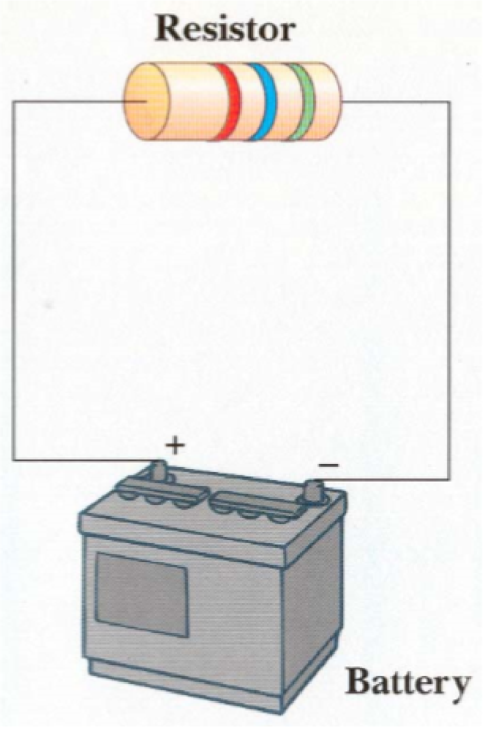
Chapter 27 Circuits

Chap. 27-1 Single-Loop Circuits
Chap. 27-2 Multi-Loop Circuits
Chap. 27-3 The Ammeter and The Voltmeter
Chap. 27-4 RC Circuits

Chap. 27-1 Single-Loop Circuits

기전력 (electromotive force : emf)

1. 기전력(electro-motive force: emf)
   - 두 단자 사이에 전위차를 유지시켜 주는 능력(힘)
   - $\mathcal{E}$: emf, 단위는 전압 (V)으로 표시

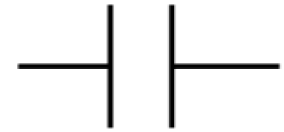


2. 기전력 장치들

   전지, 발전기, 태양전지, 연료전지등

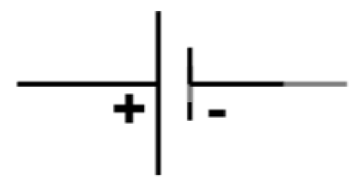
   이들을 보통 "전원(battery)"이라고 부름

Chap. 27-1 Single-Loop Circuits



- **Capacitors:**

  Purpose is to store charge (energy).
  - We have calculated the capacitance of a system
  - We had to modify Gauss' Law to account for bulk matter effects (dielectrics) … $C = \kappa C_0$
  - We calculated effective capacitance of series or parallel combinations of capacitors



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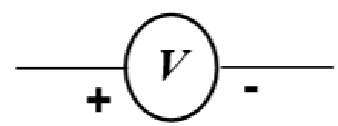
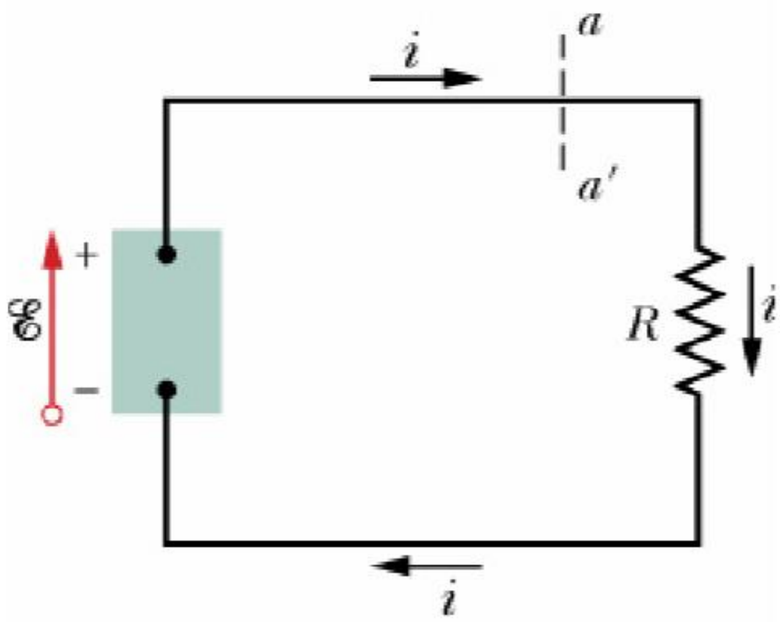
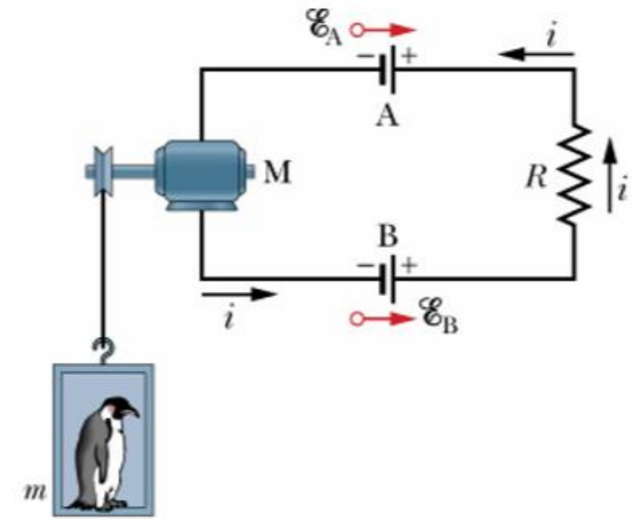


- **Batteries (Voltage sources, sources of emf):**

  Purpose is to provide a constant potential difference between two points.
  - Cannot calculate the potential difference from first principles... chemical ↔ electrical energy conversion. Non-ideal batteries will be dealt with in terms of an "internal resistance".

Chap. 27-1 Single-Loop Circuits

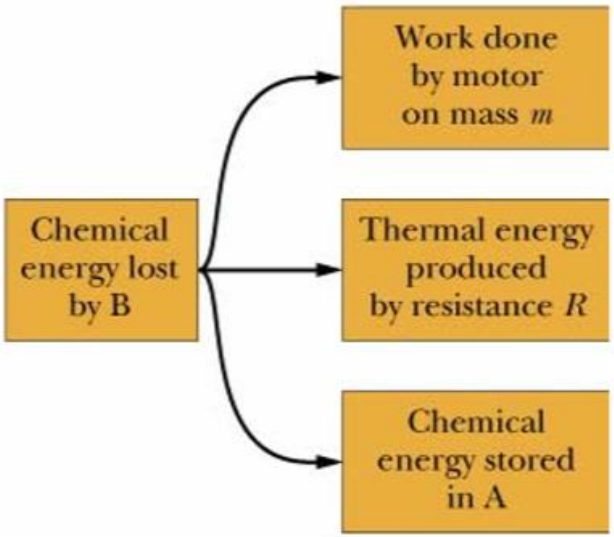




기전력이란 :

단위 전하를 낮은 퍼텐셜에서 높은 퍼텐셜로 이동시키기 위해 필요한 일

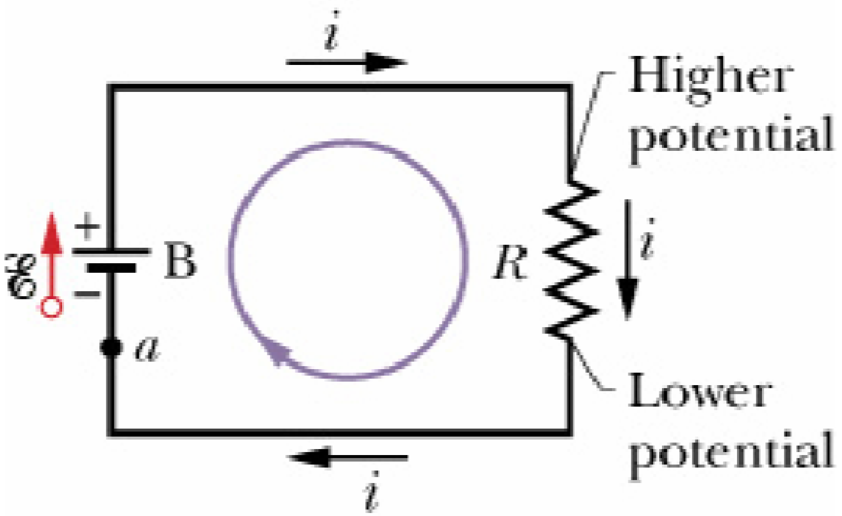
$$\varepsilon \equiv \frac{dW}{dq}$$ [J/C] =[V]



Chap. 27-1 Single-Loop Circuits

단일 회로 고리에서의 전류

에너지 보존법칙을 이용하기



기전력이 한 일 :

$$dW = \varepsilon dq = \varepsilon i dt$$

저항기에서 소모되는 열 에너지 :

$$dE = Pdt = i^2 R dt$$

$$\varepsilon i dt = i^2 R dt \quad \Rightarrow \quad \varepsilon = iR$$

$$\Rightarrow \quad \boxed{i = \frac{\varepsilon}{R}}$$

Chap. 27-1 Single-Loop Circuits

퍼텐셜 이용하기

회로규칙(loop rule) : 고리회로를 따라 퍼텐셜 차를 더해나가면 그 결과는 0 이다.

$$\sum_{closed} \Delta V = 0$$

a 에서 시작하여 전류방향으로 한바퀴 돌면,

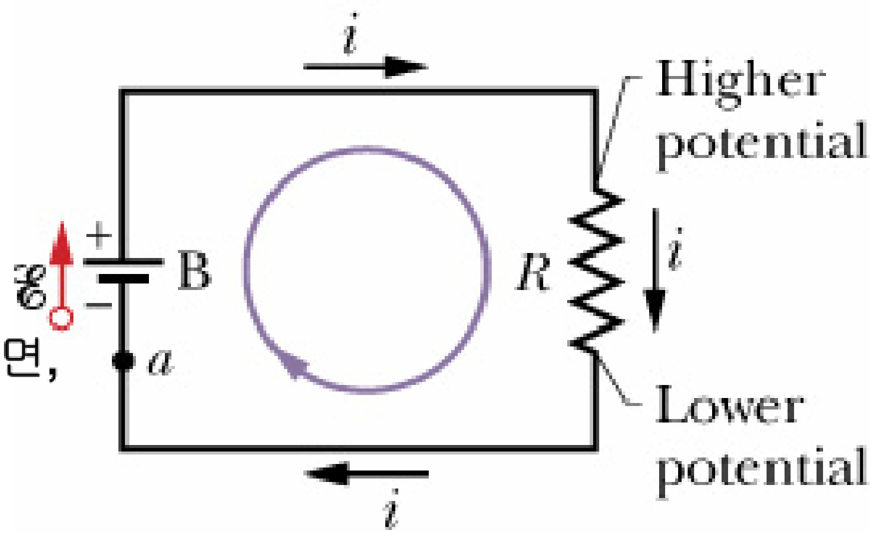
$$V_a + \varepsilon - iR = V_a$$

$$\varepsilon - iR = 0$$

a 에서 시작하여 전류방향 반대로 한바퀴 돌면,

$$iR - \varepsilon = 0$$

$$\Rightarrow \boxed{i = \frac{\varepsilon}{R}}$$

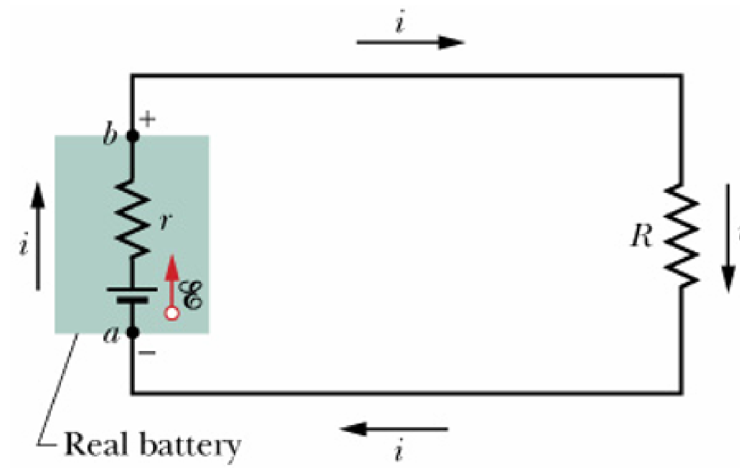


Chap. 27-1 Single-Loop Circuits

기전력장치(전원)의 내부저항

$$V_{ab} = \mathcal{E} - ir$$

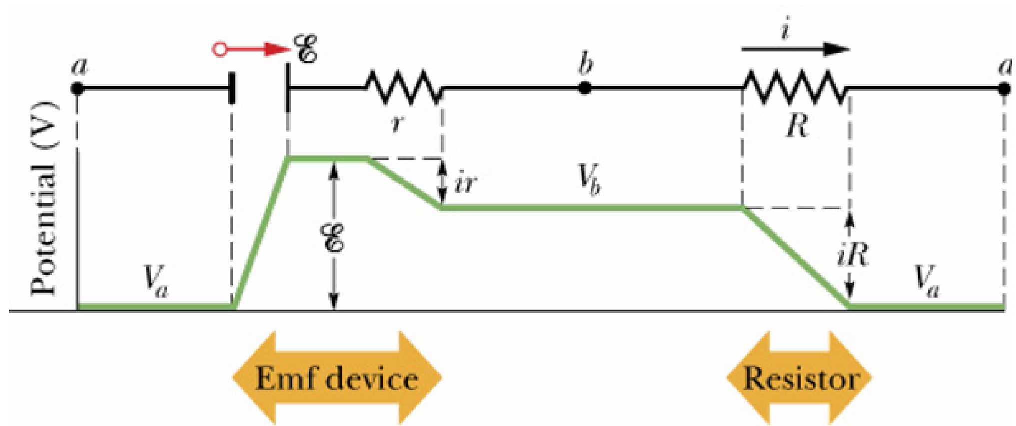
내부저항
Internal resistance



$$V_{ba} = iR$$

$$V_{ab} = V_{ba}$$

$$\mathcal{E} - ir = iR \qquad \Rightarrow i = \frac{\mathcal{E}}{R+r}$$



일률(Power) :

$$i\mathcal{E} = i^2R + i^2r$$

내부저항에 의한 열소모

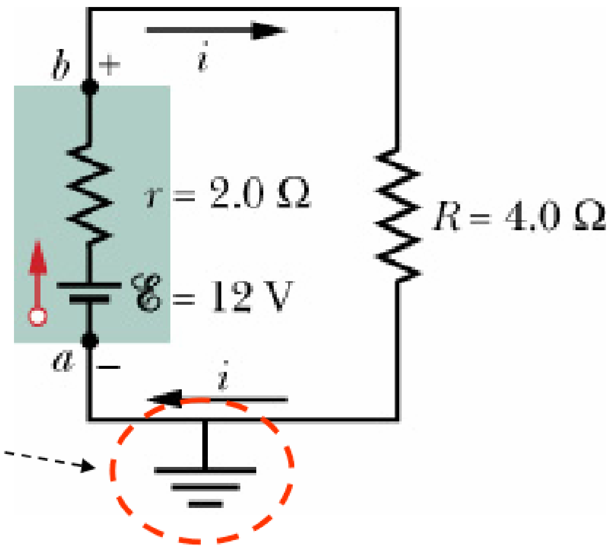
Chap. 27-1 Single-Loop Circuits

회로의 접지(ground)

접지 (ground) :

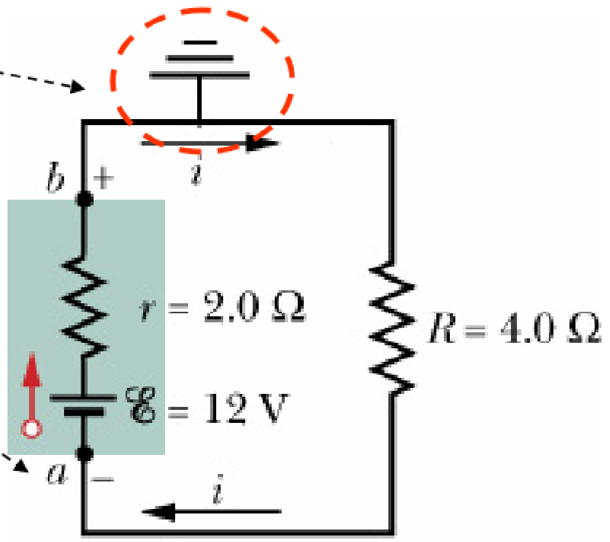
전기적으로 도체인 축축한 흙이나 지하 암반에 연결하는 것

접지에서의 퍼텐셜 = 0



$V_a = 0$

$V_b = 0$



(a 에서의 퍼텐셜은?)

$$i = \frac{\mathcal{E}}{R+r} = \frac{12V}{6\Omega} = 2A$$

$V_b = 0$ 이므로,

$V_a = -iR = -8.0\ V$

Chap. 27-2 Multi-Loop Circuits

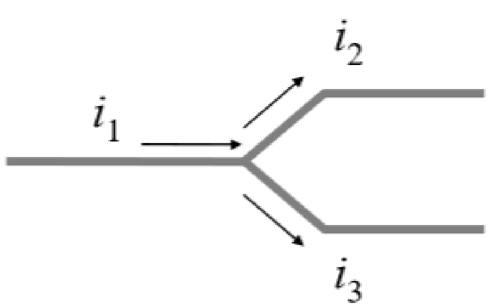
Kirchhoff 법칙 (rule)

키르히호프의 고리규칙

1. $\sum_{closed} \Delta V = 0$ → *Energy conservation*

키르히호프의 접점규칙

2. $\sum_a i_a = 0$ (**접점-junction**) → *Charge conservation*



$$\sum i = -i_1 + i_2 + i_3 = 0$$

$$i_1 = i_2 + i_3$$

Chap. 27-2 Multi-Loop Circuits

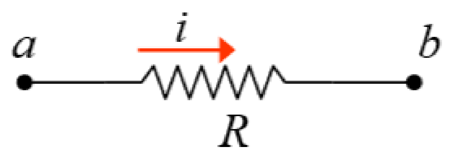
Kirchhoff의 회로규칙

키르히호프의 고리규칙

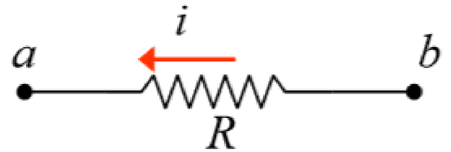
$$\sum_{closed} \Delta V = 0$$

Energy conservation

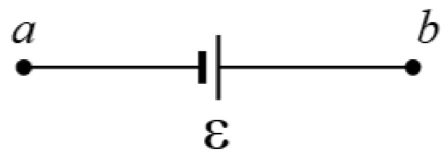
a → b 로 가는 동안 R 과 e 에서의 퍼텐셜 변화



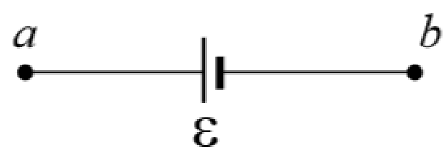
$$\Delta V = V_b - V_a = -IR$$



$$\Delta V = V_b - V_a = IR$$



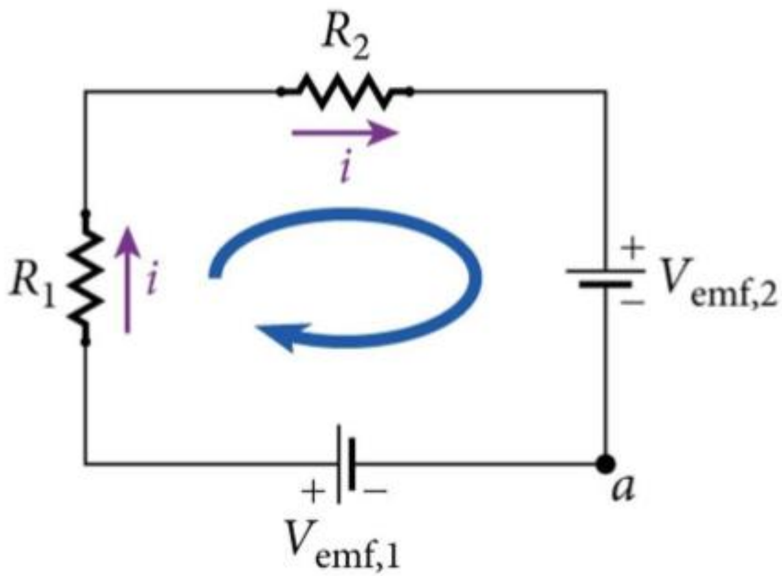
$$\Delta V = V_b - V_a = \varepsilon$$

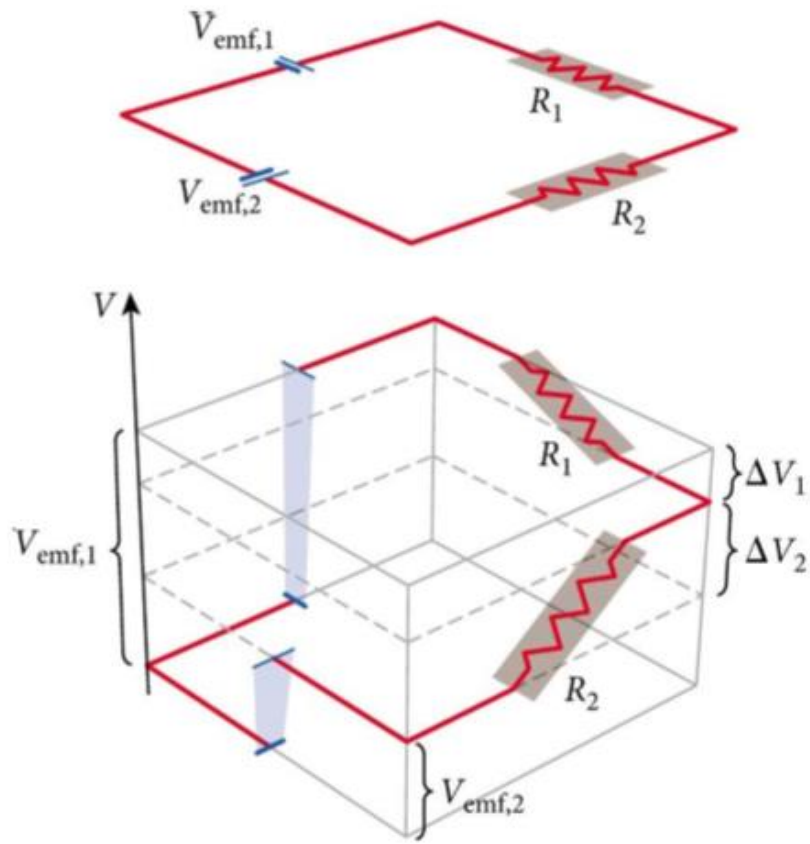


$$\Delta V = V_b - V_a = -\varepsilon$$

Chap. 27-2 Multi-Loop Circuits

- 단일고리 회로 예



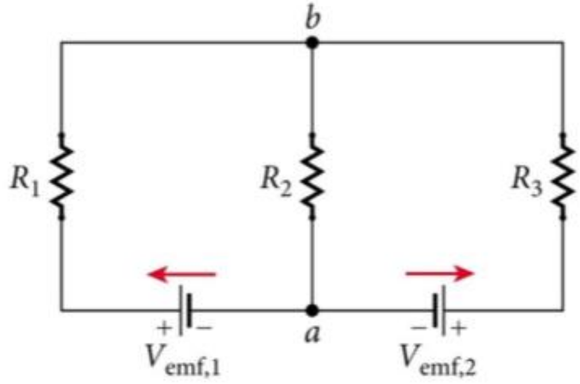


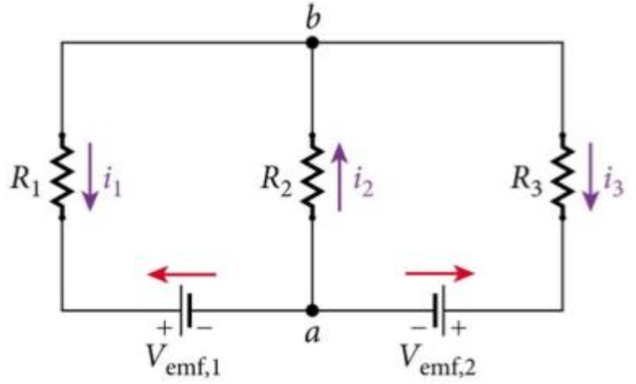
- 접점규칙 : 접점이 없다.
- 고리규칙 : $V_{\mathrm{emf},1} - iR_1 - iR_2 - V_{\mathrm{emf},2} = 0$

$$i = \frac{V_{\mathrm{emf},1} - V_{\mathrm{emf},2}}{R_1 + R_2}$$

Chap. 27-2 Multi-Loop Circuits

- **다중고리 회로 예**





- 접점규칙 : $i_2 = i_1 + i_3$

N개의 접점
⇒ N-1 개의 독립적인 식

- 고리규칙 :

$$-i_1 R_1 - V_{\mathrm{emf},1} - i_2 R_2 = 0$$

$$-i_3 R_3 - V_{\mathrm{emf},2} - i_2 R_2 = 0$$

독립적인 고리의 수

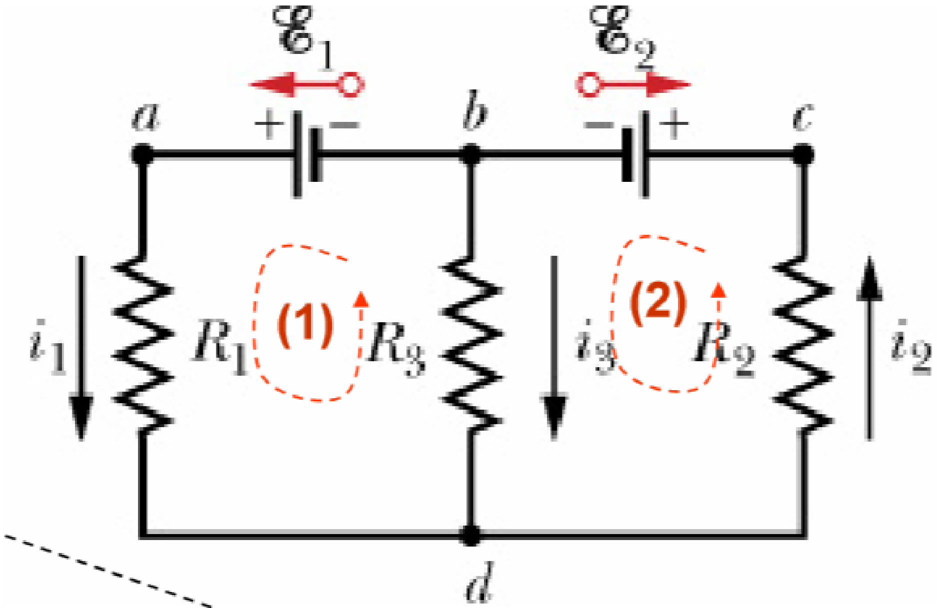
$$i_1 = -\frac{(R_2+R_3)V_{\mathrm{emf},1} - R_2 V_{\mathrm{emf},2}}{R_1R_2 + R_2R_3 + R_3R_1}$$

$$i_2 = -\frac{R_3 V_{\mathrm{emf},1} - R_1 V_{\mathrm{emf},2}}{R_1R_2 + R_2R_3 + R_3R_1}$$

$$i_3 = -\frac{-R_2 V_{\mathrm{emf},1} + (R_1+R_2)V_{\mathrm{emf},2}}{R_1R_2 + R_2R_3 + R_3R_1}$$

$$\begin{pmatrix} 1 & -1 & 1 \\ -R_1 & -R_2 & 0 \\ 0 & -R_2 & -R_3 \end{pmatrix} \begin{pmatrix} i_1 \\ i_2 \\ i_3 \end{pmatrix} = \begin{pmatrix} 0 \\ V_{\mathrm{emf},1} \\ V_{\mathrm{emf},2} \end{pmatrix}$$

Chap. 27-2 Multi-Loop Circuits



접점 b 에서,

$$\sum_a i_a = 0$$

$\Rightarrow$ $i_2 = i_1 + i_3$

(1) 번 고리에서:

$$\sum_{closed} \Delta V = 0 \Rightarrow \varepsilon_1 - i_1R_1 + i_3R_3 = 0$$

(2) 번 고리에서:

$$\sum_{closed} \Delta V = 0 \Rightarrow -i_3R_3 - i_2R_2 - \varepsilon_2 = 0$$

i_1 i_2 i_3

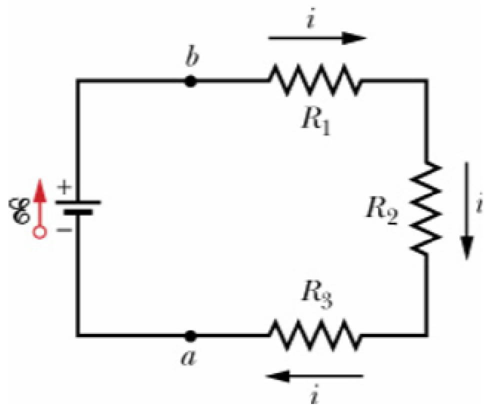
구할 수 있다.

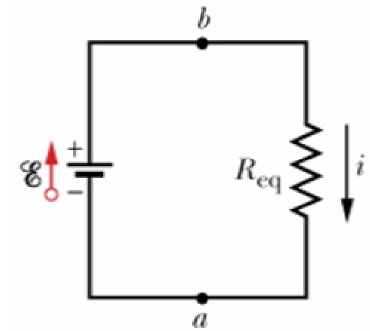
Chap. 27-2 Multi-Loop Circuits

저항 연결

직렬연결

→ 전류가 동일

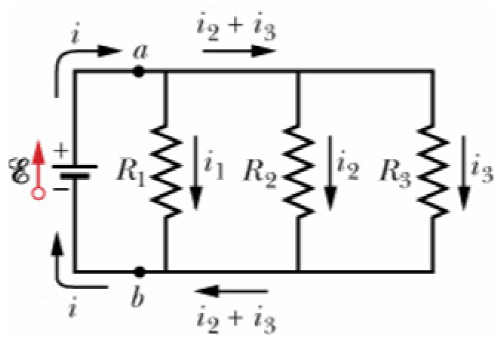


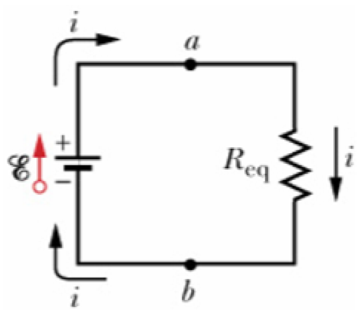


$$\varepsilon - i_1R_1 - i_2R_2 - i_3R_3 = 0 \rightarrow i = \frac{\varepsilon}{R_1 + R_2 + R_3} = \frac{\varepsilon}{R_{eq}} \rightarrow R_{eq} = \sum_{j=1}^{n} R_j$$

병렬연결

→ 퍼텐셜 차가 동일





$$i = i_1 + i_2 + i_3 = \varepsilon\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) = \frac{\varepsilon}{R_{eq}} \rightarrow \frac{1}{R_{eq}} = \sum_{j=1}^{n} \frac{1}{R_j}$$

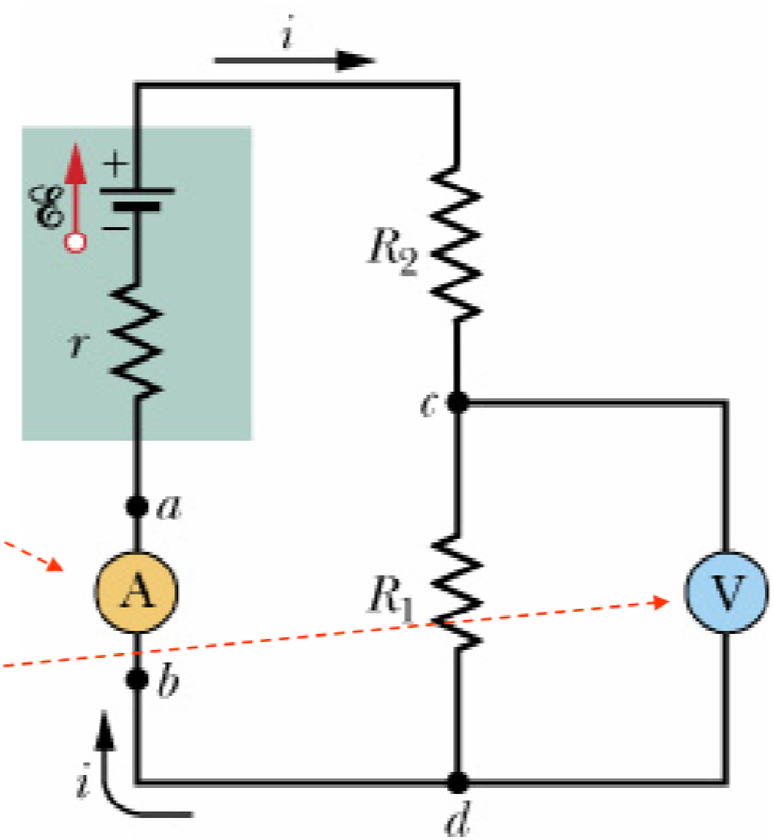
Chap. 27-3 The Ammeter and The Voltmeter

전류계

- 회로 속에 끼워 넣어 전류를 잼
- 내부저항이 아주 작아야 잰 값이 정확함 **(왜?)**

전압계

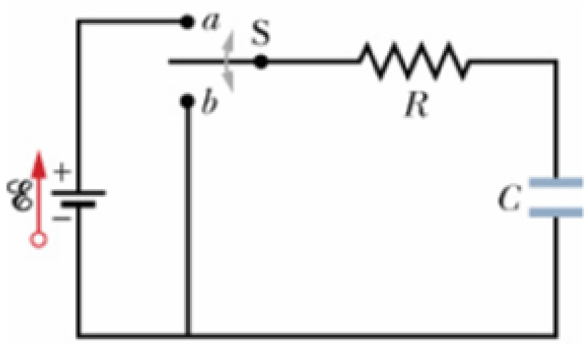
- 탐침을 두 점에 붙여 전위차를 잼
- 내부저항이 아주 커야 잰 값이 정확함 **(왜?)**



Chap. 27-4 RC Circuits

RC 회로

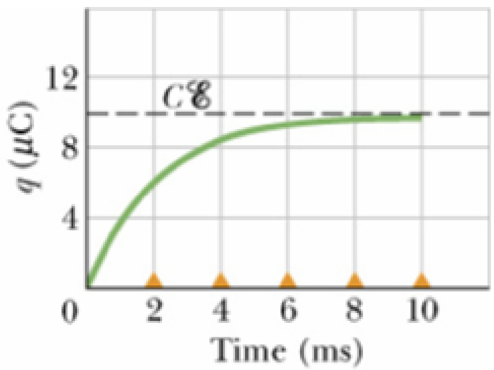
축전기의 충전 : switch가 a 에 있을 때



$$\varepsilon - iR - \frac{q}{C} = 0$$

$$i = \frac{dq}{dt}$$

$$R\frac{dq}{dt} + \frac{q}{C} = \varepsilon$$: 충전 방정식

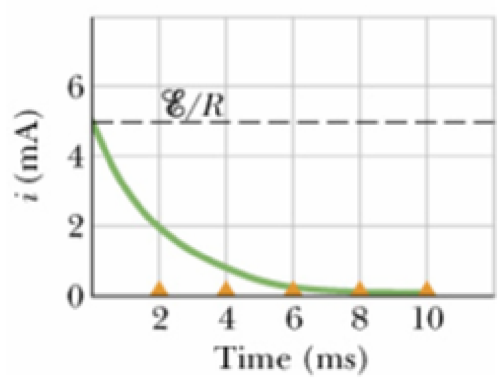


$$q(t) = C\varepsilon\left(1 - e^{-\frac{t}{RC}}\right)$$

$$\tau = RC$$

(시간상수)

$$i(t) = \left(\frac{\varepsilon}{R}\right)e^{-\frac{t}{RC}}$$



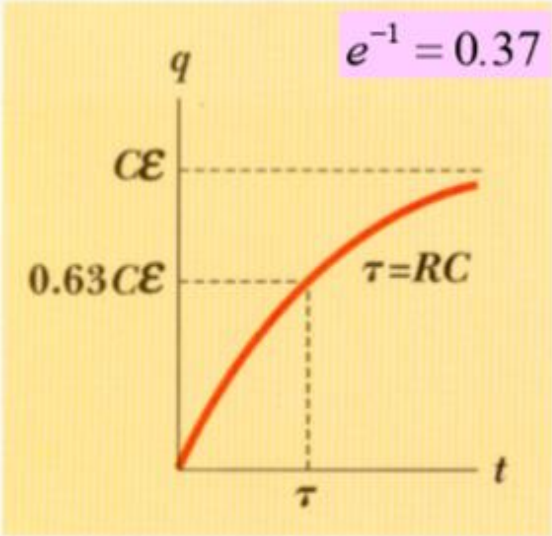
Chap. 27-4 RC Circuits

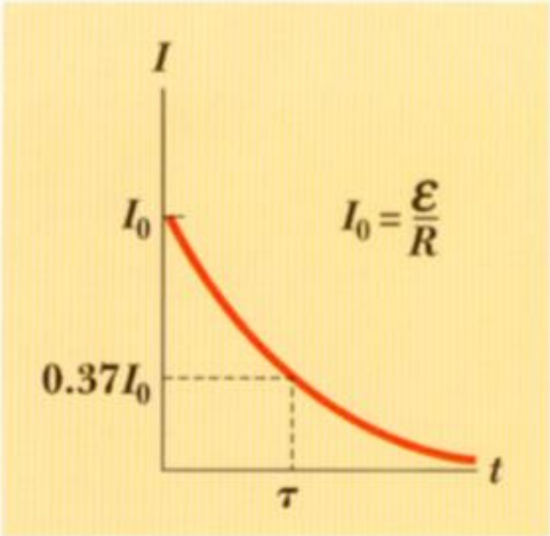
시간상수 : $\tau = RC$

$$\tau = RC = \left[\frac{\Delta V}{I}\cdot\frac{q}{\Delta V}\right] = \left[\frac{q}{I}\right] = \left[\frac{q}{q/t}\right] = T$$

$$R = 10\Omega,\ C = 1\mu F \quad \Rightarrow \tau = RC = 10^{-5}\ sec$$

$$\Rightarrow\ q(t) = C\varepsilon\left(1 - e^{-\frac{t}{RC}}\right) \qquad \Rightarrow\ i(t) = \left(\frac{\varepsilon}{R}\right)e^{-\frac{t}{RC}}$$

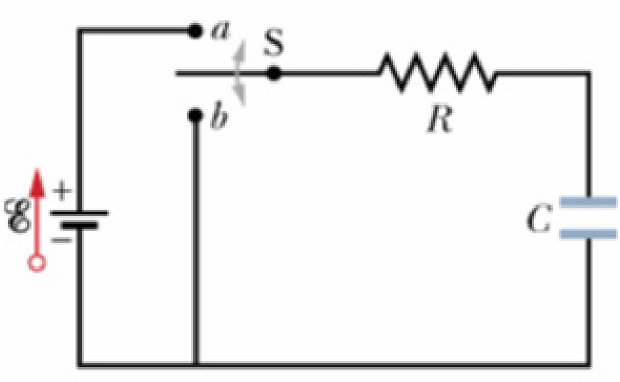




Chap. 27-4 RC Circuits

RC 회로 : 방전

축전기의 방전 : switch가 b 에 있을 때



$$R\frac{dq}{dt}+\frac{q}{C}=0$$: 방전 방정식

➡ $q(t)=q_0e^{-\frac{t}{RC}}$ $\{q_0=q(t=0)=CV_0\}$

➡ $i(t)=-\left(\frac{q_0}{RC}\right)e^{-\frac{t}{RC}}$

Electrical Safety

- Electric current flowing through the human body is dangerous.
  - The table below lists the effects of various currents.
    - Much lower currents can be dangerous if applied internally.
  - It takes voltage to drive current through the body.
  - Thus, it's a combination of high voltage and the capability to supply at least tens of milliamperes (mA) that's most dangerous.

Table 24.3 Effects of Externally Applied Current on Humans

Current Range	Effect
0.5–2 mA	Threshold of sensation
10–15 mA	Involuntary muscle contractions; can't let go
15–100 mA	Severe shock; muscle control lost; breathing difficult
100–200 mA	Fibrillation of heart; death within minutes
>200 mA	Cardiac arrest; breathing stops; severe burns

Grounding for Electrical Safety

- In conventional power systems, one side of the power line is connected to the ground.
  - This prevents the power system from reaching arbit rary high potentials with respect to ground.
  - But it presents danger in the event of a failure that brings a person into contact with the "hot" wire.
    - Grounded appliances and tools reduce this danger.
      - So do ground-fault circuit interrupters (GFCIs).