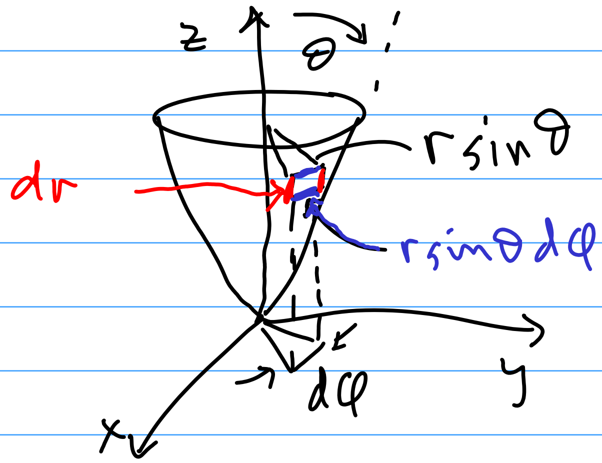
Lecture 15

Shadowitz: 4-2 capacitance, 4-3 electrostatic energy

Add 5 points to all exams for the last part of the last problem.

InkSurvey:

$$d\vec{a} = r\sin\theta\, dr\, d\varphi\, \hat{\theta}$$



$$\text{Area} = \int_0^{2\pi}\int_0^{s} r\sin\theta\, dr\, d\varphi = \frac{s^2}{2}\, 2\pi \sin\theta$$

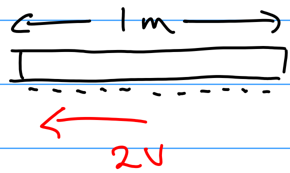
What's the flux of E for a point charge at the origin through this cone?

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{(x^2+y^2+z^2)^{3/2}}(x\hat{x}+y\hat{y}+z\hat{z}) = \frac{1}{4\pi\epsilon_0}\frac{1}{r^2}\hat{r}$$

$$\vec{E}\cdot d\vec{a} = \frac{1}{4\pi\epsilon_0}\frac{1}{r^2}\hat{r}\cdot r\sin\theta\, dr\, d\varphi\, \hat{\theta}$$

InkSurvey:

$$\lambda_0 = \frac{1000\, e}{1\, m}$$



$$L = L_0\sqrt{1 - v^2/c^2}$$

Muddiest point question: how does velocity affect Q (causal/creative)?.

What does charge invariance mean (informational)?

How do we know this (informational)?

ANS: Q is the same in all frames. Invariance means it doesn't change as viewed from different reference frames. If the electron in an atom, which moves at a much different speed from the proton had its charge dependent on speed then the light emitted from atoms would be much more difficult to model.

$$\lambda = \frac{1000q}{L_0\sqrt{1-\left(\frac{2v}{c}\right)^2}} \simeq \frac{1000q}{L_0}\left(1 + \frac{1}{2}\left(\frac{2v}{c}\right)^2 + \dots\right)$$

$\uparrow \lambda_0$

The moving ruler has a higher charge density than a stationary charged ruler.

Muddiest points:

-Why do I ask for questions and why not ask for specific types of questions?

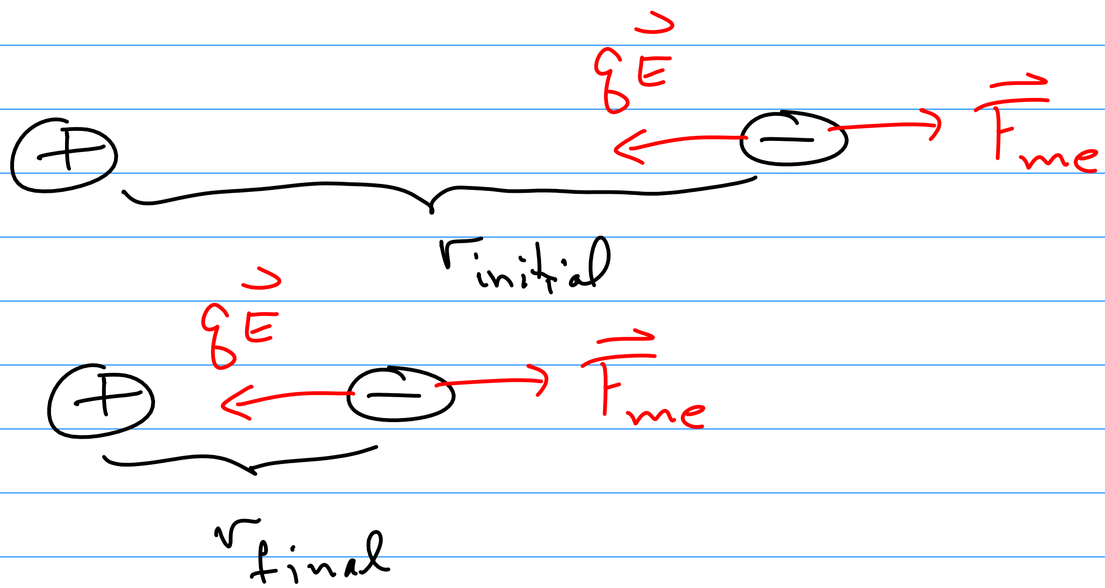
Normally I give you answers before you have asked any questions. Why would you care about such an answer?

-How are B and E related?

We will soon get to Faraday's law and the displacement current which relates these.

-What does negative work done by me mean?

It says that you have to exert a force to the charges to keep them from coming together.

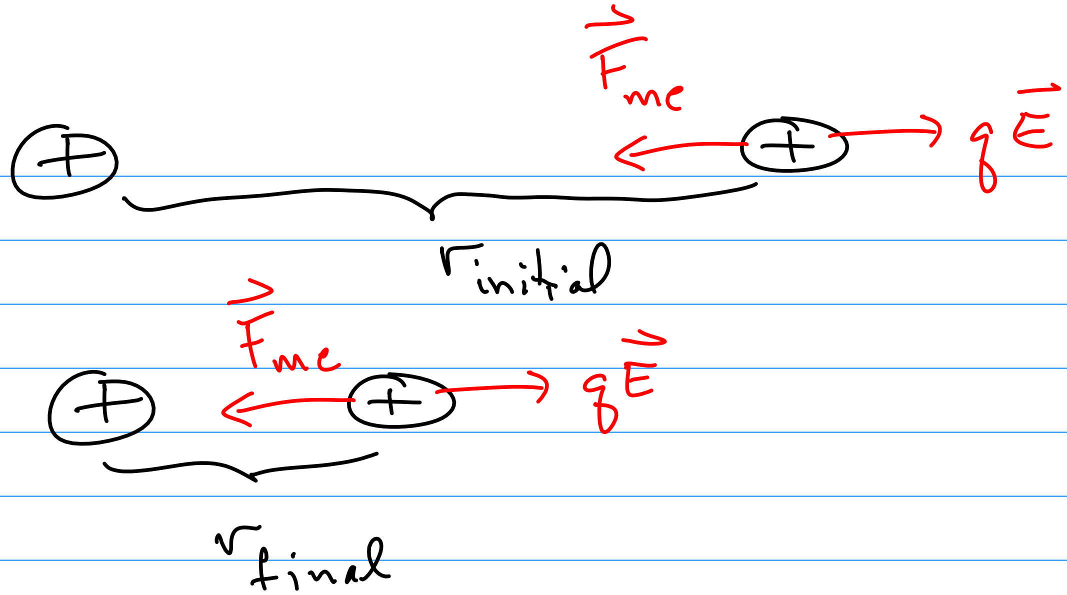


$$W_{me} = \int_{r_{int}}^{r_{final}} \vec{F}_{me} \cdot d\vec{r}$$

Assume $|\vec{F}_{me}| = $ constant

$F_{me}(r_{final} - r_{initial})$

W_{me} is neg if $r_{final} < r_{initial}$



If the force I exert is in the direction of motion the work I do is positive. I have to push the charges together and I can get that work out when they are released.

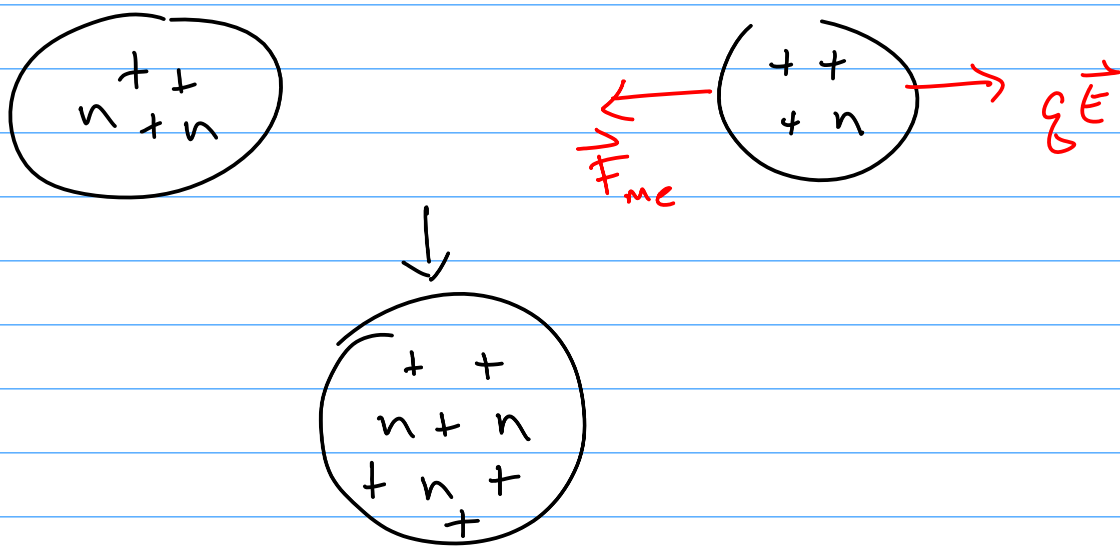
$$W_{me} = \Delta PE = PE_f - PE_i > 0 \Rightarrow PE_f > PE_i$$

-you put NaCl and take it apart and get zero net work. So what?

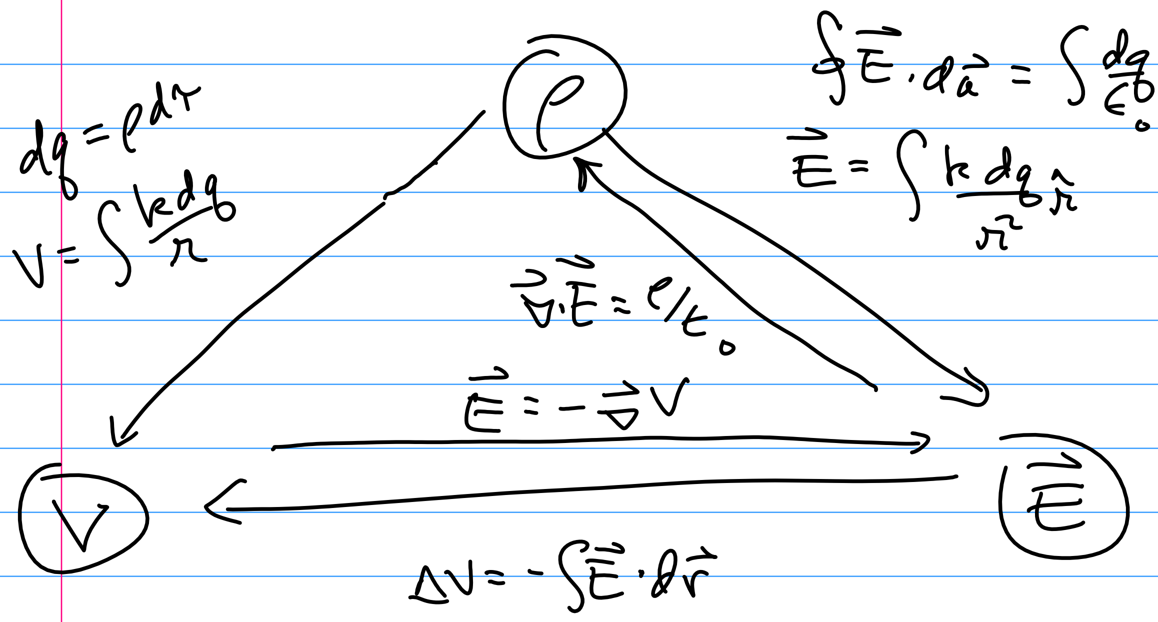
If you want to make a new material the first question to answer is its stability energetically.

-Why do charges stay together if it requires energy?

Here is an example in nuclear physics. Two nuclei are brought close enough so the nuclear force binds them into a larger nucleous. When they fission (a neutron splits them) they release their electrostatic potential energy. This is where the energy for a nuclear reator comes from.



- Where are we going?



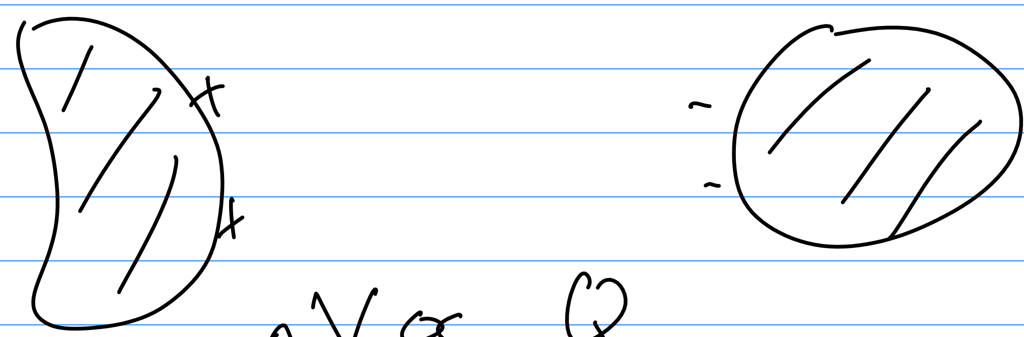
$$\vec{F} = q\vec{E}$$

$$W_{me} = \int V \, dq = \Delta PE \qquad W_{nc} = \Delta(KE + PE)$$

Questions?

Muddiest point: Explain more on V dq build up of a charge distribution.

two conductors



$$\Delta V \propto Q$$

$$\Delta V = \frac{Q}{C} \qquad C = \frac{Q}{\Delta V}$$

C is the capacitance

To bring in the first dq requires no work since V present is zero.

$$W_{me} = \int V\,dq = \int_0^{Q_f} \frac{q}{C}\,dq = \frac{1}{C}\frac{1}{2}Q_f^2$$

$$= \frac{1}{2}\frac{1}{C}(C\Delta V)^2 = \frac{1}{2}C\Delta V^2$$

Example: charging a capacitor and discharging it through a watermellon.

http://www.youtube.com/watch?v=gj1pkyCL75E

Questions:

incongruous: How did they fake this? Did they put dynamite in the mellon?

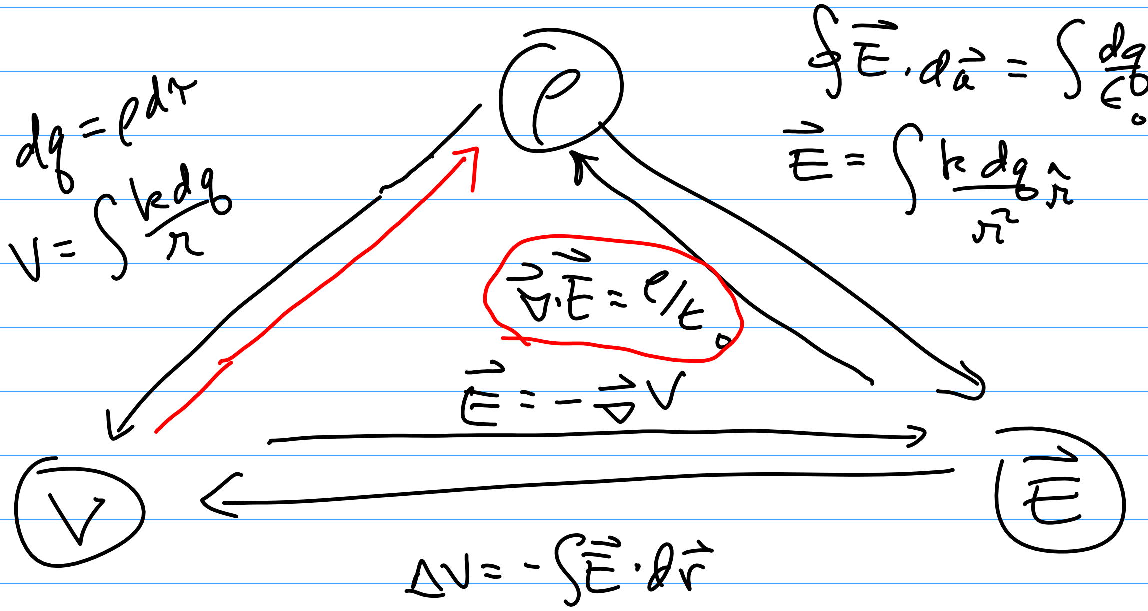
congruous: How do I calculate the effect knowing the energy stored in the caps?

modifying: Would the same thing happen to a balloon of water?

generalizing/analogy: How similar is this process to that using dynamite?
How would this differ if a high energy laser hit the watermellon?

causal/creative: Is the reason for the explosion vaporizing water due to the transfer of electrical energy into heat energy?

informational: How much energy was stored in the caps before discharge?
How can I estimate the KE of the bits after the explosion?
How far did the bits fly away?



$$\vec{\nabla}\cdot\vec{E} = \rho/\epsilon_0$$

$$\vec{\nabla}\cdot(-\vec{\nabla} V) = -\nabla^2 V$$

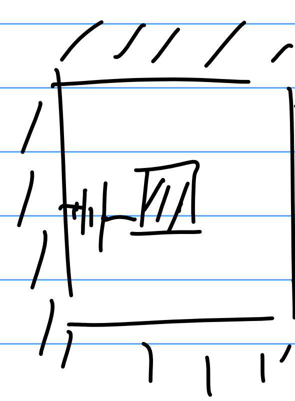
$$\nabla^2 V = -\rho/\epsilon_0$$

given V find ρ

$$\left(\hat{x}\frac{\partial}{\partial x} + \hat{y}\frac{\partial}{\partial y} + \hat{z}\frac{\partial}{\partial z}\right)\cdot\left(\hat{x}\frac{\partial}{\partial x}V + \hat{y}\frac{\partial}{\partial y}V + \hat{z}\frac{\partial}{\partial z}V\right)$$

$$= \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2}$$

In free space $\rho = 0$ $\quad \nabla^2 V = 0$



1-D

$$\frac{d^2 V}{dx^2} = 0$$