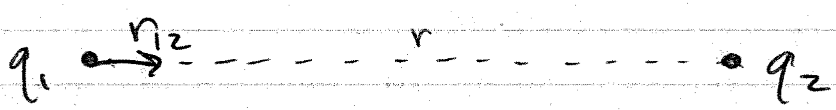
Lecture 5

5 SEP 2014

Review Coulomb's law,
work examples, charge quantization,
charge conservation

Recall Coulomb's law of electric force



$$\vec{F}_{12} = \frac{-k\cdot q_1\cdot q_2}{r^2}\,\vec{r}_{12}$$

&

$$\vec{F}_{21} = \frac{-k\cdot q_1\cdot q_2}{r^2}\,\vec{r}_{21}$$

opposites attract & "likes" repel

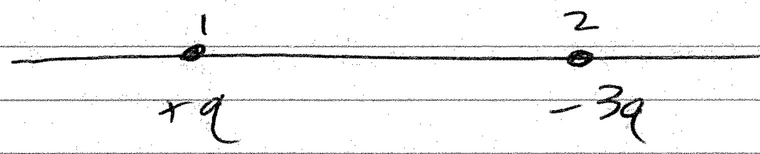
electric constant $\quad k = 8.99 \times 10^{9}\ N\cdot m^2/C^2$

q_1 & q_2 are charges of two point particles

Also see $k = \frac{1}{4\pi\varepsilon_0}$ where $\varepsilon_0 = 8.85\times10^{-1}$ $C^2/N\cdot m^2$

can use this to reason about the

QUESTION: 1st homework problem



Is it possible to place an electron (negative charge) some place to the left of both such that it is in equilibrium (i.e., net forces on it is ~~equal~~ equal to zero)

force on it due to 1 is attractive w/ magnitude $\frac{q}{r_1^2}$

→

force on it due to 2 is repulsive w/ magnitude $\frac{3q}{r_2^2}$

Since

$3q > q$ but $r_1 < r_2$

we can find a distance such that net force is zero.

Charge is Quantized

- this means that it comes in discrete "chunks"

e is the elementary charge equal to

$$e = 1.602 \times 10^{-19}\ C$$

- An important constant of nature

- This is the magnitude of charge for an electron $^{-e}$ or proton $^{+e}$

Any particle can have charge

$0, \pm e, \pm 2e, \pm 3e$, etc.

cannot have fractional charge that is detectable, such as $3.57e$

e is called the "quantum of charge"

you don't realize this unless you go to very small scales

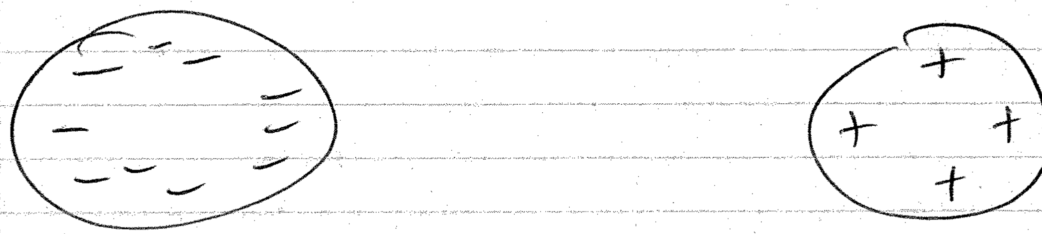
Charge conservation

- In any closed physical system, charge is conserved during any physical interaction between charged objects.
- charge is a constant of the motion

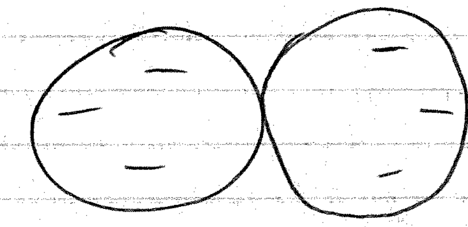
Example scenario:

Suppose we have two metal spheres one w/ charge $-50e$ & one w/ charge $+20e$

Let "−" be −5e + "+" be +5e



bring them into contact



change will spread uniformly on them + will be conserved so that total change is

$-50e + 20e = -30e$

Since the spheres are identical, the change distributes evenly + each has change −15e

(will return later to the question of when spheres have different sizes)

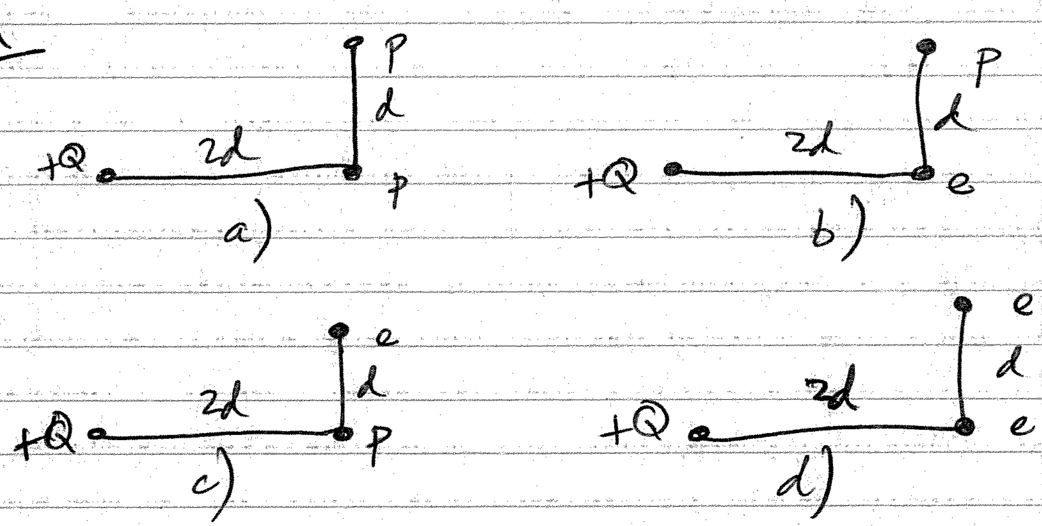
<u>electric current</u> is defined to be the rate at which charge passes through a given point

$$i = \frac{dq}{dt}$$

units are Amperes (will return to this)

More examples w/ Coulomb's law

Question



rank magnitudes of electric force

$$a = d > b = c$$

Interesting conundrum which requires some new physics outside the scope of this course:

Nucleus in an iron atom has a radius of $4.0 \times 10^{-15}\,m$ & has 26 protons.

What is the magnitude of electrostatic force between two of them?

$$F = \frac{k \cdot e \cdot e}{r^2} = \frac{8.99 \times 10^{9}\ N \cdot m^2/C^2}{(4.0 \times 10^{-15}\,m)^2}$$

$\overset{\leftarrow}{p}$ $\vec{p}$

$$\times \left(1.602 \times 10^{-19}\,C\right)^2$$

$$= 14\,N$$

small force for big objects but this is a gigantic force for protons

Why doesn't the nucleus just fly apart?

Is the attractive gravitational force strong enough to overcome this repulsion?

Let's see ...

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

Newton's law:

$$F = G \frac{m_p^2}{r^2}$$

$$= \frac{(6.67 \times 10^{-11}\ N \cdot m^2/kg^2)(1.67 \times 10^{-27}\ kg)^2}{(4.0 \times 10^{-15}\ m)^2}$$

$$= 1.2 \times 10^{-35}\ N$$

No way! This was a question that remained a mystery until the 1970s + discovery of strong nuclear force