Ashley Kim
Lab: AP Physics C Electricity and Magnetism Review Sheets
05/08/2025

Chapter 5: Electric Forces and Fields

Background/Summary:

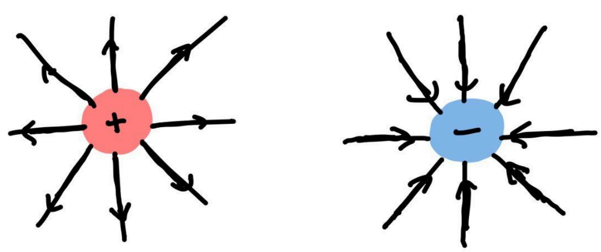
Electric forces and electric fields are foundational to understanding electrostatics. This chapter introduces Coulomb's Law, electric field concepts, field lines, and electric force interactions between charged objects. These ideas form the basis for understanding how charges influence each other through the electric field, even without physical contact.

Major Topics Covered:

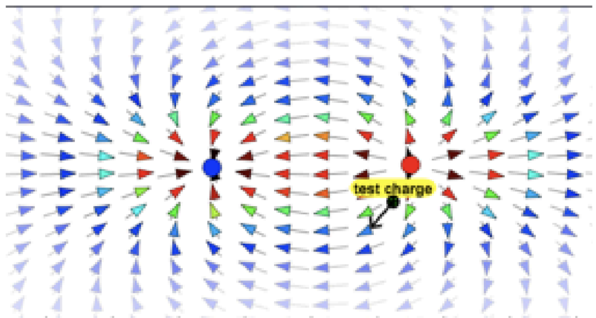
- Electric Charges and Coulomb's Law
- Electric Fields and Charge Distribution
- Drawing Electric Field Lines
- Motion of a Charge in an Electric Field
- Conductors and Insulators (basic context)

Vocabulary:

- **Electric Charge (q):** fundamental property of matter that causes it to experience a force when placed in an electric or magnetic field. Measured in coulombs (c); charges can be positive or negative.
- **Electric Field (E):** region around a charged object where other charges experience a force. $E = \frac{F}{q}$
- **Electric Force (F_s):** the force between two charged particles, calculated using Coulomb's Law. It can be attractive or repulsive depending on the sign of the charges.
- **Coulomb's Law:** a law that describes the magnitude of the electric force between two point charges: $F = k\frac{q_1 q_2}{r^2}$
- **Field Lines:** imaginary lines used to represent the direction and strength of electric fields. Lines point away from positive charges and toward negative charges; density of lines indicates field strength.



- **Point Charge:** an idealized model of a charged particle that occupies a single point in space, often used in electrostatics calculations.
- **Test Charge:** a small, positive charge used to measure the electric field at a point. It is assumed not to affect the field it is placed in.
- **Vector Field:** a field that assigns a vector (magnitude and direction) to every point in space—like the electric field.



- **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

Key Equations:

Equation	Description/When to Use:
$F_{21} = k\frac{q_1 q_2}{r^2}\hat{r}$ (vector form) F_{21}= *the force on charge 2 from charge 1* *r = distance between 2 charges* $\hat{r}$ = *unit vector that points from charge 1 towards charge 2*	**Coulomb's Law:** describes the electric force between two charged objects *Use when you need to calculate the magnitude and direction of the electrostatic force between two point charges in a vacuum or air.*
$\lvert F_E \rvert = k\left\lvert\frac{q_1 q_2}{r^2}\right\rvert$ (scalar form)	Describes the electric force between two point charges. *Use when calculating the force between two stationary charges.*
$E = \frac{F}{Q}$	Defines electric field as the force experienced per unit charge. *Use when you know the force on a charge and want to find the field.*

$E = \frac{kq}{r^2}\hat{r}$ $\hat{r}$ = *unit vector pointing from source charge to point of interest*	Gives the electric field produced by a point charge q at a distance r. *Use when calculating the field caused by a specific source charge at some location in space.*
$E_{net} = \sum_i k\frac{q_i}{r_i^2}\hat{r}$ $E_{total} = E_1 + E_2 + E_3 + \ ...$	The net electric field is the vector sum of all individual electric fields. *Use if there is more than a single charge in a region of space.*
$E = \int k\frac{dq}{r^2}\hat{r}$ $k = \frac{1}{4\pi\varepsilon_0} = 8.99e^9\ \frac{N\cdot m^2}{c^2}$	Electric field from a continuous charge distribution. *Use when charge is spread out (e.g. rod, ring, disk).*
$\lambda = \frac{q}{L} \dashrightarrow\ dq = \lambda dL\ or\ dX$ $\delta = \frac{q}{A} \dashrightarrow\ dq = \delta dA$ $\rho = \frac{q}{v} \dashrightarrow\ dq = \rho dv$	Linear charge density *Use for lines or rods* Surface charge density *Use for surfaces (disks, plates)* Volume charge density *Use for 3D objects (spheres, cubes)*

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

1) If the electric field is 200 N/C at a distance of 100 cm from a point charge *q,* what is the value of *q?* **(Easy)**

$E = \frac{kq}{r^2}$

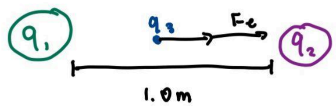
$r = 100cm \times \frac{1m}{100cm} = 1m$

$200 = \frac{(8.99e^9)q}{(1)^2}$

$\frac{200}{8.99e^9} = \frac{(\cancel{8.99e^9})q}{\cancel{8.99e^9}}$

$\boxed{q = 2.22 \times 10^{-8}\ C}$

2) Point charges $q_1 = 60\ \mu C$ and $q_2 = -30\ \mu C$ are placed 1.0 m apart. What is the force on a third charge $q_3 = 10\ \mu C$ placed midway between q_1 and q_2? **(Medium)**



$q_1 = 60\mu C \times \frac{1C}{10^6\mu C} = 6.0\times10^{-5}\ C$

$q_2 = -30\mu C \times \frac{1C}{10^6\mu C} = -3.0\times10^{-5}\ C$

$q_3 = 10\mu C \times \frac{1C}{10^6\mu C} = 1.0\times10^{-5}\ C$

$F_{e_{2-3}} = \frac{Kq_2q_3}{r^2}$

$= \frac{(8.99e^9)(-3.0\times10^{-5})(1.0\times10^{-5})}{(0.5)^2}$

$= \frac{-2.697}{(0.5)^2} = 10.8N$ attraction

$F_{e_{1-3}} = \frac{Kq_1q_3}{r^2}$

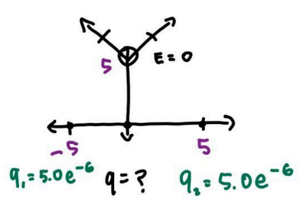
$= \frac{(8.99e^9)(6.0\times10^{-5})(1.0\times10^{-5})}{(0.5)^2} = 21.6N$ repulsion

$F_{net} = F_{e_{2-3}} + F_{e_{1-3}}$

$= 10.8 + 21.6$

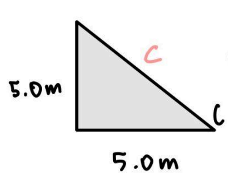
$\boxed{= 32.4N,\ \text{right}}$

3) Point charges $q_1 = q_2 = 5.0 \times 10^{-6} C$ are fixed on the x-axis at $x = -5.0\ m$ and $x = 5.0\ m$. What charge q must be placed at the origin so that the electric field vanishes at $x = 0$, $y = 5.0\ m$? **(Hard)**



- x-components of E from q_1 and q_2 cancel but the y-components add up
- we need to find the magnitudes of these y-components first

↳ $E = \frac{Kq}{r^2} = \frac{(8.99e^9)(5.0e^{-6})}{(7.07)^2} = 899\ N/C$



$a^2+b^2=c^2$

$(5)^2+(5)^2 = c^2$

$c = \sqrt{50} = 7.07m$

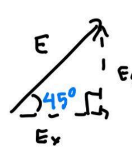
$E = \frac{Kq}{r^2}$

$1.27e^3 = \frac{(8.99e^9)\,q}{(5)^2}$

$\frac{1.27e^3}{3.596e^8} = \frac{\cancel{3.596e^8}\,q}{\cancel{3.596e^8}}$

$\boxed{q = -3.53\times10^{-6}\ C}$

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



$E_y = E\sin\theta$

$= 899\sin(45°)$

$= 636\ N/C \times 2 = 1272$

$= 1.27e^3\ N/C$