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

Electrostatics: \( \frac{dE}{dt} = 0 \) ... Kind of.

We will insist that

individual charges, \( q \) be @ rest

so \( \frac{dX_q}{dt} = 0 \)

and 2, \( E \)'s not being created or destroyed \( \frac{dE}{dt} = 0 \)

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

But how can it be when (LATER) talk about

'dynamostatics' after all

\( \vec{B} \) are sourced from moving charges = current? Answer: magnetostatics \( \Rightarrow \) is \( \frac{dI}{dt} \) or steady-state current?
again, start, \( F = q E + q \mathbf{v} \times \mathbf{B} \)

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!

For shadowing we will cause about Forces in general, instead of moment & instead only care about Electric & Magnetic Fields

\( \psi \Psi = \psi \bar{\psi} \) on particle fields

make \( B \) symmetric

d) global \( \rightarrow \) local

Introduce Gauge Fields = Force Carries

\( \nabla \Phi = \text{psi on particle fields} \)

Up to you to think

\( \psi \Phi \psi = \psi \bar{\psi} \) on particle fields

\( \nabla \Phi = \text{psi on particle fields} \)

\( E - L \cdot \frac{\partial}{\partial t} - \frac{\partial}{\partial x} \frac{\partial}{\partial x} = 0 \)

\( \nabla U - \nabla \Phi = 0 \)

Of course all of Newton’s laws contained in Euler-Lagrange

\( \text{Newton} \) \( F = m \mathbf{a} \)

\( E - L \cdot \frac{\partial}{\partial t} - \frac{\partial}{\partial x} \frac{\partial}{\partial x} = 0 \)

\( \nabla U - \frac{\partial}{\partial x} \frac{\partial}{\partial t} = 0 \)
\[ \nabla U = \vec{F} \] for conservative (All Forces are)

\[ \frac{d}{dt} \frac{d\vec{r}}{dt} = \vec{a} \]

So Newton \[ \vec{F} = ma \]

\[ E = \nabla U - \vec{a} = 0 \]

or \[ \vec{F} = ma \]

So: we get used to starting \( \Sigma \) \[ \sum \vec{F}_{\text{forces}} \]

But for more sophisticated

Start w/ Lagrangian!

To get
1) The Forces Themselves
2) all The questions of Motion

\* SEE GRIFFITHS

Intro to Elementary Particles.
Electrostatics:

\[ F = q \cdot E \]

**Coulomb**

\[ \vec{F} = \frac{k \cdot q_1 \cdot q_2}{|\vec{r}|^2} \]

**Note:**

1. \( \vec{F} \) along \( \vec{r} \) connecting 1 to 2.
2. \( q_1 = q_2 \); repel
3. \( q_1 \) and \( q_2 \); attract

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

**Yet no Quantum gravity (yet)**
3. Units...

\[ F = \frac{1}{4\pi \varepsilon_0} \frac{Q_1 Q_2}{r^2} \]

SI $\Rightarrow$ MKS $\Rightarrow$ charge $\Rightarrow$ time

Length, m
Mass, kg
Time, s

Coulombs

\[ e^- = 1.6 \times 10^{-19} \text{ C} \]

Based on magnetic force between 2-current carrying wire

and

\[ A \text{mp} = \frac{\text{charge}}{\text{time}} \]

So Ampere 1st

\[ \frac{\text{charge}}{\text{time}} \]

Charge = (Amp)(time)

Gaussian:

SI $\Rightarrow$ CGS $\Rightarrow$ (cgs, electrostatic unit) $\Rightarrow$ 1

\[ \text{cm} \text{ gram sec} \]

Such that

\[ \varepsilon_0 \]

Define change this way to get rid of nasty constants
In particular, it is defined... 

\[ 1 \text{ dyne} = (1) \frac{\text{cm}^2}{1\text{cm}^2} \]

or

\[ q = \sqrt{\text{dyne cm}^2} = (\text{dyne}) \text{ cm} \]

= stat coulomb

Why?

Regular SI units (with \( \frac{1}{\text{cm}^2} \)) are used for comparing to experiment because all experiments are done in SI units.

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

Ultimately, the chemist use natural units: \( c = h = 1 \) for particles.

See Griffiths" Intro Elect particles.
4) Ultimately, \( \vec{F}_c = \frac{kQq}{r^2} \)

\[ \Rightarrow \vec{E}_{\text{Lorentz}} = \frac{q\vec{E}(r)}{c} \]

What we are really interested in is the Electric Field \( \vec{E} \), obviously in SI units.

\[ \text{Force per unit charge} = \frac{N}{C} \]

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 \( (Q_{\text{test}} = q) \).
That could be anything

\[ \vec{F}_{\text{on}} = \frac{k e_s e_T}{r^2} \]

due to

\( q_{\text{source}} \)

New IS \( q_{\text{test}} = +1 \) Coulomb thus

\[ \vec{F}_{\text{on}} \]

due to \( q_{\text{source}} \)

\[ \frac{k e_s}{r_s} = \frac{k e_s}{\sqrt{v^2 + l^2}} \]

(\( q_{\text{in}} = +e \))

\[ \vec{E}(\vec{r}) = \frac{k e_s}{\sqrt{v^2 + l^2}} \]

due to \( q_{\text{source}} \)

alone cause dividing by (+1) \[ \vec{r} = \text{Field position} \]

which doesn't change any thing \[ \vec{r}_s = \text{source position} \]
Thus we can talk about the

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

\[ \vec{E}(\vec{r}) \] @ any \( \vec{r} \) due to \( q_5 \)

\[ \frac{1}{4 \pi \varepsilon_0} \frac{q_5}{|\vec{r}|^2} \]

Since it is a vector field, \( \vec{\mathbf{J}} = \vec{\mathbf{E}} - \vec{\mathbf{E}}_0 \)

That goes like

\[ \frac{1}{1.51^2} \]

it looks like:

Then is you want...

\( \vec{F} \)

For a charge, \( q_5 \)

outside in field due to \( q_5 \) is

\[ \vec{F}_{\text{on}} = \vec{q} \vec{E}(\vec{r}) = \vec{q} \left( \frac{1}{4 \pi \varepsilon_0} \frac{q_5}{|\vec{r}|^2} \right) \]

\( \varepsilon \) due to \( q_5 \) some thing!
OK so now we have the idea, E source make E fields, just like mass make gravitational fields, static for E & rest what we are considering.

1) Are E fields instantaneous? For example, is E made anti-particles ...

Note! E spread out, like g-fields @ C.

2) If you move a charge, what happens? Light

Answer: The 'kink' in the E field propagates @ C as well and looks like a real self propagating E&M wave = \{ real transverse \}

\[ \text{ie: Bremsstrahlung } = \text{Braking radiation} \]

* Example: Don't know if the Sun 'dies' until \( \equiv 8 \) minutes after it does.

3) OK, is the static E-field real photons
Answer: No.

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

So

\[ \mathbb{F} \text{ due to virtual photons} \]

of the loop - diagram type in Feynman diagrams

So these virtual fields = \( \mathbb{E} \) field!
Between e\(^-\) & a proton!

while
The think looks like a real transverse photon too!

I've seen this interpret

But is

catch your $\gamma$s

$u \leftrightarrow v$ your photons $\Rightarrow \text{miss}$