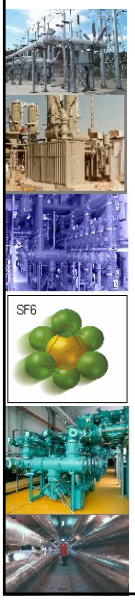
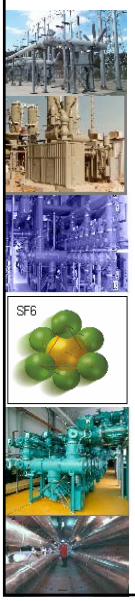


IEEE

Substations Committee
GIS Subcommittee K0
Working Group K2
Module
GIS Theory



Ionization and Excitation

- Ionization, the process of removing an electron from an atom or molecule
- Excitation, the condition in which an electron moves to a higher, unstable energy level. Relaxation results in the electron returning to a stable energy level, releasing the excess energy as a photon
  - Photo ionization
  - Nuclear particle impact
  - Electron impact
  - Thermal ionization
  - Frictional or mechanical ionization
  - Chemical

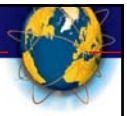
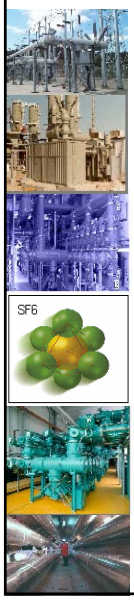
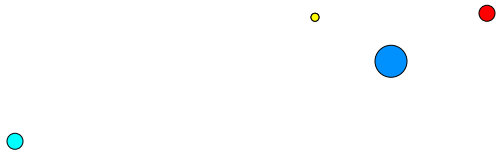


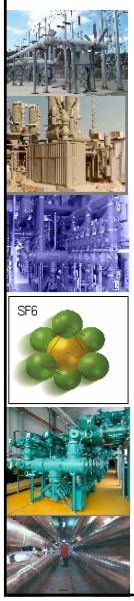
Photo Excitation

- Electron raised to higher energy state, they returns to ground state, emitting a photon
- Relaxation time
- Most important secondary process in breakdown of gases



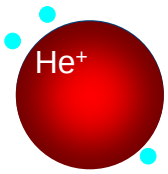


Electron Impact Ionization

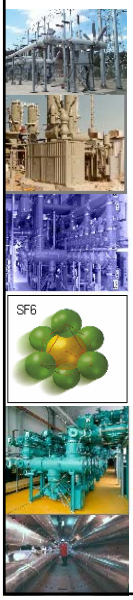


Ionization:

$He \rightarrow He^+ + e$

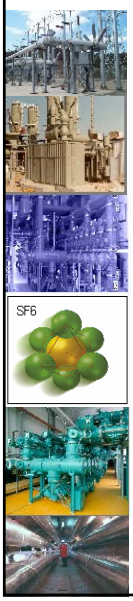


Electron is accelerated in an electric field until its energy is equal to, or greater than the ionization potential of the molecule it strikes



Ions Vs Electrons

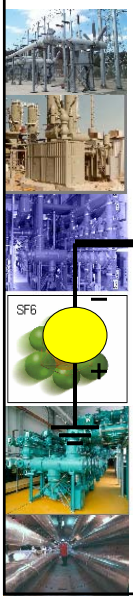
- Mass of an electron vs. mass of SF_6 1 to 125,000 (1500 lbs vs 95,000 tons)



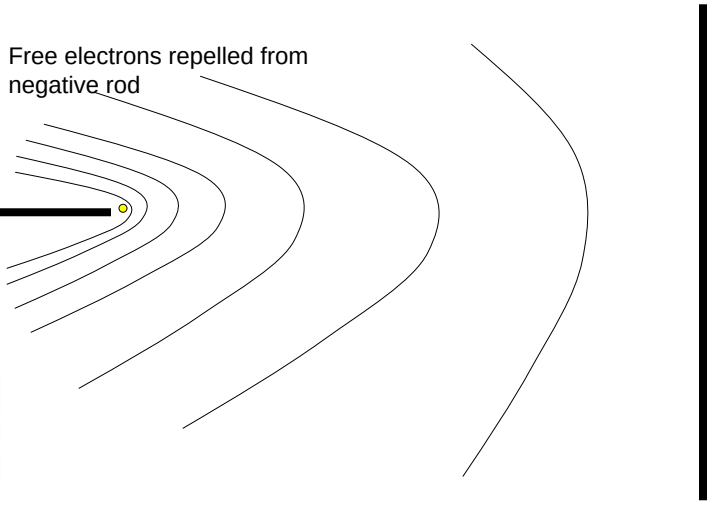
Free Electrons

- Created by ionization processes discussed
- Exist everywhere
- Create radio noise
- Impact us in many ways

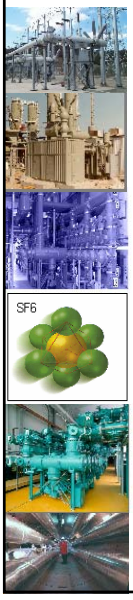
Non-homogeneous gap

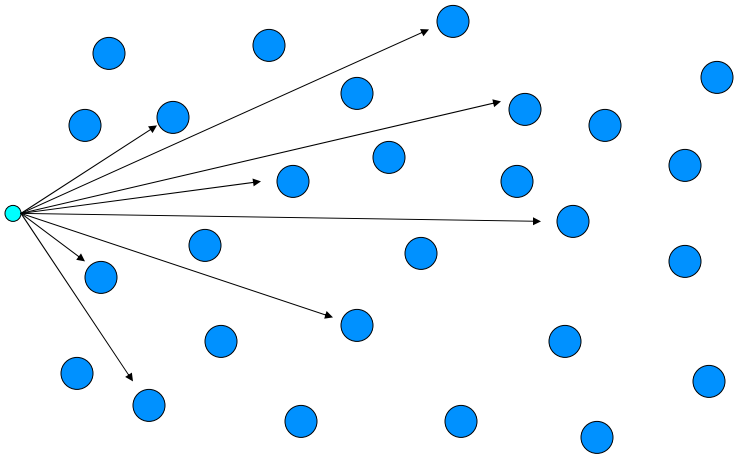


Free electrons repelled from negative rod

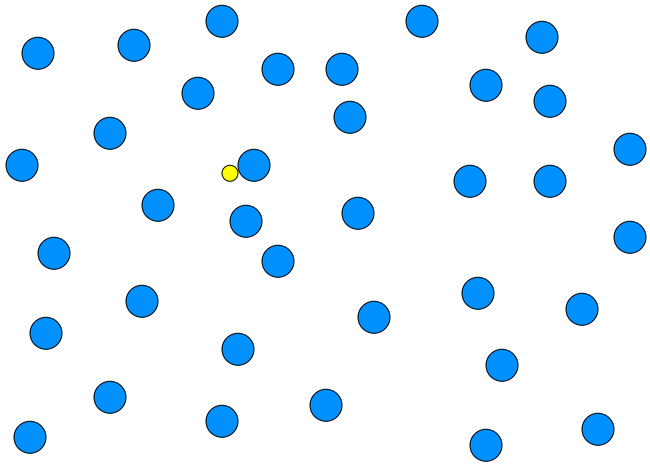


Mean Free Path

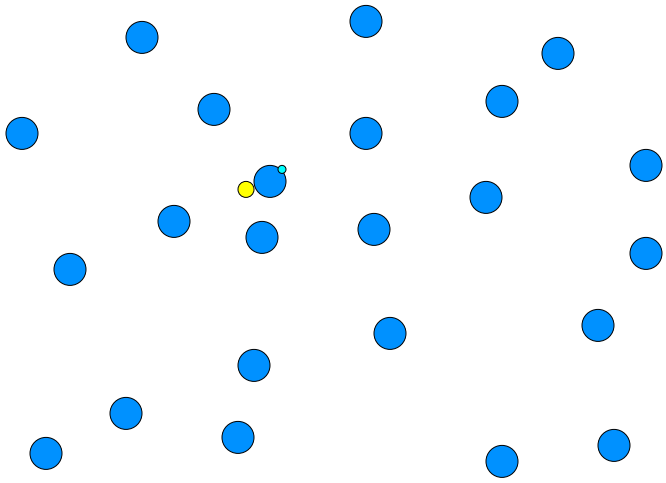




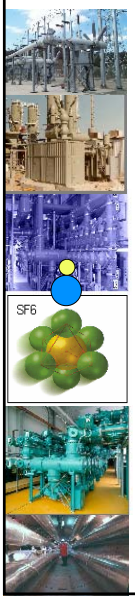
Accelerated Electron has Collisions

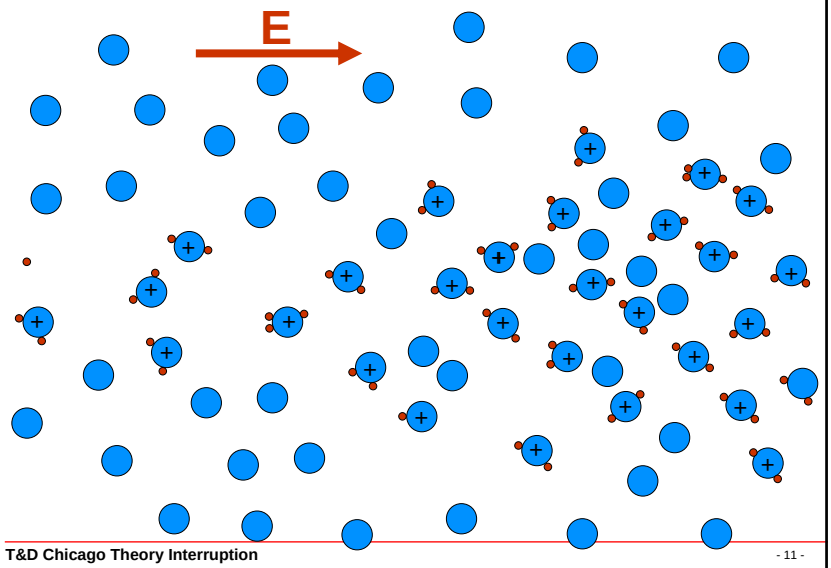


Higher Voltage (or longer path), Photo Excitation

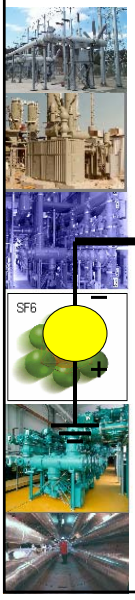


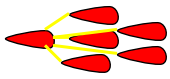
Electron Avalanche by electron Impact





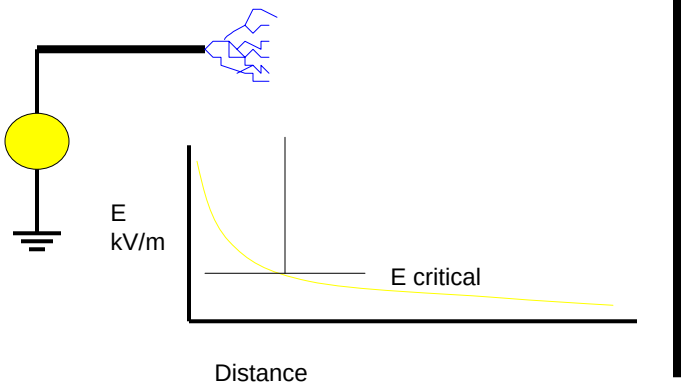
Many Collisions Produce Photons





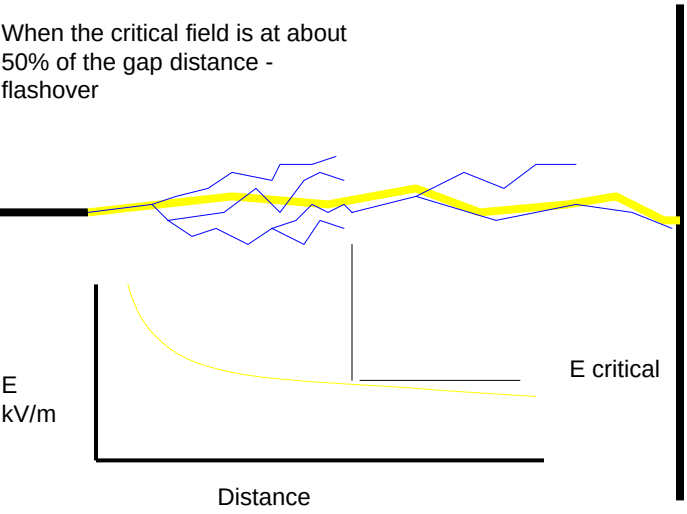
Critical Field, Lightning Impulse

Process continues until the field strength cannot accelerate electrons to sufficient velocities

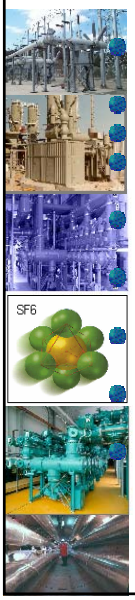


Critical Field, Lightning Impulse

When the critical field is at about 50% of the gap distance - flashover



Electrons and Ions, Comparing SF_6 and N_2



Mass of an electron changes with velocity, at rest = 9×10^{-28} grams

Mass of a hydrogen atom = 1.7×10^{-24} grams
1888 times the mass of e
Mass of nitrogen molecule = 2.32×10^{-23}

Mass of SF_6 molecule = 1.16×10^{-22}

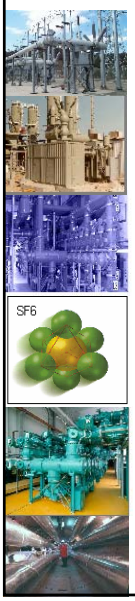
SF_6 125,000 times the mass of e

SF_6 five times the mass of nitrogen

Ionization potential of Nitrogen 15.6 eV

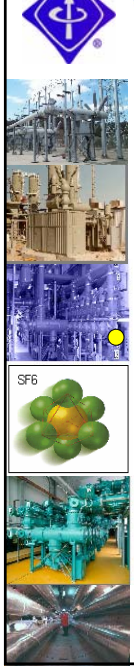
Ionization potential of SF_6 15.6 eV

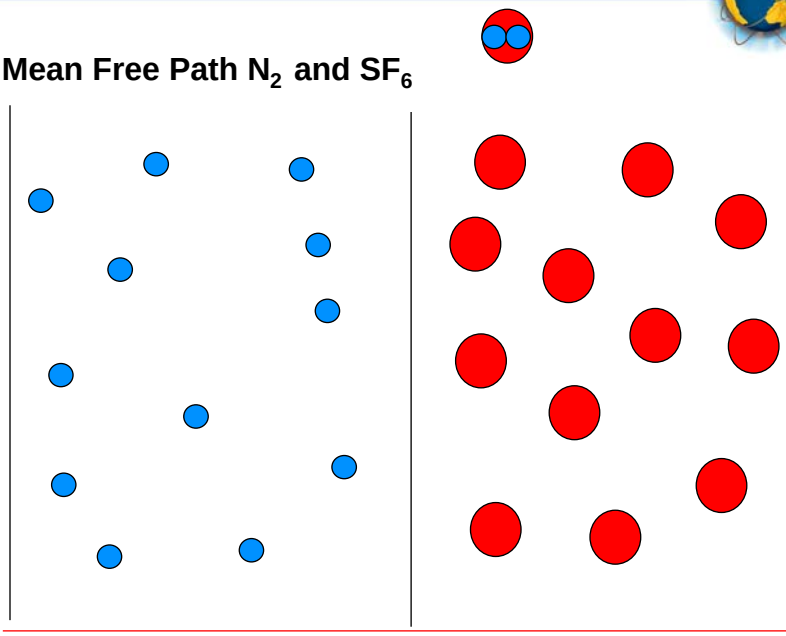
Mean Free Path



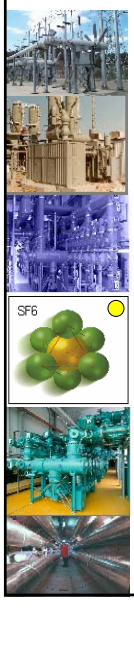
- Electrons require a certain distance to accelerate to sufficient velocity to have enough energy to cause ionization.
- The average distance between molecules is a function of the collision diameter and density.
- Collision Diameter
  - N_2 16.1 A
  - SF_6 36.5 A
- Mean Free Path
  - N_2 6×10^{-8} m
  - SF_6 2.5×10^{-8} m

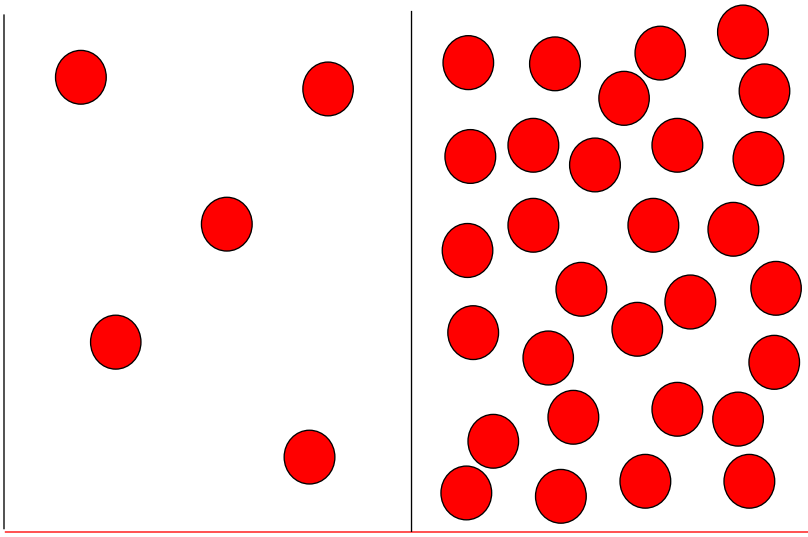
Mean Free Path N_2 and SF_6



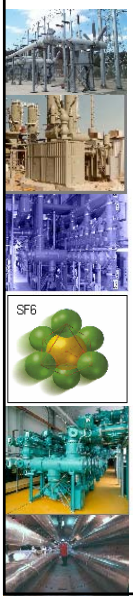


Impact of Increasing the Gas Density 6X



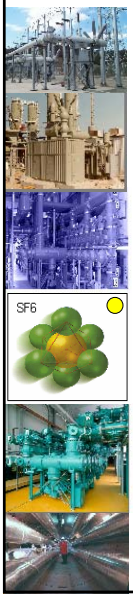


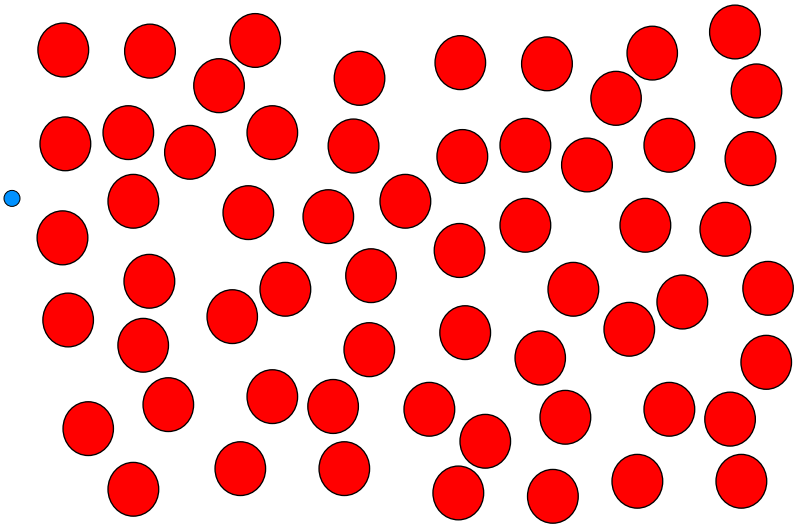
Electron Affinity

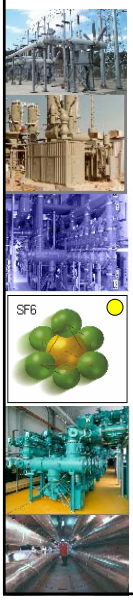


- Electro-negative
  - Electron Affinity (strong affinity for electron attachment)
  - Free electrons are often captured
  - Mechanisms $e + SF_6 \rightarrow SF_6^-$
  - Resonance capture $e + SF_6 \rightarrow SF_5^- + F$
  - Dissociative attachment
  - Energy requirements are low (0.1 eV or less)

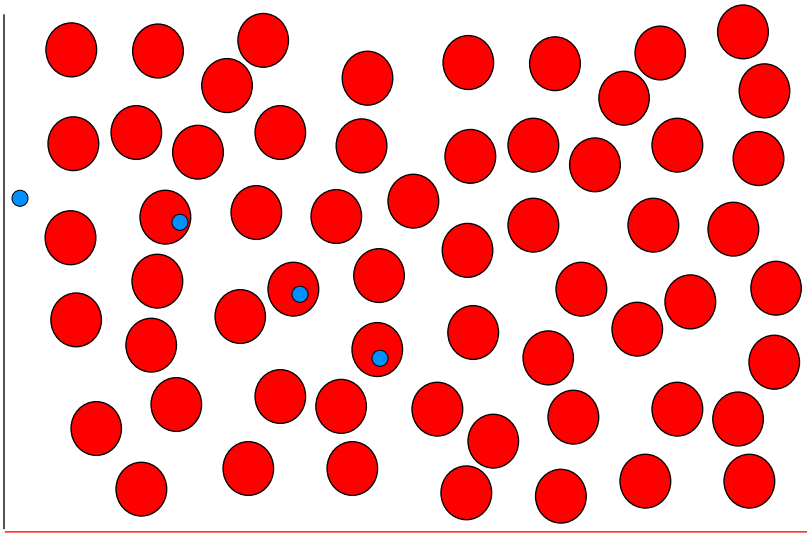
Impact Electro-negativity on Breakdown

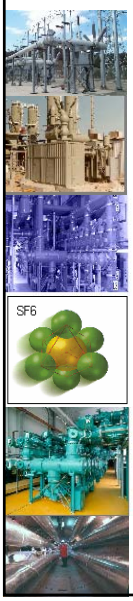






Impact Electro-negativity on Breakdown



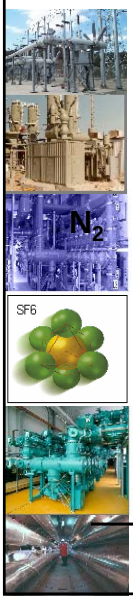


Summary, why is SF6 a Good Insulating Gas?

- Molecule is large
- Electron Affinity
- Fairly high ionization potential

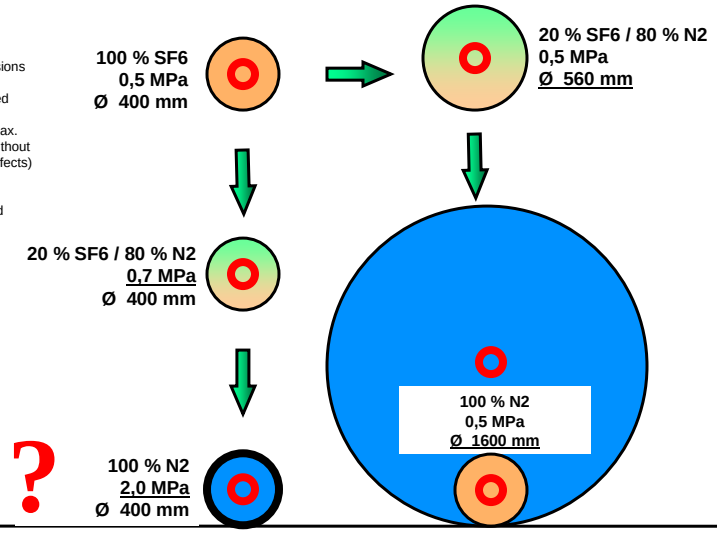
- The breakdown strength of air is dramatically increased by the addition of small quantities of SF6. In contrast, air has only a limited influence on the breakdown strength of sulfur hexafluoride. The addition of 10 % of air by volume reduces the breakdown voltage of SF6 by about 3 %, the addition of 30 % air by about 10 %.

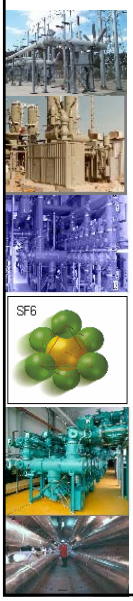
Nitrogen instead of SF_6 ?



GIS-Dimensions based on approximated breakdown voltages (coax. cylinders, without additional effects)

400 kV rated





Thank you for your attention for the GIS Theory Module.