MATERIALS

Electronic products include both circuits and enclosures. A working knowledge of a range of materials is required to be able to design and make enclosures.

Properties of materials

The choice of material will depend upon the properties needed by the product. For example, the enclosure for an outside alarm will need to be waterproof.

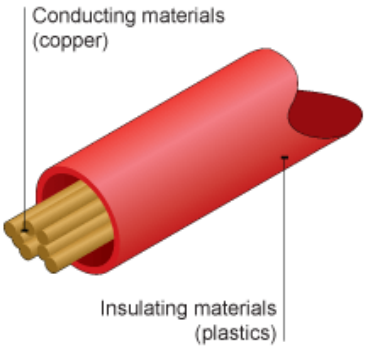
Examples of how to relate material properties to design needs

Property needed for the enclosure	Material property needed
Does the material need to allow (or prevent) electricity from passing through it?	Electrical conductivity
Does the material need to allow heat to pass through it?	Thermal conductivity
Does the enclosure need to resist scratches and wear?	Hardness
Does the material need to be resistant to knocks and bumps?	Toughness
Does the enclosure need to be in a certain price range?	Cost
Does the enclosure have to work in an environment that could damage it?	Corrosion resistance

Electrical conductivity

Electrical conductors are materials that allow electricity to flow through them easily. Most metals are good conductors.

Electrical insulators are materials that do not allow electricity to flow through them. Most plastic and ceramic materials are insulators.
In the diagram of an electrical insulator, the insulating material (plastic) surrounds the conducting material (copper wires).



Semi-conductors

There is also a small group of materials called semi-conductors. These have **both conducting and insulating properties** and they are used to make electronic components. The way in which a semi-conducting material is connected to a power supply determines whether it will conduct an electrical current or prevent it from flowing.

Types of materials

Materials are grouped into **five main categories**, based on what they are made from:

- wood
- metals
- polymers
- ceramics
- composites

Smart materials

In addition, some new materials have been developed with properties that can react to changes in their environment. Although each of these new materials fall into one of the five types, they are often classed as a separate group called smart materials.

Wood

There are two types of wood: **softwood** and **hardwood**. These names do not refer to the properties of the wood: some softwoods can be hard and some hardwoods can be soft.

Softwoods, such as pine, come from **coniferous** trees. These keep their leaves all year round. They can be grown in renewable managed forests. This means that more wood can be grown to replace that being used.

Hardwoods, such as oak or beech, come from **deciduous** trees. These lose their leaves each winter. They tend to grow slower than softwoods.

Wood is time consuming to process and only comes in relatively narrow widths, due to the sizes of tree trunks. The properties of a piece of wood may vary in different directions, depending upon the direction of the grain.

Manufactured board

Medium density fibreboard (MDF) is a manufactured board made from wood pulp which is bonded with a polymer called **urea formaldehyde**. The wood pulp is often made from the waste from cutting solid wood.

Advantages of MDF

- It is available in **larger widths** than solid wood.
- Its properties can be **uniform in different directions**.
- It is much **cheaper** than solid wood.

Metals

Metal is made from metal ores, which have to be mined and processed to transform them into usable materials. It is rare for metals to be used in pure form. Normally they are mixed with other metals to improve their properties: the mixture is called an **alloy**. Most metals are good conductors.

There are two main types of metal alloys: **ferrous and non-ferrous**. Ferrous metals contain iron. Non-ferrous metals do not contain iron. Both types of metals can be recycled.

Ferrous metals

The most common type of ferrous metal is low-carbon steel. This contains up to 0.3 percent carbon. It is stronger than most non-ferrous metals, woods and plastics. Compared to other metals, it is easy to machine, tough and cheap. However, it is prone to corrosion and rusting.

Non-ferrous metals

Most of the common non-ferrous metals have good corrosion resistance. These include:

- **Aluminium alloys**: lighter than steel, but more expensive and not as strong.
- **Copper**: one of the best electrical conductors. This is commonly used to make electrical wires.

Polymers

The correct term for plastics is polymers. Most polymers are **good insulators**. Some of the stronger polymers compare favourably with metals. They are not normally painted, but their colour can be changed by adding pigments to them.

Most polymers are made from oil, which is a non-renewable resource. They are made by a chemical reaction called **polymerisation**.

There are two main types of polymer: thermosets and thermoplastics.

Thermosets are normally made into products by moulding. Once moulded, they cannot be reshaped and they cannot be recycled.

Thermoplastics soften when heated and can be shaped when hot. The shape will harden when it is cooled, but can be reshaped when heated up again. Thermoplastics are softer and more flexible than thermosets. They can normally be **recycled**.

Typical uses of some common thermoplastics

Polymer	Properties	Example of what it is used for
High impact polystyrene (HIPS)	Softens at 95°C. Easy to mould. Light and strong.	Vacuum-formed packaging and casings
Acrylic (Polymethyl methacrylate, PMMA)	Good optical properties (can be transparent or coloured with pigments). Hard wearing and shatterproof.	Plastic windows, bath tubs, display signs
High-density polyethylene (HDPE)	Softens at 120°C. Strong.	Bowls, buckets, milk crates
Low-density polyethylene (LDPE)	Softens at 85°C. Softer, more flexible and less strong than HDPE.	Carrier bags, packaging, film
Polyvinyl chloride	Stiff and hard wearing.	Coverings for electric cables, floor and wall coverings, packaging

Smart materials

Smart materials have properties that react to changes in their environment. This means that one of **their properties can be changed by an external condition**, such as temperature, light, pressure or electricity. This change is reversible and can be repeated many times. There are a wide range of different smart materials. Each offer different properties that can be changed.

Shape-memory alloys

For most materials, if they are bent out of shape, they stay that way. However, if a part made from a shape-memory alloy (**SMA**) is bent out of shape, when it is heated above a certain temperature it will return to its original shape.

This property makes it useful for making spectacle frames - they return to their original shape if they are put in hot water after bending them.

SMAs are used as triggers to start the sprinklers in fire alarm systems, controllers for hot water valves in showers or coffee machines and for spectacle frames.

Piezoelectric materials
When a piezoelectric material is squeezed rapidly, it **produces a small electrical voltage** for a moment. If a voltage is put across the material it makes a tiny change in shape. Piezoelectric materials are being used for contact sensors for alarm systems and in microphones and headphones.

Quantum-tunnelling composite
Quantum-tunnelling composite (QTC) is a **flexible polymer which contains tiny metal particles**. It is normally an insulator but if it is squeezed it becomes a conductor.
QTC can be used to make membrane switches like those used on mobile phones, pressure sensors and speed controllers.

Electroluminescent materials
Electroluminescent materials give out **light** when an electric current is applied to them. Among many possible applications are safety signs and clothing for use at night.

Colour-change materials

Thermochromic materials change colour as the temperature changes. These are used on contact thermometers made from plastic strips and test strips on the side of batteries (where the heat comes from a resistor under the thermochromic film). They are also used as food packaging materials that show you when the product they contain is cooked to the right temperature.
Photochromic materials change colour according to different lighting conditions. They are used for security markers that can only be seen in ultraviolet light.

Comparing materials
The following table compares the properties of a range of different materials. This is a subjective comparison. The **ratings will vary** for different applications.

A chart like this can help to identify the possible materials to use in an application. Once the possible materials have been identified, the list of those suitable should be **tested** to see how well they meet the needs of the product.

Material	Conduc-tivity	Strength	Hardness	Tough-ness	Weight	Corrosion resistance	Cost
Pine	Very poor	Medium/ low	Low	Low	Low/ medium	Poor	Low
MDF	Very poor	Low	Low	Low	Low/ medium	Poor	Low
Low-carbon steel	Very good	Very good	Good	Very good	High	Poor	Low
Stainless steel	Very good	Excellent	Very good	Very good	High	Good	High
HIPS	Very poor	Medium	Low	Good	Low	Very good	Low
Acrylic (PMMA)	Very poor	Medium	Low/ medium	Good	Low	Good	Medium
SMA	Very good	Very good	Good	Very good	Medium	Good	High

Materials – Test

INSTRUCTIONS – Copy the question into your jotter then choose the correct answer and write that underneath the question.

1. In terms of material properties, what is a conductor?

- A material that is resistant to heat.
- A material that allows electricity to flow through it easily.
- A material that does not allow electricity to flow through it.

2. Which of the following is a softwood?

- Beech
- MDF
- Pine

3. What does MDF stand for?

- Maximum-density fibreboard
- Manufactured dense fibreboard
- Medium-density fibreboard

4. What is meant by a smart material?

- A material that has a property that can be changed in response to its environment
- A material that includes a microcontroller
- A material that will produce a protective film on its surface when it is put in a corrosive environment

5. Which property of a material describes how resistant it is to knocks and bumps?

- Toughness
- Strength
- Hardness

6. Which of the following statements describes a thermoplastic polymer?

- Once moulded it cannot normally be reshaped.
- It softens when heated and can be shaped when hot.
- It allows electricity to flow through itself easily but is resistant to heat

7. What type of metal alloy contains iron?

- Non-ferrous
- Ferrous
- Aluminium

8. Which type of material will produce a small electrical voltage when its shape is changed rapidly?

- Quantum tunnelling composite
- Piezoelectric
- Electroluminescent

9. Which material property shows how resistant it is to scratches and wear?

- Hardness
- Toughness
- Corrosion resistance

10. A photochromic material changes colour in response to changes in which of the following?

- Temperature
- Pressure
- Light