E.F. Deveney / BSC Physics PH438: Lect Electrostatics Intro

Note Title 10/17/2004

Start: $\vec{F}_{Lorentz} = q\vec{E} + q\vec{v}\times\vec{B}$ = Force on charged particle in external $\vec{E}$ & $\vec{B}$ fields.

Electrostatics: $\frac{\partial}{\partial t}$'s $= 0$ .... kind of.

We will insist that

individual charges, q be @ rest

so $\frac{\partial X_q}{\partial t} = 0$

and 2, q's aren't being created or destroyed, $\frac{\partial \rho}{\partial t} = 0$

So — Easy, when just discussing $\vec{E}$ fields

But, How can it be when (LATER) talk about 'Magnetostatics' after all $\vec{B}$ are sourced from moving charges = current? Answer: magnetostatics $\Rightarrow$'s $\frac{\partial I}{\partial t} = 0$ ie steady-state current?

again, start, $\vec{F}_L = q\vec{E} + q\vec{v} \times \vec{B}$

Why start w/ Force?

Well, Newton did, kind of Historical

Much Later, start w/

Lagrangian, $L = T - U$, based on

Energy! More Fundamental than Force!

$\psi^* \psi$ = psi or particle field

make 1.) $\mathcal{L}$ symmetric

2.) global → local

introduce guage fields

= Force Carries

up to you to think

Forshadowing will cause even we forget about Forces in a moment & instead only care about Electric & magnetic Fields

& of Course all of Newton's Law's Contained in Euler-Lagrange

Newton: $\vec{F} = m\vec{a}$

E-L. $\frac{\partial L}{\partial q} - \frac{\partial}{\partial t}\frac{\partial L}{\partial \dot{q}} = 0$

$\sim \nabla U - \frac{\partial}{\partial t}\frac{\partial T}{\partial \text{veloc}} = 0$

where $\nabla U = \vec{F}_{conservative}$ (All Forces are)

$\&\ \frac{\partial}{\partial t}\frac{\partial T}{\partial \dot{q}} \sim \vec{a}$

So Newton $\vec{F} = m\vec{a}$

E-L $\nabla U - \vec{a} = 0$

or $\vec{F} = m\vec{a}$

So: we get used to starting w

$\sum \vec{F}_{orces}$

But for more sophisticated

Start w/ Lagrangian!

to get
1.) The Forces Themselves
2.) all The equations of motion

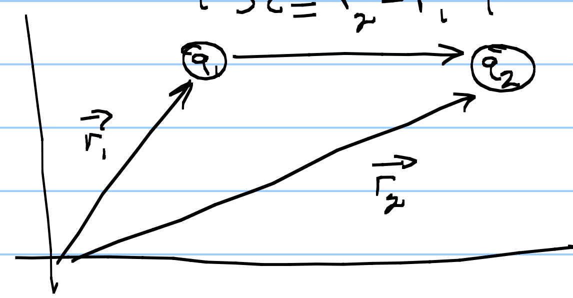
* SEE GRIFFITHS
Introduct to Elementary Particles.

Electrostatics:

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

$\vec{F}$ Coulomb on 2 from 1 :

$| \vec{\mathscr{r}} \equiv \vec{r}_2 - \vec{r}_1 |$



$$= \frac{K q_1 q_2}{|\mathscr{r}|^2} \hat{\mathscr{r}}$$

Note: 1.) $\vec{F}$ 'along' $\hat{\mathscr{r}}$ connecting 1 to 2 (ie source to field pt)

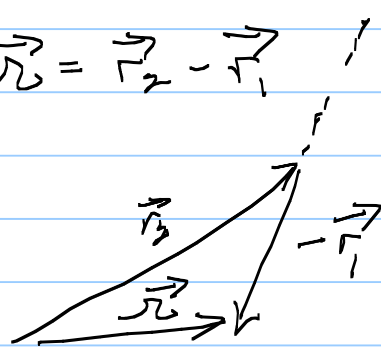
if $q_1 = q_2$; repel

q_1 opp q_2 ; attract

* Gravity oddly enough less complex, always attractive and qualitatively of same classic form

YET No Quantum gravity (yet)

2.) $\vec{\mathscr{r}} = \vec{r}_2 - \vec{r}_1$



$$\vec{F}_c = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \hat{r}$$

3.) Units ....

SI ⇒ $\underbrace{\text{MKS}}_{\text{mechanical}}$, charge , $\frac{1}{4\pi\varepsilon_0}$

1.) length, m
2.) mass, kg
3.) time, s

Coulomb
$1e^- = 1.6 \times 10^{-19} C$
Based on magnetic Force between 2-current carrying wire

How to do this Better ?

and
$\text{Amp} \equiv \frac{\text{charge}}{\text{time}}$

So Amp came 1^{st}

& ∴ Charge = (Amp)(time)

need

Gaussian:

SI ⇒ cgs , (esu electrostatic unit) , 1

cm
gram
sec

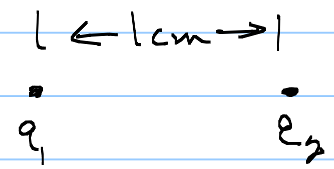
Such that

$$\therefore \quad \vec{F}_c = \frac{q_1 q_2}{r^2} \hat{r}$$

} define charge this way to get rid of nasty constants

in particular,
it is defined ....

cgs, so $\vec{F} = g\,\frac{cm}{s^2} = \text{dyne}$



$$1\ \text{dyne} = (1)\,\frac{q^2}{1\,cm^2}$$

or

$$q = \sqrt{\text{dyne}\ cm^2} = \left(\sqrt{\text{dyne}}\right) cm$$
$$= \text{statcoulomb}$$

Why?

Regular SI units (w $\frac{1}{4\pi\varepsilon_0}$) use for comparing to experiment because all experiment DONE in SI units.

But, to investigate theory, its the 'form' of the equations so constants don't matter.

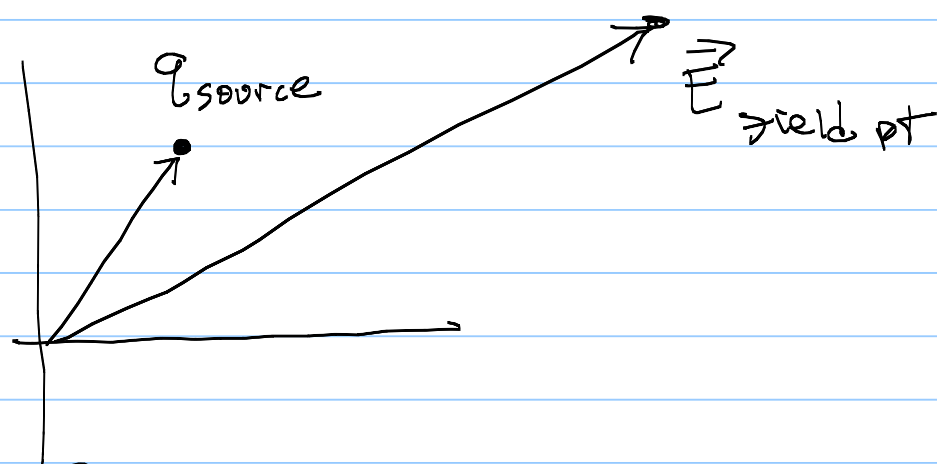
Ultimately, theorist use natural units: $c = \hbar = 1$ } see Griffiths Intro Elem Particles

4.) Ultimately, $\vec{F}_c = \frac{k q_1 q_2}{r^2}\hat{r}$

to $\vec{F}_{Lorentz} = q\vec{E}(\vec{r})$

what we are really interested is Electric Field, $\vec{E}$, obviously w/ units

$$\frac{\text{Force}}{\text{unit charge}} = \frac{N}{C}$$

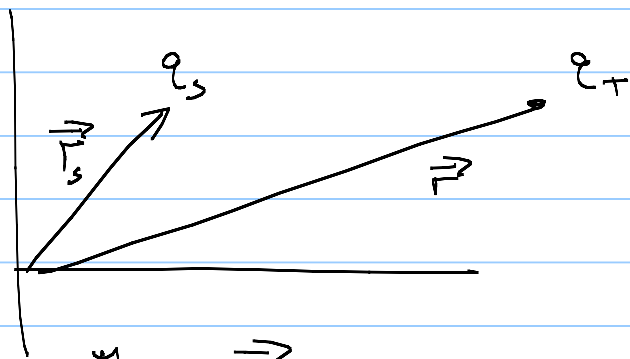


why? Ultimately want to consider the "Attribute" of an Electric field due to the source itself.

It has nothing to do with, say, a Test charge ($q_{Test} = q_2$)

That could be anything

so



Then $\vec{F}_{\substack{\text{on } q_{Test} \\ \text{due to} \\ q_{source}}} = \dfrac{K q_s q_T}{|\mathfrak{r}|^2}\,\hat{\mathfrak{r}}$

Now IS $q_{TEST} = +1$ Coulomb then

$$\frac{\vec{F}_{\substack{q_T \\ \text{due to} \\ q_s}}}{\underbrace{(q_T = 1C)}} = \frac{K q_s}{|\mathfrak{r}|^2}\,\hat{\mathfrak{r}}$$

$\vec{E}(\vec{r})$ due to q_{source} alone cause dividing by $(+1)$ which doesn't change anything $= \dfrac{K q_s}{|\mathfrak{r}|^2}\,\hat{\mathfrak{r}}$

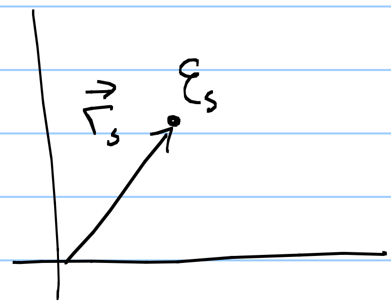
where $\hat{\mathfrak{r}} = \vec{r} - \vec{r}_s$

$\vec{r}$ = Field position

$\vec{r}_s$ = source position

Thus we can talk about the

$\vec{E}$ field of the source @ any $\vec{r}$

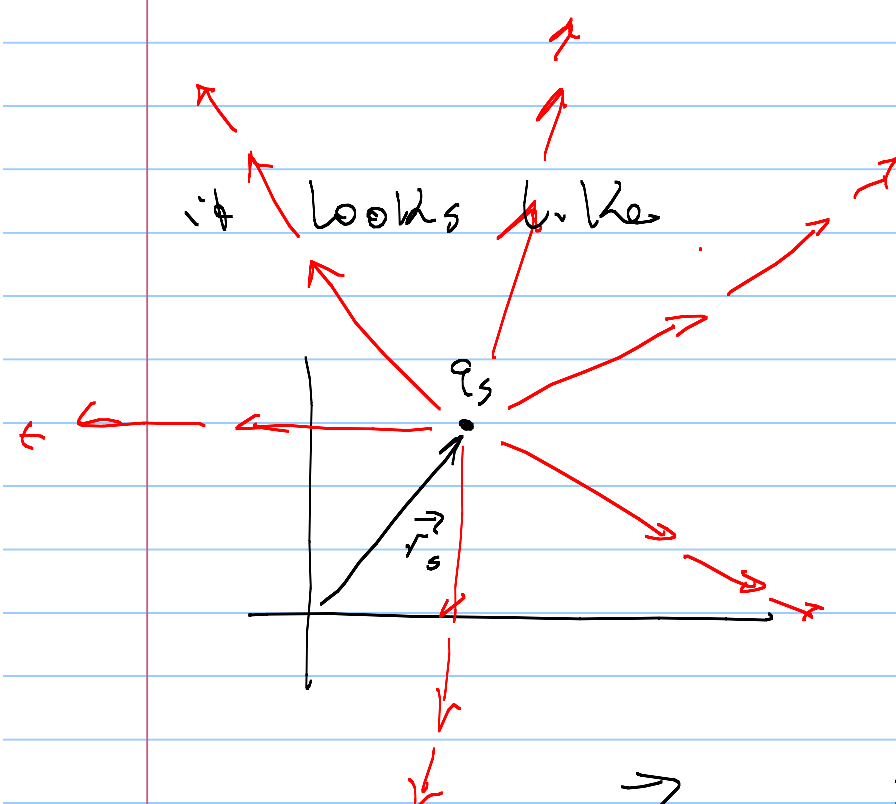


$\vec{E}(\vec{r})$ @ any $\vec{r}$ due to q_s

$$= k \frac{q_s}{|\vec{\mathscr{r}}|^2} \hat{\mathscr{r}}$$

Since it is a vector field, for $\vec{\mathscr{r}} = \vec{r} - \vec{r}_s$ that goes like $\frac{1}{|\mathscr{r}|^2} \hat{\mathscr{r}}$

it looks like



Then if you want ...

$\vec{F}$ on a charge, q, @ $\vec{r}$ in field due to q_s is

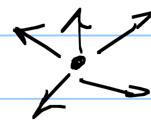
$$\vec{F}_{\substack{\text{on } q \text{ due to} \\ q_s}} = q\vec{E}(\vec{r}) = q\left(\frac{1}{4\pi\varepsilon_0} \frac{q_s}{|\mathscr{r}|^2} \hat{\mathscr{r}}\right)$$

Same thing!

OK so now we have the idea,

q_{source} make $\vec{E}$ fields.

just like mass 'make' gravitational fields



BIG ?'s now

static for q @ rest what we are considering

1.) Are $\vec{E}$ fields 'Instantenous'? For example, if I make antiparticles ...

NOPE! $\vec{E}$ spread out, like g-fields @ C

speed of Light

2.) If you move a ~~charge~~ accelerate charge, what happens?

Answer, The 'Kink' in the $\vec{E}$ field propagates @ C as well and Looks Like a real

Self propagating E & M wave = photon

real tranverse photon

ie: Brem strulung = Braking radiation

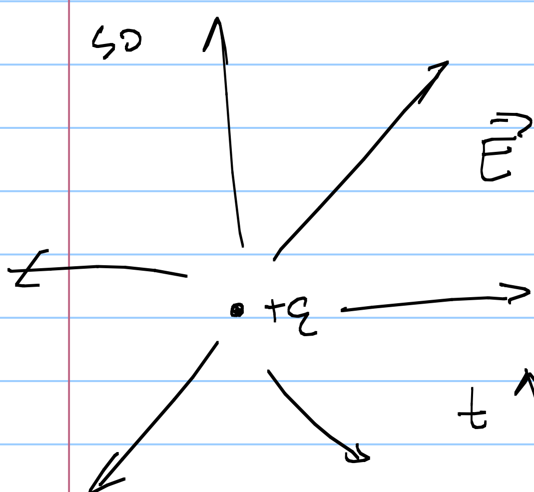
* Example: Wont Know if the Sun 'dies' until $\cong$ 8 minutes after it does

3.) OK, is the static $\vec{E}$-field real photons

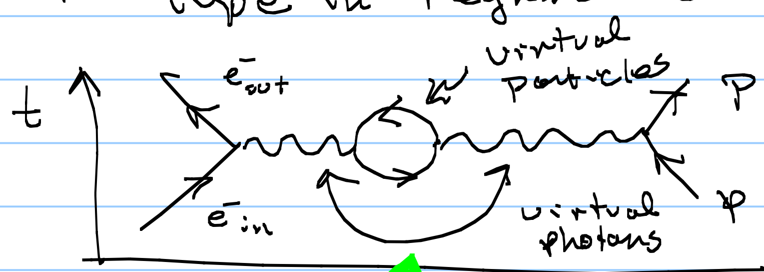
Answer: No.

Turns out that the gauge fields introduced to make global - local symmetry are of the 'virtual' type!
or
Longitudinal photons!

So



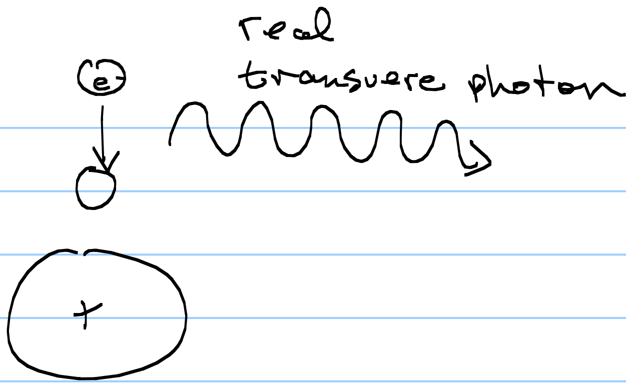
$\vec{E}$ due to virtual photons of the Loop - diagram type in Feynman diagrams

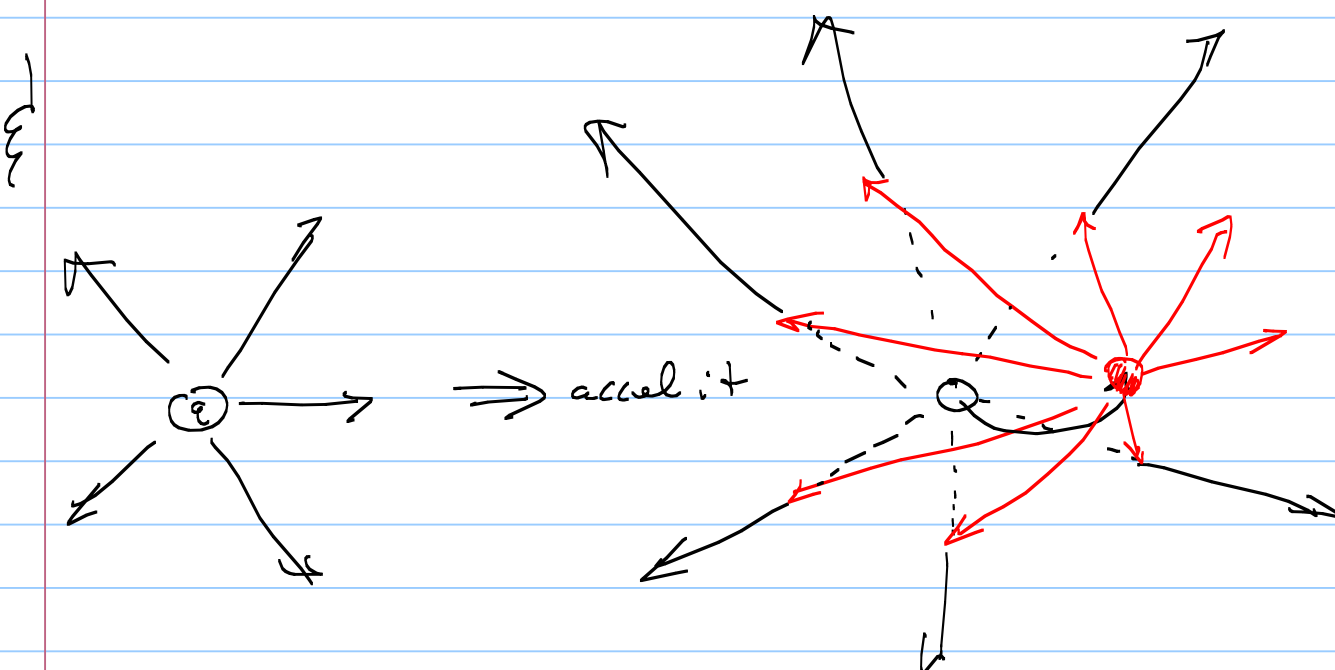


* ↓ in time ↑ = antiparticle moving forward

So these Virtual fields = $\vec{E}$ field! Between e^- & proton!

while





The kink looks like a
real transverse photon too!

I've seen this interpret