COLLEGE PHYSICS

Chapter 2 INTRODUCTION: Kinematics in One Dimension

Lesson 4

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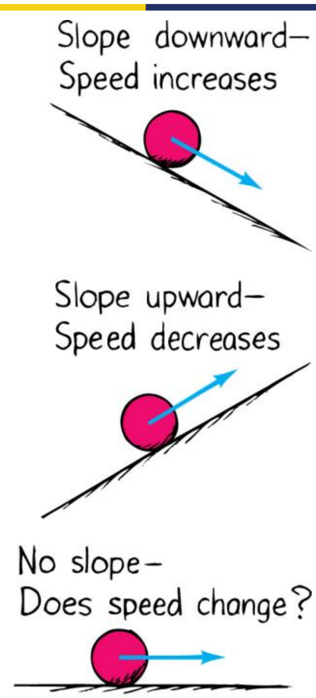
ACCELERATION

Formulated by Galileo based on his experiments with inclined planes.



ACCELERATION

- **Acceleration** is the *rate* at which velocity changes:

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{v_\mathrm{f} - v_0}{t_\mathrm{f} - t_0}$$

- In SI units, the velocity is in $\mathrm{m/s}$, and the time is in s, so the SI units for a are $\mathrm{m/s^2}$.
- This means how many meters per second the velocity changes every second.
- Acceleration is a **vector**, which is in the same direction as the change in velocity, Δv.

INSTANTANEOUS ACCELERATION

- **Average acceleration** is the change in velocity divided by the elapsed time:

$$\bar{a} = \frac{\Delta v}{\Delta t}$$

- The **instantaneous acceleration** a (a.k.a. “**acceleration**”) is your acceleration at a specific instant in time.
- a can be found by taking the limit of $\bar{a}$ as $\Delta t \to 0$.
- In certain special cases, a is constant, so the average and instantaneous accelerations are the same.

ACCELERATION: EXAMPLE

A racehorse coming out of the gate accelerates from rest to a velocity of 15.0 m/s due west in 1.80 s. What is its average acceleration?

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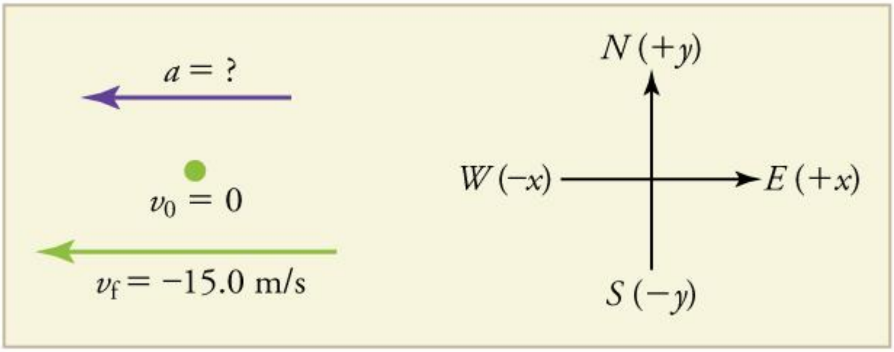


ACCELERATION: EXAMPLE

A racehorse coming out of the gate accelerates from rest to a velocity of 15.0 m/s due west in 1.80 s. What is its average acceleration?

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_0}{t_f - t_0} = \frac{-15 - 0}{1.80 - 0}$$

$$\bar{a} = -8.33 \text{ m/s}^2$$

The negative sign indicates that the horse is accelerating toward the West.

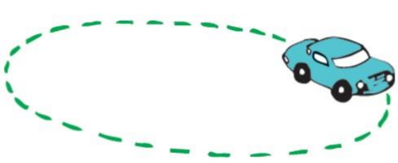
This is truly an average acceleration, because the ride is not smooth.

ACCELERATION

Because velocity is a vector, it can change in two possible ways:

1. The magnitude can change, indicating a change in speed, or
2. The direction can change, indicating that the object has changed direction.

Example: Car making a turn

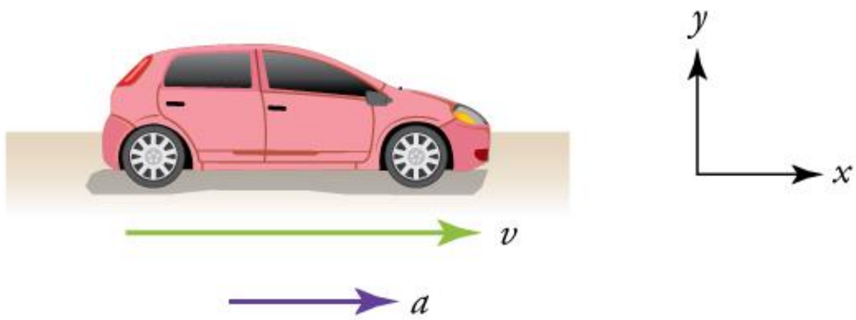


A plane decelerates, or slows down, as it comes in for landing in St. Maarten. Its acceleration is opposite in direction to its velocity. (credit: Steve Conry, Flickr)

ACCELERATION DIRECTION FOR LINEAR MOTION

- When an object is speeding up, its velocity and acceleration are in the **same** direction.
- When an object is slowing down, its velocity and acceleration are in **opposite** directions.
- Direction can be specified with + or – signs.
- For example, something with positive velocity and negative acceleration is slowing down.
- Something with negative velocity and positive acceleration is also slowing down!

GIVE IT A TRY!

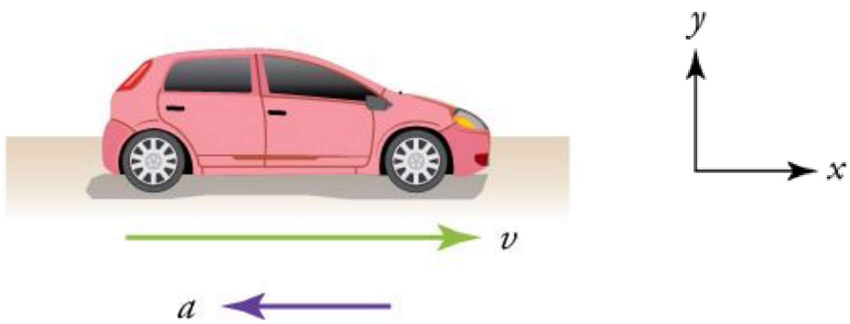


A car has positive velocity and positive acceleration. Which is true?

A. The car is speeding up.

B. The car is slowing down.

GIVE IT A TRY!

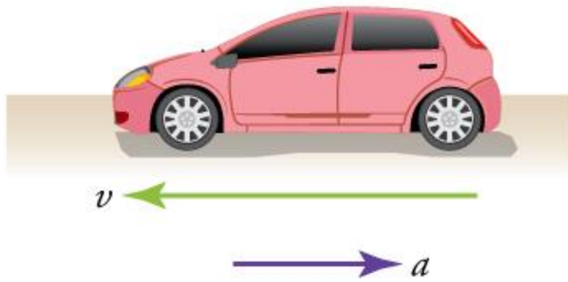


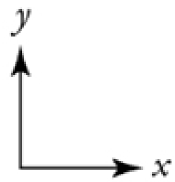
A car has positive velocity and negative acceleration. Which is true?

A. The car is speeding up.

B. The car is slowing down.

GIVE IT A TRY!



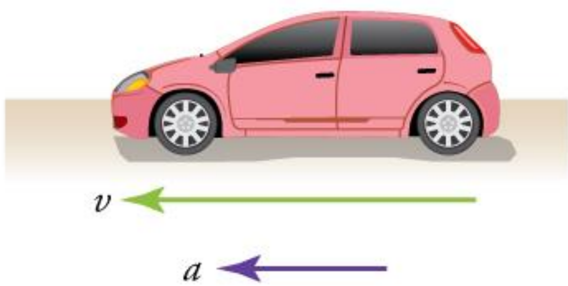


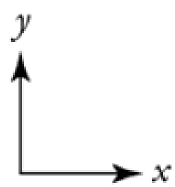
A car has negative velocity and positive acceleration. Which is true?

A. The car is speeding up.

B. The car is slowing down.

GIVE IT A TRY!





A car has negative velocity and negative acceleration. Which is true?

A. The car is speeding up.

B. The car is slowing down.

ACCELERATION: EXAMPLE

- A subway train accelerates from rest to $30.0\ \mathrm{km/h}$ in the first $20.0\ \mathrm{s}$ of its motion.
- It then travels at a constant velocity for the next $20.0\ \mathrm{s}$.
- Lastly, it slows to a stop in $8.00\ \mathrm{s}$.
- Assume that for each of these three segments of the train's motion, its acceleration is constant.
- Make graphs of velocity and acceleration for the train over these 48 seconds.

ACCELERATION: EXAMPLE

- **Speeding Up**
- A subway train accelerates from rest to $30.0\ \mathrm{km/h}$ in the first $20.0\ \mathrm{s}$ of its motion.

$$a_1 = \frac{\Delta v}{\Delta t} = \frac{v_\mathrm{f} - v_0}{t_\mathrm{f} - t_0} = \frac{30\ \mathrm{km/h}}{20\ \mathrm{s}}$$

$$a_1 = \left(\frac{30\ \cancel{\mathrm{km}}/\cancel{\mathrm{h}}}{20\ \mathrm{s}}\right)\left(\frac{10^3\ \mathrm{m}}{1\ \cancel{\mathrm{km}}}\right)\left(\frac{1\ \cancel{\mathrm{h}}}{3600\ \mathrm{s}}\right)$$

$$a_1 = 0.417\ \mathrm{m/s^2}$$

ACCELERATION: EXAMPLE

- **Constant Velocity**
- It then travels at a constant velocity for the next 20.0 s.

$$a_2 = \frac{\Delta v}{\Delta t} = \frac{v_f - v_0}{t_f - t_0} = \frac{(30 - 30)\ \text{km/h}}{20\ \text{s}}$$

$$a_2 = 0$$

ACCELERATION: EXAMPLE

- **Slowing Down**
- Lastly, it slows to a stop in 8.00 s.

$$a_3 = \frac{\Delta v}{\Delta t} = \frac{v_f - v_0}{t_f - t_0} = \frac{(0 - 30)\ \text{km/h}}{8\ \text{s}}$$

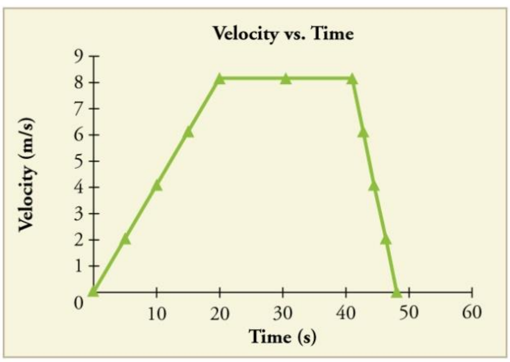
$$a_3 = \left(\frac{-30\ \text{km/h}}{8\ \text{s}}\right)\left(\frac{10^3\ \text{m}}{1\ \text{km}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)$$

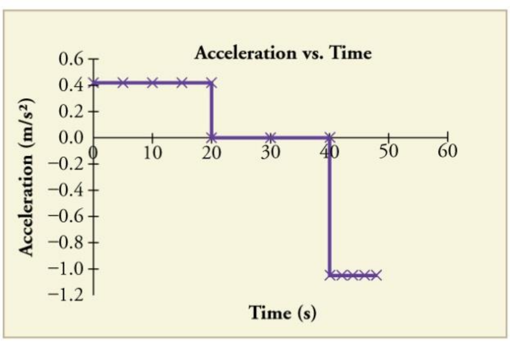
$$a_3 = -1.04\ \text{m/s}^2$$

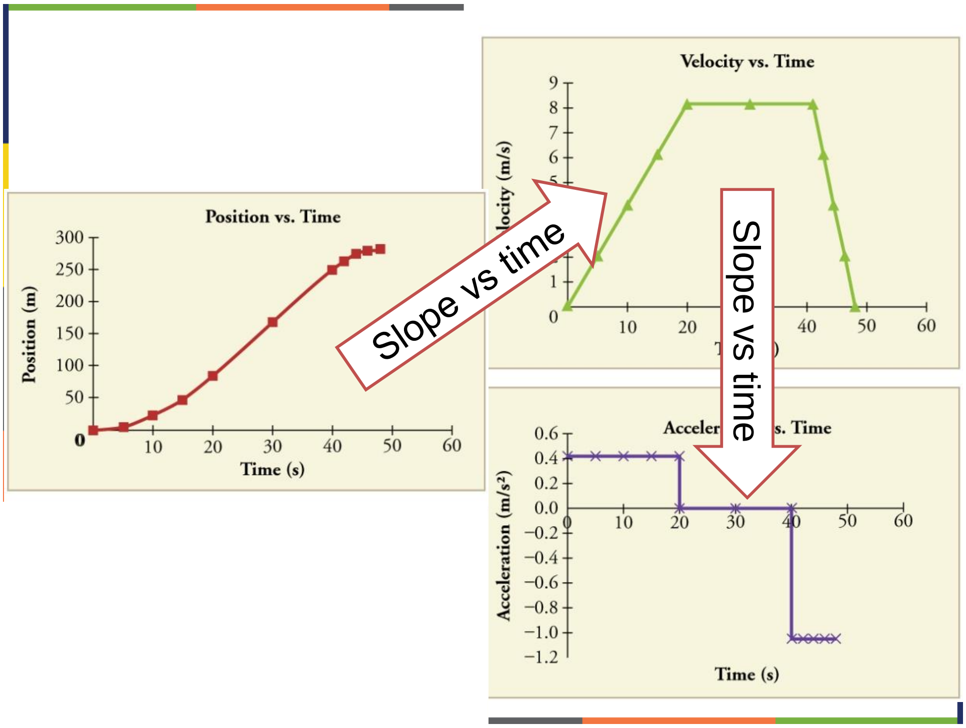
ACCELERATION: EXAMPLE

- **Cruising velocity in m/s**

$$v_2 = \left(\frac{30\ \text{km}}{\text{h}}\right)\left(\frac{10^3\ \text{m}}{1\ \text{km}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right) = 8.33\ \text{m/s}$$






Position vs. Time
Position (m)
300
250
200
150
100
50
0
10
20
30
40
50
60
Time (s)
Slope vs time
Velocity vs. Time
9
8
7
6
1
0
10
20
40
50
60
Slope vs time
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
−1.2
Acceleration (m/s²)
Time (s)