ELECTRICAL FUNDAMENTALS

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WINGSSS COLLEGE OF AVIATION TECHNOLOGY

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ELECTRICAL TERMINOLOGY

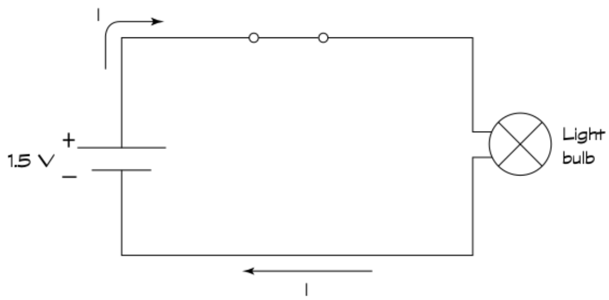
In any system of measurements, a single set of units is usually not sufficient for all the computations involved in electrical repair and maintenance. Small distances, for example, can usually be measured in inches, but larger distances are more meaningfully expressed in feet, yards, or miles. Since electrical values often vary from numbers that are a millionth part of a basic unit of measurement to very large values, it is often necessary to use a wide range of numbers to represent the values of such units as volts, amperes, or ohms. A series of prefixes which appear with the name of the unit have been devised for the various multiples or sub multiples of the basic units. There are 12 of these prefixes, which are also known as conversion factors. Four of the most commonly used prefixes used in electrical work with a short definition of each are as follows:

Mega (M) means one million (1 000 000)
Kilo (k) means one thousand (1 000)
Milli (m) means one-thousandth (1/1 ooo)
Micro (μ) means one-millionth (1/1 ooo ooo)

One of the most extensively used conversion factors, kilo, can be used to explain the use of prefixes with basic units of measurement. Kilo means 1 000, and when used with volts, is expressed as kilovolt, meaning 1 000 volts. The symbol for kilo is the letter "k". Thus, 1 000 volts is one kilovolt or 1kV. Conversely, one volt would equal one-thousandth of a kV, or 1/1 ooo kV. This could also be written 0.001 kV. Similarly, the word "milli" means one-thousandth, and thus, 1 millivolt equals one-thousandth (1/1 ooo) of a volt. ***Figure*** contains a complete list of the multiples used to express electrical quantities, together with the prefixes and symbols used to represent each number.

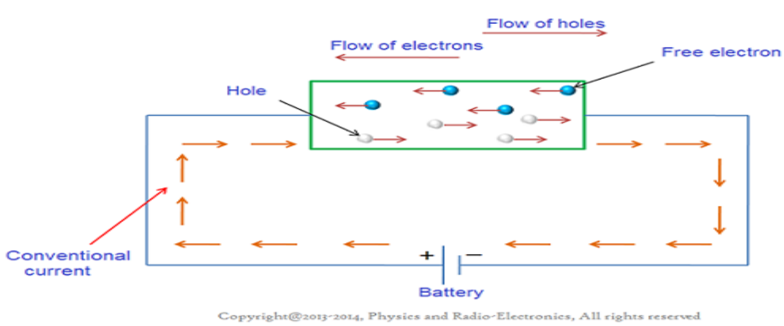
CONVENTIONAL FLOW

In conventional current flow the notation assigned to the electric charges was positive (+) for the abundance of charge and negative (-) for a lack of charge. It then seemed natural to visualize the flow of current as being from the positive (+) to the negative (-). Figure 1 shows conventional current flow. Current that flows from positive terminal of the battery to the negative terminal of the battery is called **conventional current.** Convention chosen during the discovery of electricity so called conventional current



ELECTRON FLOW

Electron flow is what actually happens where an abundance of electrons flow out of the negative (-) source to an area that lacks electrons or the positive (+) source. Both conventional flow and electron flow are used in industry. Electron flow out of the negative side of the battery through the circuit and flow back into the positive side of the battery.   Figure. 2 show electron flow.



RESISTANCE

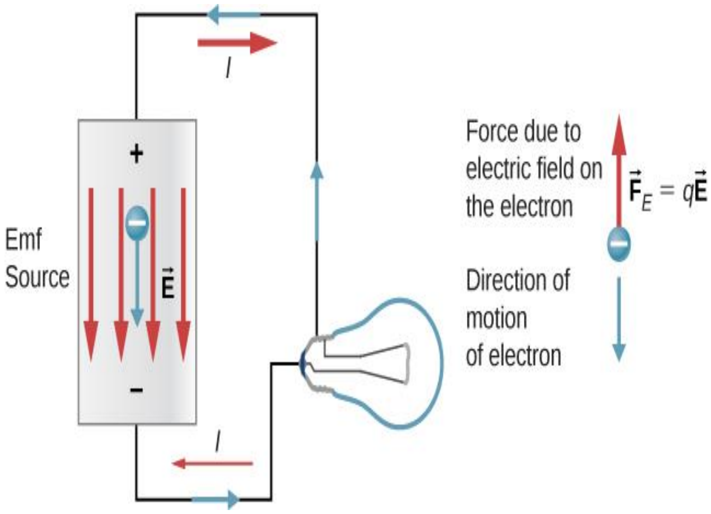
- The resistance of the conductor determines the amount of current that flows under the given voltage.
- In most cases, the greater the circuit resistance the less the current. If the resistance is reduced, then the current will increase

CURRENT

- Flow of charge is current
- Current is measured in a circuit using an ammeter which is placed in series with the component of interest in the circuit.
- I = current in amperes, A
- ΔQ = charge in coulombs, C
- Δt = time in seconds, s

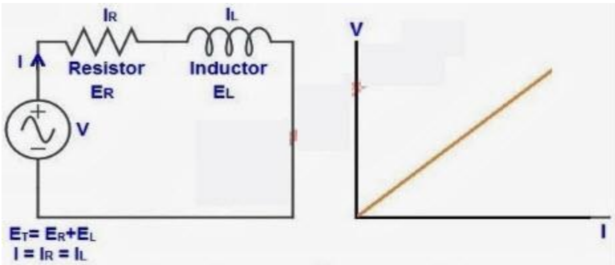
ELECTROMOTIVE FORCE

If is the force which drives the current from one point to another



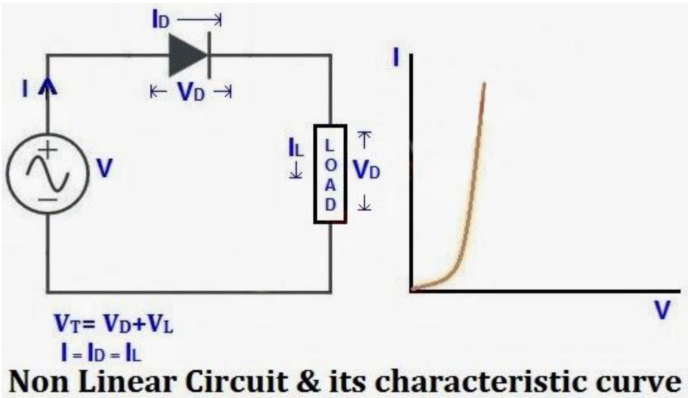
LINEAR CIRCUITS

Simply we can say that the linear circuit is an electric circuit and the parameters (voltage and current) of this circuit having resistance, capacitance, inductance depends on each other



NONLINEAR CIRCUITS

The non-linear circuit is also an electric circuit and the parameters (voltage and current) of this circuit differ



DC CIRCUITS

The closed path in which the direct current flows is called the DC circuit. The current flows in only one direction and it is mostly used in low voltage applications. The resistor is the main component of the DC circuit. DC power is widely used in low voltage applications such as charging batteries, automotive applications, aircraft applications and other low voltage, low current applications. While studying DC circuits there is a need to understand few definitions:

CIRCUIT

Electrical connection between the components is called circuit

NETWORK

Electrical connection between the circuits is called Network

LINEAR CIRCUITS

The circuits which obeys the ohm's law are called linear circuits

NON – LINEAR CIRCUITS

The circuits which does not obey the ohm's law are Non – linear Circuits

ACTIVE CIRCUITS

Circuits having external source (voltage source or current source) connected to the components are called active Circuits

PASSIVE CIRCUITS

Circuits which does not have external source connected to the components are called passive circuits

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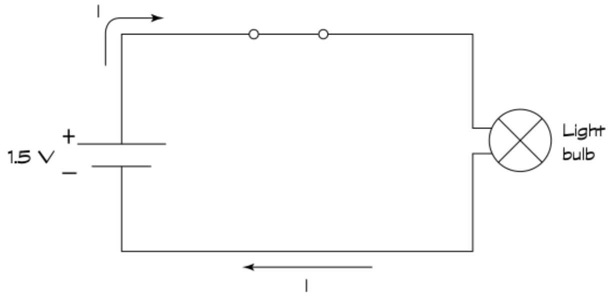

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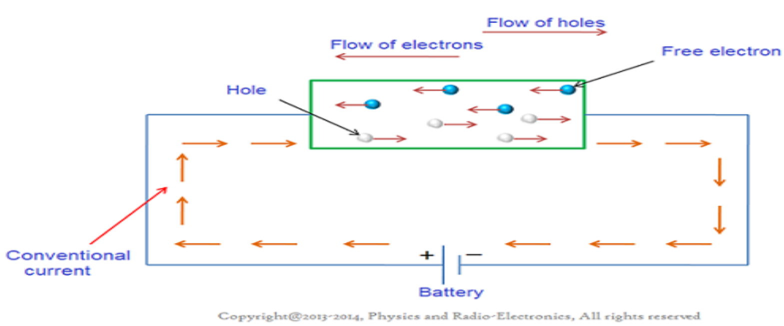

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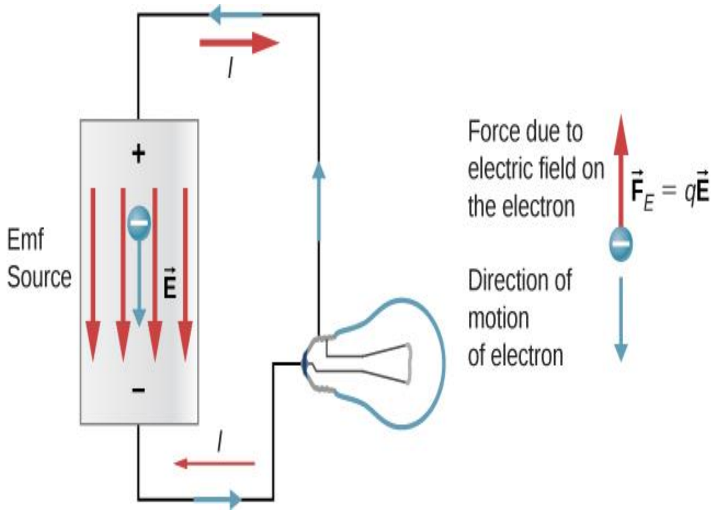


The symbol for emf is Є

$$E = \frac{\mathcal{E}}{Q}$$

E = in volts V

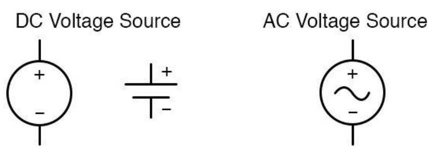
Є = Energy in joules J

Q = Charge measured in coulombs

- Potential difference in a circuit is measured using a voltmeter which is placed in parallel with the component of interest in the circuit.

VOLTAGE SOURCES

There are two types of voltage sources: ac voltage source and dc voltage source. Ideal voltage sources can be connected together in both parallel and in series for any circuit element. Series voltages add together while parallel voltages have the same value. Figure.4 shows DC voltage source and AC voltage source



VOLTAGE SOURCES IN SERIES

A voltage source is an energy source that provides a constant voltage to a load. Two or more of these sources in series will equal the algebraic sum of all the sources connected in series. The polarity of the sources must be considered when adding up the sources. The polarity will be indicated by a plus or minus sign depending on the source's position in the circuit.

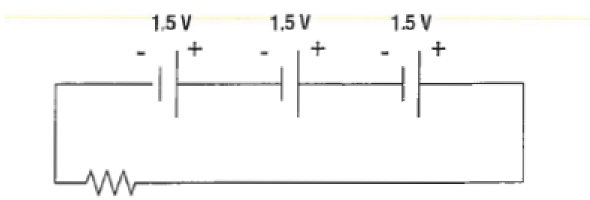


Figure. 6 shows same polarity voltage sources added

Total voltage is ET = E1 + E2 +E3

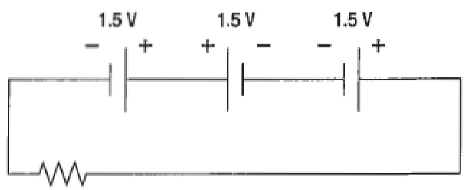


Figure. 7 shows different polarity voltage sources added

Total voltage is ET = E1 - E2 +E3

KIRCHHOFF'S VOLTAGE LAW

This law simply states that the algebraic sum of all voltages around a closed path or loop is zero. Another way of saying it: The sum of all the voltage drops equals the total source voltage. With the three resistors connected in series along with the source voltage the equation is:

$$\Sigma V = 0$$

ES - E1 - E2 - E3 = 0

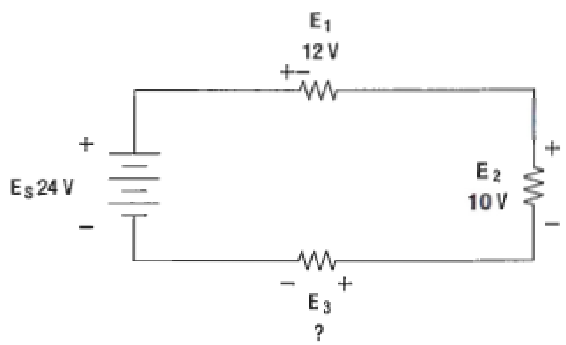
Note that the sign of the source is opposite that of the individual voltage drops. Therefore, the algebraic sum equals zero.

Another way of writing the equation is:

ES = E1 + E2 + E3

The source voltage equals the sum of the voltage drops. the polarity of the resistor is opposite that of the source voltage. The positive on the resistor is facing the positive on the source and the negative towards the negative.

Eg.7 In figure 8 determine the value of E3

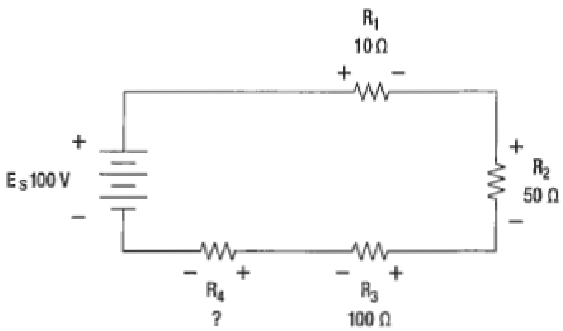


24 – 12 – 10 – E3 = 0

12 – E3 = 0

So E3 = 2V

Eg.8 In figure 8 determine the value of E4. Current is 200mA (given)



E1 = I1 x R1

= 200 x 10^{-3} x 10

= 2V

E2 = I1 x R2

= 200 x 10^{-3} x 50

= 10 V

E3 = I1 x R3

= 200 x 10^{-3} x100

= 20 V

ES - E1 - E2 - E3 - E4 = 0

200 - 2 - 20 - 20 - E4 = 0

68 – E4 = 0

E4 = 68

R4 = E4 / 200m A

R4 = 340 Ω

VOLTAGE DIVIDERS

Voltage dividers are devices that make it possible to obtain more than one voltage from a single power source. As current flows through the resistor, different voltages can be obtained between the contacts.

VOLTAGE DIVIDER RULE

The voltage is divided between two resistors which are connected in series in direct proportion to their resistance. A voltage divider can be used to scale down a very high voltage so that it can be measured by a volt meter. The high voltage is applied across the divider, and the divider output—which outputs a lower voltage that is within the meter's input range—is measured by the meter.

VX = I x RX….

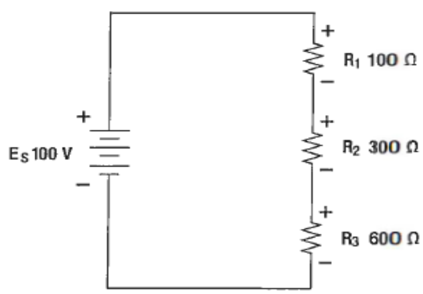
X = value of a particular resistance (R1, R2, R3...…and V1, V2, V3 …..)

Total Current is IT = VT/RT

VX = (VT/RT) x RX

VX = (RX/RT) x VT

Eg.5 Find the voltages across R1, R2, R3 BY Voltage Divider Rule



RT = 100 + 300 +600 =1000

VS = 100 V

V1 = (R1/RT) x VS

=100/1000) x 100V

= 10 V

V2 = (R2/RT) x VS

= 300/1000) x 100V

= 30 V

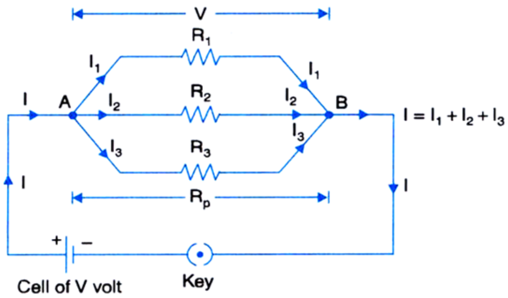
V3 = (R2/RT) x VS

= 600/1000) x 100V

= 60 V

PARALLEL DC CIRCUITS

A circuit in which two or more electrical resistances are connected across the same voltage source is called a parallel circuit. A parallel circuit consists of one or more parallel paths for current. Each of these parallel paths is called a branch. When two or more electrical components are connected in a way that one end of each component is connected to a common point and the other end is connected to another common point, then the electrical components are said to be connected in parallel, and such an electrical DC circuit is referred as a parallel DC circuit. Current gets divided between the parallel paths and voltage between the paths remains the same. Resistors are connected in parallel, then the total resistance of the circuit decreases.



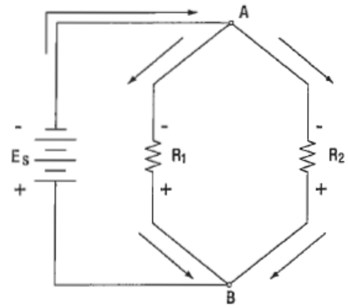
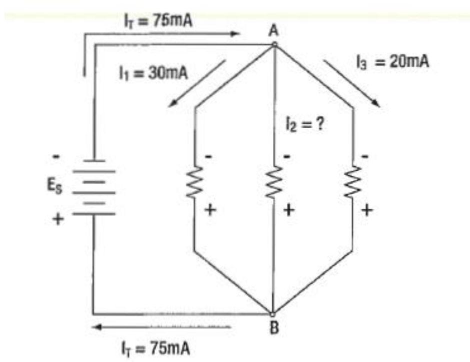


Fig shows the parallel circuits in which the voltage in all parallel paths is same and current get divided.

$$\frac{1}{R_{TOT}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \text{ ...etc.}$$

Find the current I2

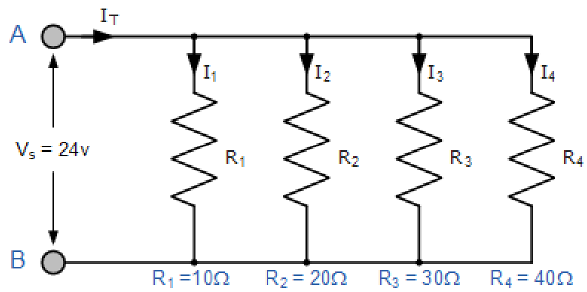


IT = I1 + I2 +I3

75mA = 30mA + I2 + 20mA

I2 = 25mA

Find the branch current, total current and total Resistance.



$$I_1 = \frac{V_S}{R_1} = \frac{24V}{10\Omega} = 2.4amps$$

$$I_2 = \frac{V_S}{R_2} = \frac{24V}{20\Omega} = 1.2amps$$

$$I_3 = \frac{V_S}{R_3} = \frac{24V}{30\Omega} = 0.8amps$$

$$I_4 = \frac{V_S}{R_4} = \frac{24V}{40\Omega} = 0.6amps$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_T} = \frac{1}{10} + \frac{1}{20} + \frac{1}{30} + \frac{1}{40}$$

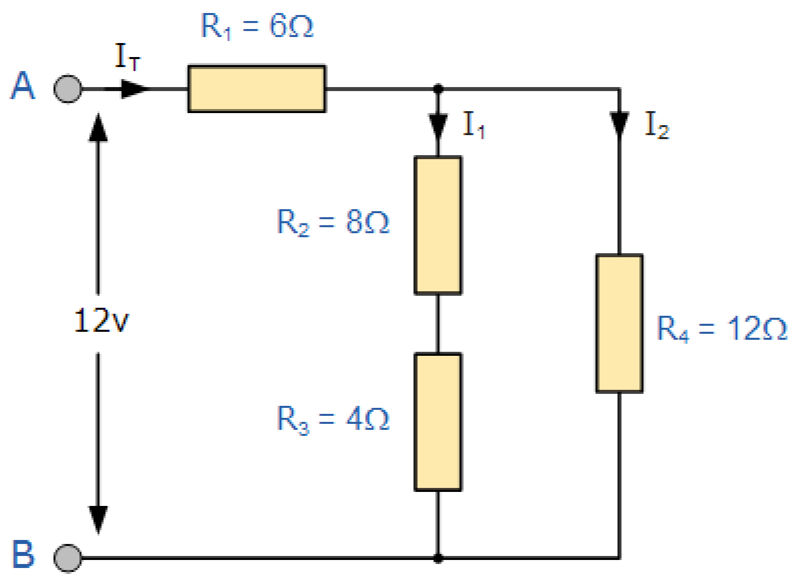
$$\frac{1}{R_T} = 0.1 + 0.05 + 0.033 + 0.025$$

$$\therefore R_T = \frac{1}{0.2083} = 4.8\Omega$$

SERIES-PARALLEL DC CIRCUITS

Resistor circuits that combine series and parallel resistors networks together are generally known as **Resistor Combination** or mixed resistor circuits. The method of calculating the circuit equivalent resistance is the same as that for any individual series or parallel circuit. We now know that resistors in series carry exactly the same current and that resistors in parallel have exactly the same voltage across them.

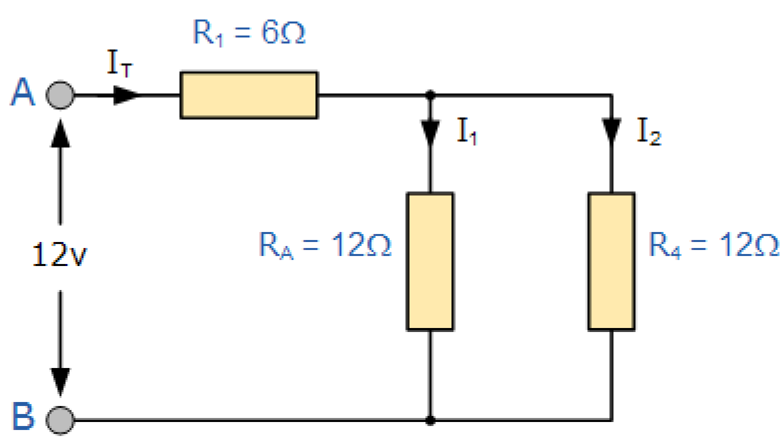
Eg 8 in the following circuit calculate the total current (IT) taken from the 12v supply.



At first glance this may seem a difficult task, but if we look a little closer we can see that the two resistors, R_2 and R_3 are actually both connected together in a "SERIES" combination so we can add them together to produce an equivalent resistance the same as we did in the series resistor tutorial. The resultant resistance for this combination would therefore be:

$R_2 + R_3 = 8\Omega + 4\Omega = 12\Omega$

So we can replace both resistor R_2 and R_3 above with a single resistor of resistance value 12Ω

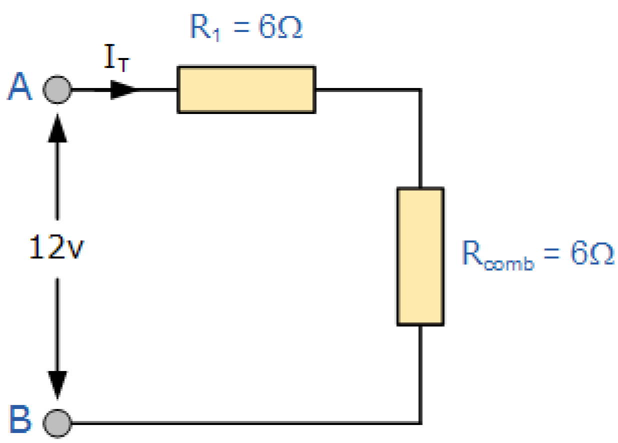


So our circuit now has a single resistor R_A in “PARALLEL” with the resistor R_4. Using our resistors in parallel equation we can reduce this parallel combination to a single equivalent resistor value of $R_{(combination)}$ using the formula for two parallel connected resistors as follows.

$$R_{(eq)} = \frac{1}{R_A} + \frac{1}{R_4} = \frac{1}{12} + \frac{1}{12} = 0.1667$$

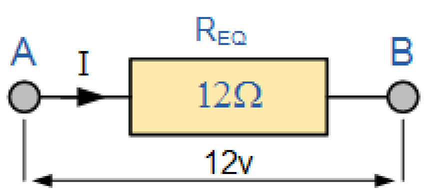
$$R_{(combination)} = \frac{1}{R_{(eq)}} = \frac{1}{0.1667} = 6\Omega$$

The resultant resistive circuit now looks something like this:



We can see that the two remaining resistances, R_1 and $R_{(comb)}$ are connected together in a “SERIES” combination and again they can be added together (resistors in series) so that the total circuit resistance between points A and B is therefore given as:

$R_{(ab)} = R_{comb} + R_1 = 6\Omega + 6\Omega = 12\Omega$



Thus a single resistor of just 12Ω can be used to replace the original four resistors connected together in the original circuit above.

By using Ohm’s Law, the value of the current (I) flowing around the circuit is calculated as:

$$\text{Circuit Current (I)} = \frac{V}{R} = \frac{12}{12} = 1\,\text{Ampere}$$

Then we can see that any complicated resistive circuit consisting of several resistors can be reduced to a simple single circuit with only one equivalent resistor by replacing all the resistors connected together in series or in parallel using the steps above.

We can take this one step further by using Ohms Law to find the two branch currents, I_1 and I_2 as shown.

$V_{(R1)} = I*R_1 = 1*6 = 6$ volts

$V_{(RA)} = V_{R4} = (12 - V_{R1}) = 6$ volts

Thus:

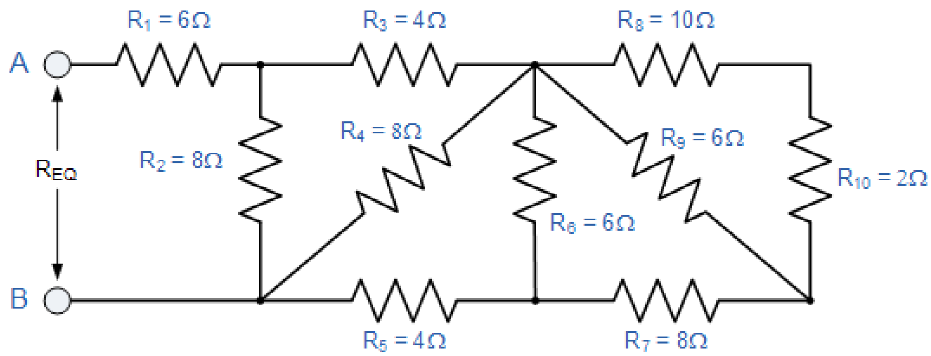
$I_1 = 6V \div R_A = 6 \div 12 = 0.5A$ or 500mA

$I_2 = 6V \div R_4 = 6 \div 12 = 0.5A$ or 500mA

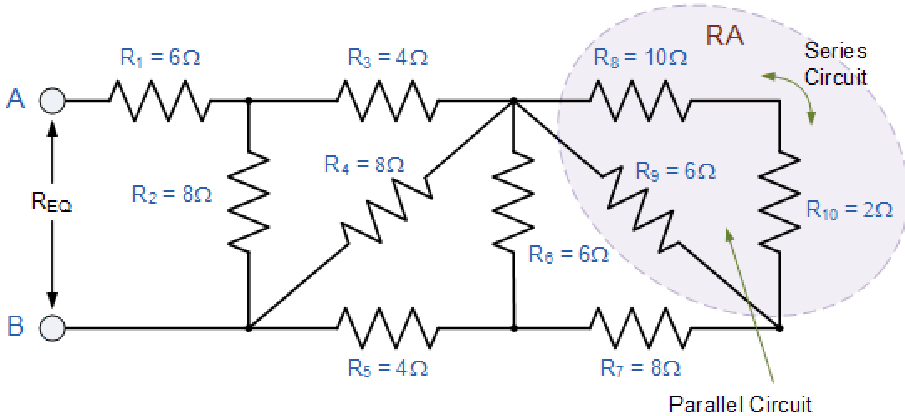
Since the resistive values of the two branches are the same at 12Ω, the two branch currents of I_1 and I_2 are also equal at 0.5A (or 500mA) each. This therefore gives a total supply current, I_T of: 0.5 + 0.5 = 1.0 amperes as calculated above.

RESISTORS IN SERIES AND PARALLEL

Eg.9 Find R_{EQ} for the following resistor combination circuit.

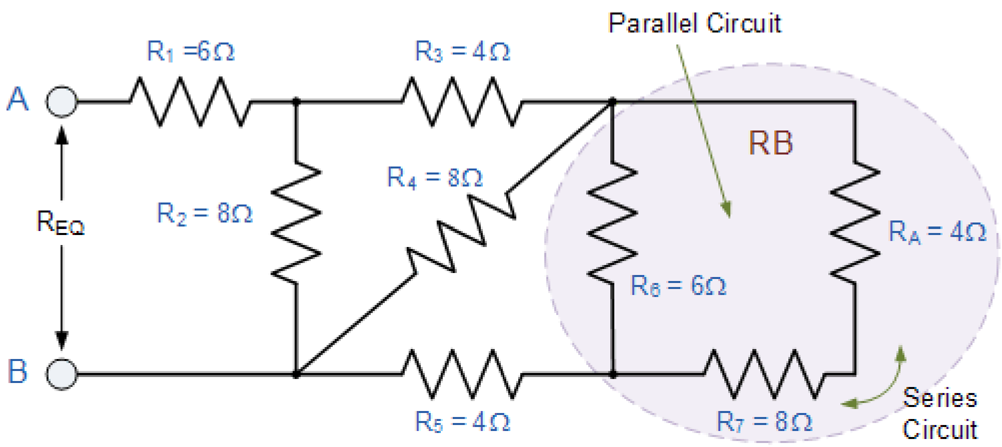


Again, at first glance this resistor ladder network may seem a complicated task, but as before it is just a combination of series and parallel resistors connected together. Starting from the right hand side and using the simplified equation for two parallel resistors, we can find the equivalent resistance of the R_8 to R_{10} combination and call it R_A.



$$R_A = \frac{R_9 \times (R_8 + R_{10})}{R_9 + R_8 + R_{10}} = \frac{6 \times (10 + 2)}{6 + 10 + 2} = 4\Omega$$

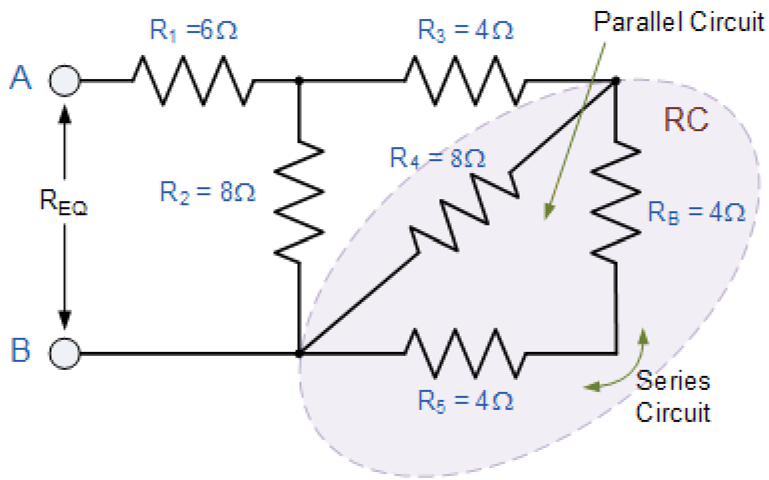
R_A is in series with R_7 therefore the total resistance will be $R_A + R_7 = 4 + 8 = 12\Omega$ as shown.



This resistive value of 12Ω is now in parallel with R_6 and can be calculated as R_B.

$$R_B = \frac{R_6 \times (R_A + R_7)}{R_6 + R_A + R_7} = \frac{6 \times (4 + 8)}{6 + 4 + 8} = 4\Omega$$

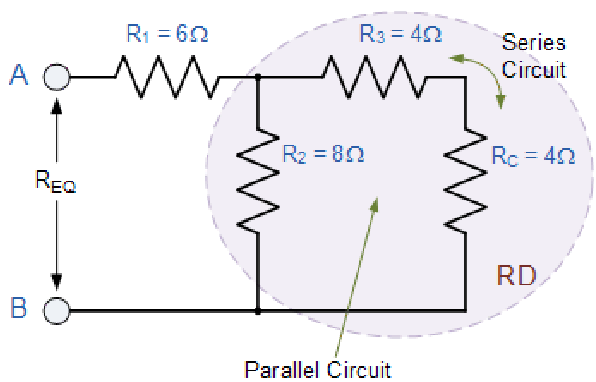
R_B is in series with R_5 therefore the total resistance will be $R_B + R_5 = 4 + 4 = 8\Omega$ as shown.



This resistive value of 8Ω is now in parallel with R_4 and can be calculated as R_C as shown.

$$R_C = \frac{R_4 \times (R_B + R_5)}{R_4 + R_B + R_5} = \frac{8 \times (4+4)}{8+4+4} = 4\Omega$$

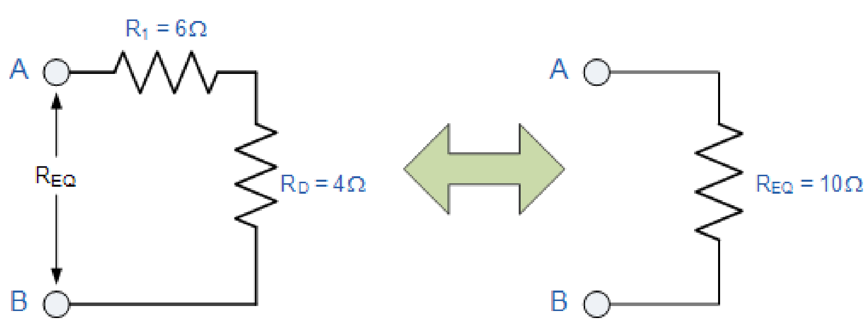
R_C is in series with R_3 therefore the total resistance will be $R_C + R_3 = 8\Omega$ as shown.



This resistive value of 8Ω is now in parallel with R_2 from which we can calculated R_D as:

$$R_D = \frac{R_2 \times (R_C + R_3)}{R_2 + R_C + R_3} = \frac{8 \times (4+4)}{8+4+4} = 4\Omega$$

R_D is in series with R_1 therefore the total resistance will be $R_D + R_1 = 4 + 6 = 10\Omega$ as shown.

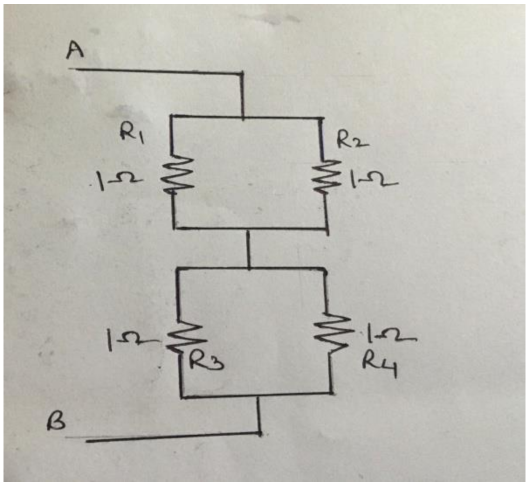


Then the complex combinational resistive network above comprising of ten individual resistors connected together in series and parallel combinations can be replaced with just one single equivalent resistance (R_{EQ}) of value 10Ω.

When solving any combinational resistor circuit that is made up of resistors in series and parallel branches, the first step we need to take is to identify the simple series and parallel resistor branches and replace them with equivalent resistors.

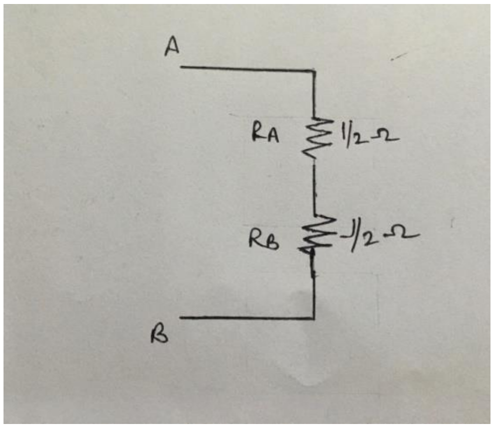
This step will allow us to reduce the complexity of the circuit and help us transform a complex combinational resistive circuit into a single equivalent resistance remembering that series circuits are voltage dividers and parallel circuits are current dividers.

Eg.10 Find Req and total current

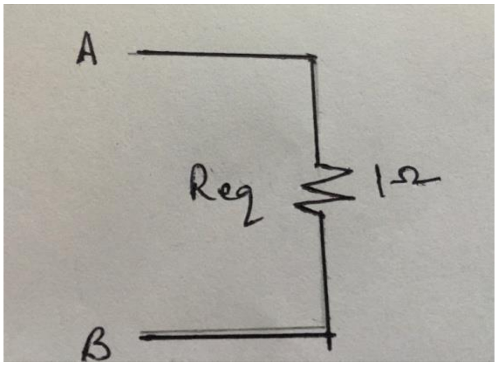


R1 parallel R2

1 Ω parallel 1 Ω = ½ Ω

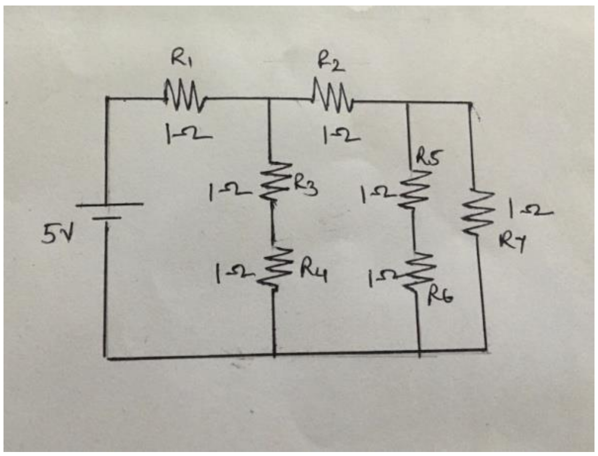


½ Ω series ½ Ω = 1 Ω



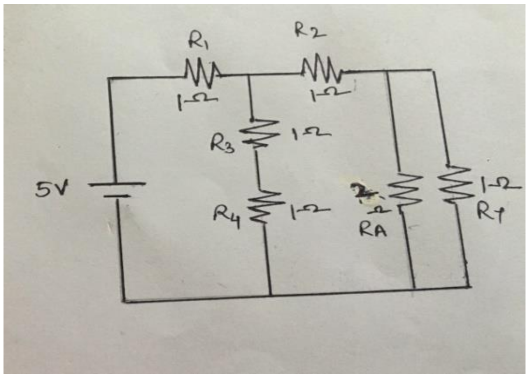
Req = 1 Ω

Eg.11 Find Req and total current



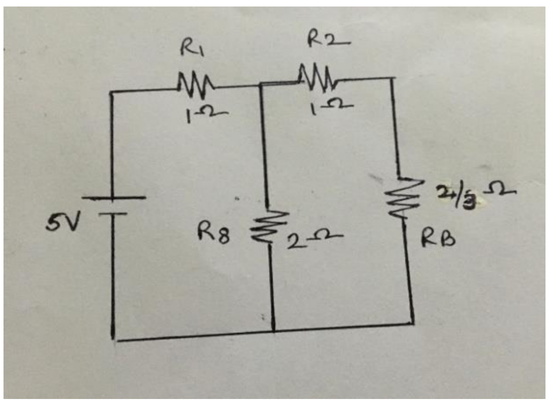
R5 and R6 in series

RA= 1Ω + 1Ω = 2Ω



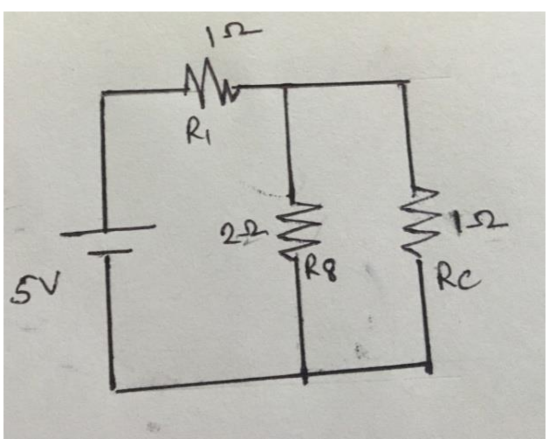
RA parallel with R7

RB = 2 Ω parallel 1 Ω = 2/3 Ω



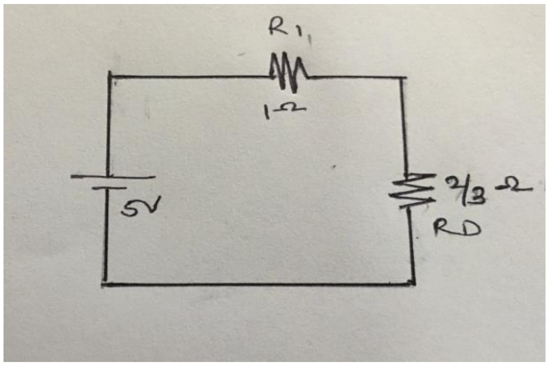
RB series with R2

RC = 2/3 Ω series 1 Ω = 1 Ω

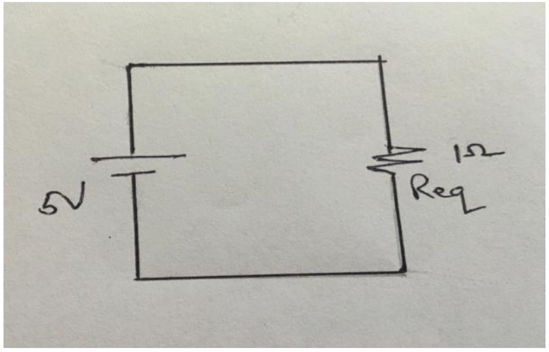


RC parallel R8

RD = 1 Ω parallel 2 Ω = 2/3 Ω



RD = 1 Ω series 2/3 Ω = 1 Ω



IT = V/R

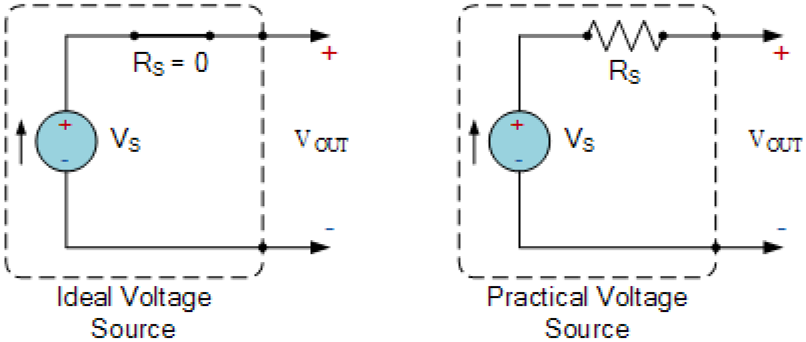
= 5/1

= 5A

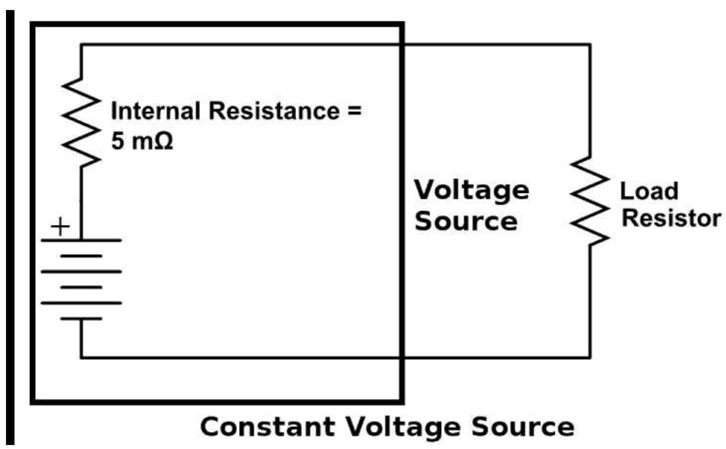
INDEPENDENT VOLTAGE SOURCE

In independent voltage source, the terminal voltage of the source is not dependent on any other source or current source.

IDEAL AND PRACTICAL VOLTAGE SOURCE



Terminal source voltage VL = V source resistance of an ideal voltage source = 0 ,therefore terminal voltage remains constant = V, so for ideal voltage source the terminal voltage is independent of the load. Without load current is = 0. But when load is connected the current will flow from positive terminal of battery to negative terminal of battery that is conventional current.



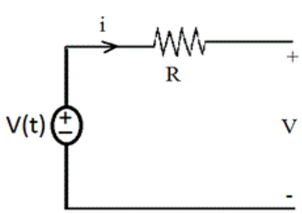


Figure- Practical voltage source

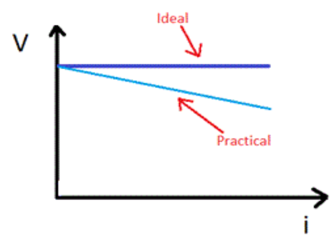
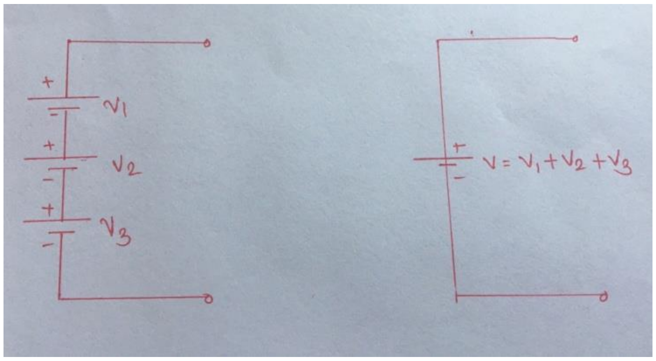
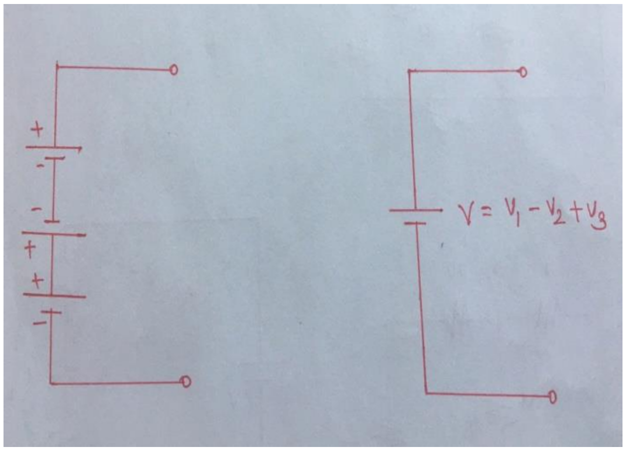
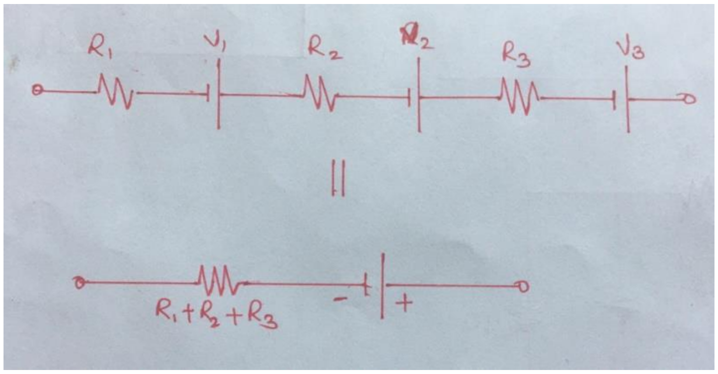


Figure- v-i characteristics

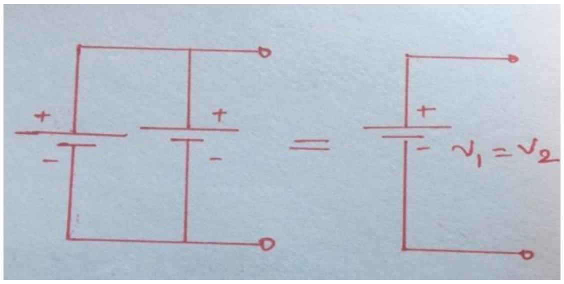
VOLTAGE SOURCES IN SERIES



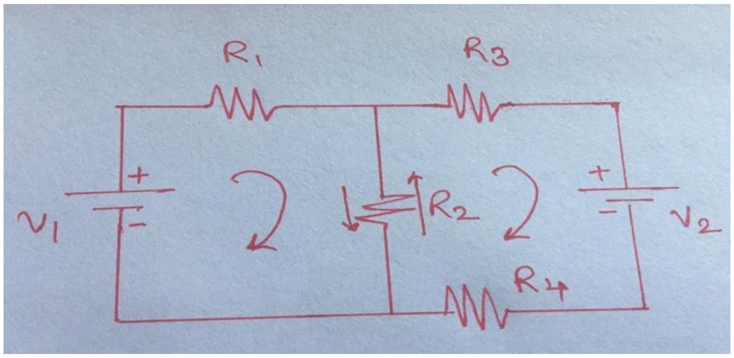


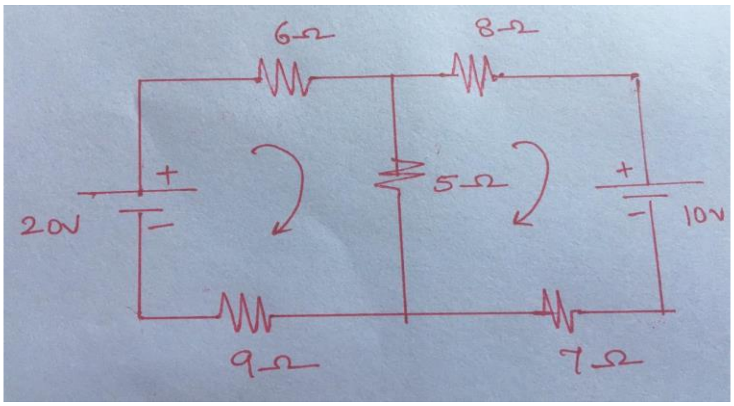


VOLTAGE SOURCES IN PARLLEL



KIRCHHOFF'S VOLTAGE LAW LOOP ANALYSIS





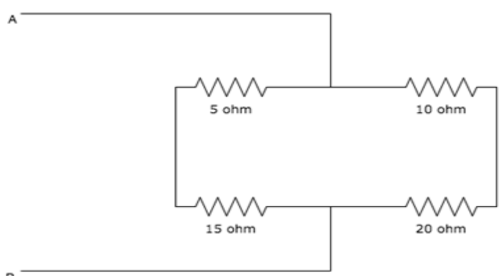
Questions

1) It is preferable to connect bulbs in series or in parallel?

- Series
- **Parallel**
- Both series and parallel
- Neither series nor parallel

Explanation: Bulbs are connected in parallel so that even if one of the bulbs blow out, the others continue to get a current supply.

2) calculate the equivalent resistance between A and B

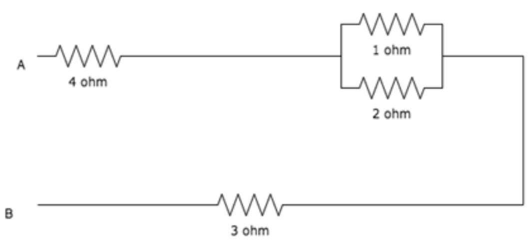


- **60 Ω**
- **15 Ω**
- <u>**12 Ω**</u>
- **48 Ω**

Explanation:

- 5 + 15 in Series
- =20
- 10 +20 in series
- =30
- 20 in parallel 30
- =12 Ω

3) calculate the equivalent resistance between A and B

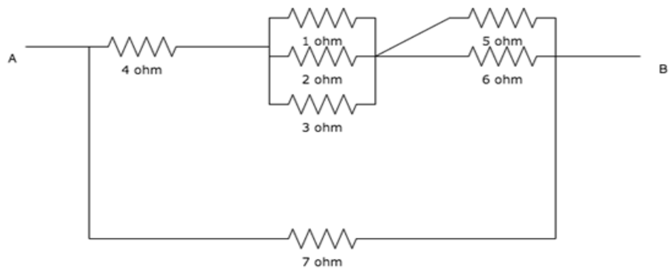


- 7 Ω
- 0 Ω
- <u>**7.67 Ω**</u>
- 0.48 Ω

Explanation:

1) **First find the parallel combination of 1** Ω and 2 Ω resistances , the answer for that is (1 X 2)/(1+2)= 0.66.
2) Then all the 3 resistances 4 Ω , 0.66 Ω and 3 Ω are in series.
   4 + 0.66 + 4 = 7.66

4) calculate the equivalent resistance between A and B



- 3.56 Ω
- 7 Ω
- **<u>14.26 Ω</u>**
- 29.69 Ω

Explanation:

- 1 +2+3 in parallel
- 1/1 +1/2 +1/3
- 1/Req=11/6
- Req= 0.5
- 5+6 in parallel
- =1/5+1/6
- (5 x6)/(5+6)
- 30/11
- 2.7
- 4 + 2.7+0.5+7
- = 14.26 Ω

5) Batteries are generally connected in______

- **<u>Series</u>**
- Parallel
- Either series or parallel
- Neither series nor parallel

6) In a _________ circuit, the total resistance is greater than the largest resistance in the circuit.

- **<u>Series</u>**
- Parallel
- Either series or parallel
- Neither series nor parallel

7) In a ____________ circuit, the total resistance is smaller than the smallest resistance in the circuit.

- Series
- **<u>Parallel</u>**
- Either series or parallel
- Neither series nor parallel

8) A voltage divider consists of two 68Ω resistors and a 24 V source. The unknown output voltage is

- 10V
- 20V
- **<u>12V</u>**
- 30V

Explanation:

- R1 =68
- R2=68
- Vin =24v
- R2/(R1+R2)*Vin
- Vout = 12V

9) To derive 18 V and 12 V from a 24 V supply requires a voltage divider with three taps.

- **<u>True</u>**
- False

10) In series, if one bulb goes out, others will

- Stay on
- **<u>Also turns off</u>**
- Blow up

- Heat up

11) In parallel circuit, the current is

- Equal
- **<u>Unequal</u>**
- More powerful
- Less powerful

12) In series circuit electrons in the current when comes to second bulb after passing through the first, have

- More energy
- **<u>Less energy</u>**
- More power
- Less power

13) Adding more bulbs to a circuit with one battery would

- Make them brighter
- Make them sharper
- **<u>Make them dimmer</u>**
- Make them colorless

14) The currents in 3 branches are 3, 4,5 amperes. What is the current leaving it?

- 0A
- Insufficient data
- The largest one among the three
- **<u>12A</u>**

Explanation:

IT = I1 + I2 + I3

12A = 3 +4 +5

15) Many resistors connected in series will?

- **<u>Divide the voltage proportionally among the resistors</u>**

- Divide the current proportionally
- Increase the source voltage in proportion to the resistors
- Reduce the power to zero

16) What happens to the current in the series circuit if the resistance is doubled ?

- It becomes zero
- It becomes infinity
- **It decreases two times**
- It becomes double the original value

17) If 2 bulbs are connected in parallel and 1 bulb blows out, what happens to the other bulb?

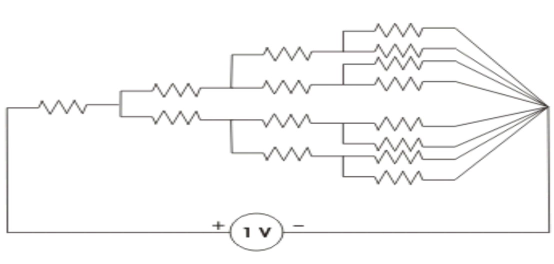
- The other bulb blows as well
- The other bulb glows with increased brightness
- The other bulb stops glowing

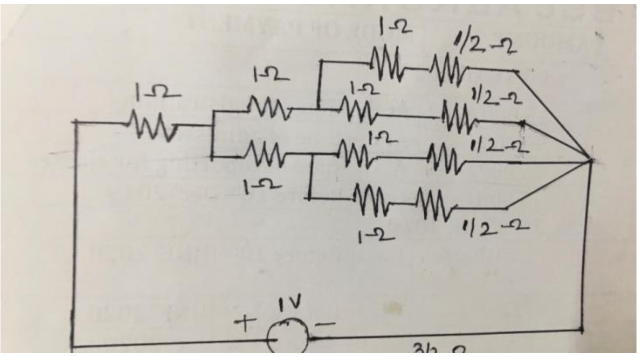
The other bulb continues to glow with same brightness

18) In parallel circuit with a number of resistors the voltage across the resistors

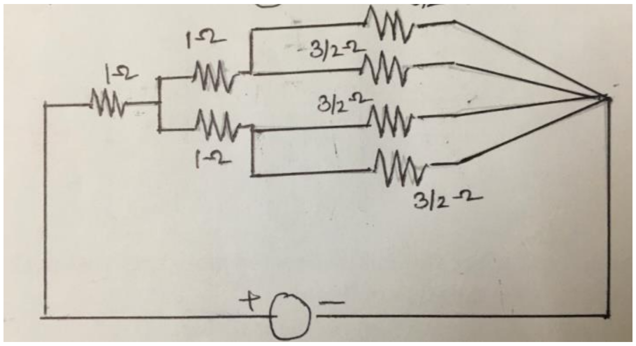
- **The same for all resistors**
- Is divided among all resistors
- Is divided proportionally among all resistors
- Is zero for all resistors

20) All the resistances in figure shown below are 1 Ω each. The value of electric current in Ampere through the battery is

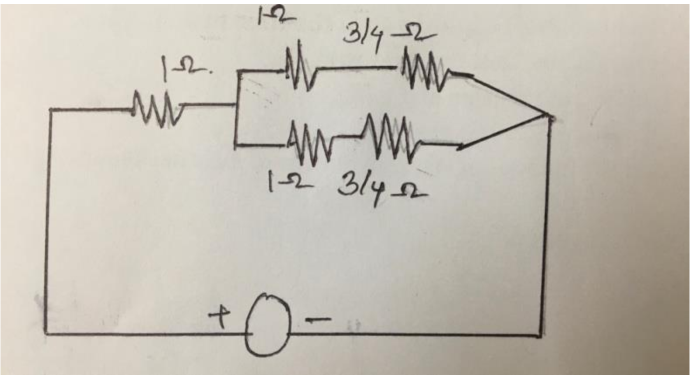




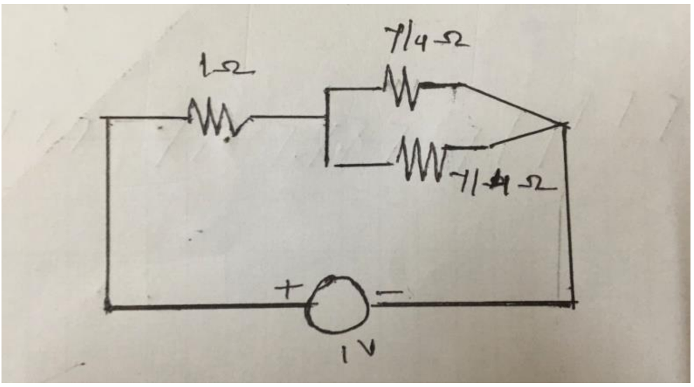
- 1 Ω parallel 1 Ω = ½



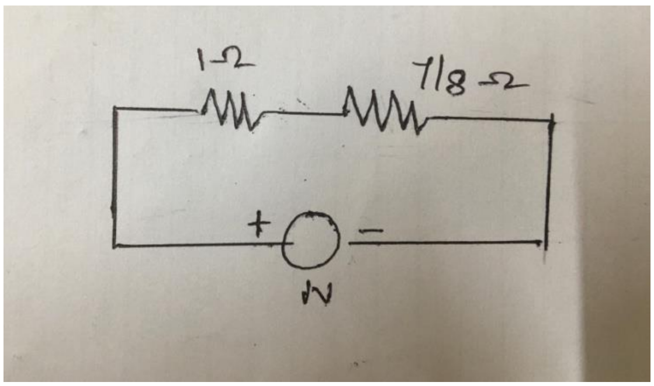
- 1 Ω in series with ½ Ω = 3/2



3/2 parallel with 3/2 =3/4



¾ series with 1 = 7/4



7/4 parallel with 7/4 = 7/8

7/8 in series with 1 = 4/15 Ω