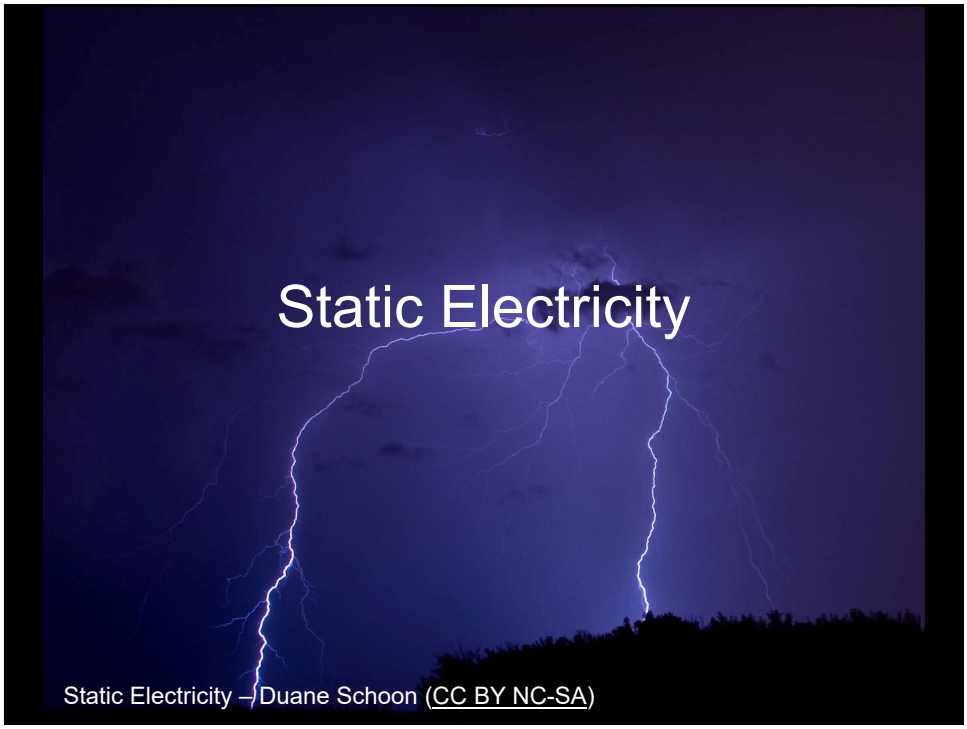
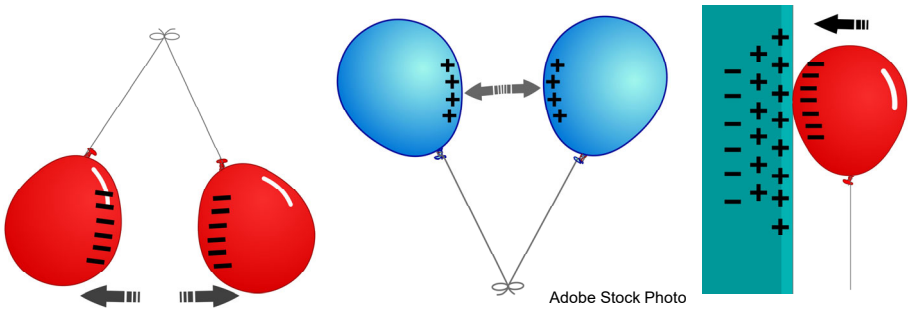


Electric Charge

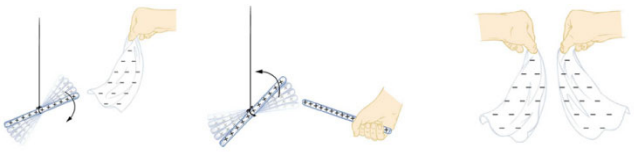
- There are two types of charge
  - Positive and negative
- Like charges repel each other
- Unlike charges attract each other



SICK! science!™ STATIC FLYER

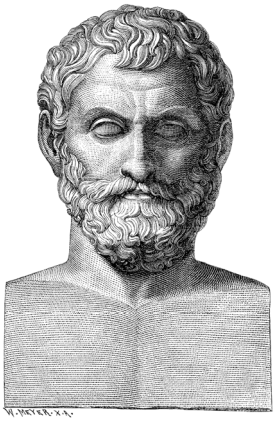
stevespangler.com/ss-video/455934161

- How do we know there are two type of electric charges?
  - When various materials are rubbed together in controlled ways, certain combinations of materials always result in a net charge of one type on one material and a net charge of the opposite type on the other material.



A glass rod becomes positively charged when rubbed with silk, whereas 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.

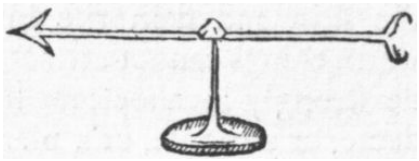
- Thales of Miletus (Greek, 585 BCE)
  - First description of static electricity
  - Recognized the attractive powers of amber rubbed with animal fur



Thales - Wilhelm Meyer (Public Domain)

Amber – Megan (CC BY-NC 2.0)

- William Gilbert (English, 1600)
  - Described electric charge as an “effluvium”
  - Developed the first device to measure electric charge (versorium)



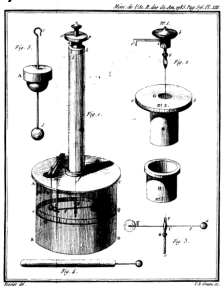
Versorium – William Gilbert, (Public Domain)

William Gilbert. Oil painting. Credit: Wellcome Collection. Attribution 4.0 International (CC BY 4.0)

- Benjamin Franklin (American, 1740's)
  - Experimented with electricity
  - Labelled charges as positive and negative
  - First used the terms: battery, charge, conductor
  - Showed that lightning was electric charge (1752)

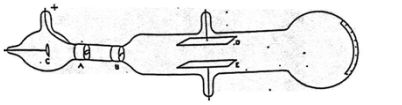
Benjamin Franklin - Joseph Siffred Duplessis, National Portrait Gallery. (Public Domain)

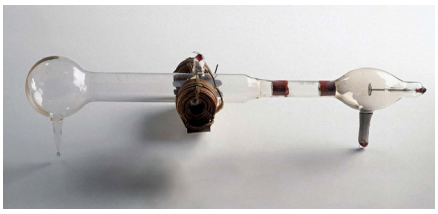
- Charles-Augustin de Coulomb (French, 1785)
  - Discovered the mathematical relationship of electrostatic forces
    - The unit of charge, Coulomb (C) was named in his honor



Charles-Augustin de Coulomb – Louis Herle. RMN-Grand Palais (Château de Versailles) / Gérard Blot
https://www.photo.rmn.fr/archive/99-003694-2C6NU0X9TUSI.html (Public Domain)
Coulomb's Torsion Balance – Charles-Augustin de Coulomb (Public Domain)

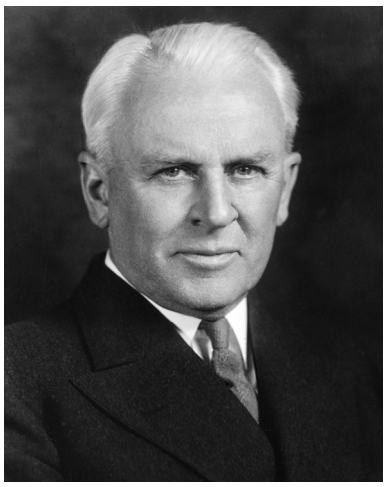
- J. J. Thomson (British), 1897
  - Discovered the electron
  - Showed that this electron was responsible for electric charge





J. J. Thomson – unknown (Public Domain)
Sketch of Cathode Ray Tube – J. J. Thomson (Public Domain)
J. J. Thomson's cathode ray tube – Cavendish Laboratory, Cambridge, Science Museum, London. (CC BY-NC-SA 4.0)

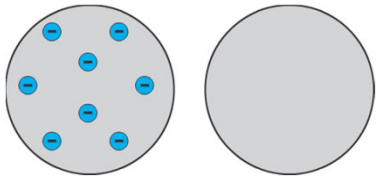
- Robert A. Millikan (American), 1913
  - Experimentally determined the charge on an electron
  - 1.6×10^{-19} C



Robert A. Millikan – unknown (Mondadori Publishers) (Public Domain)
Original oil-drop apparatus – unknown (Public Domain)

Conservation of Charge

- The law of conservation of charge says that electrical charge cannot be created or destroyed.
  - Charge can be moved around
    - Transfer of electrons between objects



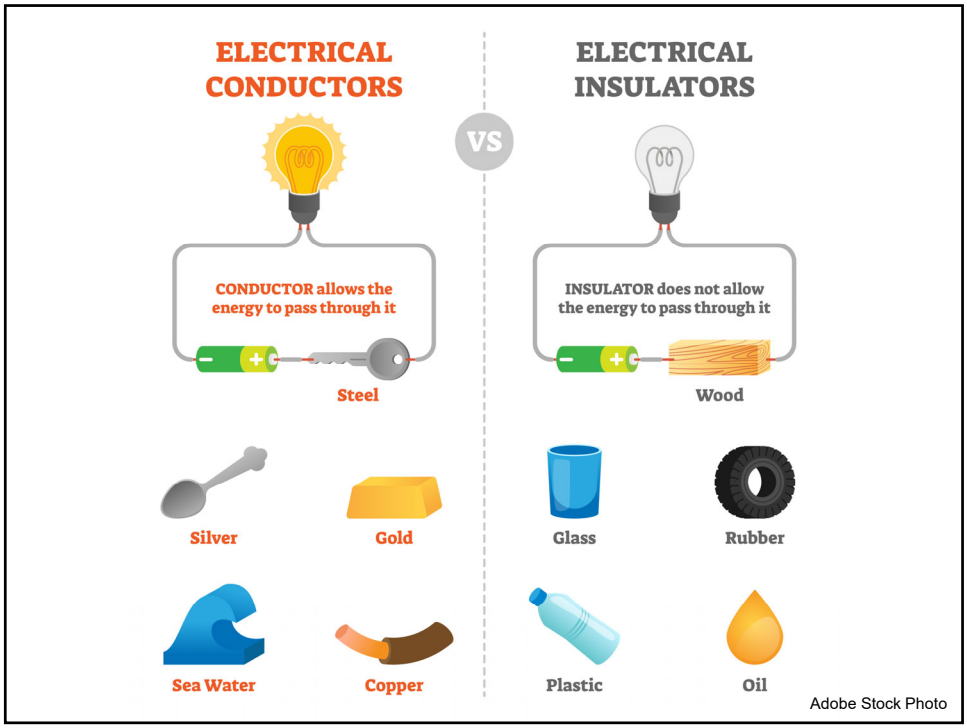
Conductors & Insulators

- Materials can be classified depending on whether they allow charge to move.

Conductor
- Charge can easily move through it

Insulator
- Charge cannot move through it

Semiconductor
- Conductivity between conductor and insulators



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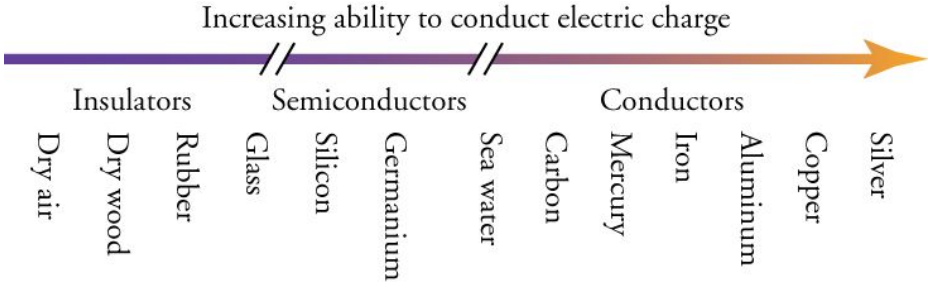


Physics. OpenStax, Rice University.
https://openstax.org/books/physics/pages/18-1-electrical-charges-conservation-of-charge-and-transfer-of-charge (CC BY 4.0)

- What happens if an excess negative charge is placed on a conducting object?
  - It spreads itself out evenly
    - The negative charges repel each other, and they move to minimize that force.

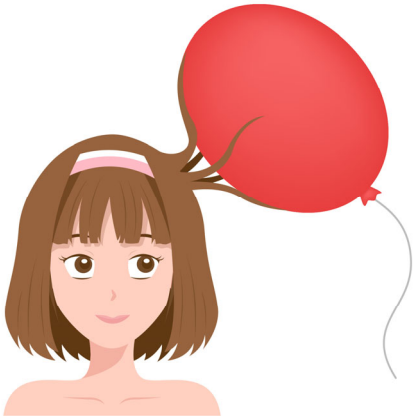
- What happens if an excess negative charge is placed on an insulating object?
  - The excess charge stays in one location
    - The negative charges repel each other but they can't move and therefore the charge is concentrated in one location.

Physics. OpenStax. https://openstax.org/books/physics/pages/18-1-electrical-charges-conservation-of-charge-and-transfer-of-charge (CC BY 4.0)

Transfer & Separation of Charge

- Charging by contact
  - When the surfaces of two objects made of different materials are placed in close contact if one of the materials holds electrons more tightly than the other, then it takes some electrons with it when the materials are separated.

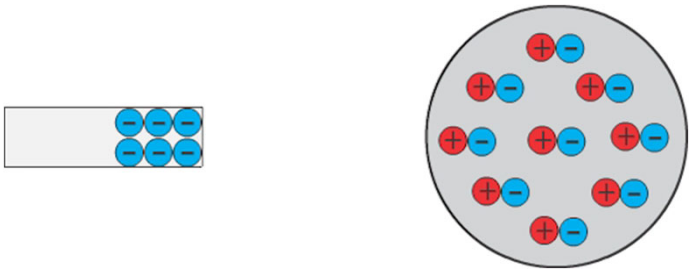
- Rubbing two surfaces together increases the transfer of electrons, because it creates a closer contact between the materials.



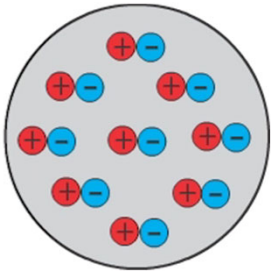
https://phet.colorado.edu/sims/html/john-travoltage/latest/john-travoltage_en.html

- Charging by conduction
  - Charged object in contact with another object
  - Excess electrons repel each other and move to be as far away as possible
    - If two objects are in contact, the electrons will distribute themselves equally over the two objects

- Charging by induction
  - Charge is created by approaching a charged object with a second object to create an unbalanced charge in the second object
  - Charges in second object separate (polarization)



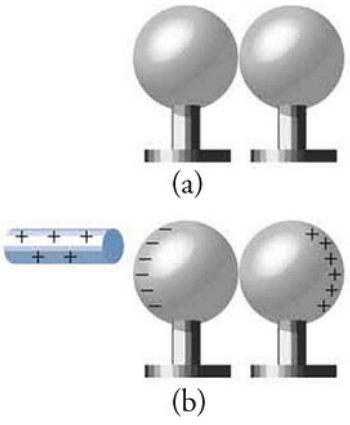
- When the charged object is removed, the charges in the second object return to their initial positions



- The second object does not remain charged
- To keep the second object charged we need to do something different.

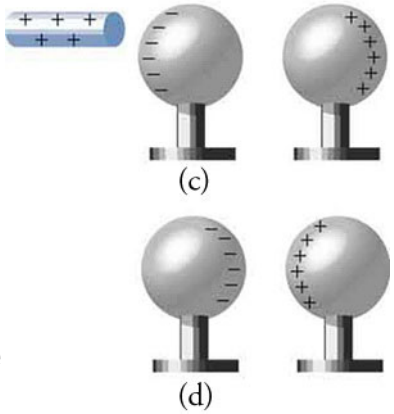
a) Two neutral conducting spheres are touching each other, so the charge is evenly spread over both spheres.

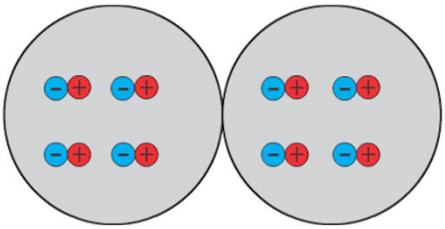
b) A positively charged rod approaches, which attracts negative charges, leaving excess positive charge on the right sphere.

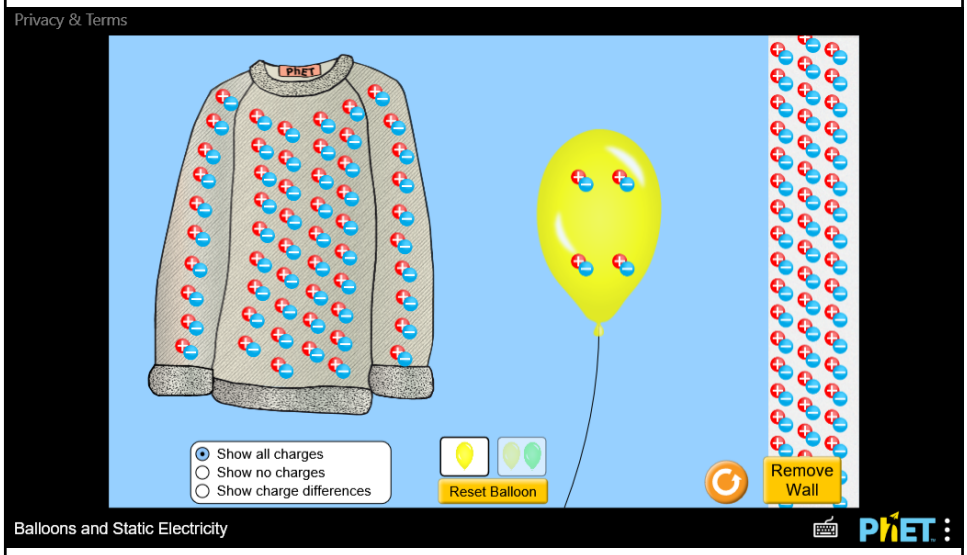


c) The spheres are separated. Each sphere now carries an equal magnitude of excess charge.

d) When the positively charged rod is removed, the excess negative charge on the left sphere is attracted to the excess positive charge on the right sphere.





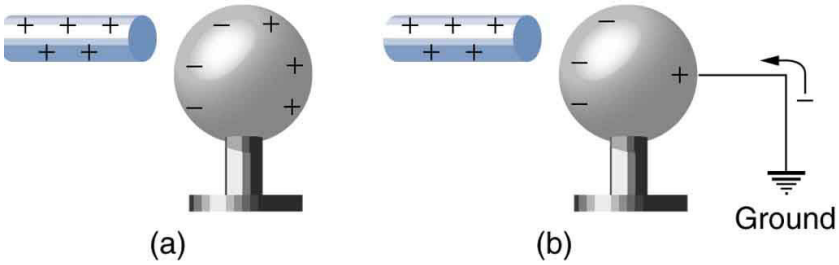


https://phet.colorado.edu/sims/html/balloons-and-static-electricity/latest/balloons-and-static-electricity_en.html

Grounding

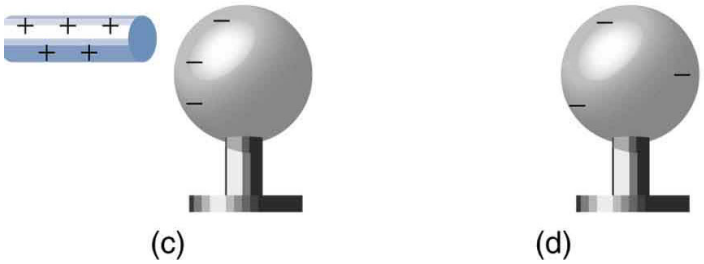
- When an object is attached to the ground by a conductor, there is a path for excess electrons to leave the object.
  - This path also allows for electrons to flow onto the object.
- The ground acts as an infinite sink or source of electrons.

- Induction charging with grounding.



a) A positively charged rod is brought near a neutral metal sphere, polarizing it.
b) The sphere is grounded, allowing electrons to be attracted from the earth's ample supply.

Image (cropped): College Physics for AP Courses. OpenStax, Rice University. https://openstax.org/books/college-physics-ap-courses/pages/18-3-conductors-and-electric-fields-in-static-equilibrium (CC BY 4.0)

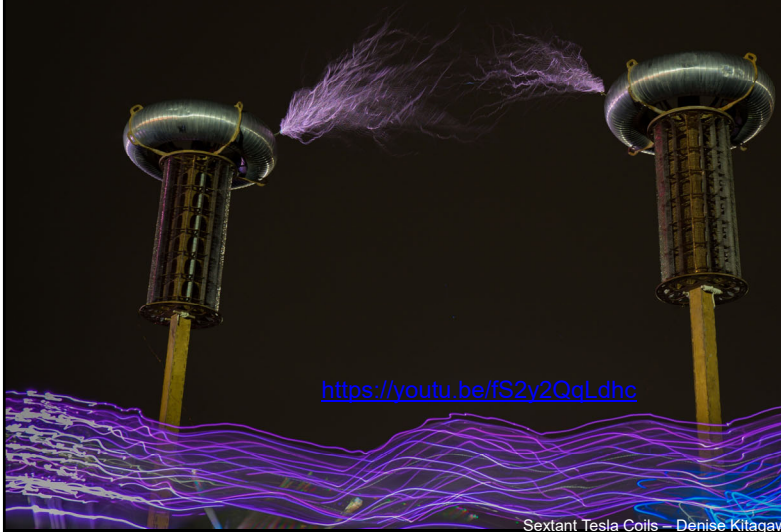


c) The ground connection is broken.
d) The positive rod is removed, leaving the sphere with an induced negative charge.

Image (cropped): College Physics for AP Courses. OpenStax, Rice University. https://openstax.org/books/college-physics-ap-courses/pages/18-3-conductors-and-electric-fields-in-static-equilibrium (CC BY 4.0)

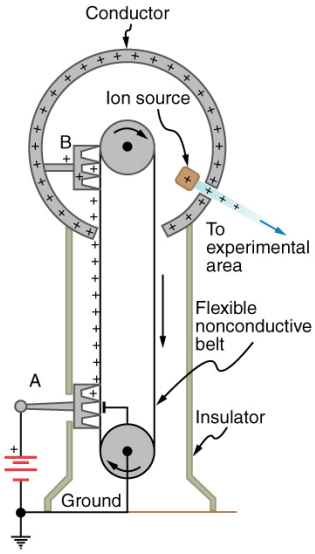
- A lightning rod is used to ground a building a protect it from the static electric charge of lightning.

Practical Applications of Electrostatics



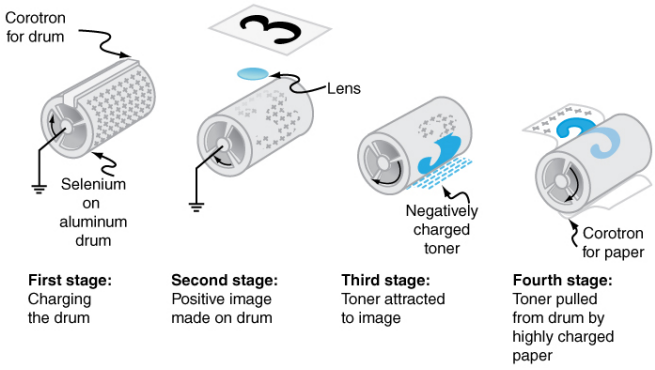
https://youtu.be/fS2y2QqLdhc

Figure 18.38



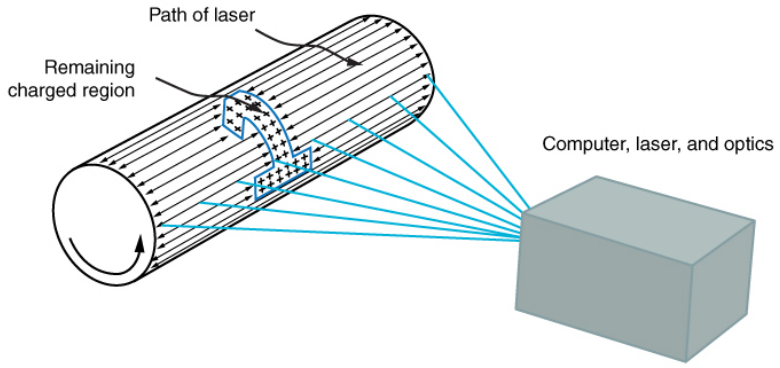
- Schematic of Van de Graaff generator. A battery (A) supplies excess positive charge to a pointed conductor, the points of which spray the charge onto a moving insulating belt near the bottom. The pointed conductor (B) on top in the large sphere picks up the charge. (The induced electric field at the points is so large that it removes the charge from the belt.) This can be done because the charge does not remain inside the conducting sphere but moves to its outside surface. An ion source inside the sphere produces positive ions, which are accelerated away from the positive sphere to high velocities.

Figure 18.39



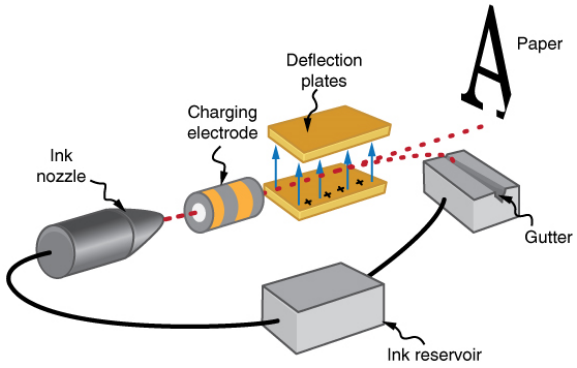
- Xerography is a dry copying process based on electrostatics. The major steps in the process are the charging of the photoconducting drum, transfer of an image creating a positive charge duplicate, attraction of toner to the charged parts of the drum, and transfer of toner to the paper. Not shown are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

Figure 18.40



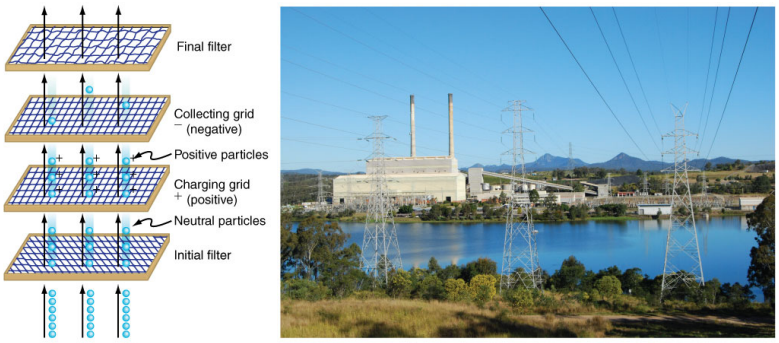
- In a laser printer, a laser beam is scanned across a photoconducting drum, leaving a positive charge image. The other steps for charging the drum and transferring the image to paper are the same as in xerography. Laser light can be very precisely controlled, enabling laser printers to produce high-quality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

Figure 18.41



- The nozzle of an ink-jet printer produces small ink droplets, which are sprayed with electrostatic charge. Various computer-driven devices are then used to direct the droplets to the correct positions on a page.

Figure 18.42



(a) Schematic of an electrostatic precipitator. Air is passed through grids of opposite charge. The first grid charges airborne particles, while the second attracts and collects them.

(b) The dramatic effect of electrostatic precipitators is seen by the absence of smoke from this power plant. (credit: Cmdalgleish, Wikimedia Commons)