Chapter 16 Static Electricity

(a) state that there are positive and negative charges and that charge is measured in coulombs

(b) state that unlike charges attract and like charges repel

(c) describe an electric field as a region in which an electric charge experiences a force

(d) draw the electric field of an isolated point charge and recall that the direction of the field lines gives the direction of the force acting on a positive test charge

(e) draw the electric field pattern between two isolated point charges

(f) show understanding that electrostatic charging by rubbing involves a transfer of electrons

(g) describe experiments to show electrostatic charging by induction

(h) describe examples where electrostatic charging may be a potential hazard

(i) describe the use of electrostatic charging in a photocopier, and apply the use of electrostatic charging to new situations

Types of charges

- A **negative charge** refers to an electron
- A **positive charge** refers to a proton or an atom which has lost electrons (ion)

Unit of charge

- 1 electron has a charge of 1.6×10^{-19} C
- 1 Coulomb of electric charge is made up of 6.25×10^{-18} electrons

Law of electrostatics

- Like charges repel and unlike charges attract

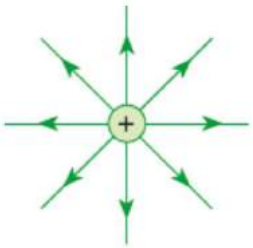
Testing the charge on an object

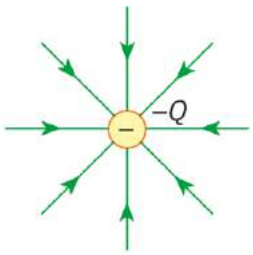
- Charged object attracts **uncharged** object
- Charged object also attracts object with the **opposite charge**
- Therefore, the only test for a charged object is repulsion

Electric field

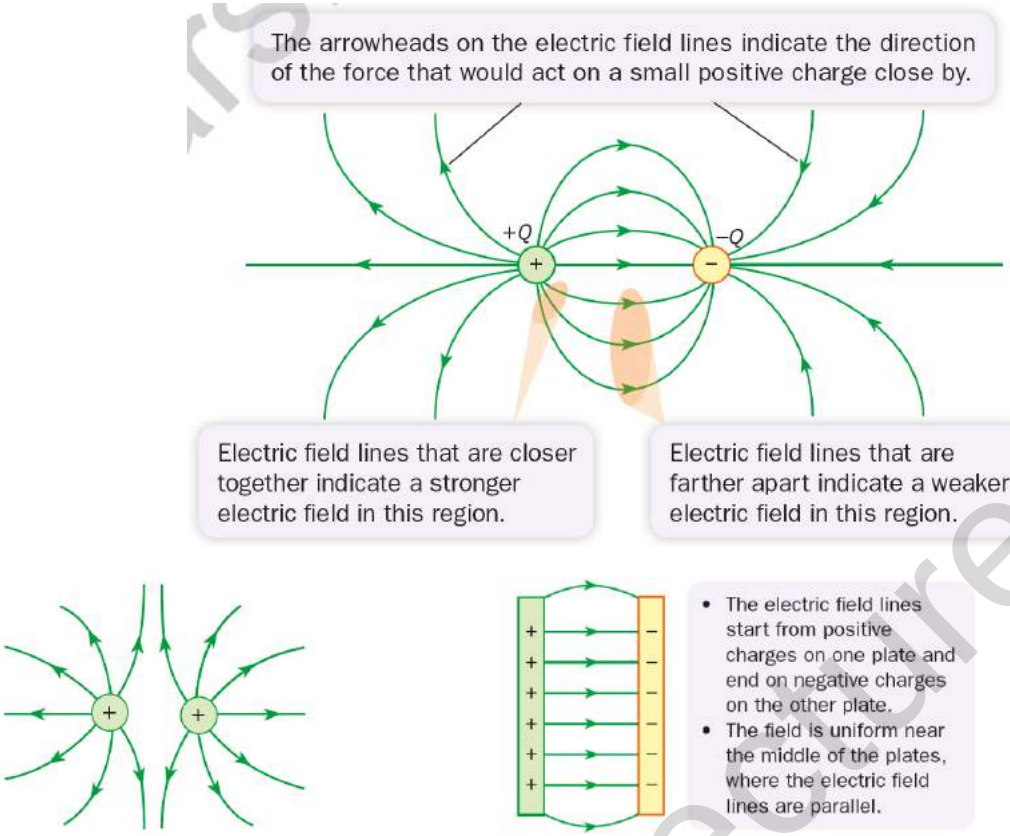
- An electric field is a region in which an **electric charge experiences a force**
- **(By convention) Direction** of an electric field line is the direction of the force exerted on a small **positive test charge** placed in the field
- Field line is **perpendicular to the surface** of the charged object
- Field lines always point away from a positive charge and towards a negative charge

Electric field of an isolated point charge

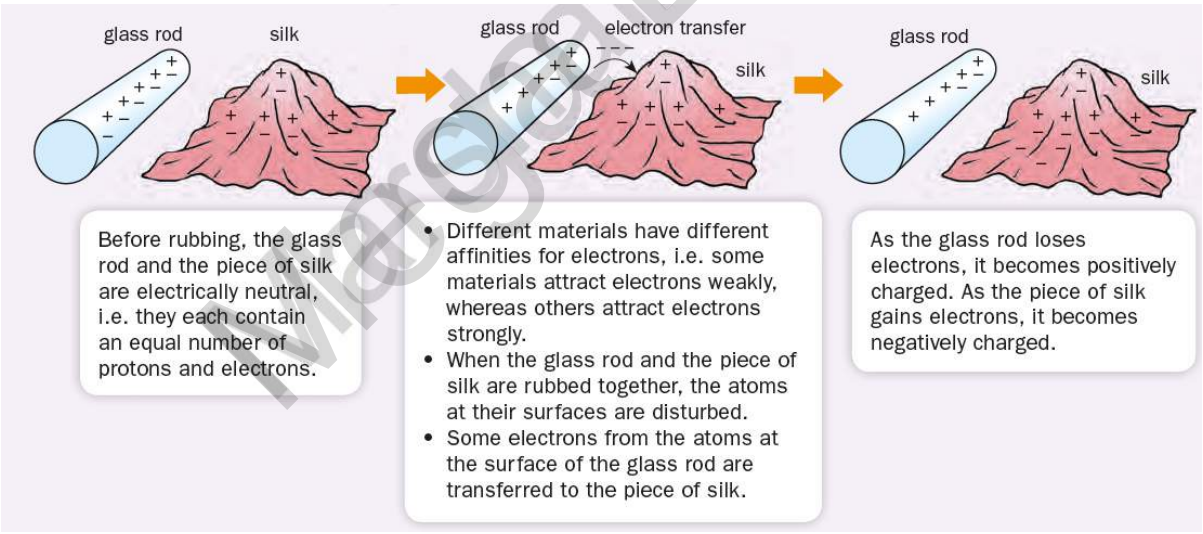




Electric field between two isolated point charges



Electrostatic charging by friction (rubbing)



Explanation:

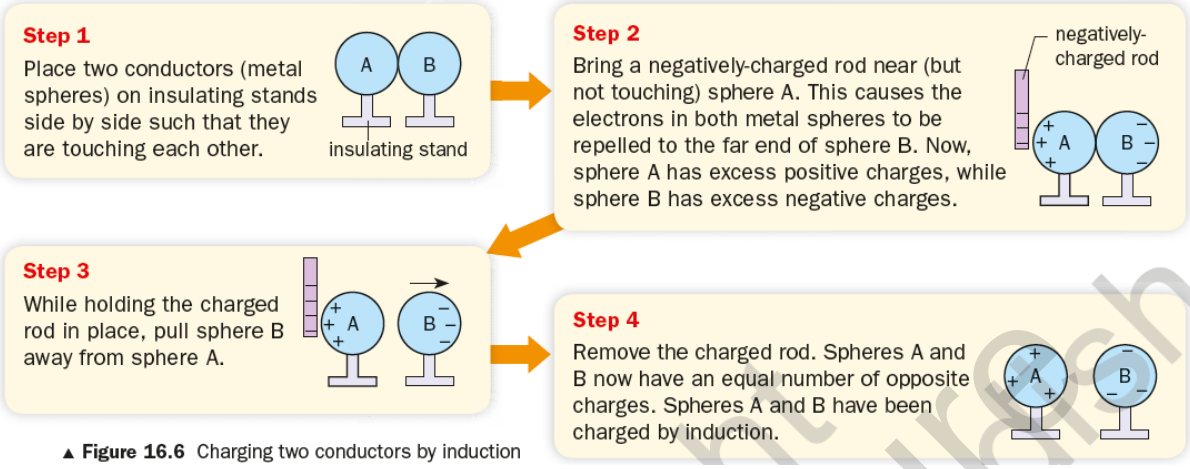
- Electrons which are loosely attached (attracted) to the atoms at the surface of the material are removed due to **friction** and deposited on the surface of the other material.
- Rubbing transfers electrons, which are negatively charged, from the surface of one material to the other.
- The triboelectric series categorises materials based on their tendency to become positively or negatively charged

Positive	Negative
Air, human body, glass, nylon, wool	Teflon, silicon, vinyl, polyethylene, rubber

*Take note: the charge on an object refers to **excess charge**

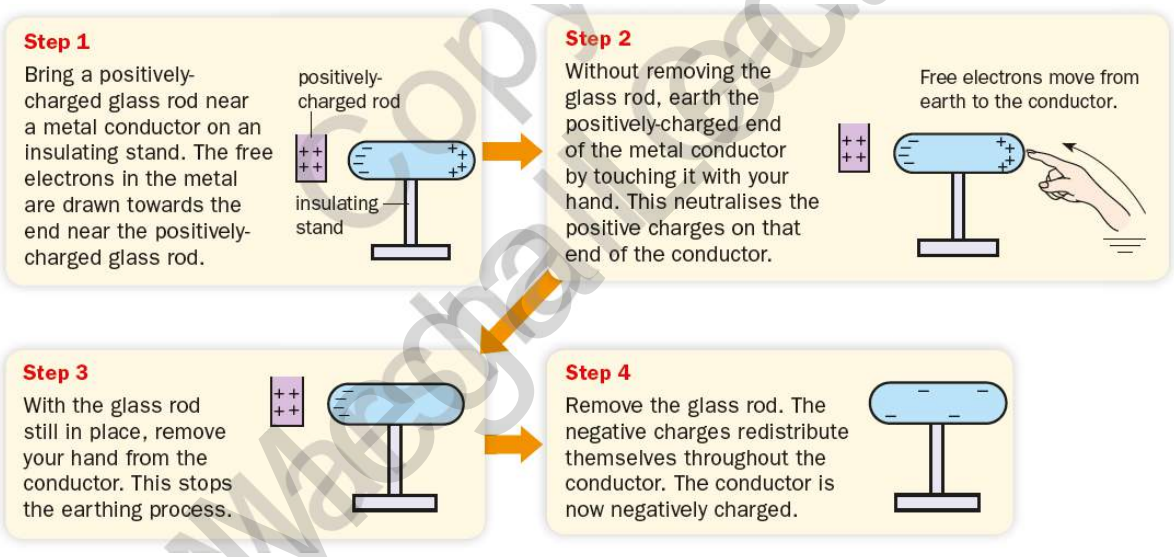
Electrostatic charging by induction

(1) Charging 2 conductors



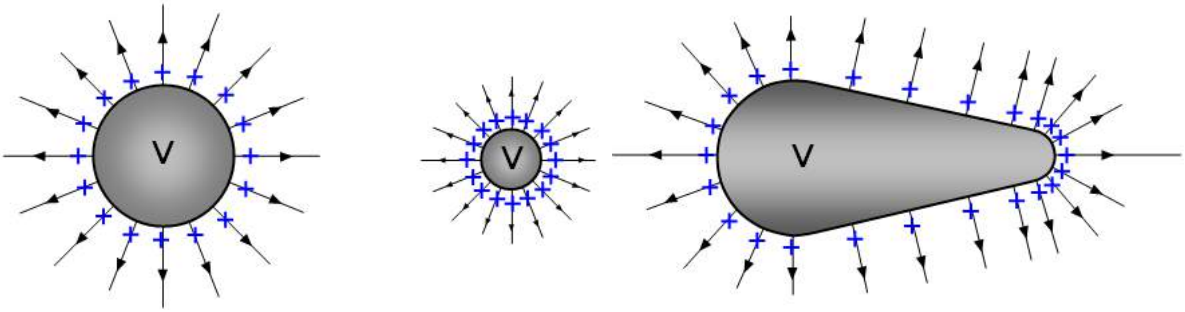
▲ **Figure 16.6** Charging two conductors by induction

(2) Charging one conductor

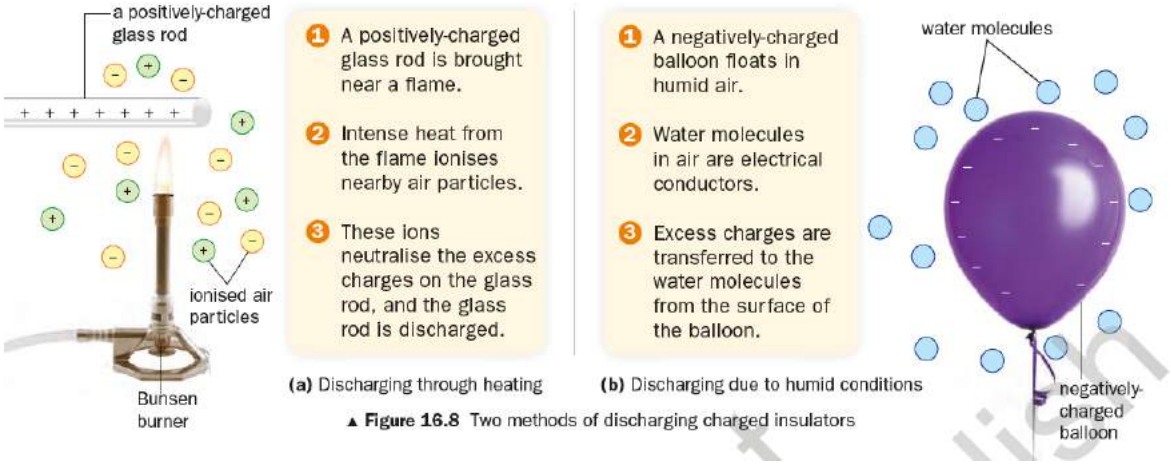


How is charge distributed on the surface of a conductor?

Charge density is highest where a surface is most sharply curved. Flat surfaces have a low charge density compared with curved surfaces and charge density is highest at corners, edges and points on conductors. (This does not apply to insulators because charge cannot flow to establish any particular distribution)



Discharging



(a) Discharging through heating (b) Discharging due to humid conditions

▲ **Figure 16.8** Two methods of discharging charged insulators

Hazards of electrostatic charging

(1) Electrostatic discharge

Electric charges can accumulate on trucks due to friction between the road and the rotating tyres of the trucks. When a sudden discharge occurs, it may cause sparks, and ignite flammable items that the trucks may be carrying. To prevent this, some older petrol tankers have metal chain at the rear of the vehicle. This chain hangs close to the ground, and provides an earthing path for excess charges.

(2) Anti-static bags

Electrostatic discharge can also damage electronic equipment, such a circuit boards and hard drives. To protect these equipment, they are usually packed in antistatic packaging. Antistatic materials have a thin layer of metallised film, which acts an an electrostatic shield for the equipment placed inside. (like a Faraday cage)

(3) Lightning

- A thundercloud is electrically charged due to the turbulent winds and moving particles of ice and water within the cloud
- Negatively charged base of cloud induces positive charge on the ground and the buildings below.
- Positive charge builds up at the points of the lightning conductor causing surrounding air particles to be ionised. The ionised air particles then stream towards the cloud.
- The steady leakage of positive charge towards the clouds from the points and the flow of electrons (from air) down the lightning conductor to earth helps to prevent a large build-up of charge on the highest point of the building.

O Level 2015

7 Fig. 7.1 shows a worker refuelling an aircraft.

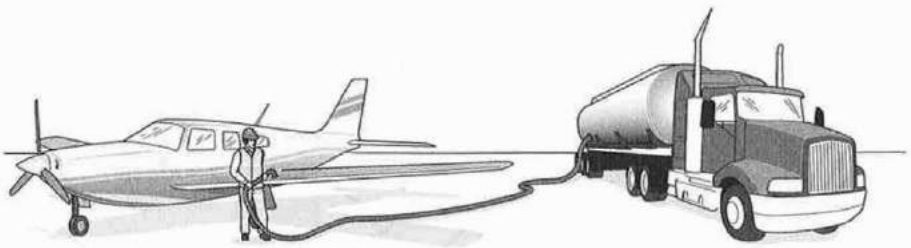


Fig. 7.1

Both the fuel and the hose through which it passes are insulators. The fuel passing into the aircraft becomes positively charged and this causes the aircraft to be positively charged.
There is then a danger that the fuel may ignite.

(a) Explain how the fuel becomes charged.

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..... [1]

(b) Suggest how the charge may cause the fuel to ignite.

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..... [1]

(c) The danger is reduced by connecting a wire from the aircraft to the ground.
Explain how this prevents the build-up of positive charge on the aircraft.

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..... [1]

(d) Apart from refuelling, state one other example where electrostatic charging is a nuisance or a potential hazard.

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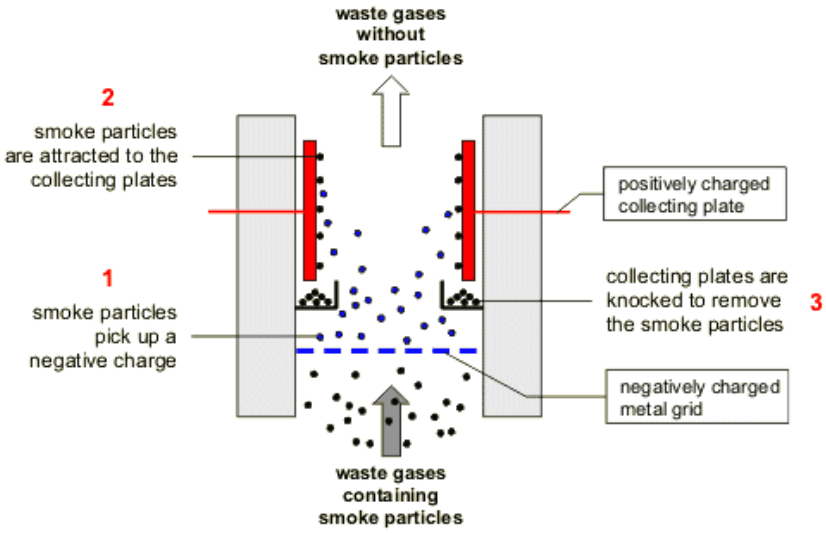
..... [1]

Applications of electrostatic charging

(1) Electrostatic precipitator

- Used to remove smoke and dust from the waste gases going up the chimneys of factories and power stations.
- The wire grid is kept highly charged so that dust particles in the gas going up the chimney are given the same charge.
- The charged particles are repelled from the wire grid and attracted to the earthed plates where they become deposited.
- These plates are tapped from time to time so that the dust particles fall down the chimney and are removed at the bottom.



(2) Fingerprinting

- Metal plate with a coating of fine powder is given a large electrical charge. The specimen is given the opposite charge.
- The powder is repelled from the metal towards the specimen.
- When the powder hits the specimen, it is stuck to the ridges of the fingerprint
- Elsewhere, the powder is repelled and falls back on to the metal plate.

(3) Photocopier

- Surface of drum is covered with selenium, which becomes conducting when exposed to light.
- Toner is sprayed on drum and sticks to part of the drum
- Paper is passed over the drum and the toner powder sticks to the paper
- The powder on the paper is melted and forms a permanent image on the paper

Method 1 (O level 2012)

(b) The working parts of one type of laser printer are shown in Fig. 11.3.

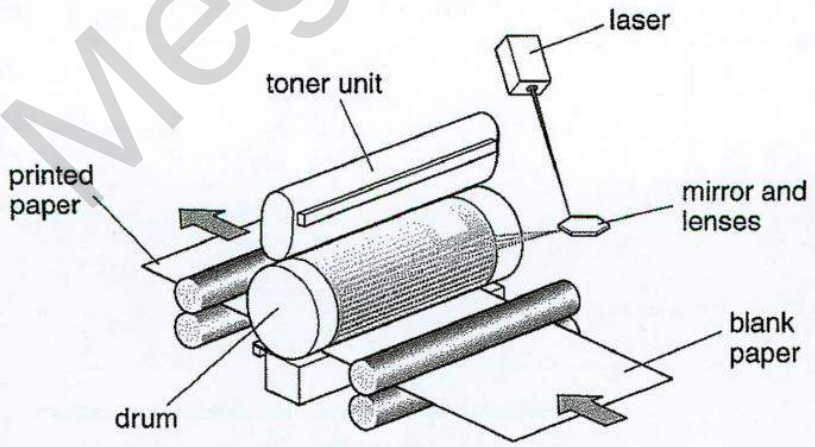


Fig. 11.3

Initially, the surface of the drum is insulating and is positively charged. It is in the dark. The inside of the drum is made of metal and is connected to earth.

The regions where light strikes the drum become conducting.

(i) Explain what happens to the charge on the drum in the regions that the light strikes.

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..... [1]

(ii) The toner, a fine black powder. is charged and sprayed on to the drum. The toner does not stick where the drum is positively charged. In such places the final print appears white. Where light strikes the drum, the final print is black.

1. Suggest why the toner does not stick to the positively charged regions of the drum.

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..... [1]

2. Suggest why the toner does stick to the conducting regions of the drum.

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..... [1]

Method 2 (O level 2007)

(b) Two stages in the production of a photocopy are shown in Fig. 8.1.

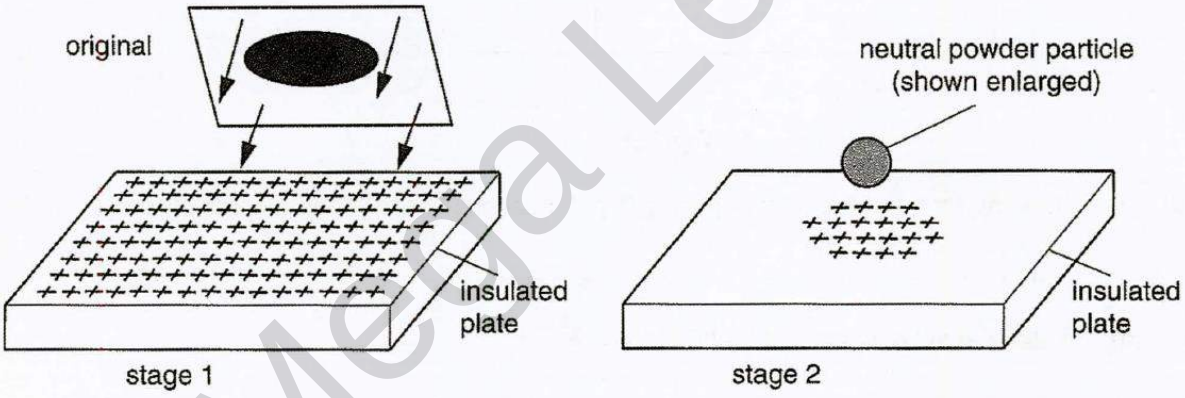

Fig. 8.1

In stage 1, reflected light from the white parts of the original hits the positively charged plate, leaving it as shown in stage 2. Black powder (toner) is then sprayed onto the plate. One neutral powder particle is shown enlarged in stage 2.

(i) Based on the information provided, state the effect of light on the charged plate.

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..... [1]

(ii) On Fig. 8.1 stage 2, draw the charge distribution on the neutral powder particle. [1]

(iii) Explain why the particle of powder is attracted to and sticks to the charged plate.

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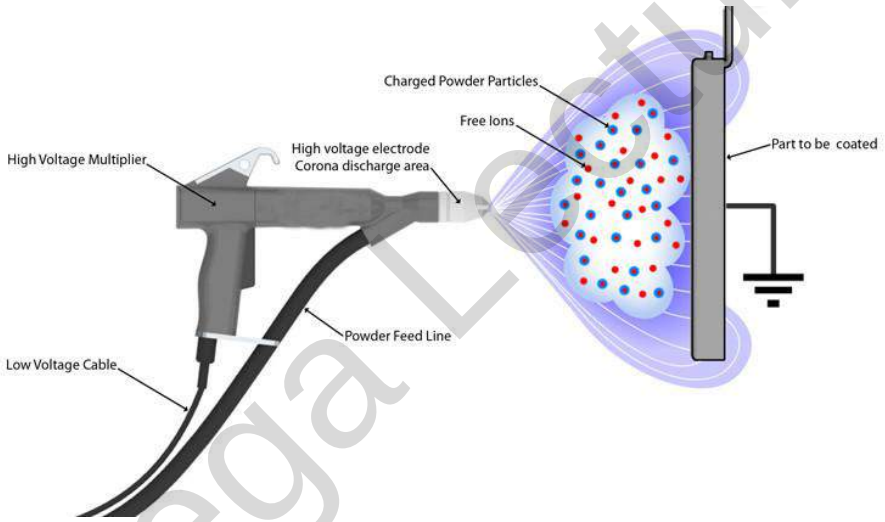
..... [2]

(4) Spray painting

A fine needle at the tip of the spray paint gun is charged negatively. This gives all the paint droplets exiting the spray gun a negative charge. If the object to be spray-painted is given a positive charge, then the paint is attracted to it covering the object evenly on all sides.



Additional information

If a negatively charged rod is brought close to a small piece of paper (which is an insulator). The excess electrons on the rod repel the electrons in the atoms which make up the paper, but attract the positively charged nuclei. Since paper is an insulator, the repelled electrons are not free to move through the paper. Instead, the atoms in the paper *polarize*: *i.e.*, their nuclei move slightly towards, and their electrons slightly away from, the rod. The **attractive force** between the excess **electrons** in the **rod** and the **atomic nuclei** in the **paper** is slightly greater than the **repulsion** between the **electrons** in the **rod** and those in the **paper**, since the electrons in the paper are, on average, **slightly further away** from the rod than the nuclei. Thus, there is a **net *attractive* force** between the rod and the paper. In fact, if the piece of paper is sufficiently light then it can actually be picked up using the rod. In summary, whenever a charged object is brought close to an insulator, the atoms in the insulator **polarize**, resulting in a net attractive force between the object and the insulator.