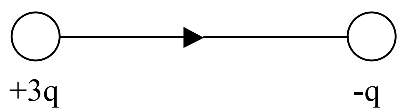
Phys 3310, HW #2, Due in class Wed Jan 23. In general, we will try to grade homeworks for clarity of explanation as well as for mere "correctness of final answer".
Lettered parts count roughly equally)

Q1. VECTOR CALCULUS PROOFS
Griffiths 1.60, parts a and d. (You may *assume* part c is correct without proof, when working on part d.)
Note: these kinds of proofs are very formal, it's hard at this stage to "see the physics", but you'll find it's helpful to get comfortable with the divergence theorem (and later Stokes theorem) in this kind of way: this is also part and parcel of E&M. (And, these sorts of formal theorems will come in useful as tools *later in the course.)*

Q2. ANGLE BETWEEN SUSPENDED CHARGES
Two charges of identical mass *m,* one with charge *q*, the other with charge 2*q,* hang from strings of length *l* from a common point. Assume *q* is sufficiently weak so that any angle you're looking for is very small, and find an approximate expression for the angle θ each charge makes with respect to the vertical. Check (show us!) that the units work out, and that the limiting behavior for large mass, large length, and/or small q are at least sensible.

Q3. TWO CHARGES
a) Sketch the field lines for the configuration of charges shown below. I drew one to get you started. Make sure that you are consistent with the number of field lines that you attach to each charge. Think about what the field should look like (how many field lines there should be) far away from the charges.



b) In the previous question, assume the +3q charge is located at x = −D and the -q is located at x = +D. What is a *fourth order* approximation to the electric field **E**(0,y,0) for points far away, but on the y axis, i.e. |y| >> D? ("fourth order" means expanding in some small quantity, then in the end keeping only terms out to (small thing)^4)
For what values of y does your series converge?
For what values of y is your approximation a good one?
Check (show us!) that the units of your answer are correct, that the direction of your E field makes sense, and that the limiting behavior (y -> infinity) makes sense.
Note: Approximating (in a problem when we have the exact answer!) may seem a little odd, but we'll find as we move on that this is often the only *way to practically solve ever more complex problems!*

(more on back)

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Q4. DISK OF CHARGE:
a) Find the electric field a distance R along the axis from a disc of radius R_0 and uniform charge density σ. [Hint: a disk can be thought of as a bunch of concentric rings. Can you first find the E field a distance R along the axis up from a thin ring of charge dq?]
b) Explicitly calculate the limiting forms of your solution at very small and at very large R (compared to R_0) and discuss.
Note: The disk of charge is an idealization of many physical devices: a capacitor plate, a small patch of any surface... Once you have solved this ideal *problem, you will be able to apply it (many times this term!) to more realistic situations.*

Q5. SPHERE OF CHARGE:
a) Find the electric field a distance z from the center of a spherical surface of radius R (Fig 2.11 in Griffiths) which carries a uniform surface charge density σ. Do this by explicit integration (i.e. starting from Griffiths Eq. 2.7), please.
You only need to treat the case $z>R$ (*outside* the sphere). Express your answer in terms of the total charge q on the sphere.
[Hint: Use the law of cosines to write $\mathscr{r}$ in terms of R and θ. I got an integral which I needed to look up - do you have access to tables, or Mathematica, or some other such tool? In the end, be careful if you get a square root to take the *positive* root:
$\sqrt{R^2+z^2-2Rz}=(R-z)$ if $R>z$, but it's $(z-R)$ if $R<z$].
b) Check your answer using knowledge from 1120 and intuition (briefly discuss - what *should* it be?) What would you expect the answer should be *inside* the sphere? Why?
c) Estimate the maximum charge you can put onto a child's balloon.
Note that estimation problems give you a lot of freedom. How big is a balloon? Why should there be a maximum at all? That's key: if the balloon sparks, it can bear no more charge. Can you look up the breakdown electric voltage of air somewhere?
*Your answer can be *very* rough, we only want an order of magnitude.*

Historical note: Newton solved part a using geometry (not calculus!!) This geometric proof is somewhat tricky and still excites debate: see R. Weinstock Am.J.Phys., 52, (1984), p. 883; H. Erlichson, Am.J.Phys.58, (1990) p. 882. R*eputedly, Newton thought calculus should be kept secret, and held up publication of Principia until he could work out these non-calculus proofs. He published calculus much later, about the same time as Leibniz published his calculus.*

Extra credit (worth half of any of the above, but *won't* count off if you don't do it)
Griffiths 2.10
Note: There is a trick that makes this easy and fun - think about it on your own awhile before asking someone for help! Think about Gauss' law.