Physics 114
Exam 2 Spring 2025

Name: Key ______________________________

For grading purposes (do not write here):

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

Sign here indicating you have followed the honor code and not cheated on this exam.

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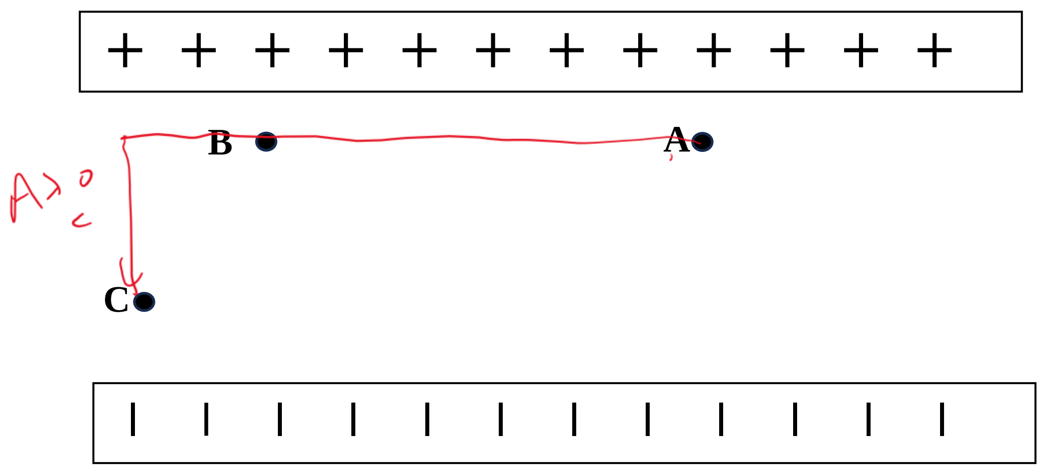
Answer each of the following questions and each of the problems. Points for each question and problem are indicated in red with the amount being spread equally among parts (a,b,c etc). Be sure to show all your work.
Use the back of the pages if necessary.

Question 1. (10 points) Consider two very large parallel plates as shown below each with an area A. One has a surface charge density of $+\sigma$ and the other has a surface charge density of $-\sigma$.

(a) If a positive charge moves from A to B (which is a horizontal displacement parallel to the plates), state the change in potential energy is positive, negative or zero. Also state whether the work done by the electric field is positive, negative or zero.

(b) If a positive charge moves from A to C, state the change in potential energy is positive, negative or zero. Also state whether the work done by the electric field is positive, negative or zero.

(c) If a negative charge moves from A to C, state the change in potential energy is positive, negative or zero. Also state whether the work done by the electric field is positive, negative or zero.



a) $\Delta U = q\Delta V$

$\Delta V = 0$

$\Delta U = 0$ This is an equipotential surface.

$W = -\Delta U = 0$

b) The path does not matter, could be as drawn. For a positive charge, it is like falling in a gravitational field, change in potential energy $\Delta U = U_f - U_i < 0$ negative. Also the $\vec{E}$ points downward so the potential $V_a > V_c$, $\Delta U = q\Delta V$, $\Delta V = V_c - V_a$ is neg & q is positive.

$W = -\Delta U$ so the work is positive. Also F on the positive charge is downward in the same direction as the displacement $W = \vec{F}\cdot\vec{s}$ is positive

Solution q1 continued

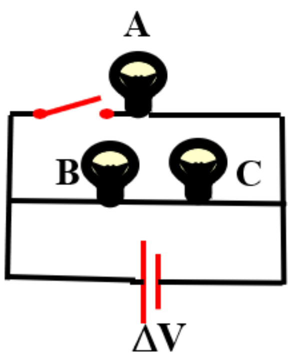
c) For a negative charge it is like lifting a book **ΔU is positive**, $\Delta U = q\Delta V$

ΔV is negative but q is negative.

$W = -\Delta U$ so **W is negative**

Also $\vec{F}$ is now in opposite direction of displacement.

Question 2. (10 points) Three identical bulbs are wired to an ideal battery as shown below with the switch initially open.



(a) As shown (with the switch open) rank the brightness of the bulbs A, B, C from highest to lowest

(b) When the switch is now closed, state whether the brightness of each bulb changes and if it does, describe how (does it become brighter, dimmer etc).

(c) Reconsider your answer now for part b except now the battery is a real battery. So (assuming a real battery now) compare whether the brightness of each bulb changes when the switch is closed and if it does, describe how (does it become brighter, dimmer etc).

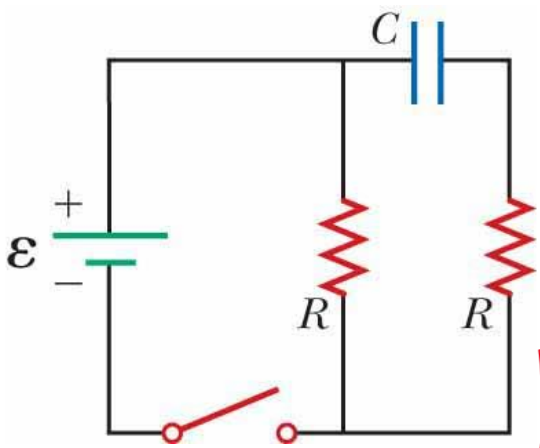
a) Bulbs B & C have the same current & resistance & $P = I^2R$ so they are equally bright. Bulb A has zero brightness as no current flow through it

so $B = C > A$

b) For an ideal battery, ΔV is constant so the brightness of B & C does not change. Bulb A turns on & hence gets brighter. [Bulb A is brighter now than B & C since the voltage across it is greater]

c) Bulb A turns on so it gets brighter but ΔV across it is less than if the battery were real. ΔV for B & C also go down so they are less bright. $\Delta V_{term} = \mathcal{E} - Ir$, $I = \frac{\mathcal{E}}{R_{eq}}$ $R_{eq} \downarrow$ $I \uparrow$ $\Delta V_{term} \downarrow$

Question 3. (10 points) Consider the circuit in the figure and assume the battery has no internal resistance.



(a) Just after the switch is closed, what is the current in the battery?

(b) After a very long time, what is the current in the battery?

(c) After a very long time, what is the voltage across the capacitor?

a) The capacitor does not yet have any charge or 0V, it is like a wire. $I = \mathcal{E}/R_{eq} = \frac{\mathcal{E}}{\left(\frac{1}{R}+\frac{1}{R}\right)^{-1}} = 2\mathcal{E}/R$

b) Now current does not flow through the capacitor. $I = \mathcal{E}/R$

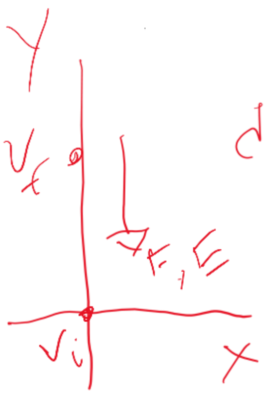
c) The voltage is maximal and $= \mathcal{E}$

Problem 1. (15 points) A very small charged sphere of mass 2 Kg and charge +5 C is moving along the y-axis in a constant, uniform electric field. At the origin its speed is 100 m/s and some time later its speed is measured to be 10 m/s when it is at y = 10 m.

(a) What is the direction of the electric field (2.5 points)?

(b) Where is the electric potential higher – at the origin or at y = 10 m (2.5 points)?

(c) What is the change in electric potential between its final and initial position ($V_f - V_i$) (10 points)??



a) The positively charged particle is slowing down. The force on the particle is downward. $\vec{F} = q\vec{E}$; $\vec{E}$ is downward

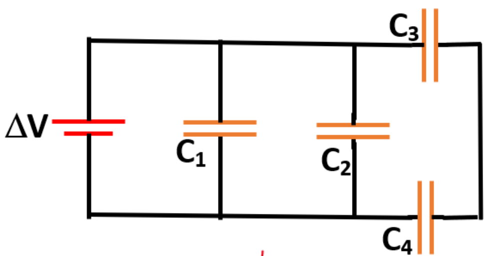
b) The electric field points from high to low potential so the final point at 10m is at a higher potential.

c) $\Delta U + \Delta K = 0$; $q\Delta V = -\Delta K$; $\Delta V = -\frac{\frac{1}{2}m(v_f^2 - v_i^2)}{q}$

$= -\frac{2(10^2 - 100^2)}{2 \cdot 5} = 1{,}980\ V$

Problem 2. (15 points). Consider the system of capacitors hooked up to a 9V battery shown below. Let $C_1 = 5\ \mu F$, $C_2 = 2\ \mu F$, $C_3 = 6\ \mu F$, $C_4 = 3\ \mu F$. (a) Find the equivalent capacitance for the circuit. Find the (b) charge and (c) voltage across each capacitor (enter then in the Table)

	C_1	C_2	C_3	C_4
Charge (μC)	45	18	18	18
Voltage (V)	9	9	3	6

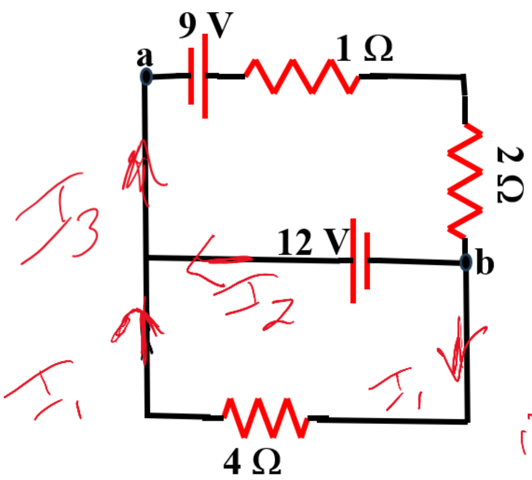


$C_s = \left(\frac{1}{3}+\frac{1}{6}\right)^{-1} = 2\ \mu F$ $C_{eq} = 5+2+2 = 9\ \mu F$, $Q_{eq} = C_{eq}V = 9\cdot 9 = 81\ \mu C$

$Q_s = C_s V_s = (2)(9) = 18\ \mu C$. series same charge. $Q_3 = Q_4 = Q_s = 18\ \mu C$

$V_3 = \frac{Q_3}{C_3} = \frac{18}{6} = 3V$ $V_4 = \frac{18}{3} = 6V$

Problem 3. (15 points) In the circuit below,



(a) (3 points) State if there are any resistors in parallel or series and describe them (which are in series and which are in parallel if any?).

(b) (6 points) Apply Kirchoff's laws to obtain 3 equations and 3 unknowns that relate the currents in the circuit. Clearly draw and label currents on the circuit.

(c) (3 points) Solve the equations to obtain the currents through each resistor and battery.

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

a) The 1Ω and the 2Ω resistors are in series. None are in parallel.

b) Using currents as drawn

$I_1 + I_2 = I_3$, $12 + 4I_1 = 0$, $9 - 3I_3 + 12 = 0$

c) The 2nd equation gives $I_1 = -3A$

The 3rd equation gives $I_3 = 7A$

Then the 1st equation gives $I_2 = 10A$

d) $V_a + 9 - (7)(3) = V_b$, $V_a - V_b = 12V$

or $V_b + 12 = V_a$

Possibly Useful Information

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

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

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

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

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

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

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

$U_f + K_f = U_i + K_i$

$K = ½ mv^2$

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

$Q = CV$

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

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

$I = dQ/dt$

$\rho = 1/\sigma$

$R = \rho L/A$

$P = IV$

$E = \sigma/\varepsilon_o$

$P_{emf} = I\varepsilon$

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

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

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

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

$U = -W_\infty$

$V = -W_\infty/q_0$

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

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

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

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

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

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

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

$C = \kappa C_0$

$\Delta V = \varepsilon - Ir$

$V = IR$

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

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

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

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

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

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

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

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