Physics 11 Field Lab: Kinematics Analysis of Shanghai Metro Line 3

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1 Objective

Measure and analyze acceleration and velocity of Shanghai Metro Line 3 train during departure from station using only basic tools (paper, pen, stopwatch, measuring tape), and compare experimental results with official train performance specifications.

2 Background

Urban rail systems like Shanghai Metro provide excellent real-world contexts for studying one-dimensional kinematics. Trains accelerate from rest, reach cruising speed, then decelerate: clear phases of motion governed by equations of constant acceleration. Shanghai Metro Line 3, opened 2001, operates modern AC03-series trains with well-documented performance characteristics.

2.1 Official Train Specifications (for comparison)

- Maximum operating speed: 80 km/h (≈ 22.2 m/s)
- Average speed (including stops): 34.4 km/h (≈ 9.6 m/s)
- Service acceleration: 1.0 km/(h·s), equivalent to 0.278 m/s^2
- Maximum (design) acceleration: 0.9-1.0 km/(h·s) under normal conditions
- Emergency deceleration: up to 1.3 km/(h·s) (≈ 0.361 m/s^2)
- Train model: AC03 (also designated 03A01), 6-car aluminum-bodied train manufactured by Alstom and CSR Nanjing Puzhen
- Power supply: 1,500 V DC via overhead lines

These values provide benchmark for evaluating student-collected data.

3 Materials (per group)

- Paper
- Pen or pencil
- Stopwatch (smartphone acceptable)
- Measuring tape

4 Location

Any above-ground station on Shanghai Metro Line 3, such as Shilong Road, Longcao Road, or Caoxi Road. These stations offer clear visibility of train motion along platform and are easily accessible. Line 3 runs from North Jiangyang Road to Shanghai South Railway Station, covering 40.3 km with frequent service.

Safety First

- Stay behind yellow safety line at all times
- Do not distract other passengers
- Follow all station staff instructions
- Teacher must supervise all measurements

5 Procedure

5.1 Part 1: Establish a Known Distance

- Use measuring tape to mark straight segment parallel to tracks along platform edge
- Recommended distance: 10.0 meters (e.g., between two pillars or platform markers)
- Record this as $\Delta x =$ __________ m

5.2 Part 2: Time the Train's Motion

- Wait for train to arrive and come to complete stop
- When train departs:
  - Start stopwatch instant front of train passes start of measured segment
  - Stop stopwatch when front of train passes end of segment
- Record time as Δt
- Repeat for 1-2 train departures (time permitting) to obtain average time and reduce human reaction error

Optional Extension: Also time train over first 5 meters after it begins moving to isolate acceleration phase.

6 Calculations (to be completed in class)

6.1 Case 1: Assuming Constant Acceleration from Rest

If train is still accelerating over your measured segment:

$$\Delta x = \frac{1}{2}a(\Delta t)^2 \quad \Rightarrow \quad a = \frac{2\Delta x}{(\Delta t)^2}$$

6.2 Case 2: Assuming Constant Velocity

If train has already reached cruising speed (more likely beyond first 10 m):

$$v = \frac{\Delta x}{\Delta t}$$

7 Analysis Questions

1. What is your experimental acceleration (in m/s^2)? How does it compare to official service acceleration of 0.278 m/s^2?

2. What is your estimated speed (in m/s and km/h)? Is it reasonable given train's maximum speed of 80 km/h?

3. Why is average speed of Line 3 only 34.4 km/h despite top speed of 80 km/h?

4. Identify two sources of experimental error (e.g., reaction time, distance estimation). How might they affect your results?

8 Extensions (Optional)

- Measure deceleration as train approaches station
- Compare acceleration during peak vs. off-peak hours (though train performance should be consistent)
- Estimate distance traveled during acceleration using your calculated a and known time to reach cruising speed

9 References

- Shanghai Metro Line 3. Wikipedia. https://en.wikipedia.org/wiki/Line_3_(Shanghai_Metro)
- Shanghai Metro AC03. Wikipedia. https://en.wikipedia.org/wiki/Shanghai_Metro_AC03
- Shanghai Metro Line 3. UrbanRail.Net. https://www.urbanrail.net/as/shan/shanghai.htm