Design and Technology

Technical principles

1.1 Materials and applications

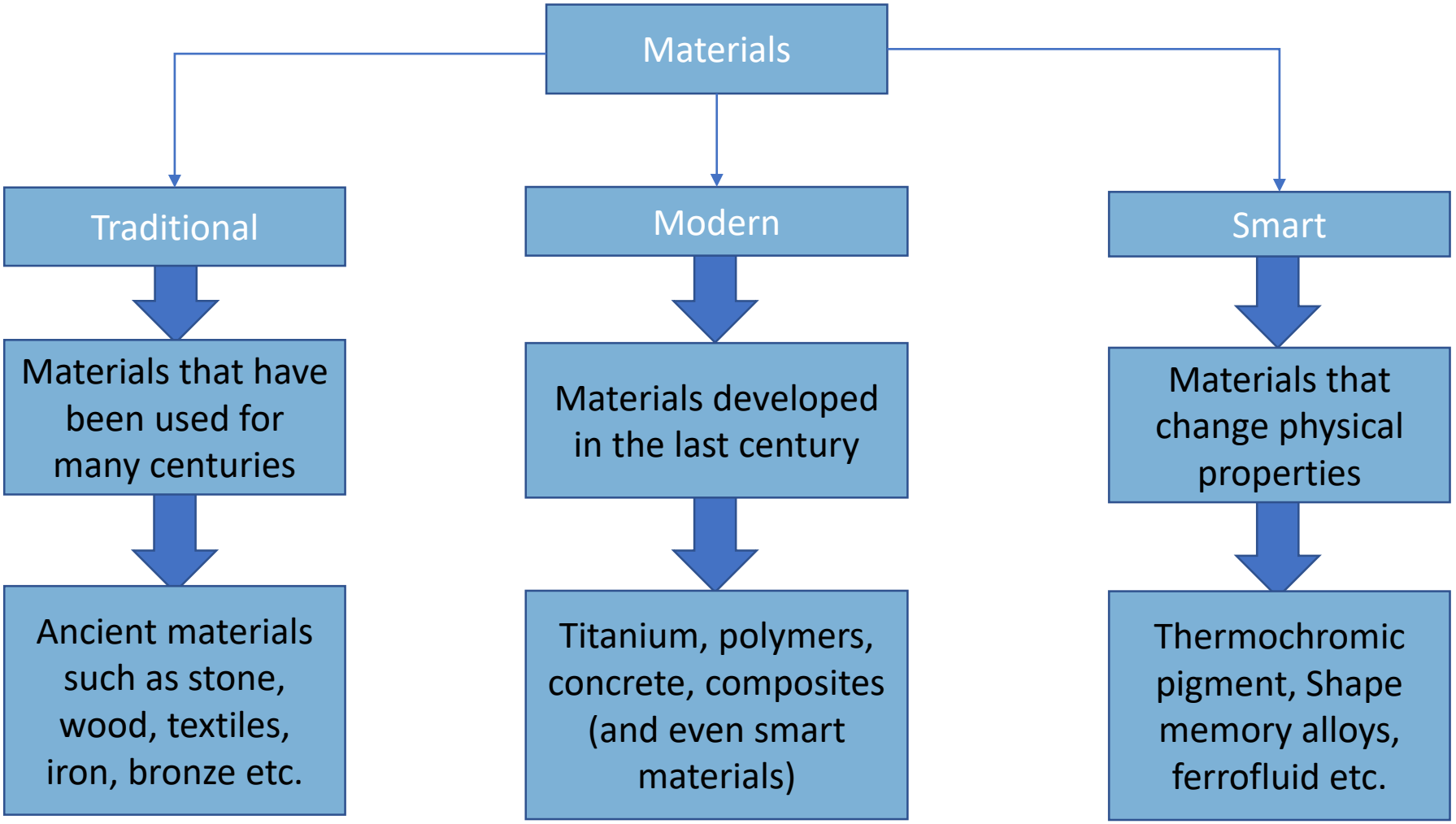
Learning Outcomes

By the end of this unit you should have developed a knowledge and understanding of:

- **the basic classification of material groups**
- **the mechanical properties and working characteristics of a range of materials**
- **the different physical properties of materials**
- **how and where to identify forces and their relative strength**
- **the different mechanical properties that specific materials possess**
- **how to take notes and revise the material effectively**

Materials

To help learn and revise, materials can be categorised in one of three ways:



Material classification

Materials for product design and engineering are generally split into groups or classifications. These are:

- Metals
- Timber/Woods
- Polymers
- Paper and board
- Composites
- Smart and modern materials

To help us learn and revise, we can divide materials into categories and sub-categories with a suitable applications for each material.

Materials and their applications

The purpose of this unit is to give you the knowledge and understanding necessary to choose the best material for a particular product or process of manufacture. Some points to note:

The properties of a material are determined largely by its structure.

- **Metals are made up of crystals that contain atoms and molecules.**
- **Woods are fibrous materials made up of an arrangement of plant cells and resins. Paper and card are derived from wood and therefore share the same molecular structure.**
- **Polymers are made up of long chain molecules containing carbon, hydrogen and oxygen atoms, along with other chemicals such as chlorine and fluorine.**

Material properties

In order to select the correct materials and manufacturing processes for a particular product of process, you will need to have a working knowledge of the physical and mechanical properties of materials and how they can be worked with, shaped, formed, joined and finished.

There are two main characteristics that a material can have:

1. **Physical properties** which refer to the actual makeup or structure of the material

2. **Mechanical properties** which refer to the way a material reacts to external forces

Physical properties

- Physical properties are those that refer to the actual matter that forms the material.
- Fusibility: the ability to change into a molten or liquid state when heated to a certain temperature.
- Density: defined as mass per unit volume. Relative density is the ratio of the density of the substance to that of pure water at 4 degrees C.
- Electrical conductivity: all materials resist the flow of electricity to some extent but conductors offer very low resistance to the flow of electrical current.
- Electrical Insulation: these offer a high resistance to the flow of electricity.
- Semi-conductors: range between the two previous extremes and allow electric current to flow under certain conditions.
- Thermal properties: how a material reacts to heat such as expansion, conductivity and insulation.

Physical properties

- **Opacity:** How much light is allowed to pass through. A fully opaque material will not allow light to pass through. While a semi opaque material will allow some light through (see translucent)
- **Transparency:** The ability for light to fully pass through so that you can see through the material e.g. glass.
- **Translucency:** The ability to transmit light through even if you cannot actually see through the material e.g. thin paper.
- **Colour:** We perceive colour by light bouncing off the surface of a material therefore this could be classed as an optical property.
- **Surface:** How light bounces off a material gives an indication of how smooth or rough the surface of the material is.

Mechanical properties

Plasticity: The ability of a material to be permanently changed in shape by an external force without damage. Many materials display this property which is why plastic materials should be referred to as Polymers.

Malleability: The ability to withstand deformation by compression.

Ductility: The ability to be drawn out (stretched).

Elasticity: The ability to flex and return to its normal shape when the force is removed.

Toughness: The ability to withstand a sudden impact. Can also refer to a materials ability to withstand bending.

Hardness: The ability to withstand abrasive wear (indentation or scratching)

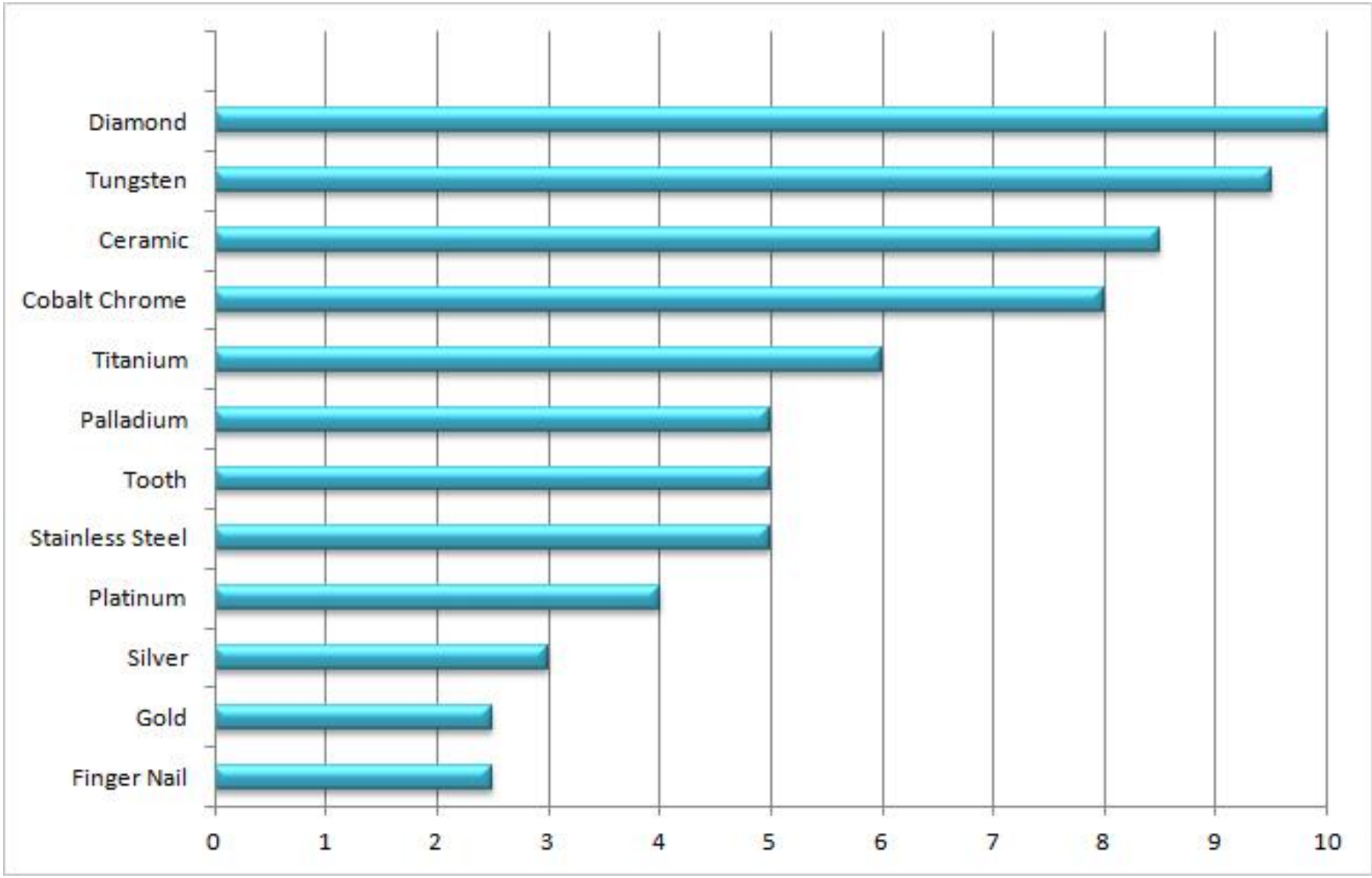
Durability: The ability of a material to withstand wear and tear as well as weathering and corrosion.

Stability: The ability to resist changes in shape and size due to its environment.

Strength: The ability to withstand forces without breaking or being permanently deformed.

Mechanical properties

This chart shows the relative hardness of a range of materials



Mechanical properties

Strength is the ability to withstand a particular force. There are various different types of forces to consider but these are the main ones.

Tensile strength is the ability to withstand stretching or pulling forces.

Compressive strength is the ability to withstand pushing or crushing forces.

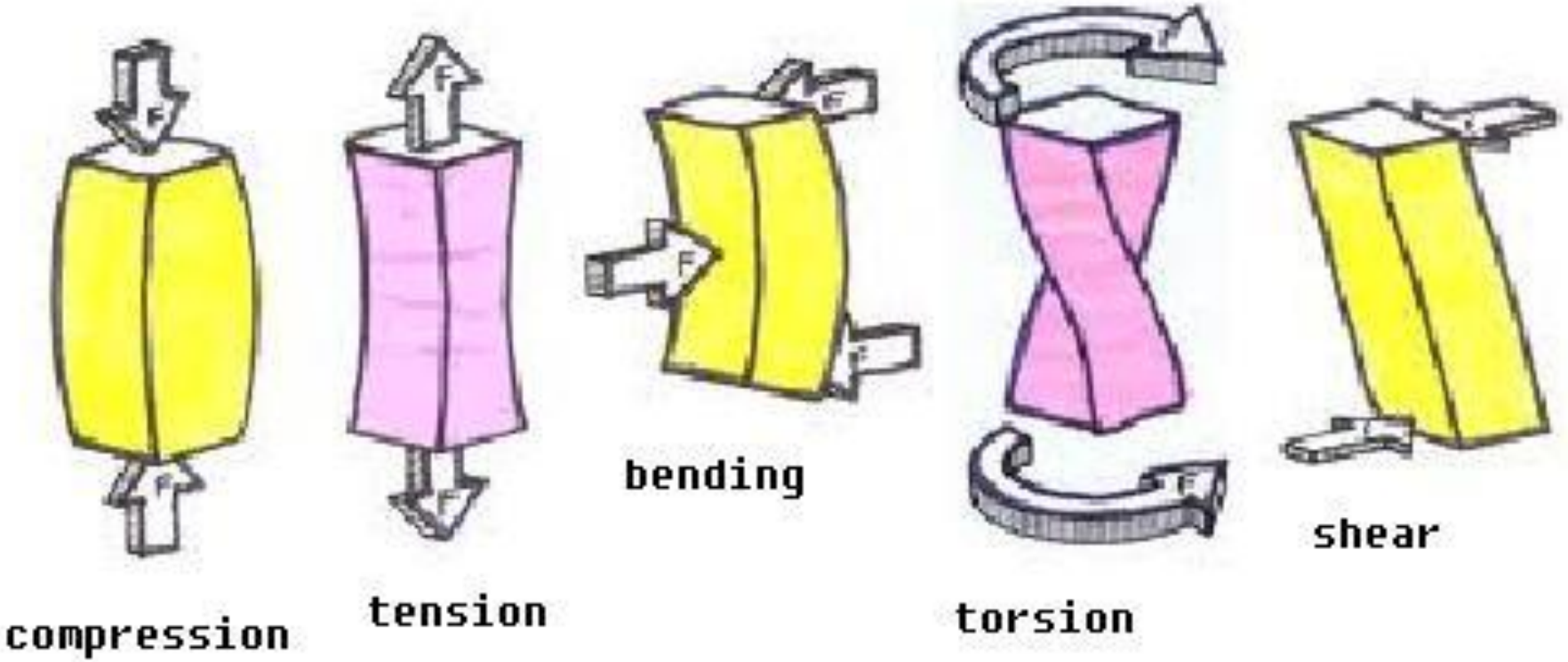
Bending strength is the ability to withstand forces which attempt to bend a material.

Shear strength is the ability to withstand sliding forces acting against each other.

Torsional strength is the ability to withstand twisting forces.

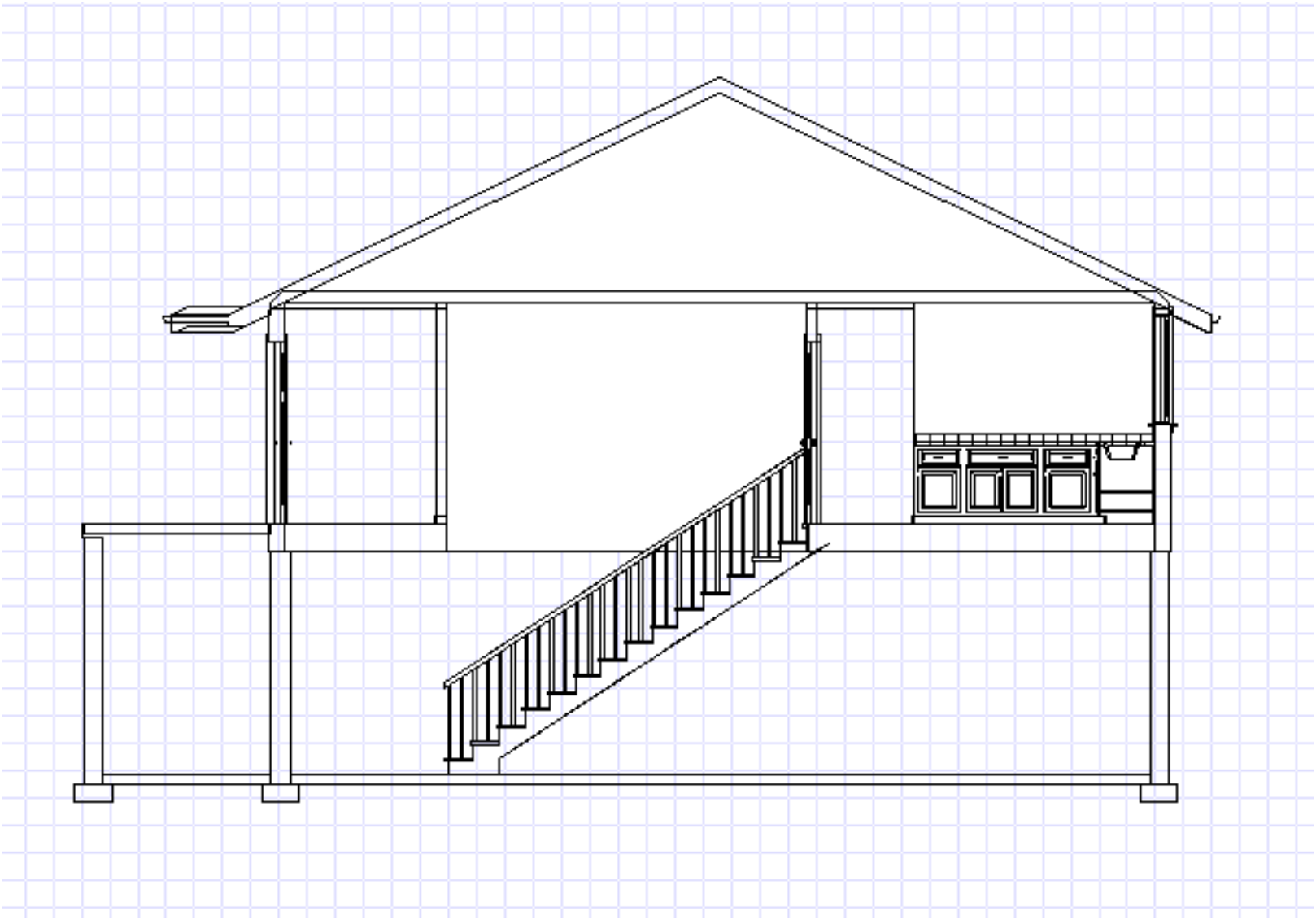
Mechanical properties

Strength is the ability to withstand a particular force therefore, if a material has **good compressive strength**, it can resist **compressive force**.



Mechanical properties

Can you identify the five forces in this house?



Mechanical properties

Can you identify the five forces in this house?

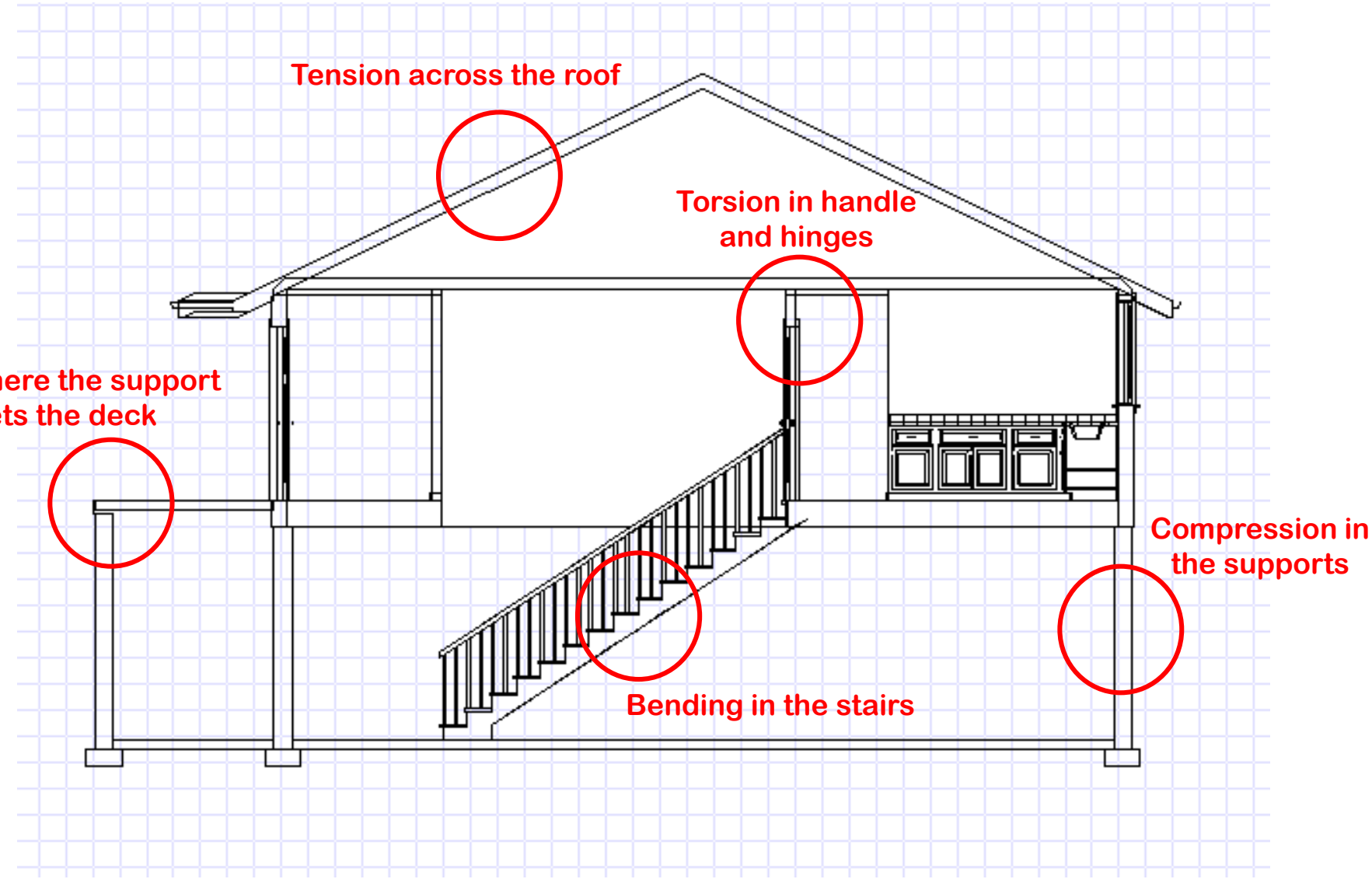


Table of properties

Complete this table of material properties

Property (+)	Material	Material	Property (-)
Plastic			
Malleable	Copper		
Ductile		Wood	
Elastic	Rubber		Rigid
Toughness			
Hardness		Chalk	
Durability			
Stability		Wood	
Strong			Weak
Fusibility		Wood	
Dense			
Conductive		Rubber	Insulator
Opaque			
Smooth			

Summary of the unit

- Materials have both physical and mechanical properties.
- Strength is resistance to force, so each force also has an associated strength (or weakness).
- Physical properties relate to the makeup of the material but can also contribute to their aesthetic qualities such as colour and texture etc.
- Materials can be categorized as traditional, modern or smart materials. Smart materials are also modern materials.
- Each material has specific properties that make it suitable for a particular application, and this may also be dependent on the manufacturing process intended. Some manufacturing processes may only be suitable for a specific material.
- There are both workshop and industrial tests for materials. These address the mechanical properties of materials not necessarily the physical ones.

Revision notes

There are seven categories of materials covered in the syllabus, but you should also be familiar with textiles, glass and ceramics making a total of ten categories. These last three will only be for reference in case an exam question requires reference to them for comparison.

Where possible, these categories have been broken down into three to help you remember more easily. Use this fact to help you identify materials and their uses.

Ensure that you can name one common application for each specific material and never answer a question with a generic term such as 'wood' or 'metal'.

Check your knowledge of these materials at the end of each unit.

Metals	Woods	Polymers	Paper and board	Composites
Smart materials	Modern materials	Glass	Ceramics	Textiles

Revision notes

For each of the material groups you study, you should be familiar with the classification, properties and stock forms available for each material.

You should be able to refer to the physical and mechanical properties of each material and why those properties make them suitable for the particular application.

We will also look at the workshop tests undertaken to identify the mechanical properties of materials.

In a later unit we will look at how those materials can be processed, enhanced and finished in the production of products and components.

Throughout you will be expected to make reference to the physical and mechanical properties we have covered in this unit.

Assessment

Please read through the notes and textbook to support your notes and this presentation. You can find questions relevant to this section in the following past papers:

2010	
2011	Q1
2012	
2013	
2014	
2015	
2016	
2017	
2018	
2019	Q1, 3, 4, 9, 18

Prep

Please attempt the past paper for next lesson and we will go through the answers together to see where you may have made a mistake or where you can improve your answers.

Please write in your homework planner:

Complete Q1-3 from AQA PROD1 Summer 2013

Next lesson: Material properties and categories