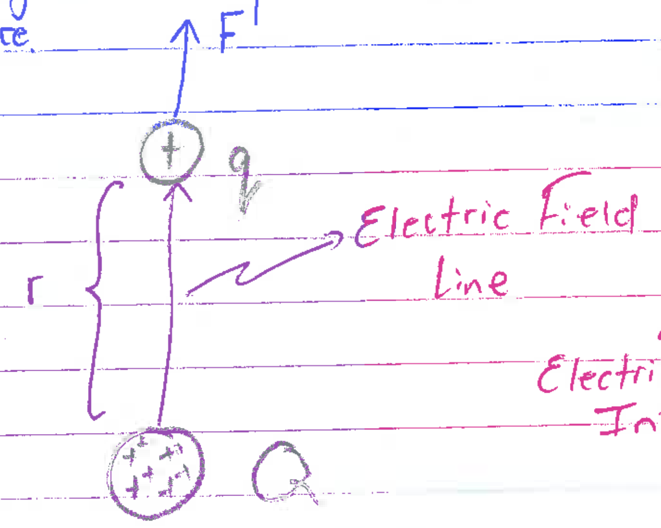
14 February 2019

Electric Field

def:
A region in space where a charge experiences a force



$$|F| = \frac{KQq}{r^2}$$

$$E = \frac{F}{q}$$

Electric Field Intensity $E = \frac{KQq}{r^2 q}$

$$E = \frac{KQ}{r^2}$$

Electro static constant $9 \cdot 10^9 \frac{Nm^2}{C^2}$

Electric field SI units Newtons per coulomb (N/C) or volts per meter (V/m).

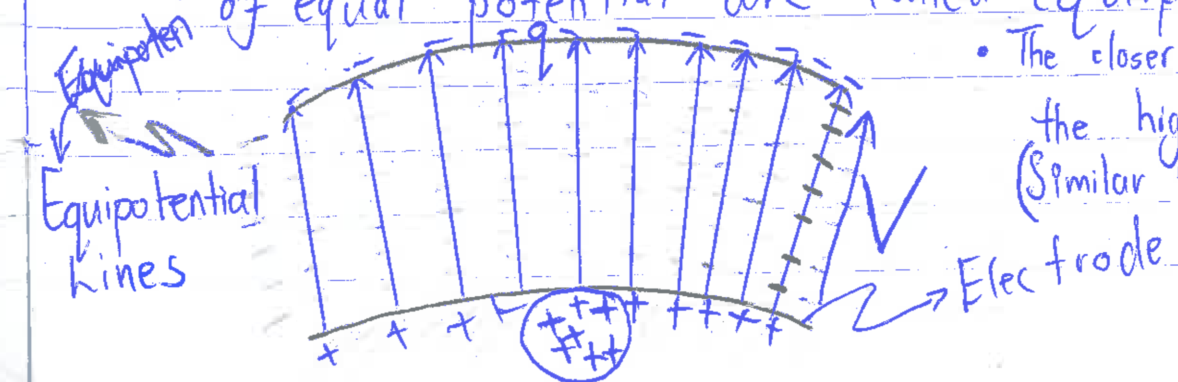
Electric field Characteristics:

- When an electrode is placed close to a charge, the charge distributes equally on the electrode.
- The e.field arrow points in direction of the force

1 * An electric field line leaves ~~at~~ the surface of electrodes at a 90° angle

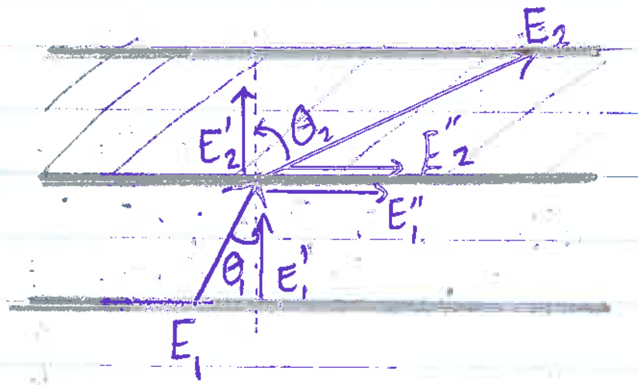
2 * Theres no potential difference inside the electrode. or electric field.

3 * The points along an electric field line has different potentials. Then the line connecting these points of equal potential are called equipotential lines.



- The closer the Equipotential lines the higher the electric field (Similar to contour lines)

4.* The behaviour of Electric field lines at dielectric boundaries



$E_1'' = E_2''$ (a) This says the horizontal components are equal

so ~~[illegible]~~ $\varepsilon_1 E_1' = \varepsilon_2 E_2'$

$$\frac{E_2'}{E_1'} = \frac{\varepsilon_1}{\varepsilon_2}$$

$$\boxed{E_2' = \frac{\varepsilon_1 E_1'}{\varepsilon_2}}$$

$$\tan\theta_1 = \frac{E_1''}{E_1'} \quad (1)$$

$$\tan\theta_2 = \frac{E_2''}{E_2'} \quad (2)$$

$$\frac{(1)}{(2)} = \frac{\tan\theta_1}{\tan\theta_2} = \frac{\frac{\cancel{E_1''}}{E_1'}}{\frac{\cancel{E_2''}}{E_2'}}$$

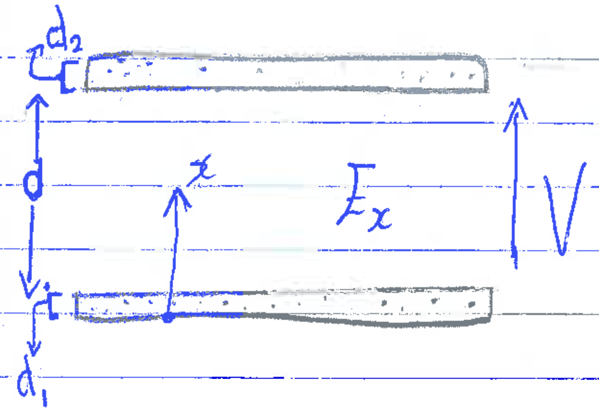
since $E_1'' = E_2''$

$$\text{from (a)}: \frac{\tan\theta_1}{\tan\theta_2} = \frac{E_2'}{E_1'} = \frac{\frac{\varepsilon_1 E_1}{\varepsilon_2}}{E_1} = \frac{\varepsilon_1}{\varepsilon_2}$$

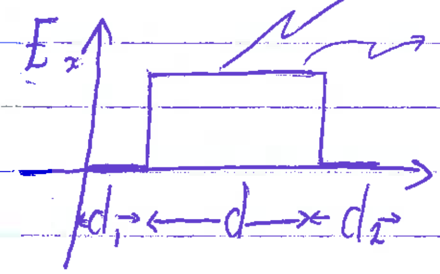
$$\frac{\tan\theta_1}{\tan\theta_2} = \frac{\varepsilon_1}{\varepsilon_2}$$

E.fields in Regular Geometry electrodes

1. Parallel Plate electrodes



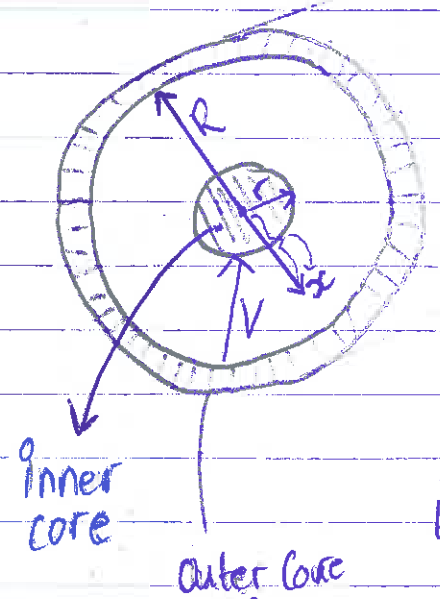
$$E_x = \frac{V}{d}$$ is constant, hence uniform electric field.



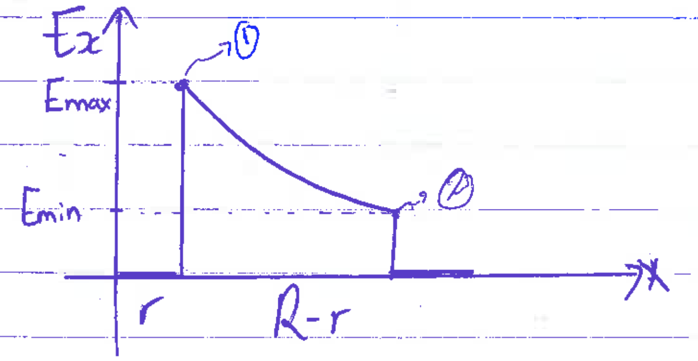
E.field Profile

The E.field in a parallel plate electrode is uniform

2. Coaxial Electrode



$$E_x = \frac{V}{x \ln\left(\frac{R}{r}\right)}$$



Emax is when $x = r$,

① $E_{max} = \dfrac{V}{r \ln\left(\frac{R}{r}\right)}$ ② $E_{min} = \dfrac{V}{R \ln\left(\frac{R}{r}\right)}$

• Given Emax and V, one would play with R & r.

$\underbrace{E_{max}}$ is minimal when $\ln\left(\frac{R}{r}\right) = 1$

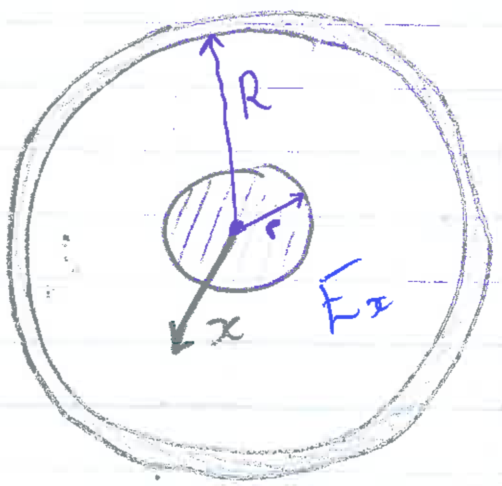
$\Rightarrow \frac{R}{r} = e = 2.71$

NB! Question 1

Determine the diameter of a single core power cable, $2R$ = diameter, and its economical inner core diameter ~~wher~~ for a single core cable in a 3 phase system with 275 kV (Always rms). $E_{max} = 15$ kV/mm (Maximum Electric Field Stress)

- $\sqrt{2} \times V_{phase} = V_{peak}$
- Line to line voltage (ALWAYS) (RMS)
- Here convert V_{rms} line to line voltage to phase V, then convert to peak voltage.

Spherical Electrode Geometry



$$E_x = \frac{V}{x^2\left(\frac{1}{r} - \frac{1}{R}\right)}$$

$$E_{max} = \frac{V}{r^2\left(\frac{1}{r} - \cancel{\frac{1}{R}}\right)}$$ → 0 when

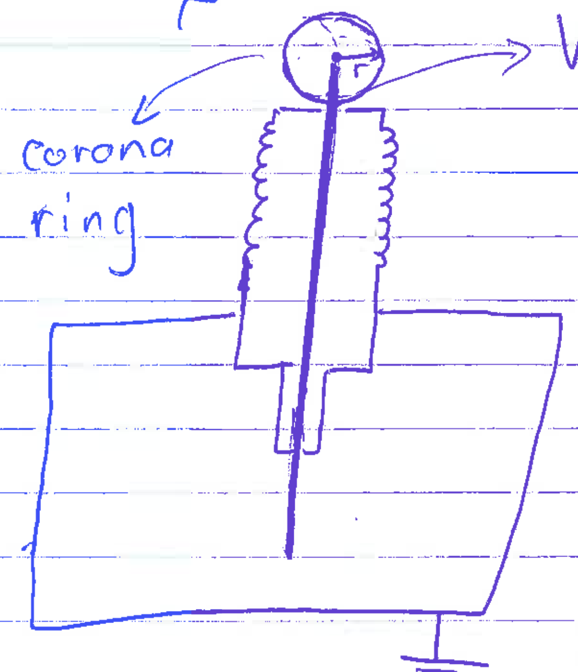
Air breaks down at

$E_{max} = \frac{V}{r}$

$E \approx 3$ kV/mm → air ionisation

This breaks down material when it does, it is Corona.

- Bushing is insulation



$E_{max} < 3$ kV/mm

- Ionised

| $2{:}15_{pm}$ Friday |

Ans: to Q1: $2R = 195.5$
Economical ... $= 81.32$ mm

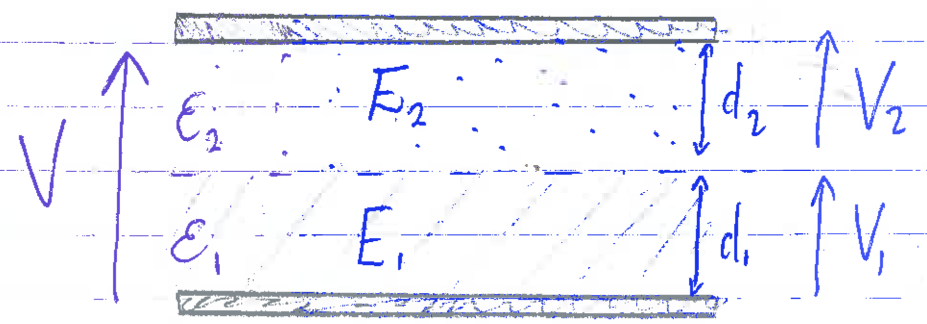
21 February 2019

Practice Question

Ans: Outer diameter ≥ 142 mm

[Calculate the outer diameter of the corona ring that needs to...]

Electric field in Multilayered dielectrics



$V = V_1 + V_2$

but:

$V_1 = d_1 E_1$

$V_2 = d_2 E_2$

so

$V = d_1 E_1 + d_2 E_2$

We also know

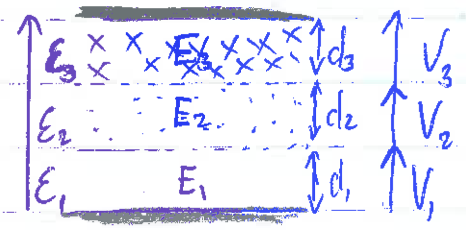
$$\varepsilon_1 E_1 = \varepsilon_2 E_2 \quad \text{, trying to solve for } E_1$$

$$\therefore \; E_2 = \frac{\varepsilon_1 E_1}{\varepsilon_2}$$

$$V = d_1 E_1 + d_2 \frac{\varepsilon_1}{\varepsilon_2} E_1$$

$$\therefore \; E_1 = \frac{V}{\frac{\varepsilon_1}{\varepsilon_1} d_1 + \frac{\varepsilon_1}{\varepsilon_2} d_2} \longrightarrow$$

How about we have:

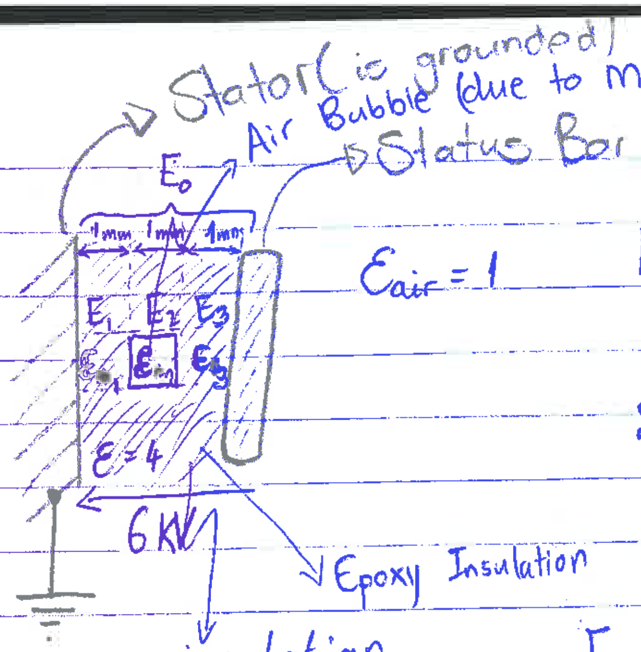


layers $= n$ $\qquad$ $E_k \rightarrow$ E. field in layer k

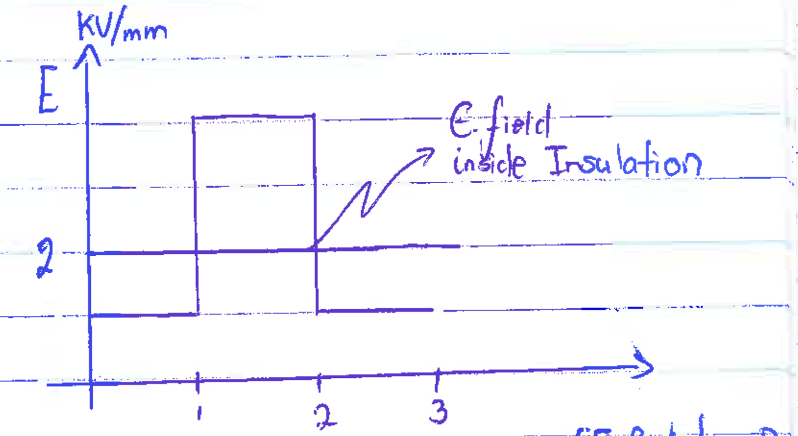
$d_1, d_2, \dots d_n$ $\qquad$ $\varepsilon_1, \varepsilon_2, \dots \varepsilon_n$

$$\boxed{E_k = \frac{V}{\frac{\varepsilon_k}{\varepsilon_1} d_1 + \frac{\varepsilon_k}{\varepsilon_2} d_2 + \dots + \frac{\varepsilon_k}{\varepsilon_n} d_n}}$$

For Plate stacked dioelectrics



$\varepsilon_{air} = 1$



$E_0 = \frac{V}{d} = \frac{6}{3} = 2$ KV/mm [E.field without the air bubble]

$$E_1 = \frac{V}{\frac{\varepsilon_1}{\varepsilon_1} d_1 + \frac{\varepsilon_1}{\varepsilon_2} d_2 + \frac{\varepsilon_1}{\varepsilon_3} d_3}$$

$$E_1 = \frac{6}{\frac{4}{4}\cdot 1 + \frac{4}{1}\cdot 1 + \frac{4}{4}\cdot 1}$$

$E_1 = 1$ KV/mm

$E_3 = E_1 = 1$ KV/mm

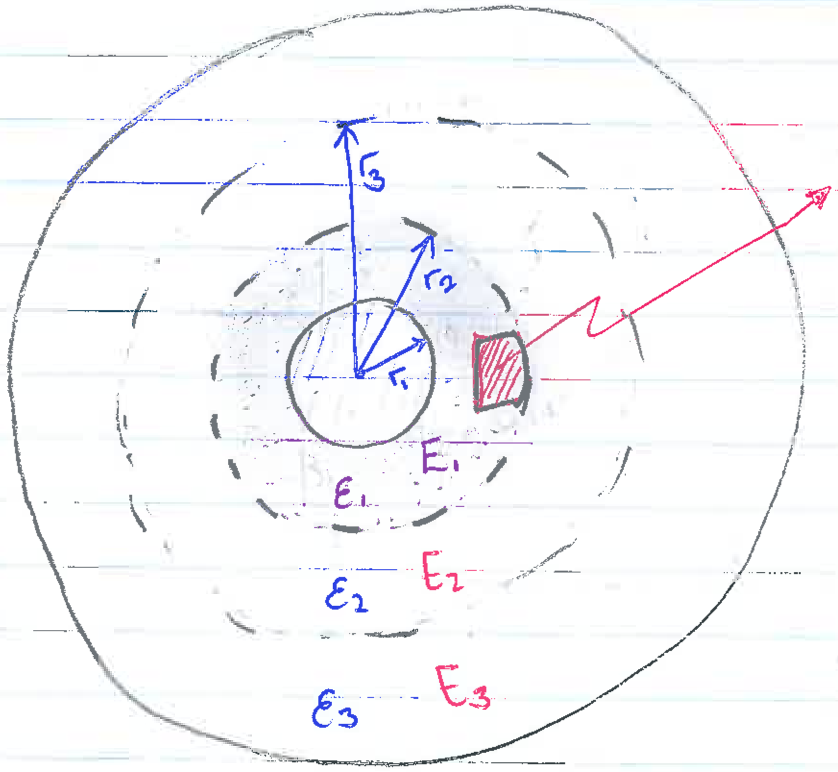
$$E_2 = \frac{V}{\frac{\varepsilon_2}{\varepsilon_1} d_1 + \frac{\varepsilon_2}{\varepsilon_2} d_2 \quad \frac{\varepsilon_2}{\varepsilon_3} d_3} = \frac{6}{\frac{1}{4}\cdot 1 + 1\cdot 1 + \frac{1}{4}\cdot 1}$$

$= 4$ KV/mm [This inside are is above

This breakdown is called a partial discharge. This because its between two insulations and not touching the electrodes.

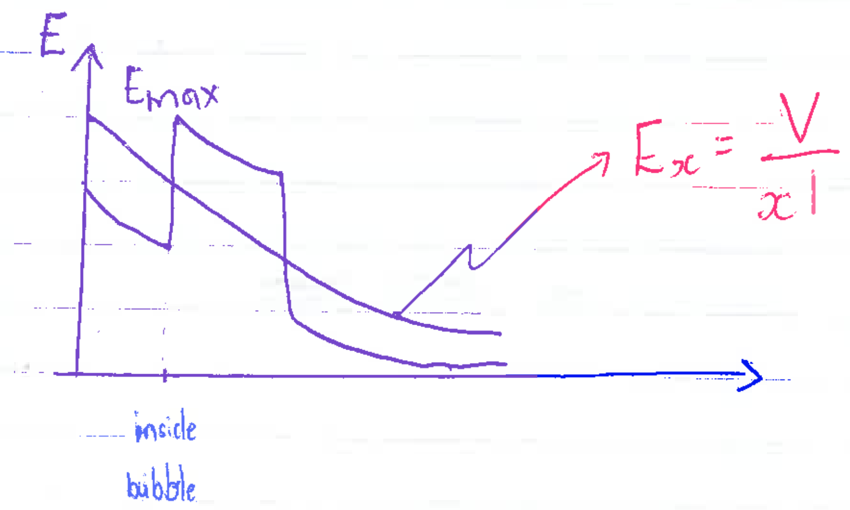
Breakdown or Electric field strength > 3 KV/mm or 2.6 KV/mm in a cavity [redacted] is partial discharge (PD)

For coaxial stacked dielectrics



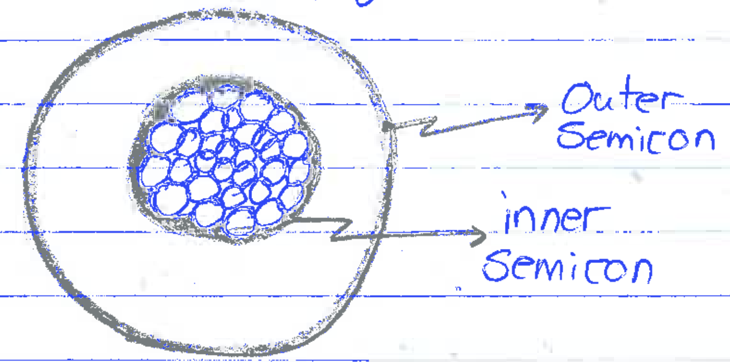
$$E_k = \frac{V}{r_k\left[\frac{\varepsilon_k}{\varepsilon_1}\ln\left(\frac{r_2}{r_1}\right) + \frac{\varepsilon_k}{\varepsilon_2}\ln\left(\frac{r_3}{r_2}\right) + \dots + \frac{\varepsilon_k}{\varepsilon_n}\ln\left(\frac{r_{n+1}}{r_n}\right)\right]}$$

Maximum E field in layer k



- We would like to ~~ad~~ have a smooth contact from the electrode to the insulation. These single stands making up the core, butl the

outer core surface, it has very small round shapes, which causes ↓ Enhanced Electric fields
Areas of



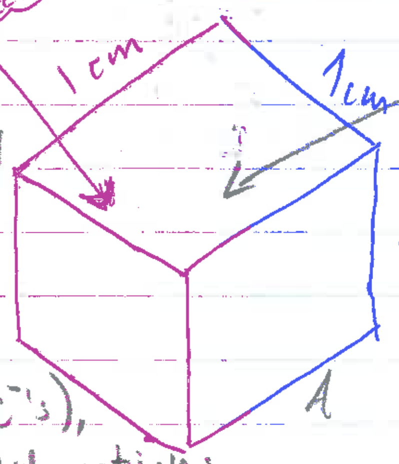
This semicon is a semiconductor, having high, but lower than the core permeability, to smoothen the core surface
permittivity

*Charge carries, ionisation

28 January 2019

Electrical Breakdown & Conduction in gases

radiation (in photon form) (packets of energy)



Inside we find air molecules, Charged carriers (+ve ions & e^-'s), Water & Solid particles

A box of these dimensions would have:

Charge Carriers
- e^- (electrons) } 10^3 pairs
- Positive ions
→ Water particles
→ solid particles
→
→ $O_2 + N_2 + CO_2 + Ar + \ldots$

Source of Radiation: Cosmos gamma

Photo ionisation

(is when a ph

$$\underbrace{h\nu}_{\text{Photon}} + m \underset{\text{re-combination}}{\overset{\Delta w > \Delta w_i}{\rightleftarrows}} m^+ + e^-$$

m^+: Positive ion; e^-: free electron

h: planck's constant $6.6 \ldots \times 10^{-34}$; ν: radiation frequenry

Δw_i → Ionisation energy

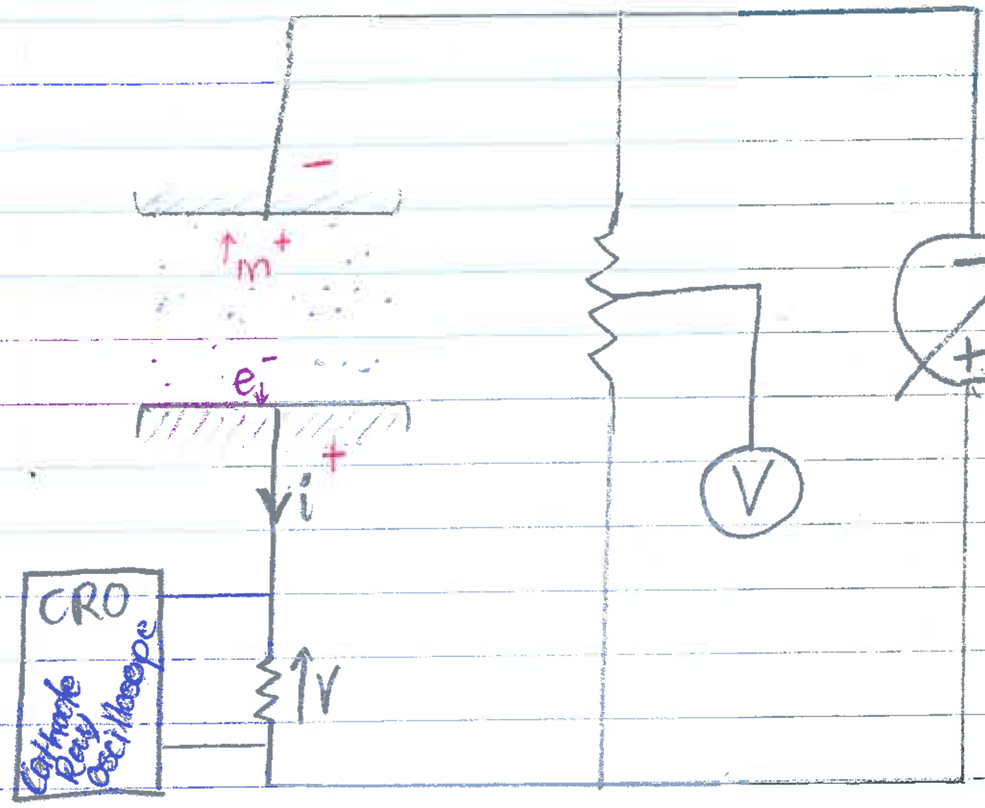
$\Delta w > \Delta w_i$ → When photon energy is greater than ionisation energy, this brings ionisation

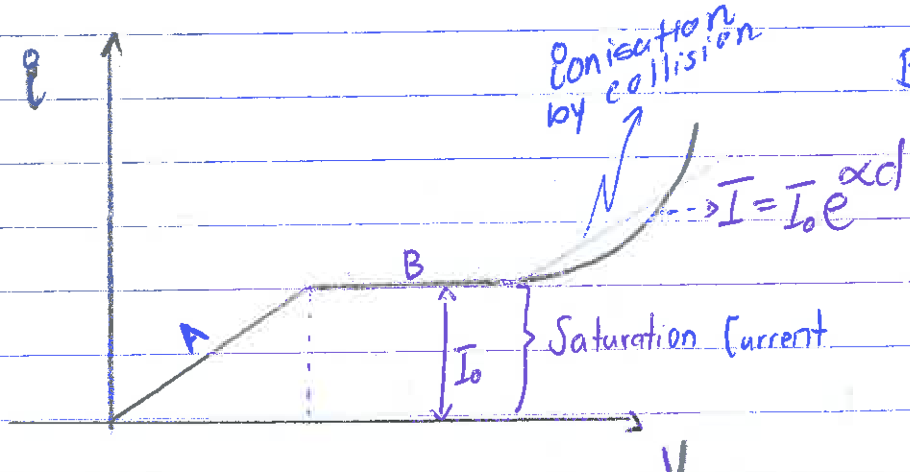
$\Delta w < \Delta w_i$ → excited molecule [Metable] This is electrons being excited, moving up a state, but not ejected.

$$h\nu + m \underset{}{\overset{\Delta w < \Delta w_i}{\rightleftarrows}} m^* \text{ excited molecule} \} \text{metable}$$

• This is an excited phase and quickly goes back and releases its energy ($h\nu$).

Townsend breakdown mechanism





B - is a point where all the free electrons and positive ions have been attracted to the respective plates. Saturation.

Here, the electron, not the photon collides with molecule. Its energy is derived from $\Delta w = q\Delta V = eV$

ionisation by electron collision — ionisation by collision

$\Delta w = q\Delta V$ (charge x Voltage Difference)

$\Delta w = eV$ (electron Volt)

V_2

e^-

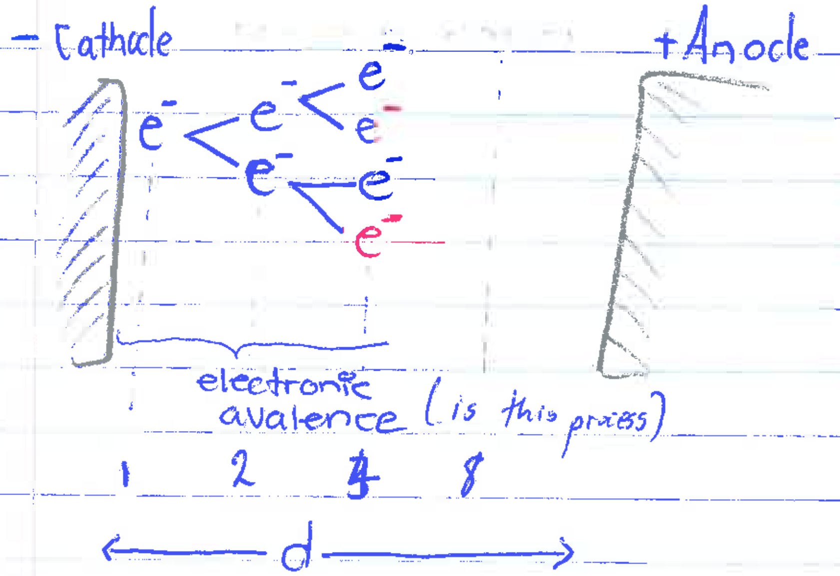
V_1

$$e^- + m \xrightarrow{\Delta w \geq \Delta w_i} m^+ + 2e^- \} \text{ inelastic}$$

$$e^- + m \xrightarrow{\Delta w < \Delta} m^* + e^- \} \text{ elastic}$$

$$\{m^* \longrightarrow m + h\nu\}$$

This was a free occurring e^- as a result of Natural ionisation.



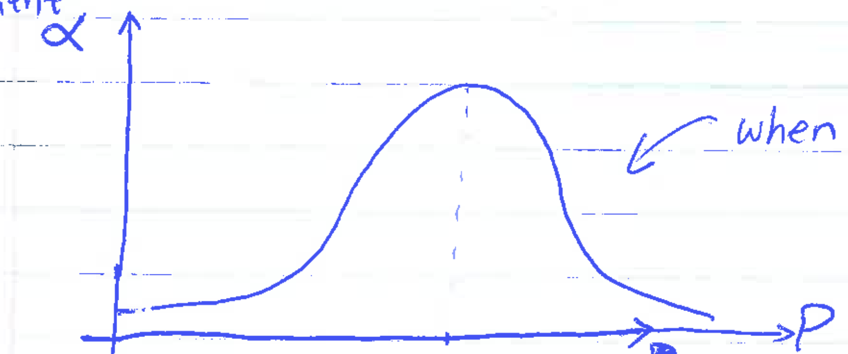
Townsend 1st ionisation coefficient → No of e / unit distance

$$N = N_0 e^{\alpha d}$$

number of initial electrons

Townsend 1st ionisation coefficient $\alpha = f(P, E)$ (Number of electrons yielded/generated)

τ : means free path (this is the distance between molecules)

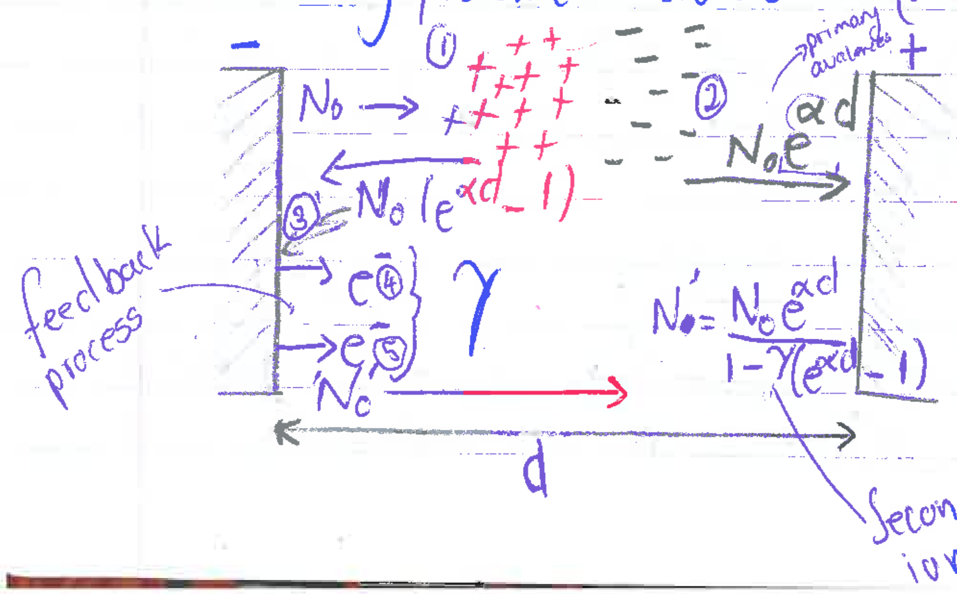


low No of molecules tightly packed

High No of molecules, but τ is too small for electrons to pass through. Since molecules are too close to each other.

There τ (mean free path) and No of molecules are just right at this presure is agt

• Increasing pressure increases the (voltage) current



③² • The positive ions gains energy travel so fast towards the they emit photons

γ - Townsend 2nd ionisation Coeffi

feedback process

γ is a function of the type of electrode, E field, Pressure,

If $N_0' =$

So N_0 (Number of electrons that come about from natural ionisation)

$N_0(e^{\alpha d}-1)$ ① Cloud of positive ions accelerating towards the cathod (- plate)

② Cloud of e^- (electrons) " to the anode : $N_0 e^{\alpha d}$

③¹ ③² The accelerating +ve ions releases photons and releases electrons (④) from these photons hitting the cathode metal surface.

⑤ electrons are released from cathode metal from the ① cloud of positive ions.

$\gamma(e^{\alpha d}-1) \geq 1$ Townsend breakdown criterion

$m + e^- \longrightarrow m^-$ → negative ion

attachment

molecules which behave to attach to electrons, though have a balanced net charge is called Electronegative Atoms.

i.e SF_6

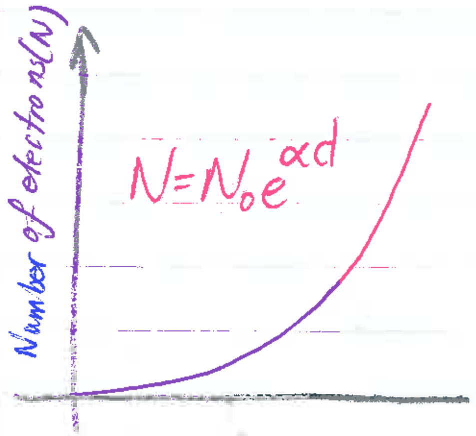
For introduction of electronegative gas

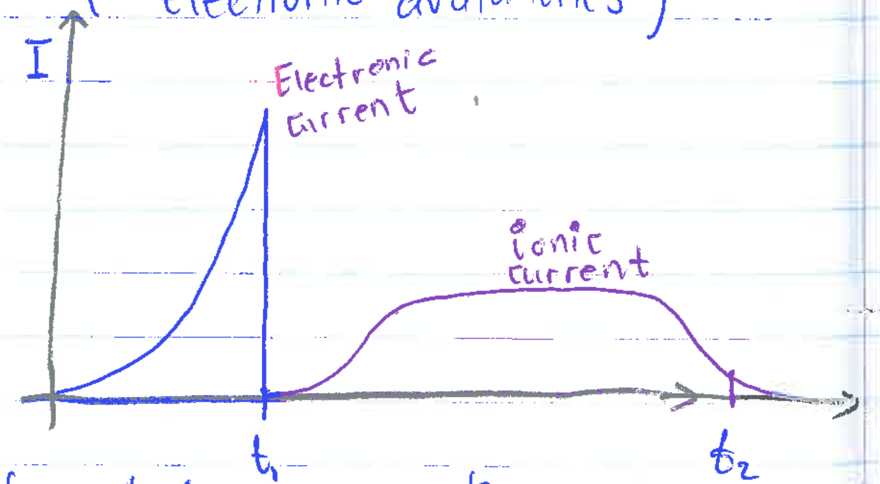
$$N = N_0 e^{(\alpha-\eta)d}$$

attachment coefficient

07 March 2019

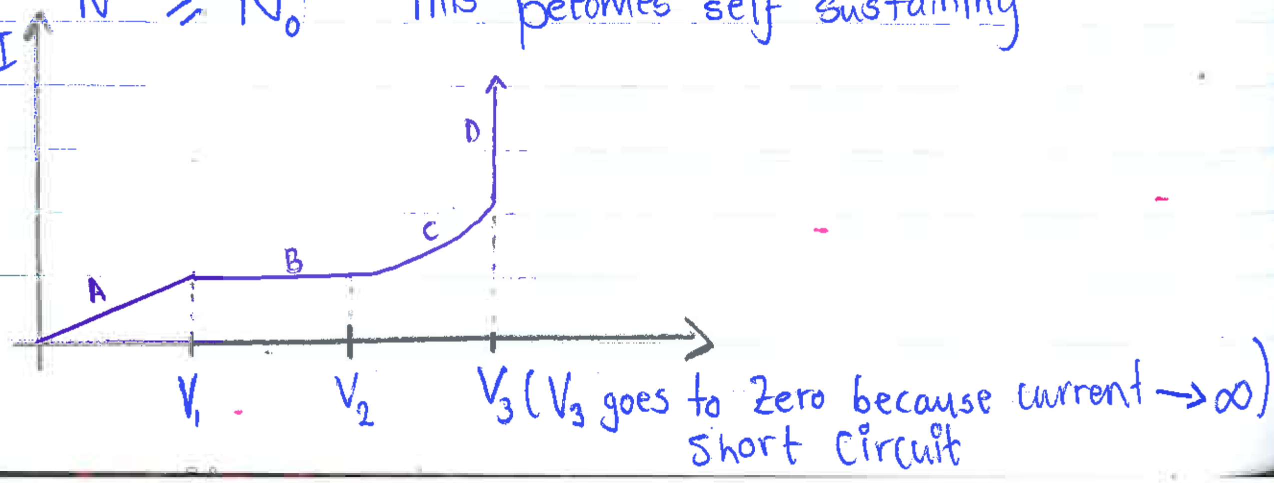
- $A + e^- = A^* + e^-$ Excitation
- $A^* = A + h\nu$ De-excitation
- $A + e^- = A^-$ Attachment
- $A^- = A + e^-$ Detachment
- $A + \text{heat} = A^+ + e^-$ Thermal ionisation
- $A + e^- = A^+ + 2e^-$ Ionisation by Collision (The process responsible for electronic avalanches)





This is for a Non-self sustaining Avalanche

if $N^+ \gg N_0$ this becomes self sustaining



γ

At V_3, the $I \to \infty$, then we have plasma (where we

* For Townsend Breakdown Mechanisms is valid for: Uniform field with a small gap

Exercise Problem

a) $I_1 = I_0 e^{\alpha d_1}$

$I_2 = I_0 e^{\alpha d_2}$

b) I_0

c) μA

$\alpha = f_1(E, P)$ 1. $\frac{\alpha}{P} = f_1\left(\frac{E}{P}\right)$ or $\alpha = Pf_1\left(\frac{E}{P}\right)$

$\gamma = f_2(E, P)$ 2 $\gamma = f_2\left(\frac{E}{P}\right)$

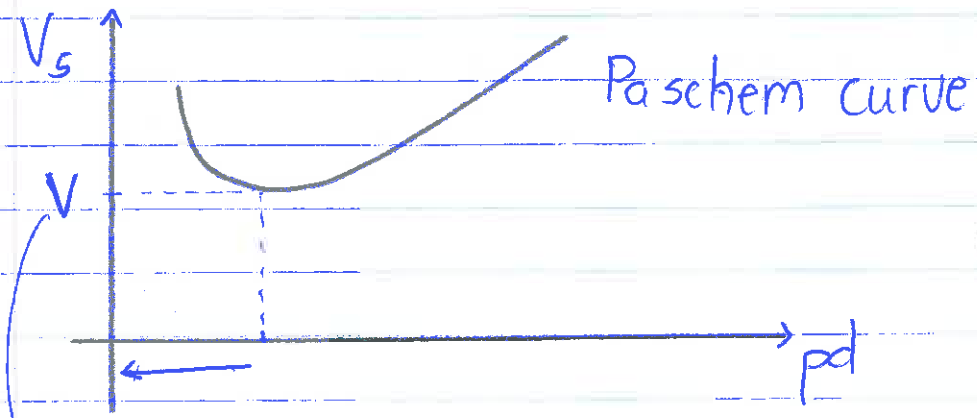
so we know: $\gamma(e^{\alpha d} - 1) = 1 \Leftarrow$ Townsend Breakdown Criterion

$$f_2\left(\frac{E}{P}\right)\cdot\left(e^{Pf_1\left(\frac{E}{P}\right)d} - 1\right) = 1$$

also $E = \frac{V}{d} \Leftarrow$ for a uniform E.field

$$f_2\left(\frac{V_s}{pd}\right)\left[e^{pdf_1\left(\frac{V_s}{pd}\right)} - 1\right] = 1$$

- This is the equation at which breakdown occurred, a spark was observed (V_s - Voltage spark)



Minimum breakdown Voltage

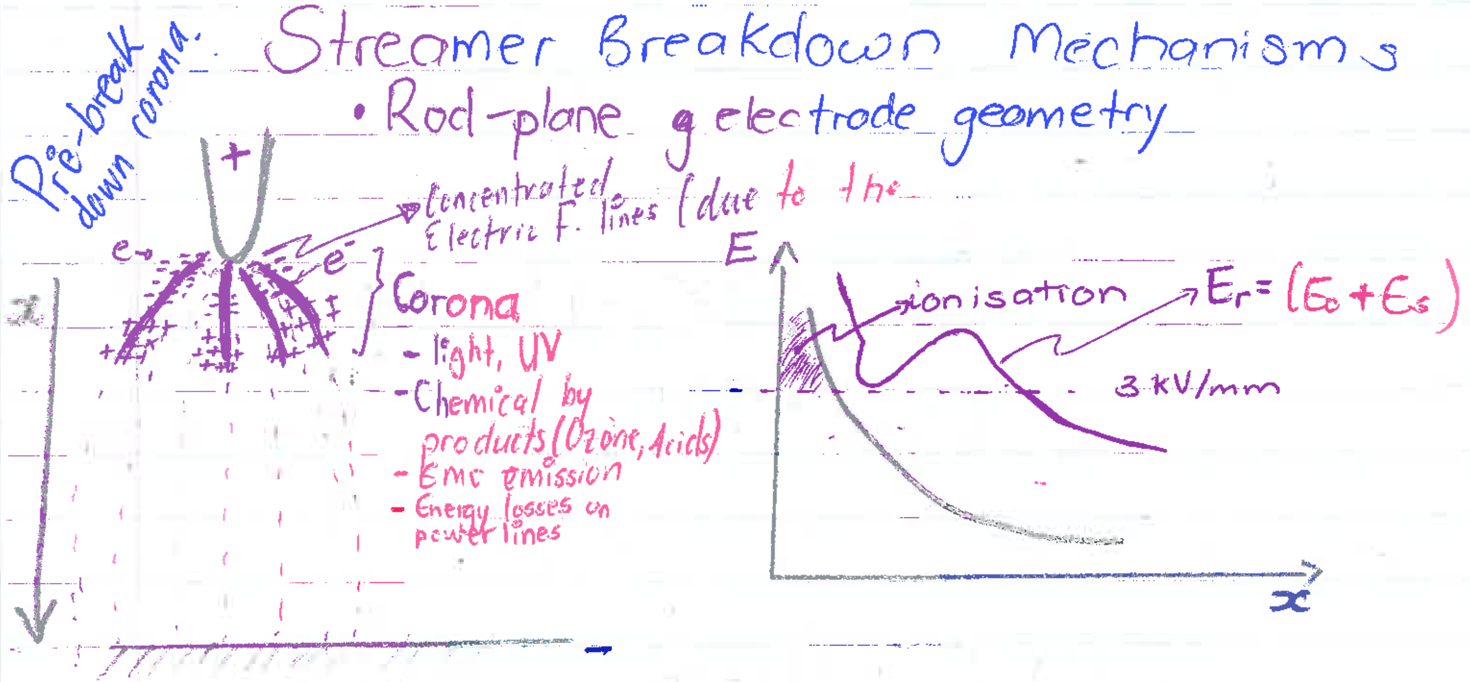
- Each gas has its own curve.

o Streamer Breakdown mechanisms — Read about it.

14 March 2019

Streamer Breakdown Mechanisms

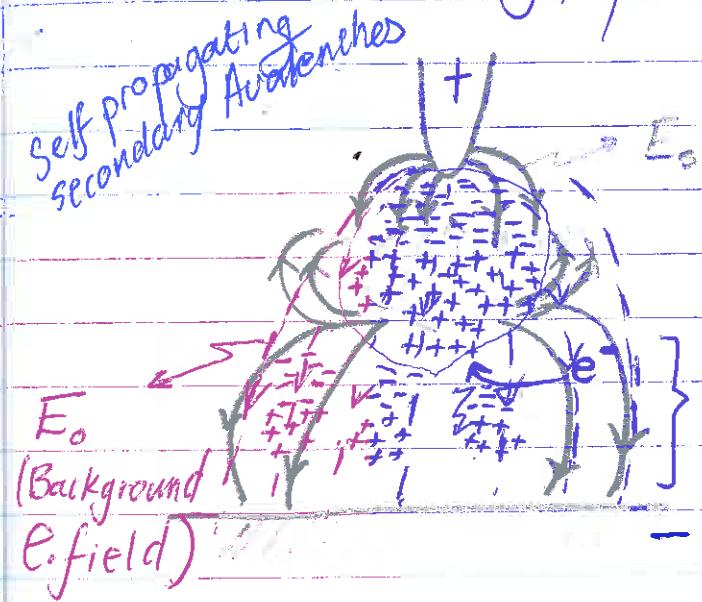
- Rod-plane electrode geometry



~~This~~ is positive Corona, because its happening at the ~~cathode~~ anode. This is Corona, it is Localised Breakdown. Makes a hissing cracking sound, gives of light.

This is corona, positive corona because its on the positive Electrode. This has air breakdown, since its not from electrode to electrode, its from electrode to the air, due to the highly concentrated electric field lines and them dissipating going down to the neg. electrode.

When the Voltage, potential difference is increased

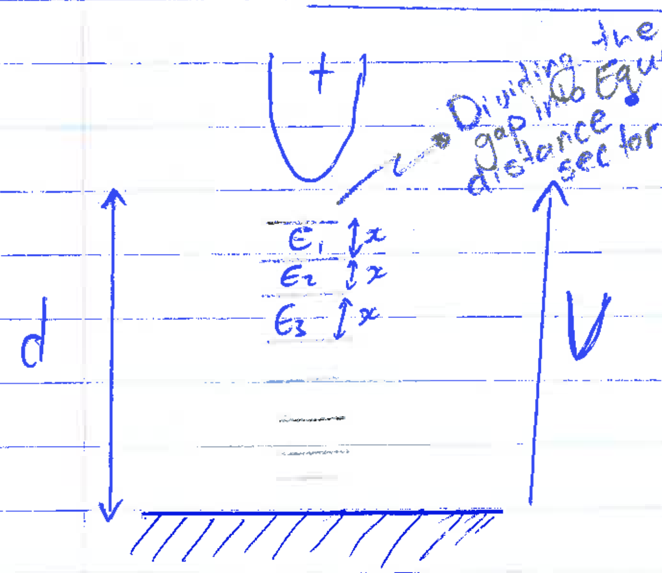


If $E_0 = E_s$ (Loeb & Meek)

or

$n = 10^8$ (Reather)

Determination of gap breakdown Voltage using e^- streamer b/down criterion



• Dividing the gap into Equal distance sector

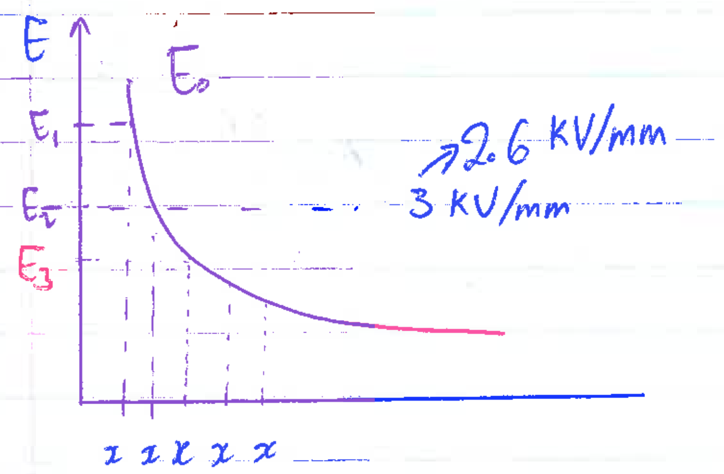
• Estimate b/down Voltage, by an iterative procedure

• The determine Average electric field in each sector

$$N = e^{\int_0^d (\alpha - \eta)\,dx} \geq 10^8$$

take Natural log

$$\underbrace{\int_0^d (\alpha - \eta)\,dx}_{K \geq 18} \geq 18$$



α, η can be read on already produced graphs

K - Number of e^- gen.

$$K_i = 1{,}6 \times [E_i - 2.2P] - 0{,}3\, X$$

empirical formula

when $K \geq 18$, the streamer b/down is satisfied

if not $K \geq 18$, then increase voltage to get to it.

$$\sum_{i=1}^{i=n} K_i \geq 18$$

This is for the section above the 3/2.6 kV line

SAN 60060-1 or IEC [A standard for pressure, temperature.

1. Short gaps, non-uniform e-field (up to 1m)

• $V_b = 500 . d \, (KV)$ — d [meters] — here 500 kV/m

AC and DC can be determined here.

2. Switching impulse $d > 2$ m

• $V_b = 500\, S .\, d^{0.5}$ (kV) ; S - gap factor

S = 1,15 for conductor-plane Electrod geometry

S = 1,3 " rod ~~plane~~ rod (rod - rod)

S = 1,9 " large conductor - rod gap

3. Calva method (for DC) [Use this for the LAB]

• $V_b = E . d [K_1 + K_2] S$; K_1 & K_2 Humidity Correction factor

E - field; d - Gap distance; S - Gap factor

+ve streamer = 500 kV/mm

−ve ...

• In FEMM, you can obtain an e.field profile

[2.] This one is perfect, the one on slides is incorrect but not too accurate.

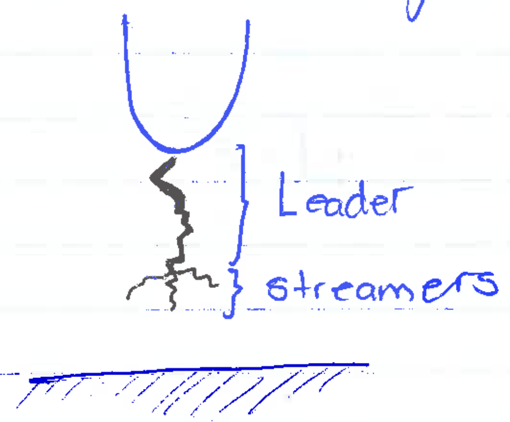
Note: We can always work from first principles, on the Left hand page (Prev. Page)

04 April 2019

SI : Swithing impulse
LI : Lightening Impulse

In Long Gaps

In slide: In larger gaps (2m >) the current in the stem of of streamer becomes high (5000 °C)



Cummalombus Clouds

The warm are and cold moving up and down "brushes" against stationary could sections, causing separation of charges.

The thin layer of positive charges are collected from the top positive charge layer to the bottom.

The electric field ~~of~~ between the cloud and (3 KV/mm) ground, have net negative in cloud and net positive on ground. When Electric field > 3 KV/mm (Air break down) we get (corona → streamer → complete breakdown) Lightning*

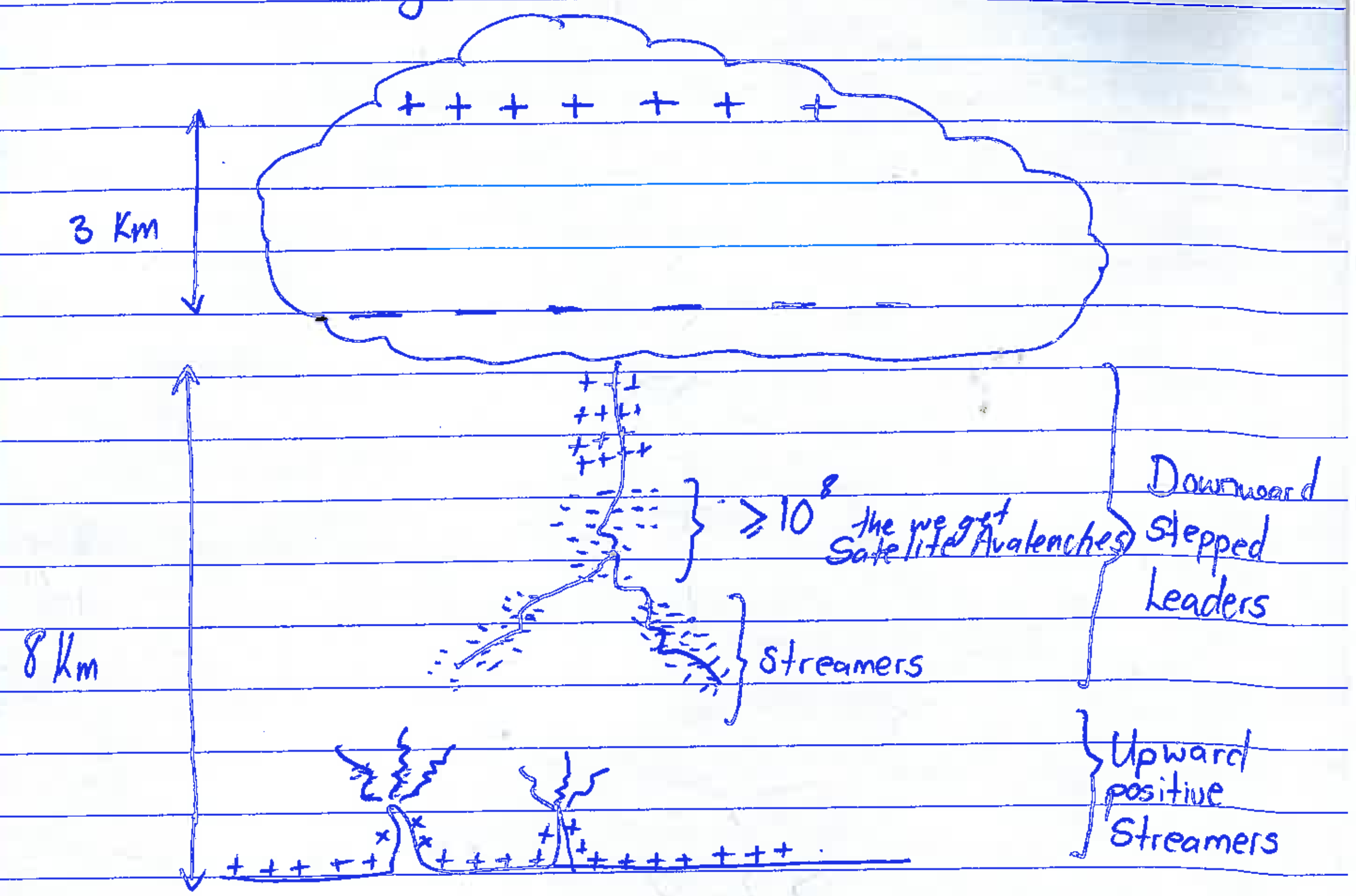
① Intra-cloud lighting - Between cloud charges, inside it.
corona → Streamer → complete

② Cloud to ground lighting
③ Inter cloud lighting - between clouds
④ 'Cloud to atmosphere' - ?

11 April 2019

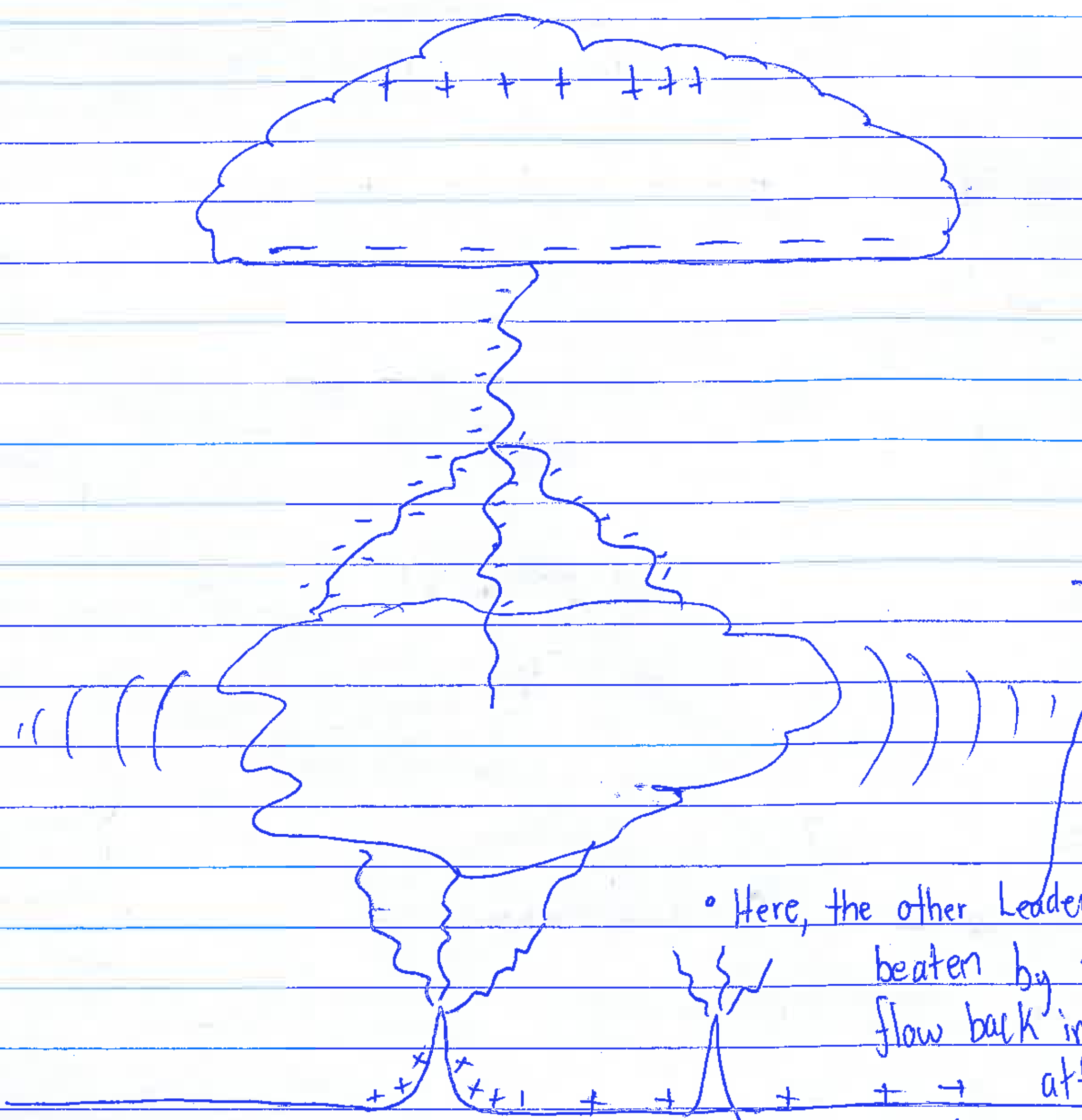
Lightning Mechanism

Stage: STEPPED LEADERS



When the primary avalench electrons - space charge - Growth of ionisation channel (streame) are the Downward Stepped Leaders.

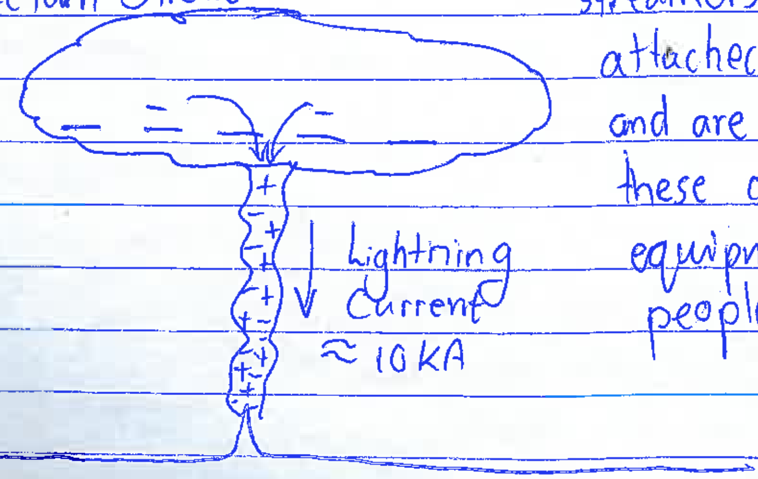
STAGE: ATTACHMENT

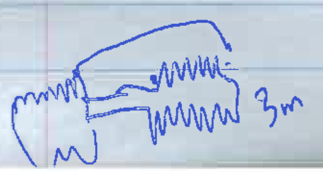


• Here, the other Leaders that are beaten by the Attachment flow back into the main attached path.

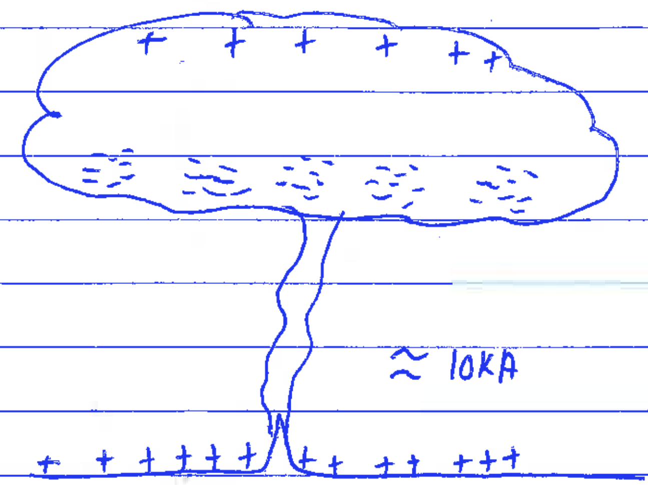
• But the Upward positive streamers which didn't get attached, flow back down and are undesirable because these cause damage to equipment and kills people.

STAGE: 1ST Return Stroke





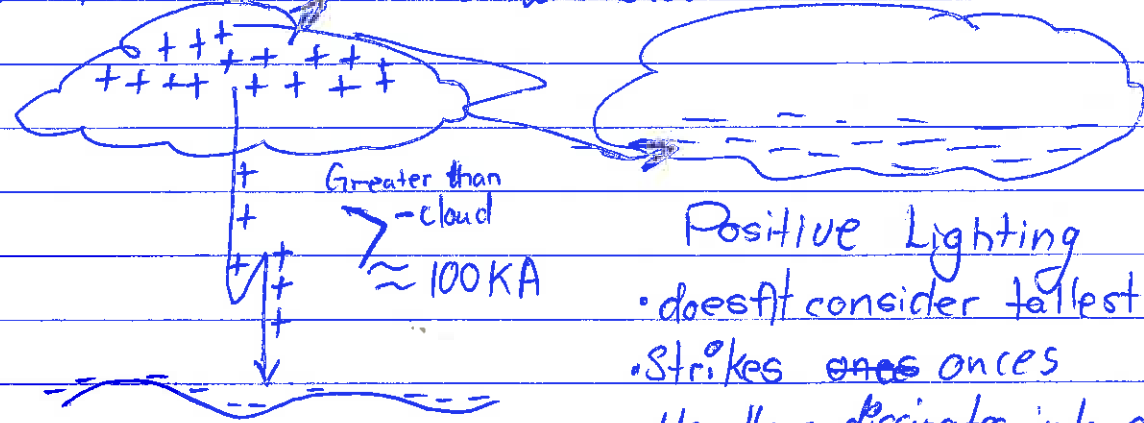
STAGE: 2nd Return Stroke



• The return strokes hit the same spot usually, but sometimes hits within the diameter of 10 km.

• The stages may continue until the ~~ch~~ negative charges are discharged through the same plasm channel (usually) or another created. Usually lightning hits the same spot. The lightning current.

POSITIVE LIGHTNING: Inter-cloud



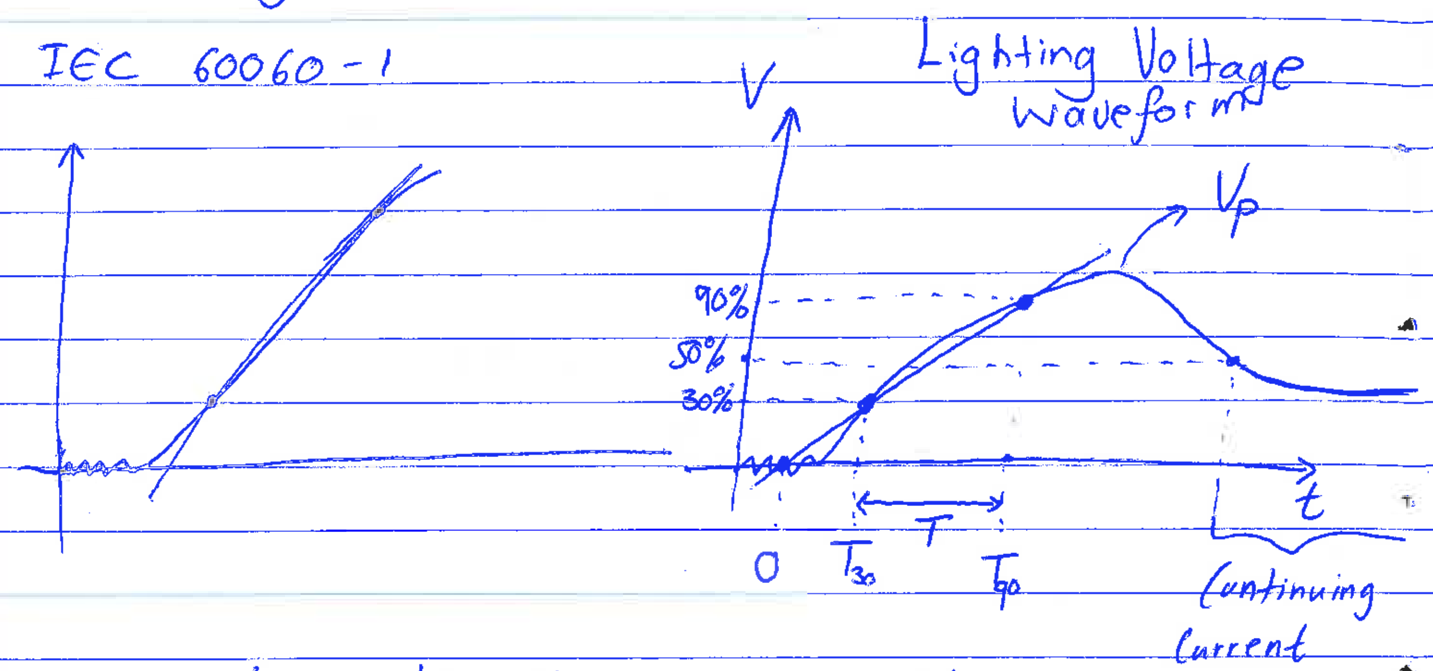
Positive Lighting
- doesn't consider tallest structure
- Strikes ~~ones~~ onces
- Usually dissipates into atmosphere

LIGHTNING INJURY + DAMAGE MECHANISMS

Lightning Current & Voltage

IEC 60060-1

Lighting Voltage Waveform



$t_{rise} = 1.67\,T = 1.2\,\mu s \pm 30\%$

where $T = T_{90} - T_{30}$

$t_{fall} = 50\,\mu s \pm 20\%$

Lightning Voltage Waveform

Standardised: V_p, 1.2/50 (V_p at 1.2 μs Rise Time and 50 μs fall Time

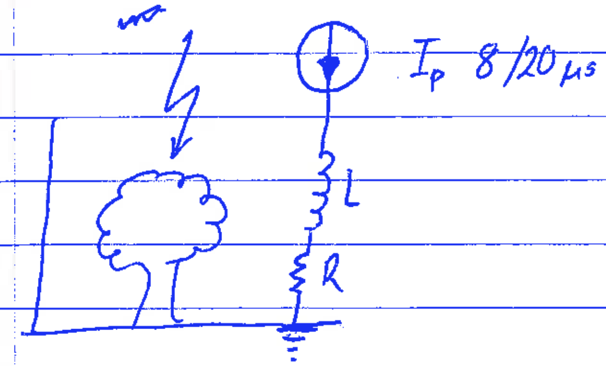
Lightning Current Waveform

Standardised: 8/20 μs

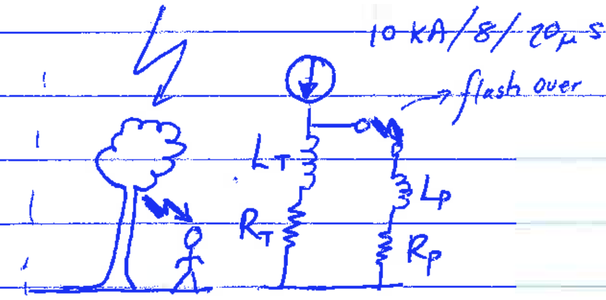
- Trapient wave phenomenon.

Lighting injury + Damage Mechanism

1. Direct Strike



2. Side flash

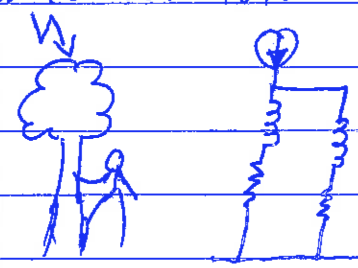


- To protect this: Shelter in Faraday Cage
- Franklin Rod,

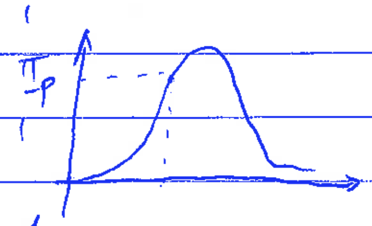
V_T : Voltage Across Tree

$V_T = I_p R_T + L_T\left(\frac{di}{dt}\right)$

3. Contact Potential

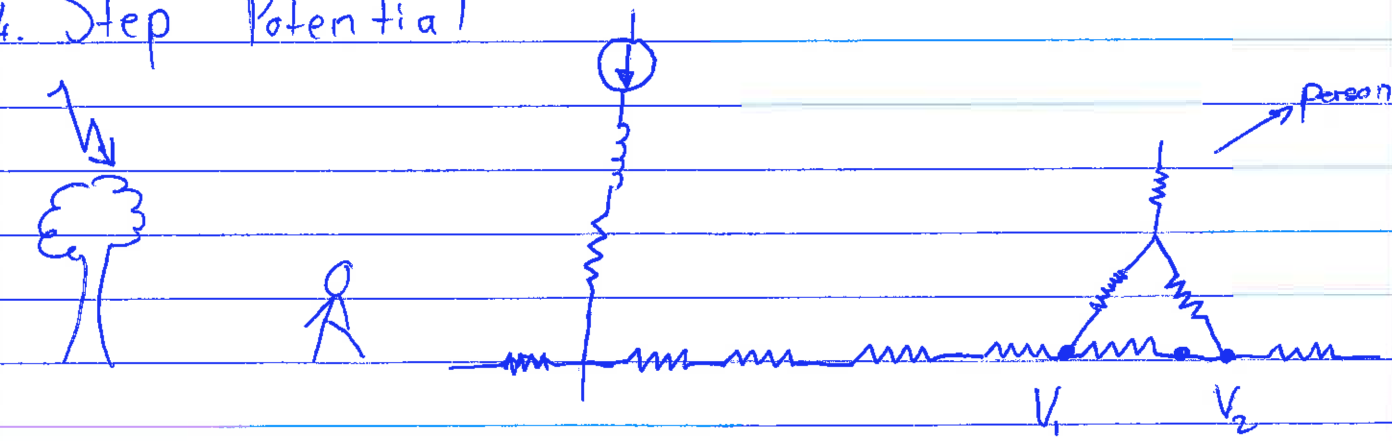


Path of least resistance so More if not all current will flow through person.



$\frac{10 \cdot 10^3}{8 \cdot 10^{-6}} = 1 \cdot 10^9$

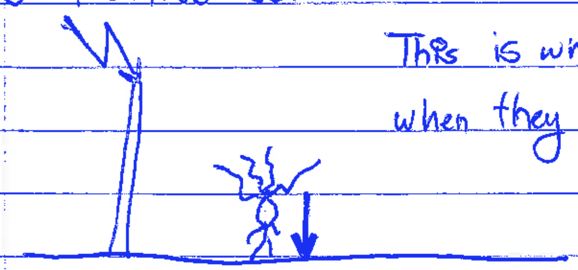
4. Step Potential



- Crouch
- Stand on one leg

5. Positive Leaders

This is when the Upward Positive streamers come back when they are not attached.



25 April 2019

double exponential form → $i = i_0 \left(e^{\frac{t}{\tau_{fall}}} - \frac{t}{e}\right.$

→ we don't adapt this, but is used for testing

Negative stroke
Negative subsequent stroke
Positive stroke

} Current

I_{peak} (KA)

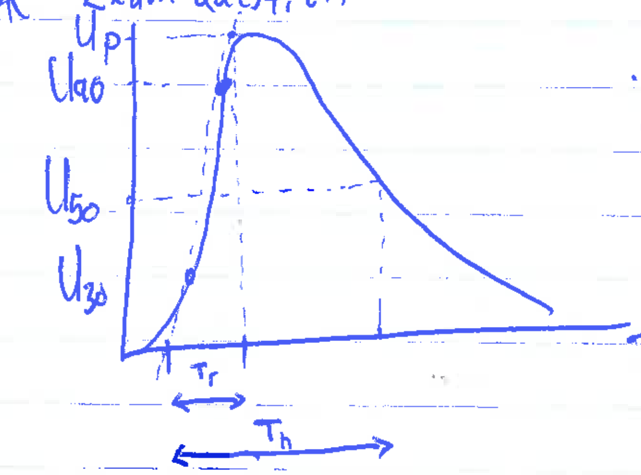
95% of lighting strikes cases are more than 4.6KA; 4KA; 4.9KA
50% // 35 KA; 20KA; 118KA
5% " 250KA; 90KA; 28.6KA

dI/dt (Rate of change of current

Two parts of lighting
Long stroke

Short stroke
- We use this, because we focusing on impulse.

*** Exam Question



- Mark at U_{90} & U_{30}
- Draw a line joining the two points

T_r : Rise time or front time
T_h : Half-wave width or tail time

Lighting impulse voltage: $T_r = 1.2\mu s$ T

Standards : are agreements and not "Bibles" they are just guideline

Rate of flow of charge → Current

Arc and flashover : more or less the same.
Breakdown

Corona → Streamer → Breakdown

If the charges pass by the minimum region of electric field

• Its between two ~~to~~ electrodes, one negative, and one positive.
The negative terminal propagates faster with streamers or charge flow. i.e electron flow.

Statistical time lag: is the time taken for the first electron to be repelled or attracted to an electrode.

Formative time lag: Time taken for the avalanche process to generate the breakdown threshold current

High voltages → results to breakdown on the rising edge
(Lower) HVoltages → " " " On the tailing edge
Votages in between, results

Arrestor: open circuit on normal voltages to transformer, short circuit for over voltages/~~or~~ transient Voltages

Marx Gen: impulse voltage wave form Generator
Switching Impulse: Lightinging Gen 1.21 50 μs

Statistical time log

02 May 2019

– Breakdown Under Voltage Impulses

There is no absolute voltage for Impulse, the voltage is deterministic (Stocastic) and we use U50 to average out.
Surge arrestor for small currents is like an open circuit. With an increase in current, they shunt the high current to protect the equipment.

Diverting a lightning voltage ... [On slide Title]
The breakdowns which occur ~~pri~~ in the rise region means it ~~is break~~ shunts the high current faster before ~~off~~ allowing it to go into the equipment it is protecting.

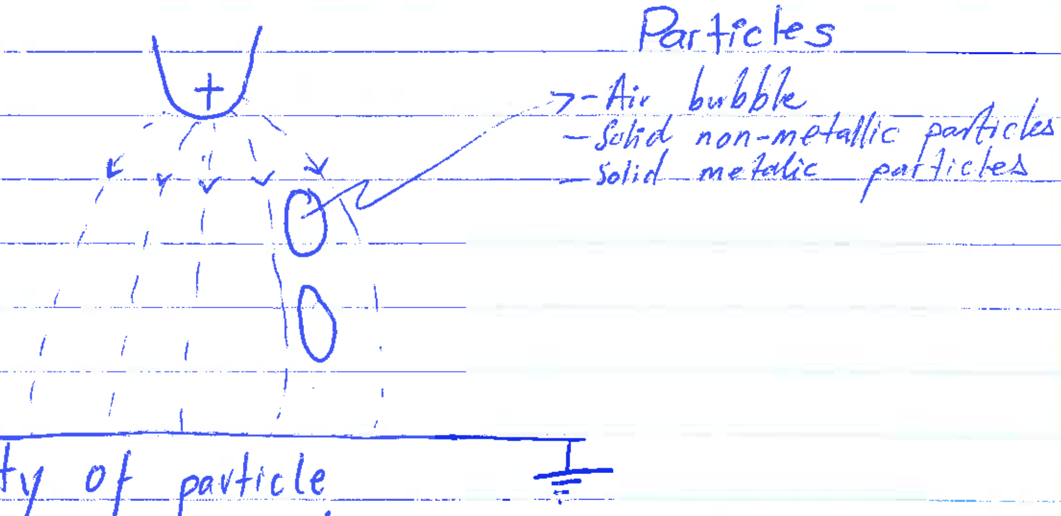
* Self curing (Insulation level of air is restored, no damage can be done to it.

Higher dielectric strength and High thermal coefficient. Thats the reason we use Oil instead of air. The liquid insulation, ~~for~~ for the ~~Sma~~ same gap size in air, a ~~lower~~ Higher voltage will be required to break down. Making it breakdown at a higher voltage.

Transformer oil : is not only used for insulation, but also for cooling of transformer.
It is to some extent self curing. too.

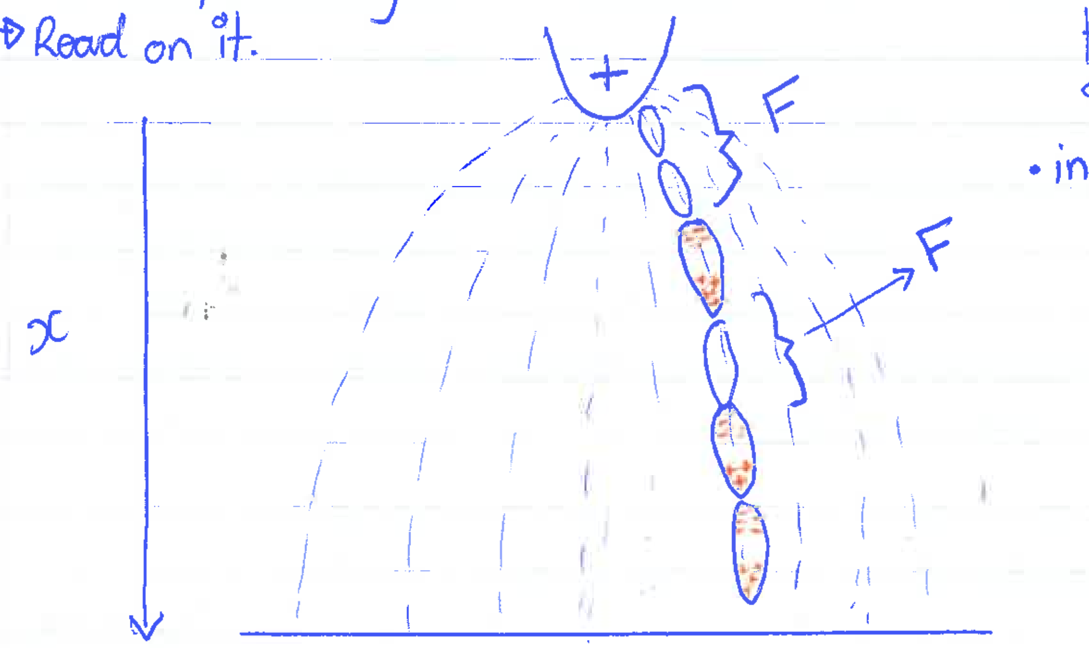
Breakdown Mechanisms in Liquid insulation

⇒ Due to Suspended particles
i.e air bubbles, solid particles.



ε - permitivity of particle
ε_{liq} - " " liquid

* Intrinsic breakdown : The breakdown of insulation (i.e insulation oil) in its puriest form and in a uniform electric field. (Non-pure things → Read on it.



Here the particles align with the E field
• in Oil insulation.

$$\bar{F} = r^3 \varepsilon_{liq} \left(\frac{\varepsilon - \varepsilon_{liq}}{\varepsilon + 2\varepsilon_{liq}} \right) E \frac{dE}{dx}$$

r - is the dimension of the particle

• This equation is for non-uniform fields.
• When the voltage is increased in the field, the particles align themselves in the line

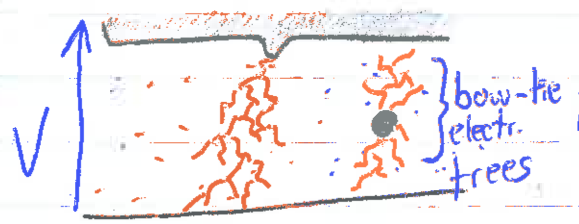
$(\varepsilon - \varepsilon_{liq})$ in the equation, when negative, the particles go/move to the less intense part (⏚), when positive, goes to (+) or (−).

• If (+) is switched to (−) only the polarity on the particles would change, but the direction of movement of the particle will still be the same. They always go to (Attracted to the region of high intensity)
• AC or DC, the movement of particles is the same.
• These particles aligning causes a path of weak insulation. Then breakdown occurs along that path.

•

Breakdown Mechanisms in Solid insulation

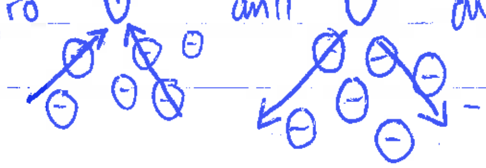
a) Electrical treeing breakdown mechanism



Breakdown due to Electrical Trees when the surface of the electrode is not smooth.

Localised Breakdown

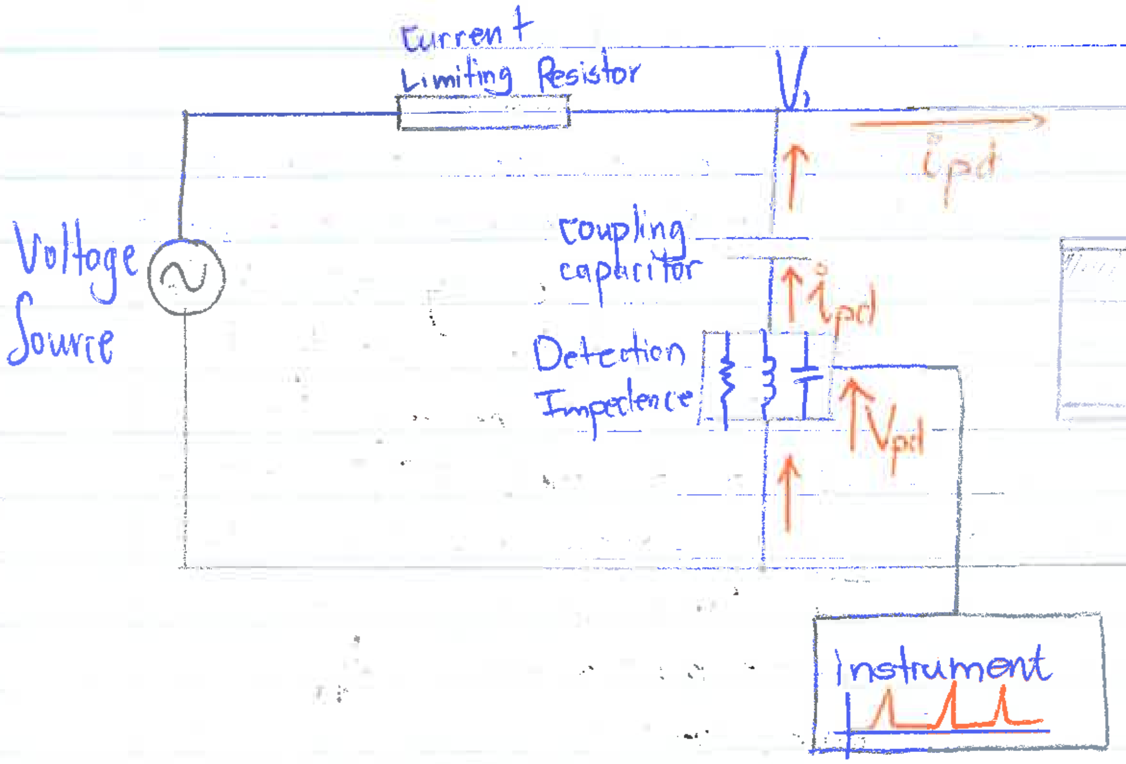
• More prevalent in AC because the electrons are pulled to and fro (+) and (−) due to the positive and negative half cycles of AC voltage.



b) Partial Discharge insulation failure mechanism

IEC 60270

- In the case we get a floshover, the Resistor is the to resist the current (Current limiting resistor)
- Coupling capacitor with an RLC component (Detection Impedence) are used for measurements



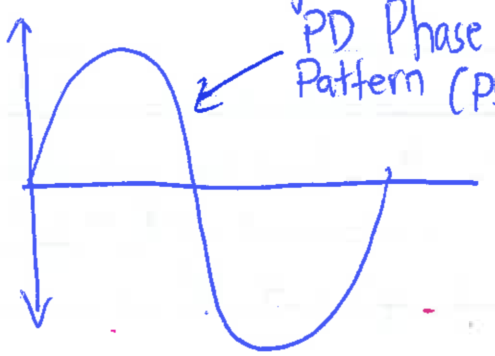
$CV = Q$

$V = \frac{Q}{C}$

$C_{Total} = C_a + C_b$

now $C_{Total} = C_b$

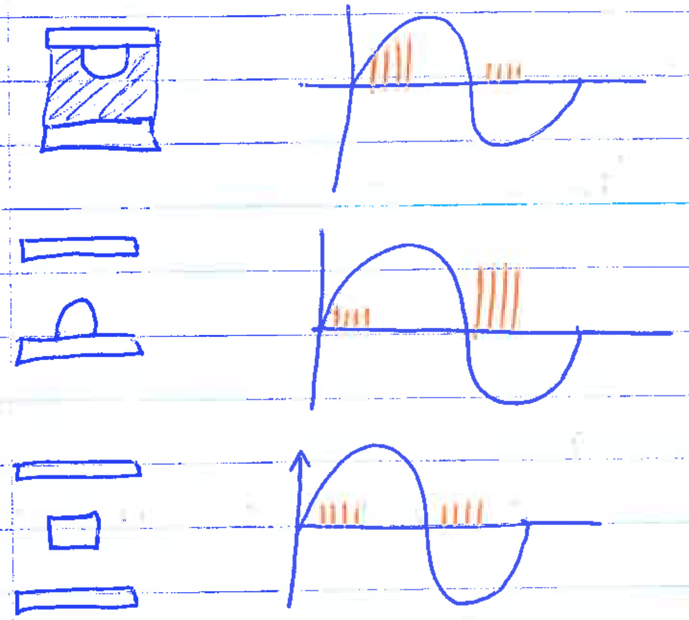
Pattern of PD has a signature on power frequency curve



Negative & positive Half cycle

pC picoCoulombs

inferred / apparent charge is measure



Higher spark magnitudes are found on the +ve half cycle.

Higher Magnitude on neg. half cycle.

same Magnitude

- Upon a PD breakdown in the cavity, Ca becomes a short circuit, then from $V = \frac{Q}{C}$, we have more capacitance, so $V_2 = V_2'$ which is much lower than V_1, so current will flow. Lowers source impedence of coupling capacitor gives the current that flows from V_1 to V_2

The Detection Impedence is where it is instead of just below the test Object is to protect it from See receiving a very high Voltage when there is complete breakd. in the insulation.

- We connect the Detection Impedence where it is for protection purposes though ~~they~~ it would give the same voltage PD readings.
- The PDIV and PDEU should be above the normal operating voltage of your equipment. These are important ~~for~~ when designing or picking the correct equipment.
- Repetition Rate, Phase Resolved Pattern
- Memory effect of partial discharge bring about the extinction voltage where, though the voltage is lowed below the PDIV, the PD still are present until the PDEV. This is the memory effect of PD.

09 May 2019

Exam possible Question:
How to determine the data sheet of an Unknown insulator. These are the tes

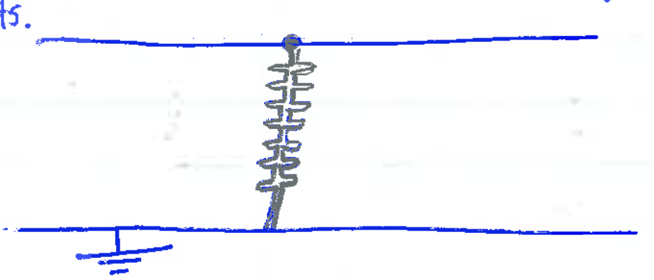
1. Electric field plotting
2. DC Voltage rating] That will cause the equipment to flashover.
3 AC Voltage rating
4. Impulse voltage rating To see if the equipment will handle lighting
5. Tan delta measurement
- Measure Current in two component. Resistive current and Imagina

$$\tan\delta = \frac{I_R}{I_m}$$

The real current is undesirable, it causes heating of the insulation. This is

$\tan\delta$ → is a measure of Dielectric Losses.

These are undesirable currents that flow in the insulator, especially the real parts.



6. PD free

Failure ID: GLSEKR-7159KV-MFGJWK-60WC03
Product ID: H0W69EA#ACQ
HDD Capacity: 500 GB

S. www.hp.com/go/csr and follow directions.

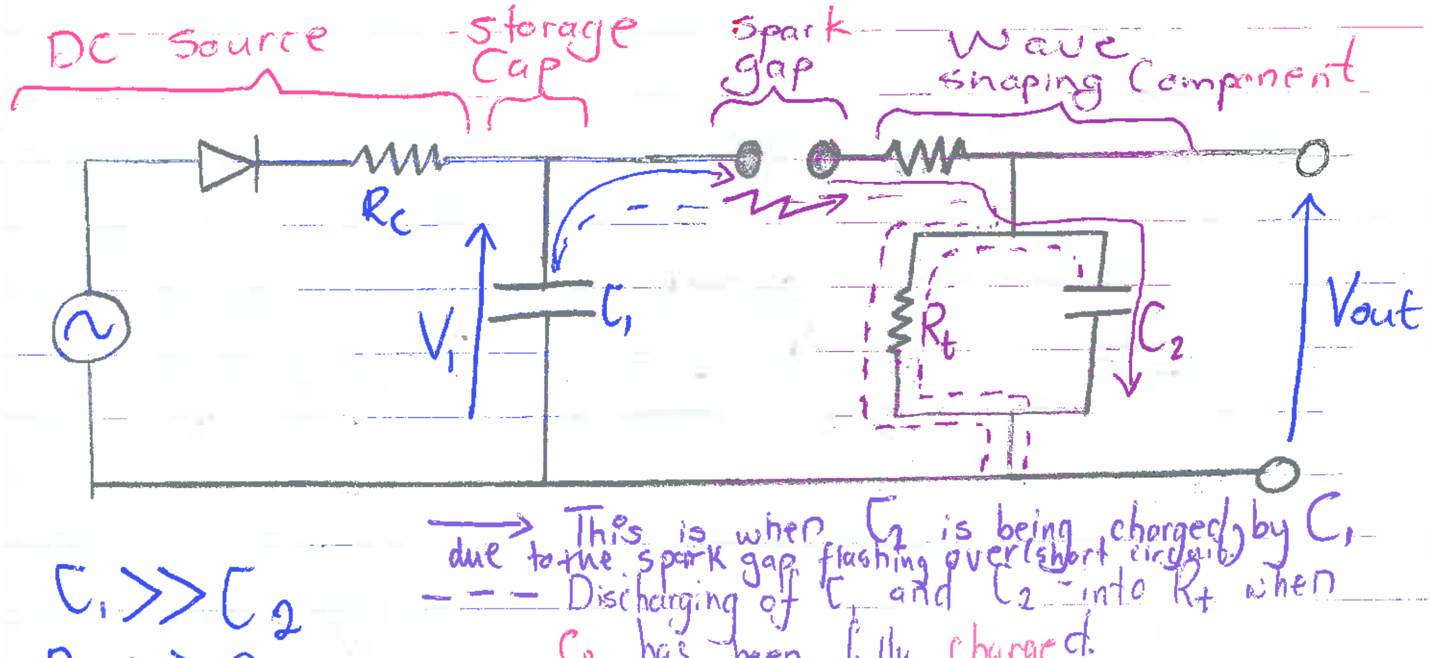
HP Automated Customer Self-repair program.

- then Explain how you would generate The DC source also for the AC Source, how would you generate those High Voltages. Too
- Under Normal and Abnormal Conditions.

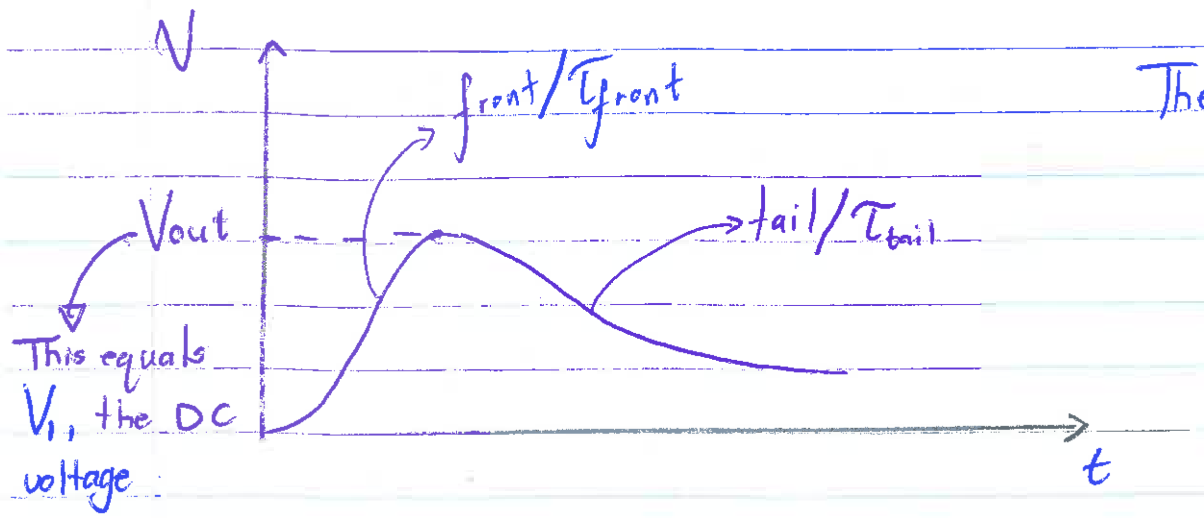
Generation of High Voltages (HV)

1. Generation of HV Impulse Voltage

R_f: front Resistance R_c - Charging Residance
R_t: tail Resistance



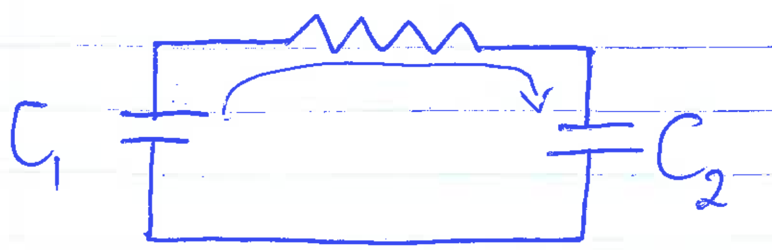
$C_1 >> C_2$
$R_t >> R_f$



The Amplitude

* τ_{front} → time Constant

Equivalent Circuit of the Charging



$$\tau_{front} = R_f C_{Total}$$

$$= R_f \frac{C_1 C_2}{C_1 + C_2}$$

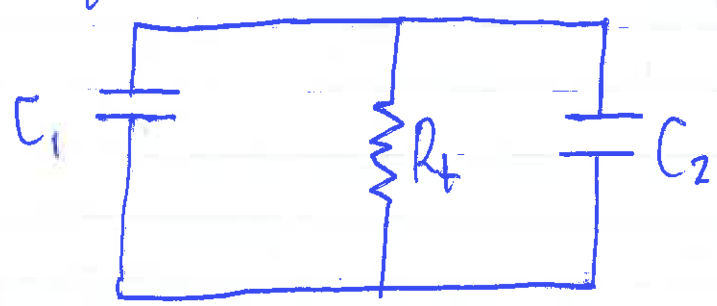
$$t_{front} = 2.96 \times \tau_{front}$$

$$= 1.2\ \mu s$$

$t_{front} = 2.96 \times \tau_{front} = 1.2\ \mu s$ rise time.

* τ_{tail} → time Constant

Equivalent circuit of Oscharging



$$\tau_{tail} = R_t C_{Total} = R_t(C_1 + C_2)$$

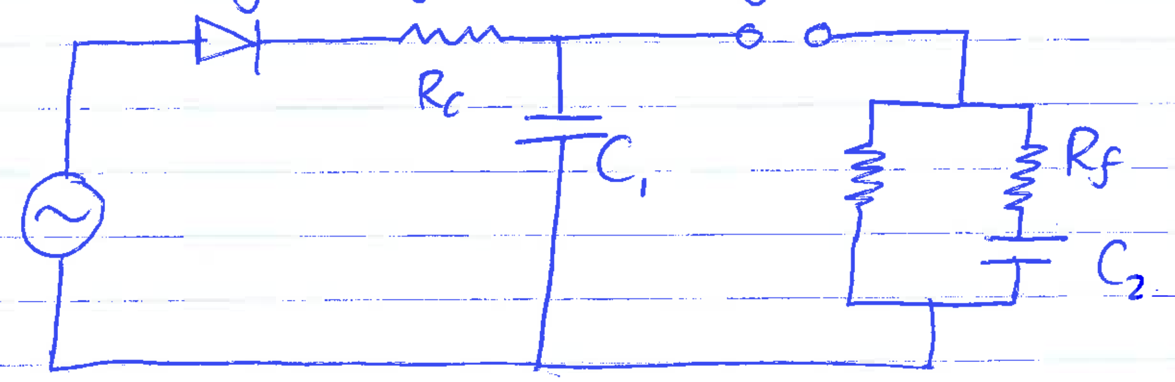
for $t_{tail} = 50\ \mu s$

$$t_{tail} = 0.73 \times \tau_{tail} = 50\ \mu s$$

Switching Impulse

$t_{front} = 2.4\ \tau_{front}$
$t_{tail} = 0.87\ \tau_{tail}$ } in textbook

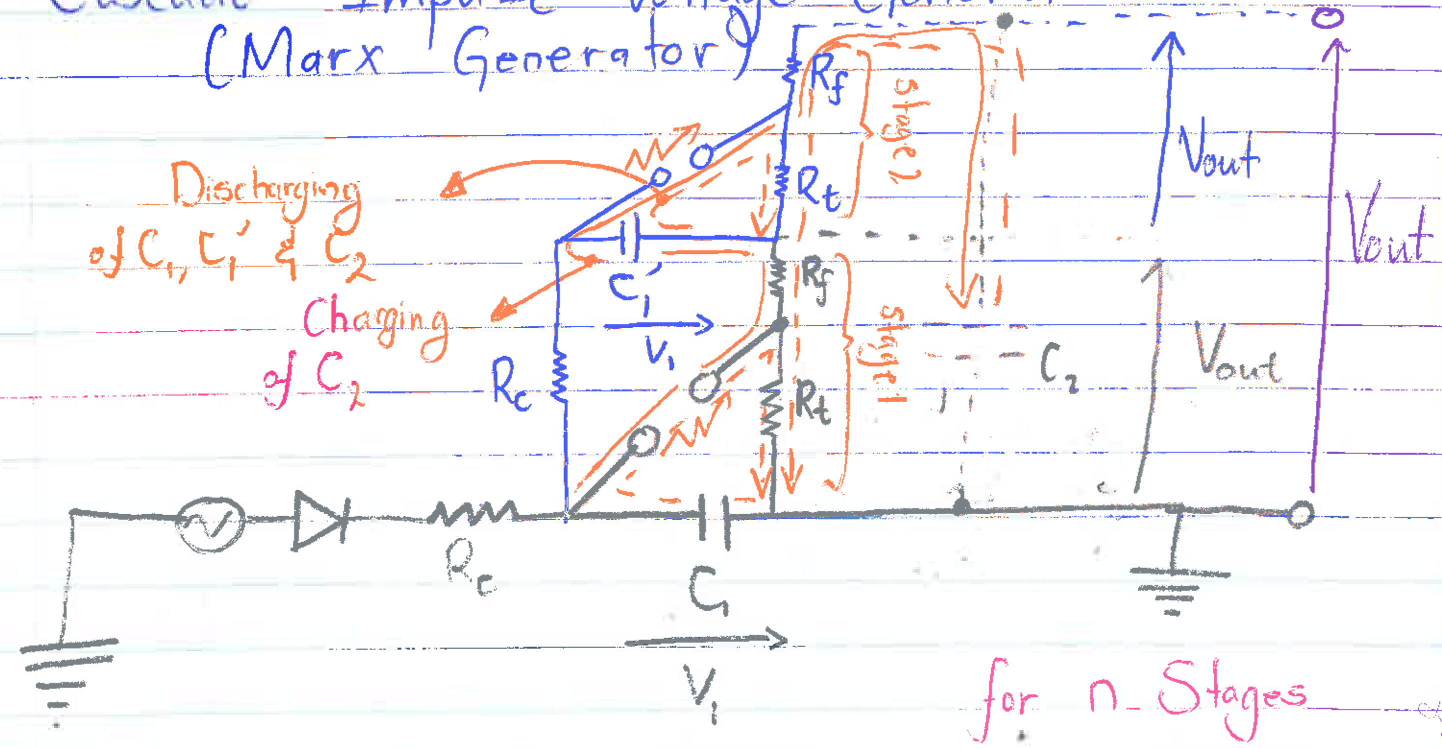
Alternative Configuration of the single stage impulse generator



There are limitation to this
- Lots of Corona
- Hard to handle the triggering at Much higher voltages
- The large voltages require big equipment, physically.

So Marx brought about a new technique.

Cascade Impulse Voltage Generator (Marx Generator)



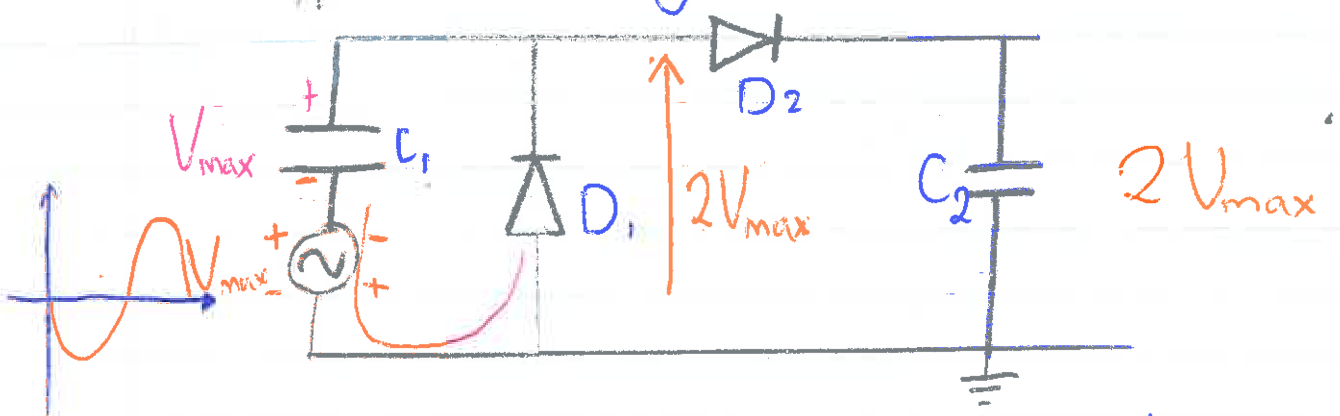
for n Stages

Output Voltage $= n.V_{out}$

- The components are rated at U_1, so we avoid Corona and Cost that comes with have large components.

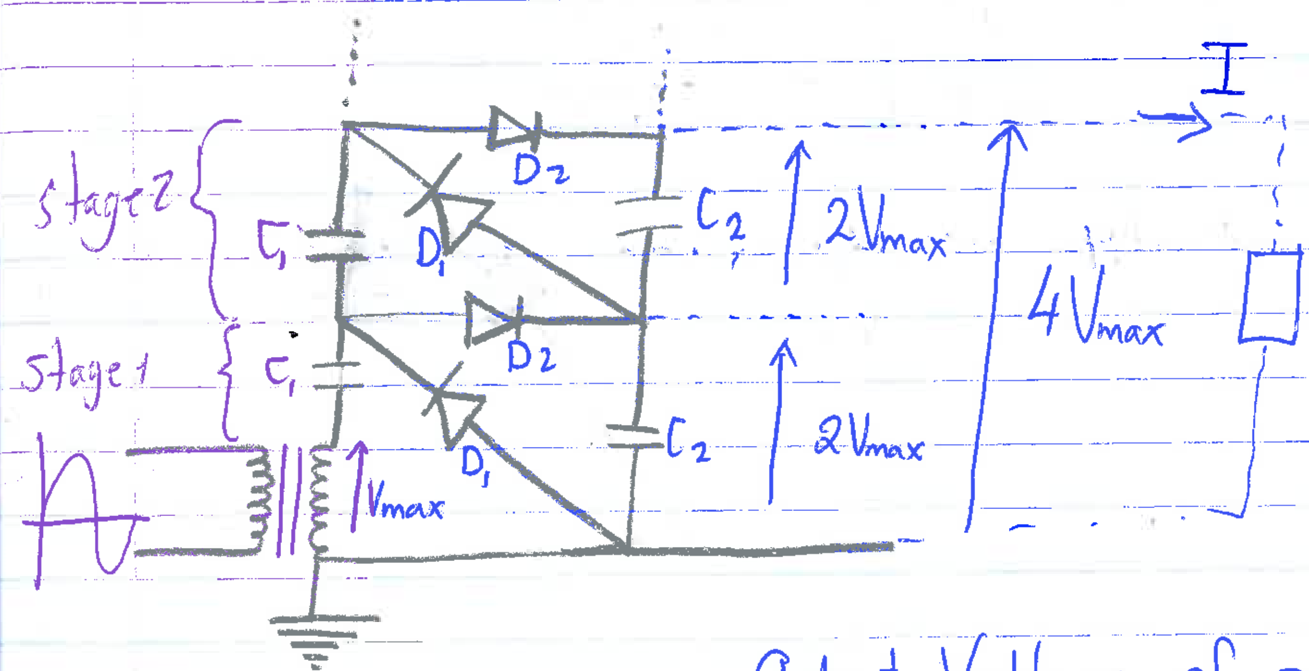
2. HVDC Generator

Greinarcher voltage double Circuit.

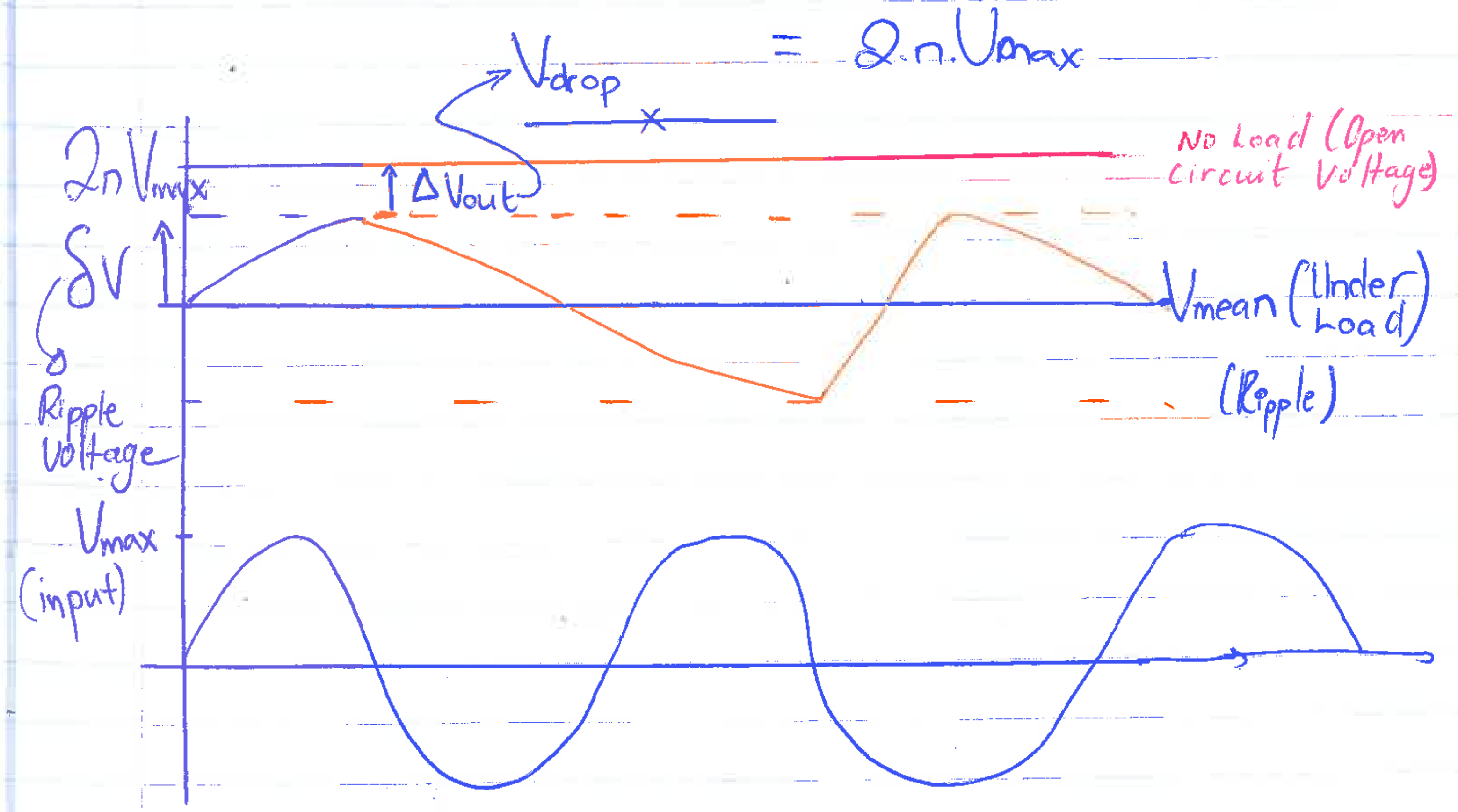


The Concept of cascading comes through because the components for such large voltage Output requirements are not available or too large to have or design.

∞ we cascade.



Output Voltage of n-stage $= 2.n.V_{max}$



- Magnitude of DC supply is quantified by the ripple voltage.

$$\Delta V_{out} = \frac{I}{fC_1}\left[\frac{2n^3}{3} + \frac{n^2}{2} - \frac{n}{6}\right]$$

Ripple Voltage → $$\delta V = \frac{I}{2fC}\left[\frac{n(n+1)}{2}\right]$$

$$\% \text{ Ripple} = \frac{\delta V}{V_{mean}} \times 100 \leq 3\%$$

16 May 2019

Generation HVAC

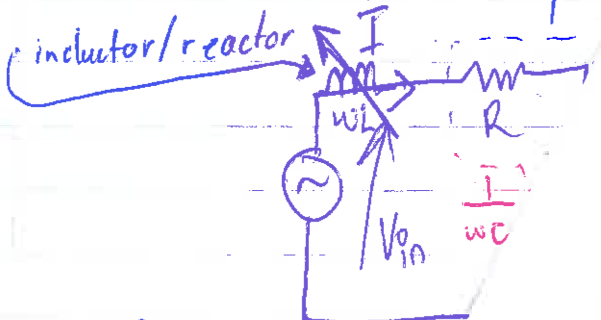
1. Cascade AC transformers
   - Gen. of HV AC

2.

2. Series Resonance (~~for Cable and~~ Power Cable or Transformers)

A cable is essentially a capacit

Cable reduced to a capaci



@ Resonance

$$wL = \frac{1}{wC}$$

- Only real power ... source. The rea... we ...

? - Copper Resistance
...ielectric losses
...istance
...nce

...oth

...ge is it
...e used to measure

- ~~Not~~ high
- Not too popular.

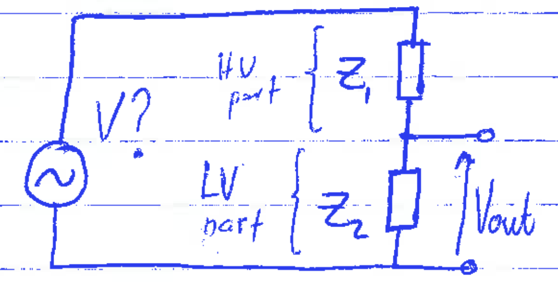
- We use low V_{in} for ~~test~~ High V_{out} cables
- When ever we test at a high V_{in}, when there is a fault ~~An advantage~~ and has a flashover, then we would have high currents. So using a smaller V_{in} will result in smaller fault currents, but the short circuit will take out the circuit out of resonance, causing a high impedance
- We don't have harmonics, clean freq, because we are testing at a fixed freq.

10 Km long, Capacitance of Cable
- length of cable we can test based on a set up. ?
- The V_{in} test voltage?

Charging currents of a cable are reduce when tested at low frequency from Test source. $V_{lf} = 0{,}1\ Hz$
$0{,}01\ Hz$

Measurement of HV

- ① Voltage divider rule is considered since there are limitations to test probes.

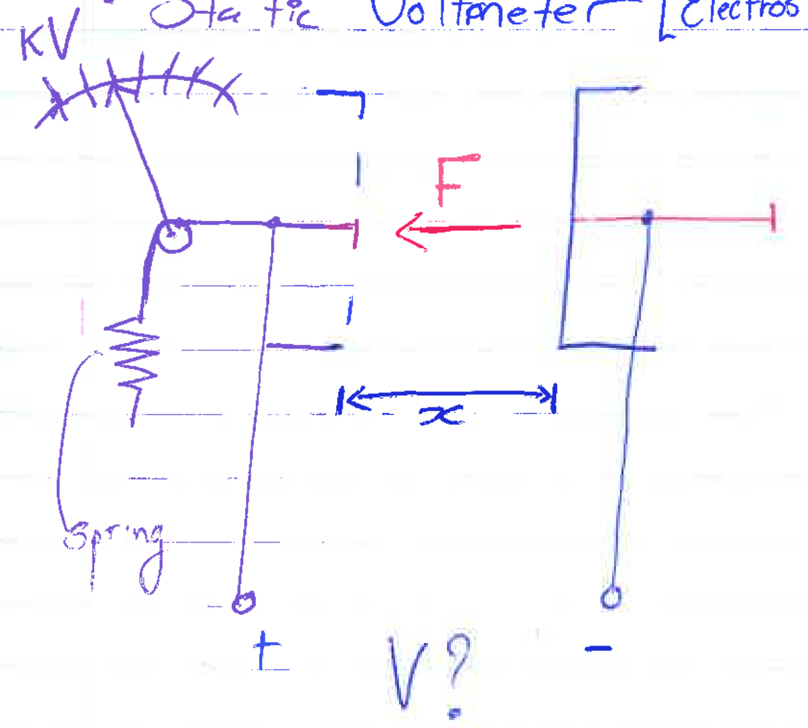


Here we would like to measure across ~ So we use a Ratio of Impedences
Z_1 → Resistors or Capacitors
Capacitive Vo

$$V_{out} = V_{in} \frac{Z_2}{Z_1 + Z_2}$$

$$\frac{V_{out}}{V_{in}} = \left(\frac{Z_2}{Z_1 + Z_2}\right) = \frac{1}{1000} \text{ (just a choice)}$$

- Static Voltmeter [Electrosta



$$F = -\frac{1}{2} \varepsilon A \frac{V^2}{x^2}$$

V_{rms} voltages
Can measure Both ~~DC~~ DC and AC
- Advantage is it can be used to measure high
- Not too popular.

110 marks Only five questions

Cavity distort E field
Predict PD using f
Voltage which causes cavity Breakdown.
Break down
Pearson Curve
Iterative method.
Project will be back
No diagrams

* Go through notes, just reading
* Go through past papers, 00:00 Check them on the wits website.
* Go through notes properly: Noting down important formula & info for the Crib sheet.

00:00
Application for Blessing & Nelisiwe online
VFS for Mon POP 2524791
~~Send email to Zakes from DBlock.~~
~~Exam papers & Class Notes (Power Points)~~

JBPS, Cosenenth Berea..., Parktown, Next fire Station
→ [redacted] 2014 Feb 10, $ Nelisiwe Links.

NSA, Highlands North, St Enders, Sandringham, Horizon High Schools
Izen 20 Next to it, John O,

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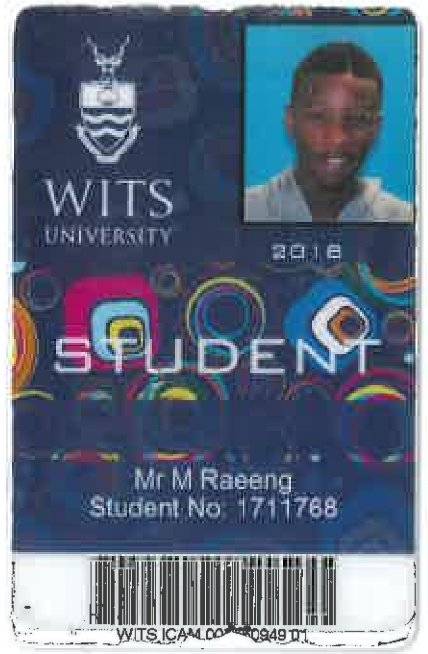
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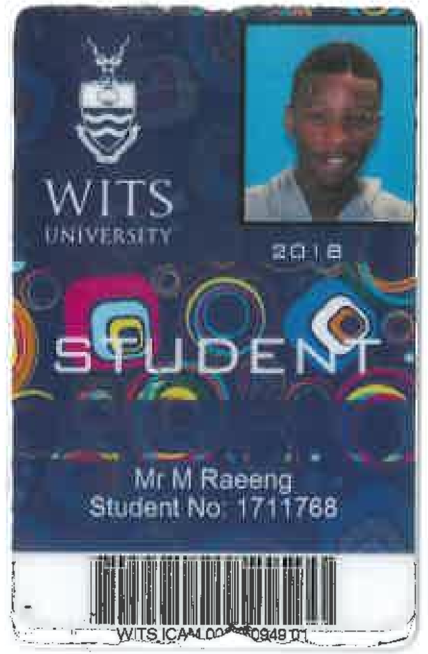
UNIVERSITY
2018
STUDENT
Mr M Raeeng
Student No: 1711768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