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Reflections

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Review of a "Kit" for IPS Experiment 3.5, The Density of a Solid

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Introduction

I recently saw a "Density of Solids" kit for Experiment 3.5 in the 9th edition of *Introductory Physical Science* (IPS-9). It included a single data sheet with these words, "this kit is designed for use in the IPS program." The two cubes supplied in this "Kit" had masses of 1.00 g and 2.64 g. Their linear dimensions were 0.7 cm. These measurements are not near those shown as "Sample Data" on page 54 in the *Introductory Physical Science Teacher's Guide and Resource Book* (IPS-9 TG).

The slab was indistinguishable from those previously used in IPS labs.

The kit's 15-cm ruler had tick marks at 1-mm intervals, but additional tick marks were added at 0.5 mm intervals between 0 and 2 cm on the ruler's scale. The kit did not include a magnifying glass.

Pre-Lab Discussion

IPS teachers review Sec. 1.3 with their students during the pre-lab discussion with special attention to Figures 1.8 through 1.10 (page 9). But these figures do not display what the students will see on the ruler in this "Kit." Students must estimate the second digit in their measurements between two tick marks 0.5 mm apart rather than 1 mm.

Linear measurements displayed in the "Sample Data" table of the IPS-9 TG (page 54) have three significant figures, except that for the height of the slab. This is so because all measurements are greater than 1 cm, except for the slab's height. All linear measurements for the cubes in the "Kit" will be less than 1 cm and have only two significant figures.

Because the two cubes in this kit differ in mass by only 1.6 g, some students may feel insecure in giving an answer to the blue question on page 50 of the textbook. Only classroom testing would let us know.

Experiment

Good lighting, a white background, and a magnifying glass are needed to make excellent linear measurements on these smaller cubes.

The IPS course is an introductory course. It addresses significant figures and uncertainty in measurements only on pages 30, 39, and 48-49. It does not belabor this issue in every experiment throughout the course, but it becomes an important issue when using these smaller cubes.

Every person makes two subjective decisions when using a ruler—where does the measure-

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KIT (from page 1)

ment begin and where does it end? For IPS students, the uncertainty is at least ±0.01 cm for both these decisions and likely more because they are beginners learning to use a ruler. The best anyone can do is to strive to make his or her best measurement and realize that it has an uncertainty of at least ±0.02 cm.

Sample Data for Cubes and Slab in the "Kit"

The data shown below were measured by an IPS author using the ruler, cubes, and slab in the "Kit."

	Length (cm)	Width (cm)	Height (cm)	Mass (g)	Volume (cm^3)	Density (g/cm^3)
Cube 1	0.70	0.68	0.71	1.00	0.34	2.9
Cube 2	0.69	0.68	0.69	2.64	0.32	8.3
Slab	7.56	2.45	0.55	29.14	1.0×10^1	2.9

An IPS student with these data would likely answer the second blue question on page 51 by saying that the Slab and Cube 2 are made of different substances. But the sheet in the "Kit" asks a different question, "Which of the two cubes appears to be made of the same material as the slab?" But the paramount question in the IPS experiment is not written in blue. It's saved for the post-lab.

Post-Lab Discussion

IPS teachers teach by trusting their students to do good work. This is done by accepting the data of every student in the class to arrive at a conclusion. IPS teachers teach students to work together to understand scientific knowledge, to take pride in their scientific data, and to have confidence in their own and their classmates' abilities and discussion contributions. IPS teachers accomplish this aim by use of histograms and class discussions during the post-lab.

The next table displays the same data for Cube 1 as shown before. But, in addition, it displays both the upper and lower limits of the density calculation, accounting for an uncertainty of ± 0.02 cm for each linear measurement.

Data for Cube 1 in this "Kit"	Length (cm)	Width (cm)	Height (cm)	Mass (g)	Volume (cm^3)	Density (g/cm^3)
Cube 1 (upper)	0.68	0.66	0.69	1.00	0.31	3.2
Cube 1 (measured)	0.70	0.68	0.71	1.00	0.34	2.9
Cube 1 (lower)	0.72	0.70	0.73	1.00	0.36	2.7

Next is shown the linear data (three significant figures) for the corresponding cube (Cube 2) on page 54 of the IPS-9 TG, plus the upper and lower values for the calculated density, for an uncertainty of ± 0.02 cm in each linear measurement.

Data for Cube 2 in the IPS-9 TG	Length (cm)	Width (cm)	Height (cm)	Mass (g)	Volume (cm^3)	Density (g/cm^3)
Cube 2 (upper)	1.23	1.23	1.23	5.26	1.86	2.83
Cube 2 (measured)	1.25	1.25	1.25	5.26	1.95	2.70
Cube 2 (lower)	1.27	1.27	1.27	5.26	2.05	2.57

What can be learned from this information? Notice that the density calculations with the "Kit" cube are likely to be at least ±0.2 g/cm^3 on either side of 2.9 g/cm^3. But density calculations made from linear measurements of three significant figures are only ±0.13 g/cm^3 on either side of 2.70 g/cm^3.

The last significant figure in any measurement is an estimate, even if it appears on an electronic balance's display. (This

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KIT (from page 2)

is taught early in IPS in Experiment 1.8, The Sensitivity of a Balance.) But measurements that have more significant figures have smaller percent errors. So if greater accuracy (less uncertainty) is a priority, measurements should be made on larger objects, recorded to as many significant figures as possible. If less accurate measurements are acceptable, make measurements on small objects. In this case, the uncertainty in the measurement will be a larger percentage of the measurement itself.

Classes using the smaller cubes will likely not duplicate the narrow width of the histogram's peak at 2.8 g/cm^3 ±0.3 g/cm^3 shown in Figure 1 on page 53 of the IPS-9 TG.

Caveat emptor.

Thanks for reading and being an IPS teacher.

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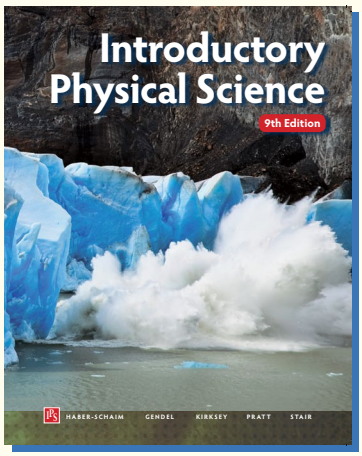

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