KINEMATICS DAY 7 — LAB: CONSTANT ACCELERATION

FRQ Type 3 of 4 — Experimental Design & Analysis: one AP free-response question always asks you to design a procedure or analyze real data. Graders look for: what you *measure*, what you measure it *with*, how you *reduce uncertainty* (repeat trials!), and how a *graph* answers the question.

THE QUESTION

Does a cart released on a ramp move with constant acceleration — and if so, what is it?

Available equipment: a ramp, a cart, a meterstick, tape, and a phone (stopwatch + camera).

AP FRQ · EXPERIMENTAL DESIGN

Part 1: Your Procedure

(a) List the quantities you will measure and the tool for each.

(b) Describe your procedure in numbered steps — enough detail that another group could repeat it without asking you anything. Include how you will reduce measurement uncertainty.

(c) If the acceleration is constant, the model is $x = \frac{1}{2}at^2$. What graph would produce a straight line, and what would its slope tell you?

DATA & LINEARIZATION

LINEARIZE IT

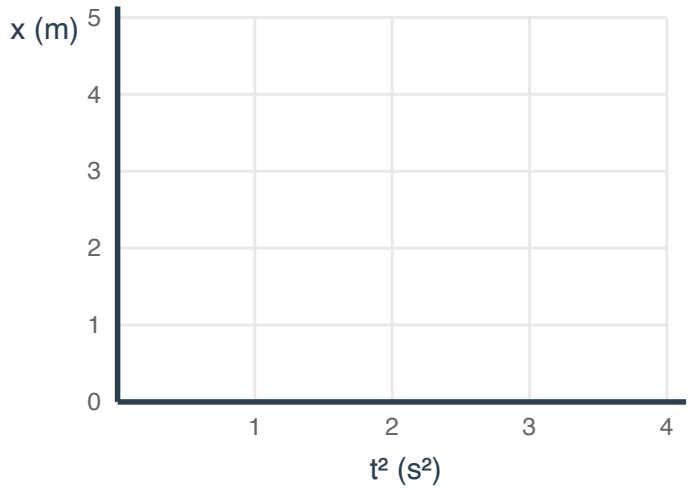
A curve is hard to judge by eye; a line isn't. Since **$x = \frac{1}{2}at^2$**, plotting **x versus t^2** (not t!) gives a straight line through the origin with **slope = a/2**.

The units prove it: slope = rise/run = $(m)/(s^2) = m/s^2$ — acceleration units, as expected.

Sample data (one group's averages over 3 trials):

t (s)	x (m)	t^2 (s^2)
0.50	0.30	
1.00	1.22	
1.50	2.71	
2.00	4.82	

Fill in the t^2 column, then plot x vs t^2 at right and draw a best-fit line.



YOU DO **Exercise 1: Read Your Line**

(a) Find the slope of your best-fit line — carry the units: $(m)/(s^2)$. **(b)** Use slope = a/2 to find the cart's acceleration. **(c)** Does the line pass near the origin? What does a near-zero intercept tell you about how well the data fits the model $x = \frac{1}{2}at^2$?

PREDICTION & PERCENT ERROR

WE DO Exercise 2: Predict, Then Compare

Using your acceleration from Exercise 1: **(a)** predict the cart's velocity at t = 2.0 s using v = at — units in the multiplication. **(b)** A photogate measured the actual velocity as 4.6 m/s. Compute the percent error: |measured − predicted| / predicted × 100%.

YOU DO Exercise 3: Error Autopsy

Name two realistic sources of error in this experiment, state whether each would push your measured acceleration *high* or *low*, and propose one fix. ("Human error" earns zero on the AP — name the actual mechanism.)

EXIT TICKET

SHOW YOUR TEACHER BEFORE YOU LEAVE

1 Why t^2?

Why do we plot x versus t^2 instead of x versus t? What do we gain?

2 Slope Meaning

Your friend's x vs t^2 graph has slope 0.95 m/s^2. What is their cart's acceleration?

PAPER PRACTICE

PRACTICE PROBLEMS — A SECOND DATA SET TO ANALYZE

P1 New Cart, New Ramp

Another group recorded this data for their cart:

t (s)	0.50	1.00	1.50	2.00
x (m)	0.20	0.80	1.80	3.20

(a) Compute t^2 for each point and find the slope of x vs t^2 (it's exact for this data). **(b)** Find the acceleration.

P2 Extrapolate

Using that acceleration, predict where the cart will be at t = 2.5 s.

P3 Percent Error

The group predicted an impact speed of 4.0 m/s but measured 4.3 m/s. Find the percent error relative to the prediction.