3. How much work is done by an applied force that moves two charges of 6.5 μC that are initially very far apart to a distance of 4.5 cm apart?

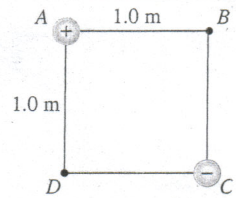
$W = \Delta U, \quad U = \frac{k q_1 q_2}{r}$

TO BRING CHARGES TOGETHER: $\Delta U = U_{NEAR} - U_{FAR}^{\,0} = \text{WORK}$

$W = U_{NEAR} = \frac{k q_1 q_2}{r}$

$= \frac{(8.99\times10^9)(6.5\times10^{-6})(6.5\times10^{-6})}{(0.045)} = \boxed{8.44\,J = W}$

25. Charges of +2.0 nC and −1.0 nC are located at opposite corners, *A* and *C*, respectively, of a square which is 1.0 m on a side. What is the electric potential at a third corner, *B*, of the square (where there is no charge)?



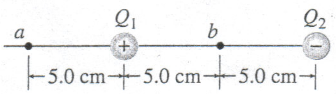
ELECTRIC POTENTIAL

$V = \sum \frac{kQ_i}{r_i}$

$V = k\left(\frac{Q_A}{r_{AB}} + \frac{Q_C}{r_{BC}}\right) = (8.99\times10^9)\left(\frac{2\times10^{-9}}{1} + \frac{-1\times10^{-9}}{1}\right)$

$\boxed{V = 8.99 \text{ VOLTS}}$

27. (a) Find the potential at points *a* and *b* in the diagram for charges Q_1 = +2.50 nC and Q_2 = −2.50 nC. (b) How much work must be done by an external agent to bring a point charge *q* from infinity to point *b*?



ELECTRIC POTENTIAL

$V = \sum \frac{kQ_i}{r_i}$

a) $V_a = k\left(\frac{Q_1}{r_{1a}} + \frac{Q_2}{r_{2a}}\right) = (8.99\times10^9)\left(\frac{2.5\times10^{-9}}{0.05} + \frac{-2.5\times10^{-9}}{0.15}\right) = \boxed{3.00\,V = V_a}$

$V_b = k\left(\frac{Q_1}{r_{1b}} + \frac{Q_2}{r_{2b}}\right) = (8.99\times10^9)\left(\frac{2.5\times10^{-9}}{0.05} + \frac{-2.5\times10^{-9}}{0.05}\right) = \boxed{0\,V = V_b}$

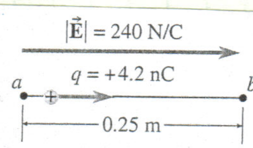
b) $\Delta V_{\infty\to b} = V_b - V_\infty^{\,0} = V_b = \boxed{0 = \Delta V_{\infty - b}}$ No Work!

30. By rewriting each unit in terms of kilograms, meters, seconds, and coulombs, show that 1 N/C = 1 V/m.

$V \sim \frac{J}{C} \sim \frac{N\cdot m}{C} \sim \frac{kg\cdot m^2}{s^2 C}$

$\frac{N}{C} \sim \frac{kg\cdot m}{s^2 C}\left(\frac{m}{m}\right) \sim \frac{kg\cdot m^2}{s^2 C m} \sim \left(\frac{kg\cdot m^2}{s^2\cdot C}\right)\left(\frac{1}{m}\right) \sim \boxed{\frac{V}{m}}$

31. A uniform electric field has magnitude 240 N/C and is directed to the right. A particle with charge +4.2 nC moves along the straight line from *a* to *b*. (a) What is the electric force that acts on the particle? (b) What is the work done on the particle by the electric field? (c) What is the potential difference $V_a - V_b$ between points *a* and *b*?



ELECTRIC FORCE $F = qE$

WORK $W = F_x \Delta x$

POTENTIAL DIFF. $\Delta V = \frac{\Delta U}{q} = \frac{W}{q}$

a) THE FORCE IS

$$F = qE = (4.2\times10^{-9})(240) = \boxed{1.01\times10^{-6}\ N = F}$$ ($\approx 1\ \mu N$)

b) THE WORK DONE FROM a TO b

$$W = F_x \Delta x = (1.01\times10^{-6})(0.25) = \boxed{2.52\times10^{-7}\ J = W}$$ ($0.25\ \mu J$)

c) THE POTENTIAL DIFFERENCE (WORK PER CHARGE)

$$\Delta V = \frac{W}{q} = \frac{2.52\times10^{-7}}{4.2\times10^{-9}} = \boxed{60\ V = V_a - V_b}$$ (V IS GREATER AT a SO IT'S +)

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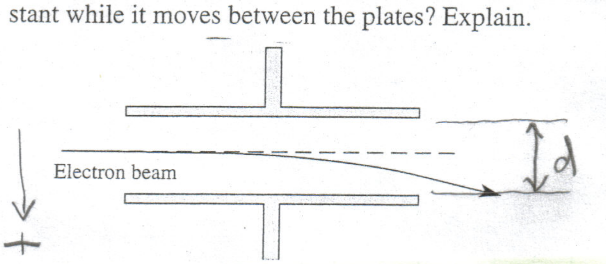
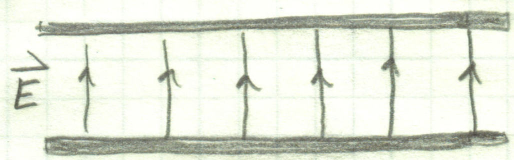
45. A beam of electrons of mass m_e is deflected vertically by the uniform electric field between two oppositely charged, parallel metal plates. The plates are a distance *d* apart and the potential difference between the plates is ΔV. (a) What is the direction of the electric field between the plates? (b) If the *y*-component of the electrons' velocity as they leave the region between the plates is v_y, derive an expression for the time it takes each electron to travel through the region between the plates in terms of ΔV, v_y, m_e, *d*, and *e*. (c) Does the electric potential energy of an electron increase, decrease, or stay constant while it moves between the plates? Explain.



a) TO SEND e^- DOWN, THE + CHARGE MUST BE ON THE BOTTOM PLATE $\Rightarrow \vec{E}$ IS UP



b) FIND TIME OF FLIGHT

$$v_y = v_{0y} + a_0 t \quad (v_{0y} = 0)$$

$$t = \frac{v_y}{a_0}$$

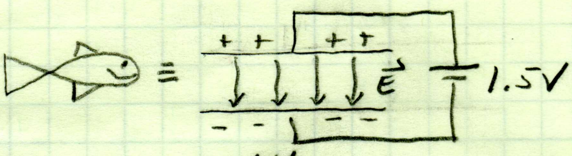
FIND a USING NEWTON'S 2ND LAW

$$F = qE = eE = e\left(\frac{\Delta V}{d}\right) = ma_0 \Rightarrow a_0 = \frac{e\Delta V}{md}$$

SO $$t = \frac{v_y}{a_0} = \boxed{\frac{md\,v_y}{e\Delta V} = t}$$

c) THE POTENTIAL ENERGY OF THE e^- DECREASES AS THE FORCE DOES WORK ON IT.

60. A shark is able to detect the presence of electric fields as small as 1.0 μV/m. To get an idea of the magnitude of this field, suppose you have a parallel plate capacitor connected to a 1.5-V battery. How far apart must the parallel plates be to have an electric field of 1.0 μV/m between the plates?



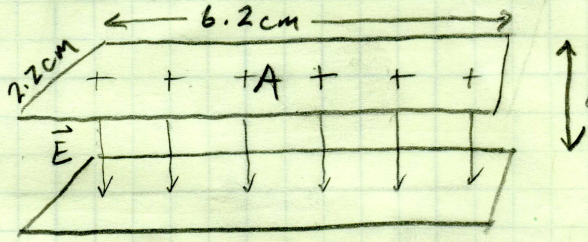
$E = 1.0\ \frac{\mu V}{m}$

FOR A ∥-PLATE CAPACITOR

$$V = Ed \Rightarrow d = \frac{V}{E} = \frac{1.5}{1.0\times10^{-6}} = \boxed{1.5\times10^{6}\,m = d}$$

~ 1500 km

65. A 6.2-cm by 2.2-cm parallel plate capacitor has the plates separated by a distance of 2.0 mm. (a) When 4.0×10^{-11} C of charge is placed on this capacitor, what is the electric field between the plates? (b) If a dielectric with dielectric constant of 5.5 is placed between the plates while the charge on the capacitor stays the same, what is the electric field in the dielectric?



$d = 2.0\,mm,\ Q = 4.0\times10^{-11}\,C$

a) FIND E

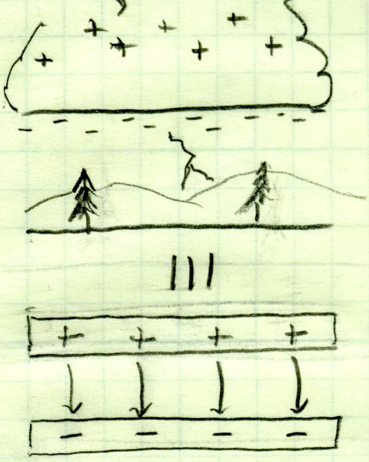
$$Q = C\Delta V = C E_0 d = \left(\frac{\epsilon_0 A}{d}\right)(E_0 d) = \epsilon_0 A E_0$$

$$\Rightarrow E_0 = \frac{Q}{\epsilon_0 A} = \frac{4.0\times10^{-11}}{(8.85\times10^{-12})(0.022)(0.062)} = \boxed{3.31\times10^{3}\,\frac{V}{m} = E_0}$$

b) ADD DIELECTRIC WITH $K = 5.5$ $C = KC_0 = \frac{K\epsilon_0 A}{d}$

$$\Rightarrow E = \frac{Q}{K\epsilon_0 A} = \frac{1}{K}(E_0) = \frac{3.31\times10^{3}}{5.5} = \boxed{6.02\times10^{2}\,\frac{V}{m} = E_K}$$

77. Figure 17.31b shows a thundercloud before a lightning strike has occurred. The bottom of the thundercloud and the Earth's surface might be modeled as a charged parallel plate capacitor. The base of the cloud, which is roughly parallel to the Earth's surface, serves as the negative plate and the region of Earth's surface under the cloud serves as the positive plate. The separation between the cloud base and the Earth's surface is small compared to the length of the cloud. (a) Find the capacitance for a thundercloud of base dimensions 4.5 km by 2.5 km located 550 m above the Earth's surface. (b) Find the energy stored in this capacitor if the charge magnitude is 18 C.



$$a)\ C = \frac{\epsilon_0 A}{d} = \frac{(8.85\times10^{-12})(4.5\times10^{3})(2.5\times10^{3})}{550} = \boxed{1.8\times10^{-7}\,F = C}$$

~ 0.18 μF

$$b)\ U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\frac{(18)^2}{1.8\times10^{-7}} = 9\times10^{8}\,J = \boxed{900\,kJ! = U}$$

85. A defibrillator consists of a 15-μF capacitor that is charged to 9.0 kV. (a) If the capacitor is discharged in 2.0 ms, how much charge passes through the body tissues? (b) What is the average power delivered to the tissues?

Energy in a Capacitor

$$U = \frac{1}{2} C \Delta V^2 = \frac{1}{2}\frac{Q^2}{C}$$

a) Total charge on capacitor passes through body

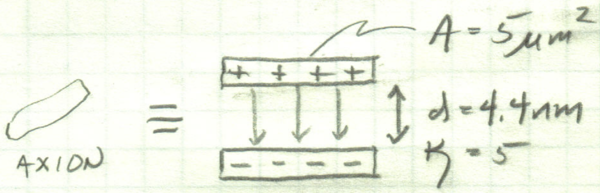
$$Q = C\Delta V = (15\times10^{-6})(9.0\times10^{3}) = \boxed{0.135\ C = Q}$$

b) Power is energy / time

$$P = \frac{U}{\Delta t} = \frac{C\Delta V^2}{2\Delta t} = \frac{(15\times10^{-6})(9\times10^{3})^2}{2(2\times10^{-3})} = \boxed{3.04\times10^{5}\ W = P}$$

0.3 MW

103. An axon has the outer part of its membrane positively charged and the inner part negatively charged. The membrane has a thickness of 4.4 nm and a dielectric constant $\kappa = 5$. If we model the axon as a parallel plate capacitor whose area is 5 μm², what is its capacitance?



Capacitance

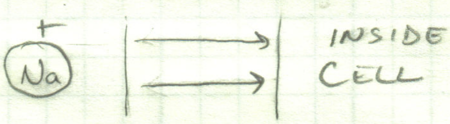
$$C = \kappa \frac{\epsilon_0 A}{d}$$

$$A = 5\,\mu m^2 \left(\frac{1\times10^{-6}\,m}{1\,\mu m}\right)^2 = 5\times10^{-12}\,m^2$$

$$C = (5)\frac{(8.85\times10^{-12})(5\times10^{-12})}{4.4\times10^{-9}} = \boxed{5.03\times10^{-14}\ F = C_{AXION}}$$

107. The inside of a cell membrane is at a potential of 90.0 mV lower than the outside. How much work does the electric field do when a sodium ion (Na^+) with a charge of $+e$ moves through the membrane from outside to inside?

$$\text{Work} = \Delta U = q\Delta V$$



$$W = e\Delta V = (1.6\times10^{-19})(90\times10^{-3}) = \boxed{1.44\times10^{-20}\ J = W}$$