ELECTROSTATICS

BASIC CONCEPTS

1. THERE ARE TWO TYPES OF CHARGE: POSITIVE AND NEGATIVE.
2. OPPOSITE CHARGES ATTRACT, LIKE CHARGES REPEL.
3. ELECTRICALLY CHARGED OBJECTS ATTRACT NEUTRAL OBJECTS.
4. ELECTRIC CHARGE RESULTS FROM THE REMOVAL OR ADDITION OF ELECTRONS.
5. ELECTRIC CHARGE IS CONSERVED.
6. CONDUCTORS ALLOW CHARGE TO FLOW; INSULATORS DO NOT.

COULOMB'S LAW

- THE ELECTRIC FORCE IS DIRECTLY PROPORTIONAL TO THE ELECTRIC CHARGES AND INVERSELY PROPORTIONAL TO THE SQUARE OF THE DISTANCE SEPARATING THE CHARGES.

$$F_e = k\frac{q_1 q_2}{r^2}$$

F_e : ELECTRIC FORCE (N)

k : ELECTROSTATIC CONSTANT ($9.00 \times 10^9 \frac{N \cdot m^2}{C^2}$)

q_1, q_2 : ELECTRIC CHARGES (C)

r : DISTANCE BETWEEN THE CHARGES (m)

- 1 COULOMB IS THE CHARGE OF 6.24×10^{18} ELECTRONS.
- ELEMENTARY CHARGE : CHARGE OF 1 PROTON/ELECTRON

$$1\,e^- \times \frac{1\,C}{6.24 \times 10^{18}\,e^-} = 1.60 \times 10^{-19}\,C$$

EXAMPLE

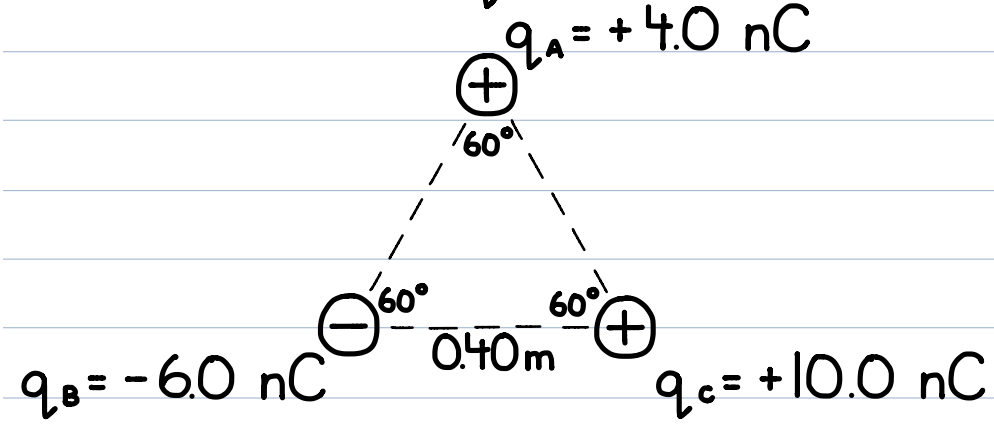
WHAT IS THE ELECTRIC FORCE BETWEEN AN ELECTRON AND A PROTON SEPARATED BY 5.29×10^{-11} m? COMPARE THIS TO THE GRAVITATIONAL FORCE BETWEEN THEM.

$m_e = 9.11 \times 10^{-31}$ kg

$m_p = 1.67 \times 10^{-27}$ kg

EXAMPLE

WHAT IS THE NET ELECTRIC FORCE ON CHARGE q_c ?



ELECTRIC FIELD

- THE ELECTRIC FIELD IS THE AREA AROUND A CHARGE WHERE ANOTHER CHARGE FEELS THE EFFECT OF THE FIRST.
- THE ELECTRIC FIELD IS EQUAL TO THE ELECTRIC FORCE PER UNIT CHARGE.

$$\vec{E} = \frac{\vec{F}_e}{q}$$

$\vec{E}$: ELECTRIC FIELD $\left(\frac{N}{C}\right)$
$\vec{F}_e$: ELECTRIC FORCE (N)
q : ELECTRIC CHARGE (C)

- FOR A POINT CHARGE :

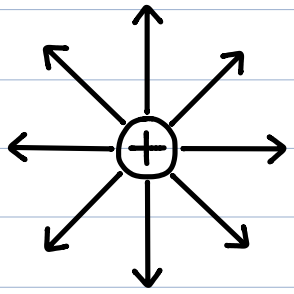
$$E = k\frac{q}{r^2}$$

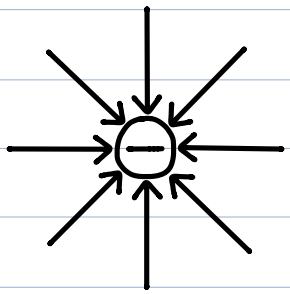
E : ELECTRIC FIELD $\left(\frac{N}{C}\right)$
k : ELECTROSTATIC CONSTANT $\left(9.00 \times 10^9 \frac{N \cdot m^2}{C^2}\right)$
q : ELECTRIC CHARGE (C)
r : DISTANCE (m)

- THE DIRECTION OF THE ELECTRIC FIELD IS THE DIRECTION IN WHICH A POSITIVE CHARGE WOULD MOVE.

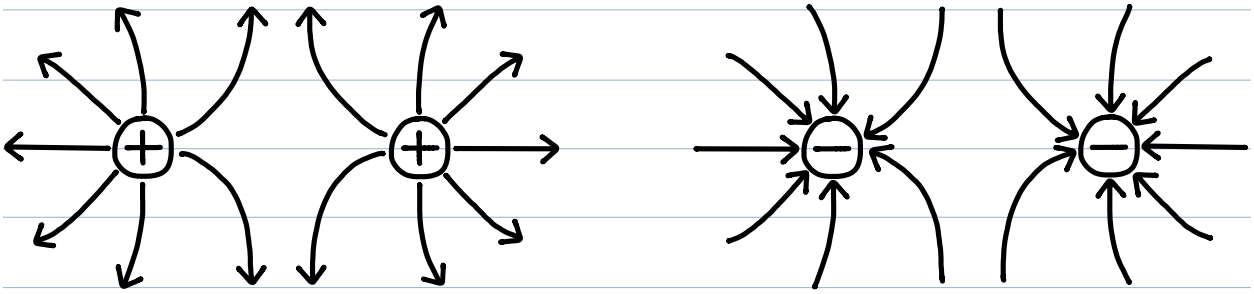
- ELECTRIC FIELD PATTERNS ARE LINES USED TO DESCRIBE ELECTRIC FIELD.
  - ELECTRIC FIELD LINES BEGIN ON POSITIVE CHARGES AND END ON NEGATIVE CHARGES.
  - THE NUMBER OF LINES ENTERING OR LEAVING A CHARGE IS PROPORTIONAL TO THE CHARGE.
  - THE DENSITY OF LINES AT A GIVEN POINT IS PROPORTIONAL TO MAGNITUDE OF THE ELECTRIC FIELD AT THAT POINT.

SINGLE POINT CHARGE

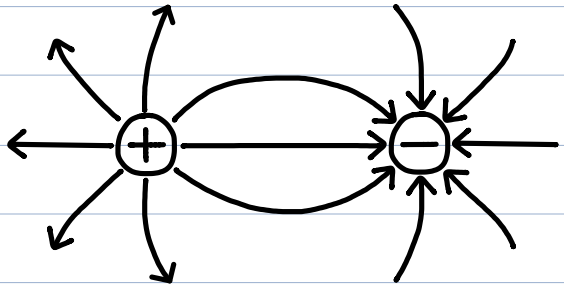




TWO LIKE CHARGES



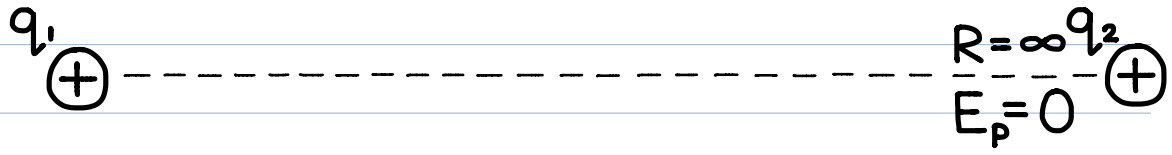
TWO OPPOSITE CHARGES

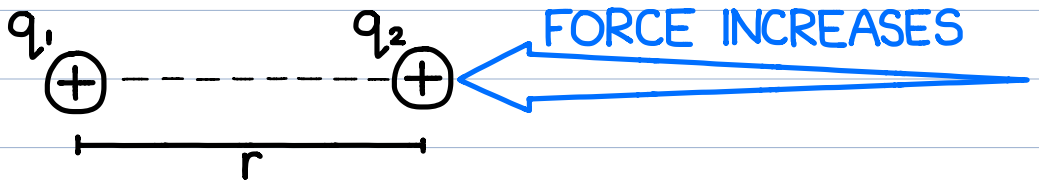


ELECTRIC POTENTIAL ENERGY

- THE ELECTRIC POTENTIAL ENERGY ASSOCIATED WITH TWO CHARGES SEPARATED BY AN INFINITE DISTANE IS ZERO.

HOW MUCH WORK IS REQURED TO BRING q_2 FROM ∞ TO A DISTANCE r ?





$$E_p = k\frac{q_1 q_2}{r}$$

E_p : ELECTRIC POTENTIAL ENERGY (J)

k : ELECTROSTATIC CONSTANT ($9.00 \times 10^9 \frac{N \cdot m^2}{C^2}$)

q_1, q_2 : ELECTRIC CHARGES (C) MUST INCLUDE +/−

r : DISTANCE BETWEEN THE CHARGES (m)

EXAMPLE

TWO PROTONS ARE INITIALLY SEPARATED BY A LARGE DISTANCE. AT WHAT SPEED MUST ONE PROTON TRAVEL TO COME A DISTANCE OF 1×10^{-15} m FROM THE OTHER?

$m_p = 1.67 \times 10^{-27}$ kg

ELECTRIC POTENTIAL AND VOLTAGE

- ELECTRIC POTENTIAL IS THE ELECTRIC POTENTIAL ENERGY PER UNIT CHARGE.
- SI UNIT: VOLT (V)

$$V = \frac{E_p}{q}$$

V : ELECTRIC POTENTIAL (V)
E_p : ELECTRIC POTENTIAL ENERGY (J)
q : ELECTRIC CHARGE (C)

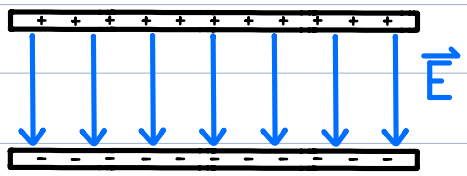
- FOR A POINT CHARGE:

$$V = k\frac{q}{r}$$

V : ELECTRIC POTENTIAL (V)
k : ELECTROSTATIC CONSTANT ($9.00 \times 10^9 \frac{N \cdot m^2}{C^2}$)
q : ELECTRIC CHARGE (C)
r : DISTANCE (m)

- ELECTRIC POTENTIAL DIFFERENCE (OR VOLTAGE) IS THE DIFFERENCE IN ELECTRIC POTENTIAL BETWEEN TWO POINTS.

- A BATTERY CAN BE USED TO CHARGE PARALLEL PLATES.
- THE ELECTRIC FIELD BETWEEN PARALLEL PLATES IS UNIFORM.



$$E = \frac{\Delta V}{d}$$

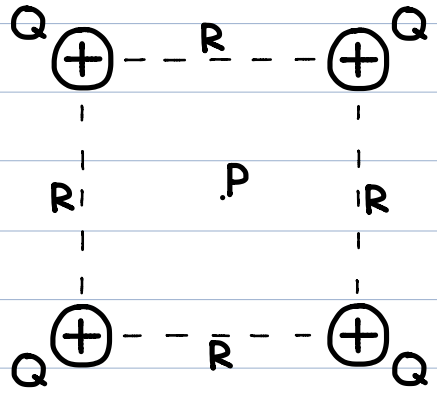
E : ELECTRIC FIELD $(\frac{V}{m})$

ΔV : POTENTIAL DIFFERENCE BETWEEN PLATES (V)

d : DISTANCE BETWEEN PLATES (m)

EXAMPLE

DETERMINE THE ELECTRIC POTENTIAL AND ELECTRIC FIELD AT THE CENTRE OF A SQUARE OF CHARGES Q AND SIDELENGTH R ?



EXAMPLE

A PROTON IS RELEASED FROM REST BETWEEN TWO CHARGED PLATES AS SHOWN. DETERMINE THE FINAL SPEED OF THE PROTON.