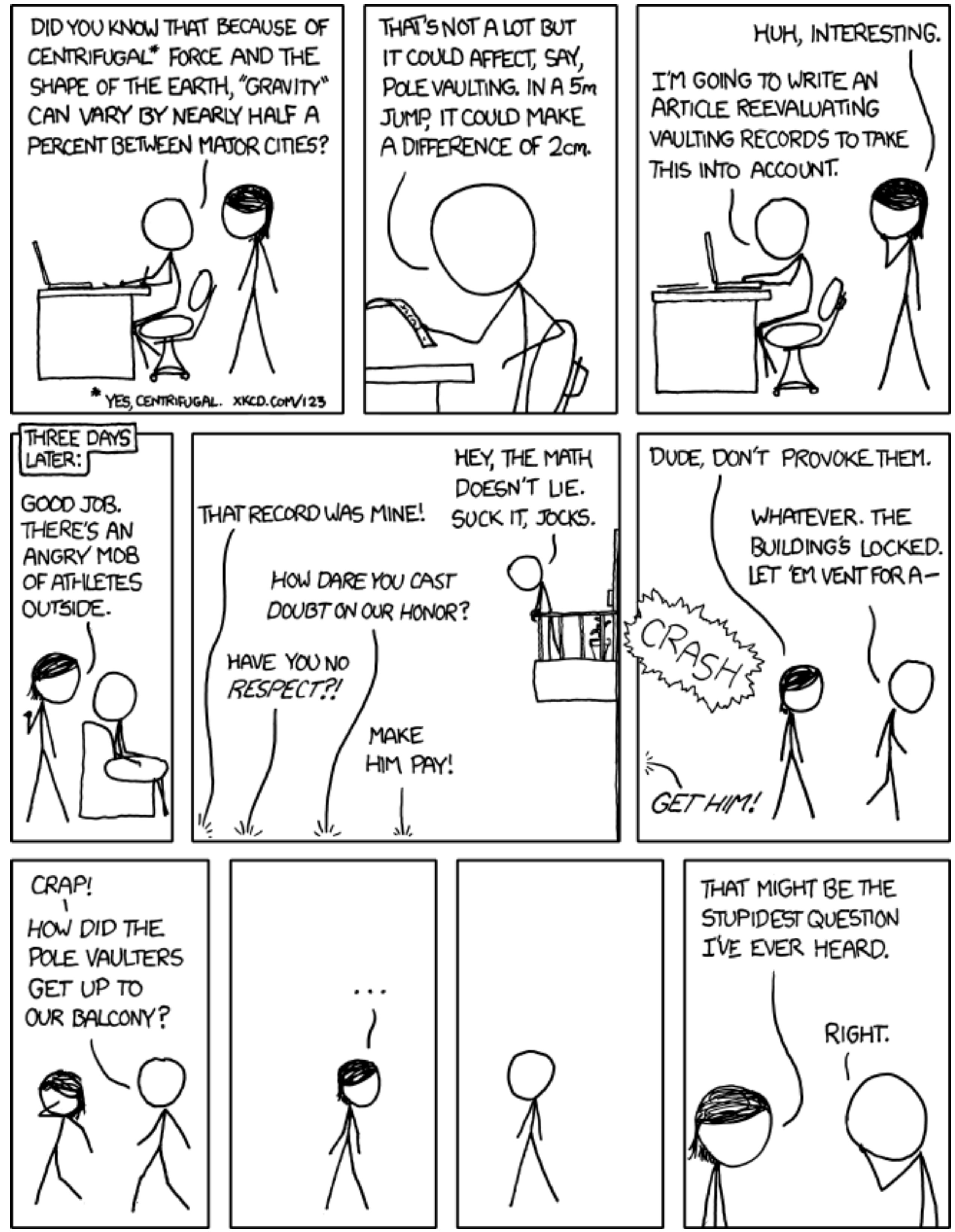
General Physics: Mechanics

PHYS-101(en)

Lecture 1b:
Motion in two and three dimensions



xkcd.com/852

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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
   - Introduction to projectile motion
   - Using vectors

Summary of motion in one dimension

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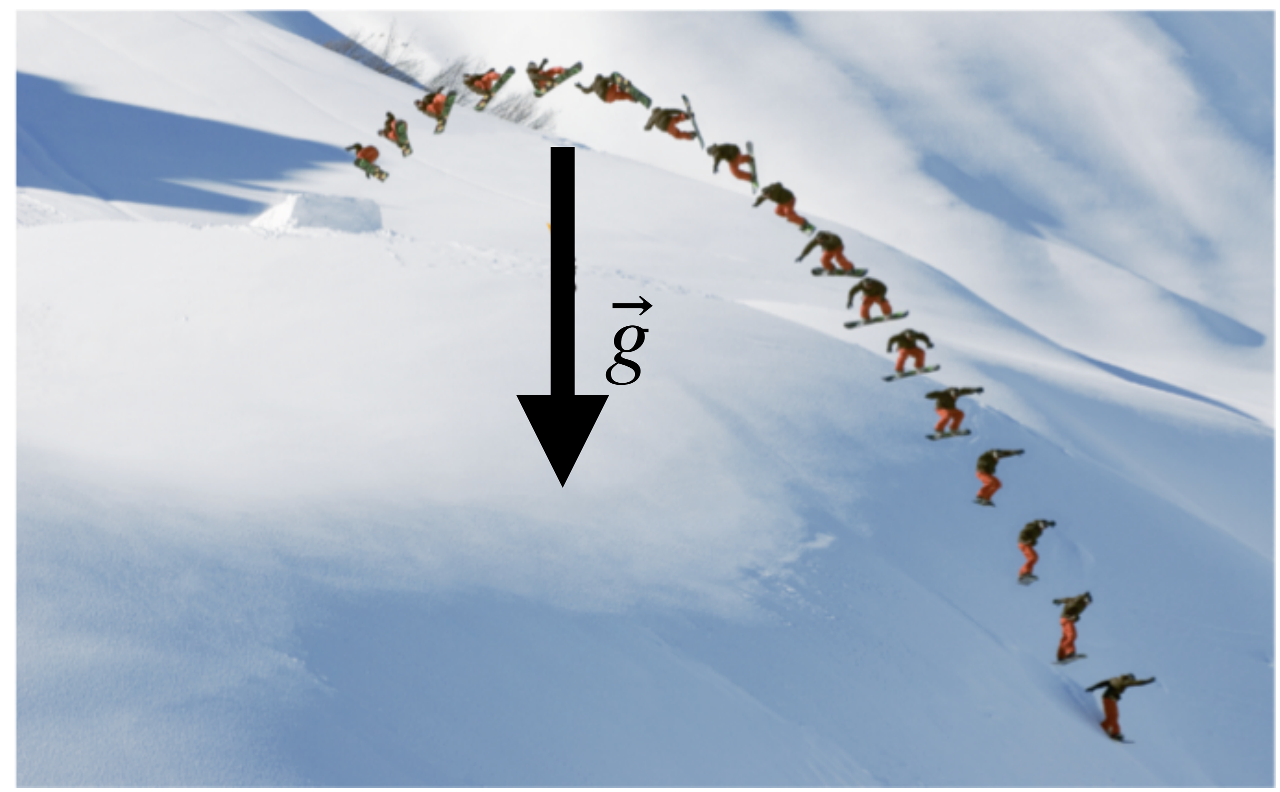
- Position of an object as a function of time denoted by $x(t)$
- Average velocity: $\overline{v} = \dfrac{\text{change of position}}{\text{time elapsed}} = \dfrac{\Delta x}{\Delta t}$
- Instantaneous velocity: $v(t) = \lim_{\Delta t \to 0} \dfrac{\Delta x}{\Delta t} = \dfrac{dx}{dt}$
- Average acceleration: $\overline{a} = \dfrac{\text{change of velocity}}{\text{time elapsed}} = \dfrac{\Delta v}{\Delta t}$
- Instantaneous acceleration:

$$a(t) = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$

Projectile motion

1D → **2D**



A projectile is an object moving in 2D under the sole influence of the Earth's gravity

Review: scalars and vectors

- A **scalar** quantity consists of a single number
  - Examples: distance traveled, speed, mass, time
- A **vector** quantity is a set of numbers, which we will use to give direction
  - A vector quantity is often indicated by putting an arrow over the top (e.g. $\vec{v}$)
  - You can visualize a vector as an arrow, which has a length (i.e. $|\vec{v}| = v$) together with an direction (e.g. $\hat{x}$)
  - Becomes very important for 2D or 3D motion
  - Examples: displacement, velocity, acceleration, force, momentum

Review: define coordinate system by vectors

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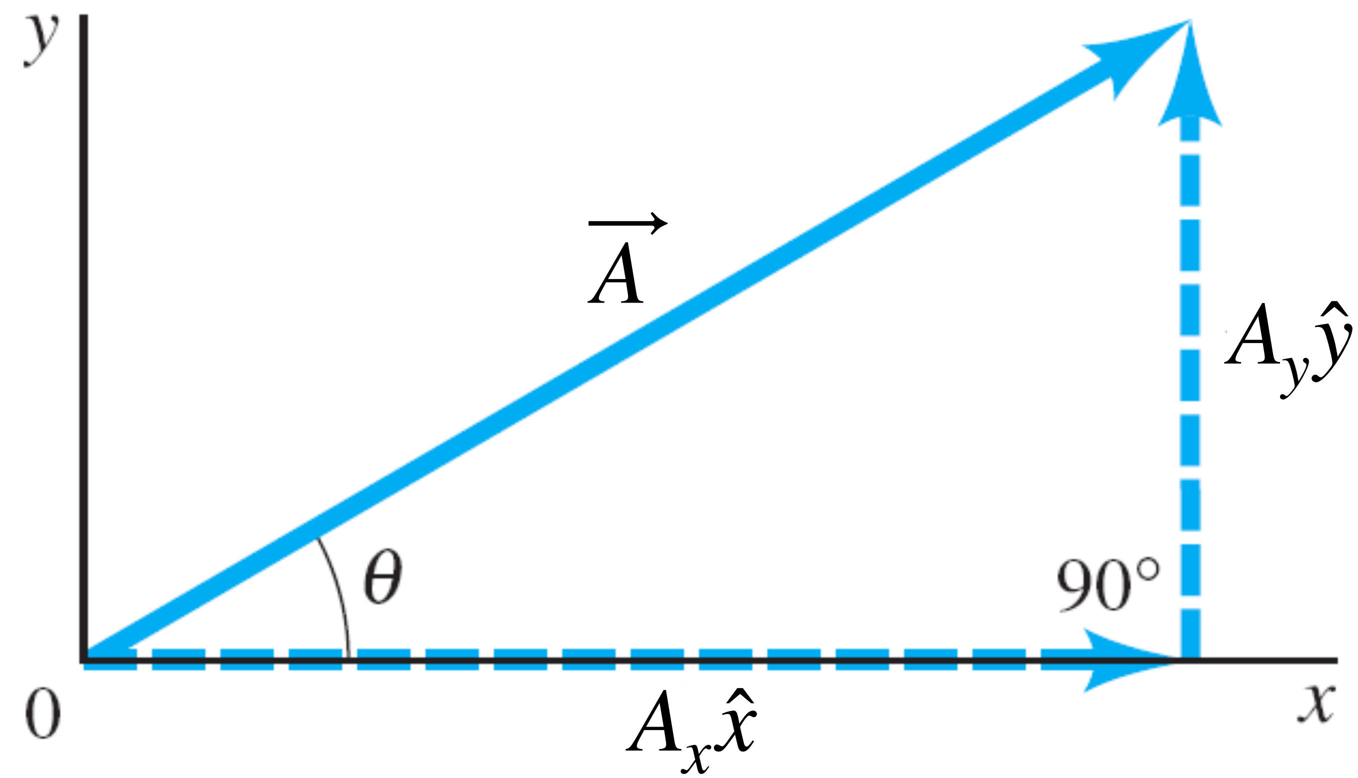
- A Cartesian coordinate system can be defined using a set of orthogonal *unit vectors* (i.e. vectors of length 1):

- Any vector can be expressed as a sum of its components parallel to the unit vectors

Review: getting components of vectors

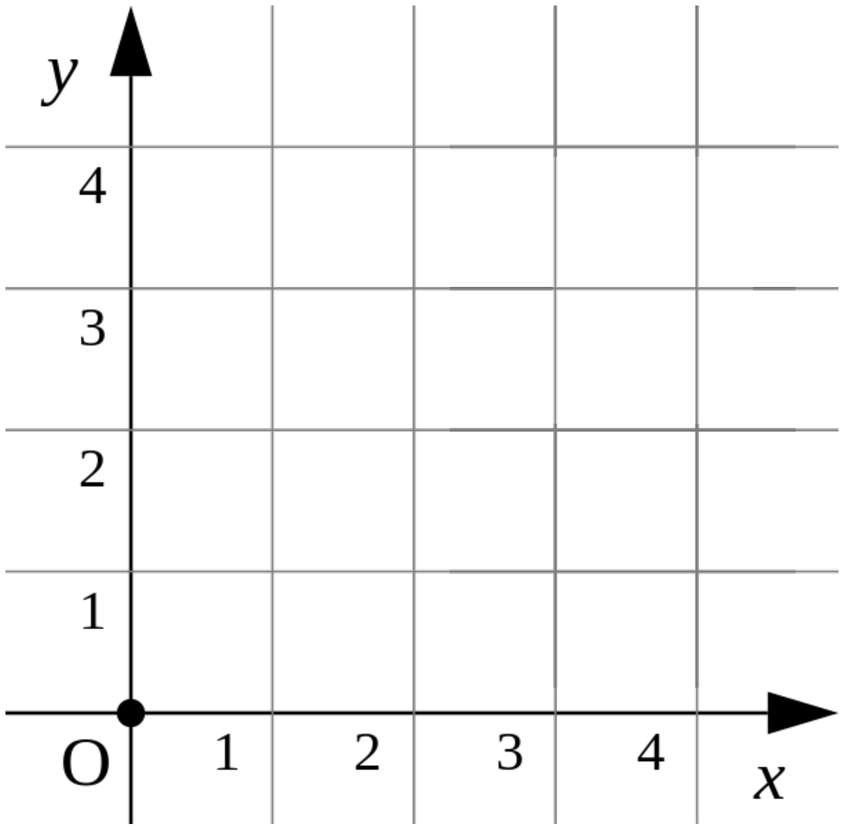
- Here $A = |\vec{A}|$ is the "norm" (i.e. length or magnitude) of a vector:

- Since the components are orthogonal, they are related by simple trigonometric functions:



Review: math with vectors

- Vector addition and subtraction are accomplished by adding or subtracting component-by-component



- Multiplying (or dividing) by a scalar

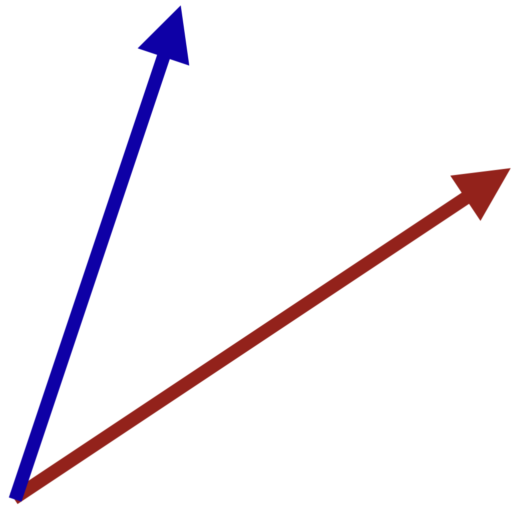
Review: dot product between two vectors

- Mathematical definition of a dot (scalar) product

- Dot product with a unit vector gives the component in that direction

Review: dot product between two vectors

- Geometric interpretation of dot product



Conceptual question

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

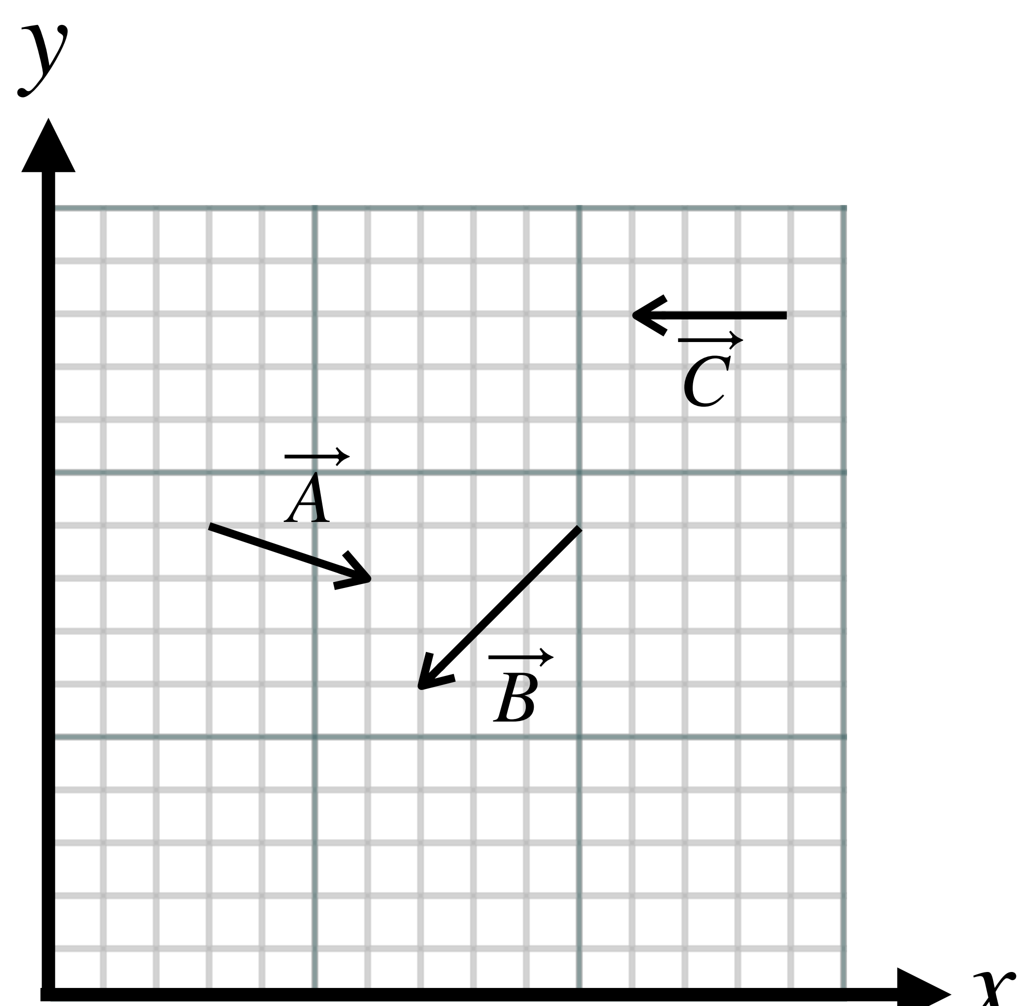
What is the value of S_x, the x component of $\vec{S}$?

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?

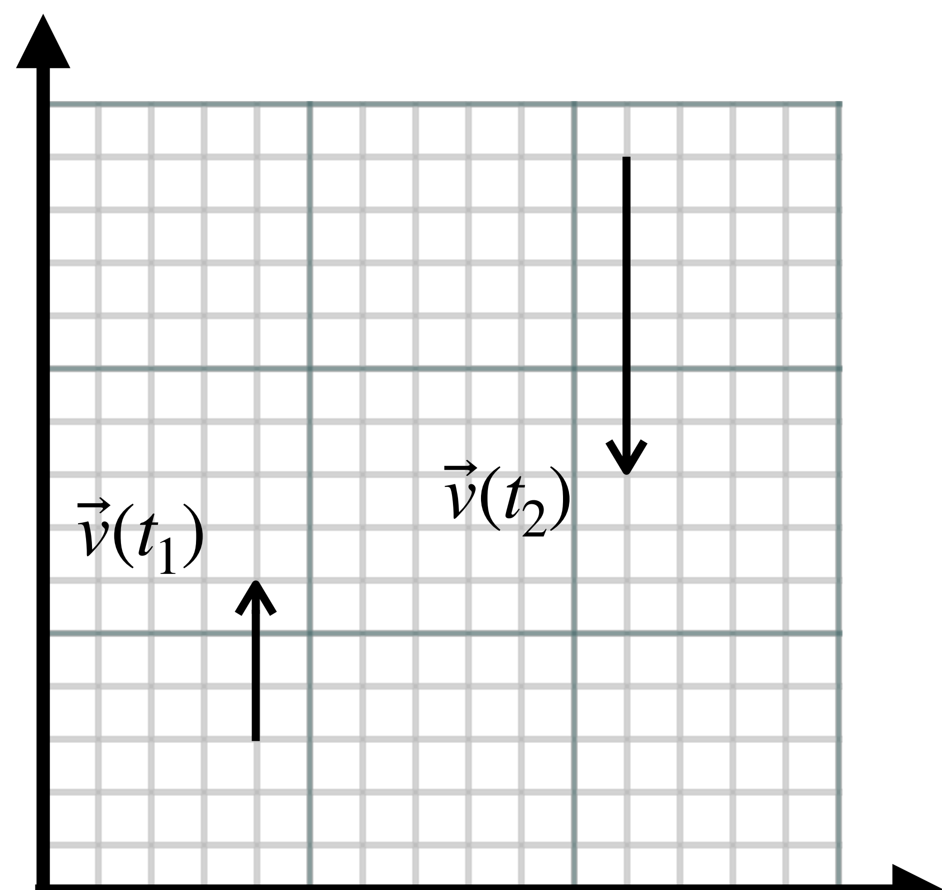
A. ↑

B. →

C. ↓

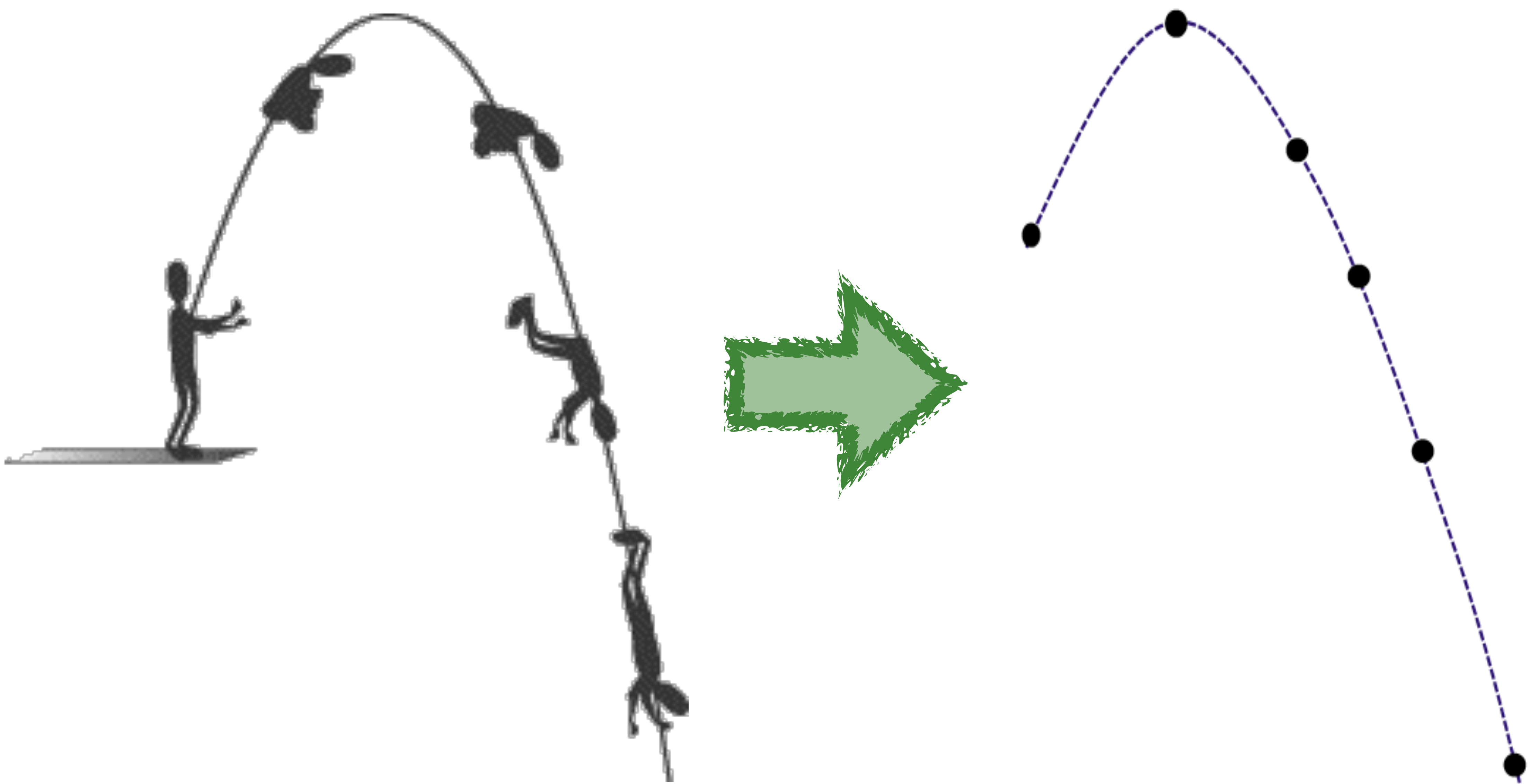
D. ←

E. None of these.



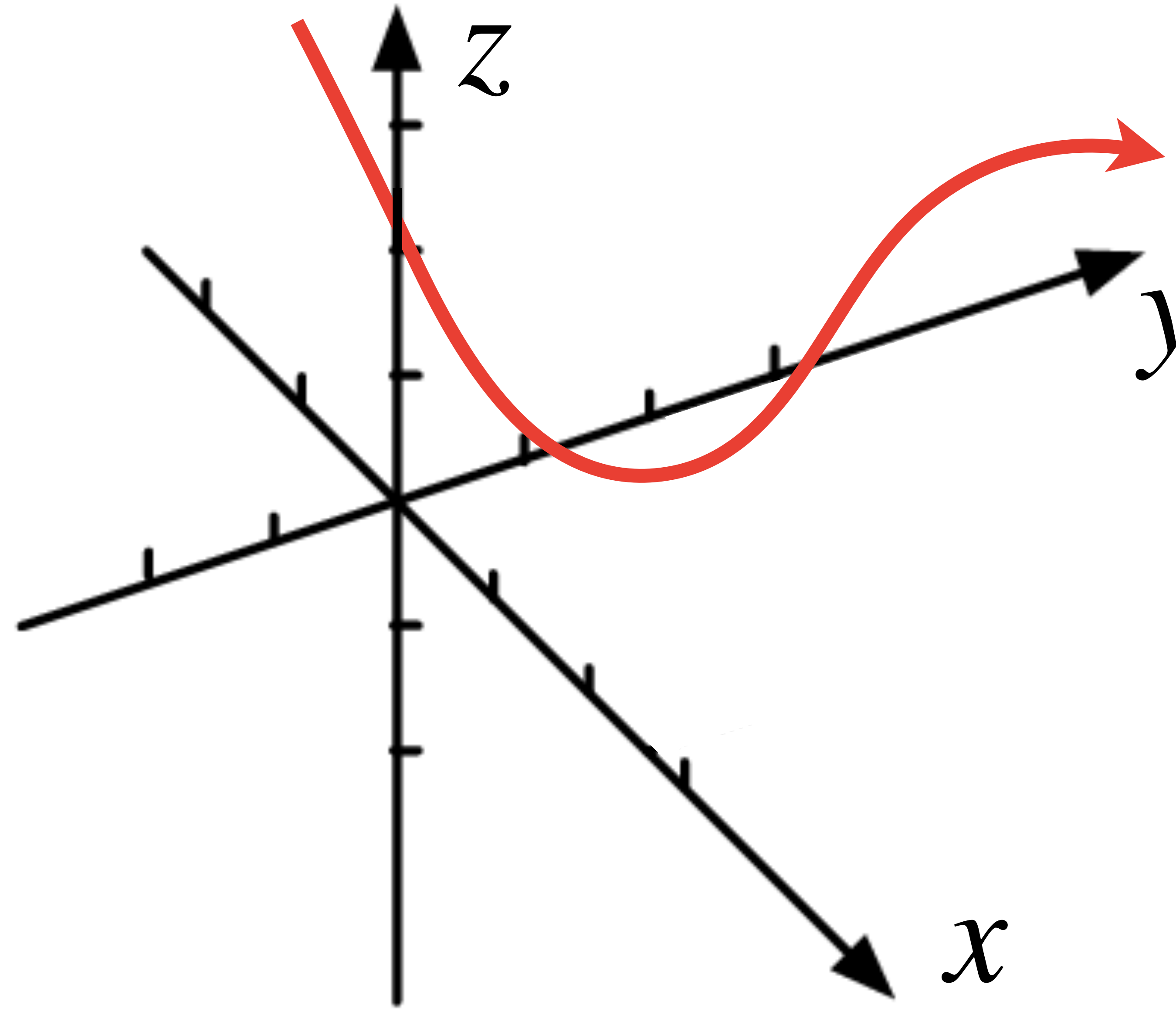
Kinematics

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



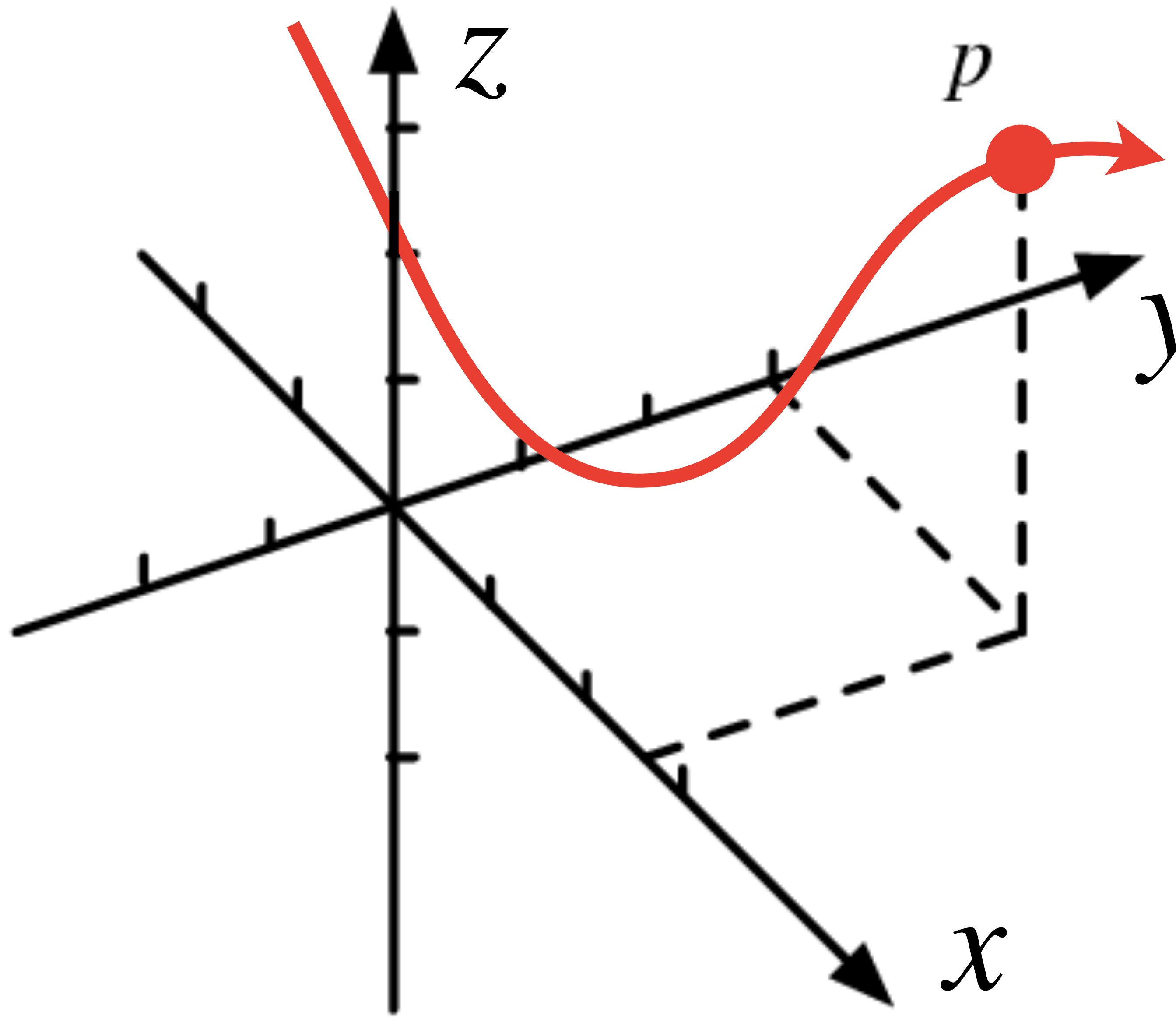
Vector position in Cartesian coordinates

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



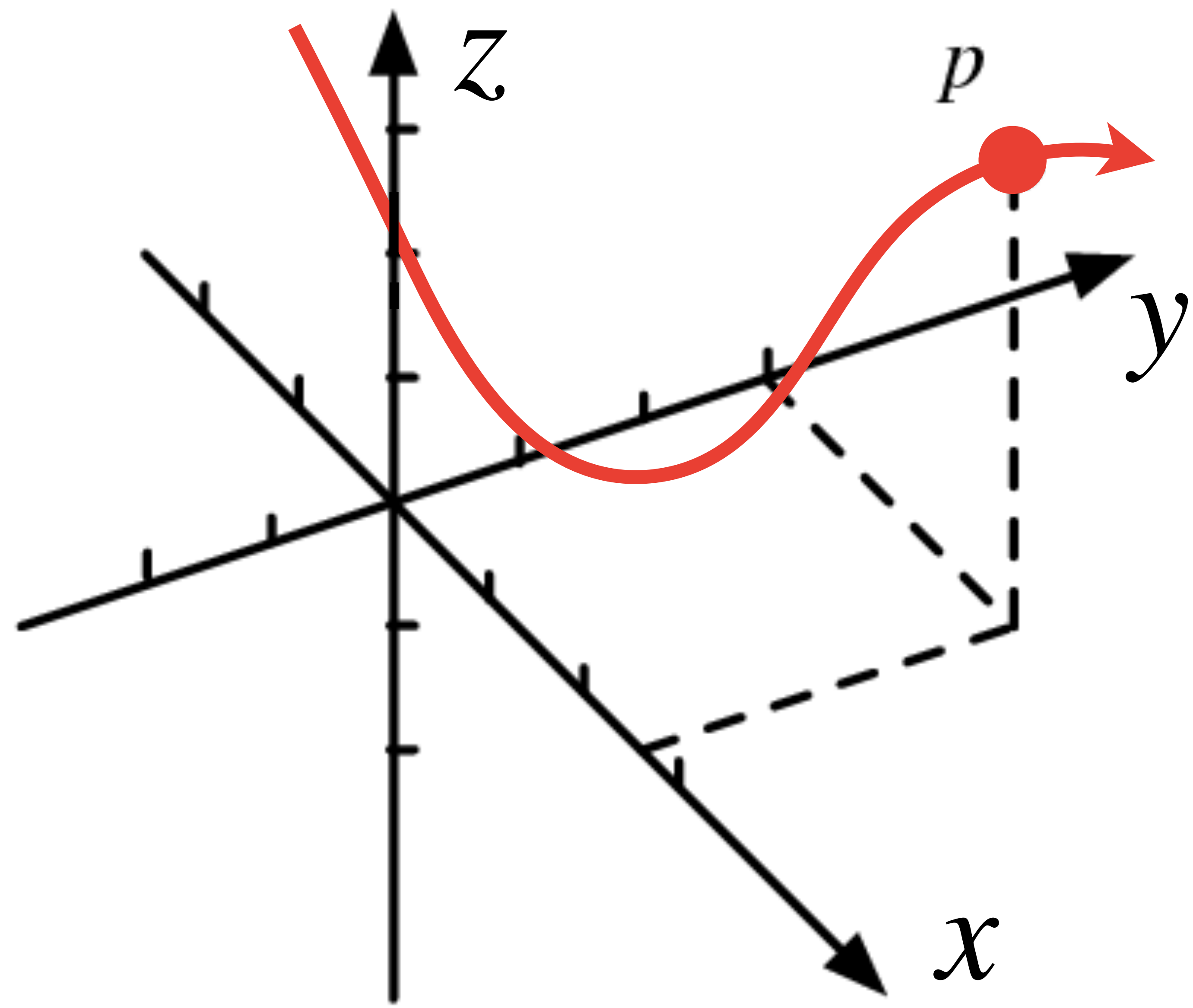
Vector displacement (Cartesian)

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



Vector velocity (Cartesian)

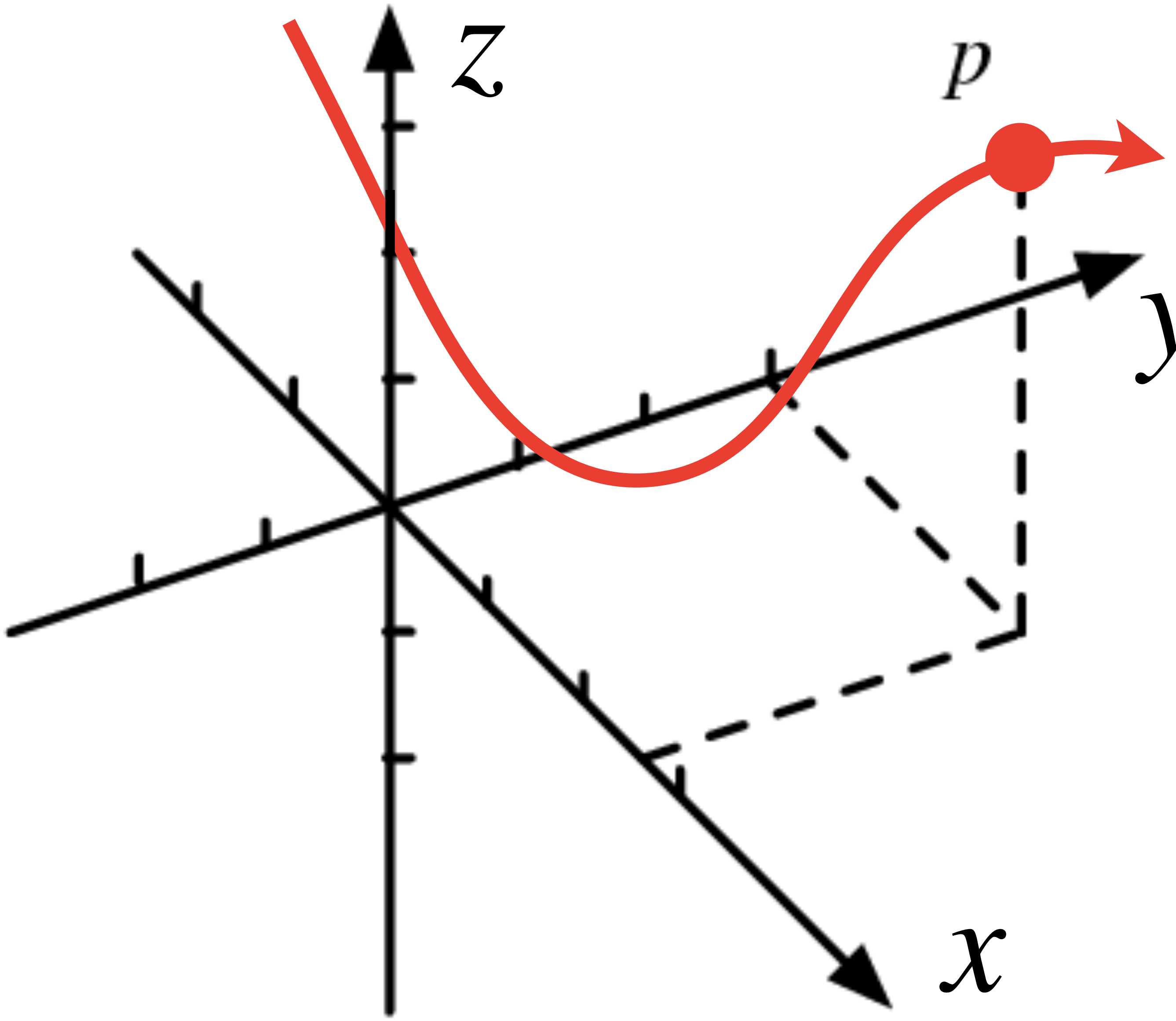
- Average velocity in 1D: $\overline{v} = \dfrac{\text{displacement}}{\text{time elapsed}} = \dfrac{\Delta x}{\Delta t}$



Vector velocity (Cartesian)

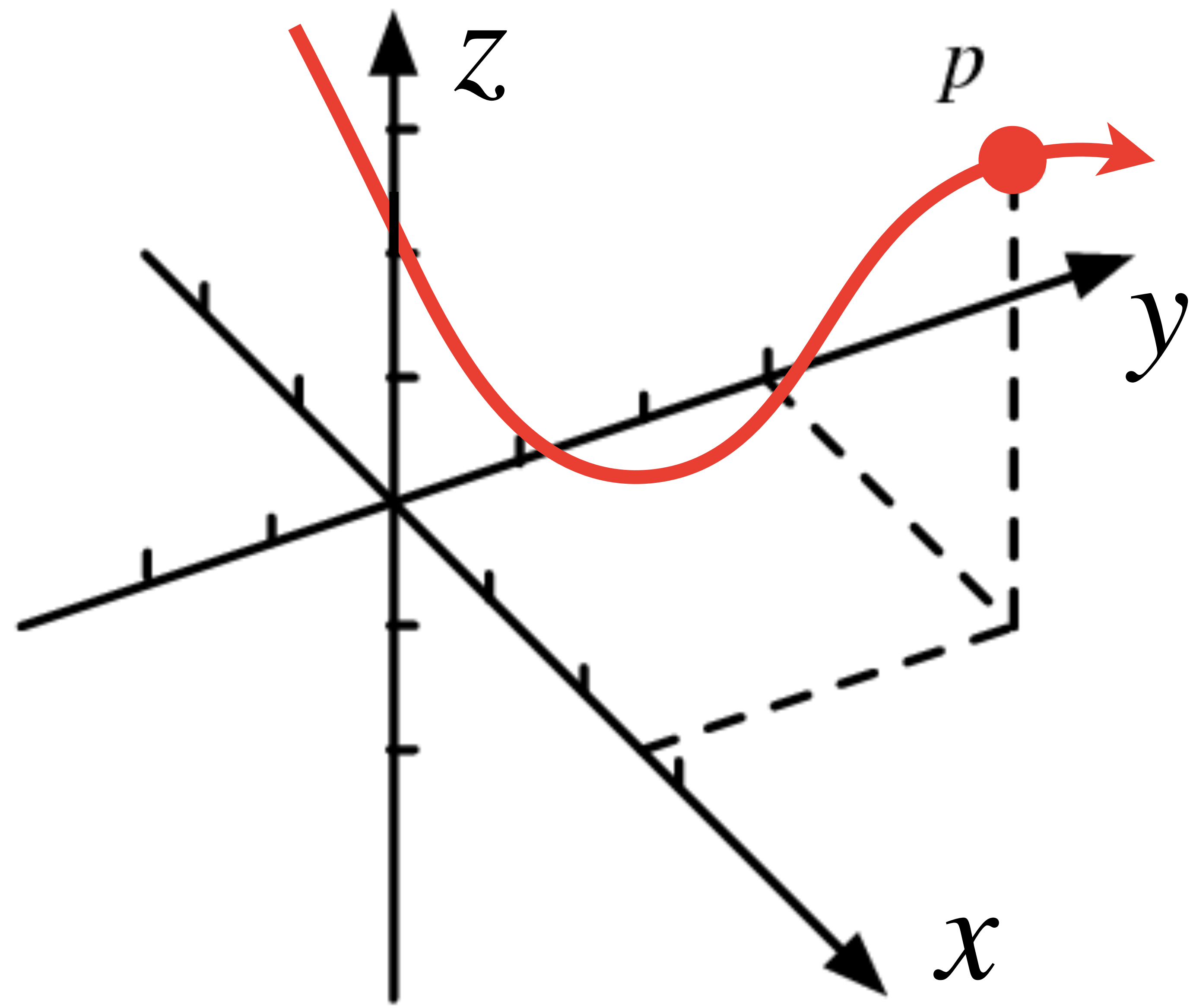
- Speed (i.e. magnitude of velocity):

- Direction:



Vector acceleration (Cartesian)

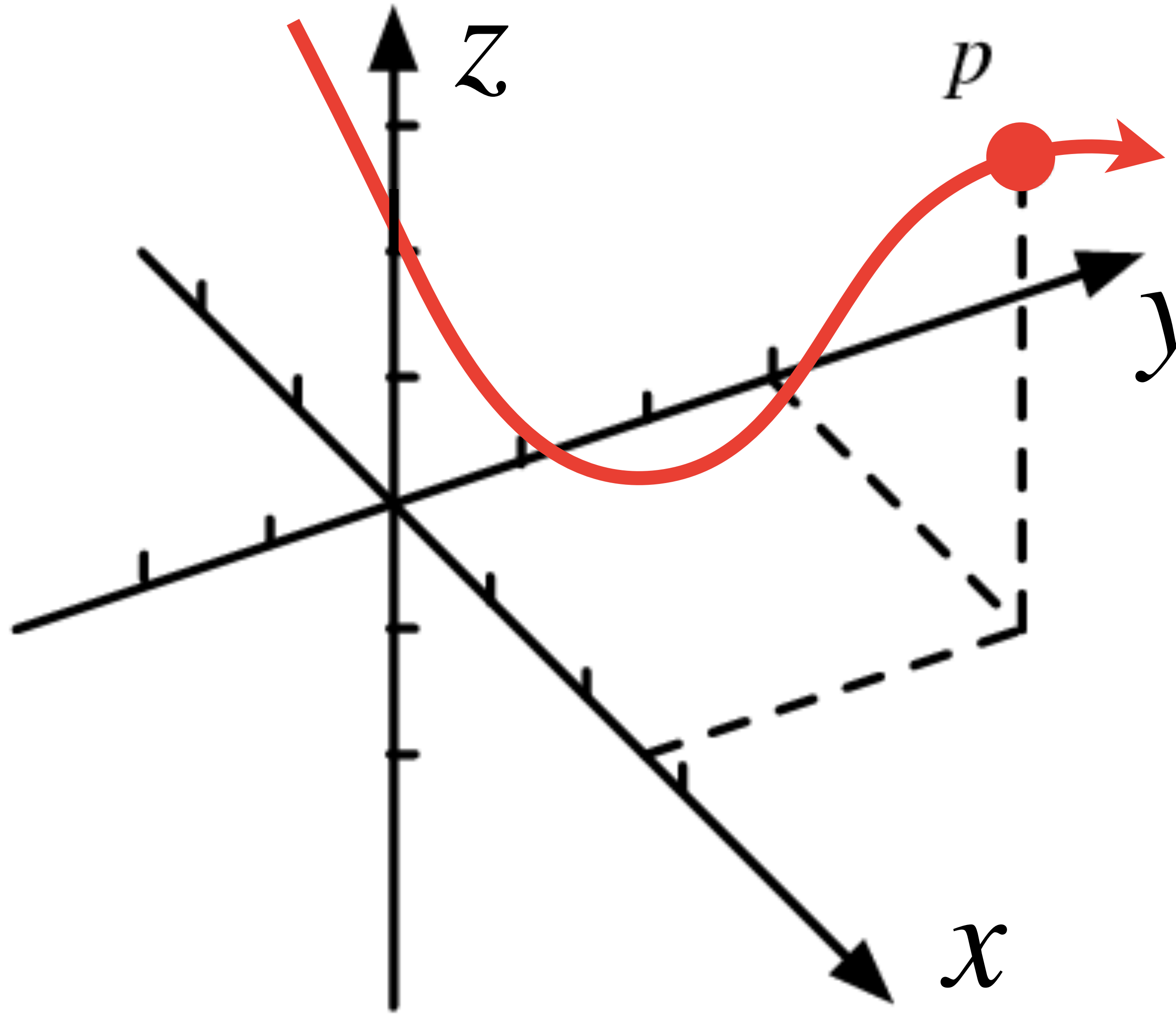
- Average acceleration in 1D: $\bar{a} = \frac{\text{change in velocity}}{\text{time elapsed}} = \frac{\Delta v}{\Delta t}$



Vector acceleration (Cartesian)

- Magnitude of the acceleration:

- Direction:



See you at the exercises tomorrow!

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- Wednesdays from 17:15 to 19:00
  - Don’t forget to sign up for a tutoring group on Moodle
  - Exercises will be found on the Moodle (bring your own paper copy or way to access them digitally)