**University of Guelph**

**ENGG*2120: Material Science**

# **Project: Material Identification**

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**Group (#04), Section 06**

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## 1.0 Introduction

The purpose of this experiment was to analyse different materials on the basis of physical and chemical properties. The unknown sample materials can be metal, ceramic, polymer or composite. Material identifying is important because materials are useful for a specific purpose because, subject to certain conditions, they function in some way. A material sample can be identified based on general characteristics. These properties include colour, smell, flavour, density, melting point, boiling point, conductivity and toughness.

A material is described as a substance to be used in certain applications. There are numerous materials around us, from buildings to spacecraft. On the basis of chemical and atomic structure samples are classified into general categories [7].

Metals and alloys are excellent conductors of electricity and heat. Because they are also ductile, they are ideal for electrical wiring. Metals are strong but malleable, which means that they can be easily bent or shaped. Five common metals are copper, lead, tin, nickel, and zinc. Alloys are stronger and tougher, less malleable, less ductile and more prone to corrosion. A combination of alloys is stronger as it includes atoms of different size components.For example- steel.

A ceramic is a solid material composed mainly of ionic and covalent bonds of an inorganic mix of metal, non-metal or metal atoms. Earthenware, porcelain and brick are common examples. [8] The ionic and Covalent bonds of ceramics have a wide range of distinctive properties, including high durability, high melting points, low thermal expansion, good chemical strength as well as brittleness. [9]

The polymers are materials consisting of long, repeating molecular chains.Polymers include covalent bonds between the polymer atoms, while Van der Waals forces hold the polymer macromolecules intact. Van der Waals is the weakest of all four kinds of bonds. Polymers are therefore highly elastic, can be melted easily, and have low resilience. Types of polymers include nylon polyethylene, polyester.

A composite material is a substance consisting of two or more substantially different physical or chemical materials that, when mixed, produce a material of different properties from its individual components. Example - plywood, fiberglass.

Many non-destructive experiments have been conducted for evaluating components for the shape and nature of the compounds, including strength of the rockwell, buoyance, conductivity and magnetic particle examination.

## 2.0 Experimental Apparatus and Procedures

### Conductivity test

Electrical conductivity is a measurement of the amount of electric current that a material can carry, or is capable of carrying a current. To measure the resistance of a metal sample of a specified length and surface, one simple ohmmeter would be used to calculate resistance using two sensors, one at each end of the sample.The ohmmeter uses the R = V / I equation automatically. This test distinguishes conductors from insulators by measuring the flow of free electrons on given samples.

**Weight analysis**

By using a top-load balance and a calibre, the mass and density of each material were determined.

**Rockwell hardness test**

It is the most widely used method for hardness testing. The Rockwell method measures an indenter's permanently depth of indentation by means of force / load. A sample is applied with a diamond or ball indenter first by a preliminary test force. The baseline indentation depth is determined after keeping the preliminary test force for a given length. To order to ensure precision, numerous tests were carried out and averaged. [10]

**Buoyancy Test**

A buoyancy experiment was performed on each material sample with water to ensure that each material's density was above / under one, verifying that a specified substance's density is above / below the water density. This is why an object whose density average is higher than the fluid in which it is immersed, tends to sink. The force can hold the sample afloat if it is less dense than the liquid.

**Magnetic Particle Inspection**

Analysis of Magnetic Particles (MPT) is a non-destructive research tool for the identification of surface and minor surface defects in most ferromagnetic materials such as iron, nickel, and cobalt and some of their alloys. The test was performed to assess whether a sample was ferromagnetic or not.

**Transparency Test**

A transparency test, also known as the clarity test, used to measure object transparency. Transparency refers to the optical distinction with which an object is shown by plastic film / sheet, glass, etc. The entity is said to be translucent when there is no dispersal or scattering of light through it.

**Bend Test**

The bending test is a simple and inexpensive quality check which enables both the ductility and solidity of a material to be evaluated. Bending measurements are conducted in order to twist the test substance at the midpoint, which allows a concave surface or curve to be moulded without a crack and usually to assess the fracture tolerance. [11]

## 3.0 Material H

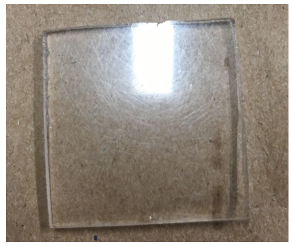

***Figure 1. Picture of material H***

### 3.1 Material Description

The material possesses a transparent square shape. The material is relatively solid and small in size with a length of 25mm and a width of 25.5mm. The material is also relatively light in weight with a total mass of 1.66 grams. The Material has relatively sharp edges which doesn't make it a perfect square with a little bit difference in the length and the width. But it feels smooth on both faces of the material.

### 3.2 Experimental Procedure

To identify the composition of the material various tests were performed during the lab to gain information on the material sample to identify the composition of the material sample. Some of the eligible tests that were performed on material H were: the bouncy test, the magnetism test, the conductivity test, the transparency test, and measurements of weight and dimensions of the material were taken.

The Bouncy test was used to test if the material floats or sink in water. The test was performed by placing the material in a cup of water and observing if the material sinks or floats, the material sank in water. Since the density and the Bouncy force are inversely proportional to each other and since material H sank in water then the Material has a relatively low bouncy force. The magnetism test was used to test the magnetic property of the material. The test was performed by placing a magnet on both sides of the material. Conducting the test on the material, material H is not magnetic. Moreover, a conductivity test was also performed using the multimeter on resistance setting, the material had a zero resistivity which concludes that the material is not conductive. A weight test was performed with the use of a top-loading scale yielding a result with 4 significant digits. A transparency test was also performed on material H by placing a white light source and observing the refraction of light through the sample. That said, the material is transparent and the light passes through the material. Finally,

The measurements of the material were taken using more than one device. The dimensions of the material (i.e: length, width, and height) were taken using a calliper which are then used to calculate the volume of the material. Moreover, the weight of the material was taken using the top loading balance which is then used along with the volume to calculate the density of the material.

### 3.3 Results

The experimental procedure conducted allowed for the collection of both quantitative and qualitative results by conducting several tests on material H. The density and volume were further calculated using the measured length, width, thickness, and the weight of material H.

***Table 1. Measurements and Calculations of Material H***

| **Test Performed** | **Measurements/Observation** |
|---|---|
| Buoyancy | Sinks in water |
| Transparency | Transparent |
| Conductivity | Not conductive (i.e: resistance = $0\,\Omega$) |
| Magnetic | Not magnetic |
| Length | $25.36\ mm$ |
| Width | $25.50\ mm$ |
| Height | $2.13\ mm$ |
| Mass | $1.66\ g$ |
| Volume | $1.38\ mm^3$ |
| Density | $1.20\,g/cm^3$ |

### 3.4 Discussion

The physical properties allow for select few materials to be predicted as the sample material H. Based on the experiments conducted as mentioned above it can be assumed based on observations that the material is a polycarbonate polymer plastic. This can be assumed and is supported by the conductivity test which determined that material H was indeed not conducive with zero resistivity, and the density of material H was obtained to be $1.20\,g/cm^3$. The density of polycarbonate plastics density is about $1.20\,g/cm^3$ which is stated by the density Omnexus data table. [10]. That said, we were unable to perform some other tests for example the Rockwell Hardness test since we hypothesize that the sample would fracture if we apply a load into it, and the melting point test due to the fact that we are not allowed to spoil the sample material. Moreover, the material was not magnetic. Since the material is not magnetic neither conductive we can conclude that the material is not a metal.

Moreover material H could not be a ceramic since it is not brittle and not heavy in weight since the measured weight material H was measured to be 1.66 grams. So from the information and the data collected we can eliminate the possibilities of the material being a metal or a ceramic.

### 3.5 Material Identification

In conclusion, based on the tests and experiments that were conducted and the results that were calculated and observed from the different tests that were performed on material H, we can conclude that material H is in the class of polymers. Since material H sinks in water, not electrically conductive, and the density of the material H was calculated to be $1.20\, g/cm^3$. the density of polycarbonate is 1.15-1.2g/cm^3 according to the Omnexus data table about polycarbonate polymers. [10]

Polycarbonates are known for their high transparency, light weight, chemical and hear resistivity. Moreover, having a good electrical insulation properties (i.e: highly resistive). Due to the fact that polycarbonates are transparent they have many different applications. Polycarbonates are also known as plastics which are used in many different applications which are typically used for robust materials such as glass like surfaces. [13]

## 4.0 Material I

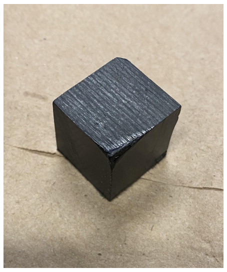

***Figure 2. Picture of Material I***

### 4.1 Material Description

Material I is a dark-black cube shaped object. The general outline of the cube is uneven with some edges slightly scratched (see ***Figure 2***). The surface of the cube is generally smooth. However, there are two sides that are somewhat smoother than the rest.

### 4.2 Experimental Procedure

To determine the physical properties of Material I, several tests were performed and results were recorded accordingly. Firstly, the measurements of the material were taken using the calliper and the analytical balance provided in the lab. The conducted measurements are used to calculate the volume and the density of the material, which are later on used to help classify important properties of the material.

The Rockwell Hardness test was not conducted since material I is not a brittle material. A conductivity test and a test for magnetic attraction were done as well, as they are good indicators to determine the class of the material, and therefore prove that the material is not classified as a metal. Finally, a buoyancy test was conducted to determine if the material is buoyant or not. Since material I sank in the water during the performance, it was concluded that material I has a low buoyancy force.

### 4.2 Results

A series of tests and measurements are done in order to narrow our search for the identification of this unknown material. One of the measurements that may be useful is the density of the material. For calculating density, measurements using the calliper are taken (i.e. length, width, and height). Multiplying length width and height presented a volume. In addition, the material is weighted to formulate the data. Using the mass and volume measurements, density of the material is calculated.

***Table 2. Measurements and Calculations of Material I***

| **Test Performed** | **Measurements/Observation** |
|---|---|
| Buoyancy | Sinks in water |
| Length | 17.76 $mm$ |
| Width | 16.68 $mm$ |
| Height | 16.40 $mm$ |
| Mass | 6.62 $g$ |
| Volume | 4.86 $mm^3$ |
| Density | $1.36\, g/cm^3$ |

### 4.3 Discussion

The weight of the sample was recorded using the top loading balance provided in the lab. The top loading balance has a readability of up to two decimal places and . The weight of the sample is 1.66 g, which is "then" used to calculate the density of the material, presented in the table below (see ***Table 2.***) Determining whether or not the material is conductive eliminates possibilities of metals and other conductive materials (there are no materials that are conductive other than metals). This test was performed several times to ensure the material was not one-sided conductive. On every trial, the multimeter read a value of 0.00. This implies that there is no current running through the material. Performing the conductivity test allowed to eliminate possibilities of a materials that are metals or metal like. According to the conductivity test that was performed in the lab, material I was eliminated as a metal.

Another test that may be of value is the buoyancy test. This test can further fortify our density results. Knowing whether the material floats or sinks, exemplifies that the material may be more or less than water. For this test we used a 250 mL beaker and added water to it. Material I was then gently placed on the surface of the water (dropped in the beaker) and it sank to the bottom of the beaker. The initial hypothesis was that it would float which this test revealed to be untrue. Material I sank in the water when performing the Buoyancy test. This illustrates that Material I, similar to Material H, has a low buoyancy force.

**4.4 Material Identification**

According to the calculations and tests performed in the lab, Material I was identified as a polymer and categorized as polyoxymethylene (POM), also known as polyformaldehyde, which is an engineering thermoplastic known for its hardness, stiffness and low friction coefficient. Additionally, polyoxymethylene has an excellent high abrasion and heat resistance. Even though the material felt and looked like some type of plastic, but polymer is a more accurate description/identification. However, classifying the material as plastic can also be partially right, since plastics are classified as polymers.

**5.0 Material C**

***Figure 3. Picture of material C***

**5.1 Material Description**

Material C is a shiny, opaque, silver cylinder (Figure 5.0). The two circular faces are jagged, presumably from being cut, while the other rectangular face is smooth. Also, the two circular faces have many dents, which seem to be from previous hardness tests conducted. The diameter of the cylinder is 16.86 mm, and with a height of 5.91 mm.

**5.2 Experimental Procedure**

The following experiments were carried out on material C:

a. Qualitative Observations
b. Weight Analysis
c. Rockwell hardness test
d. Buoyancy Test
e. Magnetic attraction
f. Bend test

Experiment a. was the first test conducted on the material. Qualitatively, many observations such as the colour, opacity, and relative hardness of the material, can aide in a hypothesis of the material of the object.

Experiment b. aided in the determination of the mass. The mass is later to be used to determine the density of the material, to narrow down which type of material is being identified.

Because of the previous tests, it was apparent that material C was a hard object, and therefore experiment c. was conducted. The reading from the Rockwell hardness test can then be compared to published values of other known material.

Experiment d. was conducted to determine what the density of the material is in comparison to water. This experiment goes hand in hand with experiment b, as the mass will be used to calculate the density.

Experiment e. was conducted to determine if the material is ferrous.

Experiment f. ties in with experiment, as because the material appears to be hard, then one can assume it will not bend. This aides in determining the permeability of the material

**5.3 Results**

***Table 3. Measurements and Calculations of Material C***

| **Test Performed** | **Measurements/Observation** |
|---|---|
| Diameter | 16.86 mm |
| Height | 5.91 mm |
| Mass | 18.23 g |
| Volume | 5.27779 cm^3 |
| Density | 3454 kg/m^3 |
| Rockwell Hardness | 96.12 HRBW |
| Buoyancy | Sinks |
| Magnetism | Magnetic |
| Bend Test | Does not bend |

## 5.4 Discussion

The first test done, qualitative observations, led to the hypothesis that the material is some type of metal. It was unlikely that the material would be a ceramic or a polymer. Through the bend test, it also supported the fact that the material is highly likely to be a metal, because metals are not permeable when they are not in the form of a sheet.

The density of material C was determined to be 3454 kg/m^3, which goes with the fact that the material sank in water. The density of water is 998 kg/m^3, whereas the density of the material is much higher than that of water. When comparing the density of material C to that of theoretical densities, it matches up mostly with that of Titanium [15]. The density of Titanium is 4.51 g/cm^3. The difference in the calculated density and the theoretical density can be attributed to human error.

The Rockwell Hardness value of Titanium on the B scale is 88 [16], as compared to what was measured, 96.12. Because a Rockwell Hardness test could be conducted in the first place, it’s clear that the material is a metal, and not something like a polymer or a ceramic

## 5.5 Material Identification

Based on the above analysis, it was determined that Material C is a metal, more specifically, Titanium. The various tests conducted and comparisons with published theoretical values point towards the hypothesis of Titanium. The most important factors considered were the Rockwell Hardness test, density comparison, and the qualitative observations. Titanium is mainly used in engine applications. Because of their high tensile strength to density ratio, high corrosion resistance, and ability to withstand moderately high temperatures without creeping [16], they are great metals to be used in compressor blades, or hydraulic system components.

## 6.0 Material B

***Figure 4. Picture of material B***

## 6.1 Material Description

Analyzing material B, there are several distinct physical properties that can help aid in the identification of the material. The material is a rectangular prism of dimensions 11.02mm and 11.05mm by 15.70mm, meaning the shape is hexagonal with error, therefore more accurately orthorhombic. The sample is a silver-grey in nature and appears to have an orange-brown rust or discolouration. The material is both dull and jagged in texture, with smoothed out circular edges.

### 6.2 Experimental Procedure

During the lab various tests were performed in order to gain adequate information on the sample to ultimately identify the material of the sample. These tests include; the Rockwell hardness test, the magnetism test, the conductivity test, and measurements of weight and dimensions of the material. Testing for hardness used the material Science Lab's Rockwell Hardness Machine on scale B, the value given from the machine can be cross referenced to other materials and the associated value. The magnetism test, involved comparing various materials attraction to a magnet to get a qualitative assessment of material B. A test for conductivity was also performed using the multimeter on resistance setting, although difficult to acquire an accurate reading of the resistivity value, the presence of a reading allowed for the qualitative observation that the material was indeed conductive. A weight test was performed with the use of a top-loading scale yielding a result with 4 significant digits. Finally, a calliper was used to determine the length, width and height of the sample material B.

### 6.3 Results

The experimental procedure conducted allowed for the collection of both quantitative and qualitative results for material D, in which the calculations of volume and density were made.

***Table 4: Quantitative Measurements and Qualitative Observations on Experiments for Material B***

| Test Performed | Measurements/Observation |
|---|---|
| Rockwell Hardness | 87.50 HRBS |
| Magnetism | Magnetic |
| Conductivity | Conductive |
| Length | 11.05 mm |
| Width | 11.02 mm |
| Height | 15.70 mm |
| Mass | 15.06 g |
| Volume | 1.912 $cm^3$ |
| Density | 7.877 $g/cm^3$ |

### 6.4 Discussion

The physical properties allow for select few materials to be predicted as the sample material B. Based on knowledge of metals, it can be assumed based on visual and tactile observation that the material is either a metal or an alloy. This can be assumed and is supported by the conductivity test which determined that material B was indeed conductive. As explained *Material Science and Engineering An Introduction* [5], metals are extremely good conductors of electricity and will have resistance, it can be confirmed that the material is a metal or an alloy. The observation that material B was magnetic allows for the specification that the sample is a magnetic metal such as iron, nickel, cobalt and their respective alloys [2]. The calculated density of 7.877g/cm$^3$ or 7877kg/m$^3$ can be referenced to the theoretical density of materials and lies in the range of Bronze Aluminum [3] , Bronze Lead and Iron [6]. Both the bronze aluminum and lead, are usually non-magnetic, however an alloy containing Iron or Nickel can increase magnetic properties. Despite the possibility of material B being of Iron Alloy, the density of the sample is more accurately referenced to that of Iron, 7870kg/m$^3$ [5] As well as the physical properties supporting the conclusion of identification as Iron, the orange-brown discolouration of the sample is a result of corrosion, which is a common property to Iron. This property can be associated with other metals, such as steel [2], however, along with the other physical properties and tested observations, it is clear that the sample is not steel. Finally, looking at the value given the Rockwell Hardness Machine Scale B of 87.50HRBS and comparing the value to that of a theoretical Iron, which yields 86HRBS. Steels have a Rockwell Hardness value between 60-70HRBS, eliminating the possibility of the material being steel based on this observation.

### 6.5 Material Identification

Based on the results obtained from the visual observation, magnetism and conductivity testing, it is clear that the material is a metal. More specifically, through the density, hardness and corrosive property, it was determined that the material was Iron. The consistency with a theoretical Iron sample for all the observations, measurements and calculations, demonstrates the certainty that material B is Iron. As mentioned briefly in the discussion, Iron has magnetic properties strong enough to concentrate magnetic fields, this makes Iron useful in many different electrical systems. Electric motors using electromagnets are made up of an Iron Core. There are several other uses for Iron, such as manufacturing Steel or use in civil design.

## 7.0 Conclusion

A significant number of qualitative analyses are carried out to establish the category class of which unidentified products belong, and each substance is divided into separate classes, depending on its qualitative characteristics. Initially, two of the materials were assumed to be metals on the basis of the visual inspection. Polycarbonates and polyoxymethylene are the other two samples, both of which are polymers. Metal B is a metal of a high Rockwell toughness and corrosion. Metal B is clearly Iron owing to its strong magnetic properties. Materials I and H are identified as a polymer since they have no electrical conductivity. The density measurements have been carried out for Materials I and H, which results in materials being classified as a polymer. Electricity was rapidly carried out by sample C and confirmed to be a metal type. Tests of density and hardness supported the hypothesis that the component is Titanium. According to the individual features and properties, the four unspecified material samples have been accurately characterised through various experiments.

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