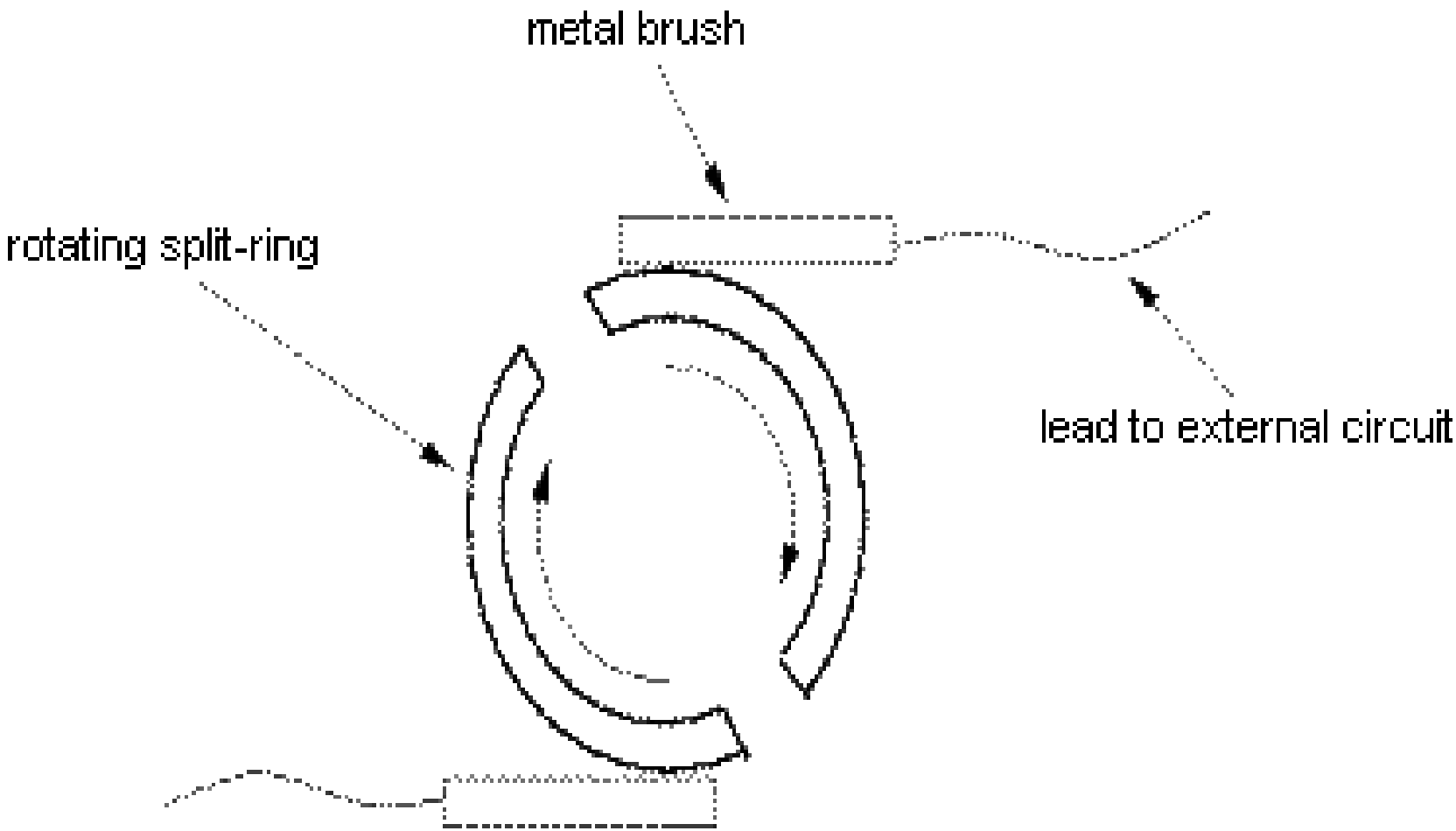
- **A magnetic field and**
- **A conductor or conductors which can so move as to cut the flux.**

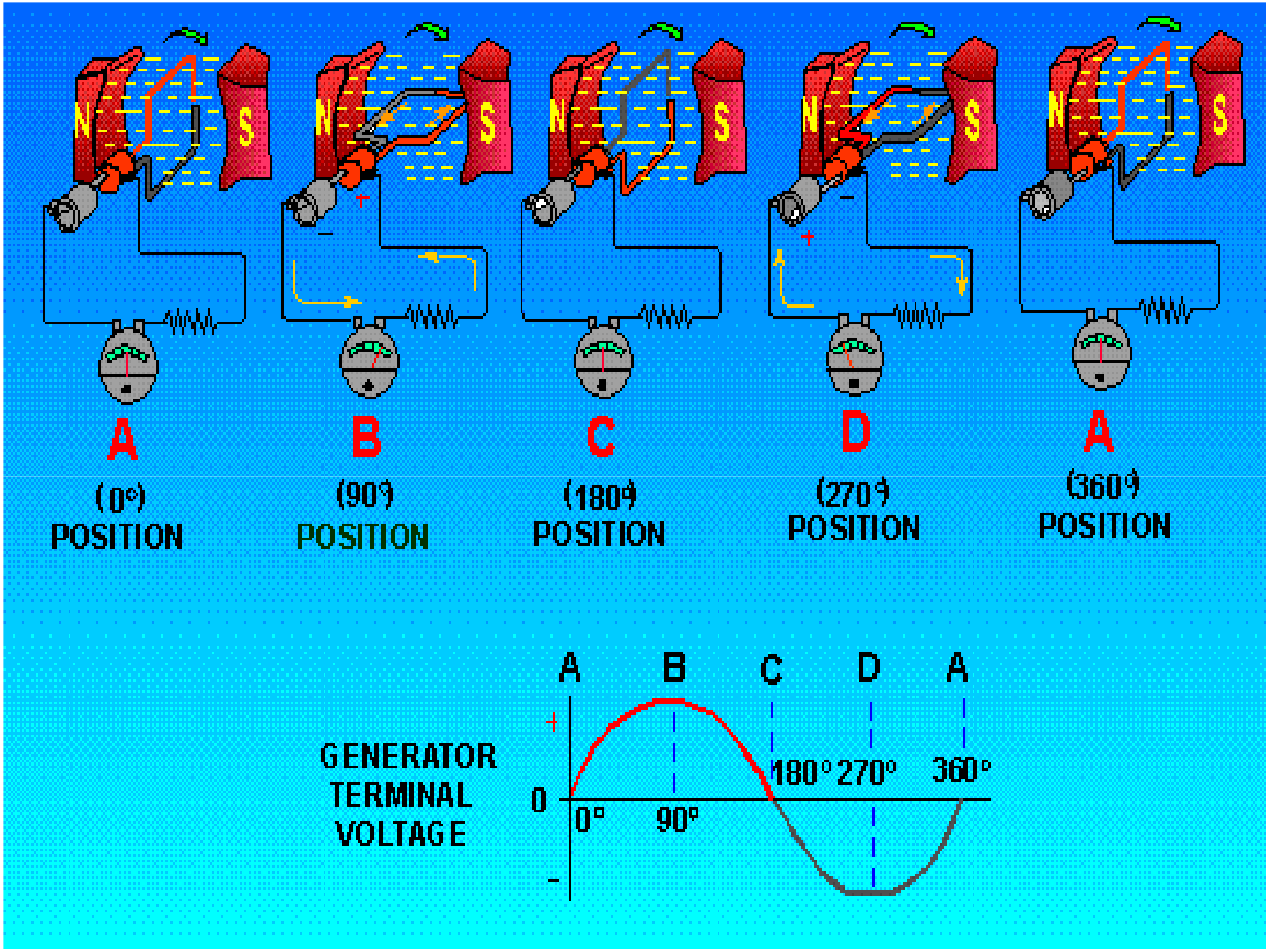




- **A single-turn rectangular copper coil abcd moving about its own axis in a magnetic field provided by either permanent magnets or electromagnets. The two ends of the coil are joined to two split-rings which are insulated from each other and from the central shaft. Two collecting brushes (of carbon or copper) press against the slip rings.**

Split ring

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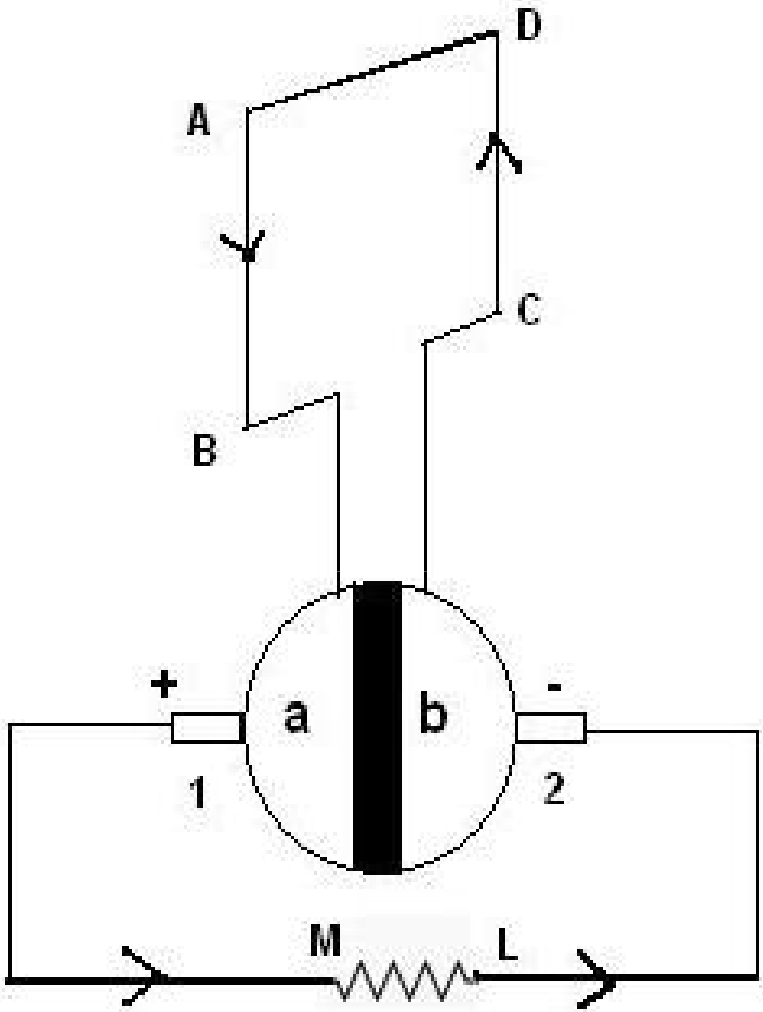


Fig.(a)

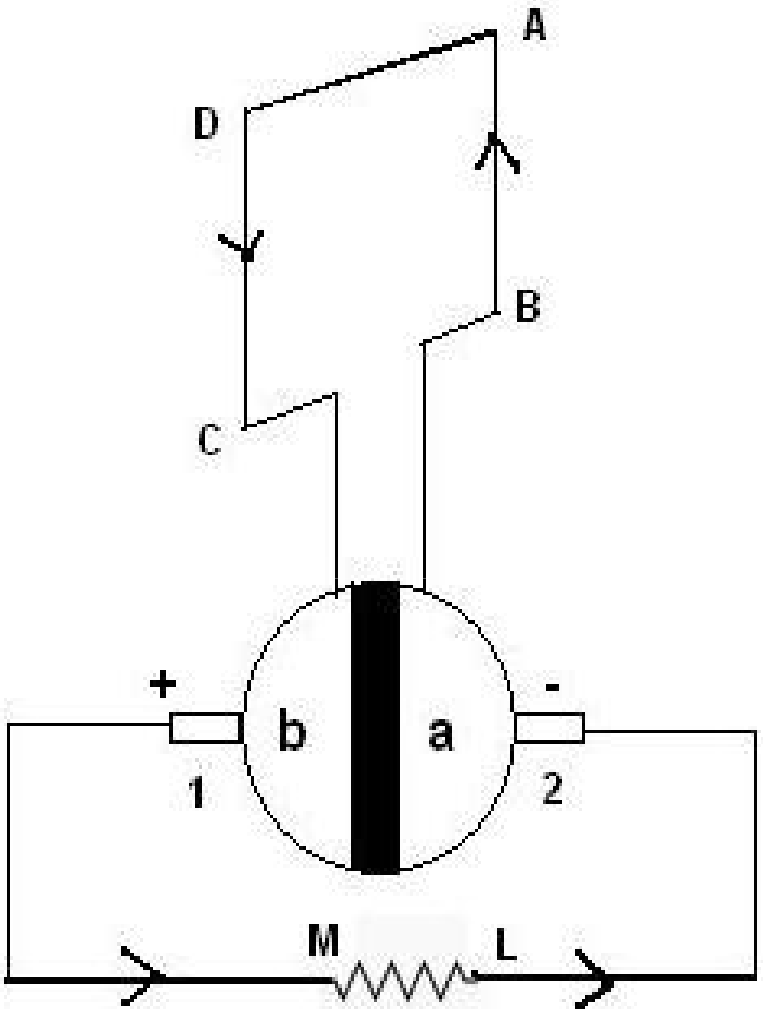
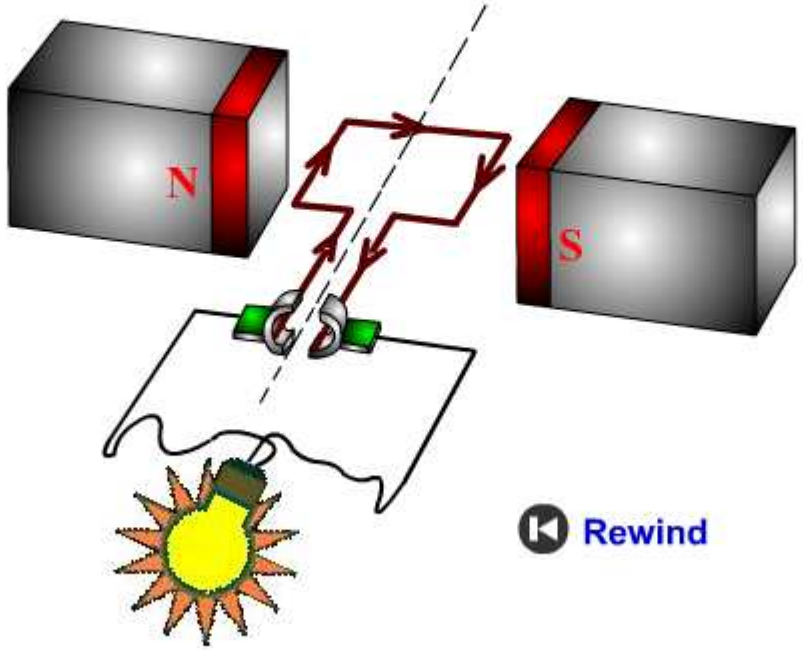


Fig.(b)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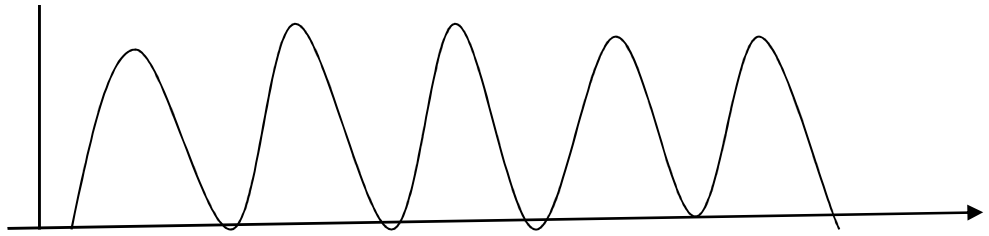

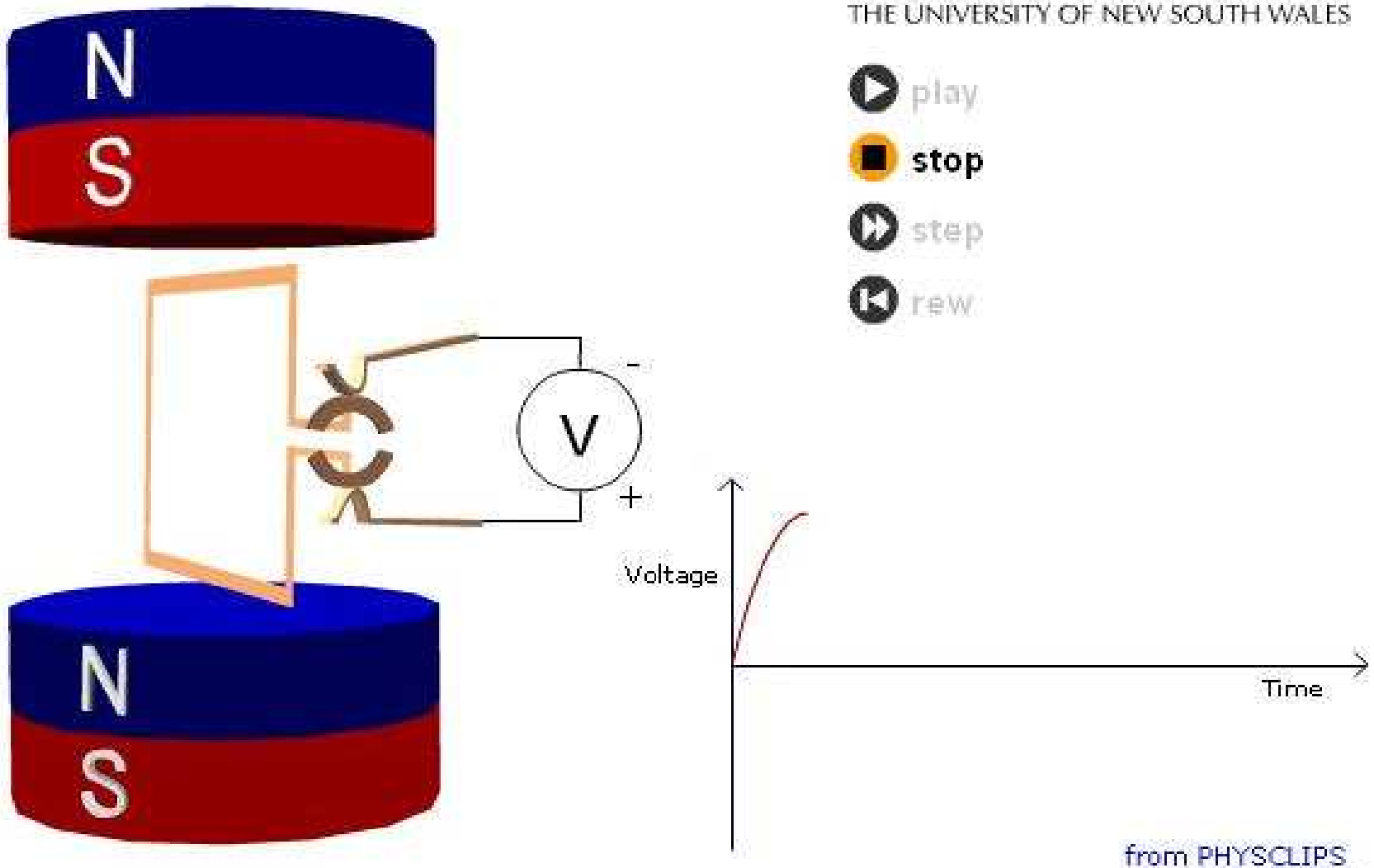

THE UNIVERSITY OF NEW SOUTH WALES

play

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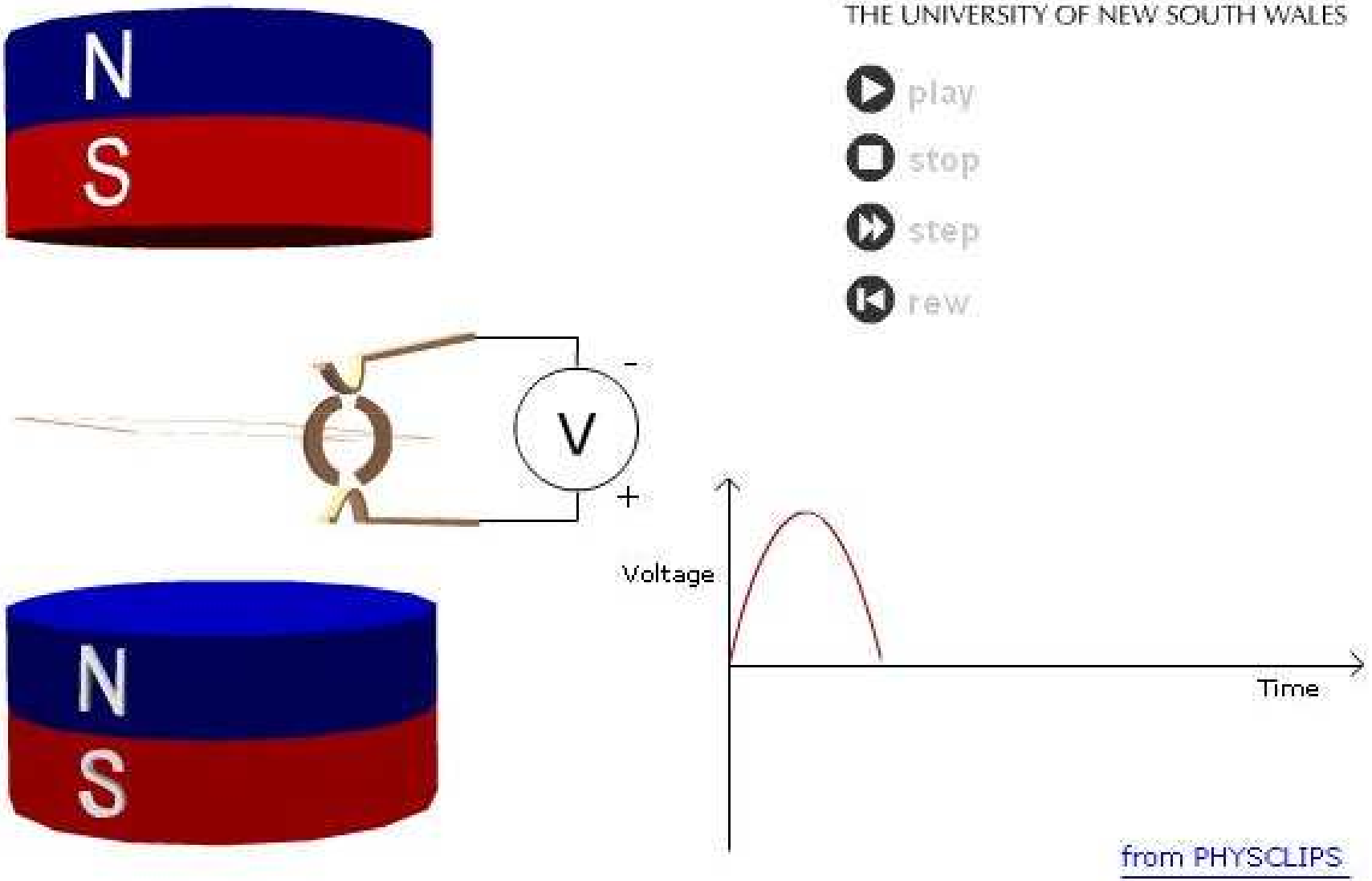
from PHYSCLIPS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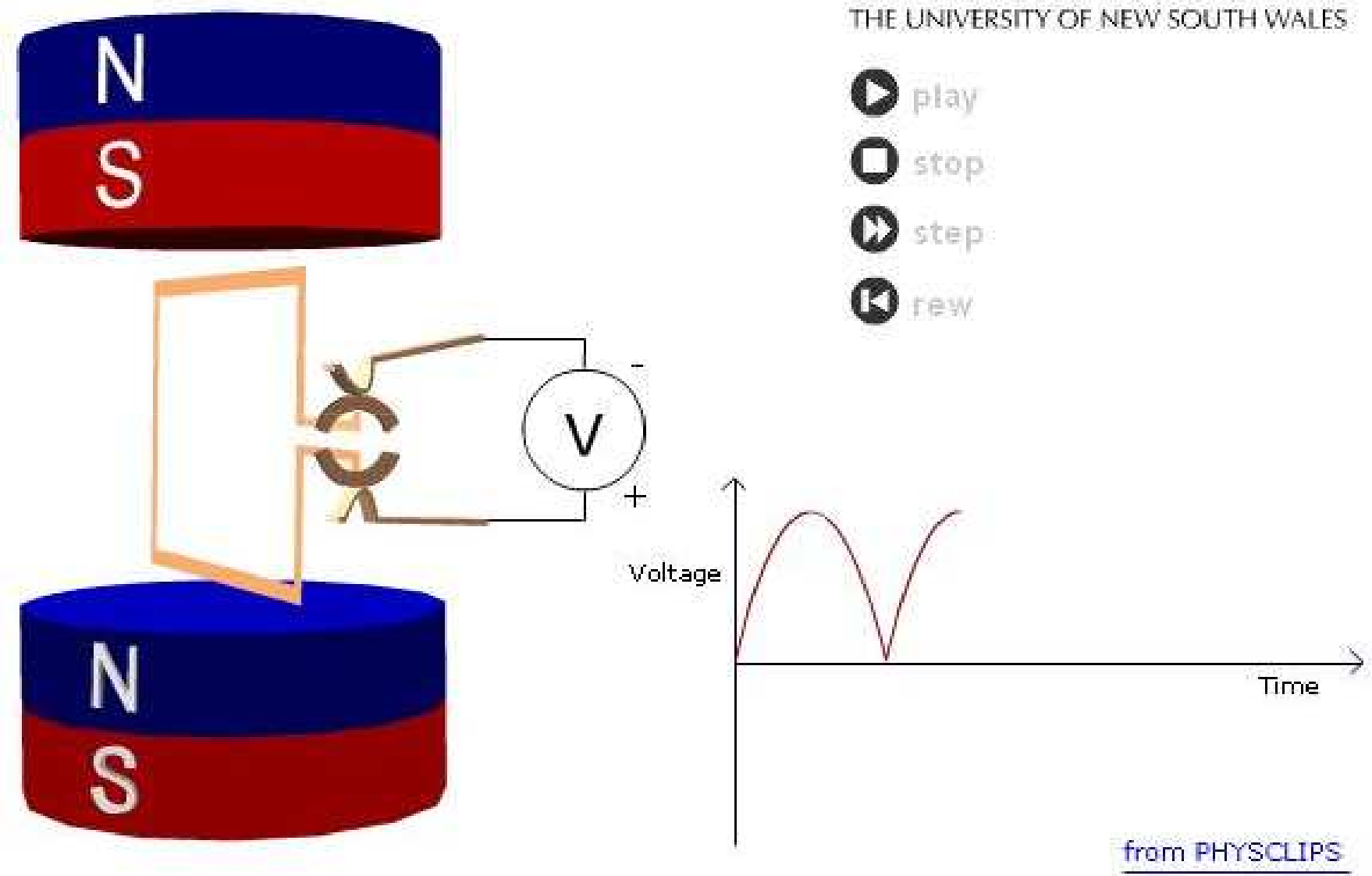
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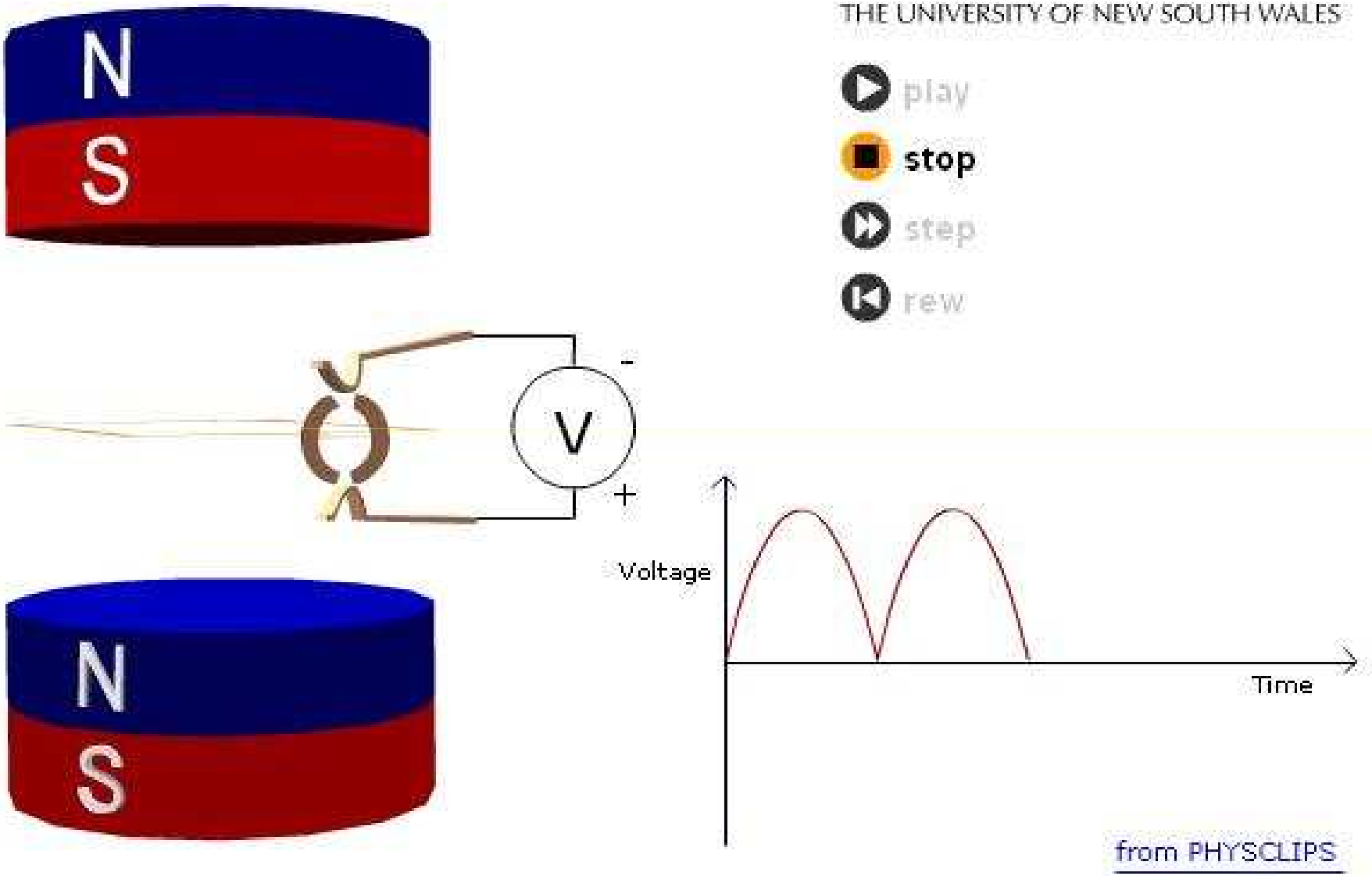
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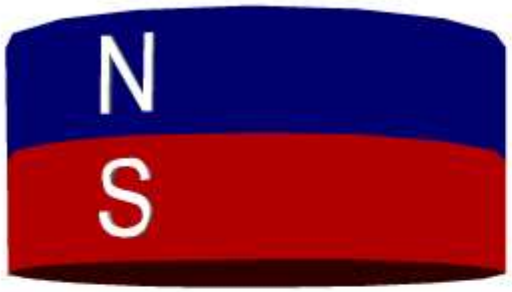

THE UNIVERSITY OF NEW SOUTH WALES

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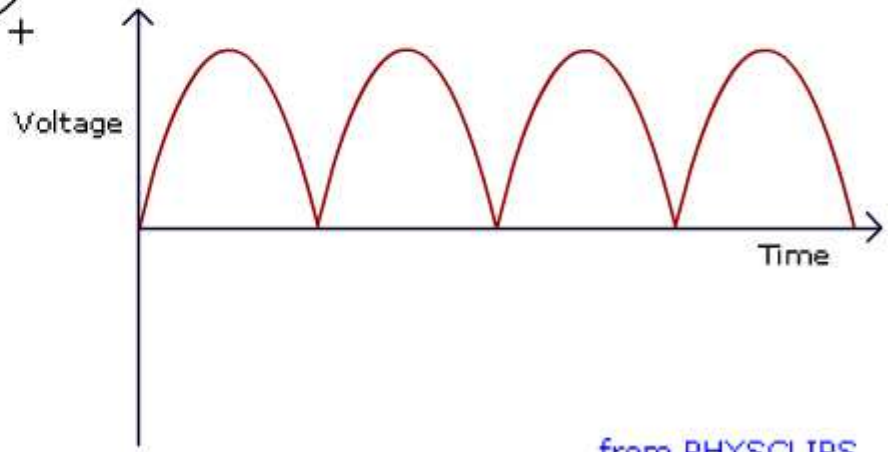


from PHYSCLIPS

D. C. Generator

Portable D. C. Generator

D. C. Generator

Principle of Operation

When a conductor rotates in a magnetic field, dynamically induced e.m.f is produced in it according to Faraday's law of electromagnetic induction

Generated E.M.F./E.M.F. Equation of a Generator

Let

φ = Flux/Pole in Wb

Z = Total No. of Armature Conductors

= No. of Slots $\times$ No. of Conductors per Slot

P = No. of Generator poles

A = No. of Parallel Paths in Armature

N = Armature rotation in rpm

E = E.M.F. induced in any parallel path in Armature

Generated E.M.F., E_g = E.M.F. generated in any one of the parallel paths i.e E

$$\text{Average E.M.F. Generated/Conductor} = \frac{d\varphi}{dt} \text{ volt}$$

Now, Flux cut/conductor in 1 revolution, $d\varphi = \varphi P$ Wb

No. of Revolutions/sec $= N/60$

$\therefore$ Time for 1 revolution, $dt = \frac{60}{N}$ sec

Hence, according to Faraday's Laws of electromagnetic induction,

$$\text{E.M.F. Generated/conductor} = \frac{d\varphi}{dt} \text{ volt}$$

$$= \frac{\varphi P}{60/N} = \frac{\varphi PN}{60} \text{ volt}$$

For Wave wound Generator

No. of Parallel Paths = 2

No. of Conductors (in series) in 1 path = Z/2

$$\text{E.M.F. Generated/path} = \frac{\varphi PN}{60} \times \frac{Z}{2} \text{ volt} = \frac{\varphi ZPN}{120} \text{ volt}$$

For Lap wound Generator

No. of Parallel Paths = P

No. of Conductors (in series) in 1 path = Z/P

$$\text{E.M.F. Generated/path} = \frac{\varphi PN}{60} \times \frac{Z}{P} \text{ volt} = \frac{\varphi ZN}{60} \text{ volt}$$

In General,

Generated E.M.F.

$$E_g = \frac{\varphi Z N}{60}\left(\frac{P}{A}\right) \text{ volt}$$

where, A = 2 for wave winding

= P for lap winding

Also,

$$E_g = \frac{1}{2\pi}\left(\frac{2\pi N}{60}\right)\varphi Z\left(\frac{P}{A}\right) \; volt = \frac{\omega\varphi Z}{2\pi}\left(\frac{P}{A}\right) volt$$

For a given D.C. Machine, Z, P and A are constants

Hence, Putting

$$k_a = \frac{ZP}{A}, \text{ we get,}$$

$$E_g = k_a \frac{\omega\varphi}{2\pi} = k_a \varphi N \text{ volts}$$

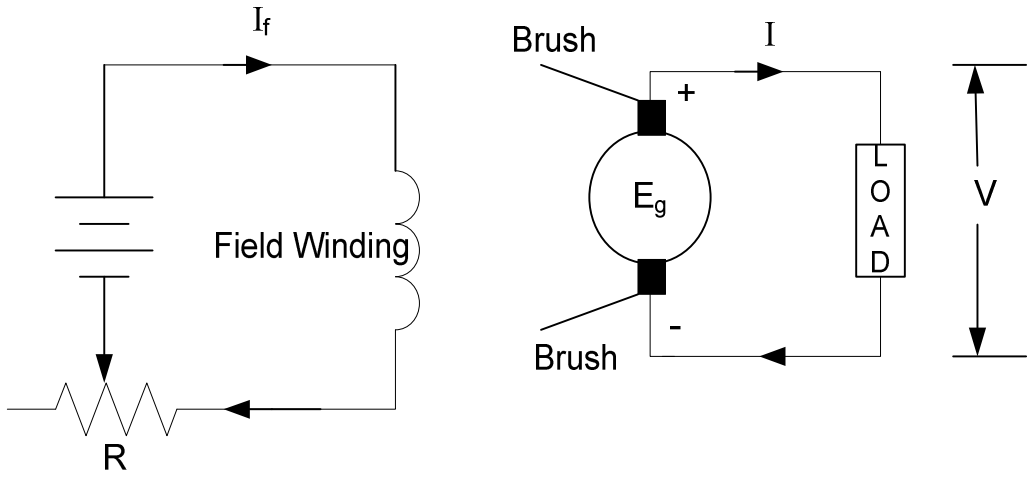
(N is in rps)

Types of D.C. Generators

According to the way in which their fields are excited, generators are classified into :

i) Separately excited D.C. Generator
ii) Self- excited D.C. Generator

i) Separately excited D.C. Generators are those whose field magnets are energized from an independent source of D.C. Current



$$V = E_g - IR_a - \text{Brush Drops}$$

R_a = Armature Resistance

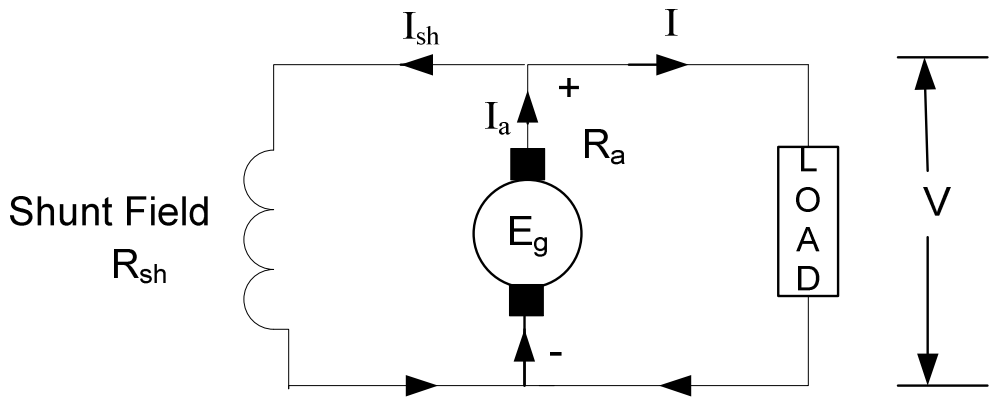
ii) Self excited D.C. Generators are those whose field magnets are energized by the currents produced by the generators themselves.

There are 3 types of self-excited D.C. Generators named according to the manner in which their field coils are connected to the armature.

These are :

- Shunt wound D.C. Generator
- Series wound D.C. Generator
- Compound wound D.C. Generator

i) Shunt wound D.C. Generator



R_{sh} – Shunt Field Resistance

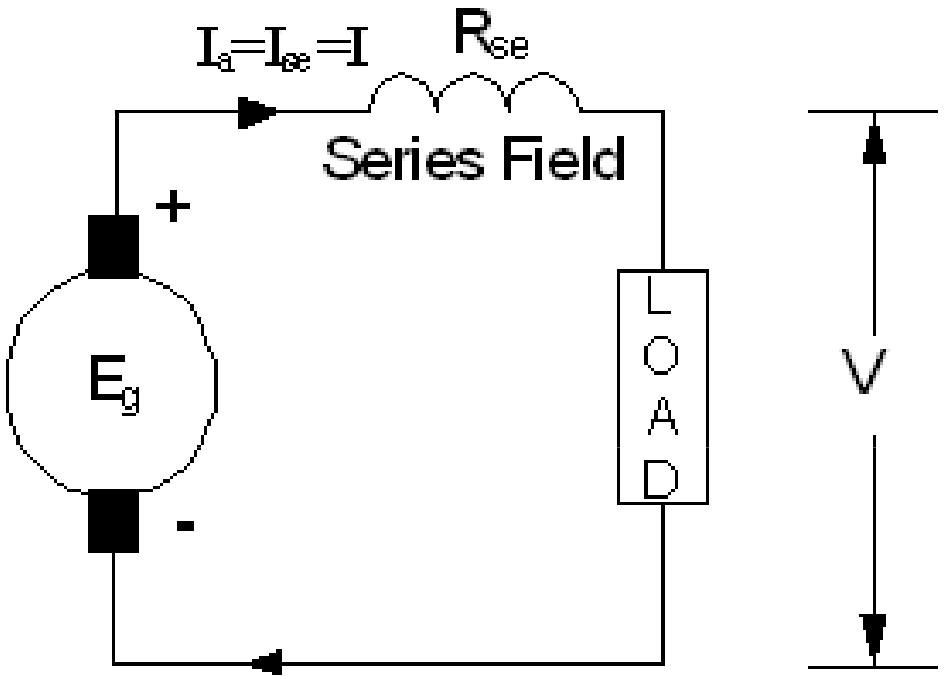
R_a - Armature Resistance

$$I_a = I + I_{sh}$$

$$V = E_g - I_a R_a - \text{Brush Drops}$$

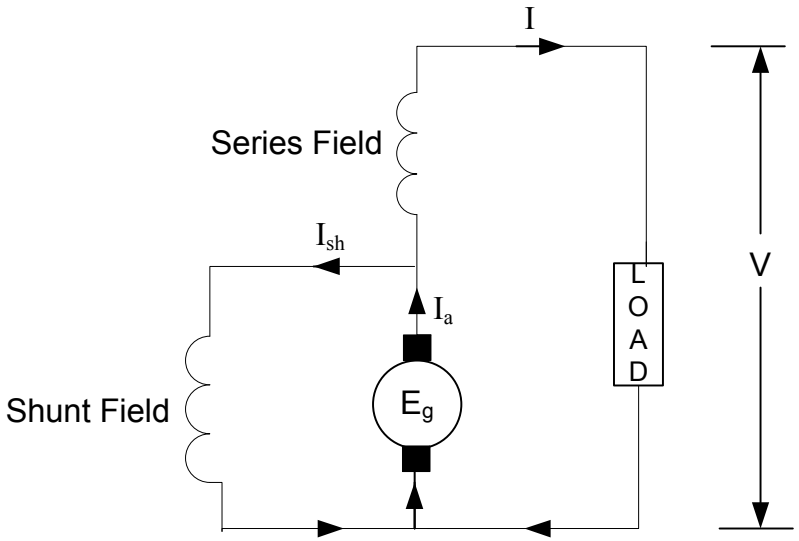
$$V = I_{sh} R_{sh}$$

ii) Series wound D.C. Generator

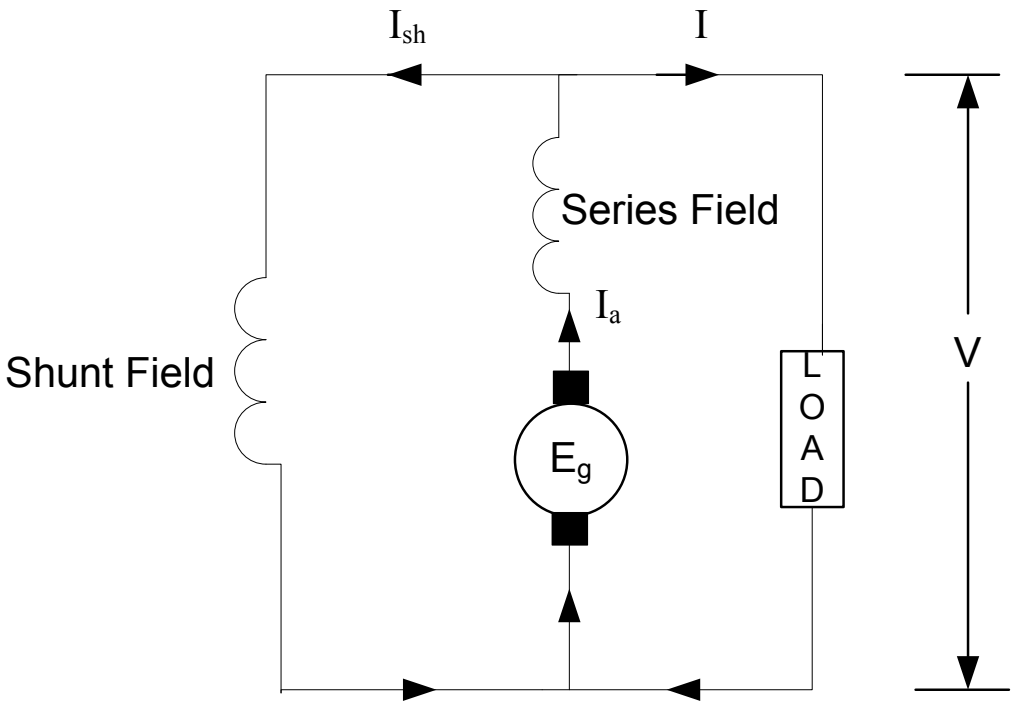


$$V = E_g - I_a (R_a + R_{se}) - \text{Brush Drops}$$

iii) Compound wound D.C. Generator



Short Shunt



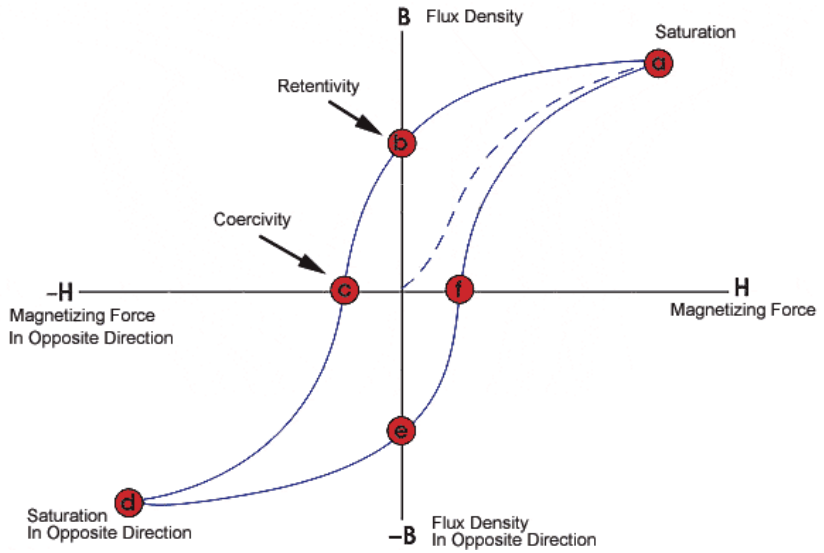
Long Shunt

Ex.1 A D.C. Shunt Generator delivers 450A at 230V and the resistance of the shunt field and armature are 50Ω and 0.03 Ω respectively. Calculate the generated EMF.

Ex.2 An 8 - pole D.C. Shunt Generator with 778 wave wound armature conductors running at 500 rpm supplies a load of 12.5Ω resistance at terminal voltage of 250V. The armature resistance is 0.24Ω and the field resistance is 250Ω . Find the armature current, the generated EMF and the flux per pole.

IRON LOSS IN THE ARMATURE

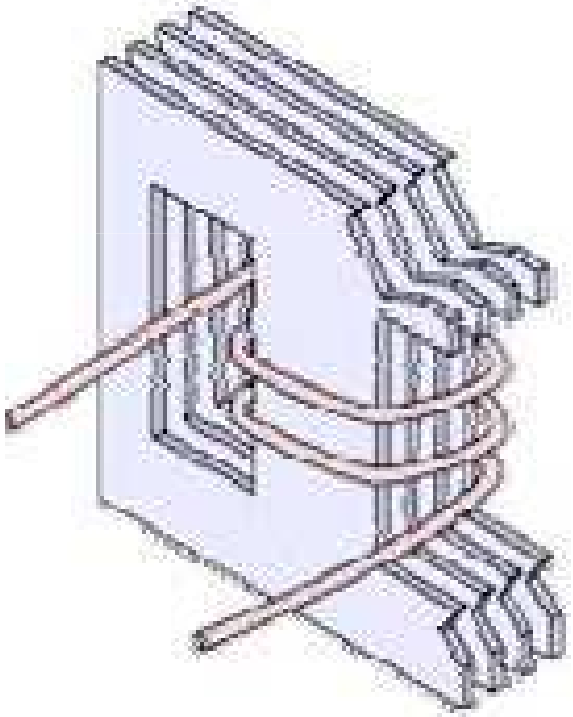
- **Hysteresis Loss**
  - This loss is due to the reversal of magnetism of the armature core.
  - (Every portion of the rotating core passes under N and S pole alternately, thereby attaining S and N polarity respectively)
  - Review:Hysteresis Loss



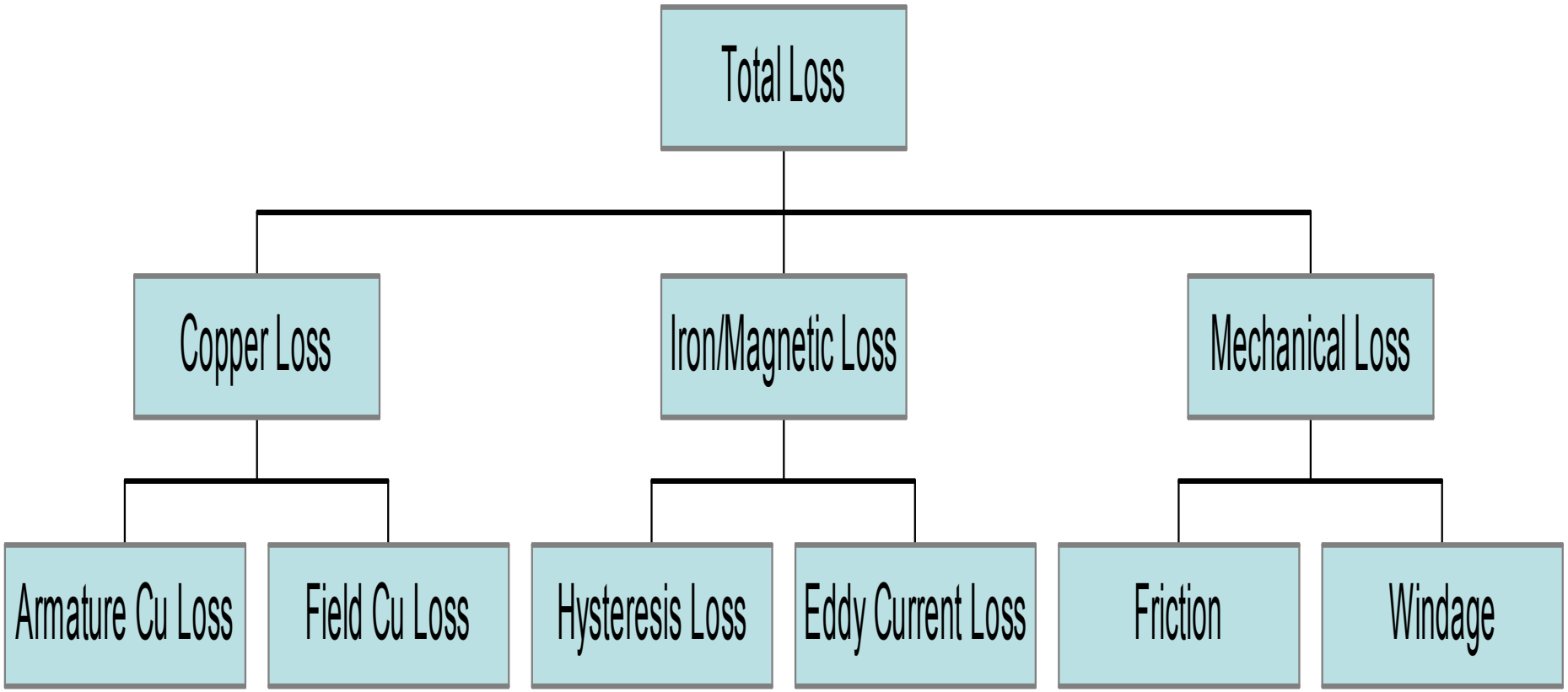
EDDY CURRENT LOSS

- **Eddy Current Loss**
  - The core material is electrically conductive.
  - When it rotates, it also cuts the flux.
  - Hence, an e.m.f. is induced in the body of the core.
  - This e.m.f. sets up current in the body of the core

Solution:Lamination



TOTAL LOSS IN DC GENERATOR

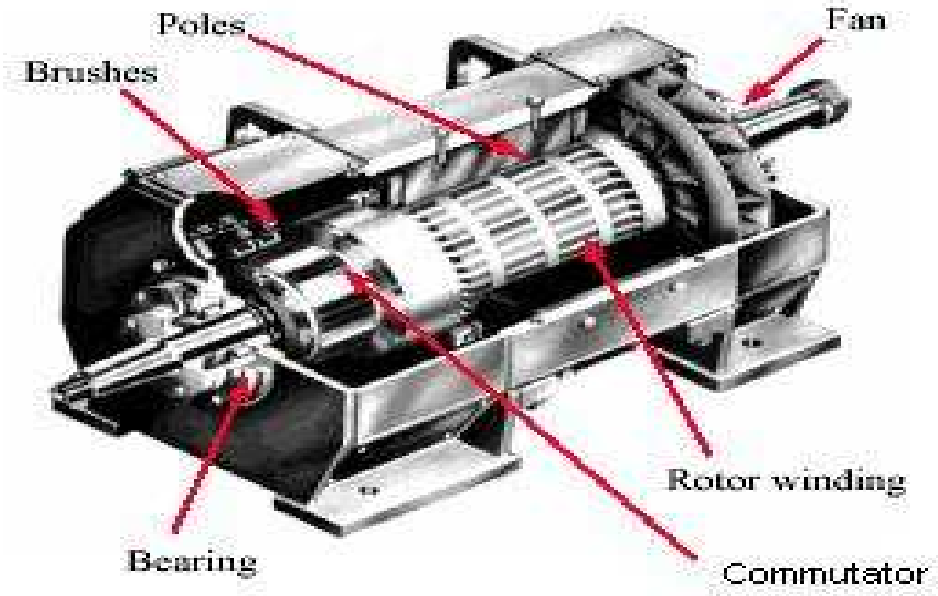


COPPER LOSS

- Copper losses (Cu losses)
  - Armature copper loss = $I_a{}^2 R_a$
  - Field copper loss = $I_f^2 R_f$
  - Loss due to brush contact resistance; usually included in the armature copper loss.

MECHANICAL LOSS

- Mechanical losses
  - Friction loss at bearings and commutator
  - Air-friction or windage loss of rotating armature

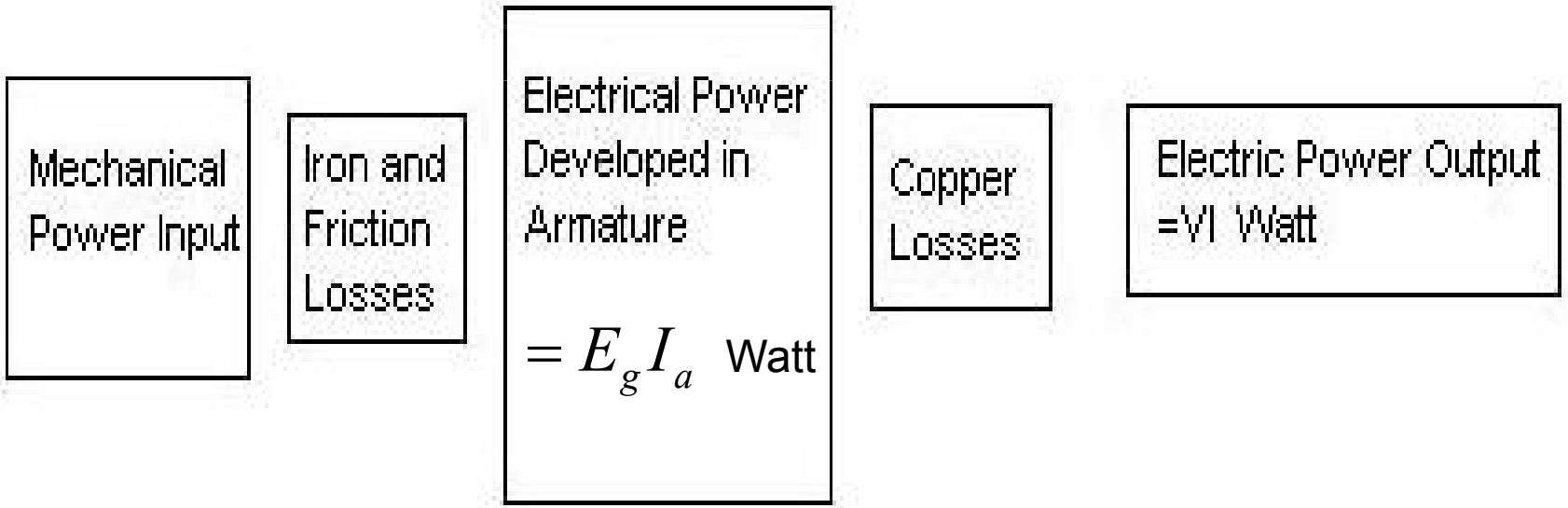


Different Losses

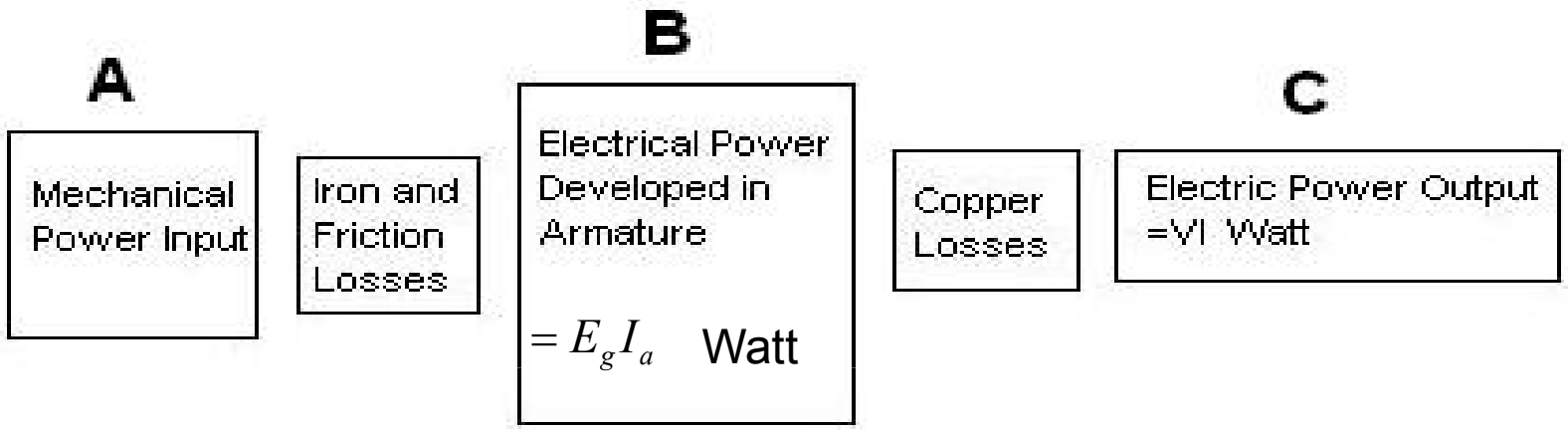
- **Stray Losses:** usually magnetic and mechanical losses are collectively known as Stray Losses.
- **Constant Losses:** W_c , consists of stray losses and shunt Cu losses.
- **Variable Loss:** varied with the load current - armature Cu loss.

GENERATOR POWER STAGES

- **Total Losses = Constant Losses + Variable Losses**



EFFIECIENCY



Mechanical Efficiency = B / A

Electrical Efficiency = C / B

Overall/Commercial Efficiency = C / A

Torque – Power Conversion

.If T_a is the torque exerted by the prime mover running at n rps, then the power developed is:

$$T_a \cdot 2\pi n \text{ watt}$$

.and the mechanical power converted into electrical power in the armature is:

$$E \cdot I_a \text{ watt}$$

then

$$\boxed{T_a \cdot 2\pi n = E \cdot I_a}$$

CONDITION FOR MAXIMUM EFFICIENCY

- Generator output = VI
- Gen input = gen output + losses

  $= VI + Ia^2Ra + Wc$

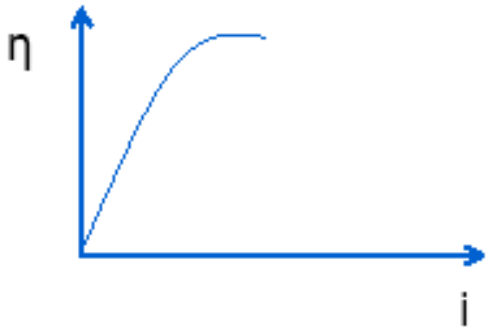
  Ia=I+Ish

- However if Ish is negligible as compared to load current, then Ia = I (approx.)
  - η = output / input = $\dfrac{1}{1+\left(\frac{IRa}{V}+\frac{Wc}{VI}\right)}$
- Efficiency is max when denominator is minimum, when:

$$\frac{d}{dI}\left(\frac{IR_a}{V}+\frac{W_c}{VI}\right)=0 \qquad \frac{R_a}{V}-\frac{W_c}{VI^2}=0 \qquad \boxed{I^2R_a=W_c}$$

CONDITION FOR MAXIMUM EFFICIENCY (2)

$$\boxed{I^2 R_a = W_c}$$



- **Variable loss = constant loss.**
- The load current corresponding to max efficiency is:

$$I = \sqrt{\frac{W_c}{R_a}}$$

Example-1

- A long shunt dynamo running at 1000 r.p.m. supplies 22 kw at a terminal voltage of 220 V .The resistance of armature ,shunt field and the series field are .05 ohm,110 and .06 ohm respectively. The overall efficiency at the above load is 88%. Find
- Cu losses
- Iron and friction losses
- The torque exerted by the prime mover

MATHS

- All the related examples of Theraja