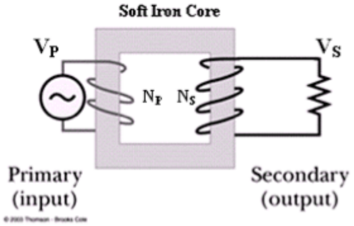
How can the voltage increase or decrease without violating the conservation of energy principle?

Ideal Transformer Formula

$$P_s = P_p$$

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



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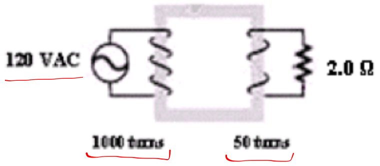
1. A 120 VAC wall outlet is used to run a small electronic appliance with a resistance of 2.0 Ω, as shown in the diagram.



a) Is the transformer a step-up [✓ or step-down] transformer? Cite evidence for your answer.

$$N_s < N_p$$

b) How much voltage does the device need?

1000:50

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \rightarrow V_s = \frac{50}{1000} 120 \text{ v} = 6\text{v}$$

c) If the current in the primary coil is 150 mA, how much current does the device use? Assume an ideal transformer.

$$P = I_p V_p = .150\text{A} \cdot 120\text{v} = \underline{18\text{w}}$$

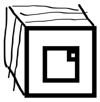
$$P = I_s V_s = 3\text{A} \; 6\text{v} = \underline{18\text{w}}$$

Real Transformers

$$eff = \frac{P_s}{P_p}$$

Reasons for power losses in real transformers

1. resistance of wires in P and S coils causes heating of coils
   (Joule heating)
2. not all flux from P coil is linked to S coil
   (flux leakage)
3. core warms up as result of cycles of flux changes (hysteresis)
   (magnetic hysteresis)
4. small currents are induced in core (eddy currents) – reduce by lamination
   (eddy currents)



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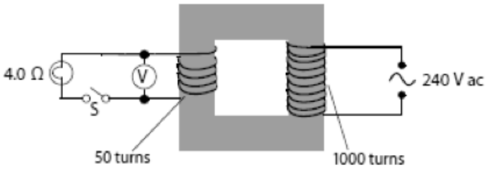
2. The figure shows a step-down transformer used to light a filament lamp with a resistance of 4.0 Ω under operating conditions. The secondary coil has an effective resistance of 0.2 Ω and the primary current is 150 mA. Calculate:



a) the reading on the voltmeter with switch S open

12 V

b) the current in the secondary coil with switch S closed

$$I_s = \frac{V_s}{R} = \frac{12V}{4.2\Omega} = 2.86A$$

c) the power dissipated in the lamp and the secondary coil

$$P_s = I_s V_s = 2.86A \cdot 12V = 34.3W$$

$$= I_L^2 R_L + I_c^2 R_c$$

$$(2.86A)^2 \times 4\Omega \quad + (2.86A)^2 \cdot .2\Omega$$

d) the power taken from the mains supply

$$P_p = I_p V_p$$

$$= .15A \cdot 240V = 36W$$

e) the efficiency of the transformer

$$\frac{34.3W}{36W} \sim .95$$

Health and Safety Concerns associated with High-Voltage Power Lines

1. Extra-low-frequency electromagnetic fields, such as those produced by electrical appliances and power lines, induce currents within a human body.

Just as AC can induce emfs and currents in secondary coils, so too can they be induced in the human body since it is a conducting medium

Changing magnetic field induces current in human body

2. Current research suggests that low-frequency fields do not harm genetic material.

f = 60 Hz individual photons of this frequency do not have enough energy
to cause ionization in the body

childhood leukemia clusters are suspected to have a link to living near overhead power cables

3. The risks attached to the inducing of current in the human body are not well-understood.

Risks are likely to be dependent on current density, frequency, and length of exposure

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Power Transmission

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Power loss in transmission lines

When current flows through a wire, some energy is lost to the surroundings as the wire heats up due to the collisions between the free electrons in the current and the lattice ions of the wire. This is known as *Joule heating* or *resistive heating*. Since the energy lost per second, or power loss, is proportional to the square of the current ($P = I^2 R$), this energy loss is also know as "I^2R loss."

Methods of reducing I^2R loss in power transmission lines

$$P = \cancel{IV} = I^2R = \cancel{V^2/R}$$

1. Reduce resistance: thicker cables – low resistivity material

   Constraints: lengths are fixed, thicker cables are heavier and more expensive

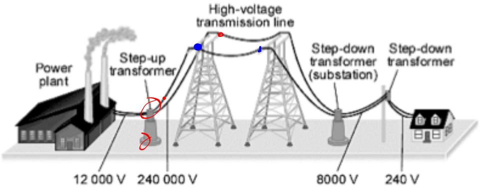
2. Increase voltage: step voltage up to very high levels

   $2 \times V = \tfrac{1}{2} \times I = \tfrac{1}{4} \times P$

   Constraints: high voltages are dangerous – must be stepped back down for household use

For economic reasons, there is no ideal value of voltage for electrical transmission. Typical values are shown below.

1. AC power is generated at a power plant at 12,000 V and then stepped up to 240,000 V by step-up transformers.
2. The high-voltage, low-current power is sent via high-voltage transmission lines long distances.
3. In local neighborhoods, the voltage is stepped-down (and current is stepped-up) to 8000 V at substations.
4. This voltage is stepped-down even further at transformers on utility poles on residential streets.



An average of 120 kW of power is delivered to a suburb from a power plant that is 10 km away. The transmission lines have a total resistance of 0.40 Ω. Calculate the power loss if the transmission voltage is

a) 240 V

$$\underset{120\text{ kW}}{P} = I\,\underset{240\text{ V}}{V}$$

$I = 500\text{A}$

$P = I^2R = (500\text{A})^2 \cdot .4\Omega$
$= 100\text{ kW}$

a) 240,000 V

$$\underset{120\text{ kW}}{P} = I\,\underset{240\text{ kV}}{V}$$

$I = .5\text{A}$

$P = I^2R$
$(.5\text{A})^2 \cdot .4\Omega = .1\text{ W}$