Properties of Materials

Different materials have different physical and mechanical properties. I kid you not.

Mechanical Properties — Learn ‘em All...

You need to be totally familiar with these terms — if you start getting strength and hardness mixed up, or get confused between malleability and ductility, you’ll drop marks all over the place.

STRENGTH:
1) A material’s strength is a measure of its ability to withstand forces without breaking.
2) Tensile strength resists pulling forces — e.g. the rope in a tug-of-war.
3) Compressive strength resists squashing forces — e.g. bridge supports.
4) Bending strength resists forces trying to bend — e.g. surfboards.
5) Shear strength resists strong sliding forces — e.g. a rivet needs to withstand shear forces.
6) Torsional strength resists twisting forces — e.g. drill bits need to withstand twisting forces.

HARDNESS:
1) The ability to withstand abrasive wear and tear, rubbing and bending.
2) Very important for tools that cut, like files and drills.

PLASTICITY:
1) If a product can change shape permanently, without breaking or cracking, it’s said to have good plastic qualities.
2) This could mean that a material is malleable (changes shape under pressure so can be moulded, e.g. by hammering) or ductile (can be drawn into wires).

BRITTLENESS:
1) Brittle materials can’t withstand much stretching.
2) Brittle materials are more likely to crack or break than change their shape.
3) Glass and acrylic react like this under force.

TOUGHNESS:
1) Tough is the opposite of brittle.
2) If a material is tough, it’s hard to break or snap.
3) Armour and bulletproof vests need to be tough.

DURABILITY:
1) If a product is durable it is able to withstand repeated use.
2) Durable products also withstand wear and tear, weathering and corrosive attack.

Wouldn’t like to be that duck...
Not a bundle of laughs, sure, but darn important stuff. Learn it, then turn over the page and write down: 1) a definition of each of the six words 2) anything else interesting about that property.
Metals

Some metals are pure metals and others (alloys) are mixtures of different metals. Both types of metal can be classified into two basic groups — ferrous and non-ferrous.

Ferrous Metals contain Iron

1) These are the metals that contain iron.
2) Because of this, almost all of them are magnetic.
3) Examples: mild steel, high-carbon steel, stainless steel.

Non-Ferrous Metals — guess what? — Don’t contain iron

1) If a metal doesn’t contain iron, it's non-ferrous.
2) Examples: aluminium, brass, copper.

An Alloy is a Mixture, e.g. Brass = Copper + Zinc

1) An alloy is a mixture of two or more metals, or a metal mixed with another element.
2) An alloy is a new material with different properties and different working characteristics.
3) Alloys can be grouped as ferrous (contains iron), e.g. steel = iron + carbon, and non-ferrous (doesn’t contain iron), e.g. brass = copper + zinc.

You can Buy Metals in Loads of Shapes and Sizes

1) Metal is extracted from the earth in the form of metal ore. It's then refined and processed to produce usable materials.
2) Metals are commonly available in a wide range of shapes and sizes, because it can be very difficult to convert one shape to another.

Metals — hahahaha...

Okay then, metals. Well, you’ve got your pure metals — like iron, copper and zinc, and you’ve got your alloys, which are mixtures — like brass and steel. Ferrous metals contain iron, e.g. steel and... err... iron. For your non-ferrous metals, remember ABC — Aluminium, Brass, Copper.

Metals

Metals are rarely used in their raw form without treating them first. Most need some kind of surface finish — either for aesthetic (appearance) reasons or to provide protection.

Heat Treatments — for Softening or Toughening

Metals can be heat-treated to change their properties and characteristics. The three main types of treatment are listed below:

1) Annealing — softening metal by heating and leaving to cool.
2) Hardening — heating and rapidly cooling a metal. The metal is heated to its upper critical temperature then plunged into cold water. It leaves the metal brittle, so is often followed by a process known as tempering...
3) Tempering — to make the metal tougher and less likely to break. When steel is tempered, it's first cleansed to make it bright in appearance and then gently heated. As it gets hotter, it changes gradually from a pale straw yellow to blue — and the colour shows you how tough it’s become.

Surface Finishes — for Protection and Looks

You need to know about a few different kinds of surface finish...

1) Painting
   A primer such as red oxide or zinc chromate is needed for steel (so that later coats of paint aren’t absorbed by the metal). Hammerite is a durable top coat that’s available in a range of colours and finishes — it offers protection and is quick drying.

2) Plastic coating
   A metal is heated evenly in an oven and then plunged into fluidised powder (i.e. very fine powder that’s made to act like a liquid by passing gas through it) for a few seconds. The metal, with its thin coating of plastic, is then returned to the oven to completely fuse it to the surface.

3) Polishing
   This may be carried out by hand or by using a buffing wheel. The wheel is coated with abrasive polish and the metal is held against the spinning wheel until the required surface finish is achieved.

4) Lacquering
   This provides a barrier against tarnishing and oxidising, and is often used on decorative items such as jewellery. A thin layer of cellulose gum or varnish is applied to leave a transparent coating.

Heat treatment? — sounds like the hairdresser’s... 

The metal must be thoroughly cleaned (e.g. with paraffin or white spirit) before adding a finish. You wouldn’t want that Hammerite peeling off now would you — what a disaster that’d be.
**Plastics**

Most plastics are produced by industry using water, oil (or coal or gas), air and salt. There are two families of plastics — thermoplastics and thermosetting plastics.

**Thermoplastics — Recyclable and Bendy**

1. Thermoplastics are recyclable.
2. They don’t resist heat very well, so they can be ground down, melted and re-used — very important in today’s society of increasing waste.
3. Thermoplastics are easily formed into shapes.
4. A moulded shape can be reheated and it will return to its original state — the material is known as having plastic memory.
5. Examples of thermoplastics: acrylate, ABS, polystyrene and polyethylene (polythene).

**Thermosetting Plastics — Non-Recyclable and (usually) Rigid**

1. These types of plastic are non-recyclable.
2. They resist heat and fire so are often used for electrical fittings and pan handles.
3. These types of plastic undergo a chemical change when heated (unlike thermoplastics) to become hard and rigid. They’re not used in schools very often.

...an’ ye can get ’em in loads of different forms...

1. Plastics can be bought in many different forms — from powders, granules, pellets and liquids (for processing into finished products), through to films, sheets, rods, tubes and extruded mouldings (complex shapes).
2. Plastics don’t need protective surface finishes, due to high resistance to corrosion and decay.
3. But for a nice appearance, wet and dry paper (silicon carbide paper) is applied to remove scratches from the plastic, and followed up with a mild abrasive polish or anti-static cream.
4. Alternatively, a buffing machine can be used. No fiddle faddle, please.

**New Plastics are still being Developed**

The following materials are fairly recently-developed and have loads of uses:

1. **Plastizote** is a closed-cell polyethylene foam that has eliminated the need for the toxic chemicals presently used in the foam industry. It’s suitable for a wide range of products, including shoe insoles, buoyancy aids and reusable packaging.
2. **Plastics that conduct electricity** can be made by putting stainless steel fibres into plastics.

**Life in plastic — it’s fantastic...**

Thermosetting plastics can’t be remoulded — i.e. once they’re set, they’re set permanently. Like when you pull a funny face and the wind changes. Something like that, anyway.

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**Wood**

Woods can be divided into two main categories — softwood and hardwood. This is not a description of the wood — it just means what type of tree it comes from.

**Softwood — Evergreen Trees, like Pine**

1. Most softwood trees are coniferous (cone bearing). They typically have thin needle-like leaves and are evergreen — e.g. pine, cedar and yew.
2. They grow in colder climates and are fast growing — most reaching maturity within 30 years. This makes them easy to replace with new trees, so they’re usually cheaper than hardwoods.

Pines:

1. There are several types of pine but they’re all generally pale yellow with brown streaks.
2. Scots pine is fairly strong but knotty.
3. Parana pine is more expensive — it’s hard and is best used for interior joinery.

**Hardwood — Deciduous Trees, like Oak**

1. Most hardwood trees are broadleaved and deciduous (they shed their leaves annually) — e.g. oak, mahogany, beech and elm.
2. Broadleaf trees grow in warm climates and are usually slow growing. They can take around a hundred years to mature, so they’re generally more expensive than softwoods.

Colours of the common hardwoods:

- mahogany
- reddish brown
- elm
- light reddish brown
- beech
- creamy/pinkish
- oak
- rich light brown

**The Bit about Woodstain...**

Most woods need protection, particularly if they’re going to be used outdoors.

Most hardwoods have an attractive grain and often don’t have paint as a surface finish.

1. Polyurethane varnish can be used to seal and protect the surface of the wood, and give it a smooth surface finish. You can buy it clear or in a wide range of colours.
2. Woodstain can be applied to wood to enhance the appearance of the wood’s grain. It’s available in natural colours but also in bright blues, reds etc. Stains usually don’t protect the wood, so varnish may need to be applied afterwards.
3. Oil can be used to maintain a natural appearance of the wood. Some oil-based finishes also offer protection to wood used outdoors.
4. Paint is often used to colour and protect wood. Emulsion paints are cheap, but they are water-based, so they don’t protect wood from water.

**I wood have put two pages in on this if I could...**

Ah... wood’s lovely, isn’t it. Except for the splinters. Or ‘specks’, as my friend Tim would have it. If he got splinters, he’d say, “Ayaz — specks!” (Don’t worry, that’s just how they talk in my part of the world.)
Manufactured Boards

Solid woods (see p27) are cut straight from the tree. Man-made woods (boards) are made from the 
bits of waste that are produced when the trunks and branches are cut into planks.

Plywood — Loads of Layers

Plywood is a very popular man-made board, used for building and general construction.

1) Plywood is very strong for its weight and thickness, compared with solid wood.
2) It’s made up of several layers — always an odd number of them.
3) The layers are glued with their grain at 90 degrees to each other — which is why it’s so strong.
4) The outside of the board can be finished with a nice veneer (a thin layer of good quality wood) to make it look better.

Blockboard and Laminboard — Blocks in a ‘Sandwich’

Blockboard and laminboard are boards of similar construction. Although not as strong as plywood, they’re a cheap substitute, especially when thicker boards are required.

1) Strips of softwood are glued together, side by side, and sandwiched between two veneers. The veneers add strength and make the board look nice.
2) The outer veneers are glued with their grain at right angles to the grain of the inner core — this makes the board stronger.
3) The softwood used is usually pine or spruce.
4) The width of the softwood for laminboard is between 5 mm and 7 mm.
5) The width of the softwood for blockboard is thicker, at between 7 mm and 25 mm.

MDF and Chipboard — MFI eat your heart out...

Medium Density Fibreboard

1) Medium density fibreboard (MDF) is a popular board that's very cost-effective (cheap).
2) MDF has smooth faces and takes paint and other finishes well.

Chipboard

1) This is produced by compressing wood particles together with glue.
2) It’s cheap but not very strong, so is usually used with a hardwood or plastic veneered surface in cheap furniture.

“Enjoying learning about wood?” — “No, I’m board”...

Man-made boards are available in large sizes — because they’re not restricted by the size of the tree, like solid wood is. Knock-down (KD) joints (see p19) are the easiest way to join these boards.

Composites and Smart Materials

Composites and "smart materials" have allowed new types of product to be made.

Composites — Improved Properties through Bonding...

Composite materials are formed from two or more materials bonded together.

1) When two or more materials are combined by bonding, a composite material is formed.
2) Mechanical and other properties are improved, resulting in excellent strength-to-weight ratios in the majority of composites.
3) Turbol is an example of a composite: woven linen is impregnated with a phenolic resin. This can then be used in gears, bearings etc.

Plastic can be Reinforced with Glass or Carbon Fibres

Glass-Reinforced Plastic (GRP)

1) Glass-Reinforced Plastic (GRP) is a popular choice for large structural items such as boats and car bodies.
2) This reinforced plastic has glass fibre strands that give greater strength to the material.
3) The glass fibre is available as woven fabric, matting and loose strands.

Carbon Fibre

1) This is similar to GRP, but instead of glass fibres, carbon fibres are used. This makes the material much stronger.
2) As well as being mechanically stronger, the material is also lighter in weight.
3) Products made from carbon-fibre composites include protective helmets, bulletproof vests and racing cars.

'Smart' Materials have Clever Properties

Nitinol

1) Nitinol is a 'shape memory alloy', and is an example of a so-called 'smart material'.
2) It can be easily shaped when cool, but returns to a 'remembered' shape when heated above a certain temperature.
3) So if your glasses are made of this and you accidentally bend them, you can just pop them into a bowl of hot water and they'll jump back into shape.

Silicon

1) Silicon is a semiconductor, meaning its resistance decreases as its temperature increases.
2) Single crystals of silicon are cut into thin wafers and have transistors (and other circuit elements) etched onto the surface. A large chip of 20 cm diameter can contain up to one thousand million circuit elements.
3) Computers have their Central Processing Unit (CPU) made from a single integrated circuit (chip).

It's amazing what a bit of bonding can do...

Shape memory alloys sound great. You can even get a 'magic spoon' that jumps into a different shape as soon as you put it in hot tea. Just one of the ways in which technology changes lives.
Fixtures and Fittings

There are many fixtures and fittings available on the market. You can use these for locking, hinging and joining. Sounds like fun.

There Are Four Main Types of Hinge

Hinges are available in steel, brass and nylon, and can be coated to match a piece of furniture. The part of the hinge that moves is called the knuckle.

1) Butt hinges are the most common type of hinge used for hanging doors.
2) The two parts of the hinge are set into the door and frame.
3) They're available in brass or steel.

1) Flush hinges are screwed directly onto the surface of the wood, so they're easier to fit than butt hinges.
2) They're usually used for lightweight jobs.

1) Tee hinges are often used outside — for things like shed doors or garden gates. The longer 'strap' allows the hinge to support a greater weight.
2) They're often covered in black enamel.

1) Pivot hinges are used when you might need to lift a door off its frame.
2) One part of the hinge is screwed to the door and the other to the door frame.

2) Most Locks and Catches Are Made from Steel or Brass

Locks need to be strong, and so tend to be made from steel, plated steel or brass.

1) Cupboard locks are screwed to the edge of cupboard doors.
2) No cutting is required when fitting the lock.
3) They can be used for both left and right locking.

1) Catches hold a door closed without locking.
2) They can be made out of brass, steel and various plastics.

Other Fixtures & Fittings

1) Shelves fitments allow a shelf to be placed into position.
2) They do not require cutting into the shelf.
3) The fitments are able to be repositioned for different shelf heights.

1) Leg fasteners can be used to attach legs to tables or chairs where the joints need to be frequently taken apart.
2) They also offer reinforcement, making the joint stronger.

Adhesives

Adhesives are used for joining materials together. The kind you need to use depends on what materials you're joining. So seatbelts on — here we go...

Polyvinyl Acetate (PVA) is used for Wood

1) Polyvinyl acetate (PVA) is a white woodworking glue.
2) There are two types of PVA — interior and exterior.
3) Interior will join wood as long as it doesn’t get wet.
4) Exterior is more expensive, but is able to join wood in damp or wet conditions.
5) PVA is white and creamy and easy to use.

Contact Adhesive is very Strong

1) This glue is rubber based, and forms a very strong bond.
2) It's applied to both surfaces, and then the surfaces are kept apart for about 10 minutes until the glue goes tacky.
3) Then when the surfaces are brought into contact, the sticking is instant.
4) Contact adhesive has a strong, unpleasant odour — so it’s best used in a well-ventilated area.

Epoxy Resin sticks almost Anything

1) The trade name for epoxy resin is Araldite.
2) Two separate substances are mixed in equal parts — they’re both thick, sticky liquids, but one is yellow and one is clear.
3) Once mixed, epoxy resin will stick almost anything — ceramic to ceramic, metal to wood, wood to plastic, etc.
4) It takes about 15 minutes to harden and is expensive.

Superglue also sticks Most Things

1) Superglue is even more expensive than epoxy resin but will stick to most things.
2) It certainly sticks to skin, so you have to be very careful.
3) It's a thin, clear liquid.
4) After applying the glue, slight pressure is required for a very strong bond.

Acrylic Cement is used for Plastics

1) Known as Tensol, this adhesive is used for plastics.
2) It's a watery, clear liquid.
3) It isn’t particularly strong, but is ideal for plastic objects where the joints aren’t going to be knocked about.

Adhesives — a gripping topic for sure...

I said it would be good, didn’t I. And I wasn’t lying, as I’m sure you’d agree. Well, let me tell you something else about adhesives... PVA is the most common wood glue used in schools.
Choosing the Best Material to Use

Selecting the right materials isn’t easy. But it’s something you’ve got to be able to do, otherwise you can end up in a right pickle.

Different Factors affect your Selection of Material

You should be able to make a good choice as long as you understand a material’s properties, and know what it’s being used for.

Functional Requirements — What does the product have to do?

Ask yourself the following questions:

1) What demand will be made on the material? (Will it have to withstand heavy loads or chemicals? Will it have to conduct heat or electricity?)

2) Will it be for outdoor or indoor use? (If it’s for outside, you need to consider whether your material will corrode.)

3) Does it need to fit in with an environment? (Your material might need to be a particular style or have a certain look.)

Economics — How much money have you got?

You’ll need to consider the following points:

1) The size of the product — materials like pewter are expensive, but may be a good choice for a small item of jewellery.

2) Scale of production — is your product a one-off, or will it be batch or mass produced? Stainless steel could be a possible material for a one-off product. But if you’re mass-producing something that would be equally as good made from some kind of plastic, that might be cheaper.

Availability of Supply — What can you get hold of?

Can you get hold of the material you want? And if you can, can you get it in a suitable form? Most materials are only available in standard forms and sizes, and it can be very expensive to get a material in any other form. This will have a direct effect on the cost and the method of manufacture.

Manufacturing Method — How will the product be made?

1) Some materials are easier to join than others (which will affect the production method used).

2) Also, the material must be suitable for the intended production method (and vice versa). For example, you can make something out of certain plastics using injection moulding, but it’s no good planning to use this technique for wood.

I reckon you should just make everything out of cheese...

You need to know about different materials so you can choose the right one for the job in hand. Don’t make a fireguard or teapot from chocolate, for example — they won’t be much use. It sounds obvious, but it’s a mistake that amateurs make all too often. Be smart — don’t be one of them.

Revision Summary for Section Three

Yowzers — what a section that was. Yep, that was one for the thrill-seekers among you, make no mistake. Lots of facts about wood and plastic. Boy oh boy, I can feel my pulse quickening at the very mention. Okay... perhaps I’m overstating things just a tad... maybe it wasn’t that exciting. But it’s definitely stuff you need to know, otherwise you might end up making something well dodgy when you come to do your project. So try these questions, and if you get any wrong, go back, check the section and then try them again. And repeat this process until you get every single question right.

1) Name six mechanical properties, and describe what they mean.

2) Explain the difference between ferrous and non-ferrous metals. Give two examples of each.

3) What is an alloy?

4) What is meant by the following terms:
   a) annealing  b) hardening  c) tempering?

5) Suggest two surface finishes for metal.

6) Name the two different kinds of plastic. How are they different? Give two examples of each.

7) What is plastizote?

8) What are the two main categories of wood? Why are they different? Give two examples of each.

9) Name one type of paint that is waterproof.

10) What is the main advantage of using plywood compared to solid wood?

11) Why are the layers in plywood glued at right angles to each other?

12) What is a ‘veneer’? Why are veneers used?

13) Describe the main difference between blockboard and laminboard.

15) What does MDF stand for?

16) How is chipboard made?

17) What is a composite material?

18) Name two composite materials and explain why they are so useful.

19) Describe the special properties of a shape memory alloy.

20) What are the four main types of hinge? Describe when each type might be used.

21) Explain the difference between a lock and a catch.

22) Name five different types of adhesive. Explain when each type might be used, and what properties make it suitable for this use.

23) Name four factors that would affect your choice of material for a product you were going to make. Explain how each factor might influence your choice.