

Re: Capacitor and Force

Source: <http://sci.tech-archive.net/Archive/sci.electronics.design/2007-10/msg02433.html>

- *From:* "Jon Slaughter" <Jon_Slaughter@xxxxxxxxxxx>
 - *Date:* Sat, 13 Oct 2007 17:15:03 -0500
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"Tom Bruhns" <k7itm@xxxxxxx> wrote in message
<news:1192302494.605177.301750@xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx>

On Oct 13, 5:12 am, "Jon Slaughter" <Jon_Slaugh...@xxxxxxxxxxx> wrote:

"The Phantom" <phan...@xxxxxxx> wrote in message

<news:pad0h3df4mvk2fdl348gaf36g70e7slcma@xxxxxxxxxxx>

On Fri, 12 Oct 2007 22:48:59 GMT, "Jon Slaughter"
<Jon_Slaugh...@xxxxxxxxxxx> wrote:

Heres the problem, due to John Perry.

My assumption about ceramic caps was wrong. I didn't know it was layered.

Since one has layers the charge is distributed between each layer.

Suppose there are $2n$ interleaved layers and charge Q . Then each layer has charge Q/n . Every layer experiences a force between every other but almost all cancel out.

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By assuming all the charge Q was on just one plate separated by a distance

r

was wrong (Which is how just 2 plates would actually work).

Some initial investigation shows that the layers have a significant effect in reducing the force. Not only is the charge on each plate reduced by Q/n but the distance between the first and last is increased because of all the layers in between. So treating a ceramic cap as a parallel plate cap is wrong as I did it. (using CV to get the charge and assuming it was on each plate because it should be Q/n but I have no idea what n is).

So there are forces there but they are much smaller than what I was thinking. For a very large parallel plate cap one has $C = \epsilon A/d$, $Q = C*V$,
 $F = k*(Q/d)^2 = k*(\epsilon A/d*V/d)^2 = k*(\epsilon A*V/d^2)^2$.

You seem particularly resistant to the notion that you are using the wrong formula to compute the force between the plates of a parallel plate capacitor. The formula for the force between point charges won't give the correct result. You have to divide the plates up into little $dx dy$ pieces,

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with each having the appropriate little bit of the total charge
on a
plate,
and integrate the force between each little bit of charge on
one plate
and
all the little bits on the other plate. See:

Yes I am resistant because the formula applies to this situation. I might
be
making some mistake in applying it but that is a totally different story
from using the wrong formula.

I know you can use calculus for the general case and that can be done but
it
shouldn't result in any significant different in this case (because of the
large degree of symmetry) and actually my result *should* be a lower
bound
since I don't take into account any forces acting at an angle.

http://web.utk.edu/~kamyshko/P231/Problem_HW_Chapter24_Force_Between...

and:

<http://mysite.du.edu/~jcalvert/phys/caps.htm>

The second reference goes through the integration necessary,
and even
gives
an example of plates of dimensions 10 cm X 10 cm and 1
mm spacing
charged
to 300 volts. Their calculated force is .00398 newtons (398
dynes).

Using your formula $k \cdot (e \cdot A \cdot V / d^2)^2$ and plugging in their
numbers:

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$$k = 8.988E9$$

$$e = 8.854E-12$$

$$A = 10\text{cm} * 10\text{cm} = .01 \text{ m}^2$$

$$V = 300$$

$$d = 1\text{mm} = .001 \text{ m}$$

we get 6.34 newtons, considerably more than the .00398 newtons they got.

I do not know why the results are so significantly different. Obviously the formula I wrote above doesn't come out with any reasonable answer and is several orders of magnitude off. (it should actually be lower) I either there is a factor wrong or something else is wrong. The logic itself should work just fine and its exactly the logic that site uses except I do not worry about charges that are not directly across from any other.

I think that is my problem though. I'm computing Q^2 which gives the interaction force between every pair of charges but doesn't take into account the angle at which the forces act so its treating it as a if the force is always constant for every particle pair. So actually I'm guessing what I should have is $k*(Q/A)*(Q/A)/d^2*A$ (as an approximation.. dimensions are wrong of course)

in this case I get about 0.006N for the example above. So the real problem, like a few have mentioned is that its wrong to assume that all the charge is concentrated at a point because when I do this I'm basically saying the force is the same over a all charge pairs when its definitely not. By realizing that the force is really only that strong for one pair and then gets drastically weaker(which for my approximation I just say its 0) I

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get a
much more reasonable approximation. But in this case it should be lower
and
its still higher ;/

I'll work on it some more and see if I can still apply the coulombs law
or
not. I do think it can be used as a first approximation but it needs to
be
used properly instead of blindly like I did. (Actually my result works
well
if the distance between the plates is much larger than the size instead
of
vice versa).

Thanks,
Jon

Jon, please consider this simple example; perhaps then you will see
why Phantom's explanation is right on. Consider two point charges,
let's say equal magnitude and opposite polarity, separated by a
distance x . They are attracted with force F . If I have another
identical pair, they will also be attracted by F . So if the two pairs
are at a distance from each other much greater than x , the total force
will be $2*f$. But if I bring them together, so the like charges are at
the same points, the force will be 2^2 or 4 times as much. OK? It
really DOES matter how in space the charges are distributed.

I never said it didn't matter. But I am approximating. Even the full blown
volume integrals are not exact. Its a matter of how accurate one wants and
I was just trying to estimate the result. The problem is that I was
calculating the force between all charge "pairs" which is Q^2 but this is
wrong because its more like Q^2/A . So my estimation was flawed and not the
fact that I can't assume they are concentrated at a point. Its just that
when I do that I should have realized what I was doing which was essentially
making the interacting force the same for all charged particle pairs(this is
not true for plates... just take the opposite corner of the opposite plate).

1 2
* *
* *
* *
* *
* *
* *
* 3

if 1 and 2 are the particles that we are trying to find the force on then
its simply Coulombs force. But with 1 and 3 its also coulombs force but the

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component in orthogonal to the plate is very small... I did not take this into account in my approximation. Essentially what I did was treat the force between 1 and 3 as the same as 1 and 2... hence the grossly over approximation. Bu only looking at the forces between directly opposite charges(like 1 and 2) then its much closer and should be a lower bound.

e.g.,

1 2
3 4
5 6
7 8

and compute the forces between 1 2, 3 4, 5 6, etc.. and add them up. In this case since they are all the same(because of the approximation) its really just as if they were point charges but we have $k*(Q/A)^2/r^2 = \text{force between 1 and 2}$. Now adding all the forces on one plate is same as multiplying by A so that its $k*Q^2/A/r^2$.

This of course assumes all forces that are at angles, like 1 4, 1 6, 1 8, etc.. are 0. This is not the case but for small d most of the orthogonal components are very small.

As Phantom says, the SAME is true for gravitational attraction; two massive plates separated by x where x is small compared with the extent of the plates will not be attracted with the same force as two point masses separated by x.

Hmm, so what your saying is that the force of gravity due to the earth, i.e., $m*g$, is wrong?

What your saying is that any time someone wanted to calculate there weight they would have to compute a volume integral?

This is simply not true. We assume the earth as a point mass and compute its force.

e.g.,

$$F = G*mE*m/r^2 = m*a \implies g = G*mE/r^2$$

which works

$$\begin{aligned} mE &= 5.97*10^{24} \text{ kg,} \\ G &= 6.67*10^{-11} \\ r &= 6.356*10^6 \end{aligned}$$

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and gives $g = 9.8 \text{ m/s}^2$

So assuming points isn't a wrong idea as you and phantom are trying to make it out to be. The problem is that it needs to be applied correctly which I didn't do. There's nothing wrong with assuming point charges for a first approximation though... don't know why you guys are trying to make it out to be bad.

Again though, if you think computing two nested volume integrals is fun then by all means go ahead and do it. I'll be waiting for your result.

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