Properties of materials

When you make a product, you have to select a suitable material. You may want to use a timber for its decorative finish but which timber? Before you choose a material you must look at your product and decide what properties the material must have for the product to work correctly without failing. For example,

- are you going to put a lot of weight on top of the product?

You will need to consider compression.

- is it a shelf to store books?

You will need to consider bending.

- is it a door post that is going to get knocked by a slamming door?

You will need to consider toughness.

The properties of materials can be divided into two groups:

Physical	weight, finish, expansion, electrical, heat, optical, magnetic.
Mechanical	tensile, compressive, shear, bending and torsional strength. elasticity, plasticity, ductility, malleability. hardness, toughness, brittleness, stiffness. creep, fatigue. corrosion.

Physical

Weight	The weight of materials can vary greatly. Balsa wood, aluminium and foamed polystyrene are light materials. Ebony, cast iron and glass reinforced plastic are heavy materials. In certain conditions, the weight of your product will be very important.
Finish	This includes: • surface texture (matt, gloss, eggshell, woodgrained) • surface coatings (paint, stain, plating) • colour.
Expansion	Materials expand at different rates. If you join two materials together which have very different coefficients of expansion, they will bend as the temperature increases and decreases. Timber expands across the grain more than it does along the grain. Wooden tabletops are never screwed to their frames as the tops will split. High humidity swells wood. MDF is used as it is very stable.

Electrical	Copper is used for electrical wiring as it is a good conductor of electricity. Rubber has a poor electrical conductivity so it is used as an insulator. Some materials can easily be charged with static electricity and this can cause considerable problems in use.
Heat	Copper saucepans allow heat to be quickly transferred from the heat source to the food. Some cooks prefer to use cast iron pans as they retain heat and even out cooking. In a refrigerator, polystyrene foam is used as a heat insulator.
Optical	Glass and clear acrylic allow light to pass through. Glass and plastics can be made translucent or opaque so that only a controlled amount of light passes through. Metals cannot pass light but they can be polished to reflect light.
Magnetic	Materials containing iron can be permanently magnetic, made to be magnetic if an electrical current is applied or non-magnetic. A large magnet placed near instruments can alter their readings. Some plastics can be electrically charged.

Mechanical

Tensile strength	All materials can be stretched by pulling at both ends (tension). The tensile strength of the material is its ability to resist this stretching. In most situations, materials are safe to use if they return to their original length when the load is removed. Materials fracture when they fail under tension.
Compression strength	All materials can be compressed by pushing at both ends. Concrete is used for building as it has high compressive strength. Concrete has no tensile strength so when it is used for beams and floors, steel reinforcing bars must be added to take the loads. Materials buckle when they fail under compression.
Bending strength	A material that is subjected to bending must have both tensile and compressive strengths. When a timber shelf bends, it is in tension along the bottom edge and in compression along the top edge. Materials *bend*, *buckle* or *fracture* when they fail under bending depending on their cross sectional shape, i.e. angle, tube.
Shear strength	In certain conditions, the loads acting on a product are trying to tear the materials apart in similar action to that of cutting paper with scissors. The ability of some fixings such as bolts, screws, rivets, welding and glues to resist shear is important as they have to withstand sideways loads. Materials *tear* or *fracture* when they fail under shear.
Torsional strength	Anything that has a twisting or rotating movement must be able to withstand torsional loads without failing, e.g. door handles. Materials fracture when they fail under torsion.

Elasticity	When materials are subjected to forces they will change shape. To be elastic, the material must return to its original shape when the load is removed. Most materials are safe to use in their elastic state. A spring has to be very elastic to work. An eraser is elastic up until it breaks.
Plasticity	When some materials are subjected to forces, they permanently change shape. Plasticity is the ability of materials not to permanently change shape. Some materials become plastic if they are overloaded and remain in the changed shape.
Malleability	This is the ability of the shape of the material to be altered in any direction by compressive forces such as hammering, pressing rolling or bending without rupturing. Usually sheet material. Malleable materials need not be strong but they must be highly plastic.
Ductility	This is the ability of a material to be stretched into long thin shapes reducing its cross sectional area. Copper has this ability and is used to make different sized wires by a process called *cold drawing*. Ductile materials must be highly plastic. Plasticine is a malleable material as it can be rolled out but it is not ductile as it easily tears apart when stretched.
Hardness	This is the ability of a material to withstand abrasive wear, surface indentation or scratching. A drill or abrasive paper must be harder than the material it is cutting.
Toughness	This is the ability of a material to withstand sudden impact loads without failing, i.e. hammering. Materials that are tough will withstand bending and shearing without cracking.

Brittleness	This is the opposite of toughness. A brittle material will crack or fail before it bends. It has little or no elastic deformation and is not ductile.
Stiffness	This is the ability of a material to withstand bending, compression, shear or torsion and is dependent on the shape or cross section of the material. A tube is stiffer than an angle, which is stiffer than a thin sheet.
Stability	Materials such as timber twist, warp and cup due to changes in humidity and temperature. MDF is used as it is dimensionally stable.
Creep	If you make a cone shaped heap of plasticine, icing or soft fudge, after time, it will sink until it is flat on the plate. This process is called creep and is a plastic deformation that takes place over a long time and usually at a high temperature such as in aircraft turbine blades. Lead and some plastics can creep at room temperatures.
Fatigue	If you put a strip of material in a vice and then repeatedly bend it backwards and forwards, after a time, the material will begin to crack at one edge. This crack gradually gets bigger along the line of bending and at the same time it requires less effort to bend. Before the crack travels across the width of bend, the material will suddenly fail. This is called *fatigue failure*. It used to be a major reason for aircraft crashes. Indentations can start fatigue cracks.
Corrosion	All materials are effected by moisture as they oxidise (rust) or rot if not protected by paint, galvanising, plastic coating etc. Chemicals can corrode all materials. Electrolytic corrosion can be just as important. An electrical circuit is created if the contact area between two different metals is wetted by a liquid electrolyte such as salt water. A very small electrical current is generated which will eat away one of the metals. A plastic handle is joined to an aluminium saucepan with a steel bolt. The aluminium will always be eaten away.