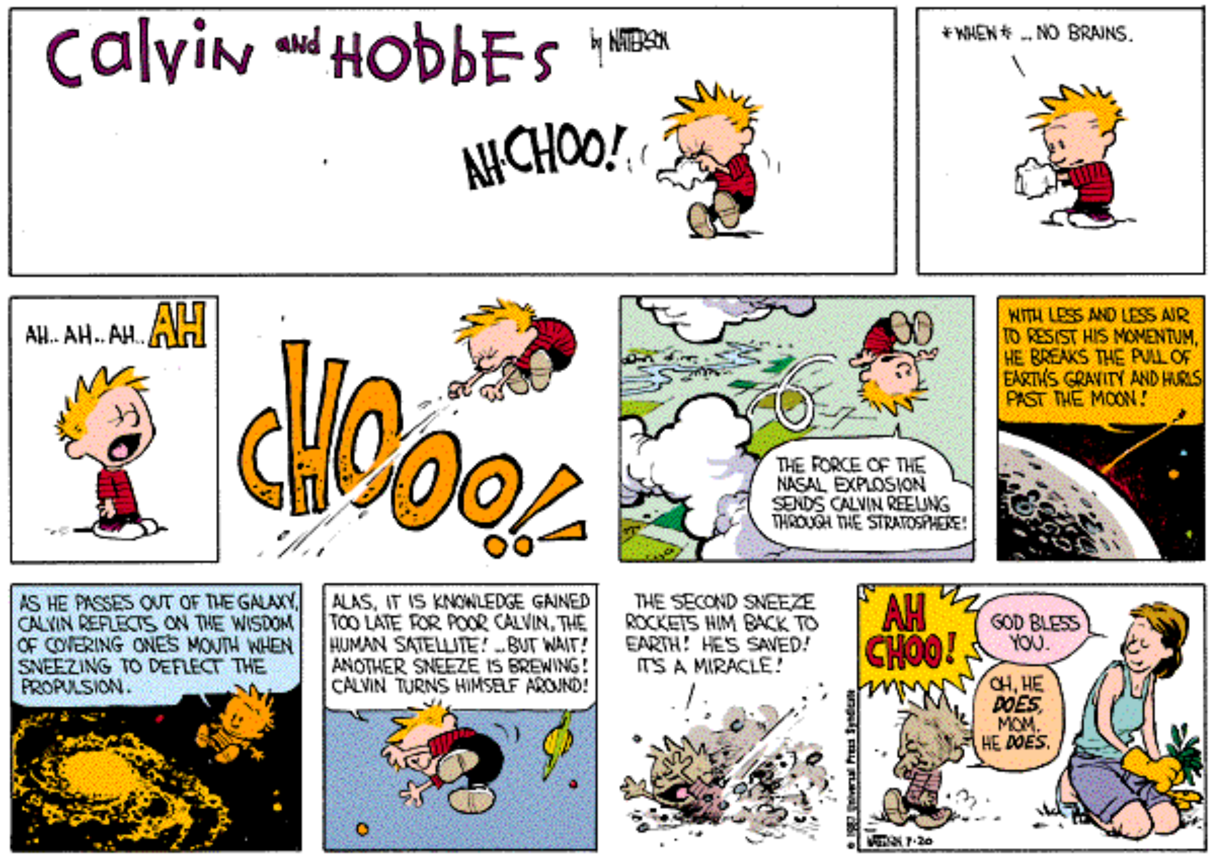
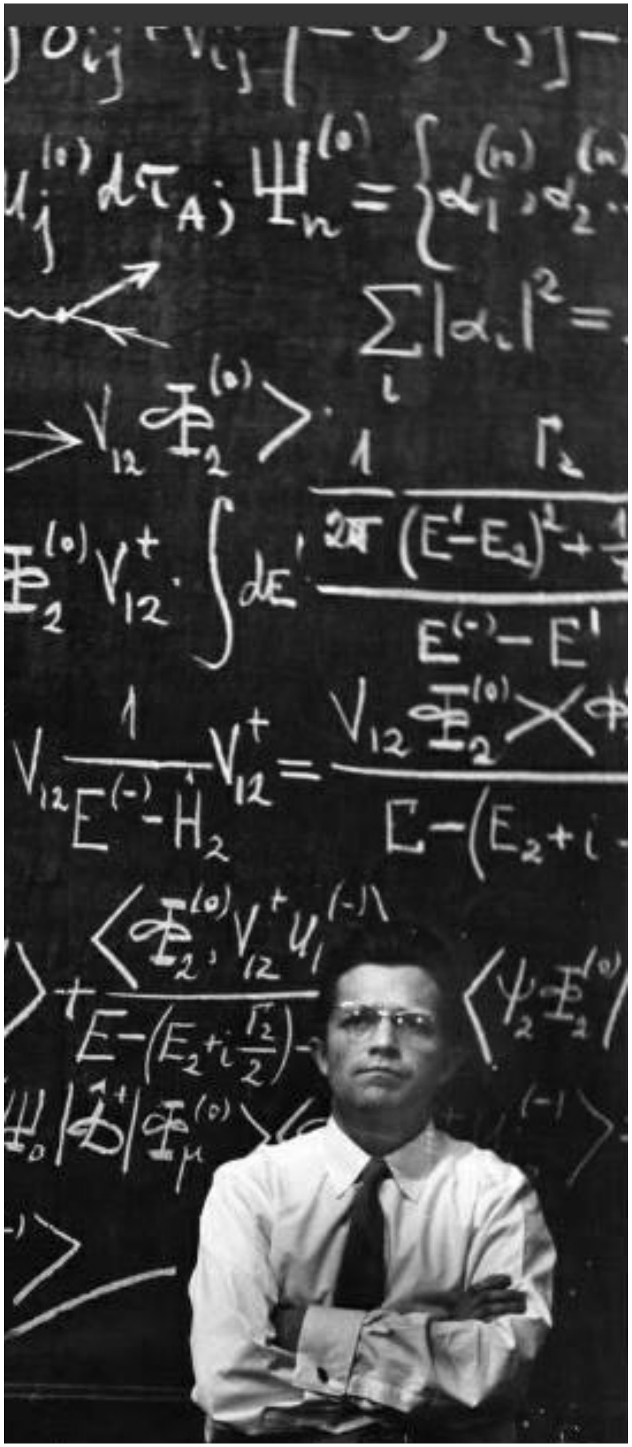
- **Theme Music:** **Fleetwood Mac**
  ***Don't stop***

- **Cartoon:**
  **Bill Waterson**
  ***Calvin & Hobbes***



# Outline

- Go over Quiz 5
- Momentum
  - Recap definition and
    the Impulse-Momentum Theorem
  - Momentum conservation
  - Examples



# The Equation of the Day

## Momentum Conservation

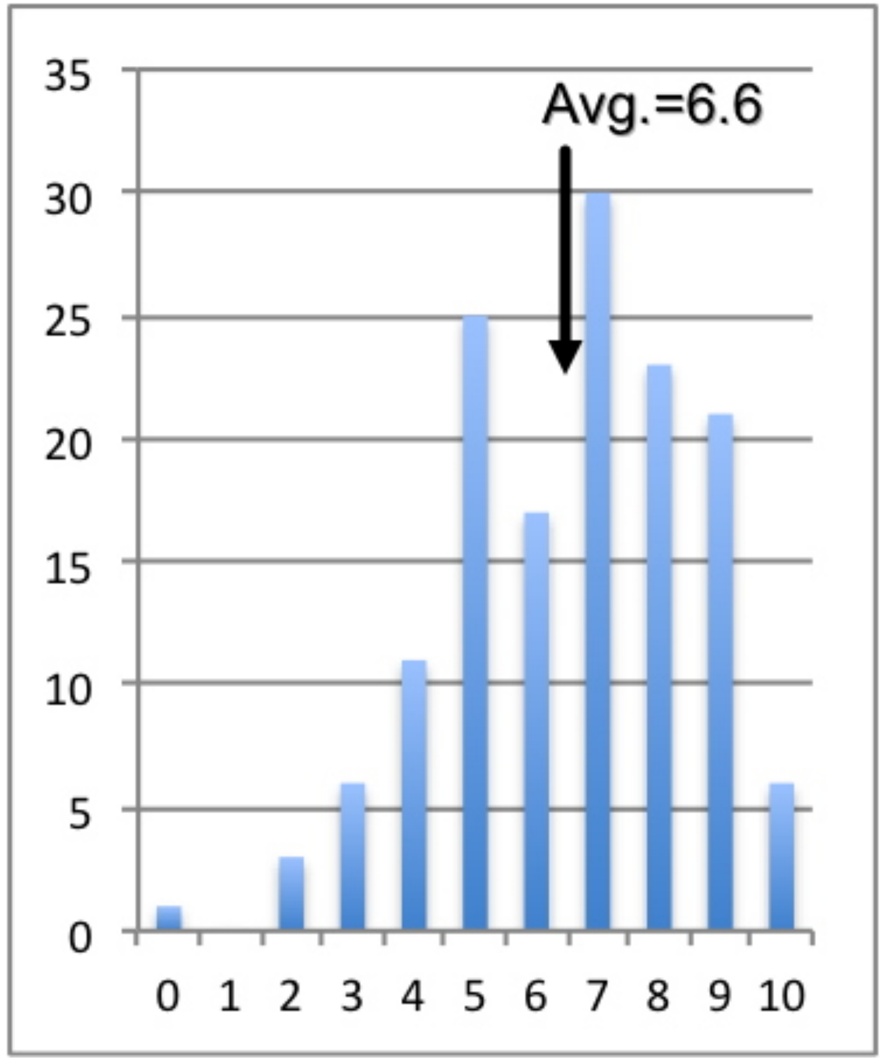
$$\vec{p}_A^{\,i} + \vec{p}_B^{\,i} = \vec{p}_A^{\,f} + \vec{p}_B^{\,f}$$

$$\Delta\vec{p}_A = -\Delta\vec{p}_B$$

# Quiz 5

| | 1 | | 2 |
|---|---|---|---|
| a | 38% | A | 12% |
| b | 44% | B | 91% |
| c | 76% | C | 63% |
| d | 73% | D | 6% |
| e | 1% | | |

| | 3.1 | 3.2 |
|---|---|---|
| a | 13% | 21% |
| b | 1% | 7% |
| c | 1% | 71% |
| d | 72% | 1% |
| e | 13% | 0% |



# Foothold ideas: Momentum

- We define the <u>momentum</u> of an object, A:

$$\vec{p}_A = m_A \vec{v}_A$$

- This is a way of defining "the amount of motion" an object has.
- Our "delta" form of N2 becomes

$$\vec{F}_A^{net} = m_A \frac{\Delta \vec{v}_A}{\Delta t} = m_A \vec{a}_A$$

which we can rewrite as

$$\vec{F}_A^{net} = \frac{\Delta(m_A \vec{v}_A)}{\Delta t} = \frac{\Delta \vec{p}_A}{\Delta t}$$

# Foothold idea:
# The Impulse-Momentum Theorem

- Newton 2 $$\vec{a}_A = \vec{F}_A^{net} / m_A$$
- Put in definition of *a* $$\frac{d\vec{v}_A}{dt} = \frac{\vec{F}_A^{net}}{m_A}$$
- Multiply up by $\Delta t$ $$m_A \Delta \vec{v}_A = \vec{F}_A^{net} \Delta t$$
- Define Impulse $$\vec{\mathscr{I}}_A^{\,net} = \vec{F}_A^{net} \Delta t$$
- Combine to get Impulse-Momentum Theorem for any object A $$\Delta \vec{p}_A = \vec{\mathscr{I}}_A^{\,net}$$

# Foothold idea: Momentum Conservation: 1

- If two objects, A and B, interact with each other and with other ("external") objects, By the IMT

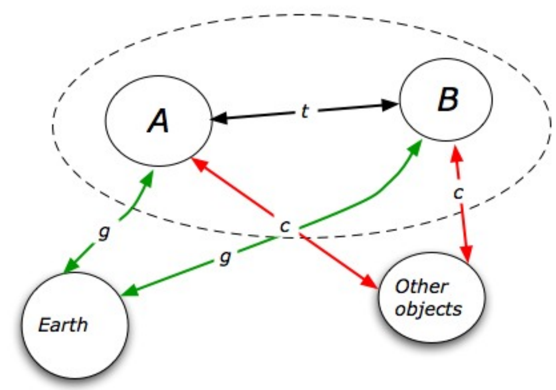
$$m_A \Delta\vec{v}_A = (\vec{F}_A^{ext} + \vec{F}_{B\to A})\Delta t$$

$$m_B \Delta\vec{v}_B = (\vec{F}_B^{ext} + \vec{F}_{A\to B})\Delta t$$

- Adding:

$$m_A \Delta\vec{v}_A + m_B \Delta\vec{v}_B = \left[\vec{F}_A^{ext} + \vec{F}_B^{ext} + \left(\vec{F}_{A\to B} + \vec{F}_{B\to A}\right)\right]\Delta t$$

$$\Delta\left(m_A\vec{v}_A + m_B\vec{v}_B\right) = \vec{F}_{AB}^{ext}\Delta t$$

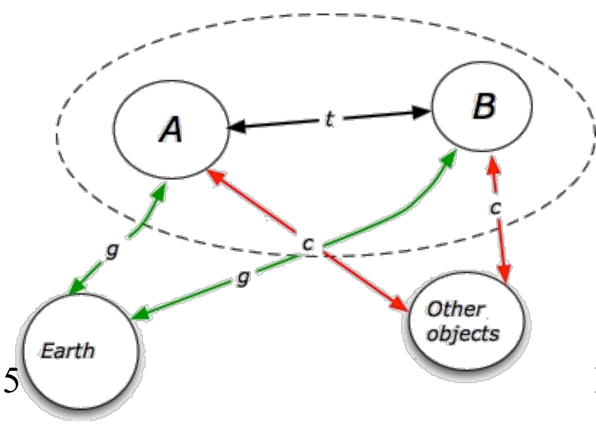


# Foothold idea: Momentum Conservation: 2

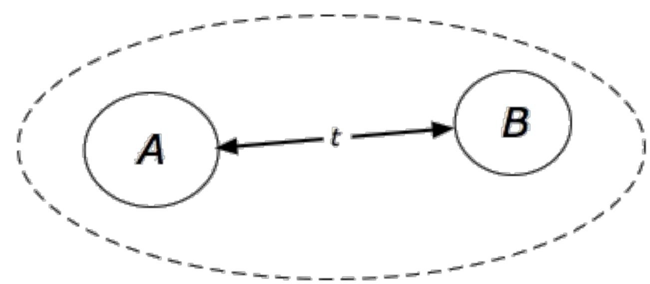
- So: If two objects interact with each other in such a way that the external forces on the pair cancel, then their momentum is conserved.

$$\Delta\left(m_A\vec{v}_A + m_B\vec{v}_B\right) = 0$$

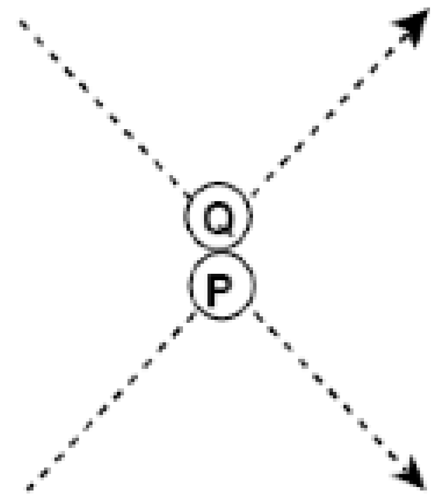
$$m_A\vec{v}_A^{\,i} + m_B\vec{v}_B^{\,i} = m_A\vec{v}_A^{\,f} + m_B\vec{v}_B^{\,f}$$



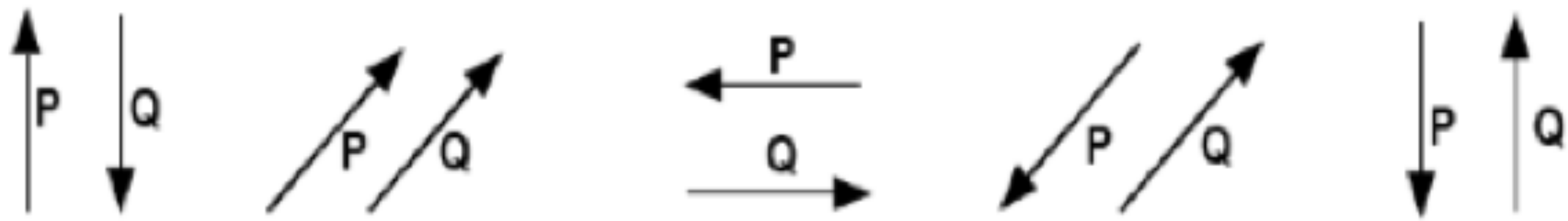

$\Rightarrow$



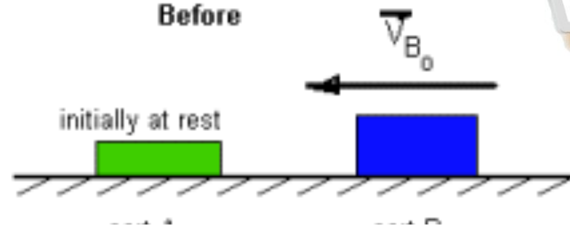
The diagram at the right depicts the path of two colliding steel balls rolling on a table. Which set of arrows best represents the direction of the change in momentum of each ball?




(1) (2) (3) (4) (5)

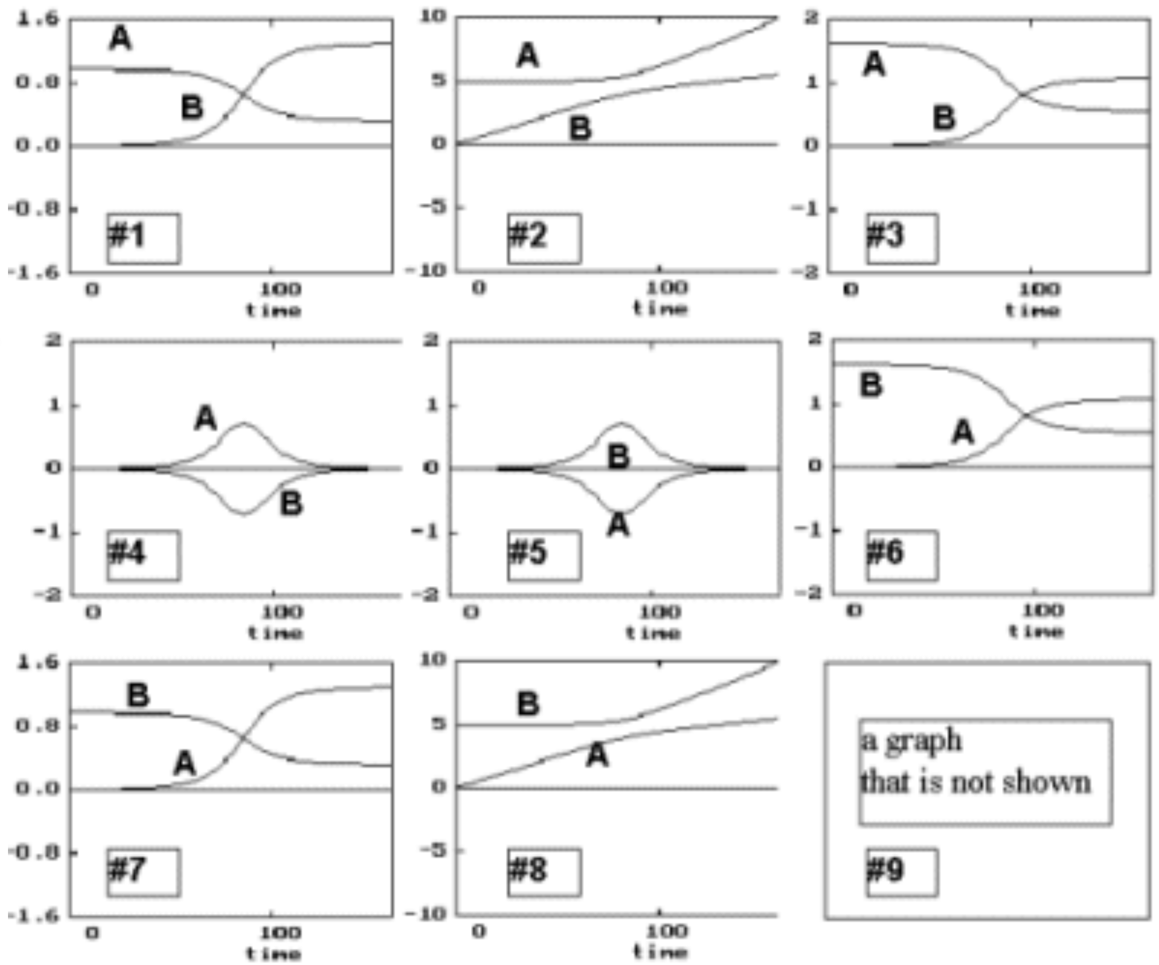



Two carts are riding on an air track. At time t = 0 cart B is at the origin traveling in the +*x* direction with speed $v_{B0}$ cart A is at the position shown and is at rest. Cart B has twice the mass of cart A. The carts "bump" each other, but don't stick together.




Which graph could represent

The **position** of the carts?



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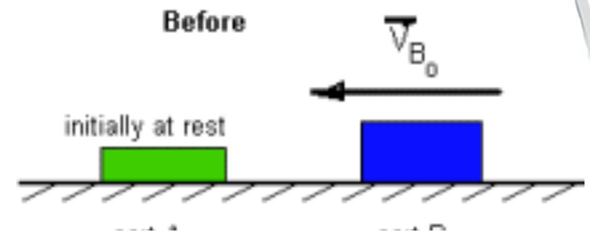


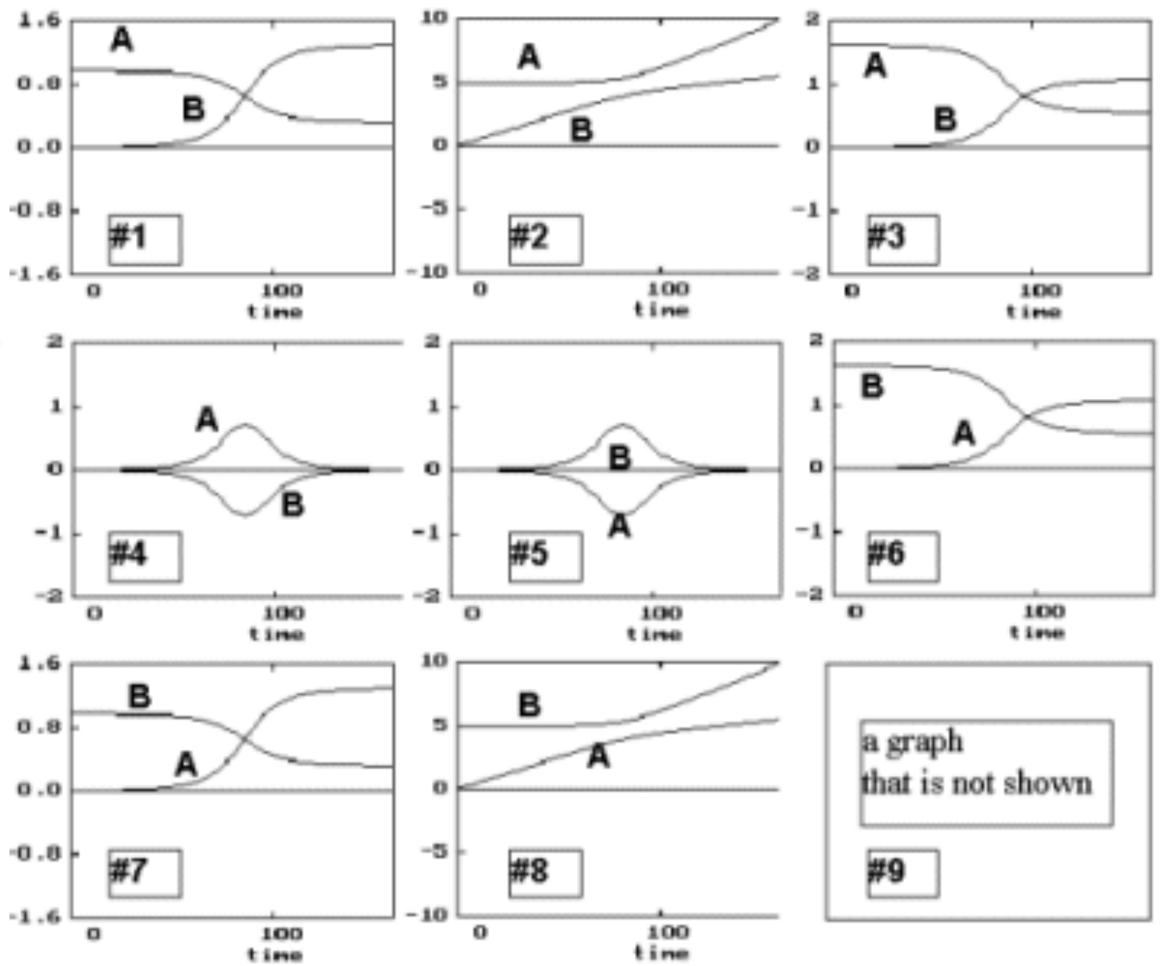


Which graph could represent

The **velocity** of the carts?

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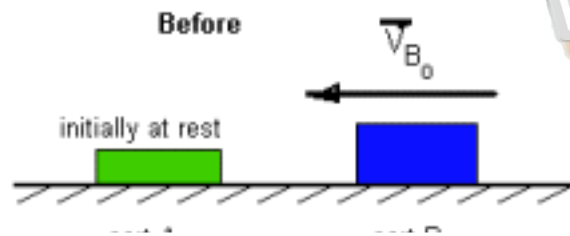
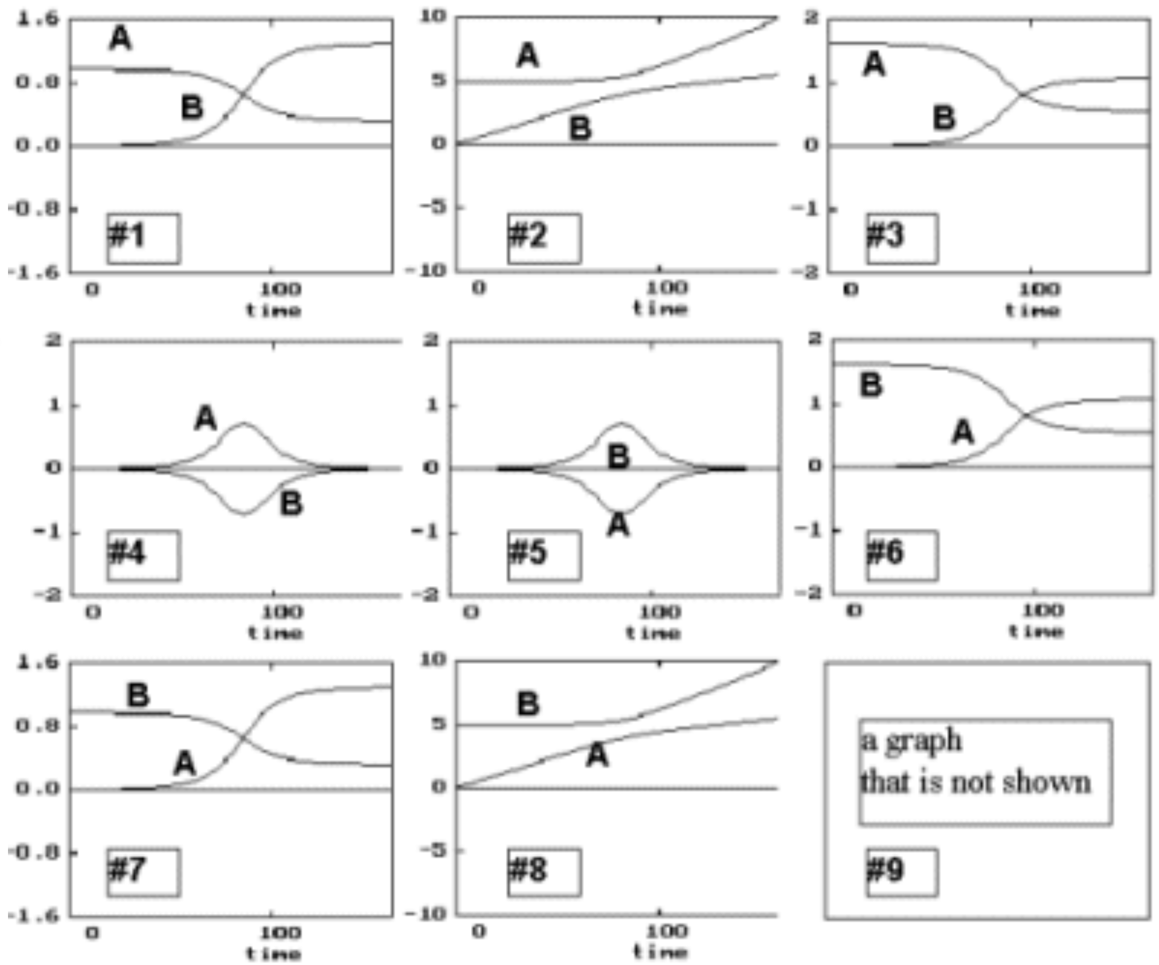



Which graph could represent

The **forces** each cart exerts on the other cart?



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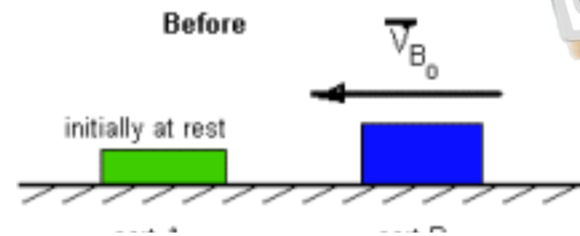
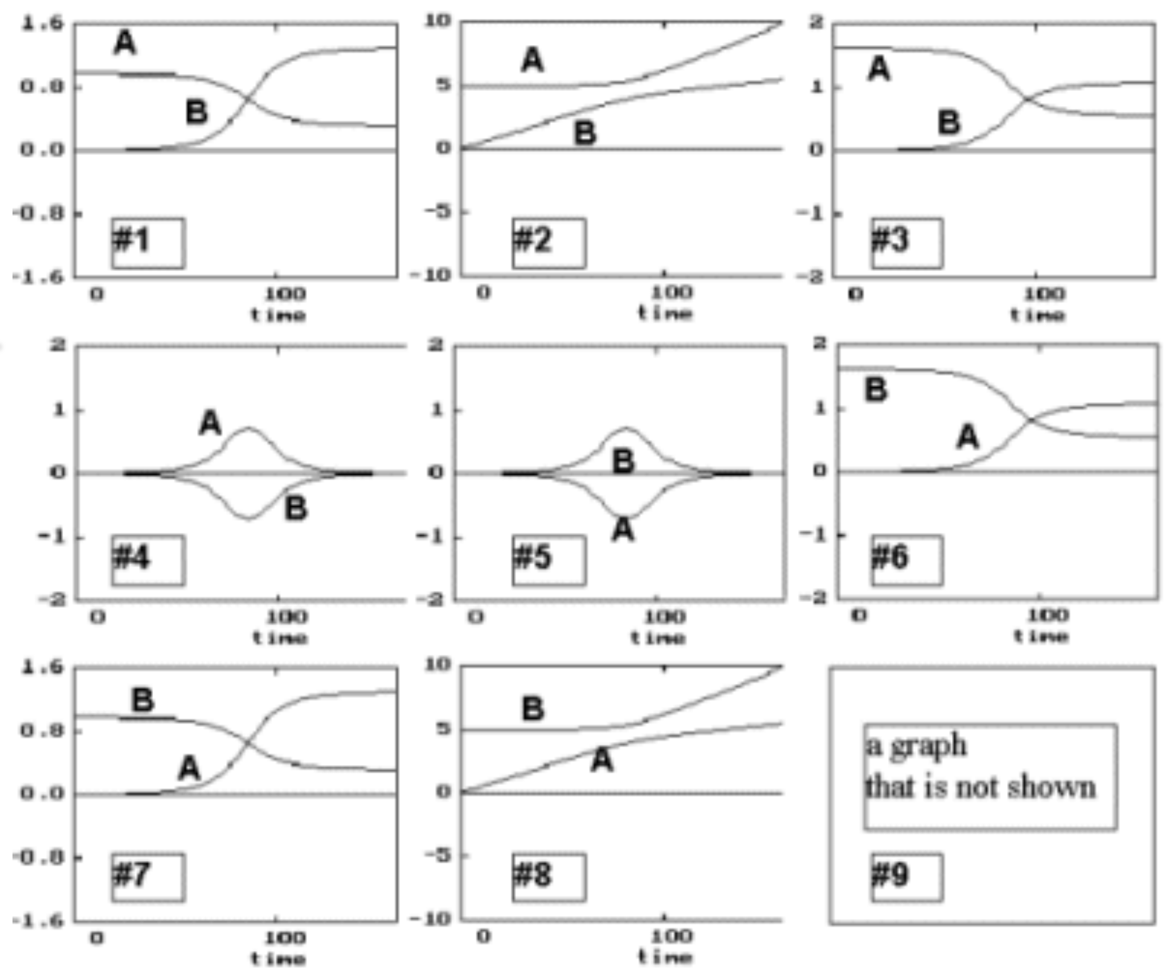


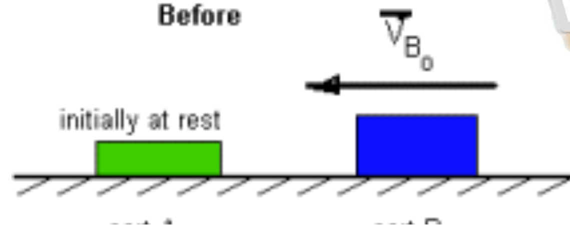




Which graph could represent

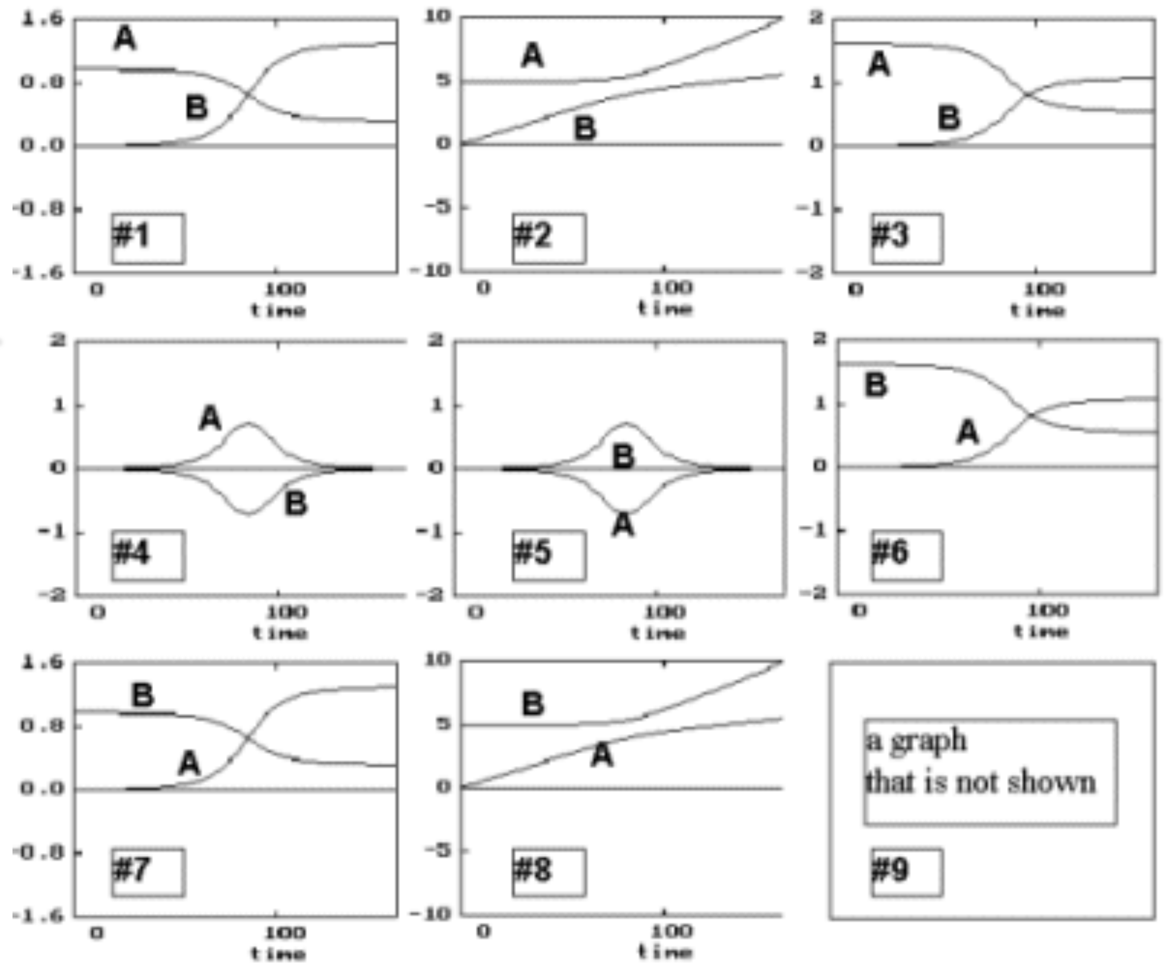
The **momentum** of the carts?

10/19/15

Two carts are riding on an air track. At time t = 0 cart B is at the origin traveling in the +*x* direction with speed $v_{B0}$ cart A is at the position shown and is at rest. Cart B has twice the mass of cart A. The carts "bump" each other, but don't stick together.

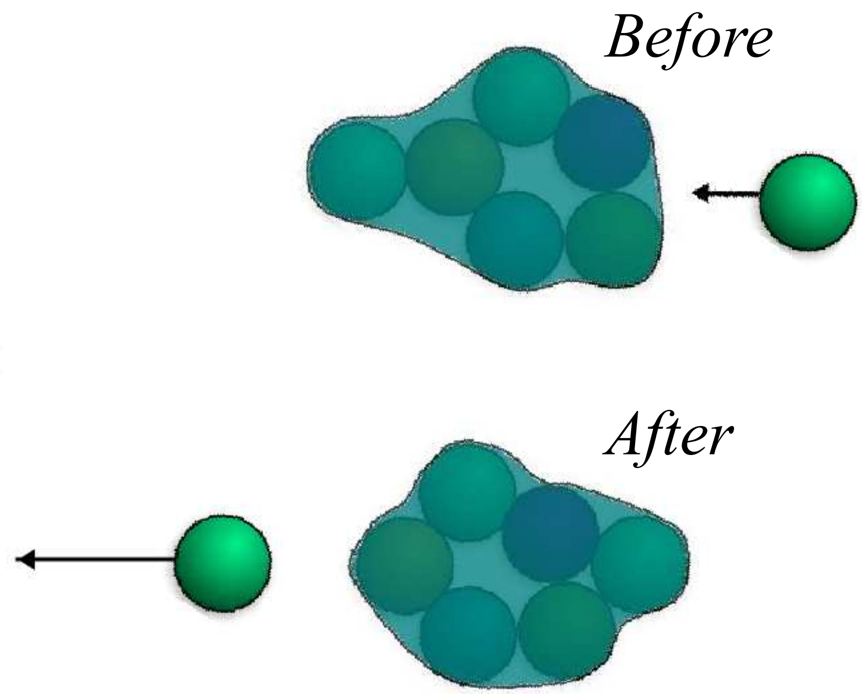

What would a graph of the **total momentum** of the carts look like?




10/19/15


A molecular cluster at rest collides with an atom. As a result, the atom becomes strongly bound to the cluster and an identical atom (from a different part of the molecule) gets shot off with much higher speed. What can you say about the motion of the reformed cluster after the collision?

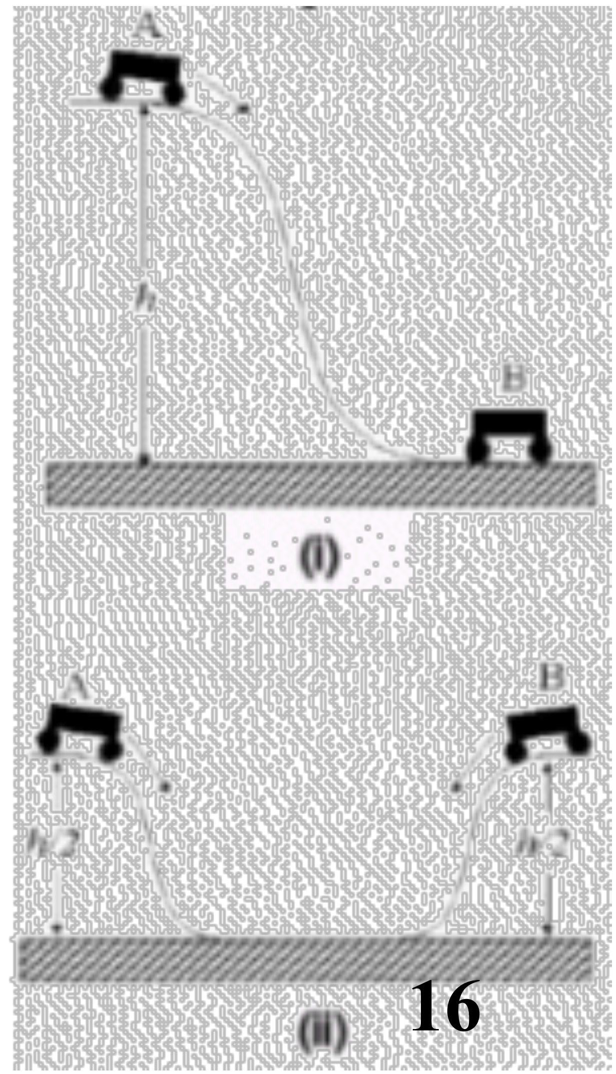
A. It will be stationary.
B. It will move to the left.
C. It will move to the right.
D. This is not really possible, despite the claim that it is.
E. You can't say anything about it from the information given.
F. Something else.




Two identical carts A and B roll down a hill and collide as shown in the figures at the right.

**(i):** A starts from rest. It rolls down and collides head-on with B which is initially at rest on the ground. The two carts stick together.

**(ii):** A and B are at rest on opposite sides of the hill. They roll down, collide head-on and stick together.




Which statement is true about the two-cart system <u>just before</u> the carts collide in the two cases?

1. The momentum of the system is zero in case (ii).
2. The momentum of the system is greater in case (i) than in case (ii).
3. The momentum of the system is greater in case (ii) than in case ii).
4. The momentum of the system is the same in both cases (but not 0).
5. More than one statement is true.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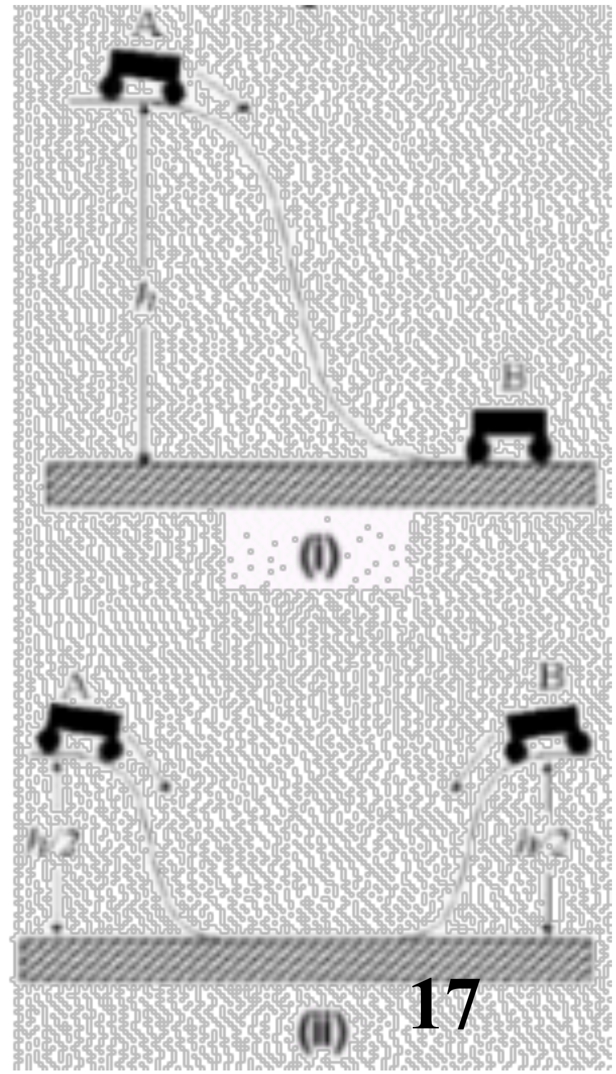


Which statement is true about the two-cart system just after the carts collide and stick in the two cases?

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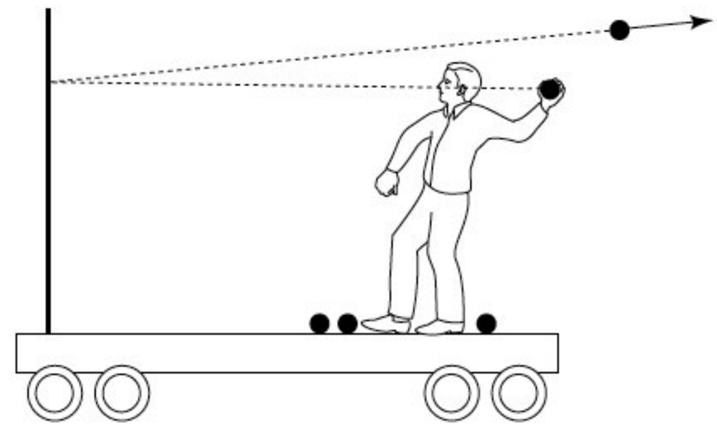
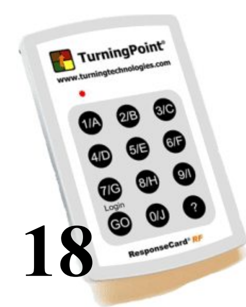
Suppose you are on a cart, initially at rest on a track with negligible friction.



You throw balls at a partition that is rigidly mounted on the cart. The balls bounce straight back as shown in the figure.

Is the total horizontal momentum of the person, cart, partition, plus all the balls conserved in the process of throwing the balls and having them bounce off the partition?

(1) Yes.
(2) No.
(3) You are not given enough information to decide.



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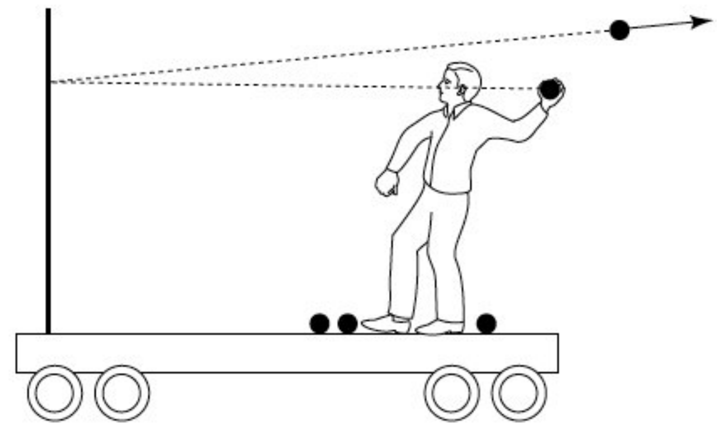

Is the cart put in motion?

(1) Yes. Towards the left
(2) Yes. Towards the right.
(3) No.
(4) You are not given enough information to decide.