Materials and Components

Choosing the correct material for any particular task is essential for a manufacturing activity. Materials are divided into: Raw materials (natural and artificial) and processed materials (artificial materials).

Natural materials exist in nature, and we use them as they are. Examples of these materials are wood, stone, sand, wool, etc. Natural resources are split into 3 categories: animal, vegetable and mineral. In technical works, most of the materials are mineral and often also vegetable as in the case of wood. Every natural material has to be modified for future use. For instance, wood has to be dried in order to remove the moisture. The element iron has to be removed from the iron oxide mineral in a mineral oven and so on. Thus, iron oxide or wood from a tree are raw materials that have to be converted into elemental iron and wood pieces, which become processed materials.

Processed materials can be obtained from other processed materials too. For example, iron is used to get steel and steel is used to obtain stainless steel. But in all these objects, where are the artificial objects? An artificial object is the one that has been created by man by means of chemical transformation- the Plastics.

Properties of Materials

Properties of materials can be divided mainly into physical and chemical properties. It's very important to define every property, including what the physical state (solid, liquid or gas) of a material is. There exists a fourth state that is not very common, called plasmatic state or plasma. All the properties defined in this lesson cannot be applied to plasma.

Extension activity: Find out further information about plasma, what its appearance is, where it can be found, what differences exist between plasma and the other physical states, etc.

A) Physical Properties

Density refers to the relation between the mass and volume of a solid. Density is measured in Kg/m$^3$, according to ISO units.

Dilation, contraction and Fusibility

Dilation: When material expands (gets bigger) due to heat
Contraction: When material shrinks or contracts (gets smaller) due to heat
Fusibility is the ability of a material to change into a liquid when heated to its melting point. Examples of melting points

Iron’s melting point............1535 ºC
Copper’s melting point...........1083 ºC

Activity to think about: Why are rails separated by a gap?

Strength refers to the resistance of a solid to being bent, broken or having its form and dimensions modified. To test the strength of a solid, try to deform it. Strength can be studied under several conditions, such as the following: Compressive strength, tensile
strength, Torque or torsion and Flexure or Bending. According to the degree of deformation, solids can be split into those with plastic deformation and those with elastic deformation. In the first case, the strength is enough to make a permanent deformation. Elastic deformed solids, however, return to their original forms at the moment the forces being exerted are over.

**Ductility** is the ability of solid materials to be drawn out into wires. It typically occurs in soft metals like copper, aluminum and tin.

**Malleability** is the ability of solid materials to be flattened into boards and plates. Usually, ductility and malleability are properties found in the same kinds of materials.

**Thermal and Electrical Conductivity**: Both are the ability of heat or electricity to run through the material, respectively. In both cases, the materials can be good conductors or bad conductors. In the latter case, the material is called an insulator. Examples: Copper is a good electrical and thermal conductor but polyethylene or Teflon is used as an insulator.

**Optical properties**
Optical properties describe how materials behave when light touches them. They can be classified into:

a) Opaque: No light travels through them, e.g. wood
b) Transparent: All light travels through them, and you can see what's behind the materials, e.g. a glass window pane
c) Translucent: All light can travel through them but you cannot see what's behind them, e.g. frosted glass

**Sound Properties**
These properties refer to the ability of materials to conduct sound. Sound is a sort of mechanical vibration, and vibration in a material produces transient elastic deformations. The behavior of a material in conducting sound depends on whether it's solid, liquid or gas because collisions between molecules are how sound is transmitted.

*Activity to think about: Could you speak on the moon?*

**B) Chemical Properties**

- **Oxidation**: The change that occurs to most metals when in contact with oxygen from air or water. Sometimes the oxidation becomes corrosion.
- **Recyclability**: Materials that can be reused to make new ones by chemical separation of their components are recyclable. Sometimes those materials that are separated to be reused are simply used as fuel.
- **Toxicity**: Materials which are harmful to the environment
- **Biodegradability**: Materials that decompose naturally with time are biodegradable. For example, an apple takes about 20 days to decompose, plastic takes about 100 years, and glass takes about 400 years.
WOOD

Wood is one of the primary energy sources used by man, and it has historically been a material used to build houses, tools, many useful objects like paper or furniture, and for purposes like heating houses, all of them essential for mankind’s evolution.

From a technical perspective, wood can be divided into two major classes: hardwoods and softwoods. There is great confusion about the terms hardwood and softwood. These terms do not refer to the wood’s technical properties but to its origin. As such, there are softwood trees which have hard wood and vice versa. Most softwood trees have spiky leaves with branches forming rings. Hardwood Trees have broad (wide) and flat leaves. The branches usually grow at different levels and never more than two at the same level.

Wood is an organic material. In a living tree it transfers water and nutrients to the leaves. It has a support function, enabling trees to reach large sizes and to stand up on their own. Wood is also the name applied to those engineered materials made from wood, such as wood chips (astillas).

In a tree trunk, not all the parts offer the same quality wood. The best parts are the sapwood (albura) and the heartwood (duramen). The wood at the center of the trunk is called heartwood and it is older, darker and more durable than the surrounding wood. As a tree grows, a thin layer of cells called the cambium generates new wood, called sapwood. Sapwood is softer and lighter in color than heartwood.

As the sapwood ages, natural substances invade the sapwood and gradually convert it into heartwood. Furniture made of heartwood will last longer than furniture made of Cambium wood.

Wood can be dated by carbon dating and in some species by dendrochronology. But it is very useful to know about the year-to-year variation in tree-ring widths, as it gives clues to the climate at that time.
The industry of wood

To match human beings’ needs, the techniques and processes used to manufacture objects from wood have been developed over thousands of years. When cutting the trunks, these have to be separated from the branches and leaves. Once a cylindrical wood trunk is attained, moisture has to be removed through dry or chemical techniques. This is the time when a tree trunk can be cut into long pieces from which even smaller pieces may be cut for other uses. All this cut wood is called timber, and many other processes will follow to give different shapes to the pieces called manufactured wood. Some of the waste material, chips and very small pieces from the cutting are also used to create artificial or manufactured boards or planks.

Artificial wood planks

Products manufactured by gluing together wood and particles like wood chips or fibers can be defined as wood products.

Plywood (Madera contrachapada) is a type of composite wood made from thin sheets of wood. Alternative layers are glued together so that they have their grain at right angles to each other for greater strength.

Fiberboard (Madera aglomerada o aglomerado)
Fiber boards are made from a mixture of glue and wood fibers and chips. It’s much cheaper than natural wood. Fiber board is heavily used in the furniture industry. For pieces that will be visible, a layer of wood is often glued onto fiberboard to give it the appearance of conventional wood, for instance, oak tree, beech tree, pinewood, etc.

Wood chips are used primarily as a raw material for technical wood processing. Sometimes, chips are also used as fuel in heating systems or similar, because of their great power of combustion. As waste material from manufacturing processes, chips are cheaper than any other fuel.

Medium Density Fiberboard (MDF)
A DM board is a cluster made with wood fibers bonded with synthetic resins by means of intense heat and pressure. It’s necessary to let the cluster dry in order to reach a medium density, more compact than the previously mentioned artificial woods.

It has a uniform and homogeneous structure and a fine texture that allows its face to offer a perfect finishing. It works almost like solid wood, able to be trimmed and cut in the same way as natural wood. Dimensional stability, unlike in solid wood, is optimal, but its weight is very high. It’s perfect
for varnishing or painting. It glues easily with no adherence problems. It’s usually sold in medium-dark brown color, and it has been defined as one of the cheapest wood materials on the market.

For an audio lesson from this section use this link:  
www.voicethread.com/share/1487095/
METALS

There are two significant groups of metals: **Ferrous metals**: contain iron and **Non-ferrous metals**: do not contain iron.

**Ferrous metals:**
The origin of the ferrous metal is the iron minerals. (Hematite, magnetite, etc.). All ferrous metals are magnetic and give little resistance to corrosion. Almost the full production of iron in the world is assigned to steel production. However, when manufacturing iron minerals, there are many different processes to obtain iron materials. In the following table some of the iron materials are described.

<table>
<thead>
<tr>
<th>Name</th>
<th>Composition</th>
<th>Properties</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild Steel (Acero Dulce)</td>
<td>0.15 to 0.30% carbon</td>
<td>Tough, high tensile strength, ductile. Because of low carbon content, it cannot be tempered (templado). It must be case hardened.</td>
<td>Girders (vigas), pipes, plates, nuts and bolts (screws), general purpose.</td>
</tr>
<tr>
<td>High Speed Steel</td>
<td>Medium carbon, tungsten, chromium and vanadium.</td>
<td>Can be hardened and tempered. Can be brittle (frágil). Retains hardness at high temperatures.</td>
<td>Cutting tools for lathes. Lathes = torno</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>18% chromium, and 8% nickel added.</td>
<td>Corrosion resistant</td>
<td>Kitchen draining boards. Pipes for food and chemical industry, cutlery, aircraft. Cutlery = cuberteria</td>
</tr>
<tr>
<td><strong>High Tensile Steel</strong></td>
<td>Low carbon steel, nickel and chromium.</td>
<td>Very strong and very tough.</td>
<td>Gears, shafts, engine parts, vehicles frames. Shaft = eje</td>
</tr>
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<td>------------------------</td>
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</tr>
<tr>
<td><strong>High Carbon Steel</strong></td>
<td>0.70% to 1.40% carbon.</td>
<td>The hardest of the carbon steels. Less ductile, tough and malleable.</td>
<td>Chisels, hammers, drills, lathe tools, and taps. Chisel = Cincel Tap = Grifo</td>
</tr>
<tr>
<td><strong>Medium Carbon Steels</strong></td>
<td>0.30% to 0.70% carbon.</td>
<td>Stronger and harder than mild steels. Less ductile, tough and malleable.</td>
<td>Metal ropes, wire, garden tools, springs.</td>
</tr>
<tr>
<td><strong>Cast Iron</strong> (Hierro fundido o fundición)</td>
<td>Remelted pig iron with small amounts of scrap steel.</td>
<td>Hard, brittle, strong, cheap, self-lubricating. Types: Whitecast iron, grey cast iron, malleable cast iron.</td>
<td>Heavy crushing machinery. Car cylinder blocks, machine tool parts, brake drums, machine handle and gear wheels, plumbing fitments and stoves.</td>
</tr>
</tbody>
</table>
**Non-Ferrous metals:** These are metals which do not contain any iron. They are not magnetic and are usually more resistant to corrosion than ferrous metals. Examples are aluminum, copper, lead, zinc and tin.

<table>
<thead>
<tr>
<th>Name</th>
<th>Composition</th>
<th>Properties</th>
<th>Uses</th>
<th>Photograph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>Pure Metal</td>
<td>Greyish-White, soft, malleable, conductive to heat and electricity. It is corrosion resistant. It can be welded but this is difficult. Needs special processes.</td>
<td>Aircraft, boats, window frames, saucepans, packaging and insulation, pistons and cranks.</td>
<td><img src="image1.jpg" alt="Photograph" /></td>
</tr>
<tr>
<td>Duraluminum</td>
<td>Aluminium +4% Copper+1%Manganese</td>
<td>Ductile, Malleable, Work Hardens.</td>
<td>Aircraft and vehicle parts.</td>
<td><img src="image2.jpg" alt="Photograph" /></td>
</tr>
<tr>
<td>Copper</td>
<td>Pure metal</td>
<td>Red, tough, ductile, High electrical conductor, corrosion resistant, Can work hard or cold. Needs frequent annealing.</td>
<td>Electrical wire, cables and conductors, water and central heating pipes and cylinders. Printed circuit boards, roofs.</td>
<td><img src="image3.jpg" alt="Photograph" /></td>
</tr>
<tr>
<td>Brass (Latón)</td>
<td>65% copper +35% zinc.</td>
<td>Very corrosive, yellow in colour, tarnishes very easily. Harder than copper. Good electrical conductor.</td>
<td>Castings, ornaments, valves, forgings.</td>
<td><img src="image4.jpg" alt="Photograph" /></td>
</tr>
<tr>
<td>Material</td>
<td>Description</td>
<td>Uses</td>
<td></td>
<td></td>
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<td>--------------</td>
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<td>----------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>Pure metal</td>
<td>The heaviest common metal. Soft, malleable, bright and shiny when new but quickly oxidizes to a dull grey. Resistant to corrosion. Protection against X-Ray machines. Paints, roof coverings, flashings.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>Pure metal</td>
<td>A layer of oxide protects it from corrosion (see below skin effect), bluish-white (a mix of blue and white), easily worked. Makes brass. Coating for steel galvanized corrugated iron roofing, tanks, buckets, rust-proof paints. Normally used to form with other metals.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tin</td>
<td>Pure metal</td>
<td>White and soft, corrosion resistant. Tinplate, making bronze. In electronics industry is used to weld components in printed circuit boards.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gilding metal</td>
<td>95% copper + 5% zinc.</td>
<td>Corrosion resistant, golden colour, enamels well. Bullets, jewellery.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Corrosion Skin Effect in some non-ferrous metals:** Metals like Aluminum and Copper, when contacting with oxygen in the air, produce a slightly surface of metal oxide. Contrary to iron, this skin of oxide avoids from corrosion penetration into the body of the metal. It can be said that it’s a kind of oxide which protects the metal piece from corrosion.
PLASTICS

Plastics or Polymers are made from coal, gas, animal protein or petrol. Plastic industries are a kind of chemical plants from where chemical reactions are made in order to compose first-step polymer materials called monomers. These materials need some manufacture process to obtain second-step or final plastic materials, such as bottles, containers, etc.

Plastics are typically polymers of high molecular mass, and may contain other substances to improve performance and/or reduce costs. Monomers of plastic are either natural or synthetic organic compounds.

The common word plastic should not be confused with the technical adjective plastic, which is applied to any material which undergoes a permanent change of shape (plastic deformation) when strained beyond a certain point. Aluminum which is stamped or forged, for instance, exhibits plasticity in this sense, but is not plastic in the common sense; in contrast, in their finished forms, some plastics will break before deforming and therefore are not plastic in the technical sense.

There are three types of plastics, from which the two first types are mainly used.

- **Thermoplastics polymers** which are plastics that do not suffer any chemical change in their composition when heated and can be molded again and again; examples are polyethylene, polystyrene, polyvinyl chloride and polytetrafluoroethylene (PTFE). Those kind of plastic are composed by long chains of polymer molecules.

- **Thermosetting polymers** can melt and take shape once; after they have solidified, they stay solid. Any other kind of process made on the final thermoset plastic would make a permanent degeneration or destruction of it. So this kind of polymer irreversibly cures. The cure may be done through heat (generally above 200 °C (392 °F)), through a chemical reaction (two-part epoxy, for example), or irradiation such as electron beam processing. Thermoset materials are usually liquid or malleable prior to curing and designed to be molded into their final form, or used as adhesives. Others are solids like that of the molding compound used in semiconductors and integrated circuits (IC's), in the way of epoxy resins.
The reason for such a different behavior consists, as it can be seen in the figure, in those link molecules used in thermoset that avoid thermosetting plastics from changing its shape. Thermoplastics object used to be formed by long chain of polymer, easy to break when heating or using dissolvent. For that reason, when heating a thermosetting it will be destroyed in most cases.

- Elastomers, also called Rubbers. In the industry are used so natural rubbers as artificial ones like Butadiene and Neoprene, used as waterproof materials, tyres, etc. Some examples of the use of elastomers and resins has been represented in the pictures below.
The most common plastics used in our society
Plastic manufacturers stamp a symbol with a number in every container or bag in order to recognize the sort of plastic is made of. In the following chart, it’s defined the number, name and uses of every plastic.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Acronym</th>
<th>Full name and uses</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="1" alt="PET" /></td>
<td>PET</td>
<td>Polyethylene terephthalate - Fizzy drink bottles and frozen ready meal packages.</td>
</tr>
<tr>
<td><img src="2" alt="HDPE" /></td>
<td>HDPE</td>
<td>High-density polyethylene - Milk and washing-up liquid bottles</td>
</tr>
<tr>
<td><img src="3" alt="PVC" /></td>
<td>PVC</td>
<td>Polyvinyl chloride - Food trays, cling film, bottles for squash, mineral water and shampoo.</td>
</tr>
<tr>
<td><img src="4" alt="LDPE" /></td>
<td>LDPE</td>
<td>Low density polyethylene - Carrier bags and bin liners.</td>
</tr>
<tr>
<td><img src="5" alt="PP" /></td>
<td>PP</td>
<td>Polypropylene - Margarine tubs, microwaveable meal trays.</td>
</tr>
<tr>
<td><img src="6" alt="PS" /></td>
<td>PS</td>
<td>Polystyrene - Yoghurt pots, foam meat or fish trays, hamburger boxes and egg cartons, vending cups, plastic cutlery, protective packaging for electronic goods and toys.</td>
</tr>
<tr>
<td><img src="7" alt="Other" /></td>
<td>Other</td>
<td>Any other plastics that do not fall into any of the above categories. For example melamine, often used in plastic plates and cups.</td>
</tr>
</tbody>
</table>

Hands-on activity:

- Search information (books, Internet sites, etc) about which plastics are used in an aircraft.
- Try to find some plastic object and recognize by its number, the kind of plastic it is. Touch it to feel its texture, its weight or any other visible properties that could distinguish from other plastics.
- Does the numbers from plastic finish at 7? Is there any more number applied to other kind of plastics?
- Find out some statistics about how much every plastic is used in our Society.
ANIMATIONS AND INFORMATION FROM INDUSTRIAL ENTERPRISES AND ORGANIZATIONS

Take a look to these web sites. In some of them, animations and information in relation to metals and plastics manufacturing has been made to make easier the understanding of the industrial works.

**METALS**

- [http://www.stahlwerke-bremen.com/](http://www.stahlwerke-bremen.com/) : Another animation from a steel company
- [http://www.cst.com.br/](http://www.cst.com.br/) : Click in “usina” to take a look to manufacturing process
  - [http://www.otua.org/default.htm](http://www.otua.org/default.htm) : Learning about steel and metals. To know further about them, click in “tout sur l’acier”---> l’acier dans tous ses états
- [http://www.schoolscience.co.uk/content/5/chemistry/steel/steelch1pg1.html](http://www.schoolscience.co.uk/content/5/chemistry/steel/steelch1pg1.html) : videos, animations and information about steel, materials properties, etc.

**PLASTICS**

- [http://www.anaipe/iini.htm](http://www.anaipe/iini.htm) : to learn about plastics and the process of creation with animated drawings