University of Science and Technology

FACULTY OF COMPUTER SCIENCE AND INFORMATION TECHNOLOGY

Course Handbook

Physics II

COURSE COORDINATOR

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Lecture five

Kirchhoff's Laws

Kirchhoff's Laws

KIRCHHOFF'S NODE (OR JUNCTION) RULE: The sum of all the currents coming into a node (i.e., a junction where three or more current-carrying leads attach) must equal the sum of all the currents leaving that node.

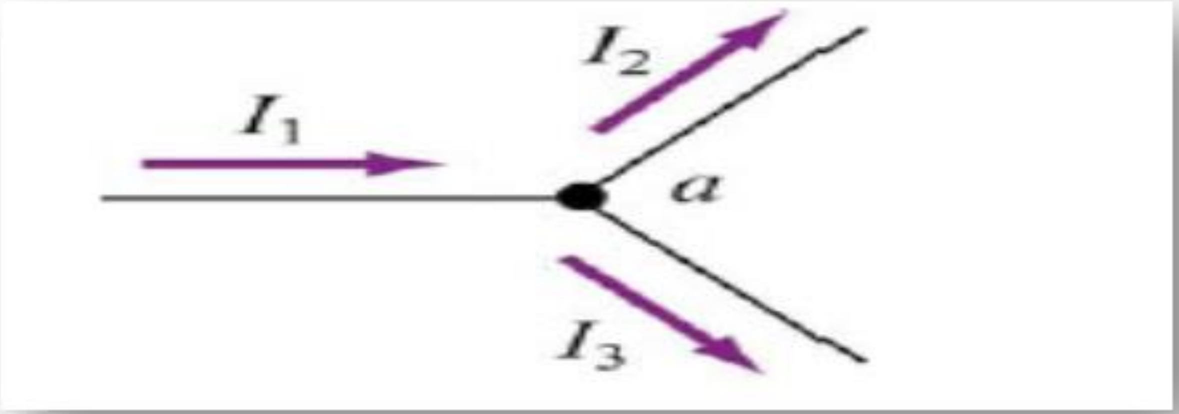
KIRCHHOFF'S LOOP (OR CIRCUIT) RULE: As one traces out a closed circuit, the algebraic sum of the potential changes encountered is zero. In this sum, a potential rise is positive and a potential drop is negative.

Current always flows from high to low potential through a resistor. As one traces through a resistor in the direction of the current, the potential change is negative because it is a potential drop.

The positive terminal of a pure emf source is always the high-potential terminal, independent of the direction of the current through the emf source.

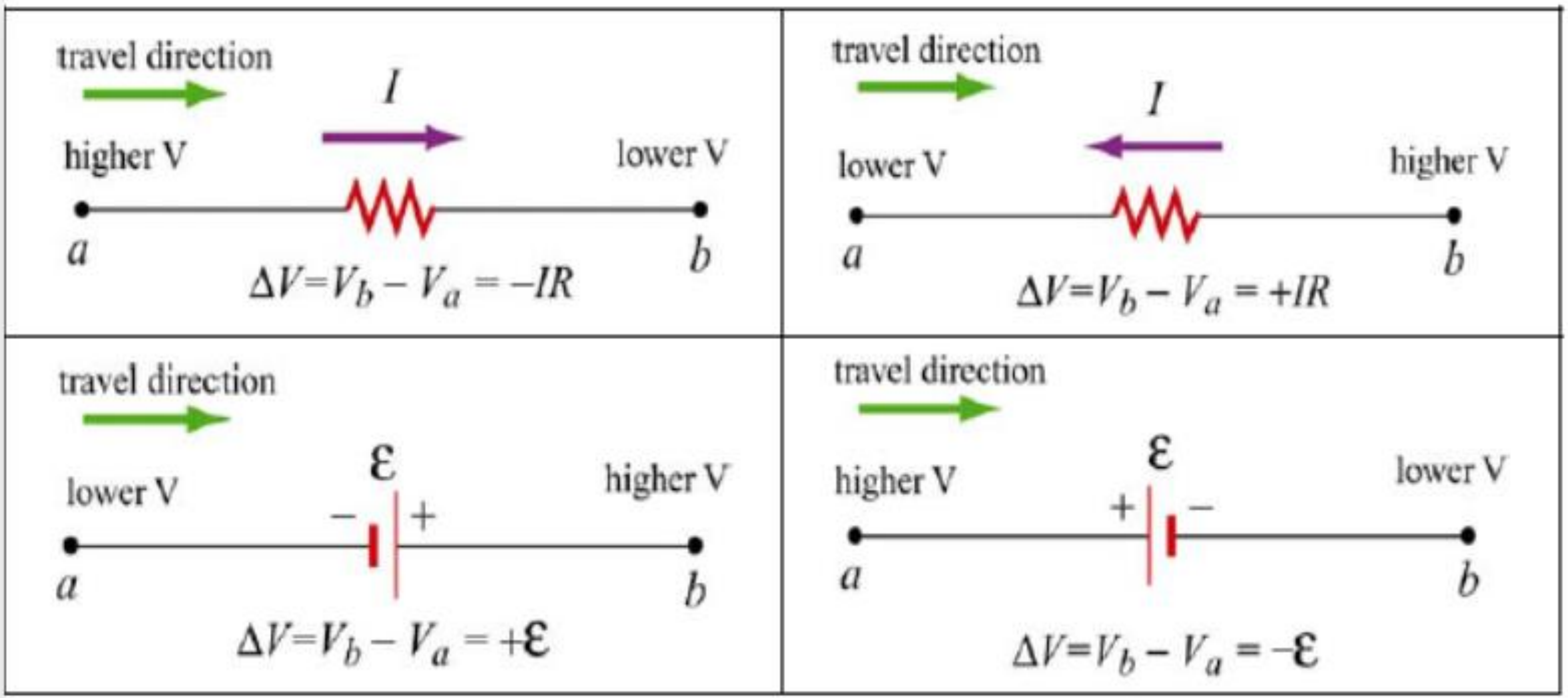
THE SET OF EQUATIONS OBTAINED by use of Kirchhoff's loop rule will be independent provided that each new loop equation contains a voltage change not included in a previous equation.

Applying the first rule on the junction shown below figure:



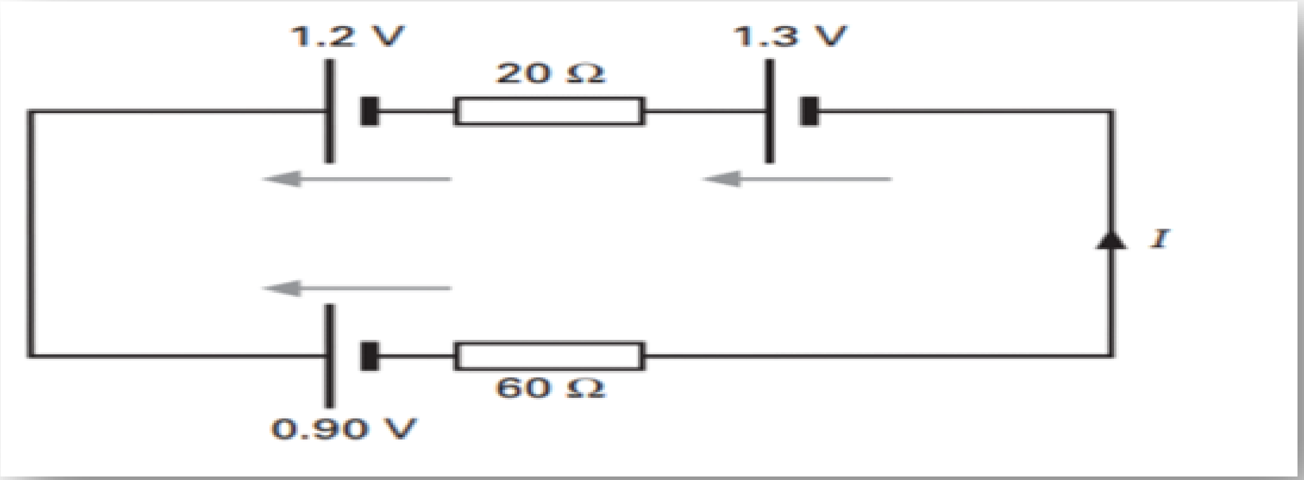
$$I_1 = I_2 + I_3$$

Applying the second rule on the following cases:



Solved Problems

determine the circuit current I



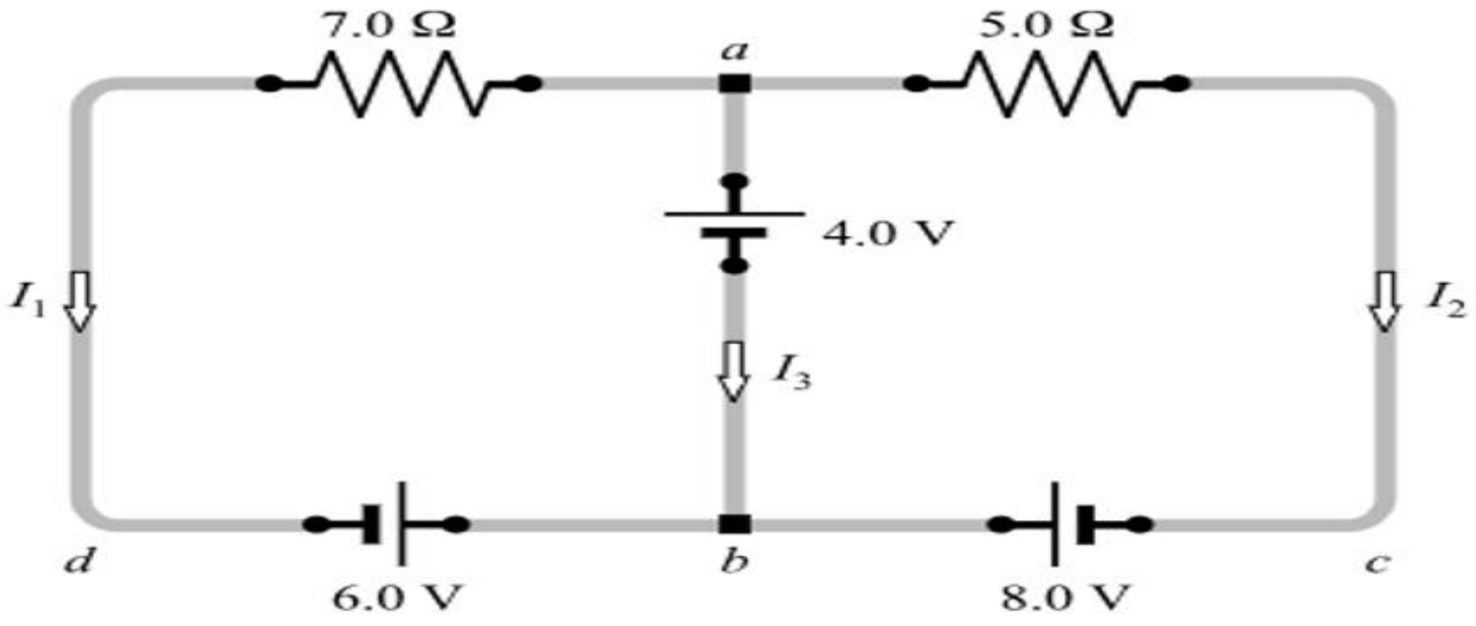
$$\sum V_{\text{close loop}} = 0$$

$$1.3 - 20I + 1.2 - 0.9 - 60I = 0$$

$$1.6 = 80I$$

$$\therefore I = 0.02A$$

Find the currents in the circuit shown in Fig. 29-1.



Current into b = current out of b

$$I_1 + I_2 + I_3 = 0 \tag{1}$$

Next we apply the loop rule to loop *adba*. In volts,

$$-7.0\,I_1 + 6.0 + 4.0 = 0 \qquad \text{or} \qquad I_1 = \frac{10.0}{7.0}\,\text{A}$$

(Why must the term $7.0\,I_1$ have a negative sign?) We then apply the loop rule to loop *abca*. In volts,

$$-4.0 - 8.0 + 5.0\,I_2 = 0 \quad \text{or} \quad I_2 = \frac{12.0}{5.0}\text{ A}$$

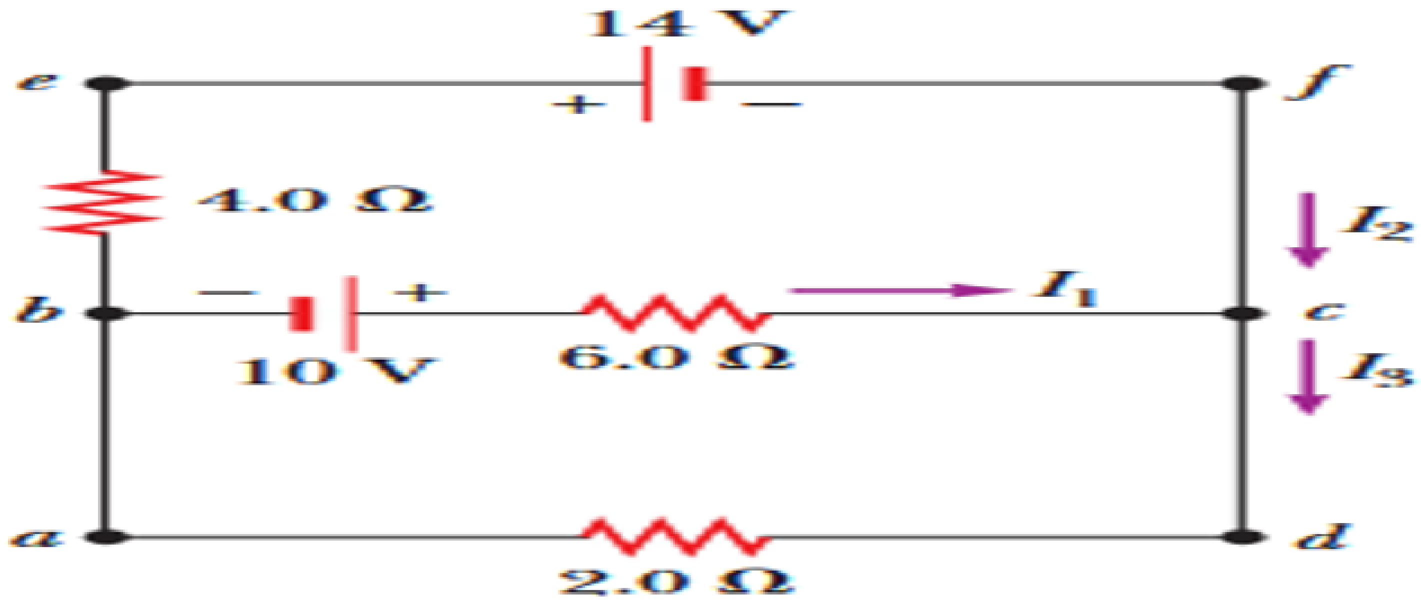
(Why must the signs be as written?)

Now we return to Eq. (*1*) to find

$$I_3 = -I_1 - I_2 = -\frac{10.0}{7.0} - \frac{12.0}{5.0} = \frac{-50 - 84}{35} = -3.8\text{ A}$$

The minus sign tells us that I_3 is opposite in direction to that shown in the figure.

Problem Find I_1, I_2, and I_3 in Figure 18.15a.



(a)

$$(1) \quad I_3 = I_1 + I_2$$

(2) Loop *abcda*: $10\text{ V} - (6.0\ \Omega)I_1 - (2.0\ \Omega)I_3 = 0$

(3) Loop *befcb*:

$$-(4.0\ \Omega)I_2 - 14\text{ V} + (6.0\ \Omega)I_1 - 10\text{ V} = 0$$

$$10 - 6.0I_1 - 2.0(I_1 + I_2) = 0$$

$$(4) \quad 10 = 8.0I_1 + 2.0I_2$$

$$(5) \quad -12 = -3.0I_1 + 2.0I_2$$

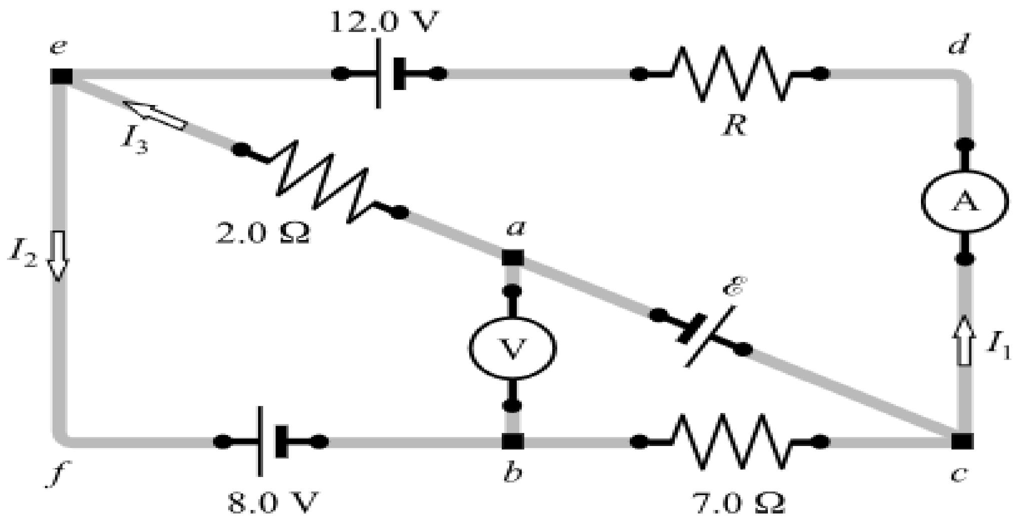
$$22 = 11I_1 \quad \longrightarrow \quad I_1 = \boxed{2.0\text{ A}}$$

$$2.0I_2 = 3.0I_1 - 12 = 3.0(2.0) - 12 = -6.0\text{ A}$$

$$I_2 = \boxed{-3.0\text{ A}}$$

$$I_3 = I_1 + I_2 = 2.0\text{ A} - 3.0\text{ A} = \boxed{-1.0\text{ A}}$$

For the circuit shown in Fig. 29-5, the resistance R is 5.0 Ω and $\mathscr{E} = 20$ V. Find the readings of the ammeter and the voltmeter. Assume the meters to be ideal.



us write the loop equation for loop *cdefc*:

$$-RI_1 + 12.0 - 8.0 - 7.0\,I_2 = 0$$

which becomes

$$5.0\,I_1 + 7.0\,I_2 = 4.0 \qquad (1)$$

Next we write the loop equation for loop *cdeac*. It is

$$-5.0\,I_1 + 12.0 + 2.0\,I_3 + 20.0 = 0$$

or

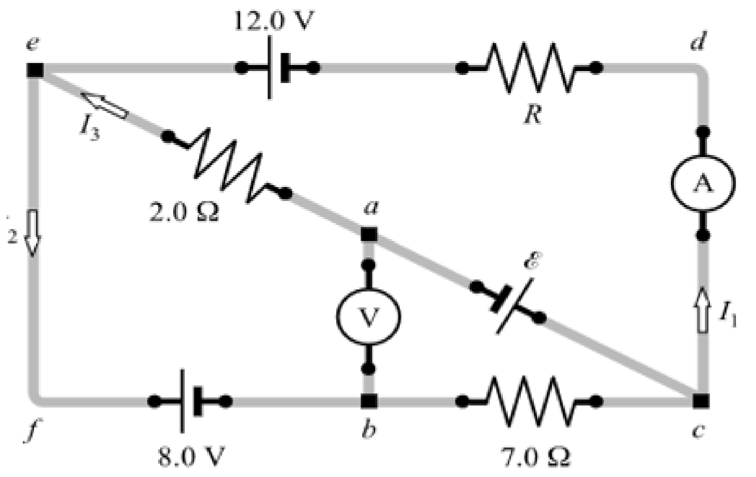
$$5.0\,I_1 - 2.0\,I_3 = 32.0 \qquad (2)$$

But the node rule applied at *e* gives

$$I_1 + I_3 = I_2 \qquad (3)$$

Substituting (*3*) in (*1*) gives

$$5.0\,I_1 + 7.0\,I_1 + 7.0\,I_3 = 4.0$$



We solve this for I_3 and substitute in (*2*) to get

$$5.0\,I_1 - 2.0\left(\frac{4.0 - 12.0\,I_1}{7.0}\right) = 32.0$$

which yields $I_1 = 3.9$ A, which is the ammeter reading. Then (*1*) gives $I_2 = -2.2$ A.

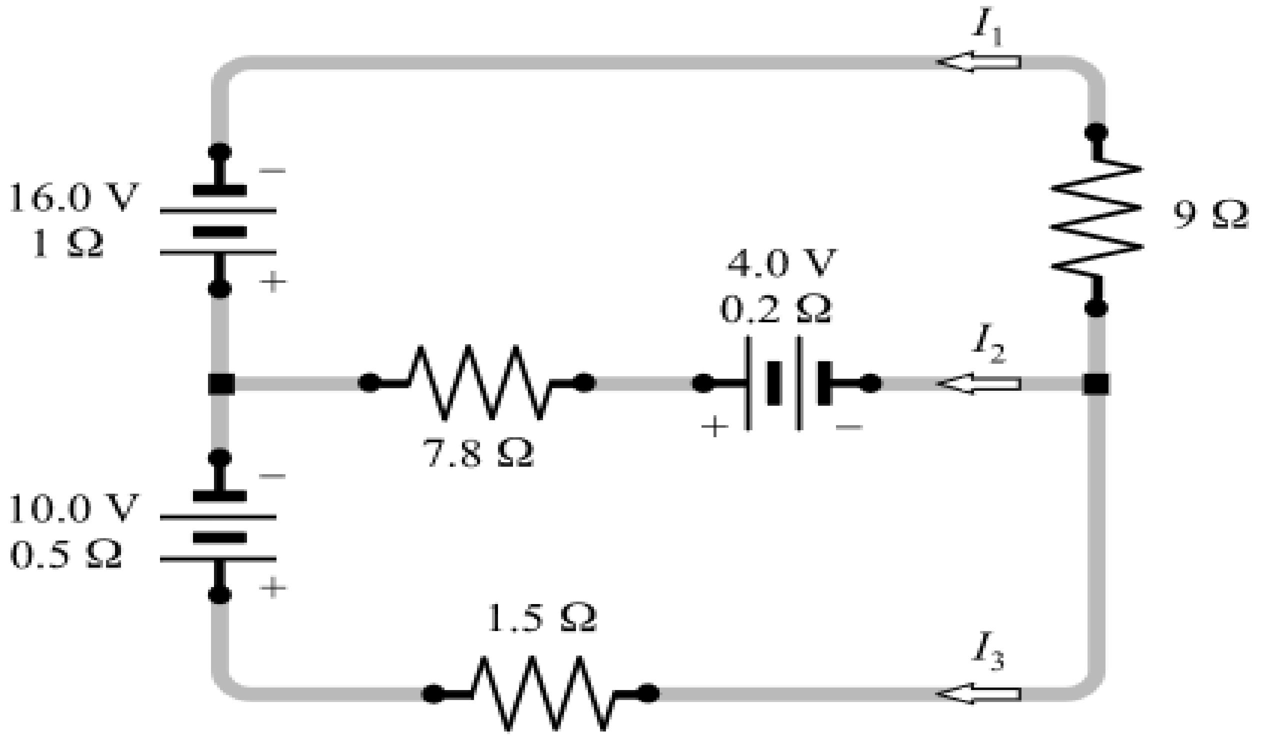
To find the voltmeter reading V_{ab}, we write the loop equation for loop *abca*:

$$V_{ab} - 7.0\,I_2 - \mathscr{E} = 0$$

Substituting the known values of I_2 and $\mathscr{E}$, then solving, we obtain $V_{ab} = 4.3$ V. Since this is the potential difference between *a* to *b*, point *b* must be at the higher potential.

Supplementary Problems

For the network shown in Fig. 29-7, determine (*a*) the three currents I_1, I_2, and I_3, and (*b*) the terminal voltages of the three batteries. *Ans.* (*a*) $I_1 = 2$ A, $I_2 = 1$ A, $I_3 = -3$ A; (*b*) $V_{16} = 14$ V, $V_4 = 3.8$ V, $V_{10} = 8.5$ V



In Fig. 29-9, $R = 10.0\ \Omega$ and $\mathcal{E} = 13$ V. Find the readings of the ideal ammeter and voltmeter.

Ans. 8.4 A, 27 V with point *a* positive