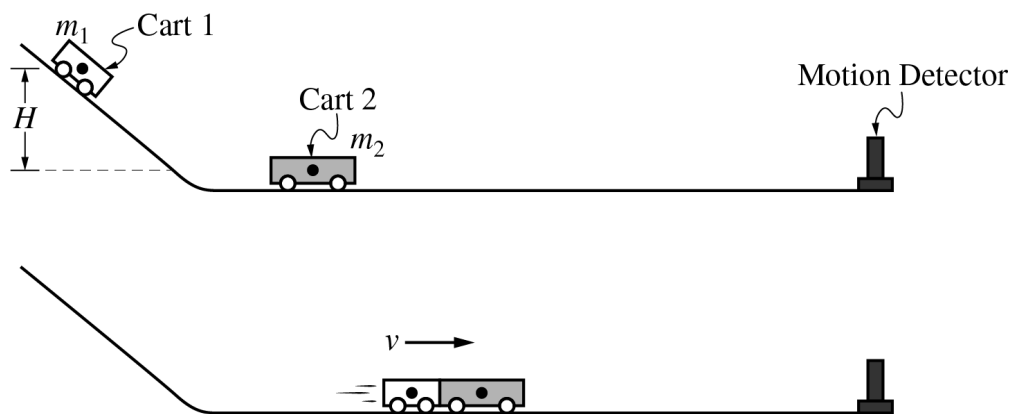




Cart 1 of mass m_1 is held at rest above the bottom of an incline. Cart 2 has mass m_2 , where $m_2 > m_1$, and is at rest at the bottom of the incline. At time $t = 0$, Cart 1 is released and then travels down the incline and smoothly transitions to the horizontal section. The center of mass of Cart 1 moves a vertical distance of H , as shown. At time t_C , Cart 1 reaches the bottom of the incline and immediately collides with and sticks to Cart 2. After the collision, the two-cart system moves with constant speed v . Frictional and rotational effects are negligible.

(a) During the collision, is the impulse on Cart 1 from Cart 2 greater than, less than, or equal to the magnitude of the impulse on Cart 2 from Cart 1?

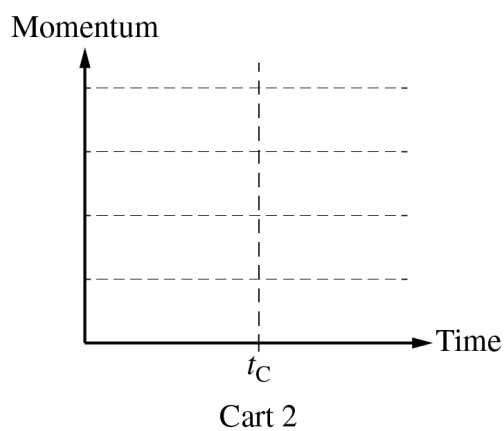
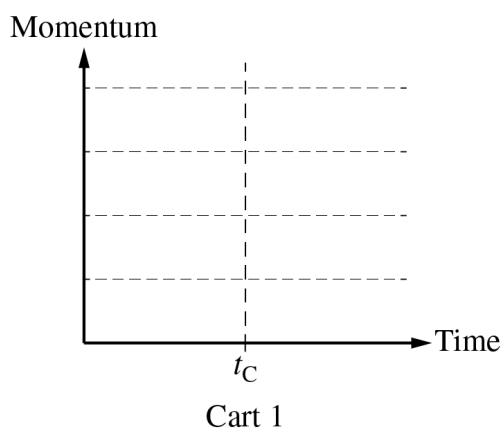
☐ Greater than ☐ Less than ☐ Equal to

Justify your answer.

GO ON TO THE NEXT PAGE.

Continue your response to **QUESTION 2** on this page.

- (b) On the following axes, draw graphs of the magnitude of the momentum of each cart as a function of time t , before and after t_C . The collision occurs in a negligible amount of time. The grid lines on each graph are drawn to the same scale.



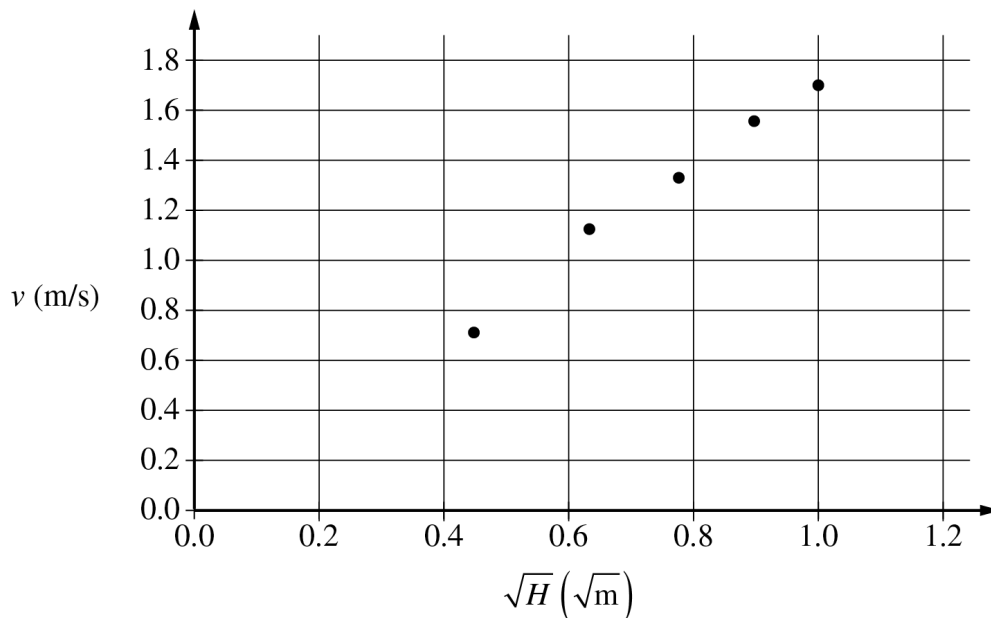
- (c) Show that the velocity v of the two-cart system after the collision is given by the equation

$$v = \sqrt{2g} \left(\frac{m_1}{m_1 + m_2} \right) \sqrt{H}.$$

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Continue your response to **QUESTION 2** on this page.

- (d) A group of students use the setup to perform an experiment. They measure the mass of Cart 1 to be $m_1 = 0.250$ kg. The mass of Cart 2 is unknown. The students perform several trials and in each trial, Cart 1 is released from a different height H and the final velocity of the two-cart system is measured. The students graph v as a function of $\sqrt{H}$, as shown below.



- i. Draw a line that represents the best fit to the data points shown.
- ii. Use the best-fit line to calculate the mass of Cart 2.

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Continue your response to **QUESTION 2** on this page.

- (e) After the experiment, the students use a balance to measure the mass of Cart 2 and find it to be less than what was determined in part (d). To explain this discrepancy, one of the students proposes that the mass of Cart 1 was incorrectly measured at the beginning of the experiment. The students measure the mass of Cart 1 again and record a new value, m_1' .

Should the students expect that m_1' will be greater than 0.250 kg, less than 0.250 kg, or equal to 0.250 kg ?

_____ $m_1' > 0.250 \text{ kg}$ _____ $m_1' < 0.250 \text{ kg}$ _____ $m_1' = 0.250 \text{ kg}$

Justify your answer.

GO ON TO THE NEXT PAGE.



Mech.2.

A block of mass $2M$ rests on a horizontal, frictionless table and is attached to a relaxed spring, as shown in the figure above. The spring is nonlinear and exerts a force $F(x) = -Bx^3$, where B is a positive constant and x is the displacement from equilibrium for the spring. A block of mass $3M$ and initial speed v_0 is moving to the left as shown.

- (a) On the dots below, which represent the blocks of mass $2M$ and $3M$, draw and label the forces (not components) that act on each block before they collide. Each force must be represented by a distinct arrow starting on, and pointing away from, the appropriate dot.

Block of Mass $2M$

Block of Mass $3M$



The two blocks collide and stick to each other. The two-block system then compresses the spring a maximum distance D , as shown above. Express your answers to parts (b), (c), and (d) in terms of M , B , v_0 , and physical constants, as appropriate.

- (b) Derive an expression for the speed of the blocks immediately after the collision.
(c) Determine an expression for the kinetic energy of the two-block system immediately after the collision.
(d) Derive an expression for the maximum distance D that the spring is compressed.

(e)

- i. In which direction is the net force, if any, on the block of mass $2M$ when the spring is at maximum compression?

____ Left ____ Right ____ The net force on the block of mass $2M$ is zero.

Justify your answer.

- ii. Which of the following correctly describes the magnitude of the net force on each of the two blocks when the spring is at maximum compression?

____ The magnitude of the net force is greater on the block of mass $2M$.
____ The magnitude of the net force is greater on the block of mass $3M$.
____ The magnitude of the net force on each block has the same nonzero value.
____ The magnitude of the net force on each block is zero.

Justify your answer.

- (f) Do the two blocks, which remain stuck together and attached to the spring, exhibit simple harmonic motion after the collision?

____ Yes ____ No

Justify your answer.