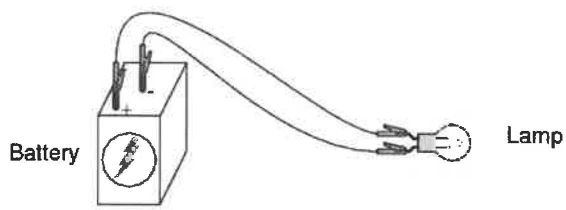
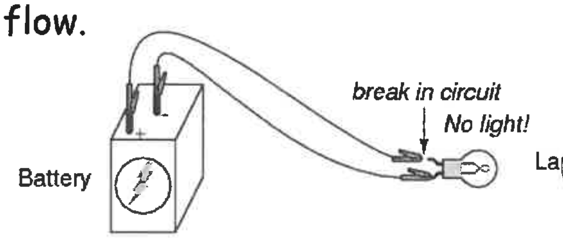
Chapter 10: Electric Circuits

- Electrons possess electric potential energy that can be transformed into heat, light, and motion.
- For such transformations to occur, a source of electric potential energy needs to connect to one or more components by means of an electric circuit (path for electric current)
- Any device in a circuit that converts electric potential energy into some other form of energy (causing an electric potential drop) is called a resistor. (or load)

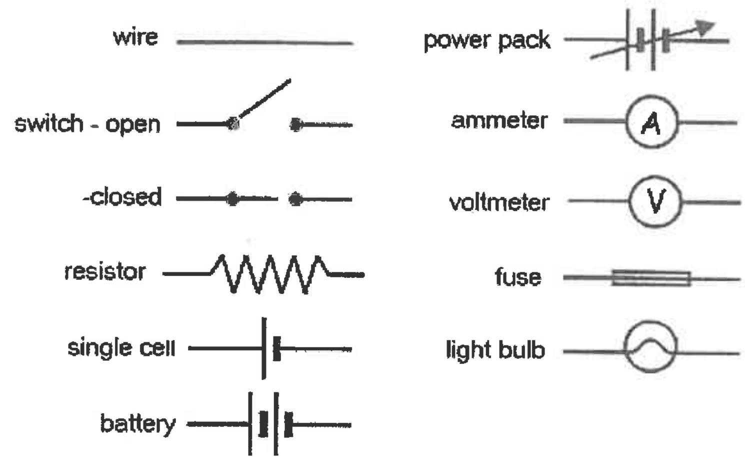


- In the above circuit, the charges pass from the positive terminal of the battery, through the light bulb, and then back to the negative terminal of the battery.
- Electric potential energy acquired in the battery is carried by electric charges as they pass through the circuit.
- The electric potential energy is transferred to the light bulb and converted to light and heat.
- Electric current can only flow through a circuit if there is a continuous conducting path.
- Any break in the circuit will stop the flow.

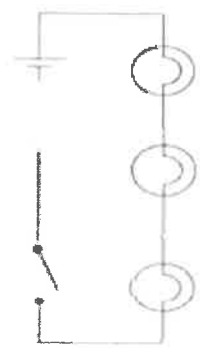


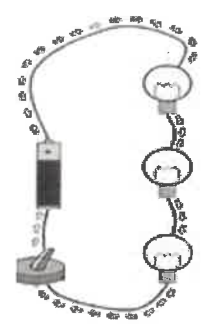
Circuits

Any circuit can be represented with a schematic diagram using a set of common symbols:



Series Circuits

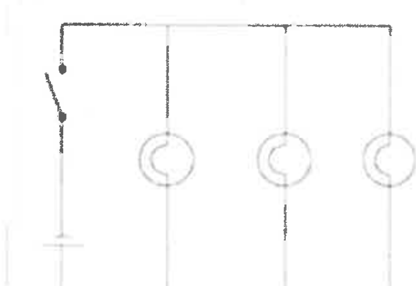


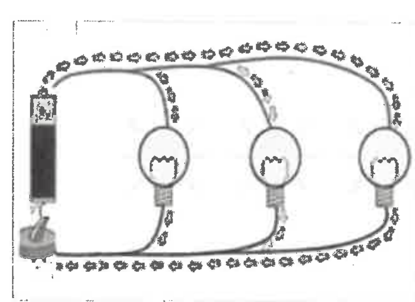


- Simple way of joining several resistors together
- Charges have only one conducting path

Parallel Circuits

- Charges can move along several paths through the circuit
- Charge could pass through only one of the several resistors before returning to the energy source.





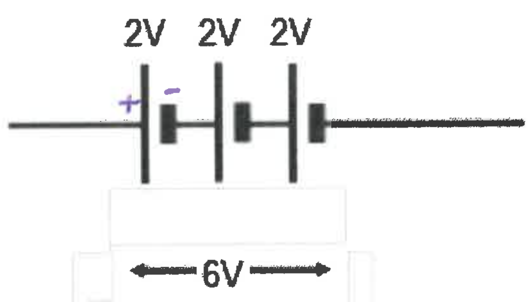
Cells vs. Batteries

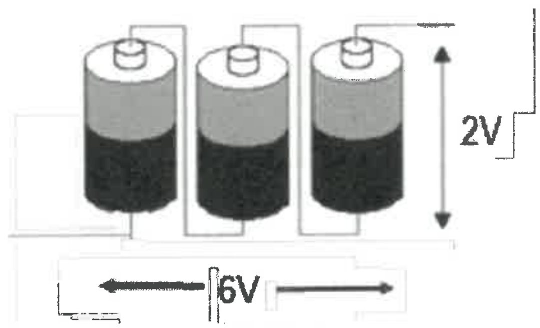
Chemical Cell - electrochemical device that converts chemical energy into electrical energy

Battery - collection of cells that work together to provide electrical energy to a circuit

Cells in Series

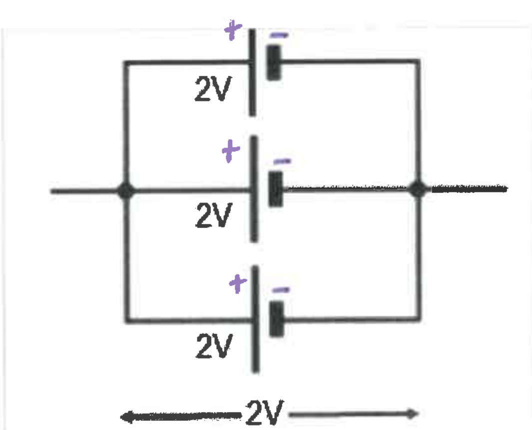
- Positive terminal is connected to negative terminal of another cell
- Voltage is cumulative

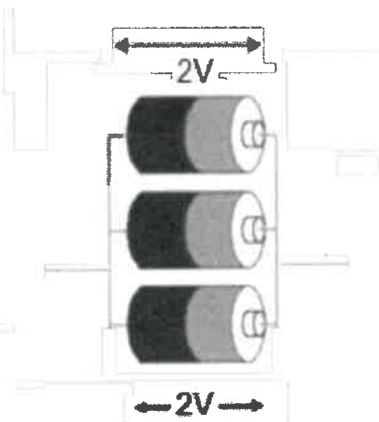




Cells in Parallel

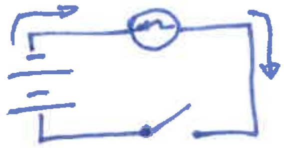
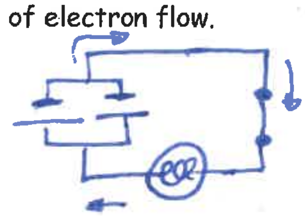
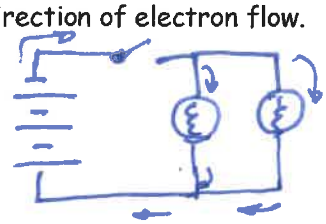
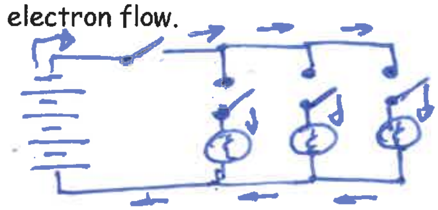
- Positive terminals are connected together
- Voltage is constant, but increases the current that flows





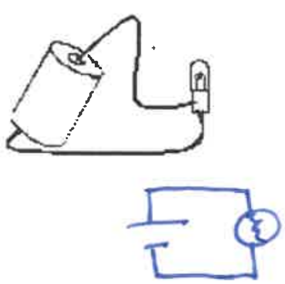
Circuit diagram worksheet

PART 1 - Convert the following descriptions to schematic circuit diagrams. Remember to always use a ruler when drawing circuit diagrams.

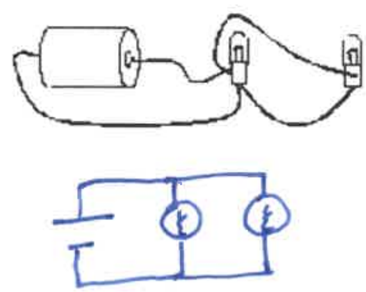
1. Draw a circuit diagram containing a battery with 2 dry cells in series, one pathway with an open switch and a lamp. Show the direction of electron flow. 	2. Draw a circuit diagram containing a battery with 2 dry cells in parallel, one pathway with a closed switch and a lamp. Show the direction of electron flow. 
3. Draw a circuit diagram containing a battery with 3 cells in series, two pathways with a lamp on each path. Add a switch that would control the lamps on both paths. Show the direction of electron flow. 	4. Draw a circuit diagram containing a battery with 4 cells in series, three pathways and a lamp on each path. Add switches to control each of the lamps and a fourth switch to control all of the lamps. Show the direction of electron flow. 

PART 2 - Convert the following pictorials to schematic circuit diagrams. Write descriptions for each pictorial.

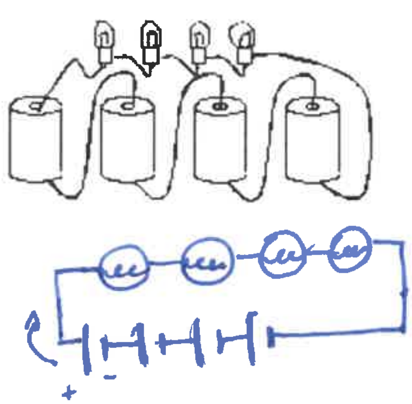
1.



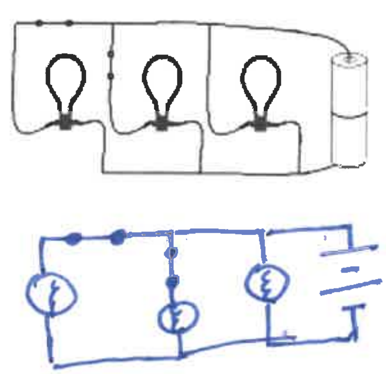
3.



2.



4.



Kirchhoff's Laws for Electric Currents

Law of Conservation of Energy

- As electrons move through an electric circuit, they gain energy in sources and lose energy in loads
- The total energy gained in one trip through a circuit is equal to the total energy lost.

Law of Conservation of Charge

- Electric charge is neither created nor destroyed in an electric circuit, nor does it accumulate at any point in the circuit.

Kirchhoff's Voltage Law:

- Around any complete path through an electric circuit, the sum of the increases in electric potential is equal to the sum of the decreases in electric potential

Kirchhoff's Current Law:

- At any junction point in an electric circuit, the total electric current into the junction is equal to the total electric current out.

* Tollway Slide

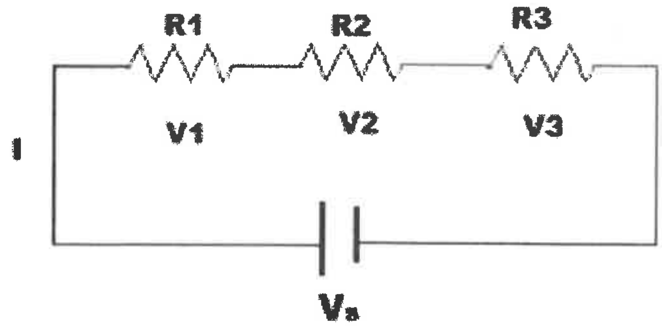
Resistance in Series

$V_s = V_1 + V_2 + V_3$

$I_sR_s = I_1R_1 + I_2R_2 + I_3R_3$

Since $I_s = I_1 = I_2 = I_3$

Then $R_s = R_1 + R_2 + R_3$



Equivalent Resistor: Resistor that has the same current and potential difference as the resistors it replaces.

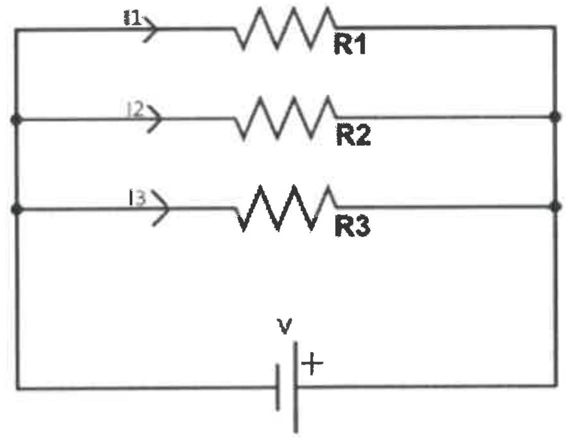
Ex.1: What is the equivalent resistor in a series circuit containing a 16 Ω light bulb, a 27 Ω heater, and a 12 Ω motor?

$$R_E = R_1 + R_2 + R_3$$
$$= 16\,\Omega + 27\,\Omega + 12\,\Omega$$
$$= 55\,\Omega$$

Ex.2: A 22 Ω, and 18 Ω and an unknown resistor are connected in series to give an equivalent resistance of 64 Ω. What is the resistance of the unknown resistor?

$$R_E = R_1 + R_2 + R_3$$
$$64\,\Omega = 22\,\Omega + 18\,\Omega + R_3$$
$$64\,\Omega = 40\,\Omega + R_3$$
$$R_3 = 64\,\Omega - 40\,\Omega$$
$$= 24\,\Omega$$

Resistance in Parallel



$I_P = I_1 + I_2 + I_3$

$I_1 = V_1/R_1 \quad I_2 = V_2/R_2 \quad I_3 = V_3/R_3$

$V_P/R_P = V_1/R_1 + V_2/R_2 + V_3/R_3$

Since $V_P = V_1 = V_2 = V_3$

$1/R_P = 1/R_1 + 1/R_2 + 1/R_3$

Example #1: Find the equivalent resistor when a 4.0 Ω bulb and a 8.0 Ω bulb are connected in parallel.

$$\frac{1}{R_E} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_E} = \frac{1}{4.0} + \frac{1}{8.0} = \frac{2}{8.0} + \frac{1}{8.0} = \frac{3}{8.0}$$

$$\frac{1}{R_E} = \frac{3}{8.0} \qquad \frac{R_E}{1} = \frac{8.0}{3} = 2.667\,\Omega = 2.7\,\Omega$$

Example #2: Calculate the equivalent resistance of two, three, four and five 60 Ω bulbs in parallel. What is the simple relationship for the equivalent resistance of n equal resistances in parallel?

2 bulbs

$$\frac{1}{R_e} = \frac{1}{60} + \frac{1}{60}$$

$$\frac{1}{R_e} = \frac{2}{60}$$

$$R_E = \frac{60}{2} = 30\,\Omega$$

3 bulbs

$$\frac{1}{R_E} = \frac{1}{60} + \frac{1}{60} + \frac{1}{60}$$

$$\frac{1}{R_E} = \frac{3}{60}$$

$$R_E = \frac{60}{3} = 20\,\Omega$$

4 bulbs

$$\frac{1}{R_E} = \frac{1}{60} + \frac{1}{60} + \frac{1}{60} + \frac{1}{60}$$

$$\frac{1}{R_E} = \frac{4}{60}$$

$$R_E = \frac{60}{4} = 15\,\Omega$$

5 bulbs

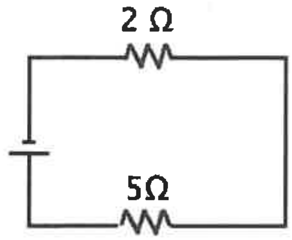
$$R_e = \frac{60}{5} = 12\,\Omega$$

n bulbs

$$R_e = \frac{60}{n}\,\Omega$$

Determine the equivalent (total) resistance for each of the following circuits below.

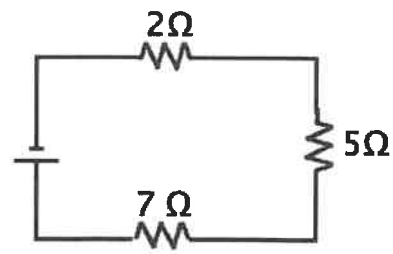
4.



$R_E = 2\Omega + 5\Omega$

$= \boxed{7\Omega}$

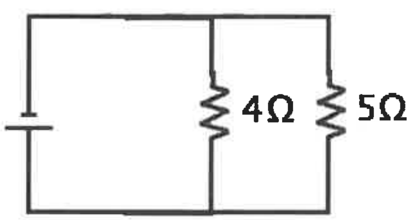
2.



$R_E = 2\Omega + 5\Omega + 7\Omega$

$= \boxed{14\Omega}$

3.



$\frac{1}{R_E} = \frac{1}{4\Omega} + \frac{1}{5\Omega}$

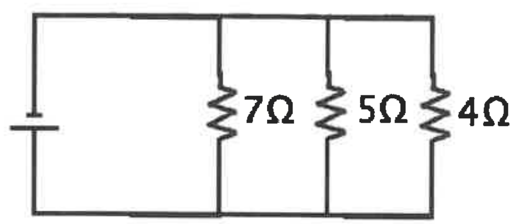
$\frac{1}{R_E} = \frac{5}{20\Omega} + \frac{4}{20\Omega}$

$\frac{1}{R_E} = \frac{9}{20\Omega}$

$R_E = \frac{20\Omega}{9} = 2.222\Omega$

$= \boxed{2.2\Omega}$

4.



$\frac{1}{R_E} = \frac{1}{7} + \frac{1}{5} + \frac{1}{4}$

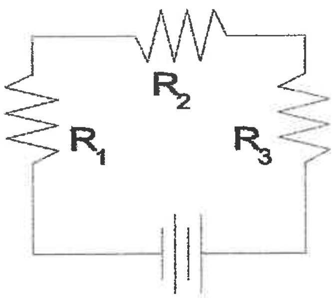
$\frac{1}{R_E} = 0.59286$

$R_E = \frac{1}{0.59286} = 1.6867\Omega$

$= \boxed{1.7\Omega}$

Resolving Electric Circuits

1. Fill out the table for the circuit below.



$R_T = R_1 + R_2 + R_3 = 60.0\Omega$

$I_T = \frac{V_T}{R_T} = 0.100A$

$I_T = I_1 = I_2 = I_3 = 0.100A$ (only 1 pathway)

$V_1 = I_1 R_1 = (0.100A)(10.0\Omega) = 1.00V$

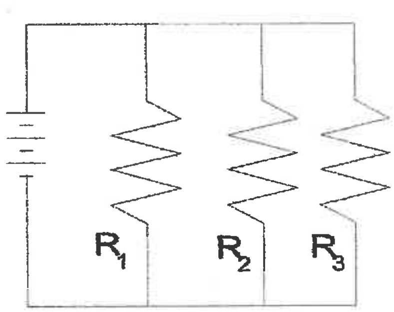
$V_2 = I_2 R_2 = (0.100A)(20.0\Omega) = 2.00V$

$V_3 = I_3 R_3 = (0.100A)(30.0\Omega) = 3.00V$

Check: $V_T = V_1 + V_2 + V_3 = 6.00V$ ✓

Circuit Position	Voltage (V)	Current (A)	Resistance (Ω)
1	1.00	0.100	10.0
2	2.00	0.100	20.0
3	3.00	0.100	30.0
Total	6.00	0.100	60.0

2. Fill out the table for the circuit below.



$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{10} + \frac{1}{20} + \frac{1}{30} = \frac{6}{60} + \frac{3}{60} + \frac{2}{60} = \frac{11}{60}$

$R_T = \frac{60}{11} = 5.45\Omega$

$I_T = \frac{V_T}{R_T} = \frac{6.00V}{5.45\Omega} = 1.10A$

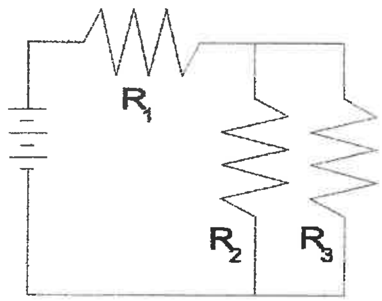
$V_T = V_1 = V_2 = V_3$ (Each pathway has same voltage drop)

$I_1 = \frac{V_1}{R_1} = 0.60A$; $I_2 = \frac{V_2}{R_2} = 0.30A$; $I_3 = \frac{V_3}{R_3} = 0.20A$

Check: $I_T = I_1 + I_2 + I_3 = 1.10A$ ✓

Circuit Position	Voltage (V)	Current (A)	Resistance (Ω)
1	6.00	0.600A	10.0
2	6.00	0.300A	20.0
3	6.00	0.200A	30.0
Total	6.00	1.10A	5.45Ω

3. Fill out the table for the circuit below.



$\frac{1}{R_{2,3}} = \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{20} + \frac{1}{30} = \frac{5}{60}$ $R_{2,3} = \frac{60.0}{5} = 12.0\Omega$

$R_T = R_1 + R_{2,3} = 10.0\Omega + 12.0\Omega = 22.0\Omega$

$I_T = \frac{V_T}{R_T} = \frac{6.00V}{22.0\Omega} = 0.273A$; $I_T = I_1 = 0.273A$

$V_1 = I_1R_1 = 2.73V$ $V_T = V_1 + V_2$; $V_2 = V_T - V_1 = 3.27V$

$V_2 = V_3 = 3.27V$

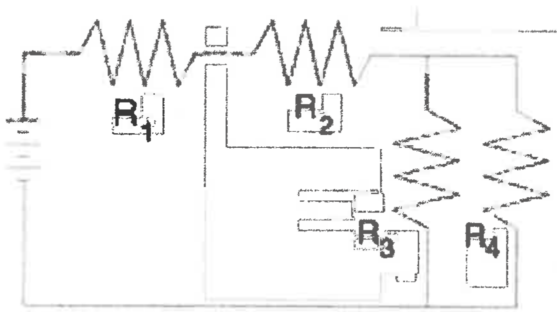
$I_2 = \frac{V_2}{R_2} = \frac{3.27}{20.0} = 0.164A$

Check: $I_2 + I_3 = I_T = 0.273A$ ✓

$I_3 = \frac{V_3}{R_3} = \frac{3.27}{30.0} = 0.109A$

Circuit Position	Voltage (V)	Current (A)	Resistance (Ω)
1	2.73	0.273	10.0
2	3.27	0.164	20.0
3	3.27	0.109	30.0
Total	6.00	0.273	22.0

4. Fill out the table for the circuit below.



$\frac{1}{R_{3,4}} = \frac{1}{R_3} + \frac{1}{R_4}$ $\frac{1}{R_{3,4}} = \frac{1}{20} + \frac{1}{30}$ $R_{3,4} = \frac{60}{5} = 12\Omega$

$R_T = R_1 + R_2 + R_{3,4} = 8 + 20 + 12 = 40.0\Omega$

$I_T = \frac{V_T}{R_T} = 3.0A$; $I_T = I_1 = I_2 = 3.0A$

$V_1 = I_1R_1 = 24V$; $V_2 = I_2R_2 = 60V$

$V_T = V_1 + V_2 + V_3$ or $V_T = V_1 + V_2 + V_4$ $V_3 = V_4 = 120 - 84 = 36V$

$I_3 = \frac{V_3}{R_3} = 1.8A$; $I_4 = \frac{V_4}{R_4} = 1.2A$

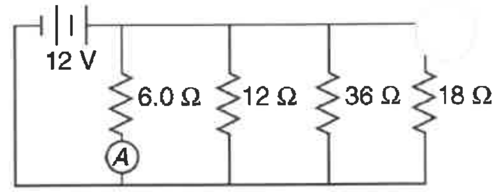
Check: $I_3 + I_4 = I_T = 3.0A$ ✓

Circuit Position	Voltage (V)	Current (A)	Resistance (Ω)
1	24	3.0	8.00
2	60	3.0	20.0
3	36	1.8	20.0
4	36	1.2	30.0
Total	120	3.0	40.0Ω

} 12Ω (rows 3–4)

CIRCUITS WORKSHEET

1. a) What is the equivalent resistance in the adjacent circuit?



$$\frac{1}{R_E} = \frac{1}{6} + \frac{1}{12} + \frac{1}{36} + \frac{1}{18}$$

$$\frac{1}{R_E} = \frac{6}{36} + \frac{3}{36} + \frac{1}{36} + \frac{2}{36} = \frac{12}{36}; \; R_E = \frac{36}{12} = 3.0\Omega$$

b) What is the current measured by ammeter A?

$V_T = V_1 = 12V$

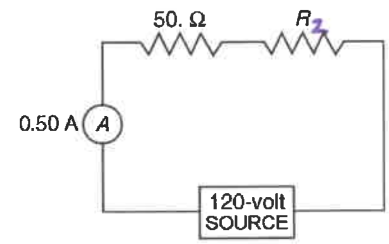
$R_1 = 6.0\Omega$

$I_1 = ?$

$$I_1 = \frac{V_1}{R_1} = \frac{12V}{6.0\Omega} = 2.0A$$

(3.0 Ω, 2.0 A)

2. A 50.-ohm resistor, an unknown resistor *R*, a 120-volt source, and an ammeter are connected in a complete circuit. The ammeter reads 0.50 ampere.



a) Calculate the equivalent resistance of the circuit shown.

$V_T = 120V$

$I_T = 0.50A$

$$R_T = \frac{V_T}{I_T} = \frac{120V}{0.50A} = 240\Omega$$

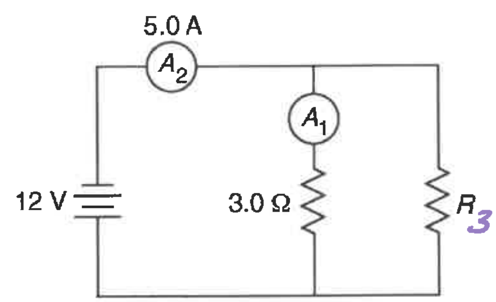
b) Determine the resistance of resistor *R* shown in the diagram.

$R_T = R_1 + R_2$ (in series)

$R_2 = R_T - R_1 = 240\Omega - 50\Omega = 190\Omega$

(240 Ω, 190 Ω)

3. A 3.0-ohm resistor, an unknown resistor, *R*, and two ammeters, A_1 and A_2, are connected as shown below with a 12-volt source. Ammeter A_2 reads a current of 5.0 amperes.



a) Determine the equivalent resistance of the circuit shown.

$R_T = ?$

$V_T = 12V$

$I_T = 5.0A$

$$R_T = \frac{V_T}{I_T} = \frac{12V}{5.0A} = 2.4\Omega$$

b) Calculate the current measured by ammeter A_1 in the diagram shown.

$V_1 = 12V$ (each path same)

$R_1 = 3.0\Omega$

$I_1 = ?$

$$I_1 = \frac{V_1}{R_1} = \frac{12V}{3.0\Omega} = 4.0A$$

c) Calculate the resistance of the unknown resistor, *R* in the diagram shown.

$V_3 = 12V$

$I_3 = I_T - I_1$

$= 5.0A - 4.0A = 1.0A$

$$R_3 = \frac{V_3}{I_3} = \frac{12V}{1.0A} = 12\Omega$$

(2.4 Ω, 4.0 A, 12 Ω)

4. The load across a 50.0-V battery consists of a series combination of two lamps with resistances of 125 Ω and 225 Ω.

a) Find the total resistance of the circuit.

$R_T = R_1 + R_2 = 125\,\Omega + 225\,\Omega = \boxed{350\,\Omega}$

b) Find the current in the circuit.

$I_T = \frac{V_T}{R_T} = \frac{50.0\,V}{350\,\Omega} = 0.14286\,A = \boxed{0.143\,A}$

c) Find the potential difference across the 125-Ω lamp.

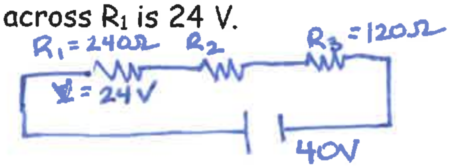
$V_1 = ?$ $\quad V = IR$

$R_1 = 125\,\Omega$ $\quad = (0.143\,A)(125\,\Omega)$

$I_1 = I_T = 0.143\,A$ $\quad = 17.857\,V = \boxed{17.9\,V}$

(350 Ω, 0.143 Ω, 17.9 V)

5. The load across a 40-V battery consists of a series combination of three resistances R_1, R_2, and R_3. R_1 is 240 Ω and R_3 is 120 Ω. The potential difference across R_1 is 24 V.



a) Find the current in the circuit.

Current is the same everywhere

∴ at Position 1:

$I_1 = \frac{V_1}{R_1} = \frac{24\,V}{240\,\Omega} = \boxed{0.10\,A}$

b) Find the equivalent resistance of the circuit.

$V_T = 40\,V$ $\quad R_T = \frac{V_T}{I_T} = \frac{40\,V}{0.1\,A} = \boxed{400\,\Omega}$

$I_T = 0.1\,A$

$R_T = ?$

c) Find the resistance of R_2.

$R_T = R_1 + R_2 + R_3$

$R_2 = R_T - (R_1 + R_3) = 400\,\Omega - (240\,\Omega + 120\,\Omega)$

$= \boxed{40\,\Omega}$

(0.1A, 400Ω, 40Ω)

6. The load across a 12-V battery consists of a series combination of three resistances R_1, R_2, and R_3. R_1 is 210 Ω, R_2 is 350 Ω, and R_3 is 120 Ω.

a) Find the equivalent resistance of the circuit.

$R_T = R_1 + R_2 + R_3 = 210\,\Omega + 350\,\Omega + 120\,\Omega$

$= \boxed{680\,\Omega}$

b) Find the current in the circuit.

$I_T = ?$ $\quad I_T = \frac{V_T}{R_T} = \frac{12\,V}{680\,\Omega} = 0.01765\,A = \boxed{0.018\,A}$

$R_T = 680\,\Omega$

$V_T = 12\,V$

c) Find the potential difference across R_3.

$I_3 = I_T = 0.01765\,A$ $\quad V_3 = I_3 R_3$

$R_3 = 120\,\Omega$ $\quad = (0.01765\,A)(120\,\Omega)$

$V_3 = ?$ $\quad = 2.1176\,V = \boxed{2.1\,V}$

(680Ω, 0.018A, 2.1V) *

7. Three resistances of 12 Ω each are connected in parallel. What is the equivalent resistance?

$\frac{1}{R_E} = \frac{1}{12} + \frac{1}{12} + \frac{1}{12} = \frac{3}{12}$ $R_E = \frac{12}{3} = 4.0\Omega$

(4.0Ω)

8. Two resistances, one 62 Ω and the other 88 Ω, are connected in parallel. The resistors are then connected to a 12-V battery.

a) What is the equivalent resistance of the parallel combination?

$\frac{1}{R_E} = \frac{1}{62\Omega} + \frac{1}{88\Omega}$; $\frac{1}{R_E} = 0.02749$; $R_E = \frac{1}{0.02749} = 36.373\Omega = 36\Omega$

b) What is the current through each resistor?

$V_T = V_1 = V_2 = 12V$

$R_1 = 62\Omega$
$V_1 = 12V$
$I_1 = ?$

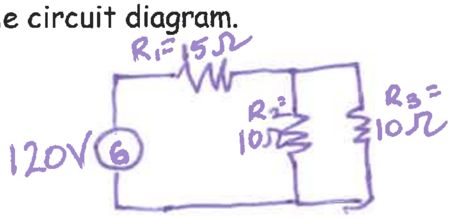
$I_1 = \frac{V_1}{R_1} = \frac{12V}{62\Omega} = 0.1935A = 0.19A$

$I_2 = \frac{V_2}{R_2} = \frac{12V}{88\Omega} = 0.1364A = 0.14A$

(36Ω, 0.19A, 0.14A)

9. A 15.0-Ω resistor is connected in series to a 120-V generator and two 10.0-Ω resistors that are connected in parallel to each other.

a) Draw the circuit diagram.



b) What is the total resistance of the load?

$R_T = R_1 + R_{2,3}$

$\frac{1}{R_{2,3}} = \frac{1}{10\Omega} + \frac{1}{10\Omega}$; $R_{2,3} = \frac{10\Omega}{2} = 5.0\Omega$

$R_T = 15.0\Omega + 5.0\Omega = 20.0\Omega$

c) What is the magnitude of the circuit current?

$I_T = ?$
$V_T = 120V$
$R_T = 20.0\Omega$

$I = \frac{V}{R} = \frac{120V}{20.0\Omega} = 6.0A$

d) What is the potential difference across the 15.0-Ω resistor?

$R_1 = 15\Omega$
$I_1 = I_T = 6.0A$
$V_1 = ?$

$V_1 = I_1 R_1 = (6.0A)(15\Omega) = 90.V$

e) What is the current in one of the 10.0-Ω resistors?

$I_2 = ?$
$R_2 = 10.0\Omega$
$V_2 = V_T - V_1 = 120.V - 90.V = 30.V$

$I_2 = \frac{V_2}{R_2} = \frac{30.V}{10.0\Omega} = 3.0A$

(20.0Ω, 6.0A, 90.V, 3.0A)

Electrical Power and Energy Costs

- ELECTRICAL <u>Power</u> is the rate at which electrical energy is <u>PRODUCED</u> OR <u>CONSUMED</u>. For example, a 60W incandescent light bulb used <u>60J</u> of electrical energy every <u>second</u>.
- A KILOWATT-HOUR (<u>1 kW·h</u>) is the scientific international (SI) unit used to measure energy usage.
- One kilowatt-hour is the amount of <u>Energy</u> a 1000W device would consume in one hour.

$$1 \text{ kW-h} = 1000\text{J/s} \times 3600\text{s} = 3.6\times10^6 \text{ J}$$

- You can tell how much <u>energy</u> a device will use by reading the power rating label.
- Electricity <u>meters</u> keep track of how much electrical energy is used in a home.

Cost to Operate = Power Rating x Time x Cost of Electricity

Ex 1: A motor uses 150 W. Electricity costs 5.6¢ /kW-h. How much would it cost to operate the motor for 1 day (24 hours)? For 1 year?

(1) $P = 0.150\text{ kW}$
$t = 24\text{h}$
$C = 5.6¢/\text{kW·h}$

$\text{Cost} = P \cdot t \cdot C$
$= (0.150\text{kW})(24\text{h})(5.6¢/\text{kW·h})$
$= 20.16¢$

(2) $365 \times 20.16¢$
$= 7358¢$
or $73.58

Ex 2: A 0.50 A light bulb is connected to a 120V outlet at your house. If the BC Hydro rate is 8.58¢/kW-h, how much will it cost to run the lightbulb 4 hours per day for 30 days?

$P = ?$
$I = 0.50\text{A}$
$V = 120\text{V}$
$C = 8.58¢/\text{kW·h}$
$t = 4 \times 30 = 120\text{h}$
$\text{Cost} = ?$

$P = IV$
$= (0.50\text{A})(120\text{V}) = 60\text{W} = 0.060\text{kW}$

$\text{Cost} = P \cdot t \cdot C$
$= (0.060\text{kW})(120\text{h})(8.58¢/\text{kW·h})$
$= 61.776¢ = 62¢$

Electrical Power & Energy

1. Make the following conversions:
   a. 1.5W = 0.0015 kW
   b. 45.2W = 0.0452 kW
   c. 23 min = 0.38 h
   d. 365 days = 8760 h

2. Your oven has a power rating of 5,000 watts.
   a. How many kilowatts is this? 5 kW
   b. If the oven is used for 2.4 hours to bake cookies, how many kilowatt-hours (kWh) are used?

   $E = P \cdot t$
   $= (5\,kW)(2.4\,h) = 12\,kW \cdot h$

   c. If your town charges $0.15 per kWh, what is the cost to use the oven to bake the cookies?

   Cost = $P \cdot t \cdot C$
   $= (12\,kW \cdot h)(\$0.15/kWh) = \$1.80$

3. For each of the appliances listed below, calculate the wattage in kilowatts and the cost per hour of use. Assume your town charges $0.10 per kWh.

Appliance	Watts	Kilowatts	Cost per Hour
Samsung Microwave	1200 W	1.2	$0.12
Kitchen Aid Mixer	325 W	0.325	$0.03
Kitchen Aid Coffee Maker	1360 W	1.36	$0.14
Philips TV	105 W	0.105	$0.01
Sharp DVD Player	14 W	0.014	$0.0014
Samsung VCR	17 W	0.017	$0.0017
Denon Receiver	100 W	0.100	$0.01
Denon CD Player			

4. Does it cost more to bake a potato in a microwave or in a conventional oven? Show your work. Assume it takes 1 hour to bake in the oven and 15 minute to bake in the microwave.

In oven, $P = 5\,kW$
$t = 1\,h$
$E = P \cdot t$
$= 5\,kW \cdot h$

In microwave:
$P = 1.2\,kW$
$t = 0.25\,h$
$E = Pt = 0.3\,kW \cdot h$

Less energy! ∴ Cheaper!

5. A light bulb is on for 2.5 hours. If the amount of electrical energy used is 30.0 kW*h, what is the power rating of the light bulb?

$P = ?$
$E = 30.0\ kW \cdot h$
$t = 2.5\ h$

$E = P \cdot t$
$P = \frac{E}{t} = \frac{30.0\ kW \cdot h}{2.5\ h} = 12\ kW$

Fix sig figs *

6. A 300W waffle iron is used for 30 minutes. Calculate the energy consumed in both joules and kW*h.

$P = 300W$
$t = 30 \times 60 = 1800s$
$E = ?$

$E = P \cdot t$
$= (300 J/s)(1800 s)$
$= 540000 J$

$P = 0.3\ kW$
$t = 0.5\ h$
$E = P \cdot t$
$= (0.3\ kW)(0.5\ h)$
$= 0.15\ kW \cdot h$

7. The current in a washing machine is 20.A when it is plugged into a 120V outlet.
   a. What is the power rating of the clothes dryer?

   $I = 20.A$
   $V = 120V$
   $P = ?$

   $P = IV$
   $= (20.A)(120V)$
   $= 2400W$

   b. If BC Hydro charges 8.5¢/kW*h, how much would it cost to run the clothes dryer over a year, if it runs on average four hours a week?

   $t = 4 \times 52 = 208\ h$
   $P = 2.4\ kW$
   $C = 8.5¢/kW \cdot h$

   $Cost = P \cdot t \cdot C$
   $= (2.4\ kW)(208\ h)(8.5¢/kW \cdot h)$
   $= 4243¢ = \$42.43$

8. How much would it cost to leave your computer on for 4 days if it drew 75W of power and the cost of electricity is $0.20 per kW*h?

$P = 0.075\ kW$
$t = 4 \times 24 = 96\ h$
$C = \$0.20/kW \cdot h$

$Cost = P \cdot t \cdot C$
$= (0.075\ kW)(96\ h)(\$0.20/kW \cdot h)$
$= \$1.44$

ANSWERS: 1a) 0.0015kW b) 0.042kW c) 0.38h d) 8760h 2a) 5kW b) 12kW*h c) $1.80 4) 4.5kW*h vs. 0.3kW*h 5) 12W 12kW 6) 5.4×10^5J or 0.15kW*h 7) $42.43 8) $1.44

Efficiency

Law of Conservation of Energy: the amount of energy present before an energy transformation is equal to the amount of energy present after the energy transformation.

However, some of the energy in a transformation is not a useful form of energy and is wasted. (heat, sound, etc.)

$$\text{Efficiency} = \frac{\text{Energy output}}{\text{Energy input}} \times 100$$

- Efficiency - the ability of a device to convert energy
- Energy Output - useful energy produced by a converter (J)
- Energy Input - energy consumed by the converter (J)

Converter	Input energy	Output energy
Car engine	Chemical (gasoline)	Kinetic (motion)

Ex#1: An internal combustion engine burns 1200J of chemical energy. The fuel is vaporized, producing very high pressures that push down on the pistons which turn the crankshaft, thus turning the wheels. In the end, only 100 J of mechanical energy is produced to move the car forward. What is the efficiency of the car's engine?

$E_I = 1200J$ $\quad Eff = \frac{E_O}{E_I} \times 100 = \frac{100J}{1200J} \times 100 = 8.3\%$

$E_O = 100J$

Ex#2: A 1200 W electric kettle is used for 10 minutes.

a) How much energy does it require?

$E_I = 1200J/s \times 600s = 720,000J$

b) If 6.0×10^5 J of energy is transferred to the water in the kettle, what is its efficiency? $E_I = 7.2 \times 10^5 J$ $\quad Eff = \frac{6.0 \times 10^5 J}{7.2 \times 10^5 J} \times 100 = 83\%$

$E_O = 6.0 \times 10^5 J$

Efficiency

1. How much electrical energy does a 1200 W electric kettle use in each of the following times?
   a. 1.0 s 1200J
   b. 1.0 min 72000J
   c. 1.0 h 4.3×10^6J
   d. 1.0 day 1.0×10^8J

2. How much heat energy does it take to heat 2.0 kg of water from 10°C to 100°C?

$Q = mC\Delta T$
$= (2.0kg)(4186 J/kg°C)(100°C-10°C) = 753480J$
$= 7.5\times10^5 J$

3. How long would it take a 1000 W kettle to do the job described in question 2, assuming that it is 100% efficient?

$E = 7.5\times10^5 J$ $P = \frac{E}{t}$ $t = \frac{E}{P}$
$P = 1000 J/s$
$t = ?$
$= \frac{7.5\times10^5 J}{1000 J/s} = 750s$

4. Several friends use a simple rope and pulley to raise a tree house from the ground into a tree. The mass of the tree house is 150 kg. By pulling together, the friends manage exert an average force of 1.6×10^3 N as they raise the tree house a distance of 3.2 m above the ground.

   a) How much work did the friends actually do to raise the tree house?

   $W = F\cdot d$
   $= (1600N)(3.2m) = 5120J$
   $= 5.1\times10^3 J$

   b) How much "useful" work was done?

   $W = F\cdot d = mgh_f$
   $= (150kg)(9.81N/kg)(3.2m) = 4709J$
   $= 4.7\times10^3 J$

   c) What is the efficiency of the rope and pulley in raising the treehouse?

   $E_I = 5120J$
   $E_o = 4709J$
   $Eff = \frac{E_o}{E_I}\times100 = \frac{4709J}{5120J}\times100 = 91.97\%$
   $= 92\%$

   d) Suggest why the efficiency of this simple machine is not 100%.

   Friction between rope + pulley

5. A container factory uses a 370 W motor to operate a conveyor belt that lifts containers from one floor to another. To raise 250 1-kg containers a vertical distance of 3.6 m, the motor runs for 45 s.

a) Determine the useful energy output.

$E_o = mgh$
$= (250\,kg)(9.81\,N/kg)(3.6\,m) = 8829\,J = 8800\,J$

b) How much energy does the motor use?

$E_I = P \cdot t$
$= (370\,W)(45\,s) = 16\,650\,J$ or $1.7 \times 10^4\,J$

c) What is the efficiency of the motorized conveyor system?

$$Eff = \frac{E_o}{E_I} \times 100 = \frac{8829\,J}{16650\,J} \times 100 = 53\%$$

6. A 60.0 kg mountain climber decides to climb a mountain that is 4.0×10^3 m high.

a) How much potential energy is gained by the climber by climbing to the top of the mountain?

$E_p = mgh$
$= (60.0\,kg)(9.81\,N/kg)(4000\,m) = 2354400\,J$
$= 2.4 \times 10^6\,J$

b) If the body's efficiency in converting energy stored as fat to mechanical energy is 25%, determine the amount of amount of energy stored that the climber will use up in providing the energy required to raise the climber up the mountain.

$Eff = 0.25$
$E_o = 2{,}354{,}400\,J$
$E_I = ?$

$$Eff = \frac{E_o}{E_I}$$
$$E_I = \frac{E_o}{Eff} = \frac{2{,}354{,}400\,J}{0.25} = 9417600\,J = 9.4 \times 10^6\,J$$

c) It is estimated that one kilogram of body fat will provide 3.8×10^7 J of energy. What amount of fat will the climber burn while climbing the mountain?

$$\frac{9{,}417{,}600\,J}{3.8 \times 10^7\,J/kg} = 0.2478\,kg = 0.25\,kg$$

ANSWERS: 1a) 1200J b) 7.2×10^4J c) 4.3×10^6J d) 1.0×10^8J 2) 7.5×10^5J 3) 750s 4a) 5100J b) 4700J c) 92% d) friction 5a) 8.8×10^3J b) 1.7×10^4J c) 53% 6a) 2.4×10^6J b) 9.4×10^6J c) 0.25kg

Chapter 10 Review

1. What is the difference between a series circuit and a parallel circuit? Include a sketch in your answer.

   Series: one pathway for current to flow.

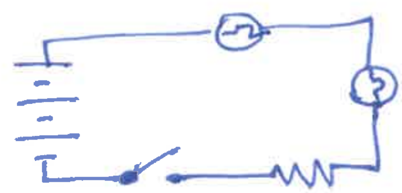
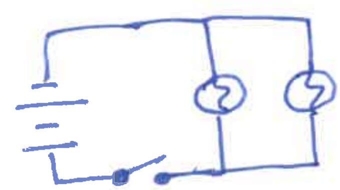
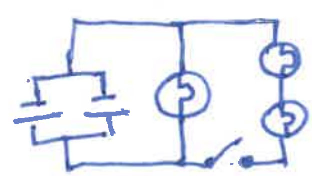
   Parallel: multiple pathways for current to flow

12. What is the difference between a cell and a battery?

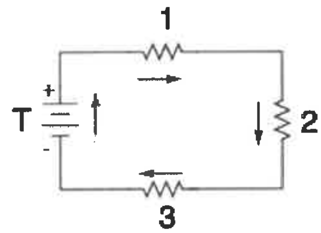
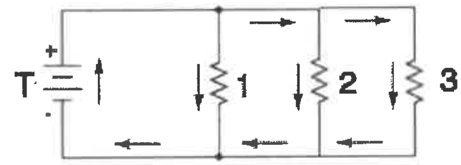
   • Cell is a device that converts chemical energy into electrical energy.

   • A battery is a collection of cells working together

2. Draw a schematic diagram of:

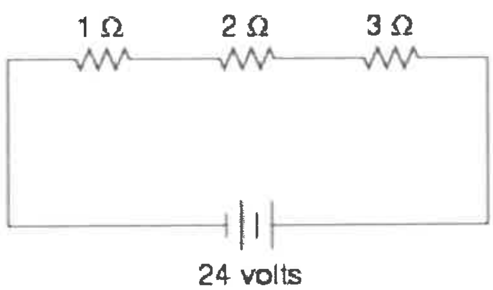
a) a circuit containing a three-cell battery, two light bulbs, a resistor, and a switch, all connected in series.	
b) A circuit containing two lightbulbs connected in parallel, with a two-cell battery as its power source. Include switches that would turn both lights off at the same time.	
c) A circuit containing three light bulbs, one which is more bright than the other two. Include a switch that will turn off only the two dimmer bulbs, and two cells connected in parallel	

3. Summarize the following relationships for a series and parallel circuit:

Type of Circuit	Series Circuit	Parallel Circuit
Schematic		
Potential Difference	$V_T = V_1 + V_2 + V_3$	$V_T = V_1 = V_2 = V_3$
Current	$I_T = I_1 = I_2 = I_3$	$I_T = I_1 + I_2 + I_3$
Resistance	$R_T = R_1 + R_2 + R_3$	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

* fix

4. In this circuit, three resistors receive the same amount of current from a single source. a) the current in the circuit. Calculate:
   b) the amount of voltage "dropped" by each resistor
   c) the amount of power dissipated by each resistor:



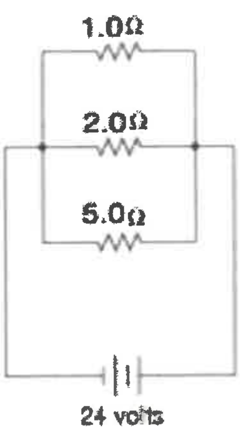
a) $R_T = 6\Omega$, $V_T = 24V$; $I_T = \frac{V_T}{R_T} = \frac{24V}{6\Omega} = 4A$

b) $V_1 = I_1 R_1 = (4A)(1\Omega) = 4V$; $V_2 = I_2 R_2 = (4A)(2\Omega) = 8V$; $V_3 = I_3 R_3 = (4A)(3\Omega) = 12V$

c) $P_1 = V_1 I_1 = (4V)(4A) = 16W$; $P_2 = (8V)(4A) = 32W$; $P_3 = (12V)(4A) = 48W$

(a) 4A; b) 4V, 8V, 16V; c) 16W; 32W; 48W)

5. In this circuit, three resistors receive the same amount of voltage (24 volts) from a single source. Calculate:
   a) The equivalent resistor for the three resistors;
   b) The total current coming out of the battery;
   c) the amount of current "drawn" by each resistor;



a) $\frac{1}{R_T} = \frac{1}{1} + \frac{1}{2} + \frac{1}{5}$

$\frac{1}{R_T} = \frac{10}{10} + \frac{5}{10} + \frac{2}{10} = \frac{17}{10}$

$R_T = \frac{10}{17} = 0.5882\Omega = 0.59\Omega$

b) $R_T = 0.588\Omega$, $V_T = 24V$, $I_T = ?$

$I_T = \frac{V_T}{R_T} = \frac{24V}{0.588\Omega} = 41A$

c) $R_1 = 1.0\Omega$, $V_1 = 24V$: $I = \frac{V}{R} = \frac{24V}{1.0\Omega} = 24A$

$R_2 = 2.0\Omega$, $V_2 = 24V$: $I = \frac{V}{R} = \frac{24}{2} = 12A$

$R_3 = 5.0\Omega$, $V_3 = 24V$: $I = \frac{V}{R} = \frac{24}{5} = 4.8A$

(a) 0.59Ω; b) 41A; c) 24A, 12A, 4.8A)