

Three Prototypes, One Winter: Reading Hand-Warmer Test Curves

Learning target: I can graph temperature-versus-time data from three hand-warmer prototypes, calculate peak rise, warming rate and time above a threshold, and decide which prototype meets the criteria and which characteristics to combine.

Data and graphing

About 45 min

Individual

MS-ETS1-3 · practice

MS-PS1-6 · practice

data analysis

independent practice

Name _____

Date _____

Period _____

Directions

A student engineering club tested three iron-powder hand-warmer prototypes in a room at 22 °C, reading each pouch's temperature every 30 minutes for 5 hours. The numbers are a teaching dataset: invented to be realistic, not measured in a lab. Plot all three curves on the blank graph, then answer the questions. Show every calculation with units. Use the criteria table to judge the prototypes; the club's constraints are listed with it.

You will need: This worksheet, Pencil, Ruler, Calculator (optional)

The club's criteria and constraints

Kind	Statement	How it is checked
Criterion 1	Peak temperature at least 42 °C	Highest reading in the table
Criterion 2	Stays at or above 38 °C for at least 3 hours	Time from the first reading at or above 38 °C to the last reading at or above 38 °C
Constraint A	Never above 50 °C (skin safety)	No reading above 50 °C
Constraint B	No more than 25 g of iron per pouch (cost)	Mass of iron used

Temperature of three prototypes over 5 hours (teaching dataset)

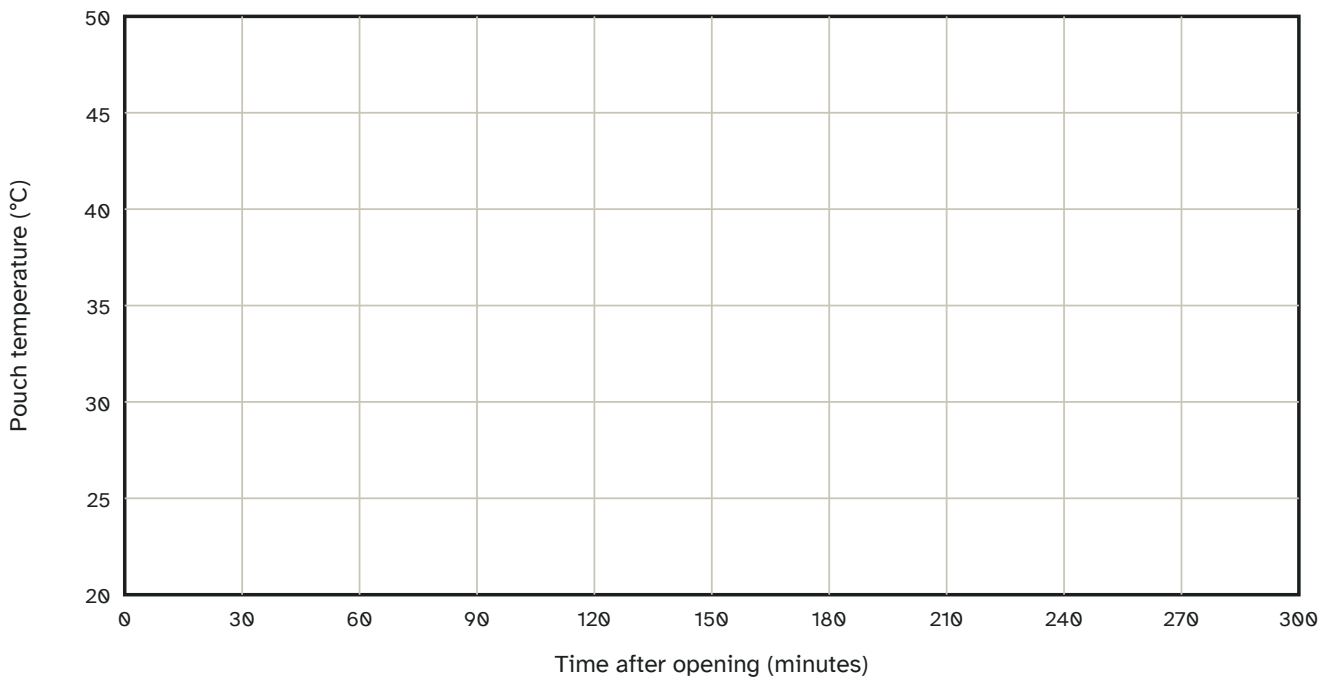
Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Time (min)	A: 10 g, thin pouch (°C)	B: 20 g, thin pouch (°C)	C: 20 g, thick pouch (°C)
0	22	22	22
30	41	44	33
60	43	49	39

Time (min)	A: 10 g, thin pouch (°C)	B: 20 g, thin pouch (°C)	C: 20 g, thick pouch (°C)
90	40	47	42
120	36	44	43
150	32	41	43
180	28	38	42
210	25	34	41
240	23	30	40
270	22	26	38
300	22	23	36

Simulated readings for a classroom scenario. Room temperature 22 °C throughout. Prototype A: 10 g iron, thin cloth pouch. Prototype B: 20 g iron, thin cloth pouch. Prototype C: 20 g iron, thick cloth pouch that lets air in slowly.

Pouch temperature versus time for prototypes A, B and C



Part A: Reading the curves

1. Complete the table from the dataset. The rise is the peak minus the 22 °C starting temperature; show one subtraction below the table.

Peak temperature (°C)	Time of peak (min)	Rise above room temperature (°C)
Prototype A		
Prototype B		
Prototype C		

2. Calculate the average warming rate of prototype A and of prototype C during the first 30 minutes, in °C per minute. Round to the nearest hundredth. Which warmed faster, and by how many times?

3. Use your dashed 38 °C line and the table to estimate how long each prototype stayed at or above 38 °C. Convert minutes to hours.

First reading at or above 38 °C (min)	Last reading at or above 38 °C (min)	Time at or above 38 °C (hours)
Prototype A		
Prototype B		
Prototype C		

Part B: Judging against the criteria

4. Write PASS or FAIL in every cell, using your answers above.

Criterion 1: peak ≥ 42 °C	Criterion 2: ≥ 38 °C for ≥ 3 h	Constraint A: never > 50 °C	Constraint B: ≤ 25 g iron
Prototype A			
Prototype B			
Prototype C			

5. Which prototype meets every criterion and constraint? Which prototype came closest to breaking Constraint A, and what reading tells you?

6. Prototypes B and C hold the same 20 g of iron, yet B got hotter and C lasted longer. Explain both differences using the thickness of the pouch, the speed of the reaction, and the idea that the same amount of iron releases the same total energy to the surroundings.

Part C: Combine the best characteristics

7. For each prototype, name its one best characteristic and its one worst result from the tests.

8. Propose a prototype D for the club that combines the best characteristics and stays inside both constraints. State the mass of iron and the pouch type, predict its peak temperature and its time at or above 38 °C, and justify both predictions with numbers from the dataset.

9. The club can run only one more test. Explain why testing prototype D with the exact same procedure (same room, same reading times) matters for comparing it fairly with A, B and C.

Rate and time, one step at a time

A warming rate is a change in temperature divided by the time it took: (reading at 30 min – reading at 0 min) ÷ 30 min, in °C per minute. Write the subtraction on one line and the division on the next. For time above 38 °C, run your finger down a prototype's column and circle every reading that is 38 or more; the time is from the first circled row to the last circled row. Divide minutes by 60 to get hours (for example, 150 min ÷ 60 = 2.5 h).

Between the readings

Prototype A read 40°C at 90 min and 36°C at 120 min, so it crossed below 38°C somewhere between those readings. Assuming the temperature fell at a steady rate between the two readings, calculate the minute at which A reached exactly 38°C and revise its time above 38°C . Then do the same for prototype B between 180 and 210 min. Write a sentence on how reading every 10 minutes instead of every 30 would change the certainty of the club's time measurements, and what it would cost in effort.