a place of mind

FACULTY OF EDUCATION

Department of
Curriculum and Pedagogy

Physics
Kinematics: Reference Frames

Science and Mathematics
Education Research Group

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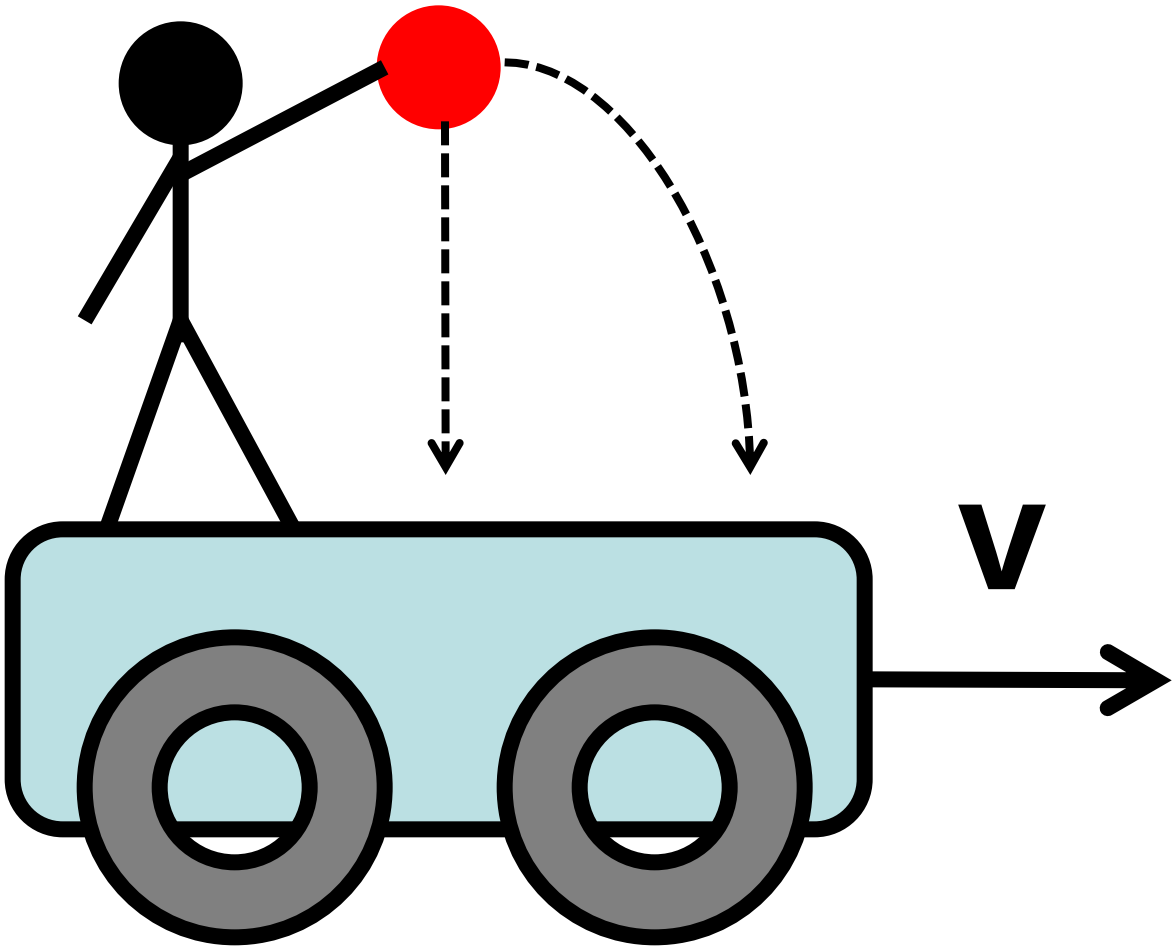
Ball on a Moving Cart



Ball on a Cart I

A. ↓

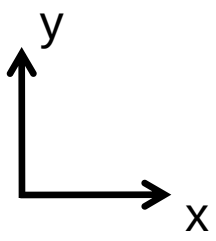
B. ↑

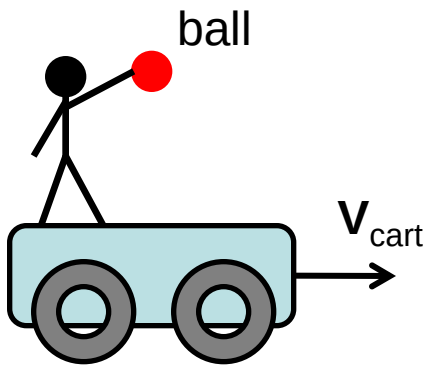
C. 0m/s

D. ←

E. →

A person is holding a ball while on a cart that is moving at a constant velocity of $\mathbf{V}_{cart}$. What is the velocity of the ball at the moment it is released, as measured by an *observer standing on the cart*?





Solution

Answer: C

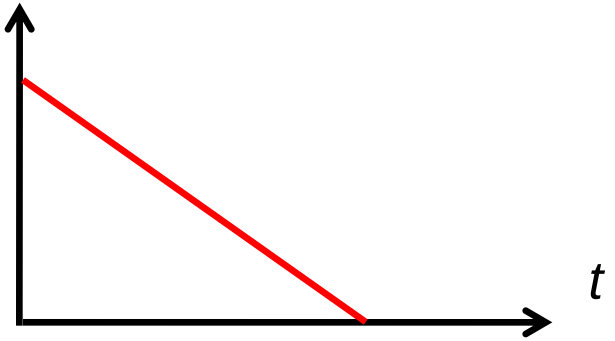
Justification: When the ball is first dropped, gravity has not yet changed the vertical velocity of the ball. Therefore, the vertical component of velocity is still 0 m/s.

Since the ball, cart, and person are moving at $\mathbf{V}_{cart}$, the horizontal component of velocity will appear to be 0 m/s when measured by the person on the cart.

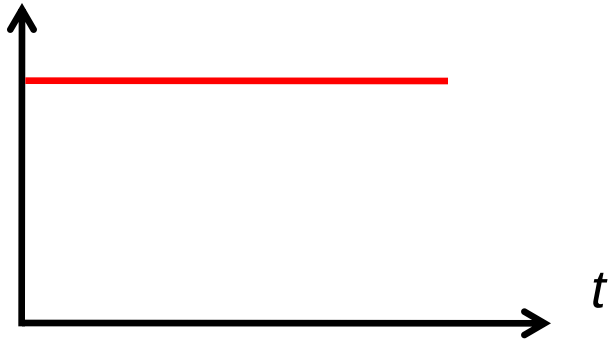
Ball on a Cart II

Consider the same scenario as the previous question. Which of the following y-t graphs best describes the motion of the ball, as seen by the *observer on the cart*. Let y = 0 be the top of the cart and t = 0 be the moment the ball is dropped.

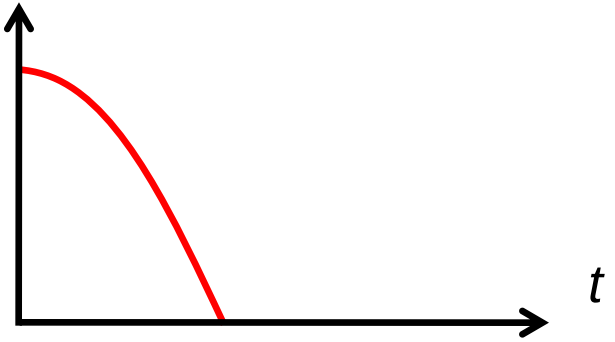
A.



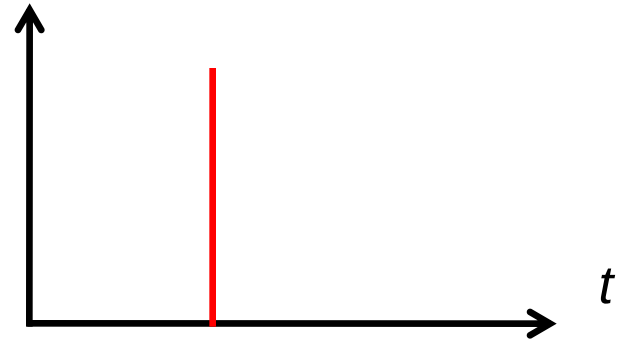
B.



C.



D.



Solution

Answer: C

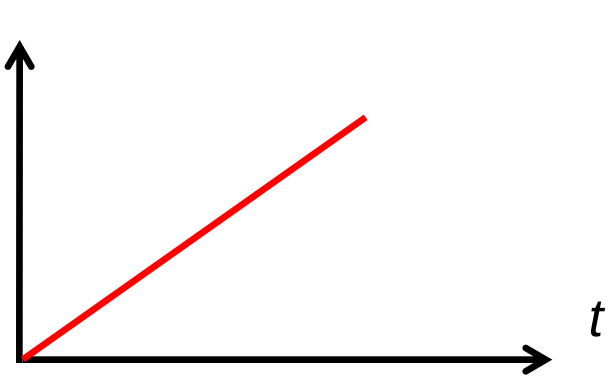
Justification: The curve in Graph C correctly shows the ball falling faster over time due to gravitational acceleration.

Graph A is incorrect because it suggests that the ball is falling with constant velocity. Graph B is incorrect because the ball has the same vertical displacement for all time t - the ball will be floating in the air! Graph D is incorrect because it suggests that the ball falls instantaneously.

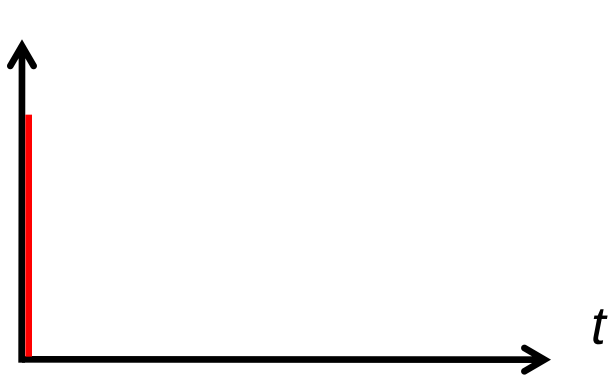
Ball on a Cart III

Consider the same scenario as the first question. Which of the following x-t graphs best describes the motion of the ball, as seen by the *observer on the cart*. Let x = 0 be the horizontal position of the ball when it is released and t = 0 be the moment the ball is dropped.

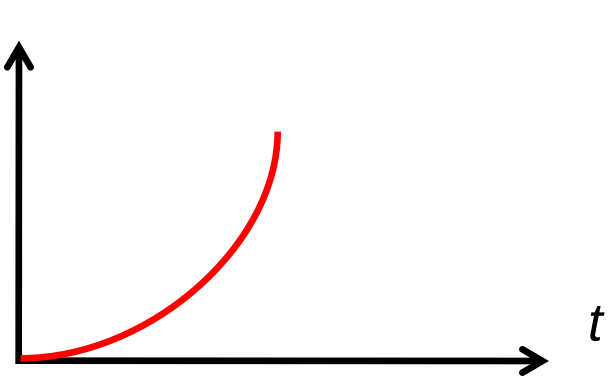
A.



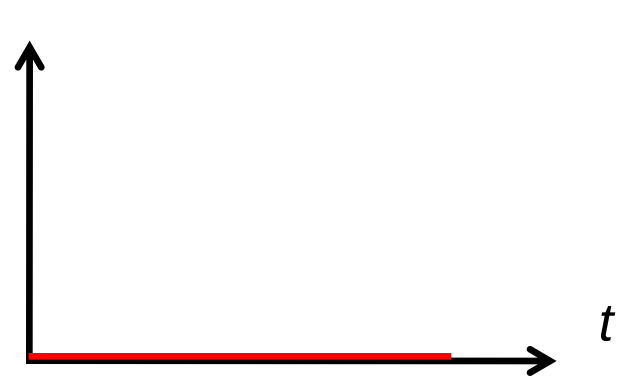
B.



C.



D.



Solution

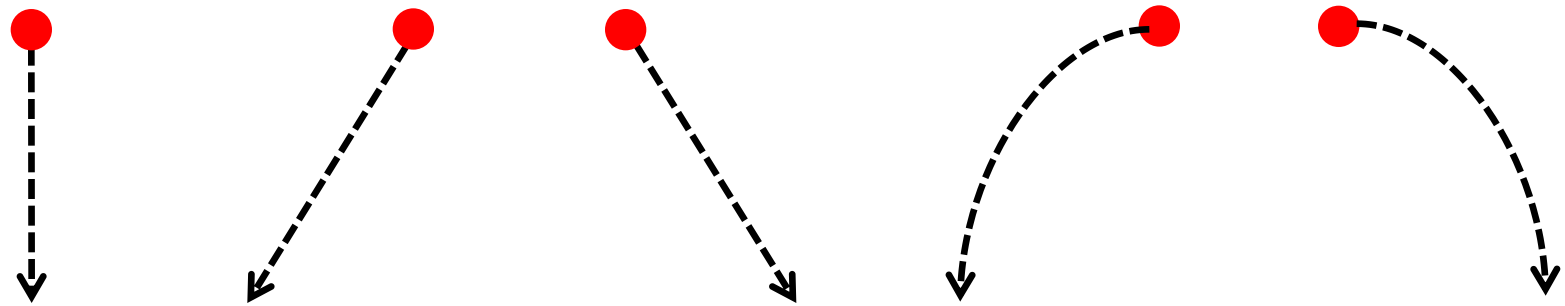
Answer: D

Justification: From Part I, we know the observer on the cart does not measure any horizontal component of velocity.

In the reference frame of the observer, the ball falls straight down, and the horizontal position of the ball doesn't change. The ball will be at x=0 for all times t>0.

Ball on a Cart IV

Which of the following correctly shows the trajectory of the ball, as seen by the *observer on the cart?*



A. B. C. D. E.

Solution

Answer: A

Justification: The person on the moving cart will see the ball drop to his feet. Recall from the previous question that there is no horizontal displacement. If the person was standing in an enclosed cart, the person would think he was dropping a ball while standing on the ground!

Ball on a Cart V

A. 0 m/s

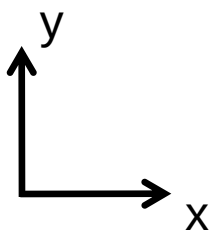
B. 

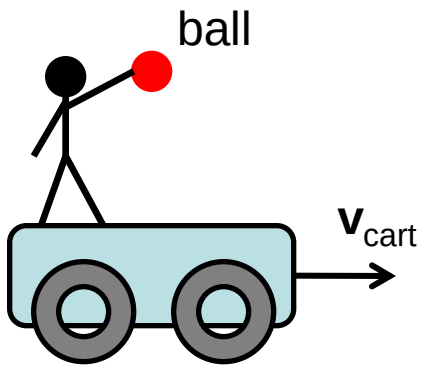
C. 

D. 

E. 

A person is holding a ball while on a cart moving at a constant velocity of $\mathbf{v}_{cart}$. What is the velocity of the ball at the moment it is released, as measured by an *observer standing on the ground*?





Solution

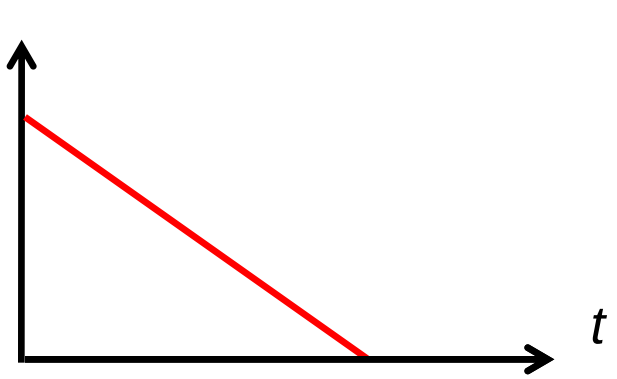
Answer: E

Justification: When the person is holding the ball, its velocity is the same as the cart's. The moment the ball is released, acceleration due to gravity has not yet changed the vertical component of the ball's velocity. Therefore, the velocity of the ball just after it has been dropped is still $\mathbf{v}_{cart}$.

Ball on a Cart VI

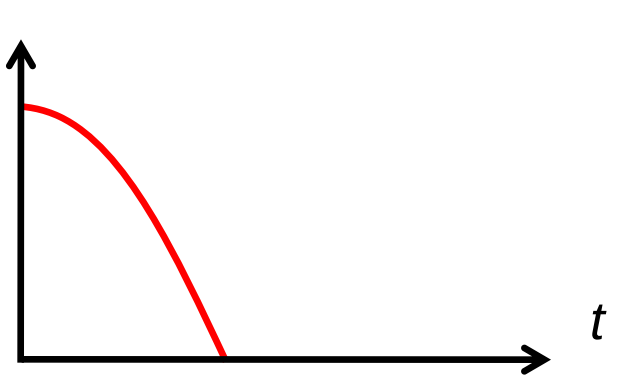
Consider the same scenario as the previous question. Which of the following y-t graphs best describes the motion of the ball, as seen by the *observer on the ground*. Let y = 0 be the top of the cart and t = 0 be the moment the ball is dropped.

A.

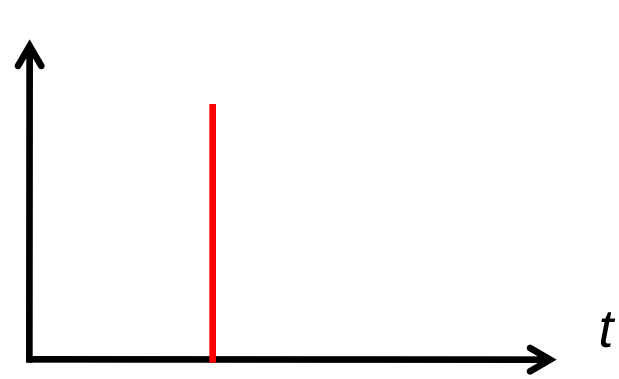


B.

C.



D.



Solution

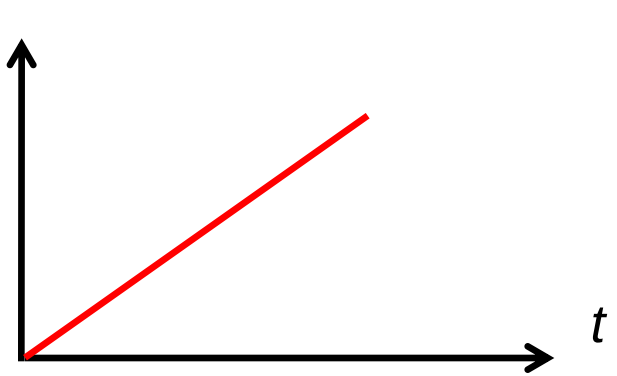
Answer: C

Justification: Both the observer on the ground and cart will measure the exact same vertical displacement (see answer for question II). The horizontal velocity of the ball does not change its vertical displacement, but does affect its total velocity at every instant in time. As the ball accelerates downward, the instantaneous velocity is adjusted by $\mathbf{v}_{cart}$.

Ball on a Cart VII

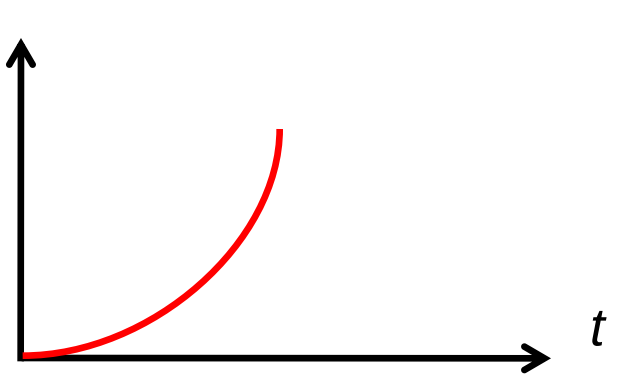
Consider the same scenario as the previous question. Which of the following x-t graphs best describes the motion of the ball, as seen by the *observer on the ground*. Let x = 0 be the position of the ball when it is released and t = 0 be the moment the ball is dropped.

A.

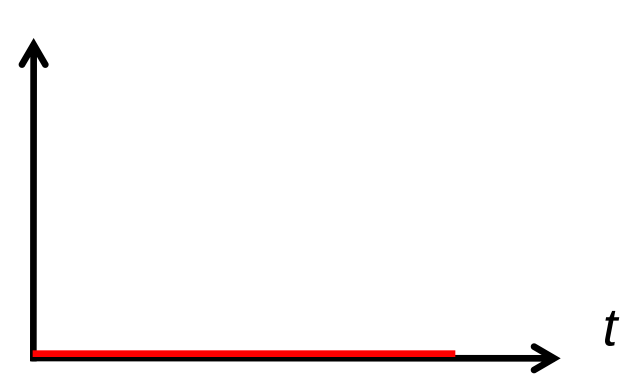


B.

C.



D.



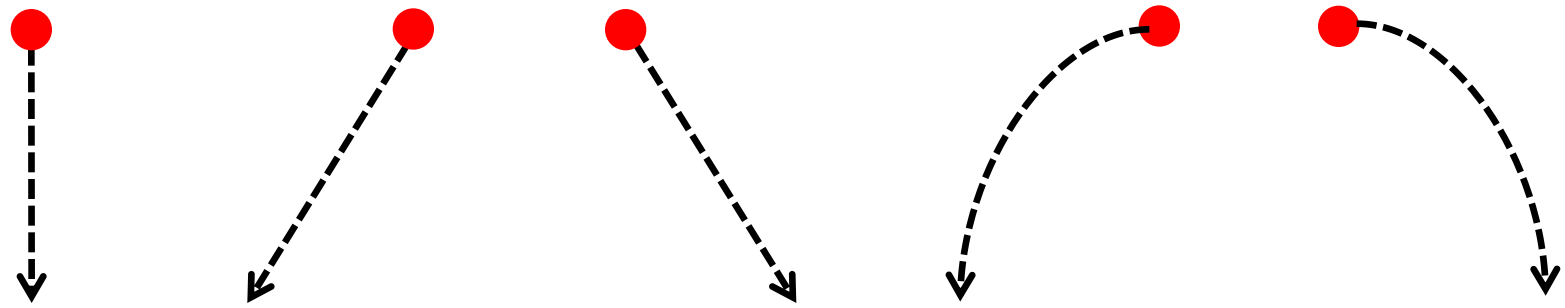
Solution

Answer: A

Justification: The person on the ground sees the ball moving to the right at a constant $\mathbf{v}_{cart}$, as discussed in part V. Acceleration due to gravity has no affect on horizontal velocity, so the horizontal displacement increases linearly over time.

Ball on a Cart VIII

Which of the following correctly shows the trajectory of the ball, as seen by the *observer on the ground?*



A. B. C. D. E.

Solution

Answer: E

Justification: The person on the ground sees the ball moving at a constant $\mathbf{v}_{cart}$. Therefore, the answer must either be either C or E since the final position of the ball is to the right of its initial position. However, due to gravitational acceleration, the ball cannot follow the linear trajectory shown in C. The ball is accelerating downwards while moving forward with constant velocity. The combination of these two motions will produce a parabolic trajectory as shown in E.