YAKIN DOĞU ÜNİVERSİTESİ
UZAKTAN EĞİTİM VE BİLİŞİM TEKNOLOJİLERİ MERKEZİ

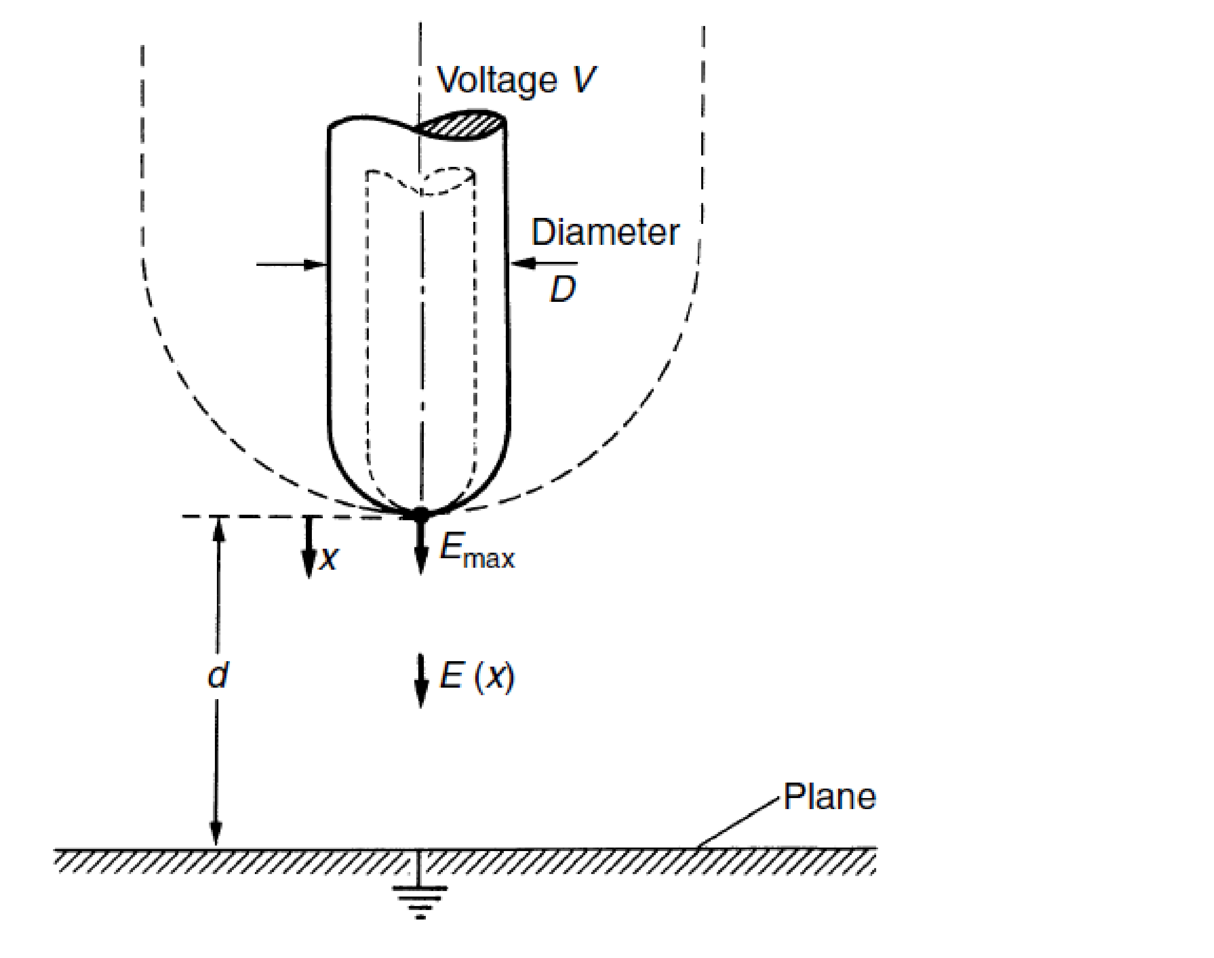
# EE 475 HIGH VOLTAGE TECHNIQUES I

Prof. Dr. Sezai Dinçer

## CORONA DISCHARGES

# 380 KV GIS

# Field factor f for a non-uniform geometry




$$f = \frac{E_{mean}}{E_{max}} = \frac{V}{dE_{max}}$$

$V_b = E_{max}\, d\, f = E_b\, d\, f$

$(E_{max} = E_b)$

# Breakdown  Stresses in Non- Uniform Geometries

In general, breakdown stresses are dependent upon the field distribution within high field regions,

Thus, models representing only those regions in which high stresses occur are, in general, sufficient; this offers definite advantages ,as the models can be reduced in size using electrode configurations in which the low field regions are absent

# Field factor for coaxial and spherical geometry

$$f = \frac{1}{\left(\frac{r_2}{r_1} - 1\right)} \ln\left(\frac{r_2}{r_1}\right).$$

coaxial

$f = E_{mean} / E_{max}$

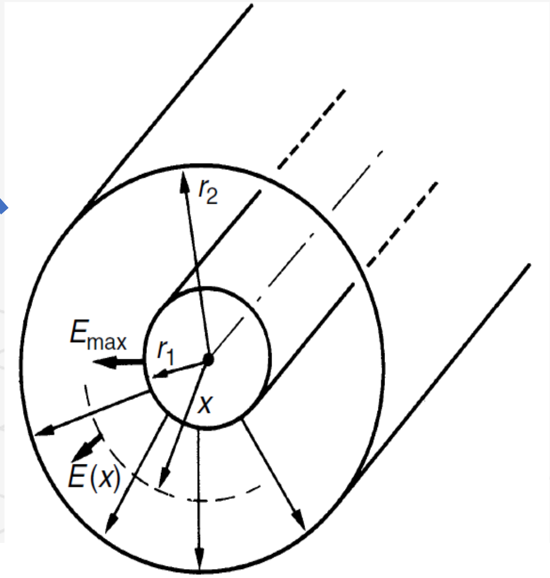
$E_{mean} = V / (r_2 - r_1)$

$$E_{max} = \frac{V}{r_1 \ln(r_2/r_1)}$$

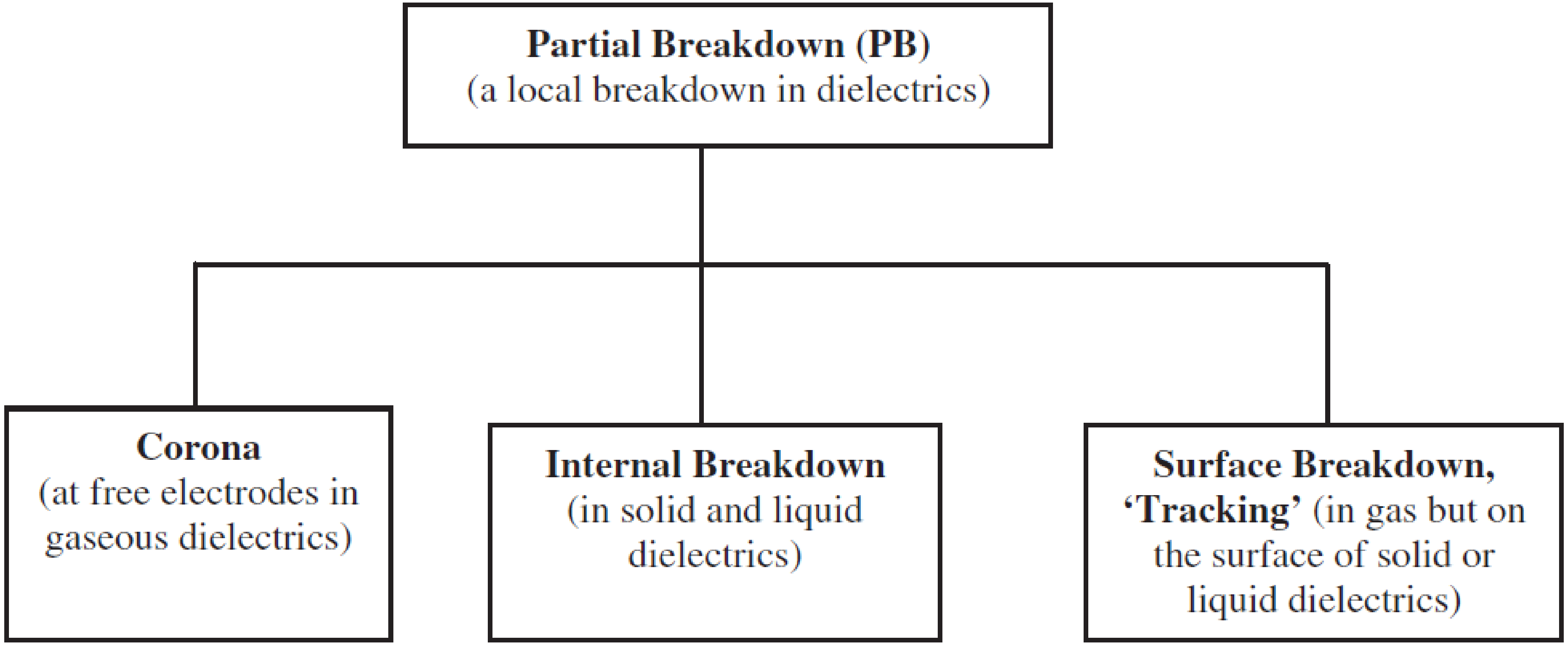
$V_b = E_{max}\, d\, f = E_b\, d\, f$

Breakdown Voltage

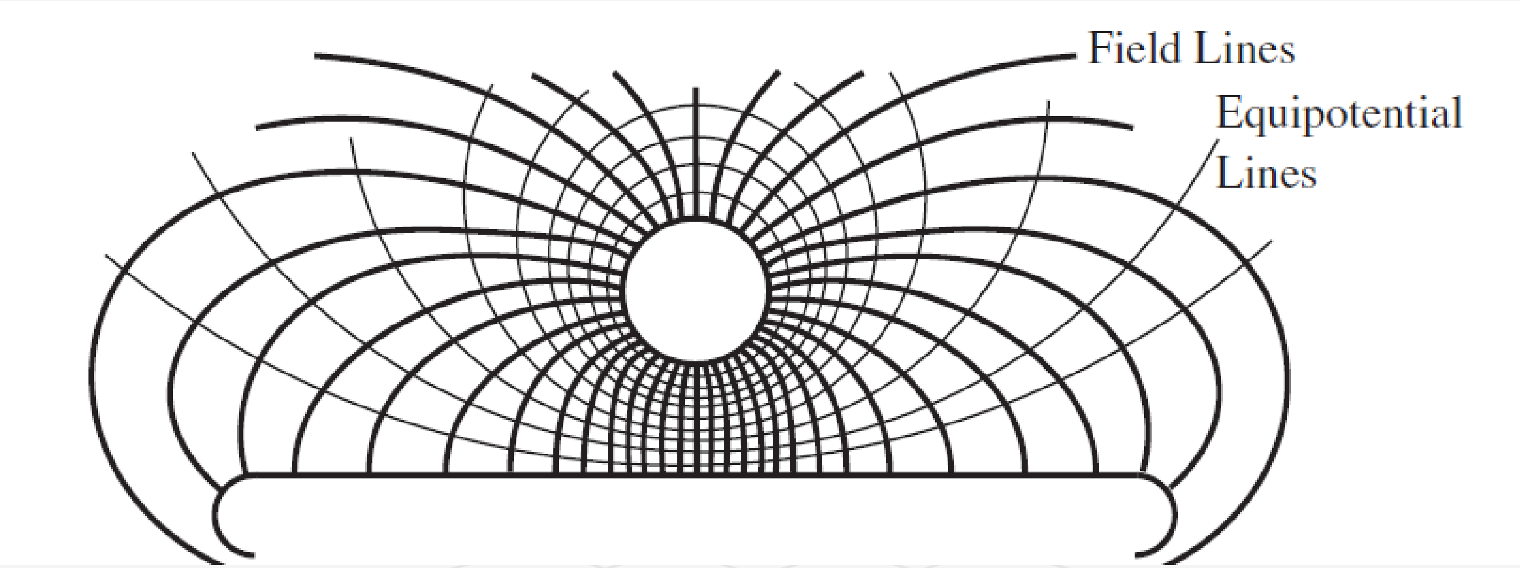
$f = R1 / R2$ spherical



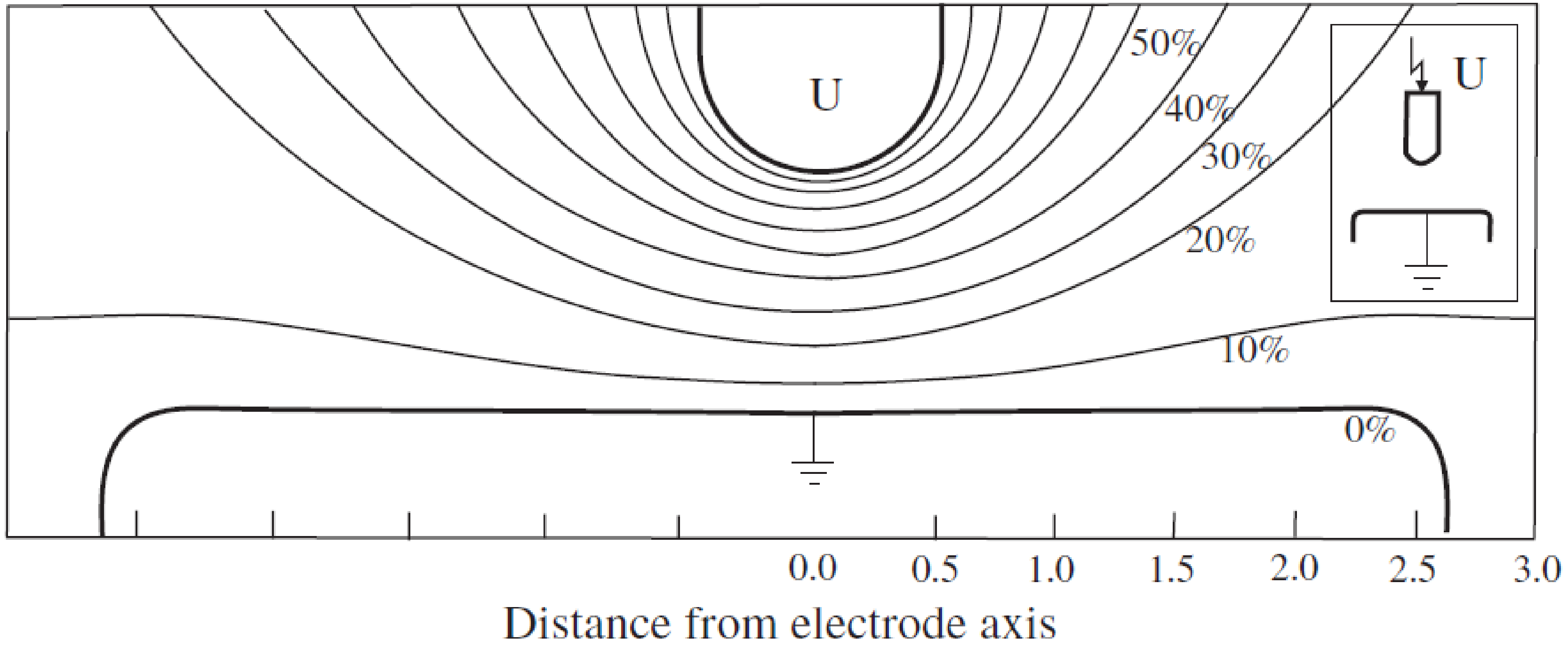
# Partial Breakdown



# Non Uniform Field Geometry

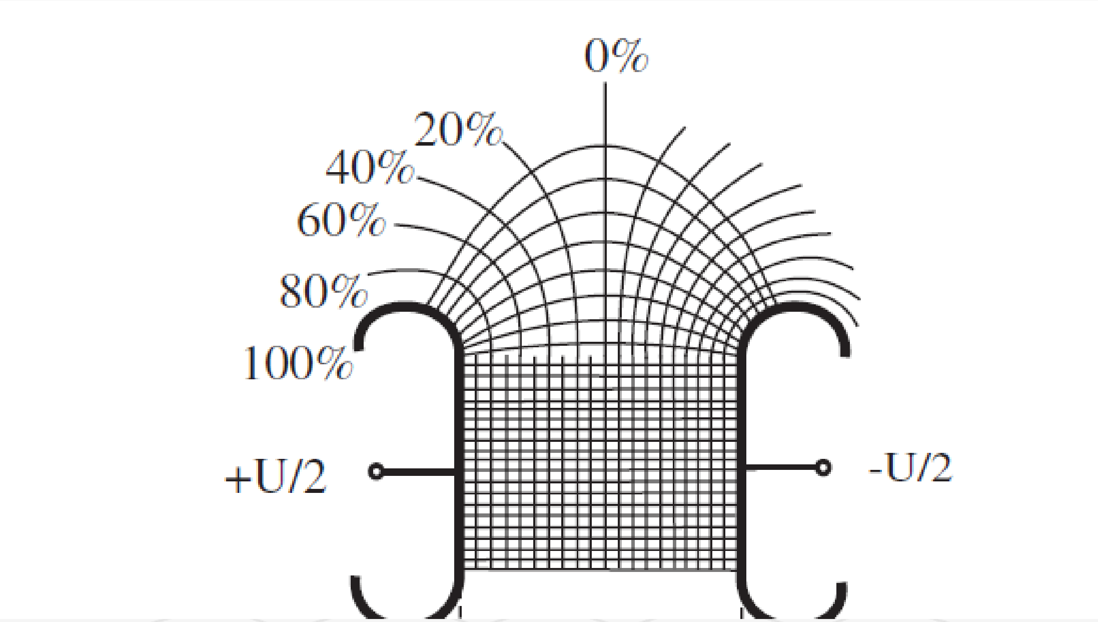


# Rod_Plane Electrode

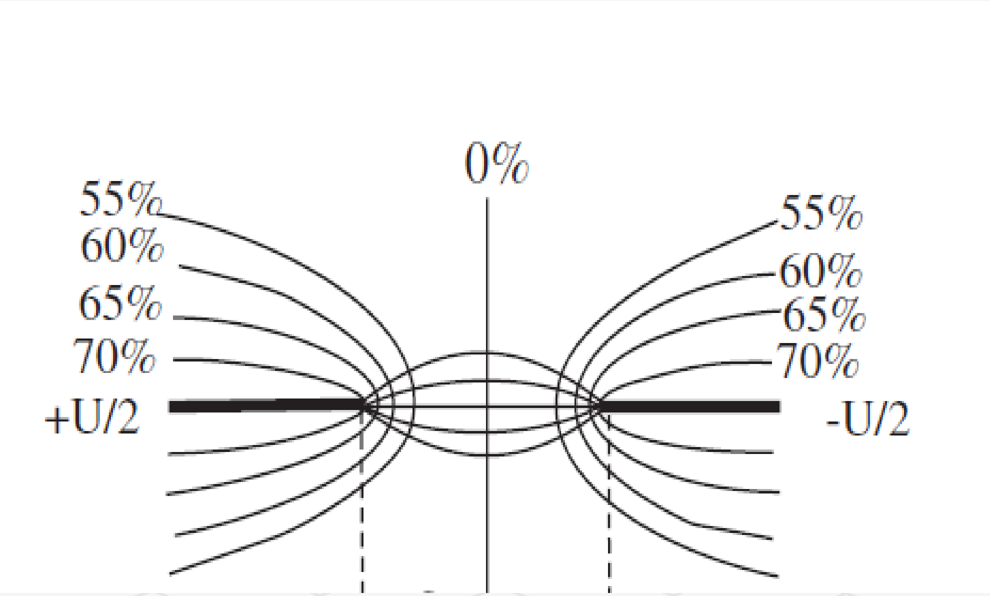



Equipotential lines for Rod-Plane electrode ; Asymmetrical voltage.

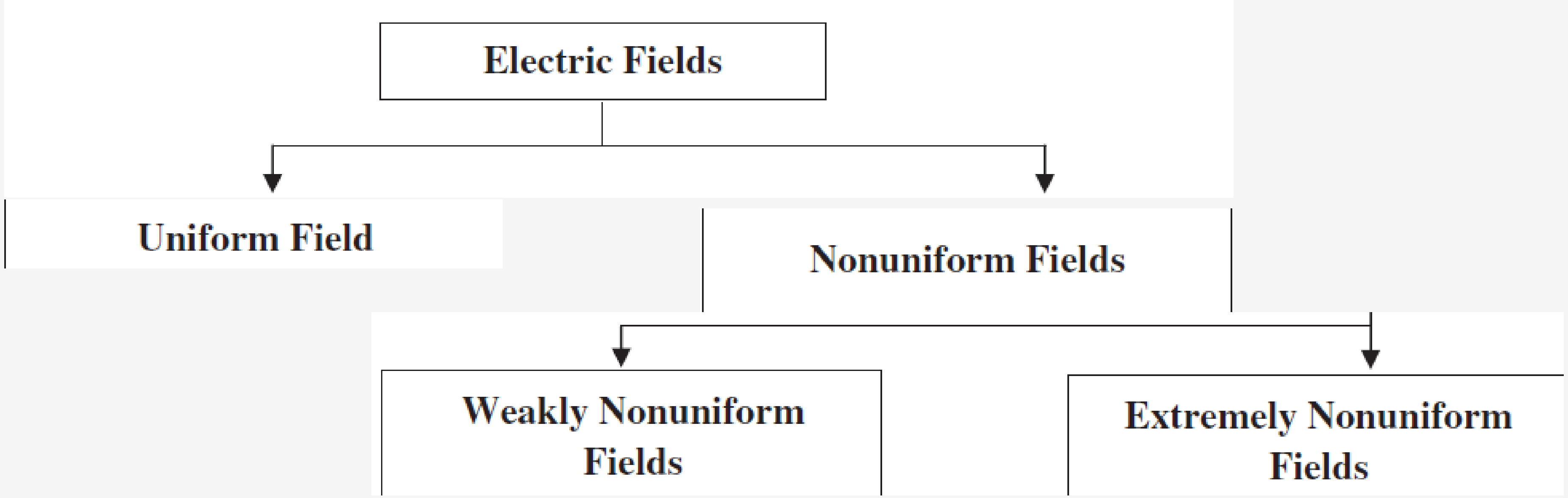
# Uniform Field Geometry

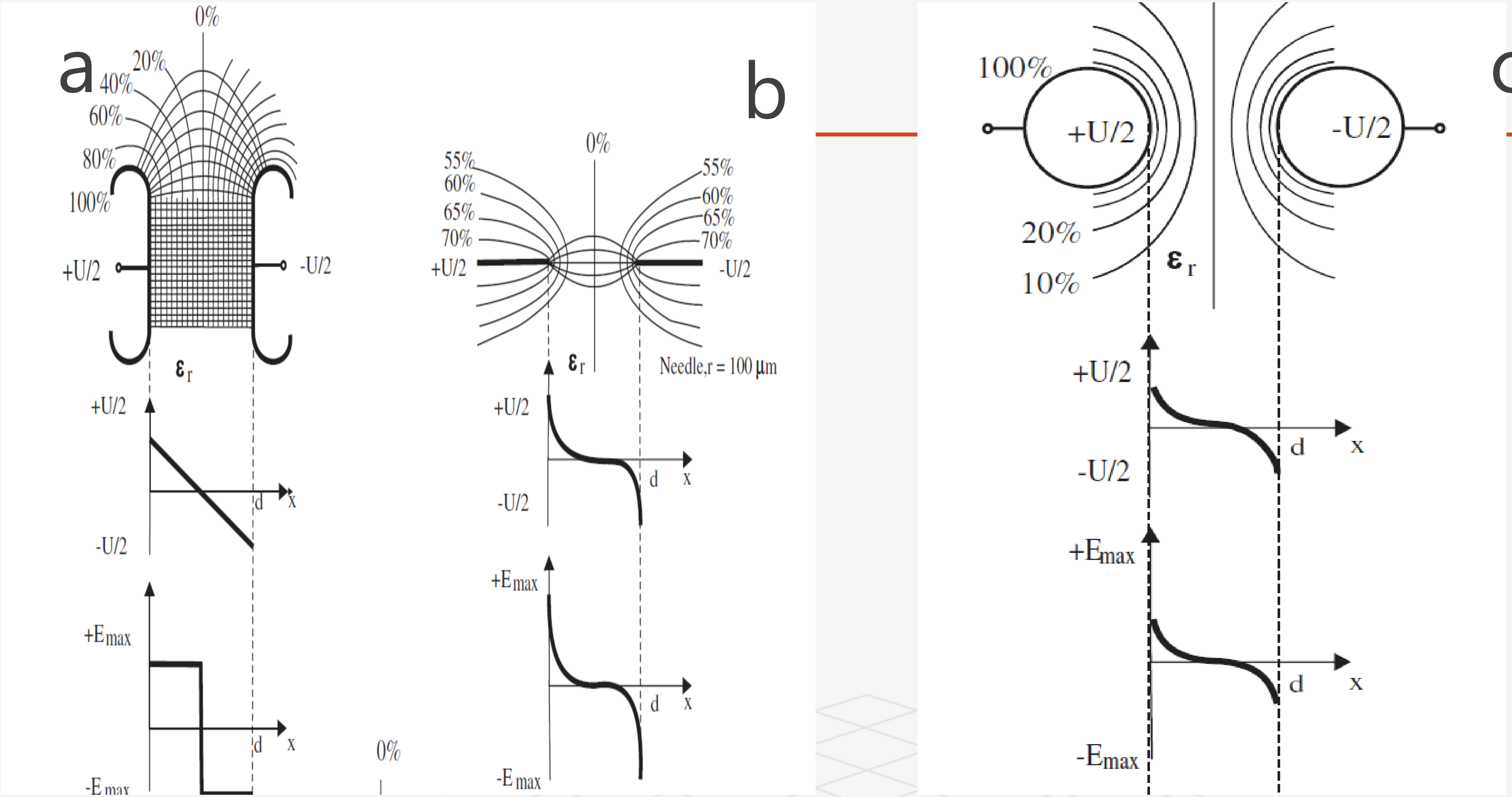


# Extremely Non Uniform Field Geometry



# Electrical Field Classification






**The field configurations (a) Uniform field between two parallel plates (c) Weakly nonuniform field between two adjacent spheres (b) Extremely nonuniform field between needle - needle electrodes**

# UNIFORM FIELD

In a " uniform field " , the potential is linearly distributed. The equi – potentials and the field lines make perfect square in the main field region. Hence the electric field intensity is constant throughout the space between the two electrodes, Figure (a). An important characteristic of the uniform field is that the insulation breakdown in such a field always takes place without any partial breakdown proceeding within the dielectric. In other words, it can be said that in uniform field configuration, the breakdown voltage is equal to the partial breakdown inception voltage,

The degree of uniformity of uniform field is numerically equal to one, Figure (a). A uniform field can be achieved between two electrodes especially designed for the given gap distance with the help of Rogowsky or Borda profiles.

# CORONA DISCHARGES

As the difference between maximum and mean field intensities in equipment increases (smaller f), the field characteristic becomes more nonuniform.

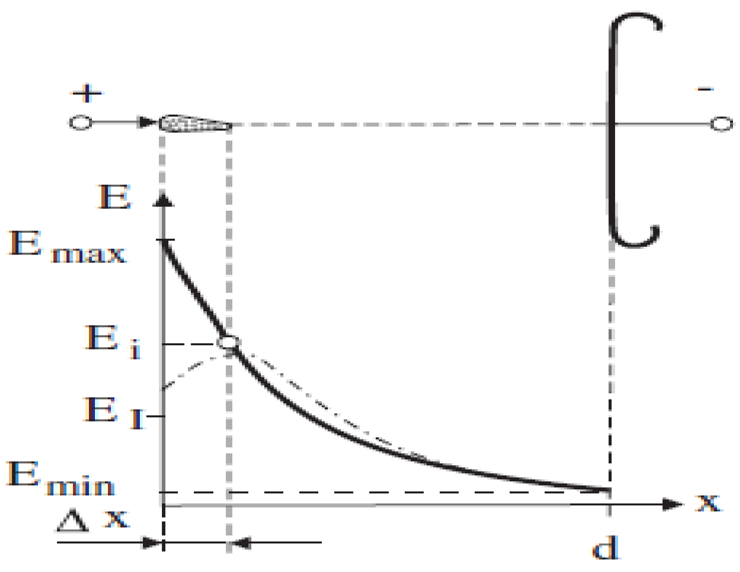
In extremely nonuniform fields at voltages much below the breakdown, a stable breakdown process confined locally to the region of extreme field intensity can be maintained. This phenomenon is known as “ Partial Breakdown ” (PB). When it occurs at free electrodes in gaseous dielectrics, it is called **Corona .(Crown in Latin)**

The most suitable electrode combinations to simulate extremely nonuniform fields are needle - plane or rod - plane electrode configurations. These asymmetrical electrode configurations have a highly localized region of extreme field intensity at the tip of the needle/rod electrode. Since the fundamental process of corona depends upon the polarity of the applied voltage, these electrode systems are found suitable for the proposed distinction between the positive and negative corona.

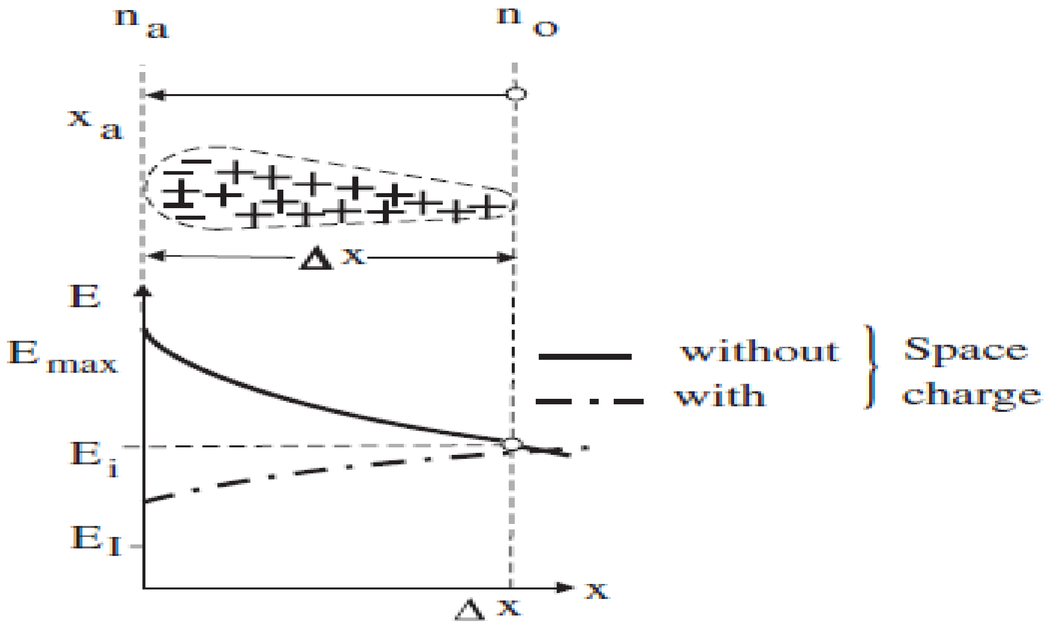
# *Positive Needle - Plane Electrode Confi guration (Positive or Anode Star Corona*

The applied field intensity *E in this case falls sharply close to the needle electrode tip.* Beyond a short distance, Δ*x, depending upon the applied voltage, the field intensity* may fall below the minimum field intensity required for impact ionization *in the Figure.(a)*

Thus, the avalanches are not able to extend themselves beyond a maximum length of Δ*x in the ionization region. It is generally much shorter than the critical* amplifi cation length *xc of the avalanche in this case. This is shown again in the Figure (b)* on a lower scale ratio diagram for *x.*



(a) Field in the gap



(b) Field in the region of ionization.

# Positive Corona

$$n_a = n_o \exp\left[\int_0^{x_a} \alpha(E_x)dx\right]$$

**In this case, the magnitude of field intensity *E strongly depends upon the* location. Since α is a function of *E, the number of electrons arriving at the anode na can be given according to the equation***

A positive space charge due to the heavy and slow ions remains at the back, having a very slow movement, especially because of rapidly decreasing applied fi eld at the anode tip. On increasing the applied voltage the ionization process is enhanced, hence stronger space charges build up. The two like polarity charges coming close to each other result in weakening the electric field in the region in front of the tip, as shown by dotted lines in Figure.

Inception of further avalanche discharge is possible only when there is a drift of space charge away from the anode with time accompanied by radial diffusion, possibly toward the cathode. This type of discontinuous process gives rise to an impulse form of discharge current at voltages above the PB inception

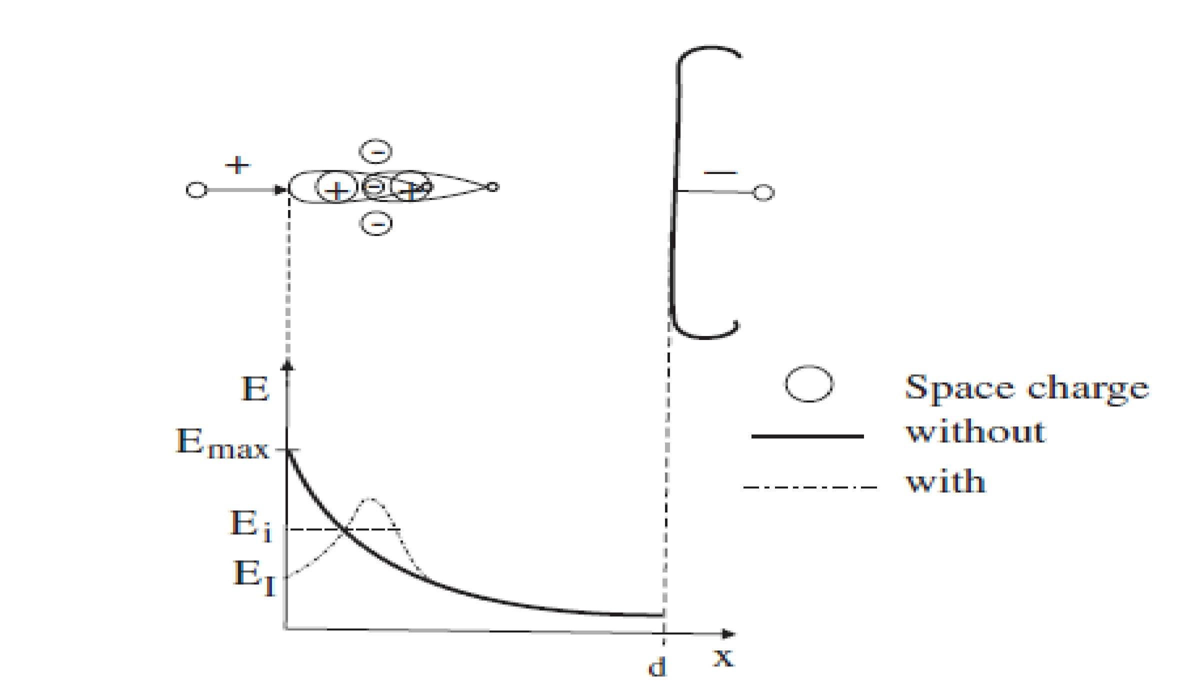
# Positive Star Corona

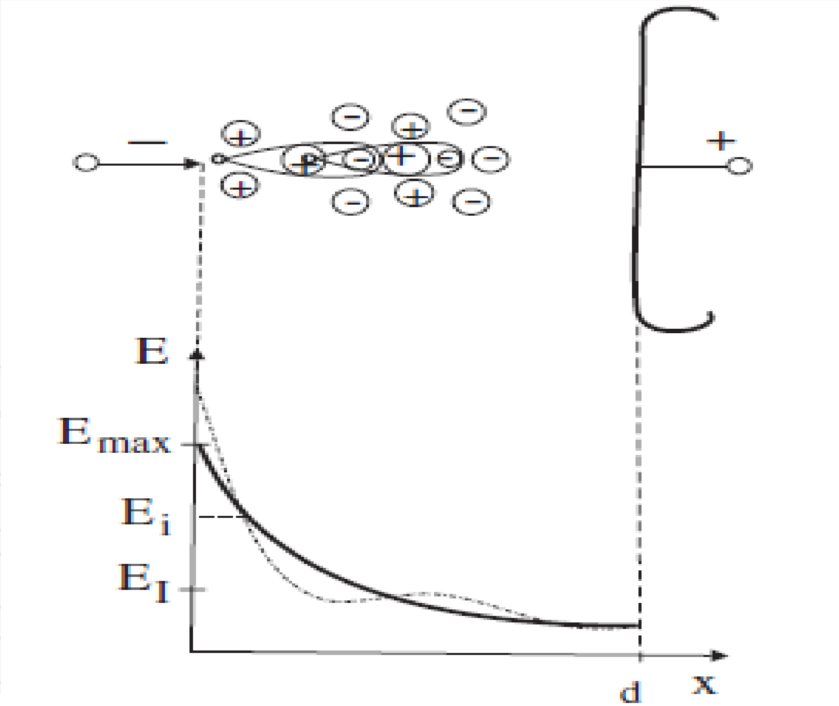
The optical impression of this quasi - stationary local breakdown process is a weak, bluish light like a " star in the sky " , adjacent to the needle tip. This light phenomenon is explained by the excited state of gas molecules due to electron impact. The atoms at higher energy levels emit a quantum of light and fall back to the original state of lower energy level. This process is known as positive or anode " star corona "

The " star corona " usually takes place at extremely sharp and pointed electrodes, for example, at needles, thin wires and sharp edges etc., on applying either *dc or the relatively slower changing power frequency ac voltages. The situation demands, on the one hand, a steep fall in potential gradient* so that the avalanches do not acquire their critical amplifi cation length, and on the other hand, that the charge carriers get enough time to build the space charge. **The audible noise produced by star corona is a continuous " hissing " sound**

# *Negative Needle - Plane Electrode Confi guration (Negative or Cathode Star Corona*

When negative polarity *dc voltage, just sufficient for the* inception of impact ionization is applied to a needle (the cathode), the condition is similar to the one discussed in the previous section only to some extent. In this case as well, the possibility of impact ionization is limited to a short distance Δ*x because* of a steep fall in potential gradient at the needle towards the plane. The ionization process started with a single electron adjacent to the needle tip is able to extend the avalanche to a maximum length of Δ*x only, analogous to the conditions shown in* Figure . Like in case of positive polarity voltage, here too the avalanches do not acquire their critical length of amplification. Hence the avalanche process limits itself to a short region adjacent to the needle tip and it is not able to expand farther

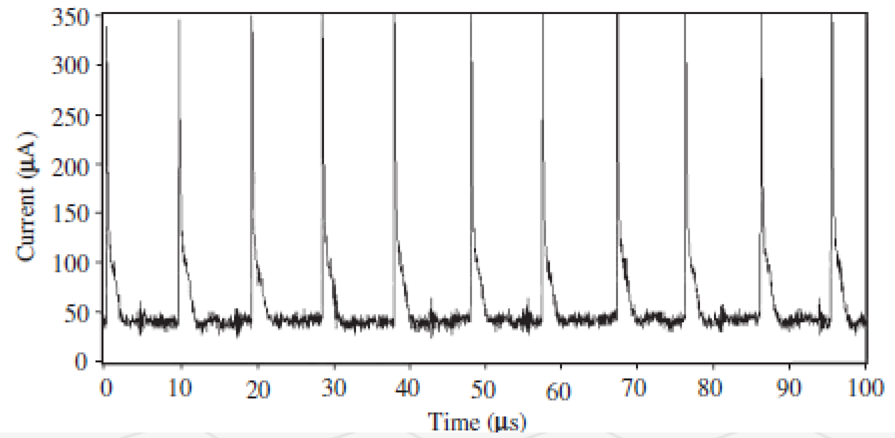


# Current Pulses

In short, it can be concluded that as in the case of positive polarity, in the case of negative polarity, a discontinuous process of charge carrier production and their migration in the dielectrics also takes place. The magnitudes of conduction currents in gaseous dielectrics without PB are fairly low. Since PB in dielectrics involve high discharge currents, the conduction current increases considerably with PB. Under static conditions above the PB inception level, an impulse form of PB current is conducted through the dielectric in a very regular and repetitive pulse form, as shown in Figure . The frequency of these current pulses may vary from a few kHz to MHz. This pulse current was first measured and studied in detail by Trichel.

Eventually, at much higher voltages, the impulse character of the PB current is lost due to overlapping of individual pulses. A direct current is then measured, which is accompanied with certain fl uctuations. A steady PB or star like " cathode corona " , similar to the anode corona is also observed in this case but it is located slightly away from the needle tip**. The cathode corona appears reddish, as compared to the bluish anode corona**.

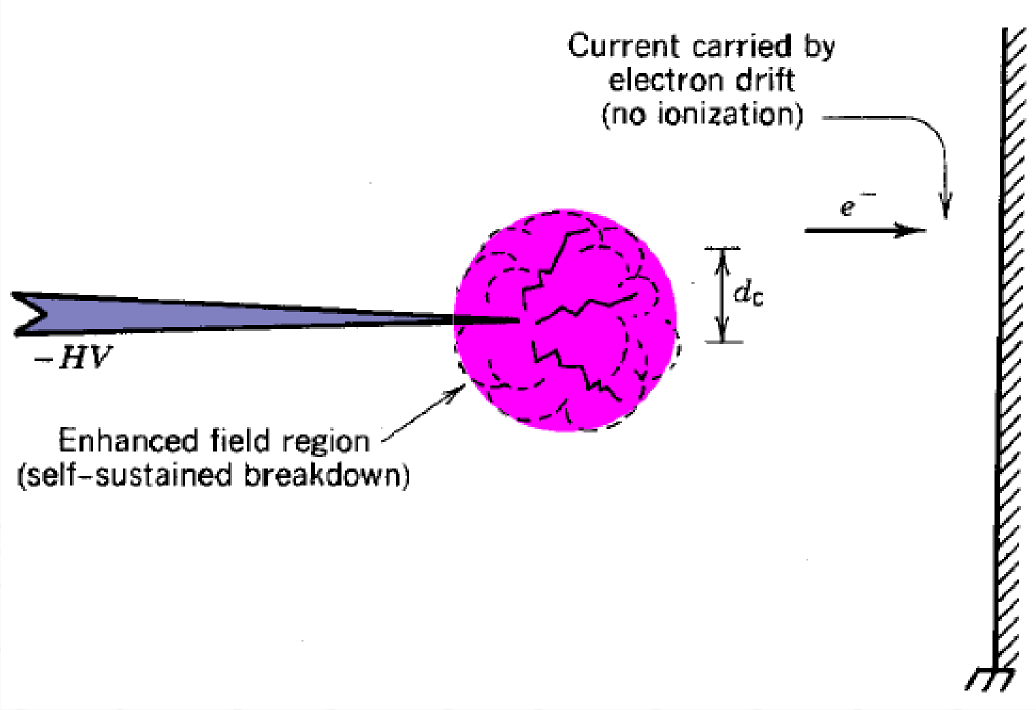



Trichel Current Pulses

# CORONA DISCHARGES

Corona discharges appear in gases in the vicinity of electrodes with small radius of curvature.

Corona (crown in Latin) is a pattern of bright sparks near a pointed electrode. In such a region, the electric field is enhanced above the breakdown limit so that electron avalanches occur.



# *POSITIVE CORONA*

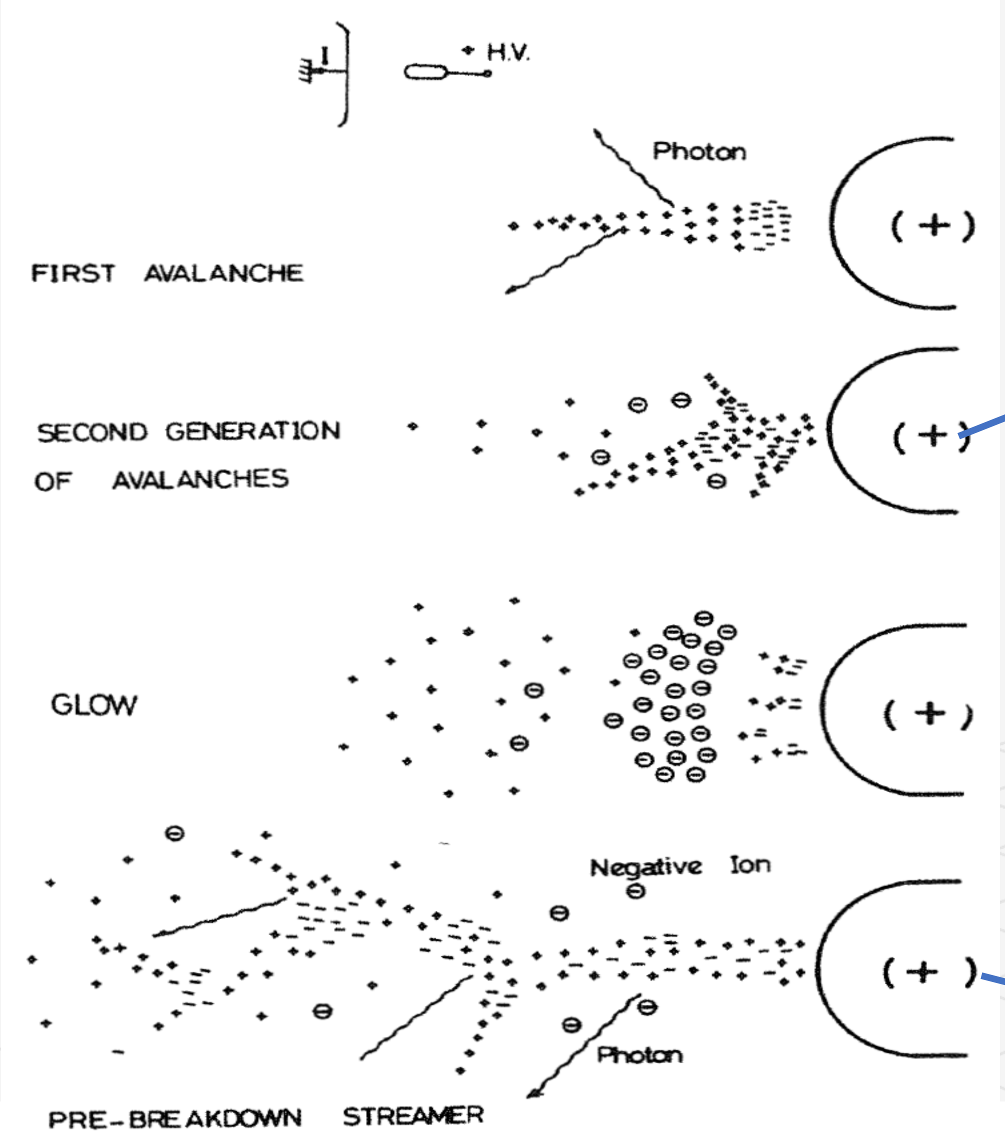
**Mechanism depending on the applied voltage level**

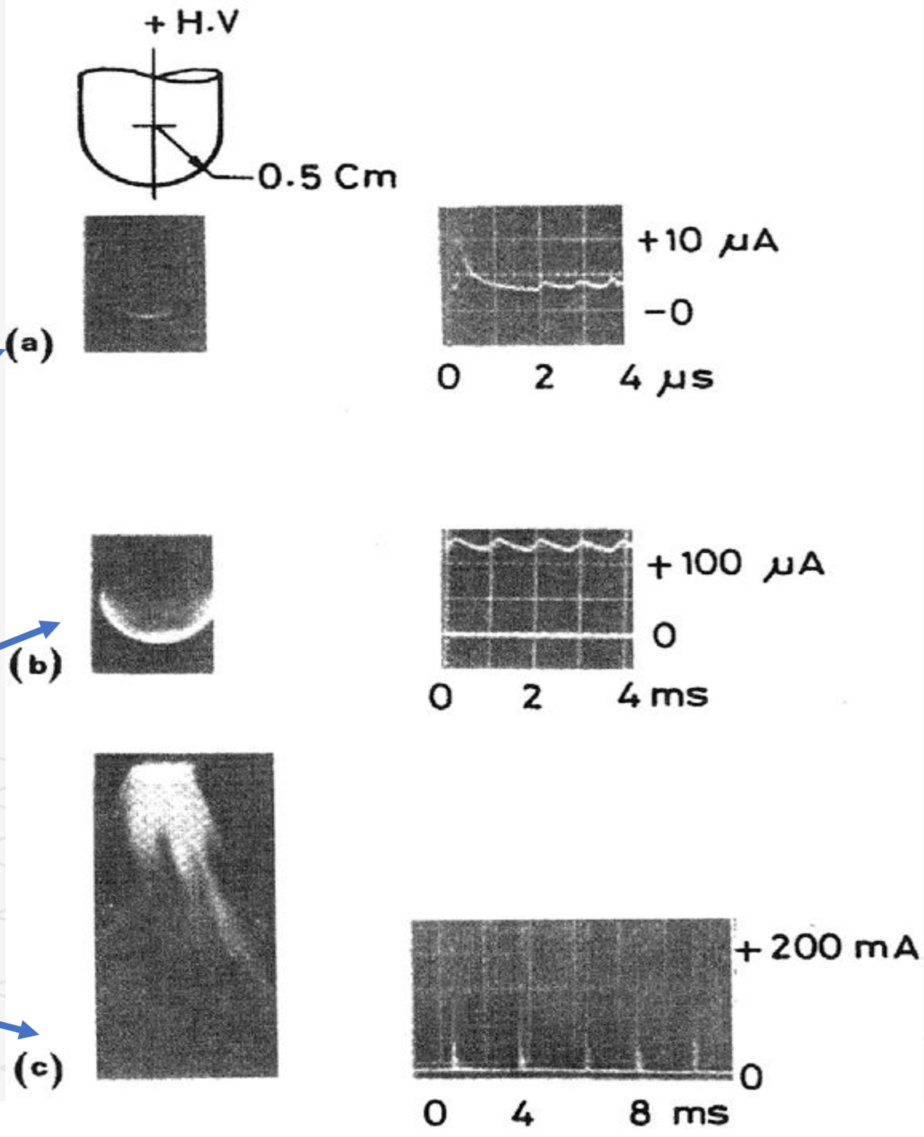
**a. At the onset level: When a free electron is driven by the field toward the anode, it produces an electron avalanche. The cloud of positive ions produced at the avalanche head near the anode forms an eventual extension to the anode. Secondary generations of avalanches get directed to the anode and to these dense clouds of positive ions. This mode of corona consists of what are called onset streamers.**

**b. At slightly higher voltages: A cloud of negative ions may form near the anode surface such that the onset-type streamers become very numerous. They are short in length, overlap in space and time, and the discharge takes the form of a 'glow' covering a significant part of the HV conductor surface. The corresponding current through the HV circuit becomes a quasi-steady current.**

**c. At still higher voltages: The clouds of negative ions at the anode can no longer maintain their stability and become ruptured by violent pre-breakdown streamers, corresponding to irregular, high-amplitude current pulses. If we continue to raise the voltage, breakdown eventually occurs across the air gap.**

# POSITIVE CORONA



# NEGATIVE CORONA

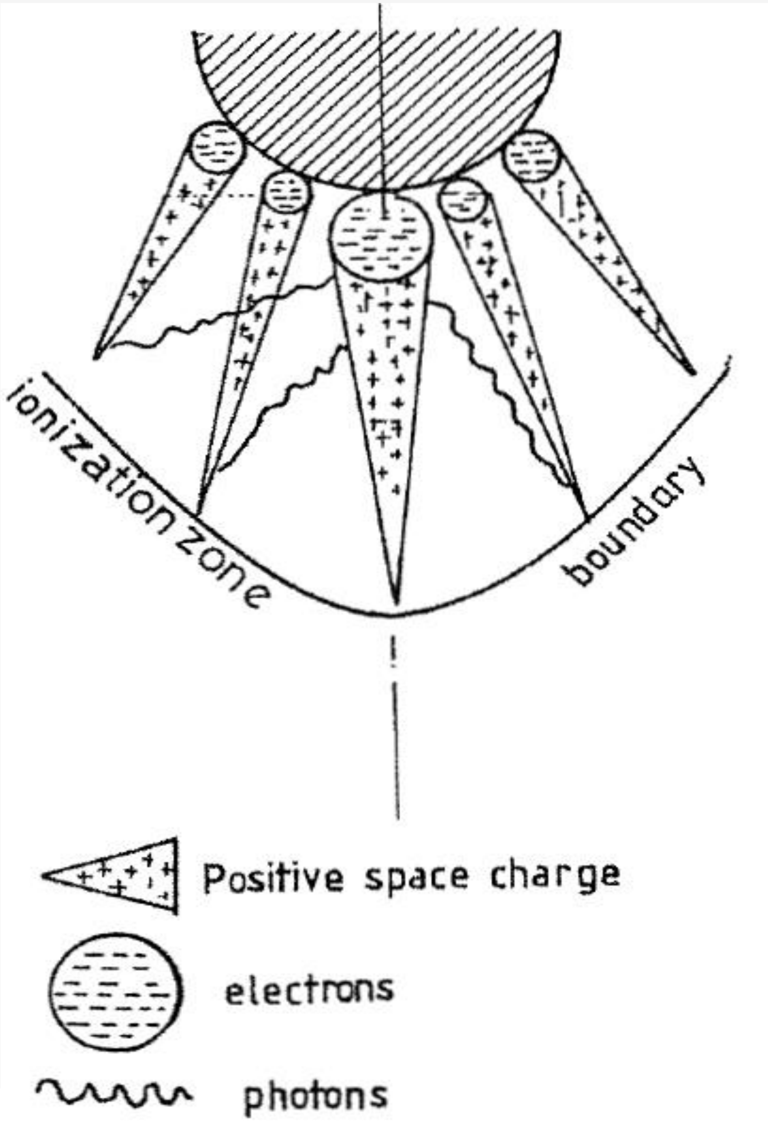
**Mechanism depending on the applied voltage level**

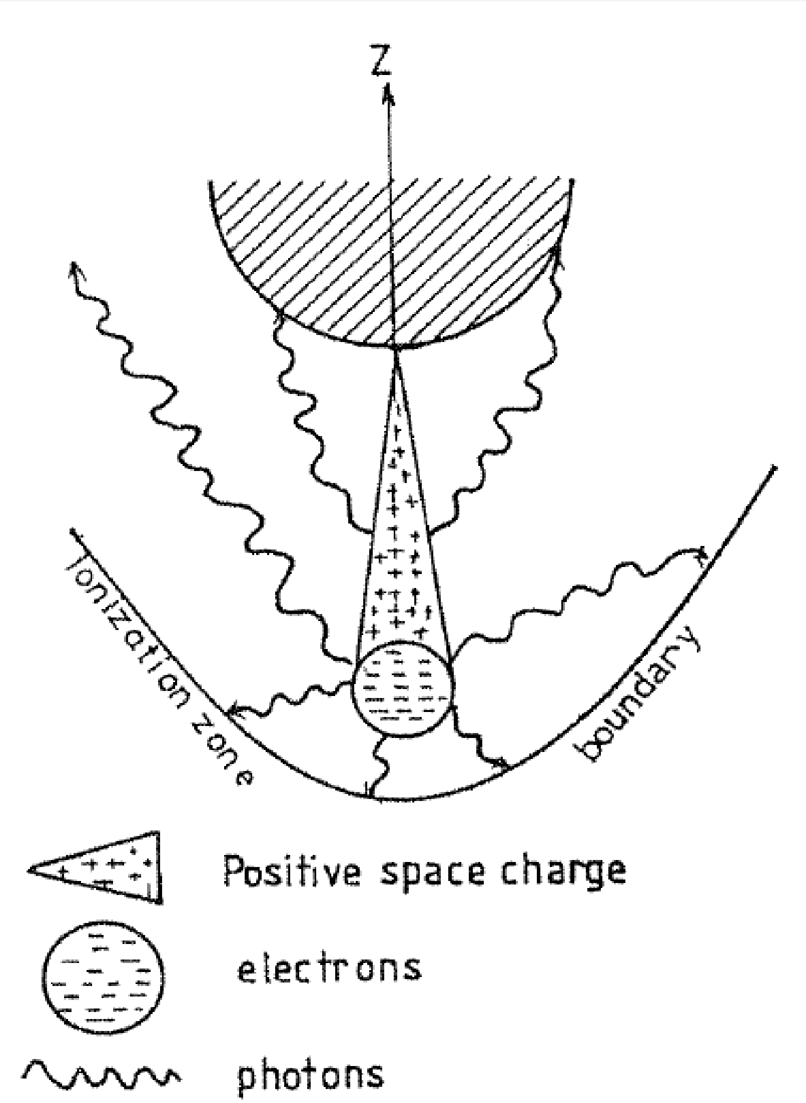
**a. At the onset level: The corona at the cathode has a rapidly and steadily pulsating mode; this is known as Trichelpulse corona. Each current pulse corresponds to one main electron avalanche occurring in the ionization zone. Drifting away from the cathode, more and more of the avalanche electrons get attached to gas molecules and form negative ions which continue to drift very slowly away from the cathode. During the process of avalanche growth, some photons radiate from the avalanche core in all directions. The photoelectrons thus produced can start subsidiary avalanches that are directed from the cathode.**

**B .At slightly higher voltages: The Trichelpulses increase in a repetition rate up to a critical level at which the negative corona gets into the steady "negative glow" mode.**

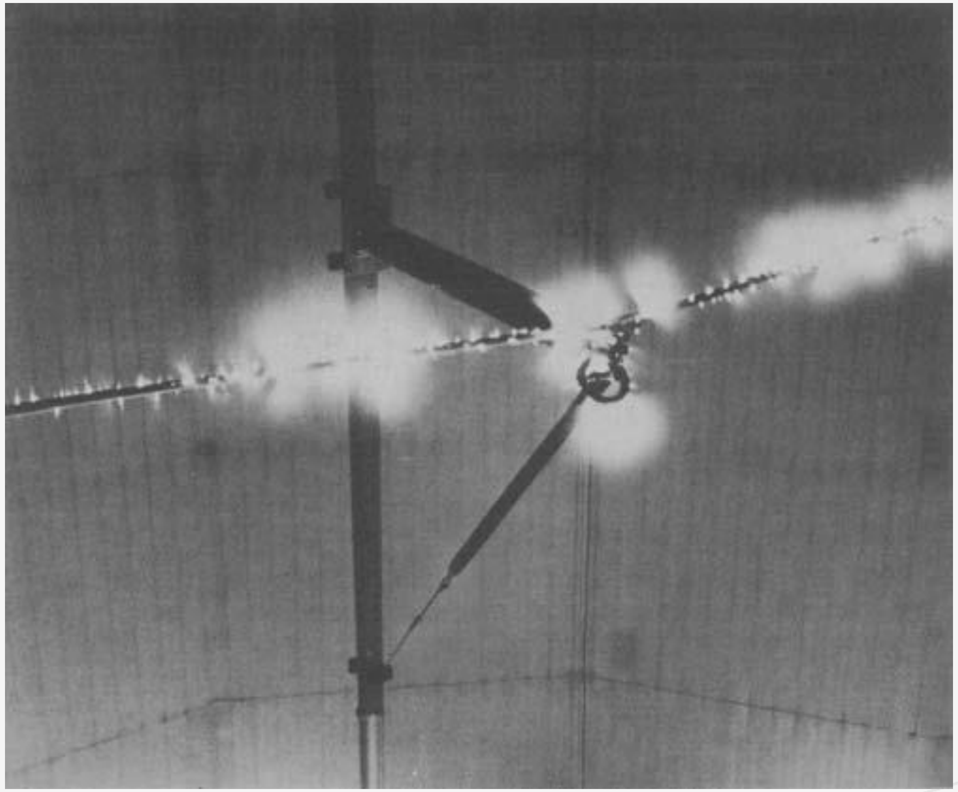
**c. At still higher voltages: Pre-breakdown streamers appear, eventually causing a complete breakdown of the gap.**

# POSITIVE CORONA VS. NEGATIVE CORONA



# CORONA



Corona testing of conductor in laboratory environment. (Courtesy of Ohio Brass Company

# REFERENCE

High voltage and electrical insulation engineering / Ravindra Arora, Wolfgang Mosch. Published by John Wiley & Sons, Inc., Hoboken, New Jersey. ISBN 978-0-470-60961-3