Physics 102 – Pledged Problem 6

Time allowed: **2 hours at a single sitting**

DUE 4PM MONDAY, March 17, 2008, in the boxes marked Phys 101-102 in the physics lounge. You may use your own textbook, your notes, and a non-programmed calculator. You may also consult the on-line solutions to the corresponding suggested problems. You should consult no other help. Show how you arrived at your answer; the correct answer by itself may not be sufficient.

Further instructions:

(a) Write legibly on **one** side of 8.5" x 11" white or lightly tinted paper.
(b) Staple all sheets together, including this one, in the upper left corner and make one vertical fold.
(c) On the outside, staple side up. Print your name in capital letters, your LAST NAME first followed by your FIRST NAME.
(d) Below your name, print the phrase "Pledged Problem 6", followed by the due date.
(e) Also indicate **start time** and **end time.**
(f) Write and sign the pledge, with the understanding you may consult the materials noted above.

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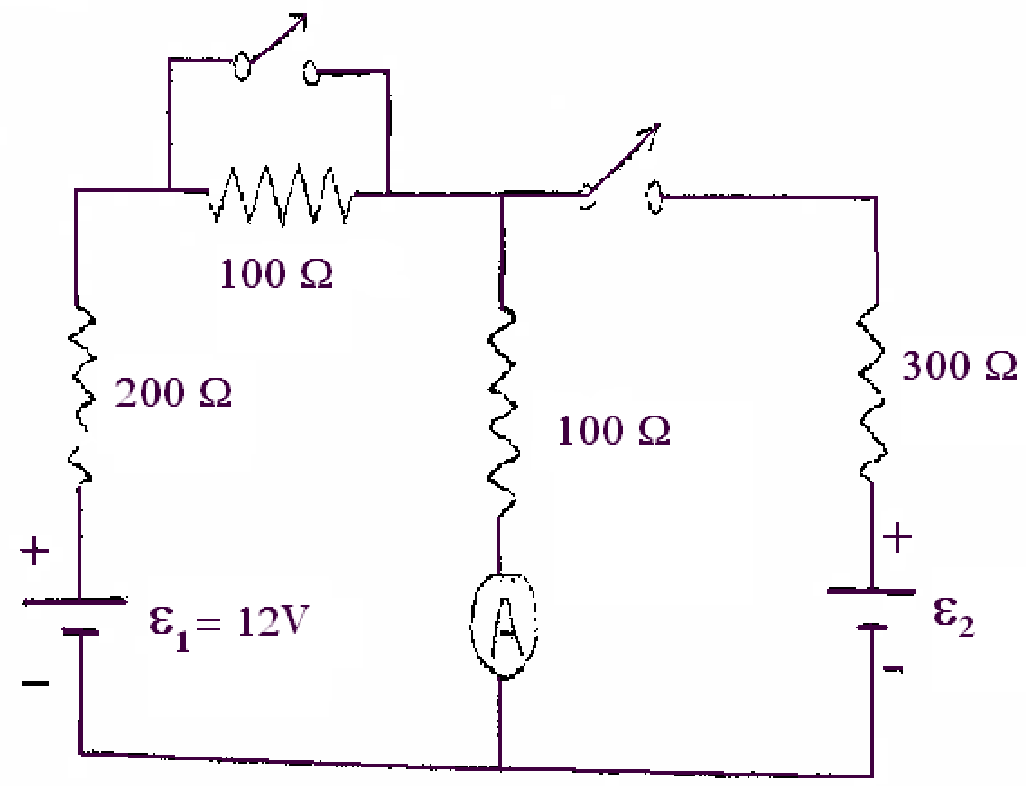
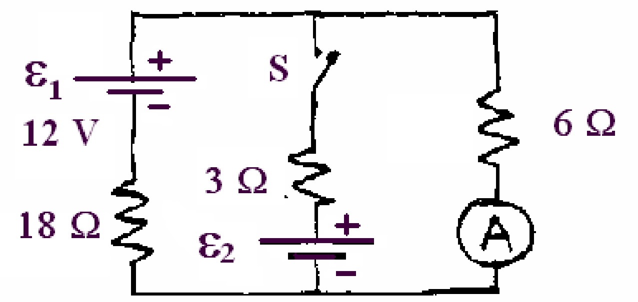
1. In the circuit below, the current through the ammeter A has the same value when both switches are open and when they are both closed. The ammeter has negligible resistance.

(a) Determine the current through the ammeter when the switches are open.

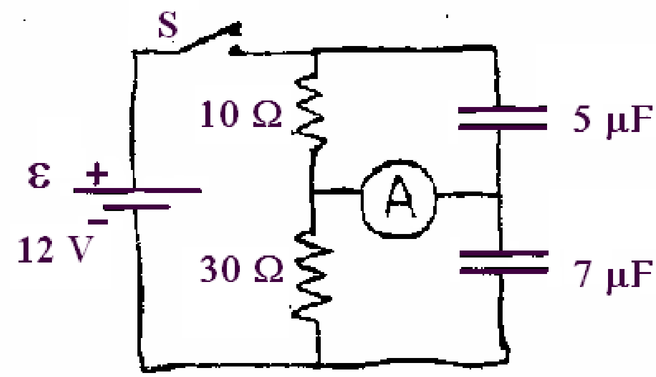
(a) Determine the value of ε_2.



2. (A) In the circuit shown to the right, the current through the ammeter A doubles when switch S is closed. Determine the emf ε_2.

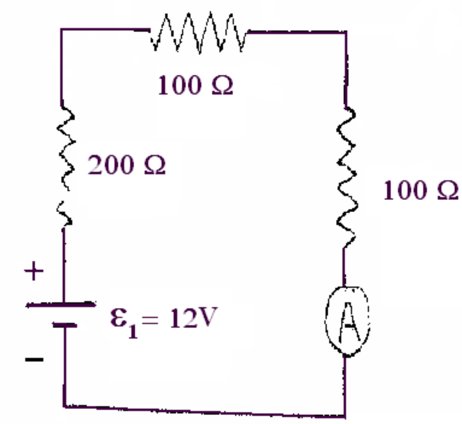


(B) In the circuit shown to the right, the capacitors are uncharged. When switch S is closed, charge flows through the ammeter A until equilibrium is achieved. Determine the total charge (not the current) that flows through the ammeter.



Solution – Pledged Problems #6

1.(a) When both switches are open, no current flows through the right loop, and the circuit simplifies to a single loop with three resistors in series, as shown. The current I through the ammeter can be determined by determining the equivalent resistance

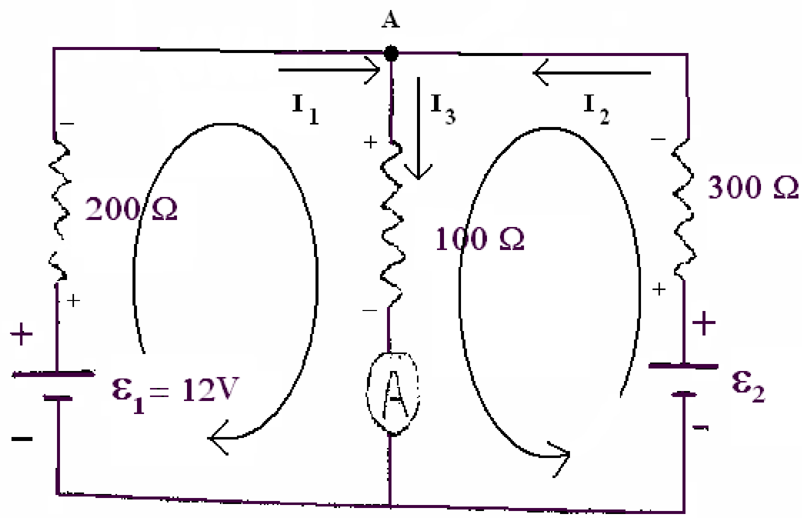


$$\begin{aligned} R &= R1 + R2 + R3 \\ &= 200\Omega + 100\Omega + 100\Omega \\ &= 400\Omega \end{aligned}$$

and applying the equation V = IR to get

$$I = \frac{V}{R} = \frac{12}{400} = \mathbf{0.030\ A}$$

(b) After the switches are closed, the circuit appears as shown below (the 100Ω resistor in the left hand loop is shorted by the closing of the switch and so no longer is included in the loop).



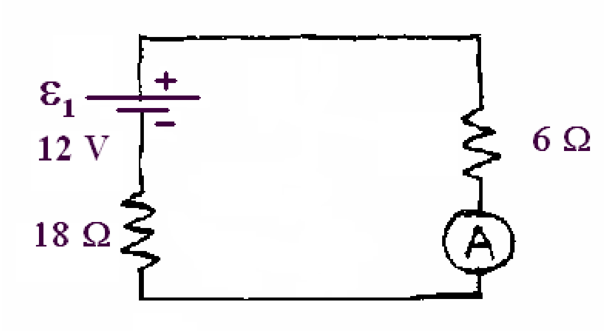
The value of ε_2 can then be determined by applying Kirchhoff's Junction and Loop rules. First, the direction of currents are selected and the potential drops across the currents are labeled, consistent with the flow of current (current will flow from the positive, or high end of a resistor to the negative, or low end). Then 3 independent equations can be generated and the results from part (a) applied ($I_3 = I$ from part (a)).

$$I_1 + I_2 - I_3 = 0$$
$$12 - 200I_1 - 100I_3 = 0$$
$$\varepsilon_2 - 300I_2 - 100I_3 = 0$$

With the substitution $I_3 = 0.030A$, the second equation produces a value of $I_1 = 0.045A$. Those results plugged into the first equation yields a value of $I_2 = -0.015A$. Finally, plugging those results into the third equation yields

$$\varepsilon_2 = 300I_2 + 100I_3 = (300)(-0.015) + (100)0.030$$
$$\boldsymbol{\varepsilon_2 = -1.5V}$$

2.(a) When the switch is open, no current flows along the center line and so that part of the circuit can be removed, leaving the circuit shown below.



The current *I* through the ammeter can be determined by determining the equivalent resistance

$$R = R1 + R2$$
$$= 18\Omega + 6\Omega$$
$$= 24\Omega$$

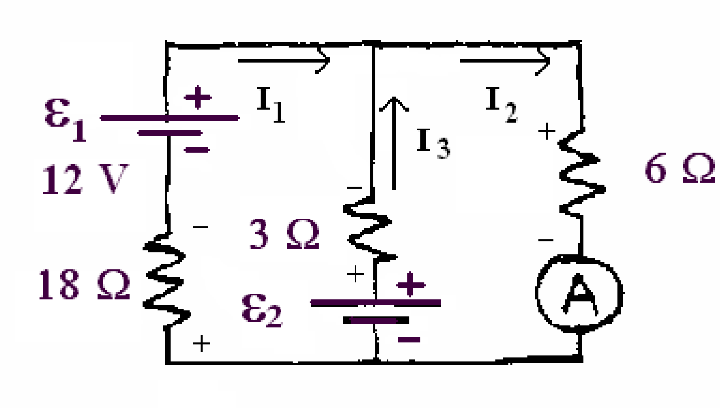
and applying the equation V = IR to get

$$I_{init} = \frac{V}{R} = \frac{12}{24} = \mathbf{0.5\ A}$$

After the switch is closed, the circuit appears as below.

Then 3 independent equations can be generated and the results from the initial part applied ($I_2 = 2 \times I_{init} = 1.0A$).

$$I_1 - I_2 + I_3 = 0$$
$$12 + 3I_3 - \varepsilon_2 - 18I_1 = 0$$
$$\varepsilon_2 - 3I_3 - 6I_2 = 0$$



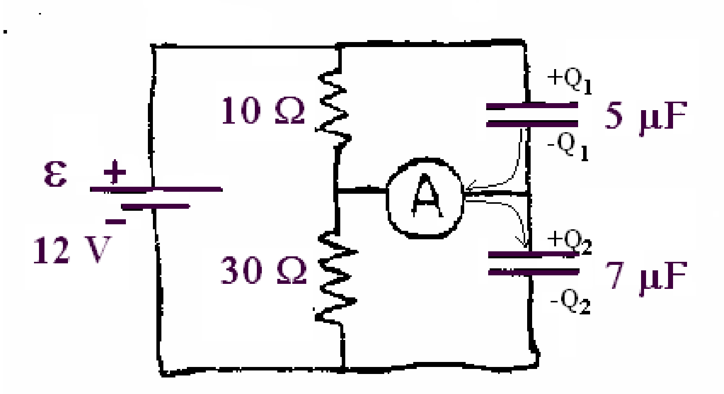
After substituting the value for I_2 into the third equation, $\varepsilon_2 - 3I_3 = 6V$, which can then be plugged into the second equation to solve for I_1

$$12 + 3I_3 - \varepsilon_2 - 18I_1 = 0$$
$$12 - 6 - 18I_1 = 0$$
$$18I_1 = 6$$
$$I_1 = 0.33A$$

With this result, the first equation indicates that $I_3 = 0.67A$ and therefore, according to the third equation,

$$\varepsilon_2 - 3(0.67) - 6(1) = 0$$
$$\boldsymbol{\varepsilon_2 = 8V}$$

(b) After the switch is closed, charge will flow through the ammeter until the potential across each capacitor equals the potential across the resistor in parallel with that capacitor. At that point, no more charge will flow through the ammeter, but will continue to flow through the two resistors in accordance with the equation $V = I(R_1 + R_2)$. The charge that will have flowed to each capacitor can be determined by using the equation $Q_i = C_i V_i$, recognizing that the charge flow associated with the upper capacitor will be negative and with the lower capacitor will be positive. The potential, V_i, across each resistor (and therefore, the corresponding capacitor) can be determined by first solving for I, and then solving for the individual potentials by using the equation $V_i = IR_i$.



Using this approach, one finds that $I = V/(R_1 + R_2) = 12V/(10\Omega + 30\Omega) = 0.3A$. The voltage, V_1, across the top resistor and capacitor is then $V_1 = (0.3A)(10\Omega) = 3V$ and the voltage, V_2, across the bottom resistor and capacitor is $V_2 = (0.3A)(30\Omega) = 9V$.

The amount of charge that will have flowed from the top capacitor will be $-Q_1 = = C_1V_1 = (5x10^{-6}F)(3V) = 1.5x10^{-5}C$ and the amount that will have flowed to the bottom capacitor will be $Q_2 = C_2V_2 = (7x10^{-6}F)(9V) = 6.3x10^{-5}C$. The total charge that will have flowed, therefore, will be

$$Q_{tot} = Q_1 + Q_2 = -1.5x10^{-5}C + 6.3x10^{-5}C$$
$$\boldsymbol{Q_{tot} = 4.8x10^{-5}C}$$