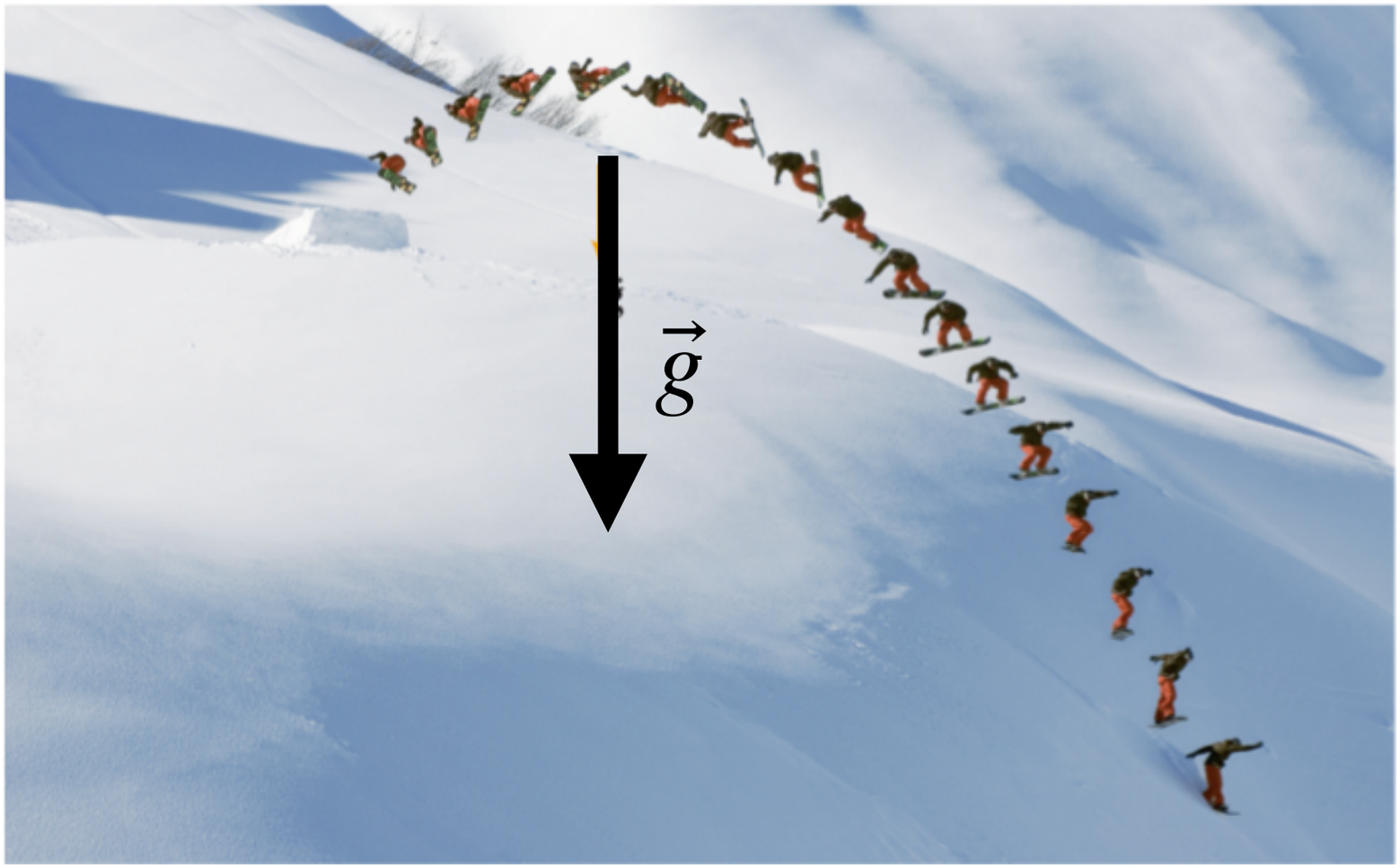
General Physics: Mechanics

PHYS-101(en)

Lecture 2b: Motion in two and three dimensions



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Today's agenda (MIT 3 and 4)

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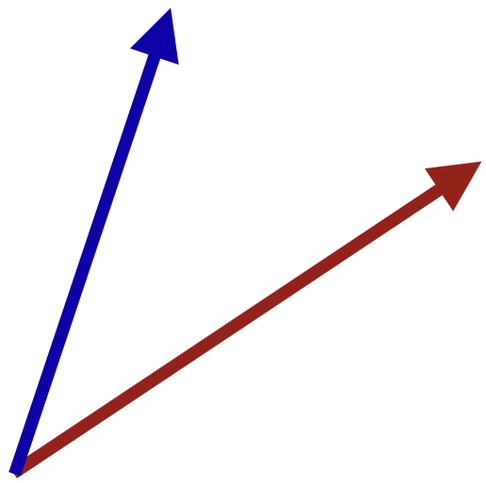
1. Motion in two and three dimensions in Cartesian coordinates
   - Acceleration due to gravity
   - Using vectors in equations
   - Projectile motion

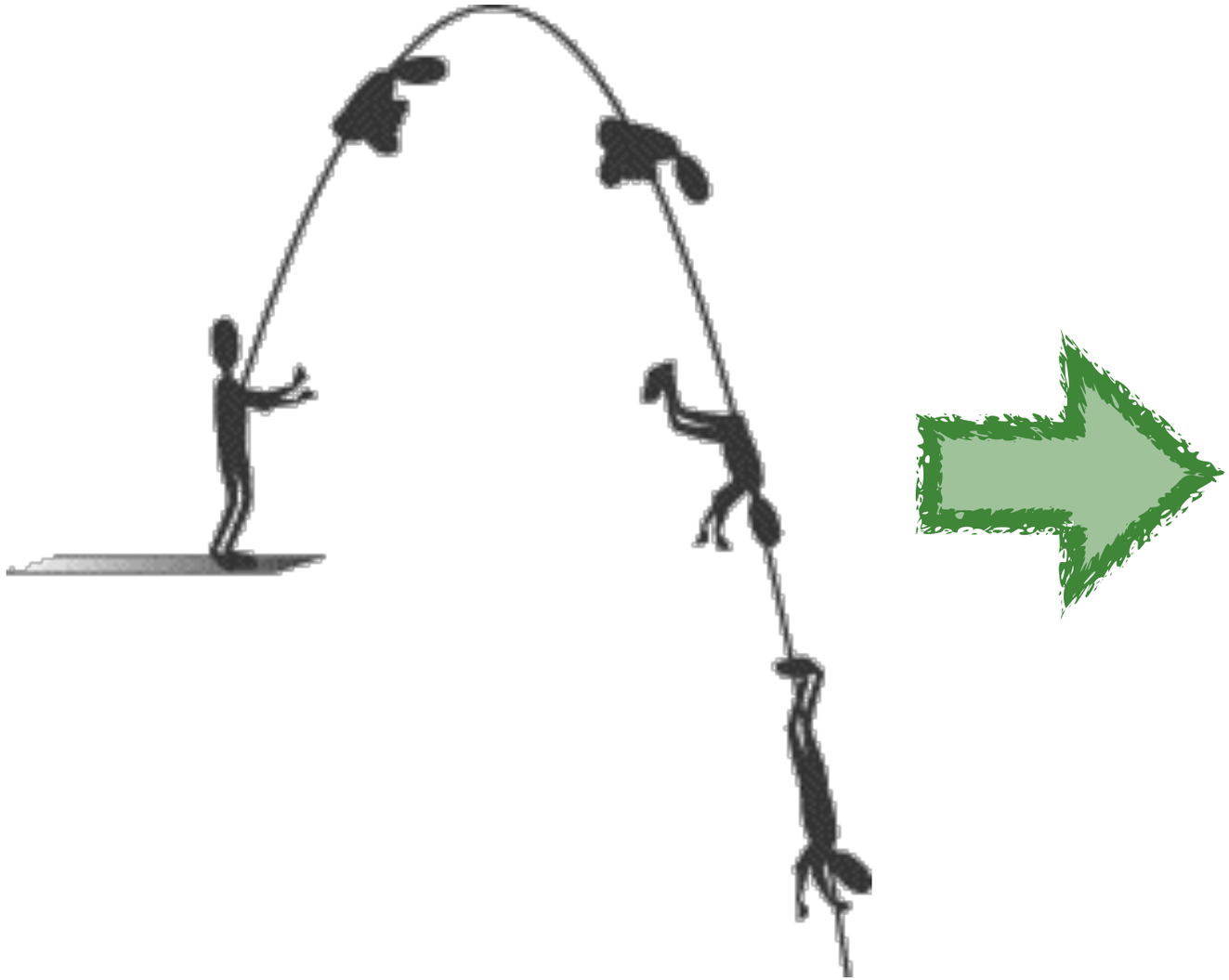
Review: dot product between two vectors

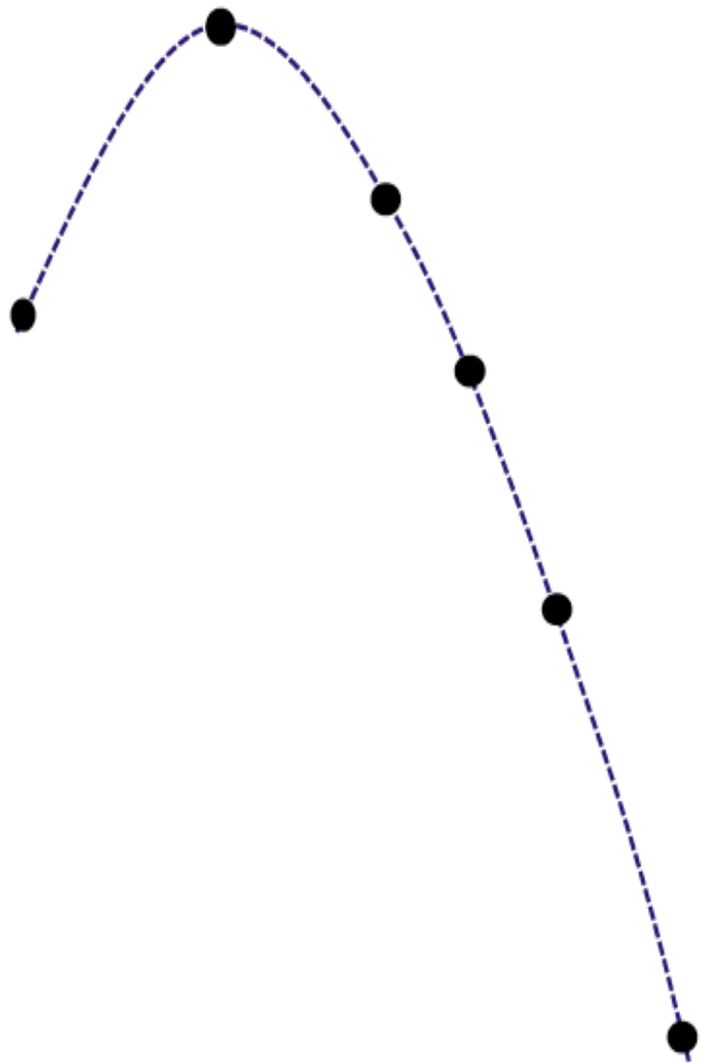
- Geometric interpretation of dot product



Kinematics

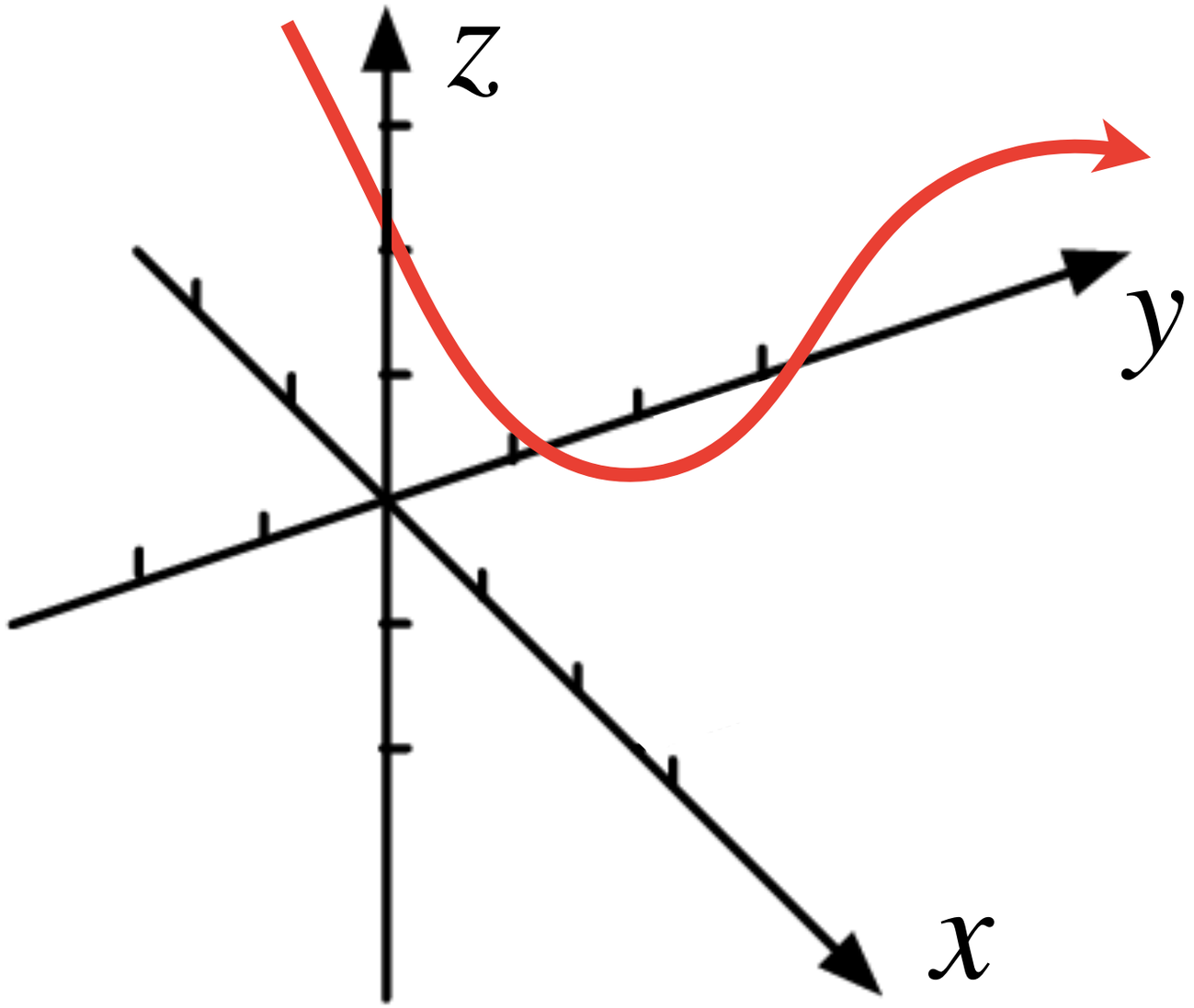
- A description of motion without considering forces
- We will approximate objects as point masses
- Need to go beyond one dimension





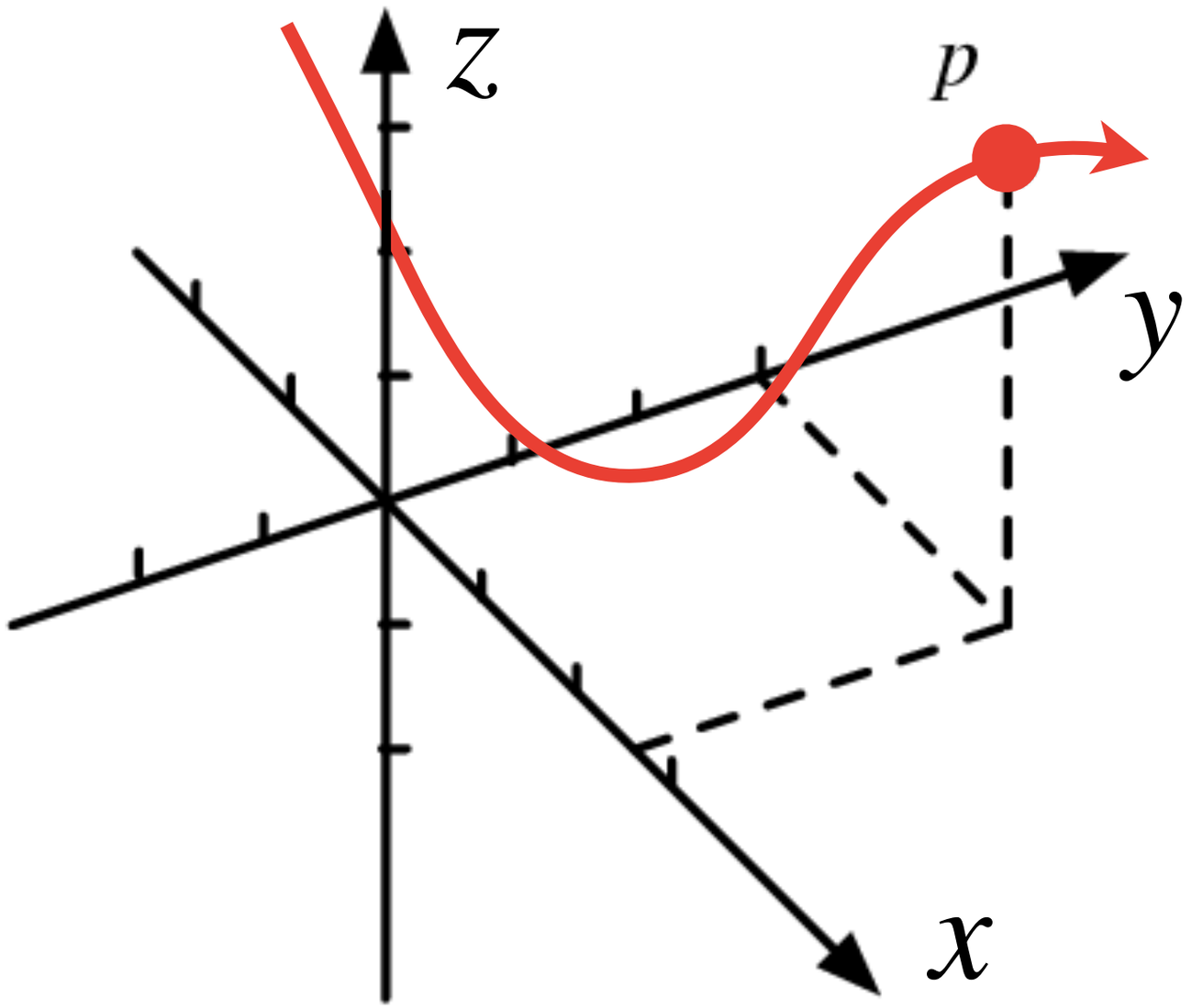
Vector position in Cartesian coordinates

- Position in 1D: $x(t)$



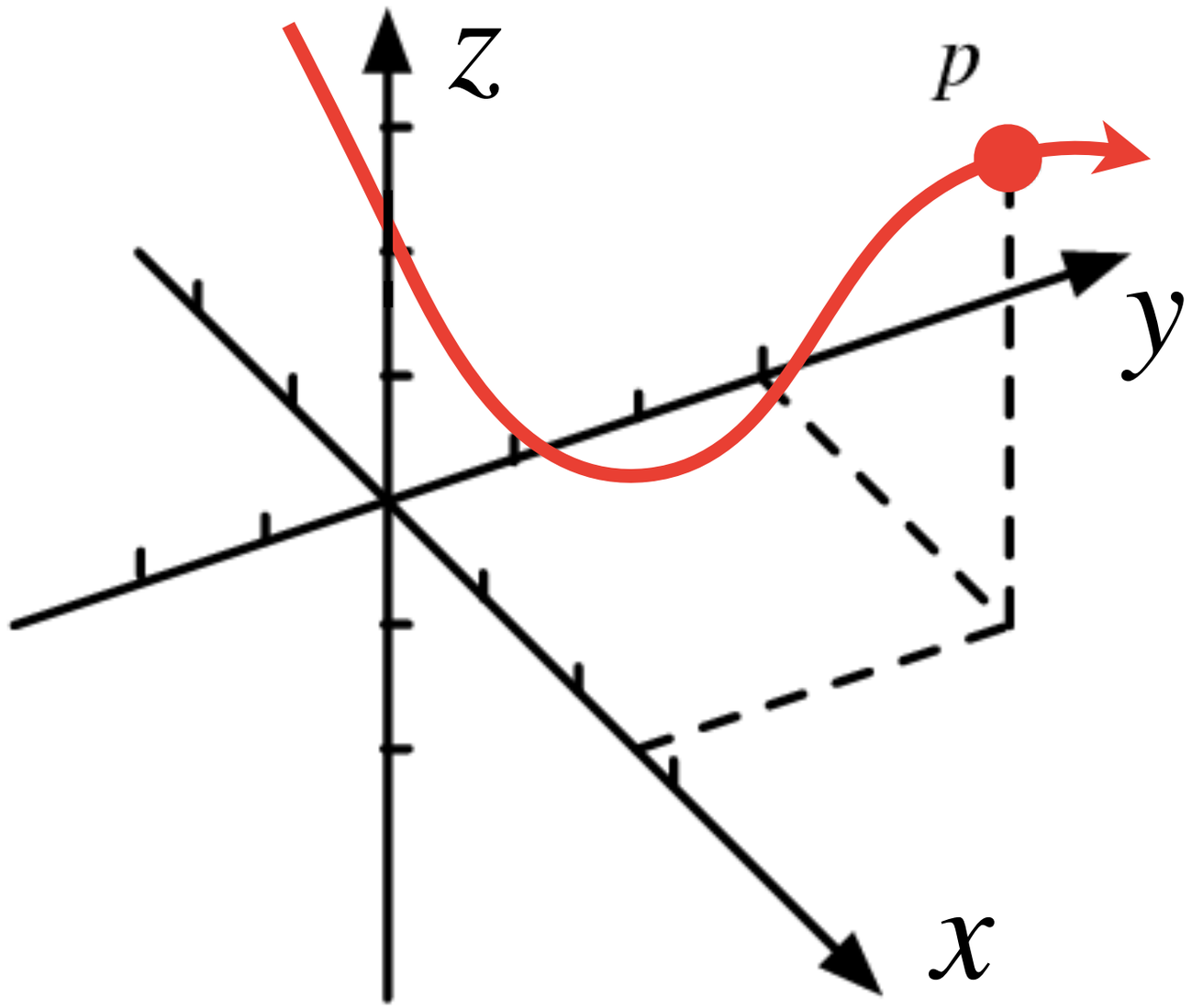
Vector displacement (Cartesian)

- Displacement in 1D: $\Delta x = x(t_2) - x(t_1)$



Vector velocity (Cartesian)

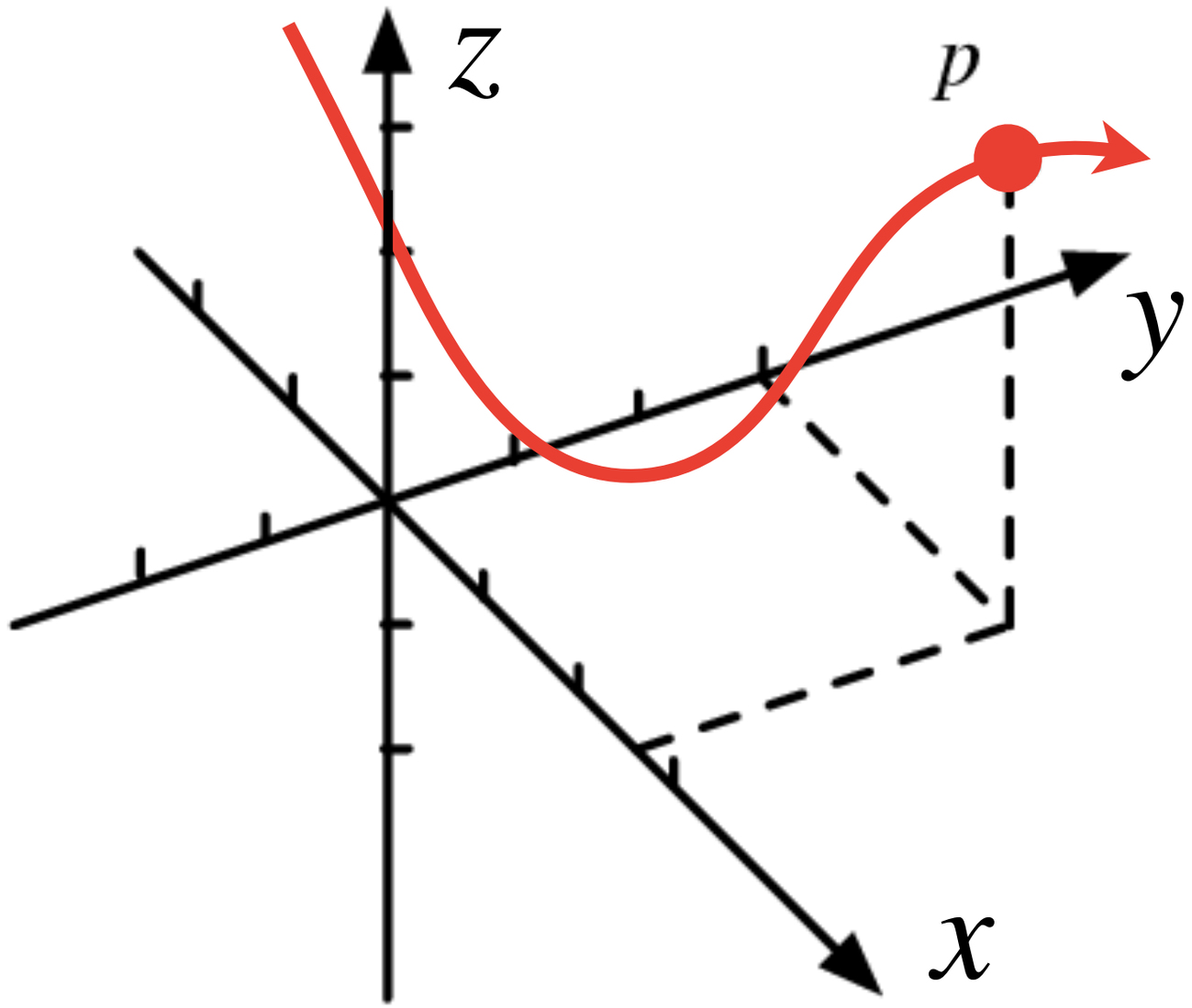
- Average velocity in 1D: $\bar{v} = \dfrac{\text{displacement}}{\text{time elapsed}} = \dfrac{\Delta x}{\Delta t}$



Vector velocity (Cartesian)

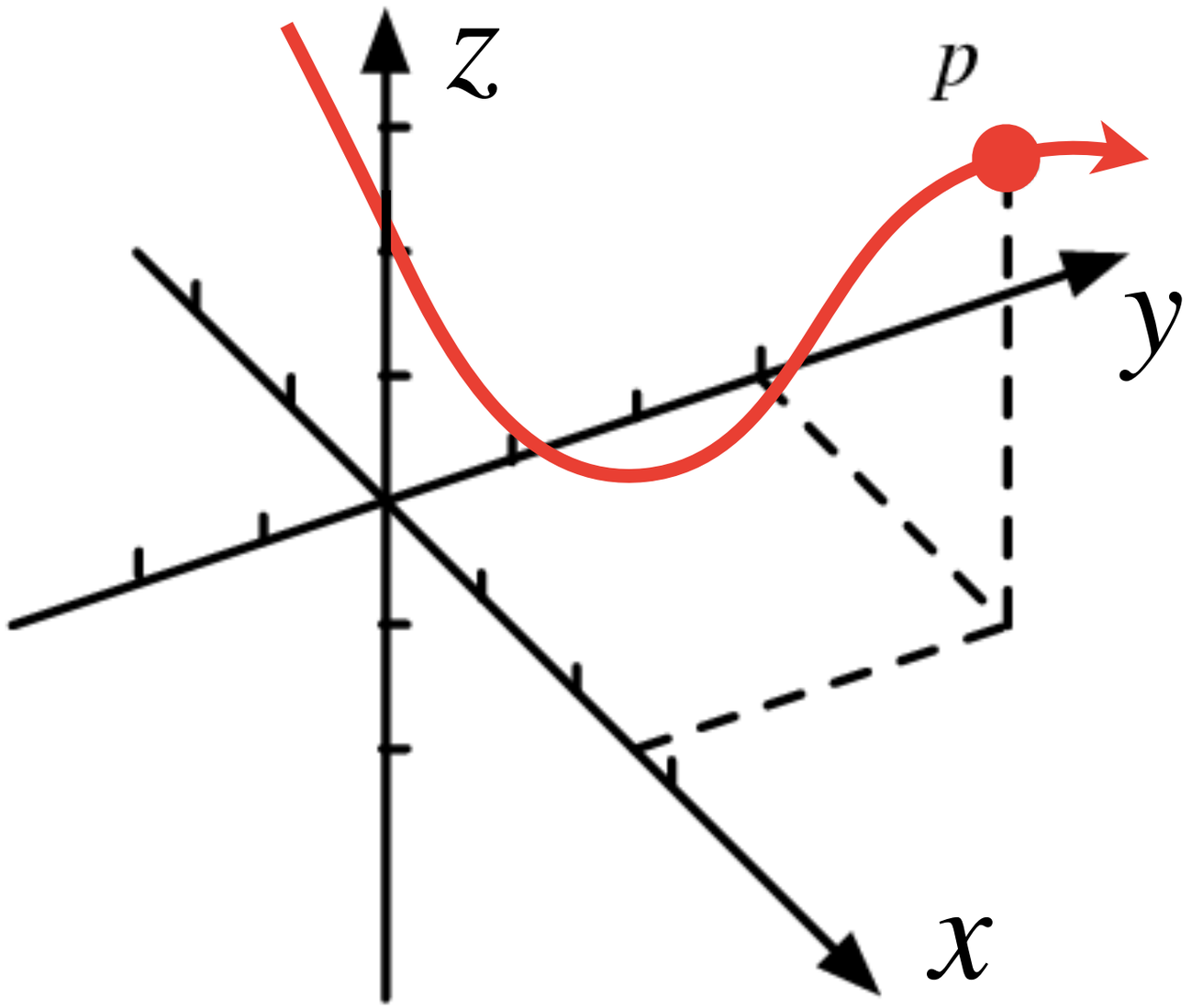
- Speed (i.e. magnitude of velocity):

- Direction:



Vector acceleration (Cartesian)

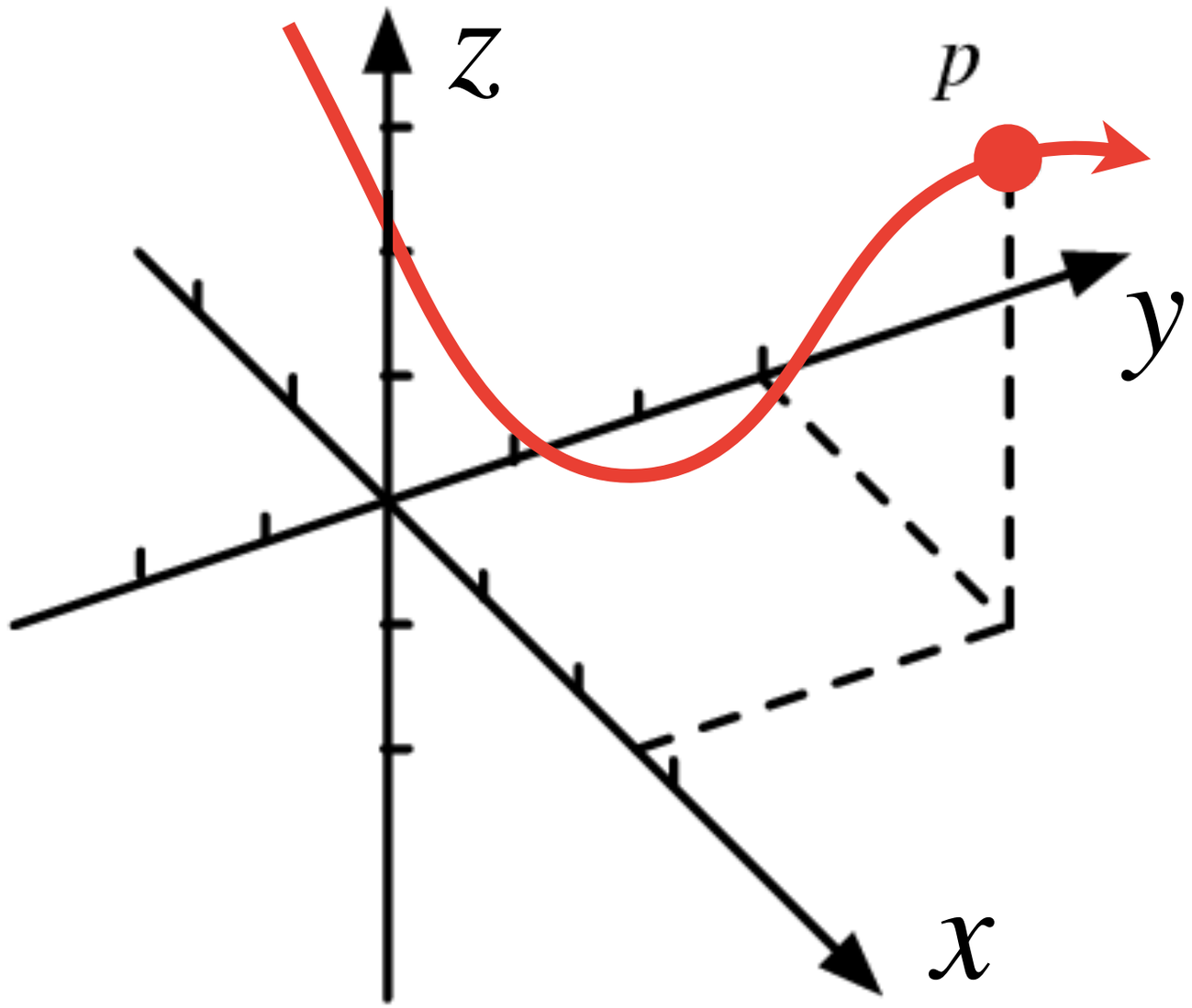
- Average acceleration in 1D: $\bar{a} = \dfrac{\text{change in velocity}}{\text{time elapsed}} = \dfrac{\Delta v}{\Delta t}$



Vector acceleration (Cartesian)

- Magnitude of the acceleration:

- Direction:



DEMO (55)

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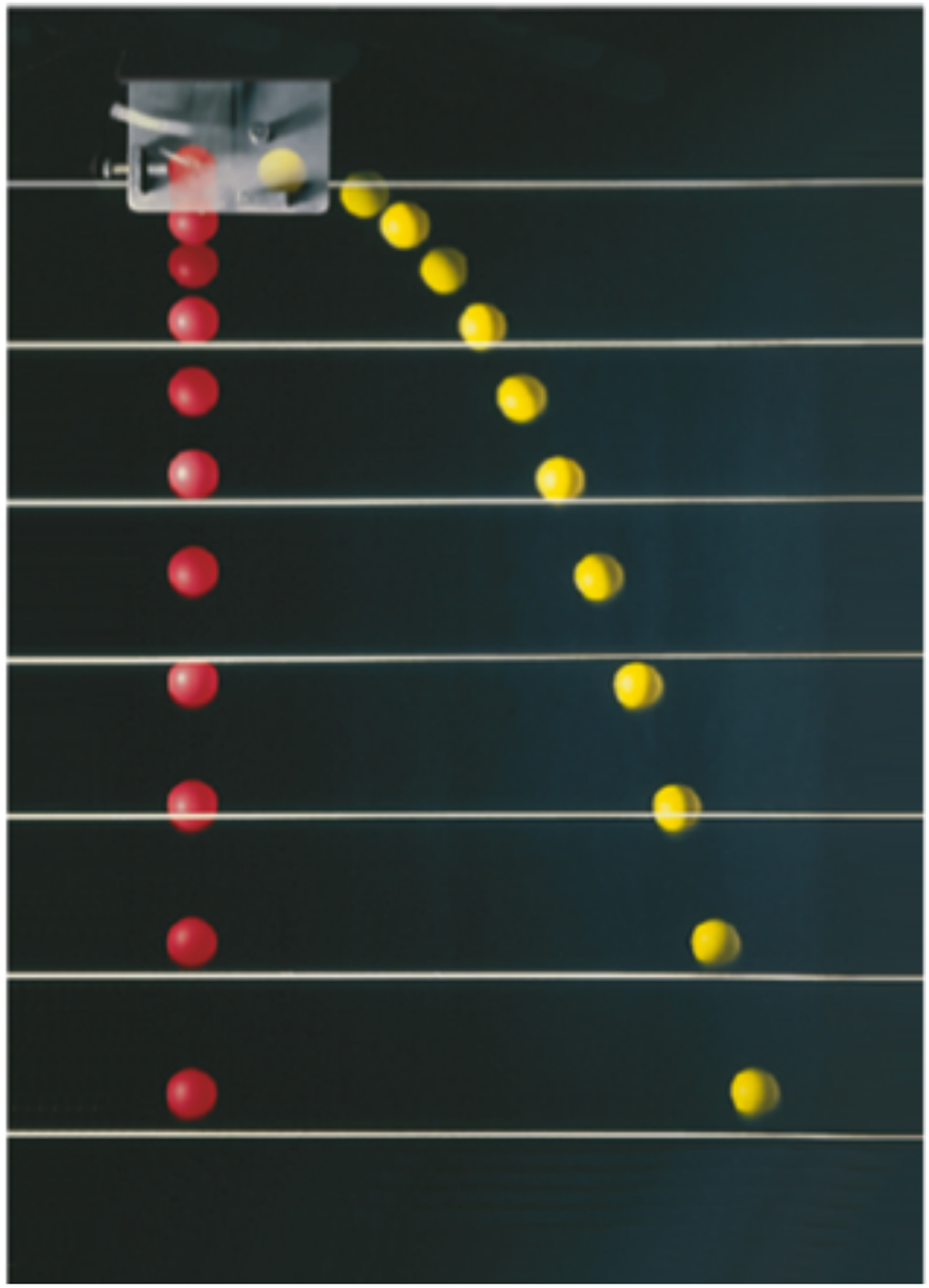
Projectile motion

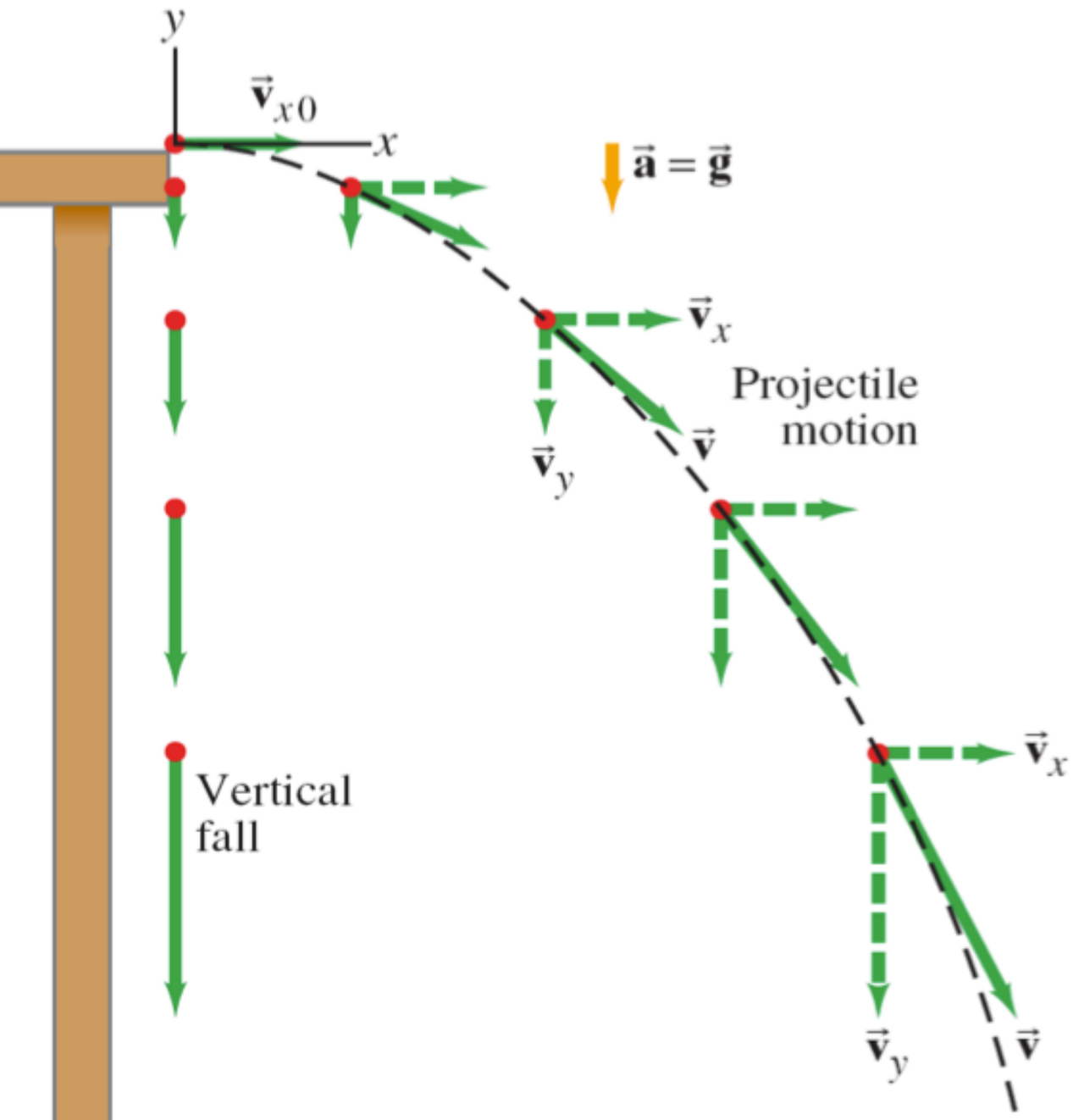
Projectile motion

- Two balls are released simultaneously under gravity
- What causes the difference in their motions?
- What equations of motion need modified?



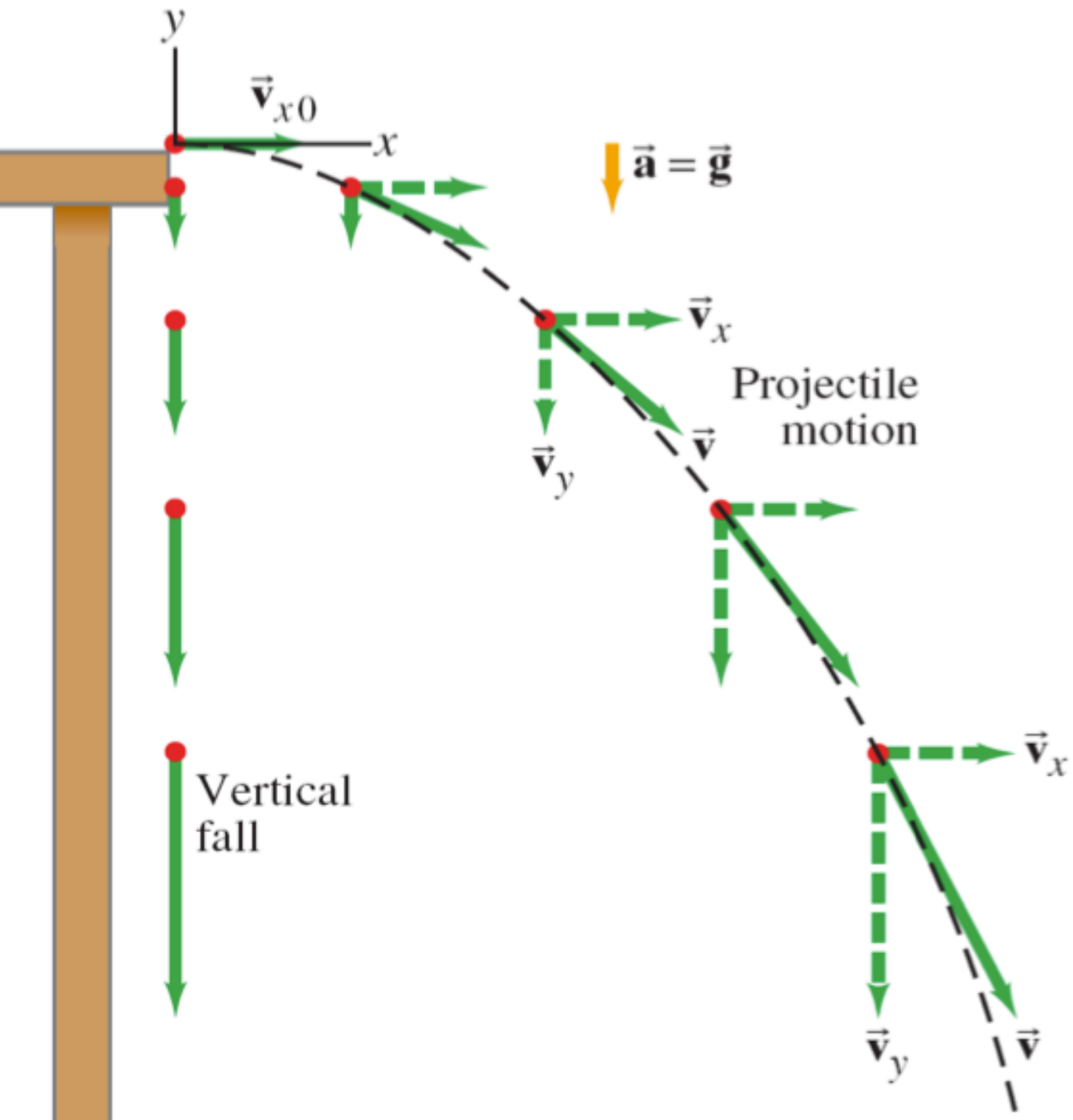
Velocity throughout projectile motion

- Motion in horizontal and vertical components are decoupled and independent



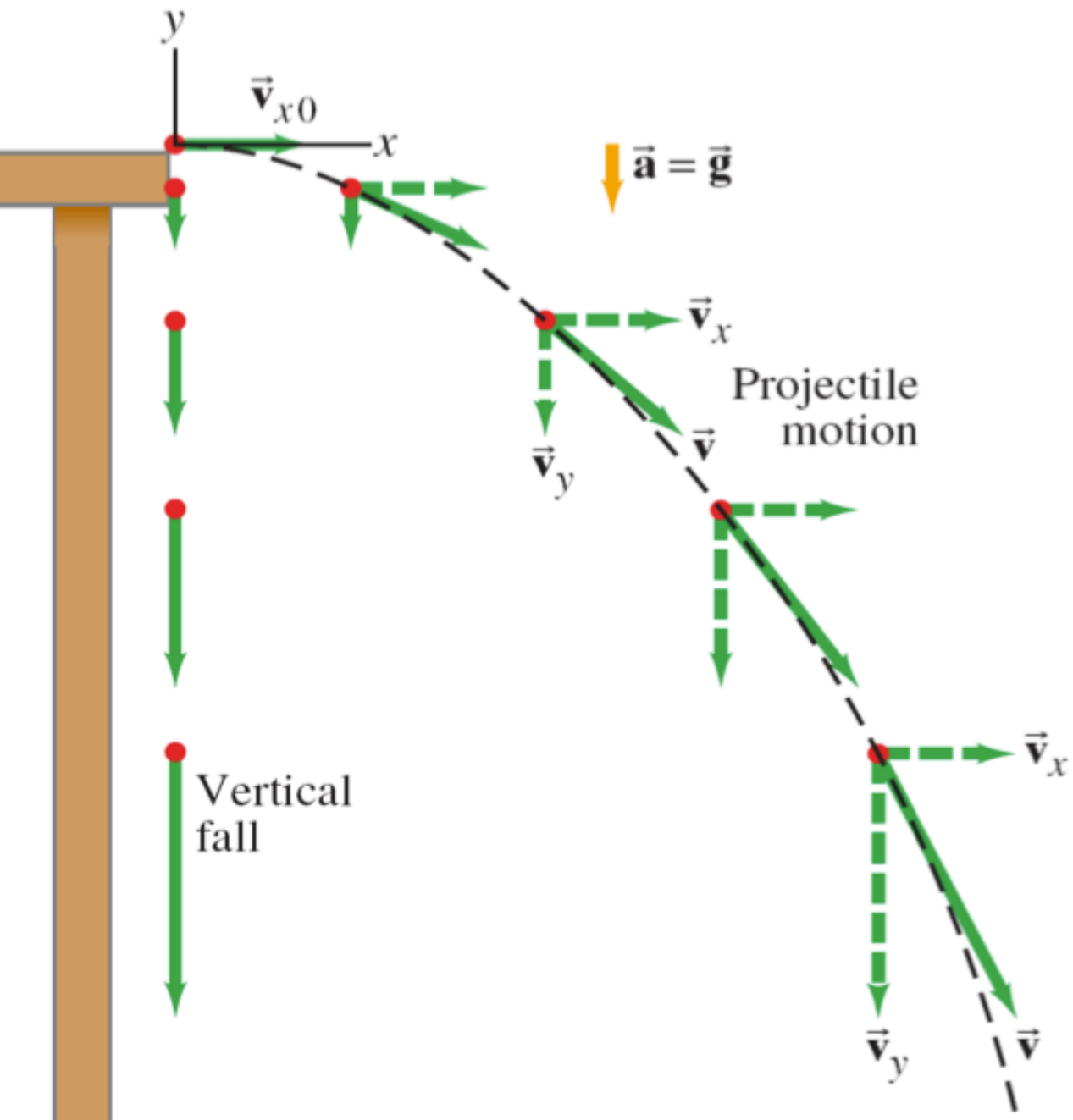
Position throughout projectile motion

- Motion in horizontal and vertical components are decoupled and independent



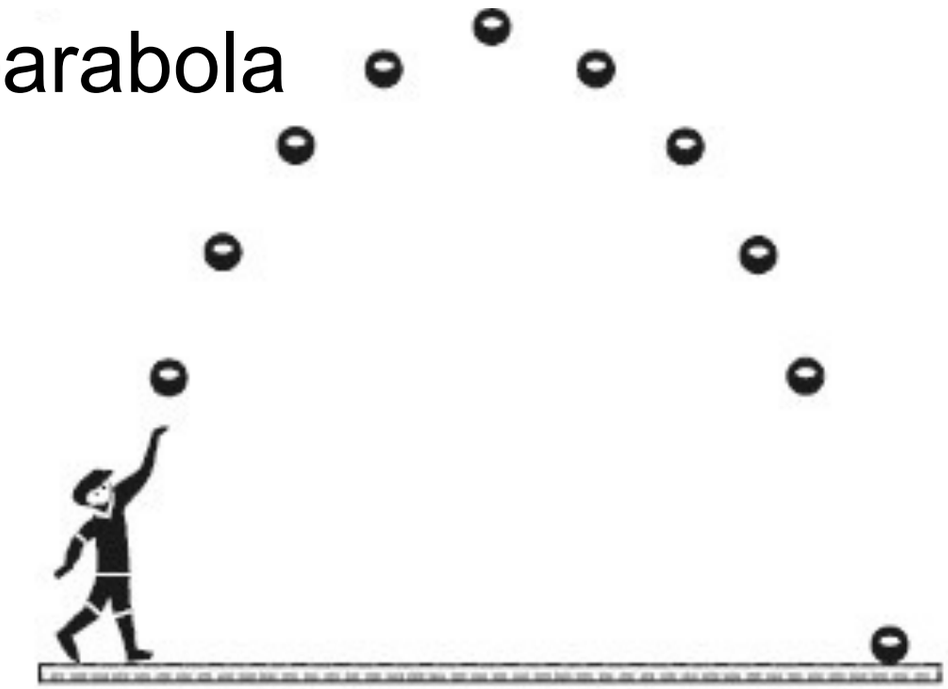
Calculating “g”

- Motion in horizontal and vertical components are decoupled and independent



Trajectory of projectile motion

- The path of a projectile is always a parabola



Conceptual question

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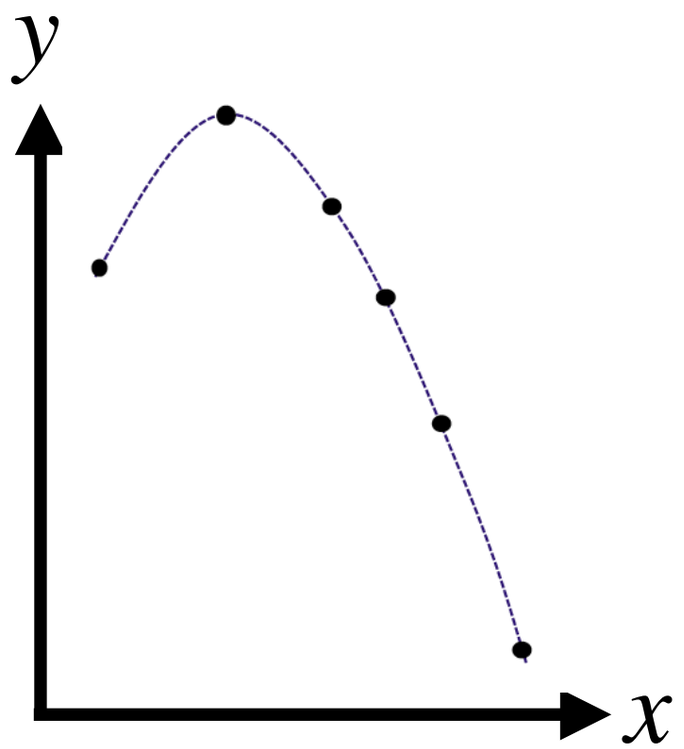
A projectile moves through the air under gravitational acceleration. At the highest point in its arc, which of the following is true? Neglect the effects of air resistance.

A. The speed and acceleration are zero.
B. The speed is equal to zero, and the acceleration is constant and not equal to zero.
C. The speed is at a minimum but not equal to zero and the acceleration is zero.
D. The speed is at a minimum but not equal to zero and the acceleration is constant and not equal to zero.
E. Neither the acceleration nor speed has yet attained its minimum value.



Summary of projectile motion

- The acceleration is

$$\vec{a}(t) = -g\hat{y}$$

- By integrating, we find the velocity is

$$\vec{v}(t) = v_{x0}\hat{x} + (-gt + v_{y0})\hat{y}$$

where v_{x0} and v_{y0} are the initial velocities in each direction

- Integrating again, the position is

$$\vec{r}(t) = (v_{x0}t + x_0)\hat{x} + (-\frac{g}{2}t^2 + v_{y0}t + y_0)\hat{y}$$

where x_0 and y_0 are the initial positions in each dimension

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The monkey and the hunter

See you at the exercises tomorrow!

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Conceptual question

Three vectors $\vec{A}$, $\vec{B}$, and $\vec{C}$ are shown below. The vector sum of these three vectors is $\vec{S} = \vec{A} + \vec{B} + \vec{C}$.

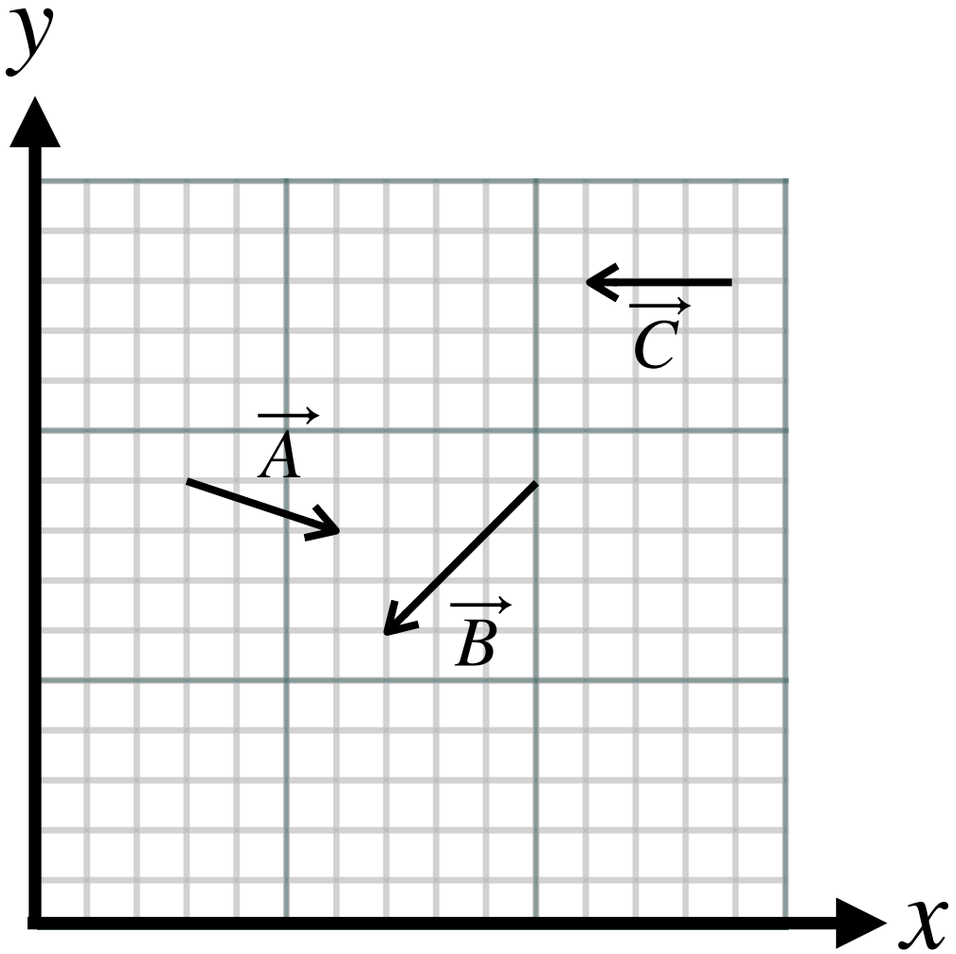
What is the value of S_x, the x component of $\vec{S}$?

A. -6

B. -4

C. 3

D. -3



Conceptual question

A particle is moving while experiencing a constant acceleration. The velocity vector is shown below at two different times, an earlier time t_1 and a later time is t_2.

What is the direction of the average acceleration vector?

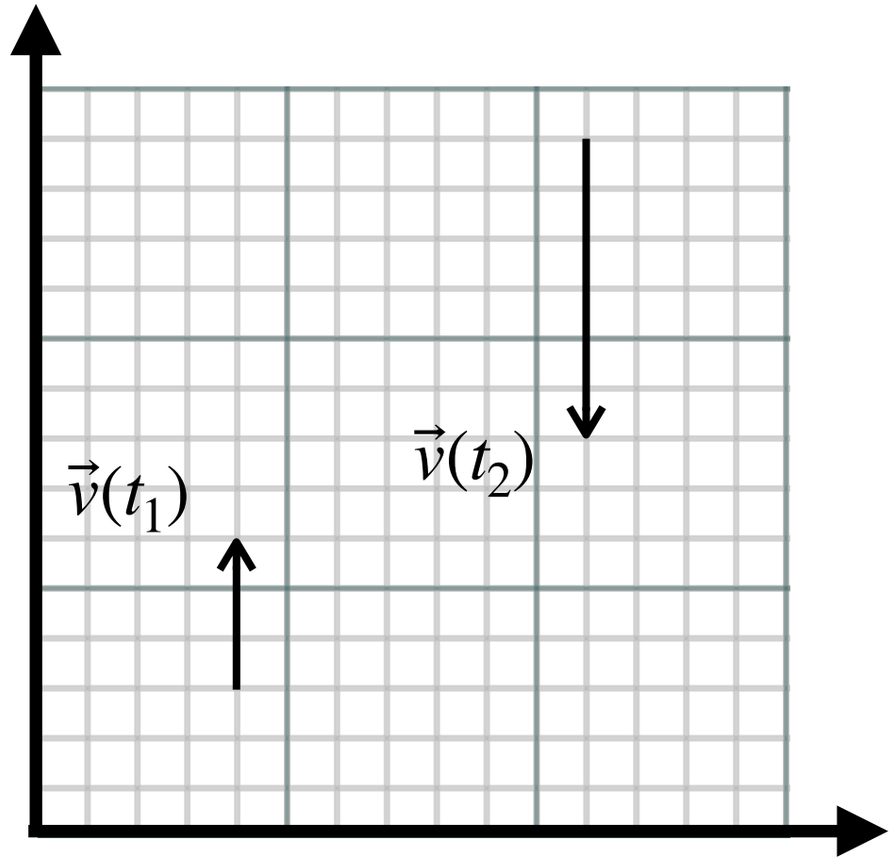
A. ↑

B. →

C. ↓

D. ←

E. None of these.



Conceptual question

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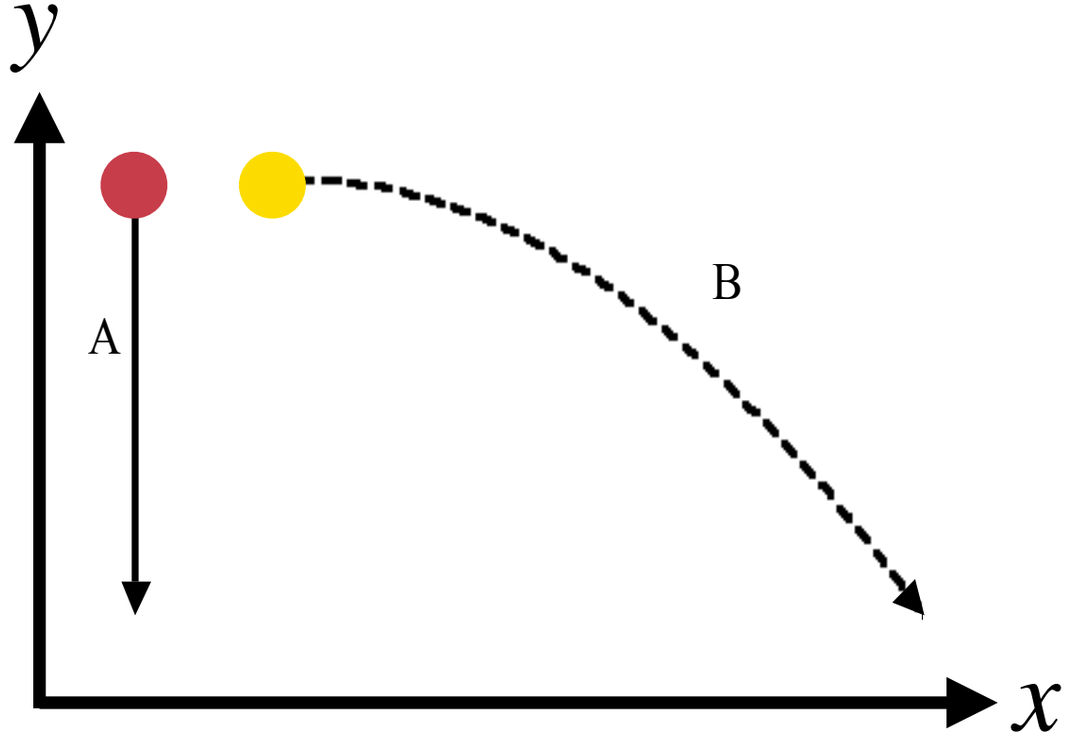
Two balls begin at rest at the same height (but not at the same place).

At time $t = 0$, the red ball is simply released and the yellow ball is launched straight horizontally.

Which one hits the ground first?



A. Ball A hits the ground first.

B. Ball B hits the ground first.

C. They both hit simultaneously.

D. It depends on which one is heavier.