Material Science – ENGG*2120: Fall 2017
LAB SUBMISSION COVER SHEET
(Must be included for all group submissions)

Lab Performed: Materials Identification Project

Date Performed: Friday, September 15th, 2017

Date Submitted: Friday, October 6th, 2017

Group Number: K1

GTA Name: Richard

GROUP PARTICIPATION EVALUATION FORM

*****ALL GROUP MEMBERS MUST SIGN TO RECEIVE THEIR MARKS*****

By signing the cover sheet each member is stating that they made a significant contribution to the writing of this lab report and that the distribution of sections completed is accurate.

One form is required for each group report submitted. One report is to be submitted **per group.**

All submissions to be submitted electronically to the dropbox in Courselink by **NO LATER THAN** 4:00 p.m., two (2) weeks after the assigned experiment is performed (unless otherwise indicated in the course outline).

Group Members		Sections Completed
Name (Printed)	**Signature**	
Noah Montag		Results (Specific for Samples A, B and C)
Melissa Hardy	MHardy	Summary, Introduction, Conclusion, Material Descriptions, Materials Identification for Material C
Daniel Sherman		Experimental Apparatus and Procedure (Overall), Experimental Procedure (Specific for each Sample), Materials Identification for Materials A and B
Bilal Ayacche		Discussion, References

MATERIALS IDENTIFICATION PROJECT

Group K1: Noah Montag (0975514), Melissa Hardy (0960180), Daniel Sherman (0954083), Bilal Ayacche (0988616)

6th October 2017

*ENGG*2120*

Dr. Ryan Clemmer, P.Eng. | University of Guelph SOE

SUMMARY

Within this report, three characteristically different materials were identified via methods of non-destructive experiments involving thermodynamic, electromagnetic, and qualitative techniques. Two of the given materials, which possessed metallic qualities, were tested by sanding down a small portion of the outer layer to determine if oxidation had occurred. Additionally, a magnetic and multi-meter were used to determine whether the materials possessed magnetic and/or conductive properties, and a Rockwell Hardness test was performed. Finally, a calorimeter was used to calculate the specific heat capacity of each respective sample and dimensions taken by a caliper and mass measured by an analytic scale were used to calculate their densities. The latter tests were also done on the plastic sample, as well as a test in which the sample was boiled to determine if the heat distortion (softening) temperature of the material was below or above 100°C.

Based on the observations recorded during all of these tests, the identities of the samples were predicted. Because of its qualitative characteristics, the identity of the plastic was narrowed down to polyethylene or nylon, but the physical and thermal characteristics of nylon (density = 1.16 g/cm^3; specific heat capacity = 2.3 J·g/K) were much closer to that of the sample (density = 1.15 g/cm^3; specific heat capacity = 2.7 J·g/K).[2] The melting point of polyethylene is approximately 110°C (whereas nylon melts at 190-350°C), and since the sample reached a maximum temperature of 118°C while being boiled and still remained completely solid, this eliminated polyethylene as a potential identity of the sample.[3,4] And even though the specific heat capacity of polyethylene (3 J·g/K) was closer to the calculated value of the sample than that of nylon, it was weighted with less importance due to the fact that there were multiple sources of error within the calorimetry experiment, including imprecision of the testing apparatus and human error. In comparison, the calculation of densities involved much more precise equipment, and thus is much more reliable.

With regards to the metallic samples, identities were narrowed down with reference to the observations from the Rockwell Hardness test. Since Material A had a hardness of C49, that reduced the potential material identities to that of wrought iron steel or cast-iron steel. Using this information in combination with the calculated density and specific heat capacity of the sample, cast-iron steel was selected as the most likely identity. As for Material B, the same process was used, and out of the two contestants, high-carbon steel and low-carbon steel, low-carbon was the most probable. Again, the specific heat capacity was weighted with less importance than density due to its larger sources of error.

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Introduction

In this experiment, three distinct materials were analyzed using non-destructive methods to determine their characteristics and ultimately their identity. Of the three samples, two were evidently metallic, and the third, a plastic. Because of the constraint on the identification procedures, innovation and collaborative thinking were used in the process of their conception. By looking at the physical characteristics of the samples, their identities were deduced to those of materials with common characteristics. Then, the contrasting characteristics of these potential materials were selected to be compared and procedures to illustrate the indicative characteristics were brainstormed, reduced to those with highest feasibility, and then fully developed.

Specific heat capacitance, heat distortion temperature, hardness, density, presence of coating/oxidation, magnetism, and electrical conductivity were selected as the characteristics to best identify the materials. To determine these, the methods of calorimetry, boiling, sanding, measuring, applying magnets and a voltmeter were used and respective results were recorded. Based off of these recorded observations, the identities of the materials were deduced and supported by scientific evidence.

Experimental Apparatus & Procedures

Experimental Apparatus

For this assignment, the equipment used were:

i. Electronic calipers to measure the dimensions of each material
ii. Electronic balance to determine the mass of each material
iii. Rockwell Hardness tester to measure the hardness of each metal
iv. Magnets to determine if each material was magnetic
v. Current source to test the conductivity of each material
vi. Stovetop, pot, tongs, digital thermometer, measuring cup and a basic calorimeter to measure the standard heat capacity of the material

Experimental Procedure

To determine the identity of each material, several tests were used to first narrow down the list of potential materials. These tests measured the material's density, hardness, conductivity, and magnetism. All appropriate safety measures were used when conducting the following tests.

The first thing that was done in the lab was each of the material's physical qualities that were visible with the eye were identified and recorded. Their height, length and width (in the case of material C, only its diameter and height) were measured and recorded for later use, as well as each material's colour and transparency.

The next test that was done was to figure out the density of each material. Two of the samples were shaped as a rectangular prism and one was cylindrical, so the process that was used differed slightly, but yielded the same data. The process for calculating each density is as follows:

(i) For materials A and B, electronic calipers were used to measure the length (l), width (w), and height (h). For material C, electronic calipers were used to measure the diameter (d) and the height (h). To ensure that the measurements were accurate, the calipers were analyzed to ensure proper alignment.

(ii) For materials A, B and C, the electronic scale was used in the lab to measure the masses of all three samples.

(iii) The densities were calculated using the general formula:

$$\rho = \frac{m}{V}.$$

For materials A and B, the volume was calculated using:

$$V = l \cdot w \cdot h,$$

and for material C, the volume was calculated using:

$$V = \frac{\pi}{4} d^2.$$

The next test that was conducted was the Rockwell hardness test. Multiple tests were conducted to ensure numerical continuity, and as such, only one value is listed.

Afterwards, magnets were used to test the magnetic properties of each material. Each of the materials was tested for ferromagnetism by being brought near the metal desks in the shop (although any piece of metal that isn't ferromagnetic will work). A material was determined to be ferromagnetic if it was attracted if it did not attract metals to it. Materials were also tested if they were attracted to a magnet. This was done so by holding a strong magnet in close proximity to each of the three samples.

Another test that was conducted was a calorimetry experiment to find the standard heat capacities of the metals. All the samples were placed in a pot of boiling water on a stove to heat them up. Then, 100 mL of water was placed into the calorimeter set-up. Using the tongs, a sample would be taken out of the pot and the temperature would be measured with the digital thermometer. Then, the sample and the lid would be placed on the calorimeter, and the thermometer was watched until the temperature stopped rising. That temperature would be recorded as the final temperature. The contents of the calorimeter would be emptied and the process would be repeated for the other samples, and multiple trials recorded. Then, the standard heat capacity would be calculated using the following formula:

$$C_{metal} = \frac{m_{water} \cdot C_{water} \cdot (T_{final} - T_{initial-water})}{m_{metal} \cdot (T_{final} - T_{initial-metal})}$$

The final test that was conducted was the conductivity test. This was done by using the current source in the lab. The device was turned on and each of the probes were held in contact with the material. If the current source beeped, then current was able to go through the material. This was also used to determine if a material was conductive or not.

Material A

Material Description

Material is a rectangular based prism in shape that is black-ish in colour, slightly worn out, hard, opaque, heavy, and has a rough surface. In comparison to material B, it is significantly taller.

Experimental Procedures

For material A, many of the tests were helpful, but some were more imperative than others in determining this material's identity.

Material A's physical properties, such as colour and mass were recorded. It led the group to the basic prediction that the material was some kind of metal.

The Rockwell hardness test was quite helpful in determining the sample's identity. It helped narrow down the sample to be some kind of hard-filed metal.

Testing the magnetic and conductive properties with magnets and a current generator strengthened the argument that the sample was some kind of metal.

The calorimetry test was used on this material. It aided in identifying the material, as it was a quantitative number that was looked up in tables.

Utilizing the method above, the density of this material was found, and it helped a lot in identifying the sample.

RESULTS

Below is a table that houses the data that was collected through several measurements, experiments, and calculations.

Table 1: Data Collected About Unknown Material A

Hardness	Density (g/cm^3)	Length (cm)	Width (cm)	Height (cm)	Conductive	Magnetic	Mass (g)	Transparency	Average Standard Heat Capacity (J·g/K)
C49	7.47	1.30	0.864	3.20	Yes	Yes	26.8	Opaque	0.549

Sample Density Calculation:

$$\rho = \frac{m}{V} \qquad V = l \cdot w \cdot h$$

$$\rho = \frac{m}{l \cdot w \cdot h}$$

$$\rho = \frac{26.8\ g}{1.30\ cm \cdot 0.864\ cm \cdot 3.20\ cm}$$

$$\rho = 7.47 \frac{g}{cm^3}.$$

Sample Calculation for Specific Heat Capacity:

$$C_{metal} = \frac{m_{water} \cdot C_{water} \cdot (T_{final} - T_{initial-water})}{m_{metal} \cdot (T_{final} - T_{initial-metal})}$$

$$C_{metal} = \frac{(26.8g) \cdot (4.184 \frac{J}{g℃}) \cdot (25.2℃ - \ 23.8℃)}{(26.8g) \cdot (25.2℃ - \ 63.7℃)}$$

$$C_{metal} = \ 0.568 \frac{J}{g℃}$$

DISCUSSION

To identify the assigned material assigned, three experiments were conducted that helped to extract valuable information and properties of the sample. The information collected narrowed the options to a more accurate prediction.

The first test was a physical appearance test. Through this experiment, it was able to be determined that Material A was a metal. The fact that the material was magnetic, hard, heavy, rough and opaque narrowed down the options further and henceforth only ferrous materials were considered. Materials such as aluminum, copper, lead, tin, titanium and zinc were eliminated from potential options.

A Rockwell Hardness test was conducted on the Material A. A value of 49.0 (Rockwell C scale) was obtained. Analyzing peer evaluated literature, and cross-referencing hardness values with our results it was able to be predicted that a possible candidate was a hard-filed steel. This result was not strong enough to come to a final conclusion, however, and therefore further experiments were needed to come up with a more specific identity.

A density calculation experiment was later conducted to help narrow down the options even further. A more specific identity was found by comparing the calculated density of 7.469 g/cm^3 and the density values in SolidWorks 2017.

To finalize the prediction, one more experiment was conducted. A calorimetry set-up determined the specific heat capacity. This experiment was explained above in the experiment procedure section.

Through this experiment we were able to find a calculated heat capacity value of 0.447 J/g °C. After calculating the heat capacity, it was noted that due to uncertainty native to the experiment, all the calorimetry setup was able to do was compare the thermal conductivity of the metals.

Using all the experiments mentioned above, it was deduced that Material A was cast iron steel.

Material Identification

Material A was found to be cast iron steel, with the help of the densities provided by SolidWorks. Cast iron steel is most commonly used for cooking-ware, as it has good oil retention.

Material B

Material Description

Material is a grey, square-based prism that has oxidized slightly. It is hard, heavy, opaque, smooth, and short in comparison to Material A.

Experimental Procedures

For Material B, each of the tests conducted provided information about the sample that was able to be used to identify the material. That being said, some tests and information were much more useful than others.

Its physical properties were useful to observe because its colour and transparency were able to be recorded, and the material's ductility was able to be predicted. The physical properties of the material allowed a rudimentary prediction that the material was a metal.

The Rockwell Hardness scale aided in the identification of the material relative to the other materials. Having a general grasp on how hard the substance was provided a further narrowing to what material the sample was. Based on the number from the Rockwell hardness test, it can be deduced that Material B is some sort of easily-machined steel.

Testing its magnetic properties provided the basis for the argument that this material was a metal. Its conductive properties allowed for a stronger argument.

The calorimetry test was used for this metal. What was found out was that Material B was better at conducting heat than Material A.

Using the method outlined above to calculate the material's density, the sample's density was found. It was an integral piece of information to determining Material B's identity.

Results

Below is a table that houses the data that was collected through several measurements, experiments, and calculations.

Table 2: Data Collected About Unknown Material B

Hardness	Density (g/cm^3)	Length (cm)	Width (cm)	Height (cm)	Conductive	Magnetic	Mass (g)	Transparency	Average Standard Heat Capacity (J·g/K)
C5.0	7.81	1.11	1.10	1.61	Yes	Yes	15.3	Opaque	0.482

Discussion

To identify the material assigned, several different experiments were conducted that helped collect enough data to predict what type of material was assigned and prove that assumption.

Results from the first experiment (Physical Observance) gave enough information to interpret that the material was a type of a metal or some type of a metallic alloy. Just by feeling the rough surface and the weight of the material, that assumption was able to be made.

Testing the metallic properties of the material reaffirmed the assumption. The sample was attracted to the magnet when held within a close proximity.

The Rockwell Hardness test was a good indicator of the material's identity. The Rockwell Hardness number, when converted to a Brinell Hardness number, narrowed the material's identity to an easily-machined steel.

During the next experiment, the density of the material was calculated. After analyzing the density from the sample, it was compared with the densities of common metals that could be possible candidates. This step depended on the assumption we made in the first and the second experiment. We were able to narrow down our options to a low carbon steel. As there are many low carbon steels in the SolidWorks Material Database, a more specific identity for the sample was not able to be found.

A calorimetry experiment was used next to determine the specific heat capacity of the sample. But due to high uncertainty values, the only use out of this information was to compare the thermal conductivity of this sample and the other metal.

Material Identification

With the help of the SolidWorks density database, Material B was found to be a low carbon steel. Low carbon steels are typically used for cold headed fasteners and bolts in building applications.

Material C

Material Description

Material C is a translucent cream-coloured cylinder. It is hard to the touch, but light when held. There were brown marks on one of the edges.

Experimental Procedures

All the experiments were able to be conducted on this material, with the exception of the Rockwell Hardness test, because the material was not hard enough.

Upon observing the physical properties of Material C, the colour, mass and relative transparency were found and recorded. The texture of the material was also observed upon handling the sample. The physical properties of the sample pointed to the same physical properties of certain types of plastics, leading to the rudimentary prediction that is was some kind of polymer.

The magnetic and conductive properties were testing using the methods outlined above. The results provided more evidence to the argument that the sample was not a metal, and potentially was a polymer.

The standard heat capacity was found for this material, and it aided in its identification. It was much larger than Materials A and B, indicating that it was not as efficient at conducting heat.

The density of the material aided in the identification significantly.

Results

Below is a table that houses the data that was collected through several measurements, experiments, and calculations.

Table 3: Data Collected About Unknown Material C

Density (g/cm^3)	Diameter (cm)	Height (cm)	Conductive	Magnetic	Mass (g)	Transparency	Average Standard Heat Capacity (J·g/K)
1.151	2.55	0.722	No	No	4.25	Translucent	2.68

DISCUSSION

To identify the material assigned, a handful of different experiments were conducted that helped collect enough data to predict what type of material the sample was.

Results from the first experiment (Physical Observance) gave enough information to safely deduce that the material was a type of plastic. This prediction was supported through the material's density, appearance, surface's texture and touch of the material. This narrowed the list of materials we had to research and helped focus on finding what type of plastic the sample was.

A conductivity test was performed which further proved that the sample was not a metal due to its lack of electrical conductivity. This test eliminated all metals from its possible identity.

After those experiments were completed and data collected was analyzed, the next test that was conducted was a buoyancy test. Through this experiment, the list of possible materials was narrowed down even further. After placing the material in water, Material C sank in. This reveals that Material C has a relatively high density compared to other plastics. No water was absorbed during this experiment, which is common with plastics. This information was very useful as it narrowed the options even more.

After those experiments were conducted, the data collected was convincing enough to predict what material was assigned and eliminate options such as metals, ceramics and composites. To prove the prediction, two more experiments were conducted.

Testing the specific heat capacity helped narrow down the material a bit more, as it eliminated plastics with a completely different specific heat capacity.

The next experiment was a density calculation. This test was one of the most effective experiment for this specific material. This experiment helped support the prediction by using the

TABLE 16-2 ■ *Properties of selected thermoplastics*

	Tensile Strength (psi)	% Elongation	Elastic Modulus (psi)	Density (g/cm^3)	Izod Impact (ft lb/in.)
Polyethylene (PE):					
Low-density	3,000	800	40,000	0.92	9.0
High-density	5,500	130	180,000	0.96	4.0
Ultra-high molecular weight	7,000	350	100,000	0.934	30.0
Polyvinyl chloride (PVC)	9,000	100	600,000	1.40	
Polypropylene (PP)	6,000	700	220,000	0.90	1.0
Polystyrene (PS)	8,000	60	450,000	1.06	0.4
Polyacrylonitrile (PAN)	9,000	4	580,000	1.15	4.8
Polymethyl methacrylate (PMMA) (acrylic, Plexiglas)	12,000	5	450,000	1.22	0.5
Polychlorotrifluoroethylene	6,000	250	300,000	2.15	2.6
Polytetrafluoroethylene (PTFE, Teflon)	7,000	400	80,000	2.17	3.0
Polyoxymethylene (POM) (acetal)	12,000	75	520,000	1.42	2.3
Polyamide (PA) (nylon)	12,000	300	500,000	1.14	2.1
Polyester (PET)	10,500	300	600,000	1.36	0.6
Polycarbonate (PC)	11,000	130	400,000	1.20	16.0
Polyimide (PI)	17,000	10	300,000	1.39	1.5
Polyetheretherketone (PEEK)	10,200	150	550,000	1.31	1.6
Polyphenylene sulfide (PPS)	9,500	2	480,000	1.30	0.5
Polyether sulfone (PES)	12,200	80	350,000	1.37	1.6
Polyamide-imide (PAI)	27,000	15	730,000	1.39	4.0

calculated density value in Table 3 and comparing this value with the densities found on Table 16-2 (Properties of Selected Thermoplastics).[5]

After comparing the results, it was determined that the material was a polyamide, nylon specifically.

Material Identification

Material C is Nylon which is a synthetic polymer. Nylon is used to manufacture parachutes, cords, and sails. Nylon fibers are useful in making fabrics, rope, carpets and musical strings, mechanical parts including machine screws, gears and power tool casings. It is also used in the manufacturing of heat-resistant composite materials.

Conclusions

Overall, the identities of the three samples were selected through the comparison of physical and chemical properties, as well as comparing qualitative and quantitative results. As Material C was the only sample that did not conduct electricity, and by looking up the density and standard heat capacity, it was able to be deduced that Material C was more specifically Nylon instead of any other type of plastic. The other two samples were some type of metal that needed to be distinguished. Using the densities provided by SolidWorks 2017, the two samples were able to be determined, and the type of alloy was more accurately selected. Material A was found to be cast iron steel and Material B was found to be some type of low carbon steel, as there were many different choices with the same density that matched.

References

[1] Askeland, Donald R., and Wendelin J. Wright. The science and engineering of materials. 7th ed., Stamford, CT, Cengage Learning, 2011.

[2] "Material Thermal Properties Database." *Burning Item Database: Department of Fire Protection Engineering*, University of Maryland School of Engineering, www.firebid.umd.edu/material-database.php.

[3] "Polyethylene | Chemical Composition and Properties." *All About Plastic Moulding*, D&M Plastics Inc., www.plasticmoulding.ca/polymers/polyethylene.htm.

[4] "Nylons | Chemical Composition and Properties." *All About Plastic Moulding*, D&M Plastics Inc., www.plasticmoulding.ca/polymers/nylons.htm

[5] Askeland, Donald R., and Wendelin J. Wright. *Science and Engineering of Materials.* SI ed., vol. 7, Cengage Learning, 2016.

"Solidworks." 2017.