TECNOLOGIAS PARA SISTEMAS DE ENERGIA ESPACIAIS

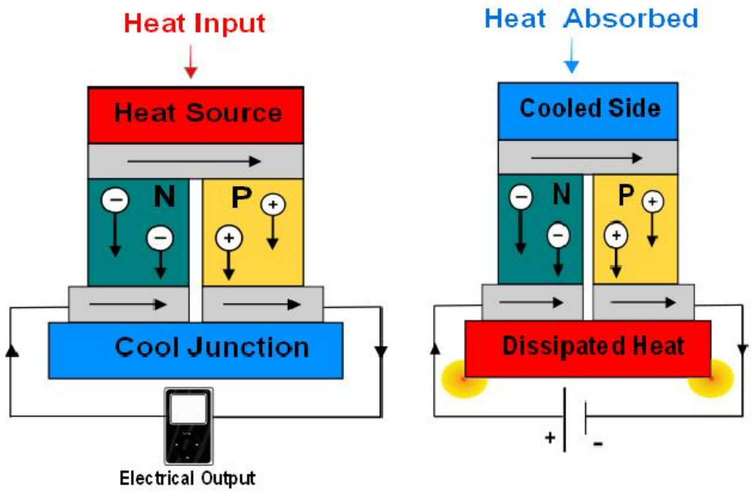
Nuno Borges Carvalho

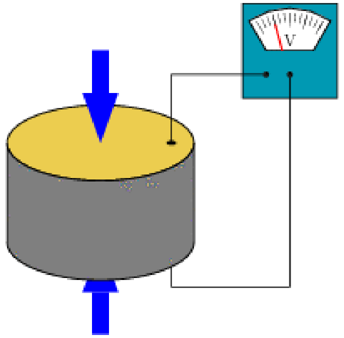
ENERGY HARVESTING - GENERATION

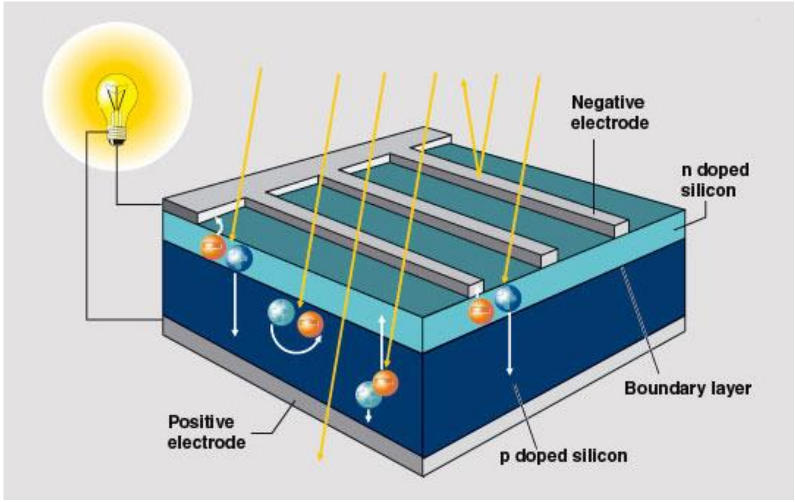
ENERGY CONVERSION

Several approaches to energy conversion can be followed as:

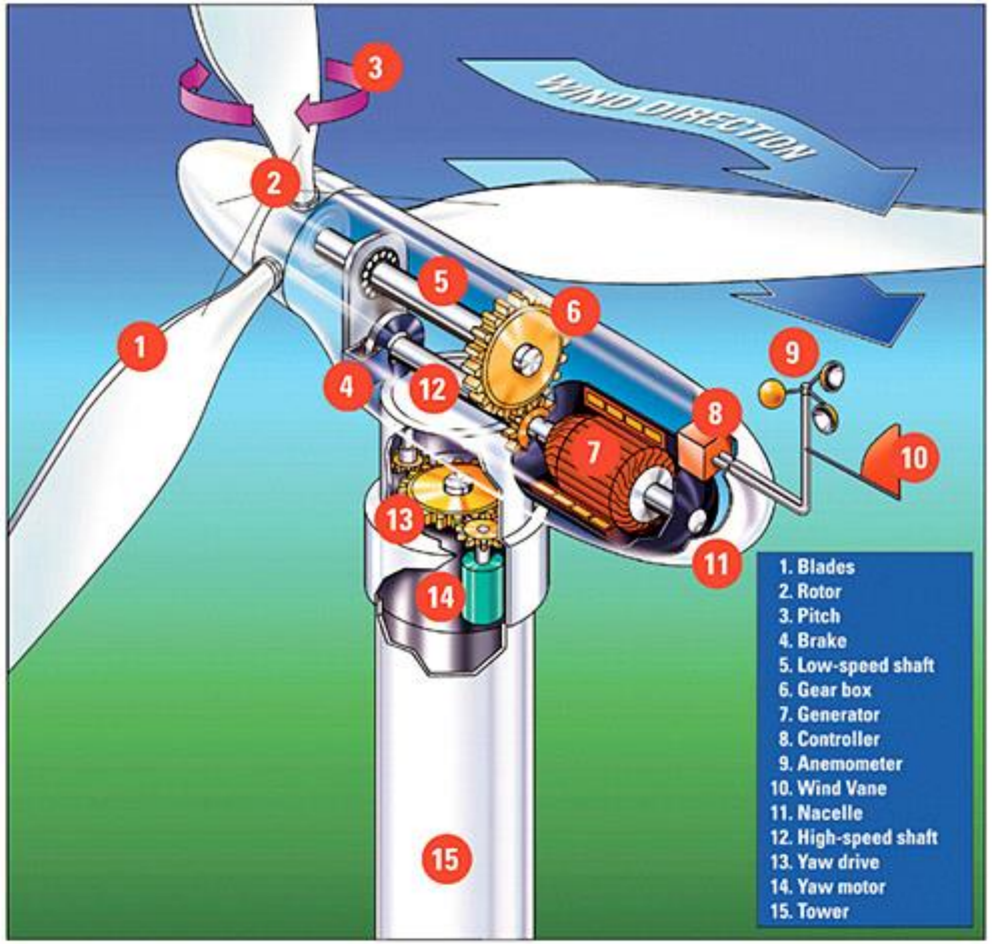
1. Thermoelectric conversion
2. Piezoelectric conversion
3. Photovoltaic conversion
4. Mechanic conversion

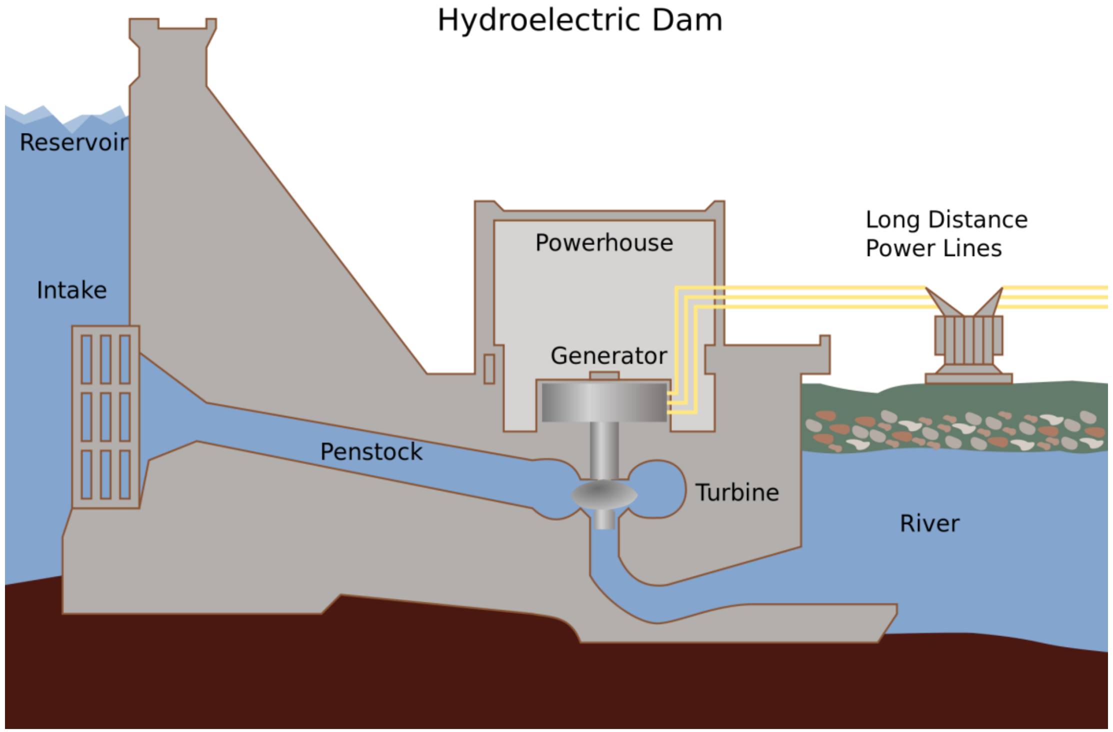






ELECTROMECHANICAL CONVERSION





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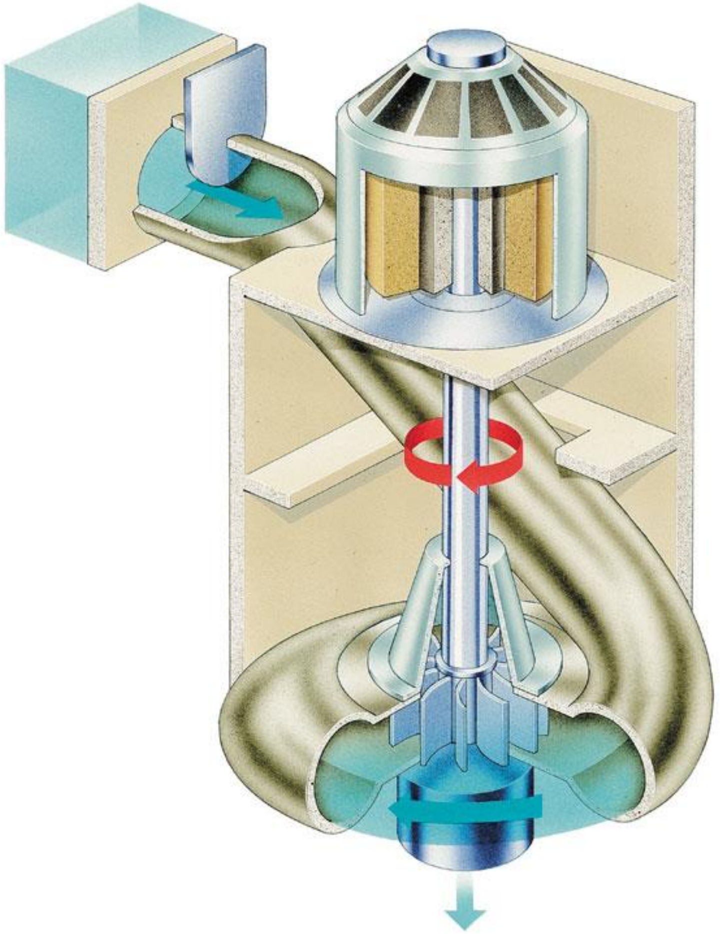

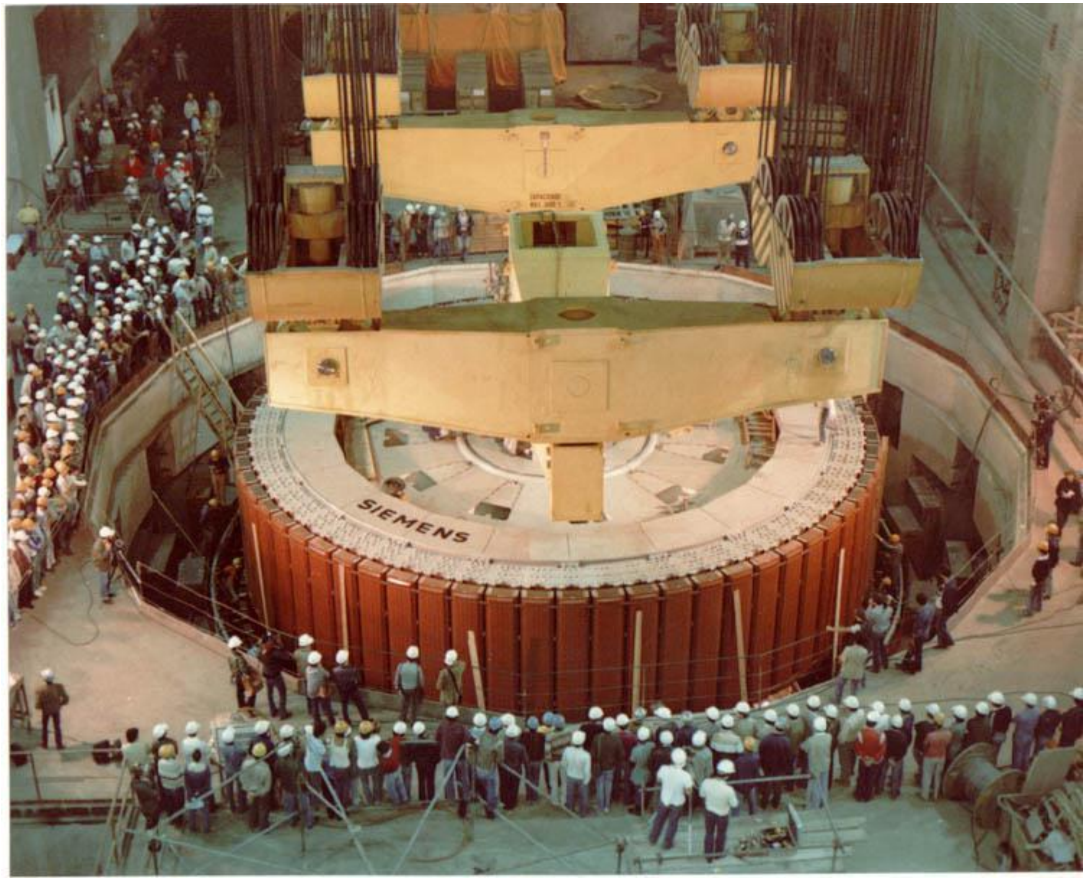

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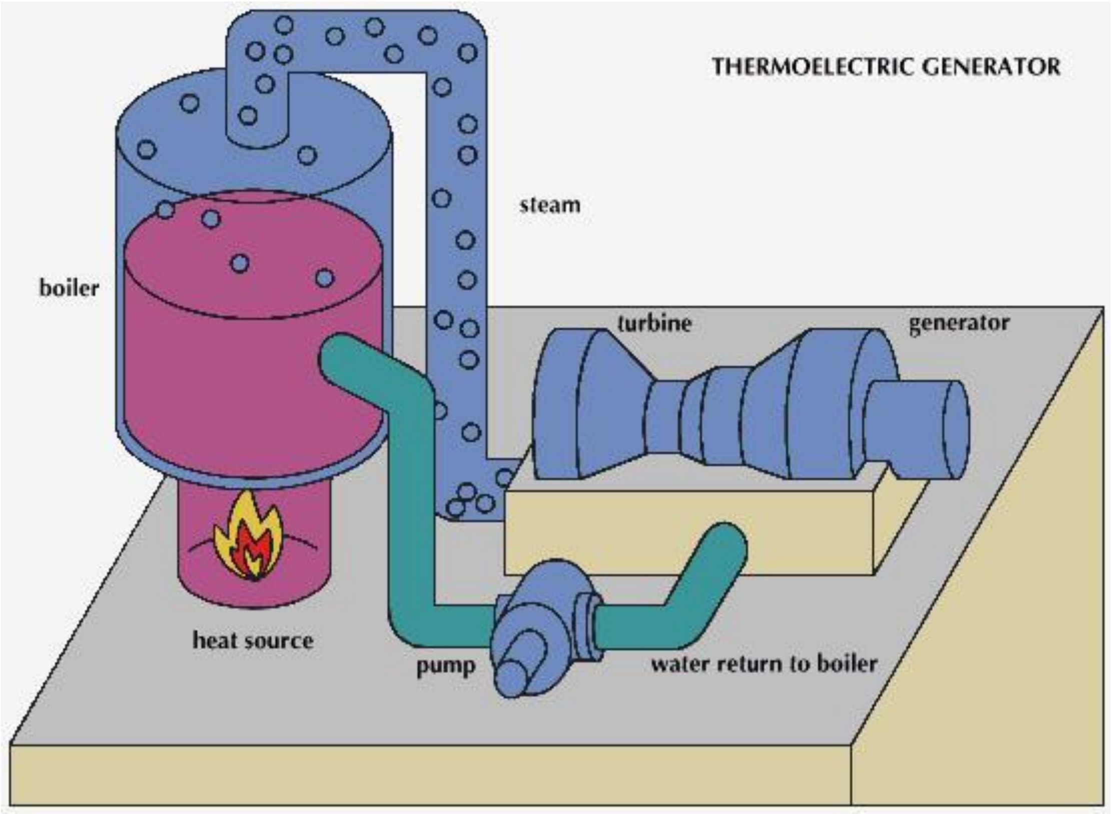
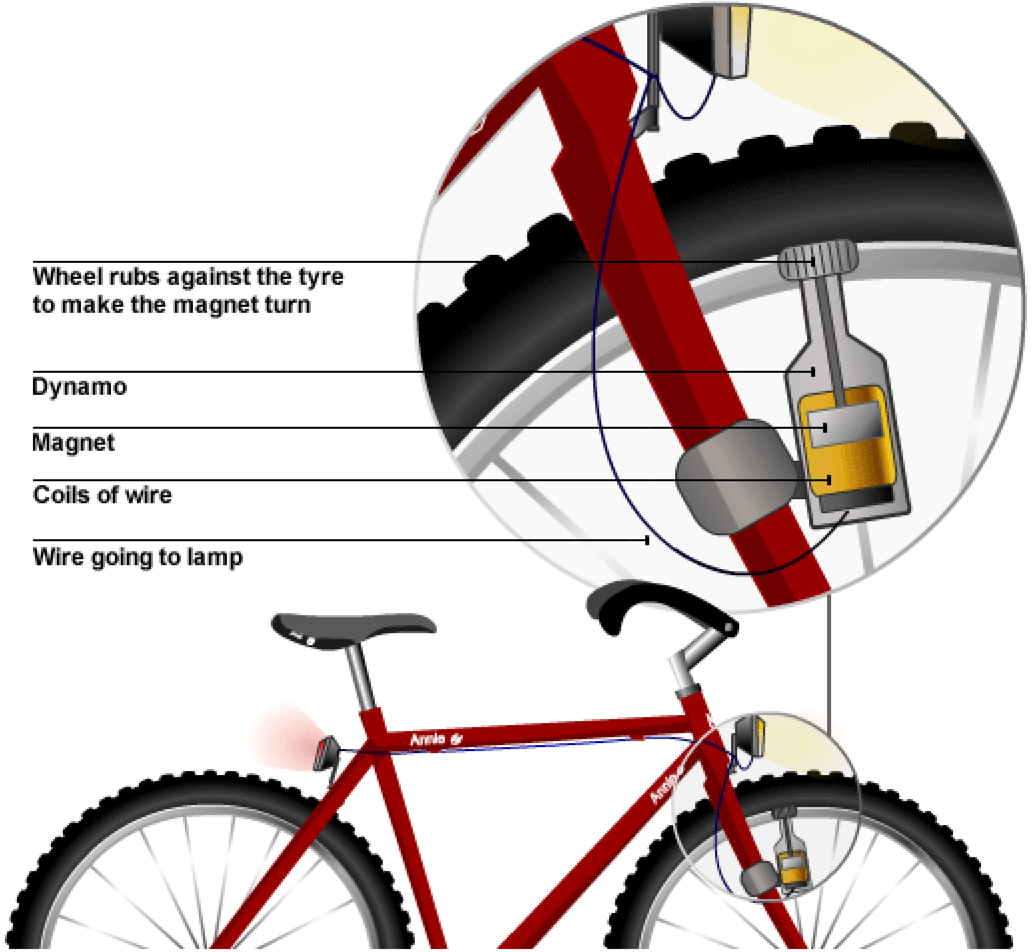
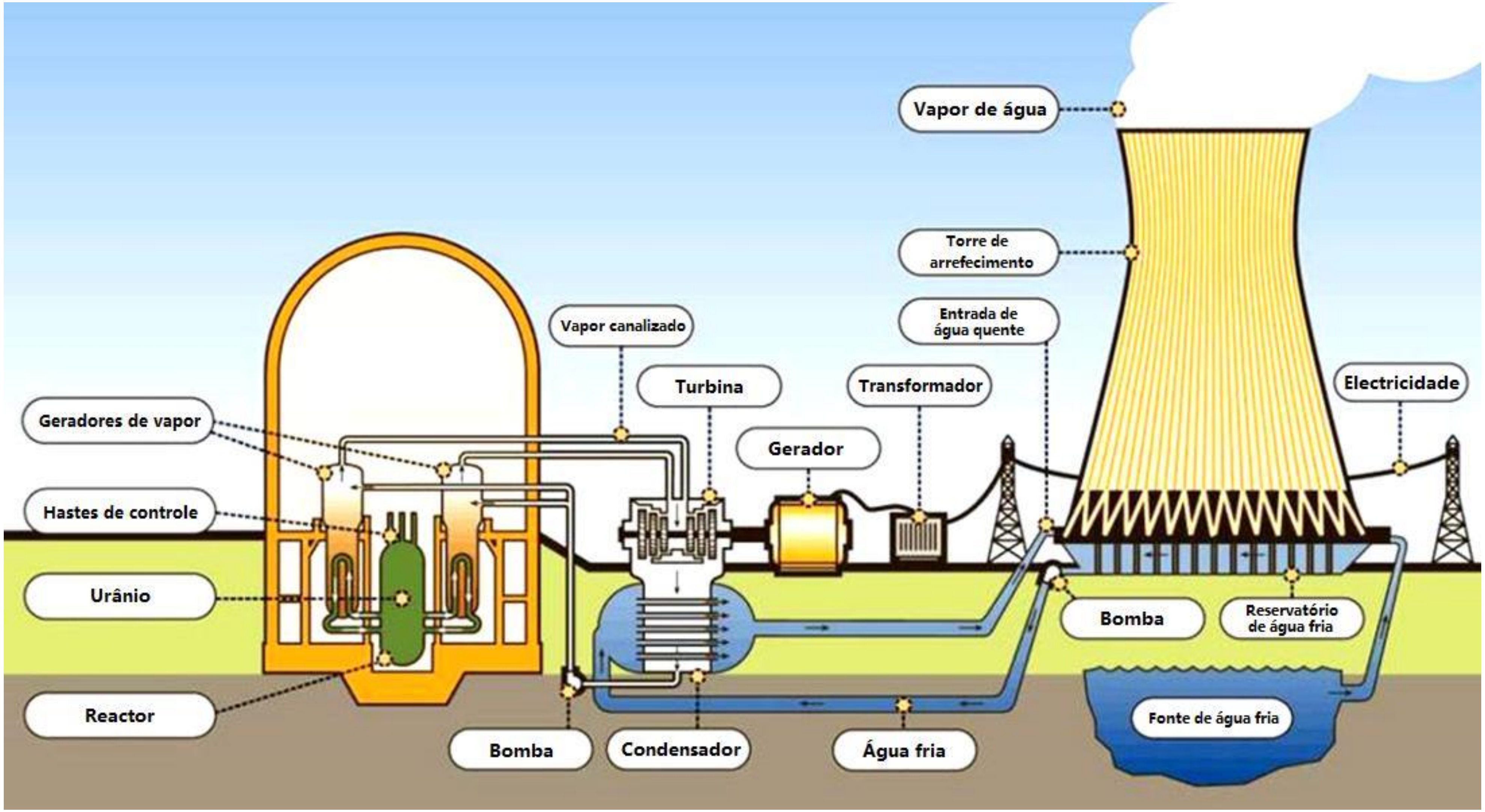




ELECTROMECHANICAL CONVERSION



ELECTROMECHANICAL CONVERSION

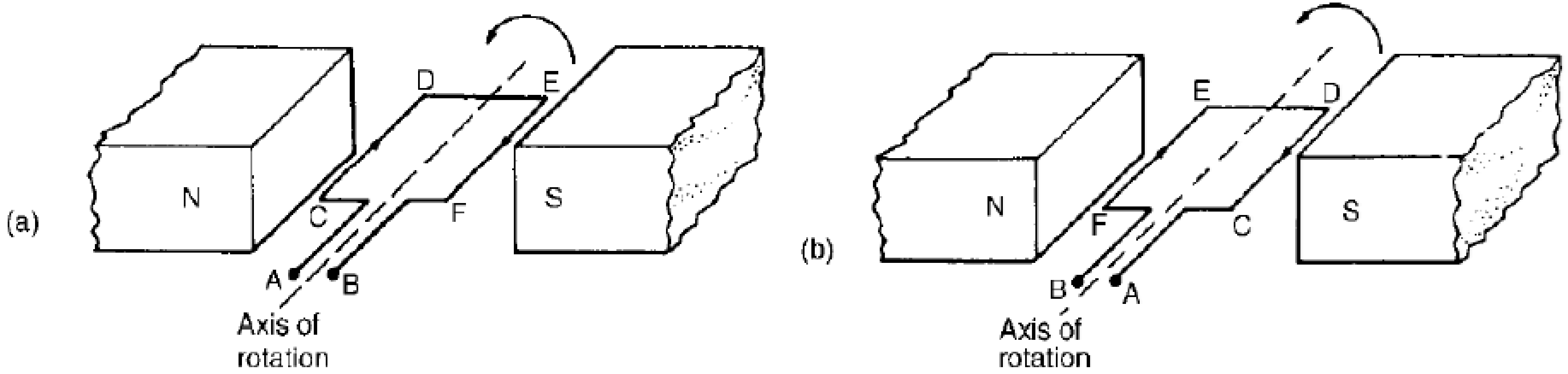
In an electromechanical conversion, mechanical energy is converted to electrical energy, this can actually be calculated using the induction law:

$\nabla \mathrm{x} E = -\frac{\partial B}{\partial t}$ Or in integral form: $e = -\frac{\partial \Phi}{\partial t}$

And the Lorentz law, which says:

$$F = q(E + v \wedge B)$$

The first one converts mechanical in electrical energy, while the second one converts electrical in mechanical energy.



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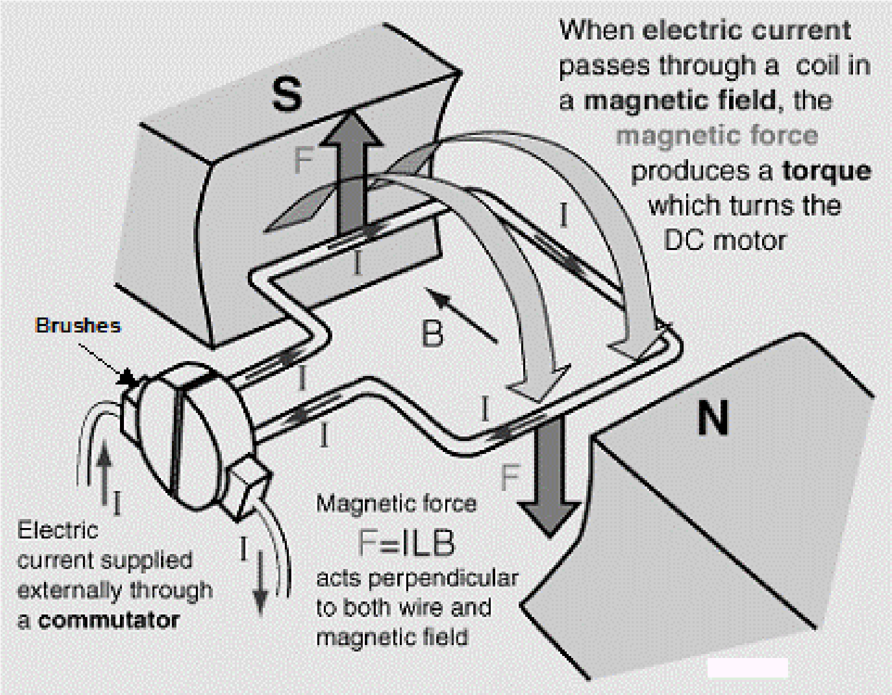
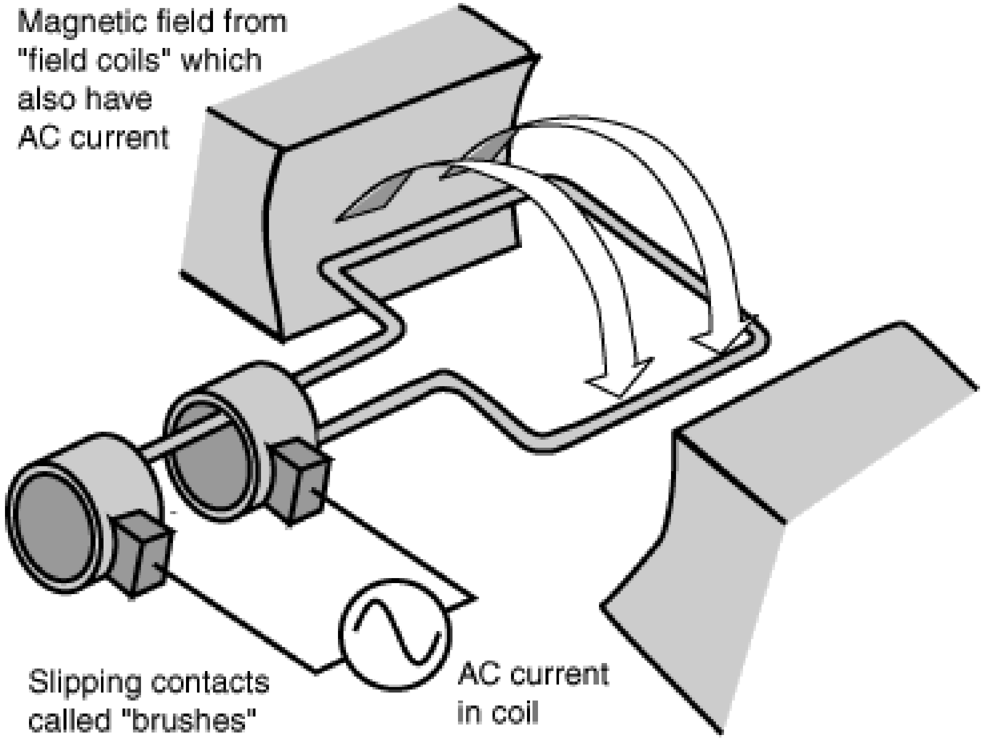
ELECTROMECHANICAL CONVERSION

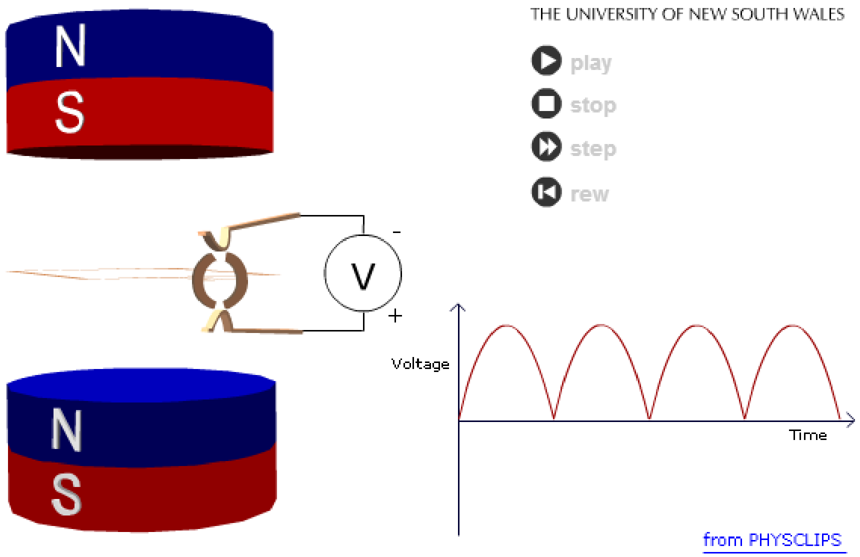


DC Generator

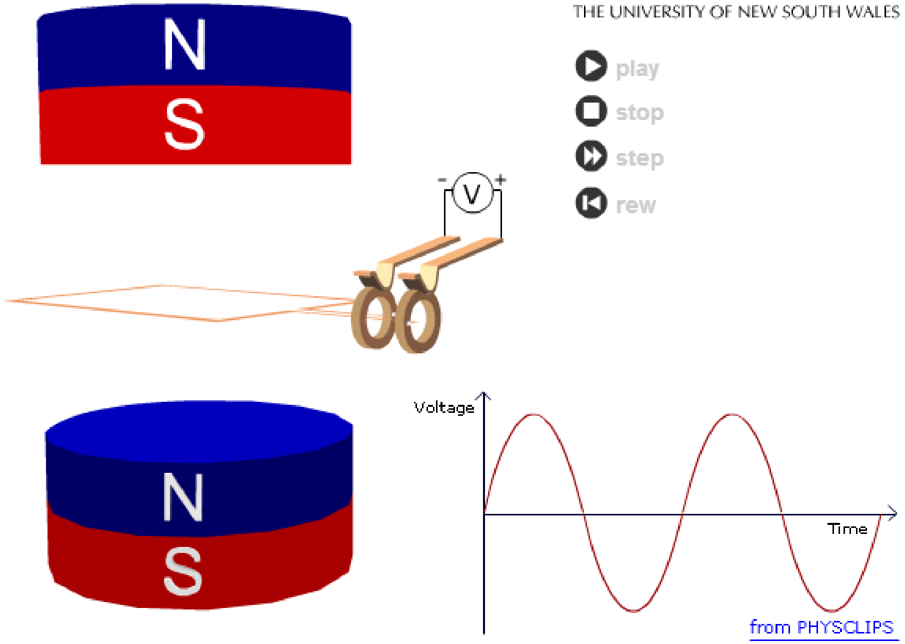


AC Generator

ELECTROMECHANICAL CONVERSION



DC Generator



AC Generator

http://www.animations.physics.unsw.edu.au/jw/electricmotors.html

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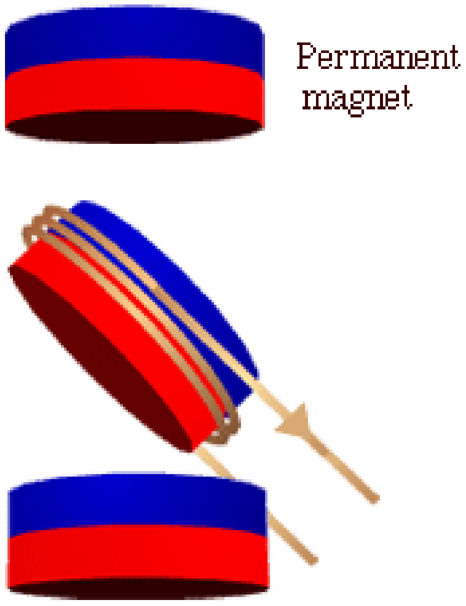
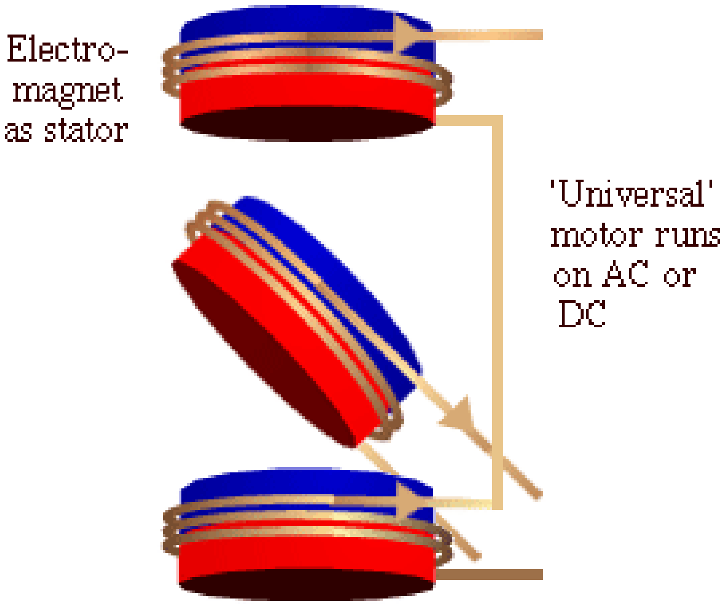
ELECTROMECHANICAL CONVERSION

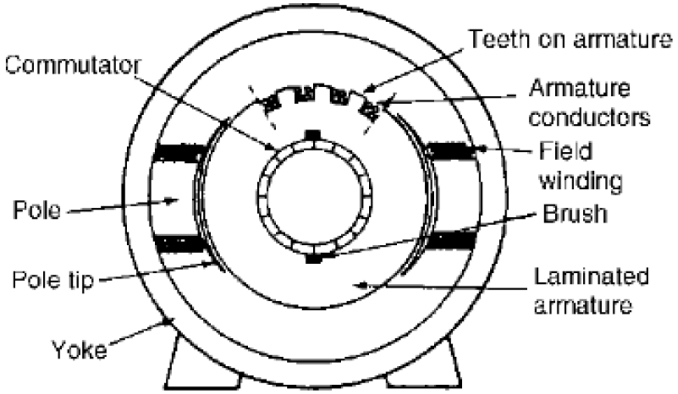




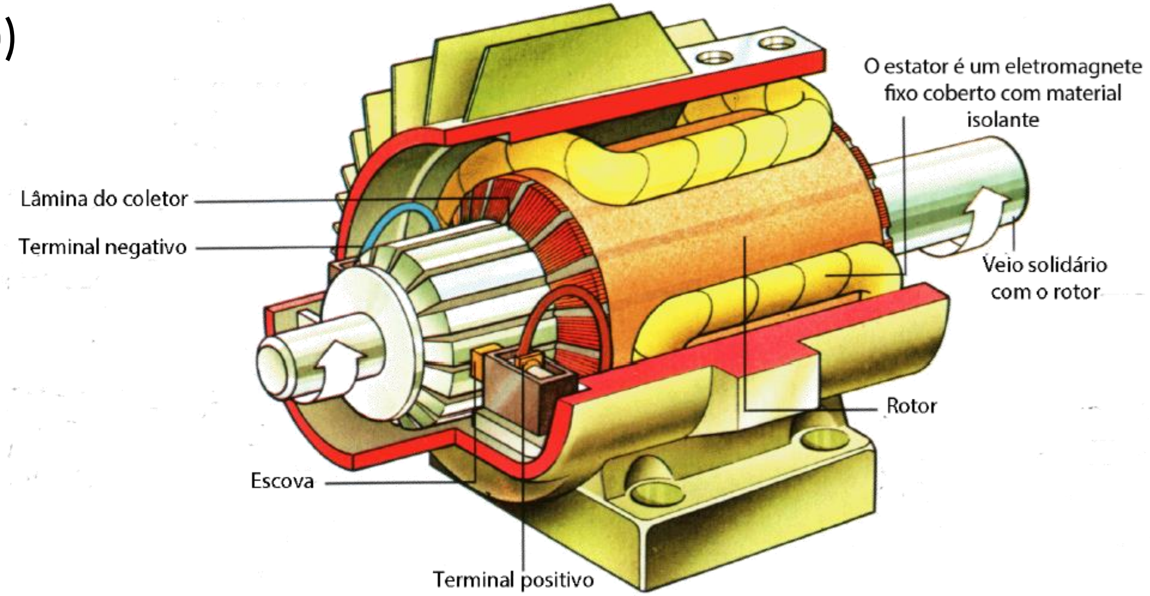
http://www.animations.physics.unsw.edu.au/jw/electricmotors.html

ELECTROMECHANICAL CONVERSION

Going back to the simple DC generator / Motor, we have:



- The stator (which is stationary)
  - The yoke (fixed external cylinder)
  - The magnetic poles
  - the field windings (espiras externas (fixas))
- The armature (which is rotating part)
  - The core
  - The armature winding (espiras móveis)
  - the commutator



ELECTROMECHANICAL CONVERSION

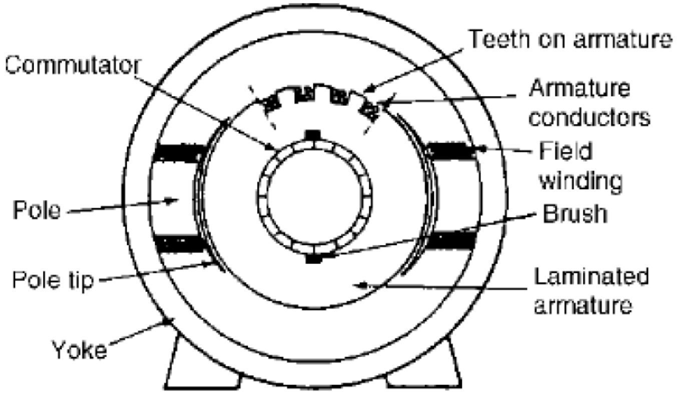
The voltage can thus be calculated by:

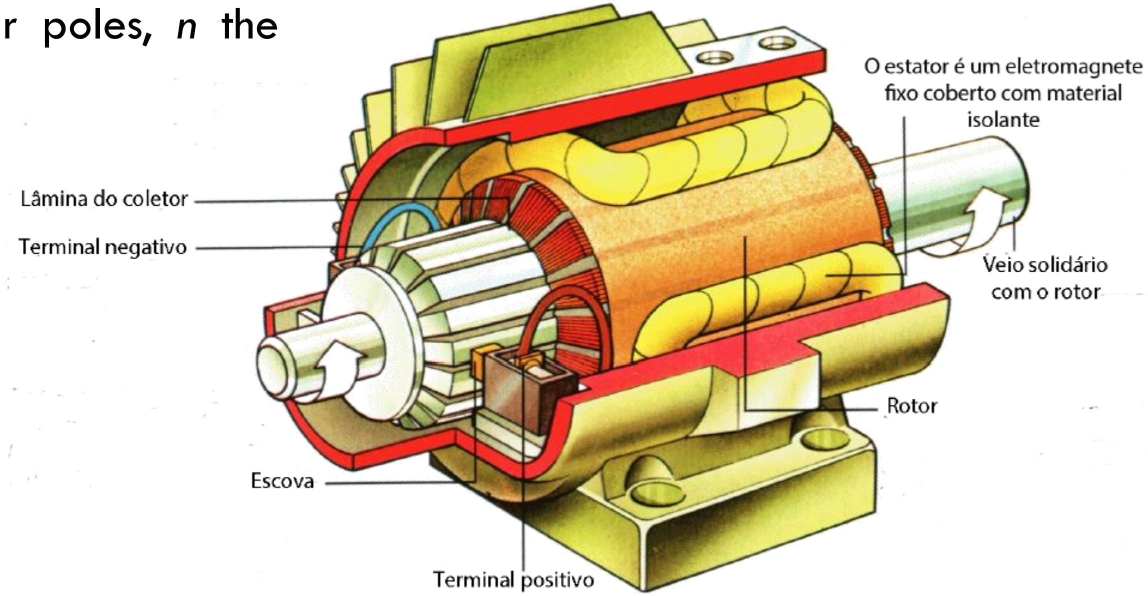
$$E = 2p\Phi n$$

per loop conductor, since we have c parallel paths through the winding between positive and negative brushes, c=2 for a wave winding and c=2*p* for a lap winding, where *p* is the number of pair poles, *n* the armature speed in rev/s and Φ the useful flux per pole:

$$E = 2p\Phi n\frac{Z}{c}$$

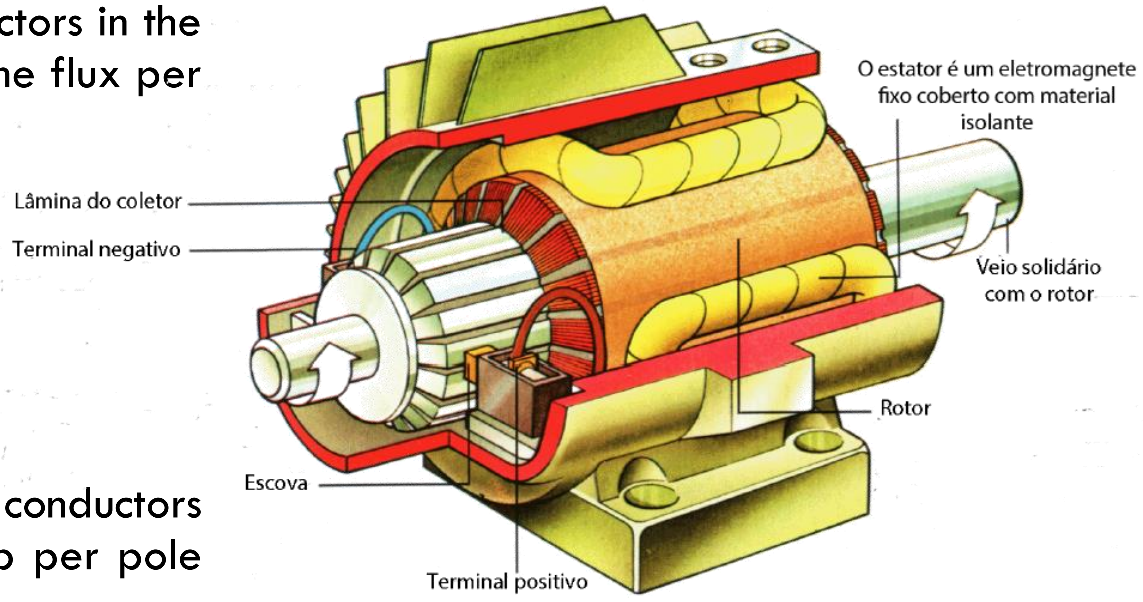
Where Z is the number of armature conductors.





ELECTROMECHANICAL CONVERSION

In a 8 pole with wave connection armature and with 600 conductors in the armature coil, if it is driven at 625 rev/min, what is the emf if the flux per pole is 20mWb?



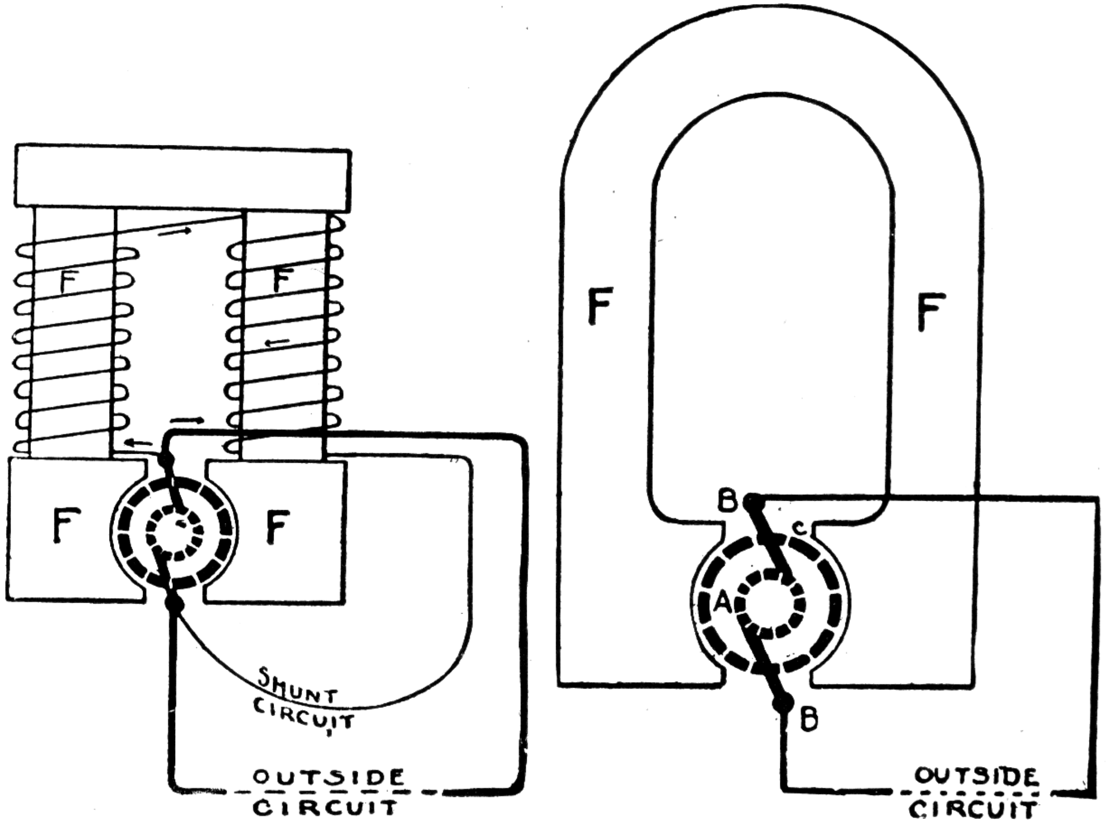
In a 4 pole generator with a lap winding with 50 slots with 16 conductors per slot, what is the speed of the machine if we have 30mWb per pole and an emf of 240V?

ELECTROMECHANICAL CONVERSION

DC generators can be divided into:

- Separately-excited generators, where the field winding is connected to a source of supply other than the armature of its own machine

- Self-excited generator, where the field winding received its supply from the armature of its own machine



ENERGY CONVERSION – THERMOELECTRIC

Thomas Seebeck, 1821, found that an electric current would flow in a closed circuit made up of two dissimilar metals, if the junctions of the metals were maintained at two different temperatures.

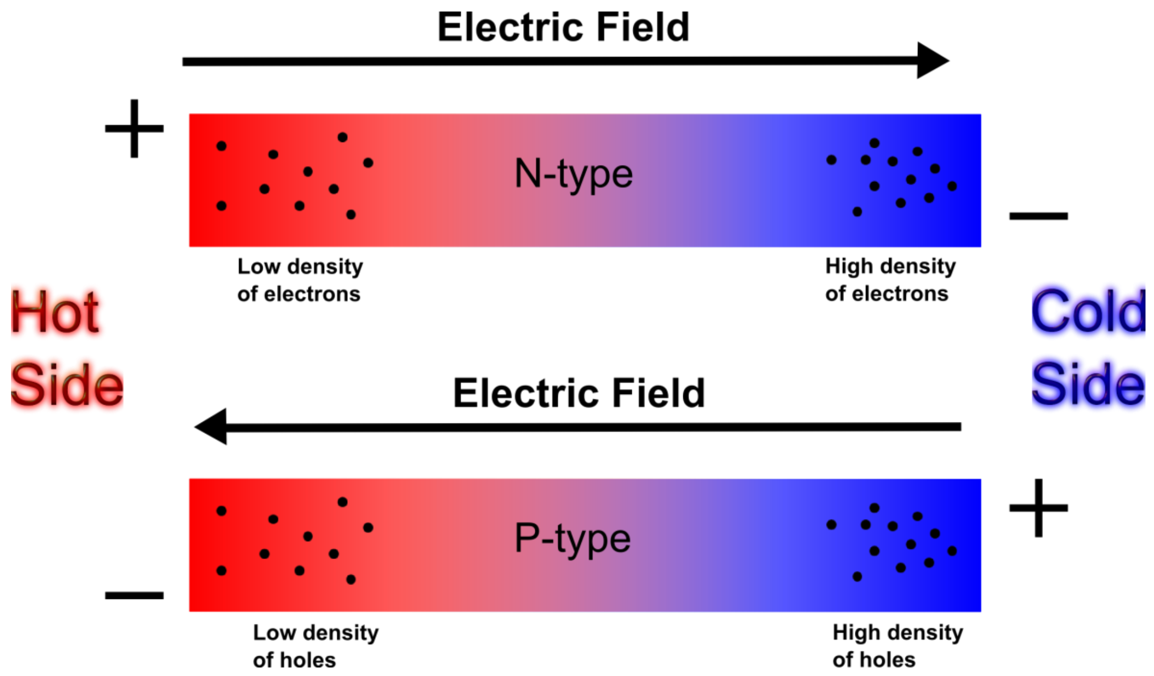
$$\alpha_{pn} = \frac{dV}{dT}$$

S is the Seebeck Coefficient with units of Volts per Kelvin

V is voltage and T is the temperature difference

$$V_{out} = N\alpha_{pn}\Delta T$$

Seebeck Effect



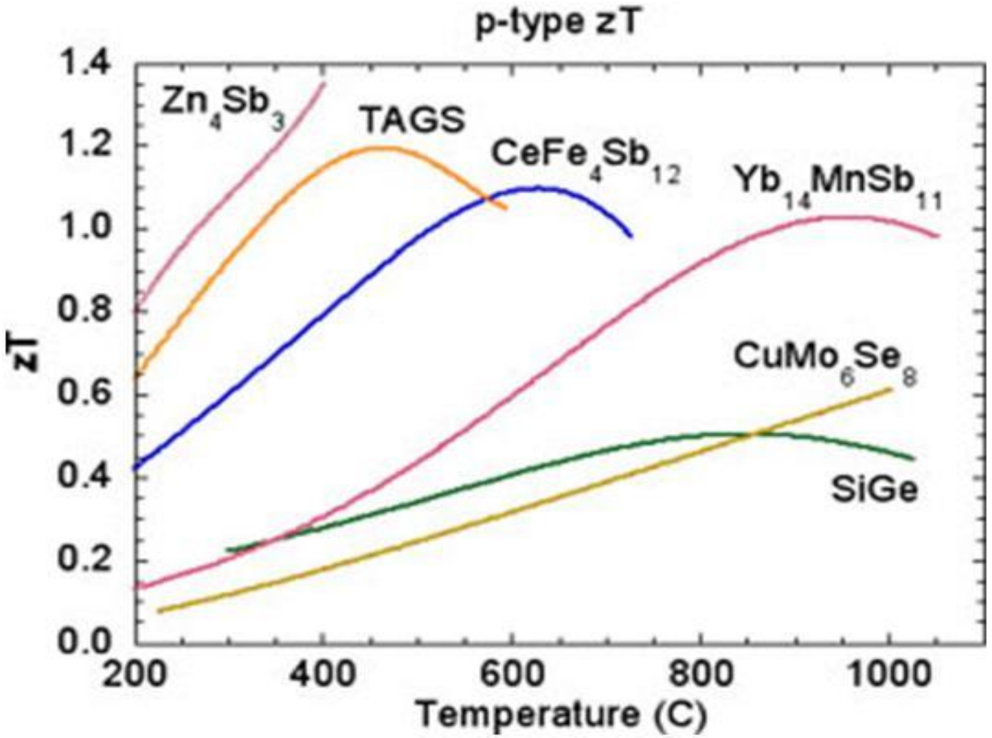
ENERGY CONVERSION – THERMOELECTRIC

The energy conversion efficiency depends strongly on the figure of merit of thermoelectric materials, called ZT

Figure of Merit

$$\mathrm{ZT} = {\alpha_{pn}}^2 \sigma T / k$$

Where T, is the average temperature, σ is the electrical conductivity, S the seebeck coefficient and k the thermal conductivity.



ENERGY CONVERSION – PIEZOELECTRIC

- **Piezoelectric Material**

  Materials with linear electromechanical interaction between mechanical and electrical states in crystalline materials

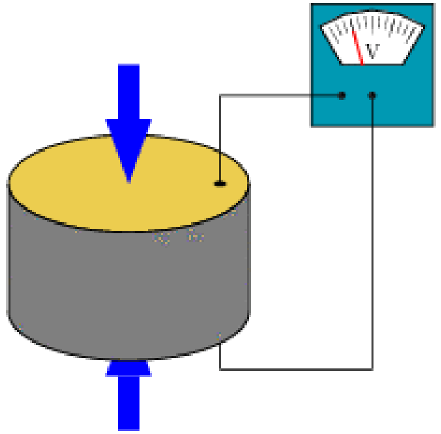
- **Piezoelectric Effect**

  Electrical potential developed within a piezoelectric material in response to an applied pressure or stress. Firstly demonstrated by Pierre and Jacques Currier in 1880.

$$\mathrm{E} = \varepsilon_s / d$$

Where E is the electric field strength, ε_s is the strain and d is the Piezoelectric coefficient.

Piezoelectric Effect



ENERGY CONVERSION – PIEZOELECTRIC

Piezoelectric Effect

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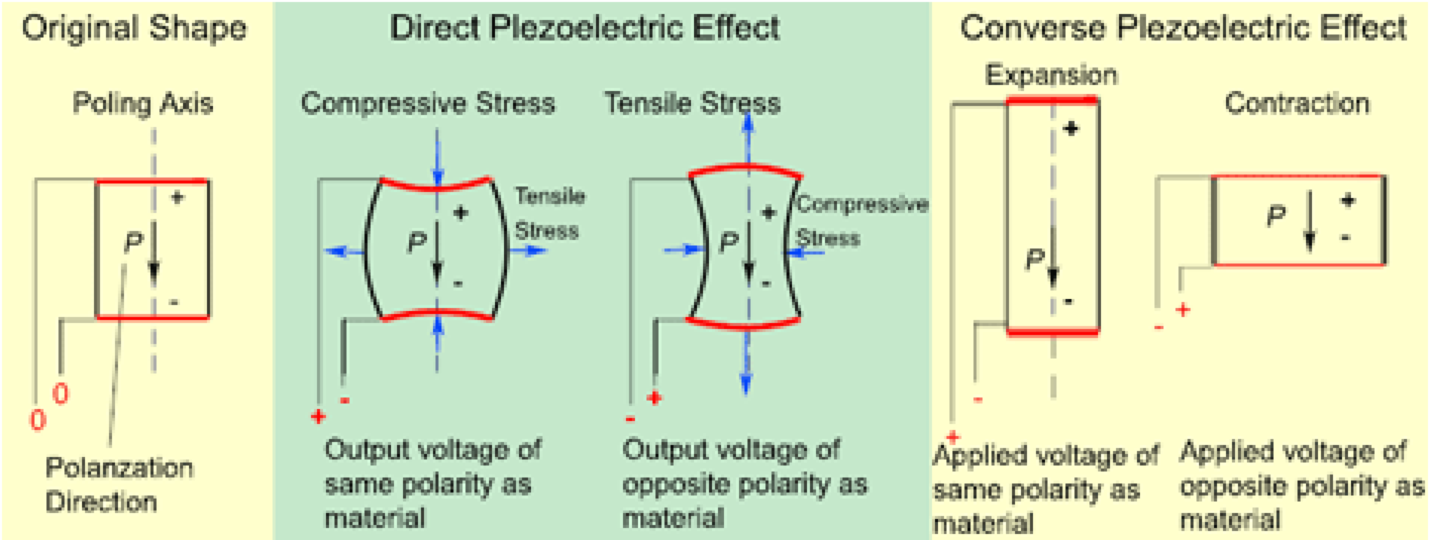
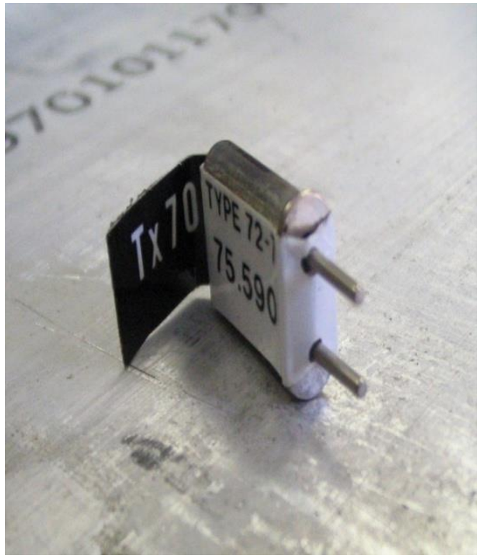
Where E is the electric field strength, ε_s is the strain and d is the Piezoelectric coefficient.

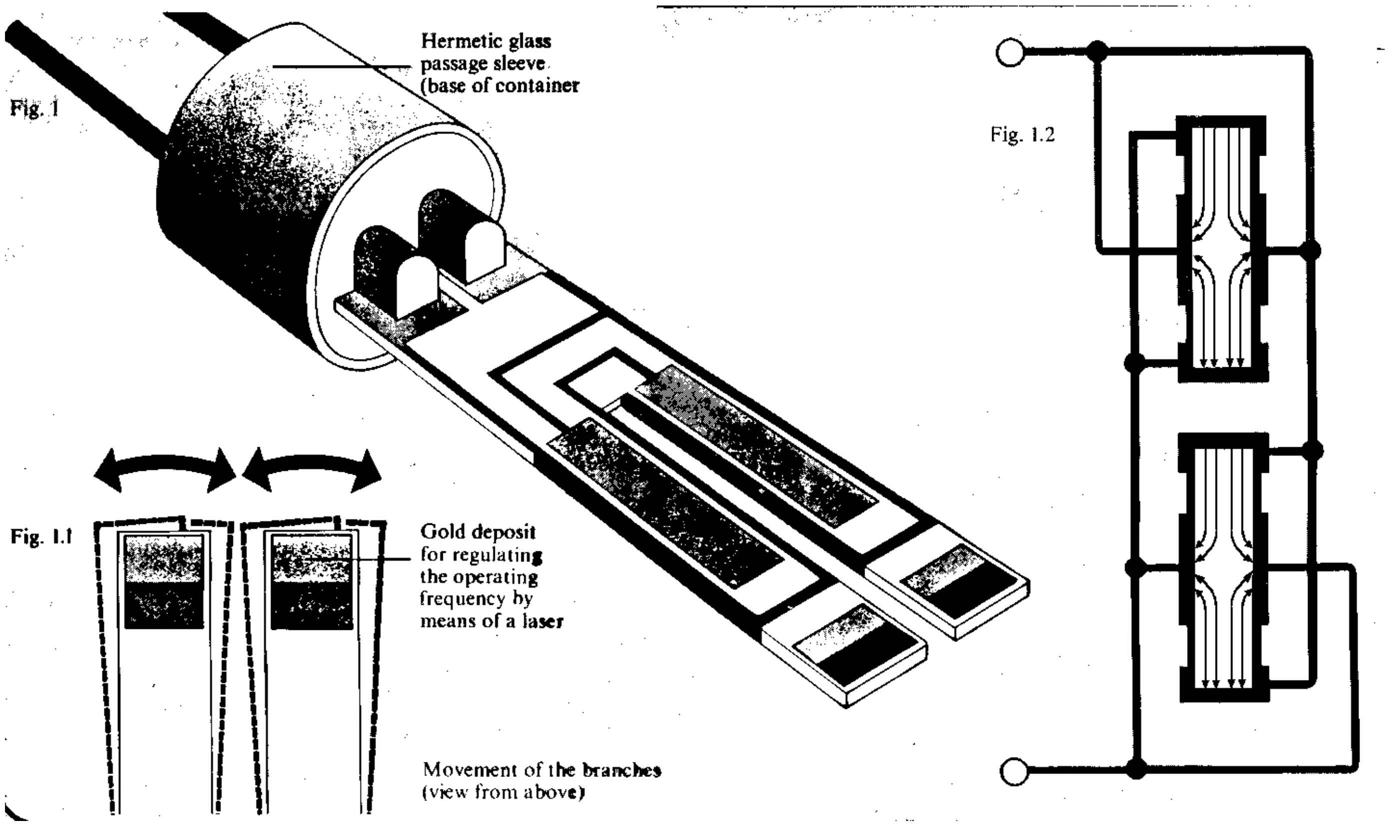


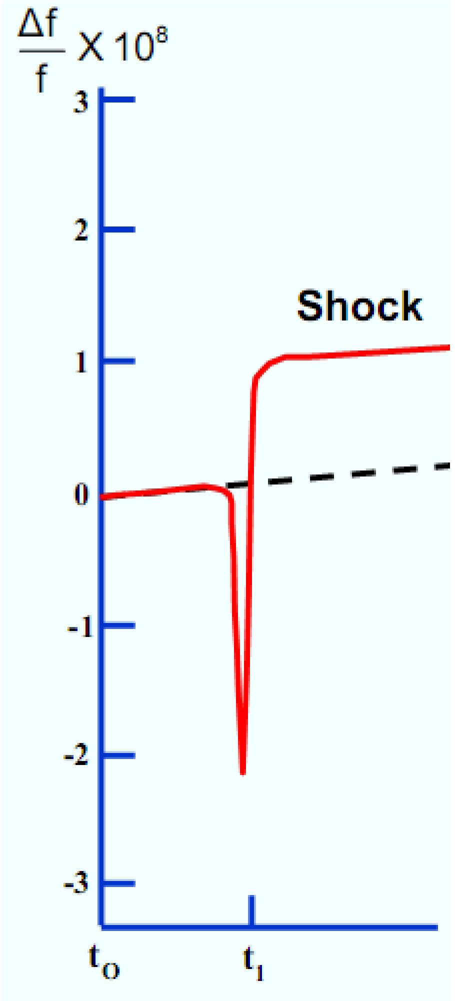
THE CRYSTAL OSCILLATOR

A crystal oscillator is an electronic circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to control an electrical signal to a very precise frequency.



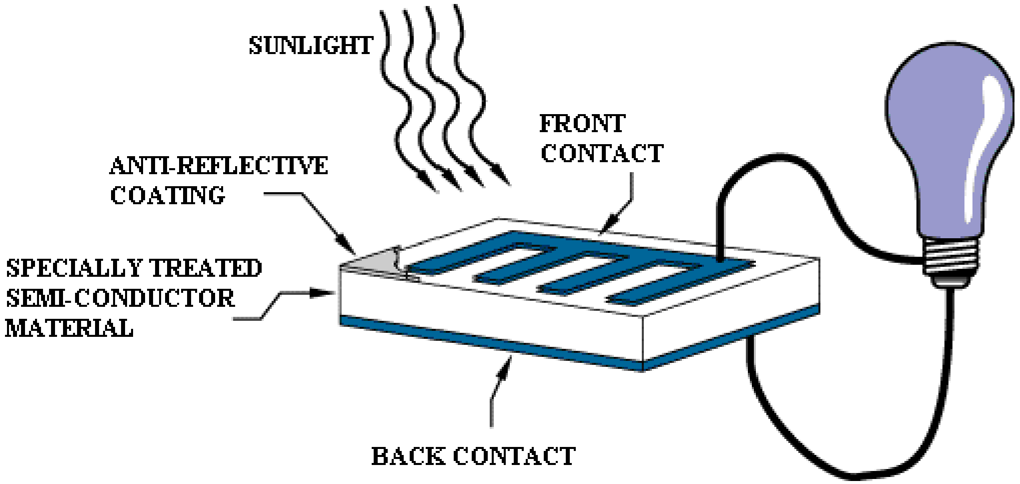
QUARTZ OSCILLATOR

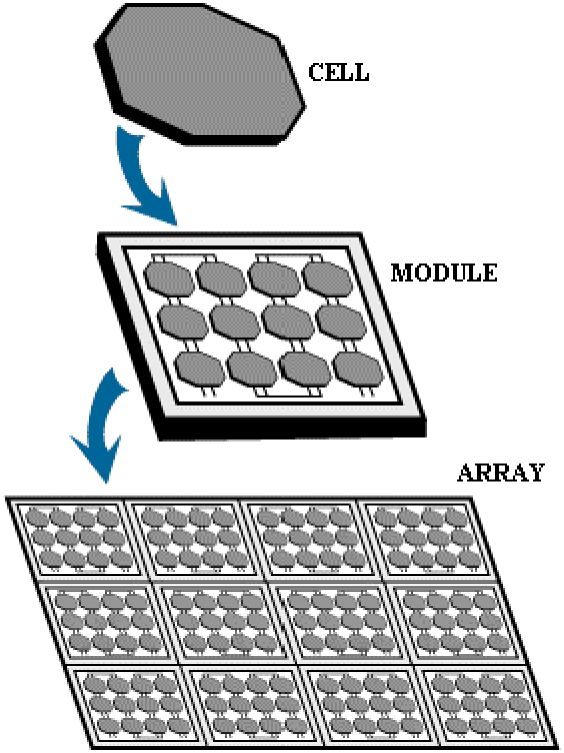




PHOTOVOLTAIC CONVERSION

In 1839 photovoltaics was discovered by French physicist Edmond Becquerel and in 1905 Albert Einstein describes the photoelectric effect, from which he received the Nobel Prize in 1921, but only in 1950 AT&T labs developed the first practical use of solar cells with 6% efficiency.

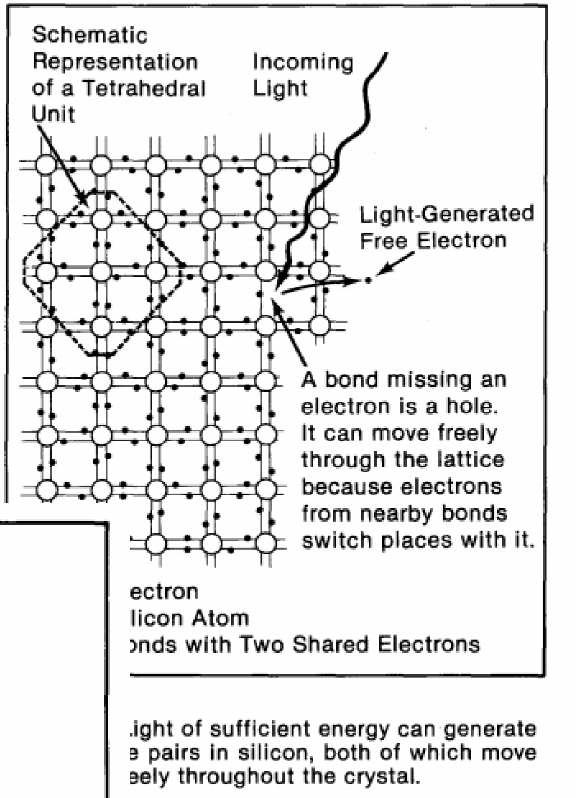




PHOTOVOLTAIC CONVERSION

Free electrons are made available by incident light

$$\xi = \frac{electric\ current}{irradiance}$$



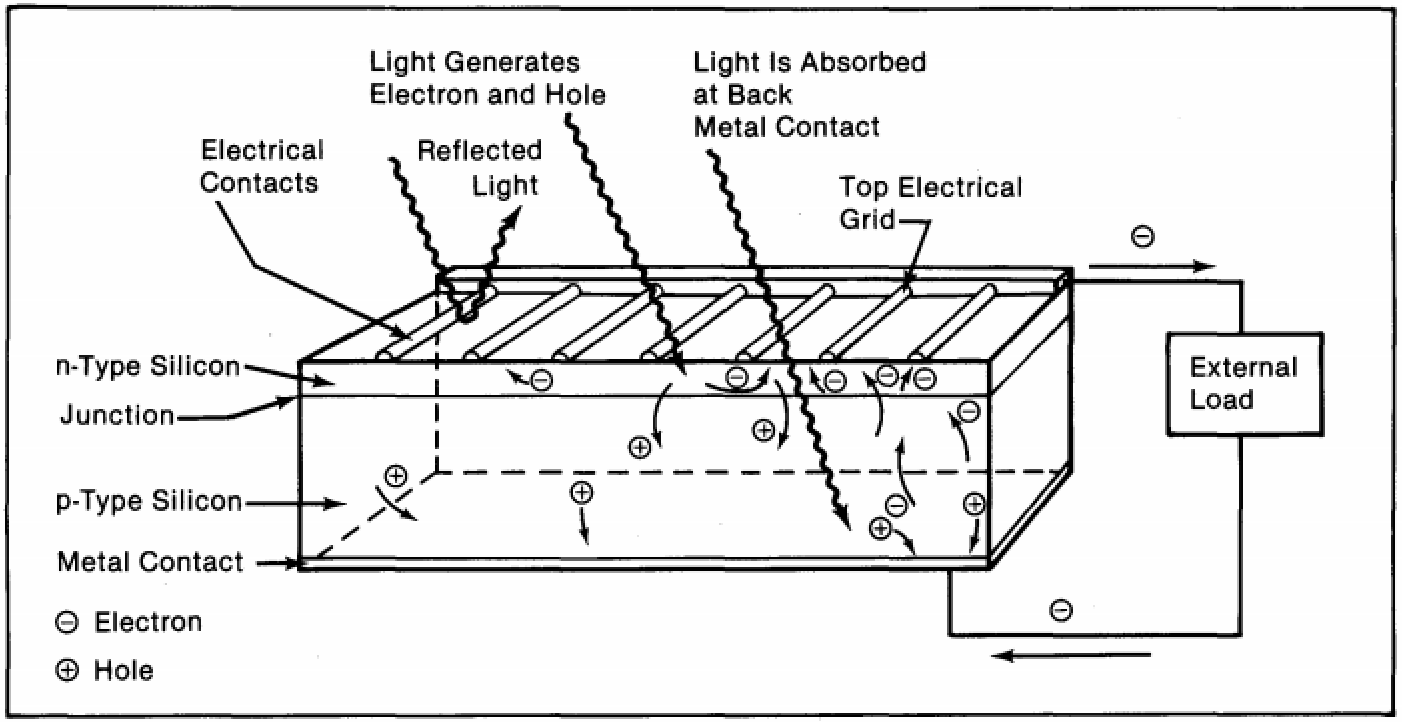
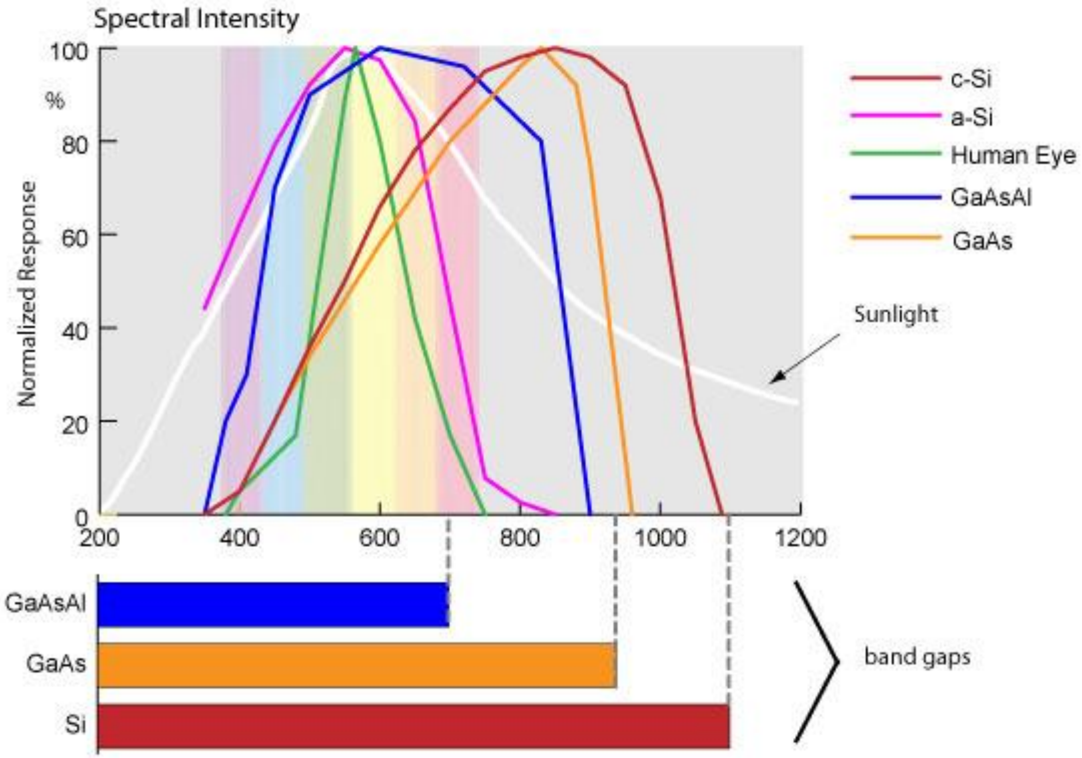
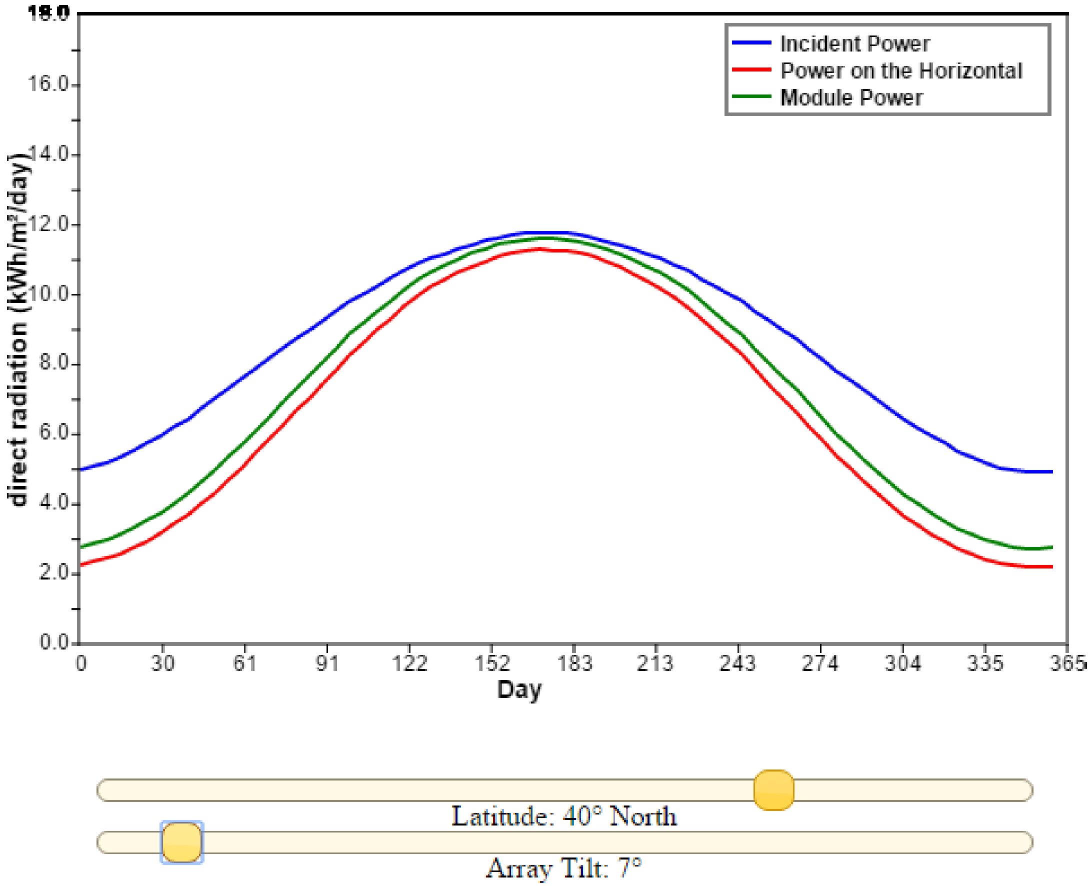


Figure 2-8. Light incident on the cell creates electron-hole pairs, which are separated by the potential barrier, creating a voltage that drives a current through an external circuit.

PHOTOVOLTAIC CONVERSION





http://www.pveducation.org/pvcdrom/properties-of-sunlight/calculation-of-solar-insolation

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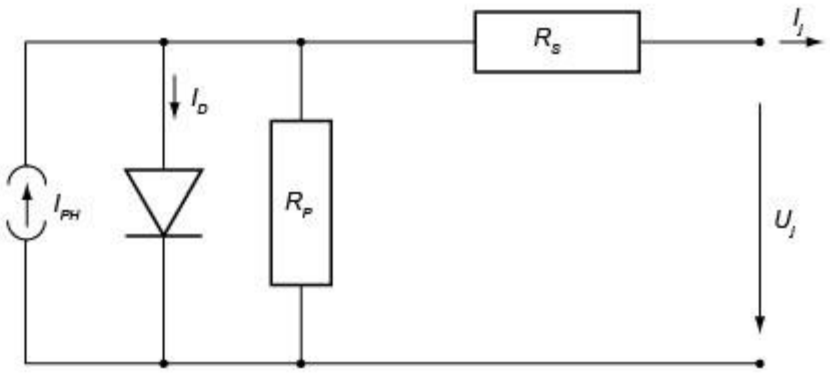
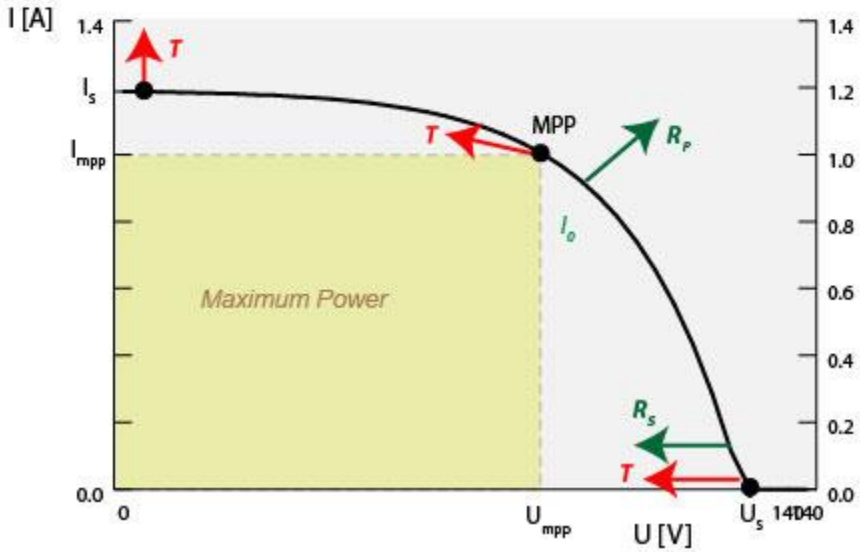
PHOTOVOLTAIC CONVERSION



Electrical equivalent circuit. The current arising from a photovoltaic cell can be calculated by:

$$I_{ph} = A_{cell} H \xi$$

Typical I-U Characteristics of a solar cell]



Where I_{ph} is the photo cell current, A_{cell} is the cell area, H is the intensity of the incoming light and ξ is the response factors with A/W unit. The equivalent circuit is as expressed in the figure, with losses being described by the resistors.

PHOTOVOLTAIC CONVERSION

Electrical Characteristics