Resources: crashwhite.com and openstax University Physics Volume 2 textbook

# Chapter 5: Electric Forces and Fields

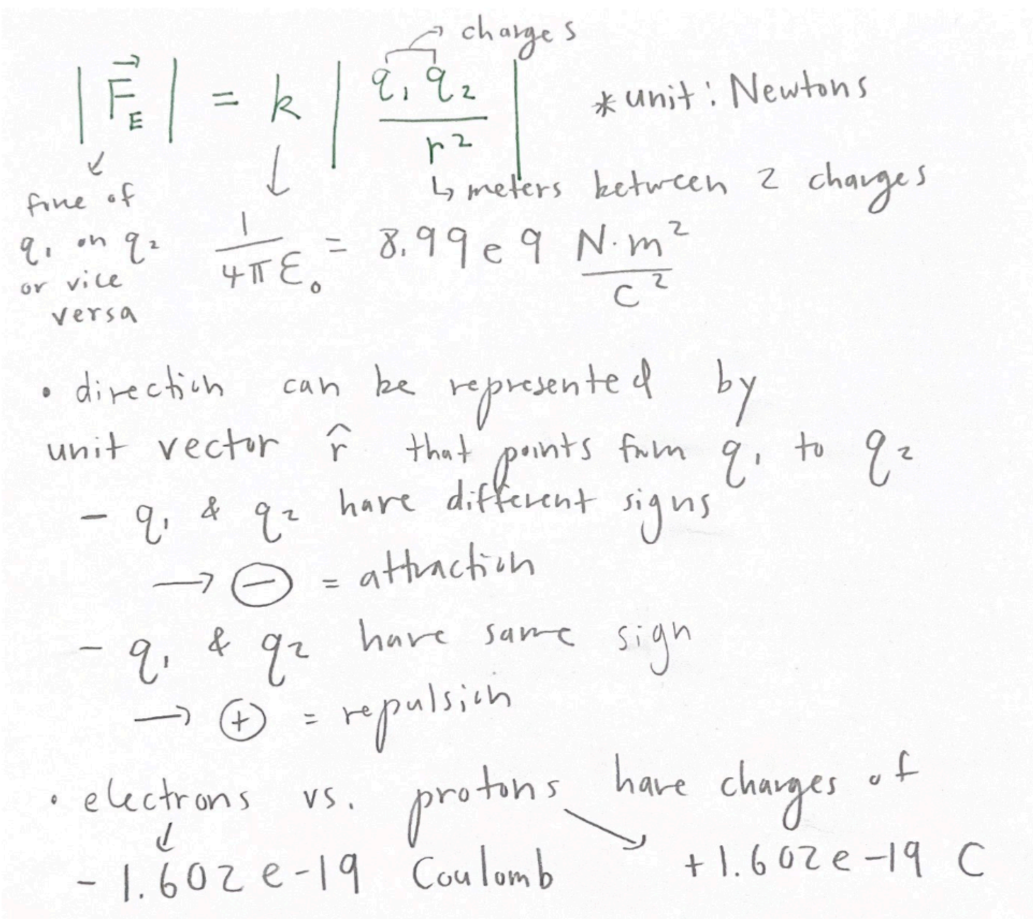
## Background/Summary:

This chapter is all about electric *charges*, which can be positive or negative. The basic principle is that like charges repel each other while opposites attract.

What forces do they exert on each other? What are the electric fields that they produce (point charge vs. continuous)? How are they acted on by electric fields?

## Major Topics (Including Formulae & When to Use):

**Coulomb's Law:** two charges will exert forces on each other that are identical in magnitude.




If charges are not aligned on a single axis, a 2-dimensional analysis is needed. Apply Coulomb's Law to each force, break forces into their component parts if applicable, and then add the like component parts together (ex: x-components) to get the component vectors of the net force.

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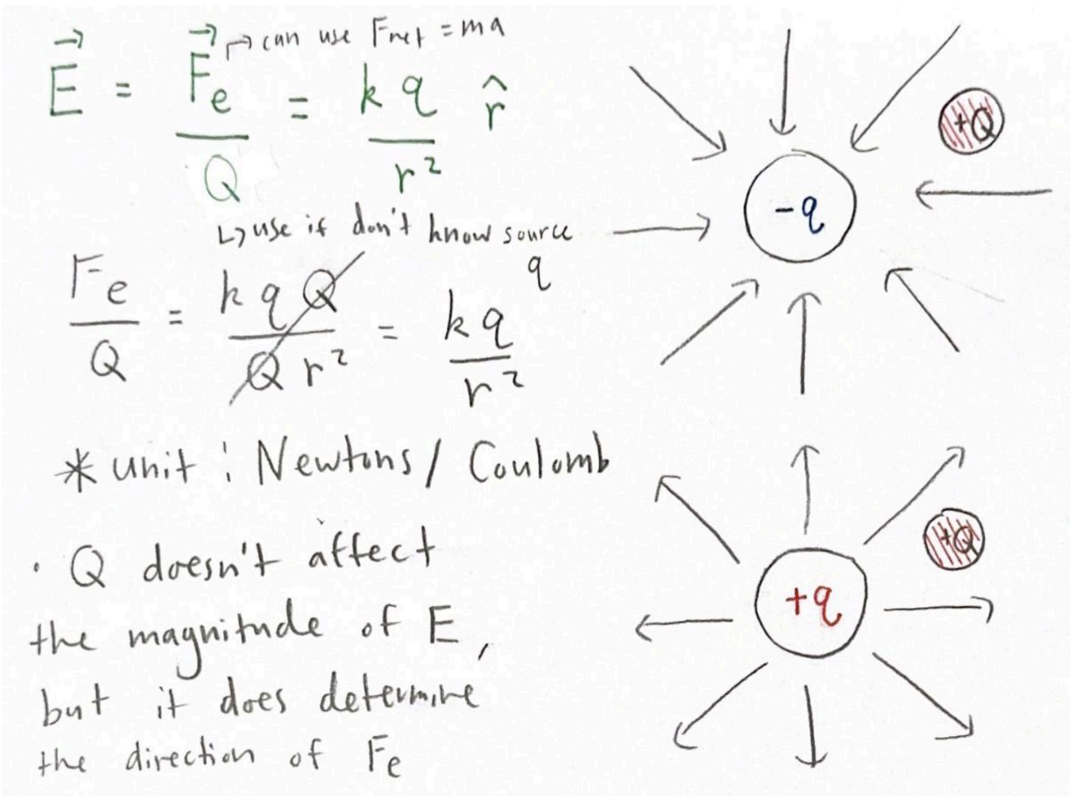
**Electric Fields & Charges in Electric Fields:** point charges, which theoretically have no mass and thus exist at a single point, produce electric fields. The direction of an electric field is the same direction as the source charge's force on a positive charge. Thus, if the source charge is positive, its electric field points away from it. If the source charge is negative, its electric field points towards it.




A positive charge experiences a force in the same direction as the electric field while a negative charge experiences a force in the OPPOSITE direction as the electric field.

**Electric Field of Continous Charges:** continuous charges also produce electric fields, but we have to use calculus to solve for theirs. Imagine the continuous charge as a sum of its infinitesimal portions, called *dq*. Each dq produces an infinitesimal portion of an electric field, dE, which can be quantified with the equation we derived earlier of $E = \frac{kq}{r^2}$ except q is dq.

Adding all the dEs through an integral gives us the net electric field. To solve this integral, we can use the charge density relationships below and substitution.

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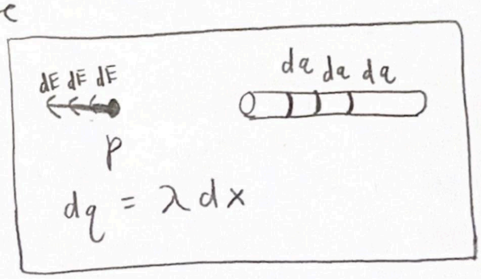
$$\vec{E} = \int k \frac{dq}{r^2}\hat{r}$$

- $\hat{r}$ → radial direction, ⊖ = toward source charge
- $k$ = 8.99e9 $\frac{N \cdot m^2}{C^2}$
- $r^2$ → distance between charge and E at point P

Linear: $\lambda = \frac{q}{L} \rightarrow dq = \lambda dL$ or $dx$

Area: $\sigma = \frac{q}{A} \rightarrow dq = \sigma dA$

Volume: $\rho = \frac{q}{V} \rightarrow dq = \rho dV$




## Vocabulary:

- **conductor:** made of metal. Conducts charge easily.
- **insulator:** rubber, plastic, wood, etc. Does not conduct charge easily because electrons are more tightly bound to the nucleus of atoms.
- **conduction:** occurs when two conductors with different charges make contact, resulting in the swapping of electrons
- **induction:** an object with a charge near a neutral conductor causes the conductor to become polarized

## Problems in Order of Difficulty (Easy, Medium, Hard):

**73**. If the electric field is 100 N/C at a distance of 50 cm from a point charge $q$, what is the value of $q$?

73. $E = \frac{kq}{r^2} \rightarrow 100 = \frac{(8.99e9)q}{(0.5)^2} \rightarrow \boxed{q = 2.78e\text{-}9\ C}$

**53**. Point charges $q_1 = 50\ \mu C$ and $q_2 = -25\ \mu C$ are placed 1.0 m apart. What is the force on a third charge $q_3 = 20\ \mu C$ placed midway between $q_1$ and $q_2$?

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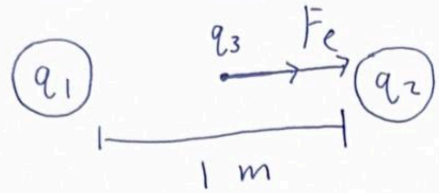
53.




$q_1 = 50\ \mu C$ $q_2 = -25\ \mu C$ $q_3 = 20\ \mu C$

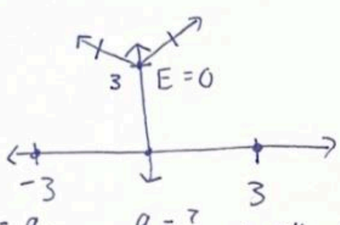
$F_{e_{2-3}} = \frac{k q_1 q_2}{r^2} = \frac{(8.99e9)(-25e-6)(20e-6)}{(0.5)^2} = 18.0\ N$, attraction

$F_{e_{1-3}} = \frac{k q_1 q_2}{r^2} = \frac{(8.99e9)(50e-6)(20e-6)}{(0.5)^2} = 36.0\ N$, repulsion

$F_{net} = Fe_{2-3} + Fe_{1-3} = 18 + 36 =$ **54.0 N, right**

**79**. Point charges $q_1 = q_2 = 4.0 \times 10^{-6}$ C are fixed on the *x*-axis at $x = -3.0$ m and $x = 3.0$ m. What charge *q* must be placed at the origin so that the electric field vanishes at $x = 0, y = 3.0$ m?

79.

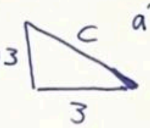


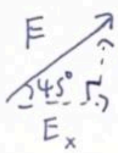

$4e-6 = q_1$ $q = ?$ $q_2 = 4e-6$

- x components of E from $q_1$ and $q_2$ cancel, but the y-components add up
- first, we need to find the magnitude of those y-components

$E = \frac{kq}{r^2} = \frac{(8.99e9)(4e-6)}{(4.24)^2}$

$E = 2000$ N/C




$E_y = E \sin\theta$
$= 2000 \sin(45°)$
$= 1414$ N/C $\times 2 = 2.83e3$ N/C

- now, what q would cancel out the E produced by $q_1$ and $q_2$?

$E = \frac{kq}{r^2} \rightarrow 2.83e3 = \frac{(8.99e9)q}{3^2} \rightarrow q =$ **$-2.83e-6$ C**

- q is negative so that its E will cancel out the E upward