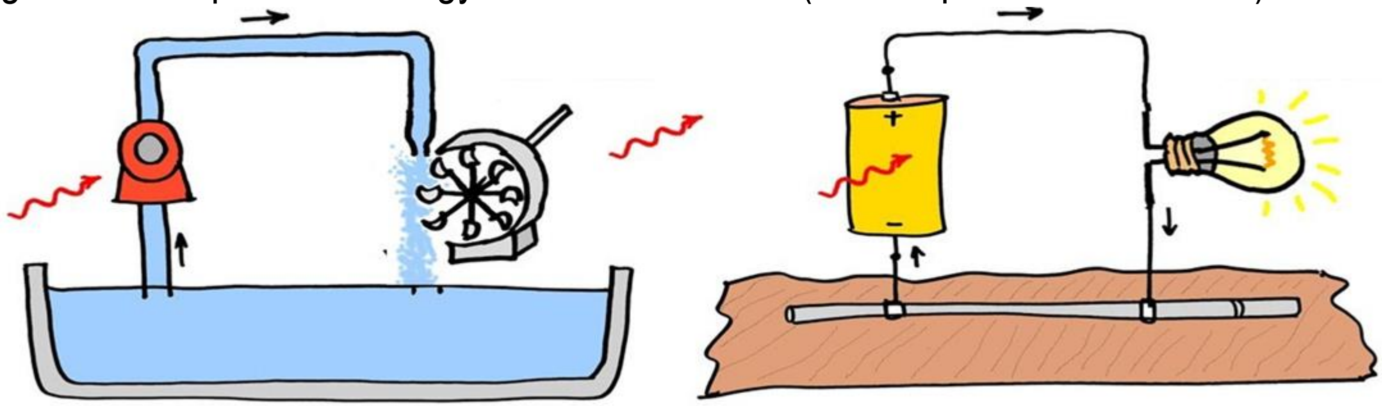
ELECTRIC ENERGY AND ELECTRIC POWER

WORK DONE BY AN ELECTRIC CURRENT

Water flows due to a difference in gravitational potential energy.

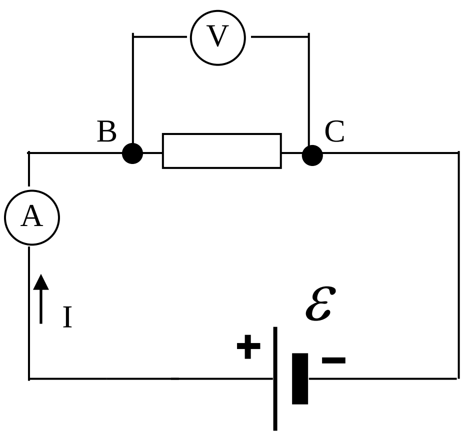
Electric current flows due to a voltage (electric potential difference)..



picture 1

♦ Charges in a wire are analogous to water in a pipe
♦ electric current is analogous to flow of the water
♦ the battery is analogous to the water pump
♦ voltage is analogous to the change in potential energy E_P.

Let us consider conductor BC of resistance R across whose ends the voltage *V* is applied (picture 2) The charge $q = I \cdot t$ will flow during the time *t* through every cross section of the conductor. This is equivalent to the fact that the charge $I \cdot t$ is carried during the time t from one end of the conductor to the other. So the work done by an electric current is given by: $W = V \cdot q = V \cdot I \cdot t$



picture 2

ELECTRICAL ENERGY AND POWER

The rate of doing work is called power. This is also the rate of consumption of energy.
The equation W= $I^2 \cdot R \cdot t$ gives the rate at which electric energy is dissipated or consumed in an electric circuit. This is also termed as electric power. The power P is given by:

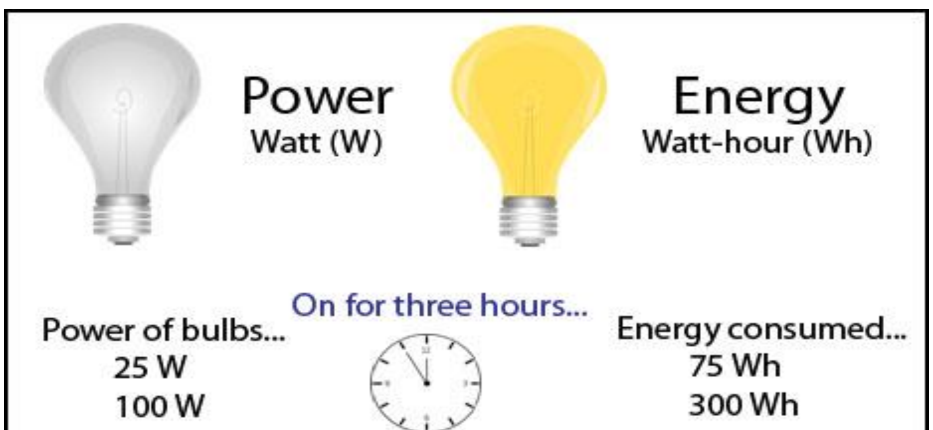
$$P = \frac{W}{t} \Rightarrow W = I^2 \cdot R \cdot t \Rightarrow P = I^2 \cdot R = V^2 \cdot R \quad \text{Or} \quad P = V \cdot I$$

The SI unit of electric power is watt (W).

It is the power consumed by a device that carries 1 A of current when operated at a potential difference of 1 V.
1 W = 1 volt × 1 ampere = 1 V A.

The unit 'watt' is very small. Therefore, in actual practice we use a much larger unit called 'kilowatt'. It is equal to 1000 watts.

Since electrical energy is the product of power and time, the unit of electric energy is, therefore, watt hour (W h). One watt hour is the energy consumed when 1 watt of power is used for 1 hour.
The electric energy E is given by: $E = P \cdot t = V \cdot I \cdot t$



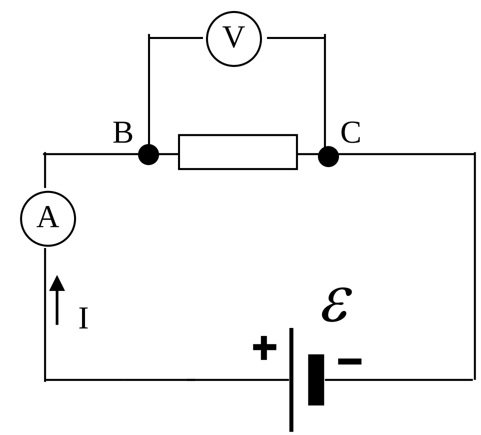
The commercial unit of electric energy is kilowatt hour (kW h), commonly known as 'unit'.
1 kW h = 1000 watt × 3600 second
= 3.6×10^6 watt second = 3.6×10^6 joule (J).

JOULE–LENZ LAW

When an electric current is passed through a conductor, the conductor becomes hot after some time and produces heat. This happens due to the conversion of some amount of electric energy, passing through the conductor, into heat energy. This effect of electric current is called heating effect of electric current.
The heating effect of electric current depends on three factors:

- The resistance, R of the conductor. A higher resistance produces more heat
- The time, t for which current flows. The longer the time the larger the amount of heat produced
- The amount of current, I. the higher the current the larger the amount of heat generated

To calculate the heat produced in a conductor, consider current I is flowing through a conductor BC of resistance R for time t (picture 3). also consider that the potential difference applied across its two ends is V.
Now, total amount of work done in moving a charge q from point B to C is given by: $W = V \cdot I \cdot t$ ⇨ $V = I \cdot R$ ⇨ $W = I^2 \cdot R \cdot t$



picture 3

Now, assuming that all the work done is converted into heat energy we can replace symbol of **'work done'** with that of **'heat produced'**. So:

$$Q = I^2 \cdot R \cdot t$$

According to ohm's law: $I = \frac{V}{R}$ ⇨ $Q = \frac{V^2}{R} \cdot t$

Joule–Lenz law states that the amount of heat dissipated from a current carrying conductor is proportional to the resistance of the conductor, the square of the current and the time needed for the current to pass through the conductor.

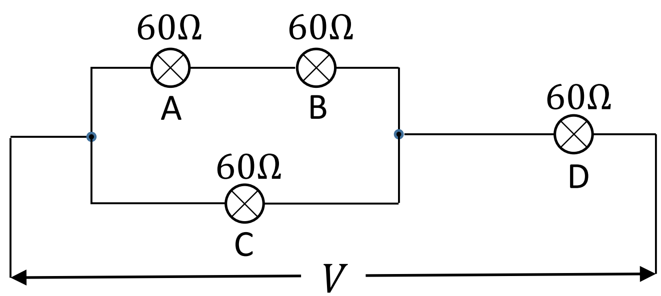
PROBLEMS

1. The resistance of bagel toaster is 12.5 Ω. To prepare a bagel, the toaster is operated for one minute from a 120-V outlet. What is the current throught the toaster? How much energy is delivered to the toaster?

2. For a single dish wash it is necessary to heat up 10 l of water in the electrical heater from 15°C to 45°C. The price of 1 kWh of electrical energy is 0,1 euro. How much does a single dish wash cost (in euros), assuming that all energy is spent exclusively on heating the water. The density of water is 1000 kg/m3 , and specific heat capacity of water 4200 J/kg°C.

3. Find the resistance of the heater which can heat up 0,5l of water from 20ºC to 80ºC for 6 minutes Efficiency of the heater is 60%. The operating voltage of the heater is 600V?

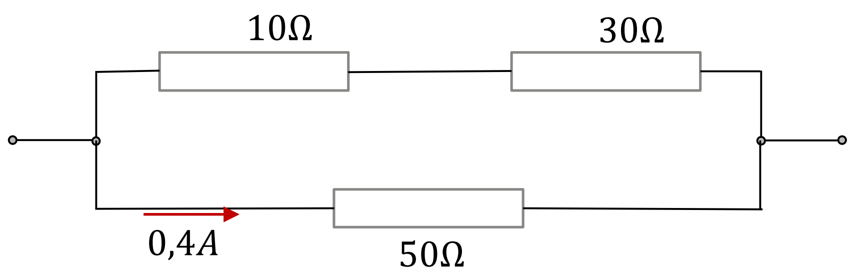
4. Four light bulbs each of constant resistence 60Ω are connected to a battery of potential difference 30V as shown in picture. Find the electric power in each bulb?



5. Two conducting wires of the same materials (with same length and diameter) are first connected in series and then in parallel in the circuit across the same potential difference. The ratio of heat produced in series and parallel combination would be:

a) 1:2 b) 2:1 c) 1:4 d) 4:1

6. The picture shows the part of the electric circuit. Find the electric power in each resistor and electric power in all resistors?



7. Resistors R_1=70Ω, R_2=80Ω, R_3=100Ω are connected to a battery of potential difference 180V as shown in picture. Find the heat released in each resistor and in all resistors for 1s?