# Electricity

Topic Review Q and A

# Q1

A negative charge of $-2.0\times10^{-4}$ C and a positive charge of $8.0\times10^{-4}$ C are separated by 0.30 m. What is the force between the two charges?

$$F = \frac{Kq_Aq_B}{d_{AB}^2} = \frac{(9.0\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(2.0\times10^{-4}\ \text{C})(8.0\times10^{-4}\ \text{C})}{(0.30\ \text{m})^2}$$

$$= 1.6\times10^4\ \text{N}$$

# Q2

A negative charge of $-6.0\times10^{-6}$ C exerts an attractive force of 65 N on a second charge that is 0.050 m away. What is the magnitude of the second charge?

$$F = \frac{Kq_A q_B}{d_{AB}^2}$$

$$q_B = \frac{F d_{AB}^2}{K q_A} = \frac{(65\ \text{N})(0.050\ \text{m})^2}{(9.0\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2)(6.0\times10^{-6}\ \text{C})}$$

$$= 3.0\times10^{-6}\ \text{C}$$

# Q3

**Electric Forces** Two charged spheres are held a distance, *r*, apart. One sphere has a charge of $+3\mu C$, and the other sphere has a charge of $+9\mu C$. Compare the force of the $+3\mu C$ sphere on the $+9\mu C$ sphere with the force of the $+9\mu C$ sphere on the $+3\mu C$ sphere.

**The forces are equal in magnitude and opposite in direction.**

# Q4

A positive and a negative charge, each of magnitude $2.5 \times 10^{-5}$ C, are separated by a distance of 15 cm. Find the force on each of the particles.

$$F = \frac{Kq_A q_B}{d^2} = \frac{(9.0 \times 10^9\ \mathrm{N \cdot m^2/C^2})(2.5 \times 10^{-5}\ \mathrm{C})(2.5 \times 10^{-5}\ \mathrm{C})}{(1.5 \times 10^{-1}\ \mathrm{m})^2}$$

$= 2.5 \times 10^2$ N, toward the other charge

# Q5

A force of $2.4\times10^{2}$ N exists between a positive charge of $8.0\times10^{-5}$ C and a positive charge of $3.0\times10^{-5}$ C. What distance separates the charges?

$$F = \frac{Kq_Aq_B}{d^2}$$

$$d = \sqrt{\frac{Kq_Aq_B}{F}} = \sqrt{\frac{(9.0\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2)(8.0\times10^{-5}\ \text{C})(3.0\times10^{-5}\ \text{C})}{2.4\times10^{2}\ \text{N}}}$$

$$= 0.30\ \text{m}$$

# Q6

Electrons and protons have equal but opposite charges. The magnitude of this charge is known as the:

*Elementary Charge = $1.60 \times 10^{-19}$ C*

A hydrogen atom contains one proton and on electron. If the electrostatic force of attraction is $8.2 \times 10^{-8}$ N, how far apart are they?

1.) $F_E = \frac{kq_1q_2}{r^2}$  $r = \sqrt{\frac{kq_1q_2}{F_E}}$

$q_{p^+} = q_{e^-} = 1.60 \times 10^{-19} C$

$$r = \sqrt{\frac{(9 \times 10^9)(1.6 \times 10^{-19})(1.6 \times 10^{-19})}{8.2 \times 10^{-8}}}$$

$$= 5.3 \times 10^{-11} m$$

# Q7

The force between a proton and an electron is $3.5\times10^{-10}$ N. What is the distance between these two particles?

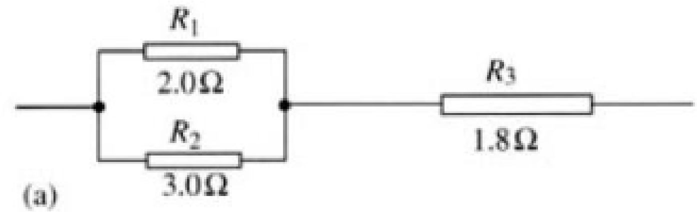
$$F = K\frac{q_A q_B}{d^2}$$

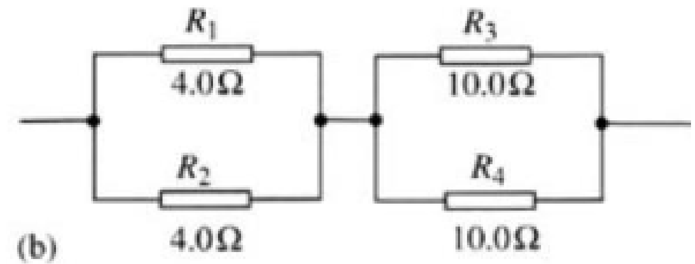
$$d = \sqrt{K\frac{q_A q_B}{F^2}}$$

$$= \sqrt{(9.0\times10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)\frac{(1.60\times10^{-19}\text{ C})(1.6\times10^{-19}\text{ C})}{3.5\times10^{-10}\text{ N}}} = 8.1\times10^{-10}\text{ m}$$

# Q8

Find the total resistance in each of the circuits




(a) $R_1$ and $R_2$ are in parallel, so together they are equivalent to a resistor $R$ where

$$\frac{1}{R} = \frac{1}{2.0} + \frac{1}{3.0} = \frac{5.0}{6.0}$$

$$\Rightarrow R = \frac{6.0}{5.0} = 1.2\,\Omega$$

Now, this $R$ is in series with $R_3$, so together they are equivalent to

$$R_{total} = (1.2 + 1.8)\,\Omega = 3.0\,\Omega$$

(b) $R_1$ and $R_2$ are in parallel, so together they are equivalent to a resistor $R$ where

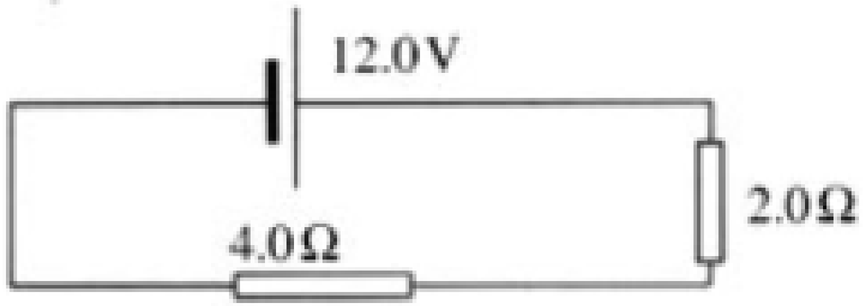
$$\frac{1}{R} = \frac{1}{4.0} + \frac{1}{4.0} = \frac{1.0}{2.0}$$

$$\Rightarrow R = \frac{2.0}{1.0} = 2.0\,\Omega$$

Similarly, $R_3$ and $R_4$ are in parallel so they are equivalent to a resistor of 5.0 Ω. The 2.0 Ω and 5.0 Ω are in series, so the overall total is 7.0 Ω.

# Q9

What is the total current in the circuit in



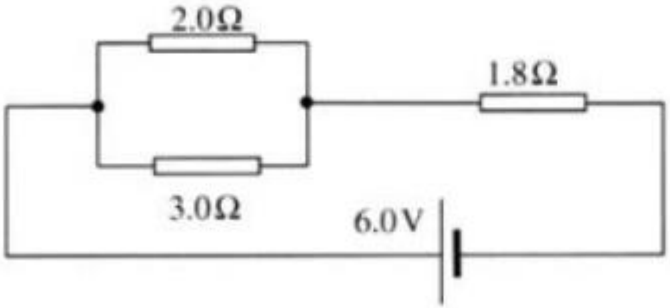

The emf of the battery is 12 V. The total resistance of the circuit is $2.0 + 4.0 = 6.0\,\Omega$. Thus, the total current is

$$I = \frac{12.0}{6.0}\,\text{A}$$

$$= 2.0\ \text{A}$$

# Q10

Find the current in each of the resistors in the




The resistors of 2.0 Ω and 3.0 Ω are connected in parallel and are equivalent to a single resistor of resistance $R$ found from

$$\frac{1}{R} = \frac{1}{2} + \frac{1}{3}$$
$$= \frac{5}{6}$$
$$\Rightarrow R = \frac{6}{5}$$
$$= 1.2\ \Omega$$

In turn, this is in series with the resistance of 1.8 Ω, so the total equivalent circuit resistance is $1.8 + 1.2 = 3.0\ \Omega$. The current that leaves the battery is thus

$$I = \frac{6.0}{3.0}$$
$$= 2.0\ \text{A}$$

The potential difference across the 1.8 Ω resistor is thus $V = 1.8 \times 2.0 = 3.6$ V, leading to a potential difference across the two parallel resistors of $V = 6.0 - 3.6 = 2.4$ V. Thus the current in the 2 Ω resistor is

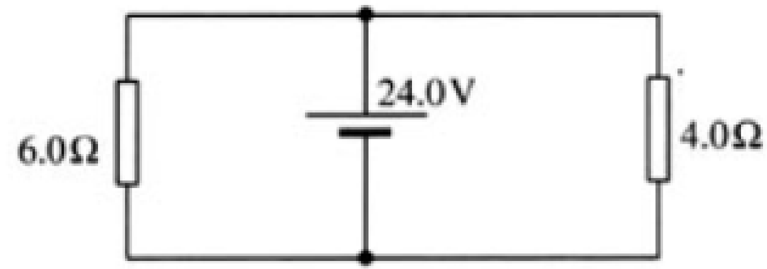
$$I = \frac{2.4}{2.0}$$
$$= 1.2\ \text{A}$$

and in the 3 Ω resistor is

$$I = \frac{2.4}{3.0}$$
$$= 0.80\ \text{A}$$

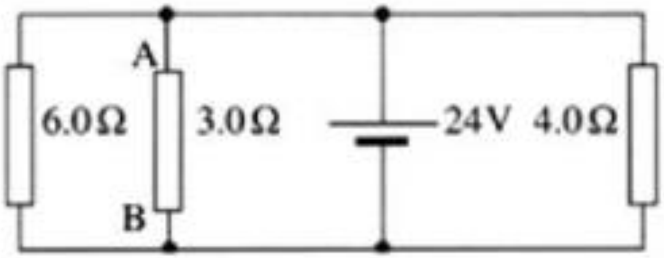
# Q11

Find the current in each resistor in the circuit in




The voltage across the 4.0 Ω resistor is 24.0 V and thus the current is 6.0 A. The voltage is 24.0 V across the other resistor as well, and so the current through it is 4.0 A. The current leaving the battery is 10.0 A.

# Q12

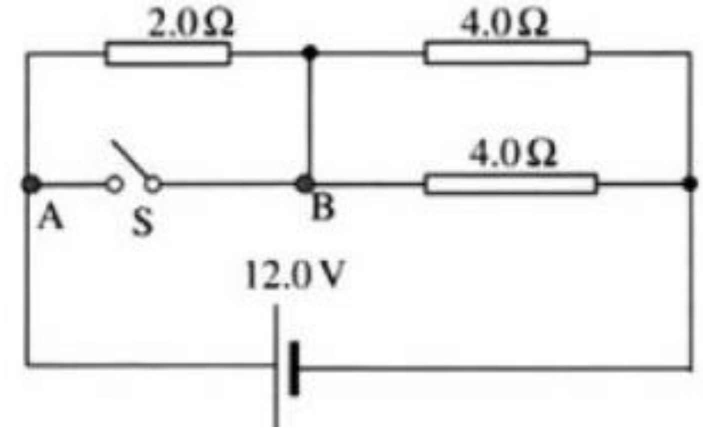



What is the potential difference between A and B? What is the current leaving the battery?

The potential difference is 24 V for all resistors. The currents in the resistors are 8 A, 6 A and 4 A, respectively. The total current is thus 18 A.

# Q13

What is the current in the 2.0 Ω resistor when the switch is open and when the switch is closed? What is the potential difference across the two marked points, A and B, when the switch is open and when the switch is closed?




When the switch is open, the total resistance is 4.0 Ω and thus the total current is 3.0 A. This is the current through the 2.0 Ω resistor. The potential at A is 12 V. The potential difference across the 2.0 Ω resistor is $2 \times 3 = 6$ V and so the potential at its right end, and hence at B, is 6 V. The potential difference across points A and B is thus 6 V.

When the switch is closed, no current flows through the 2.0 Ω resistor, since all the current takes the path through the switch, which offers no resistance. (The 2.0 Ω resistor has been *shorted out*.) The resistance of the circuit is then 2.0 Ω and the current leaving the battery is 6 A. The potential difference across points A and B is now zero. There is current flowing from A to B, but the resistance from A to B is zero. Hence the potential difference is $6 \times 0 = 0$ V.

# Q14

An electric kettle rated as 2000 W at 220 V is used to warm 2.0 L of water from 15 °C to 90 °C.

(a) How much current flows in the kettle?

(b) What is the resistance of the kettle?

(c) How long does it take to warm the water? (Specific heat capacity of water = 4200 J kg$^{-1}$ K$^{-1}$.)

(d) How much does this cost if the power company charges \$0.10 per kW h?

(a) From $P = VI$ we get $I = \frac{2000}{220} = 9.09 \approx 9.1\text{ A}$. (b) $P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P} = 24.2 \approx 24\ \Omega$. (c) The energy needed to warm the water is $Q = mc\Delta\theta = 2.0 \times 4200 \times (90 - 15) = 6.3 \times 10^5\text{ J}$. Since the power is 2000 W the time required is given by $2000 \times t = 6.3 \times 10^5 \Rightarrow t = 315\text{ s} = 5.25\text{ min}$. (d) The energy used is $2000\text{ W} \times 315\text{ s} = 2.0\text{ kW} \times \frac{315}{3600}\text{ h} = 0.175\text{ kW h}$ and so the cost is $0.175 \times 0.10\ \$ = 0.0175 \approx 0.02\ \$$

# Q15

Three appliances are connected (in parallel) to the same outlet, which provides a voltage of 220 V. A fuse connected to the outlet will blow if the current drawn from the outlet exceeds 10 A. If the three appliances are rated as 60 W, 500 W and 1200 W at 220 V, will the fuse blow?

Each appliance draws a current of $I_1 = \dfrac{60}{220} = 0.27\ \text{A}$, $I_2 = \dfrac{500}{220} = 2.27\ \text{A}$ and $I_3 = \dfrac{60}{220} = 5.45\ \text{A}$ for a total current leaving the plug of $0.27 + 2.27 + 5.45 = 7.99 \approx 8.0\ \text{A} < 10\ \text{A}$ so the fuse will not blow.

# Q16

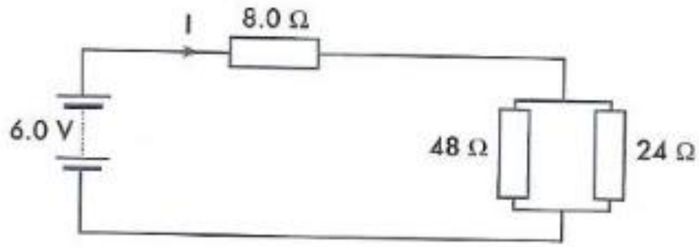
An electric kettle rated as 1200 W at 220 V and a toaster rated at 1000 W at 220 V are both connected in parallel to a source of 220 V. If the fuse connected to the source blows when the current exceeds 9.0 A, can both appliances be used at the same time?

Each appliance draws a current of $I_1 = \frac{1200}{220} = 5.45\text{ A}$ and $I_2 = \frac{1000}{220} = 4.55\text{ A}$ for a total current leaving the plug of $5.45 + 4.55 = 10\text{ A} > 9.0\text{ A}$ so the fuse will blow if both are used at the same time.

# Q17

For the circuit drawn below calculate the

(a) total resistance of the circuit,
(b) I,
(c) potential difference across the 24 Ω resistor, and
(d) power dissipated through 8.0 Ω resistor.




*(a)* *In parallel section:* $\frac{1}{R_T} = \frac{1}{48} + \frac{1}{24}$

$= \frac{1+2}{48} = \frac{3}{48}$

$\therefore R_T = 16\ \Omega$

$\therefore$ *Total resistance of circuit* $= 8.0 + 16$

$= 24\ \Omega$

*(b)* $V = IR$

$6.0 = I \times 24$

$\therefore I = 0.25\ A$

*(c)* *P.D. across parallel section* $= I R_T$

$= 0.25 \times 16$

$= 4.0\ V$

$\therefore$ *P.D. across 24 Ω resistor* $= 4.0\ V$

*(d)* $P = I^2 R$

$= (0.25)^2 \times 8.0$

$= 0.50\ W$

$\therefore$ *Power dissipated through 8.0 Ω resistor*

$= 0.50\ W$

# Q18

A television set owned by Michael is rated at 180 W and is designed to operate on a 240 V supply. If standard values for fuses are 2.00 A, 5.00 A and 10.0 A,

(a) suggest a value for a fuse to be placed in the circuit to which Michael's television is connected, and

(b) if a 10.0 A fuse was inadvertently used instead of the recommended fuse, predict what may happen if fault in the television caused a much larger current to flow in the television set.

*(a)* $P = VI$

$180 = 240\,I$

$\therefore I = 0.75\ A$

$\therefore$ *Use a 2.00 A fuse.*

*(b) Components in the television set may be damaged by the excessive current or a fire may start in the television set before the 10.0 A fuse is made to 'blow' by this larger current.*

# Q19

The 12.0 V battery in a car supplies a current of $3.50 \times 10^2$ A to provide the starter motor with maximum power.

(a) Calculate the maximum power of the starter motor.

(b) Determine the maximum resistance of the starter motor, the battery and the connective wires.

(c) Compare the thickness of the wire connecting the battery to the starter motor with the thickness of the wire used in most other circuits in the car. Give a reason for your answer.

*(a)* $P = VI = 12.0 \times 3.50 \times 10^2 = 4.20 \times 10^3\ W$

*(b)* $R = \dfrac{V}{I} = \dfrac{12.0}{3.50 \times 10^2} = 3.43 \times 10^{-2}\ \Omega$

*(c) The battery to starter motor wire is much thicker for it to have a small resistance (less than* $3.43 \times 10^{-2}\ \Omega$*) and to carry a very large current.*

# Q20

A 110-volt toaster oven draws a current of 6 amps on its highest setting as it converts electrical energy into thermal energy. What is the toaster's maximum power rating?

$$P = VI = (110V)(6A) = 660W$$

# Q21

An electric iron operating at 120 volts draws 10 amperes of current. How much heat energy is delivered by the iron in 30 seconds?

$$W = Pt = VIt = (120V)(10A)(30s) = 3.6 \times 10^4 J$$

# Q22

A potential drop of 50 volts is measured across a 250-ohm resistor. What is the power developed in the resistor?

$$P = \frac{V^2}{R} = \frac{(50V)^2}{250\Omega} = 10W$$

# Q23

A driving lamp fitted to a car is specified as a 100 W, 12.0 V lamp. Calculate

(a) the current flowing through the lamp, and

(b) the resistance of the lamp.

(a)

$$P = VI$$

$$100 = 12.0\,I$$

$$\therefore I = 8.33\ A$$

(b)

$$V = IR$$

$$12.0 = 8.33\,R$$

$$\therefore R = 1.44\ \Omega$$

# Q24

An electric motor found in a child's toy requires two 1.50 V dry cell batteries to be connected in series. If the motor draws a maximum current of 300 mA calculate

(a) the resistance of the motor, and

(b) the maximum power consumption of the toy.

*(a)*

$$V = IR$$

$$3.00 = 0.300\,R$$

$$\therefore R = 10.0\,\Omega$$

*(b)*

$$P = VI$$

$$= 3.00 \times 0.300$$

$$\therefore P = 0.900\,W$$

# Q25

A Christmas tree is decorated by a string of 16 light globes which are connected in series to a mains outlet of 240 V. If the total power consumption is 24.0 W, calculate the

(a) potential difference across each light globe, and

(b) resistance of each light globe.

(a) *Potential difference across each globe*

$$= \frac{240}{16} = 15\ V$$

(b) $$Power = \frac{V^2}{R}$$

$$R = \frac{(240)^2}{24} = 2.40 \times 10^3\ \Omega$$

*Resistance of circuit* $= 2.40 \times 10^3\ \Omega$

$$\therefore \text{Resistance of each globe} = \frac{2.40 \times 10^3}{16}$$

$$= 150\ \Omega$$

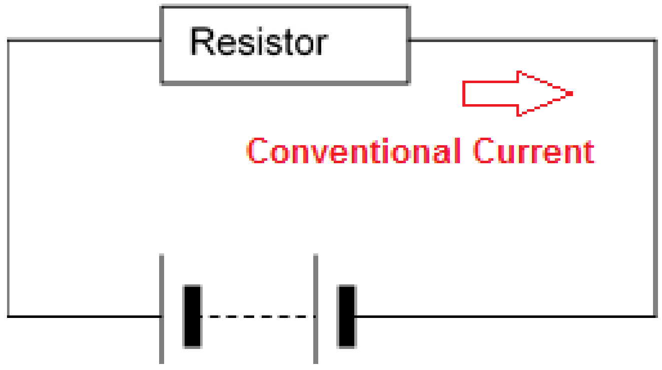
# Q26

When a resistor is connected to a battery, $6.02 \times 10^{23}$ electrons pass through the resistor in a time of 70.0 s. Calculate the current in the resistor. (2 marks)

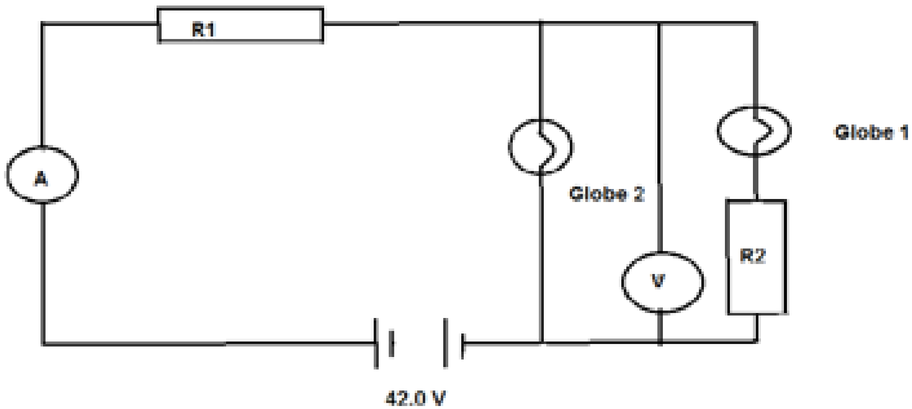
Also, put a labelled arrow on the diagram to indicate the direction of conventional current in this circuit. (1 mark)

$$I = \frac{q}{t} = \frac{1.6 \times 10^{-19} \times 6.02 \times 6.02 \times 10^{23}}{70}$$

$$I = 1.38 \times 10^{3}\ A$$



# Q27




Globe 1 is rated at 12.0 V and 3.00 W

Globe 2 is rated at 36.0 V and 12.0 W

Assume that this circuit allows both globes work at the exact values at which they are rated.

# Q27 continued

a) Determine:

(i) Current in Globe 1

**P = 3.0 W** **V = 12.0 V**

**I = P/V = 3/12**

**I = 0.250 A**

(ii) Current in Globe 2

**P = 12.0 W** **V = 36.0 V**

**I = P/V = 12/36**

**I = 0.333 A**

(iii) Resistance of R2

**V = 36 – 12 = 24**

**I = 0.250 A**

**R = V/I = 24/0.250**

**R = 96.0 Ω**

(iv) Resistance of R1

**V = 6 V**

**I = (0.333 + 0.250) = 0.583 A**

**R = V/I = 6/0.583**

**R = 10.3 Ω**

(iv) The total resistance of the circuit

**V = 36 V**

**I = (0.333 + 0.250) = 0.583 A**

**R = V/I = 36/0.583**

**R = 61.7 Ω**

# Q27 continued

b) What is the reading on the:

(i) ammeter

**0.583 A**

(ii) voltmeter

**36.0 V**

# Q28

The heating elements in a toaster are designed to get red hot in order to toast bread placed in the toaster. A typical toaster draws a current of 7.5 A when operating on household voltage (240 V).

(a) Calculate the resistance of the heating elements and the power produced by the toaster when in normal operation. (2 marks)

resistance $R = V/I = (240\ V) / (7.5\ A) = \underline{32\ \Omega}$

power $P = VI = (240\ V) \times (7.5\ A) = \underline{1800\ W}$

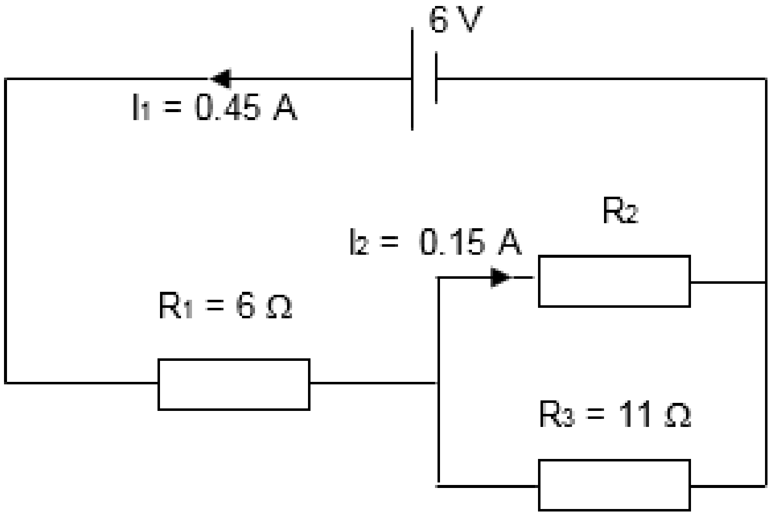
(b) Describe how and explain why the current through the heating element changes when the toaster is switched on. (2 marks)

The current through the heating element will decrease as the element heats up (✓),

as the resistance of the element increases as its temperature goes up ✓

# Q29

For the circuit shown at right state the value of each of the quantities listed below (no working out needs to be shown, just the answers)




(a) voltage drop across $R_1$ 2.7 V

(b) current through $R_3$ 0.30 A

(c) size of resistor $R_2$ 22 Ω

(d) total resistance of the circuit 13.3 Ω

# Q30

An electric kettle contains 450 mL of water at an initial temperature of 18°C. The kettle operates on mains voltage (240 V) and draws a current of 6.25 A when switched on. The kettle is 90% efficient at converting electrical energy into thermal energy in the water.

(a) Calculate the amount of heat that the kettle supplies to the water every second after it is switched on. (2 marks)

Electrical power P = V I = 240 V x 6.25 A = 1500 W ✓

Heat supplied to water every second = 90% x 1500 W

= 1350 W ✓

(b) How much heat is needed by the water to reach boiling point (100°C)?

Heat needed to reach boiling point is

$Q = m c \Delta T = 0.45 \text{ kg} \times 4180 \text{ Jkg}^{-1}\text{K}^{-1} \times (100 - 18)\text{K}$ ✓

= 154 kJ ✓

# Q30 continued

(c) How long will it take for the water to reach boiling point?

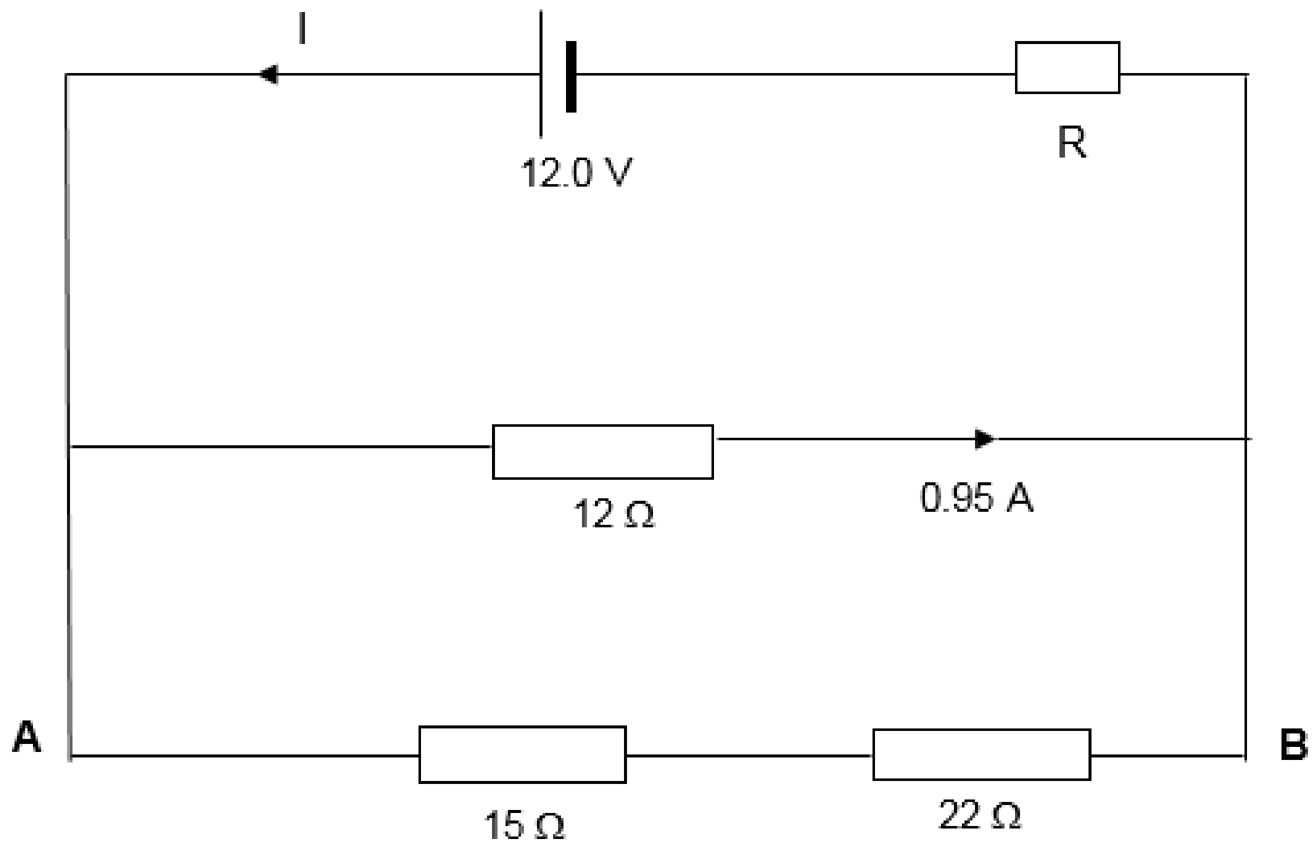
$P = Q/t \rightarrow t = Q/P$ ✓

$= (154000\ J) / (1350\ W)$

$= \underline{114\ s}$ ✓

# Q31

A 12.0 V battery is connected to a circuit with four resistors as shown in the diagram below. A current of 0.95 A flows through the 12 Ω resistor.



# Q31 continued

(a) Calculate the potential difference (voltage) between points A and B.

Voltage between A and B = voltage across 12 Ω resistor (in parallel)

V = I R = (0.95 A) x (12 Ω) = <u>11.4 V</u> ✓

(b) Find the current flowing through the 15 Ω resistor.

Current through 15 Ω resistor = current flowing between A and B ✓

I = V / R = (11.4 V) / (15 Ω + 22 Ω) = <u>0.31 A</u> ✓

# Q31 continued

(c) Determine the rate at which heat is being produced in the 22 Ω resistor.

$P = I^2 R$ ✓

$= (0.31\ A)^2 \times (22\ \Omega)$

$= \underline{2.1\ W}$ ✓

(d) What is the current I from the battery?

Current from battery I = 0.31 A + 0.95 A ✓

= <u>1.26 A</u> ✓

# Q31 continued

(e) Find the value of the resistance R in series with the battery.

Voltage drop across R = 12 V - 11.4 V = 0.60 V ✓

Resistance R = V / I = (0.60 V) / (1.26 A)

= <u>0.48 Ω</u> ✓

# Q32

- (a) What is the current involved when a truck battery sets in motion 720 C of charge in 4.00 s while starting an engine?

$$I = \frac{\Delta Q}{\Delta t} = \frac{720\text{ C}}{4.00\text{ s}} = 180\text{ C/s}$$
$$= 180\text{ A.}$$

- (b) How long does it take 1.00 C of charge to flow through a handheld calculator if a 0.300-mA current is flowing?

$$I = \Delta Q / \Delta t \text{ for time } \Delta t$$

$$\Delta t = \frac{\Delta Q}{I} = \frac{1.00\text{ C}}{0.300\times10^{-3}\text{ C/s}}$$
$$= 3.33\times10^{3}\text{ s.}$$

# Q33

- What is the resistance of an automobile headlight through which 2.50 A flows when 12.0 V is applied to it?
- $$I = V/R$$

  $$R = \frac{V}{I} = \frac{12.0\ \mathrm{V}}{2.50\ \mathrm{A}} = 4.80\ \Omega.$$

# Q34

- A car headlight filament is made of tungsten and has a cold resistance of 0.350 Ω . If the filament is a cylinder 4.00 cm long (it may be coiled to save space), what is its diameter?

| Material | Resistivity $\rho$ ( $\Omega \cdot \mathrm{m}$ ) |
|---|---|
| *Conductors* | |
| Silver | $1.59\times10^{-8}$ |
| Copper | $1.72\times10^{-8}$ |
| Gold | $2.44\times10^{-8}$ |
| Aluminum | $2.65\times10^{-8}$ |
| Tungsten | $5.6\times10^{-8}$ |

$$R = \frac{\rho L}{A}$$

$$A = \frac{\rho L}{R}$$

$$A = \frac{(5.6\times10^{-8}\ \Omega \cdot \mathrm{m})(4.00\times10^{-2}\ \mathrm{m})}{1.350\ \Omega} = 6.40\times10^{-9}\ \mathrm{m}^2.$$

# Q34 continued

The area of a circle is related to its diameter $D$ by

$$A = \frac{\pi D^2}{4}.$$

Solving for the diameter $D$, and substituting the value found for $A$, gives

$$D = 2\left(\frac{A}{p}\right)^{\frac{1}{2}} = 2\left(\frac{6.40\times10^{-9}\ \text{m}^2}{3.14}\right)^{\frac{1}{2}}$$

$$= 9.0\times10^{-5}\ \text{m}.$$

# Q35

- If the cost of electricity in your area is 12 cents per kWh, what is the total cost (capital plus operation) of using a 60-W incandescent bulb for 1000 hours (the lifetime of that bulb) if the bulb cost 25 cents? (b) If we replace this bulb with a compact fluorescent light that provides the same light output, but at one-quarter the wattage, and which costs $1.50 but lasts 10 times longer (10,000 hours), what will that total cost be?
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# Q35 continued

**Solution for (a)**

The energy used in kilowatt-hours is found by entering the power and time into the expression for energy:

$$E = Pt = (60\text{ W})(1000\text{ h}) = 60{,}000\text{ W}\cdot\text{h}.$$

In kilowatt-hours, this is

$$E = 60.0\text{ kW}\cdot\text{h}.$$

Now the electricity cost is

$$\text{cost} = (60.0\text{ kW}\cdot\text{h})(\$0.12/\text{kW}\cdot\text{h}) = \$7.20.$$

The total cost will be $7.20 for 1000 hours (about one-half year at 5 hours per day).

**Solution for (b)**

Since the CFL uses only 15 W and not 60 W, the electricity cost will be $7.20/4 = $1.80. The CFL will last 10 times longer than the incandescent, so that the investment cost will be 1/10 of the bulb cost for that time period of use, or 0.1($1.50) = $0.15. Therefore, the total cost will be $1.95 for 1000 hours.

# Q36

**A light bulb draws a current of 0.60 A. If the bulb is left on for 8.0 min, how many electrons (elementary charges) pass through the bulb?**

1 A · s is equivalent to 1 C.

$$I = \frac{Q}{\Delta t}$$

$$8.0\ \cancel{\text{min}}\ \frac{60\ \text{s}}{\cancel{\text{min}}} = 480\ \text{s}$$

**Substitute first**

$$0.60\ \text{A} = \frac{Q}{480\ \text{s}}$$

$$(0.60\ \text{A})(480\ \text{s}) = \frac{Q}{\cancel{480\ \text{s}}}\ \cancel{480\ \text{s}}$$

$$Q = 288\ \text{A} \cdot \text{s}$$

$$Q = 288\ \text{C}$$

Use the relationship between amount of charge and the elementary charge to find the number of electrons.

$$Q = Ne$$

**Substitute first**

$$288\ \text{C} = N\ 1.60 \times 10^{-19}\ \text{C}$$

$$\frac{288\ \cancel{\text{C}}}{1.60 \times 10^{-19}\ \cancel{\text{C}}} = \frac{N\ \cancel{1.60 \times 10^{-19}\ \text{C}}}{\cancel{1.60 \times 10^{-19}\ \text{C}}}$$

$$N = 1.80 \times 10^{21}$$

In the 8.0 min that the light bulb was on, $1.8 \times 10^{21}$ electrons (elementary charges) passed through it.

# Q37

**Calculate the resistance of a 15 m length of copper wire, at 20°C, that has a diameter of 0.050 cm.**

| Involved in the problem | | Known | Implied | Unknown |
| --- | --- | --- | --- | --- |
| $R$ | $A$ | $d = 0.050$ cm | $\rho = 1.7 \times 10^{-8}\ \Omega \cdot \text{m}$ | $R$ |
| $L$ | $\rho$ | $L = 15$ m | | $A$ |
| $d$ (diameter) | | | | |

**Strategy**

Use the equation relating resistance to resistivity and dimensions of the conductor.

Convert diameter to SI units. (All others are in SI units.)

Find the cross-sectional area from the diameter.

**Calculations**

$$R = \rho \frac{L}{A}$$

$$0.050\ \cancel{\text{cm}}\ \frac{\text{m}}{100\ \cancel{\text{cm}}} = 5.0 \times 10^{-4}\ \text{m}$$

$$A = \pi r^2$$

$$r = \frac{d}{2}$$

$$r = \frac{5.0 \times 10^{-4}\ \text{m}}{2} = 2.5 \times 10^{-4}\ \text{m}$$

$$A = \pi(2.5 \times 10^{-4}\ \text{m})^2$$

$$A = 1.96 \times 10^{-7}\ \text{m}^2$$

# Q37 continued

$$R = (1.7 \times 10^{-8}\ \Omega \cdot \mathrm{m})\ \frac{15\ \mathrm{m}}{1.96 \times 10^{-7}\ \mathrm{m}^2}$$

$$R = 1.3\ \frac{\Omega \cdot \cancel{\mathrm{m}} \cdot \cancel{\mathrm{m}}}{\cancel{\mathrm{m}^2}}$$

$$R = 1.3\ \Omega$$

# Q38

**What is the resistance of a load if a battery with a 9.0 V potential difference causes a current of 0.45 A to pass through the load?**

$V = IR$

**Substitute first**

$9.0\ \text{V} = (0.45\ \text{A})\,R$

$$\frac{9.0\ \text{V}}{0.45\ \text{A}} = \frac{(\cancel{0.45\ \text{A}})\,R}{\cancel{0.45\ \text{A}}}$$

$R = 20\ \Omega$

The data fit Ohm's law. The number 9 divided by approximately $\frac{1}{2}$ is the same as $9 \times 2 = 18$. The final answer, 20, is close to 18.

# Q39

Four loads (3.0 Ω, 5.0 Ω, 7.0 Ω, and 9.0 Ω) are connected in series to a 12 V battery. Find

(a) the equivalent resistance of the circuit

(b) the total current in the circuit

(c) the potential difference across the 7.0 Ω load

# Q39 continued

Use the equation for the equivalent resistance of a series circuit.

$$R_{eq} = R_1 + R_2 + R_3 + R_4$$
$$= 3.0\ \Omega + 5.0\ \Omega + 7.0\ \Omega + 9.0\ \Omega$$
$$= 24\ \Omega$$

**(a)** The equivalent resistance for the four resistors in series is 24 Ω.

Use Ohm's law, in terms of current, and the equivalent resistance to find the current in the circuit.

$$I_S = \frac{V_S}{R_{eq}}$$

$$I_S = \frac{12\ \text{V}}{24\ \Omega}$$

$1\ \frac{\text{V}}{\Omega}$ is equivalent to 1A.

$$I_S = 0.50 \frac{\text{V}}{\Omega}$$

$$I_S = 0.50\ \text{A}$$

**(b)** The current in the circuit is 0.50 1A.

Use Ohm's law, the current, and the resistance of a single resistor to find the potential drop across that resistor.

$$V_3 = I_3 R_3$$

$$I_3 = I_S$$

Since the circuit has only one closed loop, the current is the same everywhere in the circuit, so $I_3 = I_S$.

$$V_3 = (0.50\ \text{A})(7.0\ \Omega)$$

$$V_3 = 3.5\ \text{A} \cdot \Omega$$

1 A · Ω is equivalent to 1 V.

$$V_3 = 3.5\ \text{V}$$

**(c)** The potential drop across the 7.0 Ω resistor is 3.5 V.

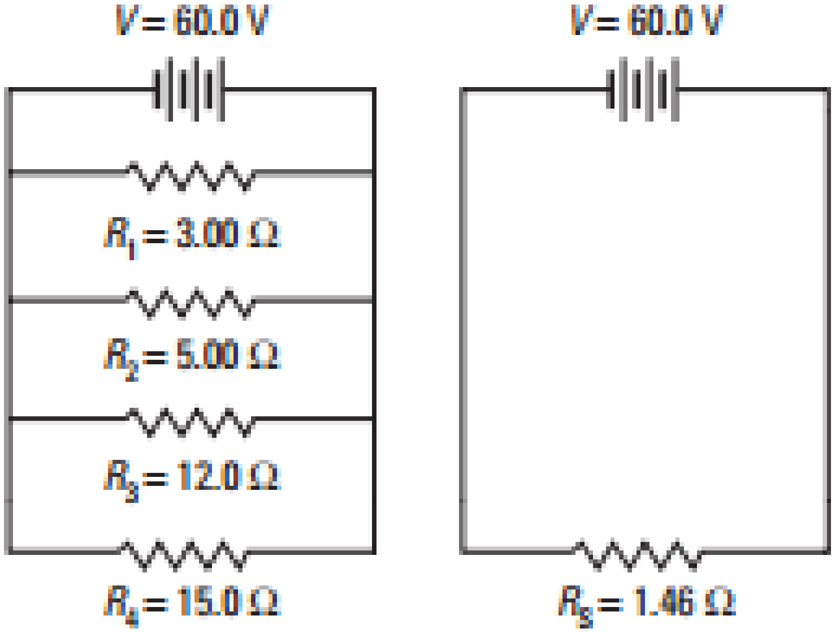
# Q40

A 60 V battery is connected to four loads of 3.0 Ω, 5.0 Ω, 12.0 Ω, and 15.0 Ω in parallel.

(a) Find the equivalent resistance of the four combined loads.

(b) Find the total current leaving the battery.

(c) Find the current through the 12.0 Ω load.



# Q40 continued

Use the equation for resistors in parallel and apply it to the four loads.

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

Substitute values for resistance and add.

$$\frac{1}{R_{eq}} = \frac{1}{3.00\ \Omega} + \frac{1}{5.00\ \Omega} + \frac{1}{12.0\ \Omega} + \frac{1}{15.0\ \Omega}$$

Find a common denominator.

Add.

$$\frac{1}{R_{eq}} = \frac{20}{60.0\ \Omega} + \frac{12}{60.0\ \Omega} + \frac{5}{60.0\ \Omega} + \frac{4}{60.0\ \Omega}$$

$$\frac{1}{R_{eq}} = \frac{41}{60.0\ \Omega}$$

**Strategy**

**Calculations**

Invert both sides of the equation. (If you invert an equality, it remains an equality.)

$$R_{eq} = \frac{60.0\ \Omega}{41}$$

Divide.

$$R_{eq} = 1.46\ \Omega$$

**(a)** The equivalent resistance of the four loads in parallel is 1.46 Ω.

Use Ohm's law, in terms of current, and the equivalent resistance to calculate the current entering and leaving the battery.

$$I_S = \frac{60.0\ \text{V}}{1.46\ \Omega}$$

# Q40 continued

$1\,\frac{\text{V}}{\Omega}$ is equivalent to an A.

$$I_S = 41.0\frac{\text{V}}{\Omega}$$

$$I_S = 41.0\text{ A}$$

**(b)** The current entering and leaving the battery is 41.0 A.

Use Ohm's law, in terms of current, to find the current through the 12.0 Ω load.

$$I_3 = \frac{60.0\text{ V}}{12.0\ \Omega}$$

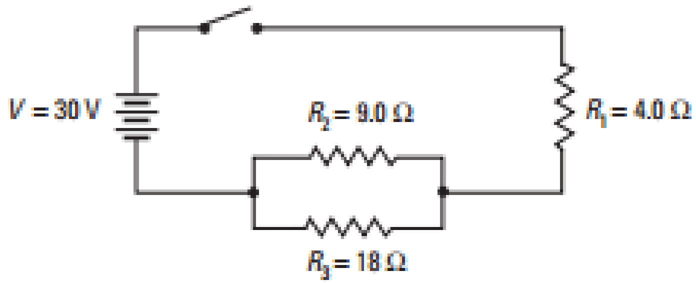
$$I_3 = 5.00\frac{\text{V}}{\Omega}$$

$$I_3 = 5.00\text{ A}$$

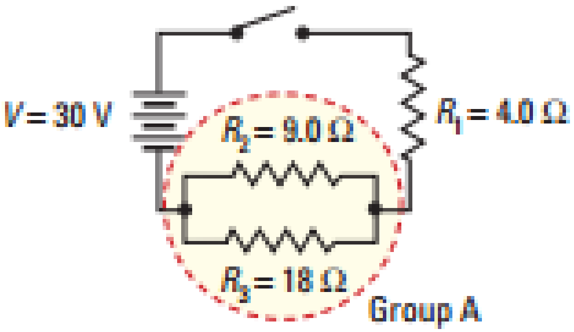
**(c)** Of the 41.0 A leaving the battery, 5.00 A are diverted to the 12.0 Ω load.

# Q41

**Find the equivalent resistance of the entire circuit shown in the diagram, as well as the current through, and the potential difference across, each load.**




| Strategy | Calculations |
| --- | --- |
| Find the equivalent resistance for the parallel Group A resistors. | $\frac{1}{R_A} = \frac{1}{R_2} + \frac{1}{R_3}$ |
| Find a common denominator. | $\frac{1}{R_A} = \frac{1}{9.0\ \Omega} + \frac{1}{18\ \Omega}$ |
| | $\frac{1}{R_A} = \frac{2}{18\ \Omega} + \frac{1}{18\ \Omega}$ |



# Q41 continued

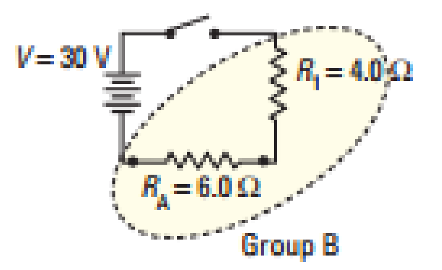
| Strategy | Calculations |
|---|---|
| Simplify. | $\frac{1}{R_A} = \frac{3}{18\ \Omega}$ |
| Invert both sides of the equation. | $\frac{1}{R_A} = \frac{1}{6.0\ \Omega}$ <br> $R_A = 6.0\ \Omega$ |
| Find the equivalent resistance of the series Group B. | $R_B = R_A + R_1$ <br> $R_B = 4.0\ \Omega + 6.0\ \Omega$ <br> $R_B = 10\ \Omega$ |

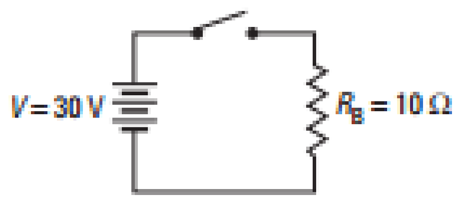
Since there is now one equivalent resistor in the circuit, the effective resistance of the entire circuit is $R_{eq} = 10\ \Omega$.

| | |
|---|---|
| Find the current entering and leaving the battery, using the potential difference of the battery and the total effective resistance of the circuit. | $I_S = \frac{V_S}{R_S}$ <br> $I_S = \frac{30\ V}{10\ \Omega}$ <br> $I_S = 3.0\ A$ |

Since there are no branches in the circuit between the battery and load $R_1$, all of the current leaving the battery passes through $R_1$. Therefore, $I_1 = 3.0\ A$.

| | |
|---|---|
| Knowing the current through $R_1$, and its resistance, you can use Ohm's law to find $V_1$. | $V_1 = I_1R_1$ <br> $V_1 = (3.0\ A)(4.0\ \Omega)$ <br> $V_1 = 12\ V$ |



# Q41 continued

The potential difference across load 1 is 12 V.

The loads $R_1$ and $R_A$ form a complete path from the anode to the cathode of the battery; therefore, the sum of the potential drops across these loads must equal that of the battery.

$$V_S = V_1 + V_A$$
$$30\text{ V} = 12\text{ V} + V_A$$
$$30\text{ V} - 12\text{ V} = V_A$$
$$V_A = 18\text{ V}$$

Since the potential difference across a parallel connection is the same for both pathways, $V_2 = 18$ V and $V_3 = 18$ V.

Knowing the potential difference across $R_2$ and $R_3$, you can find the current through each load by using Ohm's law.

$$I_2 = \frac{V_2}{R_2} \qquad I_3 = \frac{V_2}{R_3}$$
$$I_2 = \frac{18\text{ V}}{9.0\ \Omega} \qquad I_3 = \frac{18\text{ V}}{18\ \Omega}$$
$$I_2 = 2.0\text{ A} \qquad I_3 = 1.0\text{ A}$$

The current through load 2 is 2.0 A, and the current through load 3 is 1.0 A.

To summarize, the 30 V battery causes a current of 3.0 A to move through the circuit. All of the current passes through the 4.0 Ω load but then splits into two parts, with 2.0 A going through the 9.0 Ω load and 1.0 A going through the 18 Ω load. The potential drops across the 4.0 Ω, 9.0 Ω, and 18 Ω loads are 12 V, 18 V, and 18 V, respectively.

# Q42

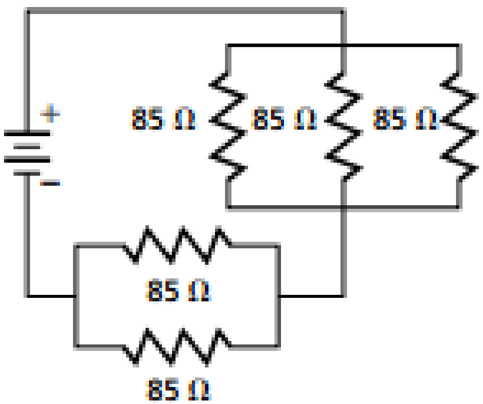
**What is the power rating of a segment of Nichrome™ wire that draws a current of 2.5 A when connected to a 12 V battery?**

| | |
|---|---|
| Use the equation that relates current and potential difference to power. | $P = IV$ |
| Substitute the known values. | $P = (2.5\ \text{A})(12\ \text{V})$ |
| | $P = 30\ \text{A}\cdot\text{V}$ |
| An A · V is equivalent to a W. | $P = 30\ \text{W}$ |

The power rating of the segment of wire is 30 W.

# Q43

Determine the total resistance of three, 85-Ω resistors connected in parallel and then series-connected to two 85-Ω resistors connected in parallel, as shown in




$$\frac{1}{R_{3\text{ in parallel}}} = \frac{1}{85\ \Omega} + \frac{1}{85\ \Omega} + \frac{1}{85\ \Omega}$$

$$R_{3\text{ in parallel}} = 28.3\ \Omega$$

$$\frac{1}{R_{2\text{ in parallel}}} = \frac{1}{85\ \Omega} + \frac{1}{85\ \Omega}$$

$$R_{2\text{ in parallel}} = 42.5\ \Omega$$

$$R = R_{3\text{ in parallel}} + R_{2\text{ in parallel}}$$

$$= 28.3\ \Omega + 42.5\ \Omega$$

$$= 71\ \Omega$$

# Q44

How many electrons flow through a light bulb each second if the current through the light bulb is 0.75 A?

From $I = q/t$, the charge flowing through the bulb in 1.0 s is

$$q = It = (0.75\ \text{A})(1.0\ \text{s}) = 0.75\ \text{C}$$

But the magnitude of the charge on each electron is $e = 1.6 \times 10^{-19}$ C. Therefore,

$$\text{Number} = \frac{\text{charge}}{\text{charge/electron}} = \frac{0.75\ \text{C}}{1.6 \times 10^{-19}\ \text{C}} = 4.7 \times 10^{18}$$

# Q45

A metal rod is 2 m long and 8 mm in diameter. Compute its resistance if the resistivity of the metal is $1.76 \times 10^{-8}\ \Omega \cdot \text{m}$.

$$R = \rho \frac{L}{A} = (1.76 \times 10^{-8}\ \Omega \cdot \text{m}) \frac{2\ \text{m}}{\pi (4 \times 10^{-3}\ \text{m})^2} = 7 \times 10^{-4}\ \Omega$$

# Q46

An electric motor takes 5.0 A from a 110 V line. Determine the power input and the energy, in J and kW·h, supplied to the motor in 2.0 h.

$$\text{Power} = P = VI = (110\ \text{V})(5.0\ \text{A}) = 0.55\ \text{kW}$$

$$\text{Energy} = Pt = (550\ \text{W})(7200\ \text{s}) = 4.0\ \text{MJ}$$

$$= (0.55\ \text{kW})(2.0\ \text{h}) = 1.1\ \text{kW}\cdot\text{h}$$

# Q47

A line having a total resistance of 0.20 Ω delivers 10.00 kW at 250 V to a small factory. What is the efficiency of the transmission?

We use $P = VI$ to find $I = P/V$. Then

$$\text{Power lost in line} = I^2R = \left(\frac{P}{V}\right)^2 R = \left(\frac{10\,000\ \text{W}}{250\ \text{V}}\right)^2 (0.20\ \Omega) = 0.32\ \text{kW}$$

$$\text{Efficiency} = \frac{\text{power delivered by line}}{\text{power supplied to line}} = \frac{10.00\ \text{kW}}{(10.00 + 0.32)\ \text{kW}} = 0.970 = 97.0\%$$

# Q48

A 120-V house circuit has the following light bulbs turned on: 40.0 W, 60.0 W, and 75.0 W. Find the equivalent resistance of these lights.

House circuits are so constructed that each device is connected in parallel with the others. From $P = VI = V^2/R$, we have for the first bulb

$$R_1 = \frac{V^2}{P_1} = \frac{(120\ \text{V})^2}{40.0\ \text{W}} = 360\ \Omega$$

Similarly, $R_2 = 240\ \Omega$ and $R_3 = 192\ \Omega$. Because they are in parallel,

$$\frac{1}{R_{eq}} = \frac{1}{360\ \Omega} + \frac{1}{240\ \Omega} + \frac{1}{192\ \Omega} \qquad \text{or} \qquad R_{eq} = 82.3\ \Omega$$

As a check, we note that the total power drawn from the line is 40.0 W + 60.0 W + 75.0 W = 175.0 W. Then, using $P = V^2/R$, we have

$$R_{eq} = \frac{V^2}{\text{total power}} = \frac{(120\ \text{V})^2}{175.0\ \text{W}} = 82.3\ \Omega$$

# Q49

What resistance must be placed in parallel with 12 Ω to obtain a combined resistance of 4 Ω?

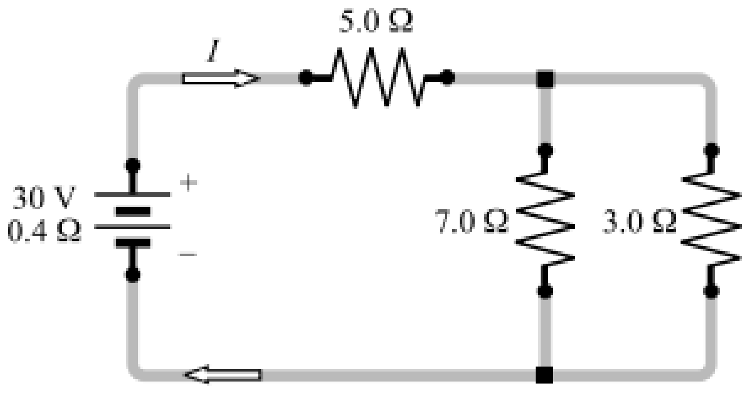
From $$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

we have $$\frac{1}{4\ \Omega} = \frac{1}{12\ \Omega} + \frac{1}{R_2}$$

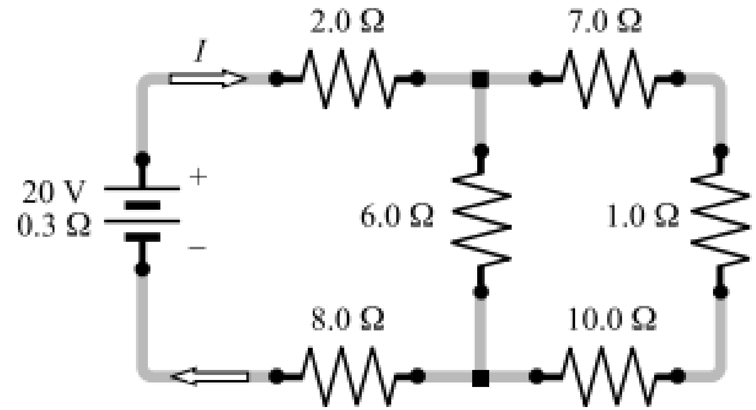
so $$R_2 = 6\ \Omega$$

# Q50

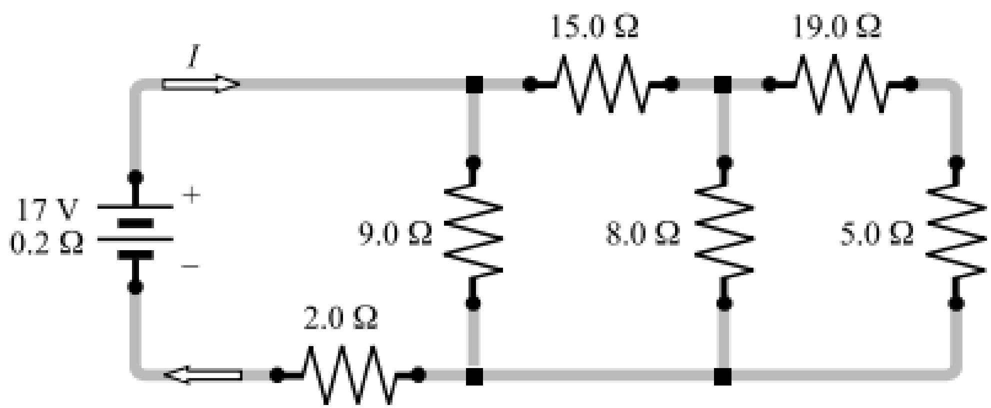
For each circuit shown determine the current *I* through the battery.




(*a*)




(*b*)




(*c*)

# Q50 continued

(*a*) The 3.0-Ω and 7.0-Ω resistors are in parallel; their joint resistance $R_1$ is found from

$$\frac{1}{R_1} = \frac{1}{3.0\ \Omega} + \frac{1}{7.0\ \Omega} = \frac{10}{21\ \Omega} \qquad \text{or} \qquad R_1 = 2.1\ \Omega$$

Then the equivalent resistance of the entire circuit is

$$R_{eq} = 2.1\ \Omega + 5.0\ \Omega + 0.4\ \Omega = 7.5\ \Omega$$

and the battery current is

$$I = \frac{\mathscr{E}}{R_{eq}} = \frac{30\ \text{V}}{7.5\ \Omega} = 4.0\ \text{A}$$

(*b*) The 7.0-Ω, 1.0-Ω, and 10.0-Ω resistors are in series; their joint resistance is 18.0 Ω. Then 18.0 Ω is in parallel with 6.0 Ω; their combined resistance $R_1$ is given by

$$\frac{1}{R_1} = \frac{1}{18.0\ \Omega} + \frac{1}{6.0\ \Omega} \qquad \text{or} \qquad R_1 = 4.5\ \Omega$$

Hence, the equivalent resistance of the entire circuit is

$$R_{eq} = 4.5\ \Omega + 2.0\ \Omega + 8.0\ \Omega + 0.3\ \Omega = 14.8\ \Omega$$

and the battery current is

$$I = \frac{\mathscr{E}}{R_{eq}} = \frac{20\ \text{V}}{14.8\ \Omega} = 1.4\ \text{A}$$

# Q50 continued

(*c*) The 5.0-Ω and 19.0-Ω resistors are in series; their joint resistance is 24.0 Ω. Then 24.0 Ω is in parallel with 8.0 Ω; their joint resistance $R_1$ is given by

$$\frac{1}{R_1} = \frac{1}{24.0\ \Omega} + \frac{1}{8.0\ \Omega} \qquad \text{or} \qquad R_1 = 6.0\ \Omega$$

Now $R_1 = 6.0\ \Omega$ is in series with 15.0 Ω; their joint resistance is $6.0\ \Omega + 15.0\ \Omega = 21.0\ \Omega$. Thus 21.0 Ω is in parallel with 9.0 Ω; their combined resistance is found from

$$\frac{1}{R_2} = \frac{1}{21.0\ \Omega} + \frac{1}{9.0\ \Omega} \qquad \text{or} \qquad R_2 = 6.3\ \Omega$$

Hence the equivalent resistance of the entire circuit is

$$R_{eq} = 6.3\ \Omega + 2.0\ \Omega + 0.2\ \Omega = 8.5\ \Omega$$

and the battery current is

$$I = \frac{\mathscr{E}}{R_{eq}} = \frac{17\ \text{V}}{8.5\ \Omega} = 2.0\ \text{A}$$