Key Concepts

Chapter 8

Electric field: $E = \frac{kq}{r^2}$ (N/C)

Dipoles

$E = \frac{V}{d}$ (V/m) (parallel plate capacitor)

Capacitors

Vector addition

Takeaways

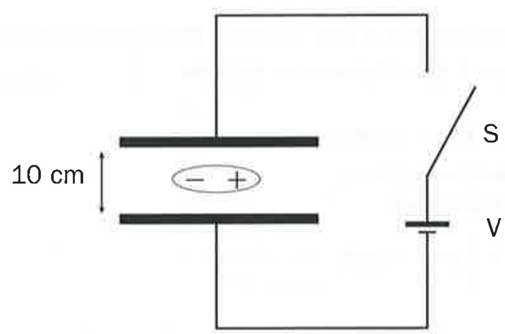
To find the net electric field (or magnetic field), find the effect of each source separately and then add them together. Remember that fields are vectors, so you have to add them like vectors: break the vectors into **X** and **Y** components and add the components separately. Then use trigonometry and the Pythagorean theorem to find the net field.

Things to Watch Out For

Most multiple-charge problems will have a geometry that allows you to cancel out certain components of the fields. Always look for an opportunity to do so, because this will save you time on Test Day.

Net Electric Field with Multiple Sources

The diagram below shows an apparatus assembled using a 120 V battery and a capacitor with 10 cm plate separation. First, switch S was closed for a long time, fully charging the plates of the capacitor. Then, switch S was opened, and a dipole with charges of 1 pC and −1 pC and a separation of 2 mm was placed between the plates of the capacitor, oriented with its positive end on the right-hand side. The dipole is held in a fixed position. What is the magnitude and direction of the electric field at a point 1 mm below the center of the dipole? ($k = 9 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2$)



1) Find the electric field due to the plates.

$$E = \frac{V}{d} = \frac{120}{0.1} = 1{,}200\ \text{V/m}$$

The electric field due to a potential difference inside a parallel plate capacitor is given by $E = \frac{V}{d}$. The voltage on the plates is the same as the voltage on the battery because the capacitor is fully charged. The top plate of the capacitor is positively charged because it was attached to the positive terminal of the battery (which is always the side with the longer line). Thus, the electric field points vertically from the top plate to the bottom plate.

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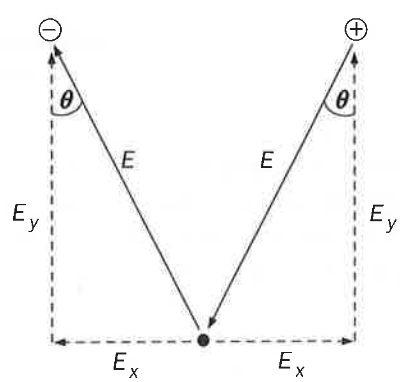
2) Draw the electric field due to the dipole.



The two charges of the dipole are best treated simultaneously because their effect partially cancels out. The electric field points away from the positive charge and towards the negative charge. Find the **X** and **Y** components of the field for both charges. Note that the **Y** components cancel each other out and that the **X** components are equal and in the same direction. Thus, the electric field due to the dipole is twice the **X** component of the electric field due to either dipole. The **X** component of the electric field is $E \sin \theta$.

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3) Calculate the electric field due to the dipole.

$$\theta = \tan^{-1}\frac{1}{1} = 45°$$

$$r = \sqrt{1^2 + 1^2} = 1.41 \text{ mm}$$

$$E_x = E \sin \theta$$

$$E = \frac{kq}{r^2}$$

$$E_x = \left(\frac{kq}{r^2}\right)\sin\theta = \left(\frac{(9\times10^9)(1\times10^{-12})}{(1.41\times10^{-3})^2}\right)\sin 45°$$

$$= 3{,}201 \text{ V/m}$$

$$E_{\text{dipole}} = 2E_x = 6{,}402 \text{ V/m}$$

Find the angle θ from trigonometry. Find r, the distance from the charges to the point, using the Pythagorean theorem. Then calculate E_x using the formula for electric field due to a point charge. The net electric field is twice E_x and is directed to the left.

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4) Find the net electric field.

$$E_{\text{net}}^{\ 2} = E_x^2 + E_y^2$$

$$E_{\text{net}}^{\ 2} = (6{,}402)^2 + (1{,}200)^2 = 4.243 \times 10^7$$

$$E_{\text{net}} = 6{,}514 \text{ V/m}$$

$$\theta = \tan^{-1}\frac{E_y}{E_x} = 10.6°$$

The net electric field is the vector sum of the electric field due to the plates and the dipole. Because one is in the x-direction and the other is in the y-direction, they form two sides of a right triangle. The length of the hypotenuse of the triangle is the magnitude of the net electric field and is given by the Pythagorean theorem. Find the angle θ from the horizontal using trigonometry.

Similar Questions

1) What is the electric field halfway between two protons separated by a distance of 1 mm?
2) A proton and an electron are separated by 1 μm. Is there a point directly between them at which the electric field is zero?
3) Three protons are positioned at the corners of an equilateral triangle with sides 2 mm in length. What is the electric field at the center of one of the edges of the triangle? ($e = 1.6 \times 10^{-19}$ C.)