

# Design Challenge: A Float-Sink Line for Five Plastics

**Learning target: I can use density data to design and justify a sequence of liquid tanks that separates mixed plastic flakes, evaluate competing designs against criteria and constraints, and recognize when density alone cannot finish the job.**

Transfer and design

About 50 min

Pairs

MS-ETS1-2 · practice

MS-ETS1-3 · practice

MS-PS1-2 · practice

engineering design

data analysis

writing

Name \_\_\_\_\_

Date \_\_\_\_\_

Period \_\_\_\_\_

## Directions

Work in pairs. Read the brief and the data table. Do the float-or-sink calculations in Part A before you design anything; a design that ignores the numbers will fail. In Part B write criteria and constraints precisely enough to test. In Part C evaluate three designs other engineers proposed. In Part D design your own line, draw it, and justify every choice with a number.

**You will need:** This worksheet, Pencil, Ruler for the flow diagram, Calculator

**The brief from Second Life Plastics** — 'We buy bales of shredded flakes that mix five plastics: polypropylene (PP), high-density polyethylene (HDPE), polystyrene (PS), PET and PVC. Buyers pay well for flakes that are one plastic only and refuse flakes that are mixed. Our building has room for at most **three tanks**. Each tank holds one liquid; flakes that float are skimmed off the top and flakes that sink are collected from the bottom, so a tank splits a stream into two. Design the line: which liquid goes in each tank, what order the streams flow, and which plastics come out of each exit. Tell us honestly what the line cannot do.'

### Data for the design (real rounded values)

| Item                                    | Density (g/cm <sup>3</sup> ) | Notes                                |
|-----------------------------------------|------------------------------|--------------------------------------|
| Polypropylene (PP) flakes               | 0.90                         | caps, yogurt tubs                    |
| High-density polyethylene (HDPE) flakes | 0.95                         | milk jugs                            |
| Polystyrene (PS) flakes                 | 1.05                         | clear cups                           |
| PET flakes                              | 1.38                         | soda bottles                         |
| PVC flakes                              | 1.40                         | blister packs, pipe                  |
| Plain water                             | 1.00                         | cheapest; safe                       |
| Salt water                              | adjustable 1.02 to 1.20      | cheap; safe; salt must be topped up  |
| Water-and-alcohol mix                   | adjustable 0.92 to 0.99      | costly; flammable; needs ventilation |

### Part A: Do the math before you design

1. Write 'floats' or 'sinks' in every box. A flake floats when its density is lower than the liquid's.

| In plain water (1.00) | In salt water set to 1.15 | In alcohol mix set to 0.93 |
|-----------------------|---------------------------|----------------------------|
| PP (0.90)             |                           |                            |
| HDPE (0.95)           |                           |                            |
| PS (1.05)             |                           |                            |
| PET (1.38)            |                           |                            |
| PVC (1.40)            |                           |                            |

2. Find the density difference between each neighboring pair of plastics (PP-HDPE, HDPE-PS, PS-PET, PET-PVC). Which pair is closest, and which liquid on the list could be set between them?

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### Part B: Define the problem precisely

A requirement you cannot test is not a requirement. 'Sort the plastics well' cannot be tested. 'Every exit stream contains one plastic only' can be tested by sampling flakes at each exit. Write your criteria (what a good design achieves) and constraints (limits the design must obey) so that each one could be checked.

3. Write three criteria and three constraints for the line. For each criterion say how you would measure it. Rank the criteria from most to least important and give a reason for your top choice.

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4. One pair of plastics cannot be separated by any liquid on the list, no matter how many tanks you had. Name the pair and use numbers to explain why.

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Part C: Evaluate three proposed designs

Three candidate designs

1 Design 1: Water first, then split both ways

Tank 1: plain water. Floaters go to Tank 2: alcohol mix at 0.93. Sinkers go to Tank 3: salt water at 1.15. Four exits.

2 Design 2: Salt first, cheap all the way

Tank 1: salt water at 1.20. Floaters go to Tank 2: salt water at 1.02. Floaters from Tank 2 go to Tank 3: plain water. Four exits.

3 Design 3: Two tanks only

Tank 1: plain water. Sinkers go to Tank 2: salt water at 1.10. Floaters from Tank 1 go straight to a bin. Three exits, one tank left empty.

5. Trace every plastic through each design using your Part A table and complete the evaluation.

| Plastics at each exit (list them) | Number of one-plastic exits | Uses the alcohol mix? | Meets the three-tank constraint? |
|-----------------------------------|-----------------------------|-----------------------|----------------------------------|
| Design 1                          |                             |                       |                                  |
| Design 2                          |                             |                       |                                  |
| Design 3                          |                             |                       |                                  |

6. Which design best meets your top criterion? Which is cheapest and safest? Name one feature from a weaker design that is still worth keeping, and say why.

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### Part D: Decide and justify

7. Design your own line (you may combine ideas from Part C). For each tank state the liquid and its density, which stream enters, and which plastics float and sink, with the numbers that prove it. Then state what your line cannot do and why. End with one sentence on the trade-off you accepted (cost, safety or purity).

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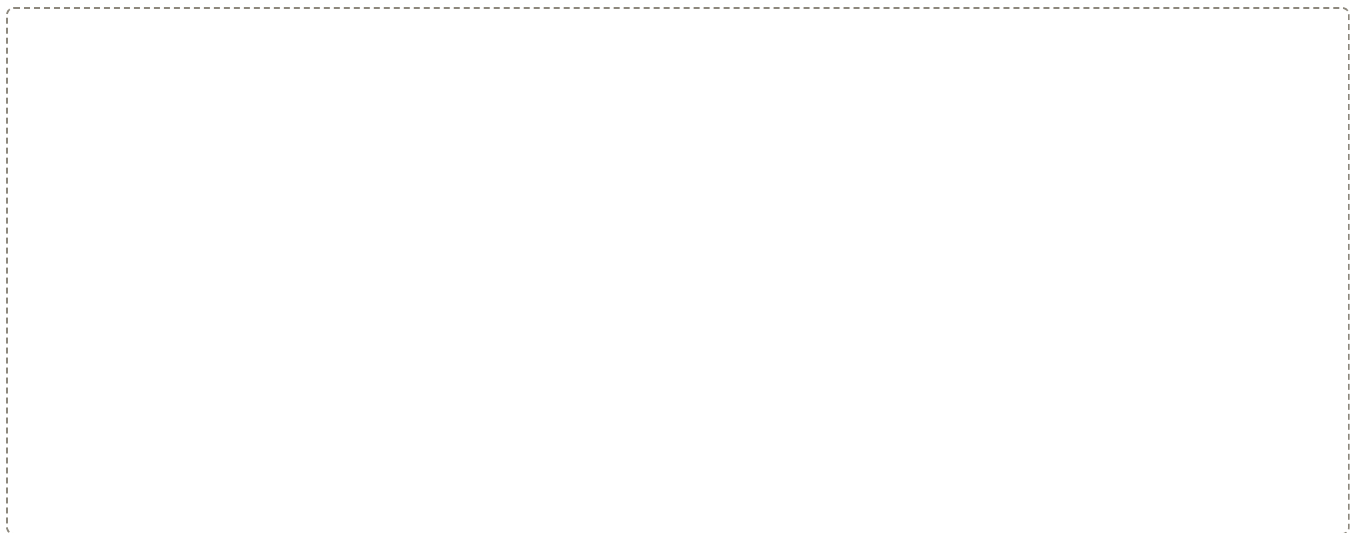
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8. Draw your line as a flow diagram: a box for each tank showing the liquid and its density, arrows labeled 'floats' and 'sinks' leaving each tank, and a labeled exit bin at the end of every path naming the plastic or plastics it holds.



9. Propose one test that uses a property **other than density** to separate the pair from q4, and name one safety or cost concern it raises. Use the data in the notes of the Reading worksheet or your own knowledge, and say what you would need to look up before trusting the test.

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### Trace one flake at a time

Pick one plastic, say PS at 1.05, and walk it through a design: in plain water (1.00) it sinks, so it goes wherever the sinkers go; in salt water at 1.15 it floats, so it is skimmed there. Write the exit it reaches. Then do the next plastic. When two plastics reach the same exit, that exit is mixed. Count the exits that hold only one plastic; that number is the design's score on purity.

### Flakes that lie

Real flakes sometimes trap tiny air bubbles, which makes a sinking flake float, and some PET bottles carry HDPE caps and PP labels that shred together. Explain how a trapped bubble changes the effective density of a flake (use a 1 cm<sup>3</sup> PET flake with 0.3 cm<sup>3</sup> of air as an example and calculate), then propose one change to the line, such as a wetting step or a second pass, that would reduce the error. Say which criterion it improves and which constraint it strains.