Separating plastic waste

Note:
This task is designed so that it can be solved with the incremental hints.
The hints are available on the media portal for printing, or the students can use them online on a tablet or smartphone via the QR code included on the worksheet.
The worksheet for the students and the hints for printing are available as separate files on the media portal of the Siemens Stiftung. General information on using tasks with incremental hints in the classroom is provided in the “Tasks with incremental hints – an introduction” document, which is also available on the media portal.

1 Topical aspects

The task addresses the fact that pure substances can be characterized by various properties and that the differences between them can be used to separate a mixture of substances. The focus here is on the property of density.
Note: Experimentation instructions on waste separation (Experimento | 10+: B3 How does waste separation work?) are available on the media portal of the Siemens Stiftung. This task can also be used to reinforce the waste separation performed in the experiment.

2 Learning prerequisites and level of difficulty

The students are required to know that substances can be characterized by a number of properties and that their density can be an important distinguishing characteristic. Knowledge of additional properties such as hardness, electrical conductivity, and magnetizability is helpful.
Density must have already been introduced as a measured value (as the quotient of mass and volume) so that the students can make sense of the table on the worksheet, as well as the fact that water has a density of approximately 1 g/cm^3. (In precise terms, the value refers to the density at a temperature of 4°C, at which water exhibits its maximum density.)
Given these prerequisites, the task has a medium level of difficulty. If the densities of various substances were determined experimentally during a previous class using the overflow method and weighing, then the task is considerably easier in the sense of a close similarity.
This also applies to previous work with chemical solutions, such as the comparison of pure water with seawater.

3 Background on the task

Plastics are ubiquitous in everyday life, which is why they also make up a large portion of the volume in household trash. Even when plastic waste is disposed of separately from the rest of the household trash in special bins or bags, the resulting mix is made up of such a wide variety of plastics that it cannot be recycled until it has been separated further. However, in practice small plastic parts mostly end up together with the other household trash in waste incinerators.

If the task is limited to the three most frequently used types of plastic, specifically polyethylene (PE), polystyrene (PS), and polyethylene terephthalate (PET), which are the preferred materials for films, molded packaging, and drink containers, a substance separation problem can be designed that is excellent for the students to work through. Of the three pure substances, only PE has a density less than that of water. PS and PE have higher densities than water and still differ significantly from each other with densities of 1.05 g/cm^3 and 1.38 g/cm^3 respectively. With a density of 1 g/cm^3, water is suitable for separating PE from a mixture of all three plastics. The two remaining plastics, PS and PET, can be separated using a salt solution (density approx. 1.1–1.2 g/cm^3).

4 The task

In the simplest form, the task can be formulated as follows:

> Think of an experiment with which you can separate three types of plastic with different densities as easily as possible. Density information is provided in the following table.

Because the context from which a task is developed fosters learning, depending on the teacher's assessment, a contextual scenario can be developed, such as the following:

> After a party, Leonie and Moritz gather up the waste: bottles, chip bags, plastic plates, etc. Moritz thinks about what will actually happen to the plastic waste. After all, they have learned that plastic can be recycled only if it has been separated by type.
> "But there are all sorts of different plastics in the recycling bins – is it even possible to separate them again?" he asks Leonie.
> She quickly replies, "I know how I would do it. I only need water and salt."
>
> **Your task:**
> Find out what Leonie will probably do. Assume that there are only three types of plastic: polyethylene, polystyrene, and polyethylene terephthalate (PET), in small pieces.
> One more thing: The three types of plastic have different densities:

Plastic	Density [g/cm^3]
Polyethylene	0.96
Polystyrene	1.05
PET	1.38

5 Variations

As the task is written, an additional hint for solving the problem is given in the context story through the mention of "water and salt." For high-achieving learning groups, this hint can be omitted.

6 Overview of the hints

Note: The hints have been prepared as a separate file for printing or can be used online via the QR codes on the worksheet.

Hint 1 Explain the task to each other again in your own words. State what you understood the task to be and what is still unclear to you.	**Answer 1** We're supposed to separate three types of plastic pieces in the easiest possible way. To do so, we should use the fact that they have different densities.
Hint 2 Carefully read the text for the task again. Then take a close look at the information in the density table.	**Answer 2** Leonie says she wants to use water and salt to separate… In the table, we see that two of the three plastics have a density of greater than 1 g/cm^3. The density of the third plastic is less than 1 g/cm^3. And water has a density of 1 g/cm^3!
Hint 3 How could you use water to separate the plastics? What will happen if you toss the mixed pieces into a jar of water?	**Answer 3** If we place pieces of all three types of plastic in a container of water, the type that is less dense than water will float on top. The other two types that are denser than water will sink. We can then fish out the polyethylene pieces from the water's surface.
Hint 4 What can Leonie do to separate the other two types of plastic using the same approach?	**Answer 4** She needs a liquid with a higher density than water.
Hint 5 What could you do to water to get a liquid with a higher density? Remember, besides water, Leonie also mentioned salt.	**Answer 5** When we add salt to water, the result is a solution with a density higher than that of water. (A saturated salt solution has a density of 1.2 g/cm^3.) If we place the two heavier plastic types into a container with a salt solution, the polystyrene will float and the PET will sink.
Hint 6 Now you have all the information you need to answer the question of how Leonie wants to separate the three types of plastic pieces.	**Answer 6** Leonie puts all the pieces of the plastic in a jar with water. The lightweight polyethylene pieces float, and the others sink. Leonie can fish out the floating pieces with a sieve. Then she adds table salt to the water. The salt solution is denser than water. Now the lighter polystyrene pieces float and the PET pieces remain at the bottom.