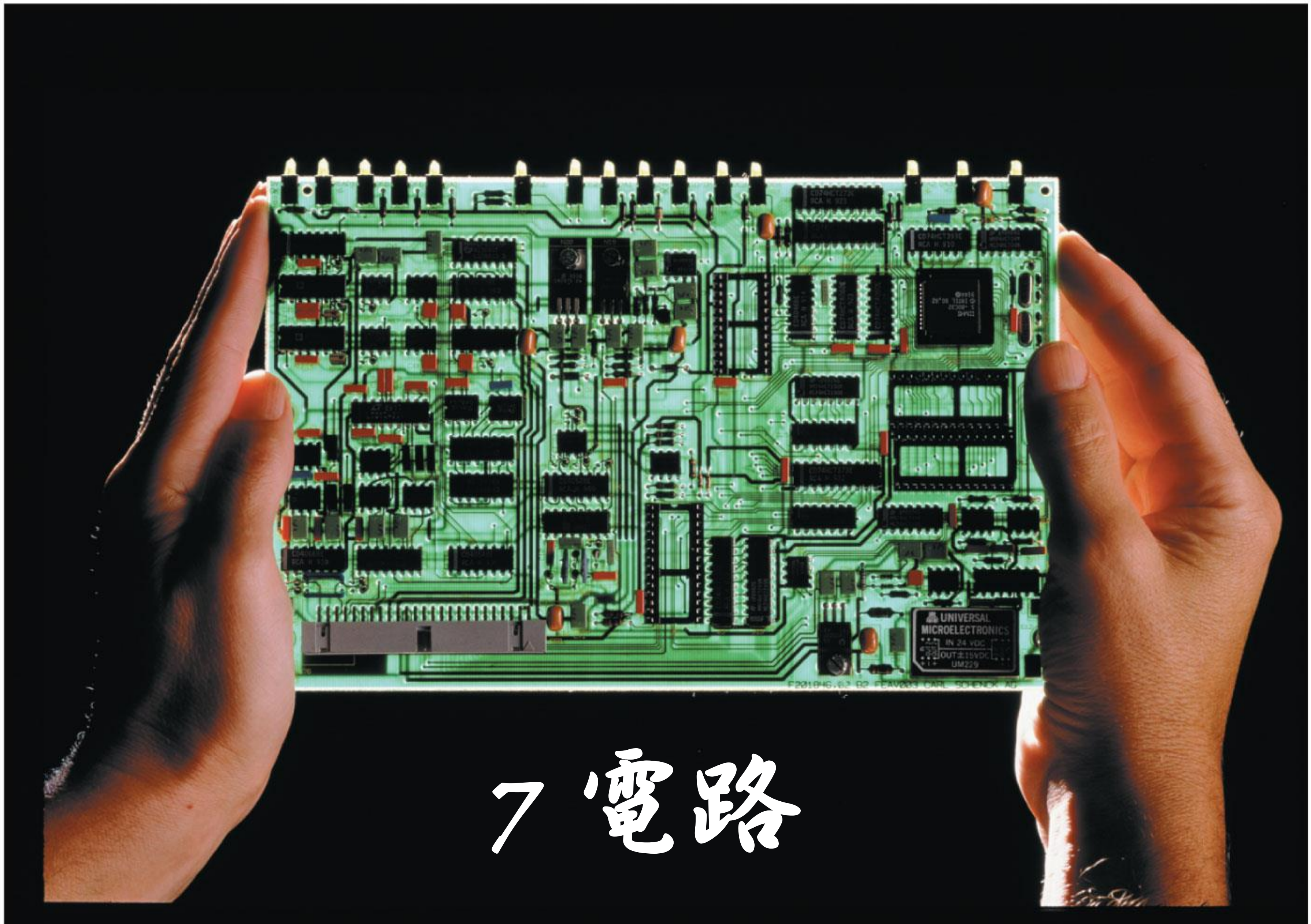
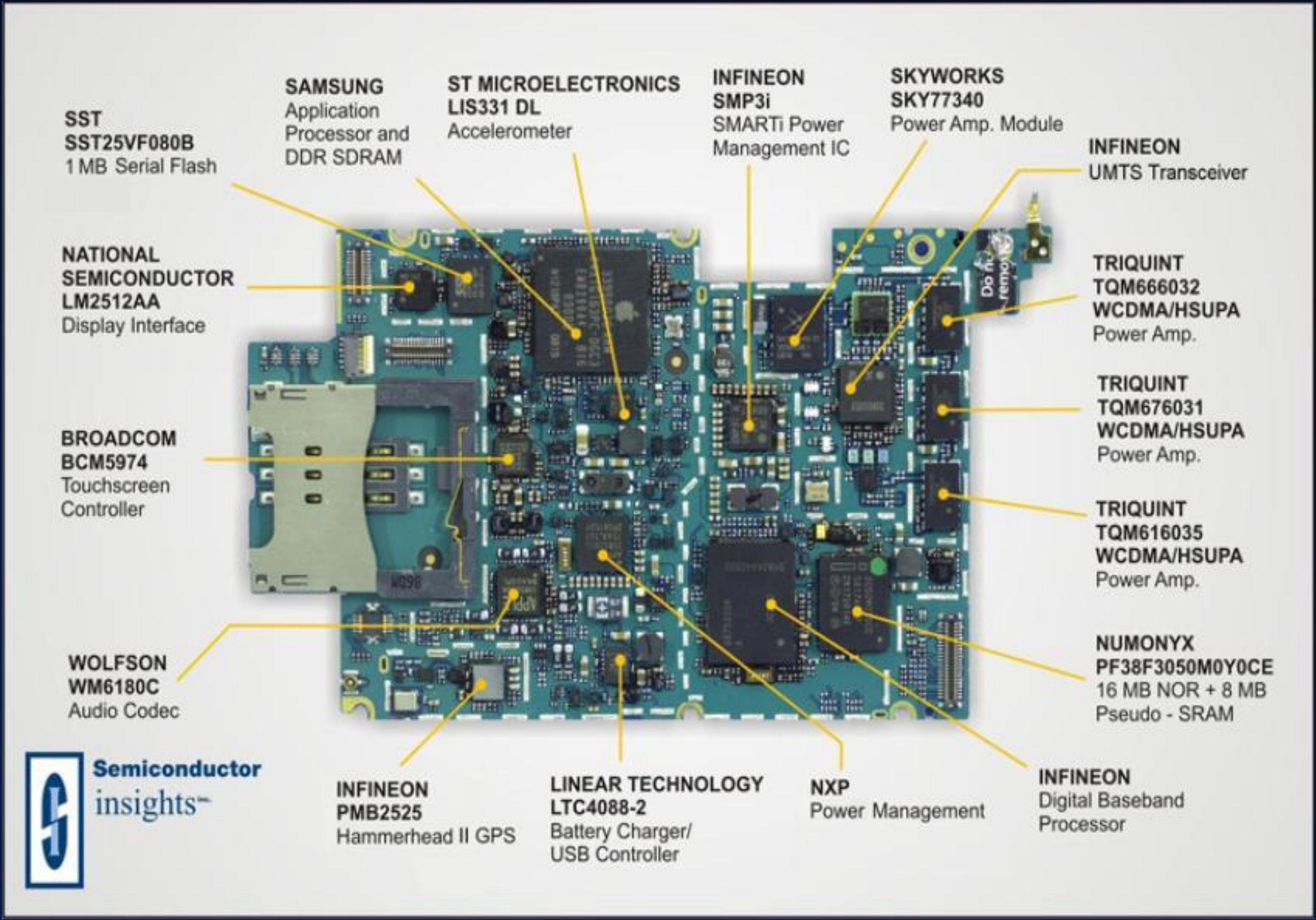


7 電路

Cellular Phone System Diagram



Outline

7.1 直流電路

7.2 串聯電阻

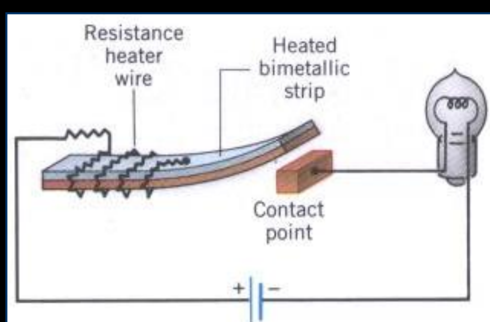
7.3 並聯電阻

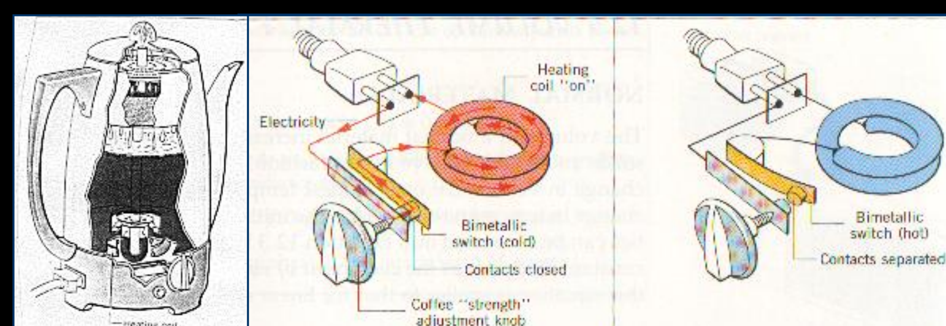
7.4 交流電路

7.5 虛擬電路實驗

7.1直流電路

- *Direct Current Circuit*
- *A bimetallic strip flasher*
- 以電阻電熱絲加熱bimetallic strip，約一秒啟閉一次，可用作警示裝置。



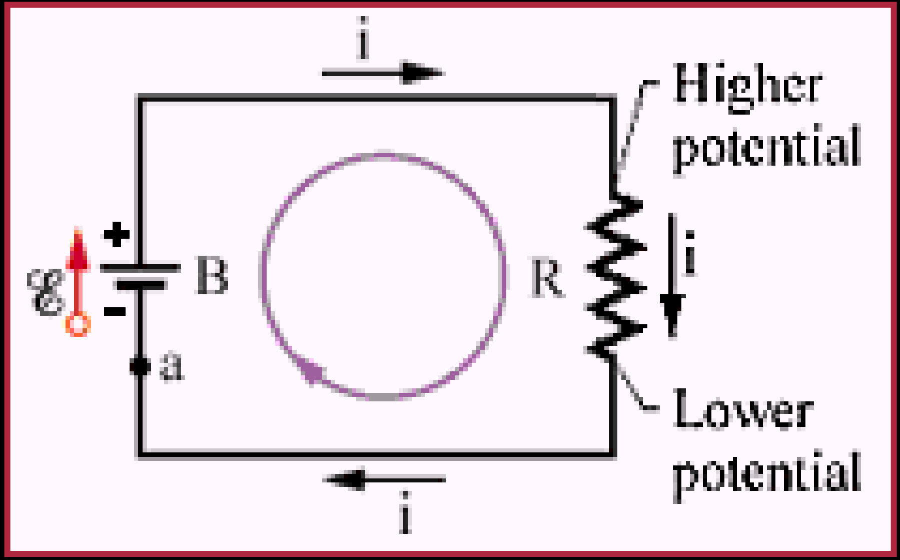


Ex.1 簡單直流電路內之電位（電壓）升降

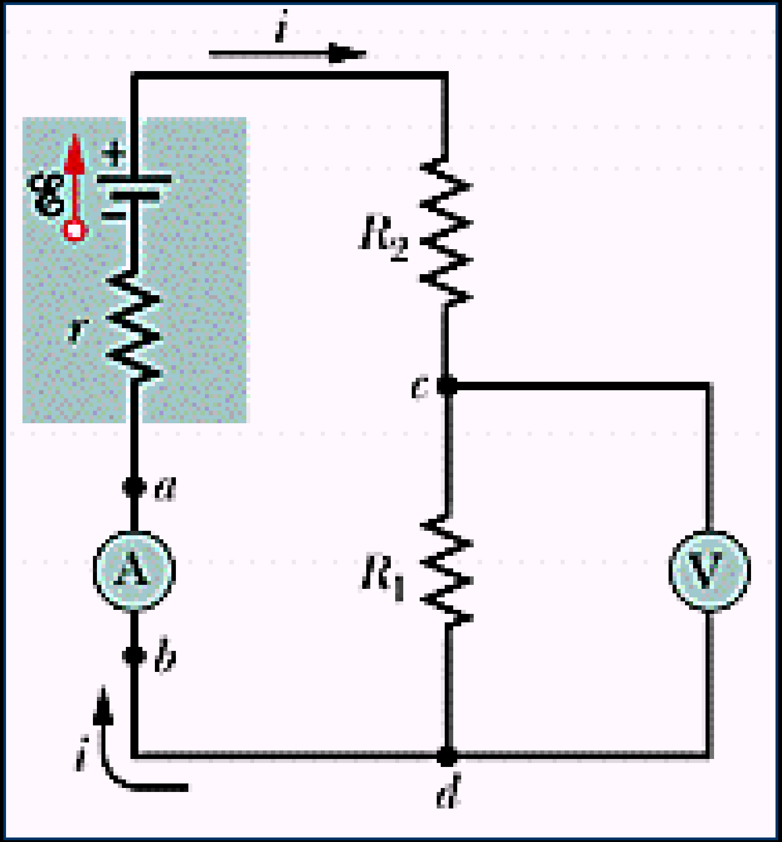
$$V_a + \mathcal{E} - iR = V_a$$

$$\mathcal{E} = iR$$

克希荷夫 Kirchhoff 迴路定理

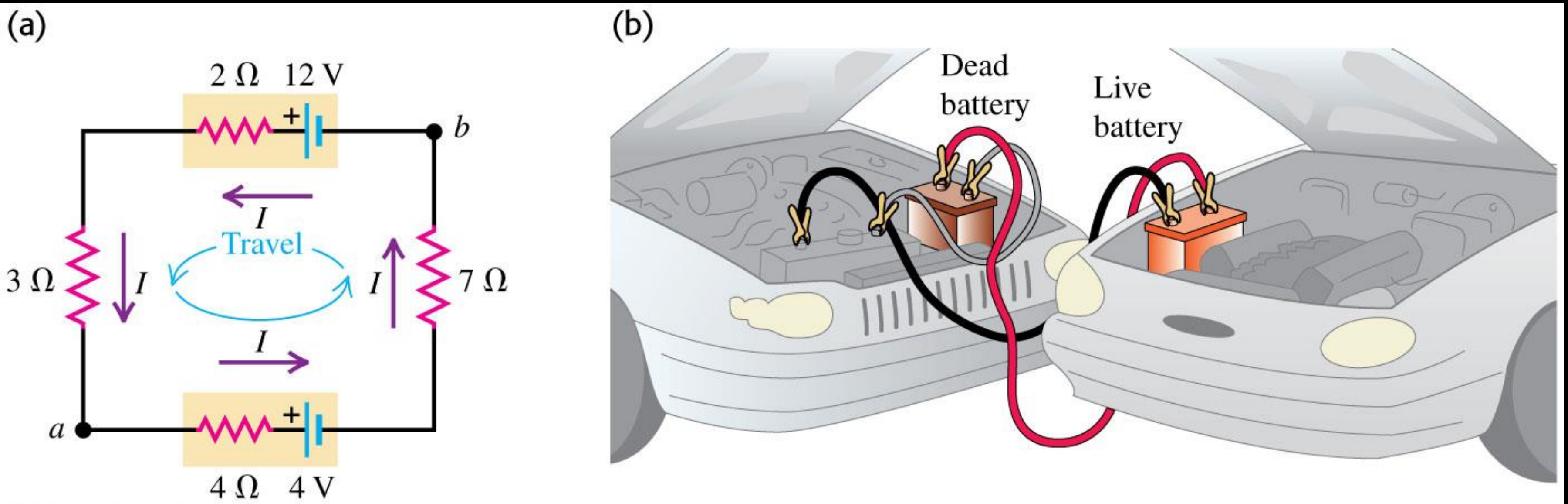


Ex.2 The Ammeter and the Voltmeter



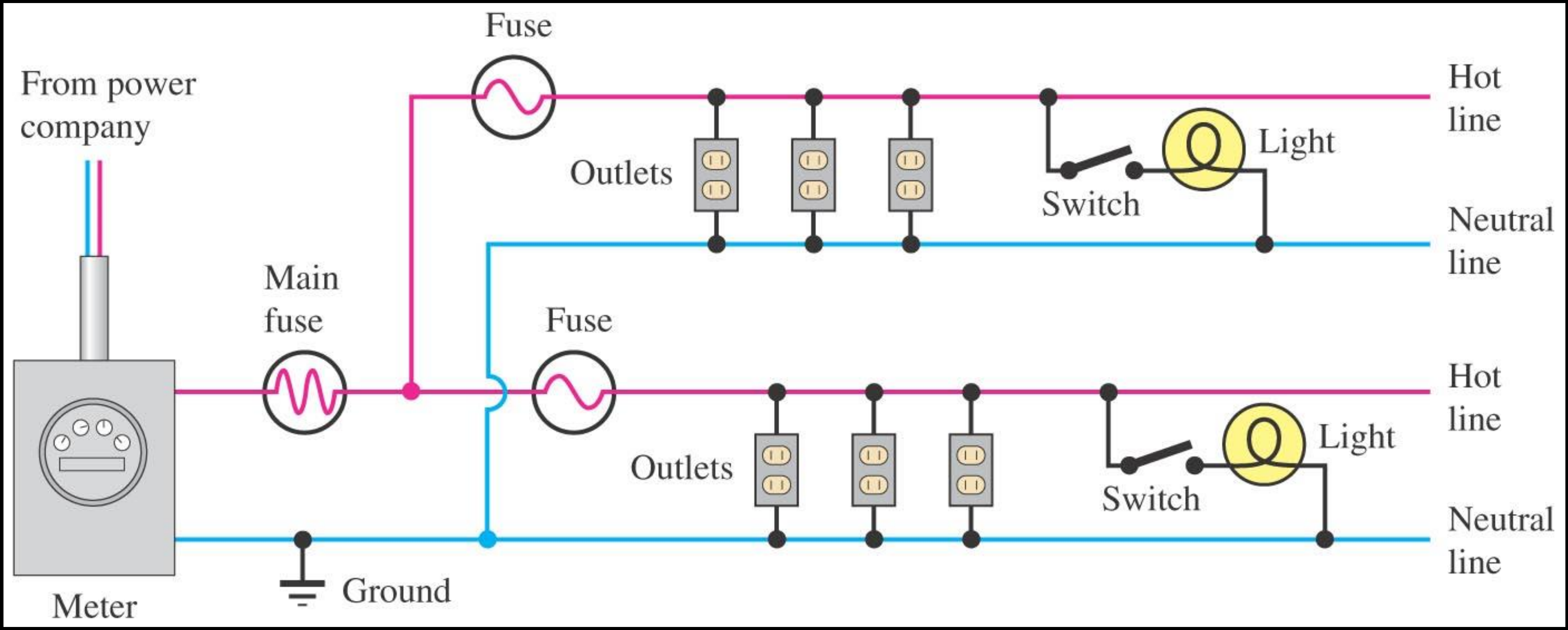
A single-loop circuit

- **Follow Example 26.3, using Figure 26.10 below.**



Power distribution systems

- Follow the text discussion using Figure 26.24 below.



Household wiring

- Figure 26.26 at the right shows why it is safer to use a three-prong plug for electrical appliances.

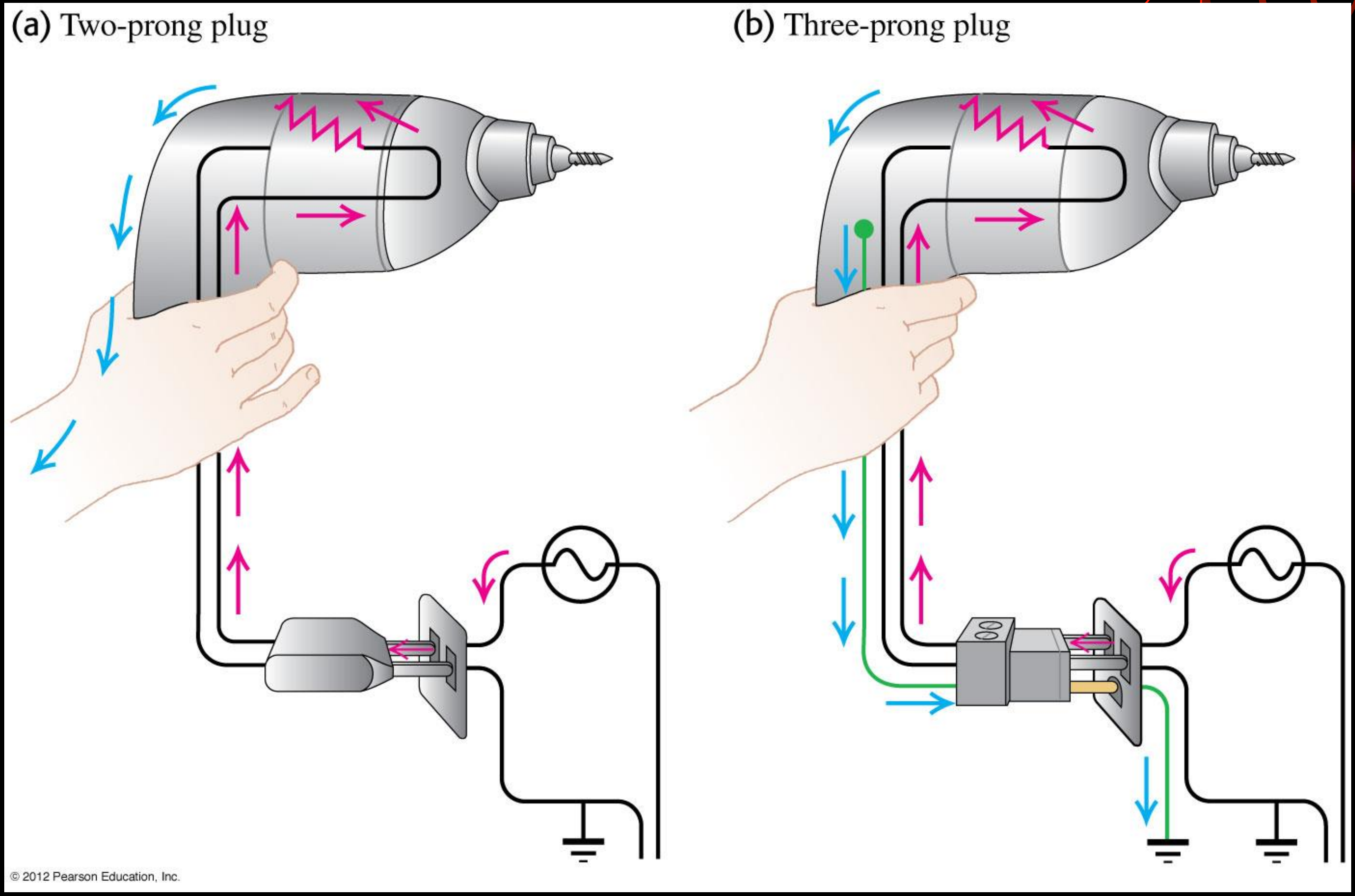
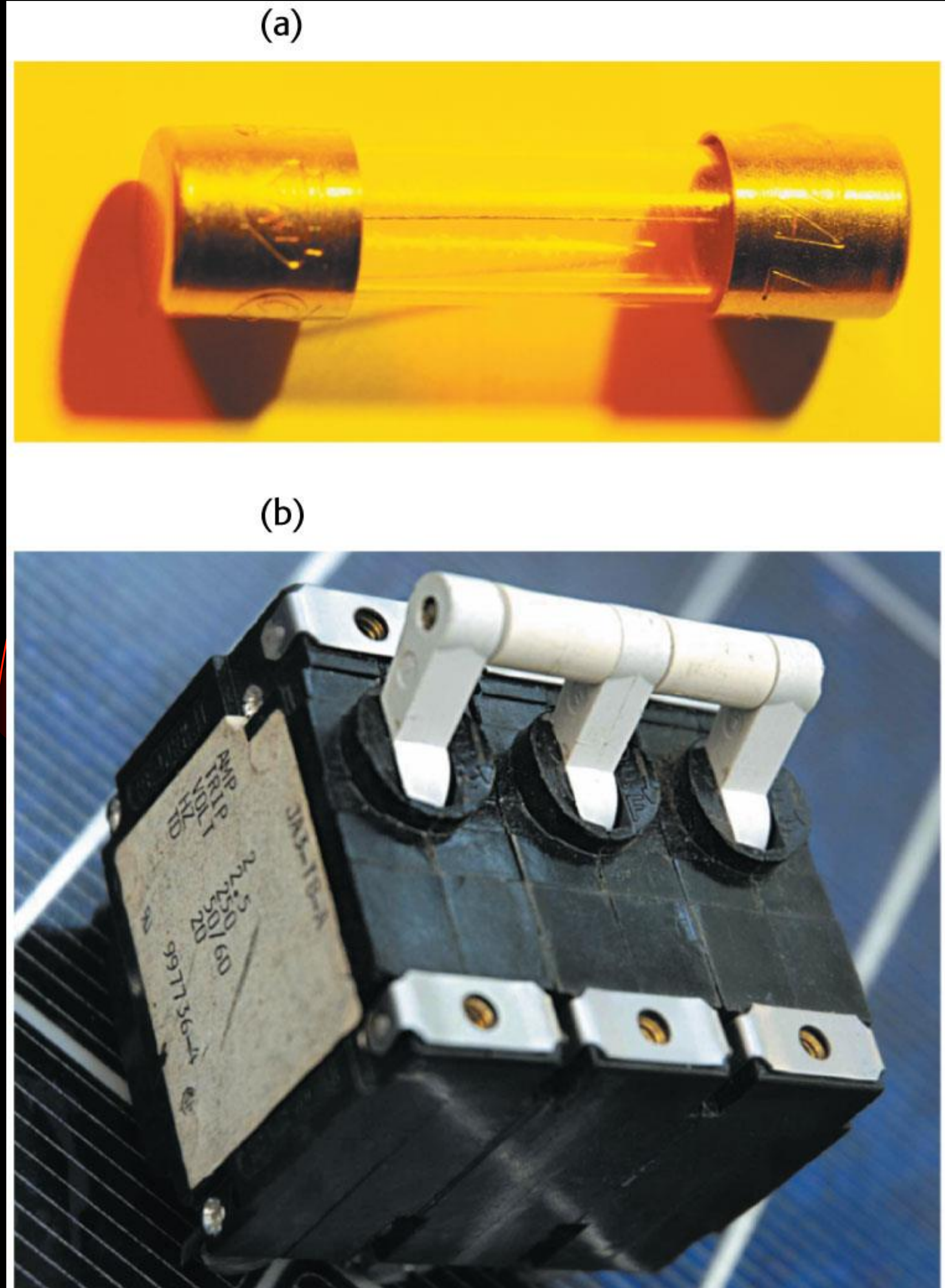


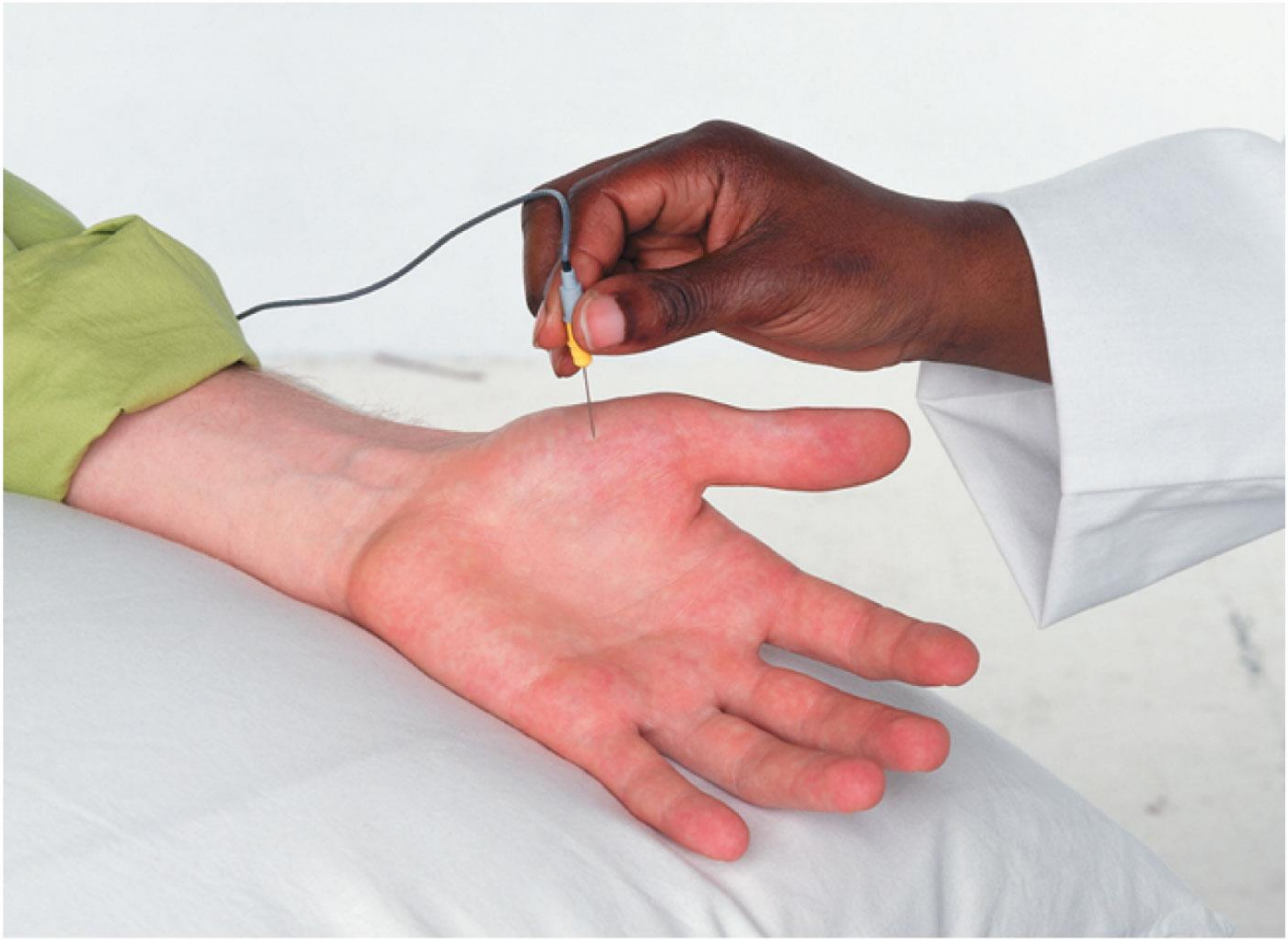
Figure 26.25

fuse

Circuit breaker

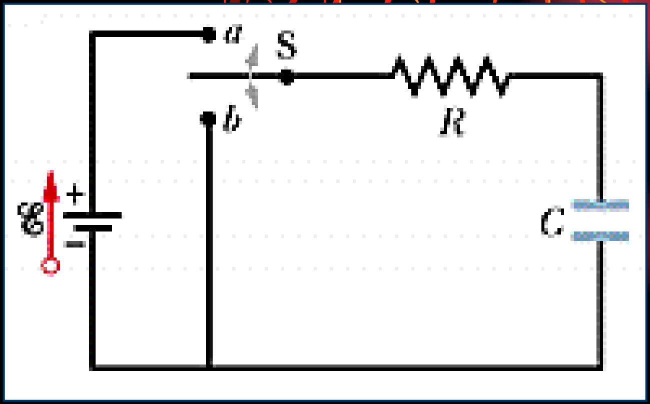


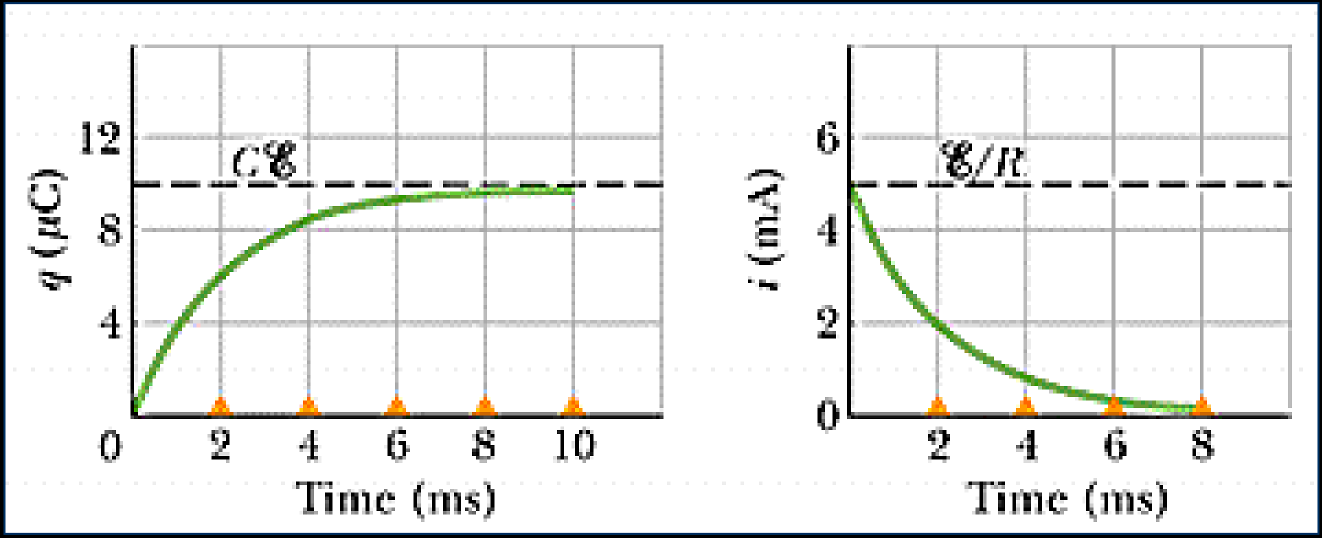
Neuromyography



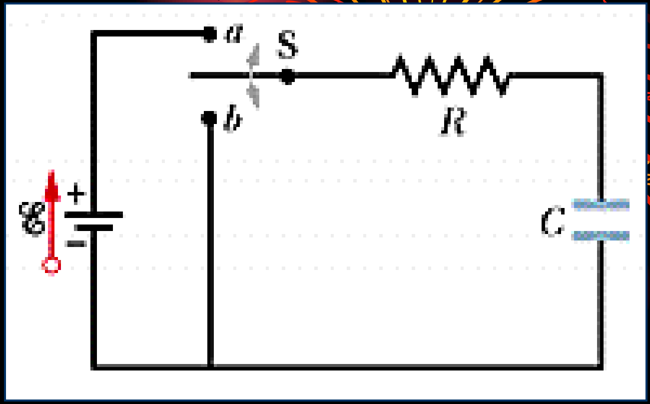
Ex.3 RC電路

電阻－電容電路





Ex.3 (cont) Charging a Capacitor



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

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

$$\rightarrow \frac{dq}{dt} = \frac{\mathcal{E}}{R} - \frac{q}{RC} = -\frac{1}{RC}(q - C\mathcal{E})$$

$$\rightarrow \frac{dq}{(q - C\mathcal{E})} = -\frac{dt}{RC} \rightarrow \frac{d(q - C\mathcal{E})}{(q - C\mathcal{E})} = -\frac{dt}{RC}$$

Ex.3 (cont)

$$\rightarrow \int \frac{d(q - C\mathcal{E})}{(q - C\mathcal{E})} = -\int \frac{dt}{RC}$$

$$\rightarrow \ln(q - C\mathcal{E}) = -\frac{t}{RC} + \text{Const.}$$

$$\rightarrow q - C\mathcal{E} = e^{-\frac{t}{RC} + \text{const}}$$

$$\rightarrow q - C\mathcal{E} = e^{-\frac{t}{RC}} e^{\text{const}} = C' e^{-\frac{t}{RC}}$$

What is C′?

Ex.3 (Initial Condition)

$$\rightarrow q(t) - C\mathcal{E} = C' e^{-\frac{t}{RC}}$$

$$\xrightarrow{t=0} 0 - C\mathcal{E} = C' e^{-\frac{0}{RC}} \rightarrow C' = -C\mathcal{E}$$

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

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

$$i = \frac{dq}{dt} = \left(\frac{\mathcal{E}}{R}\right) e^{-t/RC}$$

Ex.3 (cont)

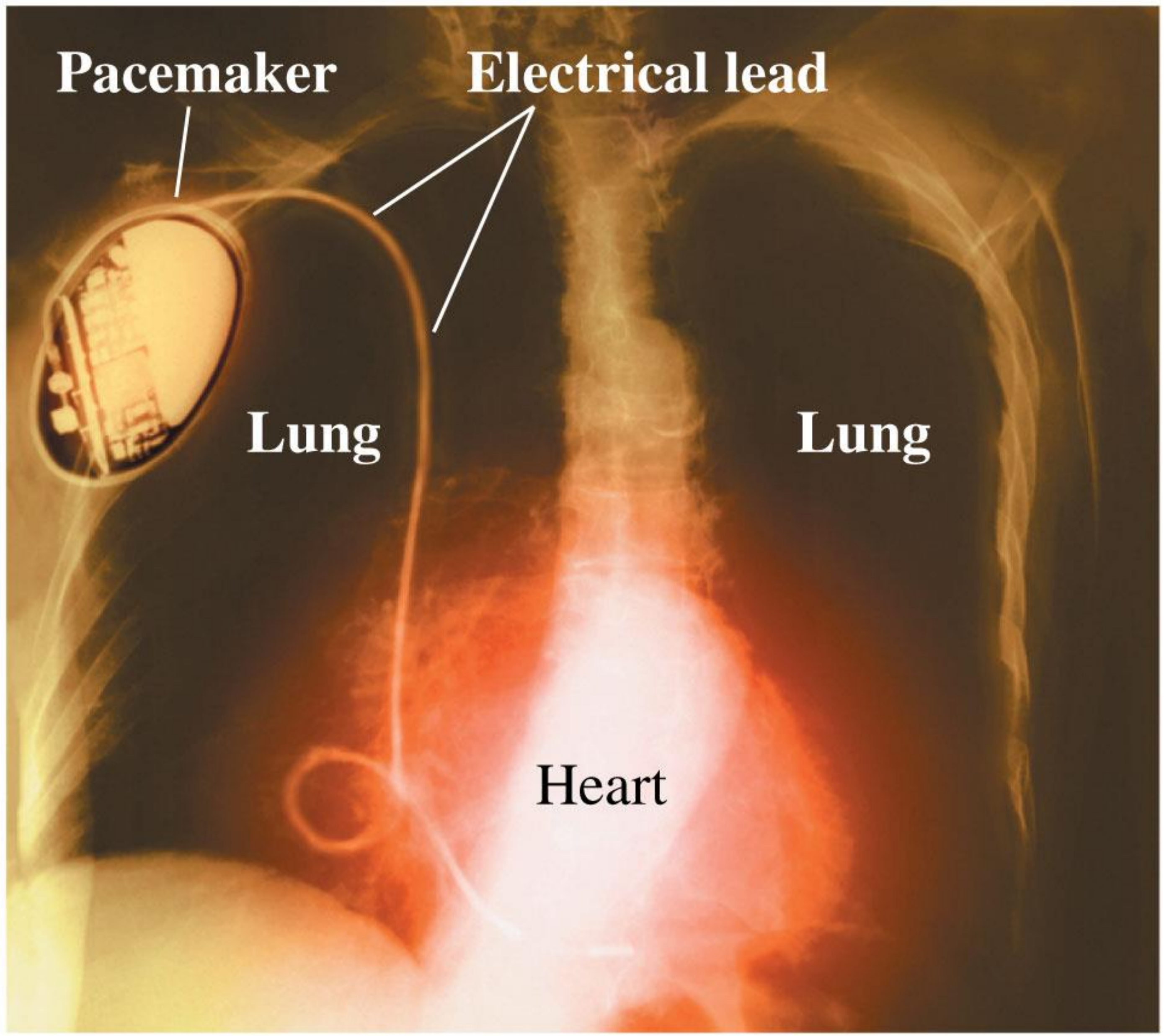
e^{-1}

$$q(RC) = C\mathcal{E}(1 - e^{-RC/RC}) = 0.63C\mathcal{E}$$

- 如果 $R = 10M\Omega \quad C = 1\mu F$

$$RC = (10 \times 10^6 \Omega)(10^{-6} F) = 10\text{s}$$

- 經過46s後，e= 0.01，充電達99%
- 可用作間歇式雨刷等電路控制．

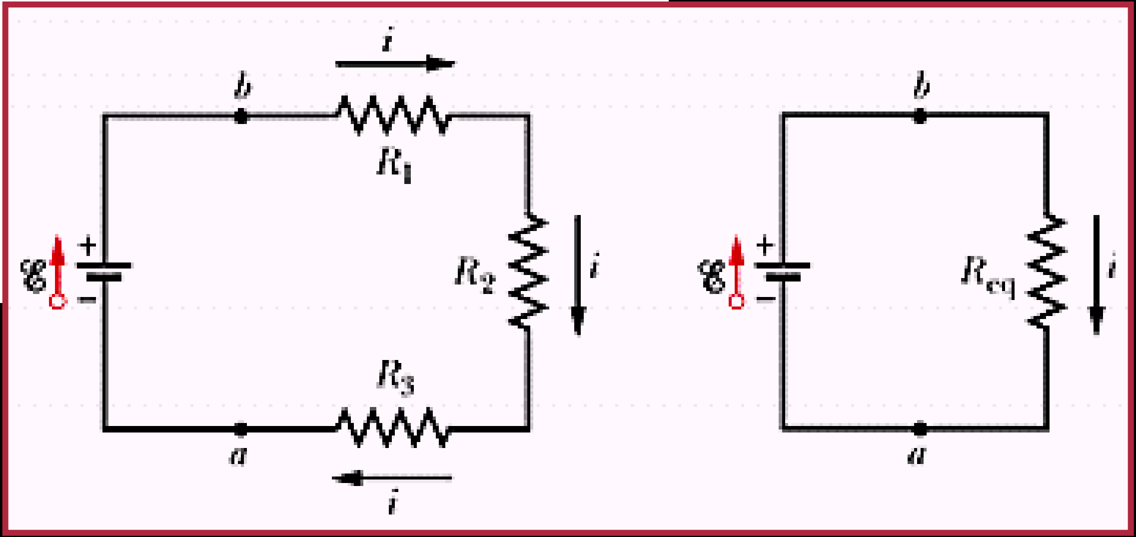

Pacemaker
Electrical lead
Lung
Lung
Heart

7.2 Resistance in series

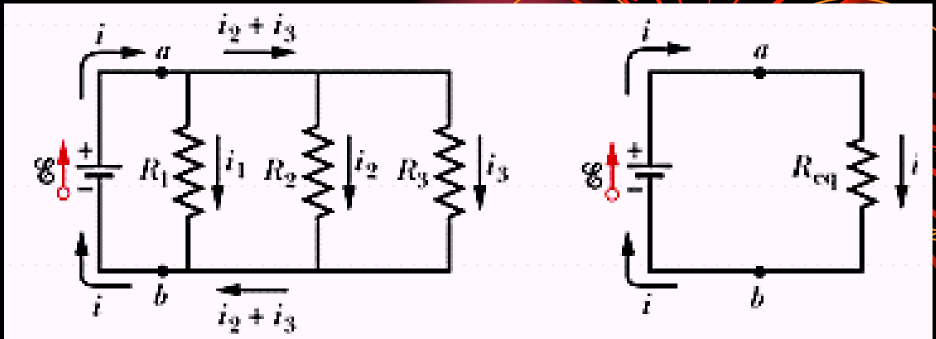
$$\mathcal{E} - iR_1 - iR_2 - iR_3 = 0$$

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

$$R_{eq} = \sum_{j=1}^{n} R_j$$



7.3 Resistors in parallel

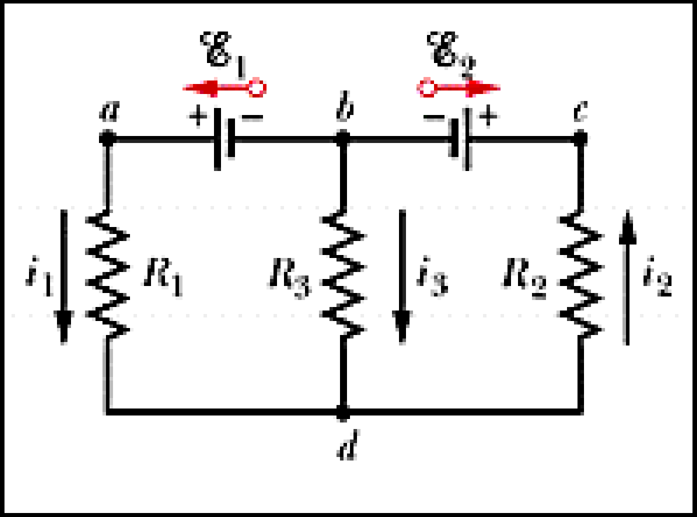


$$i_1 = \frac{\mathcal{E}}{R_1}, \; i_2 = \frac{\mathcal{E}}{R_2}, \; i_3 = \frac{\mathcal{E}}{R_3}$$

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

$$i = \frac{\mathcal{E}}{R_{eq}} \rightarrow \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Multiloop Circuits

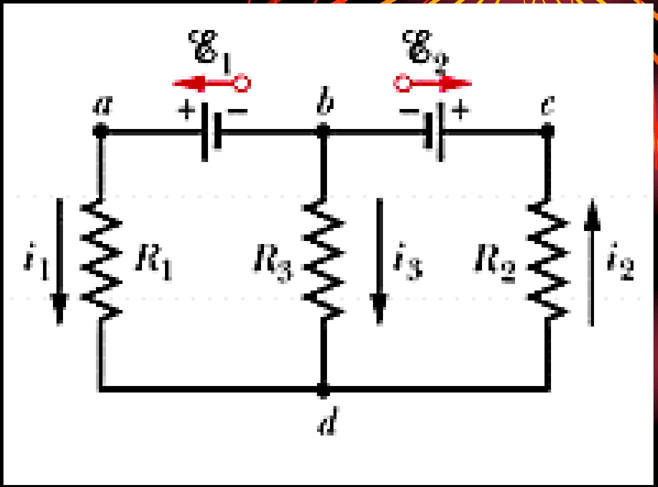


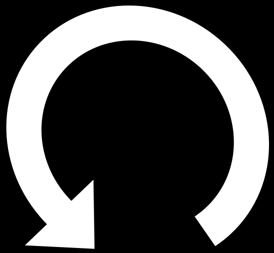
$$i_1 + i_3 = i_2$$

- The Junction rule: 流入接點之電流必等於流出者

(Kirchhoff's junction/current rule)

解System of equations (聯立方程組)



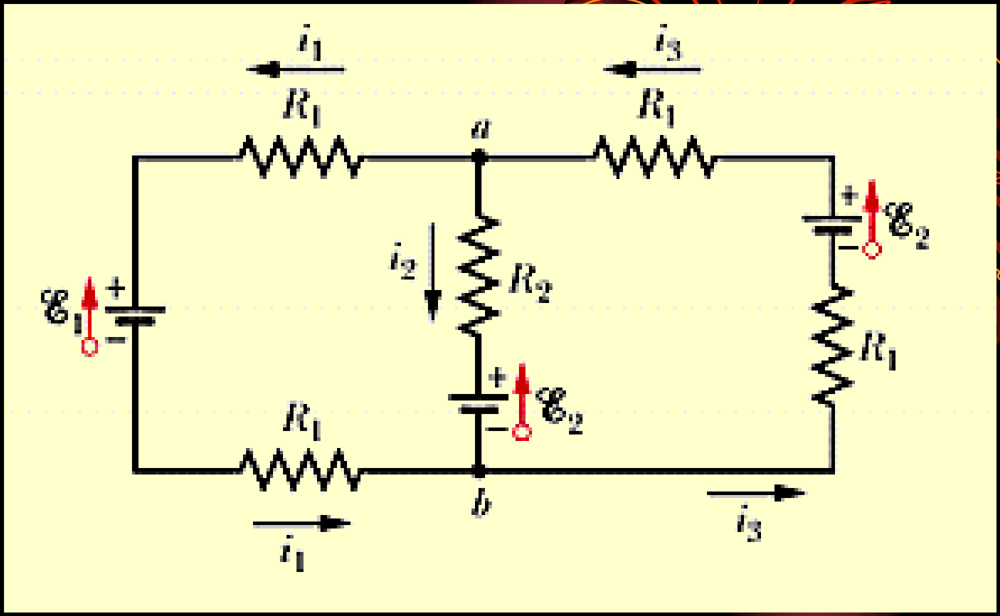


$$\mathcal{E}_1 - i_1R_1 + i_3R_3 = 0 \text{ left loop}$$

$$-i_3R_3 - i_2R_2 - \mathcal{E}_2 = 0 \text{ right loop}$$

$$\mathcal{E}_1 - i_1R_1 - i_2R_2 - \mathcal{E}_2 = 0 \text{ big loop}$$

Ex.4 What are the currents?



$$i_3 = i_1 + i_2$$

$$-i_1R_1 - \mathcal{E}_1 - i_1R_1 + \mathcal{E}_2 + i_2R_2 = 0$$

$$+i_3R_1 - \mathcal{E}_2 + i_3R_1 + \mathcal{E}_2 + i_2R_2 = 0$$

解聯立方程組

pivot equation

$$
\begin{cases}
6x_1 - 2x_2 + 2x_3 + 4x_4 = 16 \\
12x_1 - 8x_2 + 6x_3 + 10x_4 = 26 \\
3x_1 - 13x_2 + 9x_3 + 3x_4 = -19 \\
-6x_1 + 4x_2 + x_3 - 18x_4 = -34
\end{cases}
$$

$$
\begin{cases}
6x_1 - 2x_2 + 2x_3 + 4x_4 = 16 \\
- 4x_2 + 2x_3 + 2x_4 = -6 \\
- 12x_2 + 8x_3 + x_4 = -27 \\
2x_2 + 3x_3 - 14x_4 = -18
\end{cases}
$$

$$
\begin{cases}
6x_1 - 2x_2 + 2x_3 + 4x_4 = 16 \\
- 4x_2 + 2x_3 + 2x_4 = -6 \\
2x_3 - 5x_4 = -9 \\
4x_3 - 13x_4 = -21
\end{cases}
$$

高斯消去法

$$\begin{cases} 6x_1 - 2x_2 + 2x_3 + 4x_4 = 16 \\ \quad - 4x_2 + 2x_3 + 2x_4 = -6 \\ \quad\quad 2x_3 - 5x_4 = -9 \\ \quad\quad\quad - 3x_4 = -3 \end{cases}$$

pivot equation

upper triangle

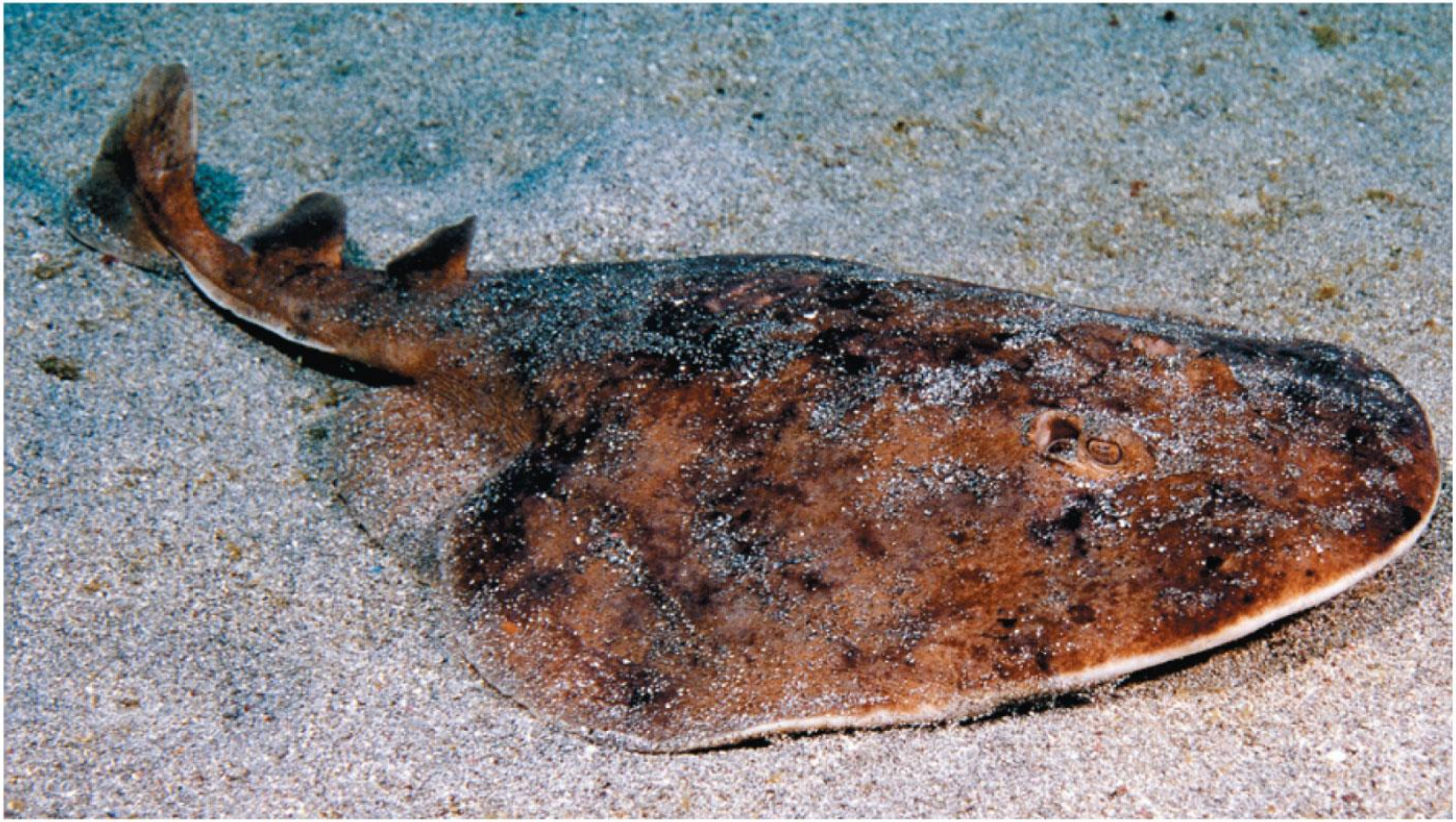
$$x_4 = \frac{-3}{-3} = 1 \qquad 2x_3 - 5 = -9$$

$$x_3 = \frac{-4}{2} = -2$$

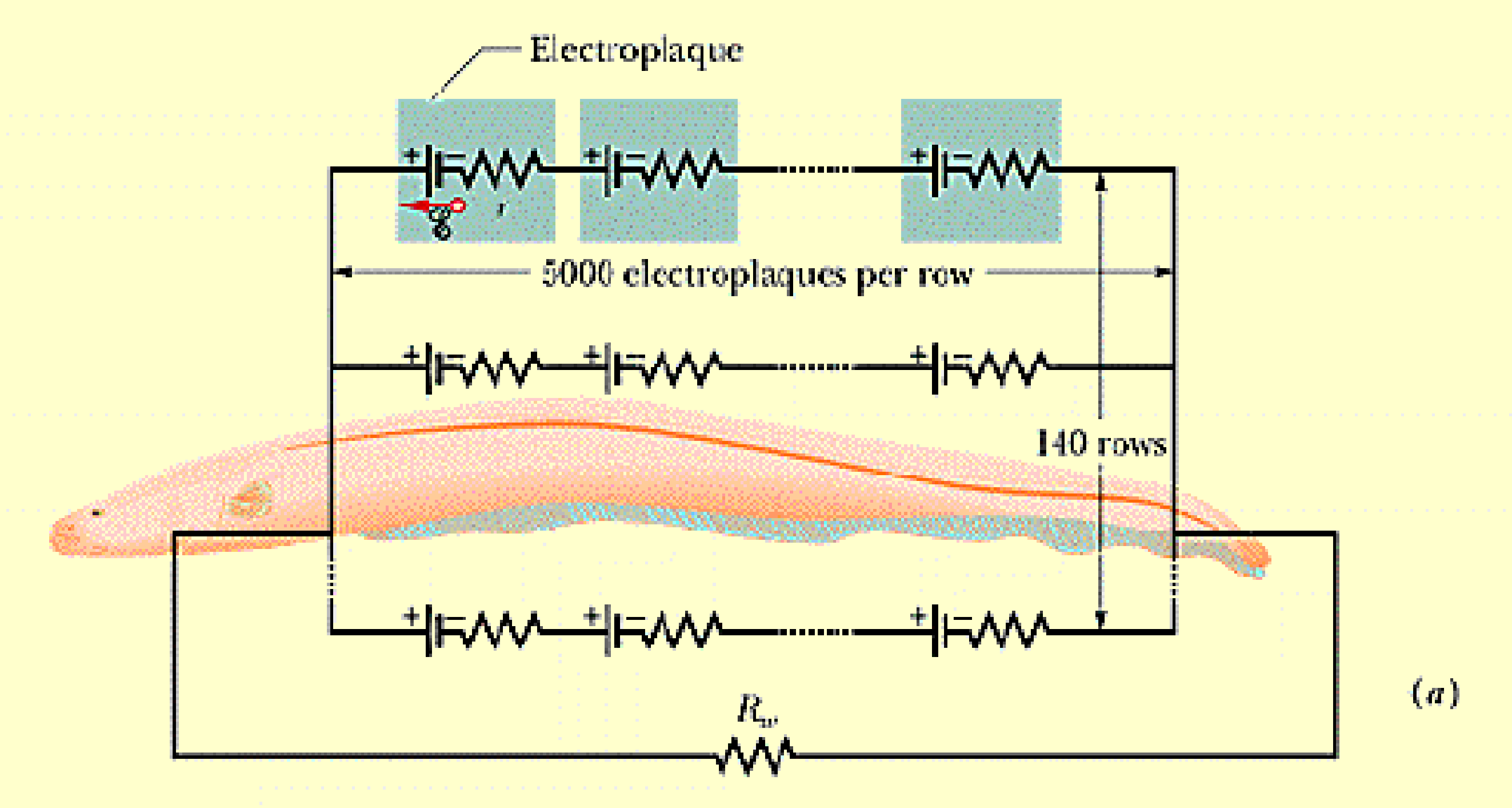
$$x_1 = 3 \qquad x_2 = 1 \qquad x_3 = -2 \qquad x_4 = 1$$

Forward Elimination and Back substitution

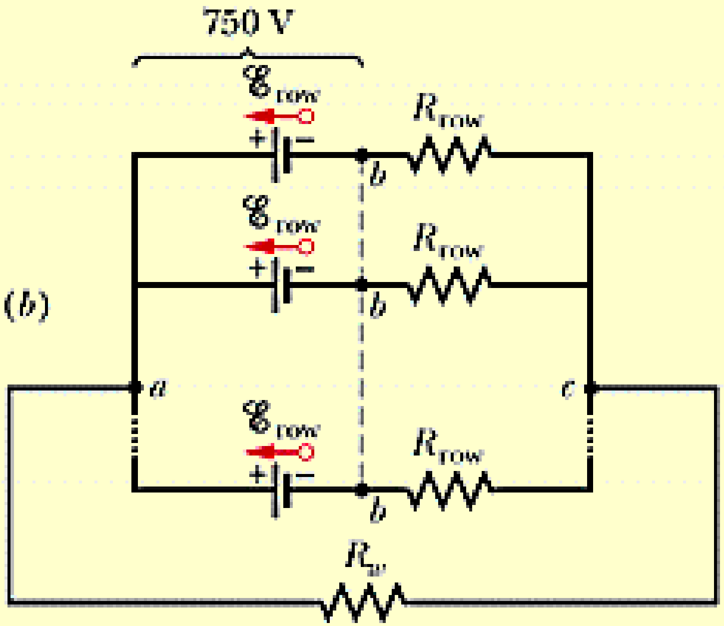
The torpedo ray

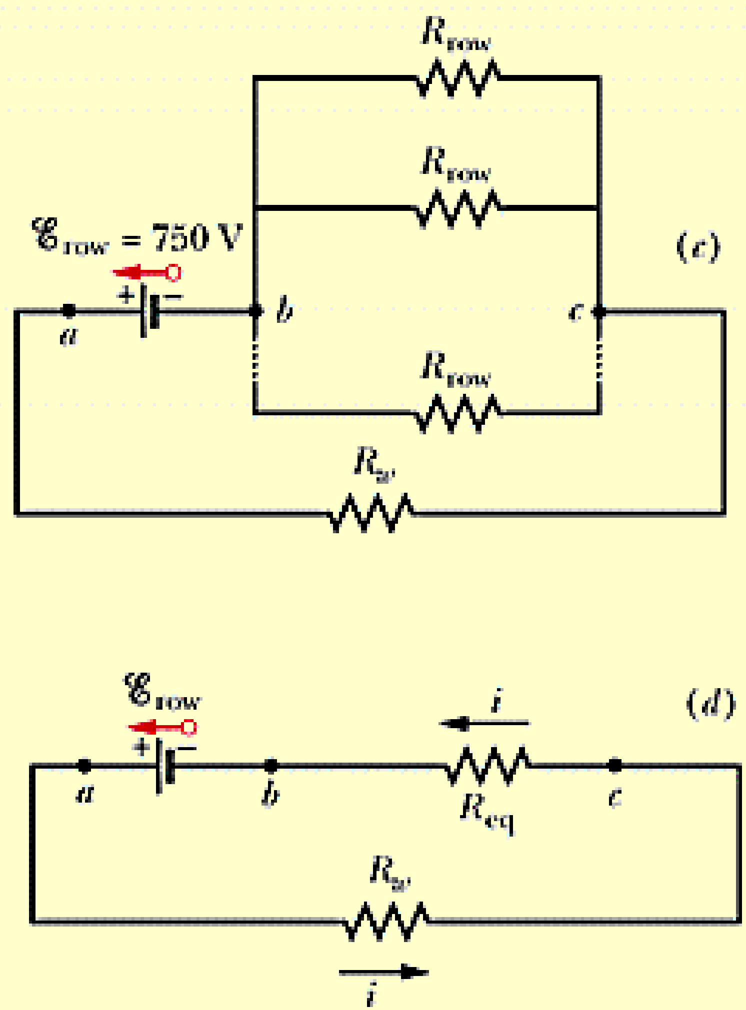


Ex.5 The electric eel



The Equivalent circuit





The surrounding water has resistance R_w.(b) The emf $\mathscr{E}_{row}$ and resistance R_{row} of each row. (c) The emf between points a and b is $\mathscr{E}_{row}$. Between points b and c are 140 parallel resistances R_{row}. (d) The simplified circuit, with R_{eq} replacing the parallel combination.

The current

0.15V

$$\mathcal{E}_{row} = 5000\mathcal{E}_{ep} = 750\text{V}$$

0.25 Ω

$$R_{row} = 5000 r_{ep} = 1250\Omega$$

$$\frac{1}{R_{eq}} = \sum_{j=1}^{140} \frac{1}{R_j} = 140\frac{1}{R_{row}} \rightarrow R_{eq} = 8.93\Omega$$

R_w=800Ω

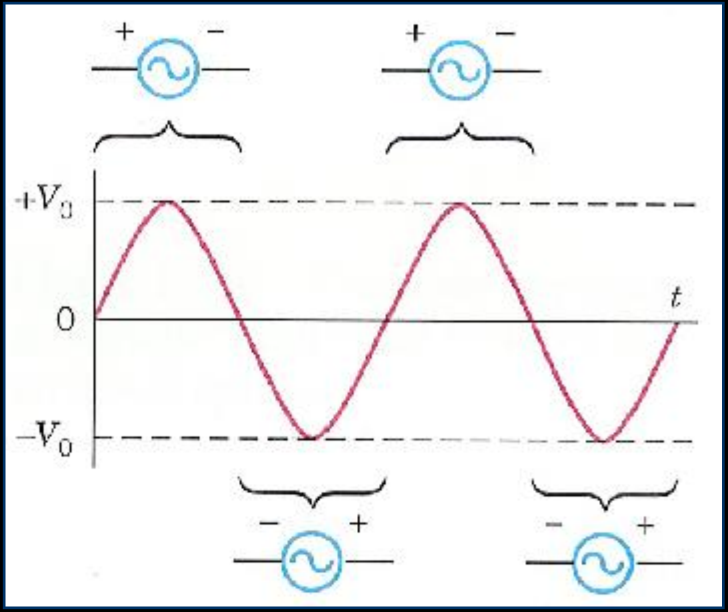
$$\mathcal{E}_{row} - iR_w - iR_{eq} = 0 \rightarrow i = 0.93\text{A}$$

$$i_{row} = i/140 = 6.6\times 10^{-3}\,\text{A}$$

7.4交流電路

- Alternating Current Circuit
- $V(t) = V_0 Sin2\pi f t$
- f 頻率 = 60H（赫）
- V_0 尖峰值，

一般家庭約170V



功率

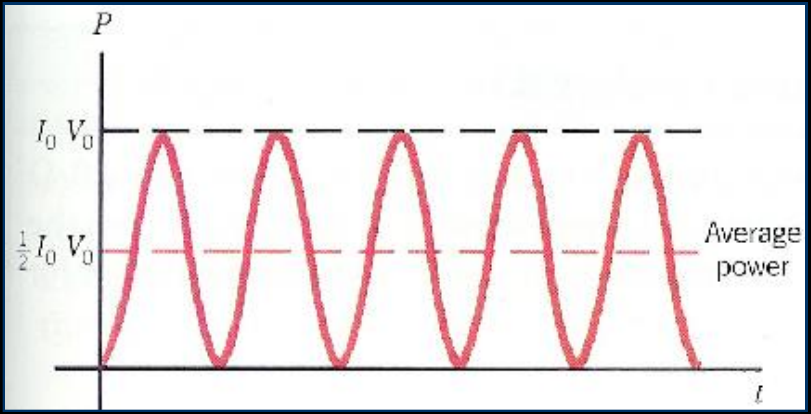
- $P(t) = I_0 V_0 \sin^2 2\pi f t$，取時間平均值

$$\overline{P} = \frac{1}{2} I_0 V_0 = \frac{I_0}{\sqrt{2}} \frac{V_0}{\sqrt{2}} = I_{rms} V_{rms}$$

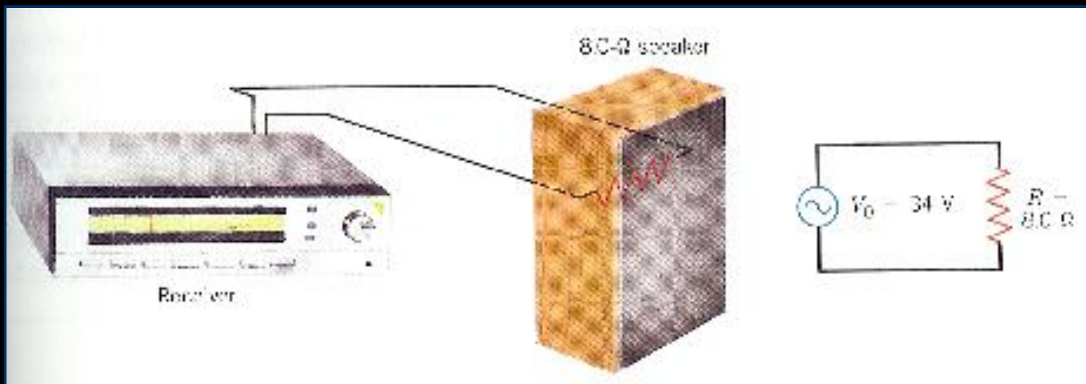
- 對交流電而言，歐姆定律變成

$$V_{rms} = I_{rms} R$$

$$\overline{P} = I_{rms} V_{rms} = I_{rms}{}^2 R = \frac{V_{rms}{}^2}{R}$$



Ex.5 72W 音箱

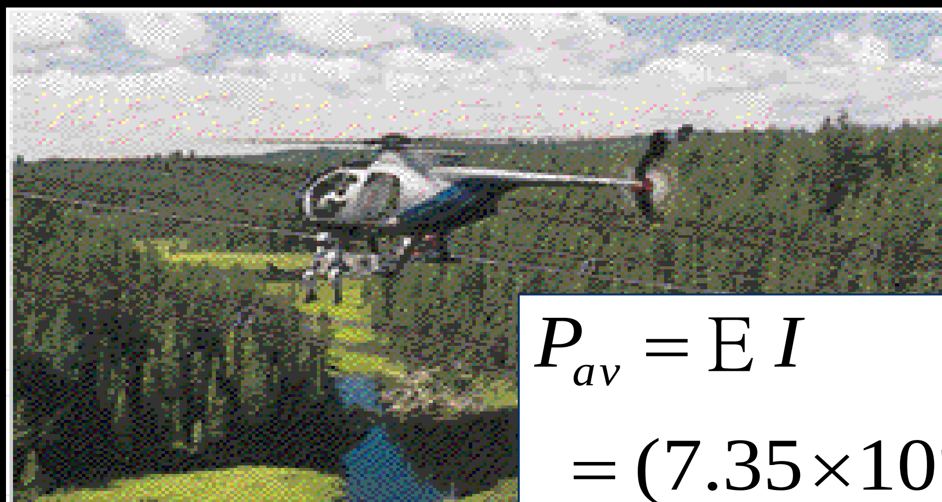


$$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{34V}{\sqrt{2}} = 24V$$

$$I_{rms} = \frac{V_{rms}}{R} = \frac{24V}{8.0\Omega} = 3.0\text{A}$$

$$\overline{P} = I_{rms} V_{rms} = 72W$$

Ex.6 A practical example
Quebec →Montreal



$$P_{av} = \mathcal{E}\, I$$

$$= (7.35\times10^{5}\,\mathrm{V})(500\mathrm{A}) = 368\mathrm{MW}$$

$$P_{av,1} = I^{2}R = (1000\mathrm{A})^{2}$$

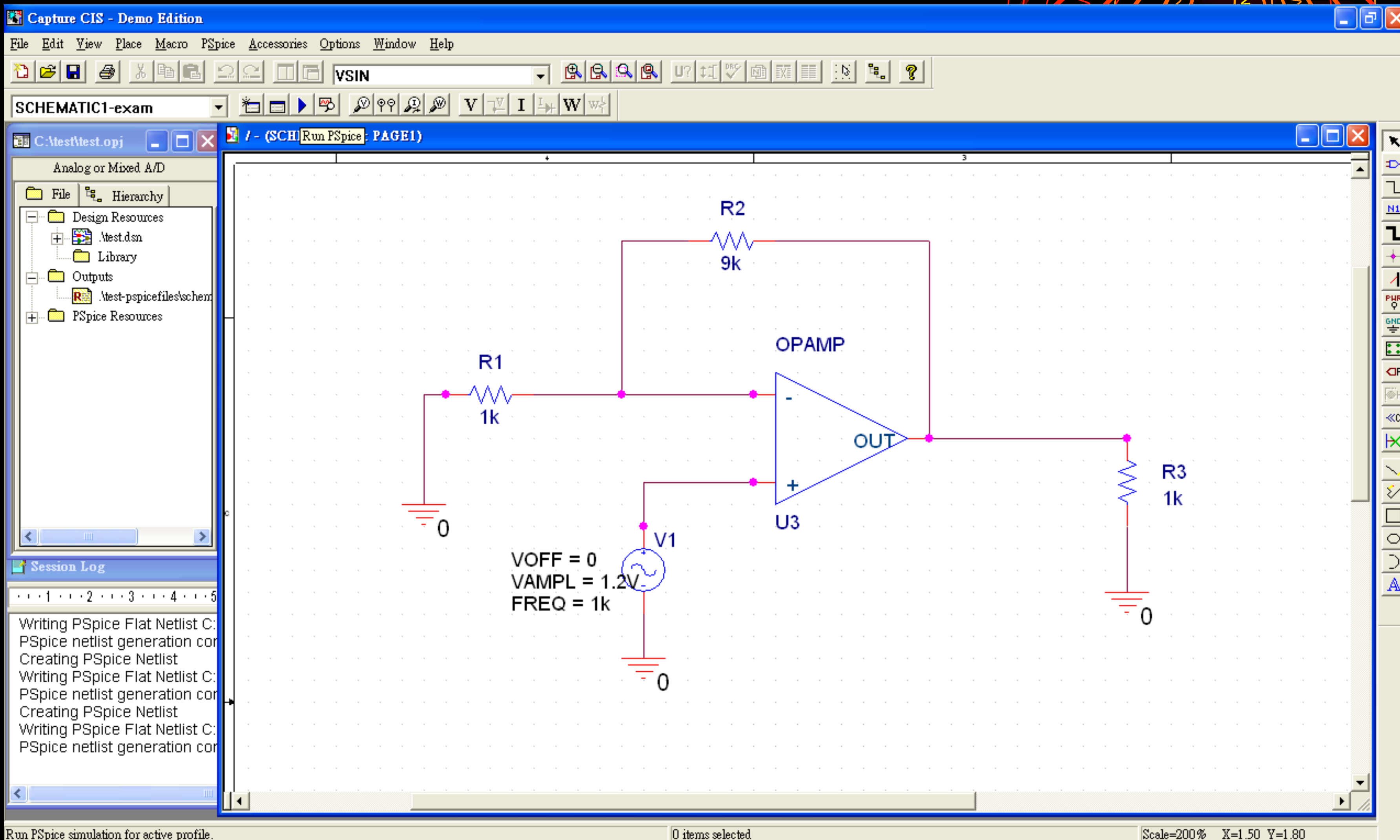
$$\times(0.22\Omega/m\times1000km) = 220\mathrm{MW}$$

$$P_{av,2} = I^{2}R = (500\mathrm{A})^{2}$$

$$\times(0.22\Omega/m\times1000km) = 55.0\mathrm{MW}$$

7.5虛擬電路實驗

7.6 Orcad-PSpice



7.7 Simulation