

# Physics

## JZL1001913C

### summer semester 2020/2021

**Wednesday, 18:20 - 19:50**

**Friday, 18:20 - 19:50**

**virtual room (ZOOM)**

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# Electrostatics

Some of the most basic characteristics of static electricity include:

- The effects of static electricity are explained by a physical quantity not previously introduced, called electric charge.
- There are only two types of charge, one called positive and the other called negative.
- Like charges repel, whereas unlike charges attract.
- The force between charges decreases with distance.

What makes plastic wrap cling? Static electricity. Not only are applications of static electricity common these days, its existence has been known since ancient times. The first record of its effects dates to ancient Greeks who noted more than 500 years B.C. that polishing amber temporarily enabled it to attract bits of straw. The very word *electric* derives from the Greek word for amber (*electron*).

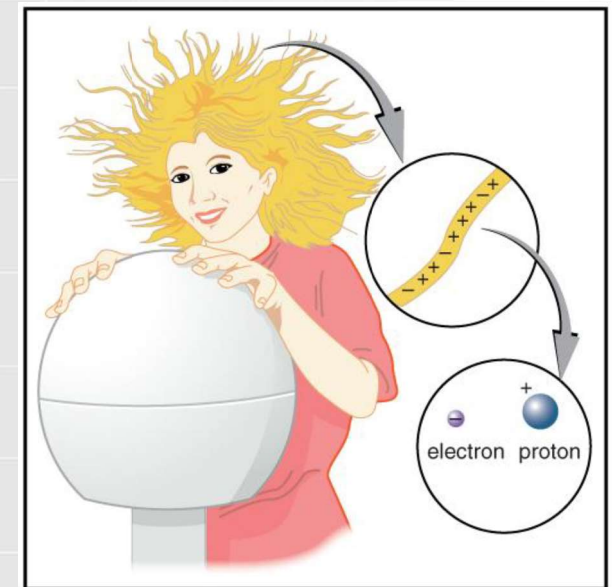




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# Electric charge

When various materials are rubbed together in controlled ways, certain combinations of materials always produce one type of charge on one material and the opposite type on the other. By convention, we call one type of charge “positive”, and the other type “negative.” For example, when glass is rubbed with silk, the glass becomes positively charged and the silk negatively charged. Since the glass and silk have opposite charges, they attract one another like clothes that have rubbed together in a dryer. Two glass rods rubbed with silk in this manner will repel one another, since each rod has positive charge on it. Similarly, two silk cloths so rubbed will repel, since both cloths have negative charge.



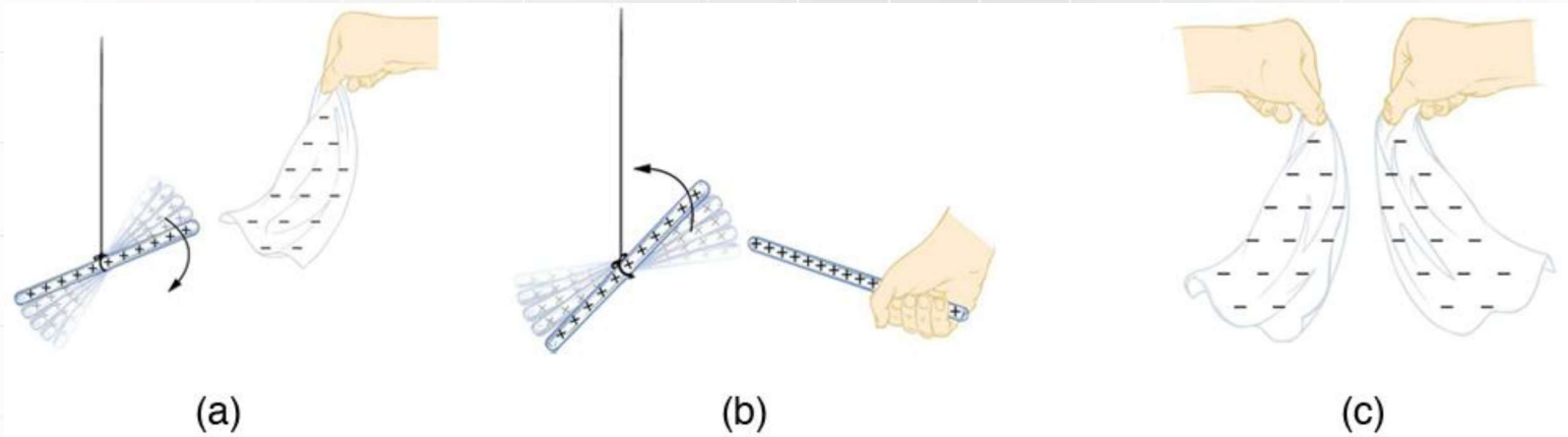


# Electrons and Protons

## - negative and positive charge

The charges of electrons and protons are identical in magnitude but opposite in sign. Furthermore, all charged objects in nature are integral multiples of this basic quantity of charge, meaning that all charges are made of combinations of a basic unit of charge. Usually, charges are formed by combinations of electrons and protons. The magnitude of this basic charge is

$$|q_e| = 1.60 \times 10^{-19} \text{ C}$$



A glass rod becomes positively charged when rubbed with silk, while the silk becomes negatively charged. (a) The glass rod is attracted to the silk because their charges are opposite. (b) Two similarly charged glass rods repel. (c) Two similarly charged silk cloths repel.

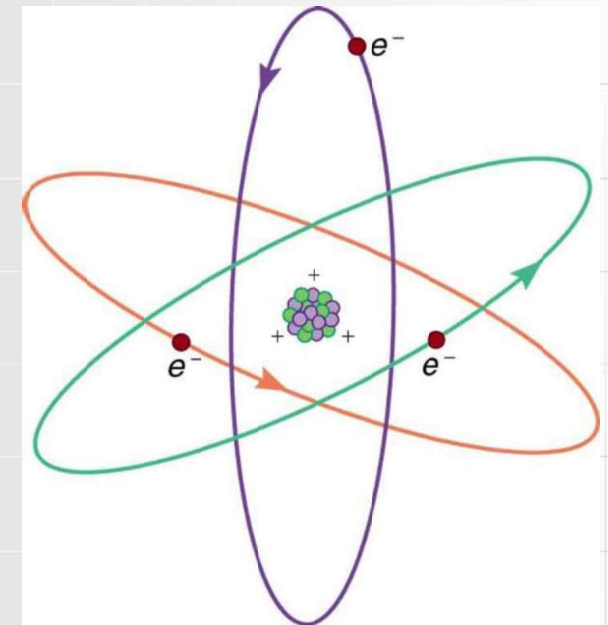


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# Model of atom

Image shows a simple model of an atom with negative electrons orbiting its positive nucleus. The nucleus is positive due to the presence of positively charged protons. Nearly all charge in nature is due to electrons and protons, which are two of the three building blocks of most matter. (The third is the neutron, which is neutral, carrying no charge.) Other charge-carrying particles are observed in cosmic rays and nuclear decay, and are created in particle accelerators. All but the electron and proton survive only a short time and are quite rare by comparison.

This simplified (and not to scale) view of an atom is called the planetary model of the atom. Negative electrons orbit a much heavier positive nucleus, as the planets orbit the much heavier sun. There the similarity ends, because forces in the atom are electromagnetic, whereas those in the planetary system are gravitational.

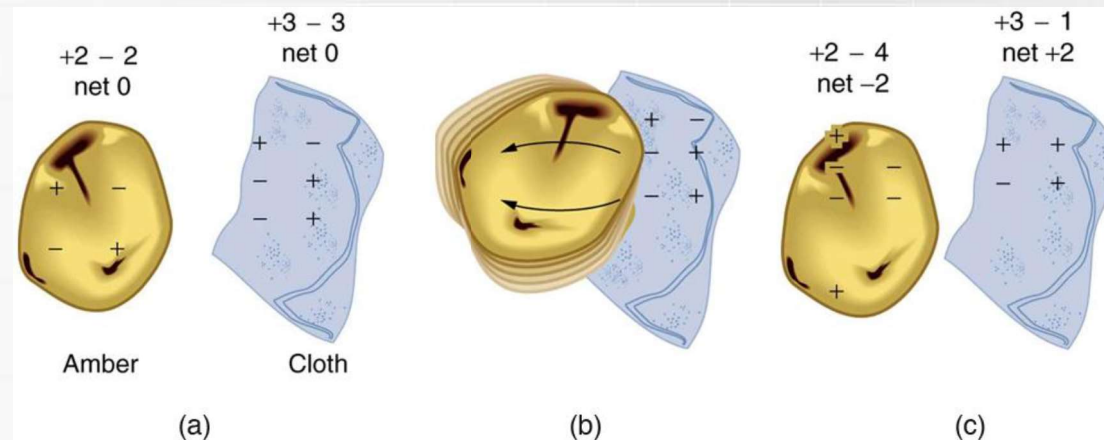






# Separation of Charge in Atoms

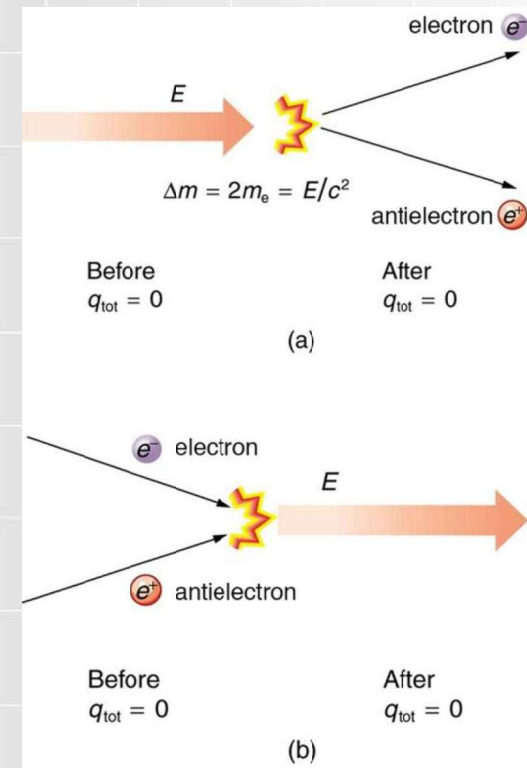
Charges in atoms and molecules can be separated—for example, by rubbing materials together. Some atoms and molecules have a greater affinity for electrons than others and will become negatively charged by close contact in rubbing, leaving the other material positively charged. Positive charge can similarly be induced by rubbing. Methods other than rubbing can also separate charges. Batteries, for example, use combinations of substances that interact in such a way as to separate charges. Chemical interactions may transfer negative charge from one substance to the other, making one battery terminal negative and leaving the first one positive.



# Law of conservation of charge

No charge is actually created or destroyed when charges are separated as we have been discussing. Rather, existing charges are moved about. In fact, in all situations the total amount of charge is always constant. This universally obeyed law of nature is called the **law of conservation of charge**.

- (a) When enough energy is present, it can be converted into matter. Here the matter created is an electron–antielectron pair.  $m_e$  is the electron's mass. The total charge before and after this event is zero.
- (b) When matter and antimatter collide, they annihilate each other; the total charge is conserved at zero before and after the annihilation.





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# Experiment: balloons and static electricity

Why does a balloon stick to your sweater? Rub a balloon on a sweater, then let go of the balloon and it flies over and sticks to the sweater. View the charges in the sweater, balloons, and the wall.





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# Conductors

Some substances, such as metals and salty water, allow charges to move through them with relative ease. Some of the electrons in metals and similar conductors are not bound to individual atoms or sites in the material. These **free electrons** can move through the material much as air moves through loose sand. Any substance that has free electrons and allows charge to move relatively freely through it is called a **conductor**. The moving electrons may collide with fixed atoms and molecules, losing some energy, but they can move in a conductor.

This power adapter uses metal wires and connectors to conduct electricity from the wall socket to a laptop computer. The conducting wires allow electrons to move freely through the cables, which are shielded by rubber and plastic. These materials act as insulators that don't allow electric charge to escape outward.





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# Insulators

Other substances, such as glass, do not allow charges to move through them. These are called insulators. Electrons and ions in insulators are bound in the structure and cannot move easily - as much as  $10^{23}$  times more slowly than in conductors. Pure water and dry table salt are insulators, for example, whereas molten salt and salty water are conductors.

Ceramic insulator used on electrified railways.

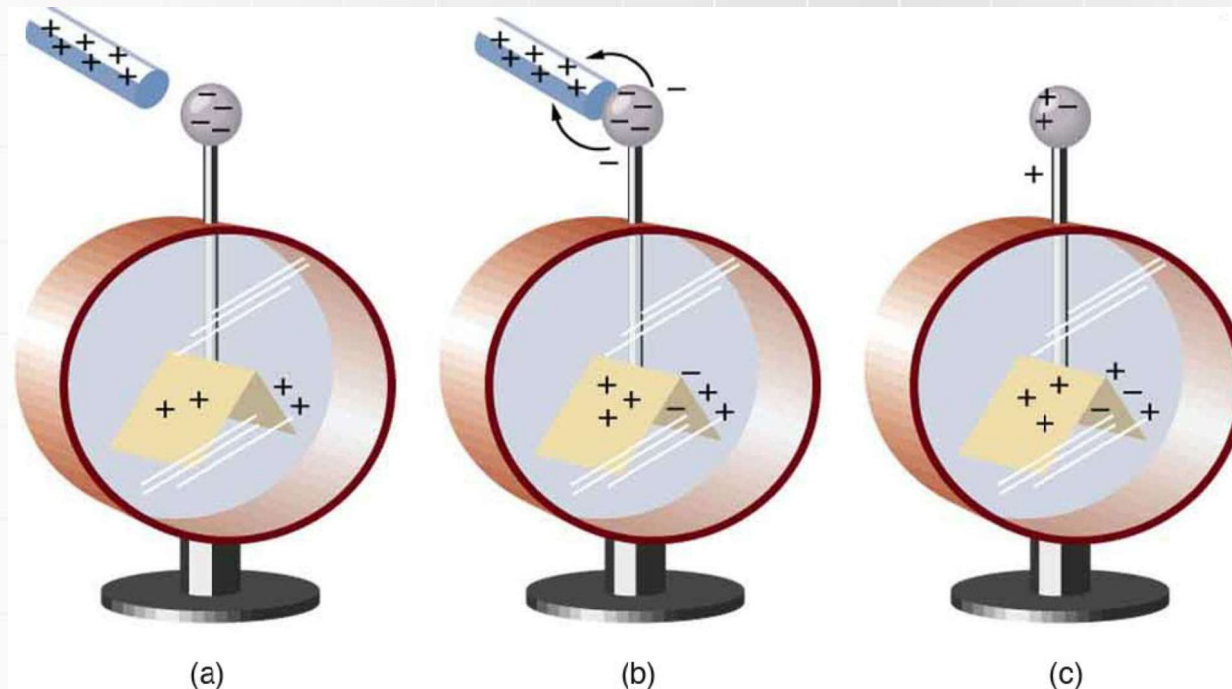




# Charging by Contact

Picture shows an electroscope being charged by touching it with a positively charged glass rod. Because the glass rod is an insulator, it must actually touch the electroscope to transfer charge to or from it. Since only electrons move in metals, we see that they are attracted to the top of the electroscope. There, some are transferred to the positive rod by touch, leaving the electroscope with a net positive charge.

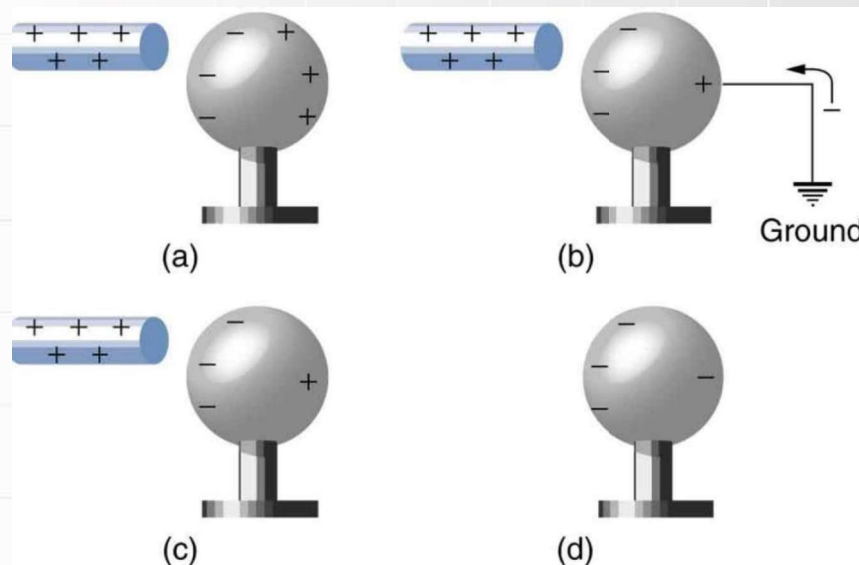
Electrostatic repulsion in the leaves of the charged electroscope separates them. The electrostatic force has a horizontal component that results in the leaves moving apart as well as a vertical component that is balanced by the gravitational force. Similarly, the electroscope can be negatively charged by contact with a negatively charged object.



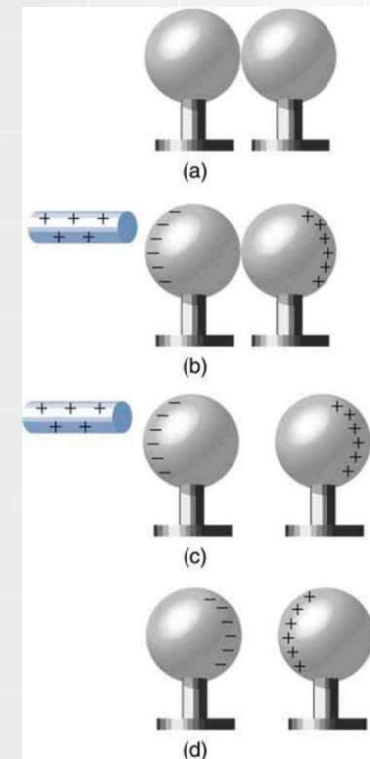


# Charging by Induction

It is not necessary to transfer excess charge directly to an object in order to charge it. Figure on right side shows a method of induction wherein a charge is created in a nearby object, without direct contact. Here we see two neutral metal spheres in contact with one another but insulated from the rest of the world. A positively charged rod is brought near one of them, attracting negative charge to that side, leaving the other sphere positively charged.



The neutral metal sphere is polarized when a charged rod is brought near it.





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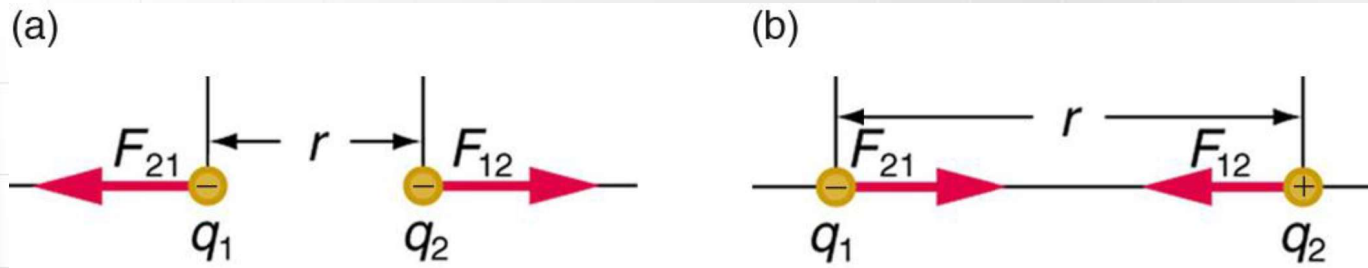
# Experiment: John Travoltage

Make sparks fly with John Travoltage. Wiggle Johnnie's foot and he picks up charges from the carpet. Bring his hand close to the door knob and get rid of the excess charge.





# Coulomb's law



$$F = k \frac{|q_1 q_2|}{r^2}$$

Coulomb's law calculates the magnitude of the force  $F$  between two point charges,  $q_1$  and  $q_2$ , separated by a distance  $r$ . In SI units, the constant  $k$  is equal to

$$k = 8.988 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{C}^2} \approx 8.99 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}$$

The electrostatic force is a vector quantity and is expressed in units of newtons. The force is understood to be along the line joining the two charges.



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# Example 1

Compare the electrostatic force between an electron and proton separated by  $0.530 \times 10^{-10} \text{m}$  with the gravitational force between them. This distance is their average separation in a hydrogen atom.



# Electric Field

To simplify things, we would prefer to have a field that depends only on  $Q$  and not on the test charge  $q$ . The electric field is defined in such a manner that it represents only the charge creating it and is unique at every point in space. Specifically, the electric field  $E$  is defined to be the ratio of the Coulomb force to the test charge:

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

where  $F$  is the electrostatic force (or Coulomb force) exerted on a positive test charge  $q$ .

$$E = \left| \frac{F}{q} \right| = k \left| \frac{qQ}{qr^2} \right| = k \frac{|Q|}{r^2}$$

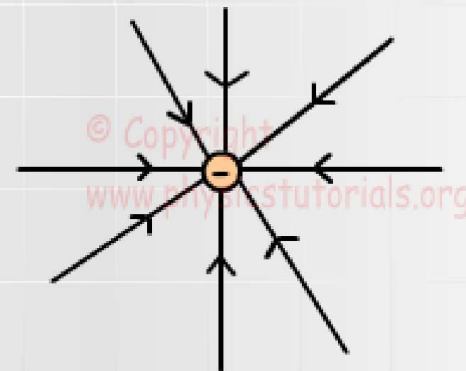
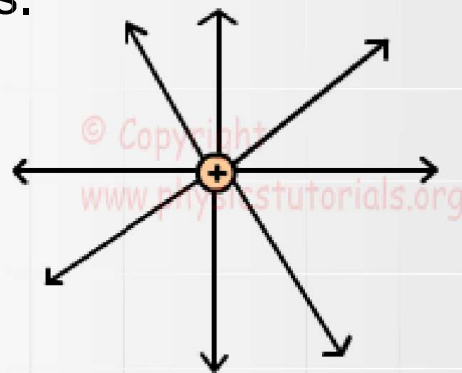


# Electric Field – point source

Electric field is a vector quantity. And it decreases with the increasing distance.

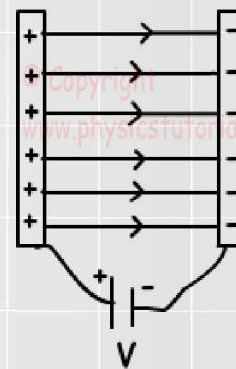
$$k=9 \times 10^9 \text{Nm}^2/\text{C}^2$$

- Electric field cannot be seen, but you can observe the effects of it on charged particles inside electric field.
- To find the electric field vector of a charge at one point, we assume that as if there is a +1 unit of charge there.
- If you want to find the total electric field of the charges more than one, you should find them one by one and add them using vector quantities.



# Electric Field – multiple charges

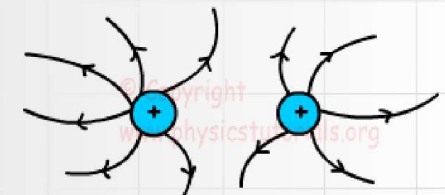
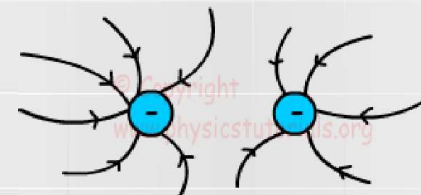
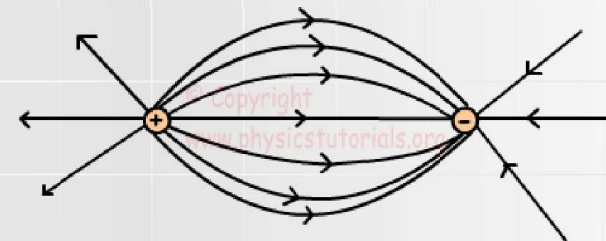
If the electric field lines are parallel to each other, we call this regular electric field and it can be possible between two oppositely charged plates.  $E$  is constant within this plates and zero outside the plates.



$$E \text{ (N/C)} = \frac{V \text{ (volt)}}{d \text{ (m)}}$$

where,  $V$  is the potential difference of power supply,  
 $d$  is the distance between the plates

Pictures given below show the path of lines of two same charges and two opposite charges.







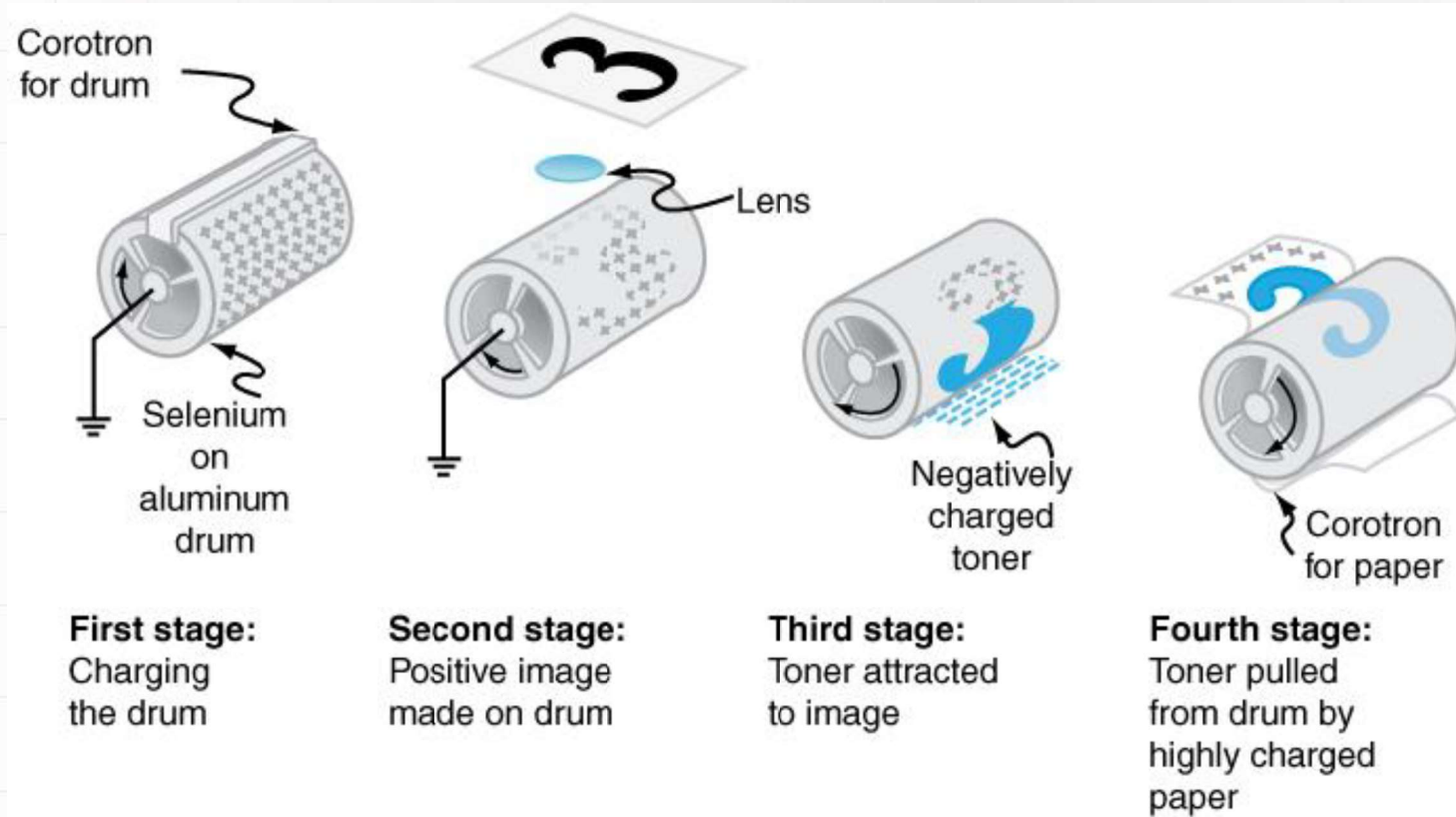
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# Example 2

Calculate the strength and direction of the electric field  $E$  due to a point charge of 2.00 nC (nano-Coulombs) at a distance of 5.00 mm from the charge.



# Xerography

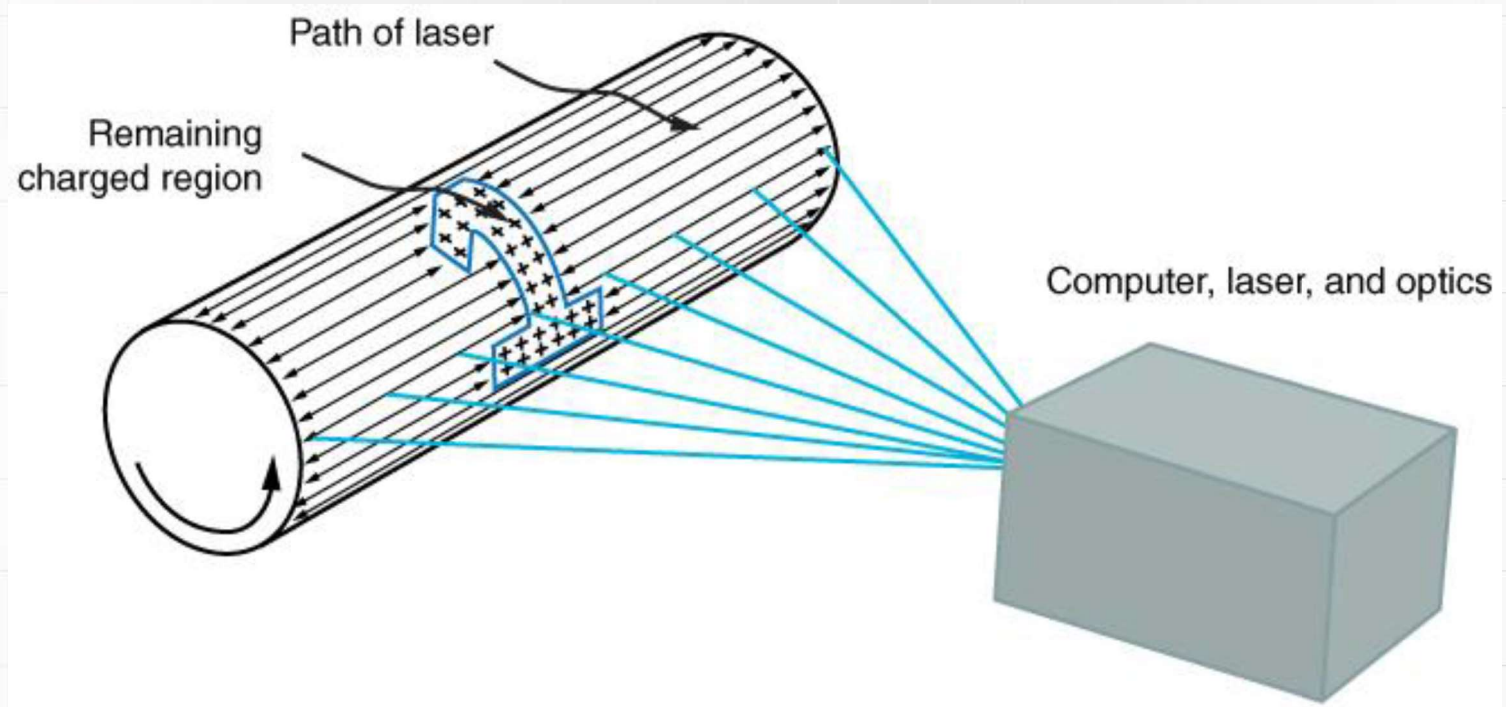


Xerography is a dry copying process based on electrostatics. The major steps in the process are the charging of the photoconducting drum, transfer of an image creating a positive charge duplicate, attraction of toner to the charged parts of the drum, and transfer of toner to the paper. Not shown are heat treatment of the paper and cleansing of the drum for the next copy.



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# Laser Printers



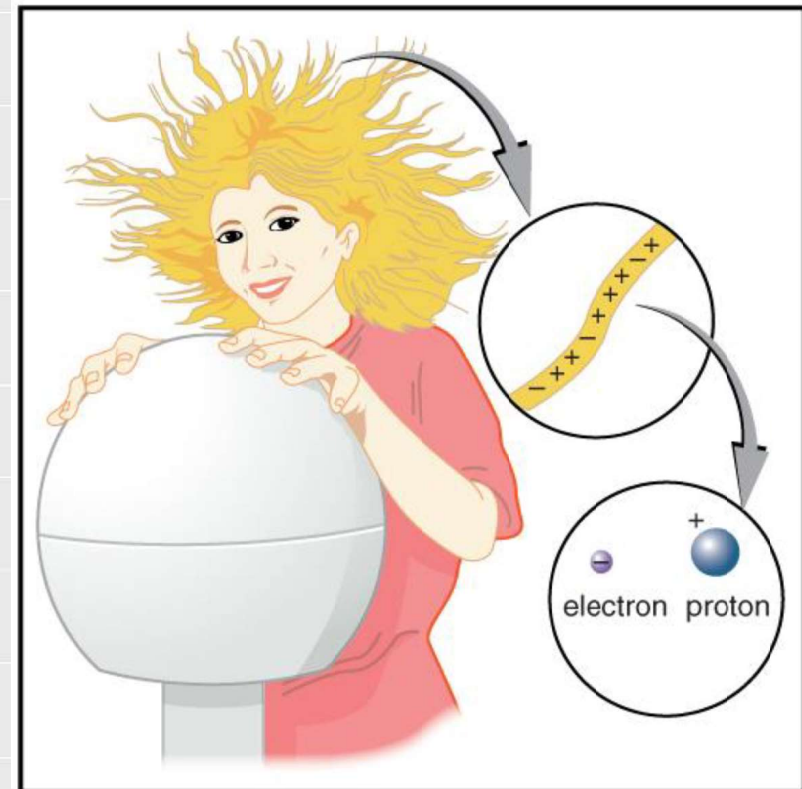
In a laser printer, a laser beam is scanned across a photoconducting drum, leaving a positive charge image. The other steps for charging the drum and transferring the image to paper are the same as in xerography. Laser light can be very precisely controlled, enabling laser printers to produce high-quality images.



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# Electrostatics

All right. So if you go to our website today, you will find I've assigned some problems and you should try to do them. They apply to this chapter.





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# Quizz

Kahoot link:

[https://kahoot.it/challenge/06202797?challenge-id=459c69ba-0699-474d-ae7d-12916780bd23\\_1620163847265](https://kahoot.it/challenge/06202797?challenge-id=459c69ba-0699-474d-ae7d-12916780bd23_1620163847265)

Deadline: 12th May 2021, 18:00