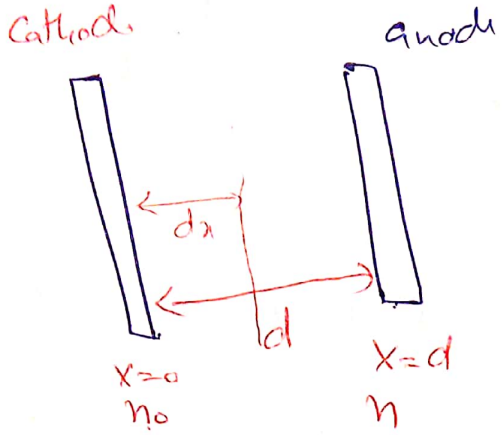
Townsend's 1st ionization (Primary ionization)



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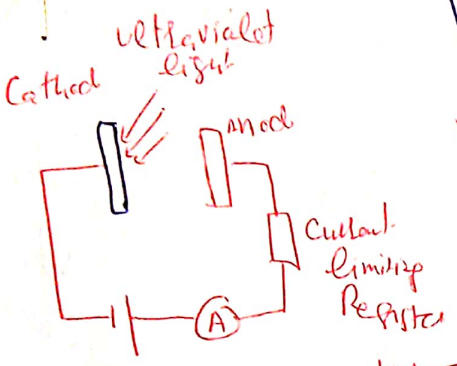
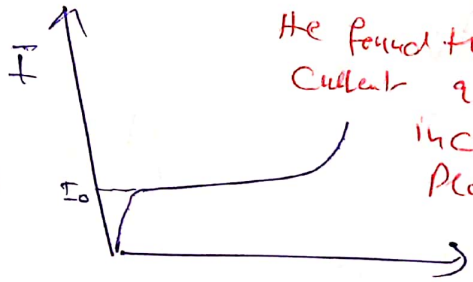


The variation in current as a function of voltage was studied by Townsend. He found that the current at first increased proportionally as the voltage is increased.



- Position ion
- electron

due by ionization collision

and then remain constant. At still higher voltages the current increases exponentially.

α = number of electron produced by the electron per unit length of ~~path~~ in the direction of field.

n_0 = no. of electrons leaving cathode.

x = these electron have made distance from cathode.

n = ~~next~~ next trans

$$dn = \alpha n \, dx$$

$$\frac{dn}{n} = \alpha \, dx$$

The exponential increase in current is due to ionization of gas by electron collision.

equal

$$\int \frac{dn}{n} = \alpha \, dx$$

$$\ln n = \alpha x + A \quad \text{—(1)}$$

integration Const

Apply initial Condition

at $x = 0$, $n = n_0$

$$A = \ln n_0$$

$$\ln n = \alpha x + \ln n_0 \quad \text{—(2)}$$

$$x = d$$

$$\ln n = \alpha d + \ln n_0$$

$$\ln n - \ln n_0 = \alpha d$$

$$\ln \frac{n}{n_0} = \alpha d$$

$$e^{\ln\left(\frac{n}{n_0}\right)} = e^{\alpha d}$$

$$\frac{n}{n_0} = e^{\alpha d}$$

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$$n = n_0 e^{\alpha d}$$

$$\boxed{I = I_0 e^{\alpha d}}$$

movement in electron is current

$\alpha \propto E/p$

Townsend current growth Equation

α is the Townsend's Primary ionisation made by electron per centimet towards the direction of electric field.

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4

an experiment, a certain gas, it was found that the steady state current is 5.5×10^{-8} A at 8kV at a certain distance of 0.4cm b/w the plain electrodes. Keeping the field constant and Reducing the distance to 0.1cm results in a current of 5.5×10^{-9}. Calculate value of α.

$I_1 = 5.5\times10^{-8}$ A, 8kV

$d_1 = 0.4$ cm.

$d_2 = 0.1$ cm 8kV

$I_2 = 5.5\times10^{-9}$ A

$I = I_0 e^{\alpha d}$

$I_1 = I_0 e^{\alpha d_1}$ — (1)

$I_2 = I_0 e^{\alpha d_2}$ — (2)

$$\frac{I_1}{I_2} = \frac{I_0 e^{\alpha d_1}}{I_0 e^{\alpha d_1}}$$

$$= e^{\alpha(d_1 - d_2)}$$

$$\frac{5.5\times10^{-8}}{5.5\times10^{-9}} = e^{\alpha(0.4-0.1)}$$

$$10 = e^{\alpha(0.3)}$$

$$\ln(10) = \ln e^{\alpha(0.3)}$$

$$\alpha = \frac{\ln(10)}{0.3} = 7.675 \text{ torr}^{-1}\text{cm}^{-1}$$

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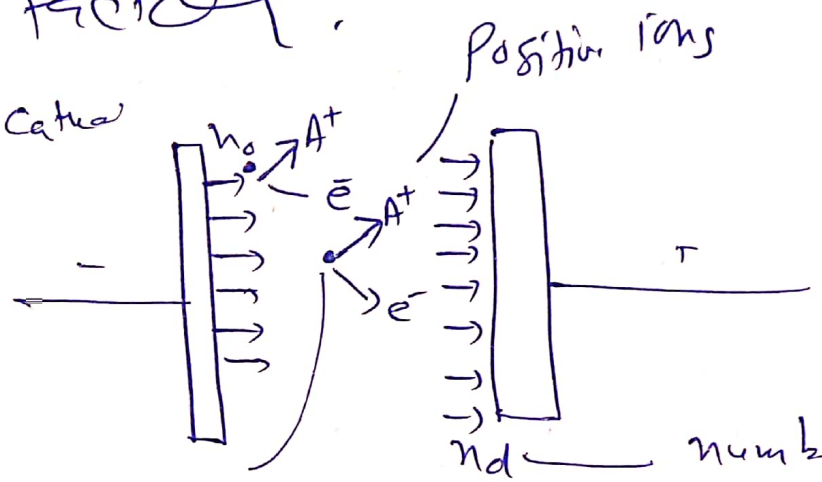
where I_0 is the intial current at c

$\exp(\alpha d)$ is called current amplifi
factor.



number of electron
gas molecules reaching anode.

Since amplification of the electron
[$\exp(\alpha d)$] is occuring in the field
the Probability of addition of
new electrons in the gap by
other processes increases.

A steady state current of 600 μA flows through a plane electrodes separated by a distance of 0.5 cm when a voltage of 10 kV is applied. Determine 'α' if current of 600 μA flows when the distance is reduced to 0.1 cm at the field kept constant at previous value.

Sol $I_1 = 600 \times 10^{-6} A$

$d_1 = 0.5 cm$ 10 kV

$10 = e^{\alpha(0.4)}$

$\alpha = \frac{\ln(10)}{0.4} = 5.756$ torr⁻¹ cm⁻¹

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Townsend Second Ionization Coefficient γ

Let n = number of electrons reaching the anode per second

n_0 = number of electrons emitted from cathode by (say) ultraviolet illumination.

n_+ = number of electrons released from cathode by positive ion bombardment.

γ = number of electrons released from cathode per incident positive ion.

Electrons may be emitted from metal surfaces by bombardment of positive ions or metastable atoms. To cause a secondary emission

$$n = (n_0 + n_+)\, e^{\alpha d}$$

$$n_+ = \gamma\left[n - (n_0 + n_+)\right]$$

[n_+ = (addi
elect

$$n_+ = \gamma n - \gamma n_0 - \gamma n_+$$

$$n_+ + \gamma n_+ = \gamma(n - n_0)$$

$$n_+(1+\gamma) = \gamma(n - n_0)$$

$$n_+ = \frac{\gamma(n - n_0)}{1+\gamma}$$

$$n = (n_0 + n_+)\, e^{\alpha d}$$

$$n = \left[n_0 + \frac{\gamma(n - n_0)}{1+\gamma}\right] e^{\alpha d}$$

$$n = \left[\frac{n_0(1+\gamma) + \gamma(n - n_0)}{1+\gamma}\right] e^{\alpha d}$$

$$n = \left[\frac{n_0 + n_0\gamma + n\gamma - n_0\gamma}{1+\gamma}\right] e^{\alpha d}$$

$$n = \left[\frac{n_0 + n\gamma}{1+\gamma}\right] e^{\alpha d}$$

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$$n(1+\gamma) = (n_0 + n\gamma)\, e^{\alpha d}$$

$$n + n\gamma = n_0 e^{\alpha d} + n\gamma e^{\alpha d}$$

$$n + n\gamma - n\gamma e^{\alpha d} = n_0 e^{\alpha d}$$

$$n\left(1 + \gamma - \gamma e^{\alpha d}\right) = n_0 e^{\alpha d}$$

$$n\left[1 + \gamma\left(1 - e^{\alpha d}\right)\right] = n_0 e^{\alpha d}$$

$$n = \frac{n_0 e^{\alpha d}}{1 + \gamma\left(1 - e^{\alpha d}\right)}$$

$$n = \frac{n_0 e^{\alpha d}}{1 - \gamma\left(e^{\alpha d} - 1\right)}$$

Townsend current Growth Equation

$$i = \frac{i_0 e^{\alpha d}}{1 - \gamma\left(e^{\alpha d} - 1\right)}$$

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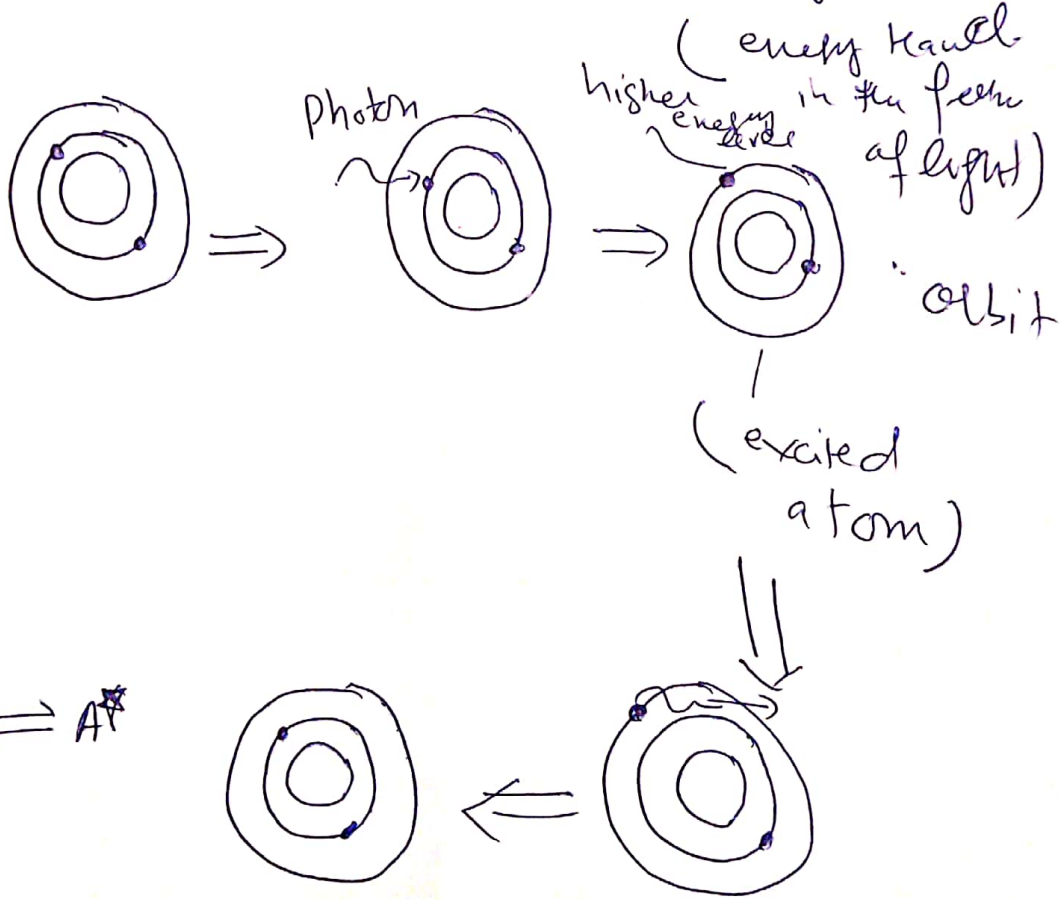
Photoionization

1

- ions toward Cathode
  Electron toward anode.

Photons Packets of energy



$hV + A \rightleftharpoons A^*$

energy release eV

2

- E is the energy in photon, which must be more than ionization Potential for Starting the Process of Photo-ionization.

(ionization potential)

- $V_i \leq E$ (Photon energy)

$E = hf$
$c = f\lambda$
$f = c/\lambda$

- $V_i \leq hc/\lambda$ $\qquad \lambda \leq c \cdot \frac{h}{V_i}$

h is Planck's constant (6.62×10^{-34} $m^2 kg/s$)

C is the velocity of light 3×10^8 m/s

$$\lambda \leq \left(\frac{1.97}{V_i}\right) \times 10^{-6} \text{ cm}$$

Photon Satisfying the wavelength ~~more~~ Less than above value can only start photo-ionization.

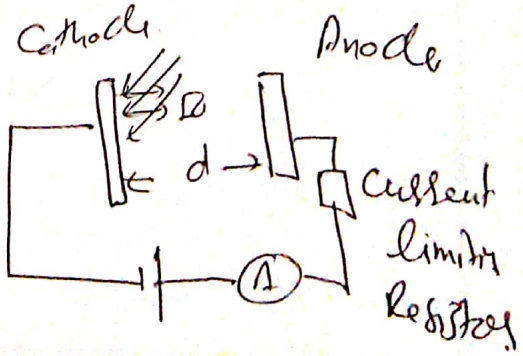
(The higher the ionization energy, the shorter will be the wavelength of the radiation capable of causing ionization.

Townsend's criterion for breakdown

$$I = \frac{I_0 e^{\alpha d}}{1-\gamma(e^{\alpha d}-1)} \quad \text{—(1)}$$

This equation gives the total average current in a gap before the occurance of breakdown.

As the distance b/w the electrode 'd' is increased, the ~~demo~~ denominator of the equation tend to zero. and at some ~~cri~~ critical distance $d = d_s$



~~if d = ds~~ - for value of $d < d_s$

I is approximately equal to I_0 (initial amount of current)

If $d = d_s$

the $I = \infty$, the current will be limited by the current limiting Resistor

$$\gamma\left[e^{\alpha d} - 1\right] = 1 \quad \text{--- (3)}$$

γ is small as $\gamma e^{\alpha d}$

$$\gamma e^{\alpha d} = 1$$

---

a) for $\gamma e^{\alpha d} < 1$ i_0 is easy to flow

b) $\gamma e^{\alpha d} = 1$ sparking threshold.

$\gamma e^{\alpha d} > 1$ spark discharge grows more rapidly.

for a given gap spacing and at a given gas pressure the value of the voltage which gives the α and γ satisfying breakdown

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Chilesian is called the spark breakdown voltage.

and corresponding distance is called sparking distance

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Paschen's law

1

→ Paschen's law is an equation that gives the breakdown voltage (V_s) that is, the voltage necessary to start a discharge or electric arc b/w two electrodes in a gas as a function of Pressure (P) and gap length (d).

$$V_s = f(P \cdot d)$$

- This equation is known as Paschen's law.
- The above equation shows that the sparking potential V is a function of Pressure and gap length (d).

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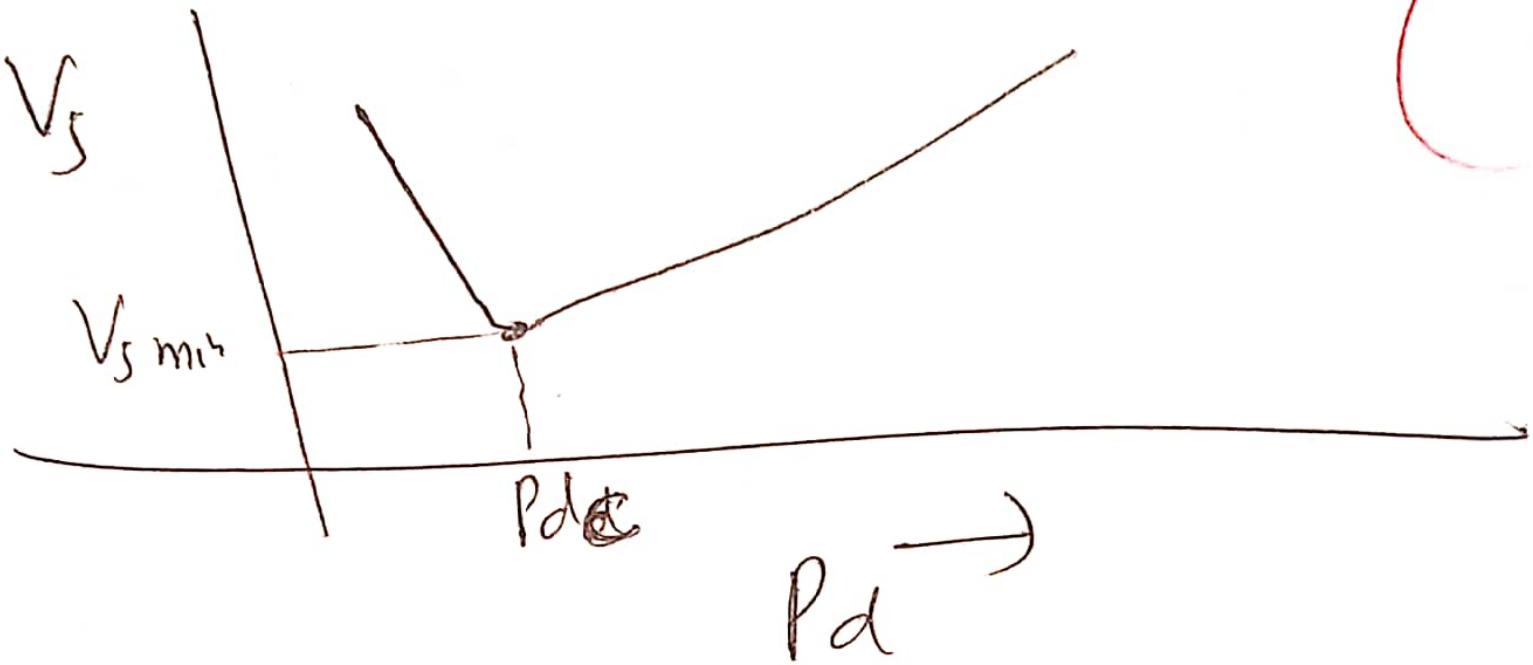
Paschen Law characteristics



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Gas Pressure $P = K$ Constant

$V \propto d$

$V \downarrow \Rightarrow d \downarrow$

$V \uparrow \Rightarrow$ increasing its original value

When $d = K$ Constant

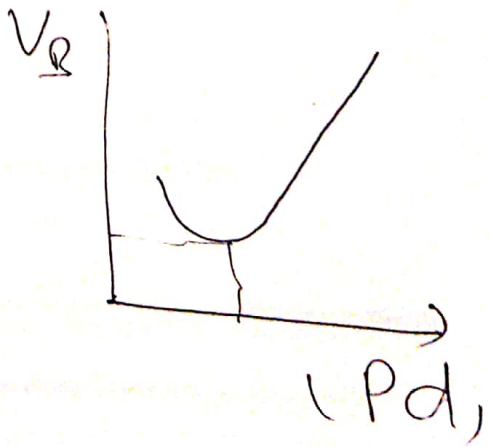
$V, \quad P$

$V \downarrow \Rightarrow P \downarrow$

but at certain point

$V \uparrow$

$V = F(Pd)$



gas Pressure

$P =$ Constant

$V_B \downarrow \Rightarrow d \downarrow$

upto some point

3

$$I = \frac{I_0 e^{\alpha d}}{1 - \gamma\left(e^{\alpha d} - 1\right)}$$

$$\gamma\left[e^{\alpha d} - 1\right] = 1 \longrightarrow (1).$$

α, γ in terms of E & p

$$\frac{\alpha}{p} = f_1\left(\frac{E}{p}\right)$$

electric field

$E = V/d$ voltage, distance

function of $= f_1\left(\frac{V}{pd}\right)$ —— (2)

$$\gamma = f_2\left(E/p\right)$$

$$= f_2\left(\frac{V}{pd}\right) \text{ —— (3)}$$

$$f_2\left(\frac{V}{pd}\right)\left[e^{p f_1\left(\frac{V}{pd}\right) d} - 1\right] = 1 \text{ —— (4)}$$

$$\boxed{V = f(pd)}$$

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1 ionization by interaction of Metastables with Atoms.

Metastable $\longrightarrow A^* \longrightarrow$ Excited atom with longer Periods.

$$A^m + B \longrightarrow A + B^+ + e^- \quad (V^m \geq V_i)$$

energy of metastable

ionization energy of atom B

$$A^m + B \longrightarrow A + B^+ \quad (V^m < V_i)$$

Another posibility for ionization by metastables is when $2V^m > V_i$ for A

$$A^m + A^m \longrightarrow A^+ + A + e + KE$$

or

$$A^m + 2A \rightarrow A_2^* + A$$

$$A_2^* \longrightarrow A + A + h\nu$$

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Thermal ionization

2

$$A \underset{}{\overset{\text{Heat}}{\rightleftharpoons}} A^{+} + e^{-} - U_i$$

where A = ~~an~~ represents a neutral atom.

A^{+} = ionized atom

e^{-} = electron removed from the ion

U_i = ionization energy.

If gas is heated sufficiently high temperature many of the neutral atoms will acquire adequate (enough) energy to ionize the atoms they strike.

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Corona Effect or corona discharge

The Phenomena of violet glow, Hissing Sound and Production of ozone gas in OHTL is known as Corona

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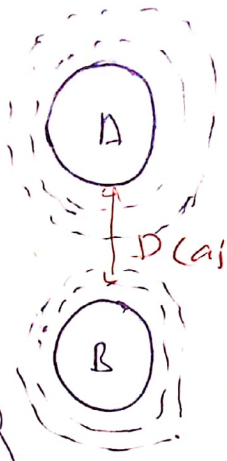


25kV

Can see by Stroboscope

30 kV/cm

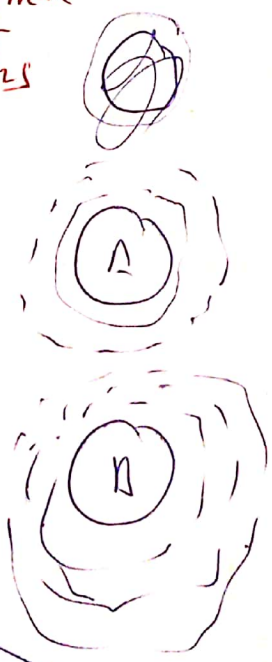
electric field intensity

The value of current flowing is negligible

→ air is not Perfect Dielectric (not perfect insulator)

– even in normal condition a lot free electrons

45 kV



40 kV/cm

enough to break insulation Property of air

→ air will loose its insulation Property

Hissing Sound

Air Dielectric medium

in air: Cosmic rays, Ultraviolet radiation, Radioactivity

Dielectric strength

30 kV/cm

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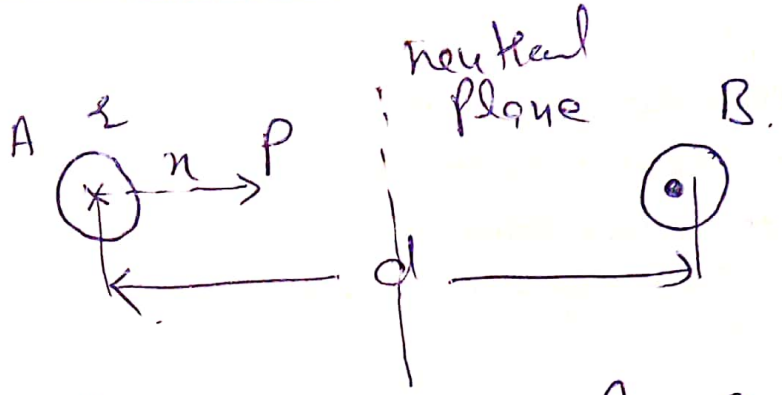
Critical voltages



Charge density at conductor A = $-q$ Coulomb/m

" " " " B = $-q$ Coulomb/m.

Radius of each conductor = r.

Electric field intensity at Point 'P' at distance x from the centre of conductor A.

$$E_1 = q/2\pi\epsilon_0 x.$$

Electric field intensity at Point 'P' from the centre of conductor B

$$E = \frac{-q}{2\pi\epsilon_0(d-x)}$$

Total electric field intensity at Point P

$$E_x = \left(\frac{q}{2\pi\epsilon_0 x}\right) - \left(-\frac{q}{2\pi\epsilon_0(d-x)}\right)$$

$$= \frac{q}{2\pi\epsilon_0 x} + \frac{q}{2\pi\epsilon_0(d-x)}$$

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$$= \frac{q}{2\pi\epsilon_0}\left(\frac{1}{x} + \frac{1}{d-x}\right)$$

$$= \frac{q}{2\pi\epsilon_0}\left(\frac{d-x+x}{x(d-x)}\right)$$

$$= \frac{q}{2\pi\epsilon_0}\left(\frac{d}{x(d-x)}\right)$$

If V' is the voltage of one Conductor with respect to Neutral plane.

$$V' = -\int_{d/2}^{r} E_x \, dx$$

$$= -\int_{d/2}^{r} \frac{q}{2\pi\epsilon_0}\left(\frac{d}{x(d-x)}\right) dx.$$

$$= \frac{q}{2\pi\epsilon_0}\Big[\ln x - \ln(d-x)\Big]_{r}^{d/2}$$

$$= \frac{q}{2\pi\epsilon_0}\Big[\{(\ln d/2 - \ln r\}\} - \{\ln(d-\tfrac{d}{2}) - \ln(d-r)$$

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$$= \frac{q}{2\pi\epsilon_0}\left[\cancel{\ln\frac{d}{2}} - \ln r - \cancel{\ln\frac{d}{2}} + \ln(d-r)\right]$$

$$= \frac{q}{2\pi\epsilon_0}\left[\ln(d-r) - \ln r\right]$$

$$V' = \frac{q}{2\pi\epsilon_0}\ln\frac{d-r}{r}$$

$$E_x = \frac{q}{2\pi\epsilon_0 x}\cdot\frac{d}{x(d-x)}$$

$$= \frac{q}{2\pi\epsilon_0}\frac{d}{x(d-x)}$$

$$\frac{q}{2\pi\epsilon_0} = \frac{V'}{\ln\left(\frac{d-r}{r}\right)}$$

$$E_x = \frac{V'}{\ln\left(\frac{d-r}{r}\right)}\frac{d}{x(d-x)}$$

Field intensity (Gradient) increases as x decreases.

g_{max} at $x = r$

$$E_{max} = g_{max} = \frac{V'}{\ln\left(\frac{d-r}{r}\right)}\frac{d}{r(d-r)}$$

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$$g_{max} = \frac{V'}{\ln\left(\frac{d-r}{r}\right)} \frac{d}{r(d-r)}$$

5

$$\boxed{g_{max} = \frac{V'}{r \ln d/r}}$$

The value of potential gradient at which ionization takes place under normal temp (25°C) and pressure (76 cm Hg) and without impurities is equal to 30 kV peak/cm.

or ~~21.1 kV (rms)~~ 21.1 kV rms/cm

and is denoted by g_0

$$\boxed{V' = r\, g_0 \ln d/r}$$

The dielectric strength at any temp t °C and pressure b cm of Hg

$$\delta = \frac{b}{76} \frac{273+25}{273+t} = \frac{3.92b}{273+t}$$

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Critical disruptive voltage. It corresponds to the gradient at the surface of the conductor equal to the breakdown strength of air.

$$V_c = r g_0 m \delta \ln d/r$$

Due to irregularity of surface, dust and dirt on the surface, there is a further reduction in the breakdown voltage.

$$\boxed{V_c = r g_0 m \delta \ln d/r}$$

m lies b/w 0.8 to 1.

Visual Critical disruptive voltage.

$$\boxed{g_v = g_0 \delta \left(1 + \frac{0.3}{\sqrt{r\delta}}\right) \text{kV/cm}}$$

$$V_v = r g_v m_v \ln d/r$$

$$= 21.1\, m_v r \delta \left(1 + \frac{0.3}{\sqrt{r\delta}}\right) \ln d/r \quad (\text{kV rms})$$

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A T.L is having three conductors laterally spaced 6m apart. The diameter of each conductor is 2 cm. The air temp is 27°C and pressure of 72 cm of Hg. If the surface factor is 0.82 and irregularity factor is 0.90. Find the critical disruptive and visual critical disruptive voltage

$$\boxed{V_c = r\, g_0\, m\, \delta \ln d/r}$$

$$\delta = \frac{3.92b}{273+t} = \frac{3.92\times 72}{273+27}$$

$$= 0.9408$$

$$V_c = 1.0 \times 21.1 \times 0.90 \times 0.9408 \ln \frac{600}{1}$$

$$\boxed{V_c = 114.29\ kV}$$

Line to Line critical disruptive voltage $= 114.29 \times \sqrt{3} = 197.95\ kV$

Visual critical disruptive voltage

$$V_v = 21.1\, m_v\, r\, \delta \left(1 + \frac{0.3}{\sqrt{r\delta}}\right) \ln d/r$$

$$= 21.1 \times 0.82 \times 1.0 \times 0.9408 \left(1 + \frac{0.3}{\sqrt{1 \times 0.9408}}\right) \ln \frac{600}{1}$$

8

Corona Loss

ionized charges near from the conductor surface take energy from the supply sup

for fair weather condition.

Peek's formula

$$P_c = 241 \times 10^{-5} + \frac{f+25}{\delta}\sqrt{\frac{r}{d}}\left(V_p - V_c\right)^2$$

KW/phase/Km.

under foul weather condition

$$P_c = 241 \times 10^{-5} \times \frac{f+25}{\delta}\sqrt{\frac{r}{d}}\left(V_p - 0.8V_c\right)^2$$

KW/phase/Km

A three phase, 50 Hz, 220 KV T.L consists of conductors of 2.0 cm diameter and spaced equilateraly at a distance of 4 m. The line conductors have smooth surface with value of $m = 0.96$. The barometric

ssure is 73 cm of Hg and
mp of 20°C. Determine the
air and stormy weather
Corona loss per km per phase

$$\delta = \frac{3.92b}{273+t} = \frac{3.92 \times 73}{273+20} = 0.9767$$

$$V_c = g_0 m \delta \ln d/r$$

$$= 1.0 \times 21.1 \times 0.96 \times 0.9767 \times \ln\left(\frac{400}{1}\right)$$

$$= 118.53 \text{ KV}$$

Phase voltage $= \frac{220 \text{ KV}}{\sqrt{3}} = 127.02 \text{ KV}$

$$P_c = 241 \times 10^{-5} \times \frac{50+25}{0.9767} \sqrt{\frac{1}{400}} (127.02 - 118.53)^2$$

$$= 0.67 \text{ KW/phase/Km}$$

$$P_c = 241 \times 10^{-5} \times \frac{50+25}{0.9767} \sqrt{\frac{1}{400}} (127.02 - 0.8 \times 118.53)^2$$

$$= 9.59 \text{ KW/phase/Km}$$

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→ air is not a perfect Dielectric (not perfect insulator

→ even in normal condition contain a lot of free electron

→ when the conductor is carrying high voltage air surrounding the conductor becomes ionize due to the electric field around it

— intensity of the electric field is maximum at the surface of the conductor and as we move away from the conductor it decreases

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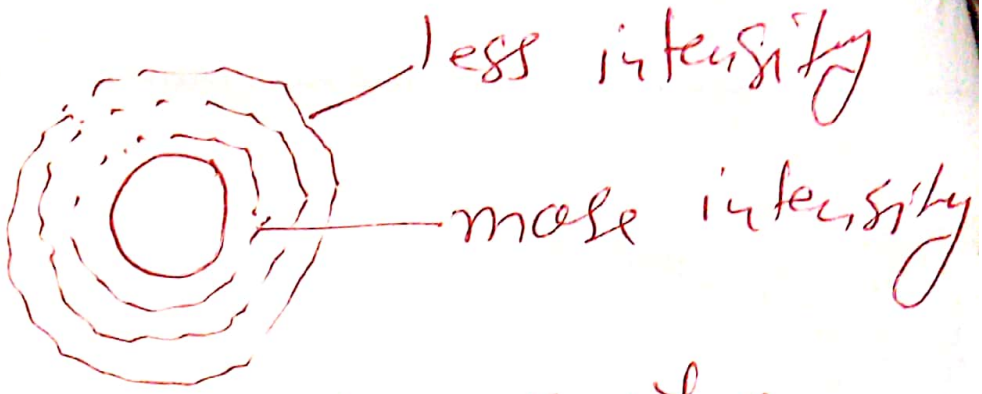

→ the air near the surface will ionize.

0.5 kW/phase/km for 100 km

→ Interference with Radio and TV.

- Ozone Gas Production (which can reduce the life of insulator)

i) Causes of corona

a) Electric field around the conductor surface either by increasing the diameter of the conductor.

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Bundling of the Conductors

→ arranging the Conductors in two, 3, 4 per phase

This arrangement helps in reducing the electric field around the conductor. and the corona effect.

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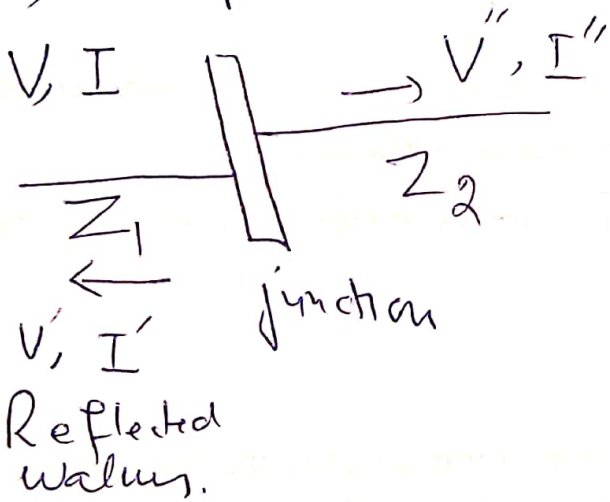
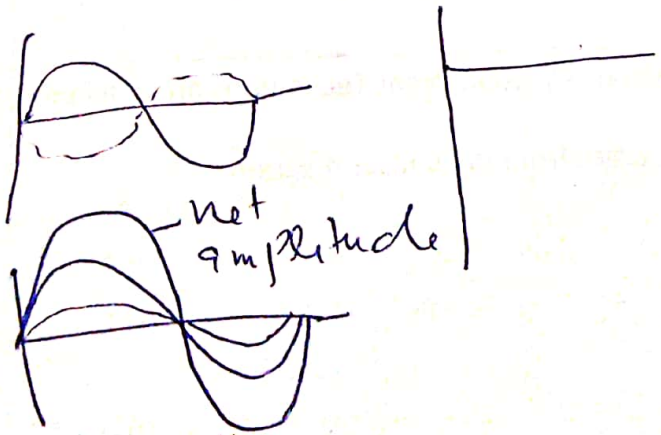
Travelling waves whenever there is a wave travelling the ToL across the junction, due to change of nature, refraction take place.



i) Destructive interference → amplitude decrease
ii) Constructive " → amplitude increases



if change in angle p.f also changes

Muhammad Ahsan ul haq

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$$V''\left(\frac{Z_1+Z_2}{Z_1Z_2}\right) = \frac{2V}{Z_1}$$

$$V'' = \frac{2V}{Z_1} \times \frac{Z_1Z_2}{Z_1+Z_2}$$

$$V'' = \left(\frac{2Z_2}{Z_1+Z_2}\right)V$$

$$\boxed{V'' = \beta V}$$

Refraction coefficient

$$I'' = I + I'$$

$$\cancel{V'' = \frac{V}{Z_1} - \frac{V'}{Z_2}}$$

$$I'' = \frac{V''}{Z_2} = \frac{V\beta}{Z_2}$$

$$I'' = \frac{1}{Z_2} \times V \times \frac{2Z_2}{Z_1+Z_2}$$

$$I'' = \left(\frac{2}{Z_1+Z_2}\right)V$$

$$\boxed{I'' = \lambda V}$$

Refraction coefficient for voltage and current are not same.

Because of Reflection and Refraction, there is a destructive interference, not amplitude decrease. No damage would

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$$V'' = V + V' \quad \text{—(1)}$$

Reflected voltage

$$I'' = I + I' \quad \text{—(2)}$$

$$I = \frac{V}{Z_1}, \quad I' = -\frac{V'}{Z_1}$$

$$I'' = \frac{V''}{Z_2}$$

from (2)

$$I'' = I + I'$$

$$\frac{V''}{Z_2} = \frac{V}{Z_1} - \frac{V'}{Z_1}$$

$$\frac{V + V'}{Z_2} = \frac{V}{Z_1} - \frac{V'}{Z_1}$$

$$\frac{V}{Z_2} + \frac{V'}{Z_2} = \frac{V}{Z_1} - \frac{V'}{Z_1}$$

$$\frac{V'}{Z_2} + \frac{V'}{Z_1} = \frac{V}{Z_1} - \frac{V}{Z_2}$$

$$V'\left(\frac{Z_1 + Z_2}{Z_1 Z_2}\right) = V\left(\frac{Z_2 - Z_1}{Z_1 Z_2}\right)$$

$$V' = \left(\frac{Z_2 - Z_1}{Z_1 + Z_2}\right) V$$

$$V' = V\alpha$$

coefficient of Reflection.

$$I' = -\frac{V'}{Z_1} = -\frac{V\alpha}{Z_1}$$

$$\boxed{I' = -I\alpha}$$

Here negative sign shows that reflected current

Now

$$I'' = I + I'$$

$$\frac{V''}{Z_2} = \frac{V}{Z_1} - \frac{V'}{Z_1}$$

from eq (1)

$$\frac{V''}{Z_2} = \frac{V}{Z_1} - \frac{1}{Z_1}(V'' - V)$$

$$\frac{V''}{Z_2} = \frac{V}{Z_1} - \frac{V''}{Z_1} + \frac{V}{Z_1}$$

$$\frac{V''}{Z_2} + \frac{V''}{Z_1} = 2V/Z_1$$

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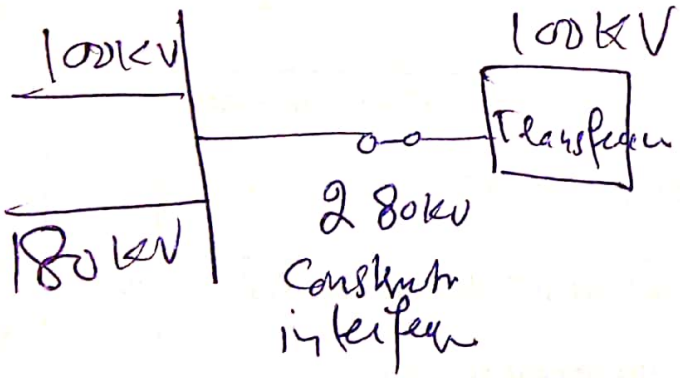
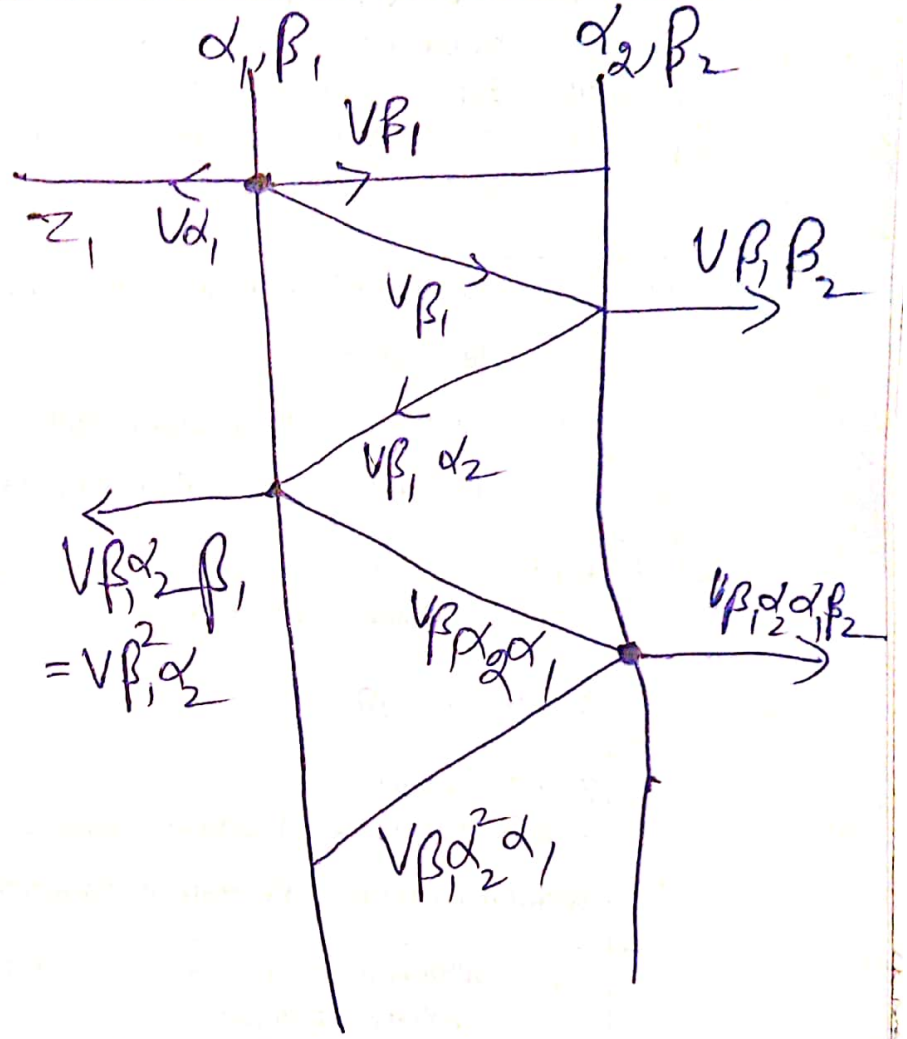
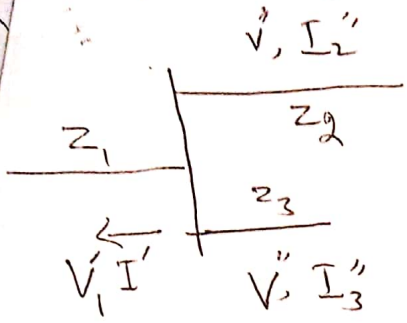
be done to equipment. Connected (eg transformer) However if there is a constructive interferen, net amplitude increase, therefore damage may occur.





Bewley Lattice diagram.

...ction and Refraction at Bifurcation.



Division of line across the junction – Bifurcation

$$V'' = V + V'$$

overall current being Refracted – $I'' = I + I'$

$$I = \frac{V}{Z_1}, \quad I' = -\frac{V'}{Z_1}$$

$$I_2'' = \frac{V''}{Z_2}, \quad I_3'' = \frac{V''}{Z_3}$$

$$I + I' = I_2'' + I_3''$$

$$\frac{V}{Z_1} + \left(-\frac{V'}{Z_1}\right) = \frac{V''}{Z_2} + \frac{V''}{Z_3} \quad \text{— (A)}$$

$$\frac{V}{Z_1} - \frac{V'}{Z_1} = \frac{V+V'}{Z_2} + \frac{V+V'}{Z_3}$$

$$\frac{V}{Z_1} - \frac{V}{Z_2} - \frac{V}{Z_3} = \frac{V'}{Z_2} + \frac{V'}{Z_3} + \frac{V'}{Z_1}$$

$$V\left(\frac{1}{Z_1} - \frac{1}{Z_2} - \frac{1}{Z_3}\right) = V'\left(\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}\right)$$

$$V' = \left[\frac{\left(\frac{1}{Z_1} - \frac{1}{Z_2} - \frac{1}{Z_3}\right)}{\left(\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}\right)}\right] V$$

For n number of lines

$$V' = V\left[\frac{\frac{1}{Z_1} - \frac{1}{Z_2} - \frac{1}{Z_3} + \cdots - \frac{1}{Z_n}}{\left(\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3} + \cdots + \frac{1}{Z_n}\right)}\right]$$

From (A)

$$\frac{V}{Z_1} - \frac{V'}{Z_1} = \frac{V''}{Z_2} + \frac{V''}{Z_3}$$

$$\frac{V}{Z_1} - \left[\frac{V''-V}{Z_1}\right] = \frac{V''}{Z_2} + \frac{V''}{Z_3}$$

$$\frac{V}{Z_1} - \frac{V''}{Z_1} + \frac{V}{Z_1} = \frac{V''}{Z_2} + \frac{V''}{Z_3}$$

$$\frac{2V}{Z_1} = \frac{V''}{Z_1} + \frac{V''}{Z_2} + \frac{V''}{Z_3}$$

$$V'' = \frac{\frac{2V}{Z_1}}{\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}}$$

for n number of lines

$$V'' = \frac{2V/Z_1}{\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3} + \cdots + \frac{1}{Z_n}}$$

Similarly $I'' = \dfrac{V''}{Z_2 \parallel Z_3}$

$$I' = -\frac{V'}{Z_1}$$

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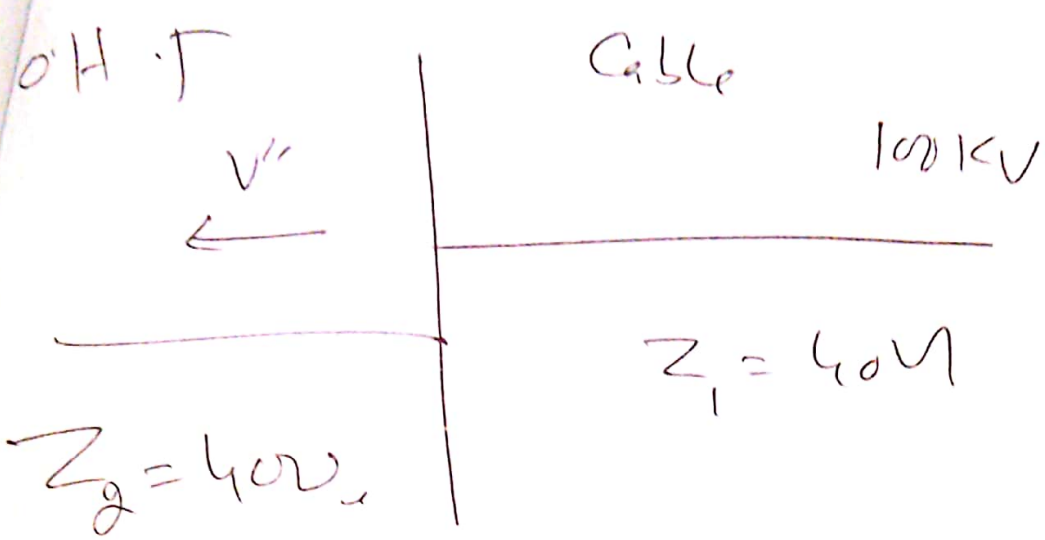


$$V'' = \frac{2Z_2}{Z_1 + Z_2} V$$

$$= \frac{2(400)}{440} \times 100\,kV$$

$$V'' = 181.8\,kV$$

it indicates Constructive interference

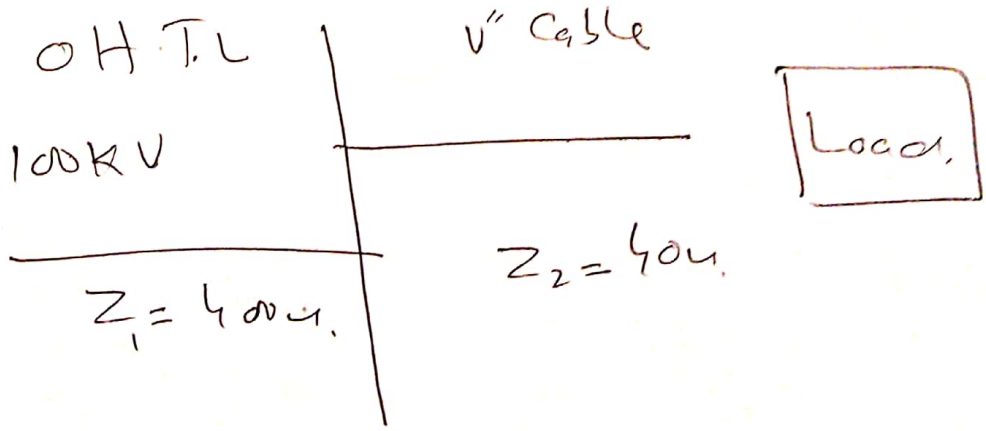
→ So, designing any power equipment, we have to keep the ~~[illegible]~~ the value and characteristics of Reflection and Refraction in mind

An O.H T.L having natural impedance of 400Ω. A Piece of cable is connected to it having a natural impedance of 40Ω. A voltage of surge 100KV is travelling

a) From O.H T.L Toward Cable.

b) From Cable to T.L

a)



$$V'' = \left(\frac{2Z_2}{Z_1+Z_2}\right)V = 2\left(\frac{2(40)}{40+400}\right)$$

$$= 18.18\,KV$$

$$I'' = \frac{V''}{Z_2} = \frac{18.18}{40} = 454.5\,A$$

⇒ It indicate destructive interference

100KV — R.V
Transition Relay

An O.H.T.L ~~which~~ with the natural impedance of 400Ω is bifurcated with two line with the natural impedance of 300Ω and 200Ω respectively. Calculate the voltage and current in the bifurcated line when 100kV surge is incident to the lines of natural impedance of 400Ω.

Sol

$Z_1 = 400\Omega$

$Z_2 = 300\Omega$

$Z_3 = 200\Omega$

$$V'' = \frac{2V/Z_1}{\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}} = \frac{2(100\,kV)/400}{\frac{1}{400} + \frac{1}{300} + \frac{1}{200}}$$

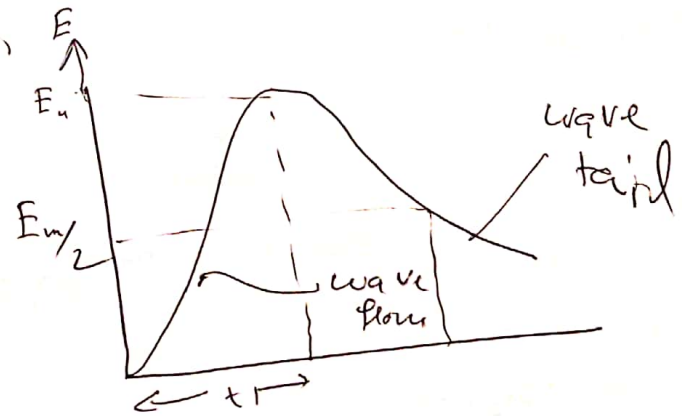
$V'' = 46.15\,kV$

for $I = ?$

DIY

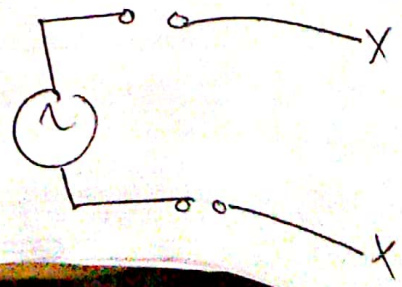
Voltage Surge

(1) A sudden rise in voltage for a very short duration on the power system is known as Voltage Surge. or thient voltage.



Causes of over voltage

i) switch surges
ii) Insulation failure
iii) Arcing ground
iv) Resonance
a) Case of an open line



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When unloaded line is connected to voltage source, a voltage wave is setup which travel along the line. On reaching the terminal point A, it is reflected back to the supply end without change of sign. The cause voltage doubling.

ii) Case of a loaded line. suppose a loaded line is suddenly interrupted. This will set up voltage $2Z_n I$ across the switch.

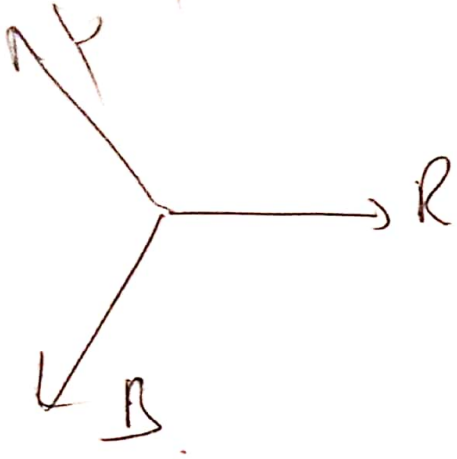
$Z_n = \sqrt{L/C}$

$= 2\sqrt{2} \times 100 \times 1000 / 100 = 282.8\,kV$

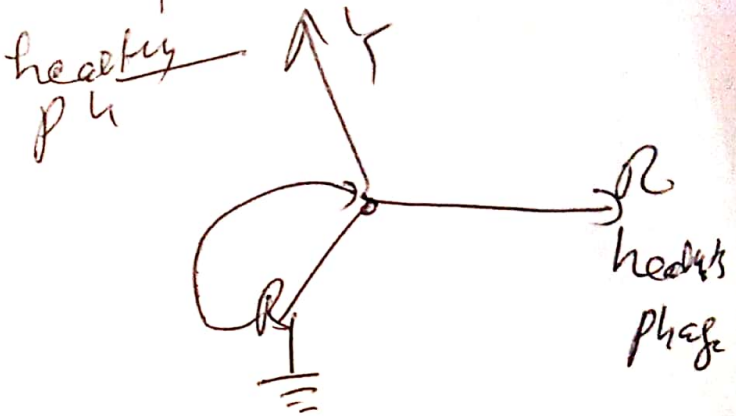
if V_m is the peak voltage

the maximum voltage to which the line may be subjected is $V_m + 282.8\,kV$

Before fault



After Earth fault



Voltage magnitude increases $\sqrt{3}$ times

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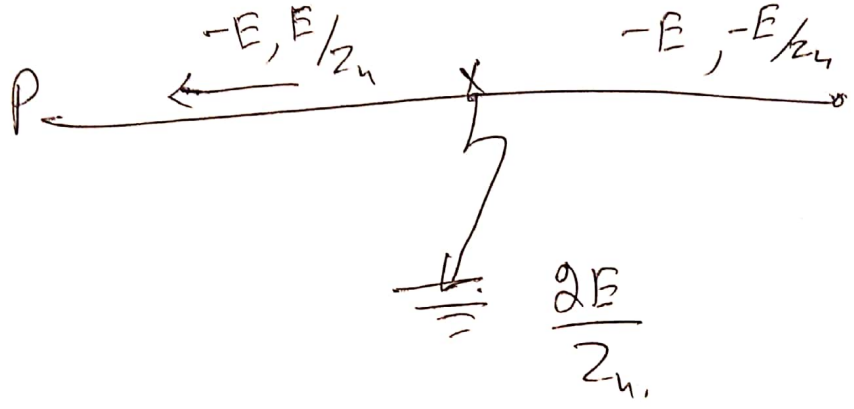
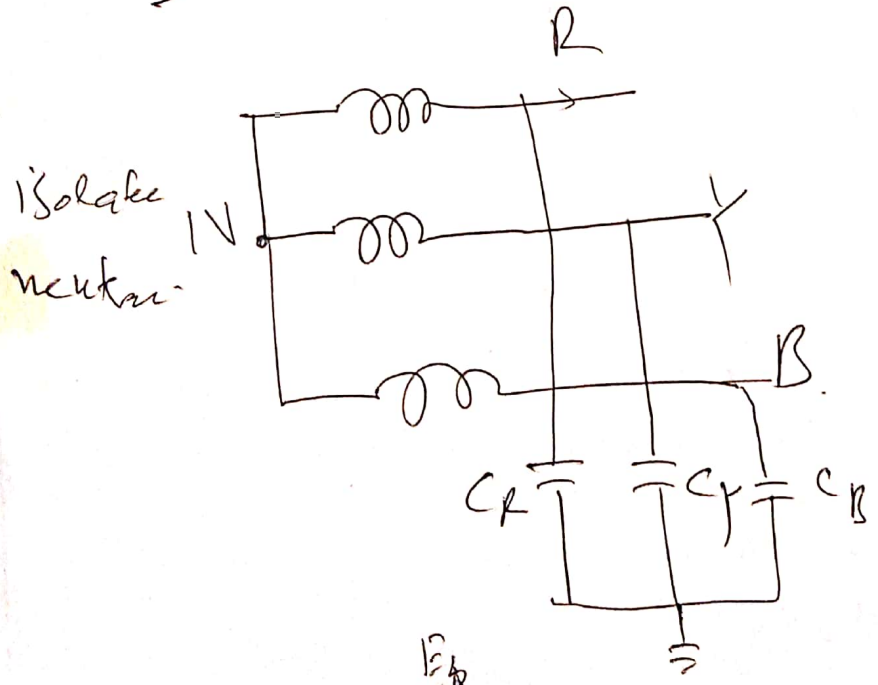
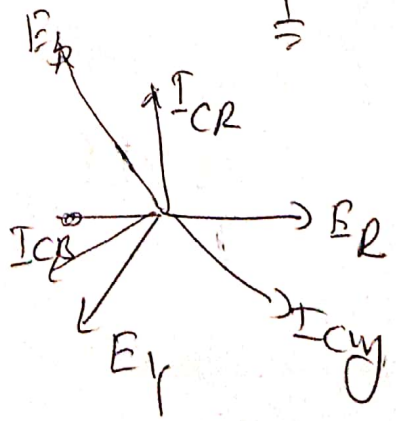
insulation Failure



Arcing Ground





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(1) Lightning → An electric discharge b/w Cloud and earth, b/w the clouds or b/w the charge centres of the same cloud is known as lightning.

→ Lightning is a huge spark and take place when the clouds are charged to such a high potential (+ve or -ve) with respect to earth, or neighbouring cloud that the dielectric strength of neighbouring medium (air) is destroyed.

→ During upthrust of warm moist air from earth, the friction b/w air and the tiny particles of water causes the building up of charges

→

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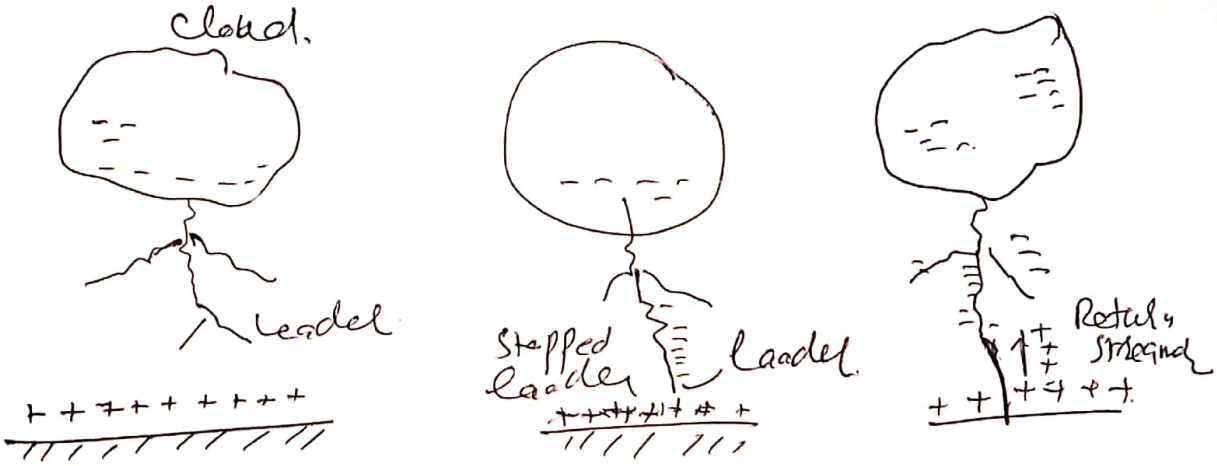
Mechanism of Lightning discharge.

(2)

→ As the charge acquired by the cloud increase, the potential b/w the cloud and earth increases and therefore, gradient in the air increases

→ When the potential gradient is sufficient (5kV/cm to 10kV/cm) to breakdown the air, the lightning stroke starts



1) As soon as the air near the cloud breaks down, a streamer called leader streamer or pilot stream streamer starts from the cloud towards the earth. The leader streamer will continue its journey towards earth as long as the cloud, from which it originates

enough charge to it to maintain the gradient at the tip of leader streamer above the strength of air.

→ leader streamer will not reach the earth.

→ current in leader streamer is low (< 100 A).

→ velocity of propagation is 0.05% that velocity of light.

(ii) → In many cases the ladder streamer continue its journey towards earth. As the leader streamer moves towards earth, it is ~~accompli~~ accompanied by point of luminesence.

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which Travel in jumps giving rise to stepped leaders.

- The velocity of stepped leader exceed one-sixth of that light
  → It give rise to first visual phenomena of discharge.

iii) As leader streamer reaches the earth, a return streamer shoots up from earth to the cloud, following the same path as the main channel of the downward leader.
→ down ward streamer has negative charge and the return streamer positive charge.

---

i) 87% lightning strokes negatively charged clouds
" " " positively " "

ii) approximately 100 strokes per second.

iii) current in the range of 10 KA to 90 KA

Types of Lightning Strokes

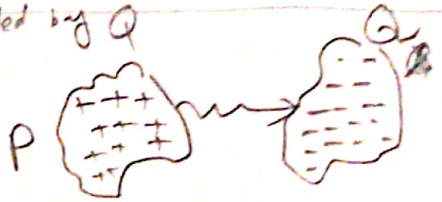
→ The cloud will induce a charge of opposite sign on the tall object (e.g. an O.H line in this case)

→ When the potential b/w the cloud and line exceeds the breakdown value of air, the lightning discharge occurs b/w the cloud and the line.

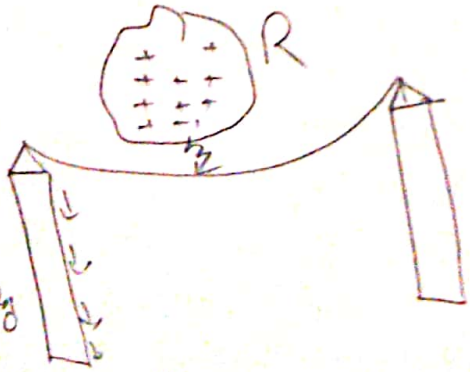
→ Stroke A will always occur on tall objects and hence protection can be provided against it

R cloud is bounded by Q

Stroke B



→ In Stroke B, the lightning discharge occurs on the O.H line as a result of stroke A b/w the cloud

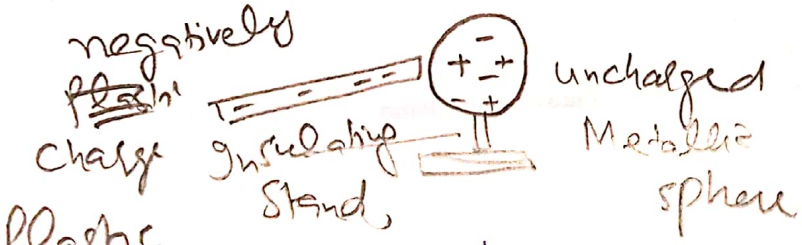


→ If the cloud P shifts to near the cloud Q, then lightning discharge will occur b/w them and charges on both clouds disappear quickly

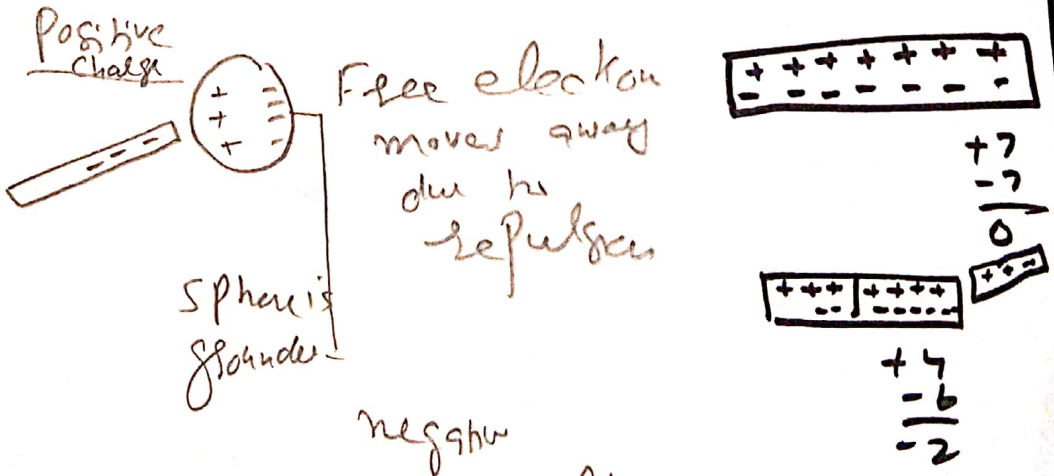
→ Cloud R suddenly become free and then discharge rapidly to earth

Electrostatic induction

It is possible to obtain charges without any contact with other charge. They are known as induced charges and the phenomena of producing induced charges is known as electrostatic induction.



neutral body means positive and negative charges are equal.



Positive charge remain due to force of attraction

negative charge flow to ground.

when plastic rod is removed

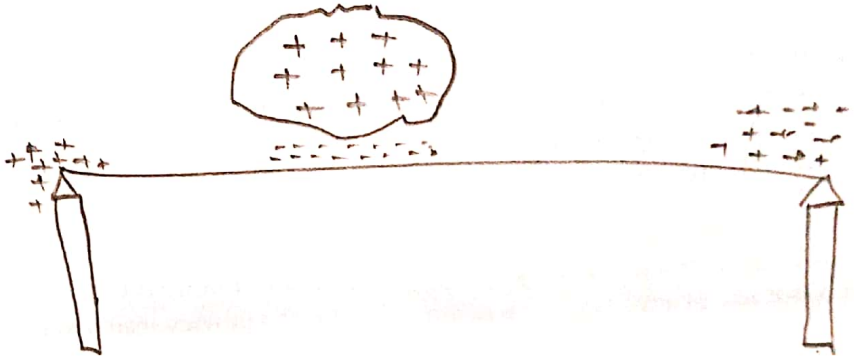
Positive charge move uniformally

Stroke B completely ignores the height of object and can even strike the ground.

- Therefore it is not possible to provide protection against stroke B.

1

Indirect Stroke



→ Indirect strokes results from the electrostatic induced charge on the conductor due to the presence of charged clouds.

→ A positively charged cloud is above the line and induces a negative charge on the line by electrostatic induction

→ This negative charge will be only on that portion of the line right under the cloud and the portions of the line away from it will be positively charged

→ The induced positive charge leaves

slowly to earth via the insulator.

When the cloud discharge to earth or to another cloud the negative charges on the wire is isolated as it cannot flow quickly to earth over the insulators.

→ The Result is that the negative charge rush along the line in both direction in the form of travelling waves.

→ Majority of surges in a T.L are caused by indirect lightning strokes.

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