Full Solution

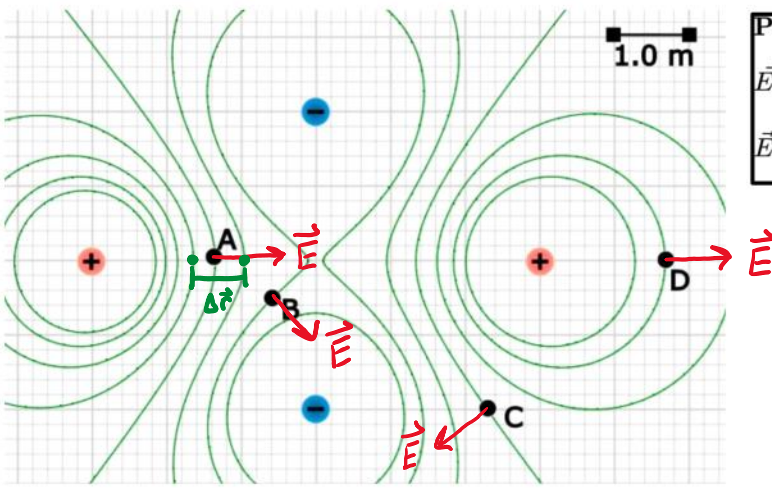
Monday, May 22, 2023 3:24 PM

Physics 203

Quizbit | Electric Potential ⇔ Electric Fields; Circuits

Part A: Work individually to produce a handwritten solution to **Part A** of this Quizbit. Submit an image of your solution to Canvas. The quality of your solution and communication is far more important than the final answer!

1. The equipotential lines pictured below were created with 4 charges of equal magnitude. **Point C** is at 0 Volts. The magnitude of the potential difference between adjacent lines is 3 Volts.



Part A Hints:

$$\vec{E}_x = -\frac{\Delta V}{\Delta x}$$

$$\vec{E} = -\left\langle \frac{\Delta V}{\Delta x}, \frac{\Delta V}{\Delta y}, \frac{\Delta V}{\Delta z} \right\rangle$$

(a) Draw a vector for each of the points labeled **A-D** representing the *direction* of the electric field at that point.

$\vec{E} \perp$ to equipotential lines, point downhill

(b) Rank the magnitude of the electric field at the four points labeled **A-D**. Explain how you determined your ranking.

$E_A > E_B > E_C \; ? \; E_D$

(c) Estimate the magnitude of the electric field at **point A**.

(C) I'll take the voltage on either side of A, and the total distance between adjacent lines

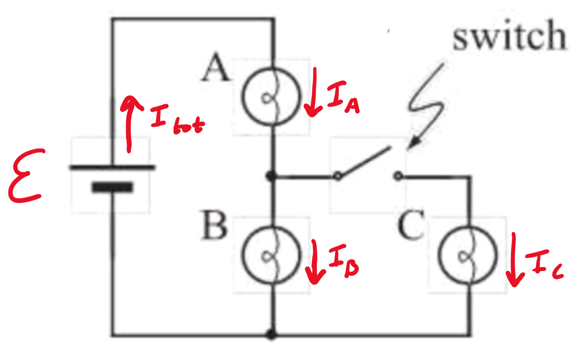
$$|E_A| = \frac{|\Delta V|}{|\Delta \vec{r}|} = \frac{6V}{\frac{3.5}{5}m} = \boxed{8.6 \frac{V}{m}}$$

When equipotential lines are closer together, $|\vec{E}|$ gets bigger ($\frac{\Delta V}{\Delta x}$ is larger!)

$|\vec{E}_d|$ is a little hard to determine b/c two lines are pretty close, but the other two are farther apart.

Part B: As a group, assign roles to each member. One person should be the writer, one should be the recorder in charge of submitting the group solution to Gradescope (or Canvas), and if you have a third member, they should be the advice giver. Write each group member's name on the solution! Make sure to rotate roles so that each person has a chance to be the writer. **Work together to produce a written solution to Part A, then additionally answer Part B.** Submit an image of your work to Gradescope or Canvas.

2. Consider the circuit shown below which includes one battery with potential difference $\mathcal{E}$, three identical lightbulbs with resistance R, and a switch that can be open (as shown) or closed to include bulb C.



(a) Write a set of equations using Kirchoff's Loop Rule and Junction rule for the circuit below while the switch is open, and Bulb C is not connected. **Solve for the current through Lightbulb A in terms of $\mathcal{E}$ and R.**

(b) Write a set of equations for the circuit if the switch was closed and Lightbulb C was connected. **Solve for the current through Lightbulb A in terms of $\mathcal{E}$ and R.**

(c) Does closing the switch (and adding lightbulb C) increase or decrease the brightness of Lightbulb A? Explain your reasoning.

Part B Hints:

$\sum I_{in} = \sum I_{out}$

$\sum \Delta V = 0$

(a) loop/voltage rule

$\Delta V = 0 = +\mathcal{E} - I_A R - I_B R$

Junction

$I_{tot} = I_A = I_B$

(b) loop/voltage

(1) $0 = +\mathcal{E} - I_A R - I_B R$

(2) $0 = +\mathcal{E} - I_A R - I_C R$

Junction

$\sum I_{in} = \sum I_{out}$

(3) $I_A = I_B + I_C$

(c) closing switch increases current in circuit (from $\frac{1}{2}\frac{\mathcal{E}}{R}$ to $\frac{2}{3}\frac{\mathcal{E}}{R}$).

Using $P = I^2 R$, we see that if I_A increases, P_A will also <u>increase</u>.

③ $\Rightarrow I_B = I_A - I_C$

① $\Rightarrow 0 = \mathcal{E} - I_A R - (I_A - I_C) R$

$0 = \mathcal{E} - 2I_A R + I_C R$

$\Rightarrow I_C = \dfrac{2I_A R - \mathcal{E}}{R} = 2I_A - \dfrac{\mathcal{E}}{R}$

② $\Rightarrow 0 = \mathcal{E} - I_A R - \left(2I_A - \frac{\mathcal{E}}{R}\right) R$

$0 = \mathcal{E} - I_A R - 2I_A R + \mathcal{E}$

$0 = 2\mathcal{E} - 3I_A R$

$\Rightarrow \boxed{I_A = \dfrac{2\mathcal{E}}{3R}}$