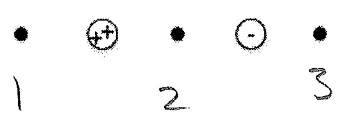
Name: Student Number:

Physics Tutorial
Potentials and Gauss

Question 1

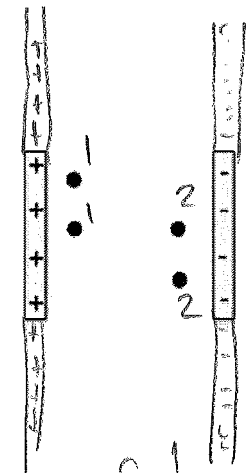
For each of the following configurations rank the electric potentials at the points from highest to lowest.

a)



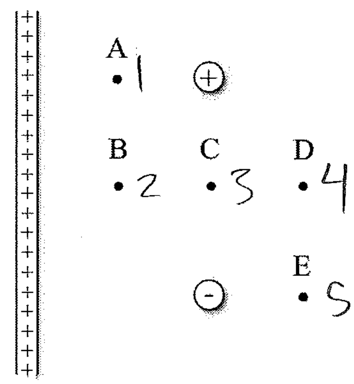
The closer to positive charge, the higher the potential.

b)



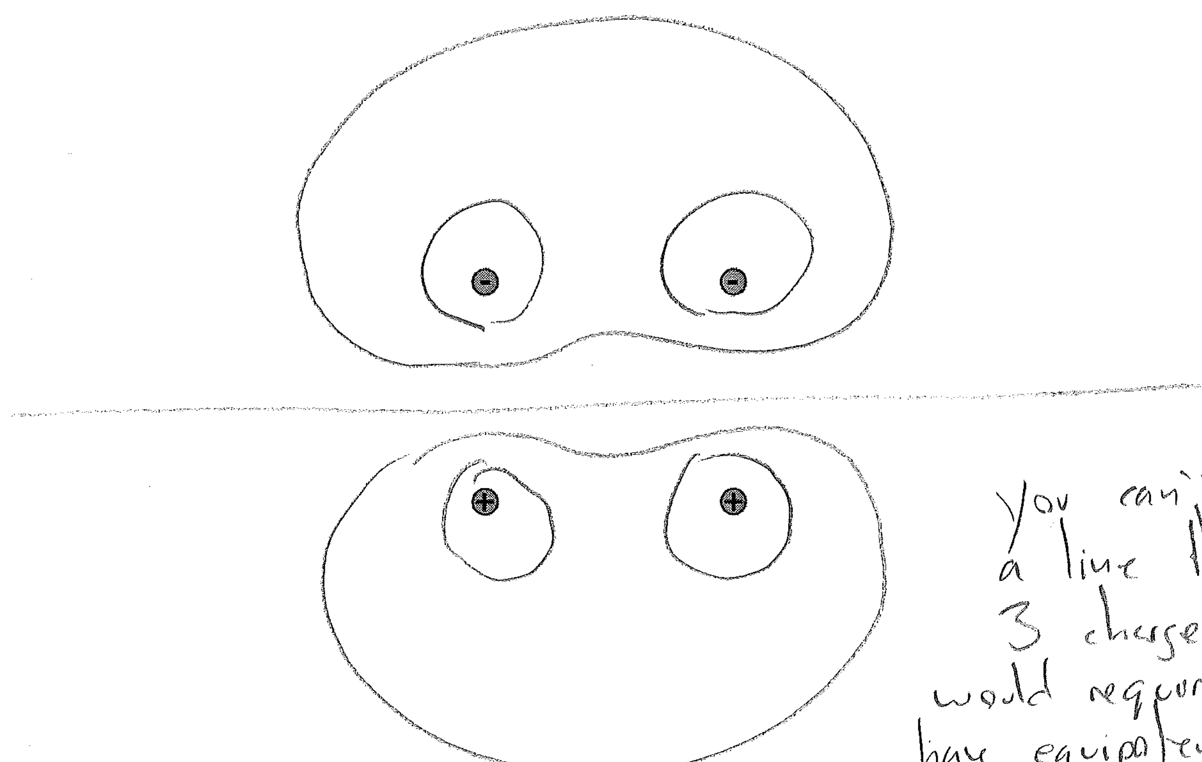
assume infinite plates

c)



Question 2

Draw the equipotentials for the charge configuration below. Be sure to label the V = 0 equipotential. Also plot equipotentials that circle one and two charges. Are there ones that circle three?



You can't draw a line that circles 3 charges. That would require you to have equipotentials that cross.

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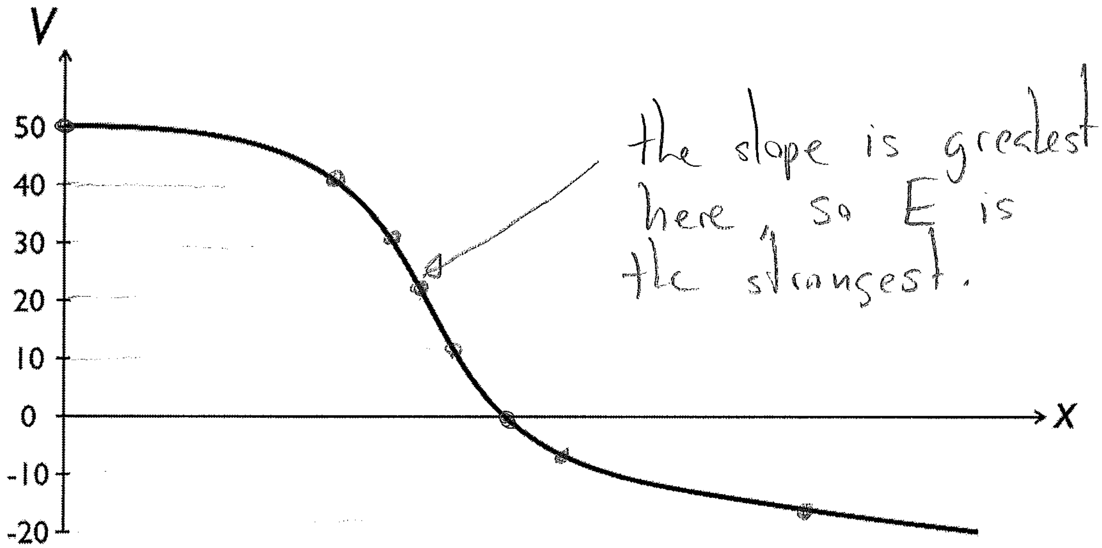
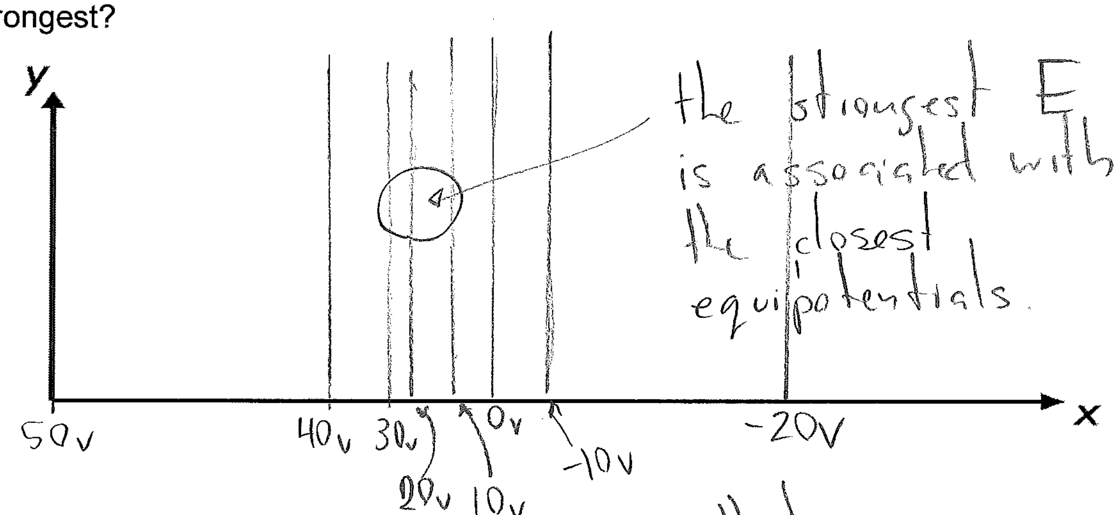
Question 3

An electric potential is plotted below. On the curve, draw dots at every 10 V for where equipotentials would occur. Where is the electric field the strongest? *(hint $E_s = - dV/ds$)*



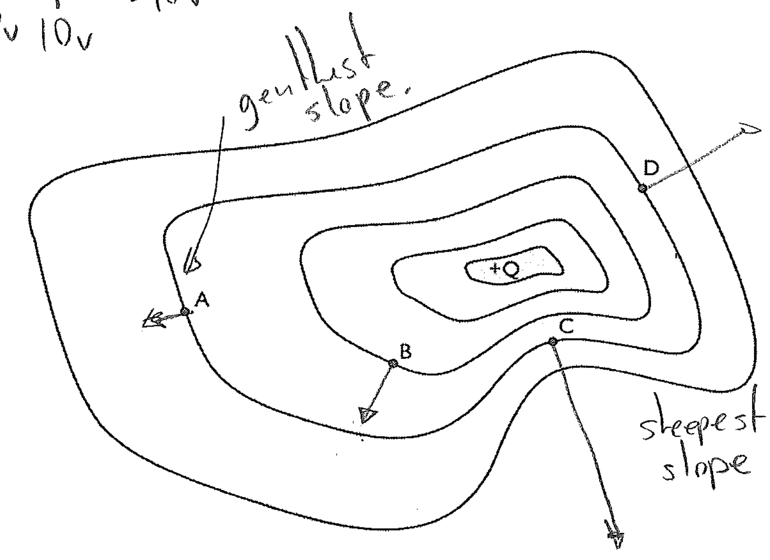
The plot above is an potential surface viewed from the side. In the space below draw what the equipotentials would look like from the top down (i.e., draw straight vertical lines). Where is the electric field the strongest?



Question 4

A bizarre, non-uniformly charged rock creates the equipotentials plotted below. The object has a positive charge +Q. Plot the electric field at points A-D. Take care to get the direction and magnitude correct.

think of a topography map for a mountain that shows elevation at even increments. How do you tell where the steepest part of the mountain is?



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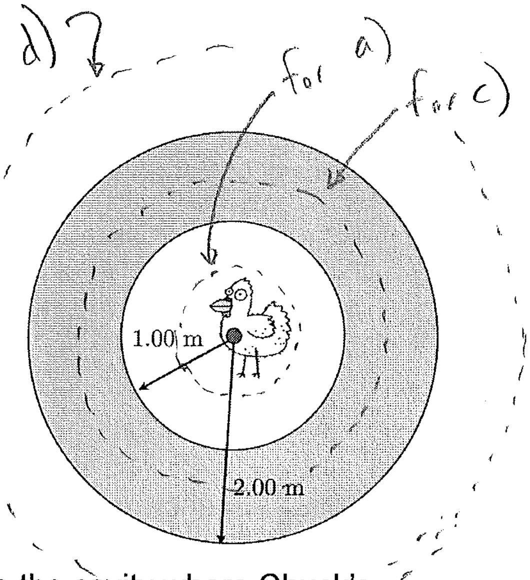
Question 5

Chuck the Charged Chicken goes "Cluck Cluck!" while floating in his metal space chicken sphere (a hollowed out metal sphere with a 1 metre thick wall to protect him from terrifying space debris).



Chuck can be modelled as a 8.00 nC point charge floating at the center of a hollow metal conductor. The outer surface of the conductor is spherical and has a radius 2 m.

a) What is the electric field at a radius of 0.5 m, which is inside the cavity where Chuck's located?

$$\Phi = \frac{Q_{encl}}{\varepsilon_0} = \frac{8nC}{\varepsilon_0} = \underset{4\pi r^2}{A}E \Rightarrow E = \frac{8nC}{4\pi(0.5m)^2\varepsilon_0} = 288\ N/C$$

b) What is the electric field inside the conductor (between 1 m and 2 m)?

The electric field is always zero inside a conductor. $E = 0$.

c) Imagine a spherical Gaussian surface centered on Chuck with a radius of 1.5m. What does Gauss's law tell you about the charge inside the Gaussian surface? Charge rests on the surface of conductors. What is the charge on the inside surface of the conductor?

Gauss says $\Phi = \frac{Q_{encl}}{\varepsilon_0} = EA = 0$ (since $E = 0$)

So $Q_{encl} = Q_{inside} + Q_{chuck} = 0 \Rightarrow Q_{inside} = -8nC$

d) Use Gauss's Law to calculate the electric field at a radius of 3 m, which is outside the conductor.

The conductor is neutral, so $Q_{inside} + Q_{outside} = 0$.
The outside surface of the conductor must has $Q_{out} = 8nC$.

From Gauss: $\Phi = \frac{Q_{encl}}{\varepsilon_0} = \frac{Q_{chuck} + Q_{in} + Q_{out}}{\varepsilon_0} = \frac{8nC}{\varepsilon_0} = EA$ $\quad E = \frac{8nC}{4\pi\varepsilon_0(3m)^2} = 8\ \frac{N}{C}$

e) How do you answers change if Chuck now has a charge of -8.00 nC?

All the signs flip on the fields and charges.

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f) Imagine now that the conductor has a net charge of +15 nC. What is the charge on the outer surface of the conductor? What is the electric field at a radius 3 m?

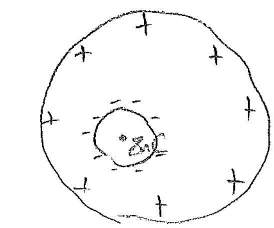
Now $Q_{conductor} = Q_{in} + Q_{out} \Rightarrow 15\,nC = -8\,nC + Q_{out}$

So $Q_{out} = 23\,nC$. Gauss says $\Phi = \frac{Q_{encl}}{\varepsilon_0} = \frac{Q_{chuck} + Q_{in} + Q_{out}}{\varepsilon_0}$

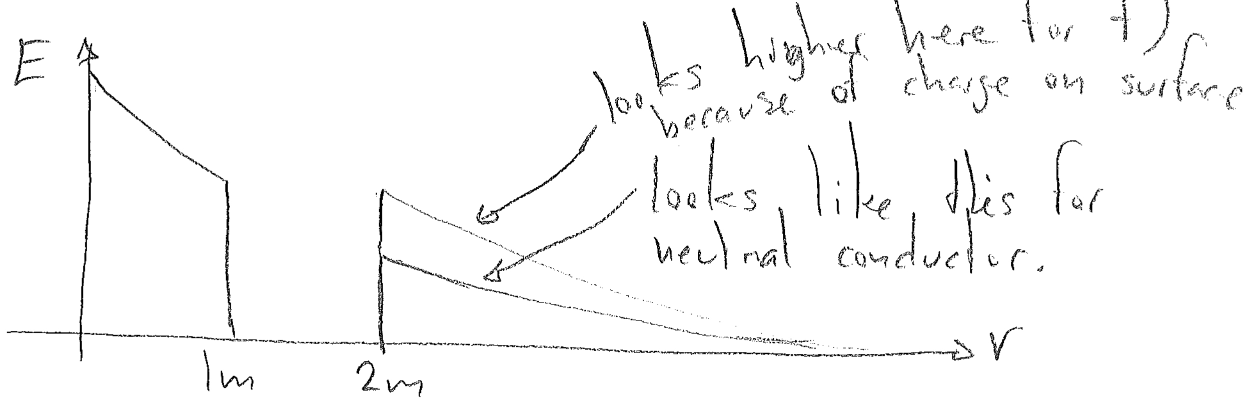
$\Rightarrow \frac{Q_{encl}}{\varepsilon_0} = \frac{23\,nC}{\varepsilon_0} \Rightarrow E = \frac{23\,nC}{4\pi\varepsilon_0 (3m)^2} = 23\,\frac{N}{C}$

g) Does your answer change is Chuck isn't centered in the conductor, but is 0.5 m to the right? Explain.

It doesn't change. The positive charge on the outside of the sphere doesn't move because $E = 0$ in the conductor. So the field has to be the same.



h) Plot the electric field of the charged conductor from f) as a function of *r*.



Question 6

a) In a weird alien solar system, the "Sun" is a long, thin, nearly massless object carrying a charge of 1 C/m. There is a planet with the same mass, orbital radius, and orbital period as Earth's, but the orbit results completely from electric forces. How much charge does this planet carry?

b) Use Gauss's Law to derive the electric field a distance *R* away from the alien Sun.

Question 7 (a curiosity)

a) Your book says that we can't use Gauss's Law to calculate the electric field of a cube. Why? Is it actually impossible?

b) For a cube with sides of length l, is there some limit in which we could use a Gaussian surface to calculate the electric field a point p?