P114	University of Rochester	NAME Soln Key - SM
S. Manly	Spring 2006

Exam 1 (February 21, 2006)

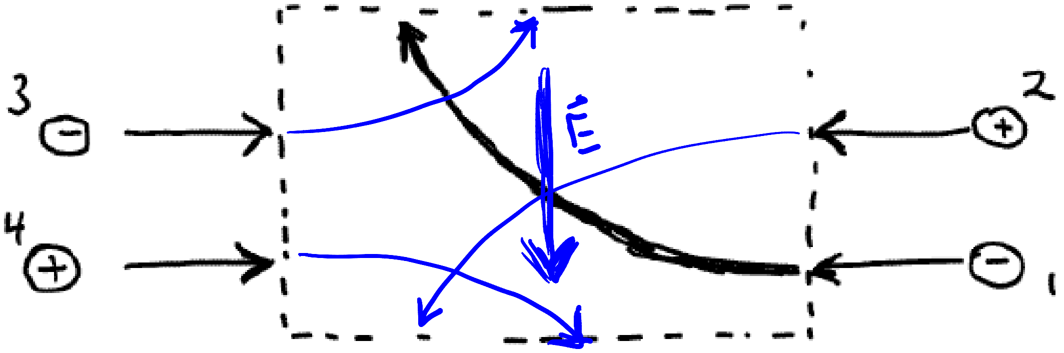
Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary. Show your work. Partial credit will be given.

Problem 1 (12 pts):

The figure below shows the path of a negatively charged particle (1) through a rectangular region of uniform electric field.

a) Indicate the direction of the electric field in the rectangular region on the drawing. Indicate to the right of the drawing why you have chosen the direction you chose for the electric field.

b) Roughly sketch the paths that would be taken by particles (2), (3) and (4) as they pass through the rectangular region.

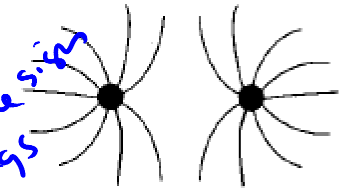


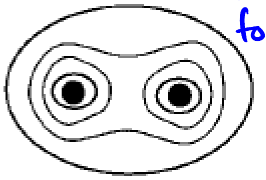
$\vec{E}$ is down (Toward bottom of paper) because $\vec{F} = q\vec{E}$ and q is negative. $\vec{E}$ down will give a constant force upward on particle ① as it traversed region

Problem 2 (12 pts):

Choose the diagram that corresponds to lines of constant potential around an electric dipole where the electric charges that make up the dipole are given by the positions of the large black dots. Justify your answer briefly to the right of the drawing.

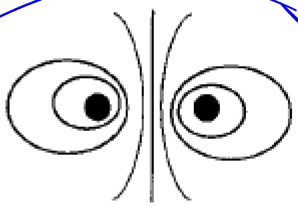
$\vec{E}$ of same sign chgs



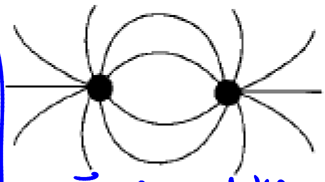


lines of equipotential for like sign charges

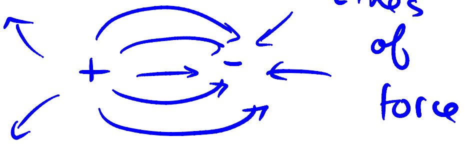
Electric dipole → unlike sign charges



lines of equipotential for unlike sign charges



$\vec{E}$ of unlike sign charges



Equipotential lines are ⊥ to the lines of force

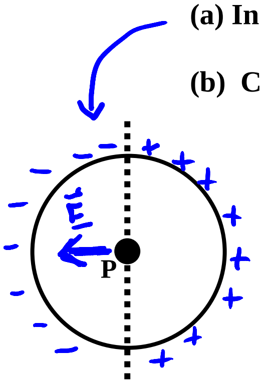
Also could say work moving charge in from ∞ against + charge of ring is exactly cancelled by work done against − charge that comes in with different sign

Problem 3 (12 pts):

A wire in the form of a circle of radius R lies in the plane of your paper. The half of the wire to the right of the dashed line carries a uniformly distributed positive charge. The half of the wire to the left of the dashed line carries a uniformly distributed negative charge which is the same in magnitude as the charge on the right side. The point P is at the center of the wire.

(a) Indicate on the sketch the direction of the electric field at point P.

(b) Calculate the electric potential at point P and justify your answer.



$\boxed{V_p = 0}$

Think of each bit of dq along wire as a discrete charge

$$V_p = \sum \frac{k\,dq}{R}$$

Each dq is same distance away and the amount of +dq = the Amount of −dq

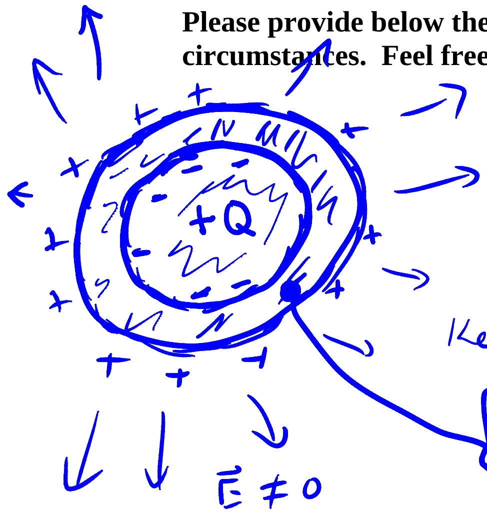
Problem 4 (14 pts):

After graduation you get a job at Sam's Discount Furniture and Electrical Engineering Emporium. Sam was very impressed with your smile and your deep understanding of electromagnetism, as well as your flare for polishing oak coffee tables. During your first day on the job, a customer comes in and buys a lovely couch for her living room. While the couch is being packed in preparation for delivery, your customer wants you to explain a little something about electrostatics that has bothered her for years. Your customer expresses her question as follows:

"Can I shield the world from an electric charge by using a conductor? I mean suppose there is a big charge sitting in space. If I surround this charge by a thick, uncharged, conducting shell, will it eliminate the electric field outside the shell?"

Please provide below the answer you would give your valued customer under these circumstances. Feel free to use diagrams or equations as necessary.

1)	/12
2)	/12
3)	/12
4)	/14
5)	/15
6)	/15
7)	/20
tot	/100



$\vec{E} = 0$ inside conductor

+Q inside cavity induces a charge of −Q on the inside of the conducting shell. This must happen to keep $\vec{E} = 0$ inside the conductor. This leaves a net positive charge of +Q on the outside of the conducting shell. So, $\vec{E}$ outside of the conducting shell is the same as that of a point charge of +Q

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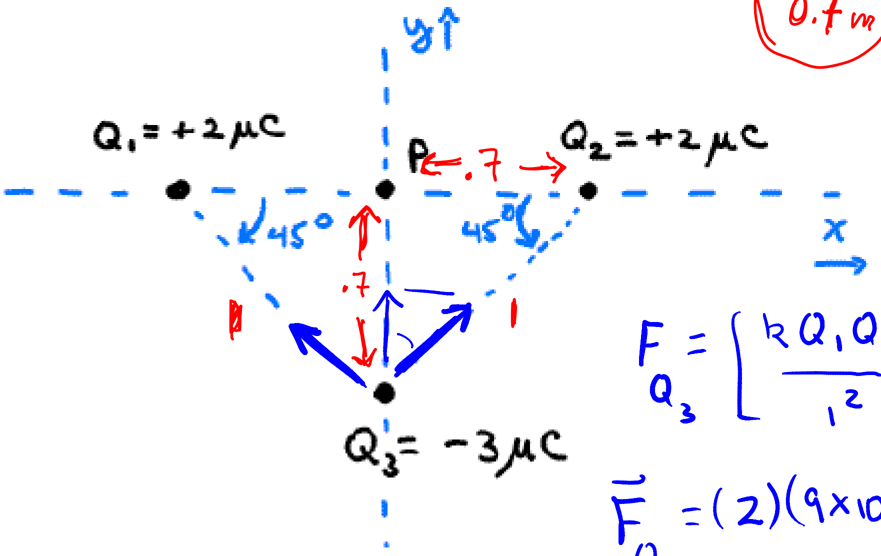
mistake on exam – students told during exam that this distance is 0.7m

Problem 5 (15 pts):

In the figure below, what electric charge can be placed at point P to insure that there is zero net electrostatic force on Q_3? Let the distance between Q_1 and Q_3 (as well as between Q_2 and Q_3) be 1 m. The distance between Q_3 and P is ~~1.4~~ m. (1 μC=10^{-6} C, k=9×10^9 Nm^2/C^2)

0.7 m



x components of F_{Q_1} and F_{Q_2} cancel.

Net force of Q_1 and Q_2 on Q_3 is

$$F_{Q_3} = \left[\frac{kQ_1Q_3}{1^2}\cos 45 + \frac{kQ_2Q_3}{1^2}\cos 45\right]\hat{y}$$

$$\vec{F}_{Q_3} = (2)(9\times10^9)(2\times10^{-6})(3\times10^{-6})\cos 45\ \hat{y}$$

charge at P must cancel this → $\vec{F}_{Q_3} = 0.076$ N upward

Q_p must be negative so its force on Q_3 is down

$$\frac{kQ_pQ_3}{(.7)^2} = .076$$

$|Q_p| = 1.4\ \mu C$

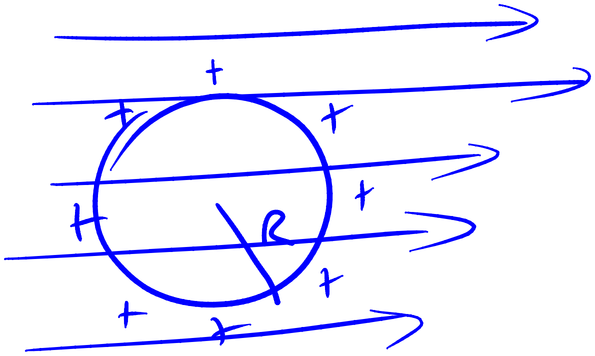
Q_p has negative electric charge

Problem 6 (15 pts):

A spherical, non-conducting, rubber balloon with radius R has a positive charge Q placed uniformly on its surface. The balloon is placed in a uniform electric field of 120 N/C. What is the net electric field inside the balloon? (Justify your answer)

* Magnitude of

$\vec{E} = 120$ N/C



$$\vec{E}_{\text{inside Balloon}} = \vec{E}_{\text{external}} + \vec{E}_{\text{balloon charge}}$$

$\vec{E}$ due to balloon charge is zero

So $\vec{E}_{\text{inside balloon}}$ is 120 N/coul

– same as external field

Problem 7 (20 pts):

A non-conducting sphere of radius R carries a total electric charge of Q_{tot} distributed according to the volume charge density $\rho(r)=A\sqrt{r}$ for r<R, where A is a constant, and $\rho=0$ for r>R.
(a) Determine (and circle) which of the following expressions is correct for A in terms of Q_{tot}. You must show how you determined this in order to get credit.

$A=\frac{3Q_{tot}}{8\pi R^{\frac{3}{2}}}$ $\boxed{A=\frac{7Q_{tot}}{8\pi R^{\frac{7}{2}}}}$ $A=\frac{Q_{tot}}{R^{\frac{3}{2}}}$ $A=\frac{Q_{tot}}{R^{\frac{7}{2}}}$ $A=\frac{3Q_{tot}}{4\pi R^{\frac{7}{2}}}$

$$Q_{TOT}=\int\rho\, dv=\int_0^R A\, r^{1/2}\, 4\pi r^2\, dr = 4\pi A\int r^{5/2} dr = 4\pi A\, R^{7/2}\big/ 7/2$$

$$Q_{TOT}=\frac{8}{7}\pi A R^{7/2} \Rightarrow A=\frac{7\,Q_{TOT}}{8\pi R^{7/2}}$$

(b) Find the electric field in all space in terms of Q_{tot} (rather than A) as a function of r.

$\underline{\underline{\text{for } r>R}}$

$$\oint E\cdot dA=\frac{Q_{encl}}{\epsilon_0} \qquad |\vec{E}|\,4\pi r^2=\frac{Q_{TOT}}{\epsilon_0}$$

$$|\vec{E}|=\frac{Q_{TOT}}{4\pi\epsilon_0 r^2} \text{ in } \hat{r} \text{ direction}$$

$\underline{\underline{\text{for } r<R}}$

$$\oint E\cdot dA=\frac{Q_{encl}}{\epsilon_0} \qquad |\vec{E}|\,4\pi r^2=\frac{1}{\epsilon_0}\int_0^r\rho\, dv$$

$$|\vec{E}|\,4\pi r^2=\frac{1}{\epsilon_0}\,4\pi A\,\frac{r^{7/2}}{7/2}$$

$$|\vec{E}|=\frac{2}{7\epsilon_0}A\,r^{3/2}$$

$$=\frac{2}{7}\frac{r^{3/2}}{\epsilon_0}\frac{7}{8\pi}\frac{Q_{TOT}}{R^{7/2}}$$

$$|\vec{E}|=\frac{Q_{TOT}}{4\pi\epsilon_0}\frac{r^{3/2}}{R^{7/2}} \text{ in } \hat{r} \text{ direction}$$

Potentially useful formulas

$$\vec{F} = \frac{k q_1 q_2}{r_{12}^2}\hat{r}_{12} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r_{12}^2}\hat{r}_{12}$$

$$\phi_E = \oint \vec{E}\cdot\vec{dA}$$

$$\oint \vec{E}\cdot\vec{dA} = \frac{Q_{encl}}{\epsilon_0}$$

$$E_S = -dV/ds$$

$$V = W/q$$

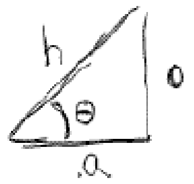
$$V_{pt\,chg} = \frac{kq}{R}$$

$$\vec{E} = \int_{vol} \frac{k\,q\,dQ}{r^2}\,dr\,\hat{r}$$

$$V = \int_{vol} \frac{k\,dQ}{r}$$

Sphere: $A = 4\pi r^2$
$V = 4/3\,\pi r^3$

cylinder: $A = 2\pi r L + 2\pi r^2$
$V = \pi r^2 L$



$\sin\theta = \frac{o}{h}$

$\cos\theta = a/h$

$\tan\theta = o/a$

$$\text{Const. Accel.}\begin{cases} V = V_0 + at \\ X = X_0 + V_0 t + \frac{1}{2}at^2 \\ V^2 = V_0^2 + 2a(x - x_0) \\ X^2 = x_0 + \frac{1}{2}(V_0 + V)t \end{cases}$$

$$a_c = \frac{mv^2}{R}$$

$$S = R\Theta$$

$$KE = \frac{1}{2}mv^2$$

$$PE_{spring} = \frac{1}{2}kx^2$$

$$\int u^n du = \frac{u^{n+1}}{n+1}$$

$$\int \frac{du}{u} = \ln|u|$$

$$\int e^u du = e^u$$

$$\int \frac{x\,dx}{\sqrt{x^2+a^2}} = \sqrt{x^2+a^2}$$