Physics 158 Electric Fields Problem Bank

Problem 1

Created by Tyler Wilson 2023
A 16 cm long wire of charge $Q = 40\,\mu$C is bent into a square.

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 20 cm above the center of the square.

b) Find the magnitude and direction of the force acting on the point charge initially.

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

Solution:

Problem 2

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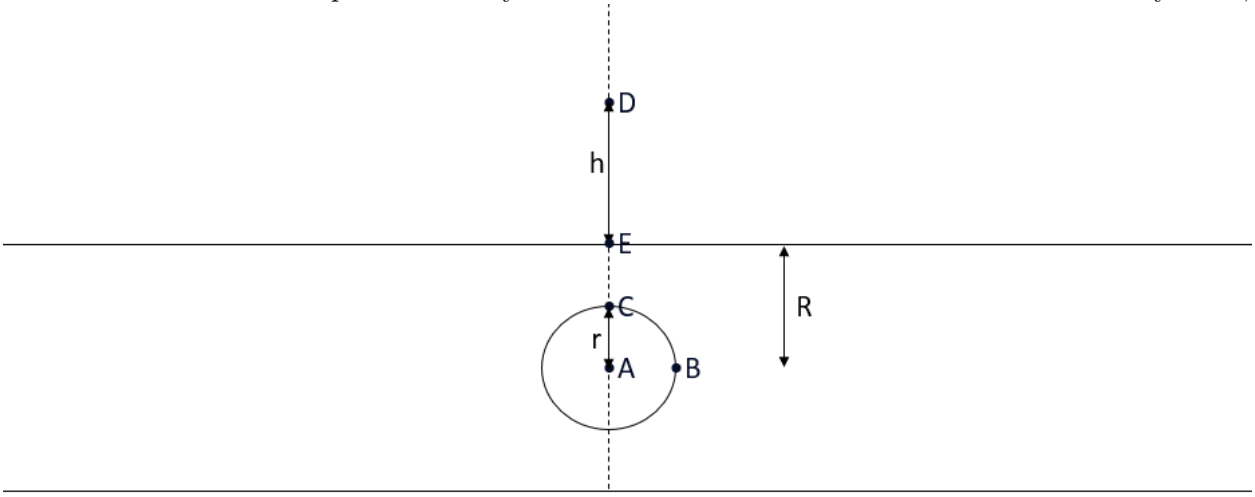
An insulating cylinder of radius $R = 5$ cm and effectively infinite length contains a uniform charge density of $10\,\text{C/m}^3$.

a) Find the electric field everywhere in space

If there is now a hollow spherical cavity of radius $r = 1$ cm 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) If $h = 10\,\text{cm}$, find the electric field outside both objects at point D.

If the potential at the point E is 0V,

f) What is the potential at point A?

Problem 3

Created by Tyler Wilson 2023
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 $\sigma = 6\,\mu\text{C}$, find the electric field strength and direction at $y = 2\,\text{m}$.

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

Hint:

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

Solution:

a) The electric field is the negative gradient of the potential. This was defined in the hint above. The electric field would then be

$$\vec{E} = -\frac{\partial}{\partial y}\left(\frac{k\sigma}{3y}\right)\hat{j} = \boxed{\frac{k\sigma}{3y^2}\hat{j}}$$

b) Plugging in these values we would get

$$\vec{E}(y=2) = \frac{k(6\cdot 10^{-6})}{3(2)^2}\hat{j} = \boxed{4495\hat{j}\,\text{N/C}}$$

c)

$$\vec{E}_x = -\frac{\partial}{\partial x}\left(\frac{k\sigma}{3y}\right) = 0$$

Therefore, the electric field in the x-direction is 0.

Problem 4

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A rectangular box has dimensions 2m by 4m by 8m. At each corner of the box sits a point charge of value Q.

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

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

c) What is the total energy of the system?

One of the point charges on the corners is removed.

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

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

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

g) What is the new total energy of the system?

Problem 5

Created by Tyler Wilson 2023
A parallel plate capacitor is hooked up to a battery in series. At time t, a dielectric is inserted into the capacitor and the volatge source is doubled. If the charge on the capacitor remains the same, find the dielectric constant.

Problem 6

Created by Tyler Wilson 2023
A resistor ($R = 2\,\Omega$) and a capacitor ($C = 16\,\mu\text{F}$) are connected in parallel to a $10\,\text{V}$ battery.

a) What is the current flowing through the resistor after a long period of time?

At time $t = t_0$ a dielectric of $\kappa = 4$ is inserted into the capacitor.

a) What is the new current flowing through the resistor at the instant the dielectric is inserted (at $t = t_0$)?

b) What is the new current flowing through the resistor after a long time has passed?