

Design Brief: A Touchable Salt-Crystal Model for Science Night

Learning target: I can define criteria and constraints for a model of an extended structure, use test data and calculations to compare three designs, and justify a design that correctly shows the repeating pattern and 1:1 ratio of table salt.

Transfer and design

About 55 min

Small group

MS-PS1-1 · assesses

MS-ETS1-1 · practice

MS-ETS1-2 · practice

MS-ETS1-3 · practice

engineering design

data analysis

writing

Name _____

Date _____

Period _____

Directions

Read the committee's brief and the price list. Work through the four parts in order with your team, writing your own answers on your own sheet. Part A is calculation; Part B turns the brief into testable criteria and constraints; Part C scores three prototypes that another class built and tested; Part D is your decision and sketch. Show every calculation. Your recommended design must be scientifically correct: a visitor who studies it should not come away believing that salt is made of molecules.

You will need: This worksheet, Pencil, Calculator, Ruler for the sketch

The committee's brief — 'For Science Night we want a hands-on model of table salt that visitors, including second graders, can pick up. After touching it, a visitor should be able to say: salt is a repeating pattern of two kinds of particles, one for one, with no smallest piece. Budget: \$40. It must fit on a 40 cm by 40 cm table square and stand no taller than 40 cm. It must survive a 1 meter drop onto a tile floor with no more than two pieces coming loose, because it will be handled by about 200 visitors. A team of four must be able to build it in two class periods (about 90 minutes). No small parts that a young child could swallow if they came loose.'

Price list for planning (estimated prices, for this exercise)

Material	Size	Estimated price
Foam balls, two colors	2.5 cm across	\$0.15 each
Wooden balls, two colors	6 cm across	\$1.50 each
Toothpicks	box of 500	\$2.00
Hot-glue sticks	pack of 20	\$3.00
Interlocking plastic bricks, two colors	2 cm cubes	\$0.08 each
Craft wire	10 m roll	\$4.00
Clear acrylic display box	25 cm cube	\$12.00
Poster board	sheet	\$1.00

Prices are rounded estimates chosen for this exercise, not quotes from a store.

Part A: Do the math before you design

A ball-and-stick salt model is a cube of balls, n balls along each edge, with every ball joined to its neighbors up, down, left, right, front and back by a stick. The number of balls is $n \times n \times n$. The number of sticks is $3 \times n \times n \times (n - 1)$. The two colors alternate so that no two neighbors are the same color.

1. Complete the table. For the color split, remember that colors alternate; when the total is odd, one color has one more ball than the other. Show the $n = 4$ row's calculations below the table.

Total balls ($n \times n \times n$)	Balls of color 1	Balls of color 2	Sticks: $3 \times n \times n \times (n - 1)$	Cost of foam balls at \$0.15 each
$n = 2$				
$n = 3$				
$n = 4$				
$n = 5$				

2. The $n = 3$ cube has 14 balls of one color and 13 of the other, yet the model is still a fair model of salt's 1:1 ratio. Explain why, and say what happens to the imbalance as n grows.

Part B: Define the problem precisely

A vague requirement cannot be tested. 'Visitors should understand salt' is vague. 'A visitor who studies the model can point to where the pattern would continue' can be tested by asking ten visitors. Criteria describe what a successful design does; constraints are limits the design must stay inside.

3. Write three **criteria** for a successful model, each with a number or a clear test. At least two must come from the science: the model must show the repeating pattern in all three directions, the 1:1 ratio, and that there is no smallest piece.

4. Write four **constraints** from the brief, each with its number or limit. Then add one constraint of your own that the committee forgot (think about who will handle the model and where it will sit).

5. Pick one of your criteria and one of your constraints and explain how each one rules out at least one possible design before any building happens.

Part C: Compare three prototypes

Three prototypes built and tested by last year's class

1 Design 1: Foam-ball lattice

A $4 \times 4 \times 4$ cube of 2.5 cm foam balls in two colors on toothpick sticks, joints dabbed with hot glue. About 19 cm on each side. Shows balls and sticks, like the models in class. Materials: 64 foam balls, toothpicks, glue.

2 Design 2: Brick checkerboard

A $6 \times 6 \times 6$ block of 2 cm interlocking bricks in two colors, each layer a checkerboard and each layer shifted so colors alternate up and down too. One corner is left unfinished, with a bag of 50 loose bricks so visitors can keep adding to the pattern. About 12 cm on each side. Bricks touch face to face; there are no sticks.

3 Design 3: The single unit

One $2 \times 2 \times 2$ cube of eight 6 cm wooden balls, four of each color, glued ball to ball. About 12 cm on each side. Labeled 'the salt unit.' Very sturdy; takes 25 minutes to build.

Prototype test results (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Design	Pieces loose after 1 m drop, trial 1	Pieces loose after 1 m drop, trial 2	Build time (minutes, team of four)	Materials cost
1: Foam-ball lattice	9	7	70	\$14.60
2: Brick checkerboard	0	1	85	\$21.28
3: The single unit	0	0	25	\$15.00

Simulated results for teaching, written to be realistic for these materials.

6. Score each design against each criterion: 2 = fully meets, 1 = partly, 0 = fails. In the constraints row, use the brief and the test data.

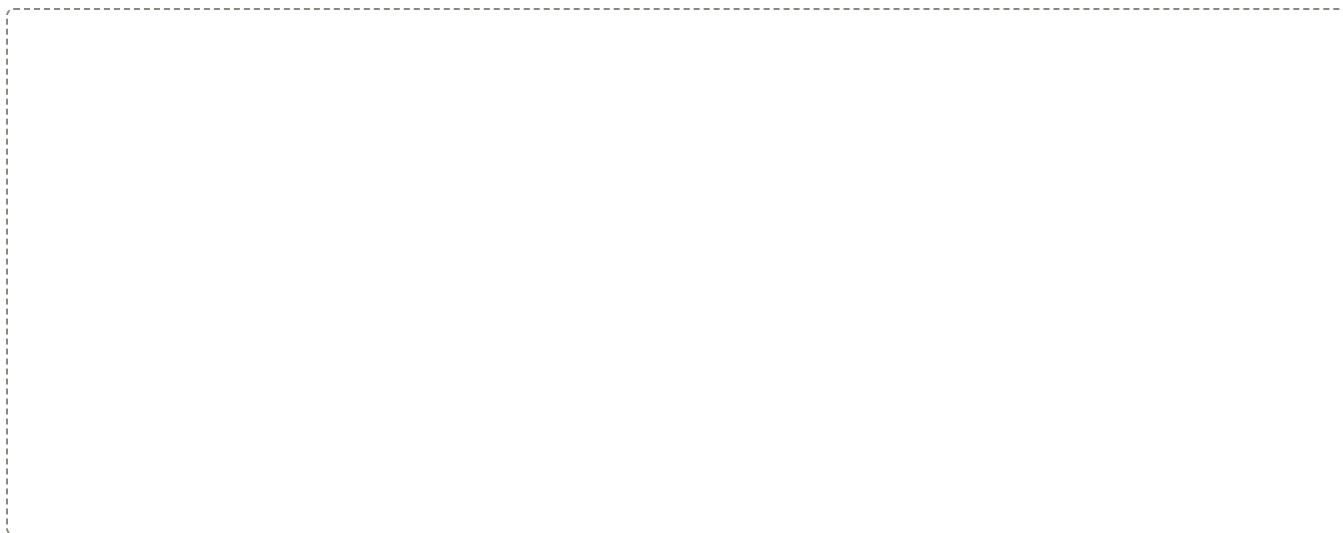
Design 1	Design 2	Design 3
Criterion 1: pattern in all three directions		
Criterion 2: 1:1 ratio visible		
Criterion 3: no smallest piece (pattern could continue)		
Your fourth criterion		
Constraints: all met? (yes/no, and which fails)		

7. Check two numbers. (a) Design 2 uses $6 \times 6 \times 6$ bricks at \$0.08 plus 50 extra bricks: calculate the brick cost and compare with the listed \$21.28. (b) Average the two drop-test results for Design 1 and state whether it meets the drop constraint. Show your work.

Part D: Decide and justify

8. Recommend one design, or a specific change that combines the best features of two designs. Justify it with your scores from q6, at least two numbers from the test data or your calculations, and one sentence on how it keeps a visitor from thinking salt is made of molecules.

9. Sketch your recommended model. Label the two kinds of particles with a legend, mark where the pattern continues beyond the model, show how a visitor can see the 1:1 ratio, and label any feature you added to pass the drop test.



Filling the Part A table

Do one row at a time. For $n = 4$: balls = $4 \times 4 \times 4 = 64$; colors split 32 and 32; sticks = $3 \times 4 \times 4 \times 3 = 144$; cost = $64 \times \$0.15 = \$9.60$. For odd n , the total is odd, so one color gets one extra ball; for $n = 3$ the split is 14 and 13. For Part C, score a design before reading the test data, then adjust the constraints row with the data; this keeps your science criteria separate from the sturdiness question.

A second model for a different structure

The committee likes your salt model and asks for a companion model of quartz, in which each silicon is joined to four oxygens and each oxygen is shared by two silicons (ratio 1:2). Explain why a simple alternating checkerboard of bricks would be the wrong model for quartz, propose a building method that shows the 1:2 ratio and the sharing, and estimate the number of balls of each color for a model with 20 silicon atoms. Then write one sentence on what both models share that a model of a water molecule would not.