

Bells on a Ramp — Regents Practice

Practice cluster in the format of the NYS Regents Examination in Physical Science: Physics. Companion to the reading passage "Galileo's Bells: Timing Gravity with a Tilted Ramp and a Musician's Ear".

Base your answers to questions 1 through 6 on the information below and on your knowledge of Physical Science: Physics. Some questions may require the use of the 2025 Edition Reference Tables for Physical Science: Physics.

Bells on a Ramp

Around 1604, Galileo Galilei wanted to study falling objects, but a dropped ball falls too quickly to time with the clocks of his day. He slowed the motion by letting a bronze ball roll from rest down a long, smooth, gently tilted ramp. To time the ball, he hung small bells along the ramp and listened as the ball struck them, comparing the rings to a steady musical beat. A group of students recreated the investigation. They released a ball from rest at the top of a long ramp and moved bells along the ramp until each bell rang exactly in step with a metronome that clicked every 0.50 s. Their results are shown in Table 1.

Table 1: Bell Positions for a Steady Beat

Bell	Time After Release, t (s)	Distance from Release Point, d (m)
1	0.50	0.05
2	1.00	0.20
3	1.50	0.45
4	2.00	0.80
5	2.50	1.25

Data are representative values for practice.

- 1** Which graph best represents the relationship between the ball's distance from the release point and time?
- (1) a straight line through the origin, rising
 - (2) a horizontal line above the time axis
 - (3) a curve through the origin that rises more and more steeply
 - (4) a curve through the origin that rises less and less steeply and levels off
- 2** Substitute numerical values into a mathematical representation that can be used to determine the magnitude of the ball's acceleration on the ramp. [1]

Next, the students placed four bells at equal spacing, 0.20 m apart, along the same ramp. They again released the ball from rest at the top and used a video recording to find the time at which each bell rang. Instead of a steady beat, the rings came faster and faster. Their results are shown in Table 2.

Table 2: Equally Spaced Bells

Bell	Distance from Release Point, d (m)	Time After Release, t (s)	Time Since Previous Ring (s)
1	0.20	1.00	1.00
2	0.40	1.41	0.41
3	0.60	1.73	0.32
4	0.80	2.00	0.27

Data are representative values for practice.

3 A student claims that the ball's speed when it strikes bell 4 is twice its speed when it strikes bell 1. Place a check mark (✓) in either the Support or Refute box below to indicate if the given information supports or refutes the student's claim. Justify your response using a mathematical relationship. [1]

☐ Support ☐ Refute

Justification:

4 Which statement best explains why the time between rings decreases in Table 2?

- (1) The ball's speed increases, so it covers each 0.20-m section in less time.
- (2) The net force on the ball increases as it rolls farther down the ramp.
- (3) The ball's acceleration increases as it rolls farther down the ramp.
- (4) The bells push the ball forward each time they are struck.

Galileo argued that a ramp is a model of free fall: as a ramp is made steeper, the ball's acceleration increases, and a vertical "ramp" is the same as simply dropping the ball. On a shallow ramp the ball speeds up in the same pattern as a falling ball, but slowly enough that the intervals between bells can be judged by ear.

Consider the Earth–ball system as the ball rolls from rest at the top of the ramp to the bottom. Assume energy losses due to friction and air resistance are negligible. Take the gravitational potential energy of the system to be zero when the ball is at the bottom of the ramp.

5 Construct an energy bar graph for the Earth–ball system at the moment the ball has descended half of the ramp's total vertical height. Shade the table below to show the amount of each type of energy as a fraction of the system's total energy, ET. [1]

Fraction of ET	PEg	KE	Either
ET			
3/4 ET			
1/2 ET			
1/4 ET			
0			

6 Which statement best describes an advantage of using a shallow ramp instead of a vertical drop in Galileo's investigation?

- (1) The ramp removes the effect of gravity, so the ball moves at a constant speed that is easy to time.
- (2) The ramp reduces the ball's acceleration, so the time intervals are long enough to judge while the motion is still uniformly accelerated.
- (3) The ramp increases the ball's mass, so the ball accelerates more slowly.
- (4) The ramp makes the ball's acceleration increase steadily, so bells placed at equal distances ring at equal time intervals.