centre de développement pédagogique
pour la formation générale en science et technologie

PLASTICS
Are our results reliable?

Study of the uncertainty of measurement

June 2008

WORKING DOCUMENT

As much in science as in technology, the study of phenomena or materials, testing theories or prototypes often requires experimental data collection. This actual collection of data in itself implies the elaboration of experimental protocols by the researcher, the use of many instruments and on occasion the creation of instruments of measure adapted to a specific context. These factors constitute many possibilities for error and merit taking a closer look.

In the case of the activity for the identification of plastics, we proceeded to a comparative test with a control sample, in order to distinguish between PEHD and PEBD. The test was based on a known characteristic property, density. Indeed, in the case of polyethylene, the two categories can be distinguished by their respective densities. So, PEHD has a density greater than 0.95 g/cm^3, while the density for PEBD is between 0.92 and 0.95 g/cm^3.

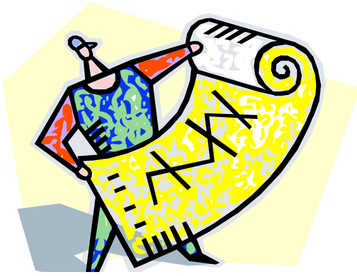
When we are looking to identify a substance, we must refer to different known properties then go on to a comparison by submitting each sample to various property tests. More often than not, we will consult reference tools that list the properties and characteristic properties of liquids, gases or solids. With a large enough number of properties, we are generally able to identify a substance that was initially unknown.

LET'S THINK ABOUT…

- **Would it be possible to identify these two substances using instruments and equipment available in your school?**
- **Would your results be reliable?**
- **Would you know how to reduce sources of error to a minimum?**

YOUR CHALLENGE :

Experimentally determine the density of two samples of polyethylene, PEHD and PEBD. You must take into account the sources of possible errors introduced by your manipulations and by the measurement apparatus at your disposal. You will have to judge the validity of your results and justify this judgment.



Some useful concepts:

1. What is absolute uncertainty and how is it expressed?

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2. How is it estimated on a graduated scale (analog apparatus)?

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3. How is it estimated on an apparatus with a digital display?

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4. What do we mean by « significant figures »?

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5. What is relative uncertainty and how is it expressed?

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6. When we deduce a measurement by an addition or subtraction of data, what do we do with the uncertainties?

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7. When we calculate a value involving a division or a multiplication, what do we do with the uncertainties?

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REMINDER: A good measurement apparatus includes three essential qualities: <u>precision,</u> <u>accuracy</u> and <u>dependability.</u>

A DISCOVERY THAT DATES BACK, BUT THAT MAY BE USEFUL TO YOU…

Archimedes, a scholar from Antiquity (287-212 B.C.), left us a considerable heritage in mathematics as well as in science and technology. Inventions such as the worm drive, the lever and the cog wheel, to name just a few, are attributed to him. He also gets credit for the discovery of a principle that he is reputed to have found while taking his bath that says: ***"Any body submerged in a fluid is buoyed up by a vertical force from bottom to top, equal to the weight of the fluid displaced."*** This principle is known today by the name "Archimedes' principle".

1. Imagine a bowl containing pebbles, water and a small bowl floating in it. By withdrawing the pebbles from the bottom of the water and putting them in the small bowl, what will happen to the level of the water? (Use Archimedes' principle to explain the result.)

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2. How can we determine the volume of an irregular solid using a scale?

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3. What could we do if the solid floated in water?

Now you are ready to take the challenge!

Material chosen:

Experimental protocol:

Compile your data and all adjustments made in the course of your work. (Justify your interventions.)

Interpretation of the data:

Conclusion:

Annex

Calculation of the density of PEBD and PEHD plastics

Calculation of the density of alcohol

Mass of the graduated cylinder:	73.190	+/-	0.005	g	0.007	%
Mass of the cylinder and the alcohol:	112.570	+/-	0.005	g	0.004	%
Volume of the alcohol:	50.0	+/-	0.5	g	1.000	%
Density of the alcohol:	0.788	+/-	0.008	g	1.025	%

Calculation of the density of PEBD

Mass of the sample in air:	0.513	+/-	0.005	g	0.975	%
Mass of the sample in alcohol:	0.078	+/-	0.005	g	6.410	%
Mass of displaced alcohol:	0.435	+/-	0.010	g	2.299	%
Volume of sample:	0.552	+/-	0,018	g	3.324	%
Density of PEHD:	0.929	+/-	0.040	g	4.299	%

So, the density of PEBD is:

Calculated:	**0.929**	**+/-**	**0.040**	**g**	**4.3**	**%**
Minimum:	**0.889**	**g**				
Maximum:	**0.969**	**g**				

Calculation of the density of PEHD

Mass of the sample in air:	0.450	+/-	0.005	g	1.111	%
Mass of the sample in alcohol:	0.078	+/-	0.005	g	6.410	%
Mass of displaced alcohol:	0.372	+/-	0.010	g	2.688	%
Volume of sample:	0.472	+/-	0.018	g	3.714	%
Density of PEHD:	0.953	+/-	0.046	g	4.825	%

So, the density of PEHD is:

Calculated:	**0.953**	**+/-**	**0.046**	**g**	**4.8**	**%**
Minimum:	**0.907**	**g**				
Maximum:	**0.999**	**g**				