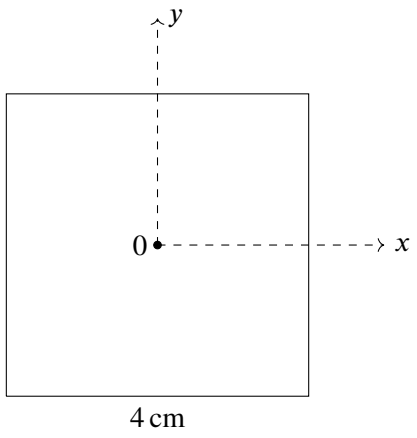
Physics 158 Written Homework 3

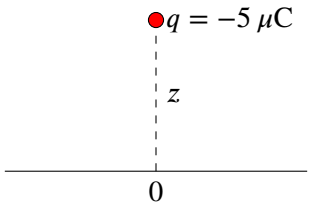
Problem 1

Difficulty: ★★☆
A 16 cm long wire of charge $Q = 40\,\mu$C is bent into a square in the xy-plane.



a) Find the electric field strength 20 cm vertically above the center of the square.

A point charge of mass $m = 100$ g and charge $-5\,\mu$C is now placed at a height $z = 20$ cm above the center of the square.



b) Find the magnitude and direction of the force acting on the point charge initially when $z = 20$ cm. (Either draw the direction of the force or use vector notation to specify the direction.)

c) Plot the acceleration of the point charge as a function of it's distance z above the center of the square.

Problem 2

Difficulty: ★☆☆
The potential above some charged Gaussian surface is given by the equation

$$V = \frac{k\sigma}{3y} \text{ Volts}$$

a) What is the equation for the electric field?

b) If $\sigma = 6\,\mu$C, find the electric field strength and direction at $y = 2$ m.

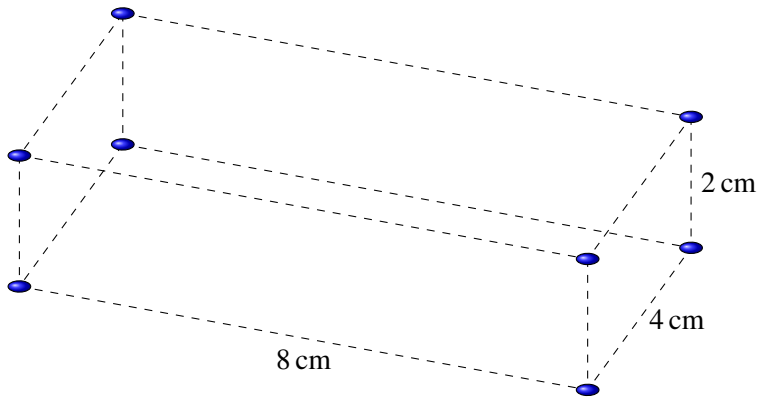
c) What can you say about the electric field in the x-direction?

Hint:

$$\vec{E} = -\frac{\partial V}{\partial x}\hat{i} - \frac{\partial V}{\partial y}\hat{j} - \frac{\partial V}{\partial z}\hat{k}$$

Problem 3

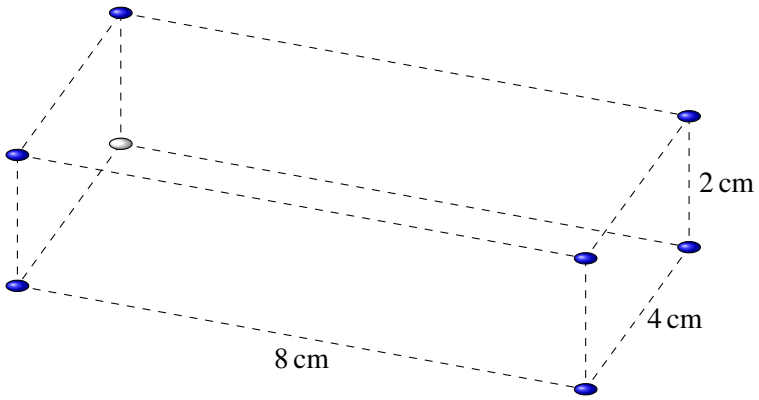
Difficulty: ★☆☆
A rectangular box has dimensions 2 m × 4 m × 8 m. At each corner of the box sits a point charge of value Q.
Leave your answers in terms of k and Q.



a) What is the electric field at the center of the box?

b) What is the potential at the center of the box?

One of the point charges on the corners is removed.



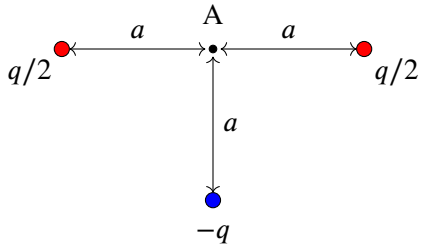
c) What is the magnitude of the new electric field at the center of the box?

d) What is the new potential at the center of the box?

e) What is the work done on the system in removing that point charge?

Problem 4

Difficulty: ★☆☆
A very rough approximation for a water molecule can be represented by the following diagram: (a negative oxygen atom (blue) with two positive hydrogen atoms (red) attached to it)
Assume $V(\infty) = 0$



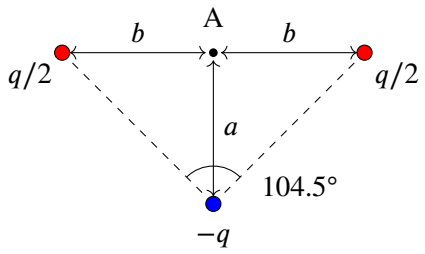
a) What is the total electrical energy stored in this molecule in terms of charge q and distance a?

b) Interpret the sign of your answer to part (a). What does it mean in terms of the work required to assemble the molecule?

c) Assuming all the charges are fixed in place, if you bring a positive test charge (q') from infinity to the point A, how much external work would be required?
(Simplify your answer as much as possible)

d) What would the new total energy stored in the system after bringing the point charge to the origin in part (c)?

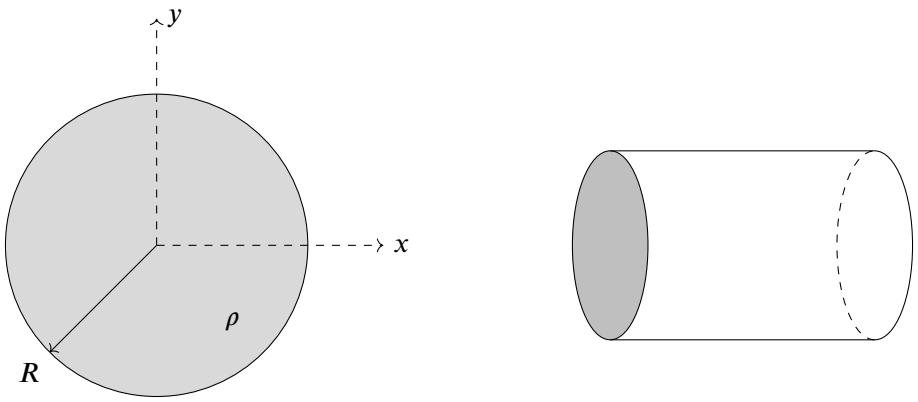
e) Note that in a real water molecle, the angle between the hydrogen atoms is 104.5° as shown below. How would this affect your answer to part (c)?



Problem 5

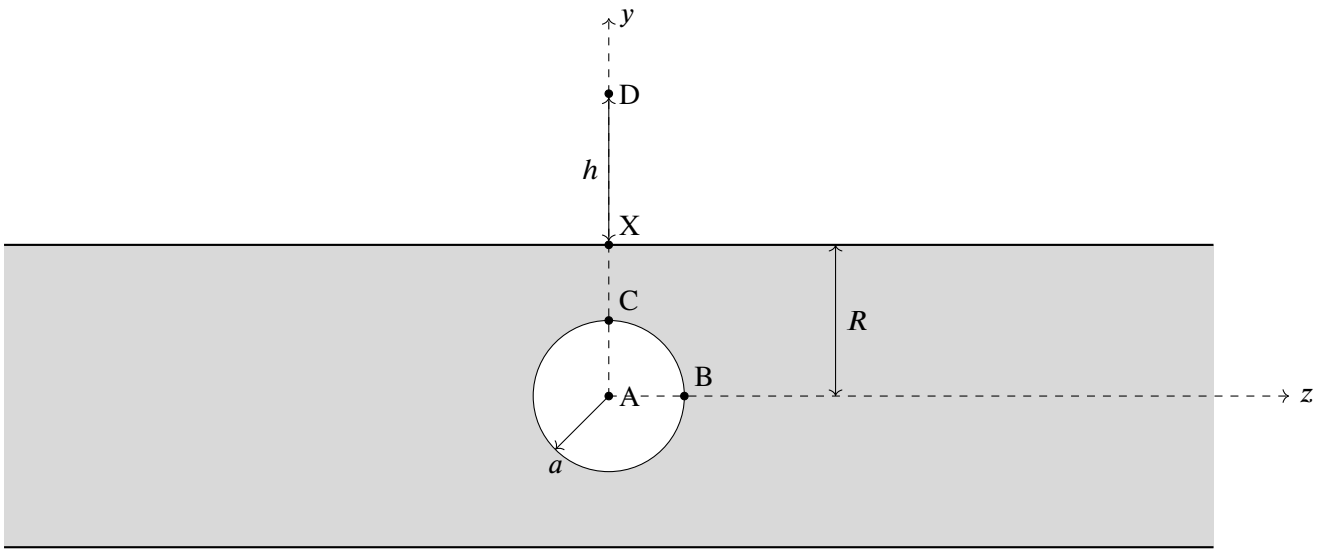
Difficulty: ★★★

An insulating cylinder of radius R and effectively infinite length in the z-direction contains a uniform charge density of ρ.



a) Find the electric field everywhere in space

If there is now a hollow spherical cavity of radius a located at the center of the cylinder,



b) Find the electric field at the center of the sphere at point A.

c) Find the electric field just outside the sphere at point B.

d) Find the electric field just outside the sphere at point C.

e) Find the electric field outside both objects at point D.

If the potential at the point X is 0V,

f) What is the potential at point A?