DLS/Stevenson East Side Science Olympiad Invitational

Saturday, January 26, 2013

Circuit Lab – Written Test

Team Number: 0 Team Name: D.C.

Team Members: Eeyore and Dumbo

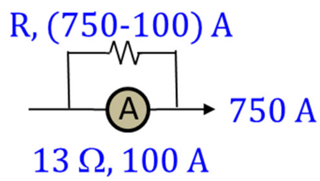
1. Please record your answers in the space provided. If you fail to record an answer, you will not get any credit for that question.
2. There is no penalty for wrong answers EXCEPT for breaking ties.
3. You may separate the pages but they ALL must be re-stapled in the correct order at end of the test.
4. You have 25 minutes to solve this test, no more.
5. Return the complete exam after you are done. Failing to do so will disqualify you from the event.

Score: 50/50 Rank: 0

Tiebreaker 1: Total Points on Practical
Tiebreaker 2: Question 1
Tiebreaker 3: Question 7
Tiebreaker 4: Question 9
Tiebreaker 5: Question 11
Tiebreaker 6: Random Choice

1. The resistance of an ammeter is 13 Ω and its scale is graduated for a current up to 100A. After an additional shunt has been connected to this ammeter it becomes possible to measure up to 750 A by this meter. The value of shunt resistance is

   a. 20.0 Ω
   b. 0.2 Ω
   c. 2.0 Ω
   d. 2.0 k Ω

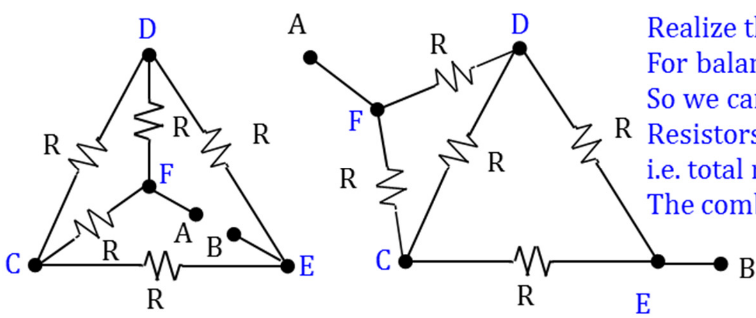


$V = 13\ \Omega * 100\ A = R * 650\ A \Rightarrow R = \underline{2\ \Omega}$

2 Points

A shunt (resistor) bypasses the excess current to keep the amperage of the ammeter same.

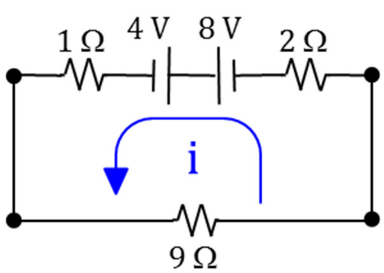
2. Find the equivalent resistance between the terminals A and B.



Realize this (FDEC) is a balanced Wheatstone's Bridge.
For balanced bridge no current can flow through the middle resistor CD.
So we can ignore the resistor CD.
Resistors FD & DE are in series, as well as FC & CE are in series
i.e. total resistance is 2R each.
The combinations (FD-DE) and (FC-CE) are in parallel.

$\frac{1}{2R} + \frac{1}{2R} = \frac{2}{2R} = \frac{1}{R} \Rightarrow$ Equivalent Resistance $= \underline{R}$ 2 Points

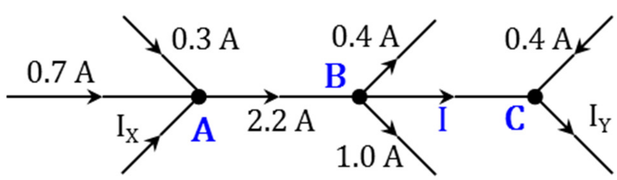
3. Find the current in the circuit shown below.



$-8\ V + 4\ V + (1+9+2)\ \Omega * i\ A = 0 \Rightarrow i = \underline{\frac{1}{3}}\ \underline{A}$

2 Points 1 for value & 1 for Units

4. For the portion of the circuit shown below, the values of I_X and I_Y are respectively

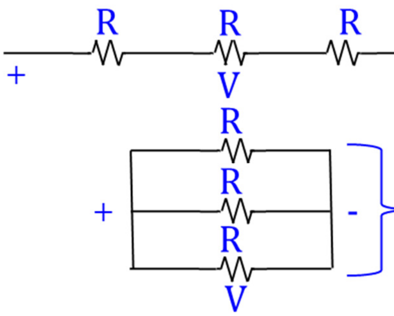


@ node A $0.7 + 0.3 - 2.2 + I_x = 0 \Rightarrow I_x = \underline{1.2}\ \underline{A}$ 2 Points 1 for value & 1 for Units

@ node B $2.2 - 0.4 - I - 1.0 = 0 \Rightarrow I = 0.8\ A$

@ node C $I + 0.4 - I_Y = 0 \Rightarrow I_x = \underline{1.2}\ \underline{A}$ 2 Points 1 for value & 1 for Units

5. Three equal resistors connected in series dissipate 10 W of power. If the same resistors are connected in parallel across the same voltage source, determine the power dissipated.



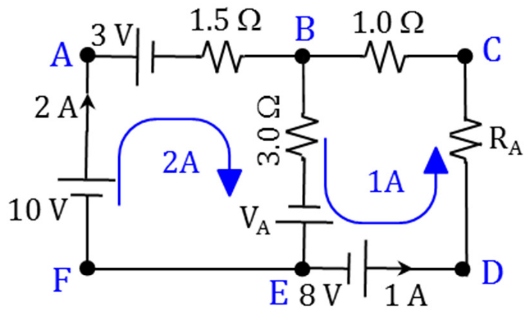
$Power = VI = \frac{V^2}{3R}$ = 10 W ⇒ $\frac{V^2}{R} = 30$ **OR**

$Power = \Sigma I^2R = 3*\left(\frac{V}{3R}\right)^2 R = \frac{V^2}{3R}$ = 10 W ⇒ $\frac{V^2}{R} = 30$

$Power = VI = \frac{3V^2}{R}$ = 3x30 W = 90 W

2 Points 1 for value & 1 for Units

6. For the following circuit, determine the Voltage V_A and Resistance R_A.



For Mesh ABEF -10 V + 3 V + 1.5 Ω *2 A + 3.0 Ω *(2+1) A - V_A= 0 ⇒ V_A = 5 V

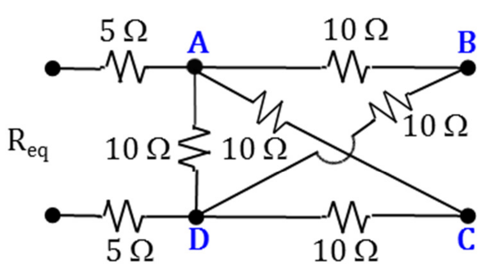
2 Points 1 for value & 1 for Units

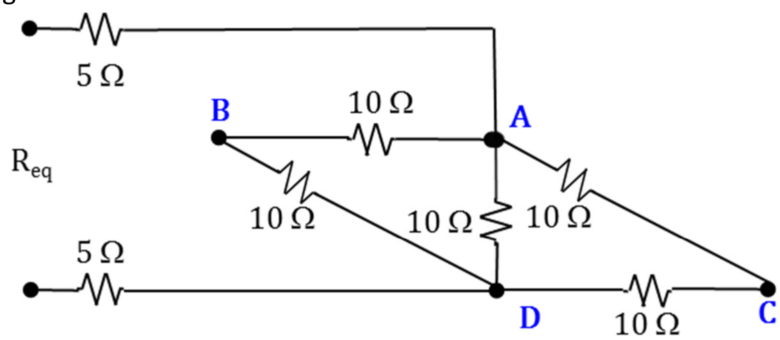
For Mesh BCDE -5 V - 8 V + R_A Ω *1 A + 1 Ω *1 A + 3.0 Ω *(2+1) A = 0 ⇒ R_A = 3 Ω

2 Points 1 for value & 1 for Units

7. In a given circuit element the direction of the current is
   a. Same as the flow of electrons
   b. Opposite to flow of electrons
   c. From positive terminal to negative terminal
   d. Both a. and b.
   e. Both a. and d.
   f. Both b. and c. 2 Points
   g. Both b. and d.
8. Identify the correct order of low to high resistivity.
   a. Silver, Aluminum, Iron, Carbon, Silicon 2 Points
   b. Iron, Silver, Aluminum, Carbon, Silicon
   c. Iron, Aluminum, Silver, Silicon, Carbon
   d. Aluminum, Iron, Carbon, Silver, Silicon
   e. Silicon, Carbon, Aluminum, Silver, Iron

9. Find the equivalent resistance for the following circuit





ABCD may look like a balanced Wheatstone's Bridge, but it is not.
If 5 Ω resistors were connected to B & C, it will be balanced Wheatstone's Bridge.
Resistors AB & BD are in series, as well as AC & CD are in series i.e. total resistance is 20 Ω each.
The combinations (AB-BD), (AC-CD) and AD are in parallel.

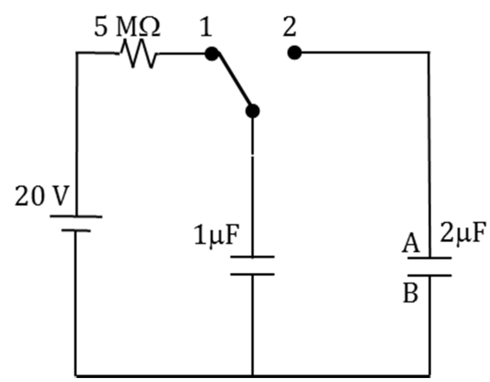
$\frac{1}{20} + \frac{1}{20} + \frac{1}{10} = \frac{4}{20} = \frac{1}{5} \Rightarrow$ Equivalent Resistance = 5 Ω

R_{eq} = 5 Ω + 5 Ω + 5 Ω = 15 Ω   2 Points, 1 point for value and 1 point for unit

10. After a long time in position 1, the 1μF capacitor is fully charged. What is the charge on this capacitor?

Q = CV = 10^{-6} F * 20 V = 20 μC

2 Points, 1 point for value, 1 point for unit



11. The switch is thrown to position 2 and stays in that position. Determine the final charge for both capacitors after the circuit has stabilized.

Insight: Total charge is conserved before and after the switch is thrown. The voltage across both capacitors will be same after the switch is thrown, and the circuit has stabilized.

Q = 20 μC = $Q_1 + Q_2$ $V = \frac{Q_1}{C_1} = \frac{Q_2}{C_2} \Rightarrow Q_2 = 2\,Q_1$

Q_1 = 6.67 μC and Q_2 = 13.33 μC 2 Points each, 1 point for value, 1 point for unit.

12. What is the polarity of plate A of the capacitor after the circuit has stabilized?

Positive 2 Points

13. How much energy was dissipated in the circuit between initial (when the switch is thrown in position 2) and final (circuit has stabilized) states?

$\Delta E = |E_f - E_i| = |\ \frac{1}{2}(\frac{Q_1^2}{C_1} + \frac{Q_2^2}{C_2})\ -\ \frac{1}{2}\frac{Q^2}{C_1}\ | = |\ |\ \frac{1}{2}(\frac{6.67^2}{1} + \frac{13.33^2}{2})\ -\ |\ \frac{1}{2}\ \frac{20^2}{1}\ | * 10^{-6} =$ 133.3 μJ

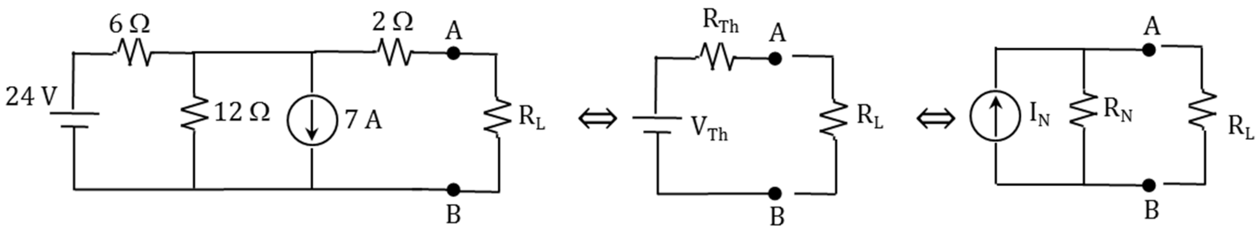
2 Points, 1 point for value, 1 point for unit.

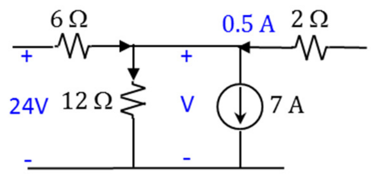
14. Define Permittivity. What are the SI units for Permittivity?

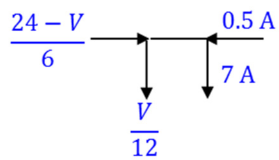
The ability of the material to polarize in the electric field and thereby reducing the electric field inside the material is called the permittivity. OR Permittivity is the measure of the resistance that is encountered when forming an electric field in a medium. OR Permittivity is a measure of how an electric field affects, and is affected by, a dielectric medium. 2 Points

SI unit is farad per meter (F/m) .OR $(A^2s^4)/(kg\ m^3)$. 2 Points

15. For the following Circuit find
   a. the value of resistance R_L, if the current through it is 0.5 A.
   b. the <u>direction</u> and <u>magnitude</u> of current through resistances 6 Ω, and 12Ω,
   c. the Thévenin equivalent voltage V_{Th},
   d. the Thévenin equivalent resistance R_{Th},
   e. the Norton equivalent current source I_N, and
   f. the Norton equivalent Resistance R_N.





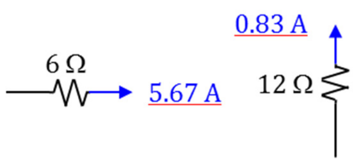


$$\frac{24-V}{6} - \frac{V}{12} + 0.5\text{ A} - 7\text{ A} = 0$$

48 – 2V – V + 6 – 84 = 0
V = -10
The –ve sign indicates actual polarity is opposite to the assumed polarity.

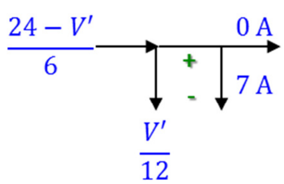
a. $V = 10 = (R_L + 2)\ 0.5 \Rightarrow R_L = \underline{18\ \Omega}$ 2 Points, 1 point for value, 1 Point for unit

b.



2 Points each,
0.5 point for value, 0.5 Point for unit,
1 point for direction

c.

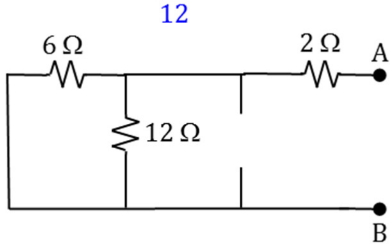


$$\frac{24-V'}{6} - \frac{V'}{12} - 7\text{ A} = 0$$

48 - 2V' – V' – 84 = 0
$V' = -12\text{ V} \Rightarrow V_{Th} = -\underline{12\text{ V}}$ 2 Points, 1 point for value and 1 point for unit

Note the assumed directions for the current have to be consistent with the assumed ground i.e. the current flows from + to – except for current source it is as shown.

d.

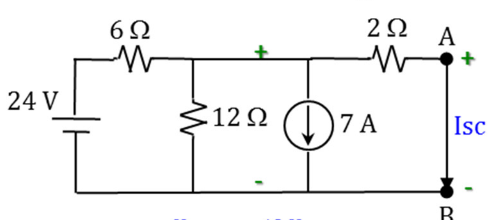


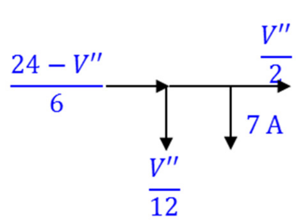
6 Ω and 12 Ω are in Parallel; and
2 Ω is in series with this combination.

$$\frac{1}{6} + \frac{1}{12} = \frac{3}{12} = \frac{1}{4} \Rightarrow R_{Th} = 4 + 2 = \underline{6\ \Omega}$$

2 Points, 1 point for value and 1 point for unit

e.





$$\frac{24-V''}{6} - \frac{V''}{12} - \frac{V''}{2} - 7\text{ A} = 0$$

48 – 2V'' – V'' – 6V'' – 84 = 0

$V'' = -4\text{ V} \Rightarrow I_{sc} = I_N = \frac{-4}{2} = \underline{-2\text{ A}}$

or $I_N = \frac{V_{Th}}{R_{Th}} = \frac{-12\ V}{6\Omega} = \underline{-2\text{ A}}$

2 Points, 1 point for value and 1 point for unit

f. $R_N = R_{Th} = \underline{6\ \Omega}$ 2 Points, 1 point for value, 1 Point for unit