Electromechanical Systems

002.0

Introduction

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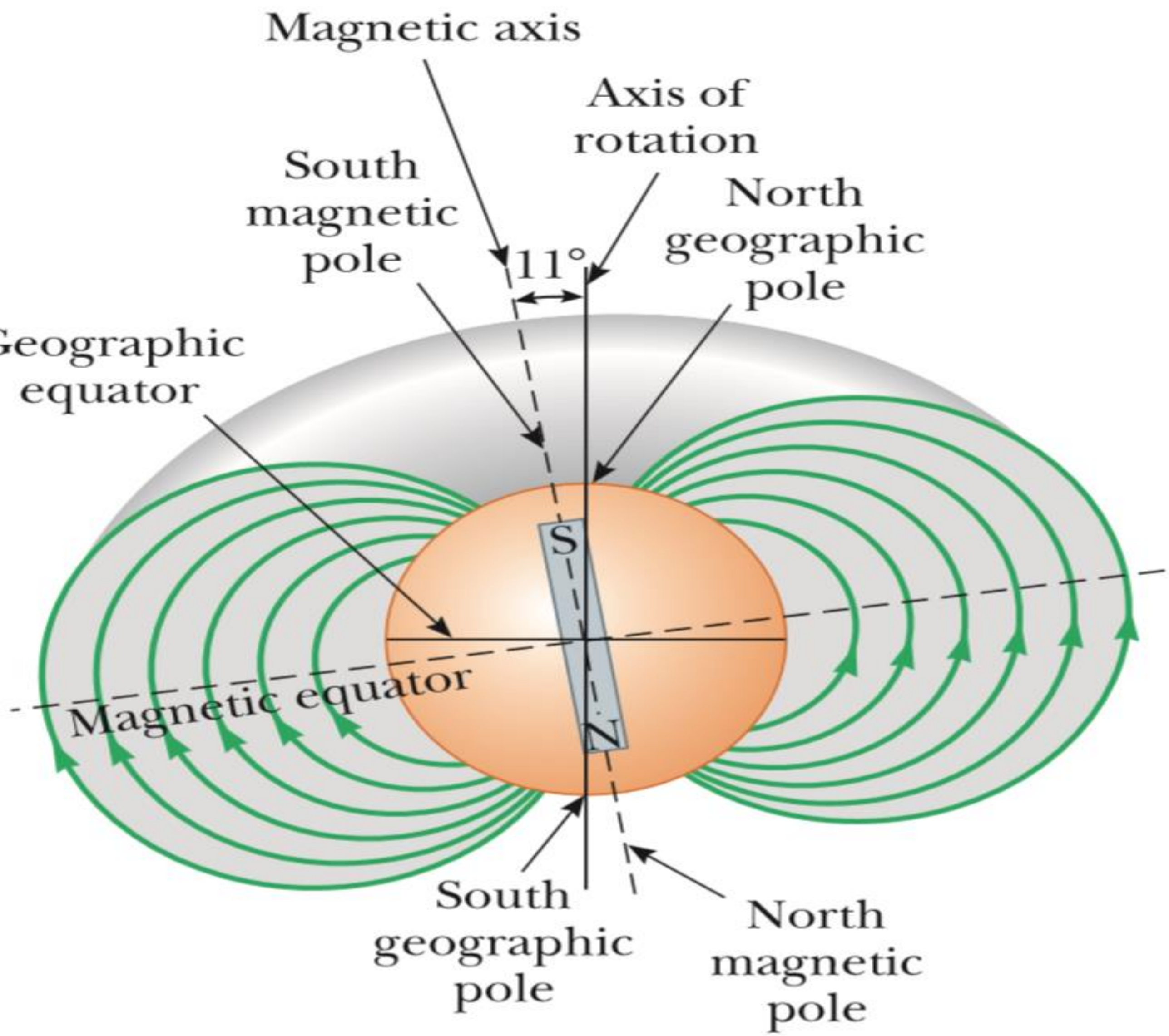
Earth’s Magnetic Field



Reference Book

Principles of Electrical Machines and Power Electronics, P C Sen

Power

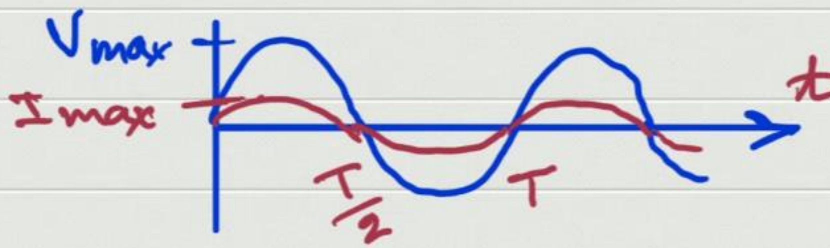
Heater and Fridge ?

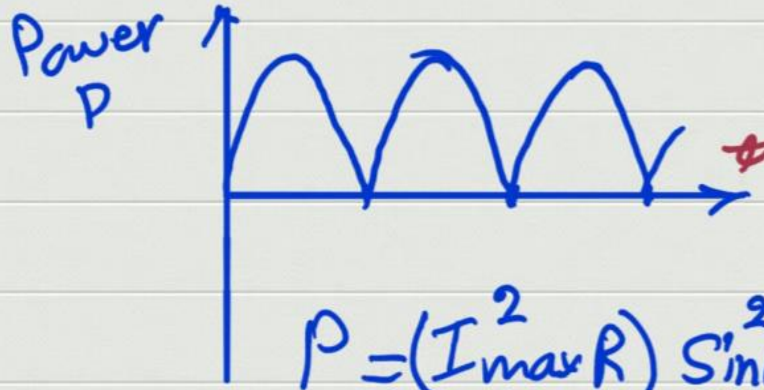
Power

$$v = V_{max}\sin(\omega t)$$
$$i = I_{max}\sin(\omega t)$$
$$P = v \times i$$

for a resistive circuit:

$$v = iR \quad \& \quad i = \frac{v}{R}$$
$$P = i^2 R \quad \text{or} \quad \frac{v^2}{R}$$
$$P = \frac{(V_{max}\sin(\omega t))^2}{R}$$
or
$$P = (I_{max}\sin(\omega t))^2 R$$





$$P = (I_{max}^2 R)\sin^2(\omega t)$$

Scaler value

$$\omega = 2\pi f = \frac{2\pi}{T}$$

@ $t = 0$, $\omega t = \frac{2\pi}{T} \times 0$, $\sin^2(0) = 0$

@ $t = \frac{T}{4}$, $\omega t = \underbrace{\frac{2\pi}{T} \cdot \frac{T}{4}}_{\pi/2}$, $\sin^2(\frac{\pi}{2}) = (1)^2 = 1$

@ $t = \frac{T}{2}$, $\omega t = \frac{2\pi}{T} \cdot \frac{T}{2} = \pi$, $\sin^2(\pi) = 0$

@ $t = \frac{3T}{4}$, $\omega t = \frac{2\pi}{T} \cdot \frac{3T}{4} = \frac{3}{2}\pi$, $\sin^2(\frac{3}{2}\pi) = 1$

@ $t = T$, $\omega t = \frac{2\pi}{T} \cdot T = 2\pi$, $\sin^2(2\pi) = 0$

so this $p(t)$ instantaneous value! Average Power?

$$P_{ave} = \frac{1}{T}\int_0^T P(t)\,dt$$

$$= \frac{2}{T}\int_0^{T/2} P(t)\,dt$$

$$P(t) = P_{max}\sin^2(\omega t)$$

$$P_{max} = I_{max}^2 R$$

$$= \underbrace{\frac{2}{T}\cdot P_{max}\cdot\int_0^{T/2}\sin^2(\omega t)\,dt}_{\frac{P_{max}}{2}}$$

The average of $\sin^2(\omega t)$ over a whole cycle is <u>0.5</u>

$$P_{ave} = \frac{I_{max}^2 R}{2}$$

<u>or</u>

$$= \frac{V_{max}^2}{2R}$$

This is valid for any alternating current supply

Root Mean Square (RMS)

$$P_{ave} = \frac{V_{rms}^2}{R} = \frac{V_{max}^2}{2R}$$

$$V_{rms}^2 = \frac{V_{max}^2}{2}$$

$$V_{rms} = \frac{V_{max}}{\sqrt{2}}$$

$$V_{rms} = 0.707\, V_{max}$$

$I_{rms} = ?$

$$P_{ave} = I_{rms}^2 \cdot R = \frac{I_{max}^2 \cdot R}{2}$$

or $I_{rms} = \dfrac{I_{max}}{\sqrt{2}}$

$$I_{rms} = 0.707\, I_{max}$$

for the 220 Volt RMS the $V_{max} = 310$ Volt

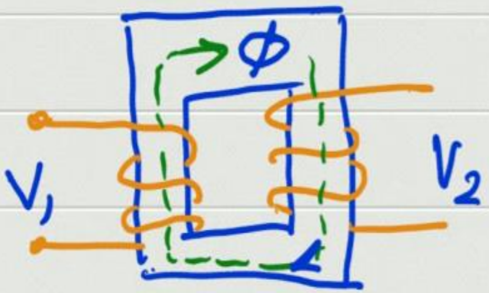
Why RMS ?

AC v DC

It was Tesla's idea to change from D.C. to A.C. to minimize transmission loss in cables

Coil

$v_1 = \frac{d\phi}{dt}$



per one turn,

for N_1 turns

$v_1 = N_1 \frac{d\phi}{dt}$ Same

$v_2 = N_2 \frac{d\phi}{dt}$

$\frac{v_1}{v_2} = \frac{N_1}{N_2}$

Power in both sides of the Trans. are the same;

$i_1 v_1 = i_2 v_2$

$\frac{v_1}{v_2} = \frac{i_2}{i_1} = \frac{N_1}{N_2}$

$\boxed{\begin{array}{l}\text{1MW ac \& d.c. system} \\ \text{220V \& for a.c. 33kV} \\ \text{(1-}\phi\text{) Cable resist. R}\end{array}}$

$P = 1\,MW = V_{ac}\, i_{ac} = V_{dc}\, i_{dc}$

$33 \times 10^3 \times i_{ac} = 10^6$

$i_{ac} = \dfrac{1000}{33} = 30\ A$

$P = V_{dc}\, I_{dc}$

$10^6 = 220 \times I_{dc}$

$I_{dc} = \dfrac{1{,}000{,}000}{220}$

$= 4545\ A$

<u>Power loss in cables:</u>

$P = i^2 R \times 2$

$= 30^2 \times 2 \times R$

$= 1800\, R$

$= 1.8 \times 10^3\, R$

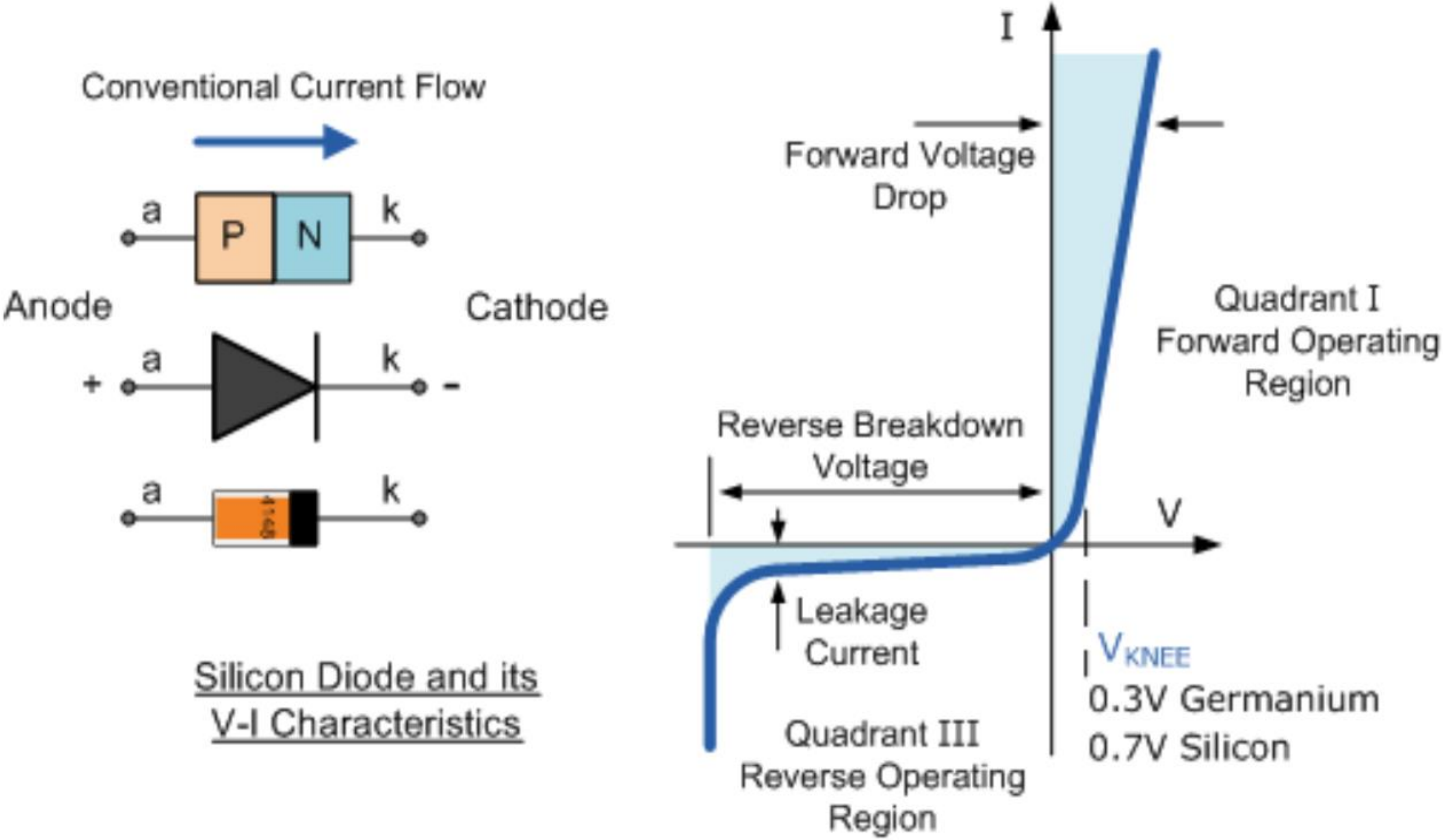
$P = I^2 \times 2 \times R$

$= 41 \times 10^6\, R$

Ratio is 23,000

I-V characteristic Curve of a Diode

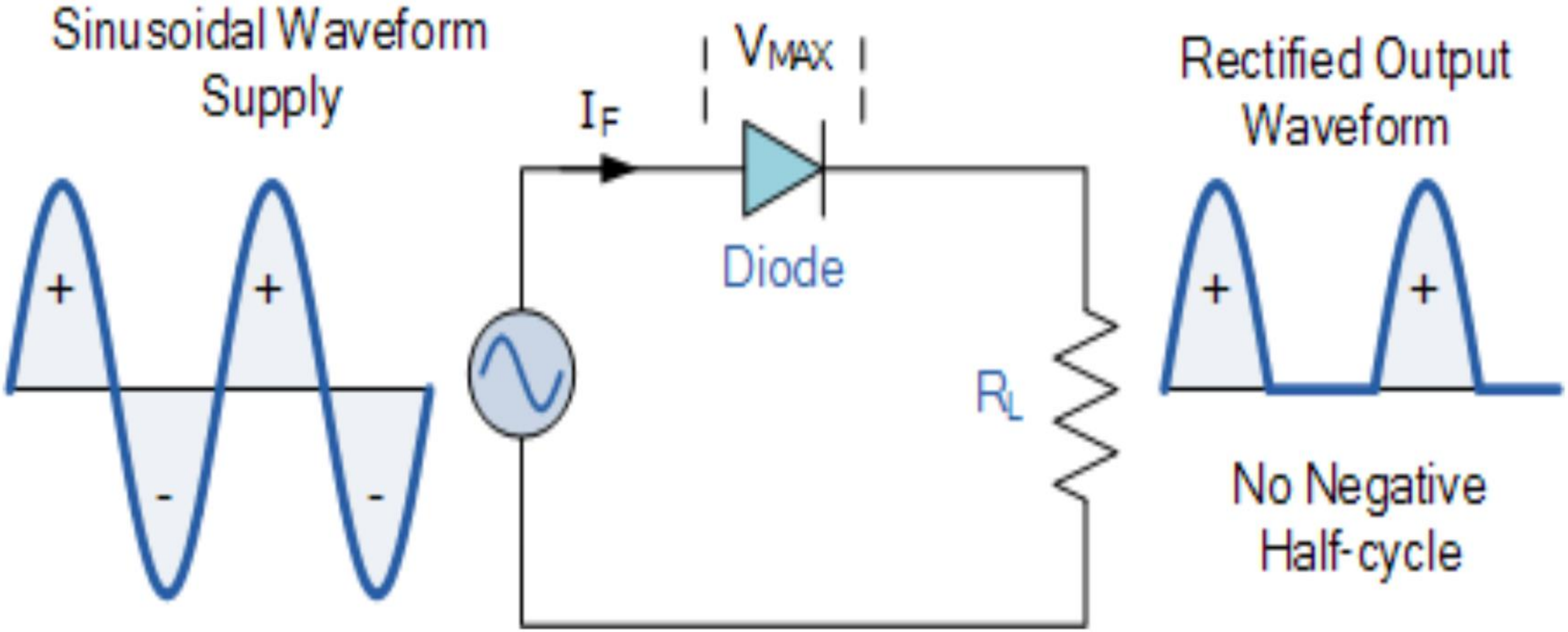
https://www.electronics-tutorials.ws/diode/diode_4.html

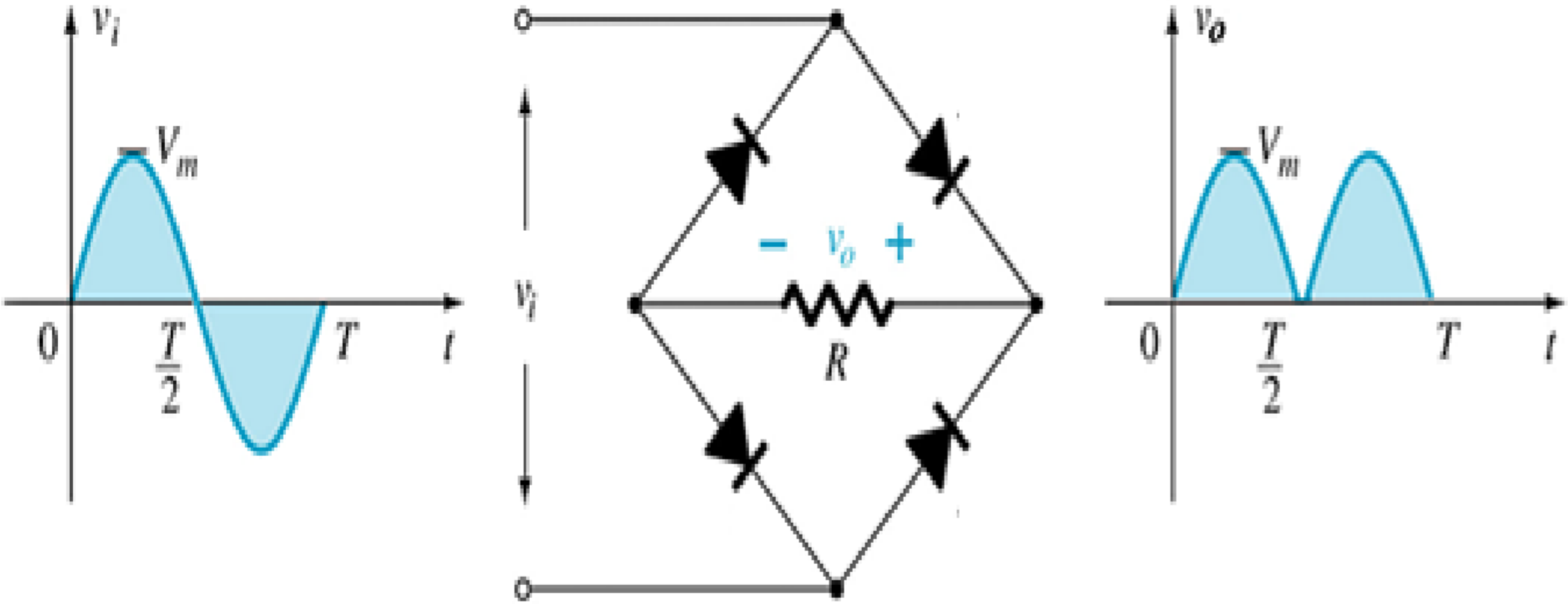


Important Parameters of a Diode

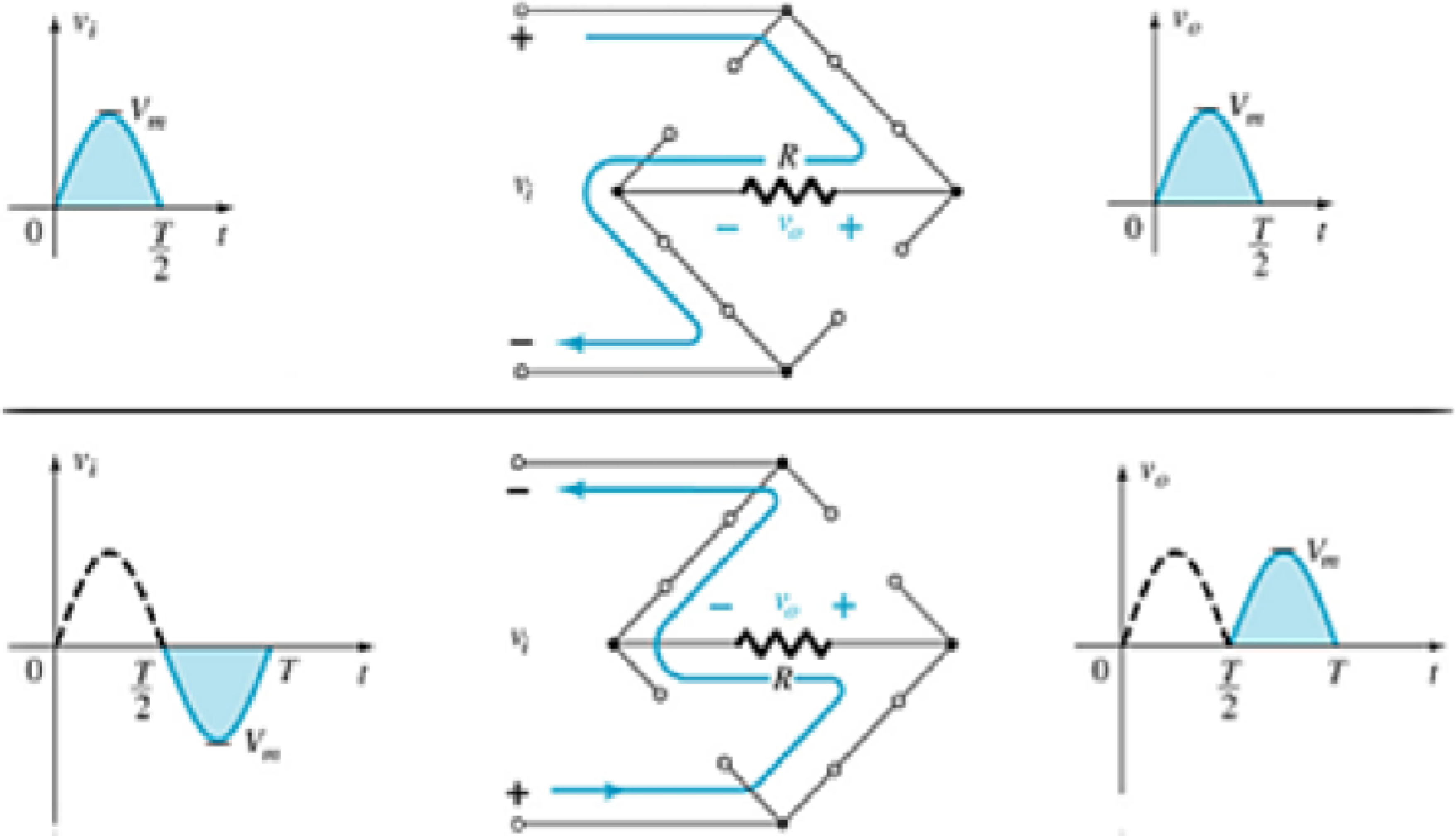
- Maximum Forward Current
- Maximum Reverse Voltage
- Total Power dissipation
- Maximum Operating Temperature (Tj)

Half Wave Rectifier





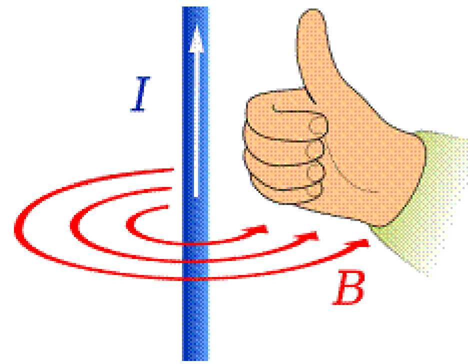
v_i
V_m
0
$\frac{T}{2}$
T
t
v_i
$-\ v_o\ +$
R
v_o
V_m
0
$\frac{T}{2}$
T
t



v_i
V_m
0
$\frac{T}{2}$
t
+
−
R
v_o
T

Electro Mechanical Interaction

Fleming's Hand Rule



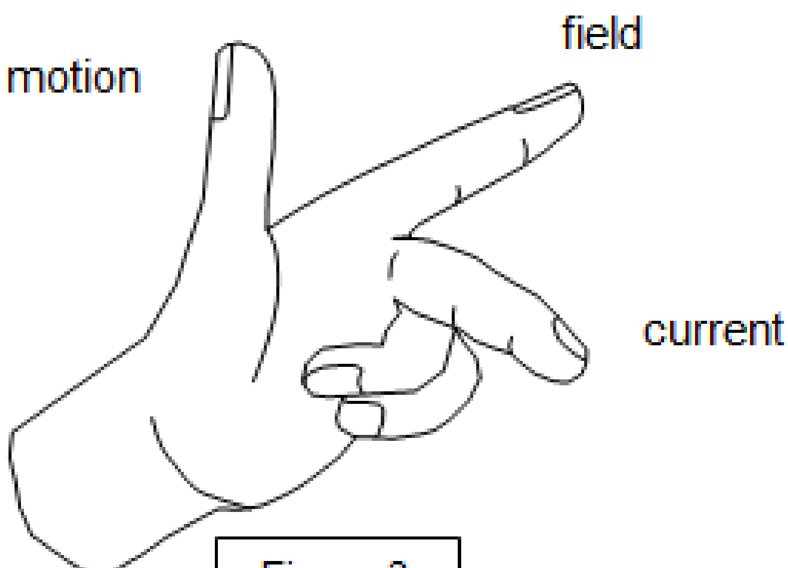
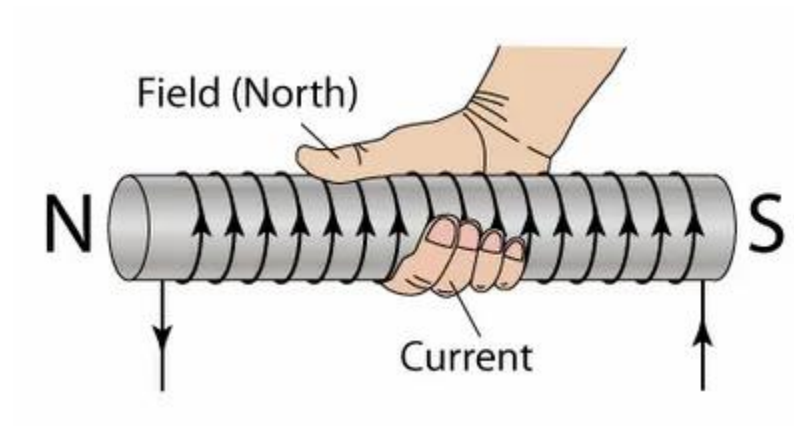
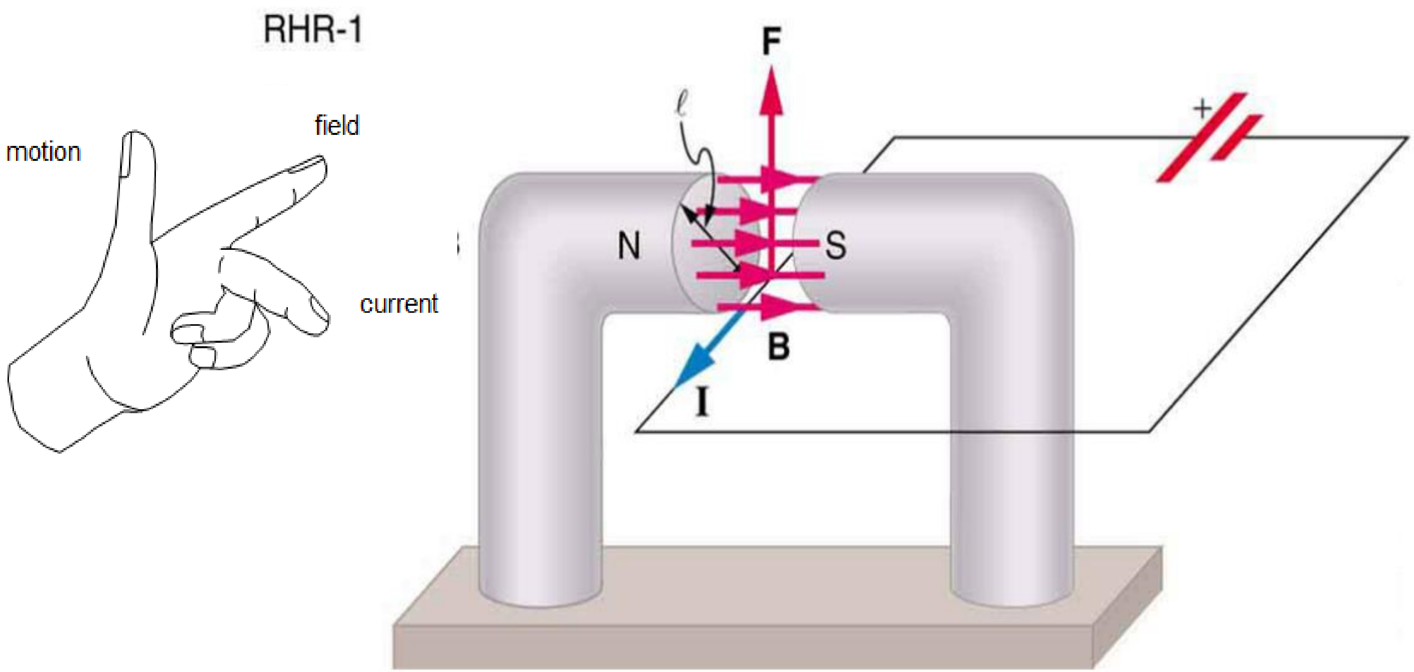


Figure 3



Current Carrying Conductor in Magnetic Field

Because charges ordinarily cannot escape a conductor, the magnetic force on charges moving in a conductor is transmitted to the conductor itself.



The magnetic field exerts a force on a current-carrying wire in a direction given by the right hand rule 1 (the same direction as that on the individual moving charges). This force can easily be large enough to move the wire, since typical currents consist of very large numbers of moving charges.

Electro mechanical force

$$F = IlBsin\theta$$

Where:

- $F,$ *is the force,*
- $I,$ *is the electric current*
- $l,$ *length of the conductor*
- $B,$ *is the magnetic flux density*
- $\theta,$ *is the angle between the current and the flux*

- **Calculate the force on the wire shown in the previous figure, given that: B = 1.70 [T], l = 15.00 [cm], and I = 25.0 [A].**

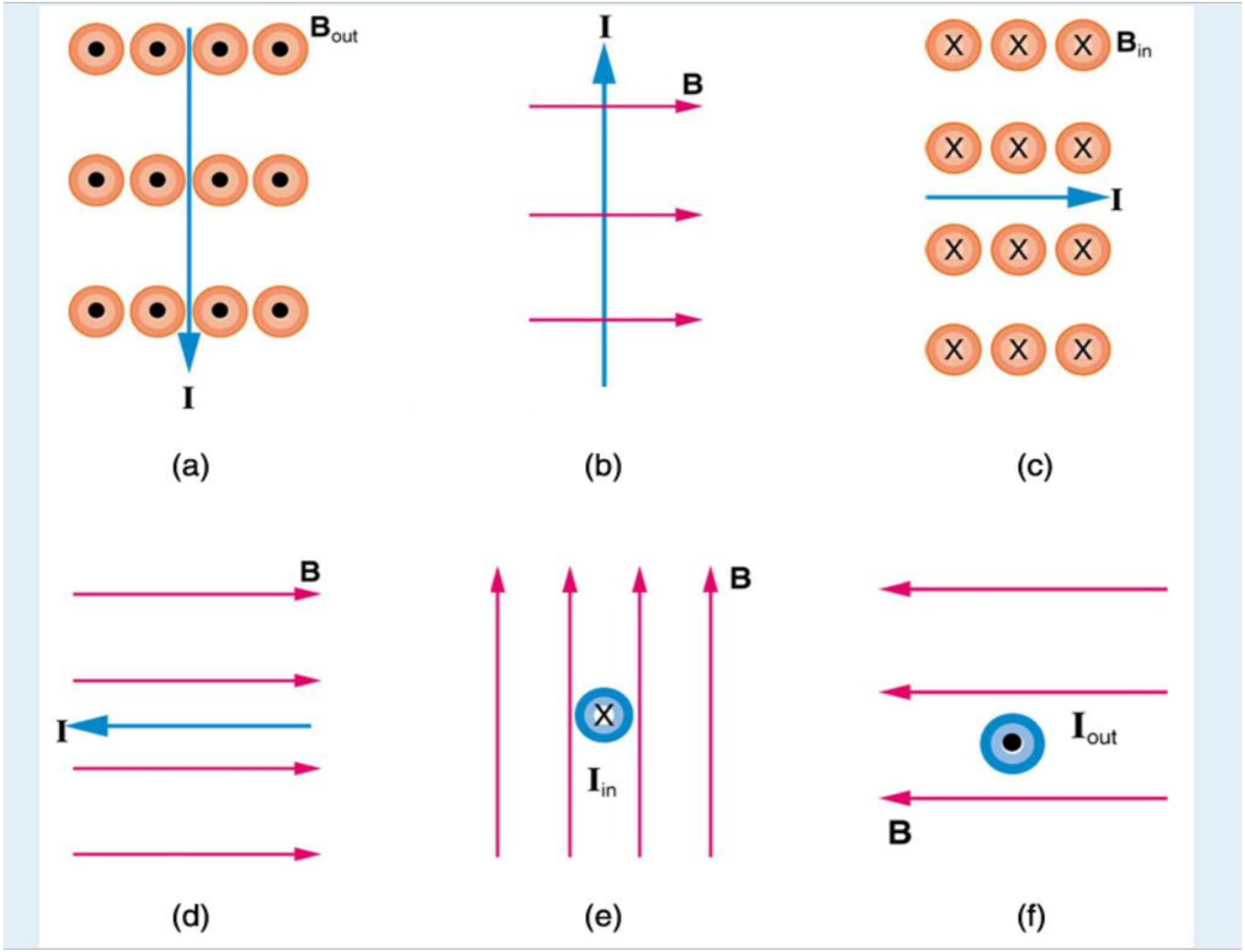
Solution

$$F = IlBsin\Theta$$

- $\Theta = 90o$
- $F[N] = 20\ x\ 0.15\ x\ 1.5\ x\ sin(90)$
- $F[N] = ?N$

- **Imagine you have a coil of n turns placed in side a magnetic flux B ?**

Question: Determine the direction of the force in the following cases



Transformer

As the name suggests, transform means changing some parameters to other form.

In ideal transformers:

$$\frac{v_1}{v_2} = \frac{N_1}{N_2} \quad \text{or} \quad v_2 = \frac{N_2}{N_1} v_1$$

$$n = \frac{N_2}{N_1}, \quad \text{then, } v_2 = n v_1$$

Hence depending on the value of "n" the transformer will step up or step down trans.

- In power generation systems, we usually have two typer of transformers depending on their applications.
- At the generator side, there will be the step up one to feed the transmission line
- Whereas at the consumer side it will be the step down transformer
- The first one is called Power Transformer and the second one is called Distribution Transformer

Distribution Transformers are, usually, energised all the time 24/7 non-stop.

The Power Transformer, however, are connected the to the generation system and if the generator are off, then it will be turned off too.

These are the two main transformer in power generation

There is some thing called Current Transformer (CT). These are coils that are connected in cascade with transmission line to prevent high current surge in the contactors.

In some electronic applications, a demand sometimes arises for maximum power transfer. This requires to have the impedance of both source and Load matched

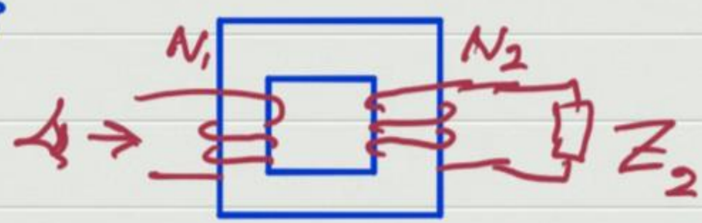
$$Z_s = R_s + jX_s \qquad Z_{12} = \left(\frac{N_1}{N_2}\right)^2 R_L$$

$$Z_L = R_L + jX_L$$

A maximum power can be transferred if we have

$$R_L = R_s \quad \text{and} \quad X_L = -X_s$$

$$Z_{12} = \left(\frac{N_1}{N_2}\right)^2 Z_2$$

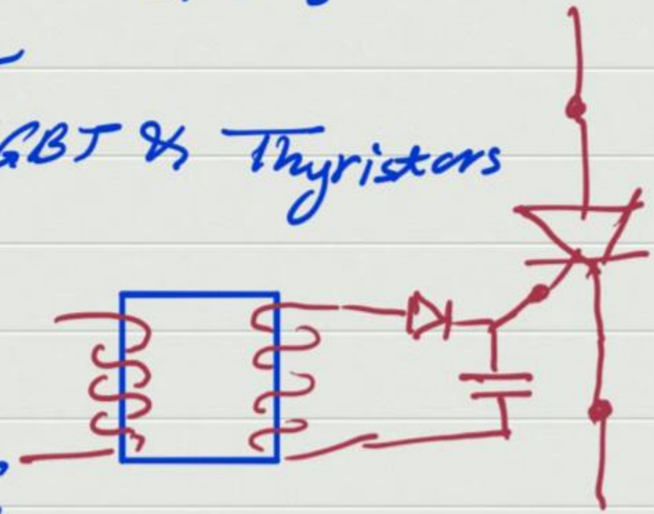


By choosing a right turns ratio, matching can be achieved.

Isolation Transformer

this is widely used in power electronics to isolate the high voltage side from the low voltage one. Mosfet, IGBT & Thyristors

This way the will be no direct electrical connection betwe the H.T. and the L.T. sides, the connection is accomplished electro-magnetically.



so conductively both side are not connected

Instrumentation and Measurement Application

- Measuring high voltage
- Measuring high current

of course these will be for a.c. as transformant will not work for d.c.

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