Basic Laws

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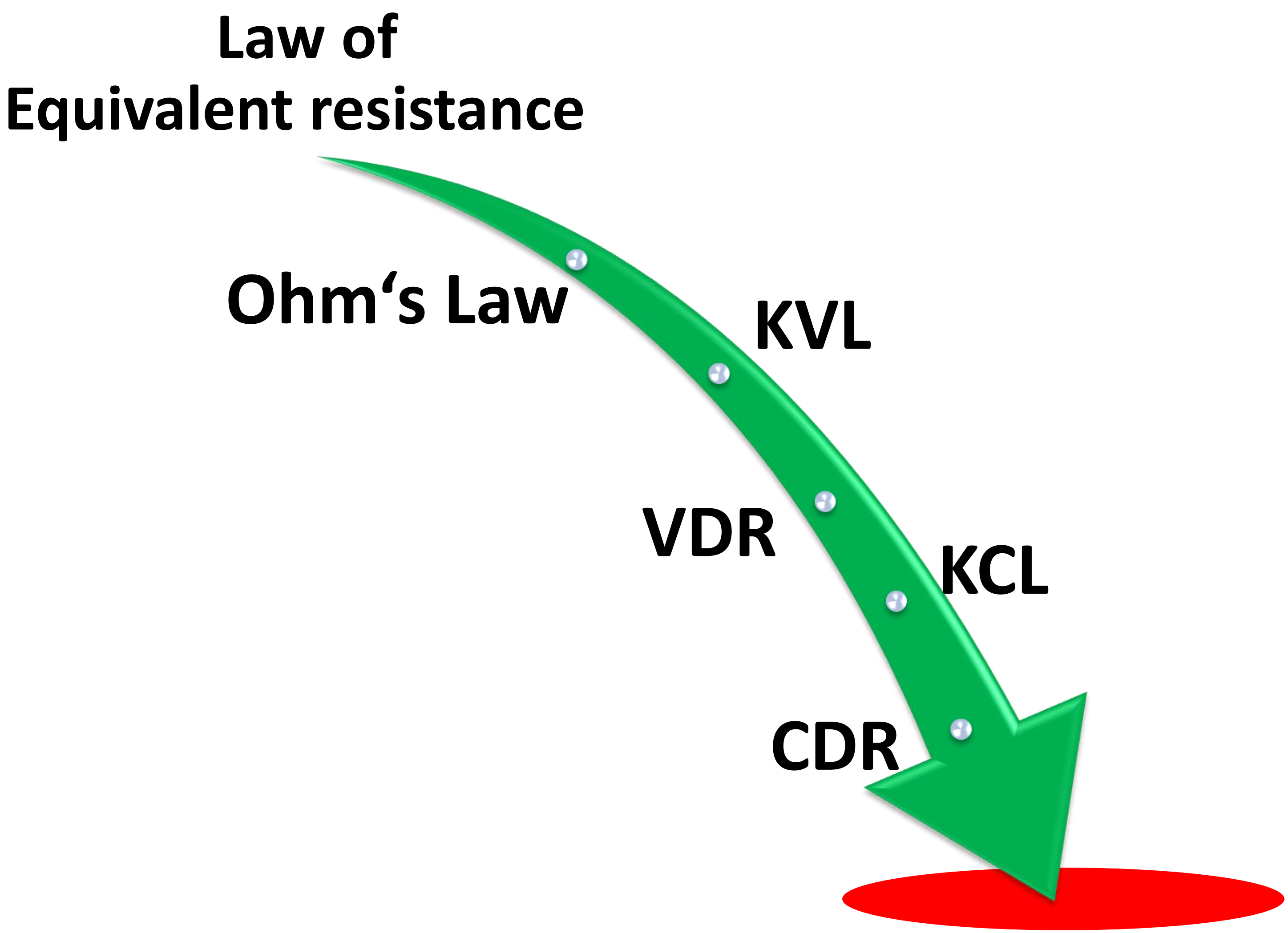


Basic Laws

Law of equivalent resistance

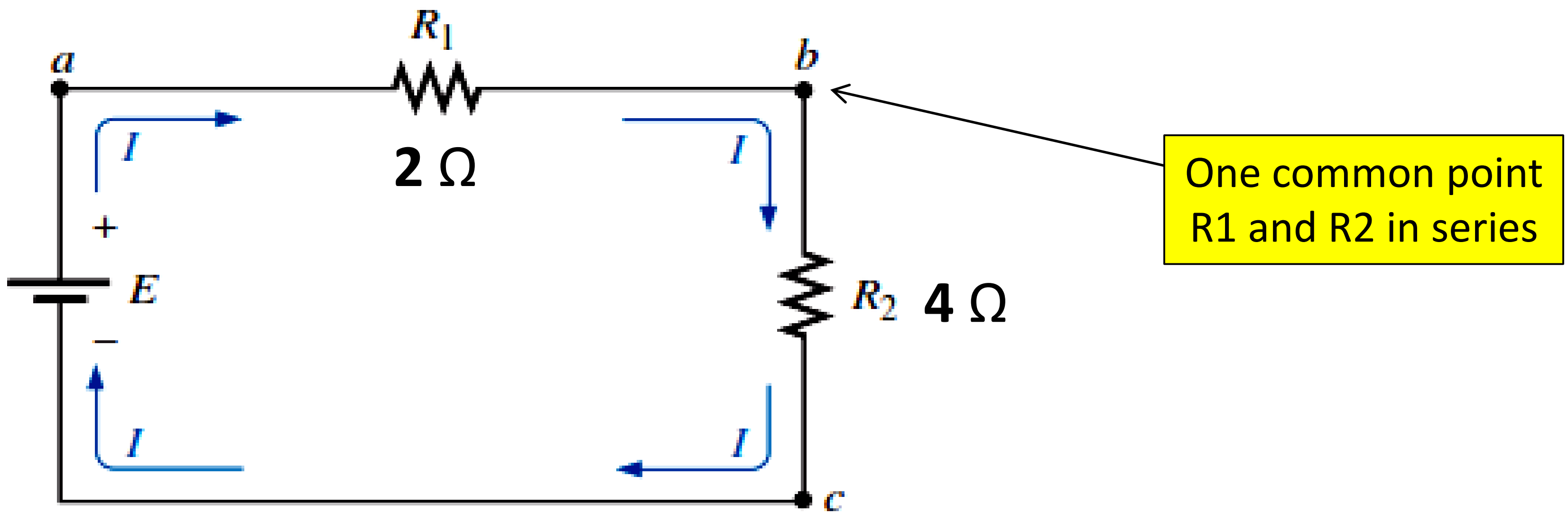
Series Circuit

Conditions to be series

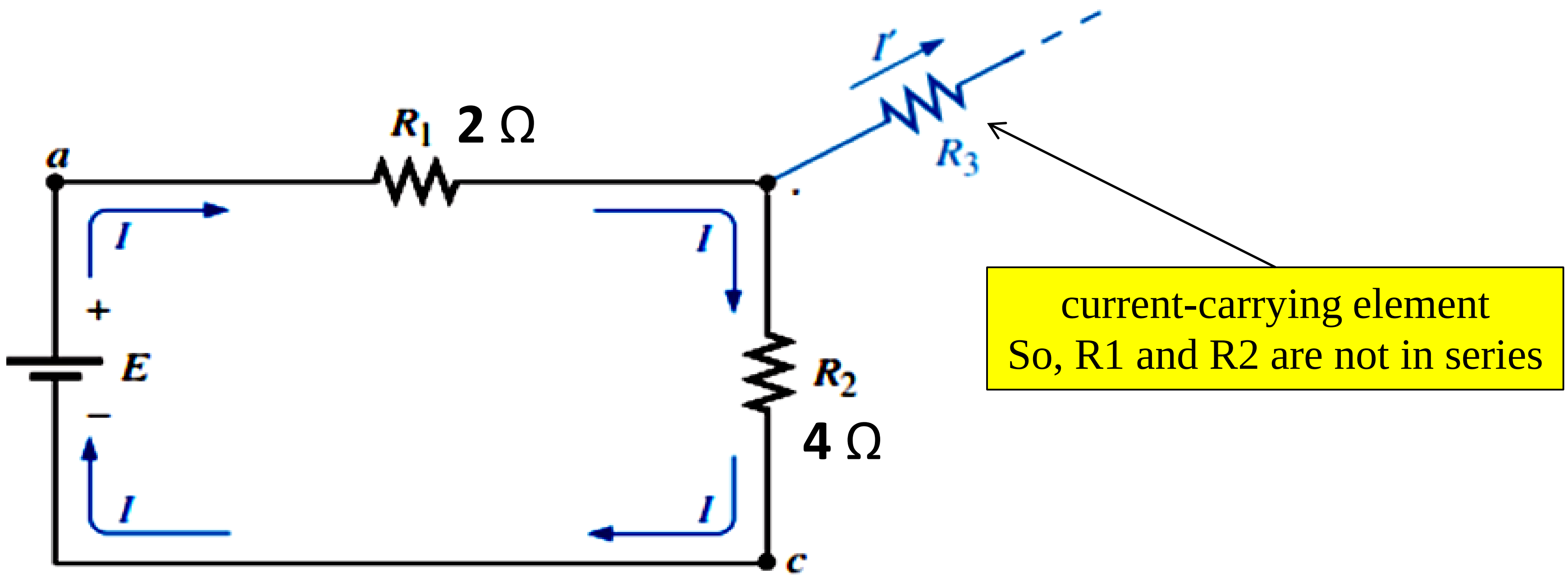
1. One common terminal.
2. No current-carrying element is connected to that common point.

Total resistance for series resistances

$$\boxed{R_T = R_1 + R_2 + R_3 + \cdots + R_N}$$



R_1
a
b
2 Ω
I
+
E
−
R_2
4 Ω
c
One common point
R1 and R2 in series



I'
R_1 2 Ω
a
R_3
I
+
E
−
R_2
4 Ω
c
current-carrying element
So, R1 and R2 are not in series

Parallel Circuit

Condition to be parallel

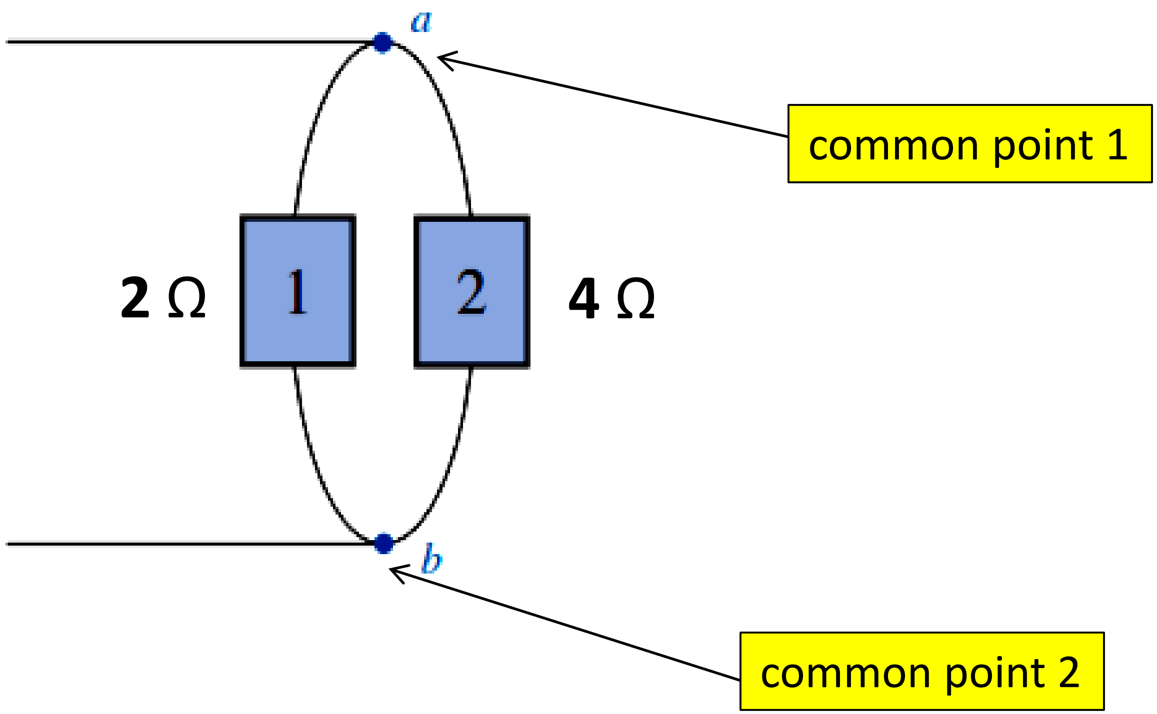
They have two common point

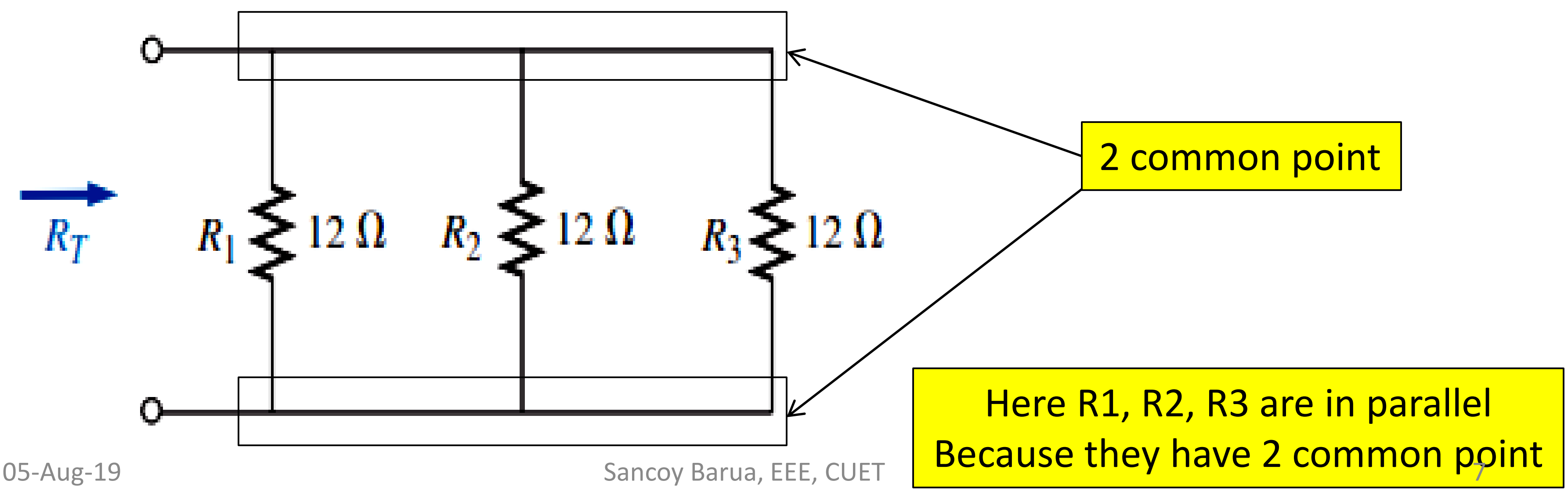
Total resistance for parallel resistances

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

$$R_T = (R_1^{-1} + R_2^{-1} + R_3^{-1} + \ldots\ldots\ldots\ldots + R_N^{-1})^{-1}$$

If all the resistance are same (i.e. R1=R2=…..=R_N=R) then, $R_T = R / N$

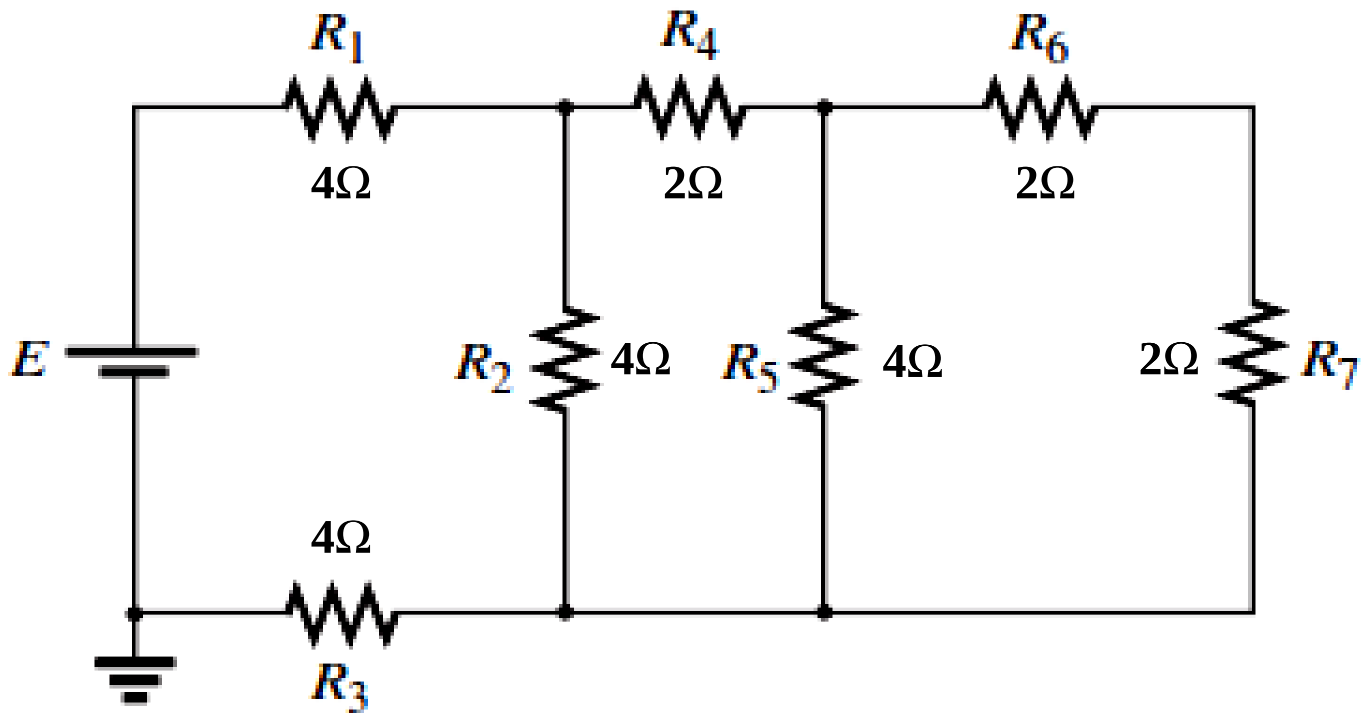

a
b
2 Ω
1
2
4 Ω
common point 1
common point 2


R_T
R_1 12 Ω
R_2 12 Ω
R_3 12 Ω
2 common point
Here R1, R2, R3 are in parallel
Because they have 2 common point

Q/A

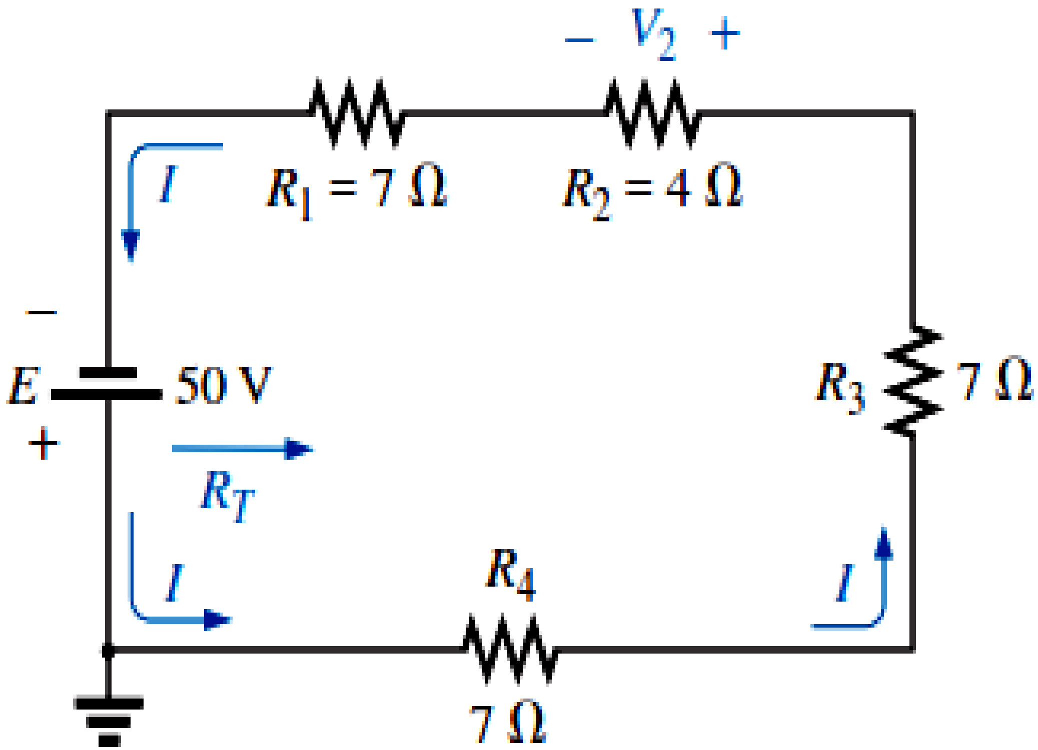
Quiz

R_T = ?



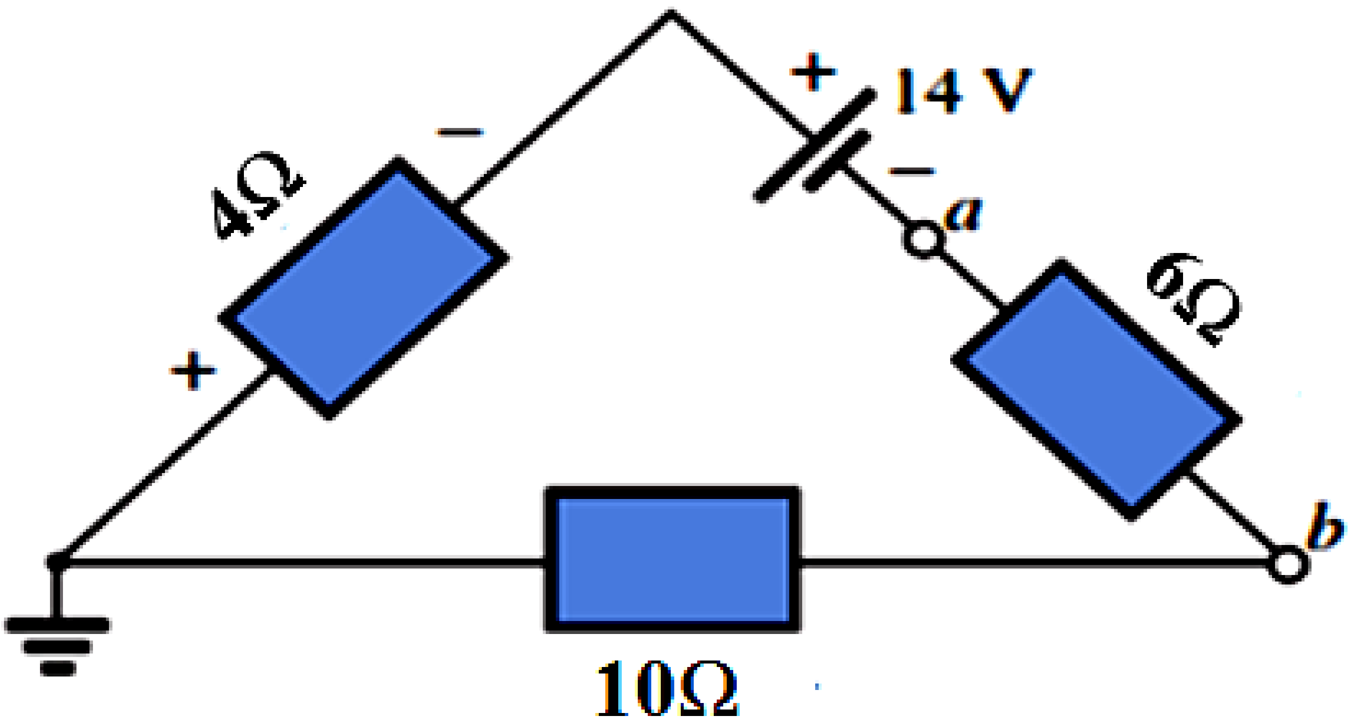
Ans: 10Ω

$R_T = ?$



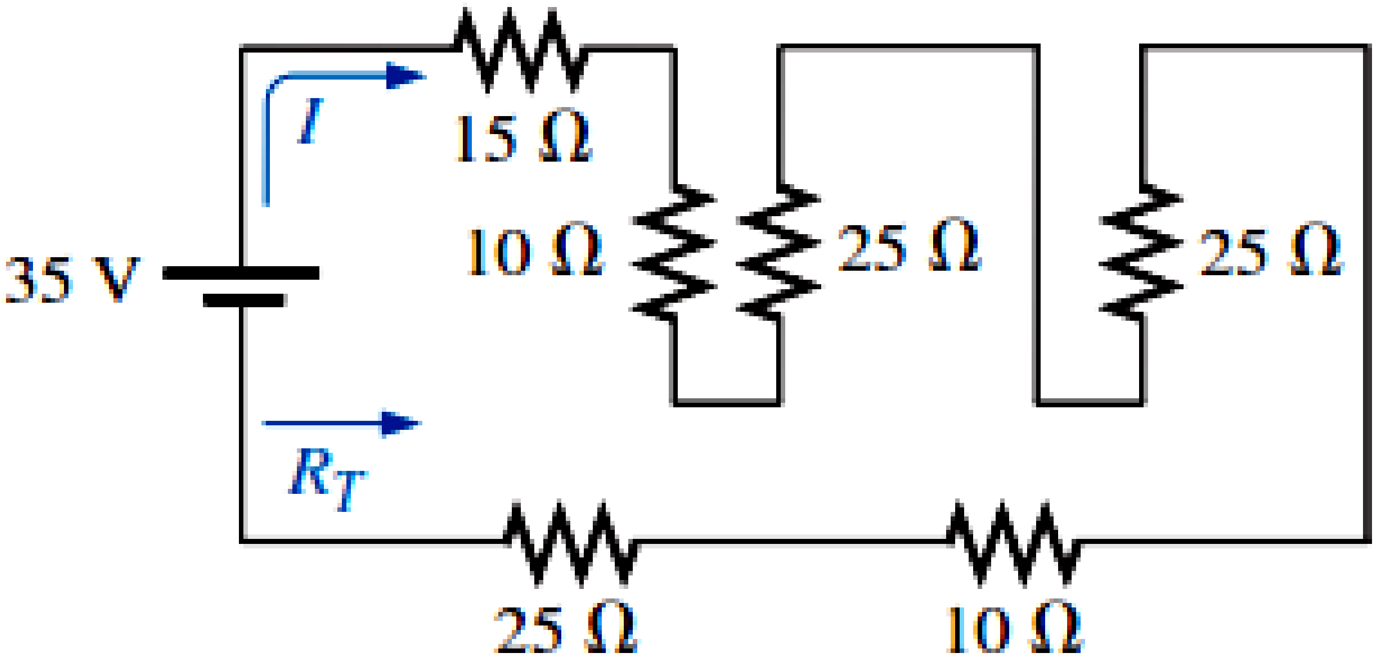
Ans: 25Ω

$R_T = ?$



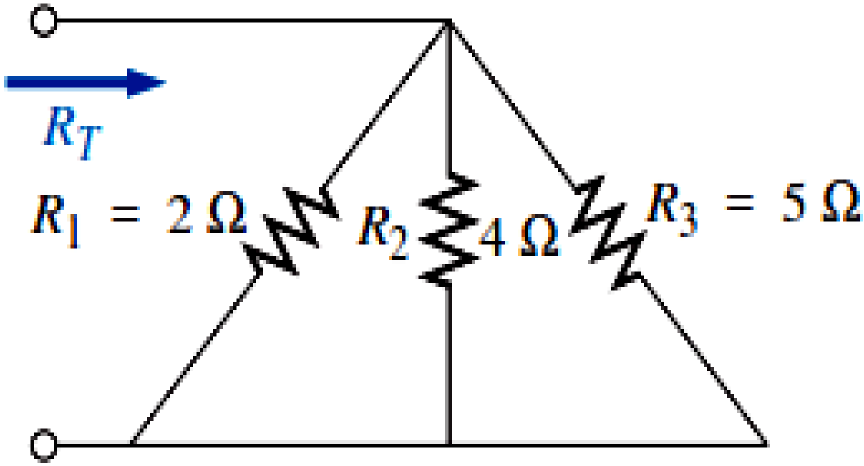
Ans: 20Ω

$R_T = ?$

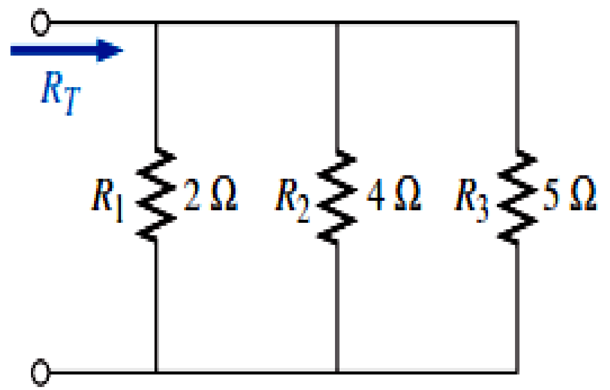


Ans: 110Ω

$R_T = ?$



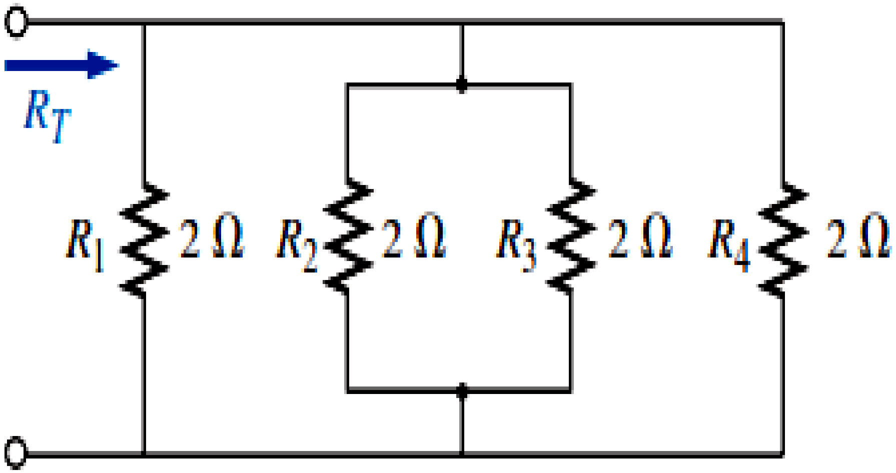
R_T
$R_1 = 2\ \Omega$
R_2
$4\ \Omega$
$R_3 = 5\ \Omega$

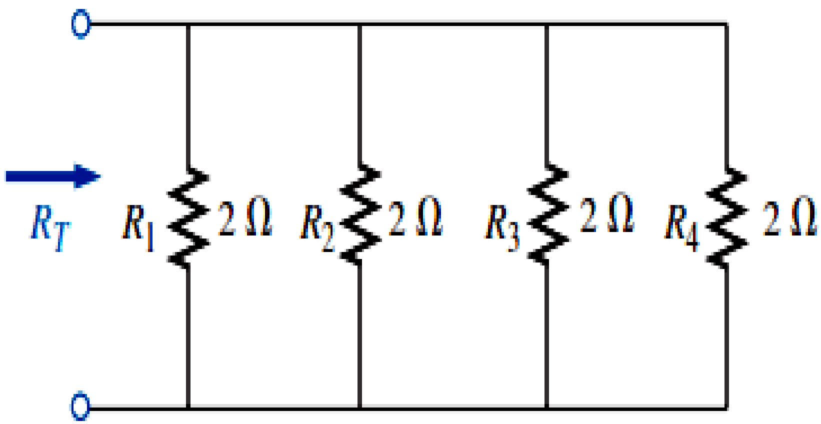


R_T
R_1
$2\ \Omega$
R_2
$4\ \Omega$
R_3
$5\ \Omega$

Ans: 1.05Ω

R_T = ?

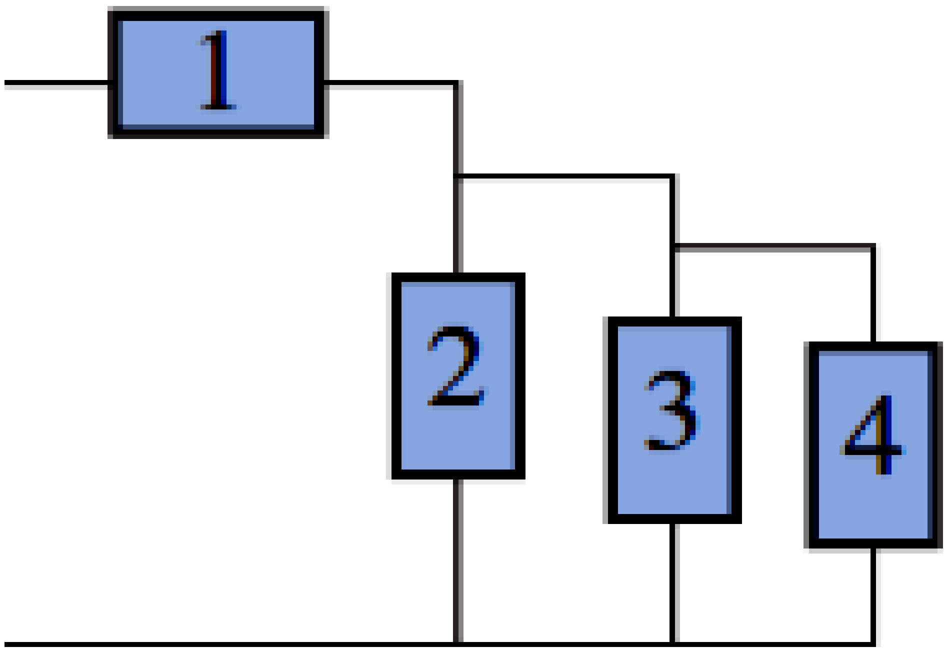




Ans: 0.5Ω

$R_T = ?$

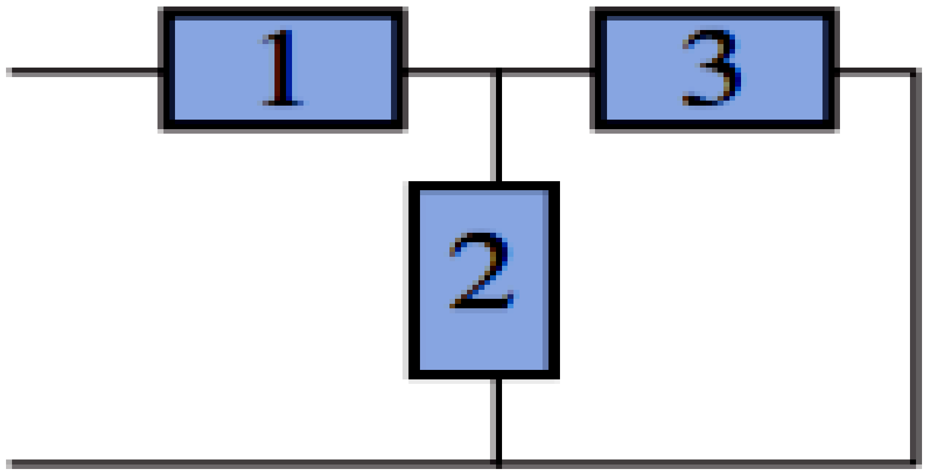
All the resistance are **9Ω**



Ans: 12Ω

$R_T = ?$

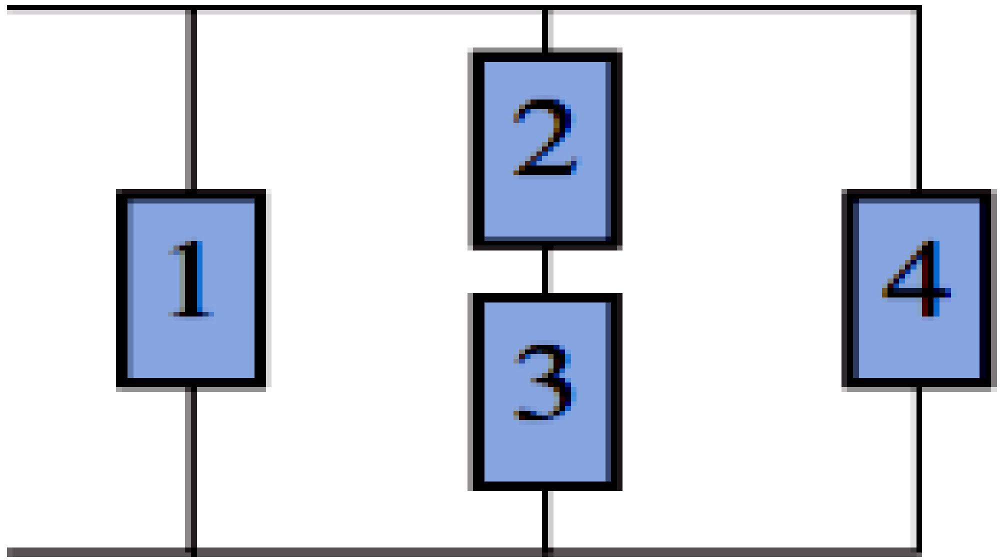
All the resistance are **8Ω**



Ans: 12Ω

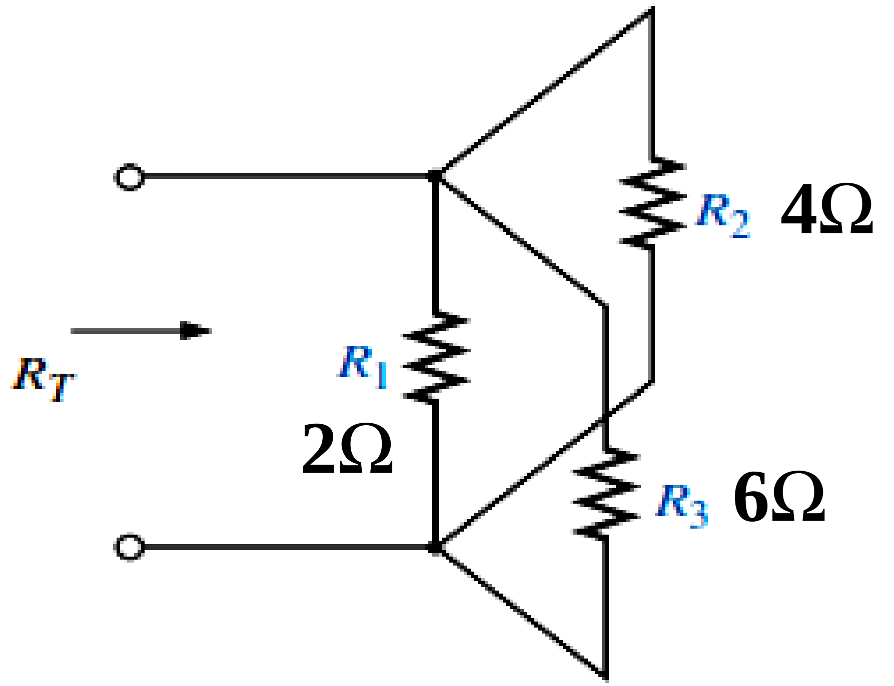
$R_T = ?$

All the resistance are **4Ω**



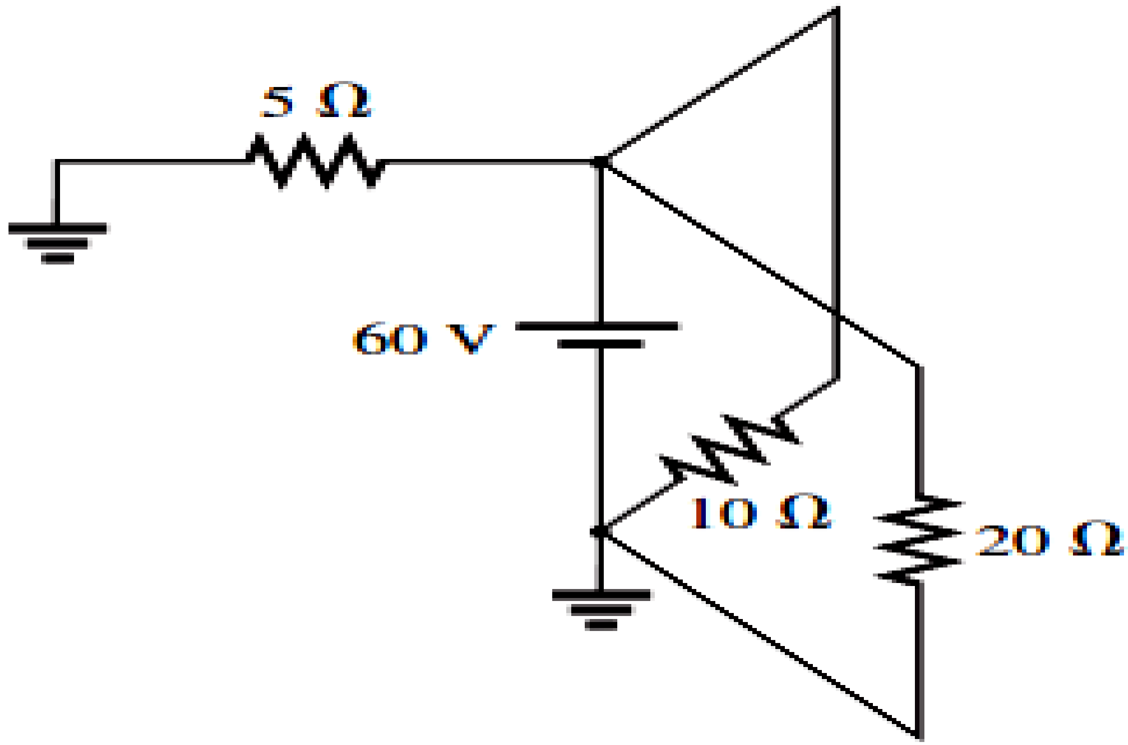
Ans: 1.60Ω

R_T = ?



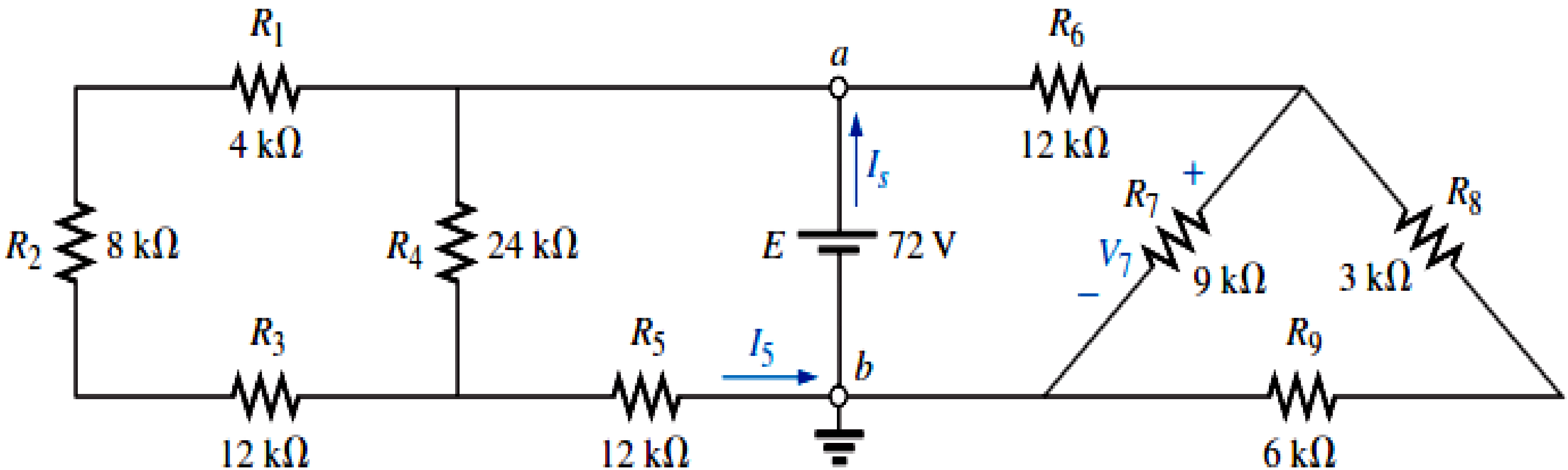
Ans: 1.09Ω

$R_T = ?$



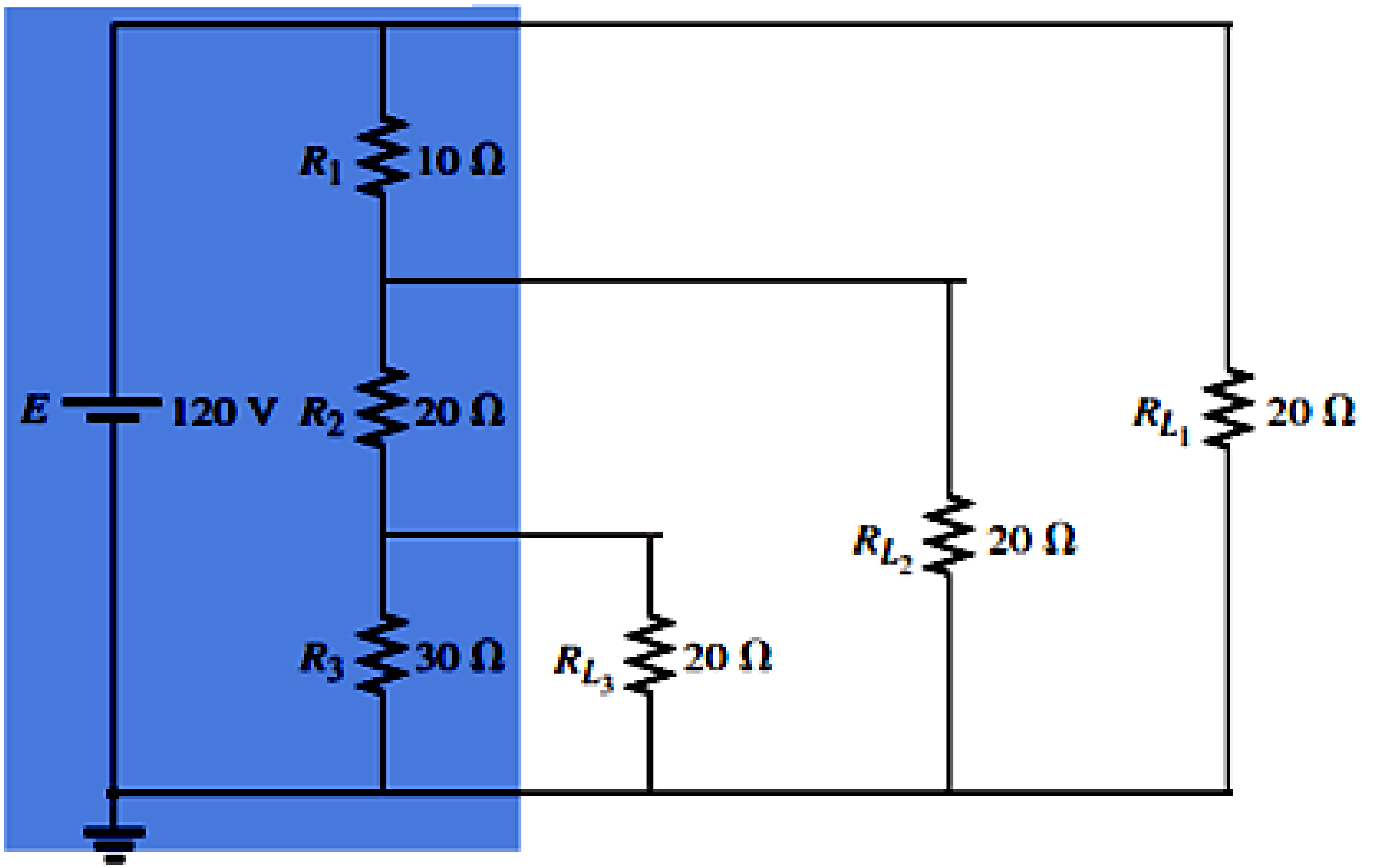
Ans: 2.86Ω

$R_T = ?$


R1
4 kΩ
a
R6
12 kΩ
Is
R7
+
R8
R2
8 kΩ
R4
24 kΩ
E
72 V
V7
9 kΩ
3 kΩ
−
R3
R5
I5
b
R9
12 kΩ
12 kΩ
6 kΩ

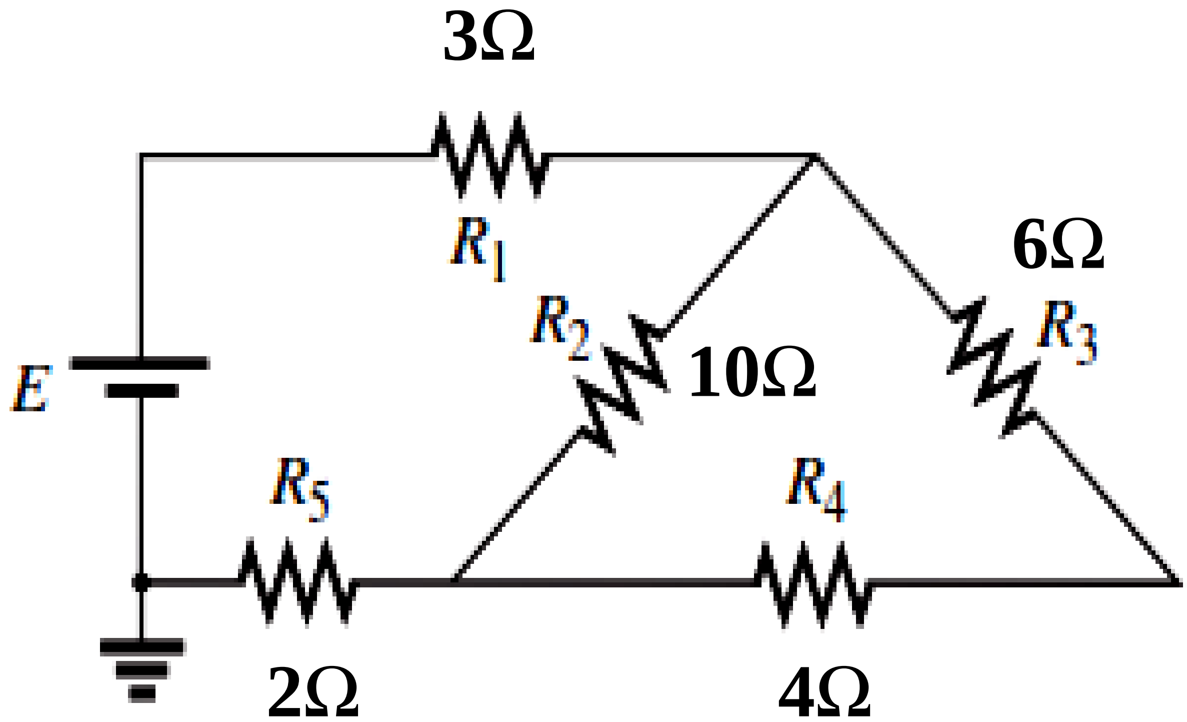
Ans: 9.78KΩ

R_T = ?



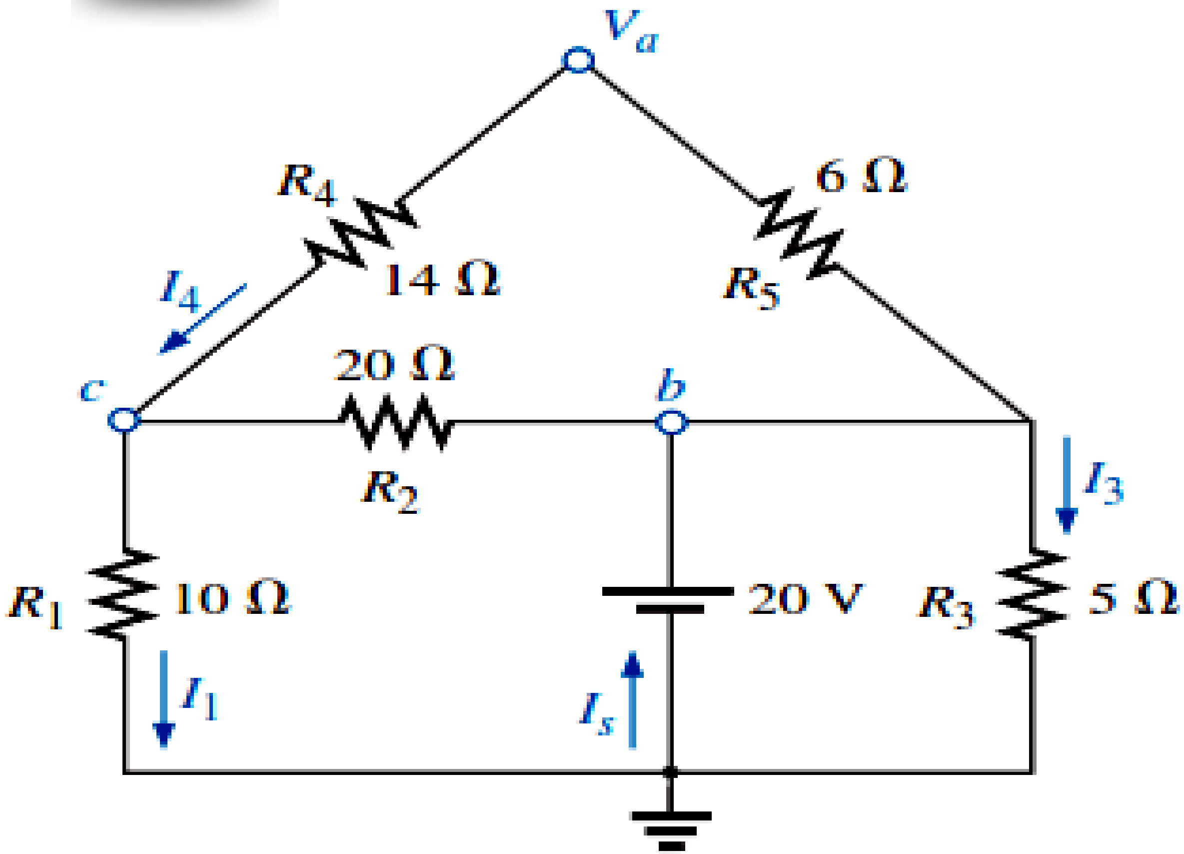
Ans: 10.55Ω

$R_T = ?$



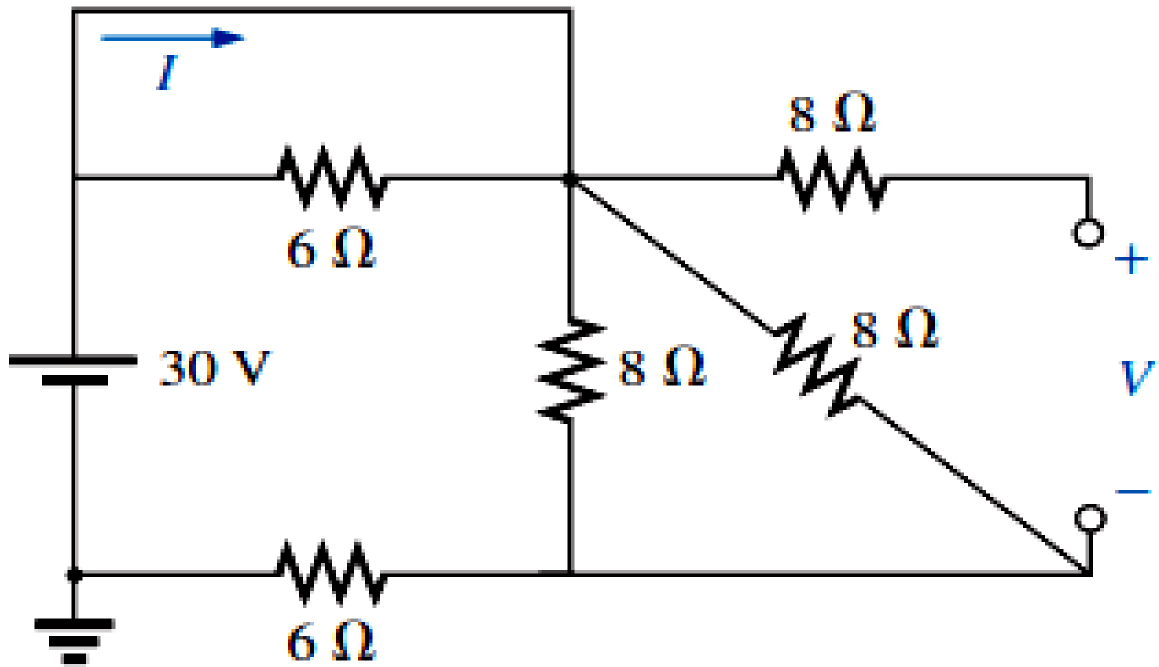
Ans: 10Ω

R_T =



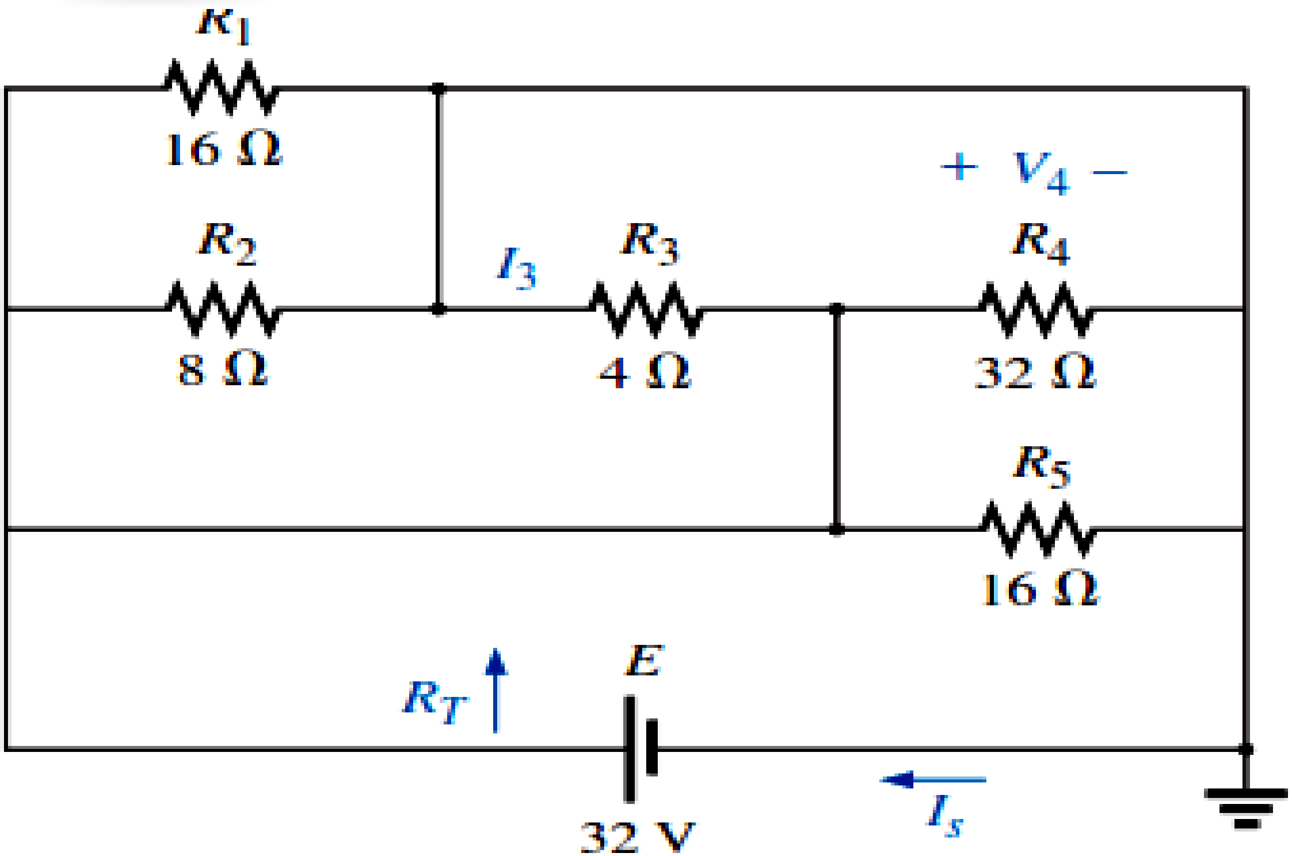
Ans: 4Ω

$R_T = ?$



Ans: 10Ω

R_T = ?



Ans: 1.88Ω

- If 2 same valued resistors are connected in parallel then, their combined resistance will be **half** of the value of a single resistor.

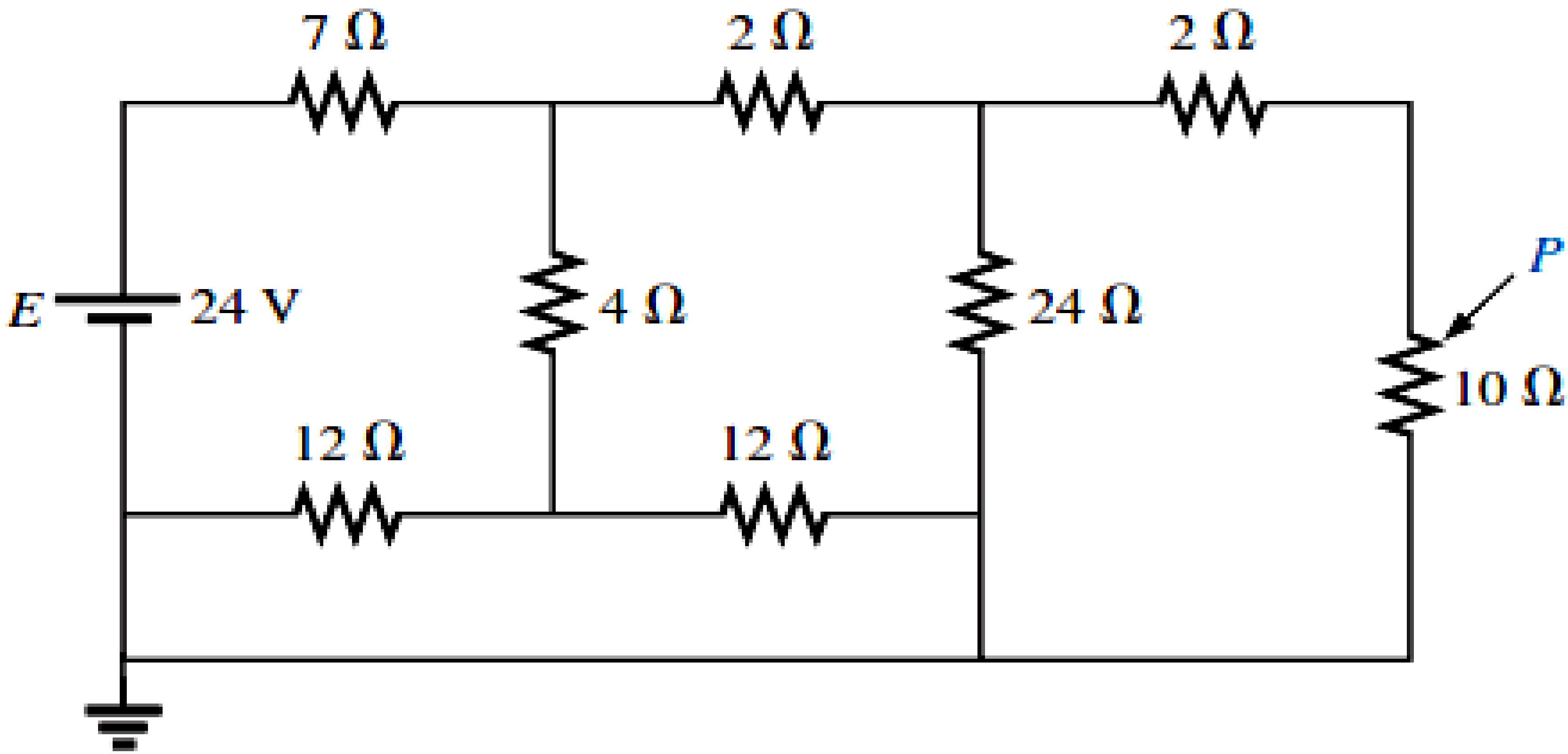
$$R_1 = R$$

$$R_2 = R$$

$$then,$$

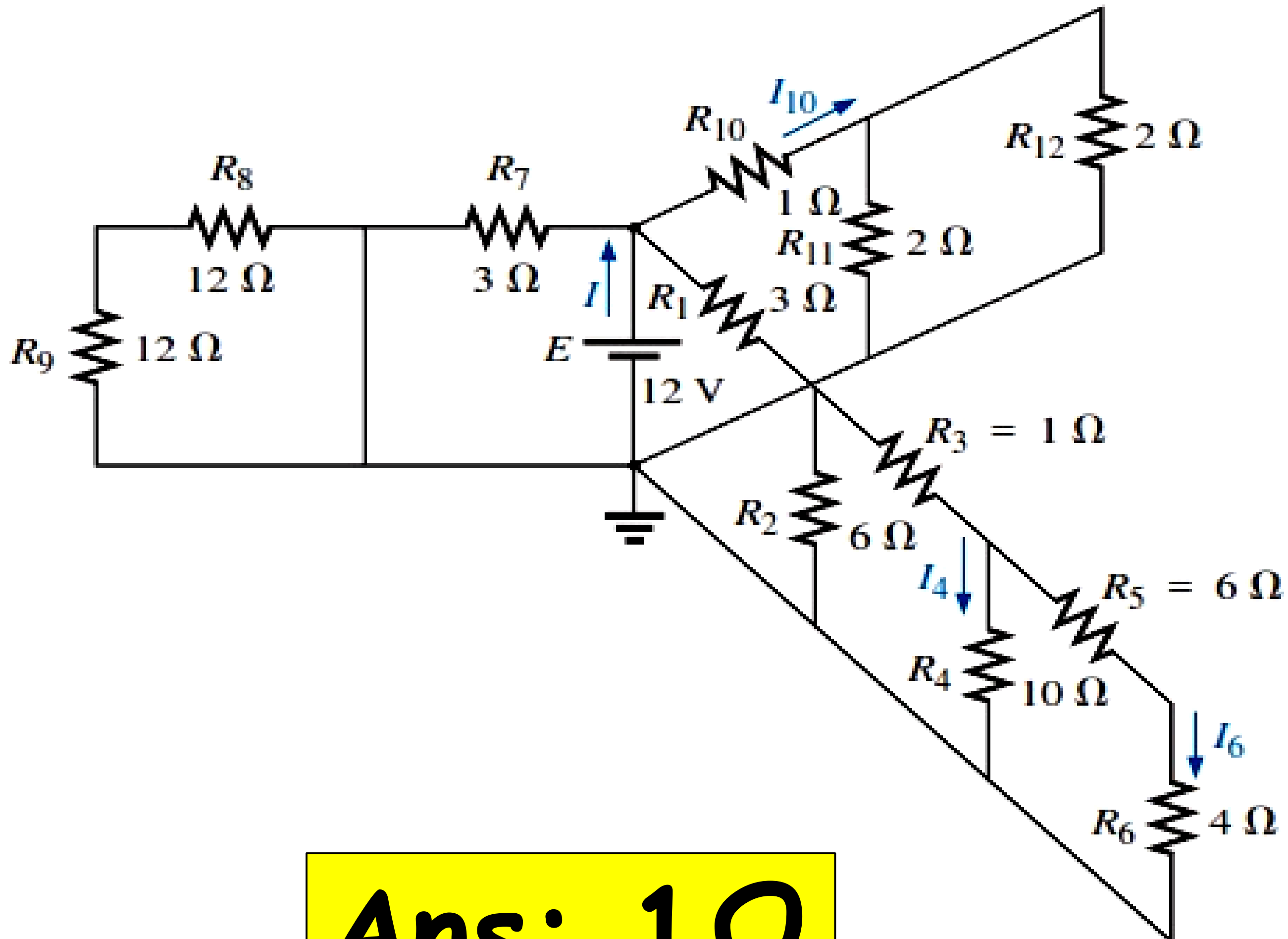
$$R_p = \frac{R_1}{2} = \frac{R}{2}$$

$R_T =$ 



Ans: 12Ω

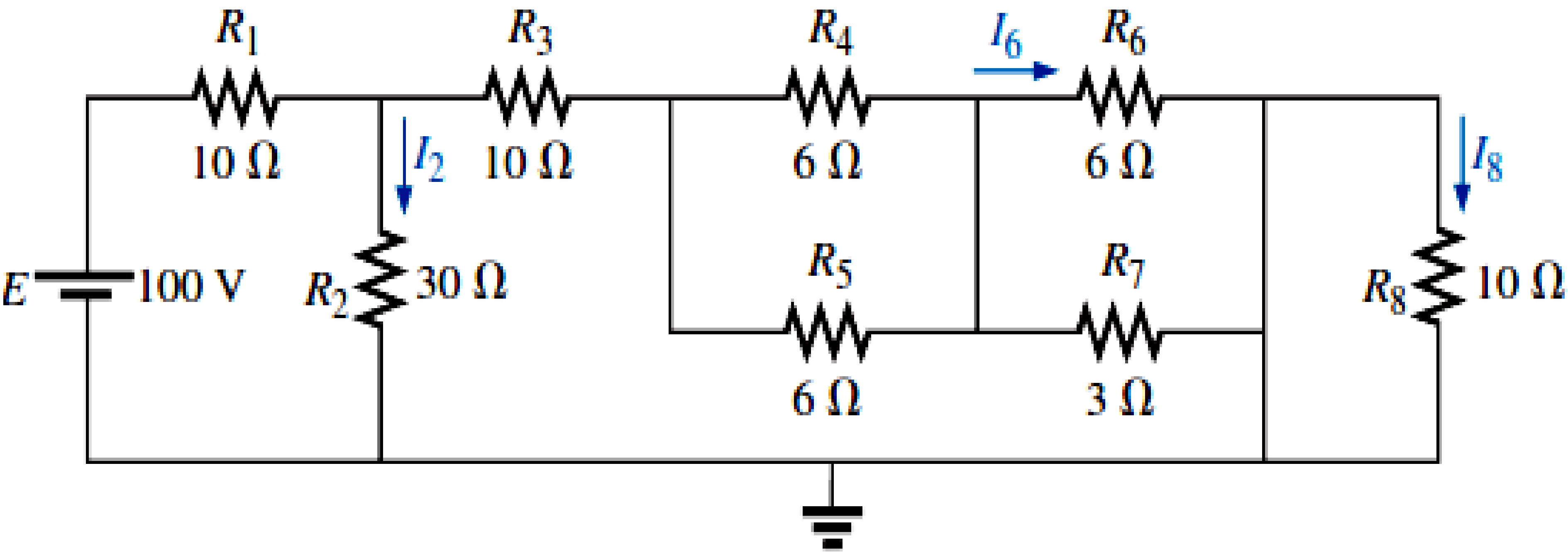
$R_T = $ 



R_8
12 Ω
R_7
3 Ω
R_9
12 Ω
I
E
12 V
R_{10}
I_{10}
1 Ω
R_{11}
2 Ω
R_{12}
2 Ω
R_1
3 Ω
R_2
6 Ω
R_3 = 1 Ω
I_4
R_4
10 Ω
R_5 = 6 Ω
I_6
R_6
4 Ω

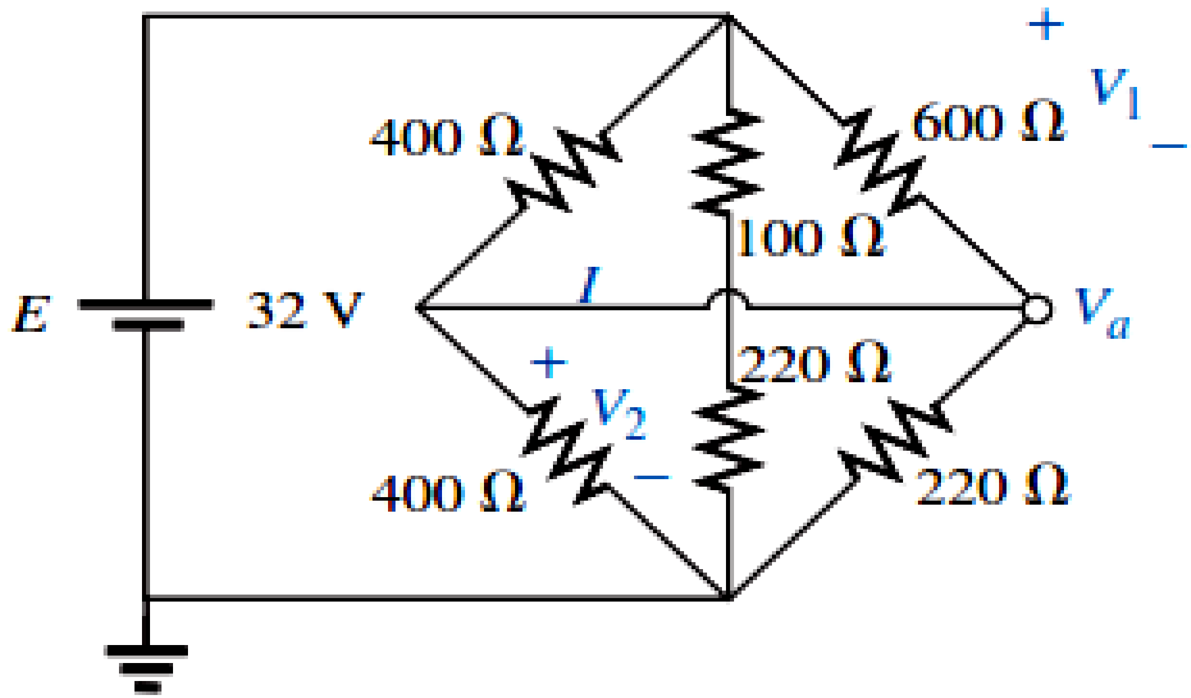
Ans: 1Ω

R_T = ?



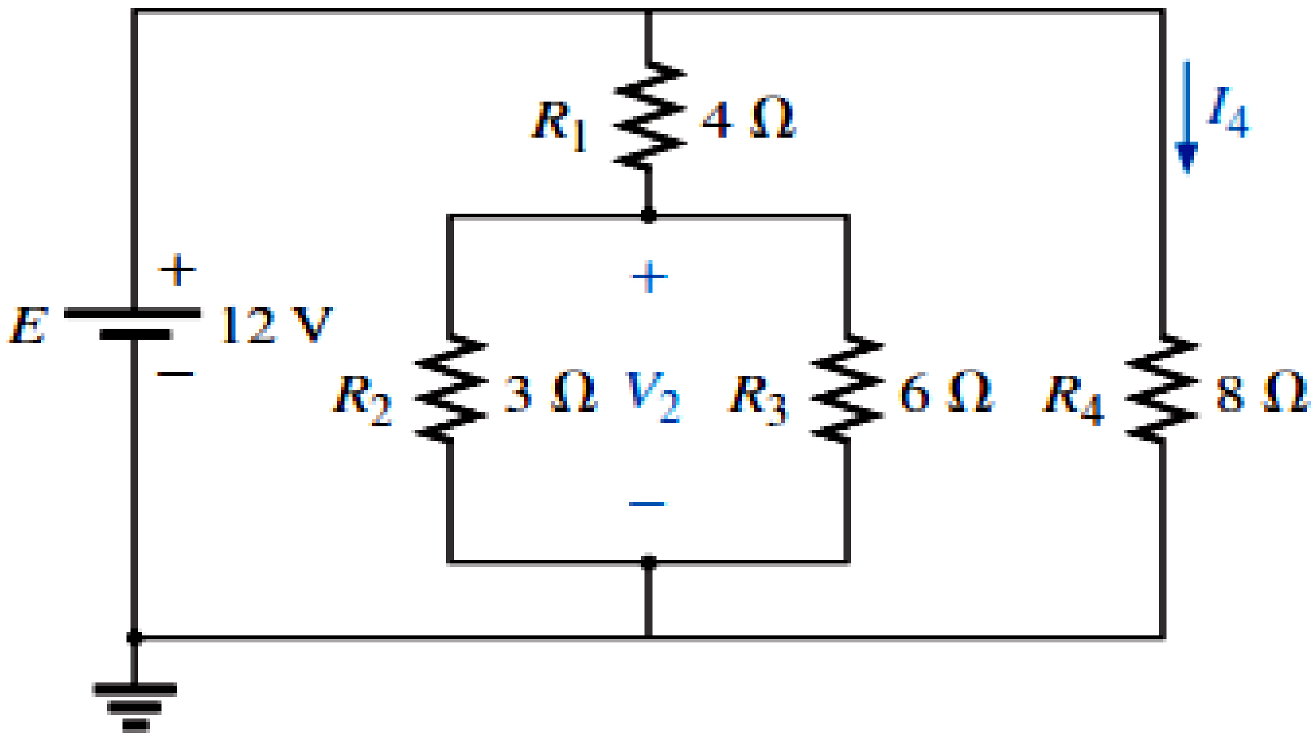
Ans: 20Ω

R_T = 



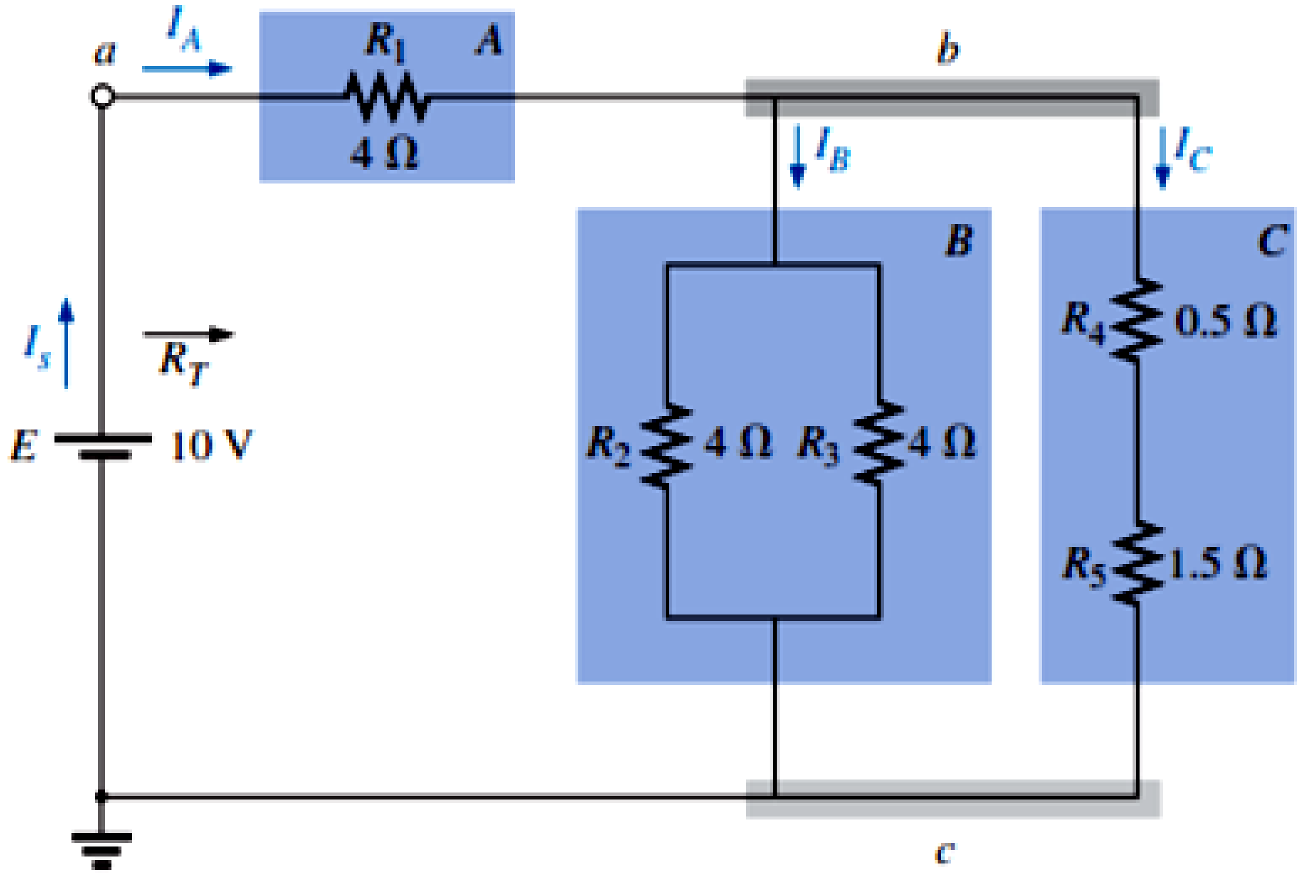
Ans: 174.12Ω

R_T = ?



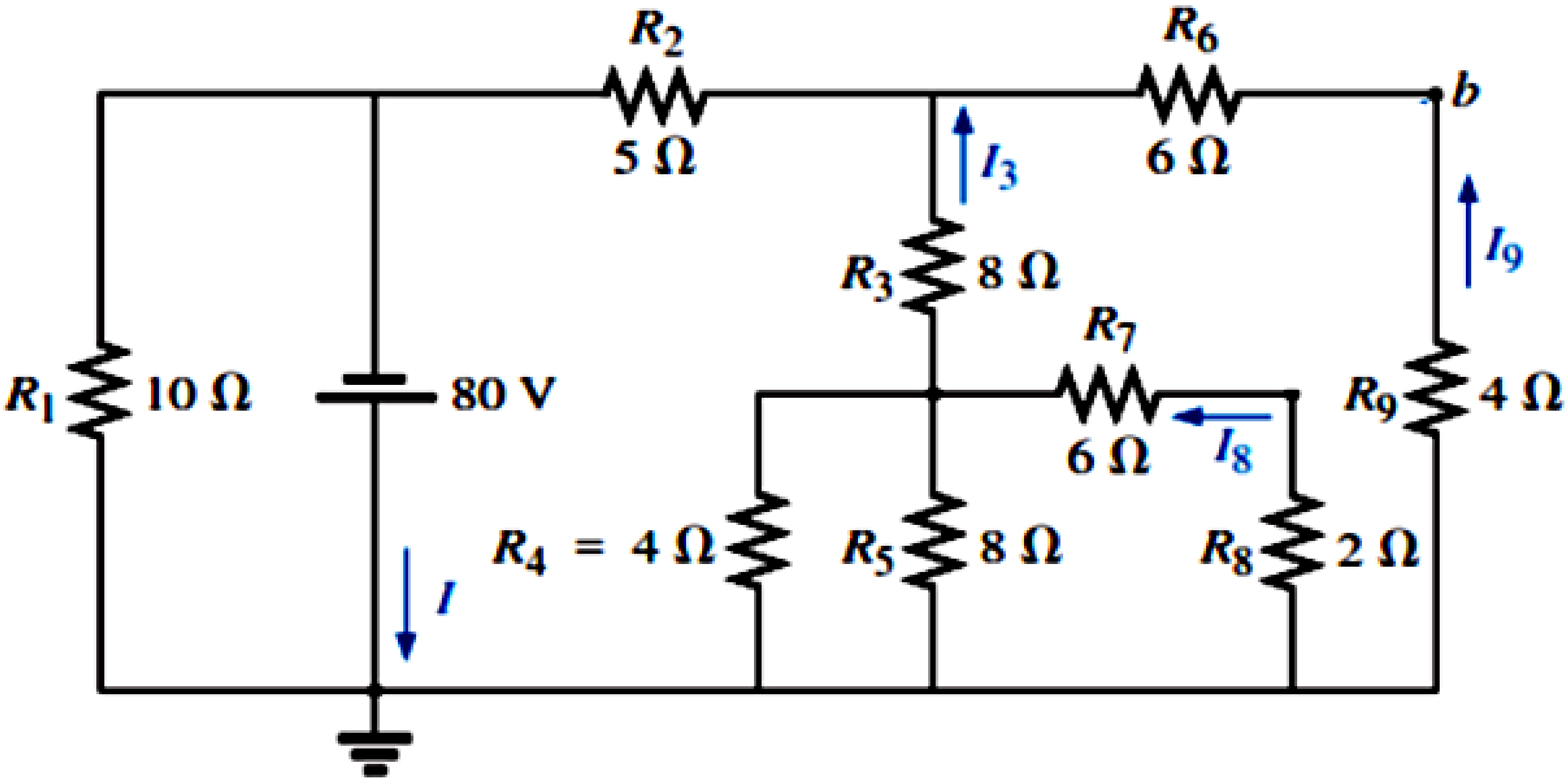
Ans: 3.43Ω

R_T = ?



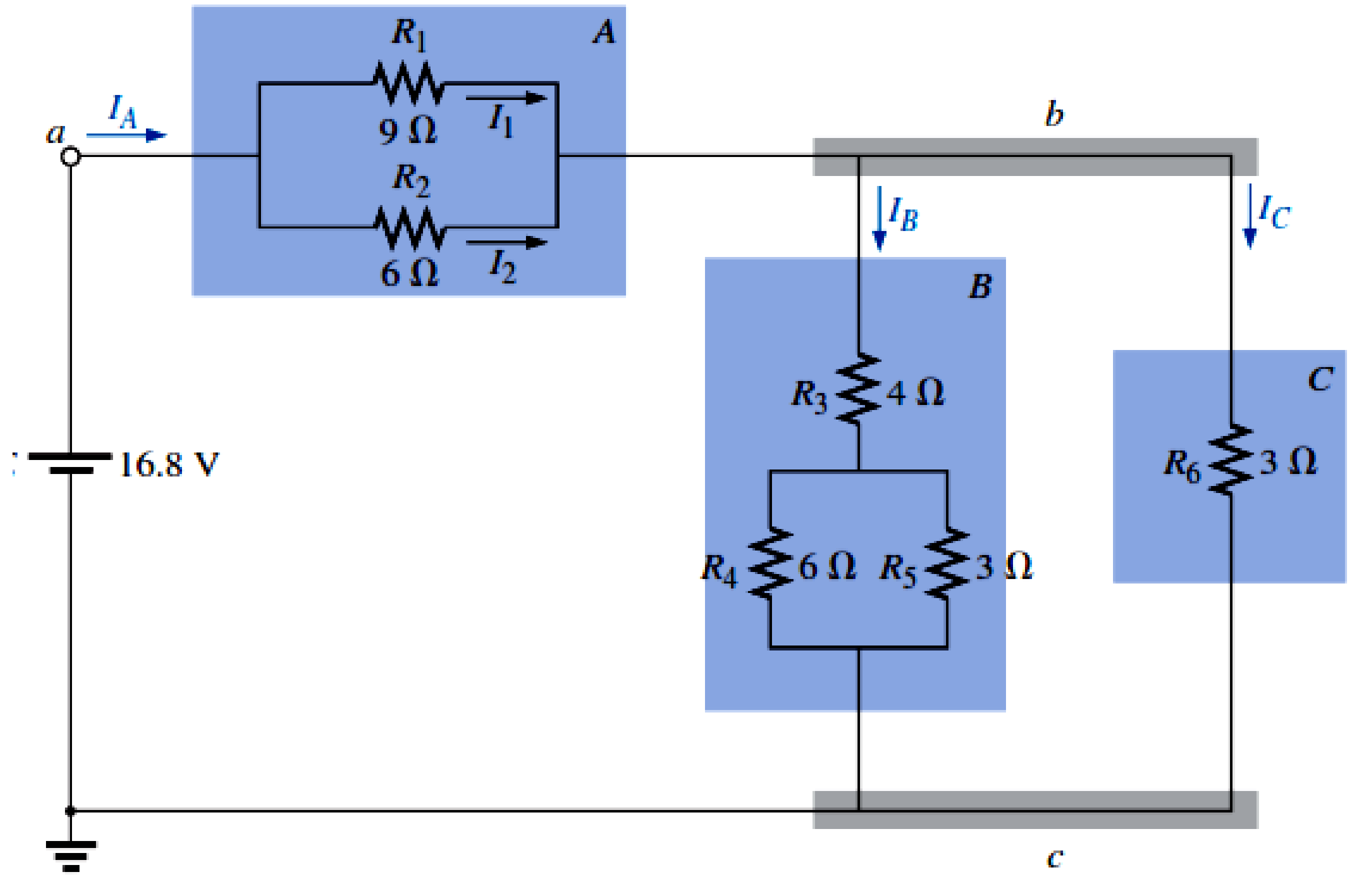
Ans: 5Ω

$R_T = ?$



Ans: 5Ω

R_T = ?



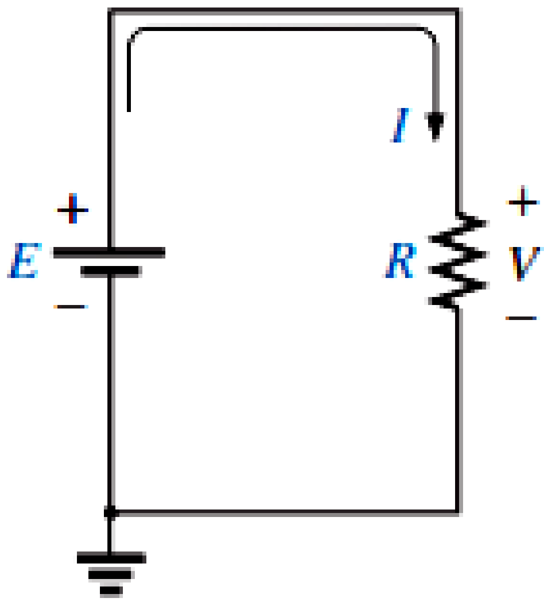
Ans: 5.6Ω

OHM'S LAW

German (Erlangen, Cologne)
(1789–1854)
Physicist and Mathematician
Professor of Physics, University of Cologne

In 1827, developed one of the most important laws of electric circuits: *Ohm's law*. When the law was first introduced, the supporting documentation was considered lacking and foolish, causing him to lose his teaching position and search for a living doing odd jobs and some tutoring. It took some 22 years for his work to be recognized as a major contribution to the field. He was then awarded a chair at the University of Munich and received the Copley Medal of the Royal Society in 1841. His research also extended into the areas of molecular physics, acoustics, and telegraphic communication.

Statement: It states that, when the conditions of the surrounding remains unchanged the current I flowing through a resistor is directly proportional to the voltage V across the resistor.



$$I \propto V$$

$I = GV$, here G=conductance

$I = \dfrac{V}{R}$, G = 1/R R is resistance

$$\boxed{I = \frac{E}{R}}$$

Here, V = E

Consider the following relationship:

$$\boxed{\text{Effect} = \frac{\text{cause}}{\text{opposition}}} \qquad \mathbf{(4.1)}$$

Every conversion of energy from one form to another can be related to this equation. In electric circuits, the *effect* we are trying to establish is the flow of charge, or *current*. The *potential difference*, or voltage, between two points is the *cause* ("pressure"), and the opposition is the *resistance* encountered.

Substituting the terms introduced above into Eq. (4.1) results in

$$\text{Current} = \frac{\text{potential difference}}{\text{resistance}}$$

and

$$\boxed{I = \frac{E}{R}} \qquad \text{(amperes, A)} \qquad \mathbf{(4.2)}$$

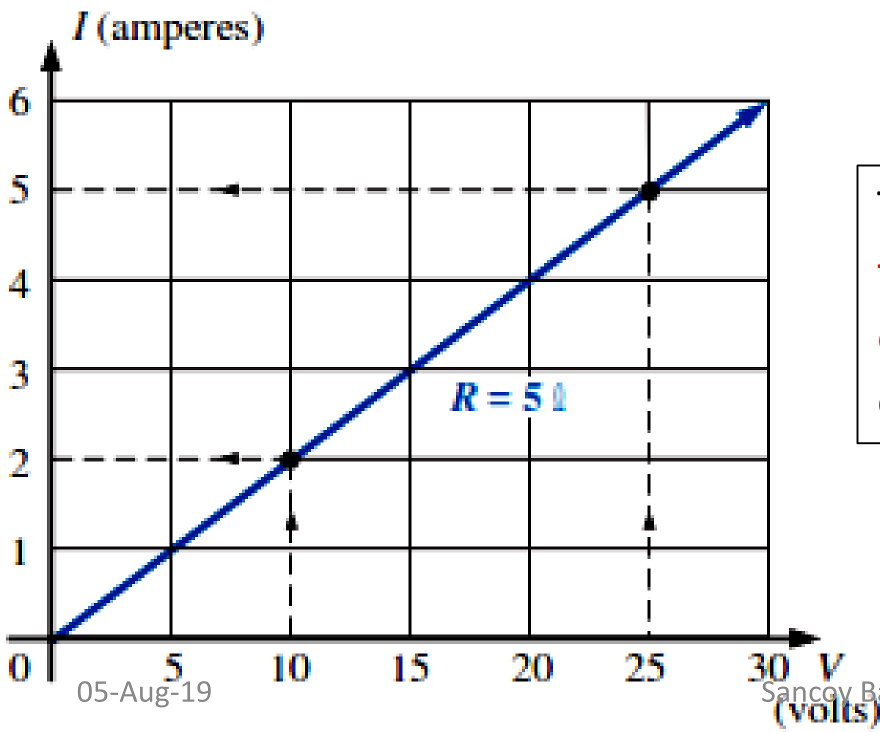
Equation (4.2) is known as Ohm's law in honor of Georg Simon Ohm

Plotting Ohm's Law

Consider current (I) in Y-axis and voltage (V) in X-axis. If the resistance (R) is 5Ω, using ohm's law we get the current which is given below-

V (volt)	0	5	10	15	20
I (amp)	0	1	2	3	4

After plotting the above value in the graph we obtain the following straight line



The **linear** (straight-line) graph reveals that the **resistance** is not changing with current or voltage level; rather, it is a **fixed** quantity throughout.

We can calculate the resistance at any point of the graph using the formula given below-

$$\boxed{R_{dc} = \frac{V}{I}}$$

For example, at V= 20V and I = 4A, $R_{dc} = V/I = 20\text{ V}/4\text{ A} = 5\ \Omega$.

If we write Ohm's law in the following manner and relate it to the basic straight-line equation

$$\begin{array}{ccccccc} I & = & \frac{1}{R} & \cdot & E & + & 0 \\ \downarrow & & \downarrow & & \downarrow & & \downarrow \\ y & = & m & \cdot & x & + & b \end{array}$$

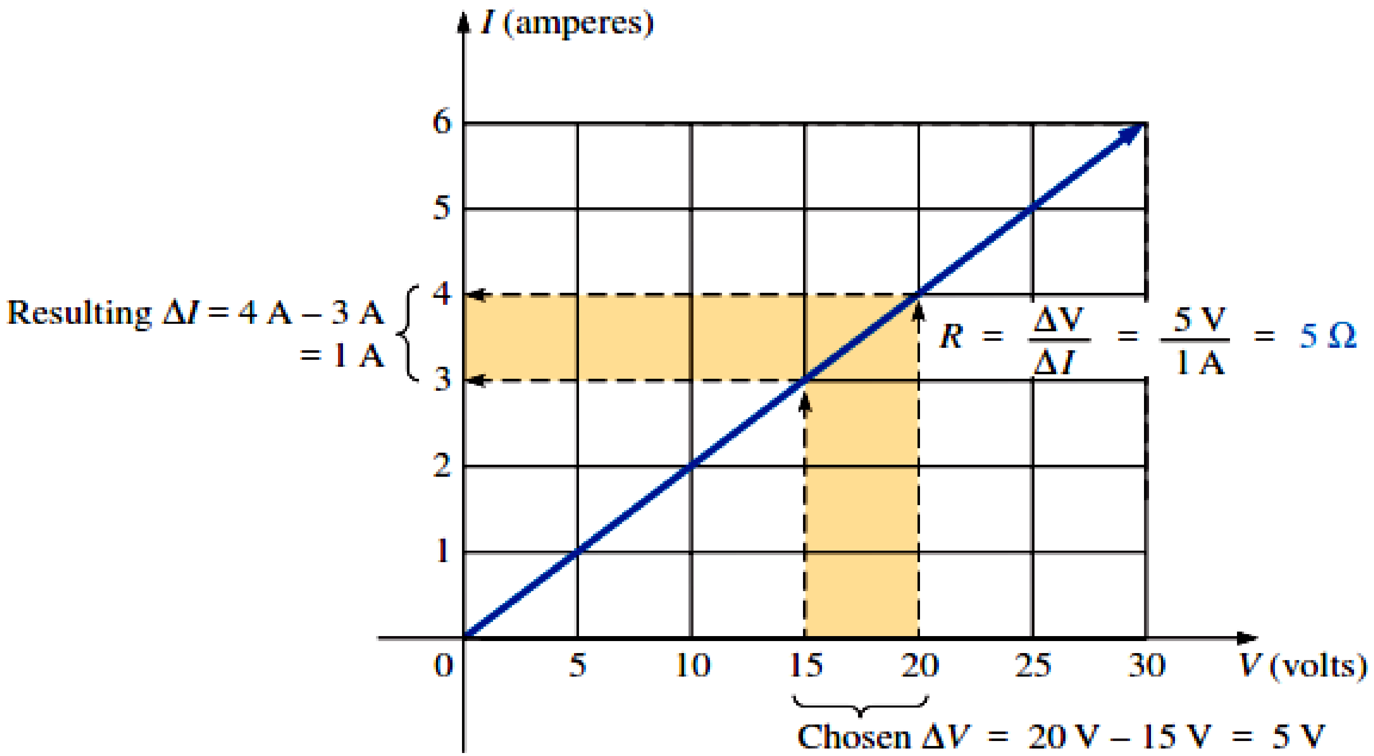
we find that the slope is equal to 1 divided by the resistance value, as indicated by the following:

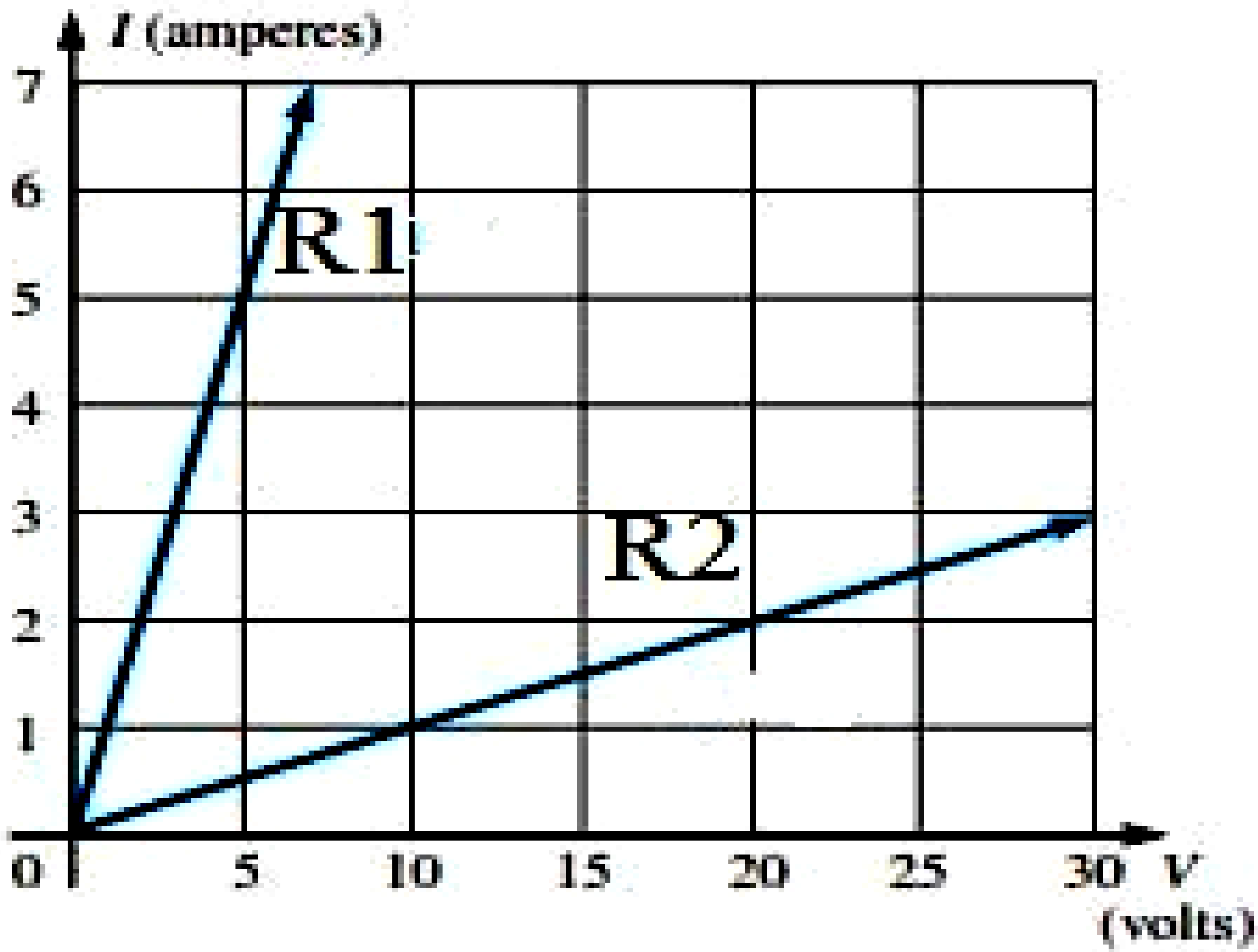
$$\boxed{m = \text{slope} = \frac{\Delta y}{\Delta x} = \frac{\Delta I}{\Delta V} = \frac{1}{R}} \qquad \textbf{(4.6)}$$

where Δ signifies a small, finite change in the variable.

Equation (4.6) clearly reveals that the greater the resistance, the less the slope. If written in the following form, Equation (4.6) can be used to determine the resistance from the linear curve:

$$\boxed{R = \frac{\Delta V}{\Delta I}} \qquad \text{(ohms)}$$





1) R1 > R2

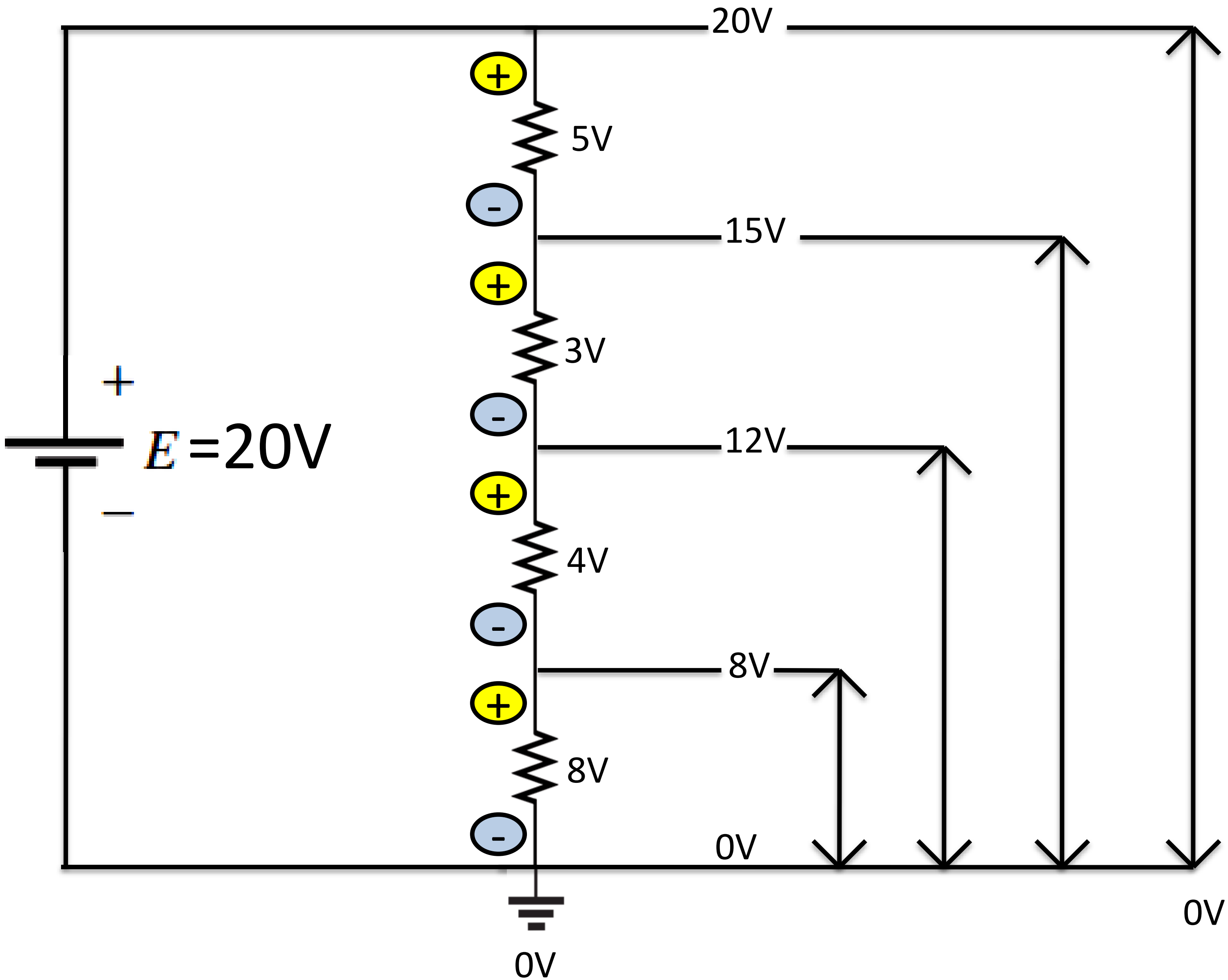
2) R1 < R2

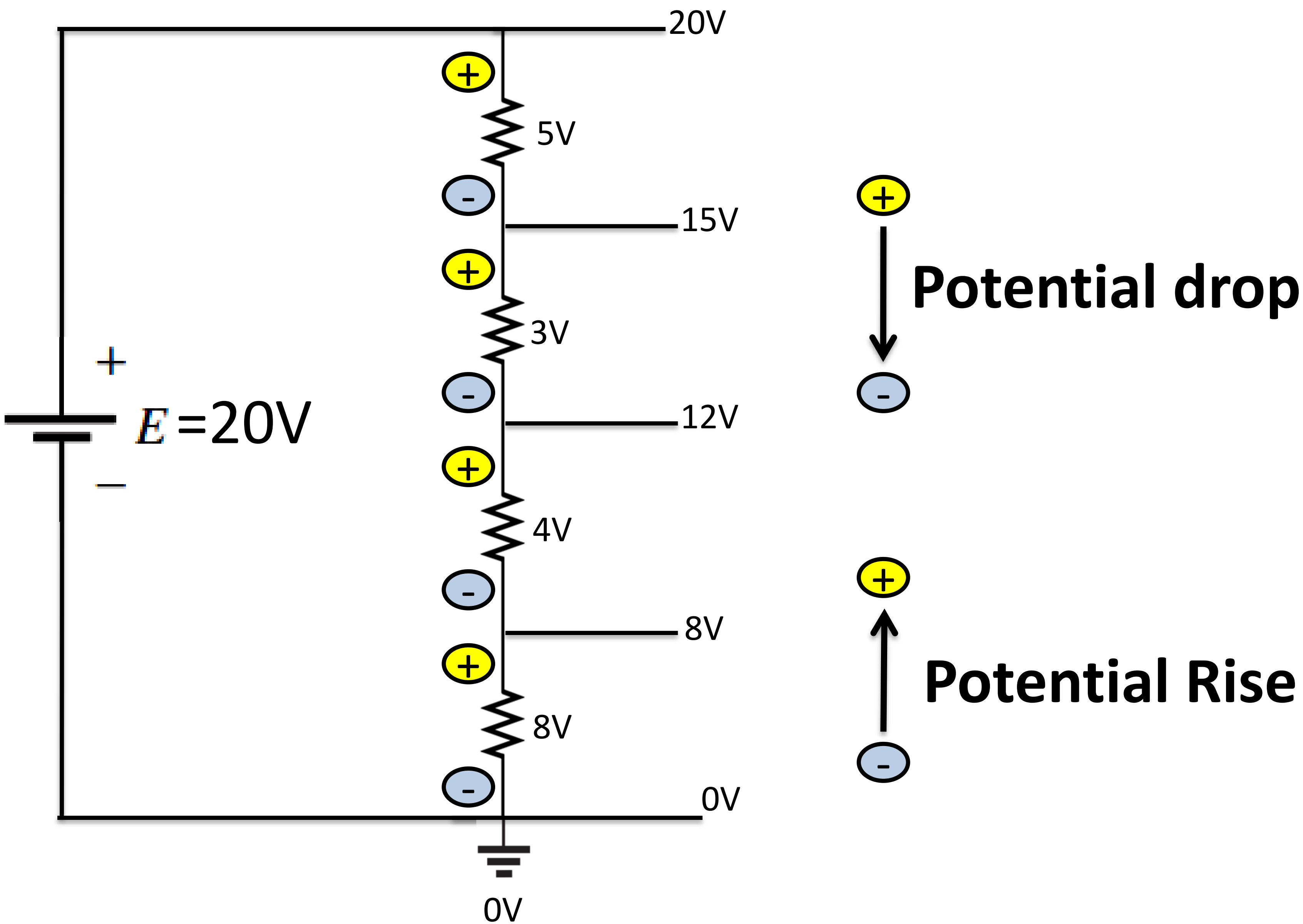
3) None

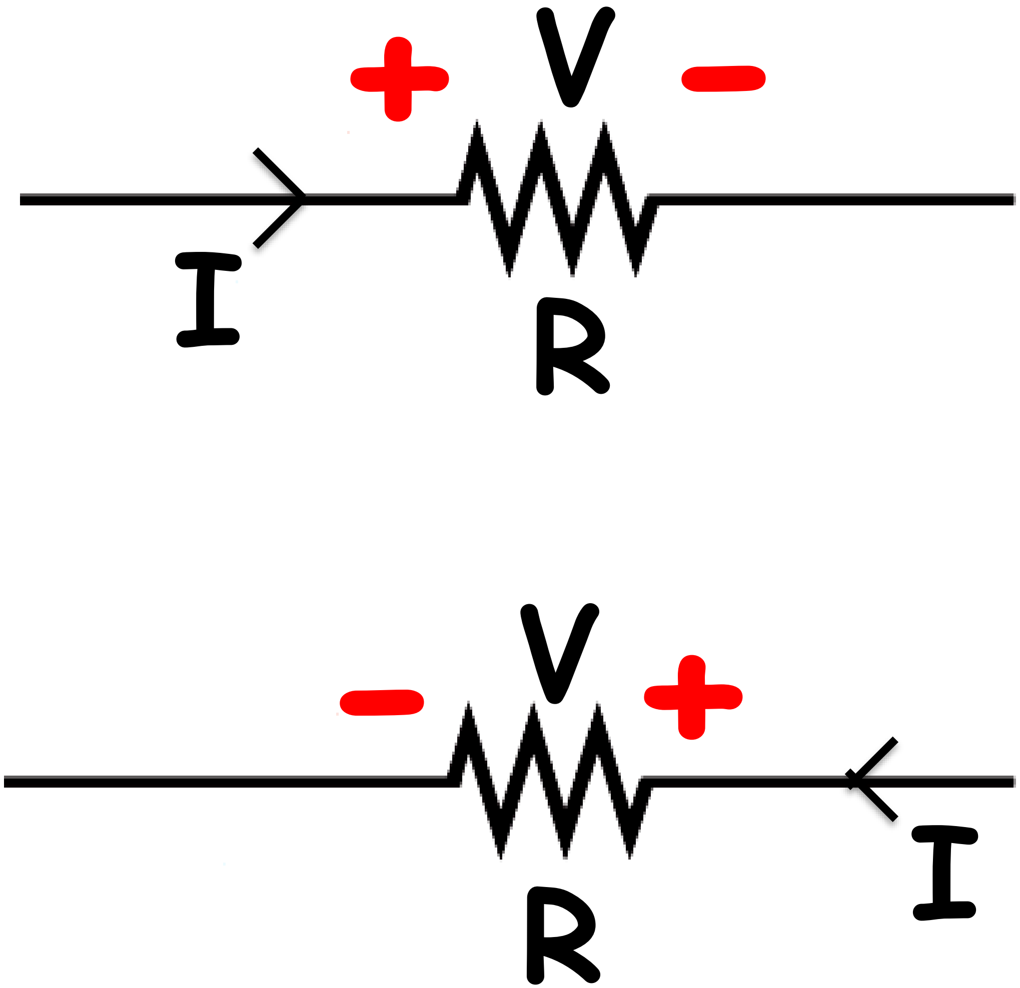
Q. If an electric heater draws 9.5 A when connected to a 120-V supply, what is the internal resistance of the heater?

Example
4.5
Exercise
13, 16

Voltage
Rise and Drop


20V
5V
15V
3V
+
E =20V
−
12V
4V
8V
8V
0V
0V
0V


20V
5V
15V
3V
12V
+
E =20V
–
4V
8V
8V
0V
0V
+
-
Potential drop
+
-
Potential Rise

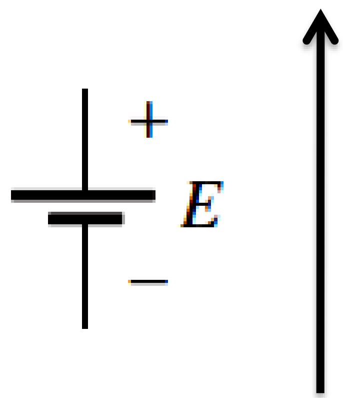


Current flow

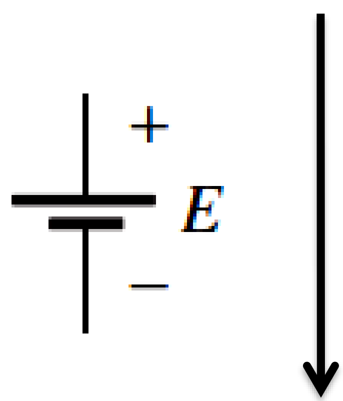
High potential +

to

Low potential -

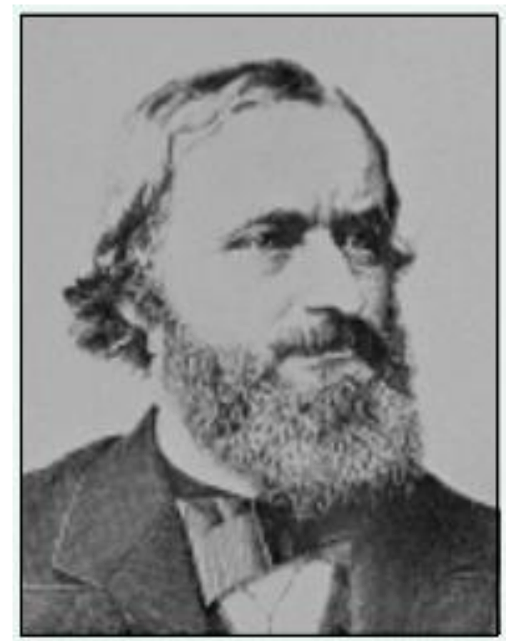


Potential Rise



Potential Drop

Kirchhoff's Voltage Law (KVL)

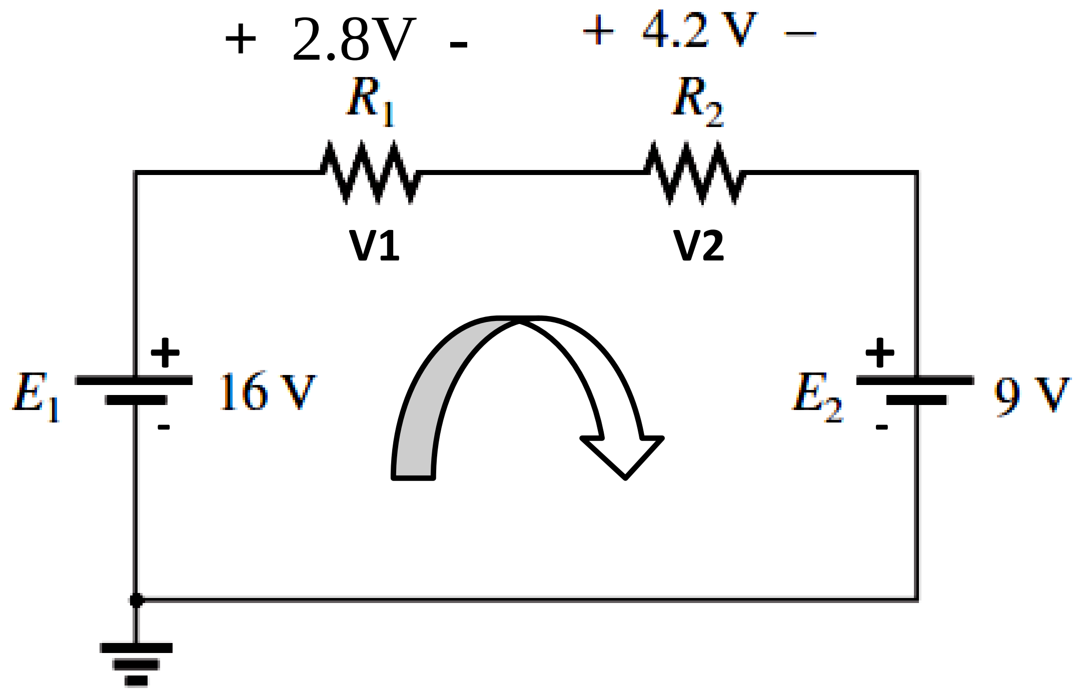


Gustav Robert Kirchhoff (1824–1887)

Statement: It states that, the algebraic sum of the potential rises and drops around a closed loop (or path) is zero.

What is the difference between Algebraic Sum & Sum?

- Sum consists of only numbers for addition.
- Simple Sum means addition of the magnitude of the given quantities.
- Algebraic Sum consists of both addition (+) & subtraction (-).
- Algebraic Sum is the sum of quantities taking both magnitude and signs.



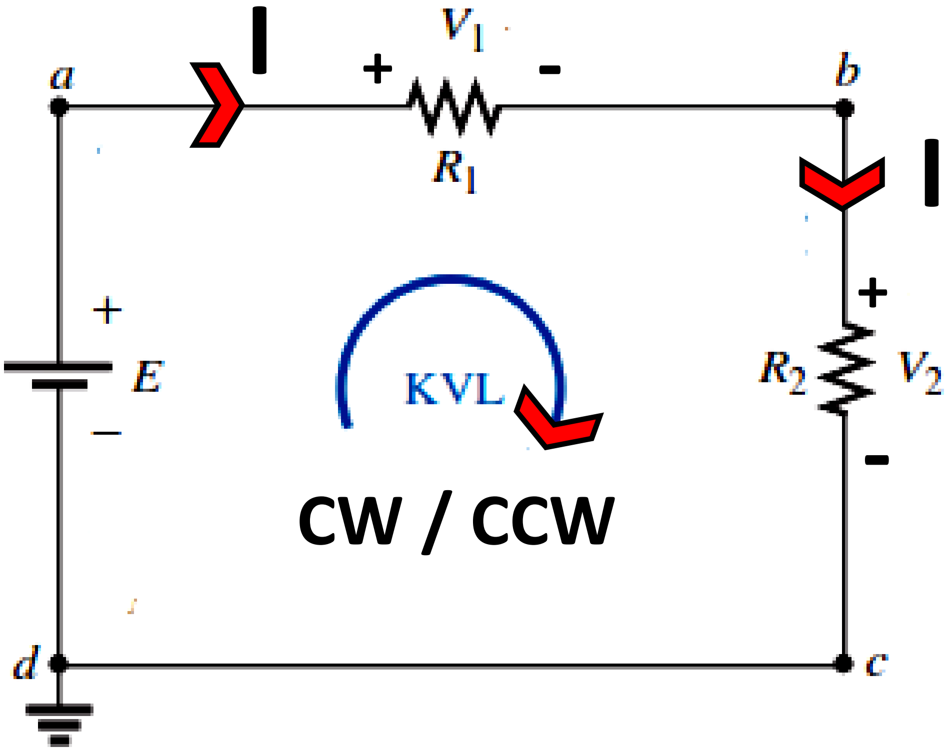
Applying KVL (clock wise),

$$+E1 - V1 - V2 - E2 = 0$$

$$+ E1 - E2 = V1 + V2$$

$$+ 16V - 9V = 2.8V + 4.2V$$

$$7V = 7V$$



$$\boxed{\Sigma_{\circlearrowright} V = 0}$$

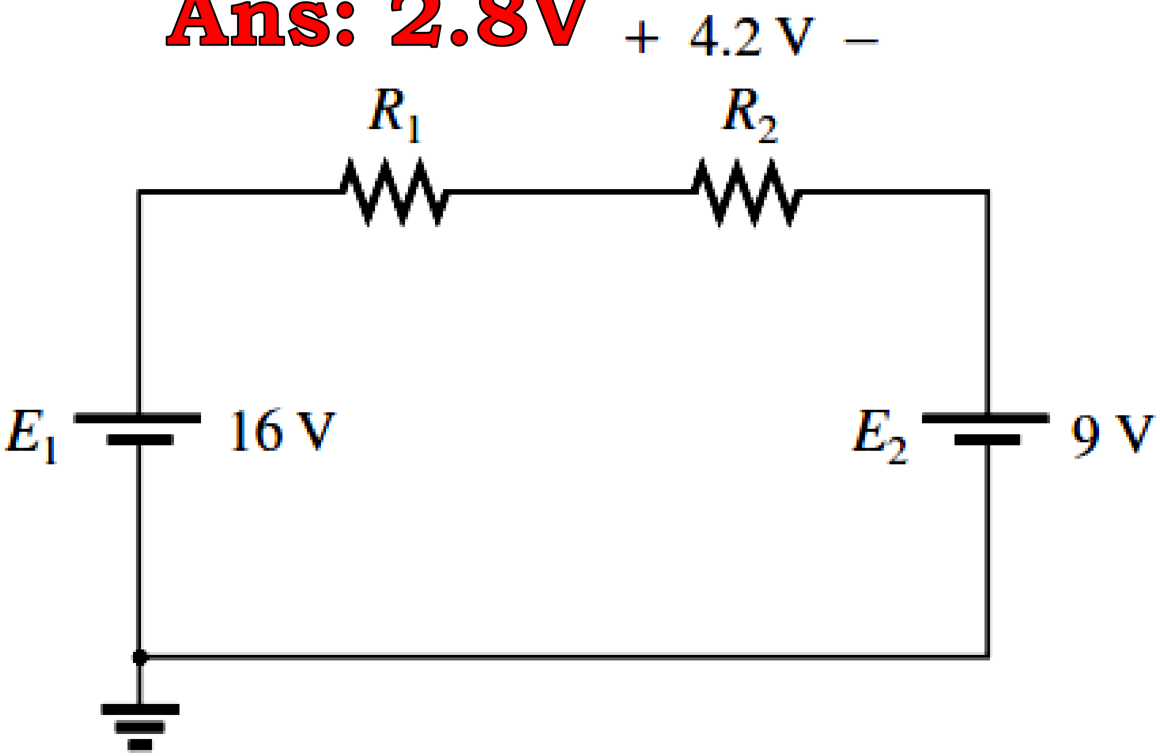
$$+E - V1 - V2 = 0$$

$$E = V1 + V2$$

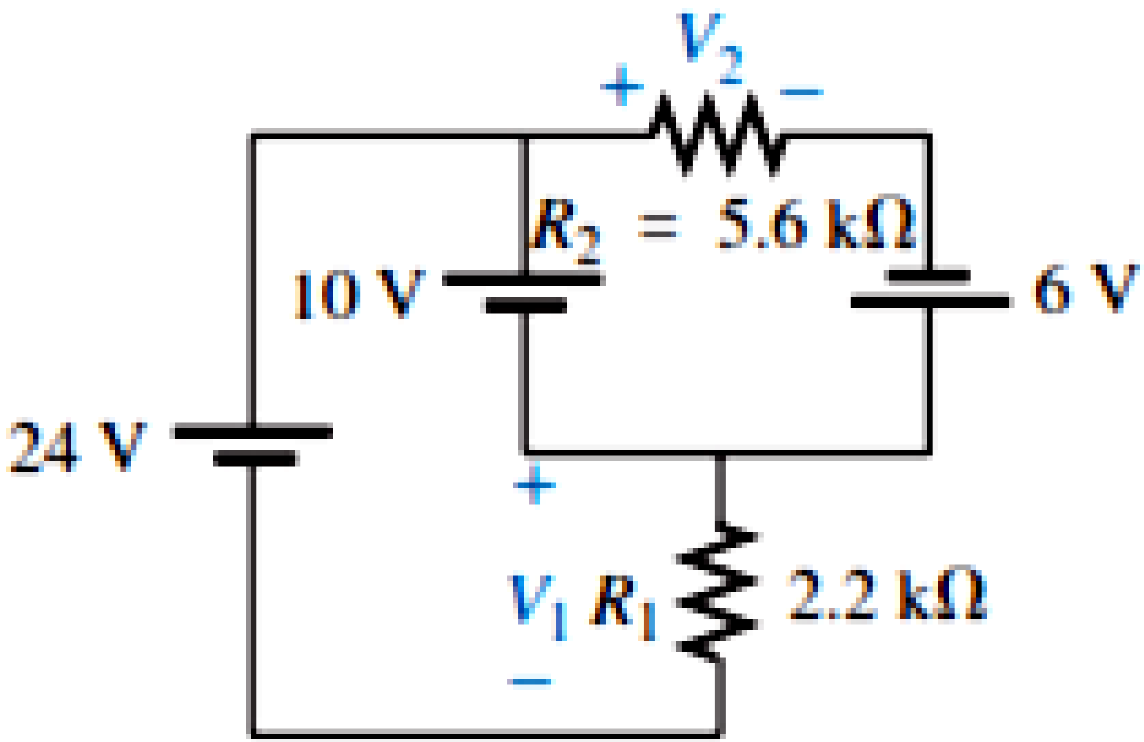
$$\boxed{\Sigma_{\circlearrowright} V_{\text{rises}} = \Sigma_{\circlearrowright} V_{\text{drops}}}$$

Using KVL find V1

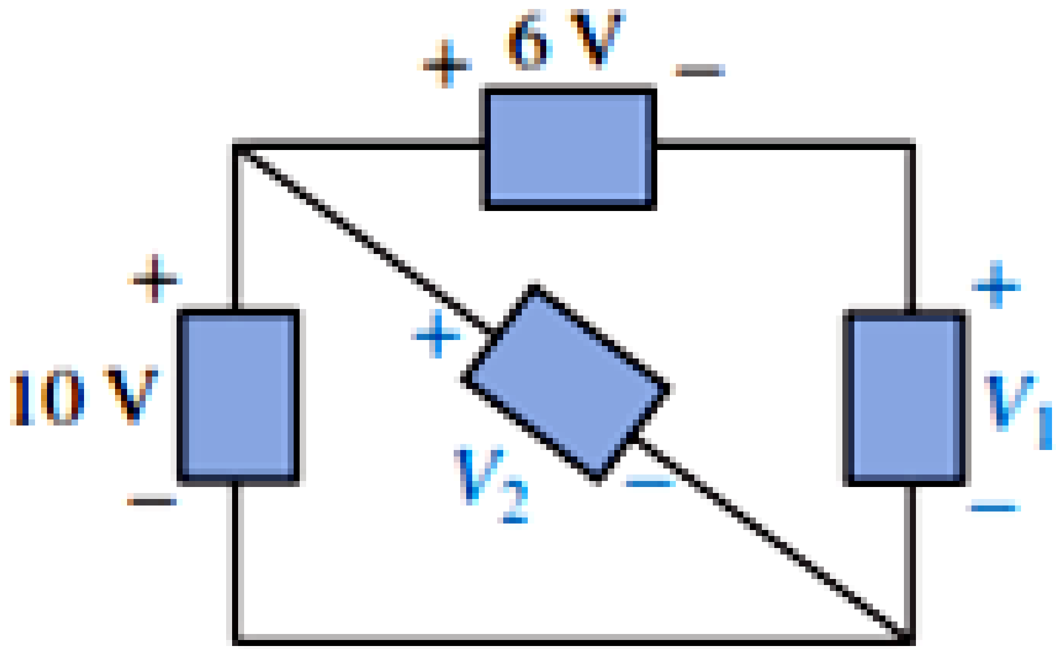
Ans: 2.8V



Using KVL find V1 and V2



Using KVL find V1 and V2

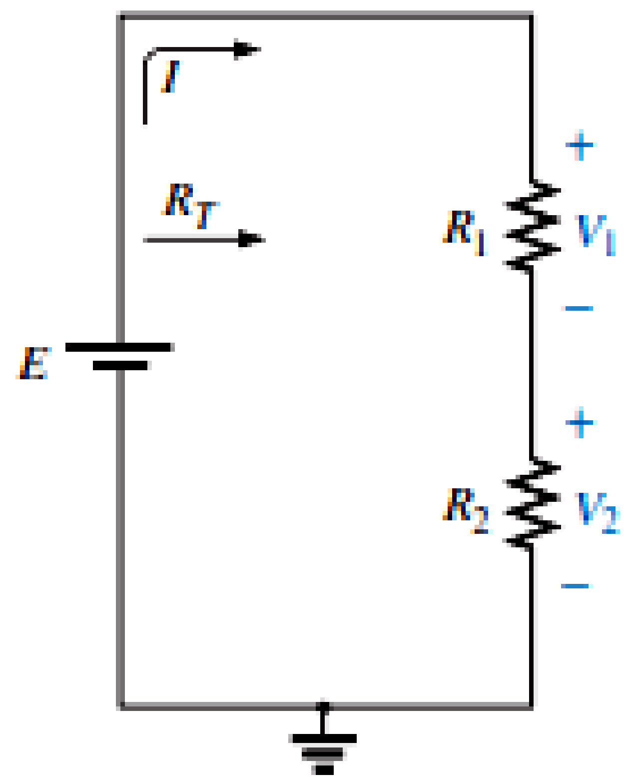


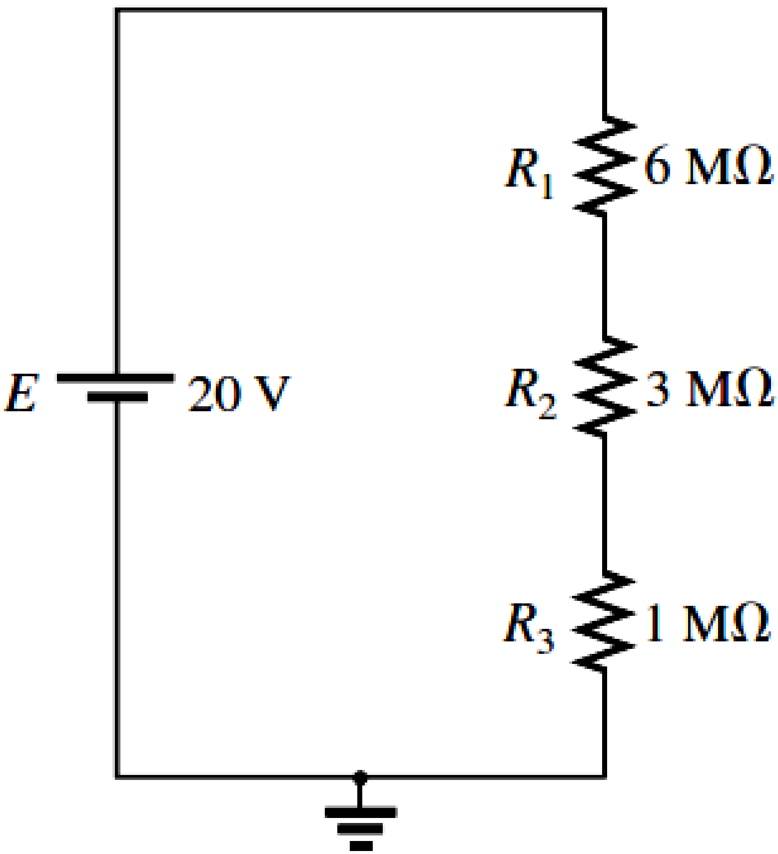
- Voltage remains same in parallel elements, divides among series elements.
- Current remains same in series elements, divides among parallel elements.

Voltage Divider Rule (VDR)

According to VDR the voltage across the resistive elements will divide as the magnitude of the resistance levels.

$$V_x = \frac{R_x E}{R_T}$$





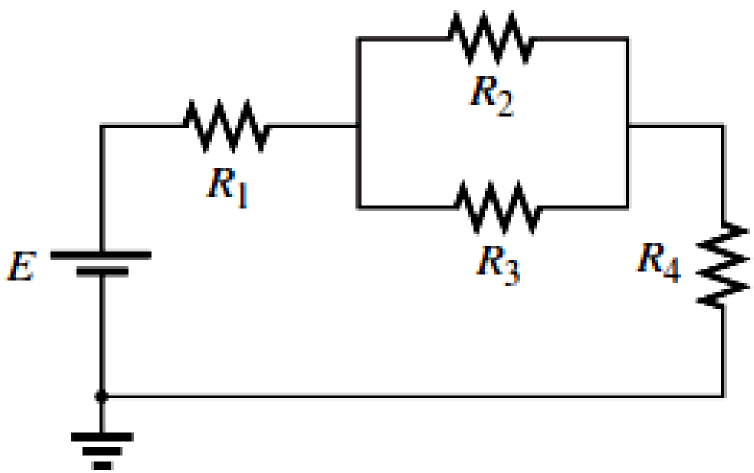
$$\boxed{V_x = \frac{R_x E}{R_T}}$$

$$V1 = \frac{R1}{R1 + R2 + R3} \times E$$

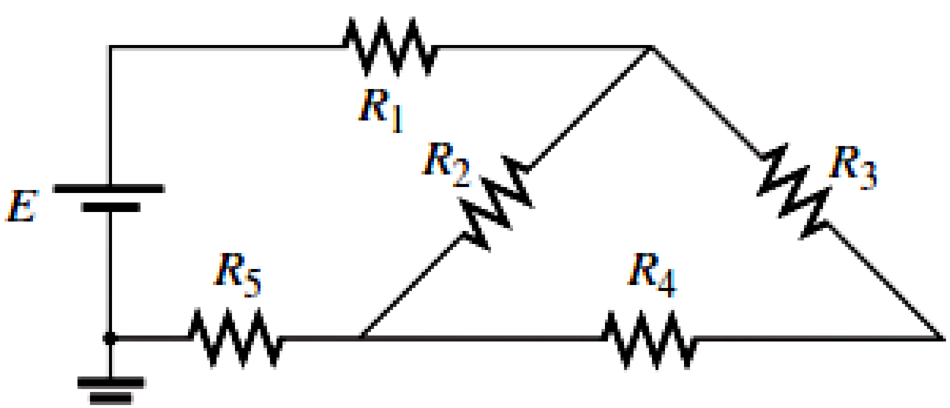
$$V1 = \frac{6}{6 + 3 + 1} \times 20 = 12V$$

$$V2 = \frac{R2}{R1 + R2 + R3} \times E$$

$$V3 = \frac{R3}{R1 + R2 + R3} \times E$$



Find voltage across the resistance R_4

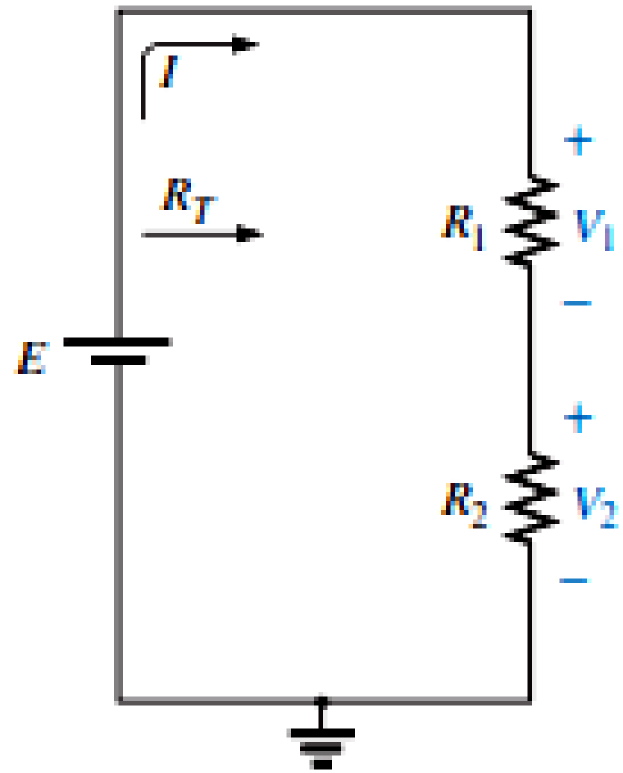


Find voltage V_{R4}

Proof

$$R_T = R_1 + R_2$$

and $$I = \frac{E}{R_T}$$



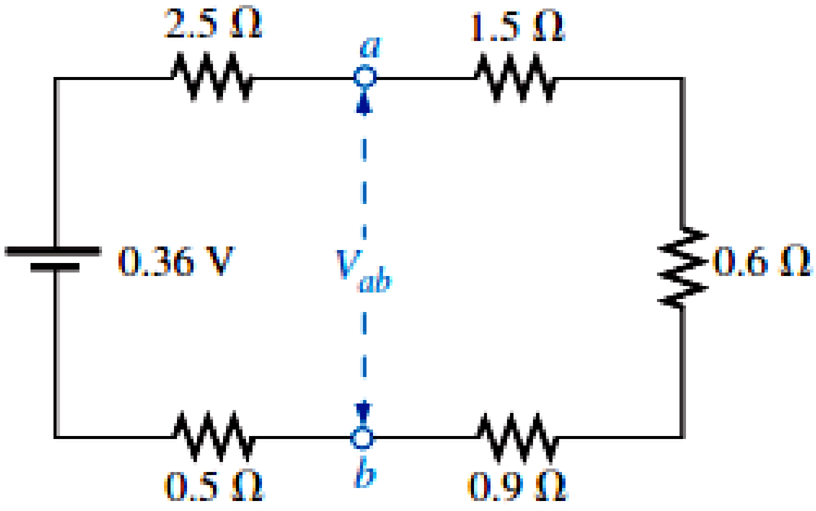
Applying Ohm's law:

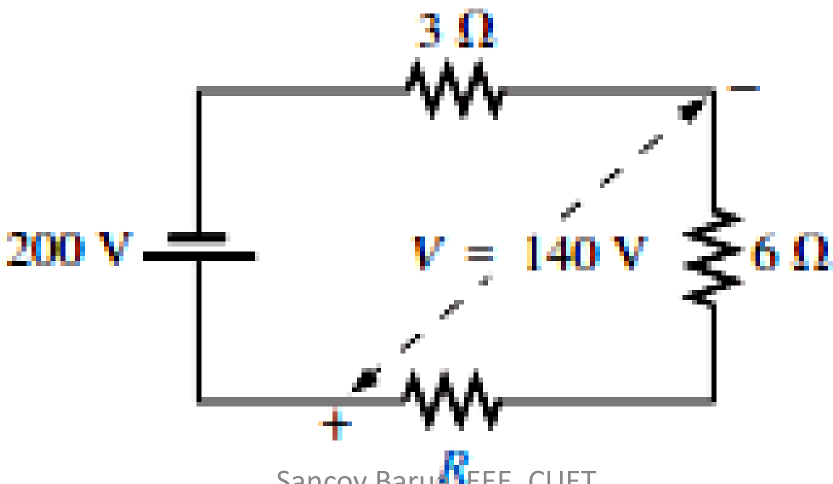
$$V_1 = IR_1 = \left(\frac{E}{R_T}\right)R_1 = \frac{R_1E}{R_T}$$

with $$V_2 = IR_2 = \left(\frac{E}{R_T}\right)R_2 = \frac{R_2E}{R_T}$$

Note that the format for V_1 and V_2 is

$$\boxed{V_x = \frac{R_xE}{R_T}}$$ (voltage divider rule)


2.5 Ω
a
1.5 Ω
0.36 V
V_{ab}
0.6 Ω
0.5 Ω
b
0.9 Ω

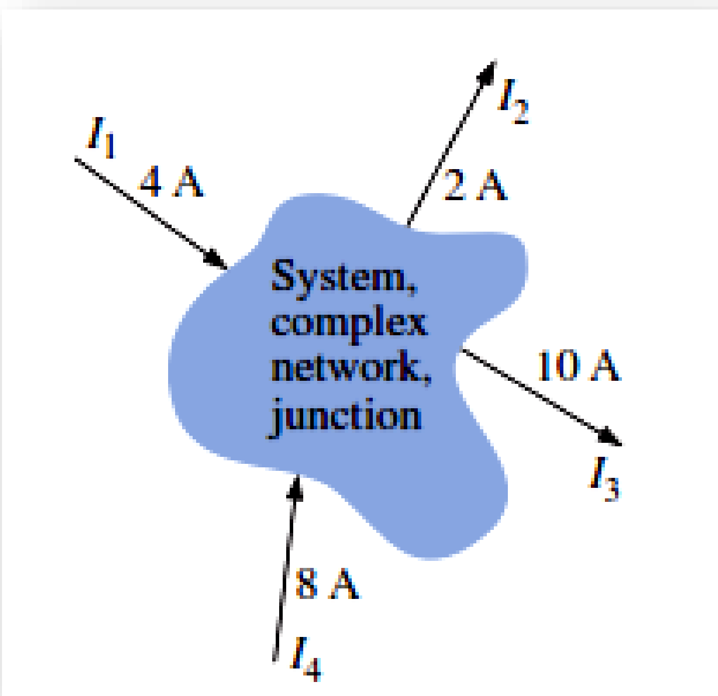

3 Ω
−
200 V
V = 140 V
6 Ω
+
R

Example
5.10, 5.12, 5.13, 5.15,
5.16, 5.18, 5.20, 5.26
Exercise
20-34

Kirchhoff's Current Law (KCL)

KIRCHHOFF'S CURRENT LAW (KCL)

Kirchhoff's current law (KCL) states that, the algebraic sum of the currents entering and leaving an area, system, or junction is zero.



$$\boxed{\Sigma I_{\text{entering}} = \Sigma I_{\text{leaving}}}$$

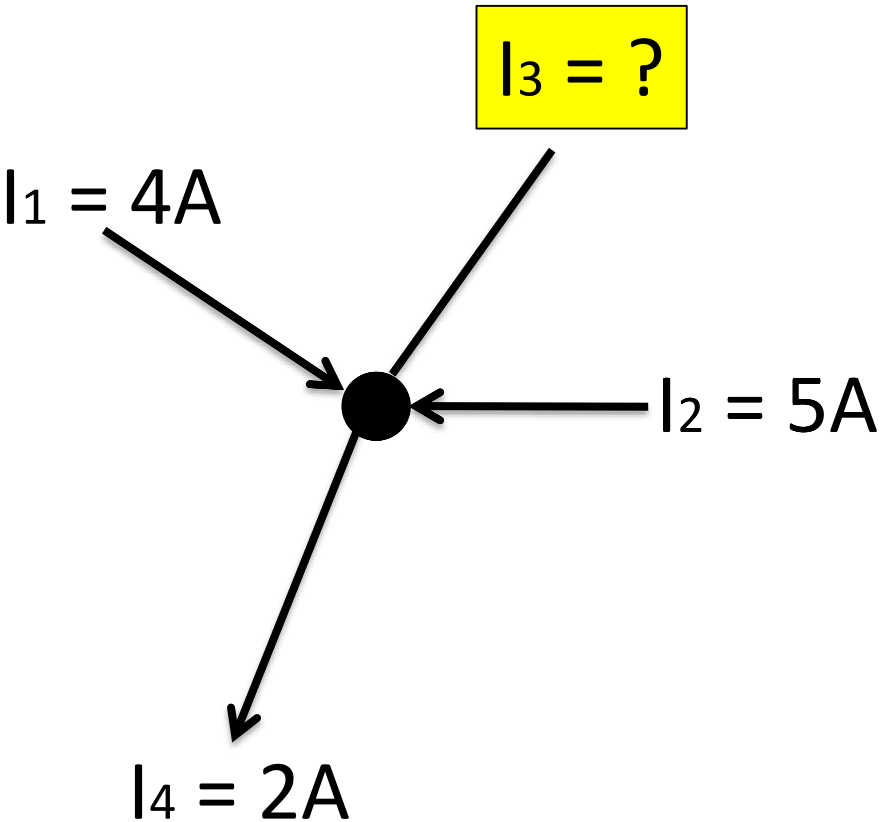
$$I_1 + I_4 = I_2 + I_3$$
$$4\text{ A} + 8\text{ A} = 2\text{ A} + 10\text{ A}$$
$$12\text{ A} = 12\text{ A}$$

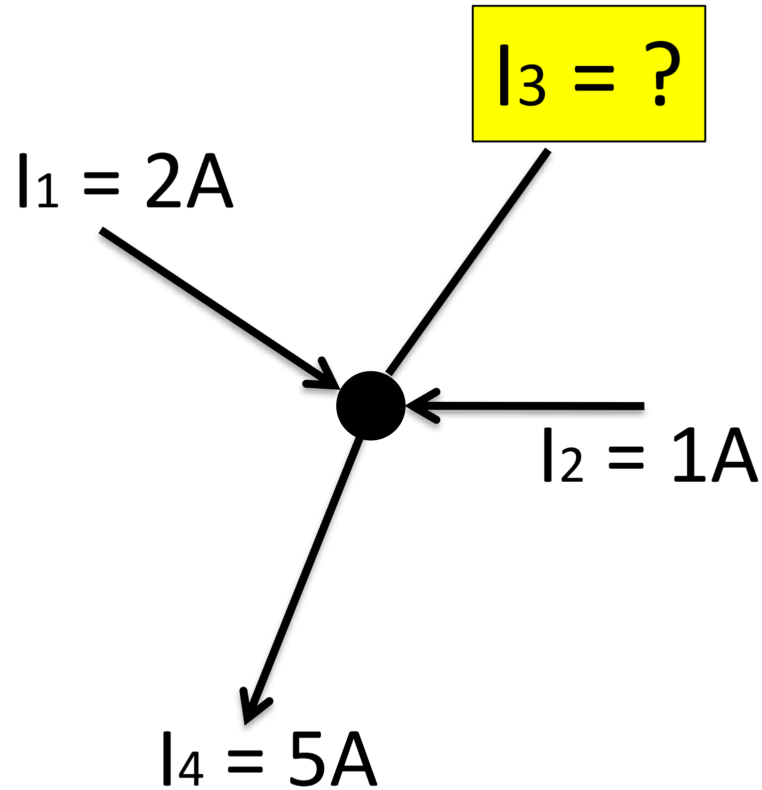
Consider the unknown is leaving

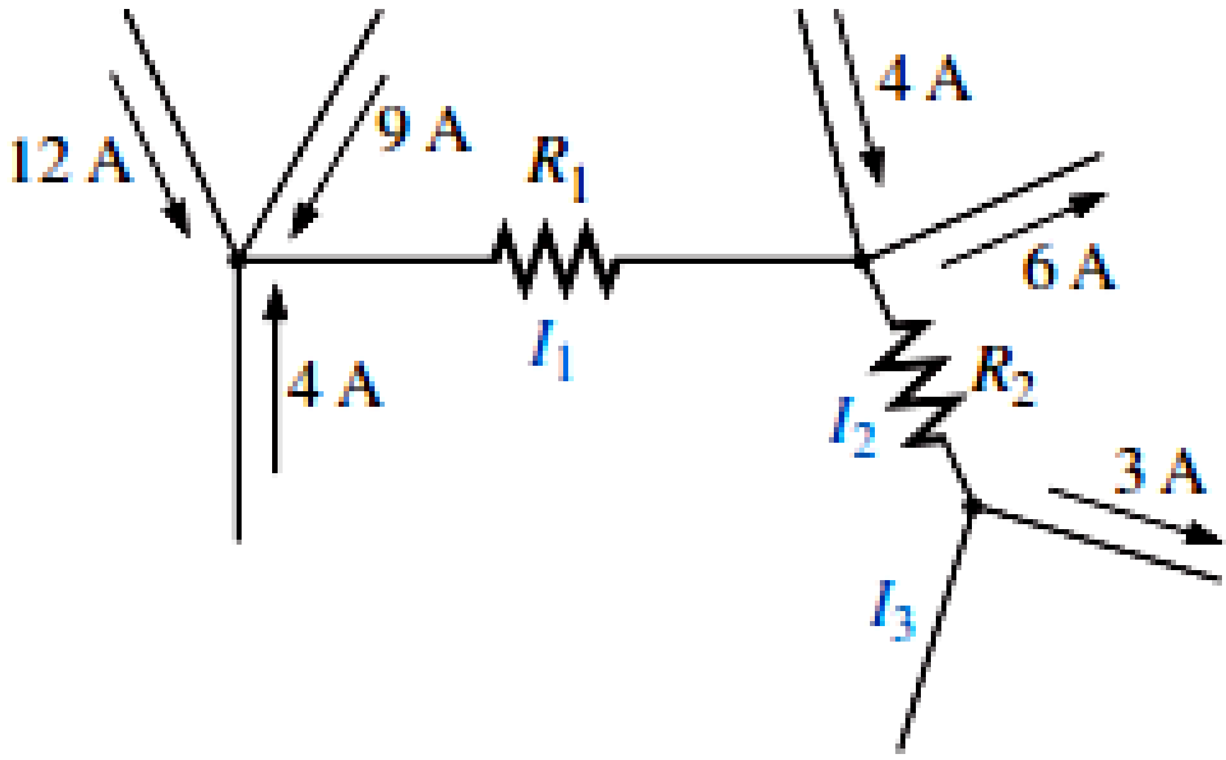
Then apply KCL

If the sign of unknown current is (+) then the current is leaving

If the sign of unknown current is (-) then the current is entering






12 A
9 A
R_1
4 A
I_1
4 A
6 A
R_2
I_2
3 A
I_3

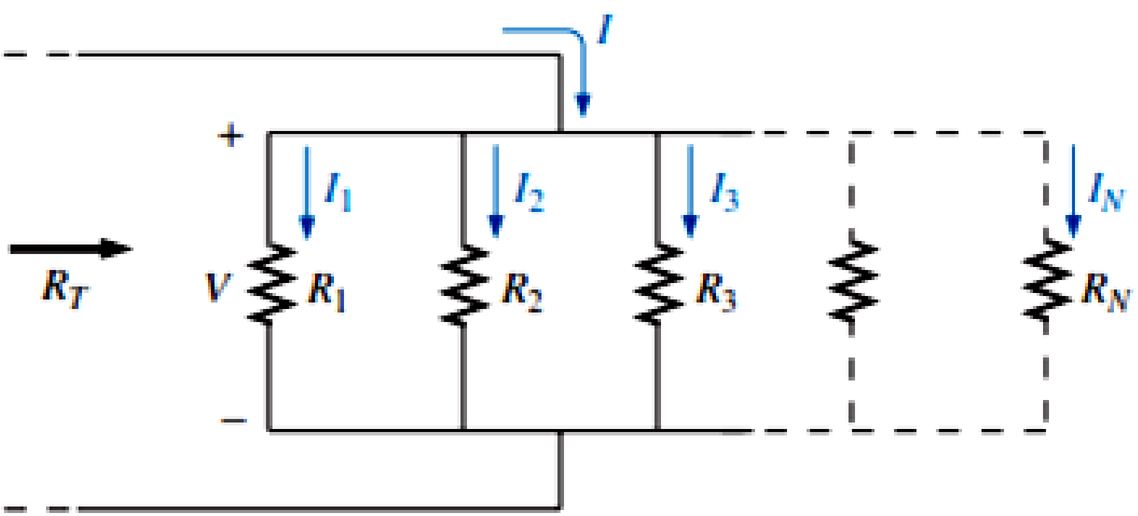
Current Divider Rule (CDR)

CURRENT DIVIDER RULE (CDR)

For two parallel elements of equal value, the current will divide equally.

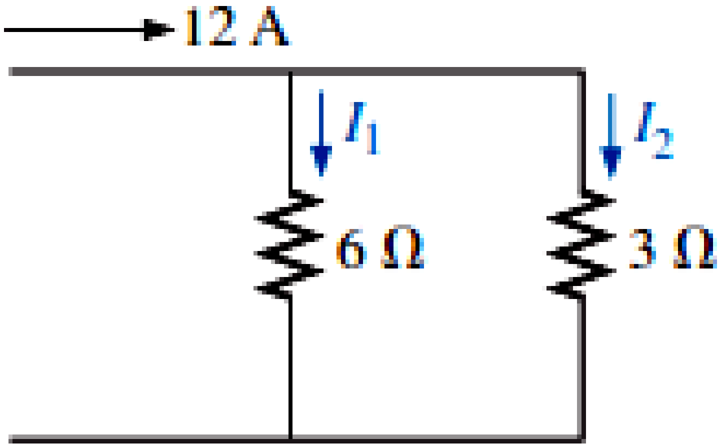
For parallel elements with different values, the **smaller** the resistance, the greater the share of input current.

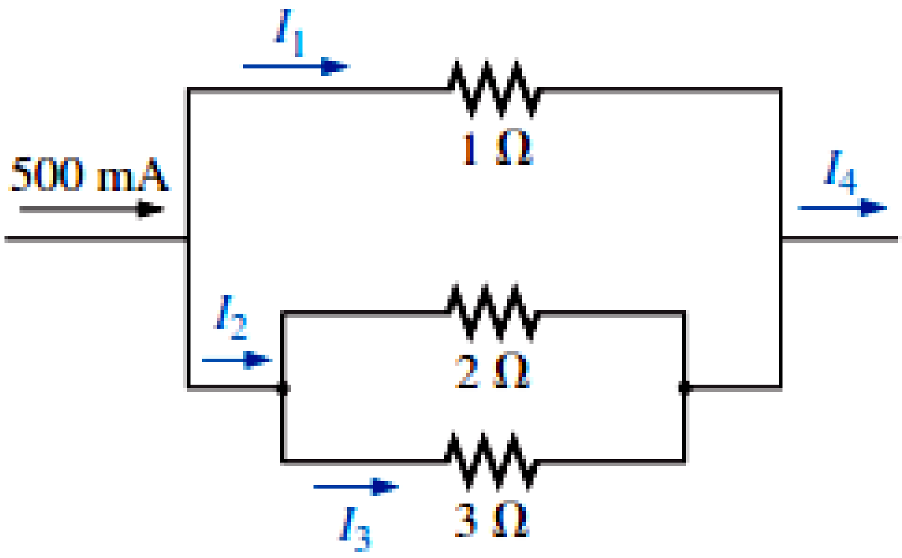
For parallel elements of different values, the current will split with a ratio equal to the inverse of their resistor values.



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

$$\boxed{I_x = \frac{R_T}{R_x} I}$$

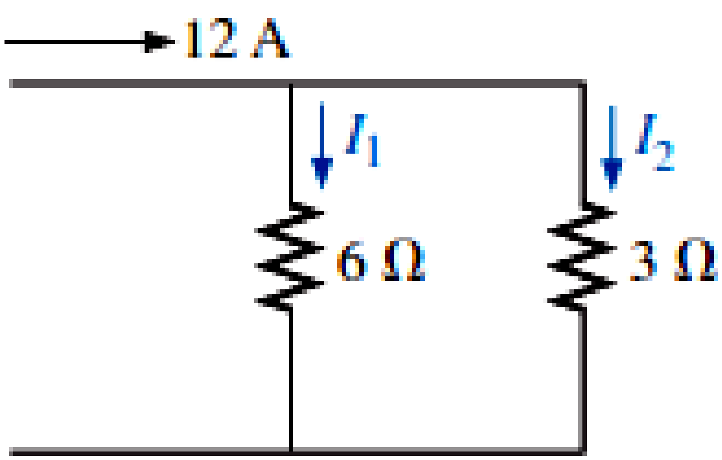

12 A
I_1
I_2
6 Ω
3 Ω

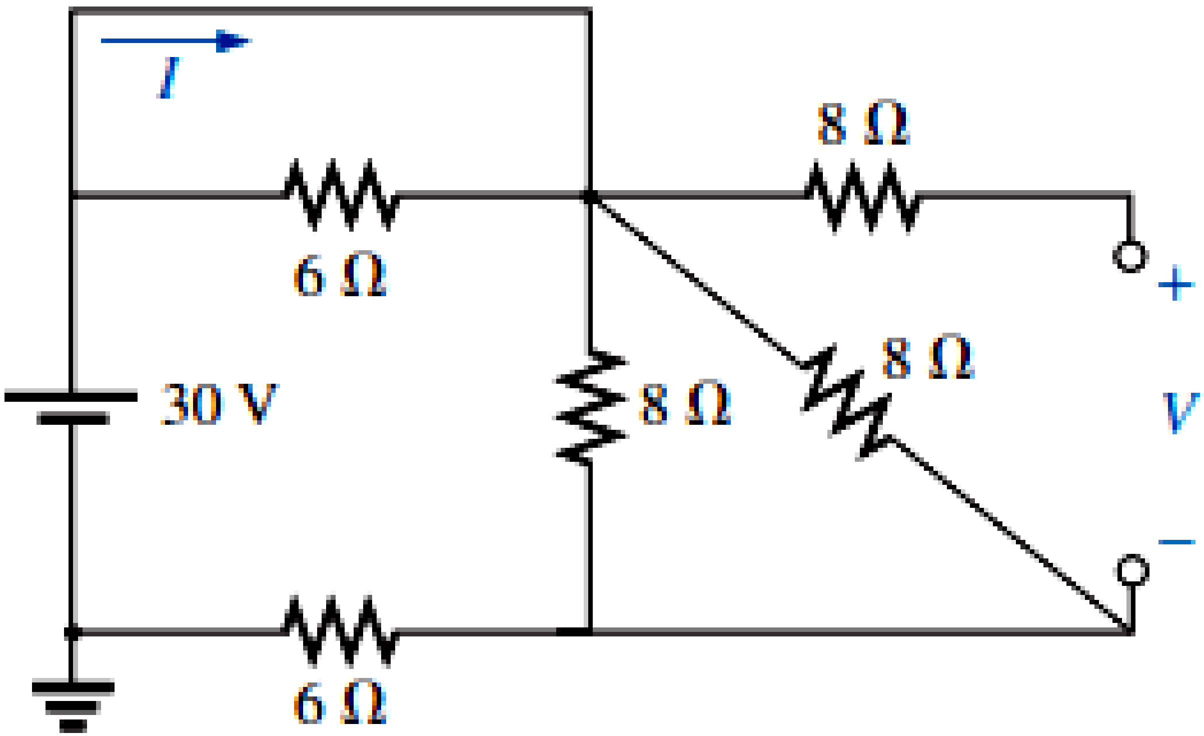

I_1
1 Ω
500 mA
I_4
I_2
2 Ω
3 Ω
I_3

CDR for 2 elements connected in parallel

$$I1 = \frac{R2}{R1 + R2} \times I$$

$$I2 = \frac{R1}{R1 + R2} \times I$$




I
8 Ω
6 Ω
+
8 Ω
30 V
8 Ω
V
−
6 Ω

Thank

You

Q/A