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4C Quiz #4

This Quizz is closed book.
Make sure to always indicate positive directions and make large and neat figures. Specify the units of numerical answers.

PROBLEM 1 (10 points).

An infinite two dimensional slab of dielectric of thicknes d and dielectric constant κ is placed in a uniform electric field $\boldsymbol{E}$ that is perpendicular to the slab's surface. Calculate the force on the dielectric by the electric field.

PROBLEM 2 (30 points).

An ideal parallel plate capacitor has area A and its plates are at a distance d. The region between the plates is initially empty. The capacitor is permanently connected to a battery that has a voltage V. At a certain moment a dielectric with dielectric constant κ is inserted. The dielectric fills the capacitor.

a. What are the charge and the stored energy in the capacitor before the dielectric is inserted? Express your answer in terms of A, d, V and whatever other variables you need but not C.

b. What are the charge and the stored energy in the capacitor after the dielectric is inserted? Also here express your answer in terms of A, d, V and whatever other variables you need but not C.

c. Compare your answers in a) and b)? If there is a difference in charge or energy what is that difference due to?

d. How much energy is delivered or received by the battery when the dielectric is inserted? Specify clearly which of the two cases applies, do not just give a sign.

e. How much work is done by the person who is inserting the dielectric? Specify clearly whether that person must do positive or negative work.

PROBLEM 3 (20 points).

An infinite two dimensional slab is placed in the x, y plane with its center plane at $z = 0$. It has a thicknes d and carries a volume charge density ρ given by $\rho = \alpha|z|$ where α is a positive constant. Calculate the electric field everywhere.

PROBLEM 4 (20 points).

An electric field $\boldsymbol{E}$ is given by $\boldsymbol{E} = \beta \boldsymbol{r}$ where the vector $\boldsymbol{r}$ is given by $\boldsymbol{r} = (x, y, z)$ and $\beta > 0$ is a constant.

a. Find the potential difference between two points A and B located at positions $\boldsymbol{r}_1$ and $\boldsymbol{r}_2$ respectively.

b. You probably did the calculation assuming that points A and B are on the same radius vector from the origin. What happens to the answer of a) if the points A and B are not on the same radius vector?

c. An electron is positioned at a distance r_2 from the origin and is initially at rest. When the electron is released and free to move, in which direction will it move and why?

d. When the electron arrives at a distance r_1 from the origin, what is its kinetic energy?

PROBLEM 5 (20 points)

Two infintely long electric currents i_1 and i_2 are positioned on the x and the y axes respectively. The currents are directed toward the positive directions of their respective coordinate axes.

a. Calculate the total magnetic field at $z = 0$ as function of x and y in the entire x, y plane.

b. Is there a region in the x, y plane where the total magnetic field is zero? If so, specify it.