# Year 11 Physics

## Magnetism and Electromagnetism

# What is a transformer?

What is a transformer?

A device used to increase or decrease voltage.

Where are transformers used?

In the national grid and household appliances.

What do we call a transformer that increases voltage?

A step-up transformer.

What do we call a transformer that decreases voltage?

A step-down transformer.

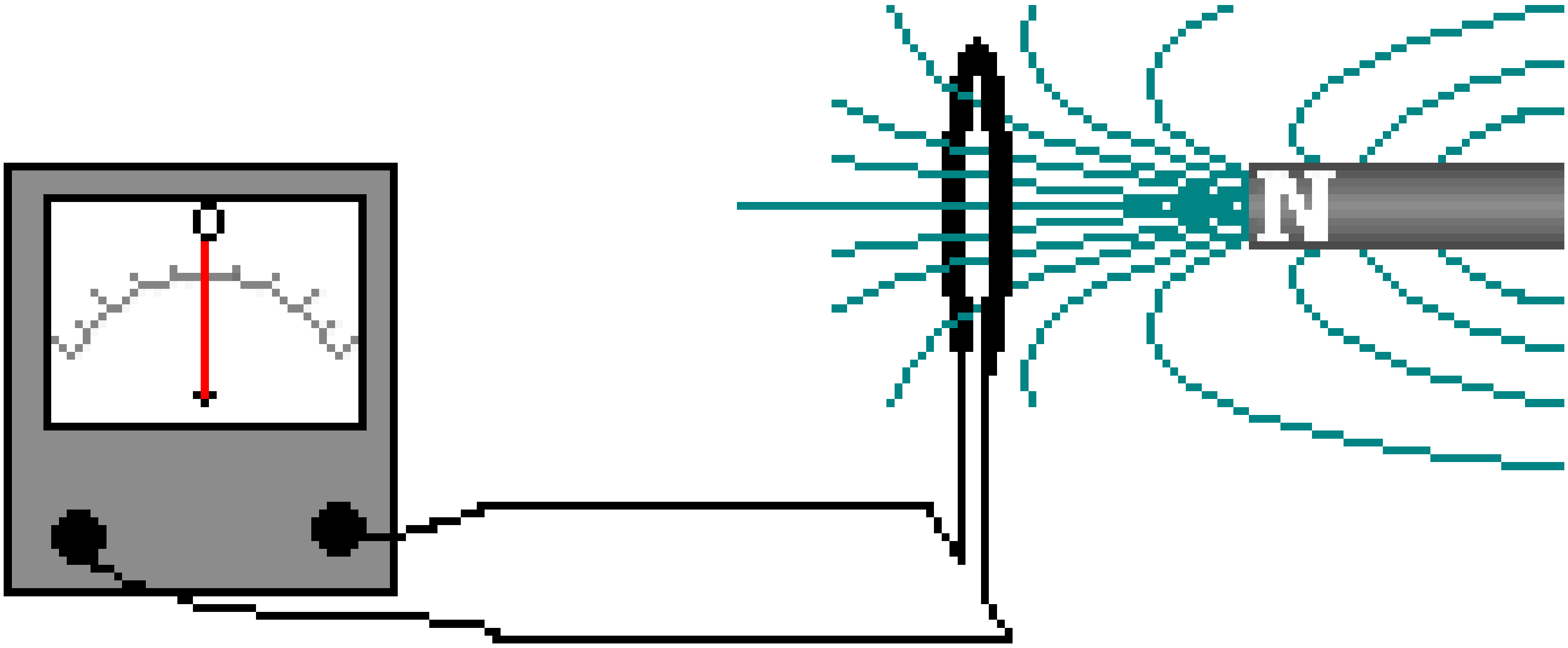
# Transformers

- A transformer has two electromagnetic coils.
- When the electricity changes in the first coil an electric voltage is created across the second coil.
- Transformers are used to change the voltage and current of the electricity that comes from Collie power station.

# How does it work?

# Transformers

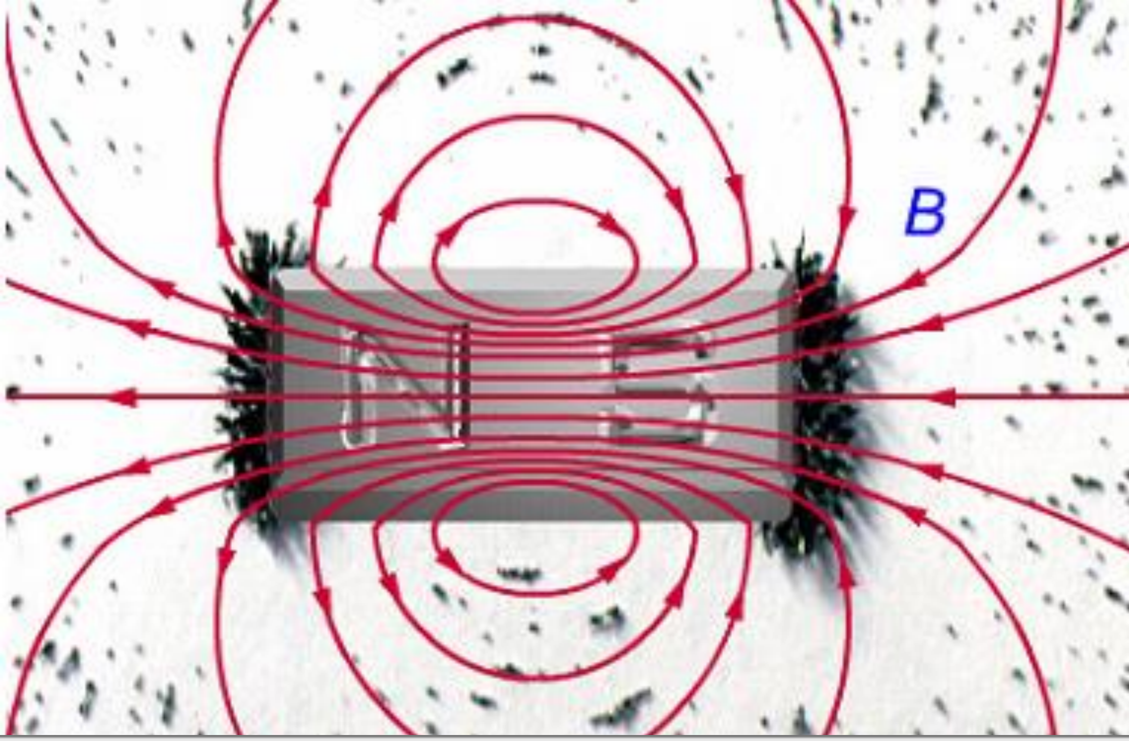
- A transformer can change the voltage and current of an electrical supply.
- Some devices need low voltage and some need some need high voltage.
- Only a.c. voltage can be transformed from one voltage to another, this is why mains electricity needs to be a.c.
- To understand a transformer we need to learn more about coils and cores.

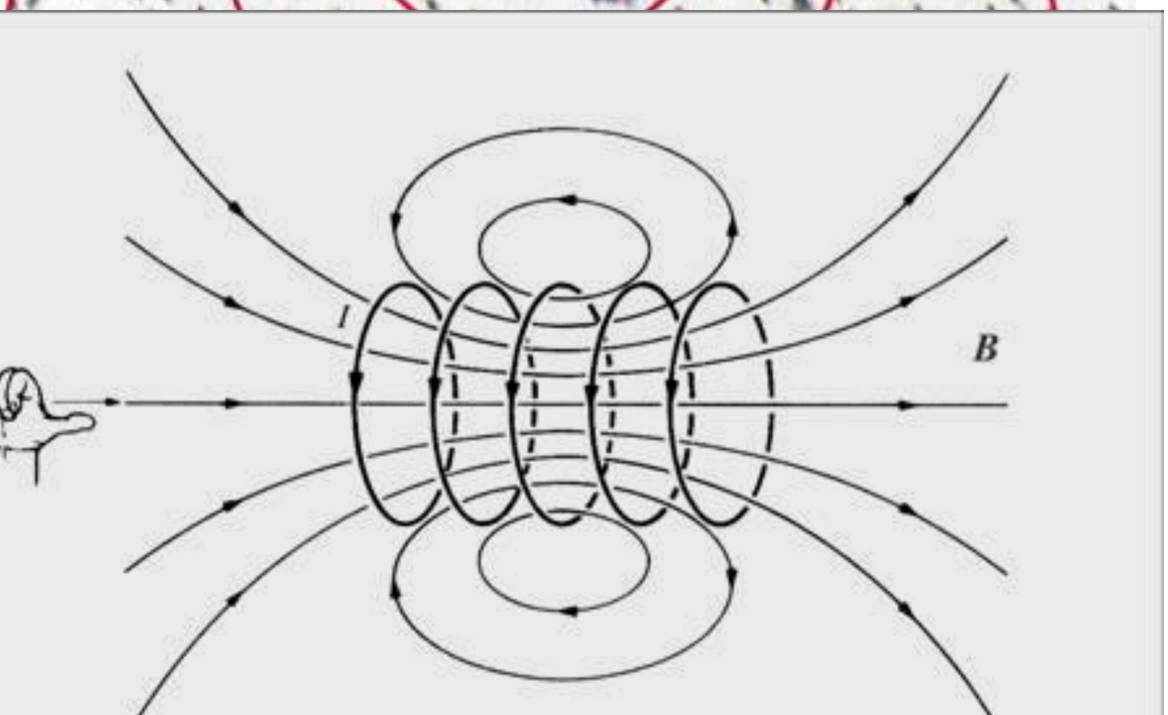



Remember this?

An electric voltage is only induced when the magnet is moving.

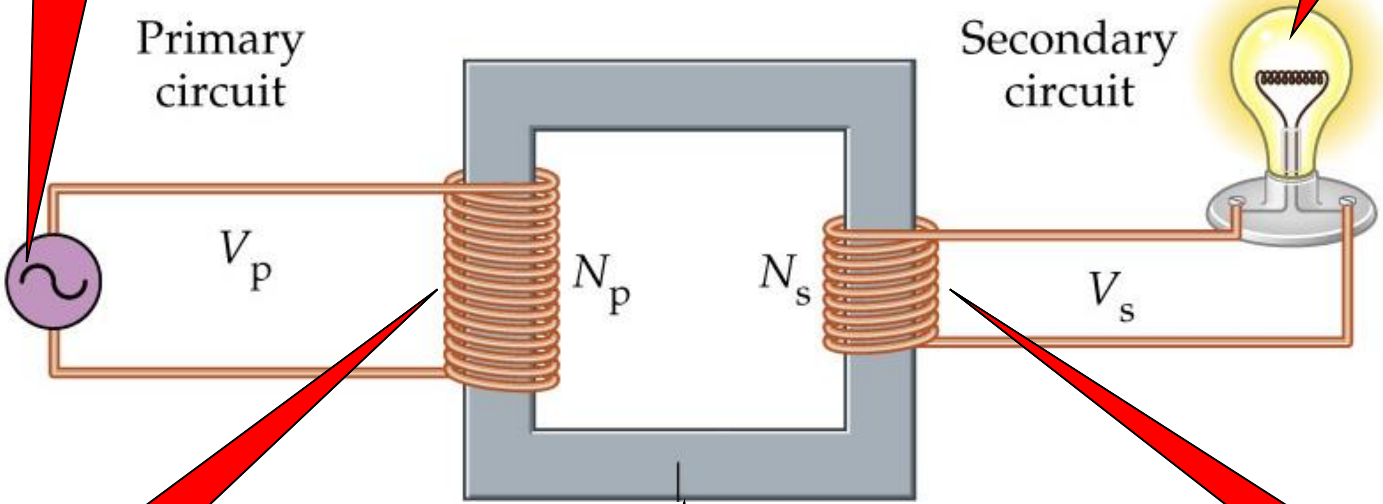
***We need a changing magnetism to make electricity.***




Bar magnet have a similar magnetic field patter to  a solenoid with current.

# What is what ?




Input a.c. voltage

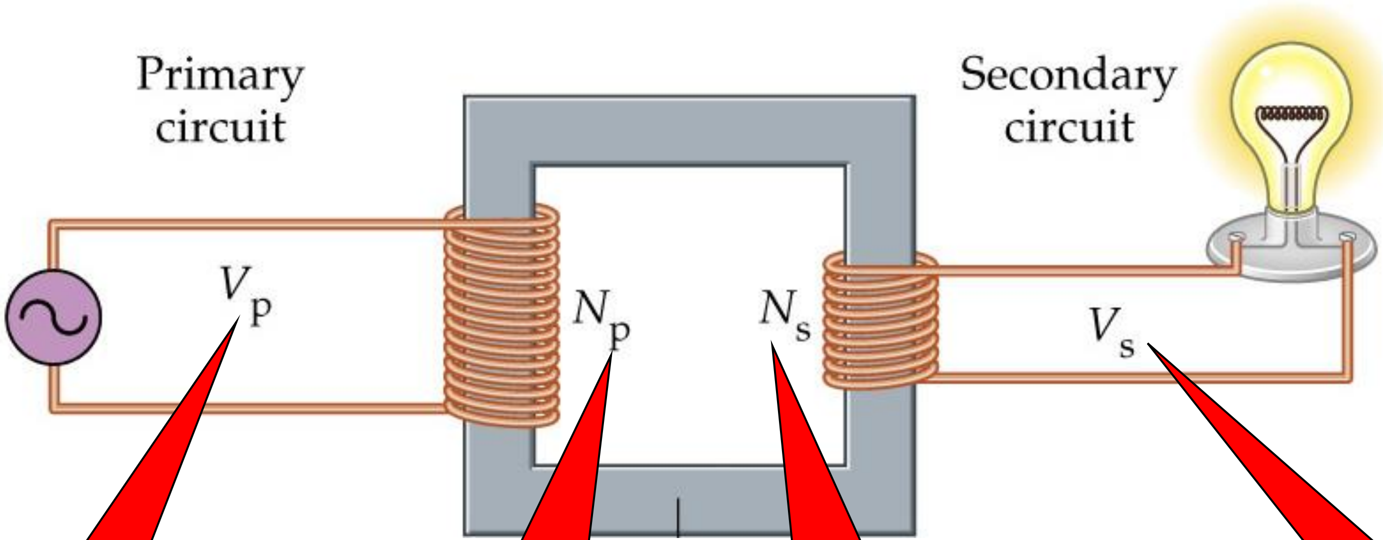
Output a.c. voltage

Input or primary coil

A soft iron ‘O’ core

Output or secondary coil

# What is what ?



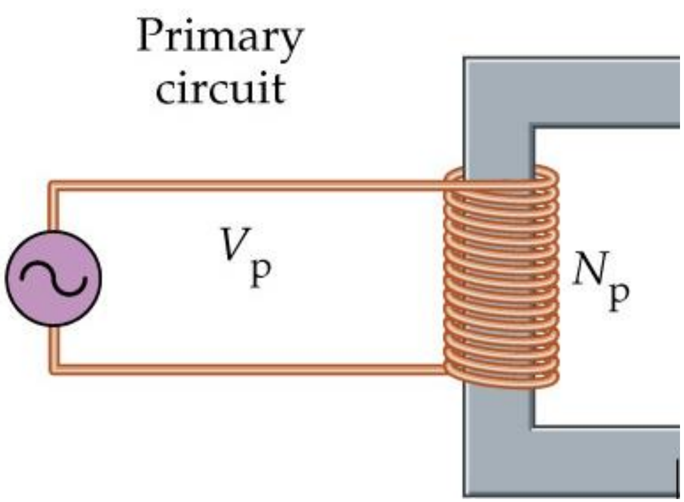

The input or primary voltage

Number of primary coils

Number of secondary coils

The output or secondary voltage

# Input side




The primary voltage creates a magnetic field when its current passes through the coil.

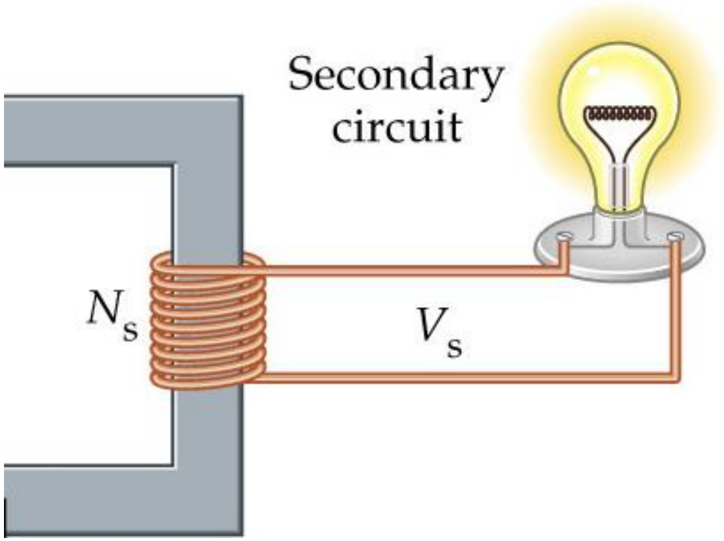
The a.c. voltage means that the magnetism through the coil is always changing.

# Output side

The magnetism from the primary coil is passed through the iron to the secondary coil.

Because the magnetism is changing a voltage is induced in the secondary coil.

The size of the output voltage depends on the size of the two coils.




Changing the magnetism is just like moving a magnet, only easier!

# Soft iron core

- Iron is a soft magnetic material, this means that it is very easy to magnetize and very easy to demagnetize.

- In a transformer the direction of electricity is changing many times each second.

- Every fraction of a second the core needs to change its magnetism. We use iron because it can change its magnetism from one direction to another very easily.

# Lamp demonstration

# Transformers

- Transformers change the voltage and current of an a.c. electrical supply.
- In the following experiment mains electricity at 220 volts enters the circuit.
- After leaving the transformer the voltage has been reduced to approximately 11 volts.


3600T
300T


# Input circuit

The voltage enters the circuit through the thick 220 volt wire and passes through the coil with 3600 turns.

# Output circuit

The voltage is induced in the smaller part of the transformer that only has 300 turns of wire.  It then travels through the thinner wires to the 11 volt lamp.

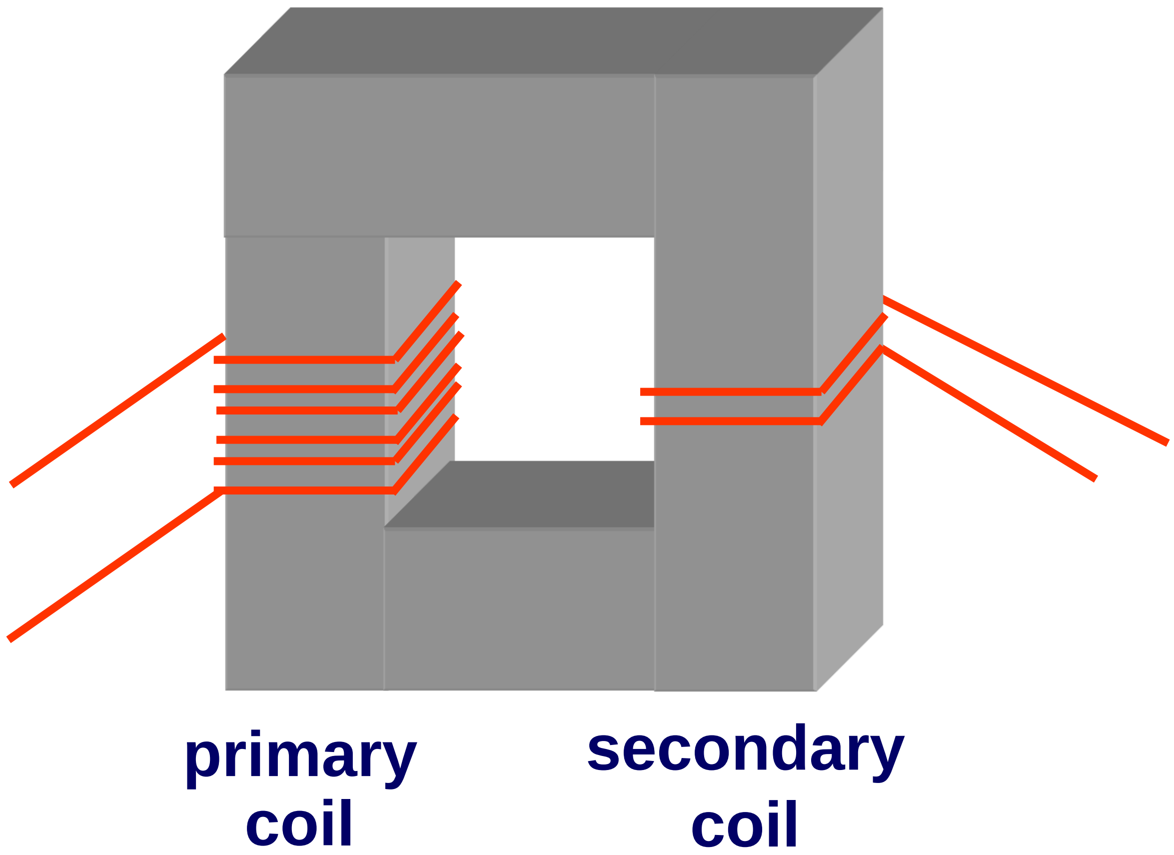

The lamp is off because the magnetism is not strong enough to go from one coil the other.


The ‘C’ core increases the magnetism.


The ‘O’ core is even stronger.

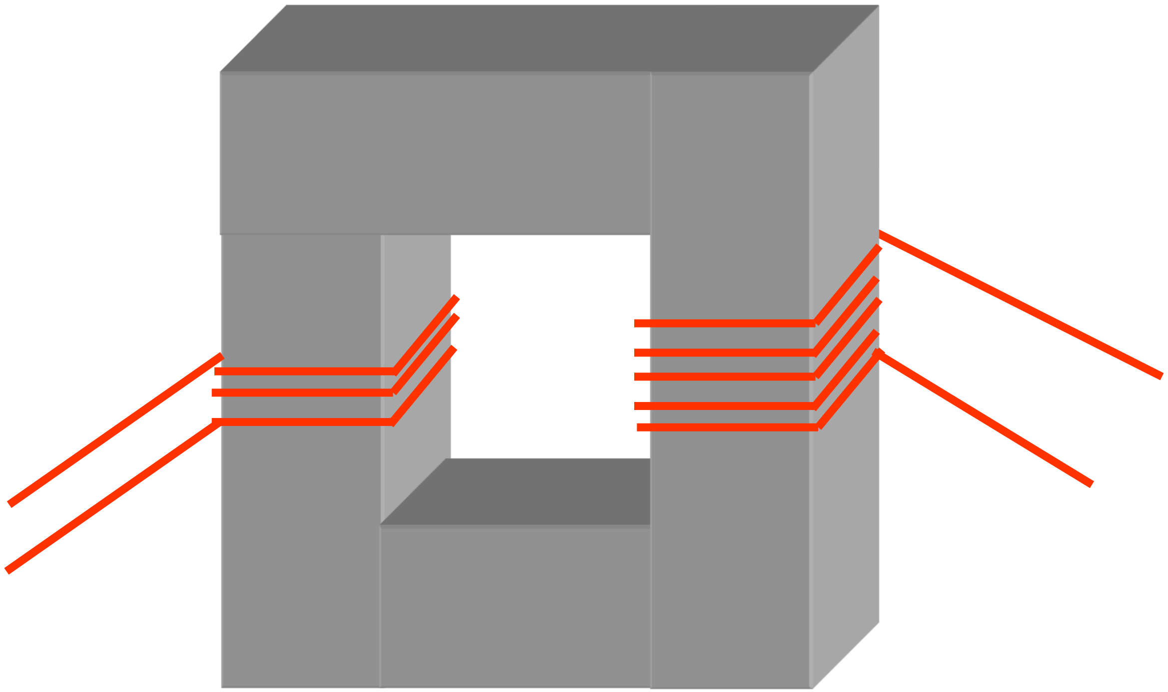
# Step up and Step down

Is this a step-up or a step-down transformer?




This a **step-down transformer** because there are **less turns in the secondary coil** than the primary coil.

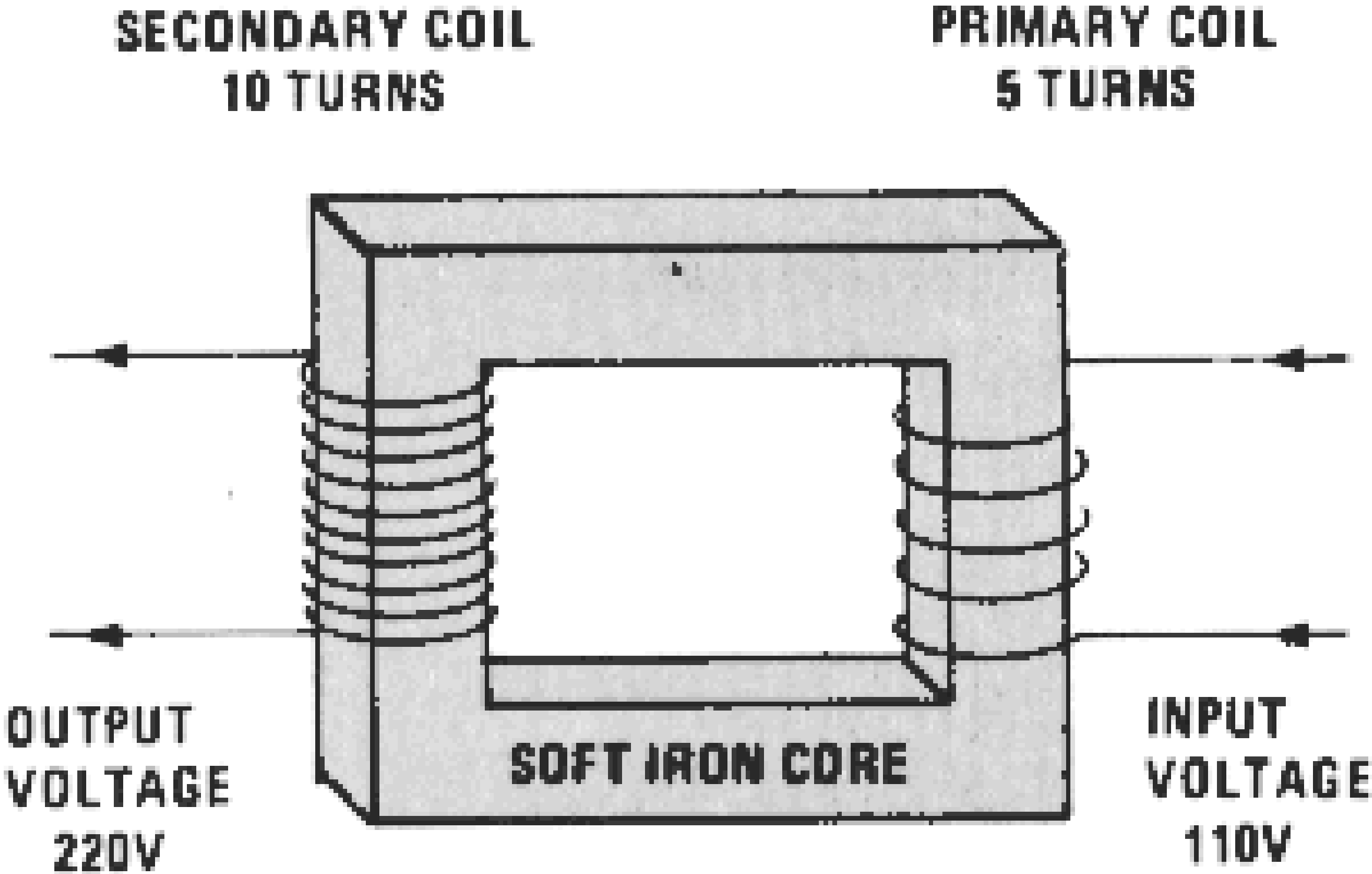
Is this a step-up or a step-down transformer?





This a **step-up transformer** because there are **more turns in the secondary coil** than the primary coil.

# Less turns = less voltage



# Transformer formula

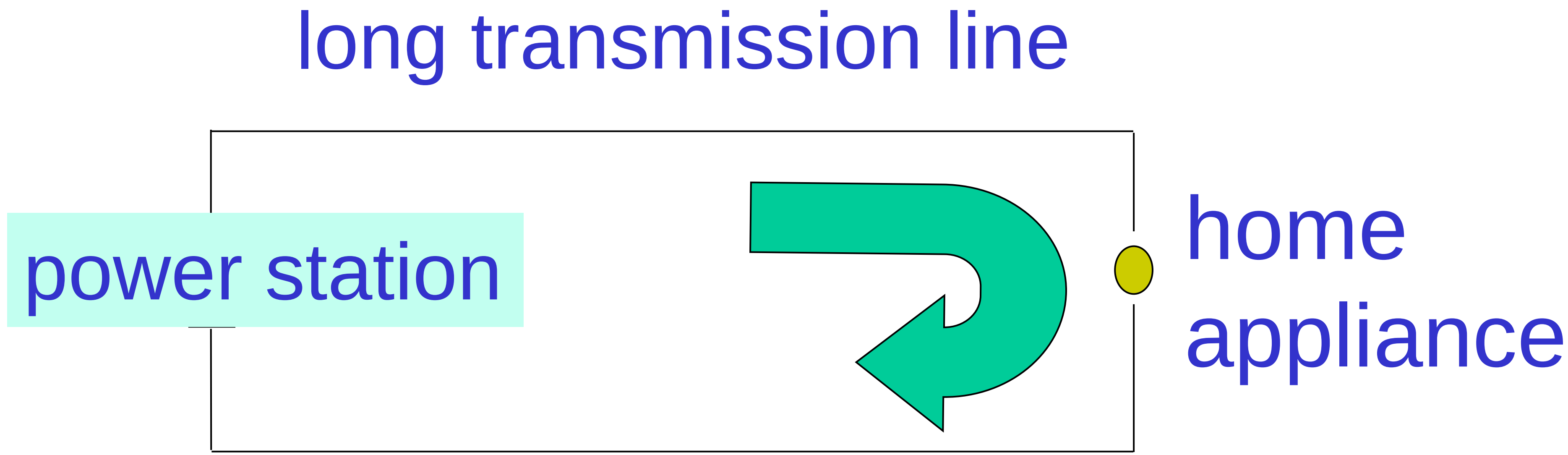
The formula for calculating voltages and coils in a transformer has four variables!

$$\frac{Secondary \quad voltage}{\text{Pr}imary \quad voltage} = \frac{Turns \quad on \quad \text{sec}ondary \quad coil}{Turns \quad on \quad primary \quad coil}$$

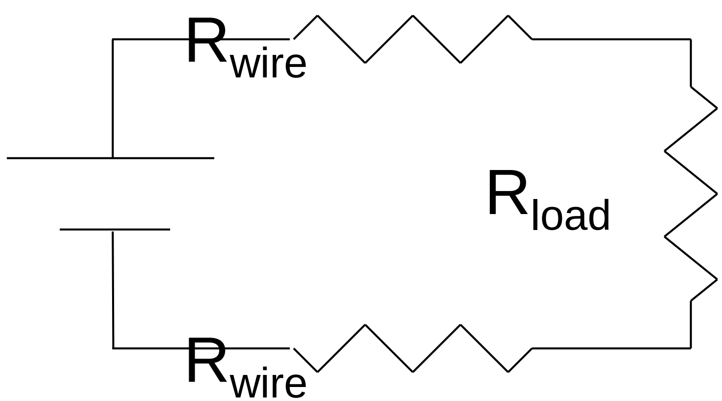
$$\frac{V_2}{V_1} = \frac{N_2}{N_1}$$

- If a transformer is 100% efficient, the power produced in the secondary coil should equal the power input of the primary coil.

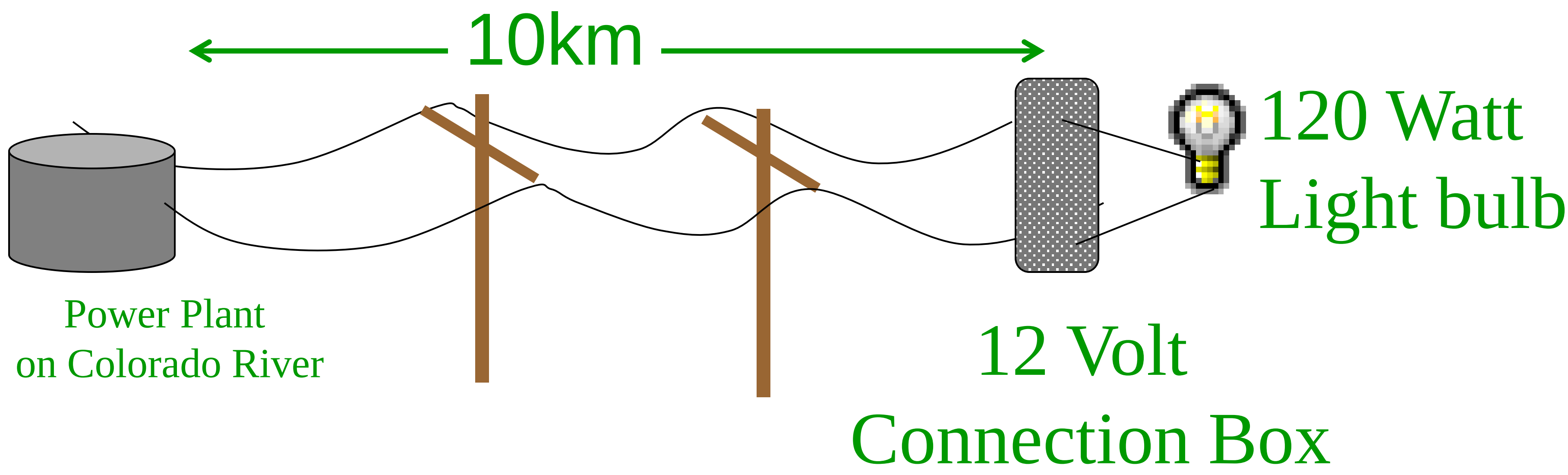
# Power Transmission




looks like:



# Power Dissipated in an Electricity Distribution System




We can figure out the current required by a single bulb using $P = VI$ so

$$I = P/V = 120 \text{ Watts}/12 \text{ Volts} = 10 \text{ Amps (!)}$$

Estimate resistance of power lines:

$$0.001\ \Omega/\text{m} \times 2\times10^5 \text{ m} = 20 \text{ Ohms}$$

Power dissipate/waste in transmission a line is

$$P = I^2 R = 10^2 \times 20 = 2{,}000 \text{ Watts!!}$$

“Efficiency” is

$$e = 120 \text{ Watts}/2120 \text{ Watts} = 5.6\%!!!$$

What could we change in order to do better?

# The Tradeoff

- The thing that kills us most is the high current through the (fixed resistance) transmission lines
- Need less current
  - it's that square in $I^2R$ that has the most dramatic effect
- But our appliance needs a certain amount of power
  - $P = VI$ so less current demands higher voltage

- Solution is high voltage transmission
  - Repeating the above calculation with 12,000 Volts delivered to the house draws only
  - $I$ = 120 Watts/12 kV = 0.01 Amps for one bulb,
  - giving
  - $P = I^2R = (0.01)220 = 20\times10^{-4}$ Watts,
  - so
  - $P$ = 0.002 Watts of power dissipated in transmission line
  - Efficiency in this case is e = 120 Watts/120.004 = 99.996%

# Example

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

1. 240 V
2. 24000V

$$P = IV$$

$$I_1 = \frac{P}{V} = \frac{120\text{x}10^3 \text{ W}}{240 \text{ V}} = 500 \text{ A}$$

Power loss:

$$P_1 = I^2 R = (500 \text{ A})^2 (0.40 \ \Omega) = 100 \text{ kW}$$

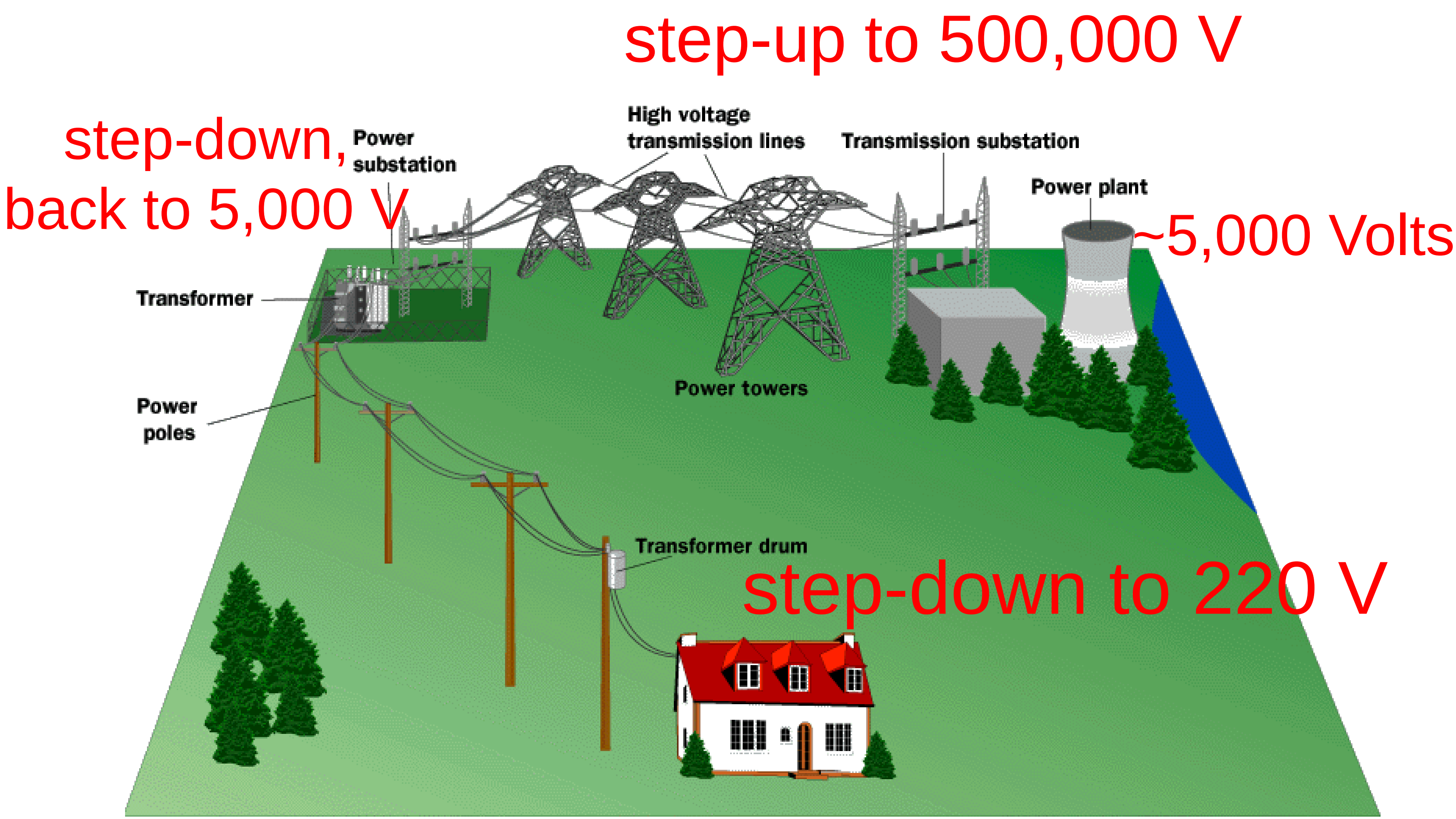
$$I_2 = \frac{P}{V} = \frac{120\text{x}10^3 \text{ W}}{24000 \text{ V}} = 5 \text{ A}$$

$$P_2 = I^2 R = (5 \text{ A})^2 (0.40 \ \Omega) = 10 \text{ W}$$

# DANGER!

- But having high voltage in each household is a recipe for disaster
  - sparks every time you plug something in
  - risk of fire
  - not cat-friendly
- Need a way to step-up/step-down voltage at will
  - can’t do this with DC, so go to AC

# A way to provide high efficiency, safe low voltage:




High Voltage Transmission Lines
Low Voltage to Consumers

# Power Transmission

- Electric power is usually transmitted over high voltage power lines.
- Copper wire has a resistance and over long runs some energy will be lost to the surroundings as heat.
- A low current (high voltage) minimizes this loss.