



Circuit Challenges

Electrical Engineer

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Application

Most of what electrical engineers do has some math involved, says Jim Clousten, the senior engineer for the Southern Interior region of B.C. Hydro.

"I use math for power calculations, figuring out the load on circuits, and determining several factors involved in a power system," he says. The simplest calculations may be completed with a calculator, while computer programs are used in more complex situations.

Clousten also uses math to calculate "fault levels." In a house, the fault level is the level at which a breaker "blows." (A breaker "blows" when it automatically turns off because of a circuit problem.)

Another item used to control the possible excessive flow of electricity is a fuse. A fuse is connected directly into an electrical circuit. If the current surges to a dangerous level, the thin metal wire in the fuse melts. This breaks the circuit, thereby preventing the wires from overheating, which may cause a fire. For safety reasons, a breaker or fuse of greater capacity than that specified for a particular circuit **should never be used**.

The prospect of electrical surges and fire must also be considered in commercial and industrial settings, especially when large amounts of electrical energy are being supplied to customers.

Practice

In pairs, list the electrical "plug-in" appliances and devices that are commonly found in a home. Note whether you think they would be heavy, medium or low-power devices. Next, compare your list with the attached results from a survey of home electrical equipment. Any particular observations?

Answer the following questions:

- How do you check the power and current ratings of an electrical device?
- How many outlets and/or lights may be joined as part of one circuit?
- How are houses equipped to monitor the safety level of circuits?
- How much power is commonly available for basic home use?

Exchange your answers with another pair in the class. Any questions? You may like to invite an electrical engineer, or an electrical expert from the city hall inspection department, to visit your classroom.

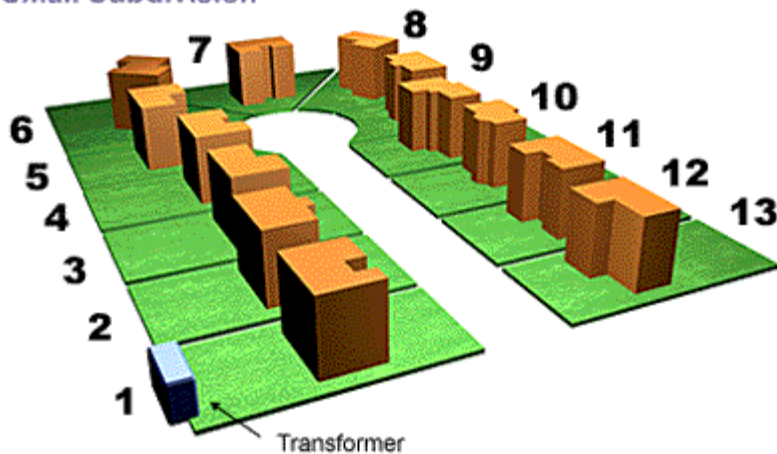
Principles Section A:

In any electrical work, you must be concerned with the safety of the circuit. Therefore, the amount of power in the circuit has to be balanced with the current and other particulars of the wiring system.

Imagine that you're the person in charge of determining the amount of power required for a small housing development to be built in your area. The power will be supplied from a special source called a transformer. The transformer will be situated on a tall power pole, or in a well-protected box to be mounted on a ground-level concrete pad.

The subdivision has 13 lots. Ten properties are to receive 200 amp/120 volt service, and three will receive 400 amp/120 volt service. The latter properties require a different level of service because of equipment that's going to be used in those homes.

Small Subdivision



The transformer is a special piece of equipment that controls the ratio of current to voltage in an electrical system. Its size must be determined for the supply of electricity to the subdivision.

To calculate the amount of basic load that the transformer is required to provide for the small housing development, use the following formula:

$$\text{watts} = \text{amps} \times \text{volts}$$

$$W = A \times V$$

Therefore, if there are 10 properties with 200 amp/120 volt services, then the total power needed is:

$$200 \times 120 \times 10 = 240,000 \text{ watts}$$

To convert large numbers of watts into more manageable terms, divide by 1,000. This creates a measure of **kilowatts**, with the symbol kW.

$$240,000 \text{ W} / 1,000 = 240 \text{ kW}$$

Now, calculate the amount of power needed to supply the three houses using 400 amp/120 volt service. Convert your answer to kilowatts.

What is the total power required for all 13 houses in the subdivision?

Check your answers against the solution for Principles Section A below.

Principles Section B:

While houses and small businesses normally utilize standard "single-phase" electricity, electrical power companies (or utility companies as they are often called), may supply power to transformers through what is called "three-phase" lines. (These different electrical systems can be studied in more depth during your science courses.)

The power in a three-phase system is measured in volt-amps. The formula used to evaluate such power is:

Volt-amps = Sq. root of 3 x voltage (volts) x current (amperes)

Any fuse that is put in the electrical system to prevent problems, even in a transformer, must be able to handle the amps flowing from the transformer at full load.

A large shopping mall is being built in your community. The developers have decided to install their own 1,000,000 volt-amp transformer to supply the mall's power. Your utility company will provide 25,000 volts from your service lines to the mall's transformer. You have a choice of using one of three fuses: 20, 23 or 25 amp. Which one should you use?

Check your answer against the solution for Principles Section B below.

Learn

Rob Maschek of West Kootenay Power says the company supplies electricity to the following businesses, each having its own transformer.

- 775,000 volt-amps -- for a wholesale warehouse distributor
- 2.5 million volt-amps -- for a super-sized shopping mall
- 4.0 million volt-amps -- for a truck manufacturing plant

If the power supplied from the service lines is rated at 12,470 volts, what size fuse should each business use to protect itself from receiving too much current? Use the power (volt-amp) formula to calculate the solutions.

Check your answers against the solution for Learn Section below.

Determine the current (amps) or watt values for each of the appliances listed in the survey of home electrical equipment. Take note of the electrical service provided for the house at the top of the page. Use the formula: watts = volts x amps.

How many of the appliances or devices have less than a 15 amp current rating? Which ones have a 30 amp, 40 amp, or even larger amperage rating? Is it possible to have several devices on the same circuit, as long as the 15 amp capacity of a breaker is not reached? What would happen if you did overstep a 15 amp level of current?

You have eight strings of Christmas lights, each with 25 bulbs of 7 watt rating. If you put them together on one circuit in your house, which has a 120 volt service, will you "blow" a 15 amp breaker when they are turned on?

If the same Christmas lights are left on for five hours each night for 20 days, at a cost of 5.97 cents per kilowatt/hour (kW-h), how much will your power bill increase in the month of December?

How much will it cost per year to operate an electric clock with a 6 watt rating, at a cost of 5.177 cents per kW-h?

Additional activities

- For a fun project, using square grid paper and an appropriate scale, try to design one of the following for homework!
 - a small subdivision
 - a small commercial center
 - a medium-sized industrial area
 - any other useful development for your community that would use electricity on a consistent basis

After a visit by an electrical expert, a field trip to an appropriate electrical supply station, or maybe even a visit to the electrical center for your school, and after researching the three-phase voltage provided in your area; calculate the amount of power required to service your development.

What size of fuses or breakers (relative to current), are required for your proposed design?

- Discuss: North Americans tend to use more energy per person than people in most other countries. How could we be more energy efficient, particularly in our homes?
- Discuss: Given the unfortunate electric power problems in parts of the North East in January 1998, discuss with your class some possible concerns power companies may have in terms of changing the way electricity is supplied to customers.

Electrical Equipment in a Home
200 amp/120 volt service

General Equipment	Watts.	Amps.
Refrigerator	_____	9.5
Washer	_____	9.0
Dishwasher	_____	9.5
Microwave oven	_____	12.0
Clothes dryer	_____	25.0
Hot Water tank	6,000	_____
Range/Oven	13,100	_____
Furnace	_____	112.0
 Garage		
Soldering iron	_____	1.2
Hand drill	_____	2.1
Small freezer	_____	2.6
Jig saw	_____	3.0
Circular saw	_____	11.0
5 x 100 W bulbs	_____	_____
 Kitchen		
Can opener	_____	1.5
Mixer	400	_____
Toaster	800	_____
Coffee maker	1200	_____
Popcorn maker	1240	_____
 Bathrooms: (2 1/2)		
8 x 60 W bulbs	_____	_____
6 x 60 W bulbs	_____	_____
3 fans at 1.2 amps	_____	_____
Hair dryer	1400	_____
 Lighting		
Ceiling lights 18x75 W	_____	_____
Track lights 6x75 W	_____	_____
Fluorescent 3x93 W	_____	_____
Table lamps 4x150 W	_____	_____

Desk lamps	2x60 W	_____	_____
Pole lamps			
2x60 W		_____	_____
1x150 W		_____	_____
Regular			
5x100 W		_____	_____
4x 60 W		_____	_____
Driveway			
4x 40 W		_____	_____
2x 60 W		_____	_____
Christmas lights			
8 strings x 25 x 7 W		_____	_____

Other

Computer		_____	2.5
Monitor		_____	1.6
Scanner		_____	1.5
Laser printer		_____	6.5
Clothes iron	1000	_____	_____
Vacuum cleaner		_____	9.6
Amplifier		_____	1.6
CD Player	15	_____	_____
Portable Stereo	16	_____	_____
VCR	17	_____	_____
TV	150	_____	_____
Water sprinkler Units			
2 x .25 amps		_____	_____
Electric clocks: 3x6 W		_____	_____

Number of appliances with less than 15 amp current rating: _____

Number of appliances with approx. 30 amp current rating: _____

Number of appliances with approx. 40 amp current rating: _____

Equipment with largest amperage rating: _____

Cost for the Christmas lights during December: \$_____

Cost per year to run the electric clock: \$_____

Curriculum Organizer:

- Problem Solving
- Patterns and Relations
- Variables and Equations

Curriculum Sub-organizer(s):

- Apply math to solving problems in another discipline.
- Working with formulae, especially one involving a radical.
- Isolating a variable - in terms of other variables.
- Use community resources to solve problems.

Prerequisites:

- ? Basic number operations.
- Basic algebra skills.
- Knowledge of scale drawings.

Resources:

- standard writing paper
- large graph paper
- pencil
- ruler and calculator

Solutions to Principles Section A

How much power is needed to supply the three houses using 400 amp/ 120 volt service?
Convert your answer to kilowatts.

watts = amps x volts

$A \times V = W$

$400 \times 120 \times 3 = 144,000 \text{ Watts}$

$144,000 / 1,000 = 144 \text{ kW}$

What is the total power required for all 13 houses in the subdivision?

$144 \text{ kW} + 240 \text{ kW} = 384 \text{ kW}$

Solution to Principles Section B

Which of three fuses, 20, 23 or 25 amp, do you use in the transformer for the shopping mall?

To calculate the current (amp), you must solve the equation for current. Therefore:

power (volt-amp) = Sq. root 3 x voltage x current

$1,000,000 = \text{Sq. root } 3 \times 25,000 \times \text{current}$

To isolate the variable Current, use basic algebra techniques to rewrite the formula as:

$1,000,000 / \text{sq. root } 3 \times 25,000 = \text{current}$

$23.09 \text{ amps} = \text{current}$

You would choose the 23 amp fuse to offer circuit protection. (Note that you round down to the nearest whole number.) If you selected a fuse with higher rating, you have endangered the safety of the mall!

Solution to Learn

Wholesale warehouse: 35.8 amps (35 amp fuse)

Shopping mall: 115.7 amps (115 amp fuse)

Truck manufacturer: 185.2 amps (185 amp fuse)