Physics 114 Exam 2 Spring 2019

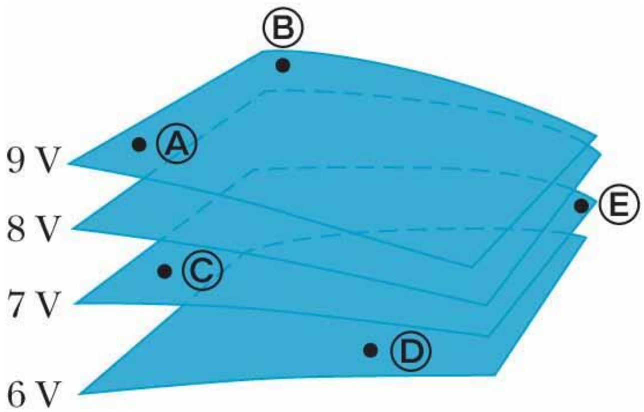
Name: ____

For grading purposes (do not write here):

Question	Problem
1.	1.
2.	2.
3.	3.

Answer each of the following questions. Points for each question are indicated in red. Unless otherwise indicated, the amount being spread among parts (a,b,c etc) are equal.
Be sure to show all your work.
Use the back of the pages if necessary.

Question 1. (10 points) The labeled points in the figure below are on a series of equipotential surfaces associated with an electric field. (a) Does the electric field point from points A to C or vice versa?



Describe (positive, negative, or zero) (i) the change in potential, (ii) change in potential energy, and (iii) work done by the electric field when

(b) A positive charge is moved from points A to B

(c)A positive charge is moved from points C to D

(d) A negative charge is moved from points C to D

(e) A positive charge is moved from points D to E

Solutions

(a) From a to c. The electric field points from high to low potential

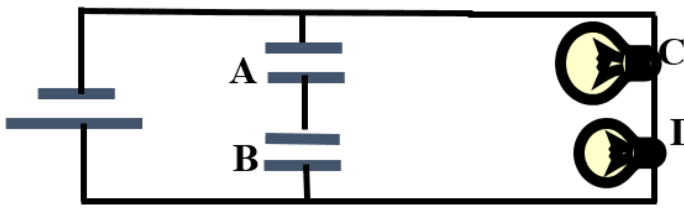
(b) This is an equipotential surface. (i) **zero**, (ii) **zero**, (iii) **zero**

(c) Here we go from high potential to low potential. (i) $\Delta V = V_f - V_i = 6\text{-}7 = -1$ V, **negative**, (ii) $\Delta V = \Delta U/q$; $\Delta U = q\Delta V$ and q is positive so, the answer is **negative**, (iii) $W = -\Delta U$ so **positive**

(d) The charge changes. (i) Same - **negative**, (ii) q is negative so the answer is now **positive**, (iii) **negative**

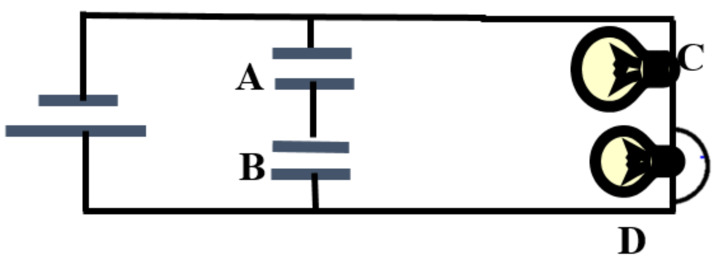
(e) Going to higher potential (i) +2V **positive**, (ii) **positive,** (iii) **negative**

Question 2. (10 points) Consider the circuit shown below where a 10 V battery is connected to two capacitors with C_A = 2 F and C_B = 4 F as well as two light bulbs. Bulb C is a 100 W bulb and bulb D is 50 W. At steady state,



(a) Which capacitor (A or B) has more charge on it or do they have the same charge?
(b) Which capacitor stores more energy or do they store them same energy?
(c) Which light bulb has more current through it (C or D) or do they have the same current through them?
(d) Which bulb has a higher resistance or do they have the same resistance?

Now one attaches a wire at either end of bulb D as shown below. The system reaches a steady state again. At steady state

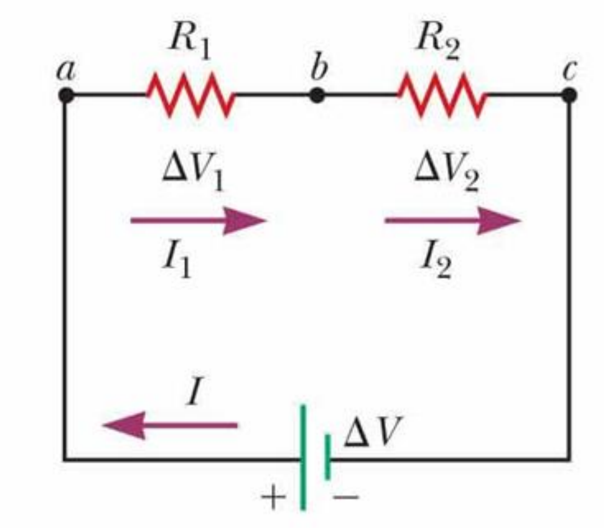


(e) What happens to the brightness of bulbs C and D. do they get brighter, dimmer, or stay the same? Compare to before the wire was attached.
(f) What happens to the charge on the capacitors? Do they increase, decrease, or stay the same?

Solutions

(a) **Same.** Capacitors in series have the same charge
(b) Since they have the same charge, use $U = \frac{Q^2}{2C}$, so it goes as the inverse of the capiciatnce. **C_A stores more energy.**
(c) **Same.** Resistors in series have the same current through them.
(d) They have the same current so $P = I^2R$. More power must mean more resistance, **Bulb C**
(e) **Bulb D gets dimmer – goes out** as it is short circuited. **Bulb C gets brighter**, it now has all 10 V across it.
(f) **Stay the same.** They have the same voltage across them.

Question 3. (10 points) Consider the circuit below where there is a *real* battery connected to two resistors. (a) If a third resistor is added in series, what happens to the current in the battery (does it increase, decrease, or stay the same?)



(b) If this third resistor is added in series, what happens to the terminal voltage across the battery?

(c) If instead of a third resistor, one were to put a capacitor in series with the two resistors, what would happen to the terminal voltage after the system reaches steady state (compare the terminal voltage before the capacitor is added to the terminal voltage after the capacitor is added in series and the system reaches a steady state.

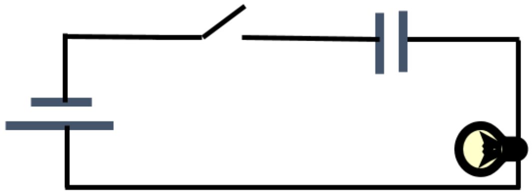
Solutions

(a) The total resistance of the circuit goes up so the current goes **down.**

(b) $\Delta V = \varepsilon - Ir$, the current goes down so the terminal voltage goes **up.**

(c) In steady state, there is no current so the terminal voltage is equal to the emf, so it is **higher (goes up).**

Problem 1. (15 points) An ideal 9 V battery is placed in a circuit with a switch, a 2 μF capacitor and a light bulb with resistance of 3000 Ω as shown below.



Immediately after the switch is closed

(a) What is the (i) current through and (ii) voltage across the light bulb?

(b) What is the (i) charge on the capacitor and (ii) the voltage across it?

At t = 10 s after the switch is closed.

(c) What is the (i) current through and (ii) voltage across the light bulb?

(d) What is the (i) charge on the capacitor and (ii) the voltage across it?

At t = 6 ms after the switch is closed,

(e) What is the (i) charge on the capacitor and (ii) the voltage across it?

Solution

(a) Immediately after the switch is closed, the capacitor is like a wire. (i)The current is just V/R = 9/3000 = **3 mA**. (ii) the same voltage supplied by the battery drops across the resistor, **V = 9V**

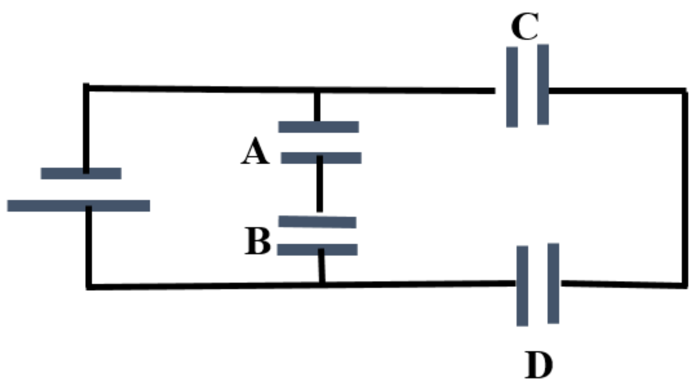
(b) There is **no (i) charge or (ii) voltage across the capacitor (=0)**. $q(t) = Q(1-e^{-t/RC})$. $t = 0$, $q = 0$. $Q = CV$, so $V = 0$.

(c) The time constant here is $RC = (3 \times 10^3)(2 \times 10^{-6}) = 6$ ms. $e^{-t/RC} = e^{-(10/0.006)} = 0$. (i) $I = (\varepsilon/R)e^{-t/RC} = \mathbf{0}$. (ii) $V = IR = \mathbf{0}$.

(d) (ii) All the **9 V** must be across the capacitor. (ii) $Q = CV = (9)(2 \times 10^{-6}) = \mathbf{18\ \mu C}$.

(e) (just for fun) $I = (\varepsilon/R)e^{-t/RC} = 0.003\, e^{-1} = 1.10$ mA. (i) $q(t) = Q(1-e^{-t/RC}) = \mathbf{11.38\ \mu C}$ or (ii) $V = Q/C = \mathbf{5.69\ V}$ or $V(t) = V_{max}(1-e^{-t/RC}) = \mathbf{5.69\ V}$

Problem 2. (15 points) Consider the circuit below. The battery is 9 V and the capacitances of the capacitors are as follows: C_A = 2 F, C_B = 4 F, C_C = 3 F and C_D = 6 F (a) Find the equivalent capacitance of the entire assembly. Determine the (b) charge on and (c) voltage across each of the four individual capacitors.



Solution

(a) Combine C and D gives $C_{CD} = (1/3 + 1/6)^{-1}$ = 2 F. Combine A and B and get $C_{AB} = (1/2+ 1/4)^{-1}$ = 4/3 F. The total equivalent capacitance is the sum of these = 10/3 **= 3.33 F**.

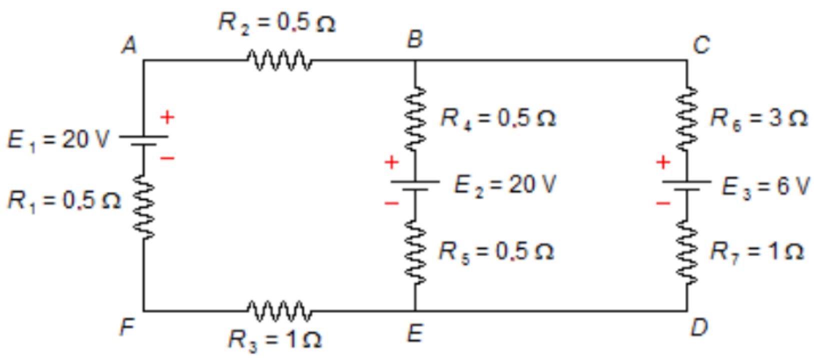
(b) and (c). C_{AB} and C_{CD} are in parallel. They have the full 9V across them. So the charges are $Q_{AB} = C_{AB}9$ = 12 C. $Q_{CD} = 9\ C_{CD}$ = 18 C. Note that the sum of these is the charge on the equivalent 3.33 F capacitor.

Since they are in series $\mathbf{Q_A = Q_B = Q_{AB} = 12\ C}$. Likewise $\mathbf{Q_C = Q_D = Q_{CD} = 18\ C}$.

$\mathbf{V_A = Q_A/C_A = 12/2 = 6\ V;\ V_B = Q_B/C_B = 12/4 = 3\ V}$

$\mathbf{V_C = Q_C/C_C = 18/3 = 6\ V;\ V_D = Q_D/C_D = 18/6 = 3\ V}$

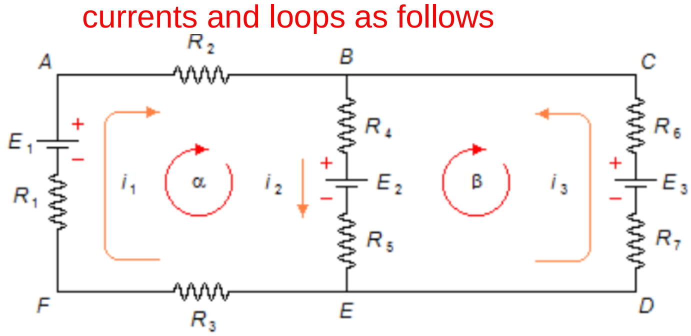
Problem 3. (15 points) Consider the circuit below. (a) As drawn, what resistors are in series (if any) and what resistors are in parallel? (b) Use Kirchoff's 1st (junction) law to relate the three distinct currents. Make sure to **clearly show** how you have defined these currents on your diagram. (c) Apply Kirchoff's loop rule to the left hand loop to obtain another equation relating the three currents. (d) Apply Kirchoff's loop rule to the right hand loop to obtain another equation relating the three currents



Solution

(a) R_2, R_1 and R_3 in the left loop are in series. R_4 and R_5 in the center are in series, and R_6 and R_7 on the right are in series. No other resistors are in series or parallel.

(b) There are different ways to do this but they are all equivalent. I choose my currents and loops as follows



As defined, $I_1 + I_3 = I_2$.

(c) $E_1 - R_2I_1 - R_4I_2 - E_2 - R_5I_2 - R_3I_1 - R_1I_1 = 0$

$20 - 0.5I_1 - 0.5I_2 - 20 - 0.5I_2 - I_1 - 0.5I_1 = 0$

$2I_1 + I_2 = 0$

(d) $R_5I_2 + E_2 + R_4I_2 + R_6I_3 - E_3 + R_7I_3 = 0$

$0.5I_2 + 20 + 0.5I_2 + 3I_3 - 6 + I_3 = 0$

$I_2 + 4I_3 + 14 = 0$

You did not have to do it, but the solutions are $I_1 = 1$ A, $I_2 = -2$ A, $I_3 = -3$A

Possibly Useful Information

$F = \frac{1}{4\pi\varepsilon_0}\frac{|q_1||q_2|}{r^2}$

$\varepsilon_0 = 8.85 \text{ X } 10^{-12} (C^2 / N - m^2)$

$e = 1.6 \text{ X } 10^{-19}$ C

$\vec{E} = \vec{F}/q_0$

$E = \frac{|q|}{4\pi\varepsilon_0 r^2}$, $E = \sigma/\varepsilon_0$

$\varepsilon_0 \Phi = \varepsilon_0 \oint \vec{E}.d\vec{A} = q_{enc}$

$\Delta x = x_2 - x_1$, $\Delta t = t_2 - t_1$

$\bar{v} = \Delta x / \Delta t$

$\bar{s}$ = (total distance) / Δt

$v = dx/dt$

$\bar{a} = \Delta v / \Delta t$

$a = dv/dt = d^2x/dt^2$

$v = v_o + at$

$g = 9.8 \text{ m/s}^2$

$x - x_o = v_o t + (½)at^2$

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$

$v^2 = v_o^2 + 2a(x-x_o)$

$\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$

$x - x_o = ½(v_o + v)t$

$\Delta\vec{r} = (x_2 - x_1)\hat{i} + (y_2 - y_1)\hat{j} + (z_2 - z_1)\hat{k}$

$x - x_o = vt - 1/2at^2$

$\bar{\vec{v}} = \Delta\vec{r} / \Delta t$, $\vec{v} = d\vec{r} / dt$

$\vec{a} = d\vec{v} / dt$

$\bar{\vec{a}} = \Delta\vec{v} / \Delta t$

$\Delta U = U_f - U_i = -W$

$\Delta V = V_f - V_i = -W/q_0 = \Delta U/q_0$

$U = -W_\infty$

$V = -W_\infty/q_0$

$V_f - V_i = -\int_i^f \vec{E}.d\vec{s}$

$V = -\int_i^f \vec{E}.d\vec{s}$

$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

$V = \sum_{i=1}^{n} V_i = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{q_i}{r_i}$

$U_f + K_f = U_i + K_i$

$V = \frac{1}{4\pi\varepsilon_0}\int\frac{dq}{r}$

$K = ½ mv^2$

$E = \frac{\Delta V}{\Delta s}$

$U = -W = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$

$Q = CV$

$C = \frac{\varepsilon_0 A}{d}$

$C = 2\pi\varepsilon_0 \frac{l}{\ln(b/a)}$

$C = 4\pi\varepsilon_0 \frac{ab}{b-a}$

$C = 4\pi\varepsilon_0 R$

$$\frac{1}{C_{eq}} = \sum \frac{1}{C_j} \text{ (series)}$$

$u = \tfrac{1}{2}\varepsilon_0 E^2$

$I = dQ/dt$

$\rho = 1/\sigma$

$R = \rho L / A$

$P = IV$

$P_{emf} = I\varepsilon$

$$\frac{1}{R_{eq}} = \sum \frac{1}{R_j} \text{ (parallel)}$$

$I = (\varepsilon/R)e^{-t/RC}$

$I = (Q/RC)e^{-t/RC}$, $I_0 = (Q/RC)$

$E = \sigma/\varepsilon_o$

$C_{eq} = \sum C_j$ (parallel)

$$U = \frac{Q^2}{2C} = \tfrac{1}{2}CV^2$$

$C = \kappa C_0$

$\Delta V = \varepsilon - Ir$

$V = IR$

$P = I^2R = V^2/R$

$I = \varepsilon/(R + r)$

$R_{eq} = \sum R_j$ (series)

$q(t) = Q(1 - e^{-t/RC})$

$q(t) = Qe^{t/RC}$

$\lambda = Q/L$, $\sigma = Q/A$, $\rho = Q/V$