MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Physics

8.02 **Fall 2007**

Please turn in your problem set at the entrance to the classroom labeled with your name and group (e.g. L01 6B). You will receive your group assignments at the beginning of class the day that this problem set is due

Problem Set 1

Due: Wednesday, September 12 at beginning of class (by 10:15/12:15)

Some notes about problem set problems:
1) All problems are graded out of 5 points, based on your display of your understanding of what is going on. You MUST show your work. Simply writing the answer will earn a score of 0 on that problem. The work must clearly show your understanding of the problem. Use some words and please write clearly so that the graders can read your writing.

2) Often problems will be very difficult. You should first try them by yourself but then work together with others and go to office hours to get more insight. At the end, though, make sure that the work you hand in is your own.

Warm Up
Every problem set will contain a couple of conceptual or straight forward analytic problems in order to ease you into the problem set

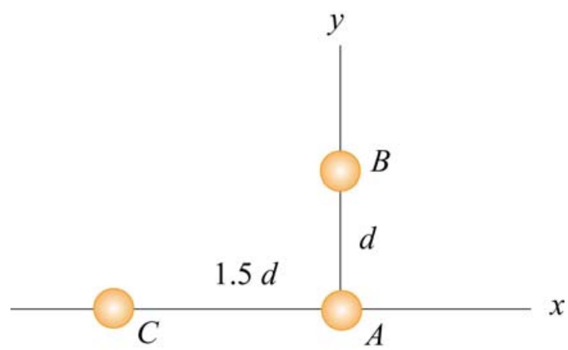
Problem 1: Two Vectors

Given two vectors, $\vec{\mathbf{A}} = (4\hat{\mathbf{i}} - 3\hat{\mathbf{j}} + 5\hat{\mathbf{k}})$ and $\vec{\mathbf{B}} = (7\hat{\mathbf{i}} + 4\hat{\mathbf{j}} + 4\hat{\mathbf{k}})$, evaluate the following:

(a) $2\vec{\mathbf{A}} + \vec{\mathbf{B}}$;
(b) $\vec{\mathbf{A}} - 3\vec{\mathbf{B}}$;
(c) $\vec{\mathbf{A}} \cdot \vec{\mathbf{B}}$;
(d) $\vec{\mathbf{A}} \times \vec{\mathbf{B}}$.
(e) What is the angle between $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$?
(f) Find a unit vector perpendicular to $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$.

Problem 2: Electrostatic Force

Consider three point charges (A, B, C) located as shown in figure at right (where d is 9.0 cm). A has positive charge 3.0 μC while B & C both have negative charge -1.0 μC. Calculate the resultant electric force on A. Be sure to specify both the magnitude and direction.

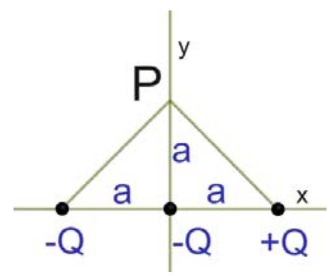


<u>Exam Problem</u>

Next, each problem set will typically include a problem that has either been used on a previous exam or is of the type that you should expect to see on an exam. I strongly encourage you to put away your notes and try to solve this problem the way you would in an exam situation.

Problem 3: Charges

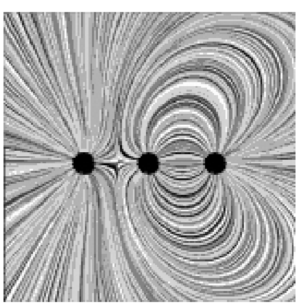
Three charges equal to $-Q$, $-Q$ and $+Q$ are located a distance a apart along the x axis (see sketch). The point P is located on the positive y-axis a distance a from the origin.

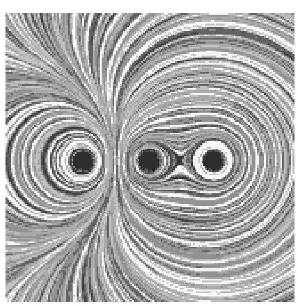


(a) What is the electric field $\vec{\mathbf{E}}$ at point P?

(b) The figures below show possible field lines for this problem. Of these figures:

_____ (enter one letter) is the correct field line representation for this problem


(a)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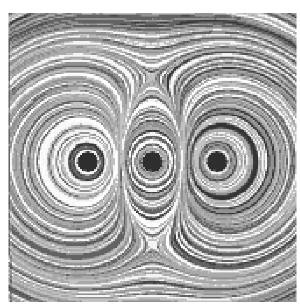
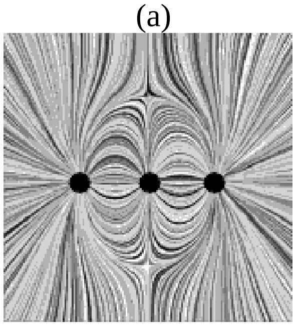
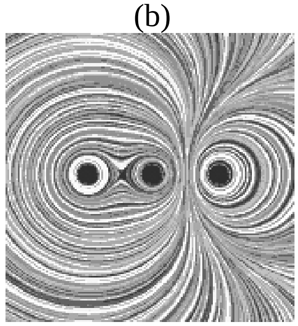
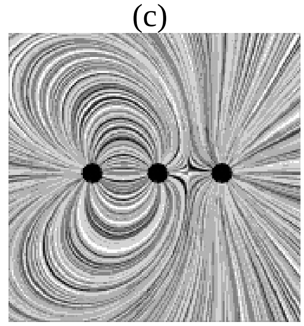

(c)


(d)


(e)


(f)

Approximations, Fermi Problems, Back of the Envelope Calculations…

Problem sets will contain some problems that require you to make numerical estimates in order to answer the questions. Of course, in the age of Google it will often be easy to find exact values for some items. Please at least try to make estimates before going that route if you must. Being able to make back of the envelope calculations and developing number intuition (i.e. is a numerical result at all reasonable?) are important parts of doing physics (as well as generically useful no matter what field you are in – that's why these are common job interview questions). Do **not** use calculators. Note that these types of problems will also appear on your exams so it is to your benefit to learn how to do these calculations without aid of Google or calculators. For an introduction to solving these types of problems I suggest at least the first chapter of an excellent book by Sanjoy Mahajan, now available online at :

http://www.inference.phy.cam.ac.uk/sanjoy/mit/book:01.pdf.

I'll add that for many people these can be the most difficult problems on the problem set (this week we'll just ease you in). They are often ill-defined and open ended, require synthesis of material we have covered in class with "common knowledge," and don't have an "exactly correct" answer. Of course, this is true of most of life. Don't bemoan it – enjoy it!

Problem 4: Got Pizza?

Just to start out, here's something that has nothing to do with physics but is kind of a classic Fermi problem (the original was "How many piano tuners in Chicago?"). How many square inches of pizza are eaten by the MIT student body per semester?

Problem 5: Charge Imbalance

We know that within the limits of measurement, the magnitudes of the negative charge on the electron and the positive charge on the proton are equal. Suppose, however, that these magnitudes differed from each other by as little as 0.0000001% (1 part in a billion). What would the force be between you and your neighbor in the TEAL classroom? Are you attracted or repelled by them? Using just this line of thought, what limit would you place on equality of electron and proton charge (e.g. 1 part in $10^{?}$)?

Now, take a break. You deserve it. And check out the electrostatic video game:
http://web.mit.edu/8.02T/www/802TEAL3D/visualizations/electrostatics/videogame/videogame.htm

Analytic Problems…

Finally, the type of problems you probably expected on an MIT physics problem set. These will tend to be a little more difficult than exam problems (and involve more math). There will usually be more than the two problems this week.

Problem 6: Polygon

Consider a 2N-sided regular polygon, centered on the origin, with each vertex a distance a away from the origin, one of which is located at (x, y) = (a, 0). A charge $+Q$ is placed at each of the 2N vertices. A charge q is placed at the origin.

(a) What is the force on the charge q at the origin?

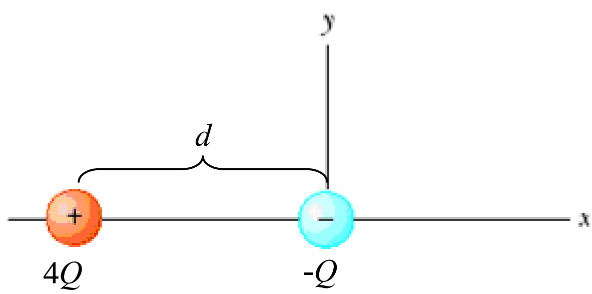
(b) Now remove the $+Q$ charge from the vertex located at (a, 0). Now what is the force on the charge q at the origin? (Don't forget: Force is a vector!)

(c) Now instead of a 2N-sided polygon, a 2N+1-sided polygon is used. Now what is the force on the charge q at the origin when $+Q$ charges are placed at all the vertices?

(d) Finally, the $+Q$ charge at (a, 0) is again removed. What now is the force on q?

Problem 7: Oscillating Charge

Two massless point charges $4Q$ and $-Q$ are fixed on the x-axis at x = $-d$ and x = 0.



(a) There is one point on the x-axis, x = x_0, where the electric field is zero. What is x_0?

(b) A third point charge q of mass m is free to move along the x-axis. What force does it feel if it is placed at x = x_0 (the location you just found)?

(c) Now q is displaced along the x-axis by a small distance a to the right. What sign of charge should q be so that it feels a force pulling it back to x = x_0?

(d) Show that if a is small compared to d ($a \ll d$) q will undergo simple harmonic motion. Determine the period of that motion. [NOTE: The motion of an object is simple harmonic if its acceleration is proportional to its position, but oppositely directed to the displacement from equilibrium. Mathematically, the equation of motion can be written as $d^2x/dt^2 = -\omega^2 x$, where ω is the angular frequency. See Review Module E for more detail. HINT: a/d is REALLY SMALL. Taylor expand]

(e) How fast will the charge q be moving when it is at the midpoint of its periodic motion?