Republic of Iraq
Ministry of Higher Education
and Scientific Research
Al-Mustaqbal University College
Computer Engineering Techniques Department

Subject: Fundamentals of Electrical Engineering

First Class

Lecture Three

By

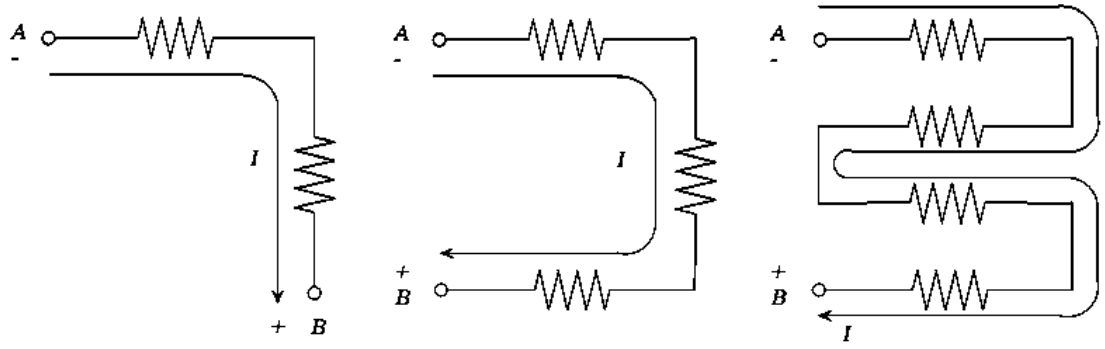
Dr. Jaber Ghaib

MSc. Sarah Abbas

دوائر التيار المستمر المحتوية على مقاومات(Resistors in DC Circuits)

١ـ دوائر المقاومات على التوالي (Series Resistors Circuits)

في اي دائرة كهربائية، تعتبر مقاومتين او اكثر موصلتان بالتوالي إذا كان نفس التيار يمر بكل مقاومة، اي ان للتيار مسار واحد فقط للمرور خلال المقاومات الموصلات بين نقطتين في الدائرة الكهربائية يتضح لنا هذا في الشكل التالي:



في جميع الدوائر السابقة نلاحظ ان التيار I المار بين نقطتين A و B هو نفسه المار في جميع المقاومات وبالتالي فان المقاومات موصلة على التوالي.

ويتم حساب قيمة المقاومة الكلية في الدائرة للمقاومات الموصله على التوالي بجمع قيم المقاومات واعتبارها مقاومة واحدة تسمى R_T

$$R_T=R_1+R_2+R_3+\ldots+R_n$$

حيث R_n ترمز لعدد المقاومات الموصلة على التوالي.

وبمعرفة قيمة المقاومة (R) والجهد (V) يمكن ايجاد التيار (I) المار في الدائرة التالية حيث

$$I = \frac{V}{R_T}$$

وكذلك يمكن حساب جهود المقاومة كل على حده

$$V_1=I\,R_1 \quad , \quad V_2 = I\,R_2 \quad , \quad V_3 = I\,R_3$$

وبالتالي فان القدرة المولد من المصدر (P_s)

$$P_s = V\ I$$

والقدرة المستهلكة في المقاومات

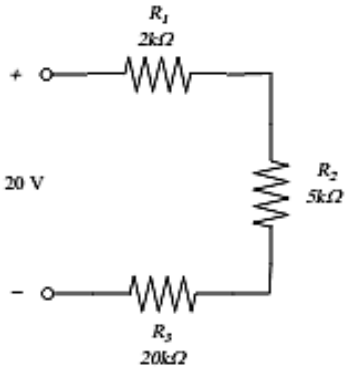
$$P_1 = I_1\ V_1 = I_1^2\ R = \frac{V_1^2}{R_1}$$

$$P_2 = I_2\ V_2 = I_2^2\ R = \frac{V_2^2}{R_2}$$

$$P_3 = I_3\ V_3 = I_3^2\ R = \frac{V_3^2}{R_3}$$

ملاحظة مهمه: التيار المار في دائرة التوالي ثابت، اي ان $I = I_1 = I_2 = I_3$ اما الجهد فهو متغير

Example 1: Calculate the total resistance R_T in the following circuit, then calculate the current following in the circuit.



Sol. $R_T = R_1 + R_2 + R_3$

$$R_T = 2k\ \Omega + 5\ k\ \Omega + 20\ k\ \Omega = 27\ k\ \Omega$$

$$I = \frac{V}{R_T}$$

$$I = \frac{20\ V}{27\ k\Omega} = 0.74\ mA$$

Example 2: Three resistances are connected in series with 12 V supply, so that the current flow is (6 mA). If one of the resistance equal to (1 k Ω), while the voltage across the second resistance is (3.6V), calculate the value of the third resistance.

Sol.

$$R_T = \frac{V}{I} = \frac{12\ V}{6\ mA} = \frac{12}{6 * 10^{-3}} = 2000\ \Omega = 2\ k\Omega$$

If the voltage across the second resistance is (3.6 V) and the current is (6 mA) then by using ohm's law

$$R = \frac{V}{I} = \frac{3.6}{6 * 10^{-3}} = 600\ \Omega$$

$$R_T = R_1 + R_2 + R_3$$

$$2000 = 1000 + 600 + R_3$$

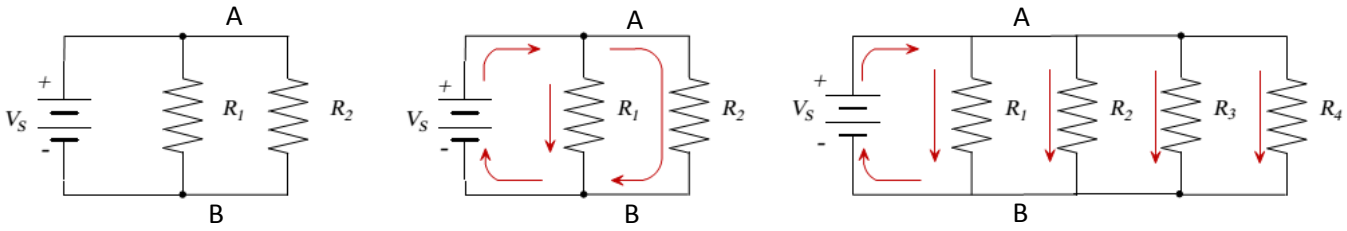
$$2000 = 1600 + R_3$$

$$R_3 = 2000\text{-}1600 = 400\ \Omega$$

2

2- دوائر المقاومات على التوازي (Parallel Resistors Circuits)

تكون مقاومتان او اكثر موصلة على التوازي اذا كان اطراف المقاومتان موصلة في نقطتين مشتركتين ويتضح هذا من الشكل التالي:



حيث انه في الدوائر السابقة تكون جميع المقاومات احد اطرافها موصل بالنقطة A و الطرف الاخر موصل بالنقطة B

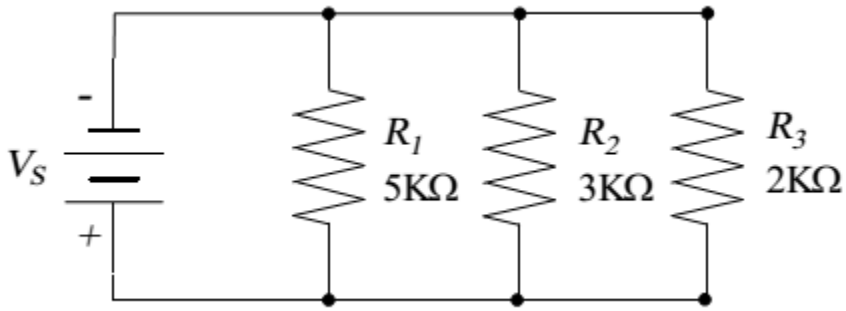
ويتم حساب المقاومة الكلية بالعلاقة التالية:

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

او

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

Example 3: calculate the total resistance of this circuit



Sol:

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

$$\frac{1}{R_T} = \frac{1}{5\ k\Omega} + \frac{1}{3\ k\Omega} + \frac{1}{2\ k\Omega}$$

$$\frac{1}{R_T} = (0.2*10^{-3}) + (0.33*10^{-3}) + (0.5*10^{-3})$$

$$\frac{1}{R_T} = (1.03*10^{-3})$$

$$R_T = 971\ \Omega$$

ويمكن بشكل عام اذا كان لدينا مقاومتان على التوازي فان المقاومة الكلية لهما هي:

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

ملاحظة:- نستخدم العلامة // للدلالة على التوازي.

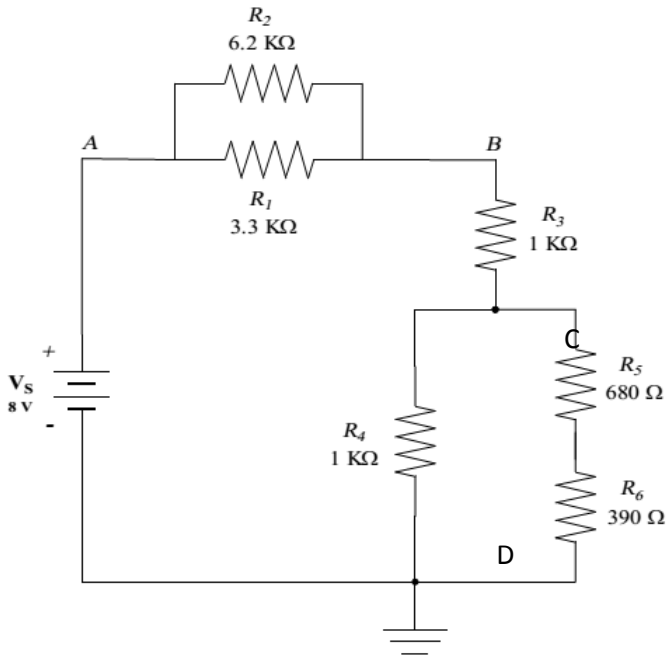
٣

- دوائر التوالي التوازي (Series-Parallel Circuits)

عندما يكون لدينا مقاومات في الدائرة الكهربائية موصلة على التوالي والتوازي فانه لحساب المقاومة الكلية فاننا نجري الخطوات التالية:

١. نوجد المقاومة الكلية للمقاومات الموصلة على التوالي مع ملاحظة ان نطبق عليها شروط ربط المقاومات على التوالي.
٢. نوجد المقاومة الكلية للمقاومات الموصلة على التوازي مع ملاحظة ان نطبق عليها شروط ربط المقاومات على التوازي.
٣. نكرر العمليات السابقة حتى نصل الى المقاومة الكلية المطلوبة.

Example 4: Calculate the total resistance in this circuit.



Sol.

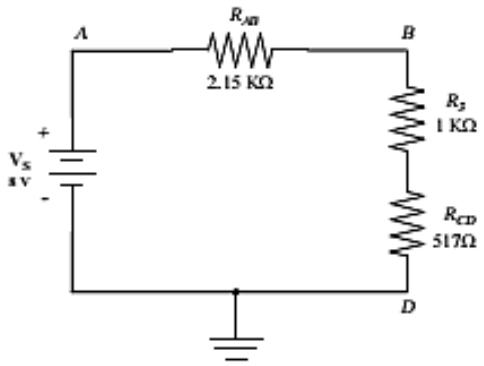
$$R_{AB} = \frac{R_1 R_2}{R_1 + R_2}$$

$$R_{AB} = \frac{(3.3\ k\Omega)(6.2\ \text{k}\Omega)}{(3.3\ k\Omega) + (6.2\ \text{k}\Omega)} = \mathbf{2.15}\ \text{k}\Omega$$

$$R_{CD} = \frac{R_4(R_5 + R_6)}{R_4 + R_5 + R_6}$$

$$R_{CD} = \frac{1k\Omega(1.07\ k\Omega)}{1k\Omega + 1.07\ k\Omega} = \mathbf{517\Omega}$$

So the circuit will be

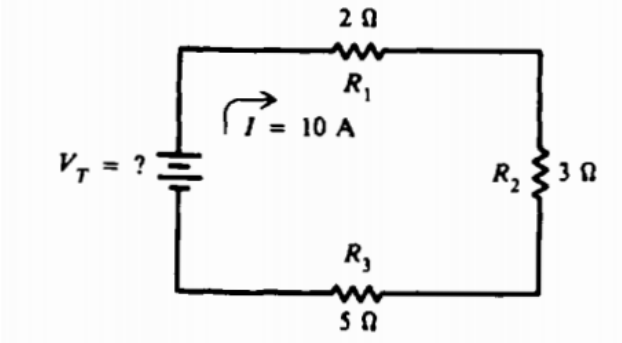


$$R_T = R_{AB} + R_3 + R_{CD}$$

$$R_T = 2.15\ k\Omega + 1\ k\Omega + 517\ \Omega$$

$$R_T = 3.6\ k\Omega$$

Example 5: find the voltage needed so that a current of 10 A will flow through the series circuit shown below



Sol:

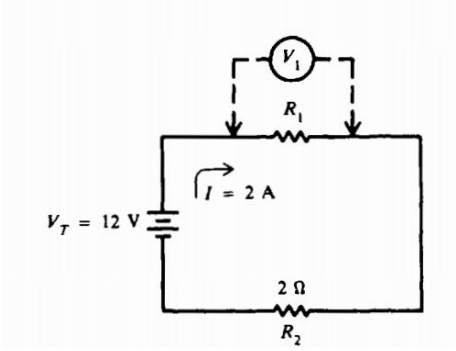
Step 1. Find total resistance.

$$R_T = R_1 + R_2 + R_3$$
$$= 2 + 3 + 5 = 10\,\Omega$$

Step 2. Find the voltage

$$V_T = IR_T$$
$$= 10(10) = 100\ \text{V}$$

Example 6: in the following circuit, a 12-V battery supplies a current of 2 A. If $R_2 = 2\Omega$, find R_1 and V_1.



Sol:

Step 1. Find R_T. By Ohm's law,

$$R_T = \frac{V_T}{I} = \frac{12}{2} = 6\,\Omega$$

Step 2. Find R_1.

$$R_T = R_1 + R_2$$

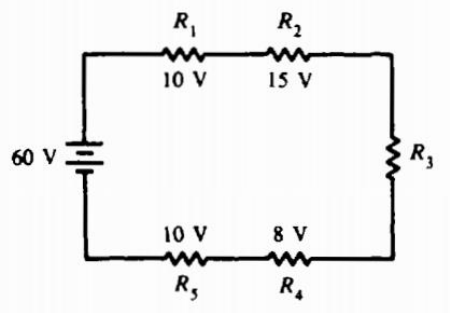
Transposing,

$$R_1 = R_T - R_2 = 6 - 2 = 4\,\Omega$$

Step 3. Find V_1.

$$V_1 = IR_1 = 2(4) = 8\text{ V}$$

Example 7: For the circuit in Fig. below, find the voltage drop of R3.



Sol:

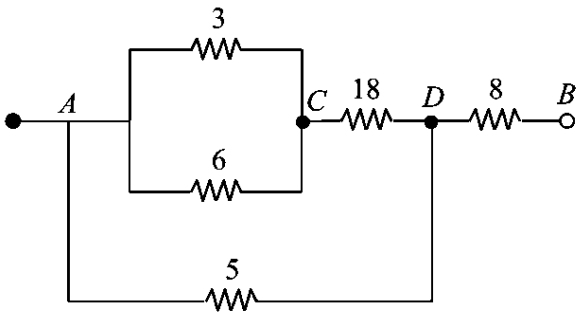
Sum of voltage drops = applied voltage

$$10 + 15 + V_3 + 8 + 10 = 60$$

$$43 + V_3 = 60$$

$$V_3 = 60 - 43 = 17\text{ V}$$

Example 8: Calculate the effective resistance of the following combination of resistances between points A and B and the total current.



Solution. Resistance between A and C

$$= 6 \parallel 3 = 2\ \Omega$$

Resistance of branch ACD $= 18 + 2 = 20\ \Omega$

Now, there are two parallel paths between points A and D of resistances 20 Ω and 5 Ω

Hence, resistance between A and $D = 20 \parallel 5 = 4\ \Omega$

$\therefore$Resistance between A and $B = 4 + 8 = 12\ \Omega$

Total circuit current = 60/12 = 5 A

Example 9: Find current through 4Ω resistance.

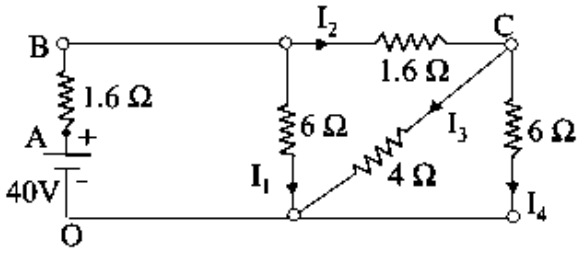


Fig. 1.26

Solution. Simplifying the series-parallel combinations, and solving the circuit, the source current is 10 amp. With respect to 0, $V_A = 40$, $V_B = 40 - 16 = 24$ volts.

I_1 = 4 amp, hence $I_2 = 6$ amp

$V_C = V_B - I_2 \times 1.6 = 24 - 9.6 = 14.4$ volts

I_3 = 14.4/4 = 3.6 amp, which is the required answer. Further $I_4 = 24$ amp.

Example 2.10. *Two resistors R_1 and R_2 are connected in parallel to a certain supply. If the current taken from the supply is 5 A, calculate the value of R_1. Given that $R_2 = 6\ \Omega$ and that current through R_1 is 2A. Also find the total power absorbed by the circuit.*

Solution. Fig. 2.13 shows the circuit arrangement.

Current through R_2, $I_2 = 5 - 2 = 3$A

Supply voltage, $V = I_2 R_2 = 3 \times 6 = 18$ V

$\therefore$ $R_1 = V/I_1 = 18/2 = \mathbf{9\ \Omega}$

Power absorbed by the circuit

$= I_1^2 R_1 + I_2^2 R_2$

$= (2)^2 \times 9 + (3)^2 \times 6$

$= 36 + 54$

$= \mathbf{90}$ watts

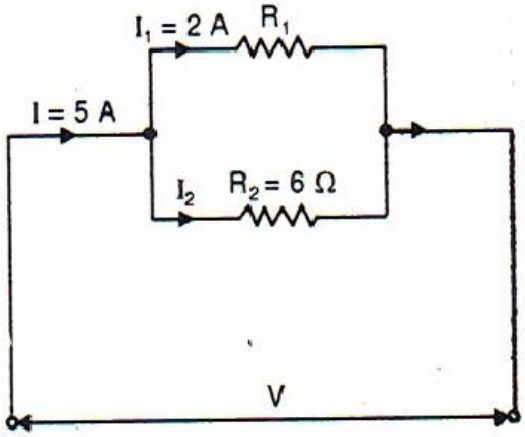


Fig. 2.13

Example 2.12. *Three resistors 4 Ω, 12 Ω and 6 Ω are connected in parallel. If the total current taken is 12 A, find the current through each resistor.*

Solution. Fig. 2.14 shows the circuit arrangement.

$$\frac{1}{R_P} = \frac{1}{4} + \frac{1}{12} + \frac{1}{6}$$

$$= \frac{6}{12}$$

$$\therefore \quad R_P = 12/6 = 2\ \Omega$$

P.D. across the parallel circuit,

$$V = I R_P = 12 \times 2$$
$$= 24\ \text{V}$$

Current through 4 Ω = 24/4 = **6 A**
Current through 12 Ω = 24/12 = **2 A**
Current through 6 Ω = 24/6 = **4 A**

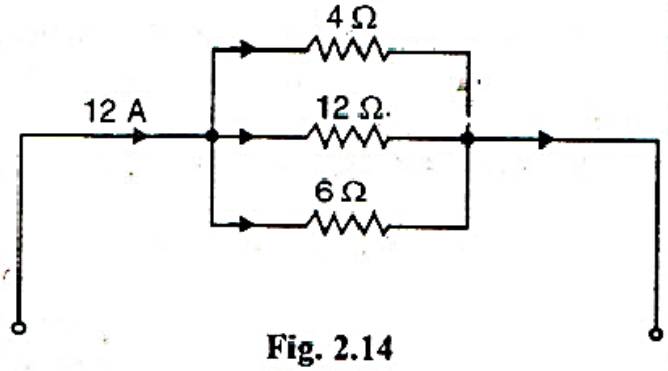


Fig. 2.14

Example 2.13. *Find the circuit current in the circuit shown in Fig. 2.15.*

Solution. The resistors in the branch *ABC* are in series and this branch is in parallel with branch *AC* (= 30 Ω).

∴ Total circuit resistance,

$$R_T = \frac{30\,(30+30)}{(30)+(30+30)} = 20\ \Omega$$

$$\therefore \text{ Circuit current, } I = \frac{V}{R_T} = \frac{2}{20} = 0{\cdot}1\ \text{A}$$

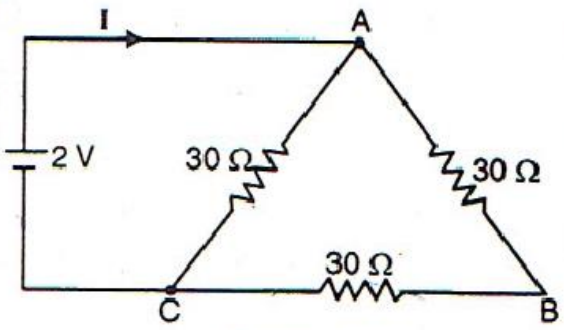


Fig. 2.15

Example 2.14. *Three equal resistors are connected as shown in Fig 2.16. Find the equivalent resistance between points A and B.*

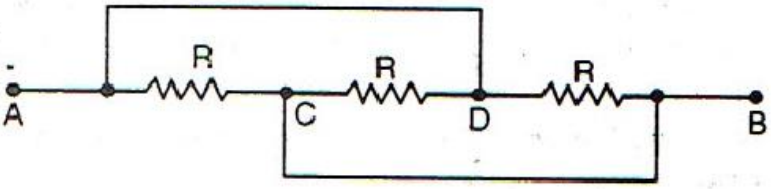


Fig. 2.16

Solution. The reader may observe that one end of each resistor is connected to point *A* and the other end of each resistor is connected to point *B*. Hence the three resistors are is parallel.

$$\therefore \quad \frac{1}{R_{AB}} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} = \frac{3}{R} \quad \text{or} \quad R_{AB} = \frac{R}{3}$$

Example 2.20. *A battery having an e.m.f. of E volts and internal resistance 0·1 Ω is connected across terminals A and B of the circuit shown in Fig.2.26. Calculate the value of E in order that power dissipated in 2 Ω resistor shall be 2 W.*

Solution. Resistance between E and F is given by :

$$\frac{1}{R_{EF}} = \frac{1}{3} + \frac{1}{2} + \frac{1}{6} = \frac{6}{6}$$

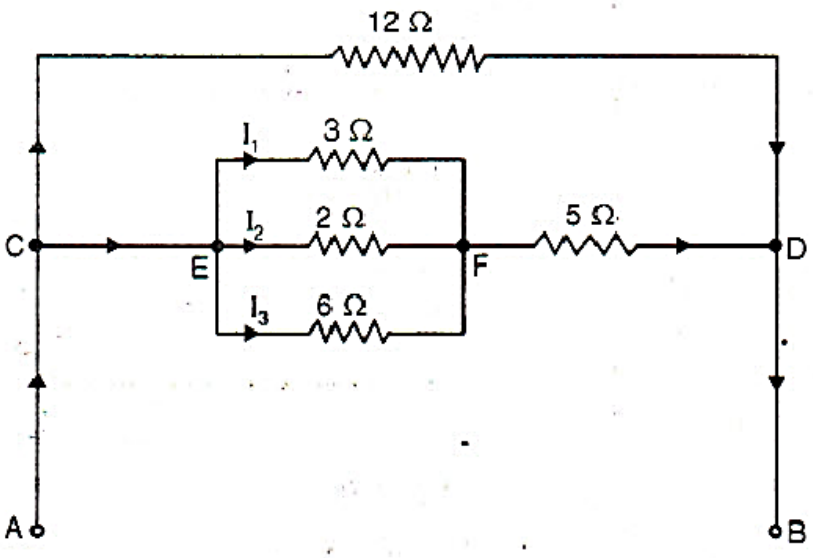


Fig. 2.26

$\therefore$ $R_{EF} = 6/6 = 1\ \Omega$

Resistance of branch $CEFD$ $= 1 + 5 = 6\ \Omega$

Current through 2 Ω $= \sqrt{\frac{\text{Power loss}}{\text{Resistance}}} = \sqrt{\frac{2}{2}} = 1\text{A}$

P.D. across EF $= 1 \times 2 = 2\text{V}$

Current through 3 Ω $= 2/3 = 0{\cdot}67\ \text{A}$

Current through 6 Ω $= 2/6 = 0{\cdot}33\ \text{A}$

Current in branch CED $= 1 + 0{\cdot}67 + 0{\cdot}33 = 2\ \text{A}$

P.D. across CD $= 6 \times 2 = 12\ \text{V}$

Current through 12 Ω $= 12/12 = 1\ \text{A}$

Current supplied by battery $= 2 + 1 = 3\ \text{A}$

$\therefore$ E = P.D. across AB or CD + Drop in battery resistance

$= 12 + 0{\cdot}1 \times 3 = \mathbf{12{\cdot}3\ V}$

Example 2.22. *Six resistors are connected as shown in Fig. 2.28. If a battery having an e.m.f. of 24 volts and internal resistance of 1Ω is connected to the terminals A and B, find (i) the current from the battery (ii) p.d. across 8Ω and 4Ω resistors (iii) the current taken from the battery if a conductor of negligible resistance is connected in parallel with 8Ω resistor.*

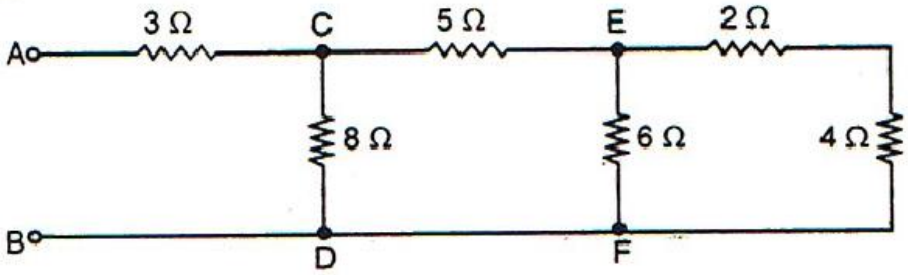


Fig. 2.28

Solution.

Resistance between E and F, $R_{EF} = \dfrac{(4+2)\times 6}{(4+2)+6} = 3\ \Omega$

Resistance between C and D, $R_{CD} = \dfrac{(5+3)\times 8}{(5+3)+8} = 4\ \Omega$

Resistance between A and B, $R_{AB} = 3 + 4 = 7\ \Omega$

Total circuit resistance, $R_T = R_{AB}$ + Supply resistance $= 7 + 1 = 8\ \Omega$

(*i*) Current from battery, $I = E/R_T = 24/8 = \mathbf{3\ A}$

(*ii*) P.D. across 8 Ω $= E - I(3+1) = 24 - 3(4) = \mathbf{12\ V}$

Current through 8 Ω = 12/8 = 1·5 A

Current through 5 Ω = 3 – 1·5 = 1·5A

P.D. across EF = 12 – 1·5 × 5 = 4·5 V

Current through 6Ω = 4·5/6 = 0·75A

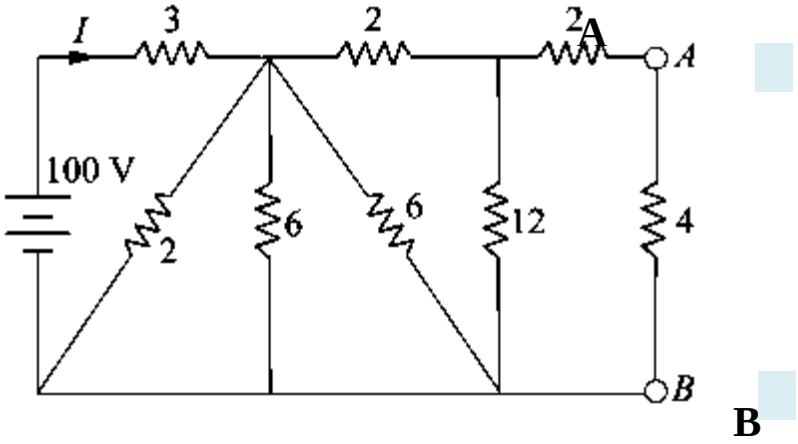
∴ Current through 4 Ω = 1·5 – 0·75 = 0·75 A

∴ Voltage across 4Ω = 0·75 × 4 = **3 V**

(*iii*) When a conductor of negligible resistance is connected across 8 Ω, then resistance between C and D is zero. Therefore, total resistance in the circuit is now 3 Ω resistor in series with 1 Ω internal resistance of battery.

∴ Current from battery = $\frac{24}{3+1}$ = **6A**

Q1: calculate the total resistance



B

Q2 What is the drop across the 150 Ω resistor in Fig. 2.6 ? **[5.33 V]**

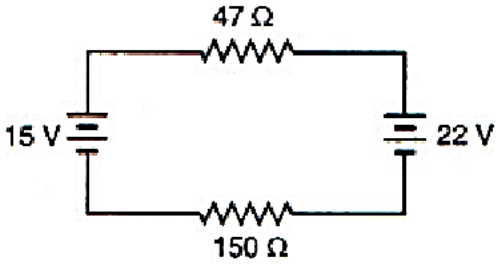


Fig. 2.6

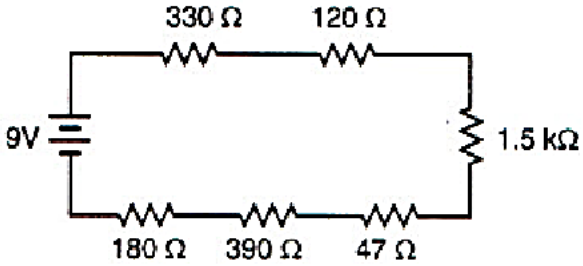


Fig. 2.7

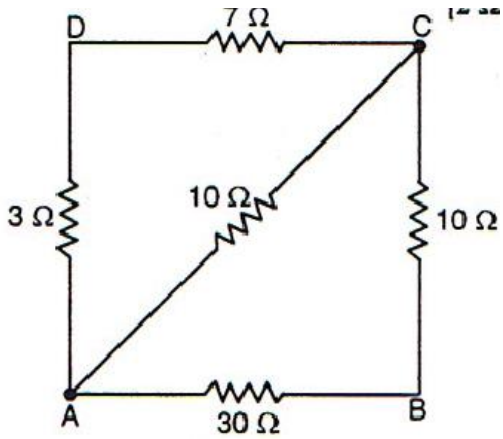
Q3 Calculate the current flow for Fig. 2.7. **[3.51 mA]**

Q4 Four resistors are in parallel. The currents in the first three resistors are 4 mA, 5 mA and 6 mA respectively. The voltage drop across the fourth resistor is 200 volts. The total power dissipated is 5 watts. Determine the values of the resistances of the branches and the total resistance.

[50 k Ω, 40 k Ω, 33·33 k Ω, 8 k Ω, 5 k Ω]

Q5 Four resistors of 2 Ω, 3 Ω, 4 Ω and 5 Ω respectively are connected in parallel. What potential difference must be applied to the group in order that total power of 100 watts may be absorbed ? **[8·826 volts]**

Q6 Find the equivalent resistance between points A and B in the circuit shown below



[10 Ω]

Q7 Find the voltage across and current through 4 kΩ resistor in the circuit shown in Fig. 2.39.

[4 V ; 1 mA]

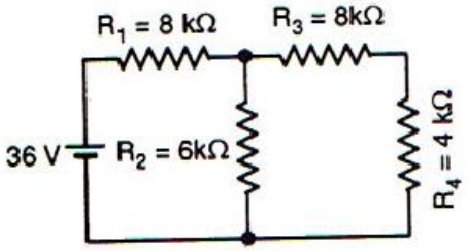


Fig. 2.39

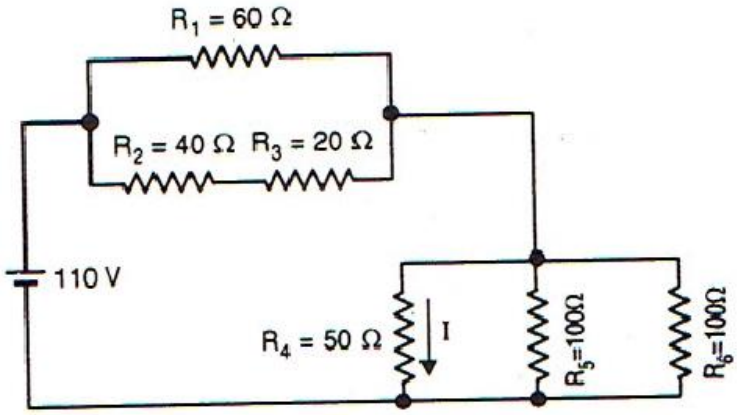


Fig. 2.40

Q8 Find the current *I* in the 50 Ω resistor in the circuit shown in Fig. 2.40. **[1 A]**