Physics 142 - Lecture 2 - Sept. 6, 2005

Electric Fields

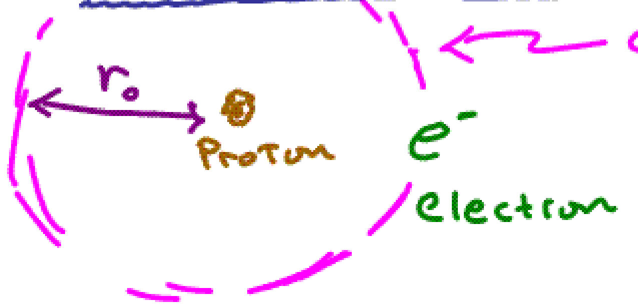
- Email List
- Workshop Signup issues
- Website Access formats okay?
- other course/org. issues?

Last time:

Coulomb's Law

$$\vec{F} = \frac{k\, q_1 q_2}{r^2}\,\hat{r}$$

H atom Example -



(a) $$\frac{F_{em}}{F_{grav}} = 2.3 \times 10^{39}$$

(b)

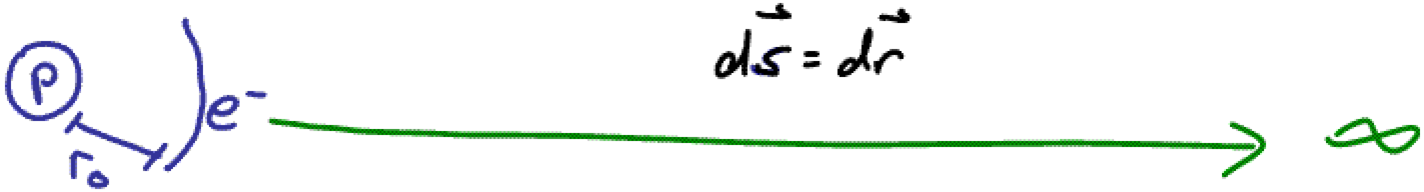
$$F_{centripetal} = F_{em} = \frac{m_e V_e^2}{r_0^2}$$

$$v_e = 2.2 \times 10^6 \ m/s$$

(c) How much energy does it take to ionize Hydrogen ?

$$\text{Energy} \sim \text{Work} = \int \vec{F} \cdot d\vec{s}$$

$$d\vec{s} = d\vec{r}$$



$$\text{Work} = \int_{r_0}^{\infty} dw = \int_{r_0}^{\infty} \vec{F}(r) \cdot dr = \int_{r_0}^{\infty} \left| \frac{k\, q_p q_e}{r^2} \right| dr$$

$$= |k\, q_p q_e| \int_{r_0}^{\infty} \frac{1}{r^2}\, dr = k\, q_p q_e \left[-\frac{1}{r} \right]_{r_0}^{\infty}$$

$$k\,e^2\left[-\cancel{\frac{1}{\infty}}^{\,0} + \frac{1}{r_0}\right] = \frac{ke^2}{r_0} = \frac{8.99\times10^{9}\,\frac{Nm^2}{C^2}\left(1.6\times10^{-19}C\right)^2}{5.29\times10^{-11}\,m}$$

$$|q_p| = |q_e| = e$$

$$W = 4.3\times10^{-18}\text{ Joules}$$

$$1\text{ Joule} = 6.2\times10^{18}\text{ electron-Volts} \equiv eV$$

$$4.3\times10^{-18}\,\cancel{J}\times\frac{6.2\times10^{18}\,eV}{1\,\cancel{J}} = 26.9\text{ eV}$$

e^- already has KE of Motion

$$E_{start} = \frac{1}{2}m_eV_e^2 = \frac{1}{2}\left(9.11\times10^{-31}kg\right)\left(2.2\times10^{6}\,m/s\right)^2$$

$$= 2.0\times10^{-18}\,J = 13.6\text{ eV}$$

Work I must do to remove e^-

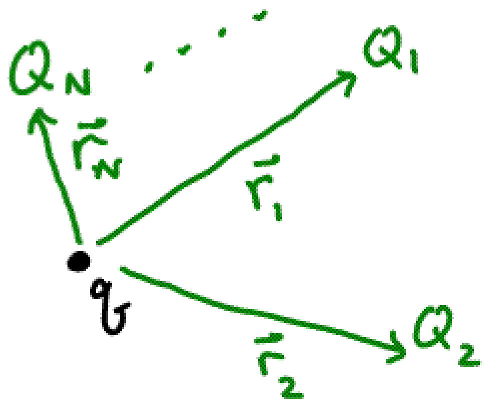
$$26.9\text{ eV} - 13.6\text{ eV} = \underline{13.3\text{ eV}}$$ close

True Ans ~ 13.6 eV

Multiple discrete charges

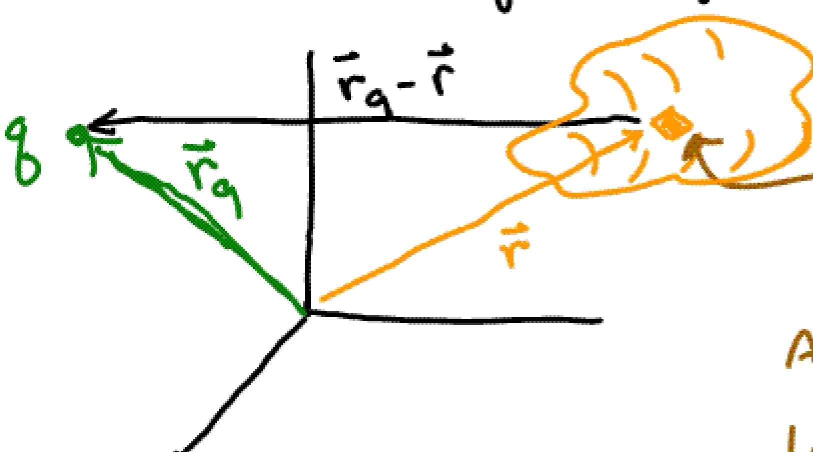
$\vec{F}$ is a vector

$$\vec{F}_{on\,q} = \vec{F}_{Q_1} + \vec{F}_{Q_2} + \dots + \vec{F}_{Q_N}$$



$$\vec{F}_{on\,q} = \frac{kQ_1 q}{r_1^2}\hat{r}_1 + \frac{kQ_2 q}{r_2^2}\hat{r}_2 + \dots + \frac{kQ_N q}{r_N^2}\hat{r}_N$$

Continuous Dist of charge



volume charge density

$$dQ = \rho(\vec{r})\,dV$$

Area $\quad dQ = \sigma\,da$

line $\quad dQ = \lambda\,ds$

$$d\vec{F}_q = \frac{k\,q\,dQ}{|\vec{r}_q - \vec{r}|^2}\,\widehat{(\vec{r}_q - \vec{r})}$$

$\rho\,dV$

$$\vec{F}_q = \int_{\text{vol of chg}} d\vec{F} = \int_{\text{vol}} \frac{k\,q\,dQ}{|\vec{r}_q - \vec{r}|^2}\,\widehat{(\vec{r}_q - \vec{r})}$$

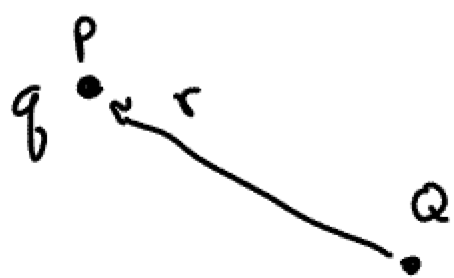
Vector and Square in denominator Make this Difficult to calculate often

Electric Field

$$\vec{F}_q = q\vec{E}$$

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

Electric Field



$$\vec{F}_q = \frac{k\,Q\,q}{r^2}\,\hat{r}$$

$$\vec{E} = \frac{k\,Q}{r^2}\,\hat{r}$$

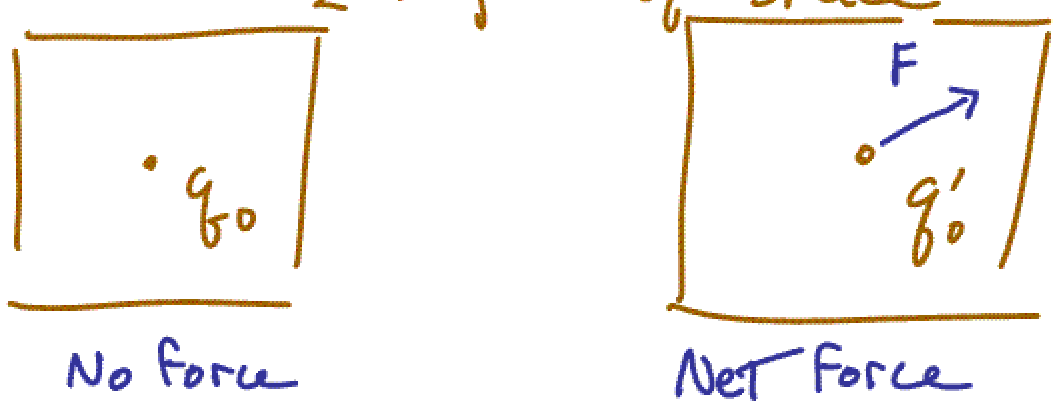
what motivates the field concept ?

After All the calculation for $\vec{E}$ is Not any easier than that for $\vec{F}$.

1) divides out magnitude and sign of test charge at point in space of interest

2) Divorces the "condition in space" creating the force from the charge distribution that creates it —

2 regions of space



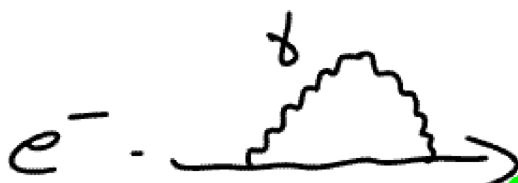
What is it that creates this force ?

What is the essence of the EM Force?

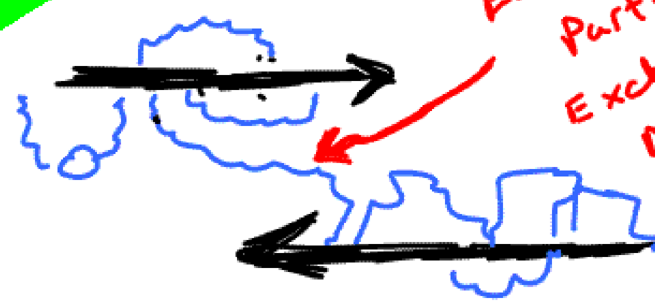
The field is a tool/invention ... but you learn to think of it as real in classical physics. The field causes the force. What is the essence of the field? I don't know...

Since I asked ... What is the modern view of the essence of the electromagnetic force?

$\Delta x \Delta p < h$ $\qquad$ $\boxed{\Delta E \Delta t < h}$



virtual particles



Exchange of virtual particle — Exchange of momentum. That's a Force!

Heisenberg's Uncertainty Principle

Can break conservation of Energy so long as we do it for a very short (unobservable) length of time.

In modern quantum field theory, the exchange of virtual particles existing through Heisenberg's loophole in energy conservation gives rise to forces.

The characteristics of the force are due to the detailed nature of the virtual particle that is exchanged.

For the Electromagnetic force the exchanged particle is a virtual photon.