electrostatics

or, electric forces when nothing is moving.
Summarizing the properties of charge:
1. Charge is quantized in units of $|e| = 1.6 \times 10^{-19}$ C
2. Electrons carry one unit of negative charge, $-e$
3. Protons carry one unit positive charge, $+e$
4. Objects become charged be gaining or losing electrons, not protons
5. Electric charge is always conserved

| Particle       | Charge [C]     | $|e|$ | Mass [kg]   |
|----------------|----------------|------|-------------|
| electron ($e^-$) | $-1.60 \times 10^{-19}$ | $-1$ | $9.11 \times 10^{-31}$ |
| proton ($p^+$)  | $+1.60 \times 10^{-19}$ | $+1$ | $1.67 \times 10^{-27}$ |
| neutron ($n^0$) | $0$             | $0$  | $1.67 \times 10^{-27}$ |
a) before

charged rubber rod

b) contact

c) after

metal sphere
“Little pieces of tissue paper (or light grains of sawdust) are attracted by a glass rod rubbed with a silk handkerchief (or by a piece of sealing wax or a rubber comb rubbed with flannel).”

- from a random 1902 science book
neutral metal sphere

charged rubber rod
\( \vec{F} \)

\( \vec{F} \)

\( \vec{r}_{12} \)

\( \vec{r}_{12} \)

\( q_1 \)

\( q_2 \)

\( q_1 \)

\( q_2 \)
| Source                                      | $|\vec{E}|$ | Source                                      | $|\vec{E}|$  |
|--------------------------------------------|------|--------------------------------------------|--------|
| Fluorescent lighting tube                  | 10   | Atmosphere (fair weather)                  | $10^2$ |
| Balloon rubbed on hair                     | $10^3$ | Atmosphere (under thundercloud)            | $10^4$ |
| Photocopier                                | $10^5$ | Spark in air                               | $10^6$ |
| Across a transistor gate dielectric        | $10^9$ | Near electron in hydrogen atom             | $10^{11}$ |
2. Three point charges lie along the $x$ axis, as shown at left. A positive charge $q_1 = 15 \mu C$ is at $x = 2 \text{ m}$, and a positive charge of $q_2 = 6 \mu C$ is at the origin. Where must a negative charge $q_3$ be placed on the $x$-axis between the two positive charges such that the resulting electric force on it is zero?
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\[ \sim 0.77\text{m from } q_2 \]

or

\[ \sim 1.23\text{m from } q_1 \]
equal charges

field:  \( A > B > C \)
opposite charges
“dipole”
e.g., LiF & HF
unequal
like
unequal
unlike
9. Which set of electric field lines could represent the electric field near two charges of the same sign, but different magnitudes?

- a
- b
- c
- d
6. A circuital ring of charge of radius has a total charge of uniformly distributed around it. The magnitude of the electric field at the center of the ring is:

- $\nabla E = k\frac{q}{b^2}$
- $\nabla E = k\frac{keq^2}{b^2}$
- $\nabla E = k\frac{keq^2}{R^2}$
- $\nabla E = k\frac{keq^2}{r^2}$

7. Two insulated dielectric spheres have a charge of $q$ and $-3q$, respectively. They are connected by a conducting wire, and after equilibrium is reached, the wire is removed such that both spheres are again isolated. What is the charge on each sphere?

- $q$, $-3q$
- $-q$, $-3q$
- $0$, $-2q$
- $2q$, $-2q$

8. An angle point charge $+q$ is placed exactly at the center of a hollow conducting sphere of radius $R$. Before placing the point charge, the conducting sphere had zero net charge. What is the magnitude of the electric field outside the conducting sphere at a distance $r$ from the center of the conducting sphere?

- $|\vec{E}| = \frac{kq}{r^2}$
- $|\vec{E}| = k\frac{keq}{(R+r)^2}$
- $|\vec{E}| = k\frac{keq}{R^2}$
- $|\vec{E}| = k\frac{keq}{r^2}$

9. Which set of electric field lines could represent the electric field near two charges of the same sign, but different magnitudes?

- a
- b
- c
- d
10. Referring again to the figure above, which set of electric field lines could represent the electric field near two charges of opposite sign and different magnitudes?

- □ a
- □ b
- □ c
- □ d
10. Referring again to the figure above, which set of electric field lines could represent the electric field near two charges of opposite sign and different magnitudes?

- [ ] a
- [ ] b
- [ ] c
- [ ] d
amoeba  conductor
conductor
E=0
conducting dome

belt

insulating stand

ground
Area = $A' = A \cos \theta$

both surfaces have the same flux!
\( Q_1 \)

\( E = 0 \)

\( Q_2 \)

\( Q_3 \)

\( R_1 \)

\( R_2 \)

(a)

(b)