Equations:

$$I = \frac{Q}{t} \quad \text{(A)}$$

$$V = \frac{W}{Q} \quad \text{(V)}$$

$$I = \frac{E}{R} \quad \text{(A)}$$

$$R = \rho \frac{\ell}{A} \quad (\Omega)$$

$$\frac{T + t_1}{R_1} = \frac{T + t_2}{R_2}$$

$$P = EI = VI = I^2R = \frac{V^2}{R}$$

$$W = Pt \quad \text{(J, W/s)}$$

$$\text{kwh} = \frac{Pt}{1000}$$

$$1 \text{ hp} = 746 \text{ W}$$

Series Circuits:

$$R_T = R_1 + R_2 + R_3 + \cdots + R_N; R_T = NR$$

$$E = V_1 + V_2 + V_3 + \cdots + V_N$$

$$I = \frac{E}{R_T}$$

$$P_T = EI = I^2R_1 + I^2R_2 + \cdots + I^2R_N$$

$$V_x = \frac{R_xE}{R_T}$$

Parallel Circuits:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_N}; R_T = \frac{R}{N}$$

$$R_T = \frac{R_1R_2}{R_1 + R_2}$$

$$I_T = \frac{E}{R_T}$$

$$I_T = I_1 + I_2 + I_3 + \cdots + I_N$$

$$I_1 = \frac{R_2I_T}{R_1 + R_2}, I_2 = \frac{R_1I_T}{R_1 + R_2}$$

PROBLEMS

SECTION 2.2 Current

1. If 24×10^{16} electrons pass through a conductor in $\frac{1}{2}$ min, determine:

a. Charge in coulombs.

b. Current.

a. 24×10^{16} electrons $\times \frac{1.6 \times 10^{-19} \text{ Coulomb}}{1 \text{ electron}} = 38.45 \times 10^{-3} \text{C}$

b. $\text{Current} = \frac{Q}{t} = \frac{38.45 \times 10^{-3} \text{C}}{30 \text{s}} = 1.282 \text{ mA}$

2. How long will it take 1600 mC to pass through a copper conductor if the current is 0.5 A?

3. How much charge has passed through a conductor if the current is 16 μA for 10 s? $Q = It$

3. Charge $Q = It = (16\mu A)(10s) = 160\mu C$

4. For a current of 1 mA, how many electrons will pass a particular point in the circuit in 1 s? Write the number out in full decimal form (all the zeros). Is it a significant number for such a small current level?

5. Write the following quantities in the most convenient form using the prefixes in Table 2.1.
   a. 0.050 A 50mA
   b. 0.0004 V 0.4mV
   c. $3 + 10^4$ V 30kV
   d. 1200 V 1.2kV
   e. 0.0000007 A 0.7μA
   f. 32,000,000 V 32MV

6. What is the resistance of 1000 ft of No. 12 house wire?

7. What is the area in circular mils of wires having the following diameters?
   a. $\frac{1}{32}$ in. a. $\frac{1}{32}in = 0.03125in = 31.25\ mils$
   b. 0.01 ft $A_{CM} = (d_{mils})^2 = (31.25\ mils)^2 = 976.56\ CM$
   c. 0.1 cm

7 (b) $0.01ft = 0.12in = 120\ mils$
$A_{CM} = (d\ mils)^2 = (120\ mils)^2 = 14,400\ CM$

(c) $0.1cm = 0.03937in = 39.37\ mils$
$A_{CM} = (39.37\ mils)^2 = 1550\ CM$

8. What is the diameter in inches of wires having the following areas in circular mils?
   a. 10,000 CM
   b. 625 CM
   c. 50,000 CM

SECTION 2.3 Voltage

9. Determine the energy expended (in joules) to bring a charge of 40 mC through a potential difference of 120 V.

9. 40mC電荷跨越120V電位差, energy?
$V = \frac{W}{Q} \rightarrow W = VQ = (120V)(40\times10^{-3}C) = 4.8\ joules$

10. What is the potential difference between two points in an electric circuit if 200 mJ of energy is required to bring a charge of 40 μC from one point to the other?

11. How much energy is required to move 18×10^{18} electrons through a potential difference of 12 V?

11. 18×10^{18}電子跨越12V, energy?
18×10^{18}電子相當於多少Q?
$Q = 18\times10^{18}\ electrons \times \frac{1.6\times10^{-19}C}{electron} = 2.88C$
$W = V \times Q = (12V)(2.88C) = 34.6J$

12. How much energy is expended to maintain a current of 10 mA between two points in an electric circuit for 5 s if the potential difference between the two points is 20 mV?

SECTION 2.5 Resistance and Ohm's Law

13. Determine the internal resistance of a battery-operated clock if a current of 1.8 mA results from an applied voltage of 1.5 V. 求battery的內部電阻

13. Ohm's Law $R = \frac{E}{I} = \frac{1.5V}{1.8mA} = 833.33\Omega$
Note: 電壓源電壓E

14. Determine the current through a soldering iron if 120 V is applied. The iron has a resistance of 18 Ω.

15. Find the voltage drop across a 2.2-MΩ resistor with a current of 30 μA passing through it. What resistance would be required to limit the current to 1.5 A if the applied voltage is 64 V? 跨越2.2MΩ的電阻的電壓降
$V = RI = (2.2M\Omega)(30\mu A) = 66V$
施予電壓64V, 限制電流1.5A,
電阻? $R = \frac{V}{I} = \frac{64V}{1.5A} = 42.67\Omega$

16. Determine the resistance of 50 ft of $\frac{1}{16}$-in.-diameter copper wire.

17. Calculate the resistance of 600 ft of No. 14 wire using Table 2.2.

18. Determine the diameter (in inches) of a copper inductor having a length of 200 ft and a resistance of 0.2 Ω.

19. What is the resistance of 1 mi of No. 12 house wire? How does it compare with the resistance of 1 kΩ connected to the end of the conductor?

20. If the resistance of a copper conductor is 2 Ω at room temperature (T = 20°C), what is its resistance at 100°C (the boiling point of water)?

21. At what temperature will the resistance of a No. 8 copper wire double if its resistance at T = 20°C is 1 Ω?

22. If the resistance of a copper conductor 400 ft long is 10 Ω at room temp. (T = 20°C), what is its resistance at −20°C.

23. **a.** Determine the resistance of a molded composition resistor with the following color bands: first: red; second: red; third: brown; fourth: gold.
b. Indicate its expected range of values.

24. Determine the color bands of a 100-kΩ resistor with a tolerance of 5%.

25. Determine the color bands of a 3.952 resistor with a tolerance of 10%.

SECTION 2.6 Power, Energy, Efficiency

26. Determine the power delivered by a 12-V battery at a current drain of 240 mA.

27. Calculate the power dissipated by a 2.2-kΩ resistor having a current of 4 mA passing through it.

28. A 280-W television set is connected to a 120-V outlet. Determine the current drawn by the set.

29. Determine the total energy dissipated by a 1400-W toaster used for 3.5 min.

30. Calculate the cost of using the following appliances for the indicated time period if the unit cost is 9 cents/kWh.
a. Six 60-W bulbs for 6 h.
b. 8-W clock for 30 days (1 month).
c. 160-W television set for 4 h 30 min.
d. 5000-W clothes dryer for 45 min.

31. Determine the cost of using an 8-W night light for 1 year (365 days) if the cost is 9 cents/kWh.

32. How long can we use a welding unit for $1.00 if the unit draws 14 A at 220 V and the cost is 9 cents/kWh?

33. Determine the applied power of a system that has an output power of 320 W and an efficiency of 86%.

34. **a.** A 2.2-hp motor has an input power demand of 2400 W. Determine its efficiency.
b. If the applied voltage is 120 V, find the input current.
c. What is the power lost in the energy transfer (in watts)?

#14 每 1000ft, 2.525Ω
因此, 600ft 的 wire, 電阻 $600\text{ft} \times \frac{2.525\Omega}{1000\text{ft}} = 1.515\Omega$

#12, 每 1000ft, 1.588Ω
因此, 1 mi = 5,280ft 的 wire, 電阻:
$5{,}280\text{ft} \times \frac{1.588\Omega}{1{,}000\text{ft}} = 8.38\Omega < 1\text{k}\Omega$

#8 t_1=20°C 為 1Ω, t_2=? 為 2Ω
Copper 絕對溫度 $T = -234.5$°C

$$\frac{T+t_1}{R_1} = \frac{T+t_2}{R_2} \qquad \frac{+234.5+20}{1\Omega} = \frac{+234.5+t_2}{2\Omega}$$

t_2 =

23. $22\Omega \times 10^1 \pm 5\%$
$209\Omega \sim 231\Omega$

25. 橙, 白, 金, 銀 Orange, white, Gold, Silver

(a) Output Power P_o = 2.2 hp = $2.2\text{hp} \times 746\text{W/hp}$

$$\eta = \frac{P_o}{P_i} = \frac{1641.2\text{W}}{2400\text{W}} = 68.4\%$$

(b) $P_i = 2400\text{W} = E \times I = (120\text{V})\, I \rightarrow I = \frac{2400\text{W}}{120\text{V}} = 20\text{A}$

(c) Power loss = $P_i - P_o$ = 758.8 W

Power = $I^2R = (4\text{mA})^2(2.2\text{k}\Omega) = 35.2\text{ mW}$

W = Pt = (1400W)(210s) = 294 kJ

下列設備耗能 = $6 \times 60\text{W} \times 6\text{h} + 8\text{W} \times 24\text{h/d} \times 30\text{d} + 160\text{W} \times 4.5\text{h} + 5000\text{W} \times \frac{3}{4}\text{h}$

(31)
1 year = 365 days = 8760 h
消耗能 $W = \frac{Pt}{1000} = \frac{8\text{W} \times 8760\text{h}}{1000} = 70.08\text{ kWh}$
Cost = W × 9 cents/kWh
= (70.08 kWh) × (9 cents/kWh)
= 630.72 ¢

(33) $\eta = 86\%$
$\eta = \frac{P_o}{P_i} \rightarrow P_i = \frac{P_o}{\eta} = \frac{320\text{W}}{0.86} = 372.09\text{W}$

(a) 有3個 System 連接，total efficiency

$\eta_T = \eta^3 = (0.9)^3 = 72.9\%$

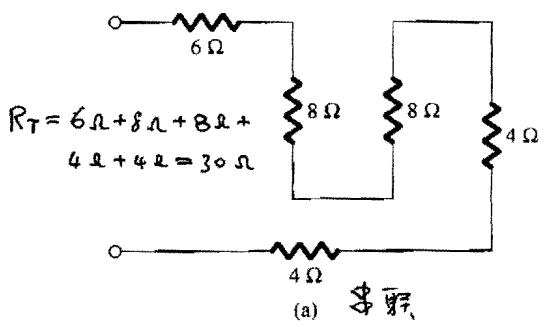
(b) 2個 $\eta = 90\%$ 的系統與1個 $\eta = 20\%$ 的系統連接

$\eta_T = (0.9)^2(0.2) = 16.2\%$

35. The total efficiency of systems in cascade (one following the other) is the product of the individual efficiencies. With this in mind:
   a. What is the total efficiency of three systems in cascade with efficiencies of 90% each?
   b. What is the total efficiency of three systems in cascade if two have an efficiency of 90% and one has an efficiency of 20%?
   c. What conclusions can you draw from the results for parts (a) and (b)?

SECTION 2.8 Series Dc Networks

36. Find the total resistance of the networks in Fig. 2.55.



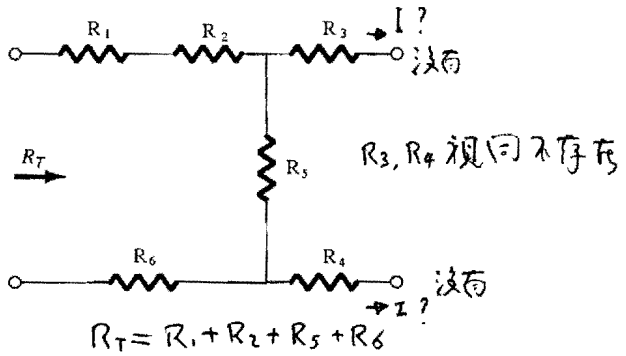
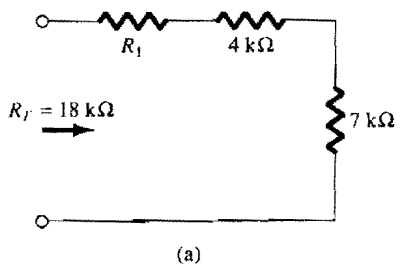


FIG. 2.55

37. Determine R_1 for the networks in Fig. 2.56.



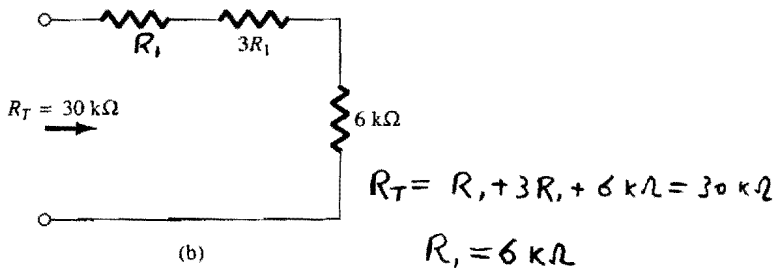


FIG. 2.56

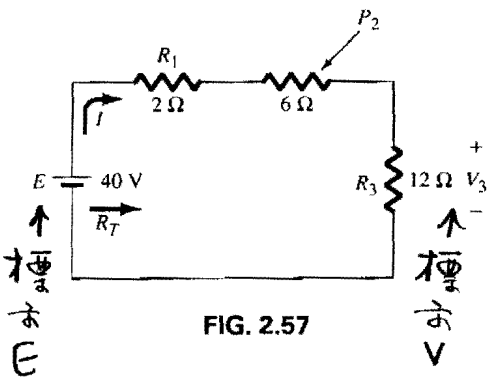


FIG. 2.57

38. For the circuit in Fig. 2.57, determine:
   a. R_T.
   b. I.
   c. V_3.
   d. P_2.

38.

a. Total resistance $R_T = 2\Omega + 6\Omega + 12\Omega = 20\Omega$

b. 由電池流出來的電流 $I = \frac{E}{R_T} = \frac{40V}{20\Omega} = 2A$

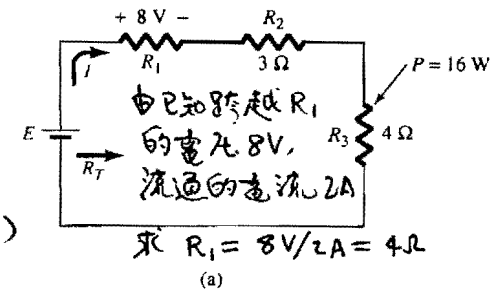
c. 流經串聯元件的電流都是 2A

因此 $V_3 = I \times R_3 = (2A)(12\Omega) = 24V$

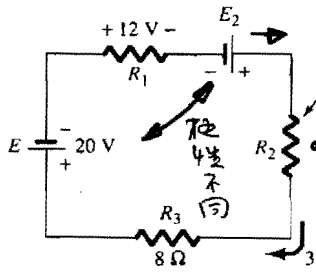
d. 6Ω 電阻消耗的 P_2

$P_2 = I^2 \times 6\Omega = (2A)^2(6\Omega) = 24W$

39. Determine the unknown quantities for the networks in Fig. 2.58.



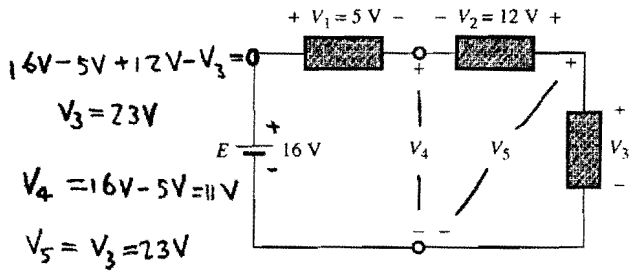
(a)



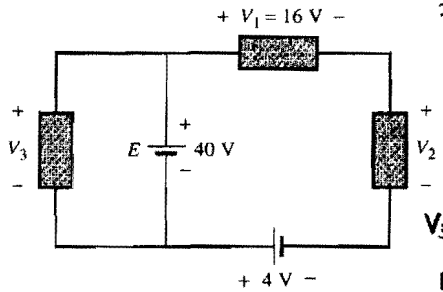
(b)

FIG. 2.58

40. Determine the unknown voltages for the circuits in Fig. 2.59 using Kirchhoff's voltage law.



(a)



(b)

FIG. 2.59

41. Determine the voltages V_3 and V_4 using the voltage-divider rule for the network in Fig. 2.60.

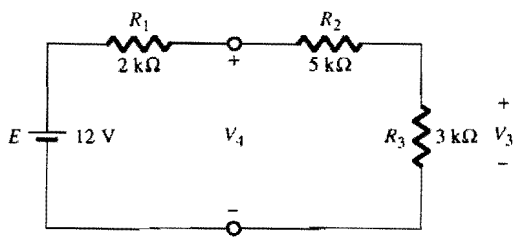


FIG. 2.60

42. Determine R_2 for the given voltage level for the network in Fig. 2.61 using the voltage-divider rule.

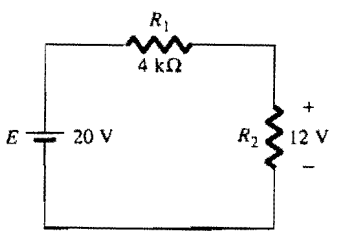


FIG. 2.61

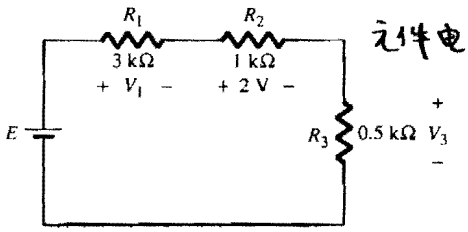


FIG. 2.62

元件电流相等

43. Determine the voltage levels V_1 and V_3 and E for the circuit in Fig. 2.62.

$\frac{V_1}{R_1} = \frac{2V}{R_2} \rightarrow V_1 = 6V$

$\frac{V_3}{R_3} = \frac{2V}{R_2} \rightarrow V_3 = 1\ V$

} 串联，电流相等。

$E = V_1 + V_2 + V_3 = 9V$

SECTION 2.10 Parallel Dc Networks

44. Determine the total resistance of the networks in Fig. 2.63.

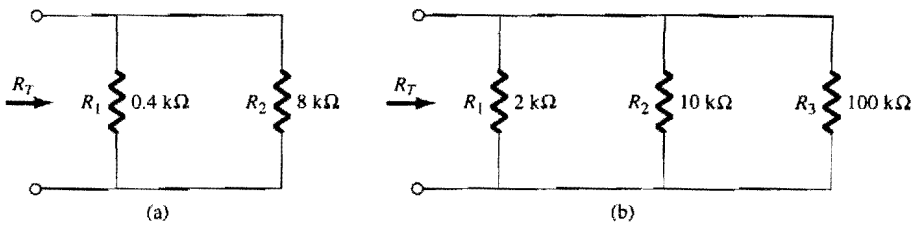


FIG. 2.63

$R_T = R_1 // R_2 // R_3$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} =$

$= 610 \times 10^{-6} S$

$R_T = \frac{1}{610 \times 10^{-6} S} = 1.639 k\Omega$

45. Determine R_1 for the networks in Fig. 2.64.

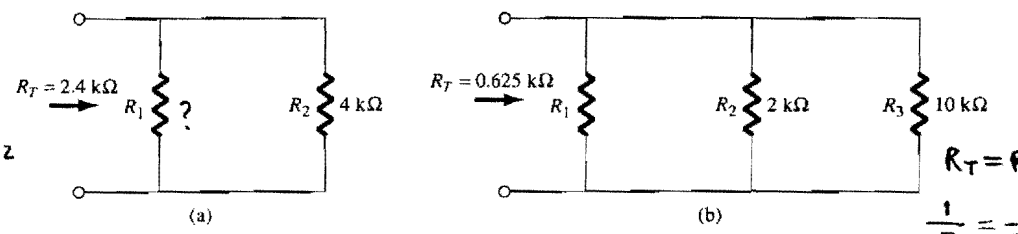


FIG. 2.64

$R_T = R_1 // R_2$

$R_T = R_1 // R_2 // R_3$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$R_1 = 1 k\Omega$

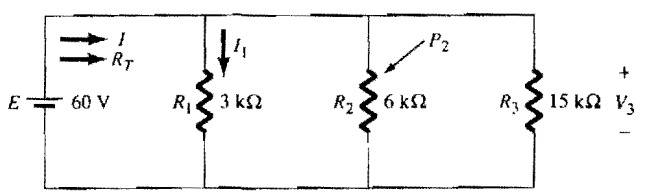


FIG. 2.65

46. For the network in Fig. 2.65 determine:
   a. R_T $R_T = R_1 // R_2 // R_3$
   b. I.
   c. I_1.
   d. V_3.
   e. P_2.

a. Total resistance R_T $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$, $R_T = 1.765 k\Omega$

b. 由 E 出来的电流 $I = \frac{E}{R_T} = \frac{60V}{1.765 k\Omega} = 33.99 mA$

c. 除 R_1, R_2, R_3 的电压降相等，等于 E

因此 $I_1 = \frac{V_{R1}}{R_1} = \frac{E}{R_1} = 20 mA$

d. $V_3 = E = 60V$

e. $P_2 = \frac{V_{R2}^2}{R_2} = \frac{(60V)^2}{6 k\Omega} = 0.6 W$

47. Determine the unknown quantities for the networks in Fig. 2.66.

$R_T = 1/(\frac{1}{R_1}+\frac{1}{R_2}) = \frac{R_1R_2}{R_1+R_2}$ $3\,k\Omega = \frac{(6k\Omega)R_2}{6k\Omega+R_2} \rightarrow R_2 = 6\,k\Omega$

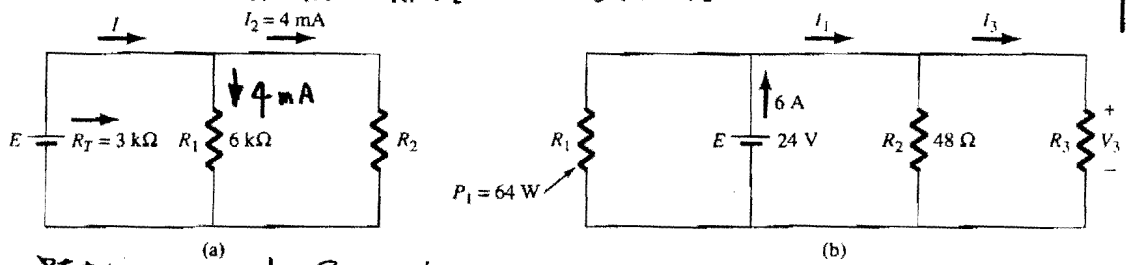
$I_2 = \frac{V_2}{R_2} = 0.5A$

$I_3 = \frac{V_3}{R_3} = 2.833A$

$I_1 = I_2 + I_3 = 3.333A$

$V_3 = 24V$

$V_2 = 24V$



R_2 与 V_2 并联 $V_2 = I_2 \times R_2 = 24V$

$E = V_2 = 24V$, $I = \frac{E}{R_T} = 8\,mA$

FIG. 2.66

R_1 与 V_1 并联 $V_1 = E = 24V$

R_1 与 P_1 并联 $P_1 = \frac{V_1^2}{R_1}$ $64W = \frac{(24V)^2}{R_1} \rightarrow R_1 = 9\Omega$

由 E 流出的支路 $I = \frac{E}{R_T} \rightarrow R_T = 4\Omega$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \rightarrow R_3 = 8.471\Omega$

48. Determine the unknown currents for the circuits in Fig. 2.67 using Kirchhoff's current law.

a: $10A = 3A + I_2 \rightarrow I_2 = 7A$

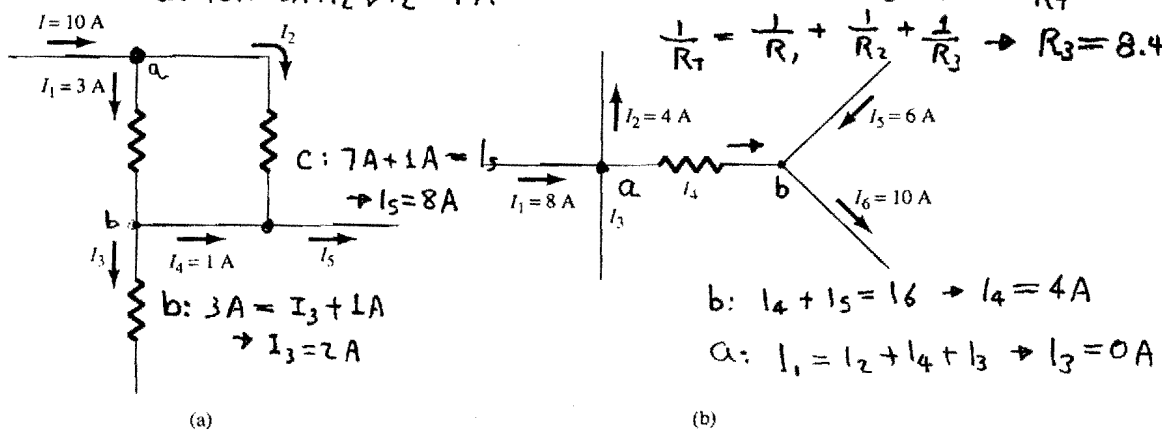


FIG. 2.67

49. Determine the currents I_1 and I_2 in Fig. 2.68 using the current-divider rule. What is the ratio R_1/R_2? How does it compare with the ratio I_1/I_2?

$I_1 = I \times \frac{R_2}{R_1+R_2} = 10mA \times \frac{40k\Omega}{40k\Omega+8k\Omega} = 8.333mA$

$I_2 = I - I_1 = 1.667\,mA$

$\frac{R_1}{R_2} = \frac{I_2}{I_1}$

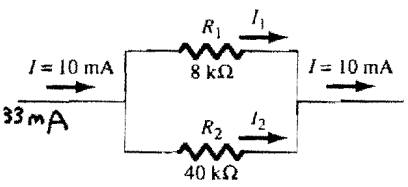


FIG. 2.68

50. Determine R_1 for the network in Fig. 2.69 using the current-divider rule.

Current-divider rule $I_{R_2} = I - I_1 = 12A - 4A = 8A$

$I_1 = I \times \frac{R_2}{R_1+R_2} \rightarrow R_1 = 16\,k\Omega$

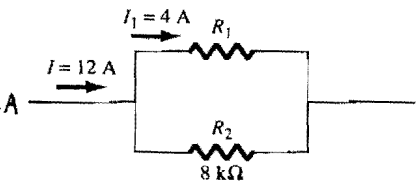


FIG. 2.69

51. Find I_1, I_3, and I for the network in Fig. 2.70.

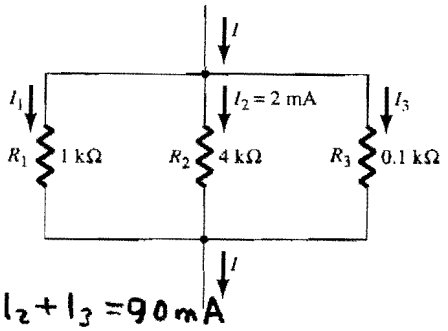


FIG. 2.70

$V_2 = I_2 \times R_2 = (2\text{mA})(4\text{k}\Omega) = 8\text{V}$

$V_1 = V_2$, $V_3 = V_2$

$I_1 = \frac{V_1}{R_1} = \frac{8\text{V}}{1\text{k}\Omega} = 8\text{mA}$

$I_3 = \frac{V_3}{R_3} = \frac{8\text{V}}{0.1\text{k}\Omega} = 80\text{mA}$ $\quad I = I_1 + I_2 + I_3 = 90\text{mA}$

SECTION 2.12 Meter Considerations

52. **a.** Sketch the location and connections of ammeters and voltmeters used to measure the currents I_1 and I_3 and voltages V_1 and V_3 in Fig. 2.71.

b. Using a voltmeter with an ohm-per-volt rating of 1000, determine the indication of the meter when it is placed across the 4-kΩ resistor if the 50-V scale is used.

c. Repeat part (b) for a meter employing an ohm-per-volt rating of 20,000.

d. Repeat part (b) for a DMM with an internal resistance of 11 MΩ.

e. Show the connection for a wattmeter reading the power delivered to R_3 and R_4.

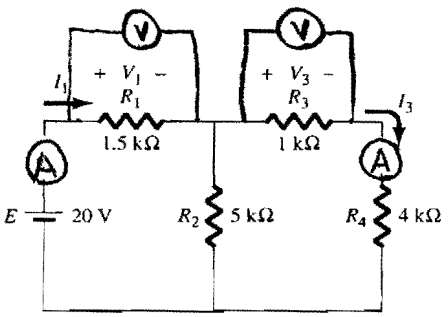
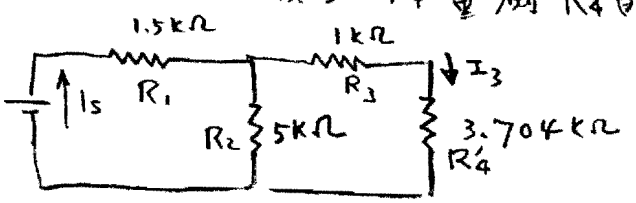


FIG. 2.71

b. Voltmeter 額定(內部電阻) 1000Ω/V

若 Scale 定於 50V, 則內部電阻為 50 kΩ

把 Voltmeter 並聯到 R_4 量測 R_4 的電壓降



$R_4 \rightarrow R_4 // R_V = 4\text{k}\Omega // 50\text{k}\Omega = 3.704\text{k}\Omega = R_4'$

$R_T = [((R_4 // R_V) + R_3) // R_2] + R_1 = 3.924\text{ k}\Omega$

($R_4 // R_V$ = 3.704; $((R_4 // R_V) + R_3) // R_2$ = 2.424 kΩ)

電源送出來的電流 $I_s = \frac{E}{R_T} = \frac{20\text{V}}{3.924\text{k}\Omega} = 5.097\text{ mA}$

$I_3 = I_s \times \frac{R_2}{(R_4 // R_V) + R_3 + R_2} = 2.626\text{ mA}$

($(R_4 // R_V) + R_3$ = 4.704 kΩ)

$V_{4\text{k}\Omega} = I_3 \times (R_4 // R_V) = (2.626\text{mA})(3.704\text{k}\Omega) = 9.73\text{V}$

(c) Voltmeter 額定為 20,000Ω/V

內部電阻 $R_V = 50\text{V} \times 20{,}000\Omega/\text{V} = 1\text{ M}\Omega$

重複前述程序 ⋯⋯ $V_{4\text{k}\Omega} \doteq 10\text{V}$