Tennis Ball Drop Lab: What to Put in Each Section

Bullet points for this specific investigation: free fall of the ball, constant-velocity walker, 5.35 m drop, moving bucket.

> **Use your own numbers.** Everything in [brackets] is a blank to fill in from your group's actual measurements. Example values below come from the given 5.35 m height, or are labeled *illustration only*. Never put an illustration value in the report as if you measured it.

Title

1 pt

- Name the concepts and the method. Example: *"Combining Free-Fall and Constant-Velocity Kinematics to Time a Dropped Tennis Ball Into a Moving Bucket"*.
- Avoid "Tennis Ball Drop Lab".

Abstract (write last)

5 pts

- **Purpose:** used kinematics of free fall and constant velocity to predict when to release a tennis ball from 5.35 m so it lands in a bucket carried by a walking partner.
- **Method:** measured the walker's average speed, computed the ball's fall time from the drop height, and calculated the delay between the "start" signal and release.
- **Results:** predicted fall time [__] s (theory 1.05 s), walker speed [__] m/s, calculated release delay [__] s; the ball [landed in / missed the bucket by __ m]; percent error [__]%.
- **Significance:** one sentence on what this shows about kinematic models and the size of the real-world effects that were ignored. Past tense throughout.

Introduction

7 pts

Paragraph 1: free fall and its history

- Define **free fall**: motion under gravity alone, constant acceleration $g \approx 9.8$ m/s² downward.
- **History:** Aristotle believed heavier objects fall faster; **Galileo** (late 1500s–early 1600s) argued and showed by ramp experiments that, without air resistance, all objects accelerate equally; **Newton** later explained why with his laws and gravitation; Apollo 15's hammer and feather drop on the Moon (1971) demonstrated it without air. Verify each fact in a source you actually read and cite it.

Paragraph 2: constant velocity and kinematic equations

- Constant velocity: $x = x_0 + vt$, where speed is unchanged, so acceleration = 0.
- Constant acceleration: $y = y_0 + v_0t + \frac{1}{2}at^2$ and $v = v_0 + at$ (and $v^2 = v_0^2 + 2a\Delta y$). Define every variable and unit and say why each applies here.
- Key idea: the two motions (vertical fall and horizontal walk) are **independent** and connected only through **time**.

Paragraph 3: purpose and hypothesis

- **Purpose:** to determine the time to release the ball so that it lands in the moving bucket.
- **Hypothesis** (a testable prediction with reasoning): *If the ball is released [__] s after the walker starts, calculated using $t = \sqrt{2h/g}$ and the walker's measured speed, then the ball will land in the bucket, because both motions reach the same point at the same time.*
- Cite at least one outside source, not only the handout and your notes.

Materials & Procedure

5 pts

- **Materials:** tennis ball, bucket, meter stick or measuring tape (state precision), stopwatch or phone timer, calculator, [anything else your group used].
- **Diagram:** balcony with drop height 5.35 m, ball path, floor, walker's start distance d, and walking direction. Label the coordinate origin.
- Summarize in **one short past-tense paragraph**: the walker's speed was measured over a known distance in [__] practice trials and averaged; fall time was calculated from height; the release delay was calculated; on drop day the teacher gave the walking distance, said "start", and the dropper released the ball after the calculated delay with no communication or timing device for the walker.
- Do **not** copy the handout's procedure.

Data / Calculations (in lieu of data)

7 pts

Measured data table (make your own)

- Columns like *Trial* | *Distance walked (m)* | *Time (s)* | *Speed (m/s)*, with units in headings only. Include several trials and the **average speed**.
- Add a small table for drop day: walking distance given [__] m, calculated delay [__] s, outcome (in bucket / missed by __ m, and on which side).

Worked calculations (show every step with units)

- **Variables needed:** drop height h = 5.35 m; g = 9.8 m/s²; walker speed v; walking distance d (given on drop day). If the bucket is held above the floor, use the actual fall height (h − bucket height) and state it.
- **Fall time:** $h = \frac{1}{2}gt^2 \rightarrow t = \sqrt{(2h/g)} = \sqrt{(2 \times 5.35 / 9.8)} \approx$ **1.05 s**.
- **Walker's time to reach the drop point:** $t_{walk} = d / v$.
- **Release delay after "start":** $t_{delay} = d/v - \sqrt{(2h/g)}$. The ball is released this many seconds after the walker begins.
- *Illustration only:* if d were 6.0 m and v were 1.2 m/s, then t_{walk} = 5.0 s and t_{delay} = 5.0 − 1.05 ≈ 3.95 s. Replace with your real values.
- **Procedure for finding the variables**: time the walker over a measured distance, repeat, average; compute fall time from the known height.

Data Analysis

17 pts

1. Velocity of the ball the instant it hits the bucket

- $v = v_0 + gt = 0 + (9.8)(1.05) \approx$ **10.2 m/s downward** (−10.2 m/s if down is negative). Check: $v = \sqrt{(2gh)} = \sqrt{(2 \times 9.8 \times 5.35)} \approx 10.2$ m/s. Show both, and use your bucket-height-adjusted h if needed.

2. The four graphs. Every graph needs a title, labeled axes with units, and a clear scale

- **a) Position vs. time, walker:** a **straight line**. Slope = the walker's **velocity** (value = your average speed, in m/s; negative if you set the origin at the drop point and the walker moves toward it). Constant slope means constant velocity.
- **b) Position (height) vs. time, ball:** a **downward-curving parabola** from 5.35 m to 0 m in about 1.05 s. Slope = the ball's **instantaneous velocity**. It is **changing** (steeper and steeper), because gravity gives it a constant acceleration, so velocity is not constant.
- **c) Velocity vs. time, walker:** a **horizontal line** at your speed. Slope = **0** = acceleration (constant velocity). Area under the line = **displacement** = v × t = d (the walking distance).
- **d) Velocity vs. time, ball:** a straight line from 0 to −10.2 m/s. Slope = **−9.8 m/s²** = acceleration due to gravity. Area (a triangle, ½ × base × height = ½ × 1.05 × 10.2) = **5.35 m** = the drop distance (negative if down is negative).

3. Post-lab calculations and percent error

- Percent error = |experimental − accepted| / accepted × 100%. Pick quantities you can actually check, such as fall time measured from slow-motion video vs. 1.05 s, or measured vs. predicted walker speed.
- Report where the ball landed relative to the bucket (distance and direction) and what timing error that miss corresponds to: miss distance ÷ walker speed ≈ timing error in seconds.
- Reminder: **no comparison to "known" physics here**. Describe and interpret your own results; save the comparison for the Discussion.

Discussion

17 pts

Open with the hypothesis and purpose

- Restate them and say directly whether the results supported them, with numbers (e.g., "the ball landed [__] m [ahead of / behind] the bucket, an error of [__] s").

Required question 1: one specific improvement to the procedure

- Pick **one** and be concrete. For example: *measure the walker's speed over the exact distance to be walked, with 5+ trials and a phone-video or photogate timer, instead of a few stopwatch trials*; or *use a metronome to keep a steady walking cadence*; or *use a release jig so the ball is dropped at the same instant, from the same point*.
- Explain **how much** it would reduce a named error (e.g., a 0.2 s reaction-time error at 1.2 m/s moves the landing spot about 0.24 m, and a typical bucket opening is only a few tens of centimeters wide, so a small error is a miss).

Required question 2: at least two "real-world" factors you ignored

- **Air resistance:** ignored in $t = \sqrt{2h/g}$. Drag reduces the ball's acceleration, so the real fall time is slightly **longer** than 1.05 s. The bucket would already be past the drop point, so the ball lands **behind** it. A light, fuzzy tennis ball is affected more than a dense ball.
- **Human reaction time (dropper):** a typical 0.15–0.25 s delay releasing the ball on time.
- **Non-constant walker speed:** the walker speeds up from rest and varies stride, but the model assumed constant v, so the bucket arrives earlier or later than predicted.
- Others you can add: ball released with a small initial velocity, air currents, ball diameter and the bucket's height vs. the floor, measurement uncertainty in h and d, g varying slightly with location.

Also include

- Compare to literature: cite your source for $g \approx 9.8$ m/s² and for the size of air resistance on a tennis ball. Do your results agree? If not, **why not**?
- Any questionable or surprising data and the likely cause.
- A suggested follow-up experiment that would **test your explanation**, e.g., dropping from different heights to see whether the fall-time error grows with height, which would point to air resistance.

Literature Cited

1 pt

- Use one consistent style and number the entries in order of first appearance.
- Put a superscript number after every fact borrowed from a source, and only cite sources you actually read.
- Good places to look: your physics textbook's chapters on free fall and 1-D kinematics (or the free OpenStax physics text), plus one outside source on the history of free fall or on air drag on a sphere. Read them first. Do not cite a source you did not open.