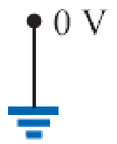
## <u>Voltage Sources and Ground</u>

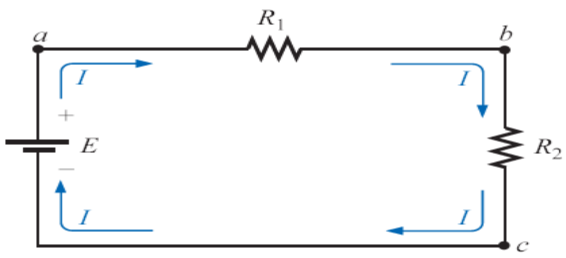
The symbol for the ground connection appears in Fig.( 1 ) with its defined




Fig(1)

Ground potential

if we take the circuit of fig (2)




Fig(2)

If Fig.( 2 )is redrawn with a grounded supply, it might appear as shown in Fig. 3(a), (b), or (c). In any case, it is understood that the negative terminal of the battery and the bottom of the resistor $R_2$ are at ground potential.

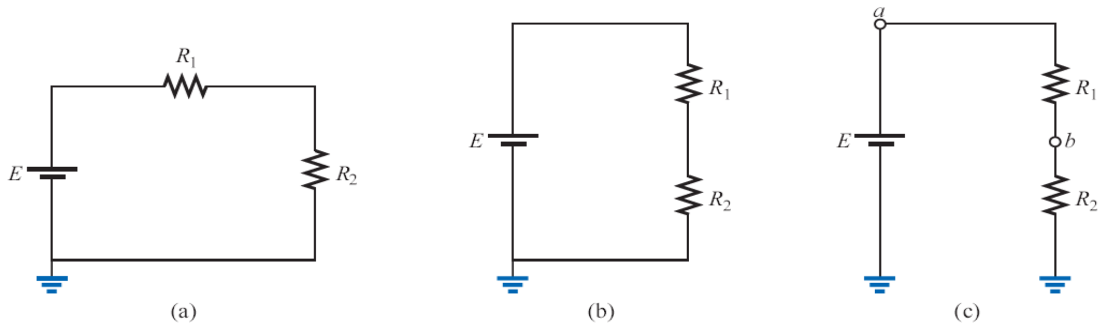



Fig (3)(a,b,c)

Three ways to sketch the same series dc circuit.

**<u>Example 1</u>** Design a circuit by using the voltage divider rule of fig (4) such that ($V_{R1} = 4V_{R2}$ ).

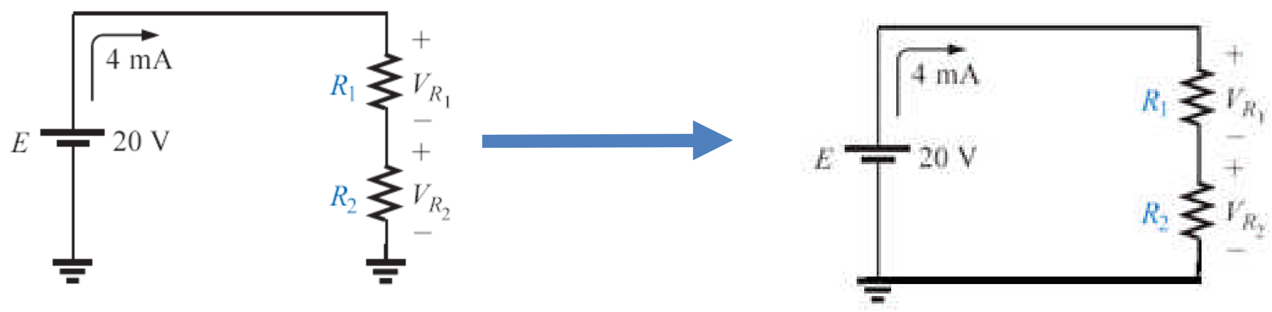



Fig.(4)

**Solution:** The total resistance is defined by :

$$R_T = \frac{E}{I} = \frac{20\text{ V}}{4\text{ mA}} = 5\text{ k}\Omega$$

Since $V_{R_1} = 4V_{R_2}$,

$$R_1 = 4R_2$$

Thus $$R_T = R_1 + R_2 = 4R_2 + R_2 = 5R_2$$

and $$5R_2 = 5\text{ k}\Omega$$
$$R_2 = \mathbf{1\text{ k}\Omega}$$

and $$R_1 = 4R_2 = \mathbf{4\text{ k}\Omega}$$

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Voltage sources may be indicated as shown in Figs. 5(a) and 6(a) rather than as illustrated in Fig. 5(b) and 6(b)..

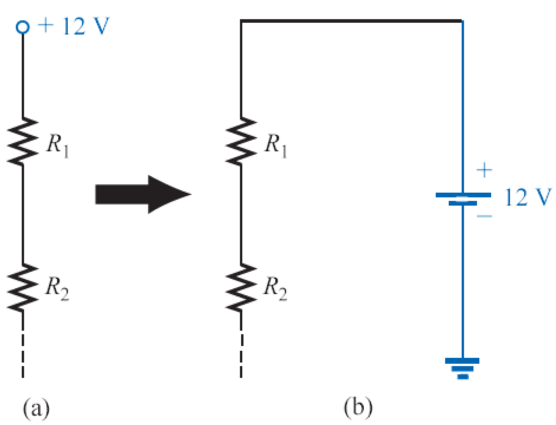
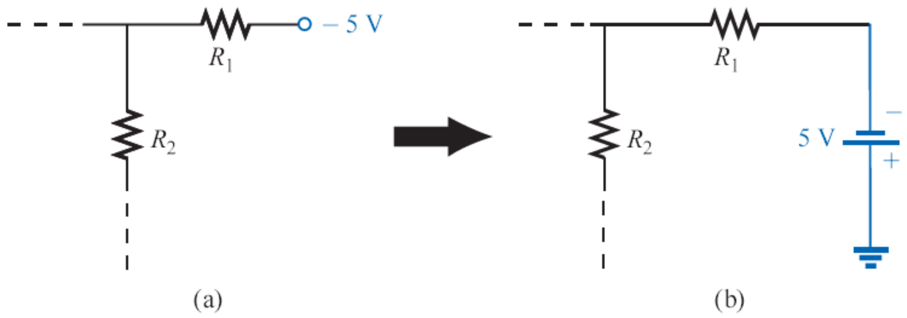



Fig (5)

Replacing the special notation for a positive dc voltage source with the standard symbol




Fig(6)

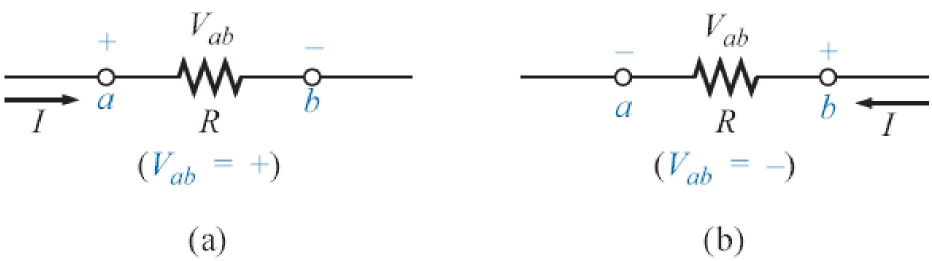
Replacing the notation for a negative dc supply with the standard symbol.

## Double-Subscript Notation

*The double-subscript notation $V_{ab}$ specifies point (a) as the higher potential. If this is not the case, negative sign must be associated with the magnitude of $V_{ab}$.*

**In other words,**

*the voltage $V_{ab}$ is the voltage at point( a)* ***with respect to (w.r.t.)*** *point (b).*




Fig(7)

The fact that voltage is an across variable and exists between two points has resulted in a double-subscript notation that defines the first subscript as the higher potential. In Fig. 7(a), the two points that define the voltage across the resistor R are denoted by (a and b). Since (a) is the first subscript for $V_{ab}$, point (a) must have a higher potential than point (b)if $V_{ab}$ is to have a positive value. If, point (b) is at a higher potential than point (a) ,$V_{ab}$ will have a negative value, as indicated in Fig. 7(b).

## Single-Subscript Notation

*The single-subscript notation ($V_a$ ) specifies the voltage at point a with respect to ground (zero volts).*

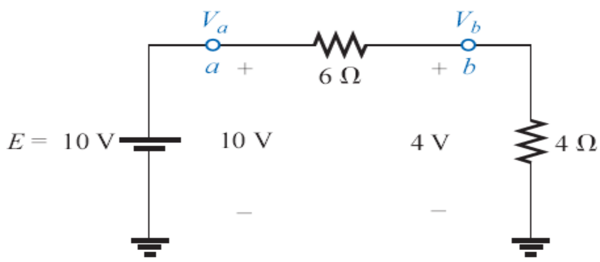



Fig.(8)

Defining the use of single-subscript notation

In Fig. 8, $V_a$ is the voltage from point (a) to ground. In this case it is obviously 10 V since it is right across the source voltage E. The voltage $V_b$ is the voltage from point (b) to ground. Because it is directly across the 4**Ω** resistor, $V_b$ = 4 V.

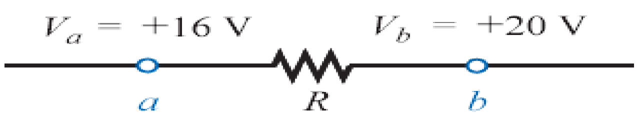
**the following relationship exists:**

$$\boxed{V_{ab} = V_a - V_b} \quad \text{———————} \quad (1)$$

So from the equation (1):

$$V_{ab} = V_a - V_b = 10\text{ V} - 4\text{ V}$$
$$= 6\text{ V}$$

**<u>EXAMPLE 2</u>** Find the voltage $V_{ab}$ for the conditions of Fig.( 9)




Fig(9)

Solution: Applying Eq.(1)

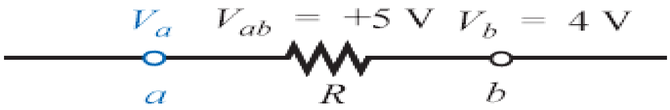
$V_{ab} = V_a - V_b$ = 16 V - 20 V

= - 4 V

☺ ***<u>Note</u>:*** ***the negative sign means that point (b) is at a higher potential than point (a).***

**EXAMPLE 3** Find the voltage $V_a$ for the configuration of Fig.( 10)

Solution: Applying Eq. (1):




Fig(10)

$$V_{ab} = V_a - V_b$$

*and* $V_a = V_{ab} + V_b = 5\ V + 4\ V$

$= 9\ V$

**EXAMPLE 4** Find the voltage $V_{ab}$ for the configuration of Fig.(11)

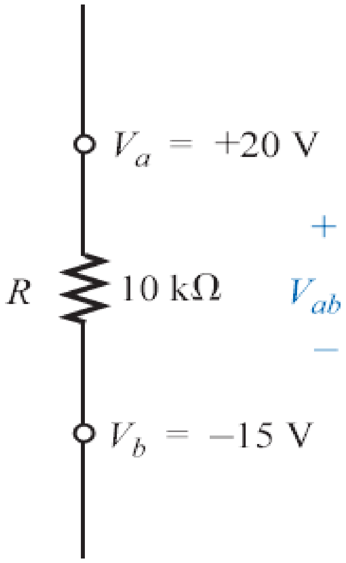



Fig (11)

Solution: Applying Eq. (1):

$$V_{ab} = V_a - V_b = 20\ V - (-15\ V) = 20\ V + 15\ V$$

$= 35\ V$

**EXAMPLE 5** Find the voltages $V_b$, $V_c$, and $V_{ac}$ for the network of Fig(12).

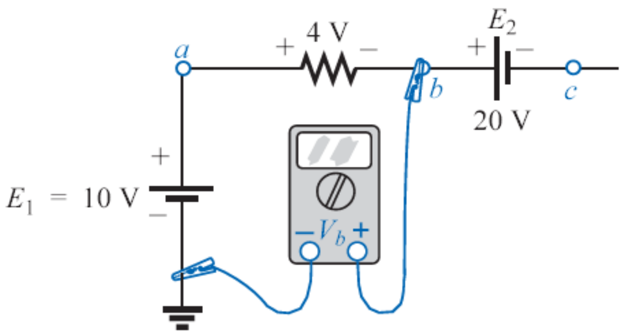



Fig (12)

**Solution**: Starting at ground potential (zero volts), we proceed through a rise of 10 V to reach point (a) and then pass through( a) drop in potential of 4 V to point (b). The result is that the meter will read :

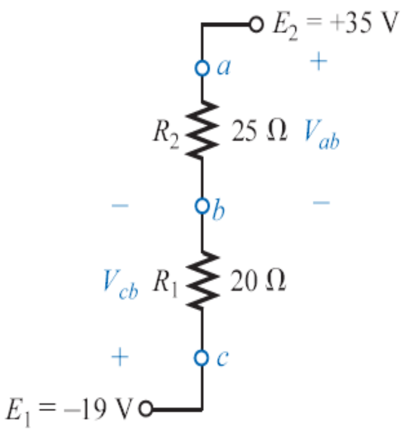
$$V_b = +10\text{ V} - 4\text{ V} = 6\text{ V}$$

$$V_c = Vb - 20\text{ V} = 6\text{ V} - 20\text{ V} = -14\text{ V}$$

$$V_{ac} = Va - Vc = 10\text{ V} - (-14\text{ V})$$

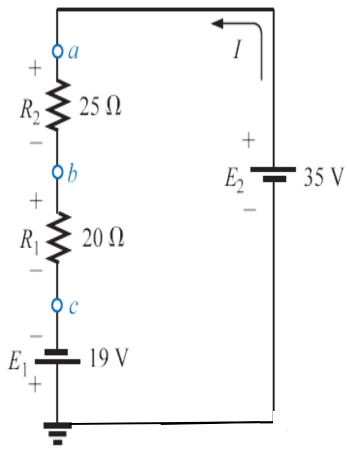
$$= 24\text{ V}$$

**EXAMPLE 6** Determine $V_{ab}$, $V_{cb}$, and $V_c$ for the network of Fig.(13)




Fig(13)

Redraw the network as shown in Fig. (14)



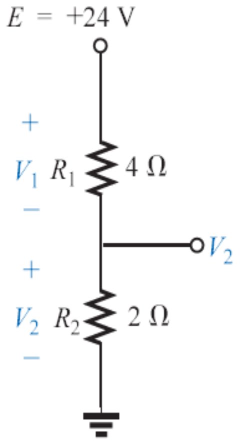

Fig(14)

$E_T$= 19+35= 54 V

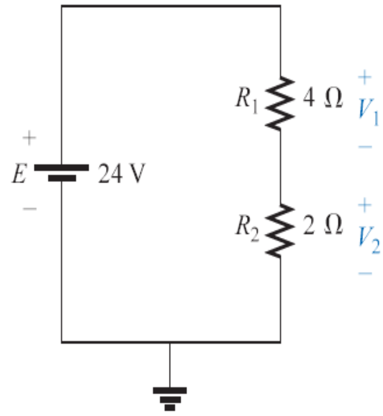
$R_T$ = 20+25 =45

Sol:
$$I = \frac{54\text{ V}}{45\ \Omega} = 1.2\text{ A}$$
$$V_{ab} = IR_2 = (1.2\text{ A})(25\ \Omega) = \mathbf{30\ V}$$
$$V_{cb} = -IR_1 = -(1.2\text{ A})(20\ \Omega) = \mathbf{-24\ V}$$
$$V_c = E_1 = \mathbf{-19\ V}$$

**EXAMPLE 7** Using the voltage divider rule, determine the voltagesV1 and V2 of Fig.(15).




Redraw the network as shown in Fig. (16)

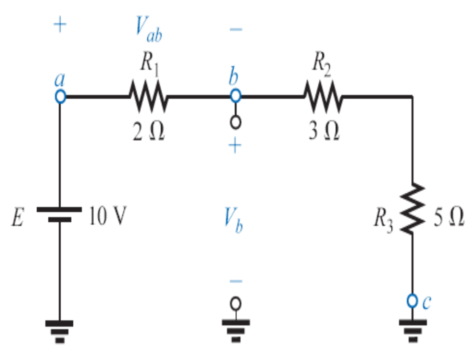



Fig(15)

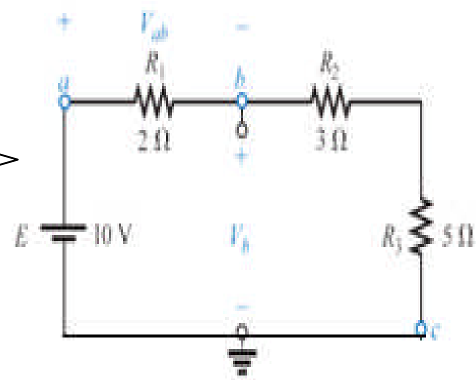
fig (16)

$$V_1 = \frac{R_1E}{R_1 + R_2} = \frac{(4\ \Omega)(24\text{ V})}{4\ \Omega + 2\ \Omega} = \mathbf{16\ V}$$
$$V_2 = \frac{R_2E}{R_1 + R_2} = \frac{(2\ \Omega)(24\text{ V})}{4\ \Omega + 2\ \Omega} = \mathbf{8\ V}$$

**EXAMPLE 8** For the network of Fig. (17)




Redraw the network as shown in Fig. (17 b)




a

Fig(17)

b

a. Calculate $V_{ab}$.
b. Determine $V_b$.
c. Calculate $V_c$.

**Solutions:**

a. Voltage divider rule:

$$V_{ab} = \frac{R_1 E}{R_T} = \frac{(2\ \Omega)(10\ \text{V})}{2\ \Omega + 3\ \Omega + 5\ \Omega} = \mathbf{+2\ V}$$

b. Voltage divider rule:

$$V_b = V_{R_2} + V_{R_3} = \frac{(R_2 + R_3)E}{R_T} = \frac{(3\ \Omega + 5\ \Omega)(10\ \text{V})}{10\ \Omega} = \mathbf{8\ V}$$

or $\quad V_b = V_a - V_{ab} = E - V_{ab} = 10\ \text{V} - 2\ \text{V} = \mathbf{8\ V}$

c. $V_c$ = ground potential = **0 V**

## INTERNAL RESISTANCE OF VOLTAGE SOURCES

Every source of voltage, whether a generator, battery, or laboratory supply as shown in Fig. 17(a), will have some internal resistance. The equivalent circuit of any source of voltage will therefore appear as shown in Fig. 17(b).

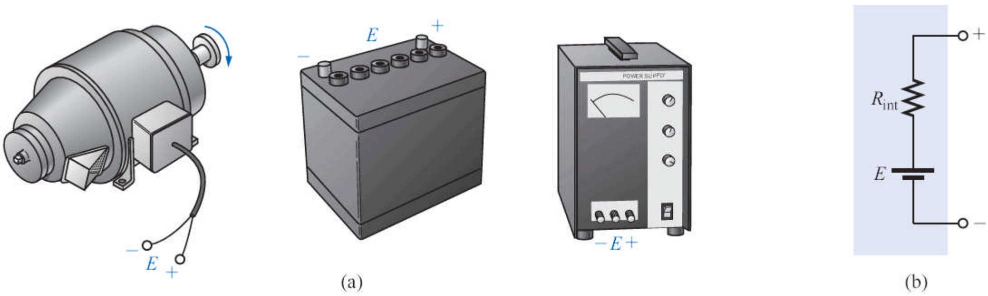
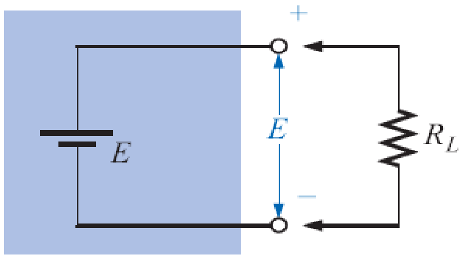



Fig (17)

(a) Sources of dc voltage; (b) equivalent circuit.

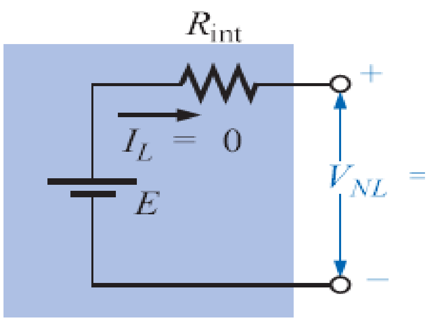
The ideal voltage source has no internal resistance and an output voltage of E volts with no load or full load. as shown in[ fig18(a)] .




(a)

Fig(18)

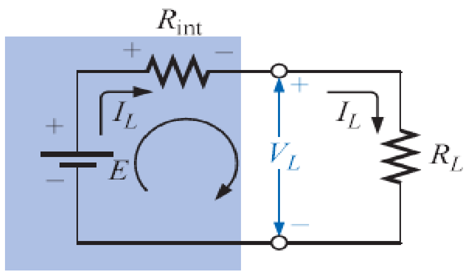
In the practical case [Fig. 18(b)], where we consider the effects of the internal resistance, the output voltage will be E volts only when no-load ($I_L = 0$) conditions exist.




(b)

Fig( 18 )

When a load is connected [fig 18c]




(c)

Fig(18)

By applying Kirchhoff's voltage law around the indicated loop of Fig18(c), we obtain:

$$E - I_L R_{\text{int}} - V_L = 0$$

or, since
$$E = V_{NL}$$

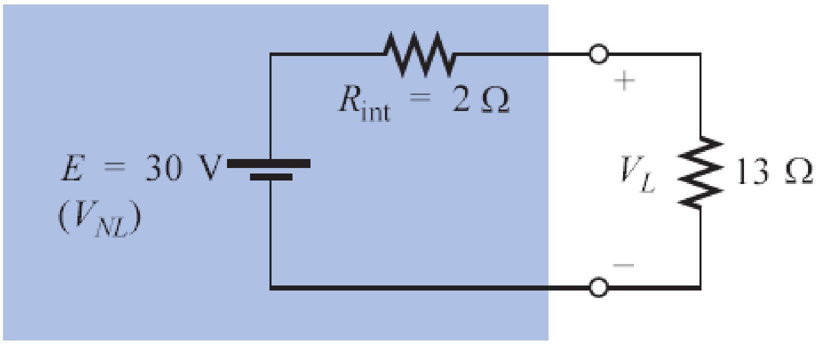
we have
$$V_{NL} - I_L R_{\text{int}} - V_L = 0$$

and
$$\boxed{V_L = V_{NL} - I_L R_{\text{int}}}$$

$$R_{\text{int}} = \frac{V_{NL} - V_L}{I_L} = \frac{V_{NL}}{I_L} - \frac{I_L R_L}{I_L}$$

and
$$\boxed{R_{\text{int}} = \frac{V_{NL}}{I_L} - R_L}$$

**EXAMPLE 9** The battery of Fig. (19) has an internal resistance of 2 Ω. Find the voltage $V_L$ and the power lost to the internal resistance if the applied load is a 13**Ω** resistor.




Fig(19)

**Solution:**

$$I_L = \frac{30\text{ V}}{2\ \Omega + 13\ \Omega} = \frac{30\text{ V}}{15\ \Omega} = 2\text{ A}$$
$$V_L = V_{NL} - I_L R_{\text{int}} = 30\text{ V} - (2\text{ A})(2\ \Omega)$$
$$P_{\text{lost}} = I_L^2 R_{\text{int}} = (2\text{ A})^2(2\ \Omega) = (4)(2) = \mathbf{8}$$