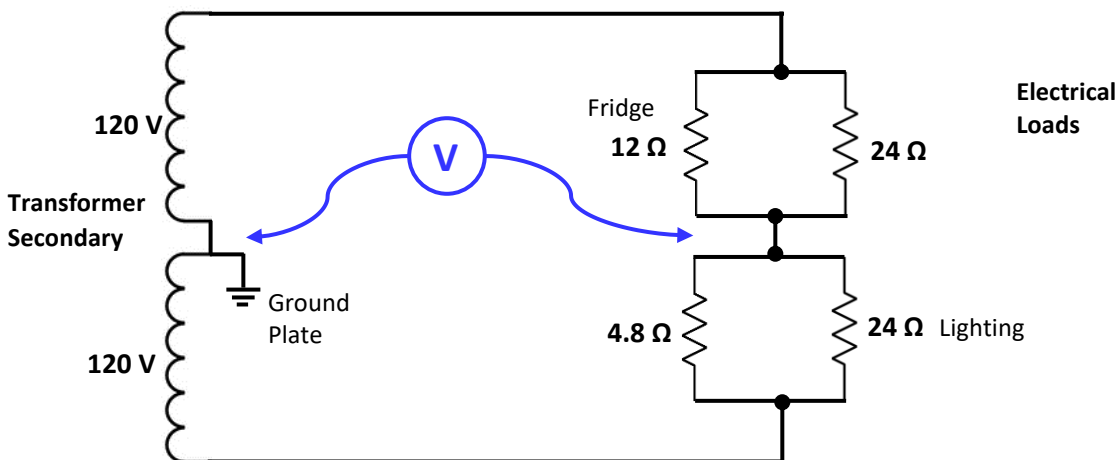


Case Study – Broken Neutral on Residential Three-Wire System

Houses in Canada are connected to the street transformer by a service cable that may be buried or strung through the air, USEB type or triplex respectively. This cable consists of three conductors sized to deliver 120/240 volts and 100, 125, or 200 amperes of current, which is transmitted by the vibration of electrons in the conductor at a rate of 60 hertz. The conductive material may be aluminum or copper. The utility company owns the service cable up to its termination point on the utility's energy meter, typically mounted on the exterior of the customer's house.

Consider a house whose lights have become much brighter than normal, but dim and flicker noticeably when the refrigerator compressor kicks in. Further investigation reveals that the cable has a broken neutral wire, perhaps caused by utility work nearby, or by a ground disturbance or tree growth that has damaged the cable.

Given the following diagram, what is the voltage imbalance caused by the broken neutral?



This question is designed to teach you about Ohm's Law and its three transformations (see Power Wheel below):

1. **$R=E/I$** This means that electric current is *inversely proportional* to the resistance: the more resistance, the less current there will be with a given voltage.
2. **$E=I \cdot R$** Tells us that voltage drop is in *direct proportion* to the resistance of a load: the more resistance, the greater the voltage required to produce the same current.
3. **$I=E/R$** Means that current is *directly proportional* to the applied voltage: the more voltage, the more current.

The broken wire means that there is nothing to tie the *loads* (resistors) to the grounded midpoint of the transformer secondary.

Because the loads are not perfectly balanced, there will be a voltage, which is causing the lights to be bright but dim when other loads in the house are operating. To find out what that voltage is, using the principles of Ohm's Law, the *effective resistance* of each set of resistors must be calculated first, also using Ohm's Law.

Because the voltage across the 12 ohm and 24 ohm resistors that are in parallel with one another is not yet known, we assign to **E** the nominal value of one volt for simplicity's sake.

For the 12 Ω resistor, the current, given by **$I = E/R$** , is

$$1/12.$$

Likewise, for the 24 Ω resistor, the current is

$$1/24$$

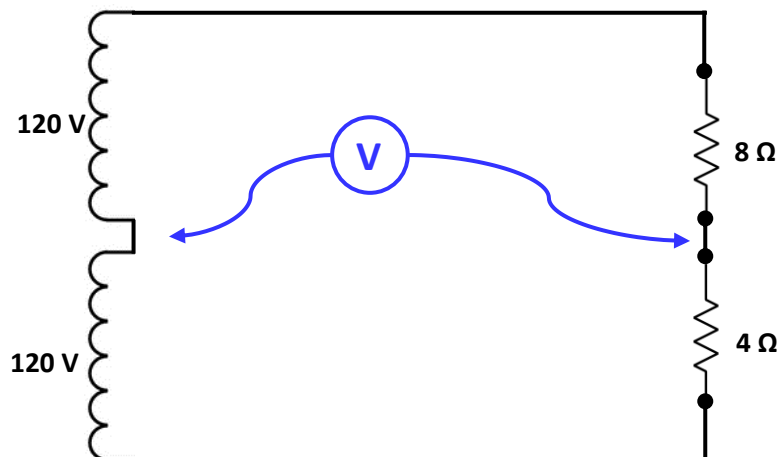
This means that the effective resistance of the upper two resistors, given by $R=E/I$, is $1/(1/12 + 1/24)$, or $8\ \Omega$. Using the inverse button on a calculator, (χ^{-1}) the equation is simpler:

$$R = (12^{-1} + 24^{-1})^{-1} = 8\ \Omega$$

The effective resistance of the 4.8 ohm and 24 ohm resistors in parallel is calculated in the same way:

$$R = (4.8^{-1} + 24^{-1})^{-1} = 4\ \Omega$$

Re-draw the diagram:



Now, it is possible to calculate the voltage drop across each resistor. The total voltage applied to the circuit is 240 V, and the total circuit resistance is $12\ \Omega$. The current is 20 amps. The voltage drop across the $8\ \Omega$ resistance is 160 V. The voltmeter will read the difference between this voltage and the midpoint of the feed transformer:

$$160 - 120 = 40\ \text{Volts}$$

Power Wheel

