a place of mind

FACULTY OF EDUCATION

Department of
Curriculum and Pedagogy

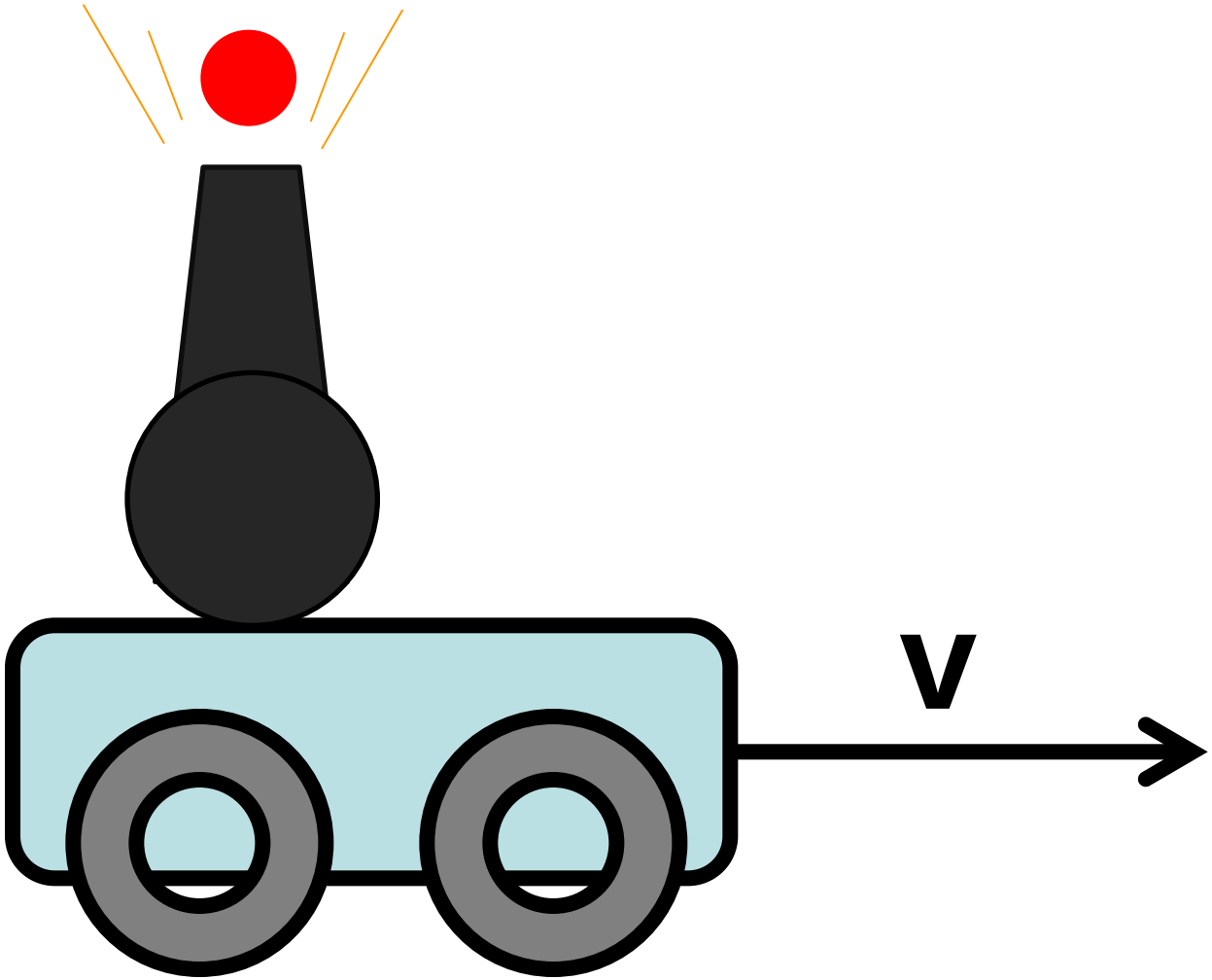
Physics

2-D Kinematics: Projectile Motion

Science and Mathematics Education Research Group

Supported by UBC Teaching and Learning Enhancement Fund 2012-2013

Cannon on a Moving Cart



Cannon on a Cart I

The following scenario is used in the next series of questions.

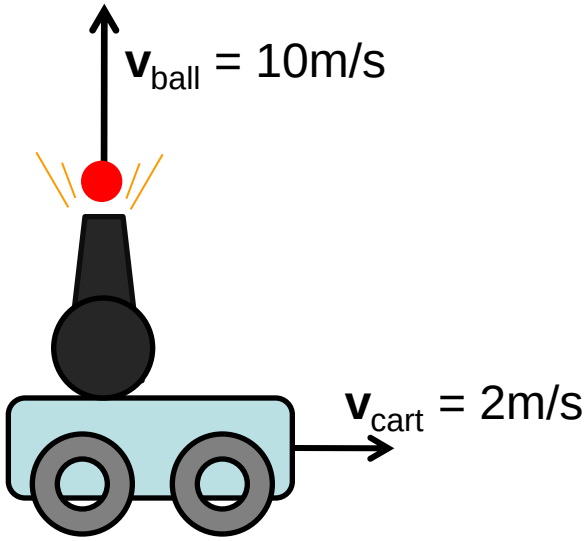
A cannon is placed on a moving cart at a constant velocity. The cannon fires a ball vertically into the air. When the ball lands, where does it land?

(Use g = 10 m/s^2)

A. On the cart

B. In front of the cart

C. Behind the cart



Solution

Answer: A

Justification: When the ball is fired, its velocity has a vertical component of 10 m/s upwards, relative to the cannon, and a horizontal component of 2 m/s to the right relatively to the ground, due to the motion of the cart.

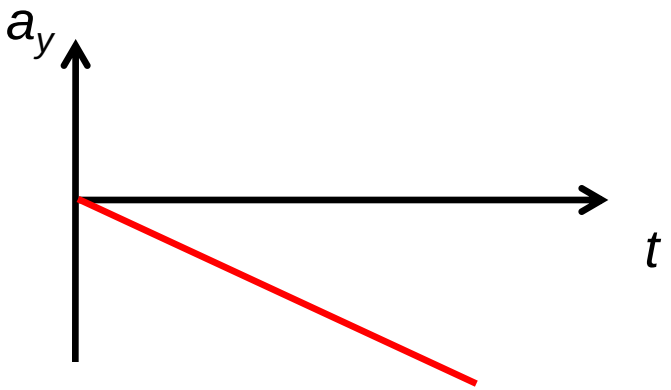
Horizontal velocity of the ball is constant, so while the ball is in the air, it continues to move with a horizontal velocity of 2 m/s – the same as the cart.

Because the cart and the ball are moving with the same horizontal velocity – in the same reference frame – the ball will land on the cart.

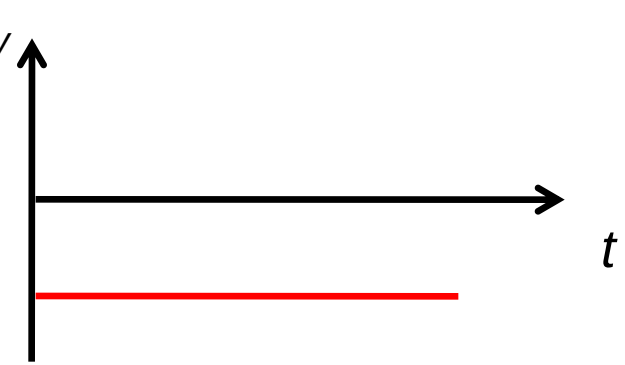
Acceleration-Time Graphs

Which acceleration versus time graph best describes the *vertical acceleration* of the ball? (Let t = 0 at the moment the ball leaves the cannon, assume up is positive and down is negative, ignore air resistance). The acceleration is measured relatively to the ground.

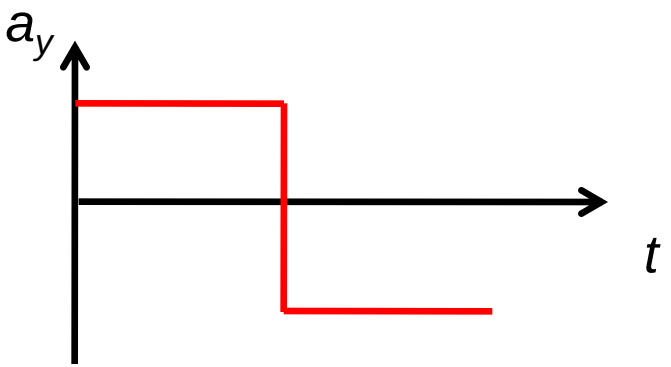
A.



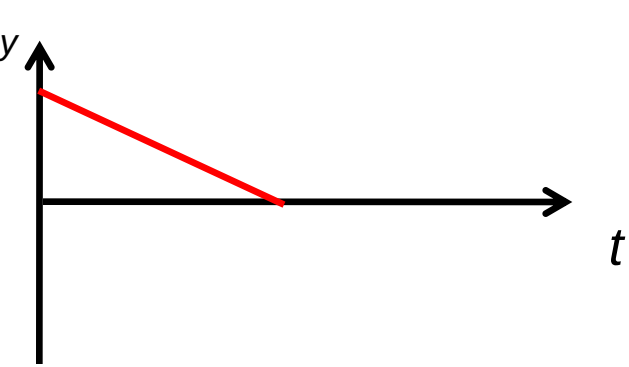
B.



C.

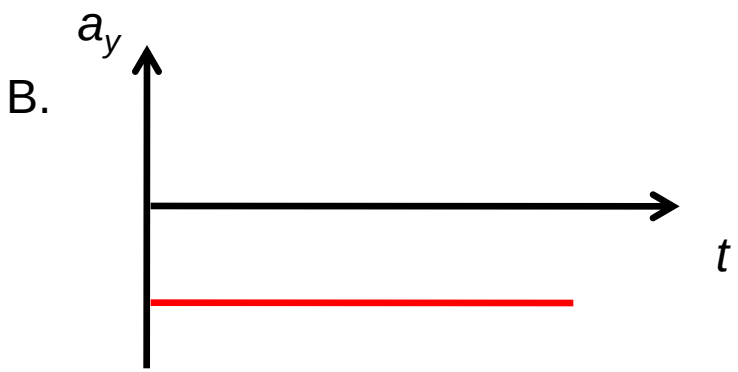


D.



Solution

Answer:

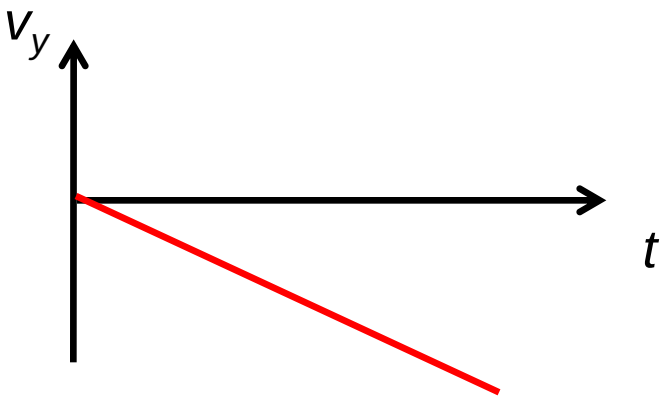


Justification: Acceleration due to gravity is constant. Graphs A and D do not show constant acceleration, but one that decreases linearly over time. Graph C shows acceleration that is constant in magnitude, although it changes in direction. Only graph B gives the constant negative value for gravitational acceleration given any time t. The negative value of the acceleration follows from our choice of positive y axis being up.

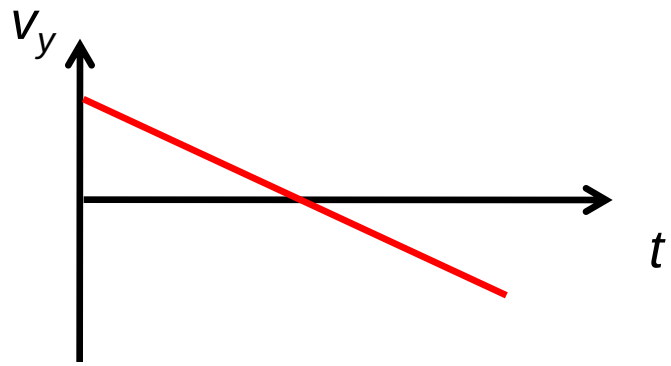
Velocity-Time Graphs

Which velocity versus time graph best describes the *vertical velocity* of the ball (relatively to the ground)? (Let t = 0 at the moment the ball leaves the cannon, assume up is positive and down is negative, ignore air resistance)

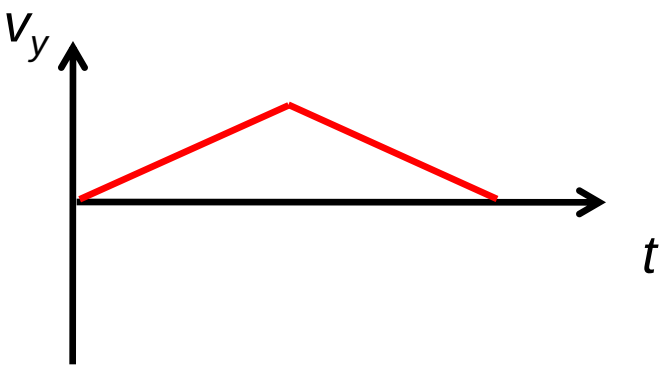
A.



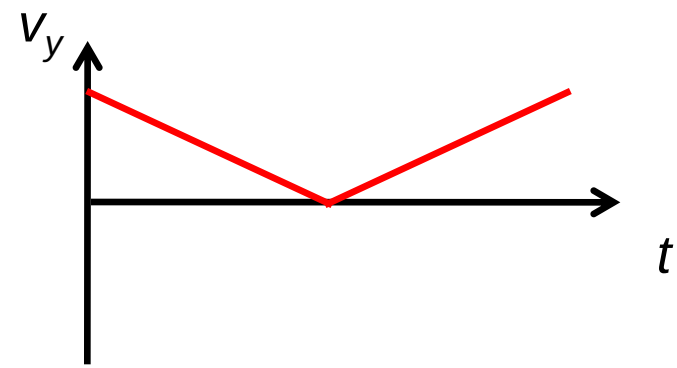
B.



C.



D.



Solution

Answer: B

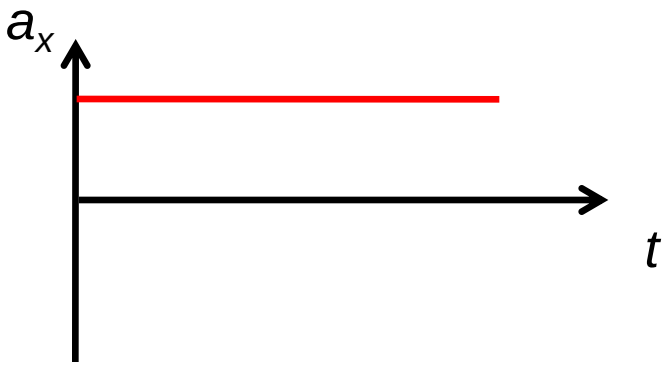
Justification: Graph A begins with an initial velocity of 0 m/s, which is incorrect. Graph C and D are incorrect because they are always positive, implying that the ball only moves upwards (positive y direction). The velocity of the ball should be negative during its fall downwards.

Graph B is correct because it decreases linearly over time from a positive velocity to a negative velocity. This agrees with the constant acceleration due to gravity. When the cannonball lands back on the cart, its vertical velocity has the same magnitude as when it was fired, but in the opposite direction.

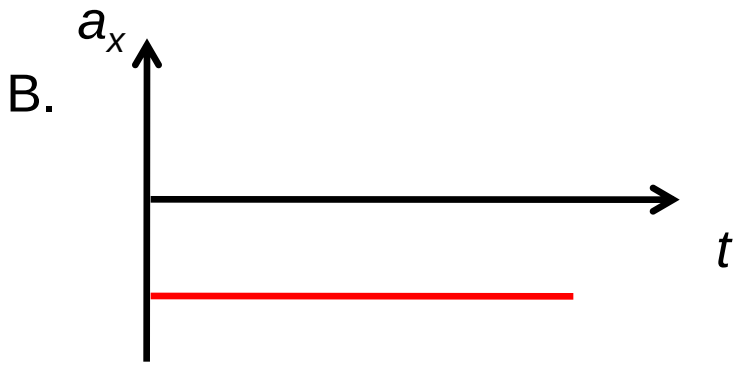
Acceleration-Time Graphs II

Which acceleration versus time graph best describes the *horizontal acceleration* of the ball (relatively to the ground)? (Let t = 0 at the moment the ball leaves the cannon, assume right is positive and left is negative, ignore air resistance)

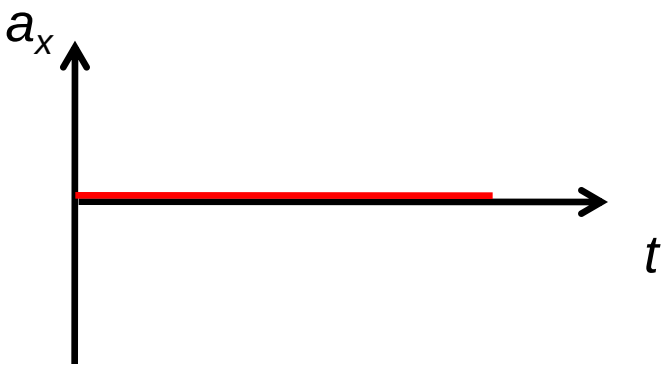
A.



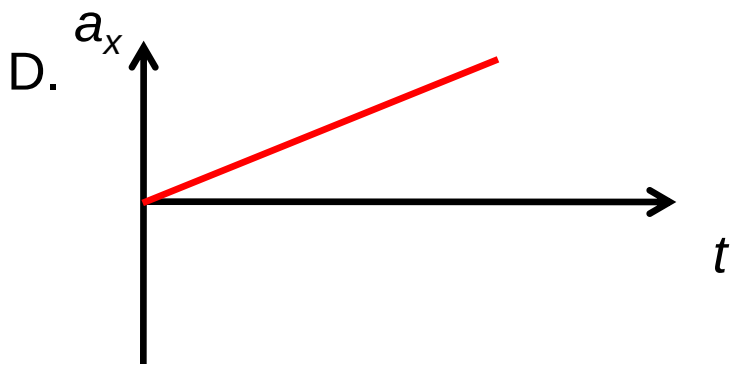
B.



C.



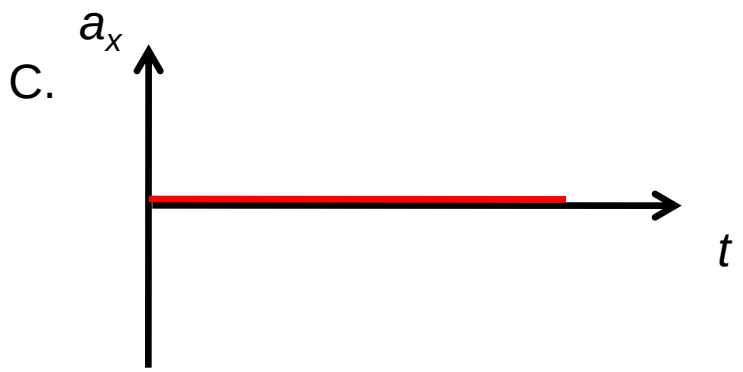
D.



Solution

Answer:

C.

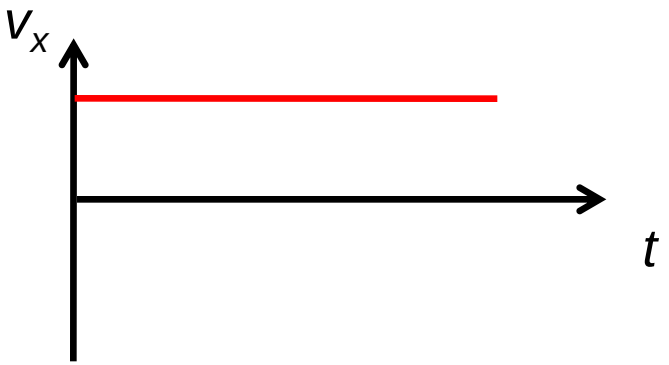


Justification: In projectile motion, horizontal velocity is always constant (provided there is no air resistance). Gravity only causes acceleration in the vertical direction, so the horizontal acceleration is 0 m/s^2.

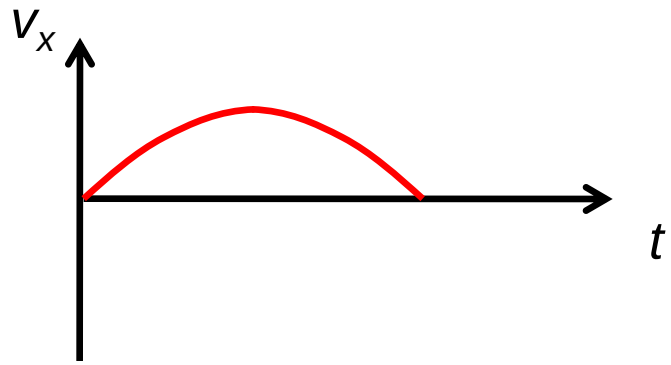
Velocity-Time Graphs II

Which velocity versus time graph best describes the *horizontal velocity* of the ball (relatively to the ground)? (Let t = 0 at the moment the ball leaves the cannon, assume right is positive and left is negative, ignore air resistance)

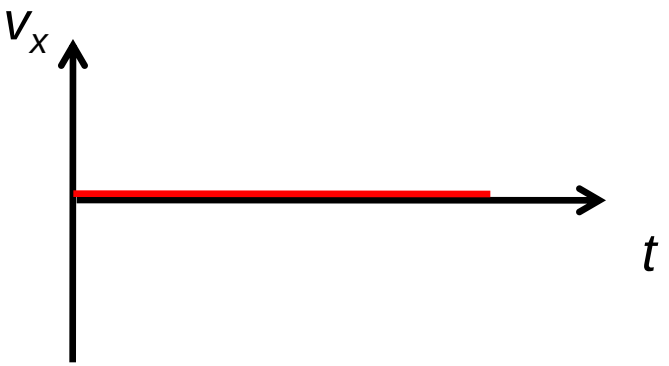
A.



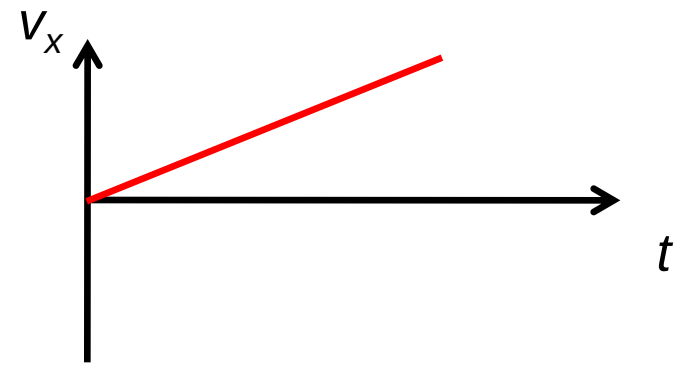
B.



C.



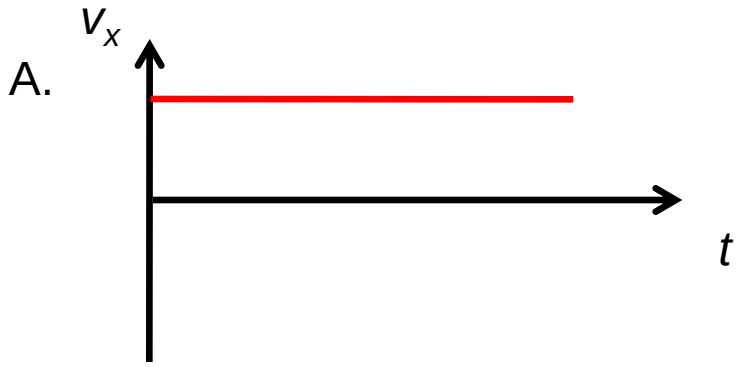
D.



Solution

Answer:

A.



Justification: Since there is no acceleration in the horizontal direction (no air resistance), the ball will always be moving at 2 m/s to the right. Only graphs A shows a non-zero constant velocity.