Applications of electrostatics analysis engineering essay



The practical application of electrostatics is represented by such devices as lightning rods and electrostatic precipitators and by such processes as xerography and the painting of automobiles. Scientific devices based on the principles of electrostatics include electrostatic generators, the field-ion microscope, and ion-drive rocket engines. There are many applications of electrostatics:-

- 1). Van de graff generator.
- 2). The electrostatic precipitator.
- 3). Xerography and Laser Printers.
- 4). Electron Gun for 6-18 GHz, 20 W Helix-TWT Amplifier.
- 5). CST particle studio simulation of a Depressed Collector.
- 6). Electrostatic Simulation of a medical X-Ray device.
- 7). Electrostatic Simulation of a High Voltage Bushing.
- 8). MEMS Comb Sensor.
- 9). Consistent charged Particle Simulation of a Pierce Gun.

The brief explanation of above applications is given below:-

The Van de Graaff Generator

Experimental results show that when a charged conductor is placed in

contact with the inside of a hollow conductor, all of the charge on the

charged conductor is transferred to the hollow conductor. In principle, the

charge on the hollow conductor and its electric potential can be increased without limit by repetition of the process.

In 1929 Robert J. Van de Graaff (1901-1967) used this principle to design and build an electrostatic generator. This type of generator is used extensively in nuclear physics research.

A schematic representation of the generator. Charge is delivered continuously to a high-potential electrode by means of a moving belt of insulating material. The high-voltage electrode is a hollow metal dome mounted on an insulating column. The belt is charged at point A by means of a corona discharge between comb-like metallic needles and a grounded grid. The needles are maintained at a positive electric potential of typically 104 V. The positive charge on the moving belt is transferred to the dome by a second comb of needles at point B. Because the electric field inside the dome is negligible, the positive charge on the belt is easily transferred to the conductor regardless of its potential. In practice, it is possible to increase the electric potential of the dome until electrical discharge occurs through th Because the "breakdown" electric field in air is about 3000000 V/m, a negatively charged oil droplet in sphere 1 m in radius can be raised to a maximum potential of 3 % 106 V. The potential can be increased further by increasing the radius of the dome and by placing the entire system in a container filled with high-pressure gas.

Van de Graaff generators can produce potential differences as large as 20 million volts. Protons accelerated through such large potential differences receive enough energy to initiate nuclear reactions between themselves and various target nuclei. Smaller generators are often seen in science classrooms and museums. If a person insulated from the ground touches the sphere of a Van de Graaff generator, his or her

body can be brought to a high electric potential. The person hair acquires a net positive charge, and each strand is repelled by all the others.

Van De Graaff Generator

The Electrostatic Precipitator

One important application of electrical discharge in gases is the electrostatic precipitator. This device removes particulate matter from combustion gases, thereby reducing air pollution. Precipitators are especially useful in coalburning power plants and in industrial operations that generate large quantities of smoke. Current systems are able to eliminate more than 99% of the ash from smoke.

A high potential difference (typically 40 to 100 kV) is maintained between a wire running down the center of a duct and the walls of the duct, which are grounded. The wire is maintained at a negative electric potential with respect to the walls, so the electric field is directed toward the wire. The values of the field near the wire become high enough to cause a corona discharge around the wire; the air near the wire contains

positive ions, electrons, and such negative ions as oxide ions.

The air to be cleaned enters the duct and moves near the wire. As the electrons and negative ions created by the discharge are accelerated toward

the outer wall by the electric field, the dirt particles in the air become charged by collisions and ion capture. Because most of the charged dirt particles are negative, they too are drawn to the duct walls by the electric field. When the duct is periodically shaken, the particles break loose and are collected at the bottom. In addition to reducing the level of particulate matter in the atmosphere the electrostatic precipitator recovers valuable materials in the form of metal oxides.

Electrostatic Precipitator

Xerography and Laser Printers

The basic idea of xerography5 was developed by Chester Carlson, who was granted a patent for the xerographic process in 1940. The unique feature of this process is the use of a photoconductive material to form an image. (A photoconductor is a material that is a poor electrical conductor in the dark but becomes a good electrical conductor when exposed to light.)

The xerographic process is illustrated in Figure 25. 31a to d. First, the surface of a plate or drum that has been coated with a thin film of photoconductive material (usually selenium or some compound of selenium) is given a positive electrostatic charge in the dark. An image of the page to be copied is then focused by a lens onto the charged surface. The photoconducting surface becomes conducting only in areas

where light strikes it. In these areas, the light produces charge carriers in the photoconductor that move the positive charge off the drum. However, positive charges remain on those areas of the photoconductor not exposed

to light, leaving a latent image of the object in the form of a positive surface https://assignbuster.com/applications-of-electrostatics-analysis-engineeringessay/ charge distribution. Next, a negatively charged powder called a toner is dusted onto the photoconducting surface. The charged powder adheres only to those areas of the surface that contain the

positively charged image. At this point, the image becomes visible. The toner (and hence the image) is then transferred to the surface of a sheet of positively charged paper. Finally, the toner is "fixed" to the surface of the paper as the toner melts while passing through high-temperature rollers. This results in a permanent copy of the original. A laser printer operates by the same principle, with the exception that a computer-directed laser beam is used to illuminate the photoconductor instead of a lens.

Xerography

Laser Printer

ELECTRON GUN FOR 6-18GHz, 20 W Helix-TWT Amplifier

Electron guns are the starting point of every charged particle application. There the DC energy is translated into an extracted beam which later on interacts with all kinds of RF structures. The design and analysis of an electron gun can be performed with the tracking code of CST PARTICLE STUDIO.

Schematic of an electron tube

The electron gun has to provide the slow wave structure with a beam, which then interacts with the electromagnetic wave existing in the structure and finally is collected in the collector. In order to enable the interaction, the particles' velocity has to match the EM-wave's velocity on the circuit. The necessary velocity determines the voltage to be applied. The electron gun then has to be designed in a way, that the emitted current is maximized. The relevant parts for the Electrostatic (Es) simulation are the cathode, focussing electrode and anode (left). Important for the Magnetostatic (Ms) simulation are the iron yoke and permanent magnets. The potentials and permanent magnets serve as sources for the Es and Ms solver of CST EMS (here run from CST PS) respectively. The iron yoke is considered as non linear material, where the working point is obtained by a non linear iteration scheme in the Ms solver.

CST PARTICLE STUDIOHYPERLINK "http://www.cst. com/Content/Applications/Article/CST+PARTICLE+STUDI OTM+Simulation+of+a+Depressed+Collector" Simulation of a Depressed Collector

CST PS simulation of a depressed collector.

A multi-stage depressed collector for the "Rijnhuizen" Fusion Free-Electron Maser (FEM) is simulated with CST RTICLE STUDIO. The results are reproduced with permission of Pulsar Physics. See also M. J. de Loos, S. B. van der Geer, Pulsar Physics, Nucl. Instr. and Meth. in Phys. Res. B, Vol 139, 1997. CST PARTICLE STUDIO(CST PS) is dedicated to simulating charged particles travelling through electromagnetic fields. To accomplish this task, CST PS requires fields from other CST STUDIO SUITE 3D EM solvers, particularly CST EM STUDIO and CST MICROWAVE STUDIO, as input. CST PS tracks charged particles through this fields, considering relativistic effect, space charge and secondary emission, delivering particle trajectories, phase space distribution, remitances. Electrostatic Simulation of a medical X-Ray device

Electric Field Distribution in the X-Ray Device

CST EM STUDIOs Electrostatic Solver can be used to establish electric breakdown fields in X-Ray devices. A STEP model of the device was imported via CST EMS's comprehensive CAD Interface. The main goal of the simulation is to determine the maximum field strength in the model. The design of the housing for the X-Ray tube can then be optimised to reduce the potential of arcing. Results may be post-processed in terms of field values at specific points, along curves or on material surfaces. The field was plotted on a central cut-plane using a logarithmic scaling to aid visualisation. Maximum field values in the model may be extracted automatically in the postprocessor.

Electrostatic Simulation of a High Voltage Bushing

Cross-sectional View of the Transformer Bushing

The above figure shows the construction of the bushing comprising a central conductor, a ceramic insulator, and a housing containing the transformer oil.

The structure was created using the powerful modeling tools in CST EM STUDIO . The bushing was created by sweeping over 360 degrees a curved profile. To complete the bushing geometry, the blend tool can be applied to round off the bushing edges. The permittivity of the ceramic has been set to 1000 with an epsilon of 2. 9 for the oil. The housing and the central conductor were both defined as perfect electric conductors (PEC).

Symmetry is exploited via the use of tangential symmetry conditions and an open boundary has been applied to reduce the simulation domain

MEMS Comb Sensor

Potential and electric field for the rectangular and triangular comb tip

The design process of the comb sensor starts with a shape optimization in CST EMS. Here two different shapes are modeled and compared.

Therefore, by using parameters a true shape optimisation of the force can be performed. After the calculation of fields the forces can be determined as a post processing step. Using appropriate boundary conditions, the single combs are assumed to be part of an infinite array. Due to its special shape the triangular comb tip has a 14% higher attracting force.

Consistent Charged Particle Simulation of a Pierce Gun

The pierce type gun example demonstrates the analysis of an electrically large gun configuration. The acceleration of the electrons takes place in only a small part of the computational domain, nearly 90% of the gun consists of a drift-tube.

The electric field is established by the cathode, which acts at the same time as particle source, a guiding electrode and the anode, which incorporates the drift-tube. The magnetic field is produced by a large current-driven coil and guided by a highly permeable cylinder which encloses the whole configuration.

The above figure shows the geometry of the gun which consists of hollow cylinders forming the guide for the magnetic field, the drift tube, the emitting cathode and the focussing cathode. typical construction features used to create the model include lofting, chamfering and blending operations. The geometric properties of the coils were created with the aid of two curves, one for the coil cross-section, the other for the coil sweep path.