Physics 114 2020 Final Solutions

Questions

1. The flux stays the same and the field increases – by a factor of 9.

2. The net work done by the force **around a closed path is zero.** The work done by the force in moving the object between two points is **independent of the path taken**.

3. **No,** the charge could be moving such that **its velocity is parallel to B.**

4. The potential produced by the battery is constant. Resistance is proportional to the length of the resistor. If the length is reduced by a factor of two, the resistance will be reduced by a factor of two. However, **(a) the potential difference across the resistor stays the same.** An ideal battery always maintains a constant potential difference across its terminals. **(b) A smaller resistance with the same applied potential difference leads to a larger current**. Note that the resistivity and cross sectional area of the original resistor and one of its halves are the same. (c) The total resistance of the circuit is decreased. Thus the **current will still increase.** However, the **potential across the terminals will be less** since there is more energy dissipated in the internal resistance.

5. (a) **To the right**. The flux is decreasing to the right so the induced field is to the right, so the current goes from left to right.

   (b) The flux increases to the left **so the induced field is to the right so the current comes out of the page or to the right.**

(c) The flux into the page decreases so the induced field is out of the page, **so the current goes from left to right.**

(d) **F** = q**v** x **B**. The force on positive charges is up. The rh rule says then that **B is into the page.**

6. (a) Bulbs A and B have the same brightness as they are in series and have the same current. Bulb C is brighter than A and B as V goes across C but is split between A and B.

   (b) V = IR. Req on the top is 2R, so less current goes through there. Most of the current goes through C.

   (c) The brightness of A and B will stay the same if you unscrew C. The same voltage goes across it.

   (d) If A is unscrewed, the brightness of C stays the same as V is still the same across it. Bulb B goes out – R goes up to infinity so I goes to zero.

7. A positive charge attracts a negative one and repels a positive one. A positively charged object can also attract a neutral object by polarizing the object. Here, molecules will be polarized with more negative charge towards the positive one.

   Thus, X is positively charged, but Z can be negatively charged or neutral.

8. (a) In series, $Q_2 = Q_1$

   (b) $Q_1 = C_1V_1$ and $Q_2 = C_2V_2$. Thus, $C_1V_1 = C_2V_2$. $V_2/V_1 = C_1/C_2 = 0.5$.

   (c) In series Q is the same, so it makes sense to compare $Q^2/2C$.

   $U_1/U_2 = C_2/C_1 = 2$. $U_2/U_1 = 0.5$.

   (d) $Q_1/Q_2 = C_1V_1/C_2V_2 = C_1/C_2$ since the voltages are the same. So $Q_2/Q_1 = 2$.

   (e) $V_2/V_1 = 1$

   (f) $U_2/U_1 = (1/2\ C_2V_2^2)/\ (1/2\ C_1V_1^2) = C_2/C_1 = 2$

(g) The ones in parallel are more dangerous. Their equivalent capacitance is the sum of the two, $3C_1$ while for the ones in series the equivalent capacitance is $(1/C_1 + 1/2C_1)^{-1} = 2C_1/3$. There is more energy in the ones in parallel.

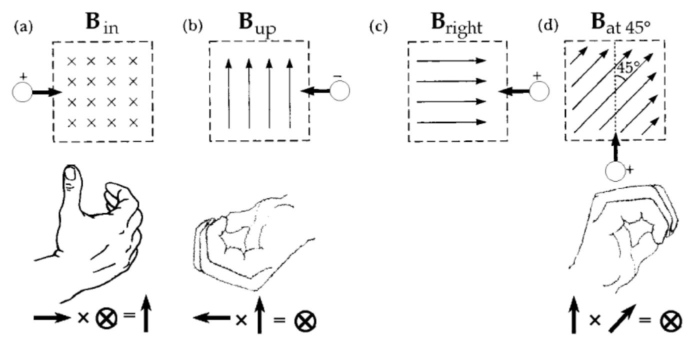
9.

(a) up

(b) out of the page, since the charge is negative.

(c) no deflection

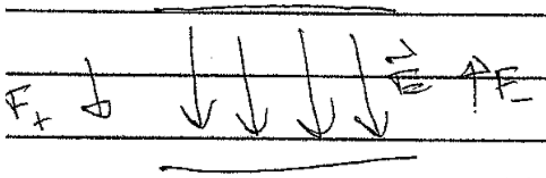
(d) into the page



10.

1. a) Its kinetic energy is increasing so its potential energy must be decreasing

b) It is moving toward higher potential. See diagram below. The electric field points from high to low potential. The force on a negative charge is towards high potential



11. B = $B_o \cos(kz - wt)\ \hat{j}$ **,** with $B_0 = E_0/c$

12. Ans $\mathbf{\Delta V_L > \Delta V_{1200} > 12\ V > \Delta V_{12}}$

Problems

1\. (a) $\boxed{E = 0}$

(b) $$E = \frac{k_e Q}{r^2} = \frac{\left(8.99\times10^{9}\right)\left(4.00\times10^{-6}\right)}{(0.0300)^2} = 4\times10^{7}\ \text{N/C}=$$

(c) $\boxed{E = 0}$

(d) $$E = \frac{k_e Q}{r^2} = \frac{\left(8.99\times10^{9}\right)(0)}{(0.0700)^2} = 0$$

2\. (a) $$\mathbf{E}_1 = \frac{k_e|q_1|}{r_1^2}(-\mathbf{j}) = \frac{\left(8.99\times10^{9}\right)\left(3.00\times10^{-9}\right)}{(0.100)^2}(-\mathbf{j}) = -\left(2.70\times10^{3}\ \text{N/C}\right)\mathbf{j}$$

$$\mathbf{E}_2 = \frac{k_e|q_2|}{r_2^2}(-\mathbf{i}) = \frac{\left(8.99\times10^{9}\right)\left(3.00\times10^{-9}\right)}{(0.300)^2}(-\mathbf{i}) = -\left(3\times10^{2}\ \text{N/C}\right)\mathbf{i}$$

$$\mathbf{E} = \mathbf{E}_2 + \mathbf{E}_1 = \boxed{-\left(5.99\times10^{2}\ \text{N/C}\right)\mathbf{i} - \left(2.70\times10^{3}\ \text{N/C}\right)\mathbf{j}}$$ i component is half

(b) $V = V_1 + V_2 = k_e[(3/.3) + (-3/0.1)] \times 10^{-9}\text{V} = (9)(10-30) = -180\text{V}$

(c) $$\mathbf{F} = q\mathbf{E} = \left(5.00\times10^{-9}\ \text{C}\right)\left(-300\,\mathbf{i} - 2700\,\mathbf{j}\right)\text{N/C}$$

$\mathbf{F} = \left(-1.50\times10^{-6}\,\mathbf{i} - 13.5\times10^{-6}\,\mathbf{j}\right)\text{N} =$

(d) U = qV = (5nC)(-180V) = -900nJ. Also need to add U from assembling –3 and –3 charges = -256nJ. So total is –1156 nJ

3. (a) $C_s = \left(\frac{1}{5.00} + \frac{1}{10.0}\right)^{-1} = 3.33\ \mu\text{F}$

$C_{p1} = 2(3.33) + 2.00 = 8.66\ \mu\text{F}$

$C_{p2} = 2(10.0) = 20.0\ \mu\text{F}$

$$C_{\text{eq}} = \left(\frac{1}{8.66} + \frac{1}{20.0}\right)^{-1} = \boxed{6.04\ \mu\text{F}}$$

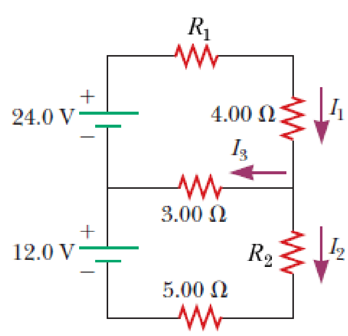
(b) $Q_{\text{eq}} = C_{\text{eq}}(\Delta V) = \left(6.04\times10^{-6}\text{ F}\right)\left(30.0\text{ V}\right) = 1.81\times10^{-4}\text{ C}$

$Q_{p1} = Q_{\text{eq}}$, so $\Delta V_{p1} = \frac{Q_{\text{eq}}}{C_{p1}} = \frac{1.81\times10^{-4}\text{ C}}{8.66\times10^{-6}\text{ F}} = 20.9\text{ V}$

$Q_3 = C_3\left(\Delta V_{p1}\right) = \left(2.00\times10^{-6}\text{ F}\right)\left(20.9\text{ V}\right) = 41.8\text{ uC}$

4.

(a) Which resistors are in series (if any)?



Ans: The R_1 and the resistor with 4Ω are in series and R_{tot1}=6Ω;

The R_2 and the resistor with 5Ω are in series and R_{tot2}=6Ω;

(b) Which resistors are in parallel?

Ans: There are no resistors in parallel.

(c) Use Kirchoff's junction rule to obtain an equation relating I_1, I_2, and I_3.

Ans: $I_1=I_2+I_3$

(d) Apply Kirchoff's loop rule to the top loop to obtain an equation relating I_1 and I_3.

Ans: $V_1-I_1R_1-I_1R_4-I_3R_3=0$ $24-2I_1-4I_1-3I_3=0$ $2I_1+I_3=8$

(e) Apply Kirchoff's loop rule to the bottom loop to obtain an equation relating I_2 and I_3

Ans: $V_2+I_3R_3-I_2R_2-I_2R_5=0$ $12+3I_3-1I_2-5I_2=0$ $2I_2-I_3=4$

5. $\mathbf{F}_B = q\mathbf{v}\times\mathbf{B} = \left(-1.60\times10^{-19}\right)\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & 3.70\times10^4 & 0 \\ 1.40 & 2.10 & 0 \end{vmatrix}$, **only the ixj component survives** $\mathbf{F}_B = \left(-1.60\times10^{-19}\text{ C}\right)\left[(0-0)\mathbf{i}+(0-0)\mathbf{j}+\left(0-(1.40\text{ T})\left(3.70\times10^4\text{ m/s}\right)\right)\mathbf{k}\right]$ = 8.29 x 10^{-15} **k N**

6. $L = \dfrac{\mu_0 N^2 A}{l} = \dfrac{\mu_0(420)^2(3.00 \infty 10^{-4})}{0.160} = 4.16 \infty 10^{-4}$ H

$\mathcal{E} = -L\dfrac{dI}{dt} \varnothing \dfrac{dI}{dt} = \dfrac{-\mathcal{E}}{L} = \dfrac{175\infty10^{-3}V}{4.16\infty10^{4}H} = -421$ A/s

7. (a) For putting energy into the inductor we have I = (ε/R)(1-$e^{-t/\tau}$), τ = L/R. This gives 220 mA = (6/4.9)(1-$e^{-t/(0.140/4.9)}$)

τ = L/R = 0.14/4.9 = 28.6 ms. I_{max} = 6/4.9 = 1.22

We have 0.22 = 1.22(1-$e^{-t/.0286}$)

$e^{-t/\tau}$ = 0.82

t = -τ*ln(0.82) = 5.66 ms

(b) I = I_{max}(1-$e^{-100/.0286}$) = 1.22(1-e^{-3500}) = 1.22 A

(c) We have I = I_{max} $e^{-t/\tau}$

0.16 = 1.22 $e^{-t/\tau}$

$t = -\tau * \ln(0.131) = 58.1$ ms