Physics 114
Exam 2 Spring 2023
Solutions

Name: ____

For grading purposes (do not write here):

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

Include a statement and signature that you have followed the honor code and not cheated on this exam.

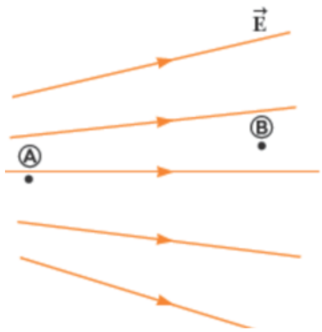
Answer each of the following questions and each of the problems. Points for each question and problem are indicated in red with the amount being spread equally among parts (a,b,c etc). Be sure to show all your work.
Use the back of the pages if necessary.

Question 1. (10 points) Consider the points A and B in an electric field drawn as shown below.

(a) Which point is at a higher potential (A or B) or are they the same?

(b) If a positive charge were to move from A to B, would the potential energy of the charge-field system increase, decrease, or remain the same? How about the work done by the electric field – would it be positive, negative or zero?

(c) If a negative charge were to move from A to B, would the potential energy of the charge-field system increase, decrease, or remain the same? How about the work done by the electric field – would it be positive, negative or zero?



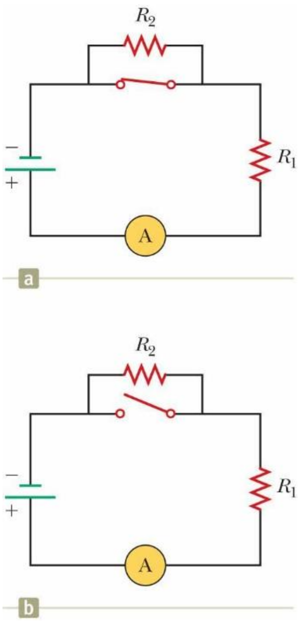
Solution

(a) **Point A is at a higher potential.** The electric field points from high to low potential.

(b) **The potential energy decreases.** The force on the positive charge is to the right so the **field does positive work** and the $\Delta U = -W$. It is like dropping a ball near the surface of the earth.

(c) **The potential energy would increase.** The force on the negative charge is to the left and so the field does **negative work**. This is like lifting a ball near the surface of the earth.

Question 2. (10 points). Consider the circuit below where there is a ***real*** battery hooked up as in the top panel. Now let the switch be opened as shown in the bottom panel.



(a) What happens to the reading in the ammeter after the switch is opened. Does it increase, decrease, or stay the same?
(b) What happens to the terminal voltage of the real battery when the switch is opened?
(c) What would happen to the terminal voltage if the battery were ideal instead of real (that is no internal resistance)?

Solution

(a) The total resistance of the circuit increases so the current **decreases**.

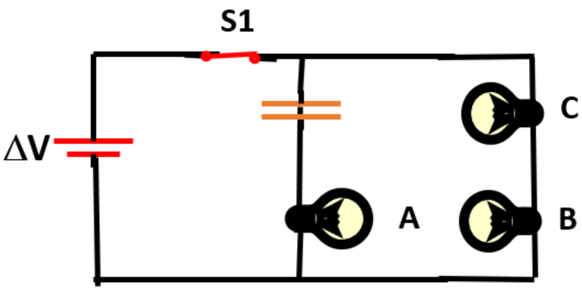
(b) The terminal **voltage increases**. $\Delta V = \varepsilon - Ir$. The current decreases so you are subtracting a smaller number.

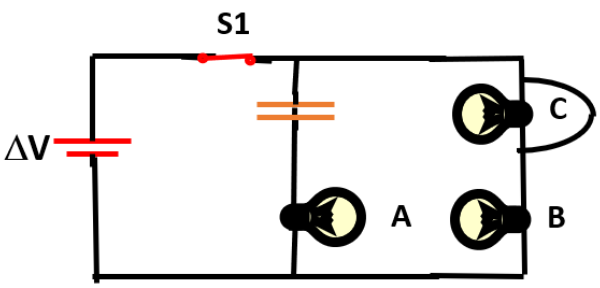
(c) The terminal voltage **stays the same**. An ideal battery maintains the same voltage regardless of the load. With $r = 0$, $\Delta V = \varepsilon$.

Question 3. (10 points) Consider the top circuit shown below which has 3 identical bulbs, a capacitor, a battery, and a switch. Imagine that the switch has been closed for a while and the system has reached a steady-state. (a) At this steady-state, compare the intensity of the light from bulbs A, B, and C – rank them in order of brightness.

(b) Now say that a wire is placed across bulb C as shown in the bottom figure. What happens to the brightness of bulb C? What happens to the brightness of bulb B?

c) Now let the wire across bulb C be taken away and the system again is left for a while so that it reaches steady state again so it is like the top circuit. Now the switch S1 is opened. Immediately after the switch is opened compare the brightness of bulbs A, B, and C. What happens to the brightness of the bulbs over a along period of time? That is, compare their brightness immediately after the swich is opened to sometime long thereafter.





Solutions

a) **C=B>A**. At steady state no current goes through the capacitor and hence no current goes through bulb A. C and B have the same current as they are in series. $P = I^2R$

b) **Bulb C goes out and Bulb B gets brighter**. Almost no current goes through C as it is short-circuited and almost all current goes through the wire, No all the voltage is across B and it get brighter. $P = V^2/R$

c) **A=B=C.** With the switch open, all bulbs are in series and have the same brightness as the capacitor discharges, The **bulbs are brightest right when the switch on and go out after a long time.**

Problem 1. (15 points) A 9 mC charge is placed at the origin.

(a) What is the electric potential at a distance x = 0.001m and x = 0.003 m?

(b) If a 3 μC charge of mass 5.4 Kg is placed at x = 0.001 m initially at rest, what would its speed be at x = 0.003 m?

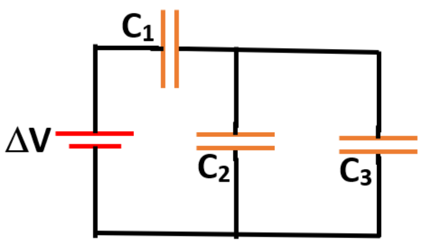
Solution

a) $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$ = $(9 \times 10^9)(9 \times 10^{-3})/(0.001)$ = **8.1×10^{10} V at 0.001 m**

At 0.003 m, we have $(9 \times 10^9)(9 \times 10^{-3})/(0.003)$ = **2.7×10^{10} V**

b) $U_f - U_i + K_f - K_i = 0$. The initial kinetic energy is zero. U = qV. So we have $K_f = - q(V_f - V_i)$. $\frac{1}{2}mv^2 = q(V_i - V_f)$. $v = \text{sqrt}(2q(V_i - V_f)/m)$ = $\text{sqrt}(6 \times 10^{-6})(5.4 \times 10^{10})/(5.4)$)= $\text{sqrt}(6 \times 10^4)$ = **245 m/s**

Problem 2. (15 points). Consider the circuit shown below where the battery has a potential of $\Delta V = 12$ V, $C_1 = 3$ μF, $C_2 = 2$ μF, and $C_3 = 4$ μF. (a) Find the equivalent (total) capacitance of the circuit and (b) the charge on and (c) voltage across each capacitor. Enter your answers for parts b and c in the Table below.

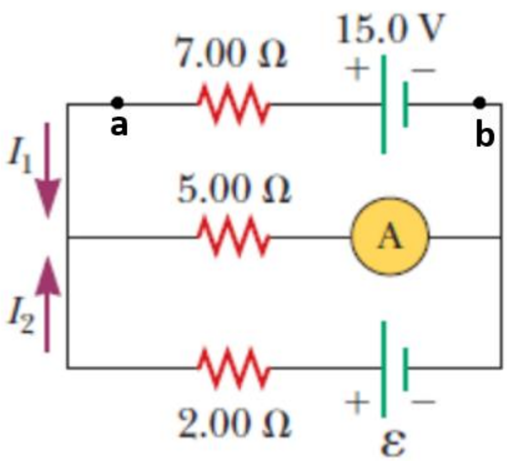


Solution

a) C2 and C3 are in parallel. Let their capacitance be called CP = 2 μF + 4 μF = 6 μF. CP is now in series with C1, so $C_{eq} = (1/6 = 1/3)^{-1} = \mathbf{2\ \mu F}$.
b) and c) Since C1 and CP are in series they have the same charge on them and this is the same charge as on C_{eq}. Q = CV = (2 μF)(12V) = 24 μC. This is the charge on C1. The voltage on C1 is then V = Q/C = 24 μC/3 μF = 8 V. This means there is 4 V on Cp so the total adds to 12 V. This same voltage can be obtained from V = Q/C = 24 μC/6 μF = 4 V. Now that we know the voltage across CP we have the voltage across C2 and C3 and get the charges. Q2 = C2V2 = (2 μF)(4V) = 8 μC. Q3 = (4 μF)(4V) = 16 μC

	C_1	C_2	C_3
Charge	24 μC	8 μC	16 μC
Voltage	8 V	4V	4V

Problem 3. (15 points). The ammeter shown in the figure below reads 2.00 A. The points a and b are drawn just to mark the locations and have no physical part in the circuit.



(a) (3 points). As drawn, state which resistors are in series and which are in parallel, if any.

(b) (6 points). Use Kirchoff's laws to obtain three independent equations involving I_1, I_2, and/or ε.

(c) (3 points). Solve the equations for I_1, I_2, and ε.

(d) (3 points). Calculate the potential difference between points a and b and state which is at a higher potential.

Solution. Call I_3 = 2 A in the middle wire going through the ammeter and have it go right.

a) N**one of the resistors are in series or parallel**.

b) For the top loop going CW
-15 + 5*2 + 7*I1 = 0 which simplifies to 7*I1 = 5
For the left junction, I1 + I2 = I3 = 2.
For the bottom loop, going CW
-5*I3+ ε - 2*I2 = 0, ε - 2*I2 = 10

c) The first equation gives **I1 = 0.714 A**. Then, from the 2nd equation, **I2** = 2 – 0.714 = **1.29** A. From the last equation we have **ε** = 10 + 2*I2 = 10 + 2.6 = **12.6 V**

d) Starting at b and going to the left we have
V_b + 15 – 7*0.714 = V_a. **V_b – V_a = -10 V. V_a is at a higher potential.**

Possibly Useful Information

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

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

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

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

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

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

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

$U_f + K_f = U_i + K_i$

$K = ½ mv^2$

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

$Q = CV$

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

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

$I = dQ/dt$

$$\rho = 1/\sigma$$

$$R = \rho L / A$$

$P = IV$

$E = \sigma/\varepsilon_o$

$P_{emf} = I\varepsilon$

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

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

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

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

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

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

$U = -W_\infty$

$V = -W_\infty/q_0$

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

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

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

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

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

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

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

$C = \kappa C_0$

$\Delta V = \varepsilon - Ir$

$V = IR$

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

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

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

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

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

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