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INSTITUTE OF APPLIED TECHNOLOGY

Engineering Materials

Module 1: Introduction to Engineering Materials

PREPARED BY

IAT Curriculum Unit

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Module 1: Introduction to Engineering Materials

Module Objectives:

After the completion of this module, the student should be able to:

1. State the importance of engineering materials.
2. Explain the general properties of metals and non-metals.
3. Distinguish between ferrous and non-ferrous metals.
4. List applications for selected pure metals and alloys.
5. Identify metals based on their appearance.
6. Identify ferrous metals using the spark test.
7. Identify metals shapes, sizes, and specifications for purchasing.
8. Identify two groups of non-metallic materials called plastics and ceramics.
9. Identify applications for Plastics and ceramic materials.
10. Identify uses of composite materials.

Module Contents:

1. Introduction

This course is about engineering materials which is of great importance to anyone involved in engineering.

All engineering students need to have a basic understanding of why a particular material is used for a specific job.

Students also need to know how to choose the best material for any projects they are making, and to recognize the advantages and limitations of different materials.

2. What is a Material?

Before we can answer this question we must know about **"Matter"**.

Our entire world is made of different sorts of **matter**.

The three major states of matter are **solid**; **liquid** and **gas**.

What are the other states of matter?

All matter is made of **atoms**. Atoms are the smallest complete part of any matter which is consisted of neutrons, protons, and electrons. See Fig 1.1a.

The atoms usually join together to form **molecules**. A molecule is the name we give to **two or more atoms chemically joined together**.

Fig. 1.1b shows a water **molecule** (H_2O) which is **two Hydrogen atoms** chemically combined with **one Oxygen atom**.

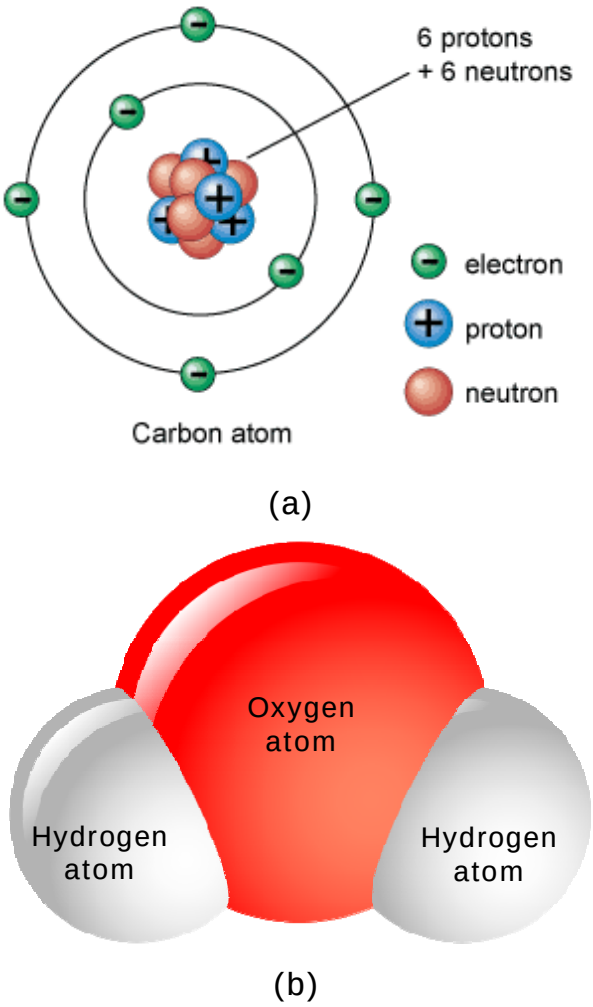
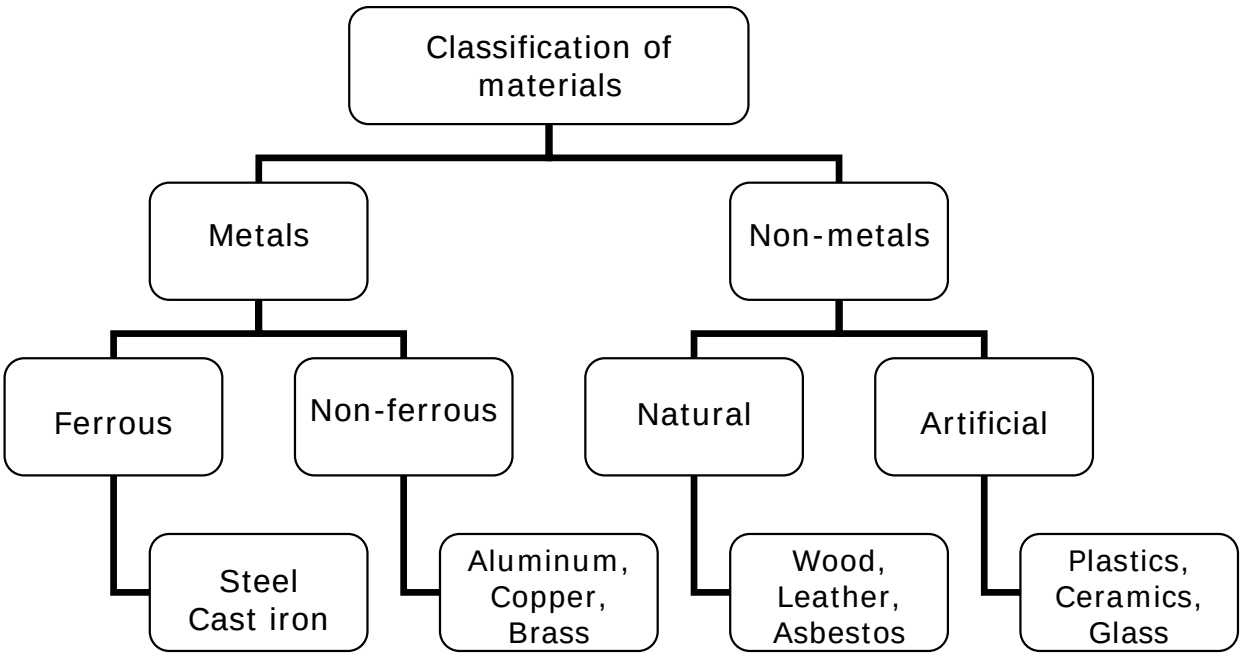


Fig. 1.1: (a) Carbon atom. (b)Water molecule

The **solid matter** is the **material.** Materials are classified into **metals** and **non-metals**. Fig. 1.2a shows a simple classification of materials.

Fig. 1.2(b,c) shows an example of a pump made from a **metallic** material and another pump made from a **non-metallic** material.



(a)

(b)

(c)

Fig. 1.2: (a) Classification of materials (b) Metallic pump. (c) Non-metallic pump.

3. Metals:

Nearly all of the **metals** we use are obtained from the **earths crust** as **metallic ores**.

To use these metals they must be **cleaned** to remove the other elements in the ore, we call this process **refining**.

Metals are classified into **ferrous** metals and **non-ferrous** metals.

The term **ferrous** is derived from the Latin word "**Ferrum**" which means "**containing iron**" thus ferrous metals contain iron and Non-ferrous metals do not.

Ferrous metals are often **Magnetic**, but this property is not sufficient to classify a metal as ferrous or Non-ferrous for example:

Stainless steel, a ferrous metal is **not magnetic**, while **cobalt** is **magnetic** but non ferrous. See Fig. 1.3.

(a).

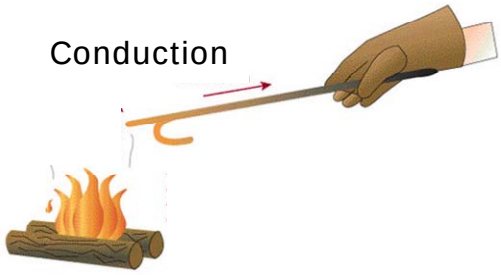
(b)

Fig. 1.3: (a) Stainless steel cooking pot. (b) Cobalt metal.

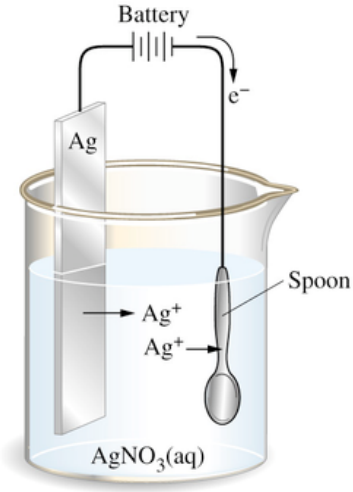
3.1 Properties of metals:

There are common properties shared by all metals:

1. Good **conductors of heat and electricity** as shown in Fig. 1.4a and Fig. 1.4b.
2. Show **metallic luster**. See in Fig. 1.4c.



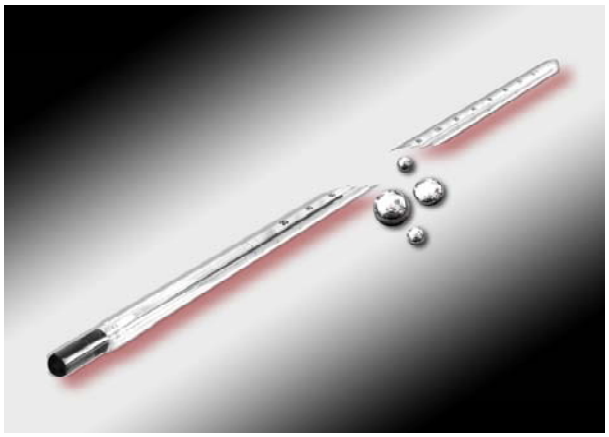
(a)



(b)

(c)

3. **Opaque**.
4. **Solids** in room temperature (except mercury which is liquid and is used in thermometers) as shown in Fig. 1.4d



(d)

Fig. 1.4: (a) Metals are good heat conductors. (b) Metals conduct electricity. (c) Metallic luster (d) Mercury thermometer

3.2 Metals and alloys

Pure metals are not used in most of the engineering applications. **Special properties** of metals can be achieved by mixing metals or adding other elements, to produce **alloys**.

3.3 Ferrous metals and alloys

The two general classes of ferrous metals are Steel, and cast iron. Steels are the most important ferrous metals and they are generally classified with their carbon content.

3.3.1 Types of steels

Steel can be custom-made to fit a wide range of requirements. Iron was replaced for nearly all its applications by a range of iron **alloys** called **steels**. See Fig. 1.5.

Fig. 1.5: An iron ore.

Carbon steel

Carbon steel is an alloy of iron (Fe) and carbon (C) .Plain carbon steels are the most important metal alloys in our world.

There are many different **types of carbon steel.**

1. Low carbon steels (0.01 to 0.25% carbon)

Car body panels are made from low carbon steel. See Fig. 1.6.

Fig. 1.6: Car body panels made from low carbon steel.

2. Medium carbon steels (0.25 to 0.6% carbon)

Crankshaft made from medium carbon steel. See Fig. 1.7.

Fig. 1.7: Crankshaft made from medium carbon steel.

3. High carbon steels (0.6 to 1.4% carbon)

Hand file made from high carbon steel. See Fig. 1.8.

Fig. 1.8: Hand file made from high carbon steel.

High speed steel (HSS)

Cutting tools are made from this type of steel. The tools are used for machining hard materials at high speeds. Fig. 1.9 shows a high speed steel drilling bit.

Fig. 1.9: Drilling bit made from high speed steel.

Cast iron

It is used for casting large gear wheels, engineer's vices, cylinder blocks and general types of castings used in engineering. See Fig. 1.10.

Fig. 1.10: Cylinder block made from cast iron.

Activity 1:

Watch the metals video (first 3 mins) and visit your classroom blog created by your instructor and comment on the following topic: What effect does the carbon content have on the steel properties?

3.4 Non-ferrous metals and alloys

Aluminum

Aluminum is **refined** from the ore called **bauxite (aluminum oxide)**. It is made by a process called **smelting**. Dubal is an **aluminum smelting** company in the emirate of Dubai.

Aluminum and its alloys can be **shaped** by most **forming processes**.

Pure aluminum is not a strong or hard metal. Aluminum can be alloyed with other elements such as **Silicon**, **magnesium**, and **copper** to make it **harder** and **stronger**.

Aluminum and its alloys are used to make many things, such as, **aircraft bodies**, **ships hulls**, **power cables**, **radiators**, **cooking pans**, **aluminum foil** for food products etc. See Fig. 1.11.

(a)

(b)

(c)

(d)

Fig. 1.11: (a) Aircraft frame structure (b) Ship's hull. (c) Radiator. (d)Aluminum foil

Copper

Copper is refined from an ore called **copper pyrites**. Man has used copper for over 5,000 years.

Copper can be alloyed with **Zinc** to make **Brass** and can be alloyed with **Tin** to make **Bronze**.

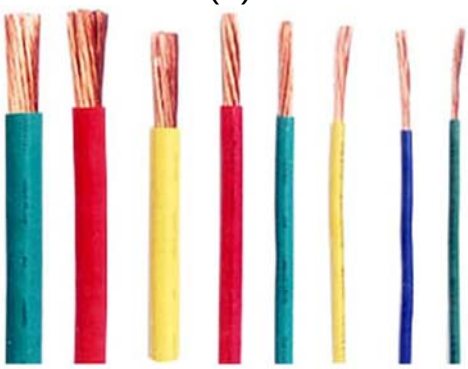
Copper is used for its **high thermal** and electrical **conductivity** and **resistance to corrosion** to make **electrical cables** and **wires**, the **bottoms of cooking pans** and **water pipes.** See Fig. 1.12.

Activity 2:

Look at an electric soldering iron and visit your classroom blog to do the following:

1. List the materials used to manufacture it.
2. Discuss what properties each of the materials used has and write them down.

(a)



(b)

(c)

(d)

Fig. 1.12: (a) Electrical cable. (b) Electrical wires. (c) The bottom of a cooking pan. (d) Water pipes and elbows.

Brass

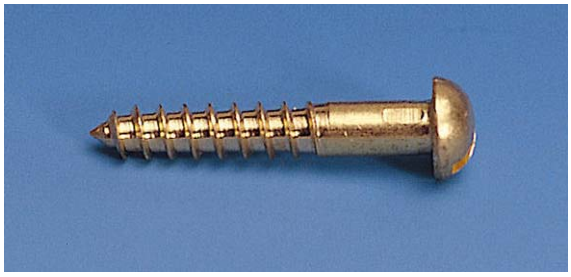
Brass has a **bright gold**-like appearance While **Bronze** is **reddish brown**.

Brass has better hardness and tensile strength than **copper**.

Brass may be rolled, extruded, drawn, forged and cast etc.

Some of its uses are **electrical plug contacts**, **screws**, **cartridge cases** and **jewelers.** See Fig. 1.13.

(a)



(b)

(c)

(d)

Fig. 1.13: (a) Electrical plug contacts. (b) Screw. (c) Necklace (d) Cartridge cases.

3.5 Identification of Metals

It is often necessary to determine the type of metals being used by observing its physical appearance. Some of the more common machine shop metals and their appearance, use, etc., are found in Table 1.1. Metals are usually identified by one of four methods:

1. Appearance.
2. Spark testing.
3. Manufacturer's stamp.
4. Code color painted on the bar.

The latter two methods are most commonly used and are probably the most reliable. Each manufacturer, however, may use his own system of stamps or code colors.

Table 1.1: Identification of metals.

Metal	**Category**	**Appearance**
Cast iron	Ferrous	Grey, rough sandy surface
Low carbon steel (Machine steel)	Ferrous	Black, scaly surface
High speed steel	Ferrous	Black, glossy
Stainless steel	Ferrous	Silver
Aluminum	Non-Ferrous	Light grey
Brass	Non-Ferrous	Yellow (various shades) rough if cast, smooth if rolled.
Copper	Non-Ferrous	Reddish brown

Activity 3:

Watch the metals video (minutes 3 to 9) and visit your classroom blog and answer the following question:

What is the best way to identify metals and why?

3.5.1 Spark Testing

Ferrous metals can be identified by observing a characteristic spark that result when the metals are ground with a grinding wheel.

An element such as carbon burns rapidly, resulting in a bursting of the particles. Depending on the composition of the metal that is being ground, spark bursts will vary in color, intensity, size, shape, and the distance they fly. Spark testing may be used to identify a number of metals as shown in Fig. 1.14.

3.5.2 Practical Task 1:

Select 3 different types of ferrous metals and one type of non-ferrous metal available in the work shop and try to identify them using the spark test. What are your observations for the non-ferrous metal?

3.6 Shapes and Sizes of Metals

Metals are manufactured in a wide variety of shapes and sizes. When ordering steel for work, it is recommended that it is purchased a little larger than the finished size - allow for the manufacturing operations.

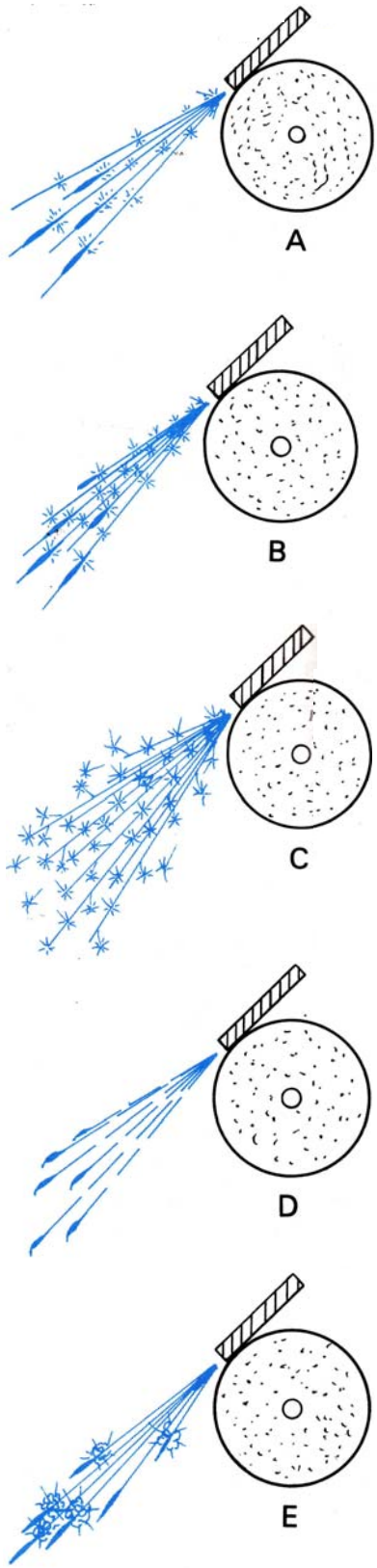


Fig. 1.14: (A) Low carbon steel. (B) Medium carbon steel. (C) High carbon or Tool steel. (D) High speed steel. (E) Cast iron.

3.6.1 Specifications for Purchasing

There is a proper method for specifying the sizes and dimensions of metal when ordering. See Fig. 1.15.

1. Round material has only two dimensions; therefore, when ordering, specify the diameter first and then the length.

For example: Ø25mm x 6 MTR

2. Flat or rectangular material has three dimensions: thickness, width, and length, and should be ordered in that sequence.

For example:2mm x 10mm x 6 MTR

3. Square material has three dimensions: however, the thickness and width are the same. When ordering, specify the thickness (or width) and then the length.

For example:5mm x 6 MTR

4. Hexagonal material has only two dimensions; the distance across flats and the length and should be ordered in that sequence.

For example: 15mm x 6 MTR hex bar.

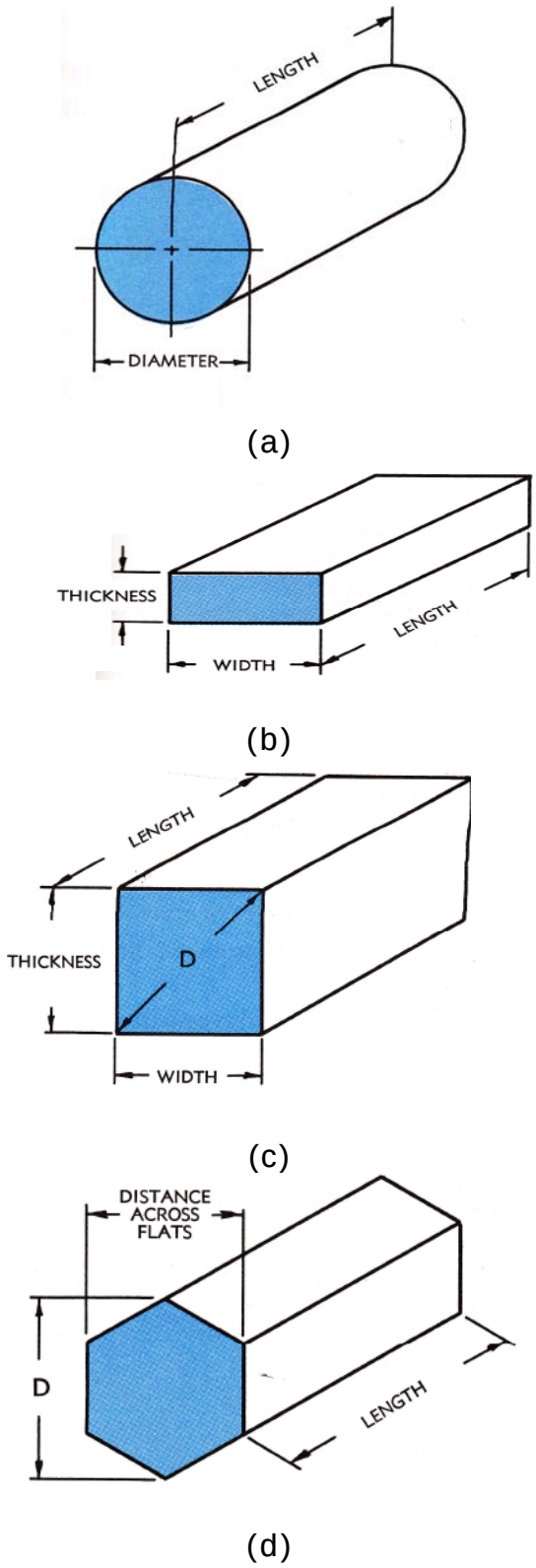


Fig. 1.15: (a) Round. (b) Rectangular. (c) Square. (d) Hexagon.

Activity 4:

Visit your classroom blog and comment on the following topic:

What is the difference between plate, sheet, strips, and bars?

4. Non-metals

Non-metals are basically defined as elements that are not metals.

4.1 Properties of non-metals:

1. They are **poor conductors** of **heat** and **electricity**.
2. They are **brittle**, **not ductile** in their solid state.
3. They show **no metallic luster**.
4. They may be **transparent**.
5. They have **low density**.

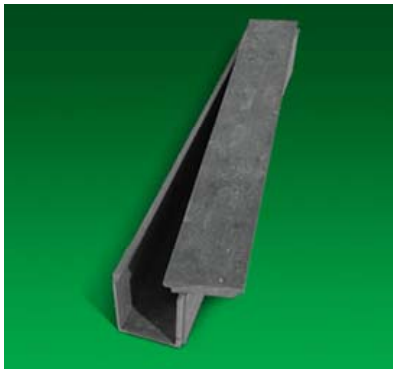
4.2 Examples of non-metals:

Plastics

Plastics are man made materials. Many plastics are made from **oil**. Plastics are now being used more and more in engineering and other applications. They are **light** and can be **made into complicated shapes** more easily and **cheaply** than metals.

The word "**plastic**" means to **shape easily**.

Applications include **cable ducts**, **kitchenware**, **car rear light lenses**, and **plastic pipes**. See Fig. 1.16



(a)

(b)

(d)

(c)

Fig. 1.16: (a) Cable duct. (b) Kitchenware. (c) Pipes. (d) Car rear light lenses

Ceramics

Ceramics is the production of objects by shaping pieces of clay which then hardened by baking.

Ceramic materials are non-metallic compounds.

They have many uses including:

Floor and **wall tiles**, **refractory linings for furnaces**, **glassware**, **special cutting tools** and **high voltage electrical insulation.** See Fig. 1.17.

(a)

(b)

(c)

(d)

(e)

Fig. 1.17: (a) Floor and wall tiles. (b) Glass ware. (c) Furnace lining. (d) Cutting tools. (e) High voltage ceramic electrical insulators.

Composite materials

Many modern applications of materials, such as aerospace, transport and sports, need unusual combinations of mechanical properties that cannot be found in one type of materials.

Composite materials consist of two or more different materials bounded together. An example of such materials is the Fiber-reinforced plastic (FRP) and its applications include **aerospace**, **construction industries**. See Fig. 1.18 (a-c)

(c)

Another example of this kind of material is the glass reinforced plastic (GRP) which is used in **building yachts**, **automotives**, and **sport equipment**. See Fig. 1.18 (d-e).

(a)

(b)

(d)

(e)

Fig. 1.18: (a) FRP spacecrafts. (b) FRP dome used in the construction industry. (c) FRP candy machine. (d) GRP yacht. (e) GRP car frame.

5. Project

Each group of 6 students **designs** a display showing specimens of metals (ferrous and non-ferrous) and non-metals. Label them according to the type, classification, and use.

6. Supplementary recourses:

1. Metals video.
2. Alloy steel video.
3. Plastic manufacturing video.
4. Composites manufacturing video.
5. Focus educational software (metals)

7. References:

1. Modern Engineering Materials edition 2.
2. Engineering Materials text book.
3. Material and Processes in Manufacturing; Degarmo, Black and Kohser, Prentice Hall, Ch. 2, pp. 38-45, 7th Ed., 1997.
4. AQA Design and Technology (Systems and Control Technology)
5. Machine Tool and Manufacturing Technology By Steve F.Krar, Mario Rapisarda and Albert F. Check.

Student's notes