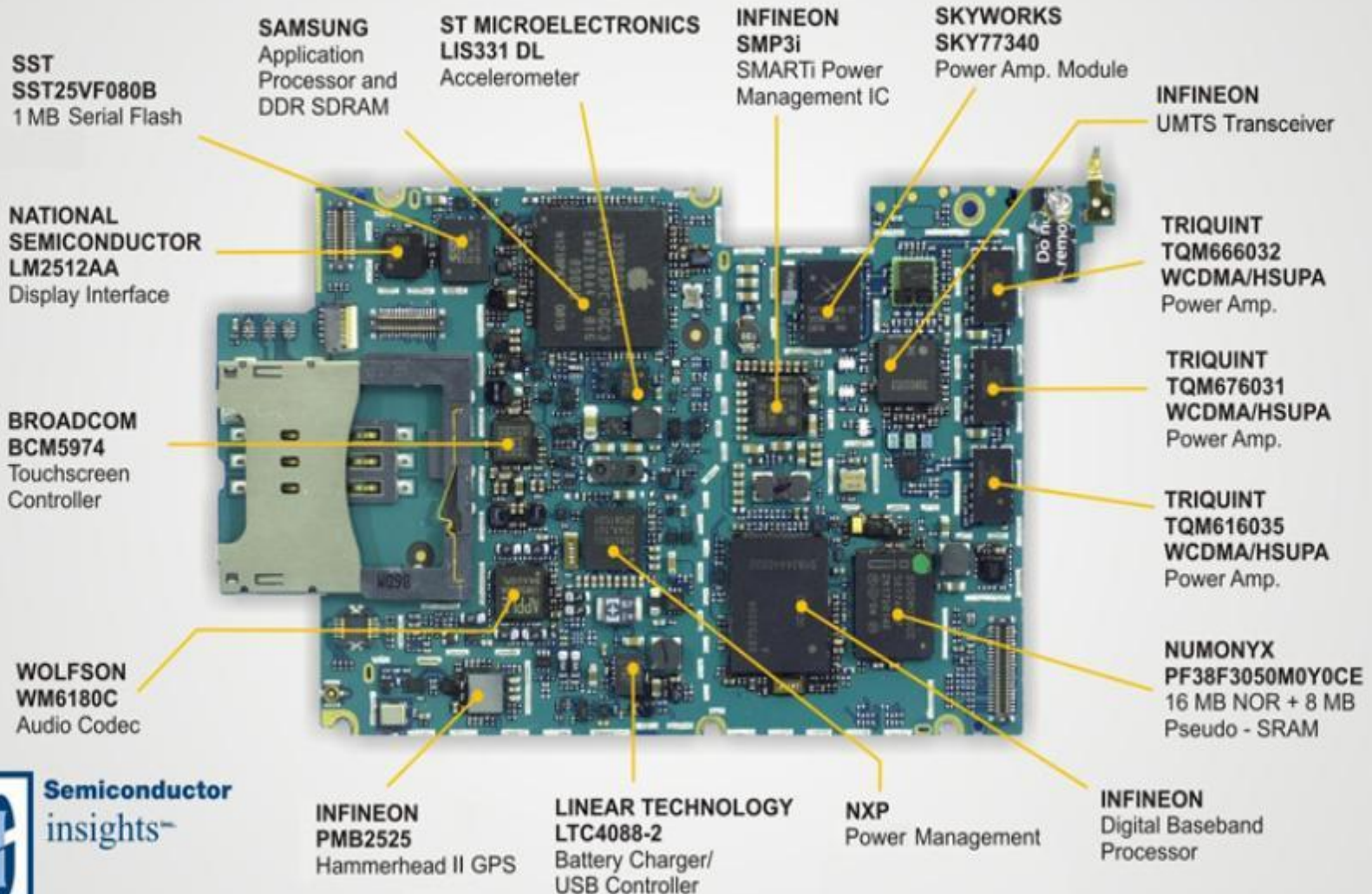


7 電路

Cellular Phone System Diagram



Outline

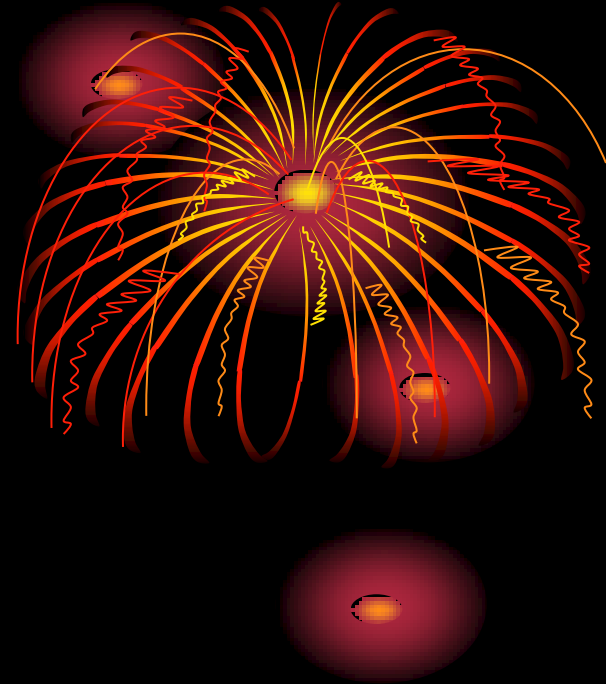
7.1 直流電路

7.2 串聯電阻

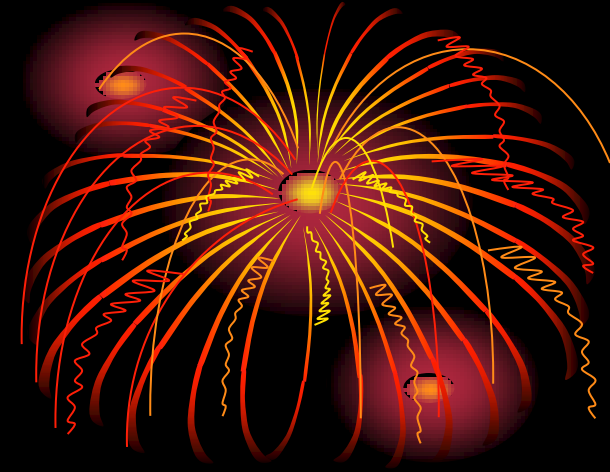
7.3 並聯電阻

7.4 交流電路

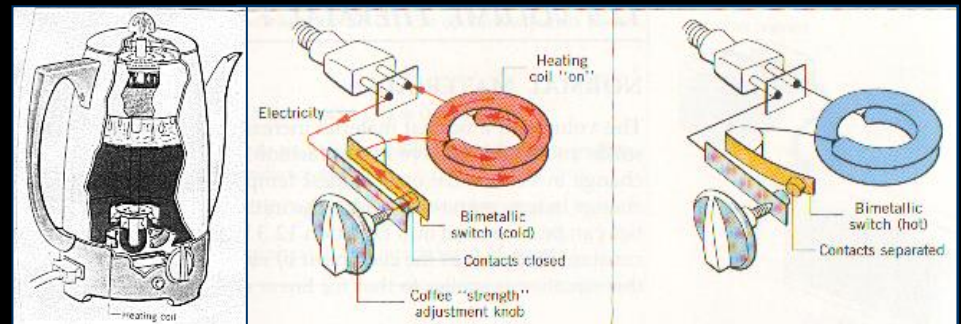
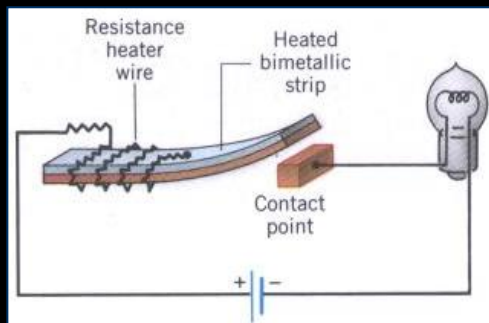
7.5 虛擬電路實驗



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。

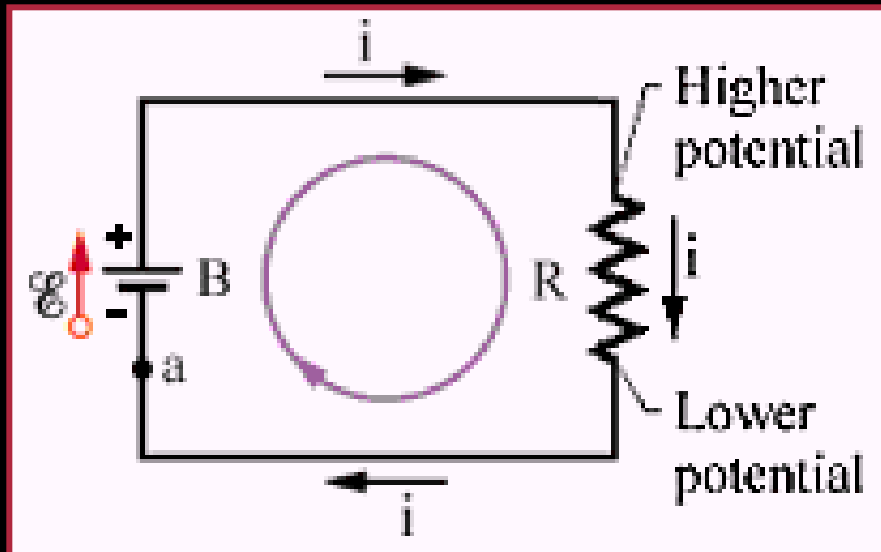


Ex.1 簡單直流電路內之電位 (電壓) 升降

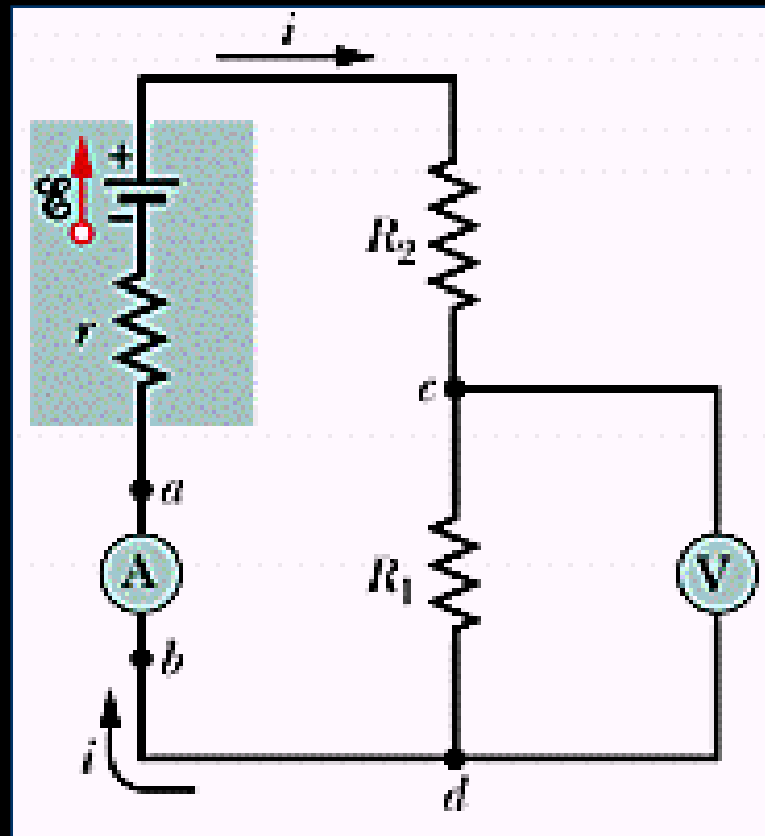
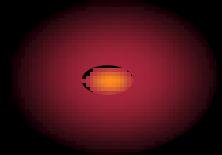
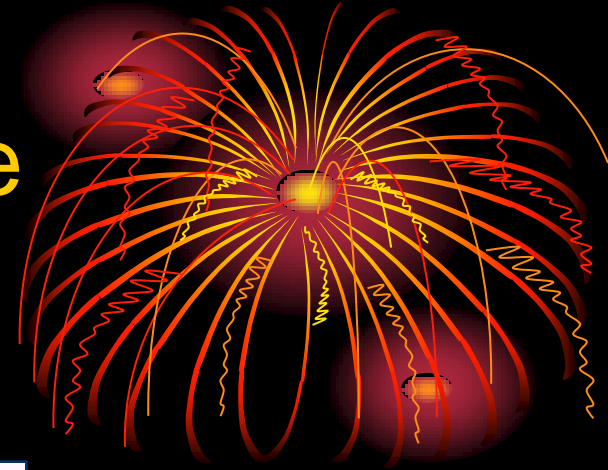


$$V_a + \mathcal{E} - iR = V_a$$
$$\mathcal{E} = iR$$

克希荷夫
Kirchhoff 迴
路定理



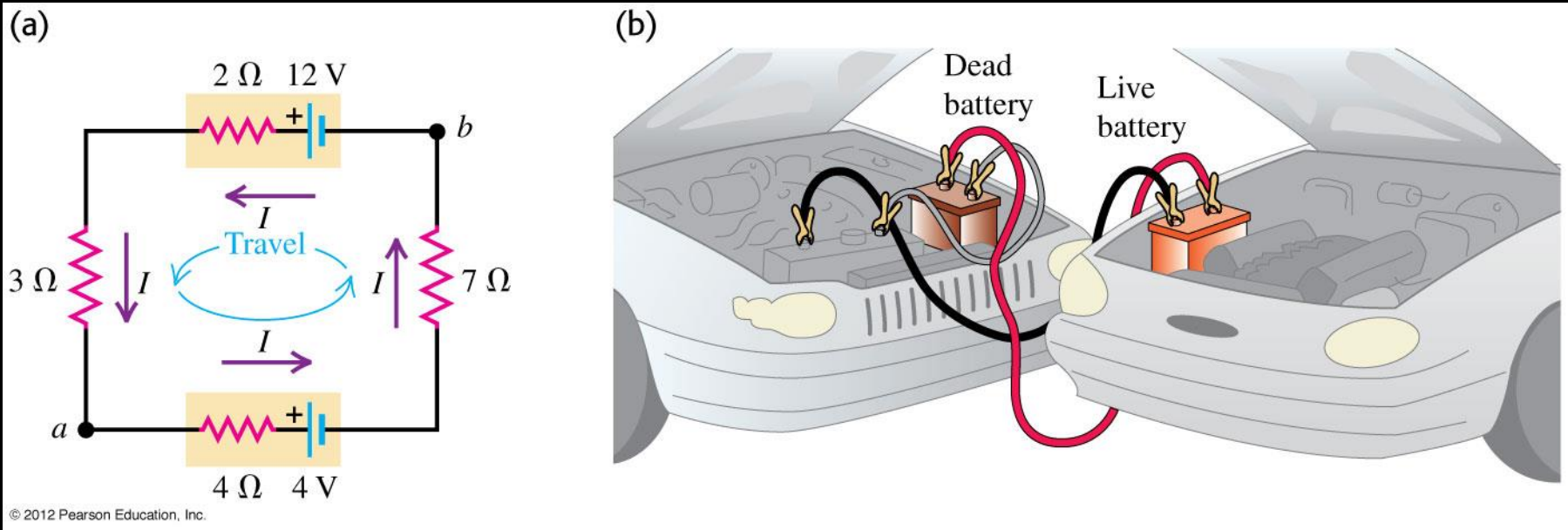
Ex.2 The Ammeter and the Voltmeter



A single-loop circuit

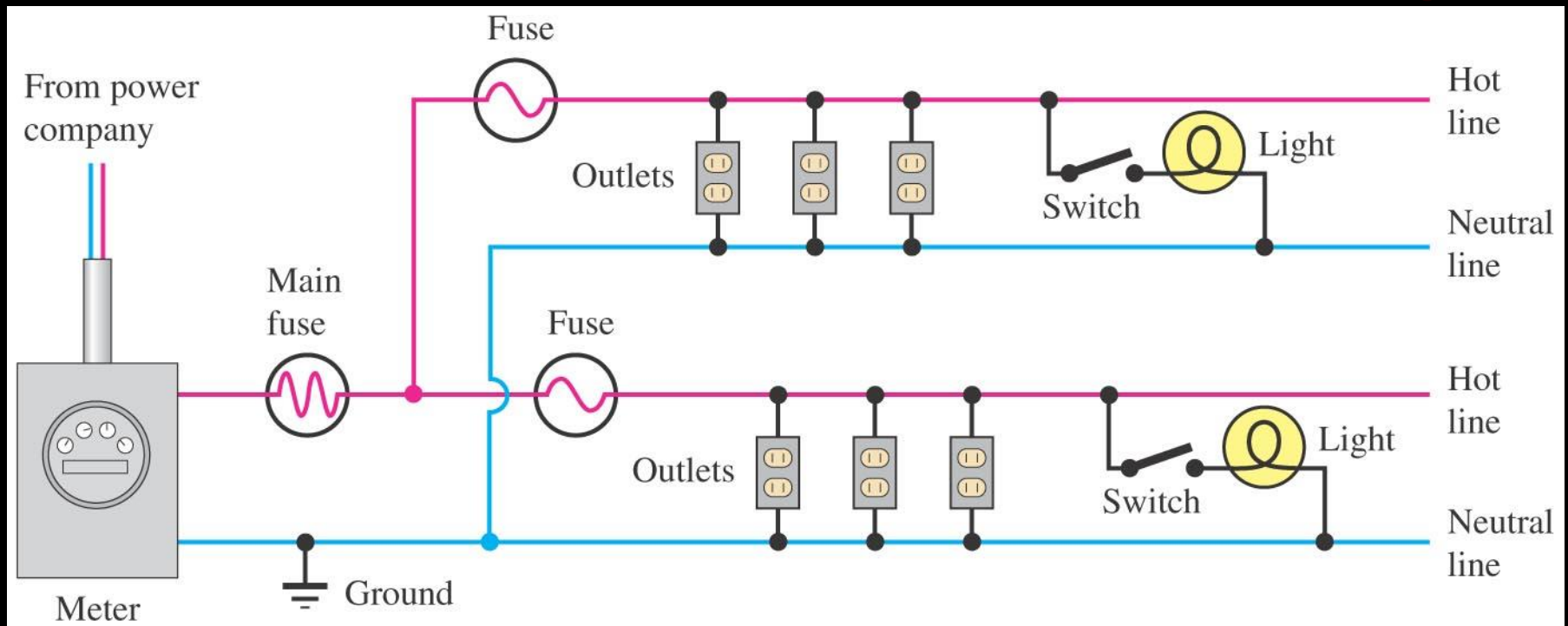


- Follow Example 26.3, using Figure 26.10 below.



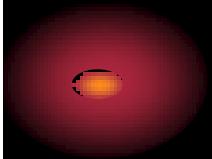
Power distribution systems

- Follow the text discussion using Figure 26.24 below.



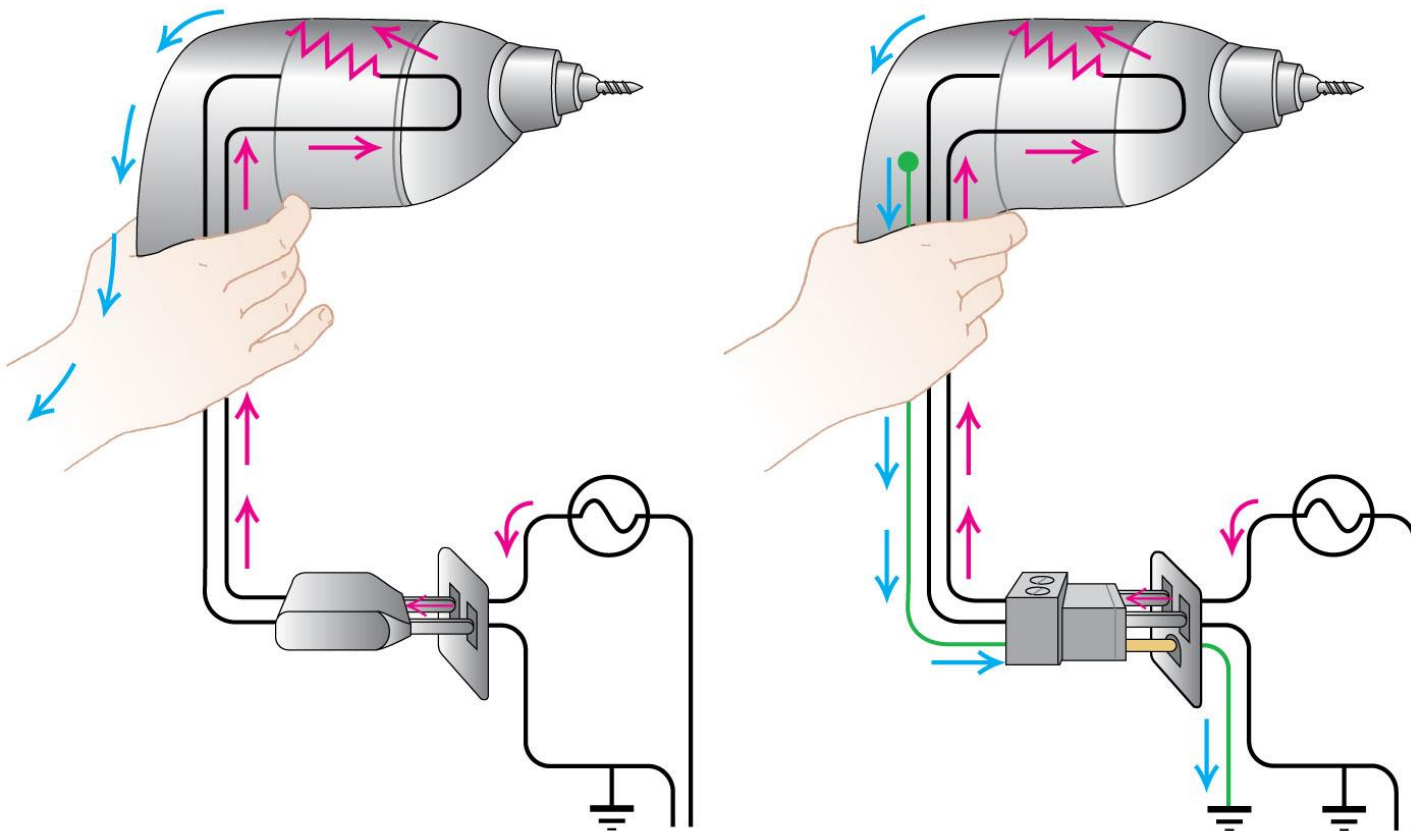
Household wiring

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



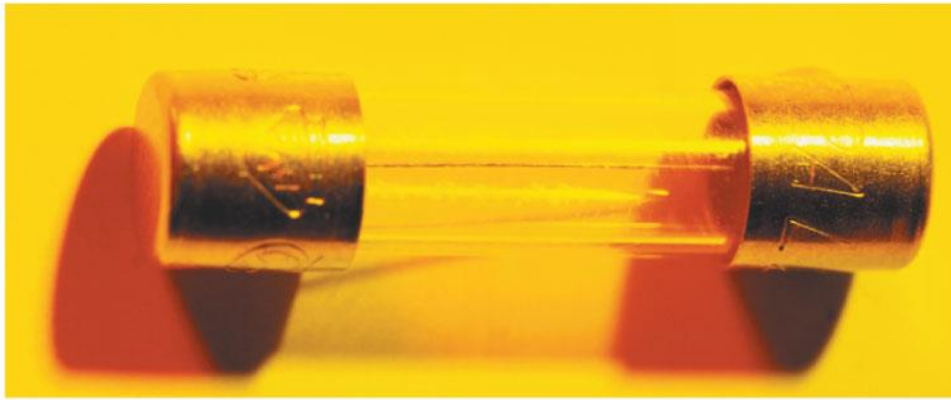
(a) Two-prong plug

(b) Three-prong plug

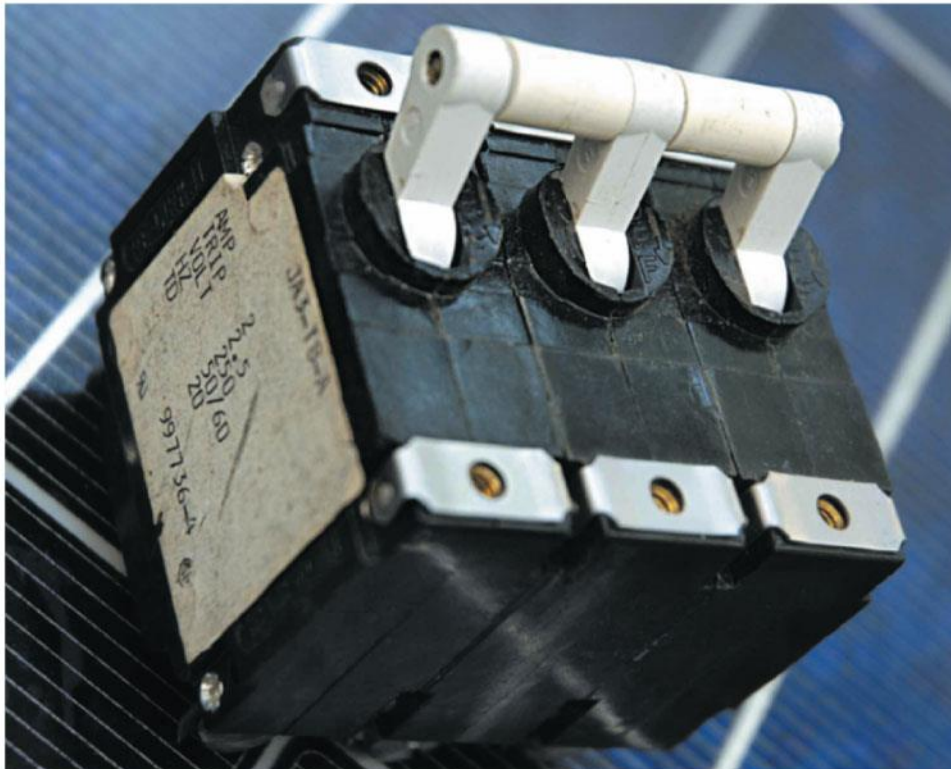


fuse

(a)



(b)

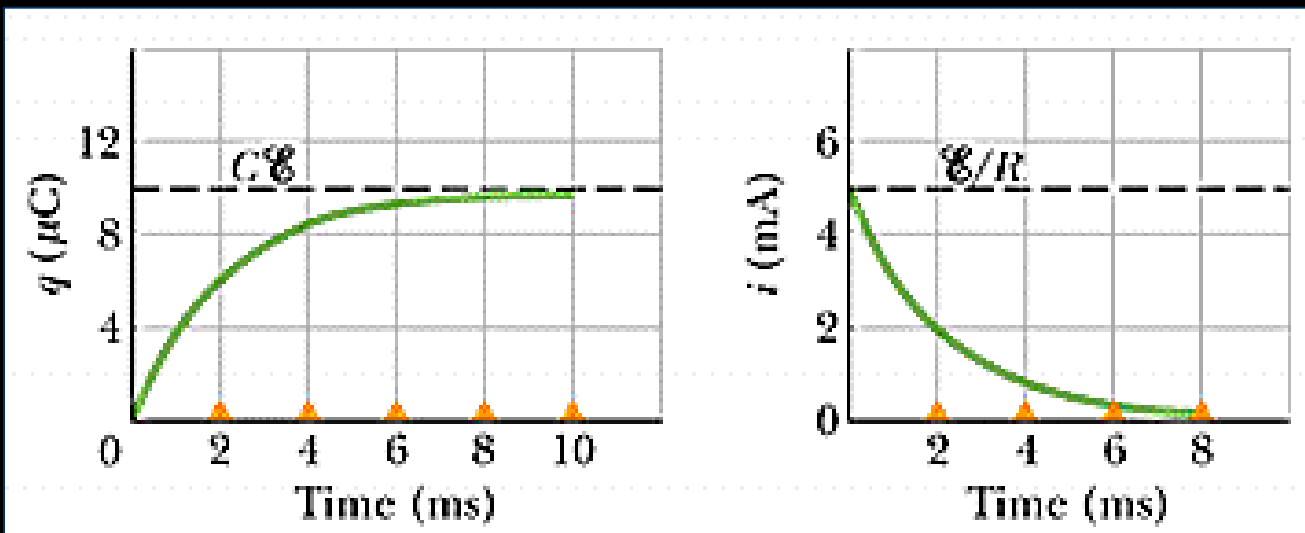
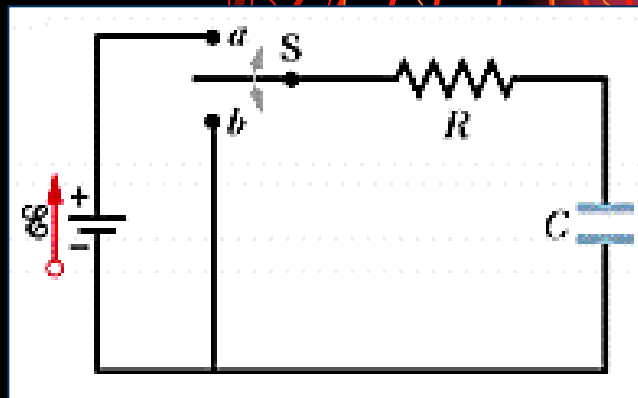
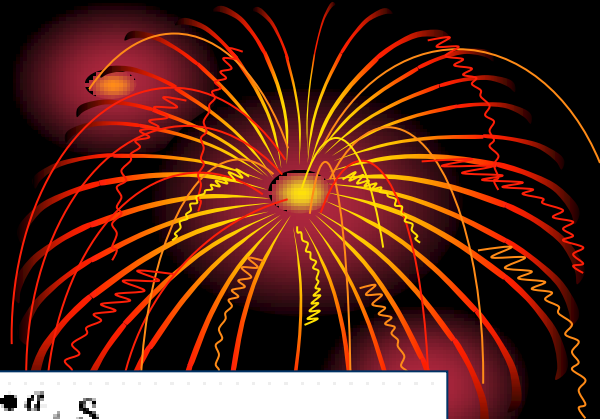


Circuit
breaker

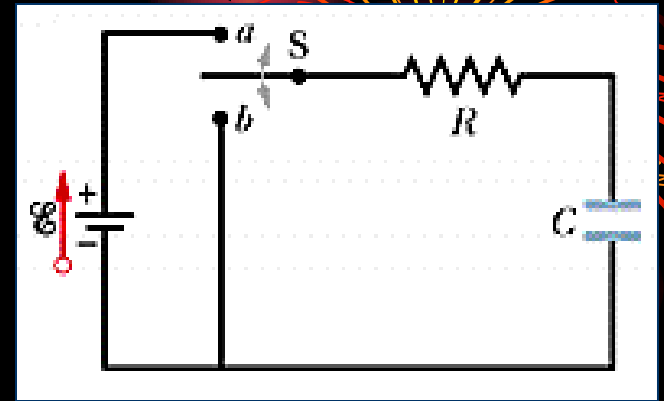


Ex.3 RC 電路

電阻—電容電路



Ex.3 (cont) Charging a Capacitor



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

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

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

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

Ex.3 (cont)

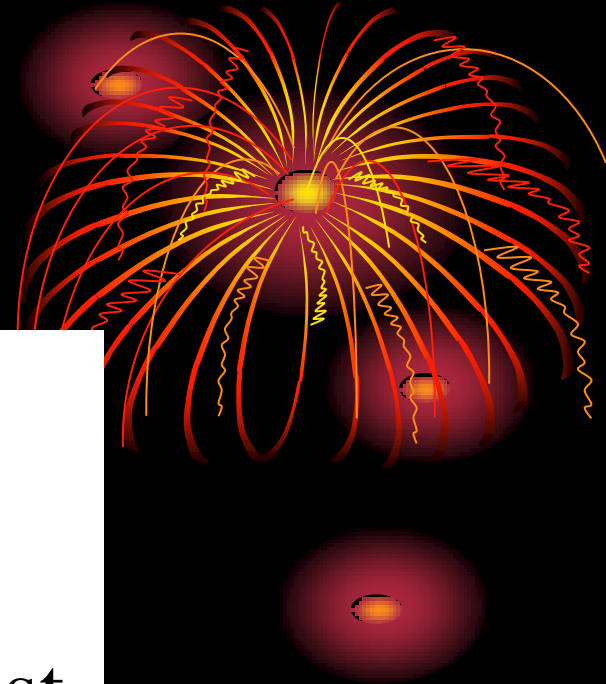
$$\rightarrow \int \frac{d(q - C\mathcal{E})}{(q - C\mathcal{E})} = - \int \frac{dt}{RC}$$

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

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

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

What is C' ?



Ex.3 (Initial Condition)

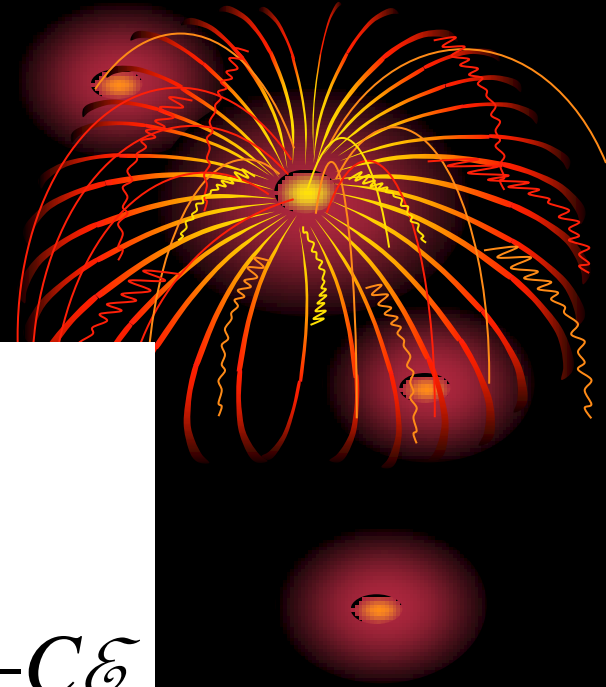
$$\rightarrow q(t) - C\mathcal{E} = C' e^{-\frac{t}{RC}}$$

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

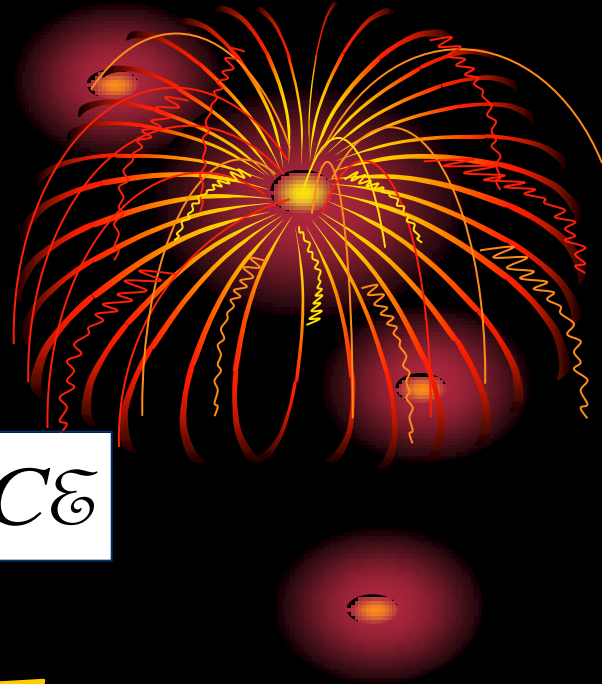
$$\rightarrow q(t) - C\mathcal{E} = -C\mathcal{E} e^{-\frac{t}{RC}}$$

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

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



Ex.3 (cont)



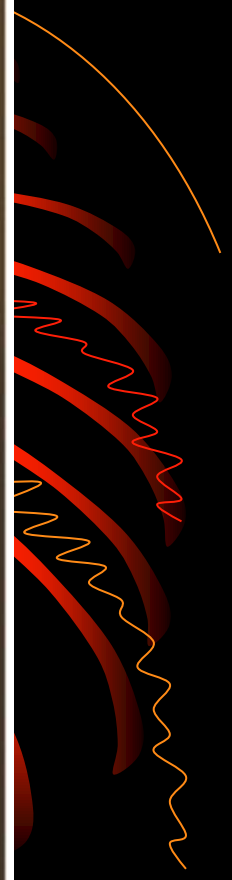
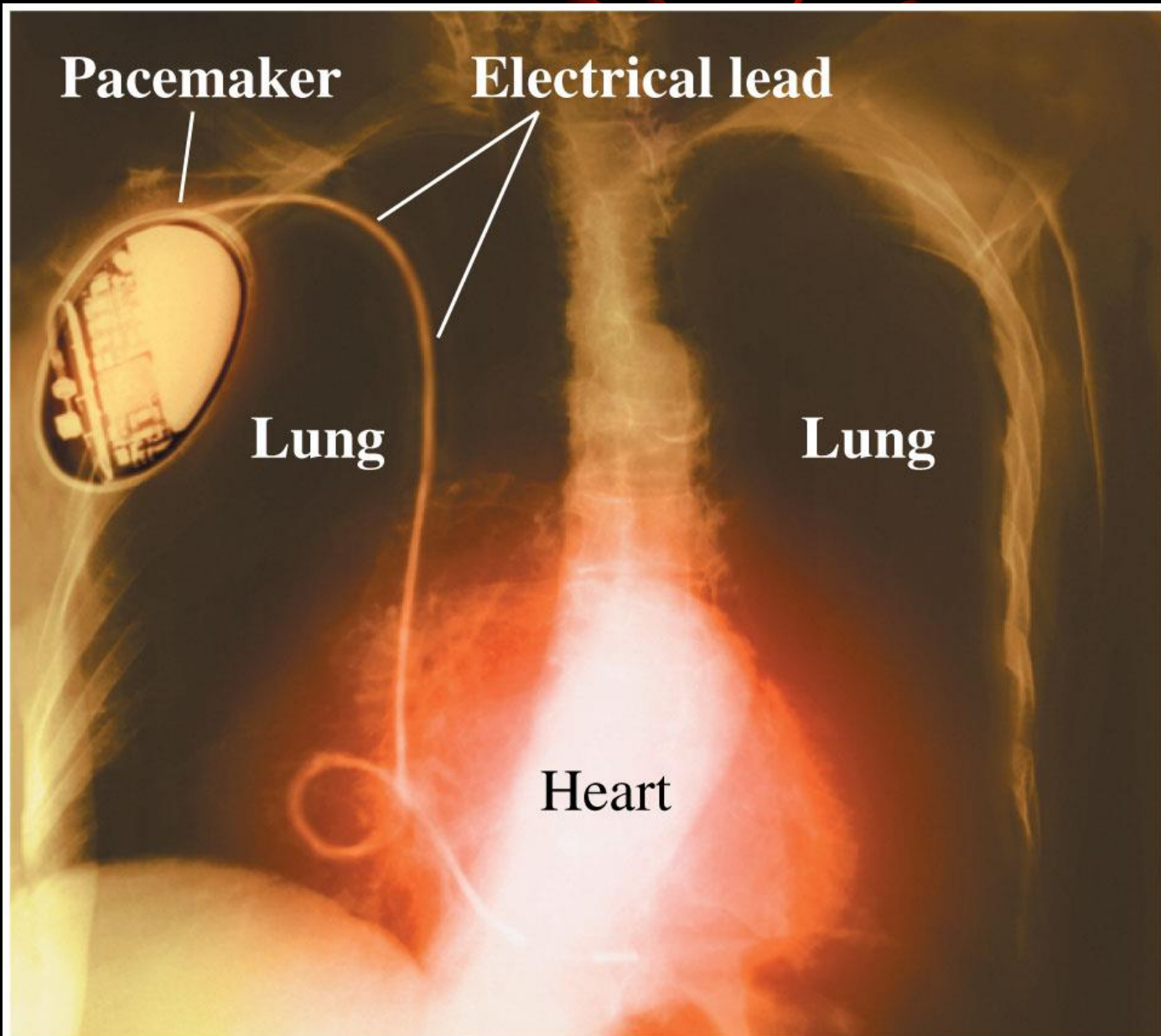
$$q(RC) = C\varepsilon(1 - e^{-RC/RC}) = 0.63C\varepsilon$$

e^{-1}

- 如果 $R = 10\text{M}\Omega$ $C = 1\mu\text{F}$

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

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

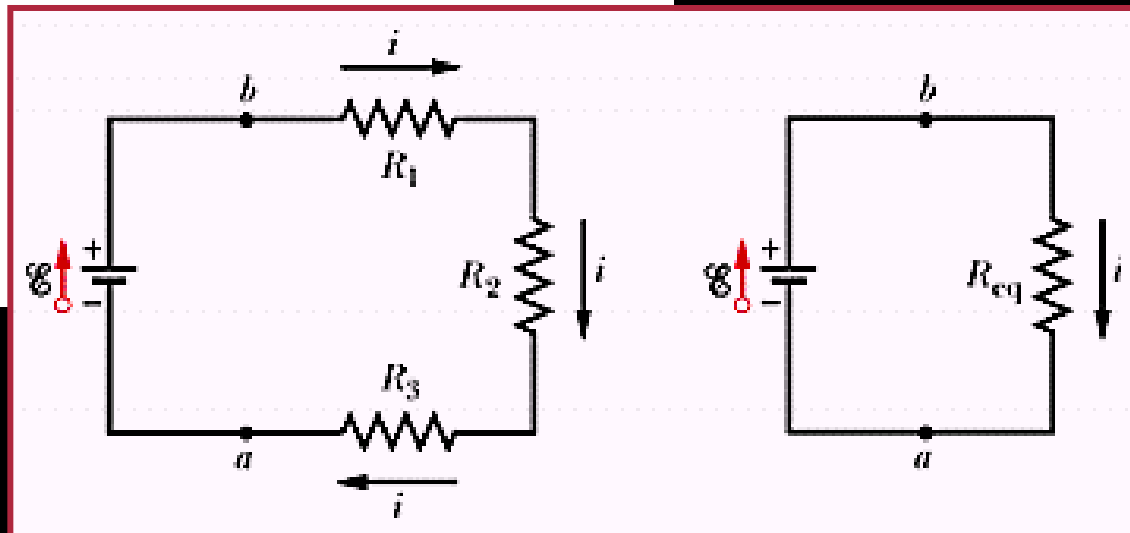


7.2 Resistance in series

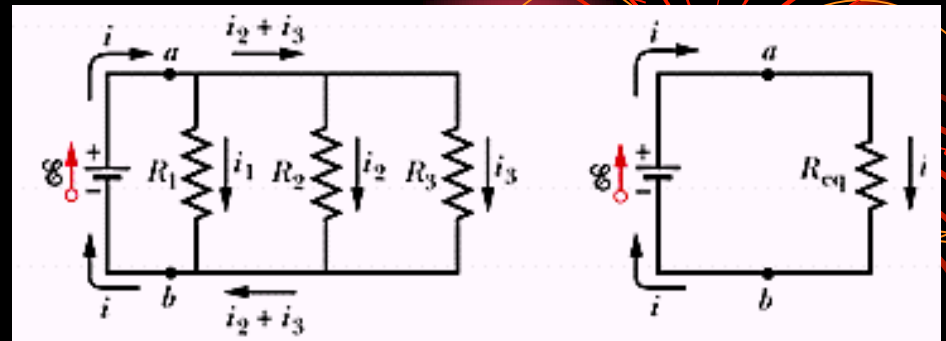
$$\mathcal{E} - iR_1 - iR_2 - iR_3 = 0$$

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

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



7.3 Resistors in parallel

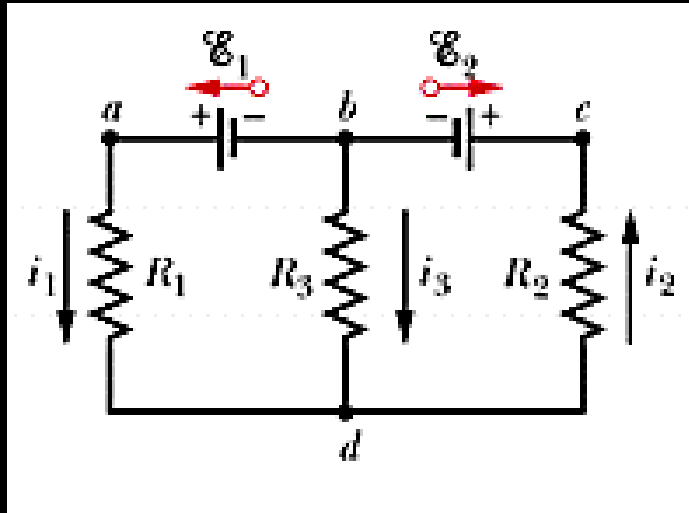


$$i_1 = \frac{\mathcal{E}}{R_1}, \quad i_2 = \frac{\mathcal{E}}{R_2}, \quad i_3 = \frac{\mathcal{E}}{R_3}$$

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

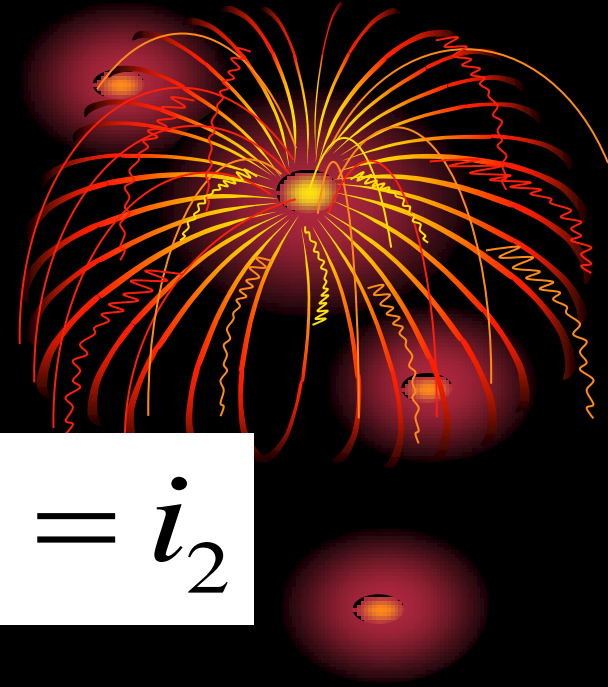
$$i = \frac{\mathcal{E}}{R_{eq}} \rightarrow \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Multiloop Circuits

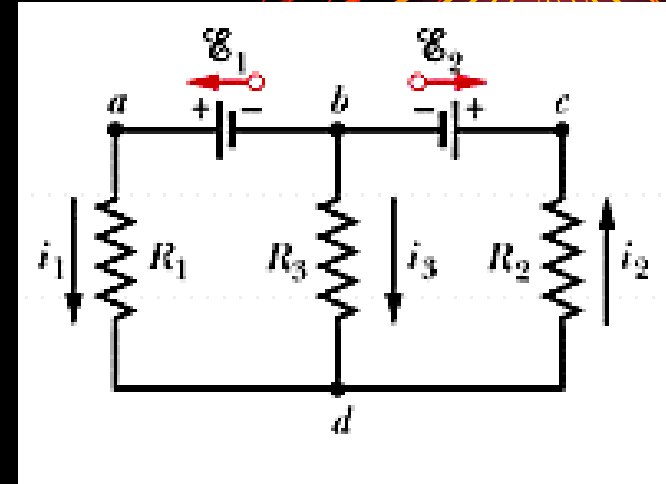


$$i_1 + i_3 = i_2$$

- The Junction rule: 流入接點之電流必等於流出者
(Kirchhoff's junction/current rule)



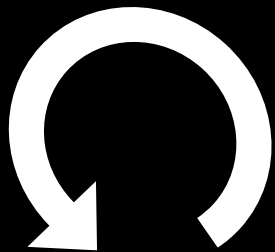
解 System of equations (聯立方程組)



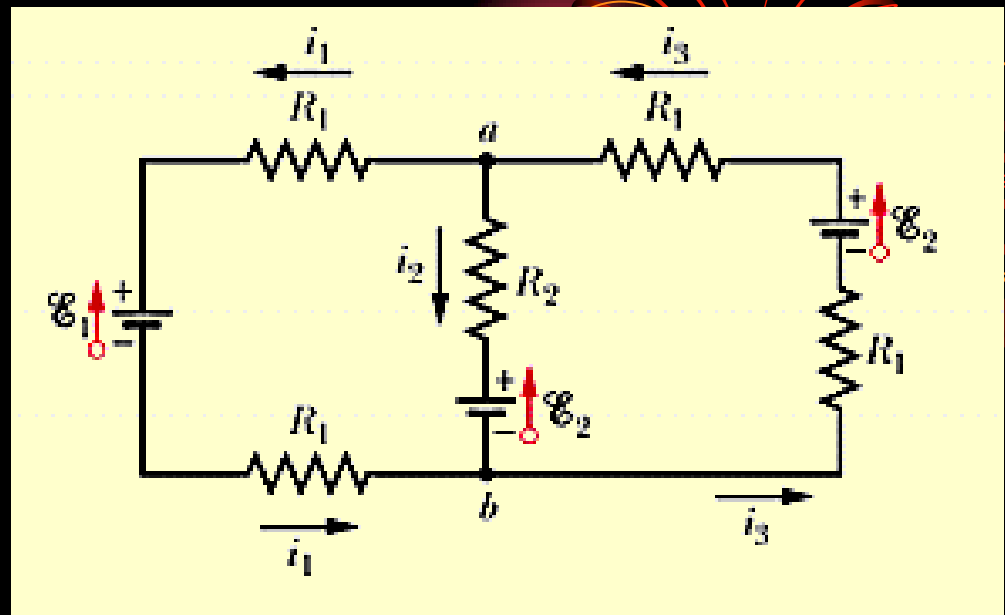
$$\mathcal{E}_1 - i_1 R_1 + i_3 R_3 = 0 \text{ left loop}$$

$$-i_3 R_3 - i_2 R_2 - \mathcal{E}_2 = 0 \text{ right loop}$$

$$\mathcal{E}_1 - i_1 R_1 - i_2 R_2 - \mathcal{E}_2 = 0 \text{ big loop}$$



Ex.4 What are the currents?



$$i_3 = i_1 + i_2$$

$$-i_1 R_1 - \mathcal{E}_1 - i_1 R_1 + \mathcal{E}_2 + i_2 R_2 = 0$$

$$+i_3 R_1 - \mathcal{E}_2 + i_3 R_1 + \mathcal{E}_2 + i_2 R_2 = 0$$

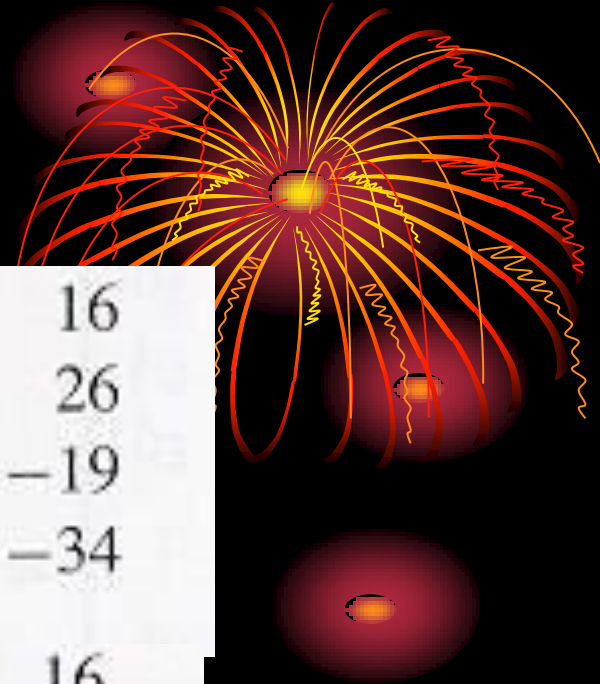
解聯立方程組

*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

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

pivot equation

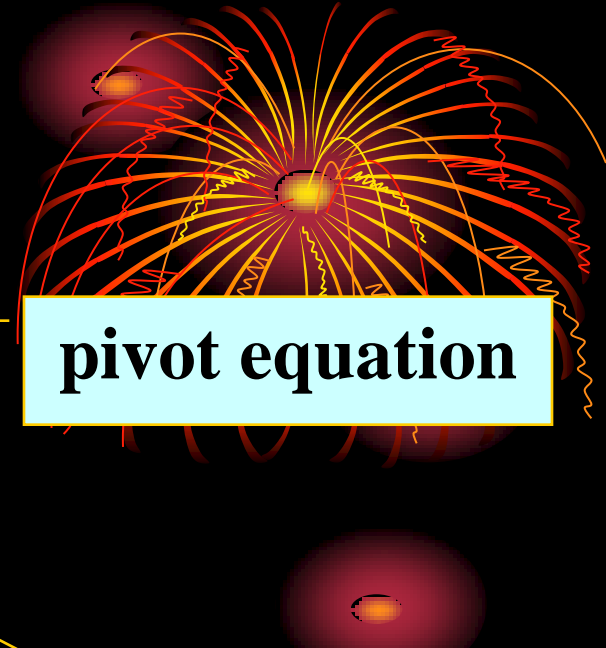
$$x_4 = \frac{-3}{-3} = 1 \quad 2x_3 - 5 = -9$$

upper triangle

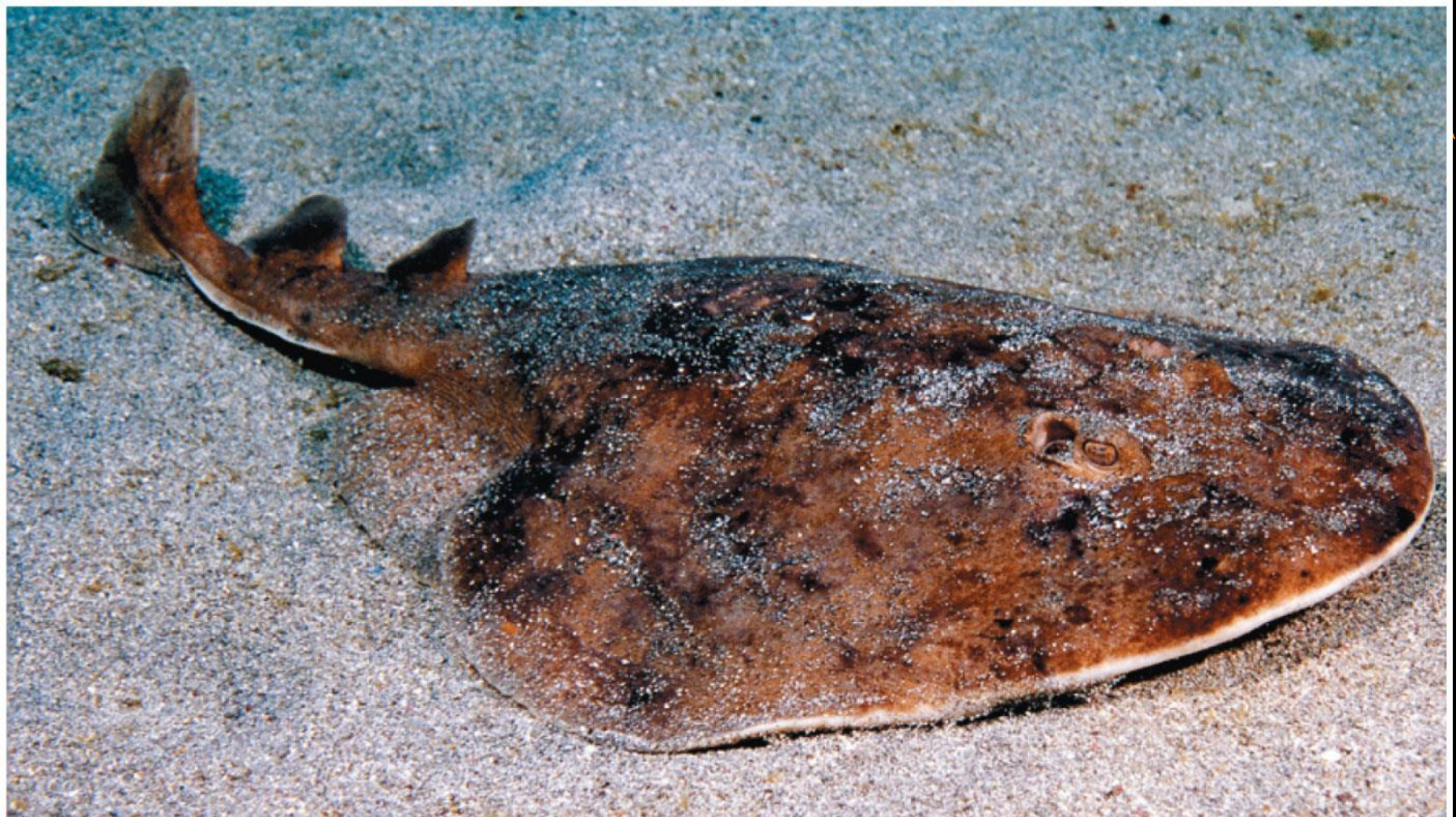
$$x_3 = \frac{-4}{2} = -2$$

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

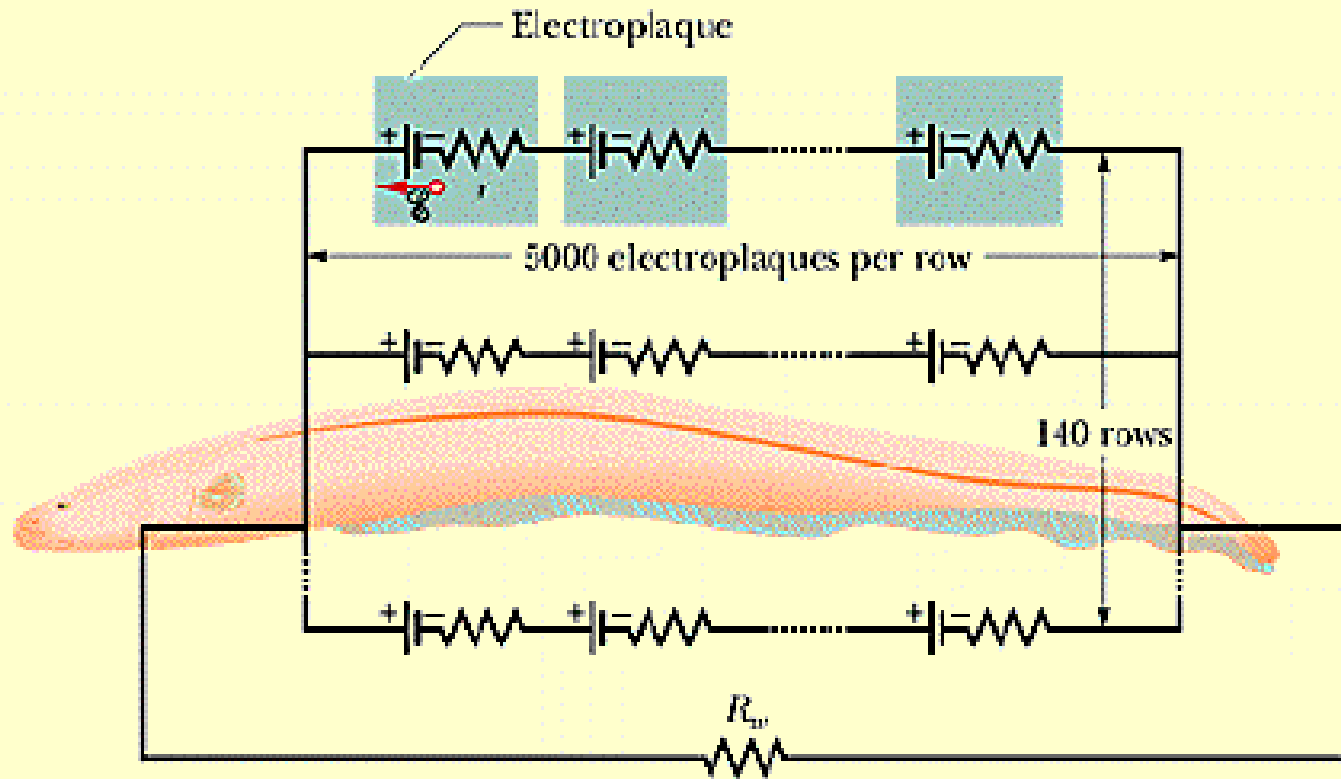
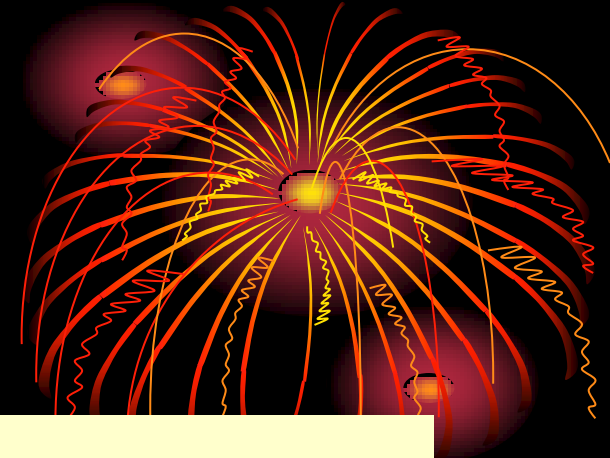
Forward Elimination and Back substitution



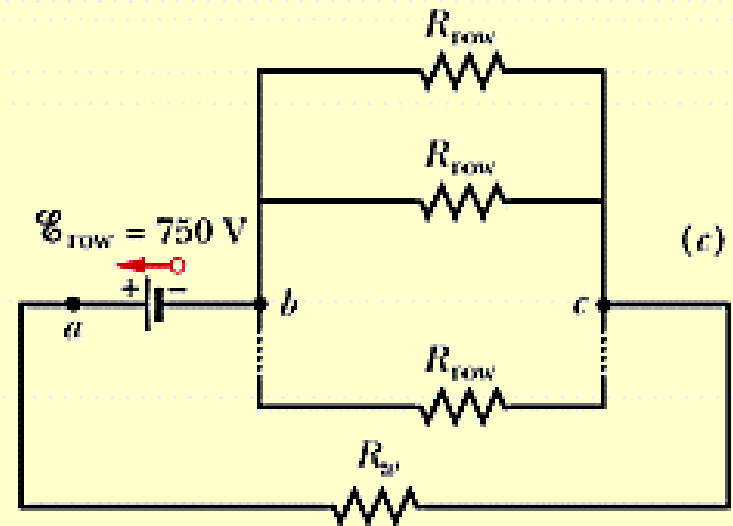
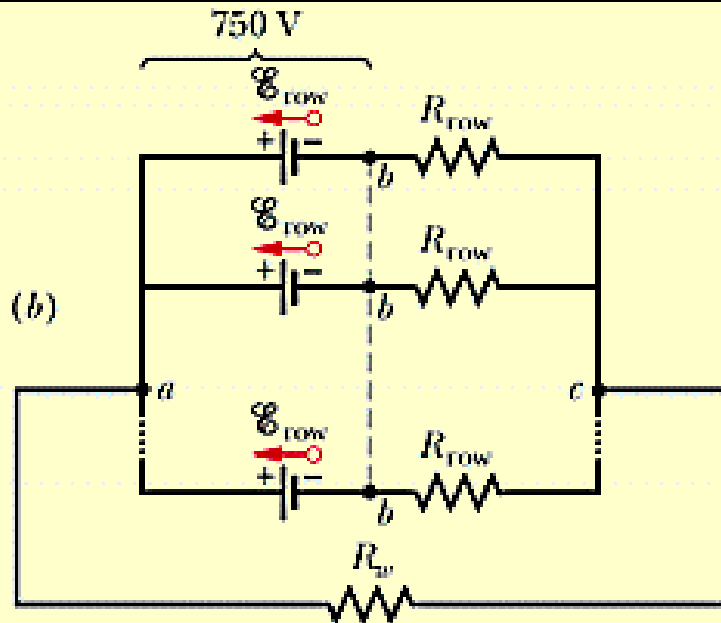
The torpedo ray



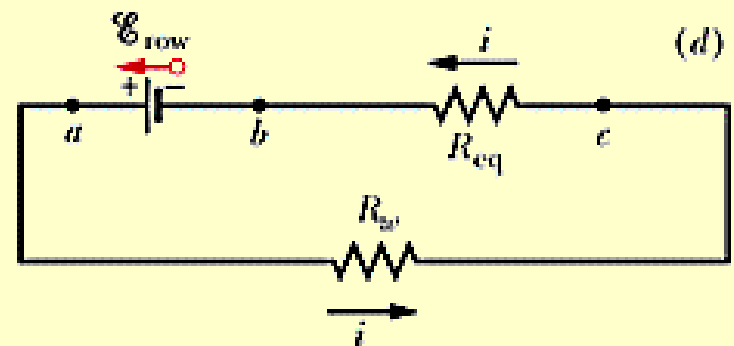
Ex.5 The electric eel



The Equivalent circuit



The surrounding water has resistance R_w . (b) The emf \mathcal{E}_{row} and resistance R_{row} of each row. (c) The emf between points a and b is \mathcal{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

$$0.15V$$

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

$$0.25\Omega$$

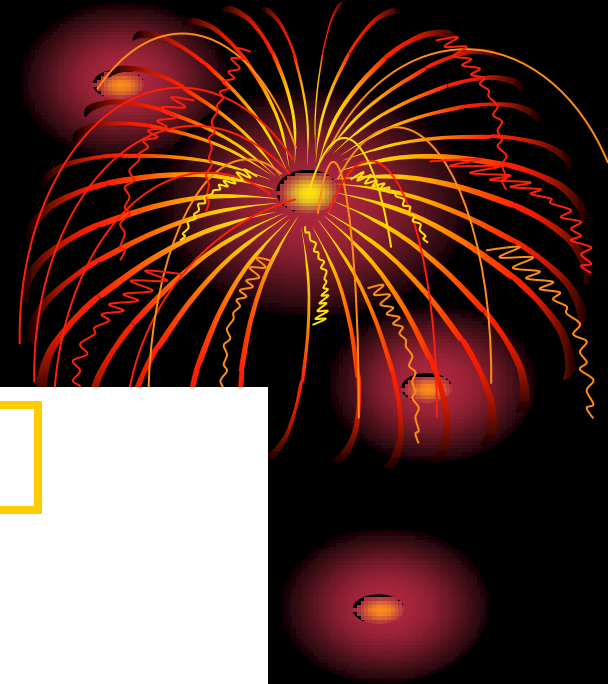
$$R_{row} = 5000r_{ep} = 1250\Omega$$

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

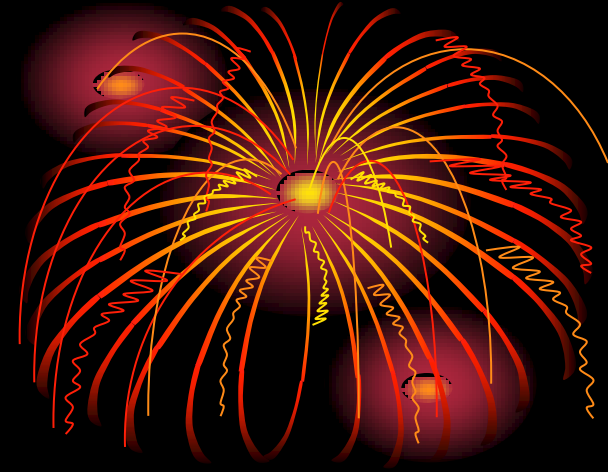
$$R_w = 800\Omega$$

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

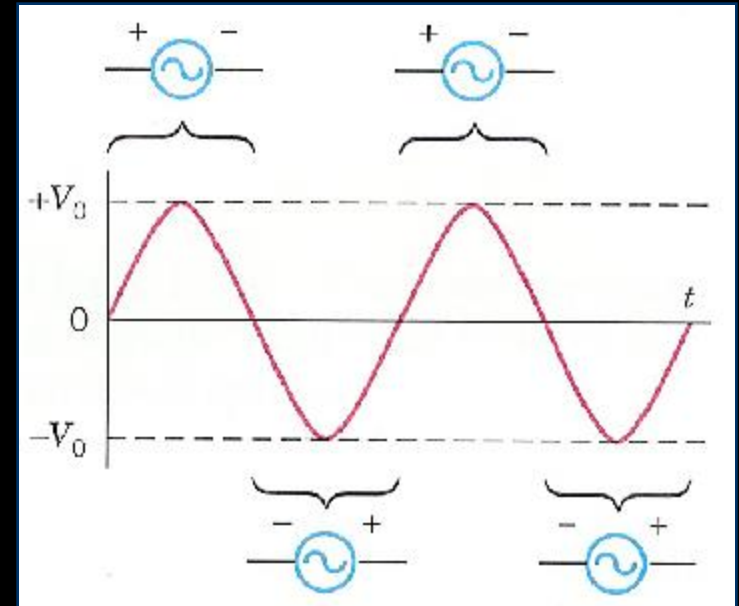
$$i_{row} = i / 140 = 6.6 \times 10^{-3} A$$



7.4 交流電路



- *Alternating Current Circuit*
- $V(t) = V_0 \sin 2\pi f t$
- f 頻率 = 60Hz (赫)
- V_0 尖峰值，
一般家庭約170V



功率



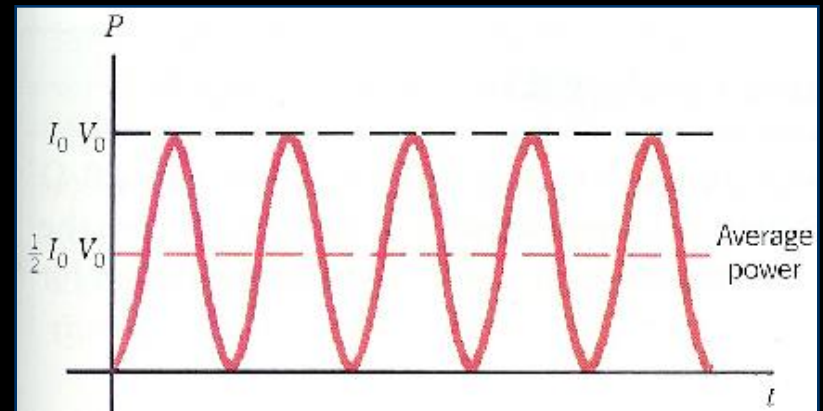
- $P(t) = I_0 V_0 \sin^2 2\pi f t$ ，取時間平均值

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

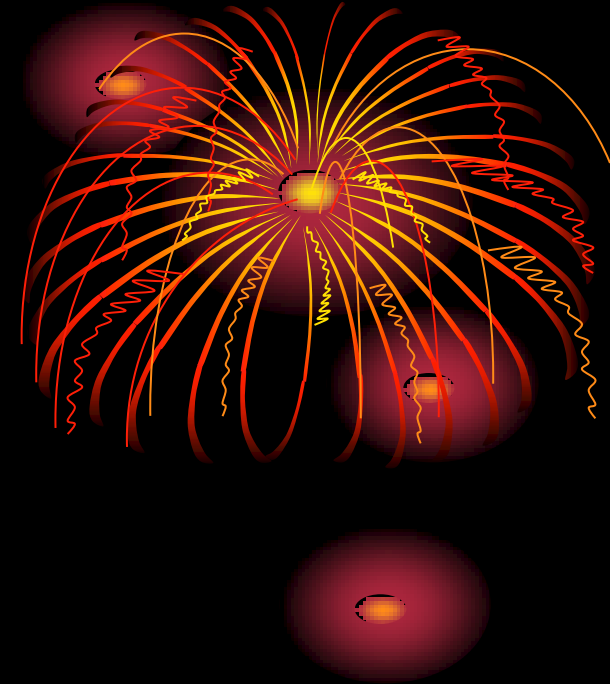
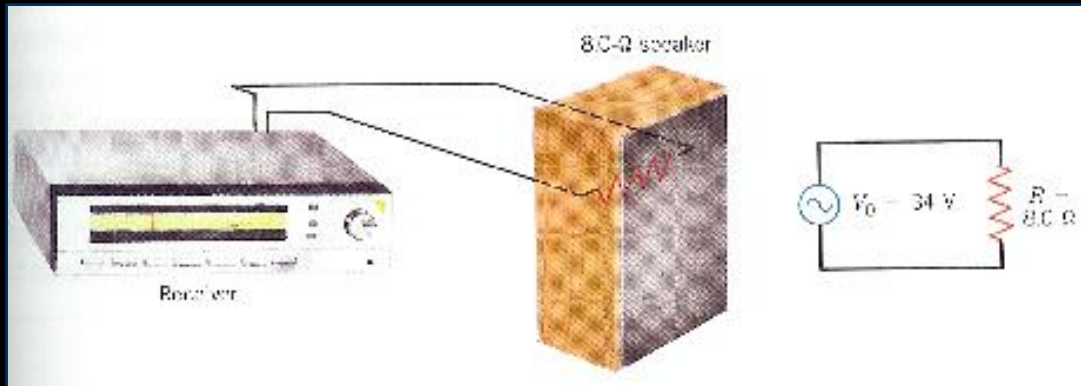
- 對交流電而言，歐姆定律變成

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

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



Ex.5 72W 音箱



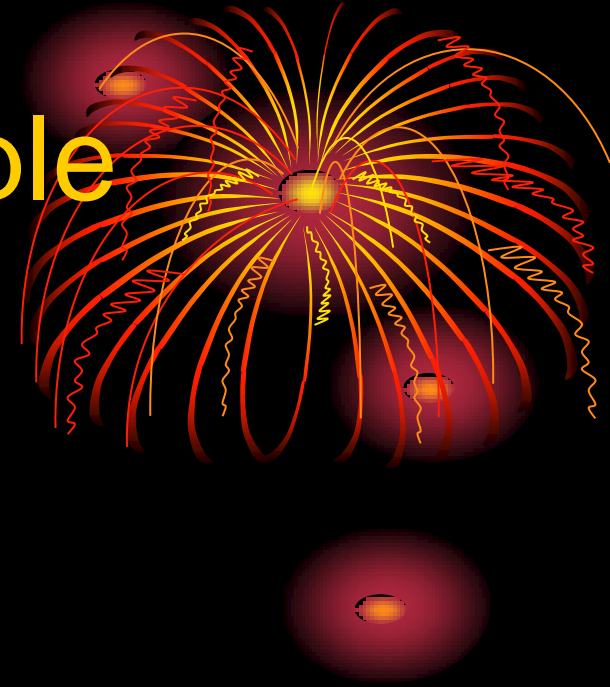
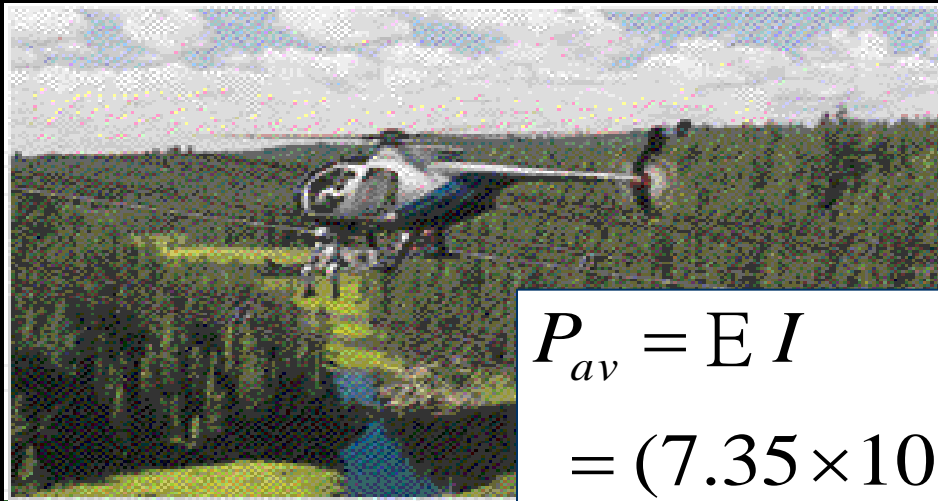
$$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{34\text{V}}{\sqrt{2}} = 24\text{V}$$

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

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

Ex.6 A practical example

Quebec → Montreal



$$P_{av} = E I$$

$$= (7.35 \times 10^5 \text{ V})(500 \text{ A}) = 368 \text{ M W}$$

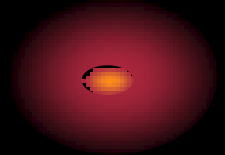
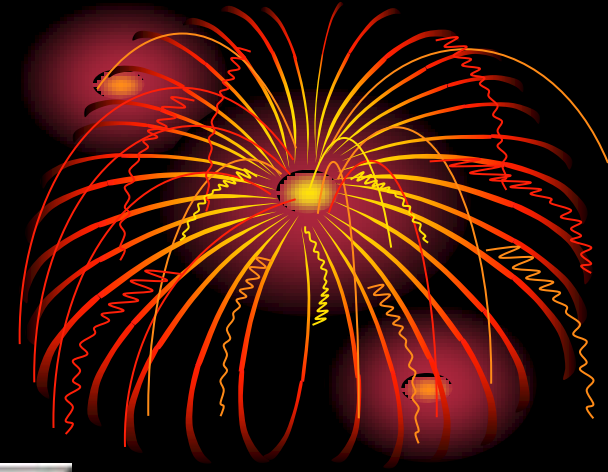
$$P_{av,1} = I^2 R = (1000 \text{ A})^2$$

$$\times (0.22 \Omega / m \times 1000 \text{ km}) = 220 \text{ M W}$$

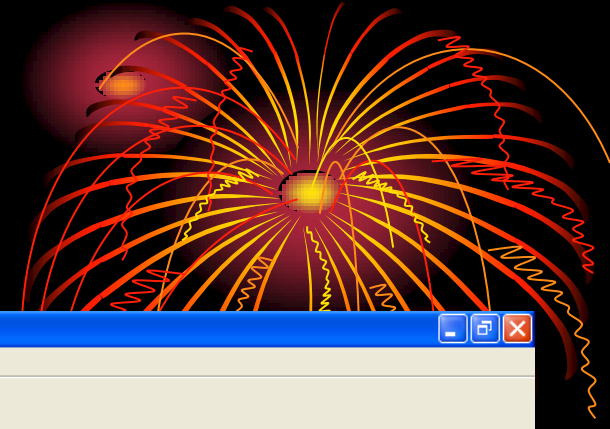
$$P_{av,2} = I^2 R = (500 \text{ A})^2$$

$$\times (0.22 \Omega / m \times 1000 \text{ km}) = 55.0 \text{ M W}$$

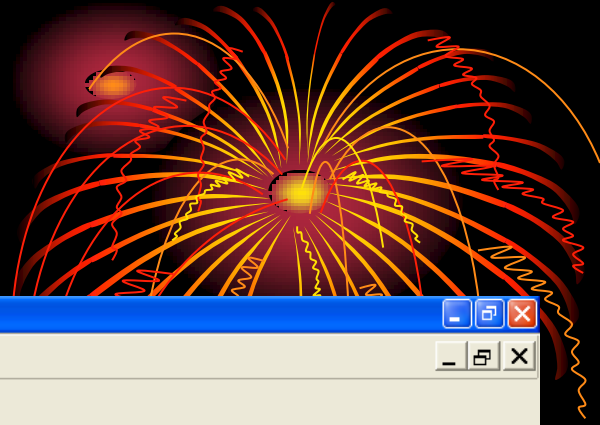
7.5 虛擬電路實驗



7.6 Orcad-PSpice



The screenshot displays the Orcad-PSpice software interface. The title bar reads "Capture CIS - Demo Edition". The menu bar includes "File", "Edit", "View", "Place", "Macro", "PSpice", "Accessories", "Options", "Window", and "Help". The toolbar contains various icons for file operations, simulation, and editing. The main window shows a schematic diagram of an inverting amplifier circuit. The circuit includes a sine wave voltage source V1 with parameters VOFF = 0, VAMPL = 1.2V, and FREQ = 1k. A 1k resistor R1 is connected between the source and the inverting input of an operational amplifier U3. A feedback network consisting of a 9k resistor R2 is connected between the output and the inverting input. The non-inverting input of U3 is connected to ground. The output of the amplifier is connected to a 1k resistor R3, which is also connected to ground. The output node is labeled "OUT". The left sidebar shows a file hierarchy for "C:\test\test.opj" with folders for "Design Resources", "Outputs", and "PSpice Resources". The bottom status bar indicates "Run PSpice simulation for active profile.", "0 items selected", and "Scale=200% X=1.50 Y=1.80".



7.7 Simulation

SCHMATIC1-exam - PSpice A/D Demo - [exam (active)]

File Edit View Simulation Trace Plot Tools Window Help

SCHMATIC1-exam

exam (active)

Simulation running...
** Profile: "SCHEMATIC1-exam" [C:\test\test-PSpiceFiles\SCHEMATIC1\exam.sim]
Reading and checking circuit
Circuit read in and checked, no errors
Calculating bias point for Transient Analysis
Bias point calculated
Transient Analysis
Transient Analysis finished
Simulation complete

Time step = 9.497E-06 Time = .01 End = .01

Analysis Watch Devices

For Help, press F1

Time = .01 100%

