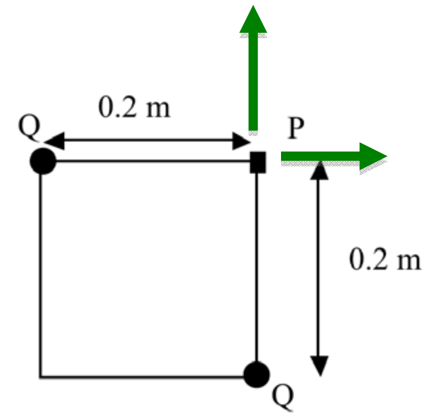
1. For the two charges, Q = +5 nC, at opposite points of the square shown,
   a) Find the potential energy that results from the two charges.
   b) What does the sign of the potential energy tell you?
   c) Find the Electric Field at the point P (x = 3cm, y=0) (Magnitude AND direction)
   d) Find the electric force on a charge of -10 nC placed at point P. (Magnitude AND direction)



a) $U_E = \dfrac{kq_1q_2}{r}$ r=$\sqrt{x^2+y^2} = \sqrt{0.2^2+0.2^2} = 0.28m$

$$U_E = \frac{8.99x10^{+9}\,Nm^2/C^2(+5x10^{-9}C)(+5x10^{-9}C)}{0.28m}$$

$$= +8.0x10^{-7}J$$

b)The positive sign on the potential energy tells me that the force is repulsive

c)The electric field is a vector. We need to find the x and y component of the field due to each charge and do a vector addition.
The top left charge only has an x-component

$$E_x = \frac{kQ}{r^2} = \frac{8.99x10^9\,Nm^2/C^2(5x10^{-9}C)}{(0.2m)^2} = 1.12x10^3\,N/C \text{ +x-direction}$$

The bottom right hand charge only has a y- component

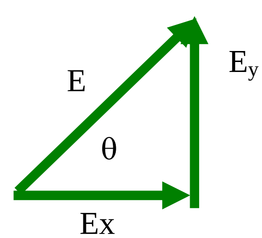
$$E_y = \frac{kQ}{r^2} = \frac{8.99x10^9\,Nm^2/C^2(5x10^{-9}C)}{(0.2m)^2} = 1.12x10^3\,N/C \text{ +x direction}$$

The magnitude magnitude of the electric field is found using the Pythagorean theorem

$$E = \sqrt{E_x^2+E_y^2} = \sqrt{1120^2+1120^2} = 1.58x10^3\,N/C$$

The direction is given by

$$\theta = \tan^{-1}\left(\frac{E_y}{E_x}\right) = \tan^{-1}\left(\frac{1120}{1120}\right) = 45°$$



above the +x axis

$$F_E = qE = (10x10^{-9}C)(1.58x10^3\,N/C) = 1.58x10^{-5}\,N$$

d) since the charge is negative, the force is in the opposite direction of the electric field so 45° below netagive x-direction

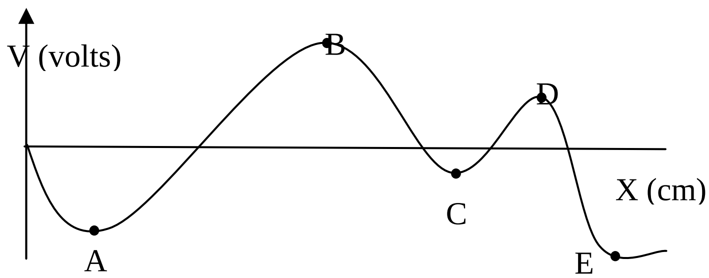
2. An electric potential as a function of distance as shown below.

a. An electron is initially sitting at point A. What is the minimum kinetic energy the electron will need to get from point A to point C?

b. A proton is initially sitting at point A. What is the minimum kinetic energy the proton will need to get from point A to point C?

c. Does your answer change for the electron if the particle moves from A to E? Explain.

d. Does your answer change for the proton if the particle moves from A to E? Explain.



Point	Potential (V)
A	-80
B	+100
C	-15
D	+50
E	-100

a) An electron at point A will be attracted to the more positive potential at point B. It will gain Kinetic energy that is equal to $U=q\Delta V=q(100V- -80V)=q(180V)$. It will have plenty of kinetic energy to overcome the repulsion in going from B to C.

b) A proton at point A will not want to go to the more positive potential at point B. It will need $KE=U=q\Delta V=q(100V- -80V)=q(180V)=1.6x10^{-19}C(180V)=2.88x10^{-17}J$

c) If the electron needs to go to E, since E is at a lower potential than A, the electron will need initial $KE=U=q\Delta V=q(-100V- -80V)=1.6x10^{-19}C(-20V)$

d) No. Once the proton has enough energy to B, it will be able to go to E.

3. A parallel plate capacitor has a charge of 0.02 μC on each plate with a potential difference of 240 V. The parallel plates are separated by 0.40 mm of air.

a) What is the capacitance for this capacitor?

b) What is the area of a single plate?

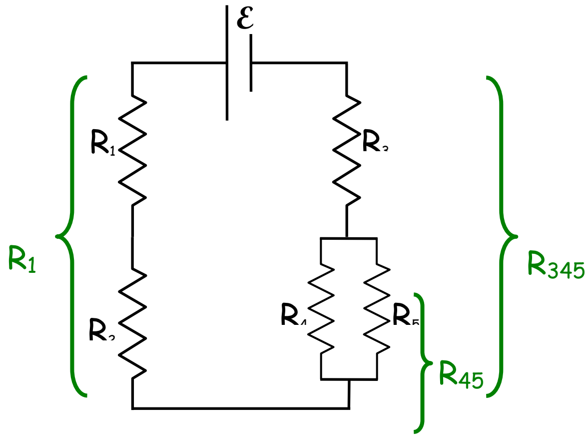
c) At what voltage will the air between the plates become ionized? Assume a dielectric strength of 3.0 kV/mm for air.

a) $Q=CV$ $\quad C=Q/V=(0.02x10^{-6}F)/240V=8.33x10^{-11}F$

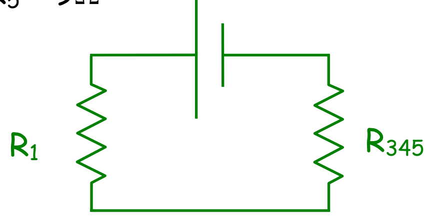
b) $C=\varepsilon_o A/d$ $\quad A=Cd/\varepsilon_o =(8.33x10^{-11}F)(0.4x10^{-3}m)/(8.85x10^{-12}C^2/Nm^2)=0.0038m^2$

c) The dielectric breakdown is 3000V/mm and the thickness is 0.4 mm so..
$V=(3000V/mm)(0.4mm)=1200V$

4. [20] For the circuit shown, **a)** find the equivalent resistance and the b) the voltage across R_5 **c)** current through R_5.



$\mathcal{E}$ = 4V
$R_1 = 2\Omega$
$R_2 = 3\Omega$
$R_3 = 5\Omega$
$R_4 = 7\Omega$
$R_5 = 9\Omega$



a) Resolve the parallel pair of

$$\frac{1}{R_{45}} = \frac{1}{R_4} + \frac{1}{R_5} = \frac{R_5 + R_4}{R_4 R_5}$$

Resolve the right side series:

$$R_{345} = R_3 + R_{45} = R_3 + \frac{R_4 R_5}{R_5 + R_4}$$

Resolve the left side series:

$$R_{12} = R_1 + R_2$$

Resolve the total series:

$$R_{12345} = R_1 + R_2 + R_3 + R_{45}$$

$$R_{12345} = R_1 + R_2 + R_3 + \frac{R_4 R_5}{R_5 + R_4}$$

Substitute values:

$$R_{12345} = 2 + 3 + 5 + \frac{7 \times 9}{9+7} = 10 + 3.94$$

$$\boxed{R_{12345} = 13.94\ \Omega}$$

b) Find the total current:

$$V = R_{12345} I_{total} \Rightarrow I_{total} = \frac{E}{R_{12345}}$$

$$I_{total} = \frac{4}{13.94} = 0.287A = 287mA$$

The voltage across the set is:

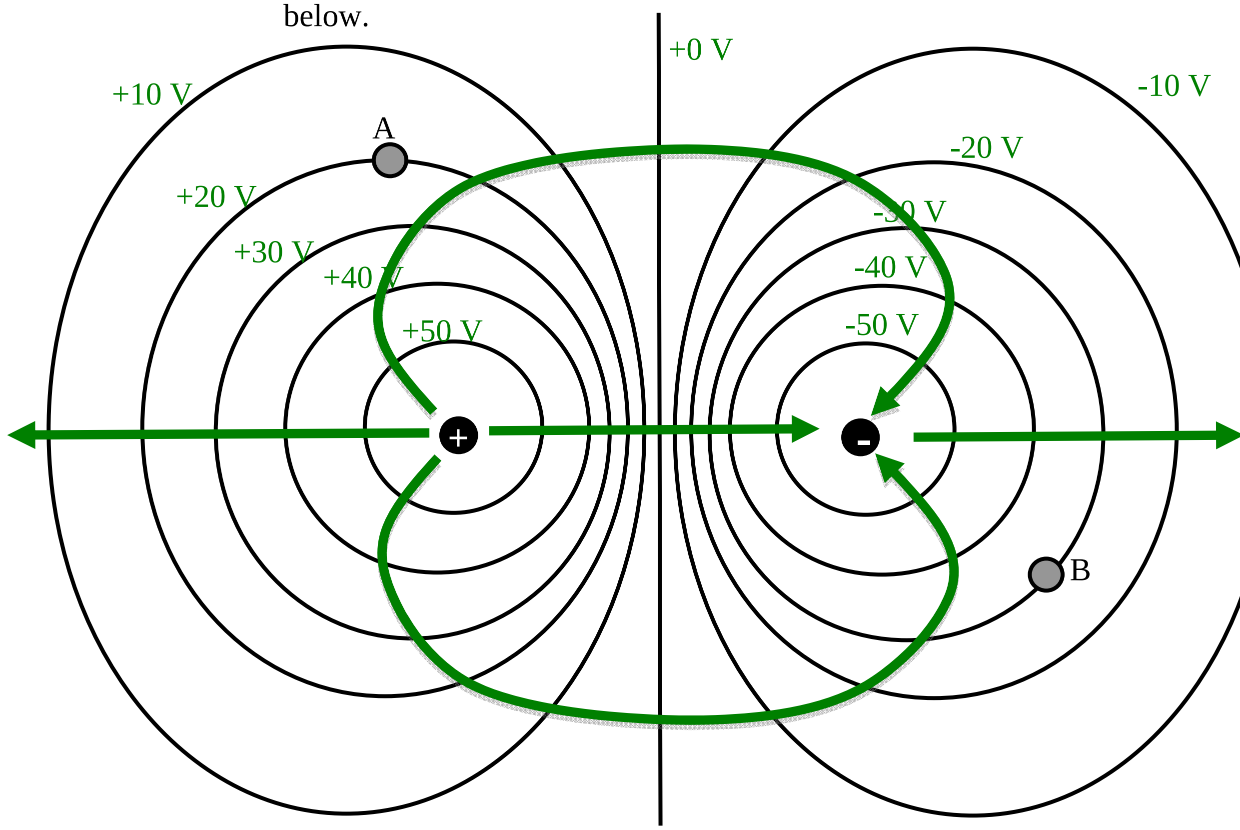
$$V_{45} = I_{total} R_{45} = (0.287)(3.94)$$
$$V_{45} = 1.13\ V = V_5$$

The current through R_5 is determined by the

$$I_5 = \frac{V_{45}}{R_5} = \frac{1.13}{9} = 0.126\ A$$

Constants to know and love:
$k = 9 \times 10^9$ N-m^2/C^2
$G = 6.67 \times 10^{-11}$ N-m^2/kg^2
$e = 1.60 \times 10^{-19}$ C
$m_e = 9.11 \times 10^{-31}$ kg
$m_p = 1.67 \times 10^{-27}$ kg
$c = 3.0 \times 10^8$ m/s
$N_A = 6.02 \times 10^{23}$

2. Below is a sketch of the equipotential lines for a dipole where the positive charge is on the left and the negative charge is on the right. The equipotential lines are spaced at 10 Volt intervals with the line nearest each charge having a magnitude of 50V.
    a. Label the potential of each line shown below.
    b. How much work is done by the electric force when an electron is moved from point A to point B?
    c. What is the change in potential energy for the electron in part b?
    d. What does the sign of the change in potential energy mean?
    e. Sketch the Electric field lines for the two point charge system shown below.



b)

$Work = -\Delta U_E = -q\Delta V = -q(V_B - V_A)$

$= -(-1.6x10^{-19}C)(-30V - +20V) = -8.0x10^{-18}J$

c) $\Delta U_E = -work = 8.0x10^{-18}J$

d) The positive sign on the potential energy means that we are storing more energy in the location of the electron by moving it to a place it does not want to go.