Physics 225

Section 2

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Lecture 2

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Quantity	Unit
mass	kg
time	s
length	m
area	m^2
volume	m^3
velocity (v)	m/s
acceleration	m/s^2

Dimensional analysis

- Both sides of an equation must have the same units
  - This limits the kinds of equations you can write
  - Example: distance *d*, velocity *v*, and time *t* are related

Variable	d	t	v
Units	m	s	m/s

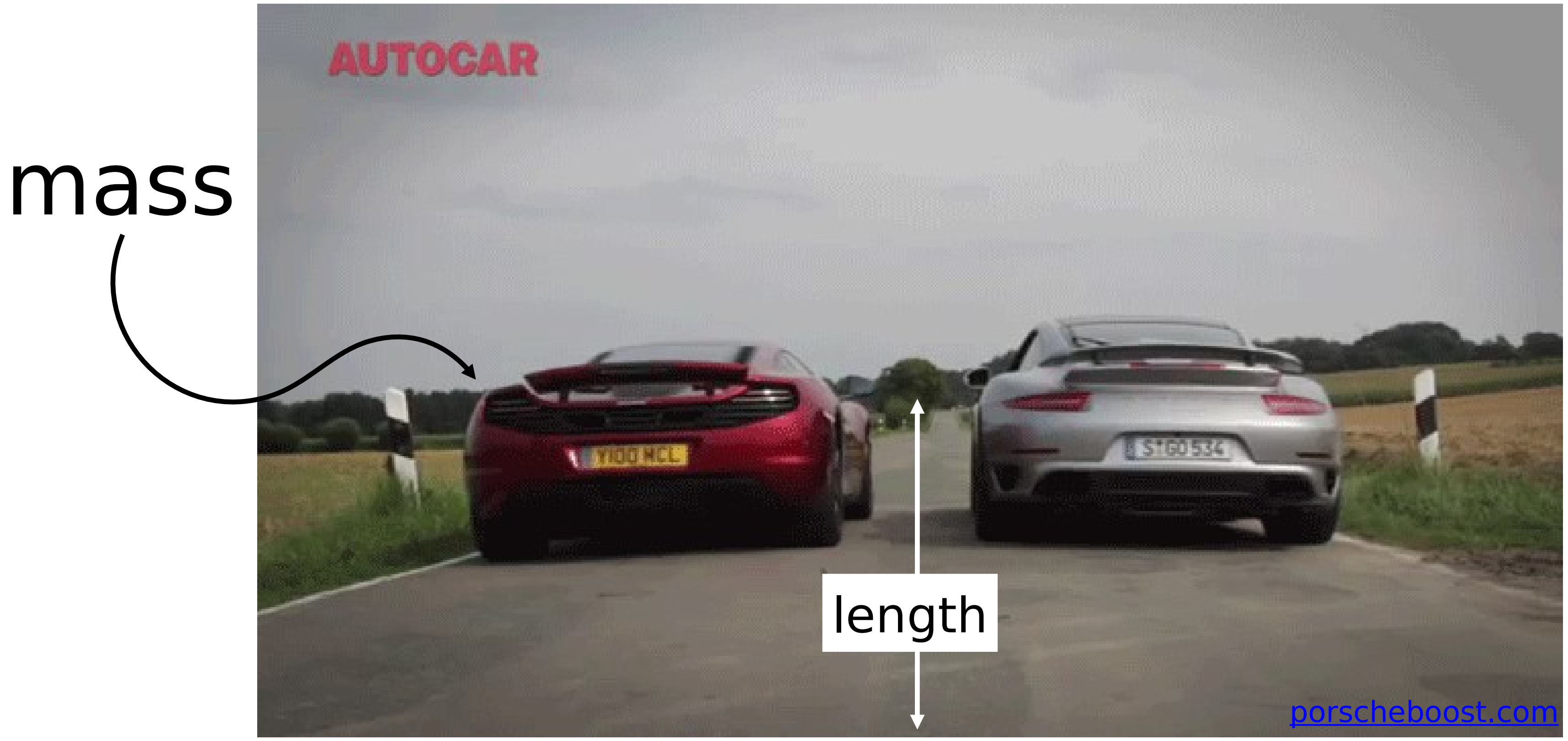
  - Equations must have the same units left and right

$$d = v \quad t$$

$$\text{m} = \text{m}/\cancel{\text{s}} \quad \cancel{\text{s}}$$

real answer: $d = vt$

Today: 1D Motion and Acceleration

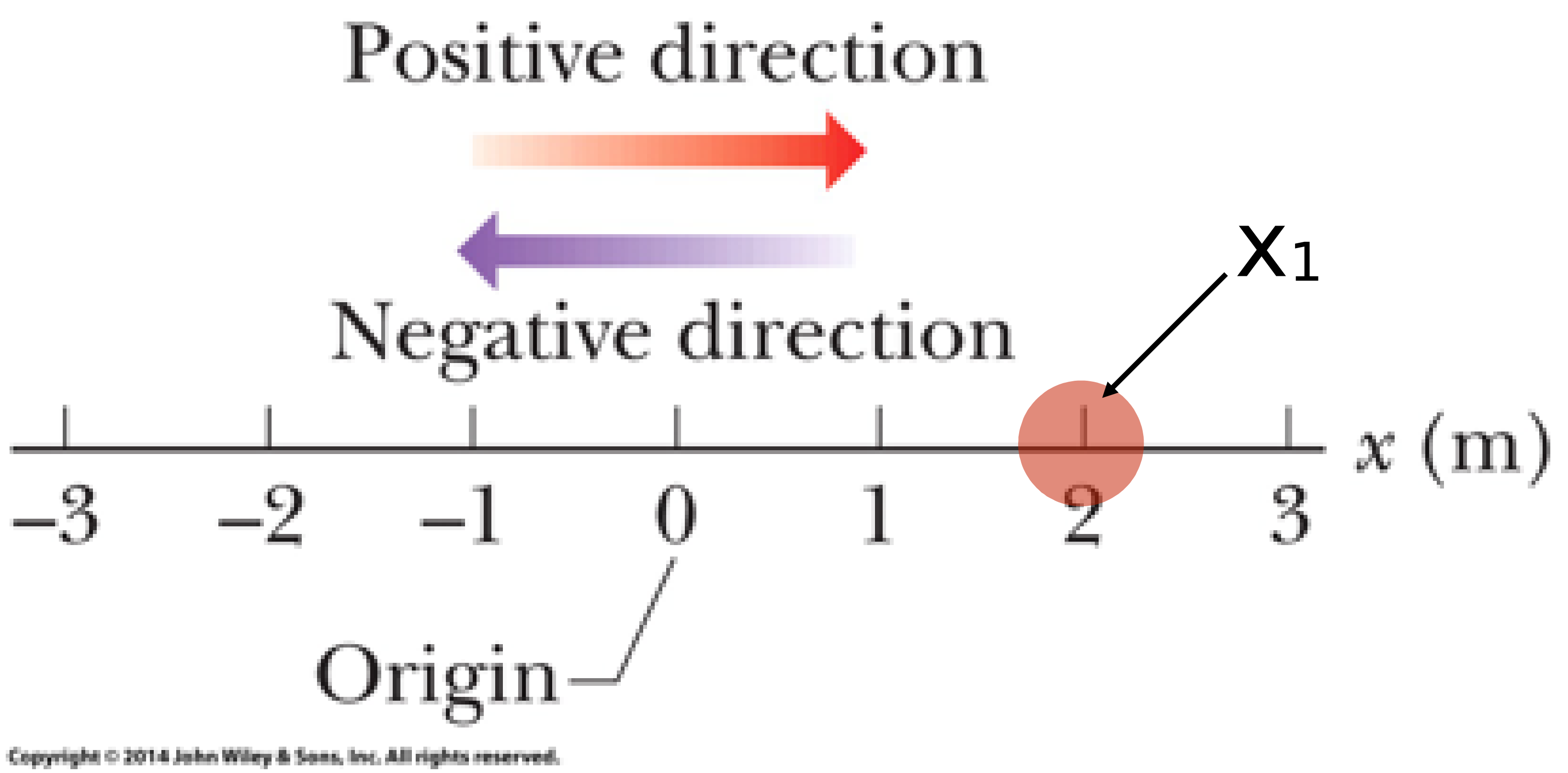


- **Take Home Message**
  - We can use units to describe the **motion of objects** quantitatively: position, velocity, acceleration
  - **Constant acceleration** is a special type of problem that allows us to derive a couple useful equations of motion

1D Motion

- But what is the distance, velocity, time, etc?

- **Position** is the location of the particle <u>relative to some reference point</u> (e.g. origin).



Distance

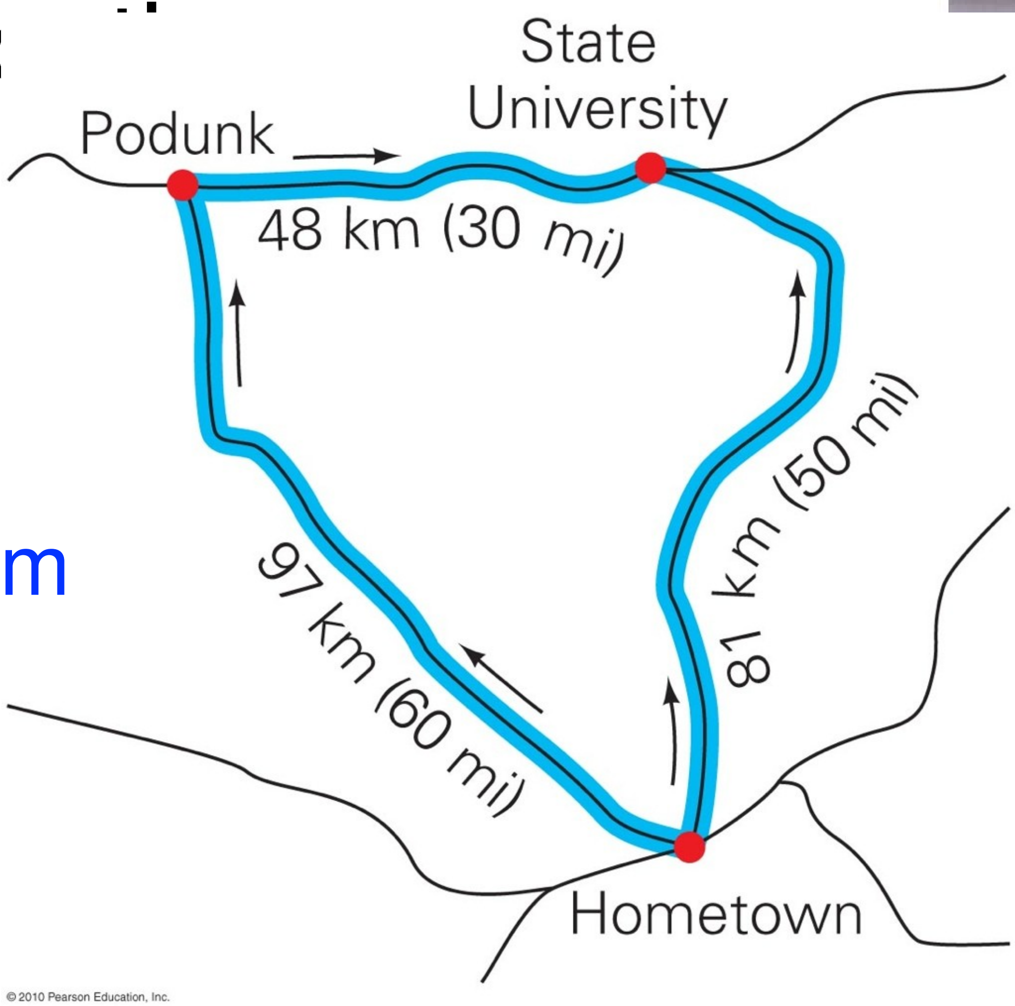
- Distance = length of path traveled
  - Scalar = number + units
  - SI unit: m
  - Depends on

Odometer = measured distance

Distance from Hometown to State University:

81 km (Eastern route)

97 km + 48 km = 145 km (by way of Podunk)



Speed

Speedometer: measure (instantaneous) speed

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Odometer = measure distance

- Speed = scalar
  - Average

$$\bar{s} = \frac{d}{\Delta t} = \frac{d}{t - t_0} = \frac{d}{t}$$

  - SI unit: m/s
  - Instantaneous

$$\bar{s} \to s \text{ as } \Delta t \to 0$$

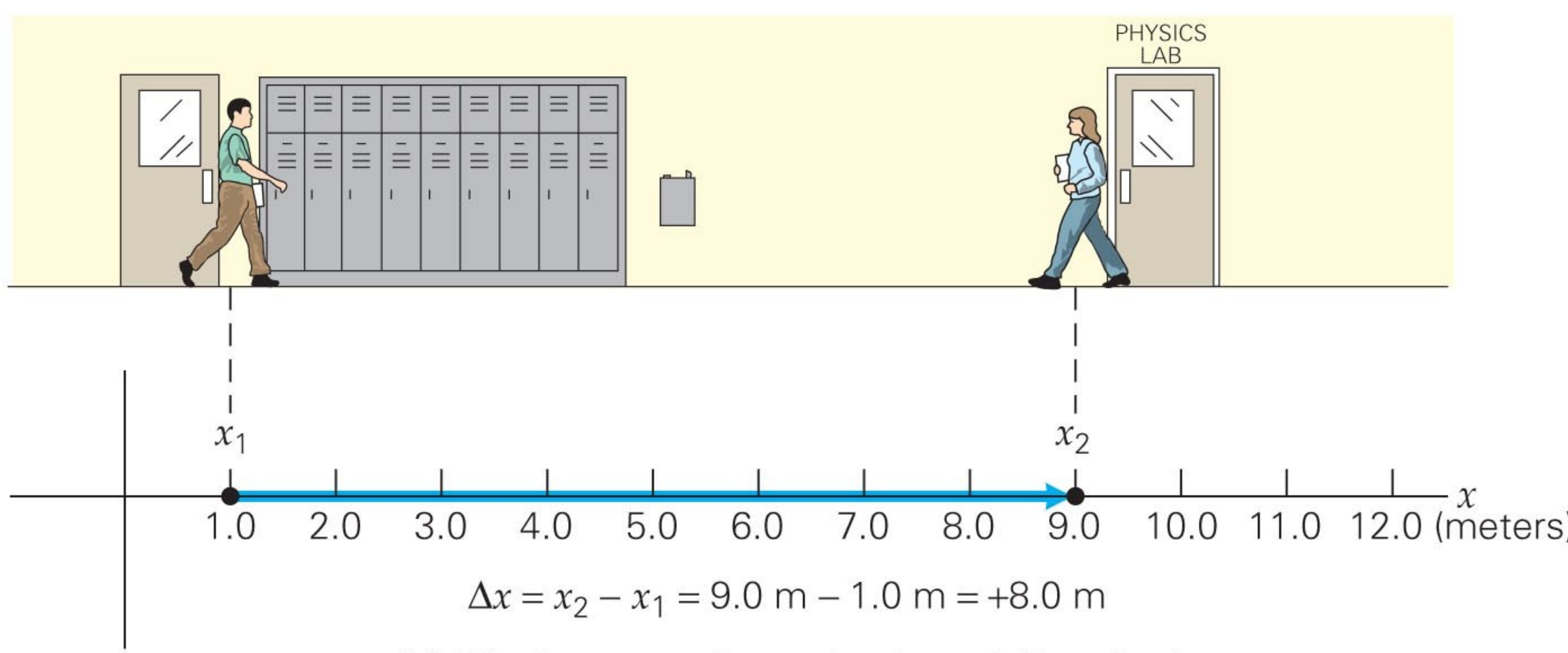
$$s = \text{speed at a particular instant of time}$$

Scalars vs Vectors

- Scalars are quantities that can be expressed solely in terms of a number
  - Distance is an example of a scalar
- Vectors are quantities that are expressed in terms of:
  1. A magnitude
  2. A direction
- In 1D, the direction of the vector can be represented by a '+' or a '-' sign.

Displacement

- Magnitude = straight-line distance from start point to end point (SI unit: m)
- Direction = from start point to end point
- Depends only on start, end point (*not on path*)
    - *Position = displacement from chosen point ("origin")*



(b) Displacement (magnitude and direction)

Clicker Question #1a

- I drive 0.3 miles west from the 57 offramp toward campus. Then I u-turn and drive 0.2 miles east. **What distance did I travel?**

A 0.1 miles

B 0.2 miles

C 0.3 miles

D 0.5 miles

Clicker Question #1b

- I drive 0.3 miles west from the 57 offramp toward campus. Then I u-turn and drive 0.2 miles east. **What is my displacement?**

A 0.1 miles

B 0.2 miles

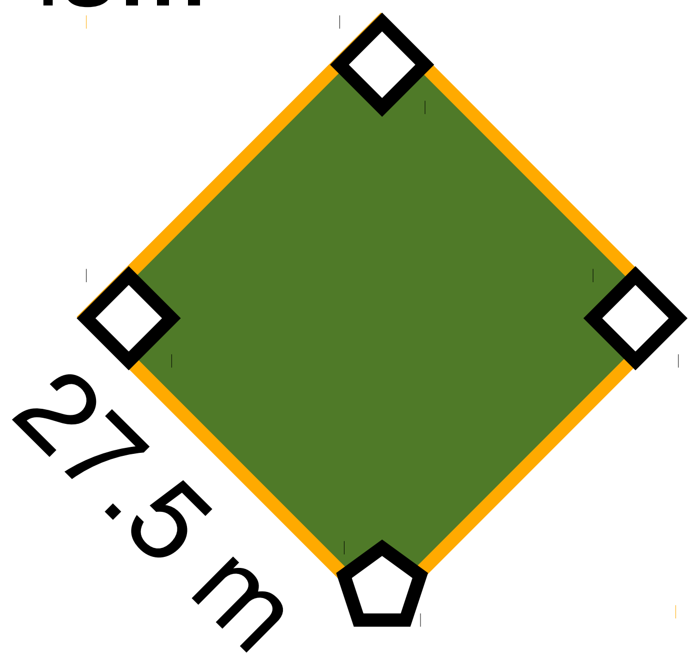
C 0.3 miles

D 0.5 miles

west!

Clicker question #2a

- The distance around a baseball diamond is 110 m. A runner runs the bases in 10 s. The runner's **distance** traveled is...



A 110 m

B 110 m, clockwise

C 110 m, counterclockwise

D 0 m

Clicker question #2b

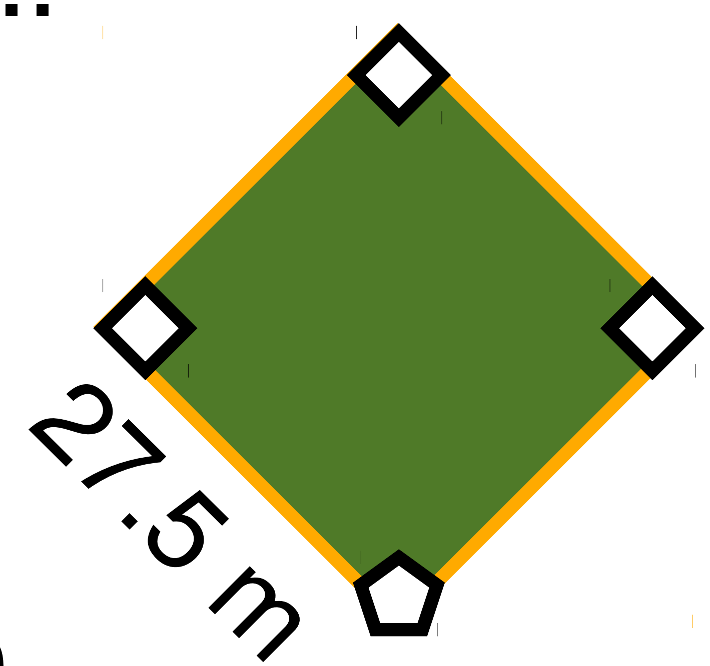
- The distance around a baseball diamond is 110 m. A runner runs the bases in 10 s. The runner's **displacement** is...

A 110 m

B 110 m, clockwise

C 110 m, counterclockwise

D 0 m



Velocity

- Vector $\vec{\mathbf{v}}$
  - Defined as the rate of change of displacement
    - In 1D, magnitude & direction (SI unit: m/s) is

$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{x - x_0}{t - t_0} = \frac{x - x_0}{t}$$

$\Delta x =$ displacement from start to end $\quad \bar{v} =$ average velocity

$\Delta t =$ time to travel from start to end

$x =$ final position; $x_0 =$ initial position

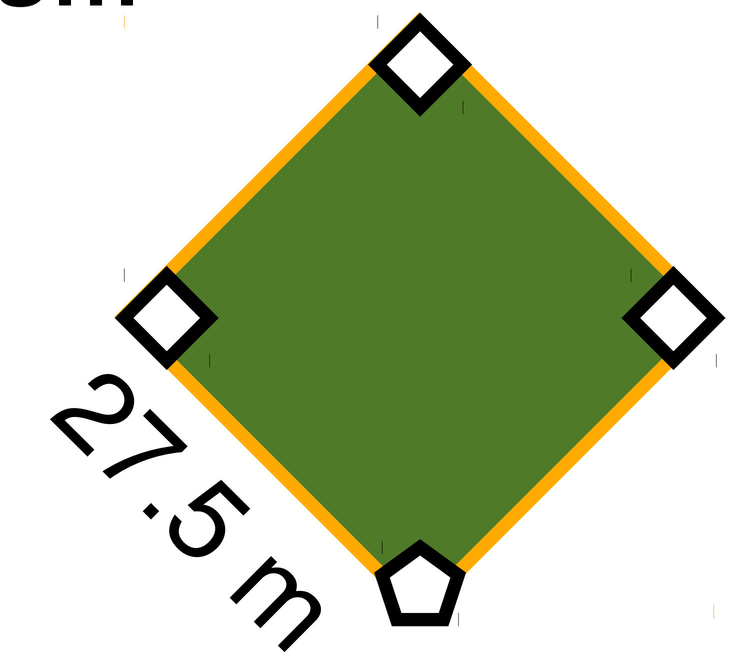
$t =$ final time; $t_0 =$ initial time

  - Instantaneous $\quad \bar{v} \to v$ as $\Delta t \to 0 \quad v = \frac{dx}{dt}$

$v =$ velocity at a particular instant of time

Clicker question #3a

- The distance around a baseball diamond is 110 m. A runner runs the bases in 10 s. The runner's **average speed** is...



A 11 m/s, clockwise

B 11 m/s, counterclock.

C 11 m/s

D 0 m/s

Clicker question #3b

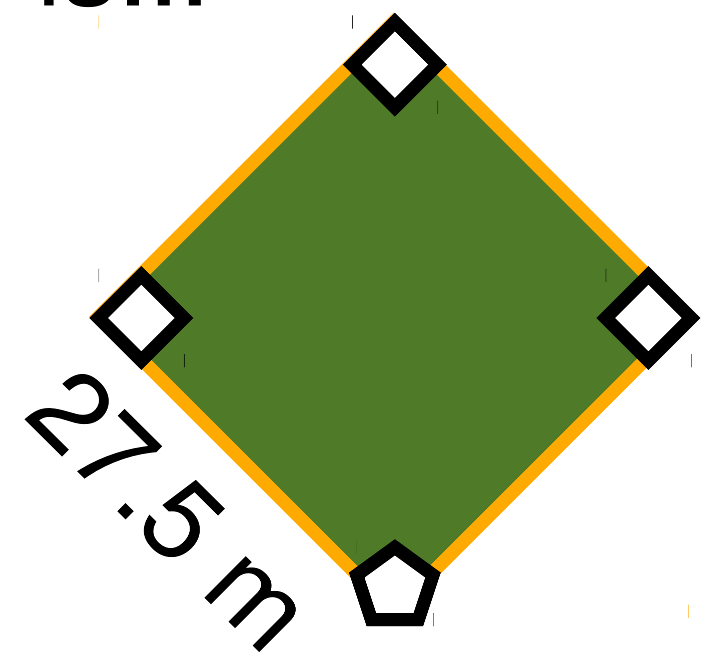
- The distance around a baseball diamond is 110 m. A runner runs the bases in 10 s. The runner's **average velocity** is...

A 11 m/s, clockwise

B 11 m/s, counterclock.

C 11 m/s

D 0 m/s



Acceleration

- Vector $\vec{\mathbf{a}}$
  - Defined as the rate of change of velocity
    - (SI unit: (m/s)/s = m/s^2)
    - Points toward <u>change</u> in velocity. In 1D:

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{v - v_0}{t - t_0} = \frac{v - v_0}{t}$$

$\Delta v =$ change in velocity from start to end

$\Delta t =$ time to travel from start to end

$v =$ final velocity; $v_0 =$ initial velocity

$t =$ final time; $t_0 =$ initial time

$\bar{v} =$ average velocity

  - Instantaneous

$$\bar{a} \rightarrow a \qquad \Delta t \rightarrow 0 \rightarrow dt$$

$$a = \frac{dv}{dt} = \frac{d^2x}{dt^2}$$

Clicker question #6a

- A white bronco is traveling north on I-405 at 35 mi/hr. If it **speeds up**, its **acceleration** points

A North

B South

C Not enough information to tell.

D The accel. is 0.

Clicker question #7b

- A white bronco is traveling north on I-405 at 35 mi/hr. If it **slows down**, its **acceleration** points

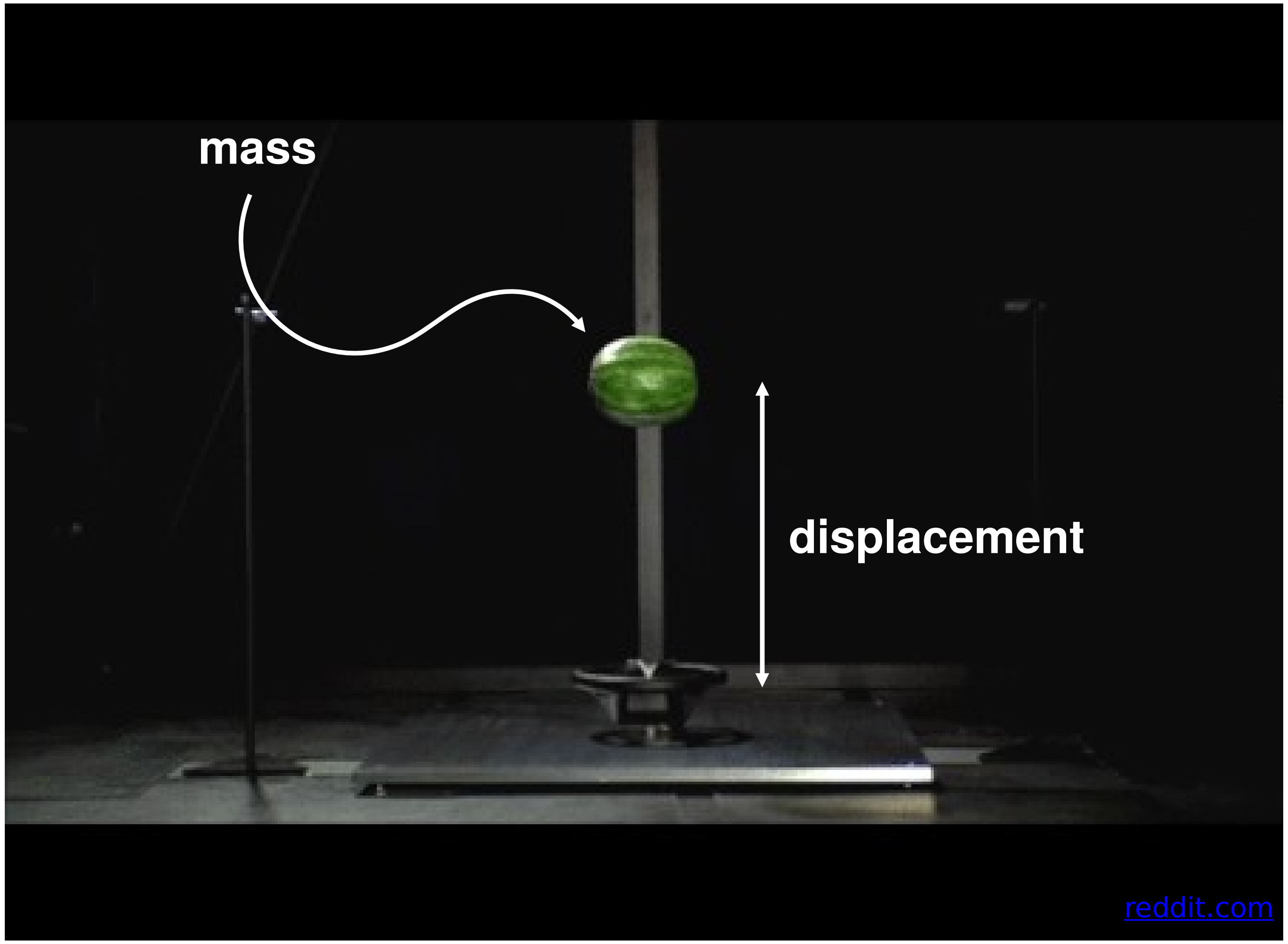
A North

B South

C Not enough information to tell.

D The accel. is 0.

Motion - Acceleration



- **Constant acceleration** is a special type of problem that allows us to derive a couple useful equations of motion
- A little bit of **calculus** provides some intuitive information and helps avoid memorizing equations!

Kinematic equations

- 5 equations describe motion with *constant acceleration*

$$a = \text{acceleration} = \text{constant}$$

- Let's derive the **two** most important ones

$$(\text{here we let the initial time } t_0 = 0)$$

$$a = \frac{dv}{dt} \Rightarrow v = \int dta = a \int dt = at + v_0$$

$$v = \frac{dx}{dt} \Rightarrow x = \int dt(at + v_0) = \frac{1}{2}at^2 + v_0 t + x_0$$

$t =$ final time
$x =$ final position
$v =$ final velocity
$x_0 =$ initial position
$v_0 =$ initial velocity

for constant acceleration

$$\boxed{\begin{aligned} v &= v_0 + at \\ x &= x_0 + v_0 t + \tfrac{1}{2}at^2 \end{aligned}}$$

Kinematic equations

- So then why do we need 3 (5) equations to describe constant acceleration?

$a = \text{acceleration} = \text{constant}$

- We don't!… but additional equations may be useful to solve certain problems.

- Sometimes it's convenient to have an equation that doesn't contain t

$$v = v_0 + at \quad \Rightarrow \quad t = \frac{v - v_0}{a}$$

$$x = x_0 + v_0 t + \frac{1}{2} a t^2$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

$t =$ final time
$x =$ final position
$v =$ final velocity
$x_0 =$ initial position
$v_0 =$ initial velocity

Useful Equations

$$v = v_0 + at$$

$$x = x_0 + v_0 t + \frac{1}{2} a t^2$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

Ex: Luigi Kart

- Luigi is in a go-kart on a long straight track running left to right. When the race starts at t=0, his car is 5 m to the right of an “x” painted on the track. Starting from rest, he accelerates at a rate of 2.0 m/s^2. How far from the x is he after 3.0s?

Problem Solving tips

1. Choose an origin.
2. Choose a positive direction
3. Apply them consistently!
4. Write out all the variables that you know (givens) and which ones you don't (goals)

Clicker question #4a

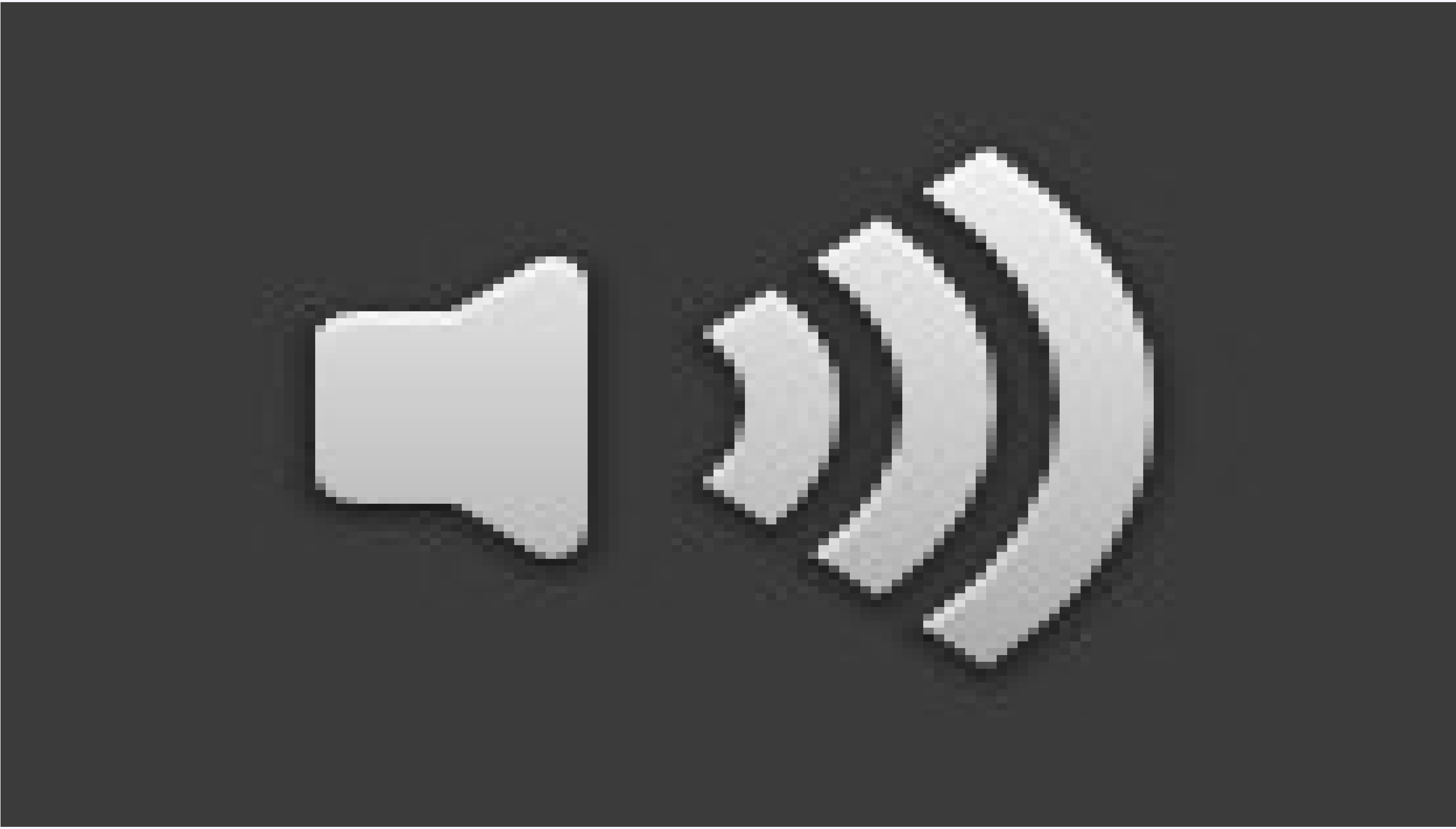
Feather, bowling ball dropped from same height. Which will land first **in a tube full of air**?

A  lands first

B they land at the same time

C  lands first

At ambient conditions



https://www.youtube.com/watch?v=E43-CfukE

Clicker question #4b

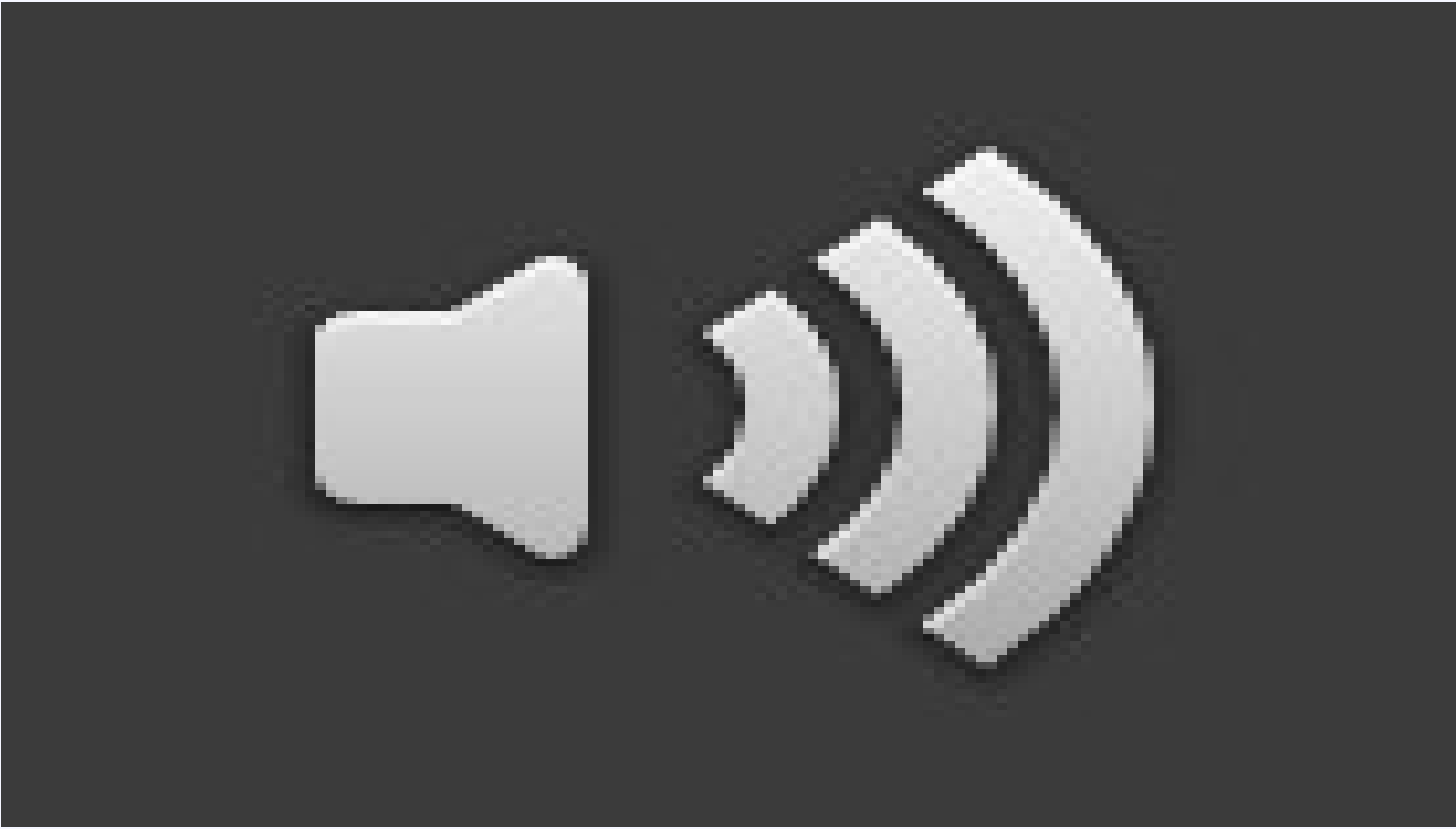
Feather, bowling ball dropped from same height.
Which will land first **in a vacuum tube**?

A  lands first

B they land at the same time

C  lands first

In vacuum



https://www.youtube.com/watch?v=E43-CfukE

Let's recall

Position x

Displacement $\Delta x = x_2 - x_1$

Velocity $v_{\text{avg}} = \dfrac{\Delta x}{\Delta t} = \dfrac{x_2 - x_1}{t_2 - t_1}$

Acceleration $a_{\text{avg}} = \dfrac{v_2 - v_1}{t_2 - t_1} = \dfrac{\Delta v}{\Delta t}$

Clicker question #5a

- How do we write an equation for the **instantaneous velocity**?
  Hint: limit as $\Delta t \to 0$

$$v_{\text{avg}} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}$$

A $\quad v = \frac{\Delta x}{\Delta t}$

B $\quad v = \frac{\Delta x}{dt}$

C $\quad v = \frac{dx}{dt}$

D $\quad v = \Delta x dt$

Clicker question #5b

- How do we write an equation for the **instantaneous acceleration**?
  Hint: limit as $\Delta t \to 0$

$$a_{\text{avg}} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}$$

A $a = \left(\frac{dx}{dt}\right)^2$

B $a = \frac{dv}{dt}$

C $a = \frac{d^2x}{dt^2}$

D both B and C

Next time…

- More 1D motion
  - Acceleration
  - Graphical integration in motion analysis