FORCES DAY 6 — LAB: NEWTON'S SECOND LAW

FRQ Type — Experimental Design & Analysis: this lab is run AP-style. Graders look for: what you measure, what you measure it with, what you hold constant, how you reduce uncertainty (repeat trials!), and how a straight-line graph answers the question.

THE QUESTION

Is acceleration really proportional to net force — and can a graph weigh our cart?

Equipment: low-friction cart and track, pulley, string, hanging mass set (washers), motion sensor (or phone + tape), balance.

AP FRQ · EXPERIMENTAL DESIGN **Part 1: Your Procedure**

(a) The hanging washers provide the pulling force F. Describe how to *vary F without changing the system's total mass. Hint: where can washers live when they are not hanging?*

(b) List each quantity you will measure and the tool you will measure it with.

(c) Write a numbered procedure another group could follow without asking you anything. Include how many trials per force value and why repeating matters.

DATA & THE A VS F GRAPH

WHY A VS F IS A LINE

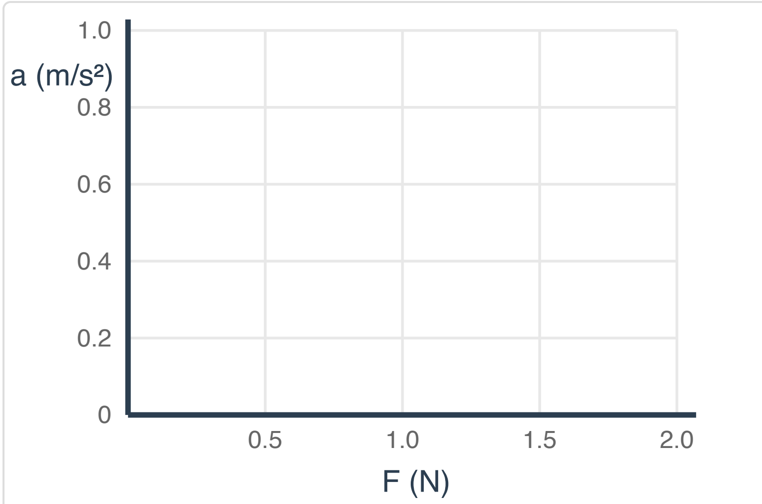
Newton's Second Law rearranged: **$a = (1/m)\cdot F$** — so plotting **a versus F** gives a straight line through the origin with **slope = 1/m**.

The units prove it: slope = $(m/s^2)/N = (m/s^2)/(kg\cdot m/s^2) = 1/kg$ — an inverse mass, exactly as the law predicts.

Sample data (averages over 3 trials):

F (N)	a (m/s^2)
0.50	0.21
1.00	0.46
1.50	0.70
2.00	0.96

Plot the points at right and draw a best-fit line. Notice whether it passes exactly through the origin — that detail matters on page 4.



READING THE LINE

YOU DO **Exercise 1: Weigh the Cart with a Graph**

(a) Find the slope of your best-fit line, carrying the units $(m/s^2)/N$. **(b)** Use slope = 1/m to find the system's mass. **(c)** A balance reads the system at 2.1 kg. Compute the percent error of your graph-derived mass relative to the balance reading.

WE DO **Exercise 2: Predict a New Point**

Using your slope, predict the acceleration when F = 3.0 N — units multiplying through. Why is this prediction an *extrapolation*, and why does extrapolating deserve less trust than reading between measured points?

Slope, not single points. Computing m = F/a from one data point throws away the rest of your data and absorbs that point's noise. The best-fit slope averages every measurement at once — that's the whole reason we graph.

THE TELLTALE INTERCEPT

YOU DO **Exercise 3: What the Intercept Confesses**

A careful fit of the sample data gives $a \approx (0.50\ 1/\text{kg})\cdot F - 0.04\ \text{m/s}^2$. The line misses the origin by $-0.04\ \text{m/s}^2$. **(a)** What physical effect does a small negative intercept reveal? **(b)** Estimate the size of that effect in newtons for the 2.0 kg system: $F = (2.0\ \text{kg})(0.04\ \text{m/s}^2)$.

YOU DO **Exercise 4: Error Autopsy**

Name two realistic error sources in this lab. For each, state whether it pushes the measured mass *high* or *low*, and propose one fix. ("Human error" earns zero — name the mechanism.)

PAPER PRACTICE

PRACTICE PROBLEMS — A SECOND DATA SET TO ANALYZE

P1 Another Group's Cart

A frictionless air-track group recorded:

F (N)	0.50	1.00	1.50	2.00
a (m/s²)	0.125	0.250	0.375	0.500

(a) Find the slope of a vs F (this data is exact). **(b)** Find the system's mass from the slope.

P2 Extrapolate

Predict that system's acceleration at F = 3.0 N.

P3 Reverse the Graph

A different group plotted F on the y-axis versus a on the x-axis and got slope 5.2. What are the slope's units in that orientation, and what physical quantity does it equal directly?