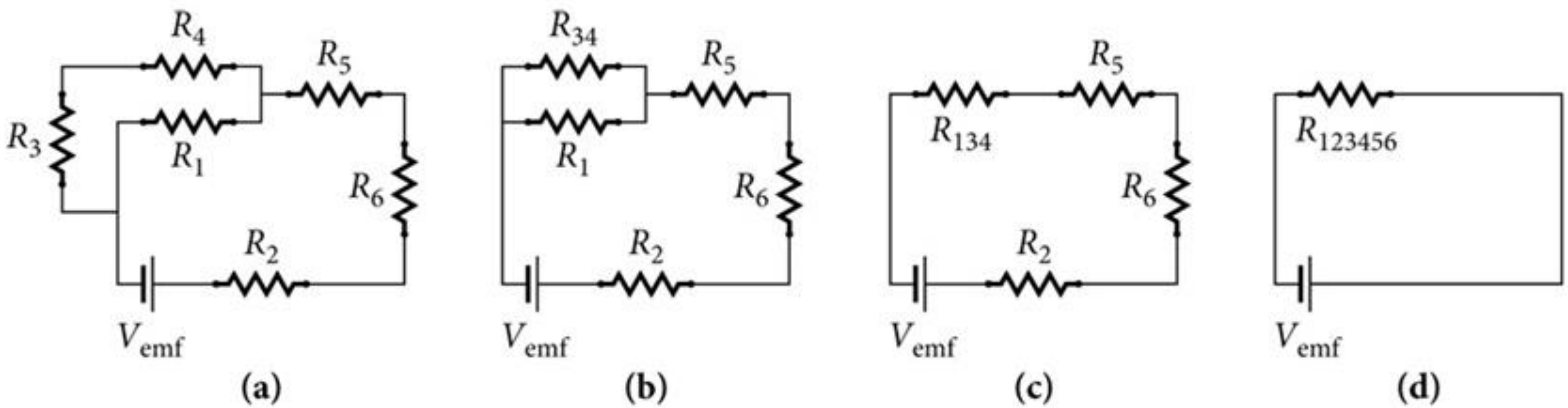
Copyright statement

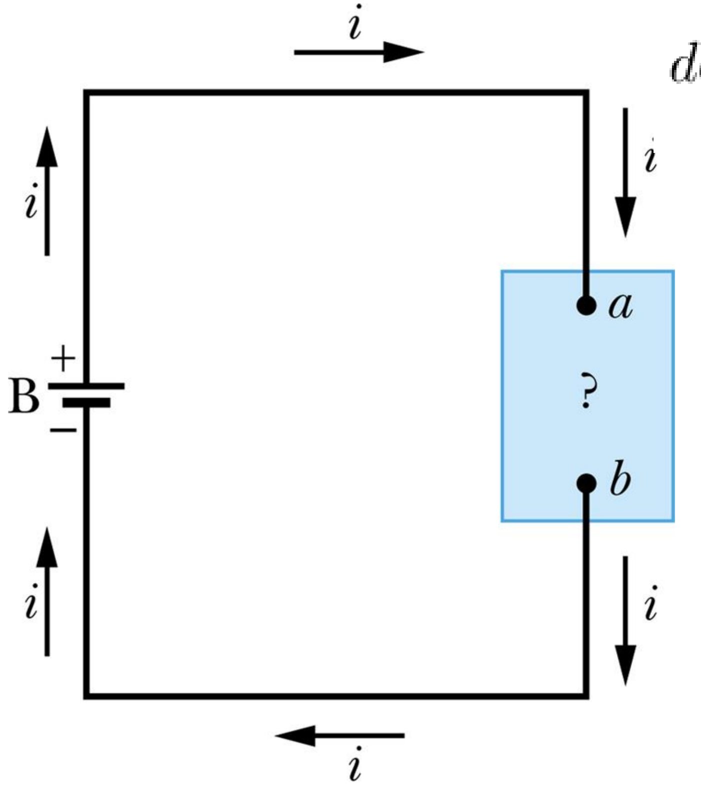
- The images and the pictures in this lecture are provided by the CDs accompanied by the books
  1. University Physics, Bauer and Westfall, McGraw-Hill, 2011.
  2. Principles of Physics, Halliday, Resnick, and Walker, Wiley, 8^{th} and 9^{th} Ed.
- The rest is made by me.

Example 2



R_4
R_5
R_3
R_1
R_6
R_2
V_{emf}
(a)
R_{34}
R_5
R_1
R_6
R_2
V_{emf}
(b)
R_5
R_{134}
R_6
R_2
V_{emf}
(c)
R_{123456}
V_{emf}
(d)

Energy and power in circuits

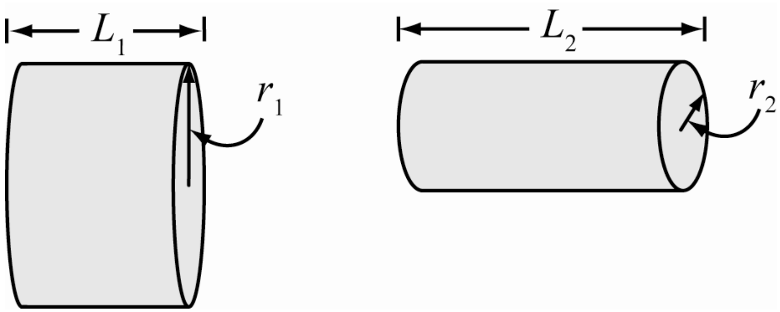


$$dU = dqV = i\,dtV \rightarrow P = iV = i^2 R = \frac{V^2}{R}$$

SI unit: $\mathrm{V} \cdot \mathrm{A}$

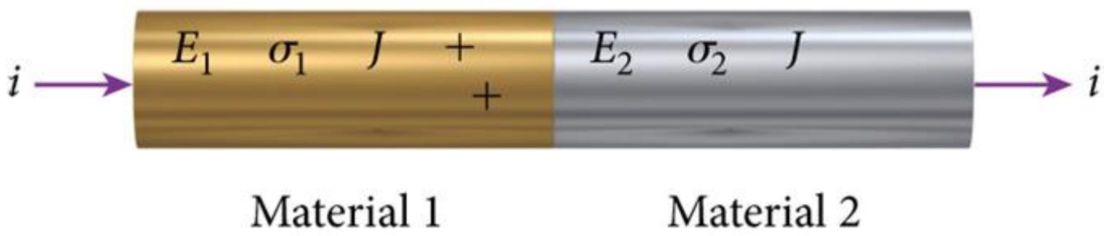
$$1\mathrm{V} \cdot \mathrm{A} = \left(1\frac{\mathrm{J}}{\mathrm{C}}\right)\left(1\frac{\mathrm{C}}{\mathrm{s}}\right) = 1\frac{\mathrm{J}}{\mathrm{s}} = 1\mathrm{W}$$

Problem 1



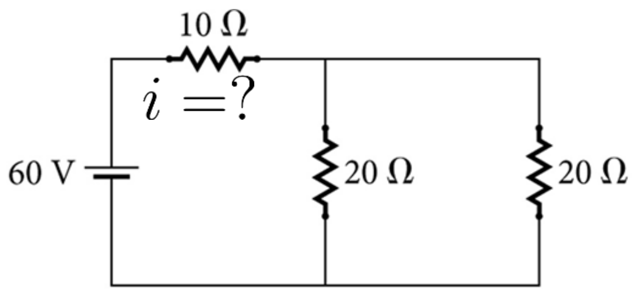
$$\frac{\Delta R}{R} = ?$$

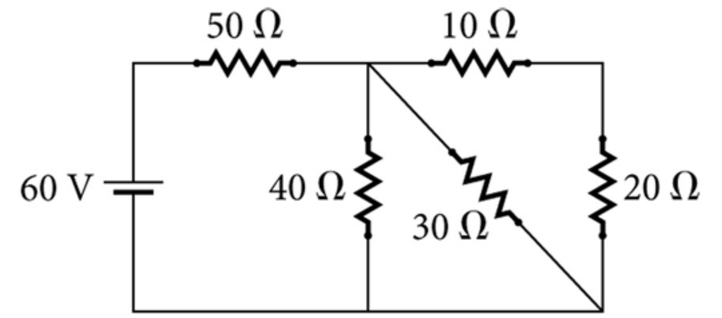
Problem 25.37



$$q = \epsilon_0 i(1/\sigma_2 - 1/\sigma_1)$$

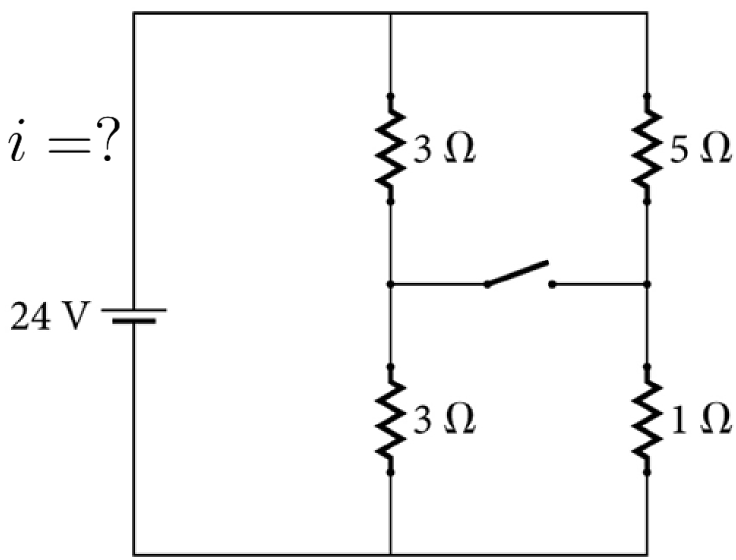
Problems 25.46, 47



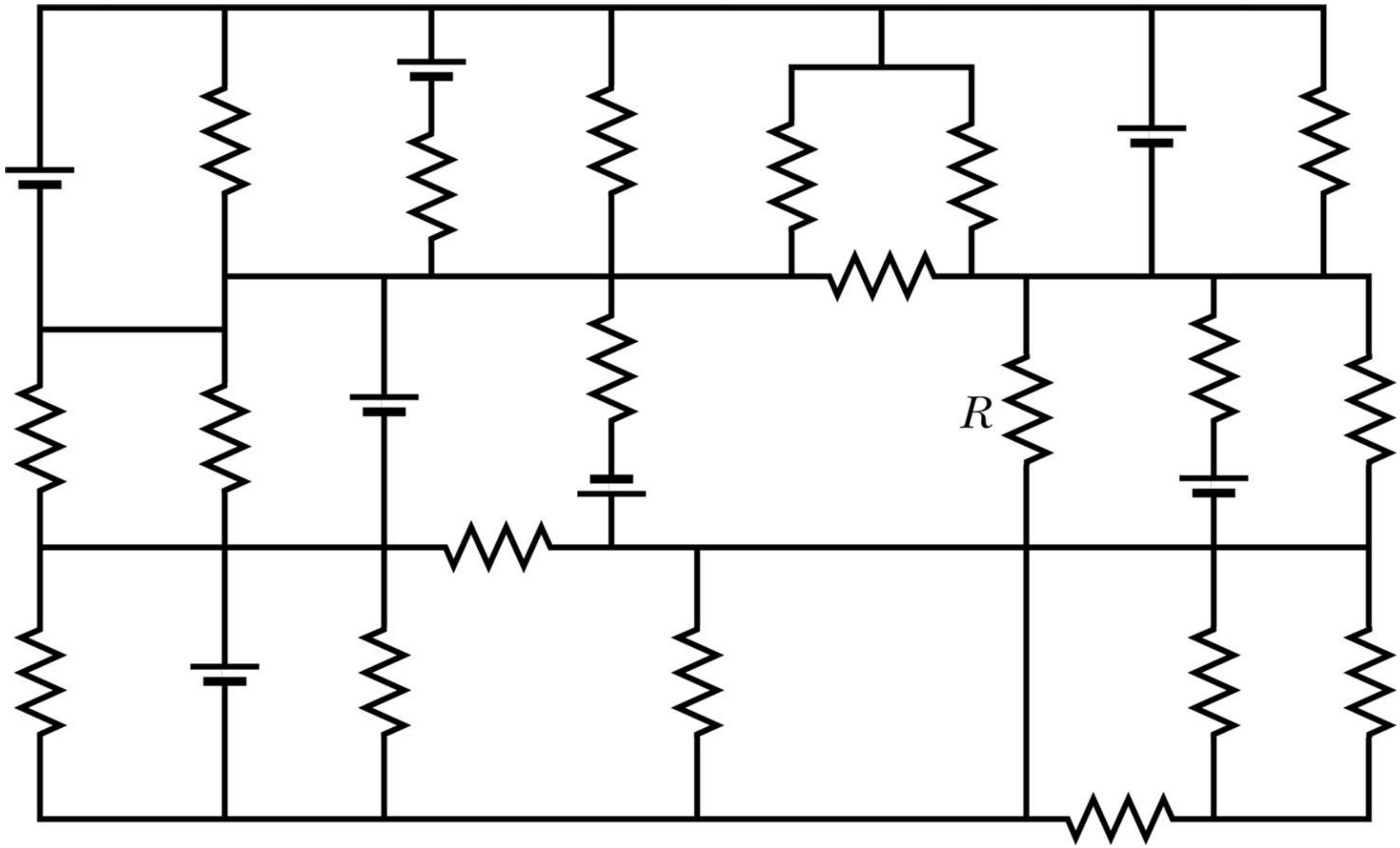


$R_{\text{eq}} = ?$

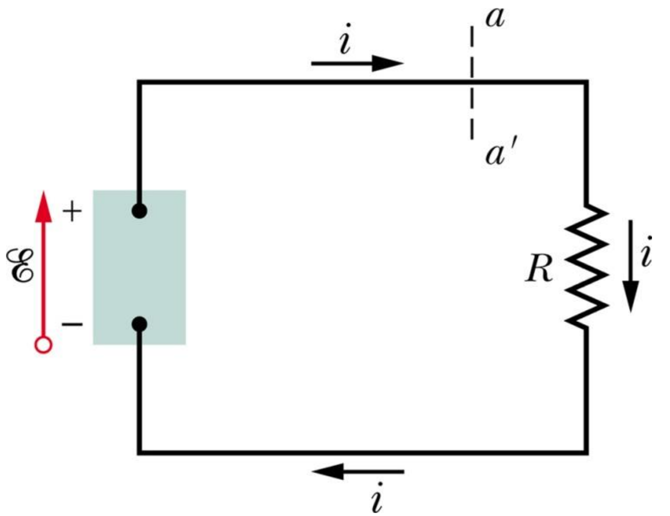
Problem 25.48



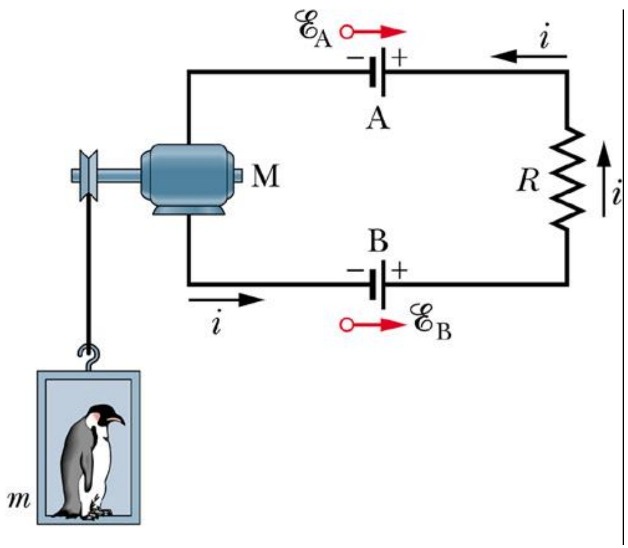
Chap. 26 Direct current circuits

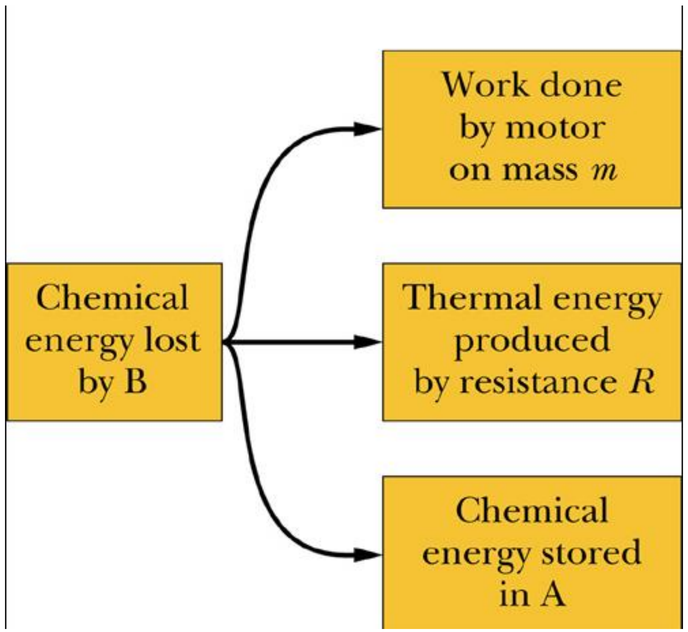


Electromotive force (emf)



$$\mathcal{E} = \frac{dW}{dq}$$



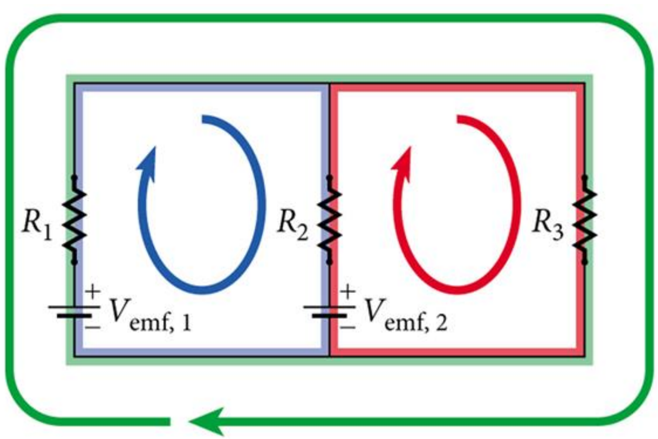


Kirchhoff's rules
(Junction rule)

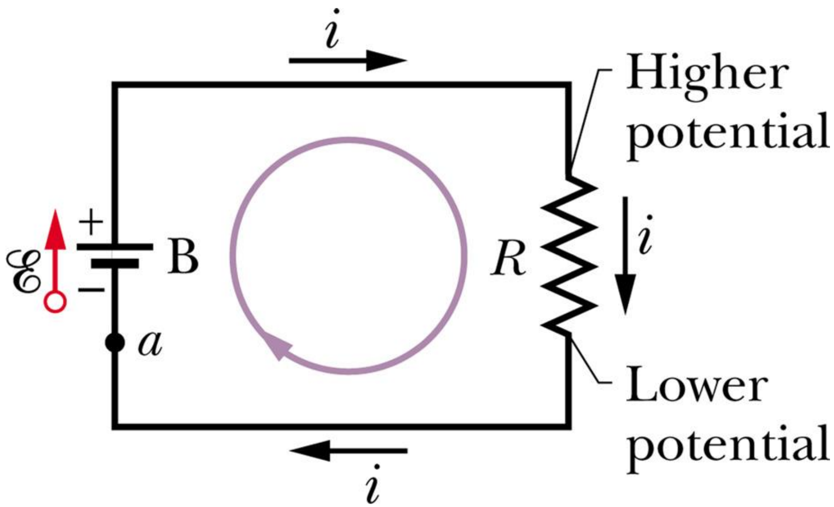
The sum of the currents at a junction is conserved. $$\sum_{k=1}^{n} i_k = 0$$

Kirchhoff's Loop Rule

The potential difference around a complete circuit loop must sum to zero.



Single-loop circuit



Energy method

$$dW = \mathcal{E} dq = \mathcal{E} i dt$$

$$\mathcal{E} i dt = i^2 R dt$$

$$\mathcal{E} = iR$$

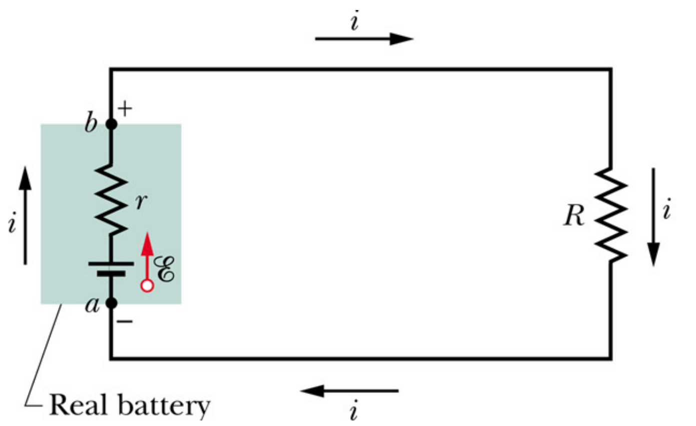
$$i = \frac{\mathcal{E}}{R}$$

Potential method

$$V_a + \mathcal{E} - iR = V_a$$

$$i = \frac{\mathcal{E}}{R}$$

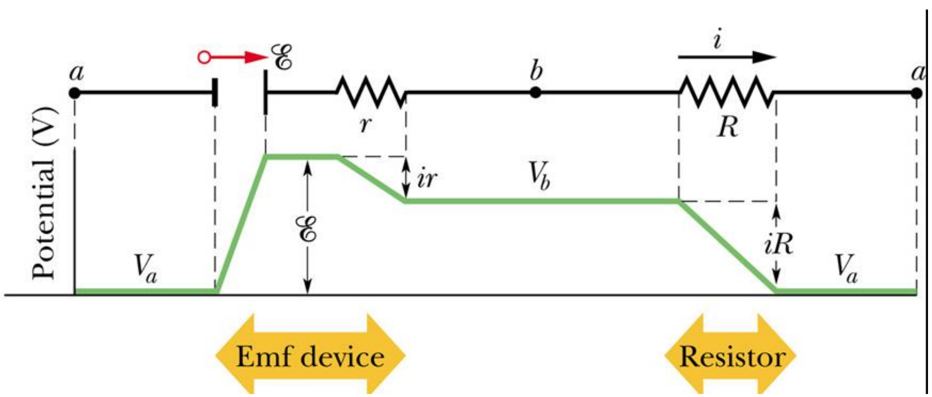
Internal resistance



current $\mathcal{E} - ir - iR = 0$

$$i = \frac{\mathcal{E}}{R + r}$$

Potential difference between a battery



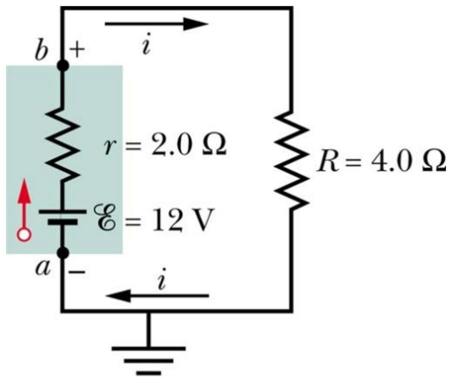
$$V_a + \mathcal{E} - ir = V_b$$

$$V_a - V_b = \mathcal{E} - ir = \mathcal{E}\frac{R}{R + r}$$

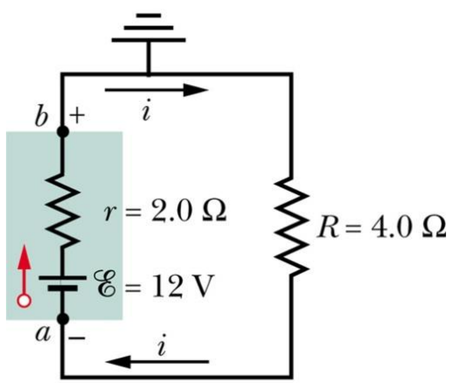
$$V_b - iR = V_a$$

$$V_a - V_b = iR = \mathcal{E}\frac{R}{R + r}$$

Power, potential and emf



(a)



(b)

Power from emf to charges

$$P = iV$$

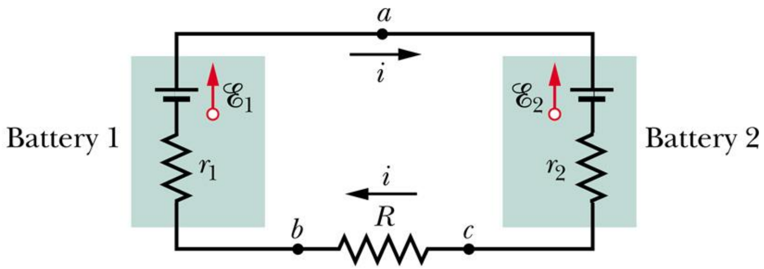
$$P = i(\mathcal{E} - ir) = i\mathcal{E} - i^2 r$$

내부소모율 P_r

기전력의 일률 P_{emf}

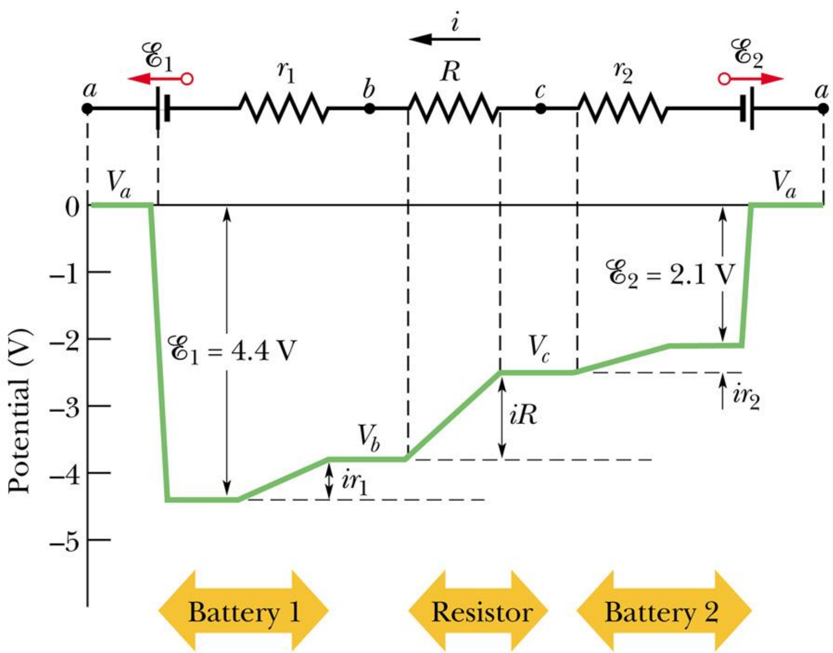
Example 1

(a)



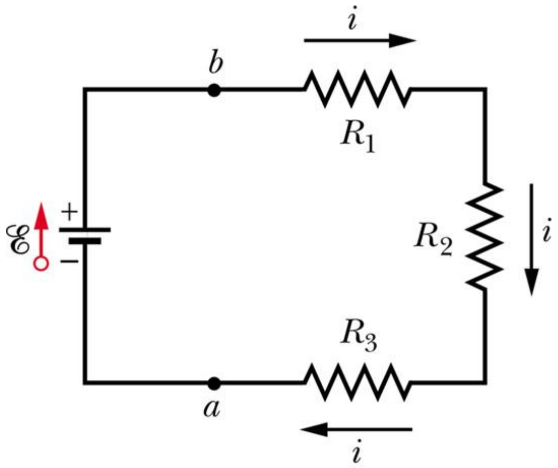
a
i
ℰ1
ℰ2
Battery 1
Battery 2
r1
r2
i
R
b
c

(b)

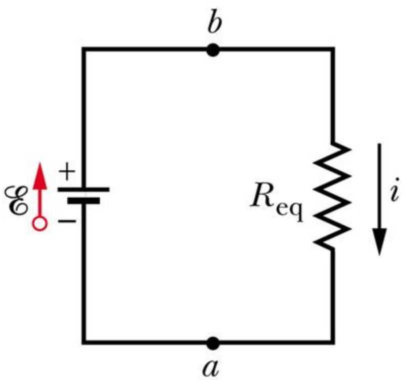


i
ℰ1
ℰ2
a
r1
b
R
c
r2
a
Va
Va
0
−1
−2
−3
−4
−5
Potential (V)
ℰ2 = 2.1 V
ℰ1 = 4.4 V
Vc
Vb
ir2
iR
ir1
Battery 1
Resistor
Battery 2

Resistors in series



(a)



(b)

$$\mathcal{E} - iR_1 - iR_2 - iR_3 = 0$$

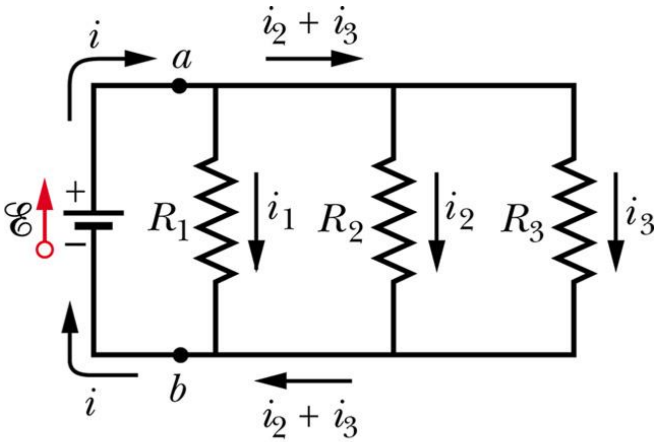
$$i = \frac{\mathcal{E}}{R_1 + R_2 + R_3} = \frac{\mathcal{E}}{R_{\text{eq}}}$$

$$R_{\text{eq}} = R_1 + R_2 + R_3$$

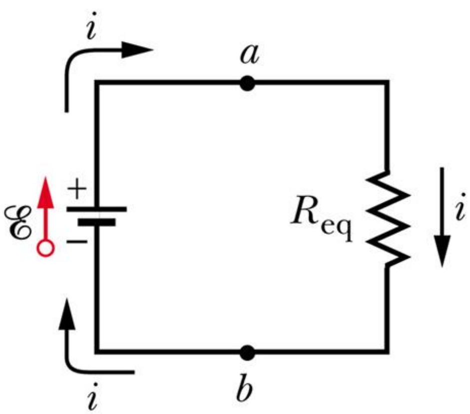
n resistors connected in series

$$R_{\text{eq}} = \sum_{i=1}^{n} R_i$$

Resistors in parallel



(a)



(b)

$$i_1 = \frac{V}{R_1}, \quad i_2 = \frac{V}{R_2}, \quad i_3 = \frac{V}{R_3}$$

$$i = i_1 + i_2 + i_3 = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

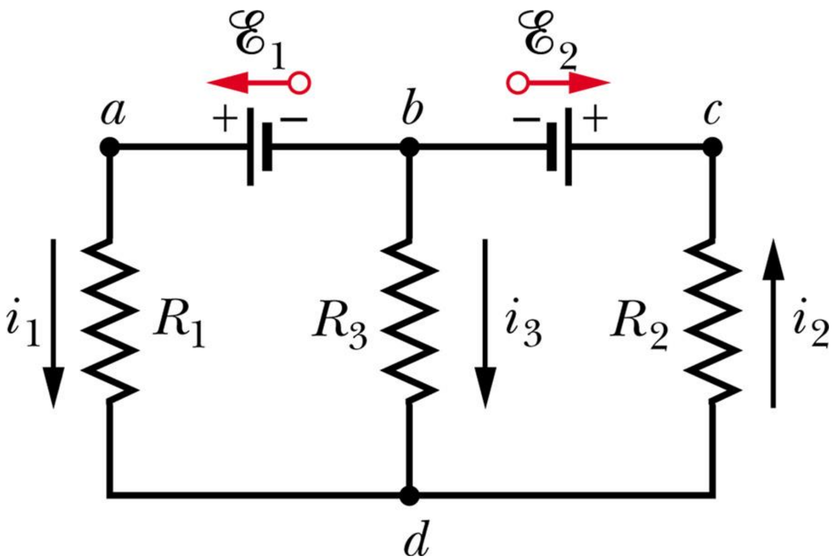
$$i = \frac{V}{R_{eq}}$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

n resistors connected in parallel

$$\frac{1}{R_{eq}} = \sum_{i=1}^{n} \frac{1}{R_i}$$

Multiloop circuits



Branch rule: $i_2 = i_1 + i_3$

Loop rule:

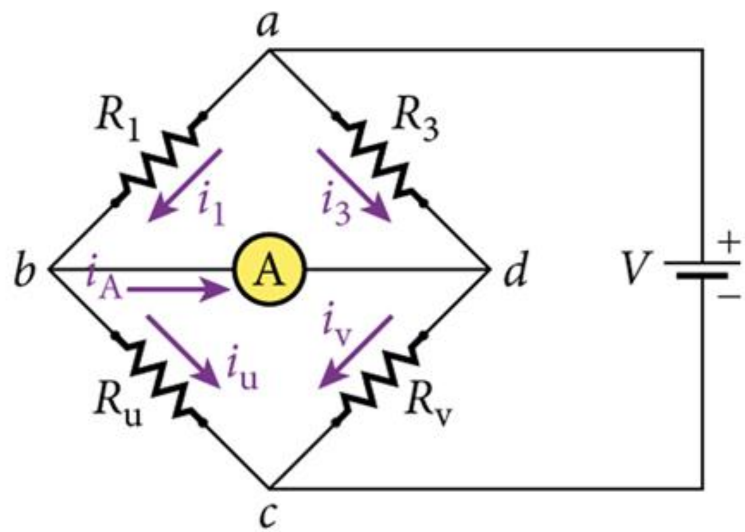
(bad) $\mathcal{E}_1 - i_1 R_1 + i_3 R_3 = 0$

(bdc) $-i_3 R_3 - i_2 R_2 - \mathcal{E}_2 = 0$

(badc) $\mathcal{E}_1 - i_1 R_1 - i_2 R_2 - \mathcal{E}_2 = 0$

Not an independent equation!

Solved problem 26.2
The Wheatstone bridge



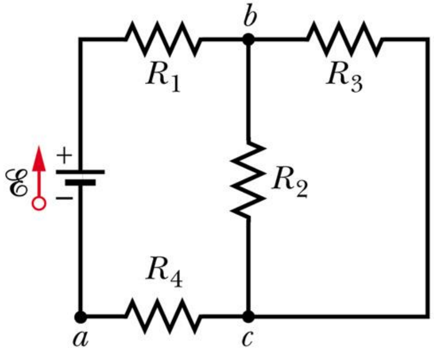
adb $$-i_3 R_3 + i_A R_A + i_1 R_1 = 0$$

cbd $$i_u R_u - i_A R_A - i_V R_V = 0$$

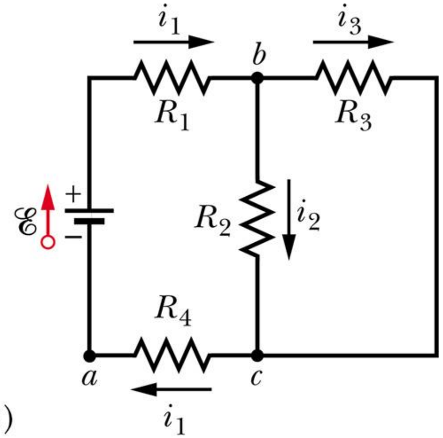
b $$i_1 = i_A + i_u$$

d $$i_3 + i_A = i_V$$

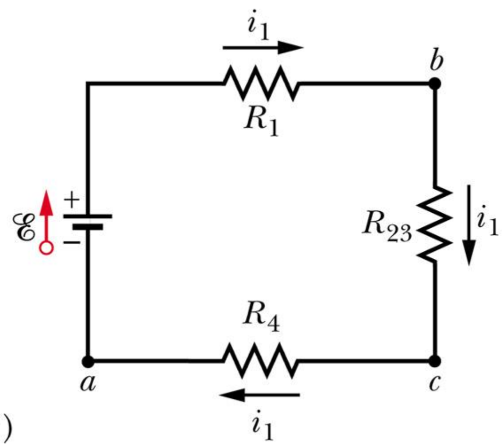
Example 2



(a)

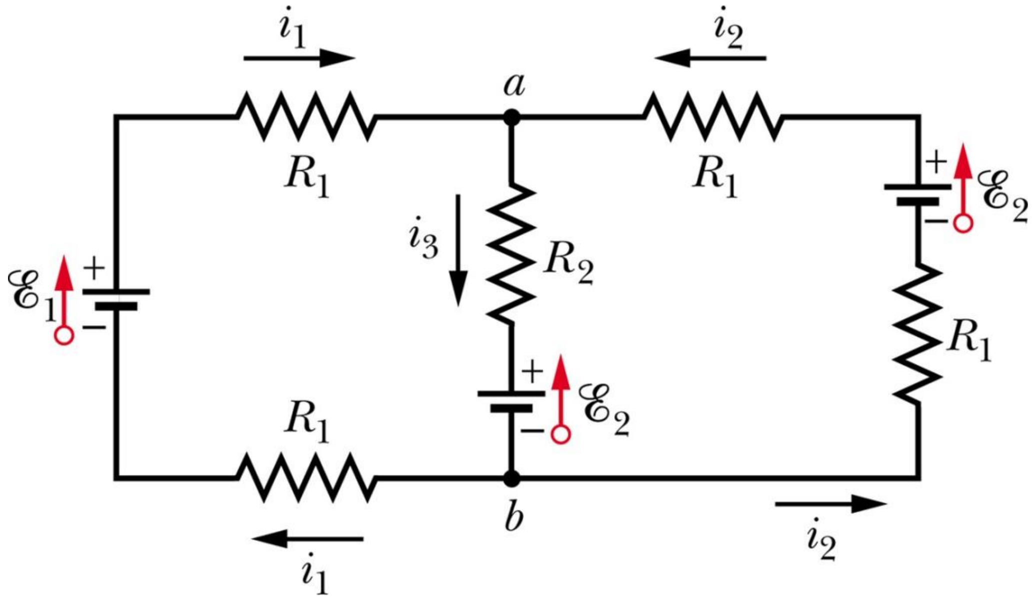


(b)

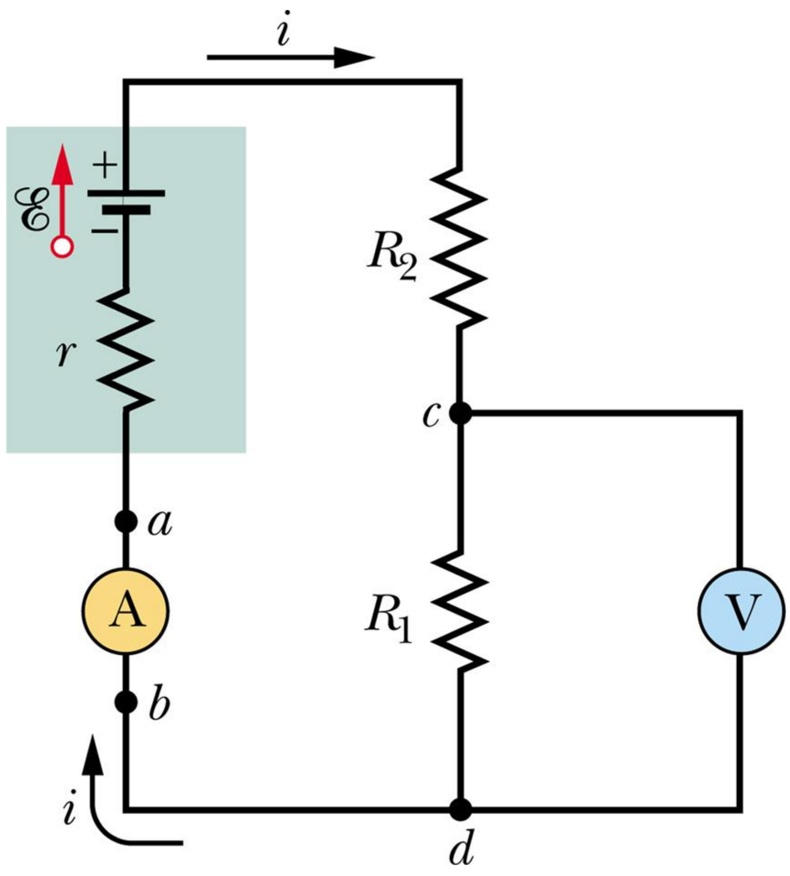


(c)

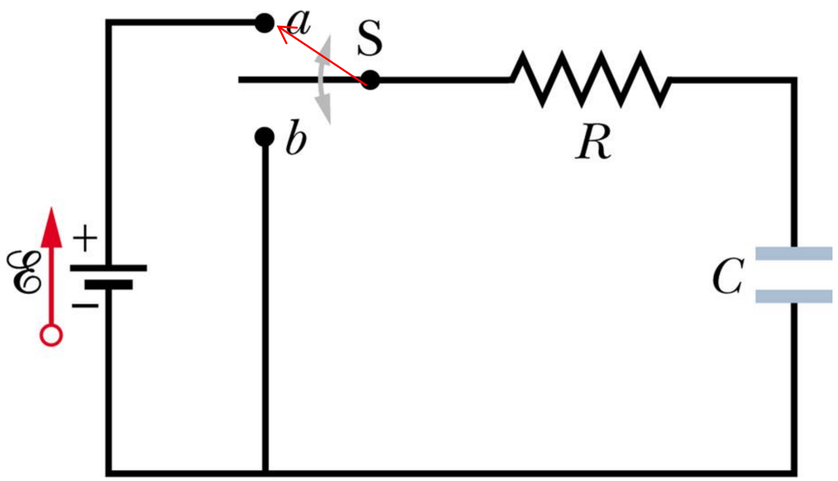
Example 3



Voltmeter and ammeter



RC circuit



Charging a capacitor

$$\mathcal{E} - iR - \frac{q}{C} = 0 \qquad i = \frac{dq}{dt}$$

$$R\frac{dq}{dt} + \frac{q}{C} = \mathcal{E}$$

우선 $\mathcal{E} = 0$ 인 경우 (homogeneous eq.)

$q = Ae^{at}$ 라고 놓으면, 위 식은

$$Ra + \frac{1}{C} = 0 \rightarrow a = -\frac{1}{RC}$$

$\mathcal{E} \neq 0$ 일 경우 가장 간단한 해는 $q = C\mathcal{E}$

$$q(t) = Ae^{-t/RC} + C\mathcal{E}$$

$t = 0$일 때 $q = 0$므로

$$A = -C\mathcal{E}$$

$$q(t) = C\mathcal{E}(1 - e^{-t/RC})$$