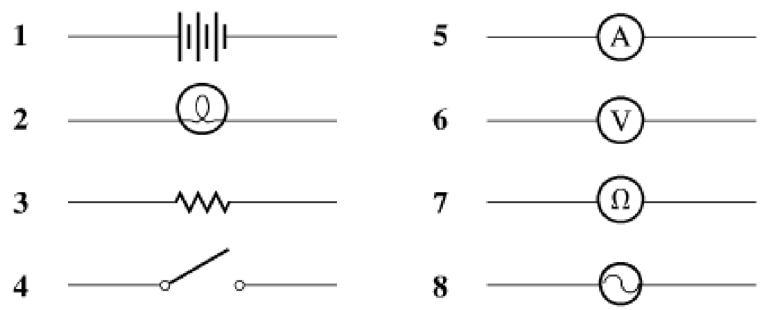
Sample Diploma Problem

Use the following information to answer numerical-response question 2 and question 5.

Symbols for Circuit Components



Numerical Response

2. Match a numbered symbol shown in the table above to each of the terms below. (Use each number only once.)

Switch ____________ (Record in the **first** box)

Battery ____________ (Record in the **second** box)

Bulb ____________ (Record in the **third** box)

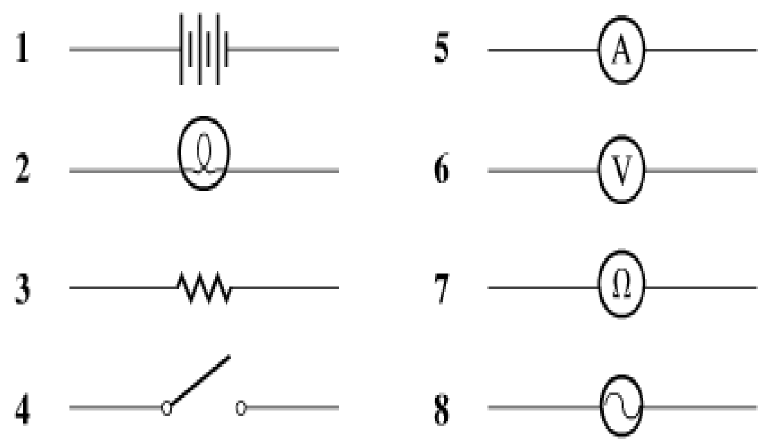
Ohmmeter ____________ (Record in the **fourth** box)

4, 1, 2, 7

(Record all **four digits** of your answer in the numerical-response boxes at the bottom of the screen.)

Use the following information to answer numerical-response question 2 and question 5.

Symbols for Circuit Components



5. Component **5**, shown in the table above, is used to directly measure

A. power

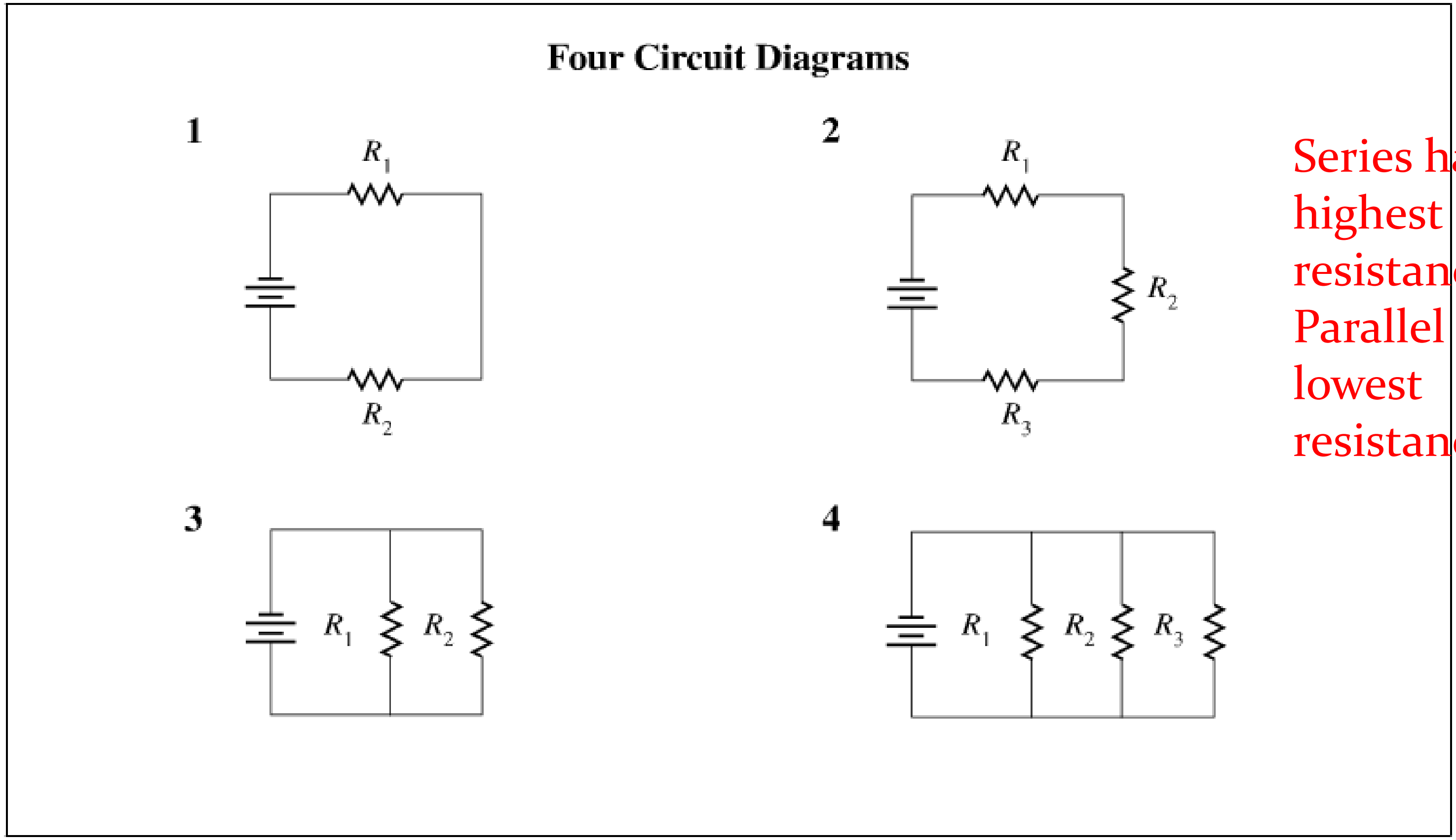
B. current

C. voltage

D. resistance

Ammeter – measure electric current

Use the following information to answer numerical-response question 4.



Series have highest resistance Parallel have lowest resistance

Numerical Response

4. If all of the resistors in the numbered circuits shown above are identical, the order of the circuits from **highest** total resistance to **lowest** total resistance would be

__________ , __________ , __________ , and __________ .

highest **lowest**

2,1,3,4

(Record all **four digits** of your answer in the response boxes at the bottom of the screen.)

Sample Diploma Problem

For resistances connected in parallel

Numerical Response

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

5. The total resistance provided by two 4.00 Ω speakers connected in parallel is __________ Ω.

(Record your **three-digit answer** in the response boxes at the bottom of the screen.)

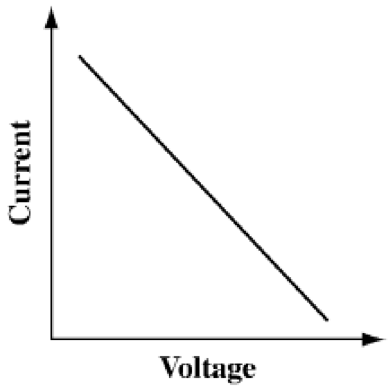
¼ + ¼ = ½ → $(1/2)^{-1}$ → 2

Use the following information to answer question 6.

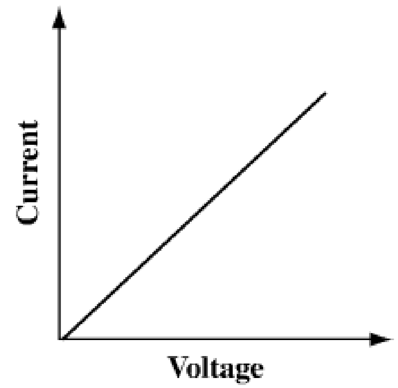
The relationship between voltage, current, and resistance can be represented by the formula $V = IR$.

6. Which of the following graphs represents the relationship between voltage and current at a constant resistance?

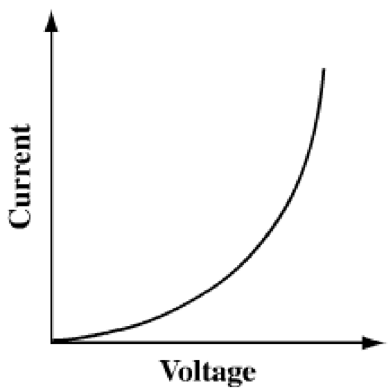
A.



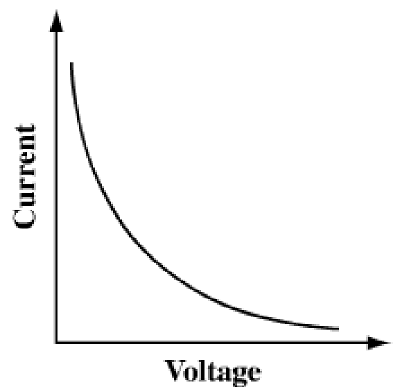
B.



C.



D.



Sample Diploma Problem

12. Fuses and circuit breakers are safety devices that interrupt a circuit in response to a dangerously high

A. charge

B. current

C. voltage

D. resistance

Power

Curriculum

- describe electrical energy in kilowatt hours and joules, using the equation $E_e = Pt$ for electrical energy and the equation $P = VI$ for power
- describe the operation of a transformer, in terms of the relationship among current, voltage and the number of turns in the primary and secondary coils, using the equation $N\text{p} / N\text{s} = V\text{p} / V\text{s} = I\text{s} / I\text{p}$
- calculate current voltage and the number of turns in the primary and secondary coils of electrical transformers

1.5) Transmitting electrical energy

- All electrical devices use energy; that energy needs to be transported to the device.

- Every device has a power rating = *energy consumed per second.*

- Determined using:

  - Power (W) or (J/s)
  - Energy (J)
  - time (s)

$$P = \frac{E}{t}$$

Example

- A microwave has a power rating of 800 W. It runs for 30 min or 1800 s. How much energy does the microwave use?

- E = Pxt
- (800)(1800) = 1.44 $x10^6$J

Example

- How long would it take to run a 100 W light bulb and use 734 J of energy?
- P x t = E

T = E / P

 734 J

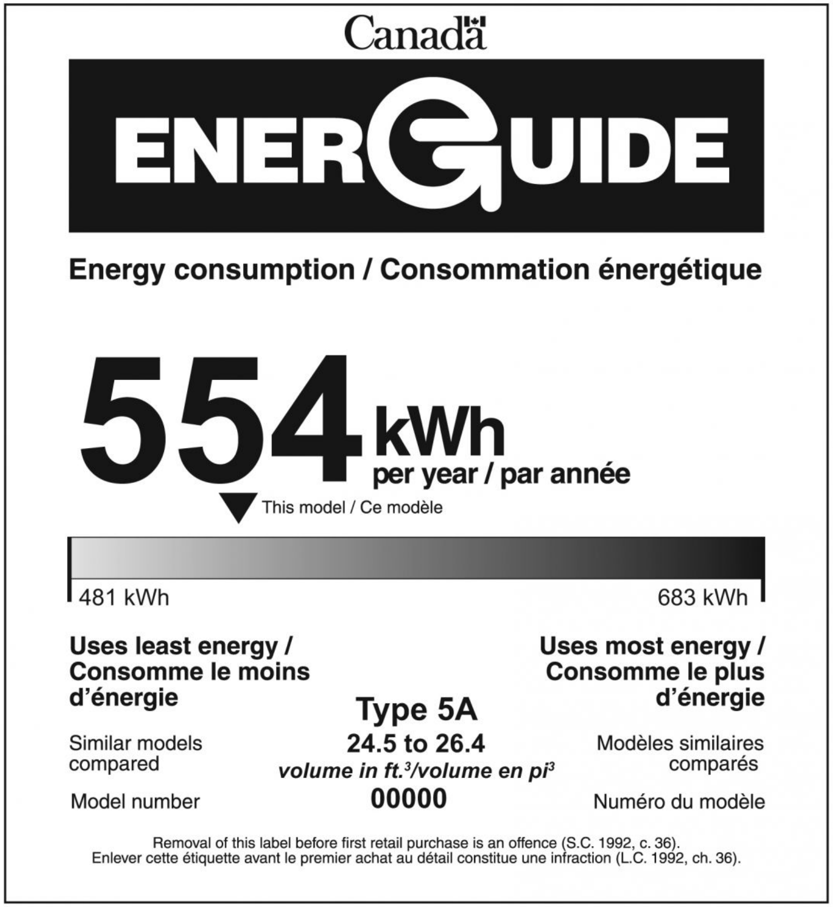
--------- = 7.34s

 100W

Kilowatt Hours

- Common electrical devices use a lot of joules
- Because so much energy is used, the unit of **kilowatt hour** is often used
- Kilowatt hour is a measure of energy
- Everything is the same as the last formula except:
  - 1 kW= 1000 W
  - 1 h = 3600 s

Kilowatt Hours



Example

- A microwave has a power rating of 0.800 kW. It runs for 30 min or 1800 s. How much energy does the microwave use, in kW·h?

- E = p x t
- (0.800 KW) x (1800s/3600s)
- =0.4kW.h

Example

- You bake a potato in a 1.20 kW toaster oven for 25 min.
  - How many joules of electricity did the toaster oven use?
  - E = p x t → (1.20 x 1000) x (25 x 60) = 1.8 x 10^{6} J
  - How many kilowatt hours did it use?
  - E = p x t → (1.20KW) (25/60) = 0.5 kW.h
  - If it cost 9.3 ¢ / kWh, how much does it cost to bake the potato?
  - 0.5 x 9.3 = 4.65 cents so about 5 cents

Power

- Power is also related to voltage and current
- The formula for power is:

$$P = IV$$

Example

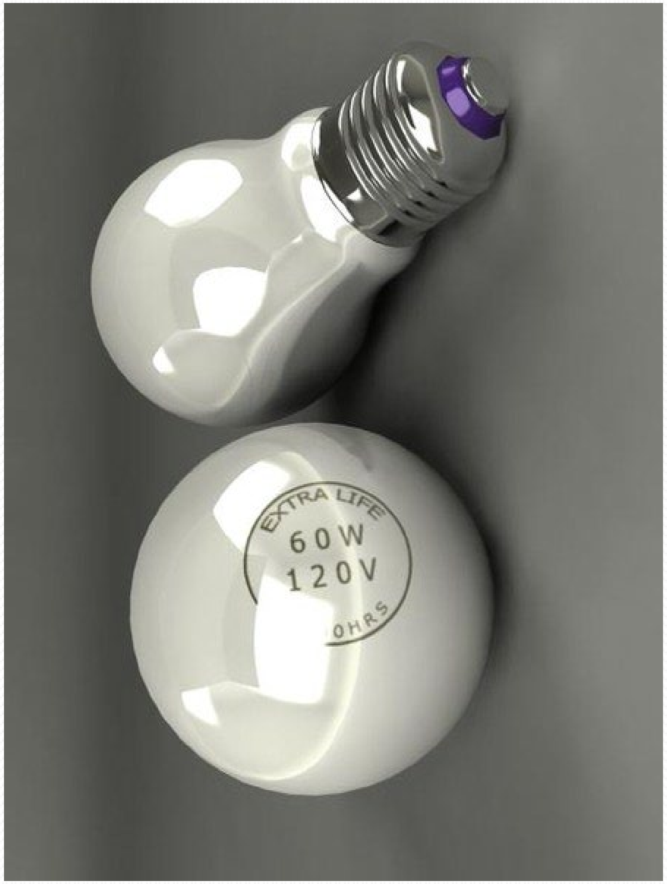
- Find the power of a toaster that draws in 4 A of current and has a voltage of 200 V

- P = I x V

- 4 x 200 = 800W

Example

- Find the current this light bulb requires



$I = p/v$

$$\frac{60W}{120\ V} = 0.5\ A$$

New formula for power

$$V = IR \qquad P = IV$$

You can combine these two formulas to get…

$$P = I^2R$$

Example

- The volume is turned up in a car with a 4.0 Ω speaker so that 4.50 A of alternating current flows in the speaker. Calculate the power consumed by this speaker.
- Use… $P = I^2R$ R = 4 I = 4.5 P=?
- $4.5^2 * 4$
- =81 W

$V = I R$

Board Question

- Find the current provided by 12.0V battery passing through a 60 Ω lightbulb.

$V/R = I$

$12.0\ V / 60 = 0.2\ A$

Board Question $P = I^2R$

- Find the resistance when 1.34 kW of power is supplied with 40 A of current.

R=?
P = 1.34kW **note units!
I= 40A

$$\frac{(1.34 * 10^3)}{(40)^2}$$

$= 0.8375\Omega$

Challenge Question

- 9300 kWh of energy is supplied to a home in 3 days. If they have 120 V outlets, find the current available to their home.

I = P/V → P = E /t

P = E / t

9300 KWH / (24 x 3) = 129.16 kW

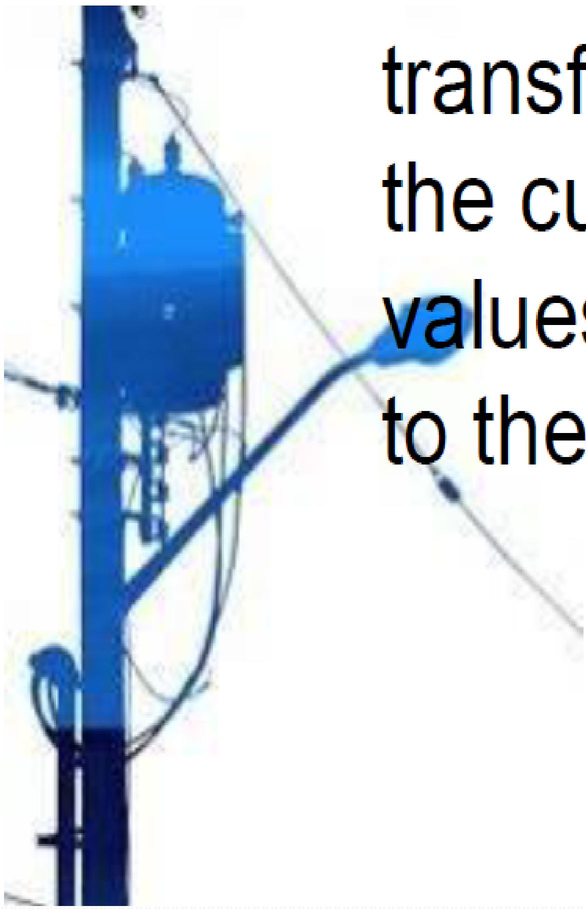
I = P/V

(129.16 x 1000)/120V = 1076 A

Transporting Electricity

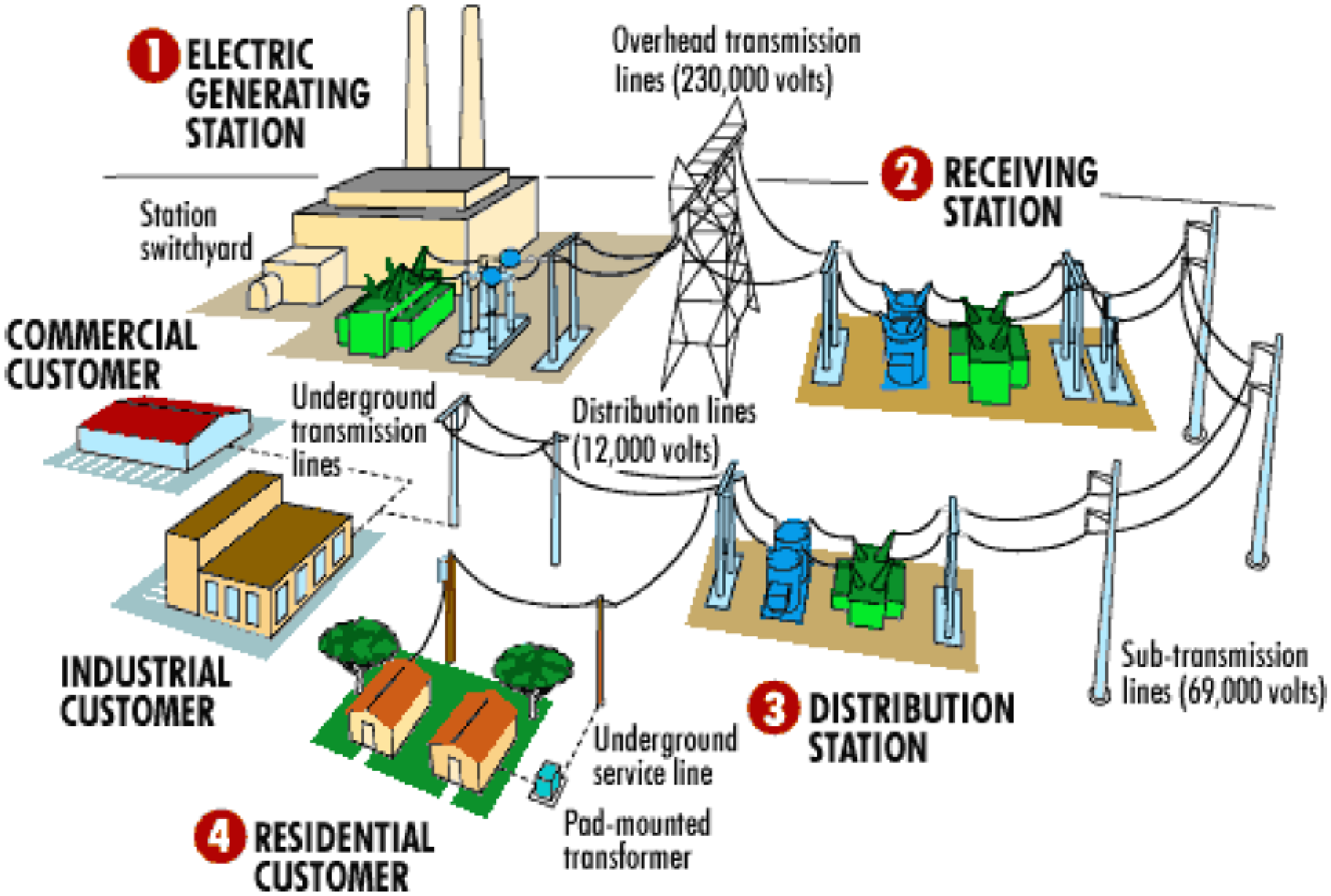
- When electricity is transported long distance some of the energy is lost as heat
- In order to reduce the heat lost, current must be kept as low as possible

ELECTRICAL DISTRIBUTION & TRANSFORMERS

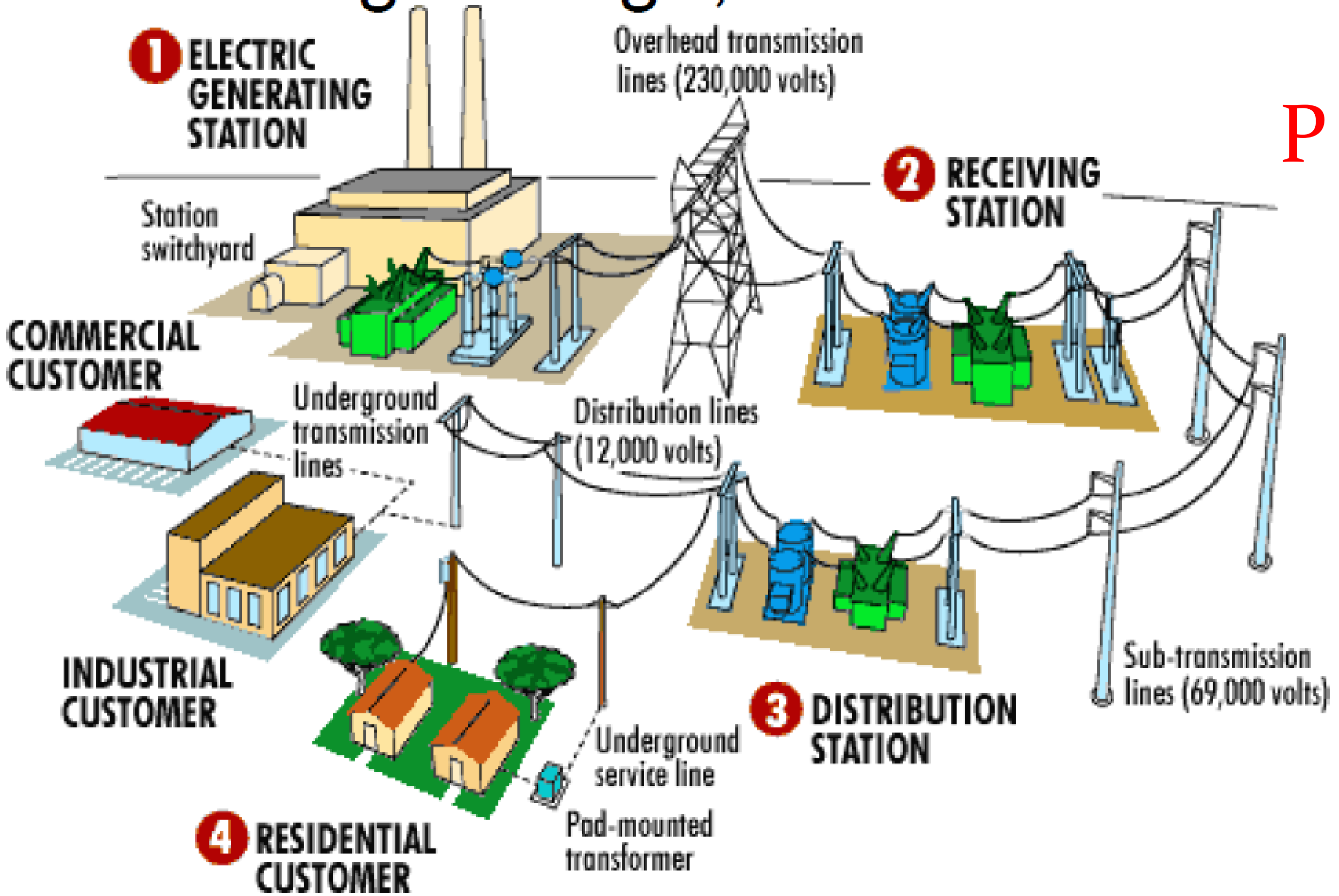


- The major use of transformers is to change the current and voltage values from the input side to the output side

- Generating stations use transformers to step up voltages (reduces current), before sending the energy to the city on large diameter (low resistance) wires



- The power dissipated in the wire depends on the square of the current, less energy is wasted heating up the transmission lines when voltage is high, rather than current



$P = I^2R$

Summary of Power Transmission

Power Generation

Transformers
step up voltage

Transport of electricity can use a low current and a high voltage which is efficient

Transformers
step down voltage to a safe level before the electricity enters homes

Example

- A 100-km length of transmission cable has a resistance of 5.0 Ω. This cable transmits 500 kW of power from the generator to a small town.
  - Determine the electric current required to transmit the 500 kW of power if the voltage used within the system is 5000 V

$$\frac{P}{V} = \text{I} \quad \rightarrow \frac{(500\ x\ 103)}{5000} = 100\ \text{A}$$

A 100-km length of transmission cable has a resistance of 5.0 Ω. This cable transmits 500 kW of power from the generator to a small town.

- Calculate the power lost due to heating effects through the 100 km of conducting cable

- $P = I^2R$ → $I = 100$ (from previous question) $R = 5$
-

$(100^2)(5) = 50\ 000$ W (power lost)

A 100-km length of transmission cable has a resistance of 5.0 Ω. This cable transmits 500 kW of power from the generator to a small town.

- Determine the percentage of the transmitted power that was lost due to heating effects in this arrangement.

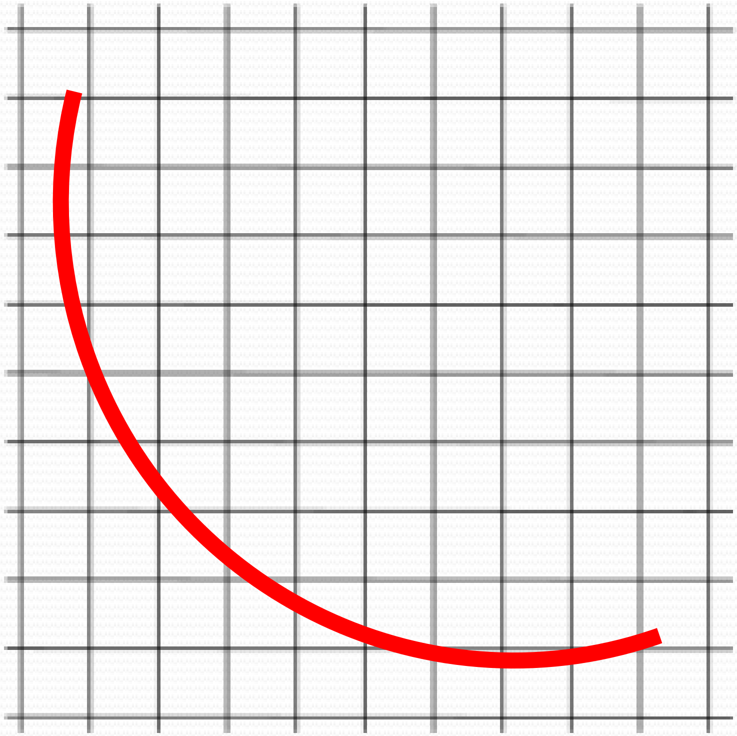
- $\frac{power\ lost}{p}$ x 100 → $\frac{50\ 000}{(500\ x\ 1000)}$ x 100 = 10%

A 100-km length of transmission cable has a resistance of 5.0 Ω. This cable transmits 500 kW of power from the generator to a small town.

- Repeat the analysis by increasing the voltage within the system to 50 000 V

- $\frac{P}{V}$ = I
- $\frac{(500\ x\ 1000)}{50\ 000}$ = 10 A
- P = I^2R
- 10^2 x 5 = 500 W (power post)
- $\frac{power\ lost}{p}$ x 100 → $\frac{500}{(500\ x\ 1000)}$ x 100 = 0.1 %

What can we infer about the relationship between the equation P= I x V?



To keep power the same:
I (current) must go down as voltage (v) goes up

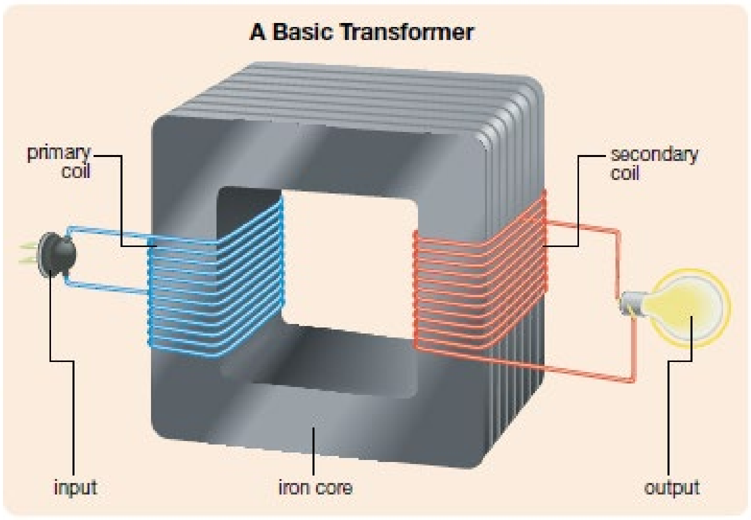
P(same) = ↓I x V↑

This is different than the V = I x R

↑V = ↑I x R

Transformers

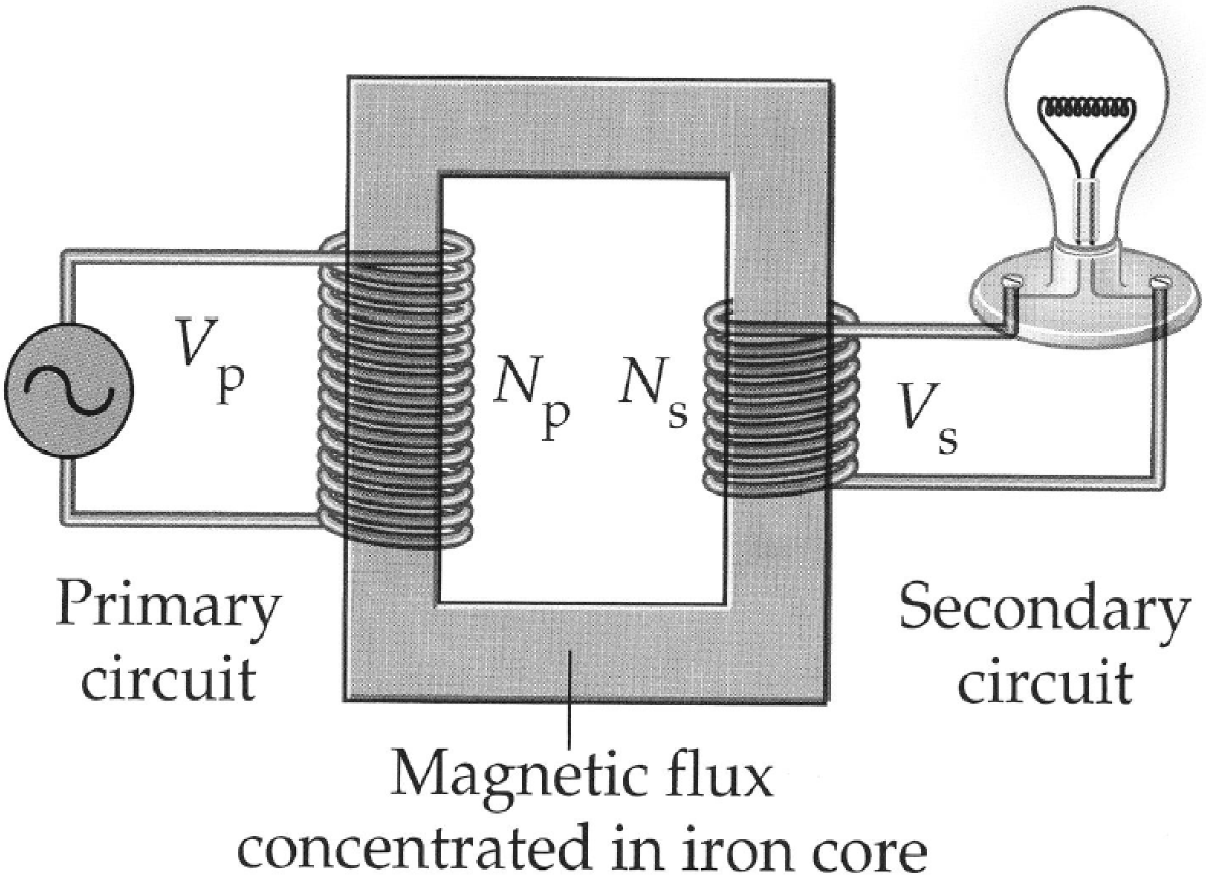
- Since electricity needs a high voltage to be transported over long distances, it must be stepped down to be safely used in homes
- **Transformers** are devices that can be used to step up (increase v) or step down (decrease v) voltages



Transformer theory

- Transformers are basically two coils of wire wound on an iron core
- The coils are wound on an iron core to concentrate the magnetic field

- There is no electrical connection between the coils. They interact only through a changing magnetic field

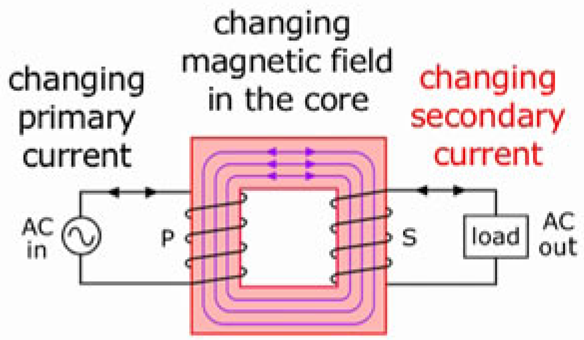


Changing voltage

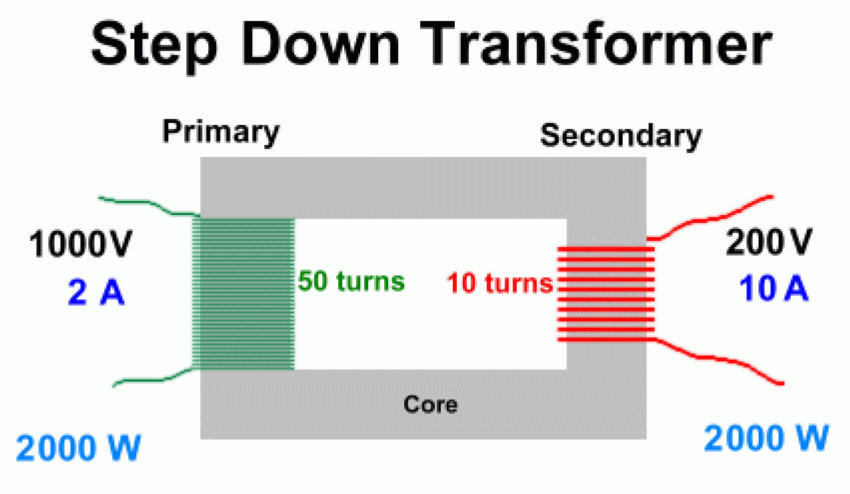
- Transformers can change the voltage of an electrical supply by:
  - stepping it up (increasing it)
  - stepping it down (decreasing it)
- <u>step up transformers</u>: more secondary coils than primary coils
- <u>step down transformers</u>: fewer secondary coils than primary coils

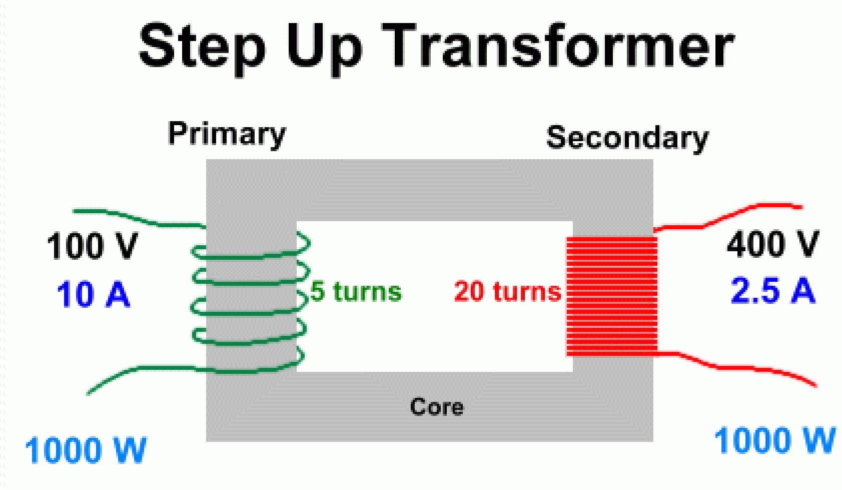
$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$

*** See page 3 in data book**



Which transformer steps up voltage?





What happens to current when voltage is stepped up?
Hint: Power stays the same!

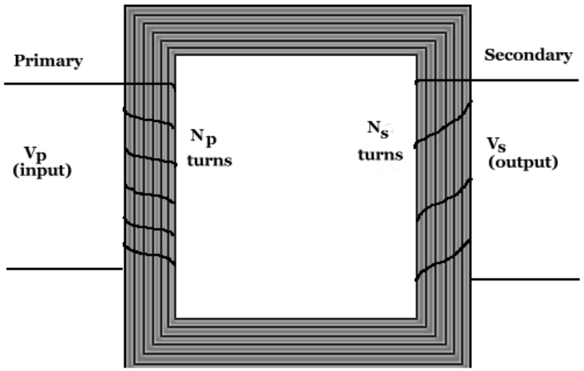
Transformer videos

Transformer Calculations

Ideal Transformers

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}, \quad \frac{N_p}{N_s} = \frac{I_s}{I_p}, \quad \frac{V_p}{V_s} = \frac{I_s}{I_p}$$

- N = number of turns
- p = primary
- s = secondary
- I = current
- V = voltage



Example

- A large neon sign is powered by a high-voltage power supply. The power supply takes a 240-V input and then uses a transformer to increase the voltage to 12 000 V to operate the sign.
  - Does the power supply use a step-up or step-down transformer?
    - Step up because V is increasing

A large neon sign is powered by a high-voltage power supply. The power supply takes a 240-V input and then uses a transformer to increase the voltage to 12 000 V to operate the sign.

- If the transformer has 125 turns of wire on the primary coil, determine the number of coils on the secondary coil. (step up = more secondary coils)

Ideal Transformers

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}, \quad \frac{N_p}{N_s} = \frac{I_s}{I_p}, \quad \frac{V_p}{V_s} = \frac{I_s}{I_p}$$

Np = 125, Ns = ?, Vp(input)= 240 V, Vs (output)= 12000V

$$\frac{Vs \ x \ Np}{Vp} = \text{Ns} \rightarrow \frac{(12000)(125)}{240} = 6.25 \text{ x } 10^3$$

The secondary coil of the transformer has 6 250 turns of wire

A large neon sign is powered by a high-voltage power supply. The power supply takes a 240-V input and then uses a transformer to increase the voltage to 12 000 V to operate the sign.

- The power supply requires 25.0 A of input current. Determine the output current that powers the sign.

$$\frac{V_p}{V_s} = \frac{I_s}{I_p}$$

Vp = 240 V, Vs = 12 000V, Ip = 25.0A, Is = ?

$$\frac{(240\ x\ 25.0)}{12\ 000V} = 0.500\ \text{A}$$

The output current to power the sign is 0.500 A

Board Question

Ideal Transformers

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}, \quad \frac{N_p}{N_s} = \frac{I_s}{I_p}, \quad \frac{V_p}{V_s} = \frac{I_s}{I_p}$$

- The transformer on a power pole takes input voltage of 4.00 kV and then delivers 240 V to a home
  - Is this a step up or step down device?
    - This is a step down because V is decreasing
  - If there are 180 turns on the secondary coil in the transformer, determine the number of turns on the primary wire
  - Ns = 180 Vp = (4 x 1000) Vs = 240 Np=?
  - The secondary coil would require 3000 turns of wire

The transformer on a power pole takes input voltage of 4.00 kV and then delivers 240 V to a home

Ideal Transformers

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}, \quad \frac{N_p}{N_s} = \frac{I_s}{I_p}, \quad \frac{V_p}{V_s} = \frac{I_s}{I_p}$$

- If the maximum current supplied to the home is 100 A, determine the current supplied to the transformer
- I output = home   I input = power supply

- Vp= 4000V Vs = 240   Is = 100A   Ip = ?
- $\frac{100x240}{(4000)}$ = 6 A

Sample Diploma Problem

Use the following information to answer question 3 and numerical-response 1.

The South American electric eel can produce a low-voltage discharge to detect prey or a high-voltage discharge to stun prey.

Numerical Response

1. If an electric eel produces a 485 V discharge with a current of 1.12 A, then the power of the discharge is __543__ W.

(Record your **three-digit answer** in the numerical-response boxes at the bottom of the screen.)

Use the following information to answer numerical-response question 3.

Some Definitions for Electrical Properties

1	Change in potential energy per unit charge
2	Process slowing electron flow
3	Rate of electron flow
4	Rate of energy use

Numerical Response

3. Match each of the definitions for electrical properties numbered above with the term it defines given below.

Current 3__________ (Record in the **first** box)

Power 4__________ (Record in the **second** box)

Resistance 2__________ (Record in the **third** box)

Voltage 1__________ (Record in the **fourth** box)

(Record your answer in the response boxes at the bottom of the screen.)

Numerical Response

0.4kW

6. If a warehouse is continuously lit by 32 lights, each with a power rating of 400 W, then the energy used, in kilowatt hours by all the lights in the barn in one **24-hour** period is _____ kW·h.

(Record your **three-digit** answer in the response boxes at the bottom of the screen.)

32 x 0.4KW x 24 h = 30.72 kWh

Use the following information to answer question 7.

A student created the following spreadsheet to show the relationships associated with the primary and secondary coils of a transformer.

Transformer Relationships

SPREADSHEET

File Edit View Insert Format Tools Data Window Help

Transformer Relationships (Read-Only)

	A	B	C	D	
1	Number of turns on primary coil	Number of turns on secondary coil	Voltage in primary coil (V)	Voltage in secondary coil (V)	
2	4	4	8	8	
3	4	8	8	16	
4	4	2	8	4	
5	4	1	8		
6					
7					

7. The value that should be in cell D5 in the spreadsheet above is

A. 1
B. 2
C. 4
D. 8

Use the following information to answer question 9.

A transformer between a power line and a line entering a house has a primary voltage of 7000 V and a secondary voltage of 240 V.

9. If a transformer at the power line is drawing a primary current of 3.43 A then the secondary current entering the house is

A. 0.118 A

B. 100 A

C. 2.40×10^4 A

D. 5.76×10^6 A

Ideal Transformers

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}, \quad \frac{N_p}{N_s} = \frac{I_s}{I_p}, \quad \frac{V_p}{V_s} = \frac{I_s}{I_p}$$

Vp = 7000
Vs = 240
Ip = 3.43
Is = ?