Calculating Electric Field and Electric Force

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The International unit of charge is the Coulomb (C)

Electric Field strength is given by:

$$\vec{E} = F_e/q' \quad \text{(this was discovered experimentally.)}$$

- Where q' (C) is the test charge in the field
- $\vec{F}_e$ is the Electrical Force exerted of the test charge by the source charge
- $\vec{E}$ is the Electric field strength

There is another way to define the Force on one charge by another charge.

Calculating Electric Field and Electric Force

The International unit of change is the Coulomb (C)

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

Coulomb's Law

Where:
r = distance between the two charges (in meters)

$k_e = 8.9876 \times 10^9\ Nm^2/C$
$\approx 9 \times 10^9\ Nm^2/C$

$\frac{Nm^2}{C}$

q = electric charge

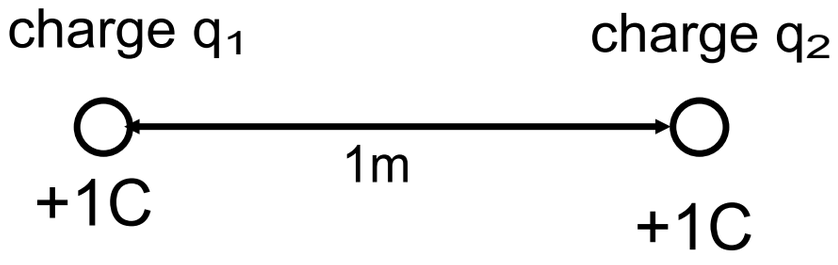
k_e is called Coulomb's constant or the electric force constant or electrostatic constant. It is a value calculated in Electromagnetic theory from the speed of light, and two other constants.

Named for Charles Augustine de Coulomb (1736-1806)

You will learn more about how he came up with this relationship in other courses.

For now, regrettably I ask that you just accept that this is true, or check it out on line.

How Big is a Coulomb?



$$\vec{F}_e = k_e \frac{q_1 q_2}{r^2}$$

$$= 9 \times 10^9 \text{ N}$$

a) For a 50 kg person how much acceleration is needed to generate a force this big?

$$a = \frac{F}{m}$$

$$= \frac{9 \times 10^9 \text{ N}}{50 \text{ kg}}$$

$$= 1.8 \times 10^8 \text{ m/s}^2$$

Features of Electric Force

$$\vec{F}_e = \frac{k_e q_1 q_2}{r^2}$$

- if a charge doubles the force (E)will double
- If both charges double the force (E) will x4

Since q and E are directly proportional.

- If the distance doubles the force (E) will 1/4

Since $\vec{r}$ and $\vec{E}$ have an inverse square relationship.

The magnitude of the charge on a single electron $1e^- = 1.602 \times 10^{-19}$ C

Example Find the electric force F_e if two point charges, one +46 μC and the second - 30 μC are separated by a distance of 1.0 m.

-12.42 N

$$\vec{F}_e = \frac{k_e q_1 q_2}{r^2}$$

$q_1 = +46\,\mu C$

$q_2 = -30\,\mu C$

$r = 1.0\,m$

$k_e = 9 \times 10^9$

$= \frac{9 \times 10^9 (+46)(-30)}{1}$

$= -12.42\,N$

$\approx -10\,N$

μ - micro

$\rightarrow 1 \times 10^{-6}$

n - nano

$\rightarrow 1 \times 10^{-9}$

Note: the negative sign for a force tells us that it is an attractive force.

Electric Fields and Forces in 1 Dimension

We define the electric field strength as the force per unit charge. (Similar to gravitational field strength being defined as force per unit mass)

Electric field strength (on the test charge q) = Force / Unit Charge

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

$$F_e = Eq'$$

E = electric field strength on test charge q'

F_e = electric force acting on q'

q' = test charge in the field

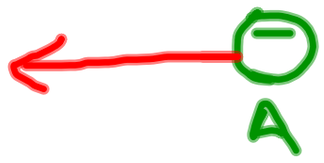
$$F_e = Eq' = \frac{k_e q_1 q_2}{r^2}$$

The direction of the electric field E depends on:

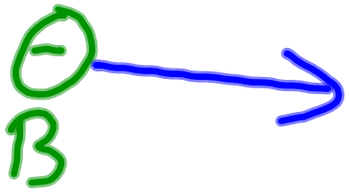
a) whether the two charges are alike (+ ve, + ve, or - ve,- ve

b) spatial orientation

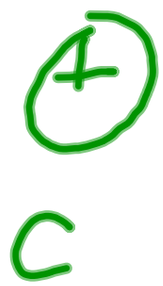
Force of B on A



Force of A on B



Force of D on C

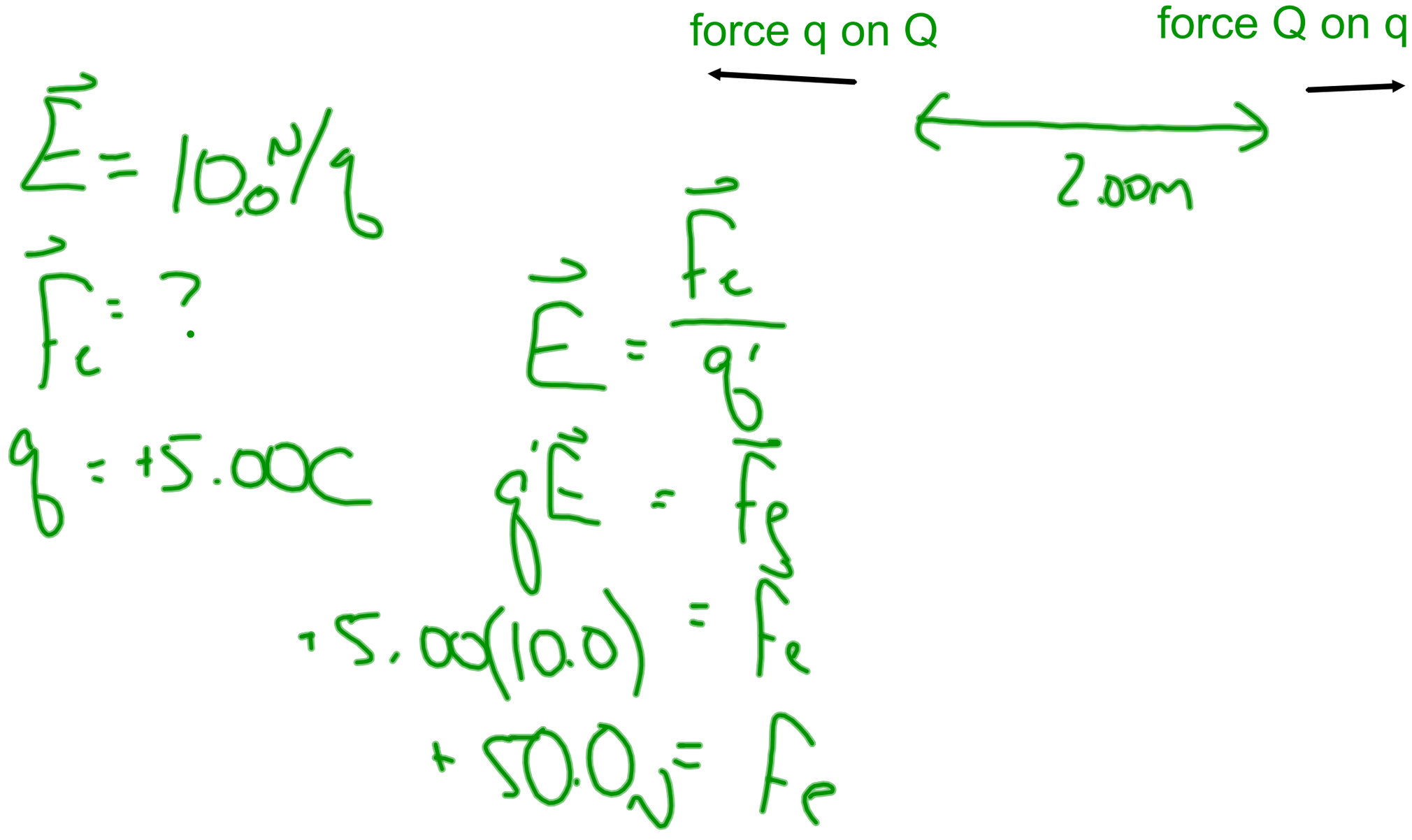


Force of C on D

Direction of the Force on a Charge by a Second Charge

- The direction of the force on a positive charge by a positive charge is away from the charge.
- The direction of the force on a negative charge by a negative charge is away from the charge.
- The direction of the force on a positive charge by a negative charge is toward the positive charge.
- The direction of the force on a negative charge by a positive charge is toward the positive charge.

Example: Find the electric force on a test charge of +5.00 C placed at a distance of 2.00 m to the right of a point (source) charge of +Q. The strength of the electric field at q is 10.0 N/C.



like charges imply force is away from +ve particle

Example: A +ve test charge of 4.0×10^{-5} C is places in an electric field. The force on it is +0.60 N acting at 10°. What is the magnitude and direction of the electric field at the location of the test charge? 1.5×10^4 N/C

$q' = 4.0 \times 10^{-5}$ C

$\vec{F}_e = 0.6\text{N}$ at 10°

$\vec{E} = ?$

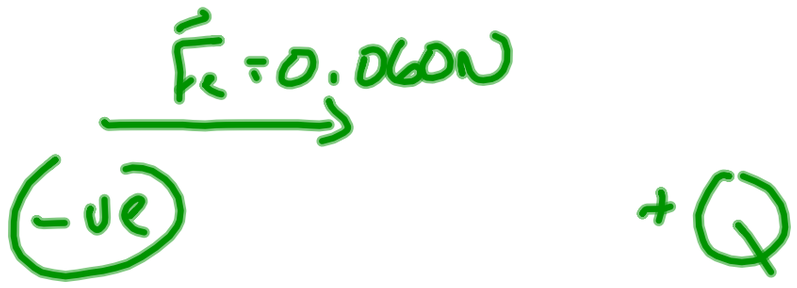
$$\vec{E} = \frac{\vec{F}_e}{q'}$$

$$= \frac{0.6\text{N}}{4.0 \times 10^{-5}\text{C}}$$

$$= 1.5 \times 10^4 \text{ N/C}$$

at 10°

Example 3: A -ve test charge of 2.0 x 10^{-8} C experiences a force of 0.060 N to the right in an electric field. What is the magnitude and direction of the electric field?



$q' = 2.0 \times 10^{-8} C$

$F_e = 0.060N$

$\vec{E} = ?$

$$\vec{E} = \frac{F_e}{q'}$$

$$= \frac{0.060N}{2.0 \times 10^{-8} C}$$

$$= 3 \times 10^6 N/C \text{ left}$$

Note: the -ve test charge is a trick twist since the sign rules that we use with a more standard +ve test charge are reversed.

Read Pages

12-13

Q 1-3 page 26

Assignment

Electric field Handouts A and B

page 29 questions 1-10

The physics Classroom(Electric Fields)