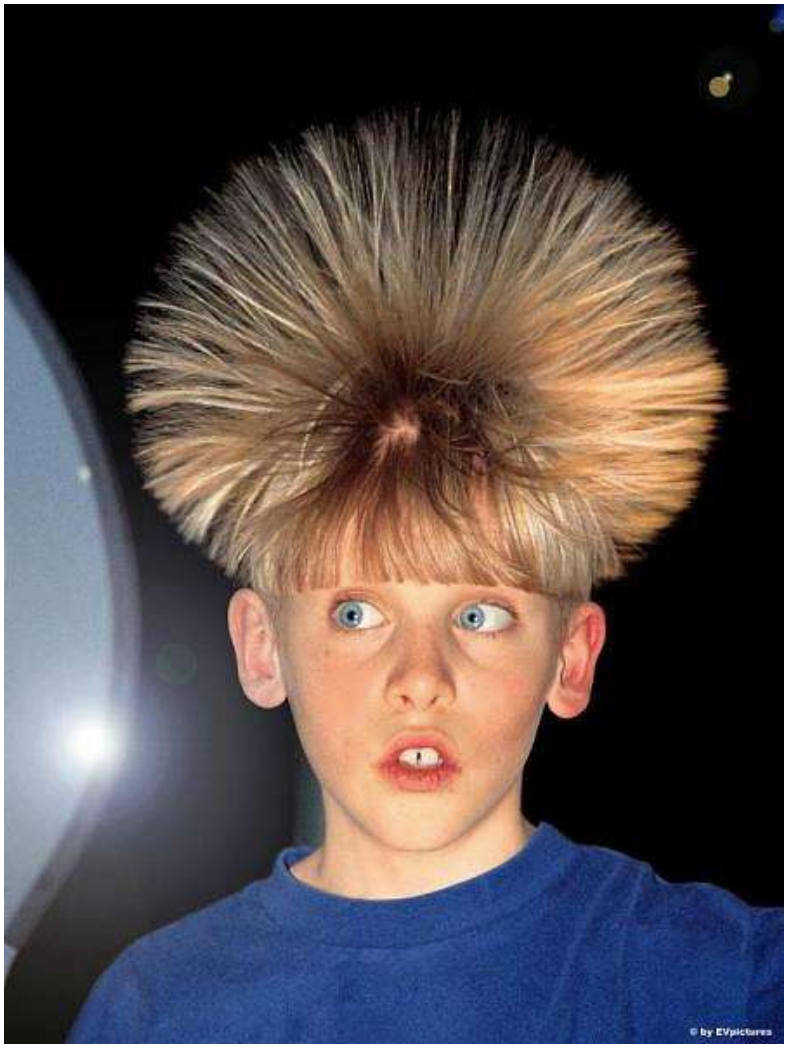
Electricity and Magnetism



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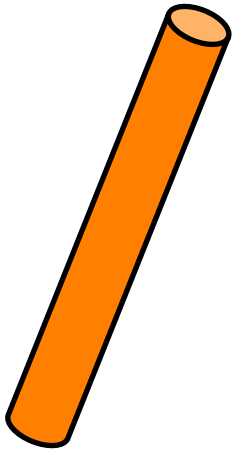
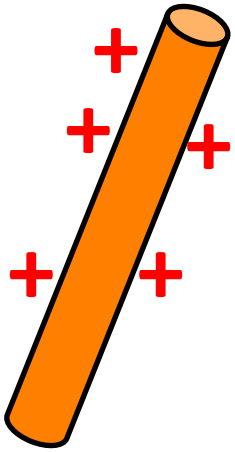


Acrylic

⇒



Acrylic

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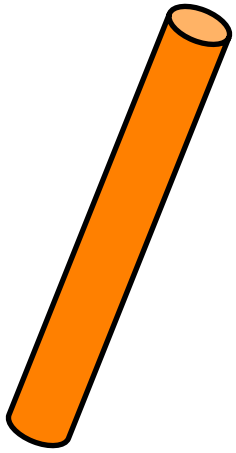
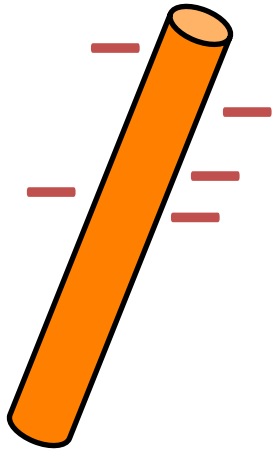


PVC or UVB

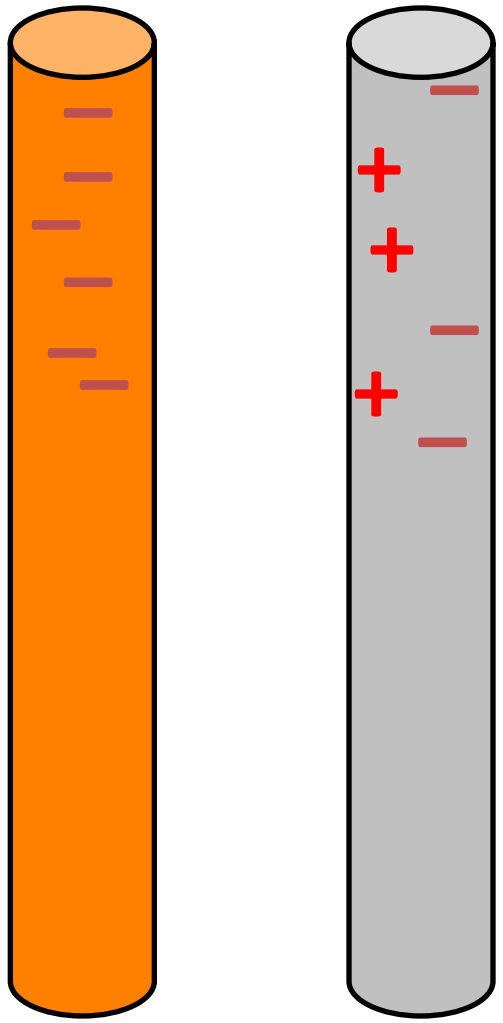
⇒



PVC or UVB

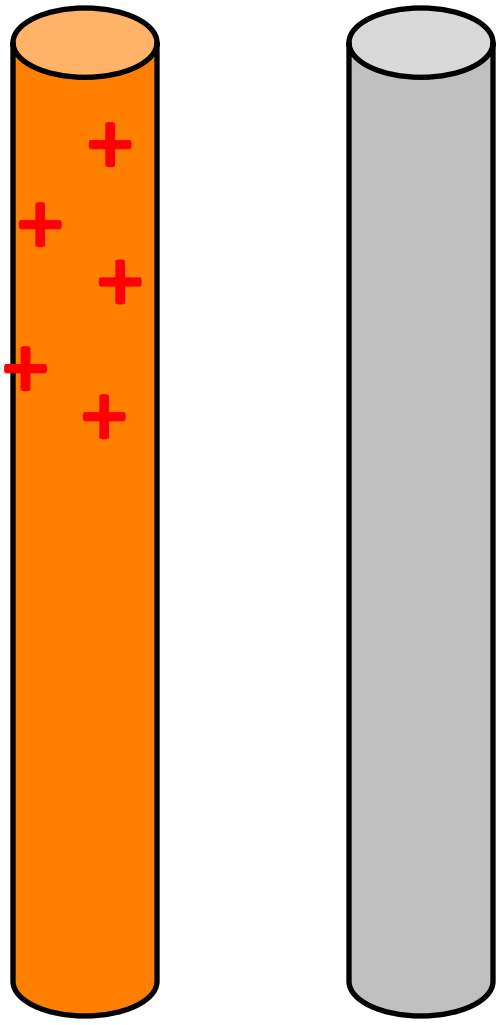
Interaction of Two Charges

Negatively Charged Rod and Metal Rod

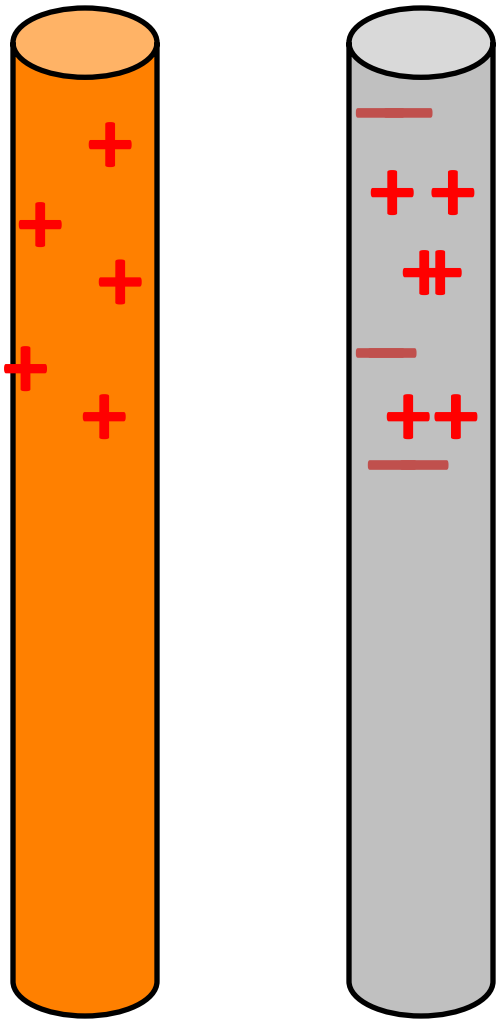


PVC Metal

Attraction !



Attraction
or
repulsion?



Acrylic Metal

Attraction!

What if we use wood instead of metal?

Charge on Balloon Simulation

Summary of observations

- Positive repels positive
- Negative repels negative
- Positive attracts negative
- Neutral bodies tend to be attracted to charged bodies because of charge separation (“polarization”)
- Forces are larger when charges are closer

Clicker Question

A positively charged rod and a negatively charged rod are in close proximity, without touching. What happens?

A. The positive rod is attracted to the negative rod, and the negative rod is repelled from the positive rod.
B. The positive rod is repelled from the negative rod, and the negative rod is attracted to the positive rod.
C. The two rods attract to each other.
D. The two rods repel each other.
E. There will be no electric force between the rods because the positive and negative forces cancel.

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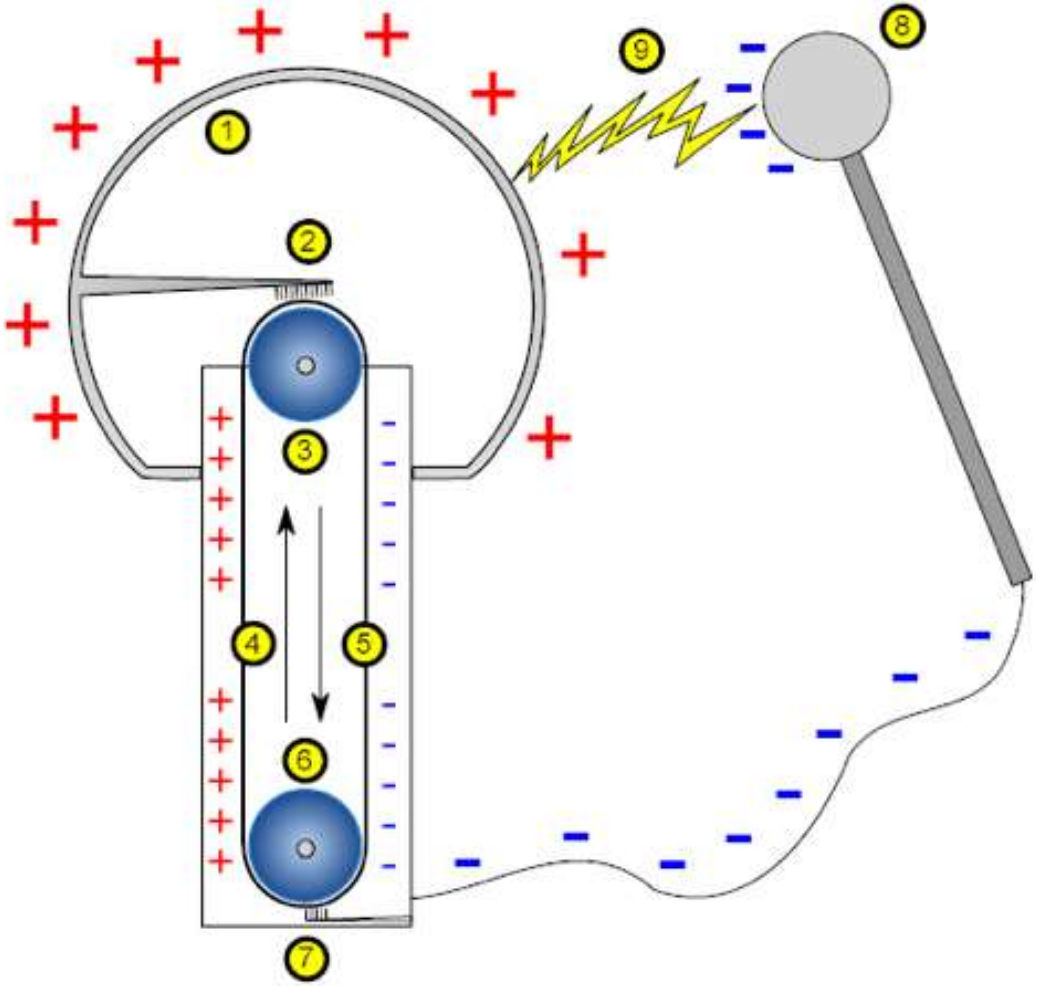
Van de Graaff generator



Clicker Question

A girl's hair is standing up because she is touching a Van de Graaff generator. What can we conclude about the girl's net charge?

A. Her charge must be positive. Negative charge would cause the hairs to clump together.
B. Her charge must be negative. Positive charge would cause the hairs to clump together.
C. Her charge could be positive, negative, or zero.
D. Her charge could be positive or negative, but not zero.
E. Some hairs are clearly positively charged, others are negatively charged, so they repel each other.

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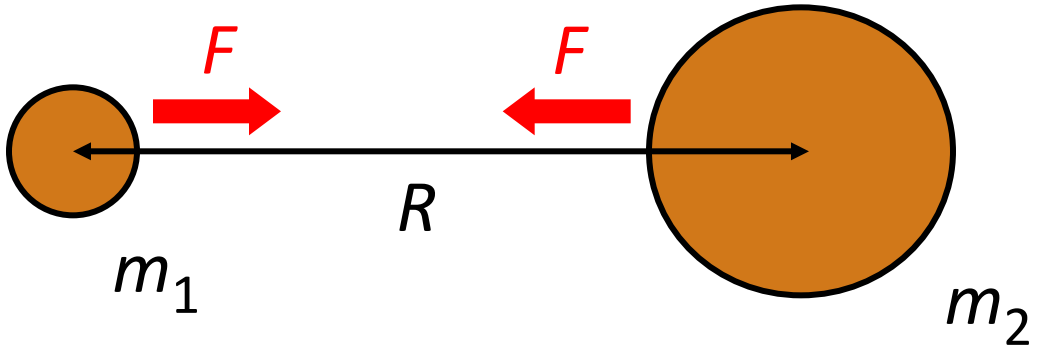
Charles Augustin de Coulomb (1783)

Coulomb's law:

- Force is proportional to product of charges
- Force is inversely proportional to square of distance
- Unit of *charge* is named after him: Coulomb (C)

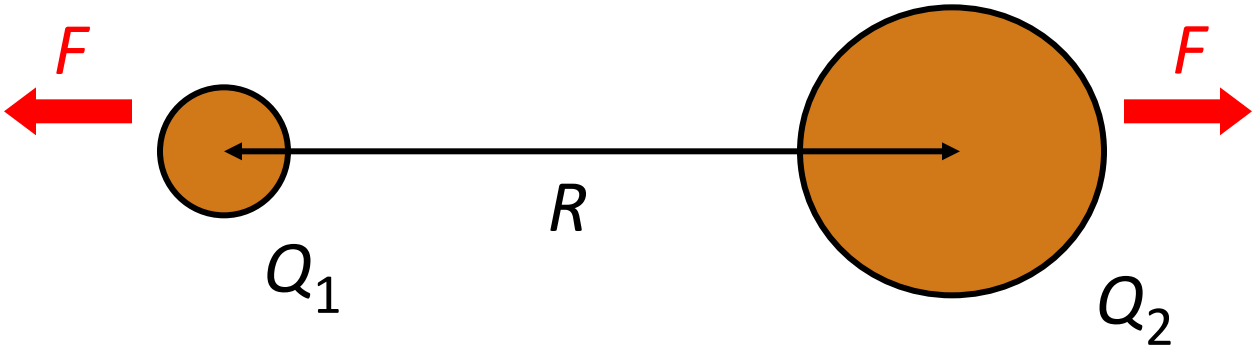
Newton's law of gravitation



$$F = G \frac{m_1 m_2}{R^2}$$

$G = 6.7 \times 10^{-11}$ (metric units)

Coulomb's law



$$F = k \frac{Q_1 Q_2}{R^2}$$

$k = 9.0 \times 10^9$ (metric units)

Gravitation law vs. Coulomb's law

$$F = G\frac{m_1 m_2}{R^2}$$

$$F = k\frac{Q_1 Q_2}{R^2}$$

$G = 6.7 \times 10^{-11}$ (metric units)

$k = 9.0 \times 10^{9}$ (metric units)

Similarities:

- Mathematical form
- Distance law

Differences:

- Electric forces can be repulsive or attractive!
- Electric forces are much stronger!

Clicker Question

A positive charge of 1 C exerts an electrostatic force of F1 on a positive charge of 50 C. The 50 C charge exerts a force of F2 on the 1 C charge. How do the forces compare?

A. $|F1| > |F2|$
B. $|F1| < |F2|$
C. $F1 = F2$
D. $F1 = - F2$

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Clicker Question

Two electric charges repel each other with a force of 2 N. If the distance between the charges is halved, the repulsive force

A. quadruples.
B. doubles.
C. remains the same.
D. is reduced by half.
E. is reduced by one quarter.

Clicker Question

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Clicker Question

A. Electrostatic forces can be repulsive or attractive, just like gravitational forces.
B. Electrostatic forces can be repulsive or attractive, whereas gravitational forces are always repulsive.
C. Positive charges attract negative charges, and positive masses repel negative masses.
D. Positive charges attract positive charges, and positive masses attract positive masses.
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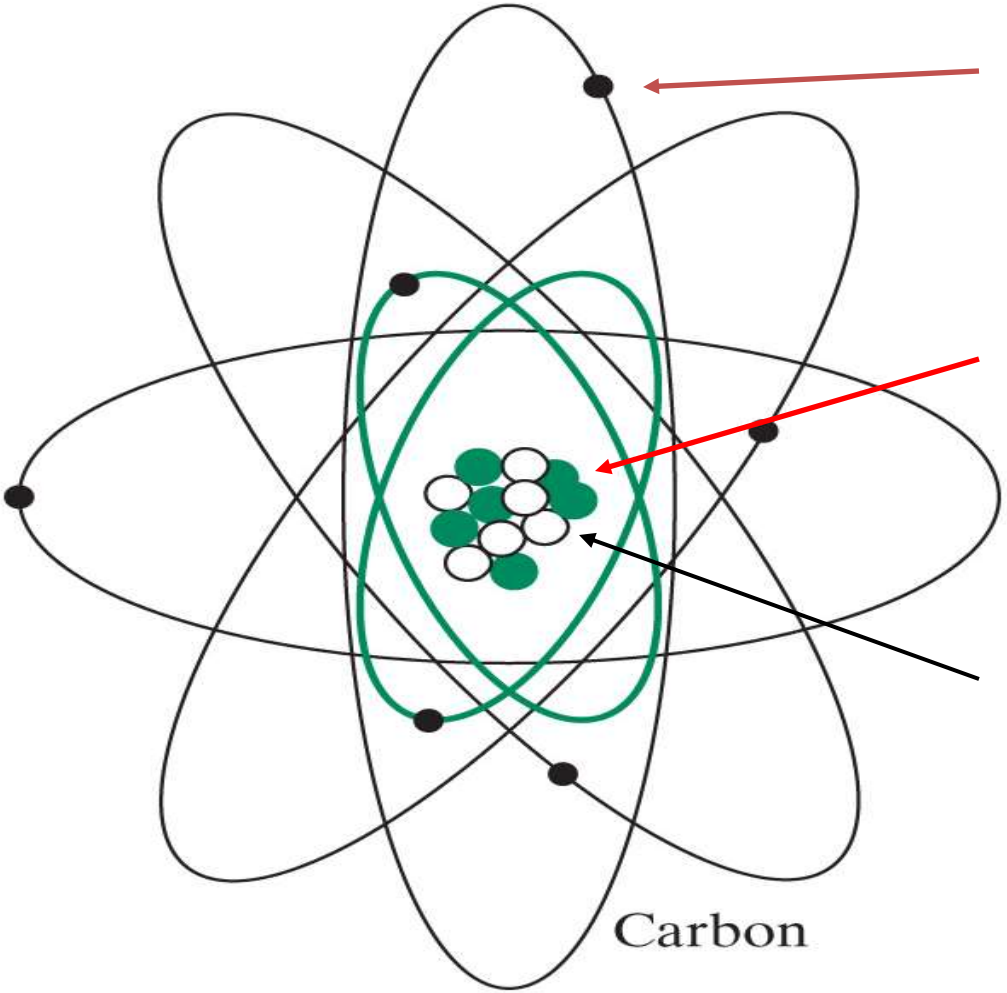
Planetary model of the atom



Electrons (–)

Protons (+)

Neutrons

Gravitation law vs. Coulomb's law

$$F = G\frac{m_1 m_2}{R^2}$$

$$F = k\frac{Q_1 Q_2}{R^2}$$

$G = 6.7 \times 10^{-11}$ (metric units)

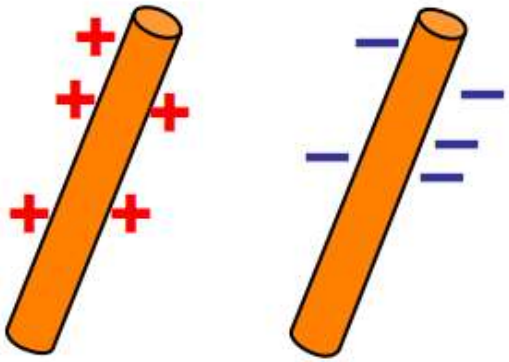
$k = 9.0 \times 10^{9}$ (metric units)

Forces between proton and electron in H atom

- Gravitational attraction of 4.2×10^{-47} N
- Electrical attraction of 9×10^{-8} N
- Recall Cavendish experiment, vs. charged rods!

Electrical neutrality of ordinary matter

$N_e / N_p = 0.9999$



$N_e / N_p = 1.0001$

(Neutrality at level of 1 part in 10^4)

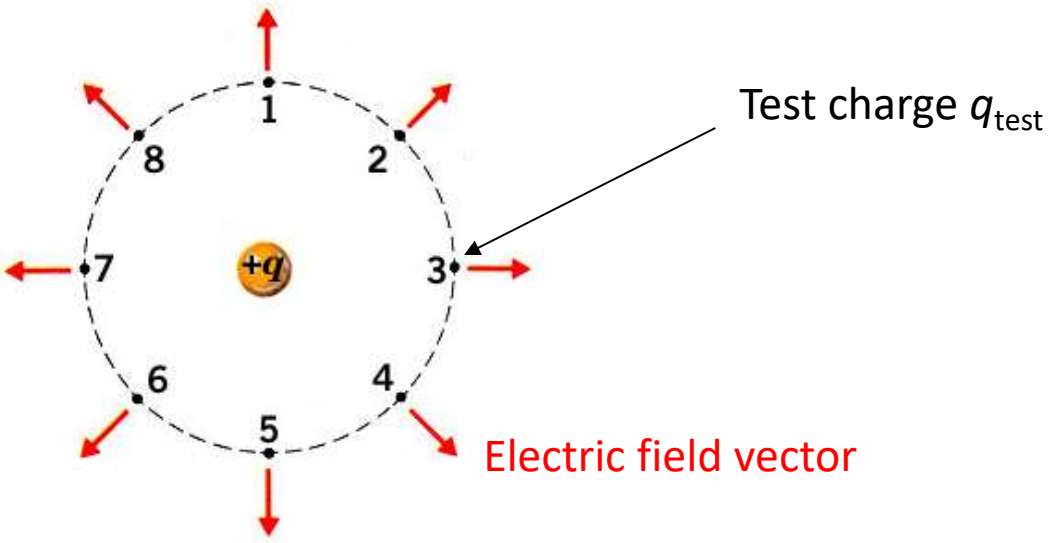
Then: $F_{elec} / F_{grav} = 10^{28}$

Need neutrality at level of 1 part in 10^{18} to get comparable forces !

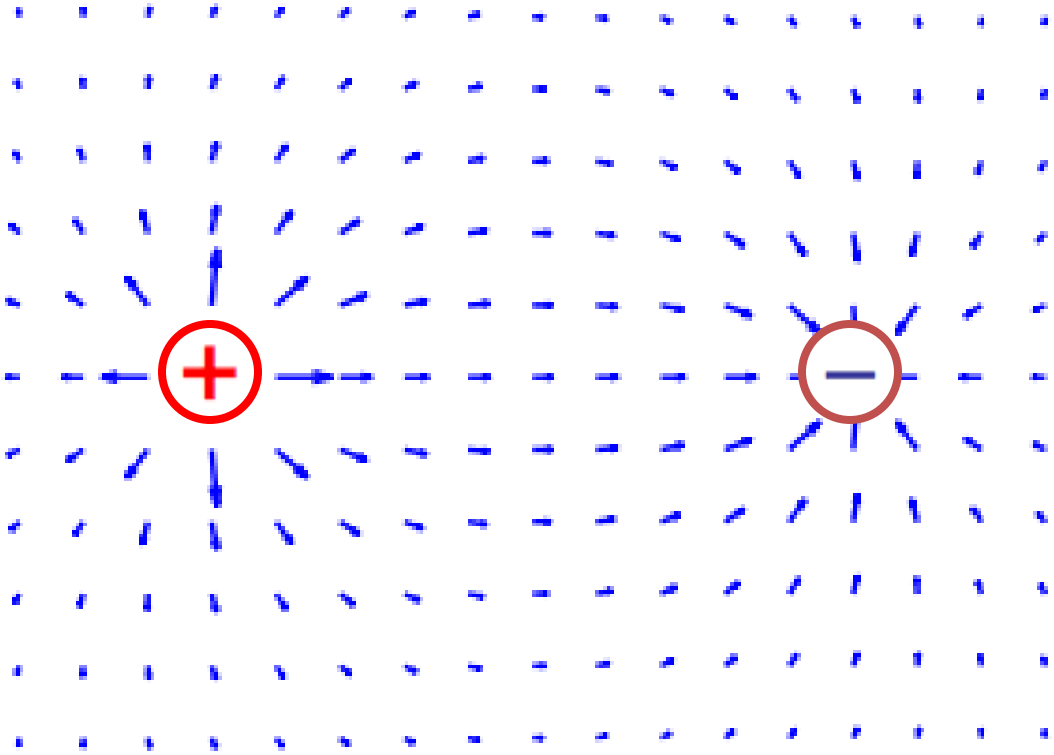
Earth is neutral to about 1 part in 10^{26} !

Electric Field

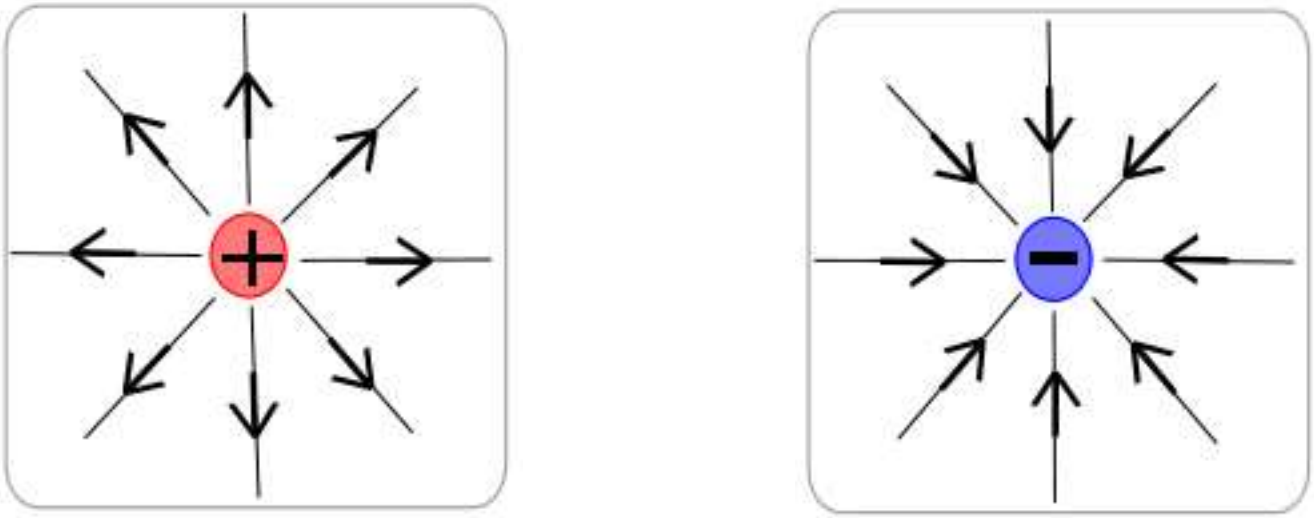
- When a charged body experiences an electric force, we consider there to be an “electric field”.
- In particular, since the force is proportional to the charge on the body, what characterizes the field is the force per unit charge.
- In other words, the electric field is just the force at any given point in space that a unit charge (1 Coulomb) would experience if placed at that point.
- It is a vector.



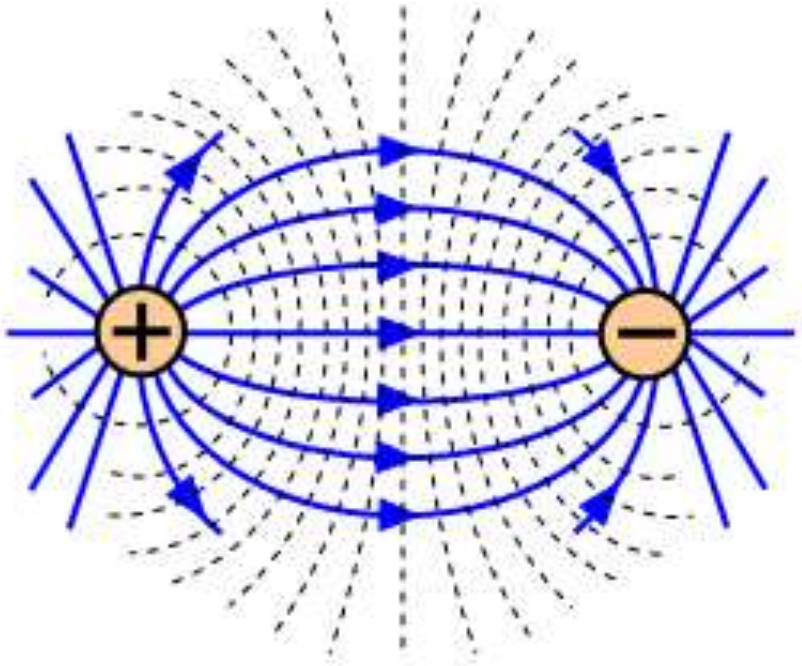
Visualizing electric fields: Field vectors



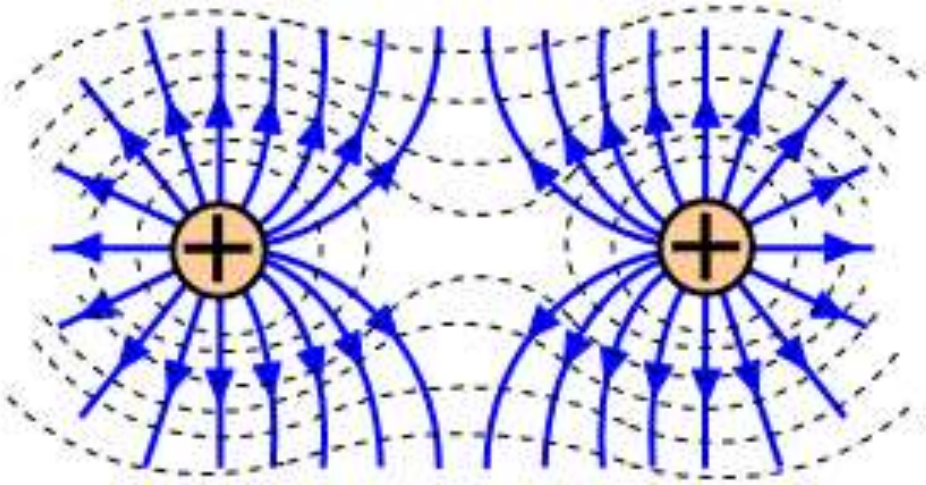
Visualizing electric fields: Field lines



Visualizing electric fields: Field lines



Visualizing electric fields: Field lines



Are electric fields “real” ?

Visualizing electric fields: Field lines