

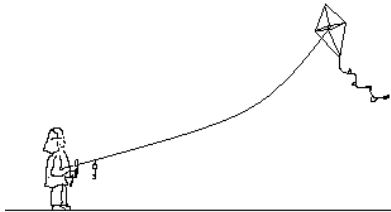
State Any Assumptions You Need To Make -- Show All Work -- Circle Any Final Answers
Use Your Time Wisely - Work on What You Can - Be Sure to Write Down Equations
BOLDFACE Variables Are Vectors - Feel Free to Ask Any Questions

Poor Richard's Book of Physics (50,000 points)

1.) Benjamin Franklin is flying his kite into an electrical storm. A thunderstorm cloud 2000. meters overhead has a net charge of $Q = +113 \text{ C}$. Assuming it acts like a point charge, (a) what is the strength of the electric field, E , that Ben sees on the ground?

(b) What is the potential difference, ΔV , between the charged cloud and the neutral ground?

(c) If the metal key that is hanging from the wire has a charge $q = +1.04 \times 10^{-3} \text{ C}$, then find the electric force, F_E , on the key from the overhead thunderstorm cloud.



(d) Ben Franklin would have said that his *single electric fluid* would have been added to the metal key to reach $q = +1.04 \times 10^{-3} \text{ C}$. In truth, how many electrons would have been *added* or *subtracted* to make this q ?

(e) Underneath the thunderstorm, a charge of $Q = -113 \text{ C}$ is spread out onto the ground, covering an area of 100. meters \times 100. meters. Use Gauss's Law to find the magnitude of the electric field, E , treating the ground as a sheet of charges.

This Problem Should Cap Off The Start of the New Year of the Snake (50,000 points)

2.) A parallel plate capacitor consists of plates with an area $A = 0.100 \text{ m}^2$ and a separation of $d = 7.00 \text{ cm}$.
 (a) Find the capacitance, C . $\epsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$

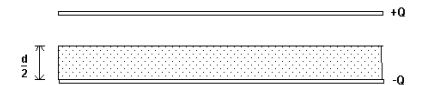
(b) If this capacitor is hooked up to a 512 volt battery, find the magnitude of the constant electric field, E , between the plates, using the " $V = Ed$ " equation. Sketch some of the E-field lines between the plates in the diagram. *You do not need the answer to (a) for this part.*



(c) Find the magnitude of the electric field between the plates, using the equation $E = \frac{\sigma}{\epsilon_0}$. The capacitor equation, $C = Q/V$, will get you the charge on one of the plates. *If you did not get an answer to (a), use $C = 12.6 \text{ pF}$.*

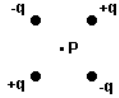
(d) How much energy is stored in this capacitor when fully charged?

(e) If half the capacitor is filled with water ($\kappa = 80$, Dielectric Strength = ∞), then this becomes two capacitors in *series*. Find the equivalent capacitance of this waterlogged capacitor.



Four Charges and An E-Field (50,000 points)

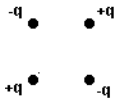
3.) Four charges, $|q| = 6.00 \times 10^{-6} \text{ C}$, are rigidly arranged in a square ($L = 10.0 \text{ cm} = 0.100 \text{ m}$) as shown. (a) Find the electric field vector, \vec{E}_{total} , at the center of the square of charges at point P.



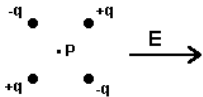
(b) Find the electric field vector, \vec{E}_{total} , at a point $+10.0 \text{ cm } \hat{k}$ (0.100 m) out of the plane of the paper, above the point P.

(c) Find the force vector, \vec{F}_{total} , on the upper left charge due to the other three charges.

(d) One of the $+q$ charges and one of the $-q$ charges can be thought of as forming a dipole. Find the dipole moment, p , of any of these dipoles, and sketch all the possible dipole vectors, \vec{p} .



(e) A constant electric field, $\vec{E} = 150. \text{ N/C } \hat{i}$, applies everywhere. Show whether these four charges, rigidly held together, will translate or rotate in the applied E-field.



The Great Accelerator (50,000 points)

4.) The Stanford Linear Accelerator, SLAC, is a real machine that takes electrons and accelerates them for most of a mile up to speeds as great as 99.99% the speed of light. Consider an electron ($m_e = 9.11 \times 10^{-31} \text{ kg}$) in a constant electric field that starts from rest and ends up at $1.00 \times 10^8 \text{ m/s}^\dagger$ after traveling in the $+x$ direction a distance of 1150 meters in 23.0 μsec . Using our old friend from the kinematic equations, *The Equation Without Time*, we find that $a = \frac{v^2}{2d}$ or $a = 4.35 \times 10^{12} \text{ m/s}^2$. (a) What is the magnitude and direction of the force on the electron?

(b) What is the magnitude and direction of the constant E-field required in part (a)?

(c) The electron volt is a unit of work (energy) defined as $1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$. Use the change in the kinetic energy of the electron from rest to $1.00 \times 10^8 \text{ m/s}$, expressed in eV's, to find the magnitude of the potential difference ΔV from one end of the accelerator to the other. *Ignore the minus signs in this problem.*

(d) Although it doesn't take very long for an electron to travel down the accelerator, suppose someone was worried about it not falling at all during its trip down the tube. Find the magnitude and direction of a second E-field that would cancel the weight of the electron.

(e) In the space below, make a sketch of some of the electric field lines and some equipotential surfaces due to two positive charges, q_1 and q_2 , where $q_1 = 2 q_2$.



[†] This is only one-third the speed of light, well below the threshold of where we have to worry about using Relativity.