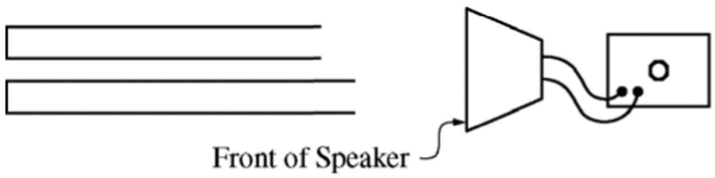
Free-Response Questions

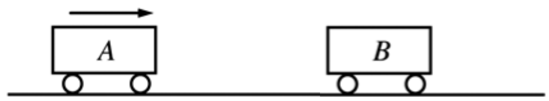
Directions: Question 1 is a short free-response question that requires about 12 minutes to answer and is worth 7 points. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.



1. The figure above shows two tubes that are identical except for their slightly different lengths. Both tubes have one open end and one closed end. A speaker connected to a variable frequency generator is placed in front of the tubes, as shown. The speaker is set to produce a note of very low frequency and then turned on. The frequency is then slowly increased to produce resonances in the tubes. Students observe that at first only one of the tubes resonates at a time. Later, as the frequency gets very high, there are times when both tubes resonate.

   In a clear, coherent, paragraph-length answer, explain why there are some high frequencies, but no low frequencies, at which both tubes resonate. You may include diagrams and/or equations as part of your explanation.

Essential Knowledge	**6.D.3:** Standing waves are the result of the addition of incident and reflected waves that are confined to a region and have nodes and antinodes. Examples should include waves on a fixed length of string, and sound waves in both closed and open tubes.
	6.D.4: The possible wavelengths of a standing wave are determined by the size of the region to which it is confined.
Learning Objectives	**6.D.3.2:** The student is able to predict properties of standing waves that result from the addition of incident and reflected waves that are confined to a region and have nodes and antinodes.
	6.D.3.4: The student is able to describe representations and models of situations in which standing waves result from the addition of incident and reflected waves confined to a region.
	6.D.4.1: The student is able to challenge with evidence the claim that the wavelengths of standing waves are determined by the frequency of the source regardless of the size of the region.
Science Practices	**1.2:** The student can describe representations and models of natural or man–made phenomena and systems in the domain.
	6.1: The student can justify claims with evidence.
	6.4: The student can make claims and predictions about natural phenomena based on scientific theories and models.

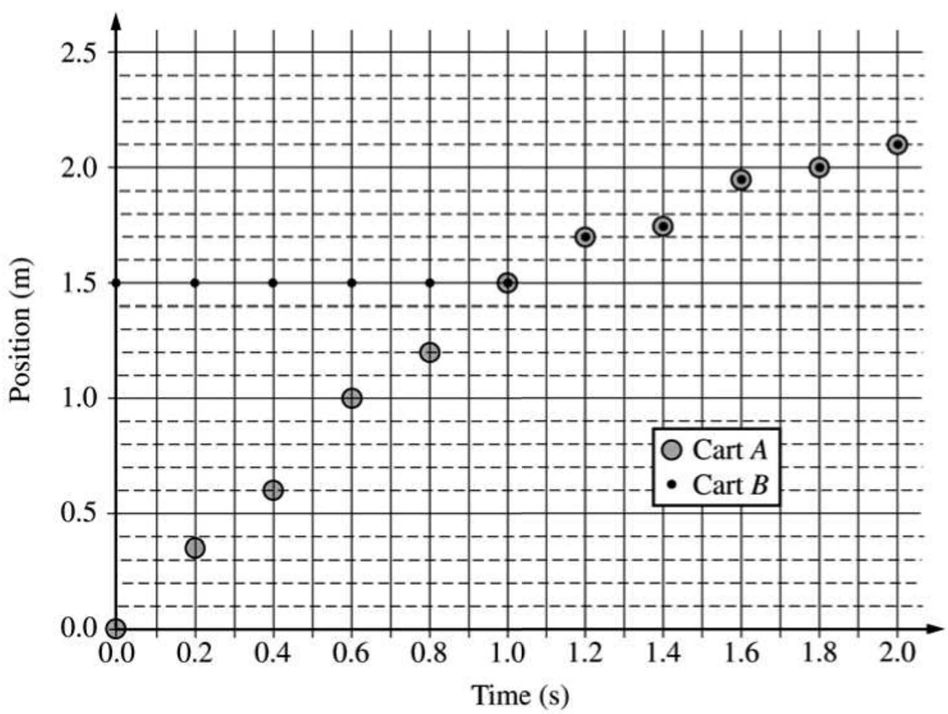


2. A group of students has two carts, A and B, with wheels that turn with negligible friction. The carts can travel along a straight horizontal track. Cart A has known mass m_A. The students are asked to use a one-dimensional collision between the carts to determine the mass of cart B. Before the collision, cart A travels to the right and cart B is initially at rest, as shown above. After the collision, the carts stick together.

   (a) Describe an experimental procedure to determine the velocities of the carts before and after a collision, including all the additional equipment you would need. You may include a labeled diagram of your setup to help in your description. Indicate what measurements you would take and how you would take them. Include enough detail so that another student could carry out your procedure.

   (b) There will be sources of error in the measurements taken in the experiment, both before and after the collision. For your experimental procedure, will the uncertainty in the calculated value of the mass of cart B be affected more by the error in the measurements taken before the collision or by those taken after the collision, or will it be equally affected by both sets of measurements? Justify your answer.

A group of students took measurements for one collision. A graph of the students' data is shown below.



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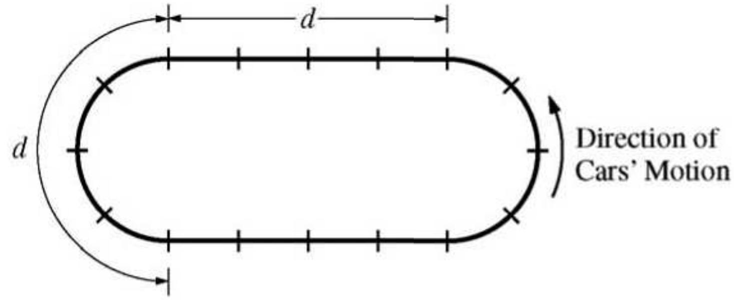
(c) Given $m_A = 0.50$ kg, use the graph to calculate the mass of cart B. Explicitly indicate the principles used in your calculations.

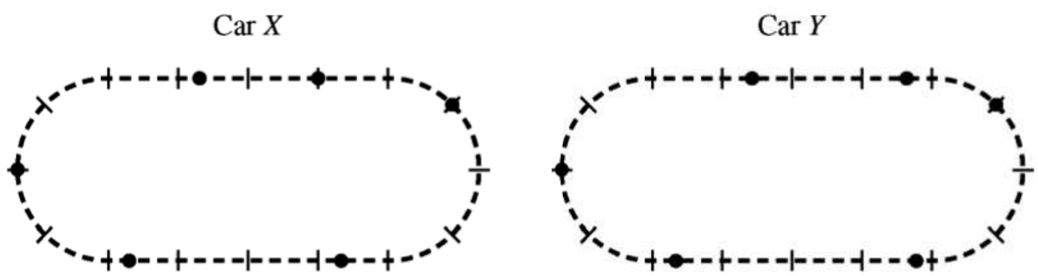
(d) The students are now asked to consider the kinetic energy changes in an inelastic collision, specifically whether the initial values of one of the physical quantities affect the fraction of mechanical energy dissipated in the collision. How could you modify the experiment to investigate this question? Be sure to explicitly describe the calculations you would make, specifying all equations you would use (but do not actually do any algebra or arithmetic).

Essential Knowledge	**3.A.1:** An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.
	5.D.1: In a collision between objects, linear momentum is conserved. In an elastic collision, kinetic energy is the same before and after.
	5.D.2: In a collision between objects, linear momentum is conserved. In an inelastic collision, kinetic energy is not the same before and after the collision.
Learning Objectives	**3.A.1.2:** The student is able to design an experimental investigation of the motion of an object.
	5.D.1.4: The student is able to design an experimental test of an application of the principle of the conservation of linear momentum, predict an outcome of the experiment using the principle, analyze data generated by that experiment whose uncertainties are expressed numerically, and evaluate the match between the prediction and the outcome.
	5.D.2.2: The student is able to plan data collection strategies to test the law of conservation of momentum in a two-object collision that is elastic or inelastic and analyze the resulting data graphically.
Science Practices	**4.2:** The student can *design a plan* for collecting data to answer a particular scientific question.
	5.1: The student can *analyze data* to identify patterns or relationships.
	5.3: The student can *evaluate the evidence provided by data sets* in relation to a particular scientific question.



3. The figure above represents a racetrack with semicircular sections connected by straight sections. Each section has length d, and markers along the track are spaced $d/4$ apart. Two people drive cars counterclockwise around the track, as shown. Car X goes around the curves at constant speed v_c, increases speed at constant acceleration for half of each straight section to reach a maximum speed of $2v_c$, then brakes at constant acceleration for the other half of each straight section to return to speed v_c. Car Y also goes around the curves at constant speed v_c, increases speed at constant acceleration for one-fourth of each straight section to reach the same maximum speed $2v_c$, stays at that speed for half of each straight section, then brakes at constant acceleration for the remaining fourth of each straight section to return to speed v_c.

   (a) On the figures below, draw an arrow showing the direction of the net force on each of the cars at the positions noted by the dots. If the net force is zero at any position, label the dot with 0.



   (b)

   i. Indicate which car, if either, completes one trip around the track in less time, and justify your answer qualitatively without using equations.

   ii. Justify your answer about which car, if either, completes one trip around the track in less time quantitatively with appropriate equations.

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(c) Explain how your equations in part (b) ii reexpress your reasoning in part (b) i. Do not simply refer to any final results of your calculations, but instead indicate how terms in your equations correspond to concepts in your qualitative explanation.

Essential Knowledge	**3.A.1:** An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.
	3.A.2: Forces are described by vectors.
Learning Objectives	**3.A.1.1:** The student is able to express the motion of an object using narrative, mathematical, and graphical representations.
	3.A.2.1: The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation.
Science Practices	**1.1:** The student can *create representations and models* of natural or man-made phenomena and systems in the domain.
	1.5: The student can *reexpress key elements of natural phenomena across multiple representations* in the domain.
	2.2: The student can *apply mathematical routines* to quantities that describe natural phenomena.