

General Physics - E&M (PHY 1308) Lecture Notes

Homework002

SteveSekula, 1 February 2011 (created 26 August 2010)

no tags

Homework 2

Expectations for the quality of your handed-in homework are available at <http://www.physics.smu.edu/sekula/phy1308/homework.pdf>. Failure to meet these guidelines will result in loss of points as detailed in that document.

Reading Assignment:

Chapter 20.4-20.5, Chapter 22, (Skip Chapter 21)

Practice Problems:

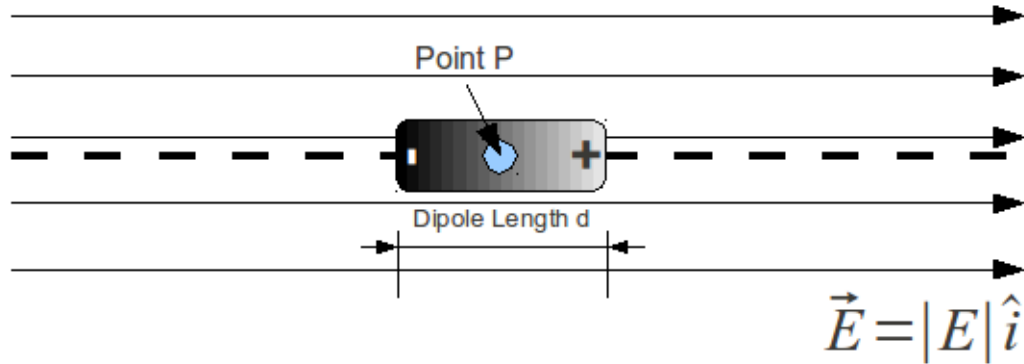
These are not required; they are odd-numbered problems from Wolfson that may help you to warm up for the required problems.

- CH20-51
 - CH22-17
 - CH22-21
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Required Problems:

- SS-5 [20 Points]
- SS-6 [20 Points]
- SS-7 [30 Points]
- OPTIONAL: Bonus Exam Points (see end of assignment)

Problem SS-5: The behavior of a dielectric material



As discussed in class, a *dielectric* material is an insulator whose molecules possess, or can be induced to possess, a dipole moment. Dielectrics are observed to weaken electric fields. Let us explore this.

1. Consider the picture below of a dipolar molecule immersed in a uniform electric field, $\vec{E} = |E|\hat{i}$. The dipole is oriented such that the positive end is in front of the negative end. Show that the uniform electric field has been weakened by the presence of the dipole; that is, at point P halfway between the ends of the dipole (see the drawing), demonstrate that the total electric field is weaker in strength than $|E|$.
2. Lightning and sparks occur because the electric potential between two points exceeds the dielectric breakdown point of air, which is about $30.0 \times 10^6 \text{V/m}$ (that is, if two points separated by a meter represent a change in potential of $30.0 \times 10^6 \text{V}$, then sparking can occur). If a stronger dielectric material than air is placed between those two same points, do you expect sparking to still occur? Explain and/or defend your answer.

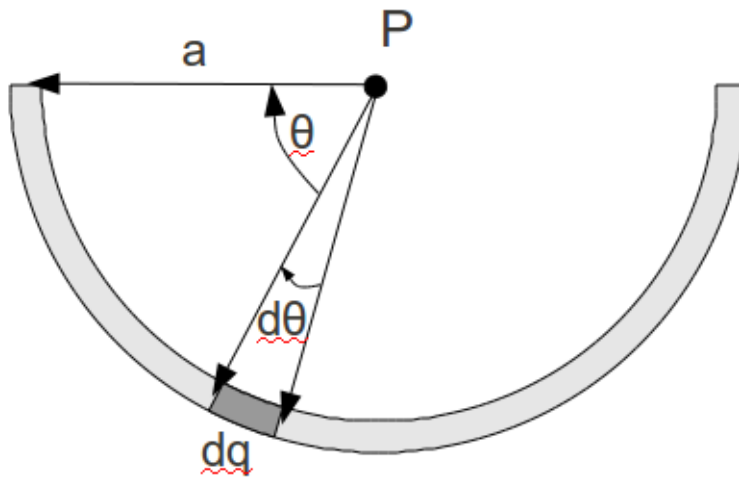
Problem SS-6: Photomultiplier tubes and the dynode

Phototubes are light detector devices that are critical components in medical imaging technology (for instance, in combination with light-sensitive crystals

in PET scanners. c.f. Johannes Czernin, Magnus Dahlbom, O. Ratib, and Christiaan Schiepers, "Atlas of PET/CT Imaging in Oncology", 2004). A key part of the phototube is a "dynode" - a small, cup-shaped piece of metal that is used to accelerate electrons (amplifying the signal) produced when photons strike the phototube.

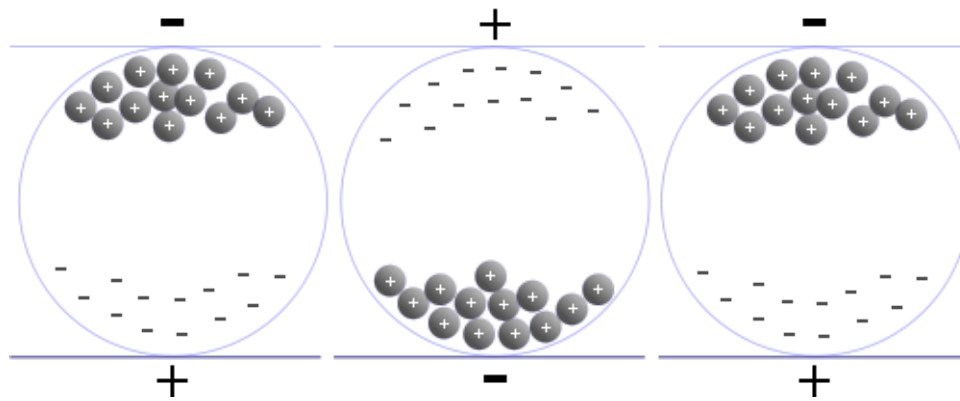
Consider such a cup, in two dimensions, as illustrated below. Treat it as a perfect semicircle of radius a whose center is located at point P . If the cup carries a total electric charge of Q distributed uniformly over its length, determine the electric field \vec{E} at the point P .

Hints: treat the cup as a series of small units of charge, dq (see illustration), and write dq in terms of the small unit of angle $d\theta$ subtended by the small unit of charge. It will be helpful to review the relationship between radius, angle, and arclength. Then integrate over $d\theta$ to obtain the net field at P .



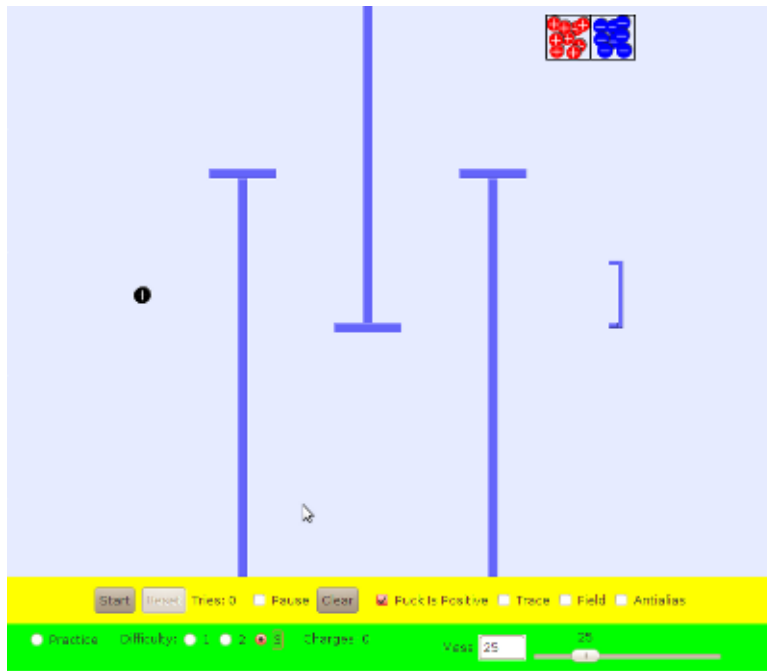
Problem SS-7: Electrophoretic Ink Displays

Electrophoretic ink, or *E-Ink*, is a technology that allows images to be formed on a flat surface simply through the application of weak electric fields (c.f. the Amazon Kindle, or the Barnes and Noble Nook). The electric fields, depending on whether they originate from areas of positive or negative charge, cause small droplets of white material (the actual "ink"), suspended in a dark oil, to drift closer to or further away the surface of the "paper" (see illustration below).



1. Consider one of these small droplets, a white one made from titanium dioxide. Model it as a point charge. It takes about 0.2 seconds for the page-turn to happen on an *E-Ink* based device. A "page-turn" corresponds to the movement of white particles closer or further away from the paper surface, as appropriate, to achieve the lettering on the new page. If each white droplet carries a charge of $-16e$, has a mass of $6.7 \times 10^{-15} \text{ kg}$, and has to cross a distance of $40.0 \mu\text{m}$ when going from the bottom to the top of the pixel, estimate the strength of the electric field to which the droplet is subjected. Assume that there are no collisions during the movement of a droplet.
2. Using your answer from the last question, determine the electric potential across each pixel. If you didn't obtain an answer to the previous question, assume that $\vec{E} = (-3.0\hat{i}) \text{ N/C}$, where \hat{i} is a unit vector pointing from the bottom of the pixel to the top (this is not the correct numerical answer to the previous question).
3. How much work is done in moving the droplet through the potential difference in the previous question? If you were unable to obtain a numerical answer, assume $V = 1.2 \times 10^{-4} \text{ N} \cdot \text{m/C}$ (this is not the numerical answer to the previous question).

Bonus Exam Points: Electric Field Hockey (Due Date: Feb. 11, 5 pm)



Welcome to your first opportunity for bonus points on an exam. Your job is simple: get the electrically charged puck in the game "Electric Field Hockey" (available from <http://phet.colorado.edu/en/simulation/electric-hockey>) from its starting point to the goal in the shortest time possible, using as few charges as possible, and keeping the puck on the gameboard. Results must be submitted electronically (see below) by 5pm on Friday, Feb. 11. *If you need access to a computer, please let the instructor know.*

Here are the rules:

Rules

1. You must do this on Level 3 of the game (click the "Level 3" radio button at the bottom of the game)
2. You must use the default puck settings (mass=25 and "puck is positive"). Don't change any of these settings.
3. You MUST keep the puck on the visible gameboard at all times.
4. You must put a movie of your performance up on YouTube and submit the link to the video as proof of your accomplishment. Tips on recording the game are given below. In the video, it must be clear how many charges were on the board (the game keeps count at the bottom of the window) and the time counter must also be clear in the video.

Scoring

- **If you produce a video showing that you guided the puck to the goal, you will obtain 5 extra points on the first in-class exam.**
- **If your time is less than 5.3 seconds, you get an additional 5 points.**
 - 5.3 seconds is the current record for this game, held by a previous classmate in PHY1308.
 - *Your time is calculated as follows: the time it takes to get the puck to the goal, PLUS 0.2 seconds for each charge on the board.*

Recording the Game

You need to record the game and make a movie, which you can then upload to [YouTube](#). Here are programs that let you easily record such a movie on different operating systems:

- Windows: [CamStudio](http://camstudio.org/) (<http://camstudio.org/>) - note, this records audio from your microphone, too, so if you don't want your voice in the movie make sure to disable audio recording.
- Mac: Copernicus (<http://www.danicsoft.com/software/copernicus/>)
- Linux: "Record My Desktop" (<http://recordmydesktop.sourceforge.net/about.php>)
- All platforms: record the screen with a cameraphone (have a friend help you).

I recommend you work on your layout of the charges for directing the puck. Once you have it setup the way you want, then click the "Reset" button one last time, start recording your desktop, and click the "Start" button in the game. Upload the video to [YouTube](#), and then send me the link to the video. If you're having trouble getting the video uploaded, let me know and we can arrange a dropoff on a thumbdrive, etc.

Strategy

Remember your basic knowledge about charge! Like charges repel, unlike charges attract. Charges exert a force on each other, accelerating the motion of the puck. You can speed up the puck by attracting it toward a location or repelling it from a location. Combinations of charges will be needed to keep the puck from touching the walls or flying off the board. If you'd like to see the path of the puck, turn on "Trace" (at the bottom of the game window)

Good luck, and have fun!