Distance, Displacement, Speed, and Velocity

Questions for Consideration

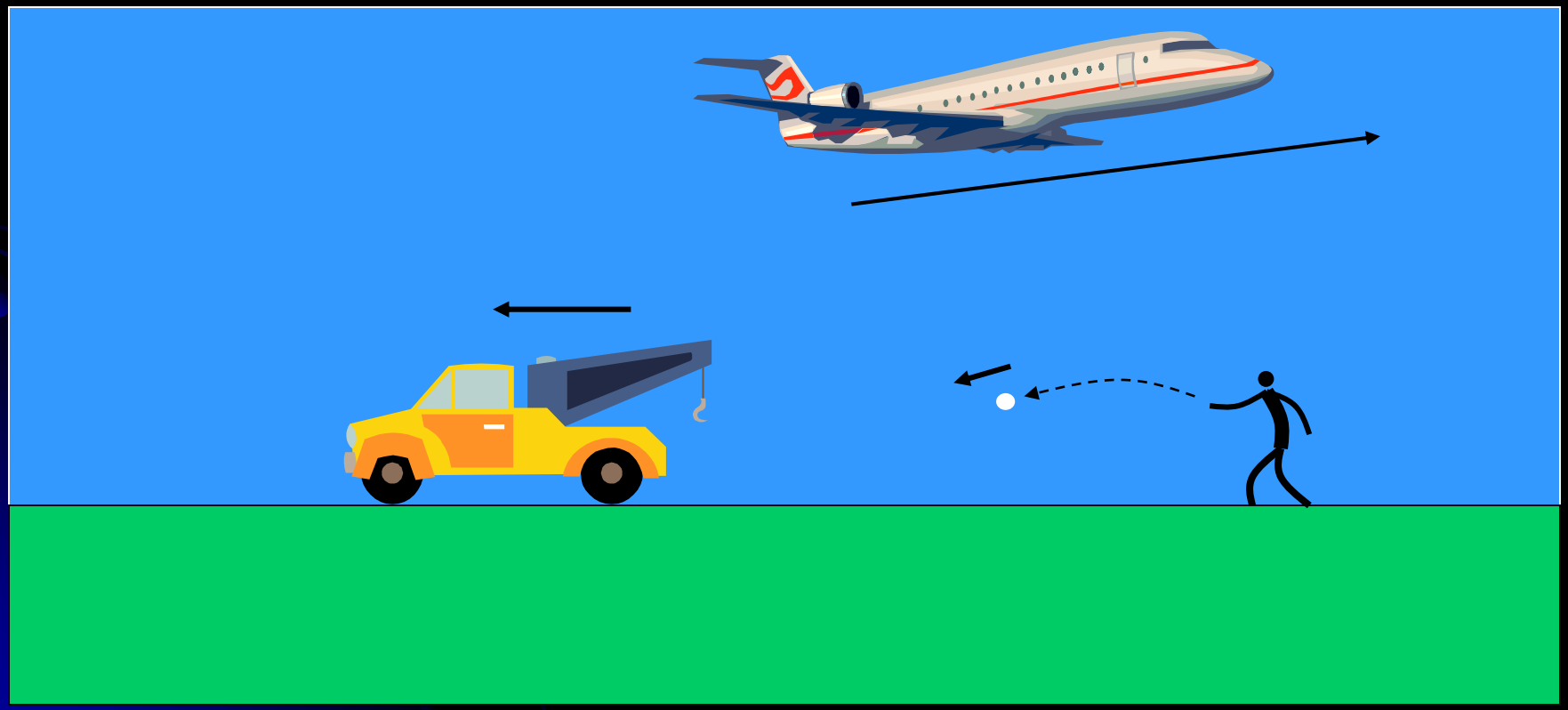
- What is frame of reference?
- What is distance?
- How is displacement different from distance?
- What is speed?
- What is velocity?
- What are scalar and vector quantities?

Frame of Reference

- Coordinate frame within which to measure position, motion, or other properties of an object.
- OR...
- Observational frame tied to the motion of an observer.
- In Newtonian physics, all motion must be defined in terms of a reference frame.
- Relative Motion

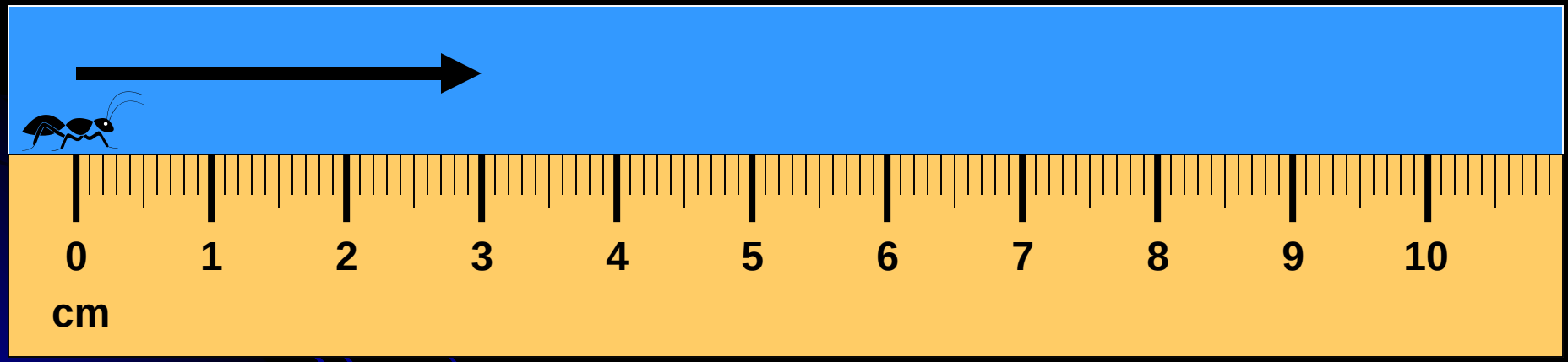
Reference Frame

- Is the speed of the ball different relative to the pitcher, the truck driver, and the jet pilot? Why or why not?



Distance

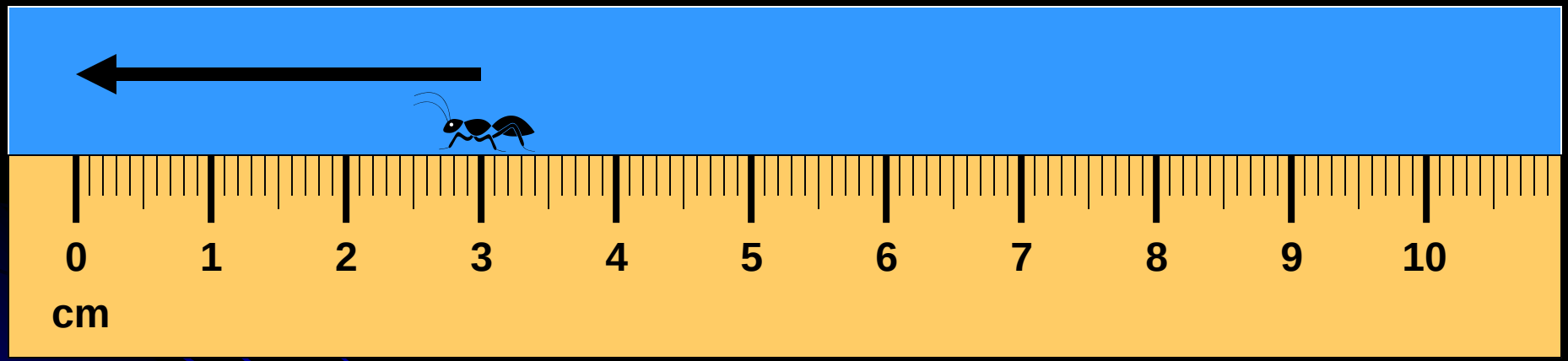
- Distance (d) – how far an object travels.
  - Does *not* depend on direction.
- Imagine an ant crawling along a ruler.



- What *distance* did the ant travel?
  - d = 3 cm

Distance

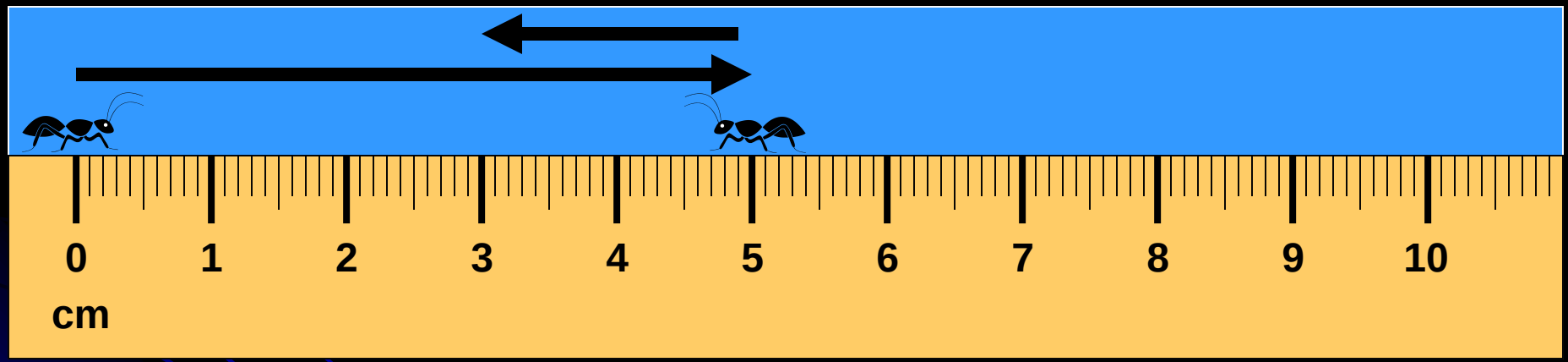
- Distance does not depend on direction.
- Here's our intrepid ant explorer again.



- Now what distance did the ant travel?
  - d = 3 cm
- Does his direction change the answer?

Distance

- Distance does not depend on direction.
- Let's follow the ant again.



- What distance did the ant walk this time?
- d = 7 cm

Displacement

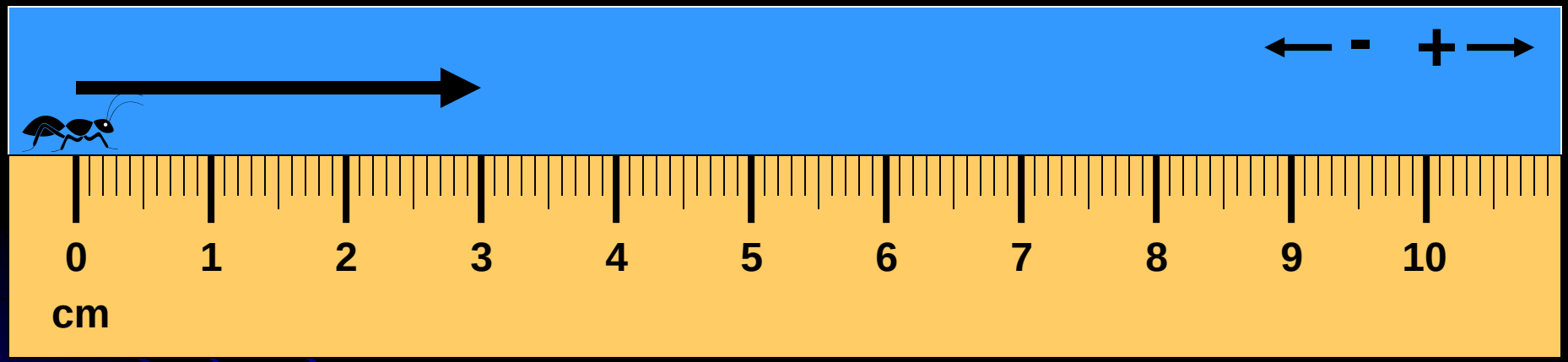
- Displacement (Δx) – difference between an object's final position and its starting position.
  - *Does* depend on direction.
- Displacement = final position – initial position
- $\Delta x = x_{final} - x_{initial}$
- In order to define displacement, we need directions.
- Examples of directions:
  - + and –
  - N, S, E, W
  - Angles

Displacement vs. Distance

- Example of distance:
  - The ant walked 3 cm.
- Example of displacement:
  - The ant walked 3 cm EAST.
- An object's distance traveled and its displacement aren't always the same!

Displacement

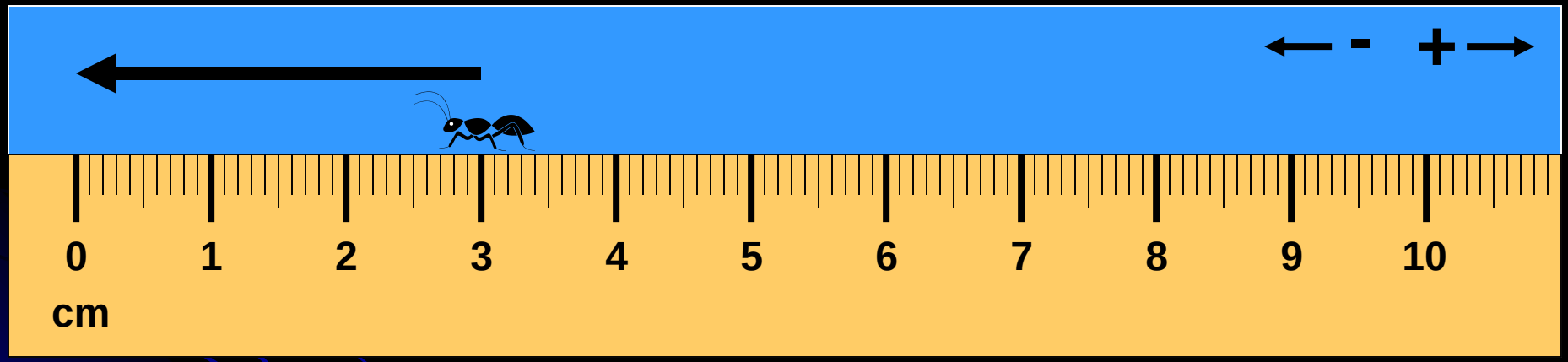
- Let's revisit our ant, and this time we'll find his displacement.



- Distance: 3 cm
- Displacement: +3 cm
  - The positive gives the ant a direction!

Displacement

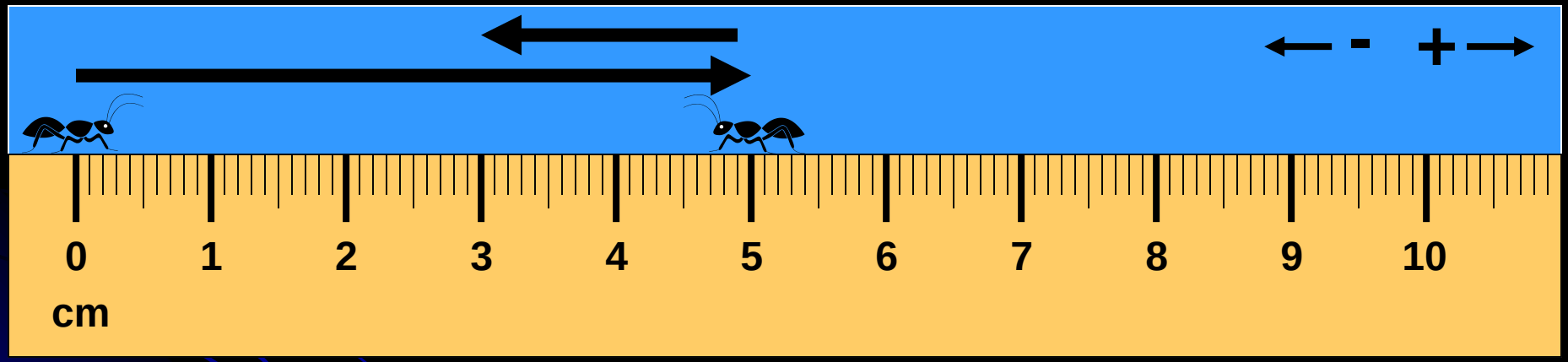
- Find the ant's displacement again.
  - Remember, displacement has direction!



- Distance: 3 cm
- Displacement: -3 cm

Displacement

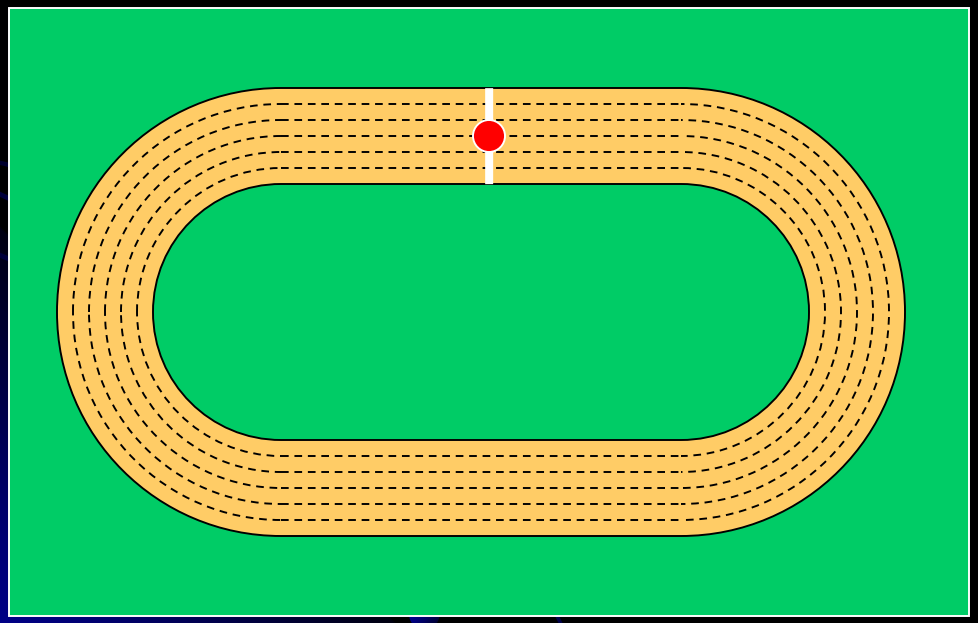
- Find the distance and displacement of the ant.



- Distance: 7 cm
- Displacement: +3 cm

Displacement vs. Distance

- An athlete runs around a track that is 100 meters long three times, then stops.
  - What is the athlete's distance and displacement?



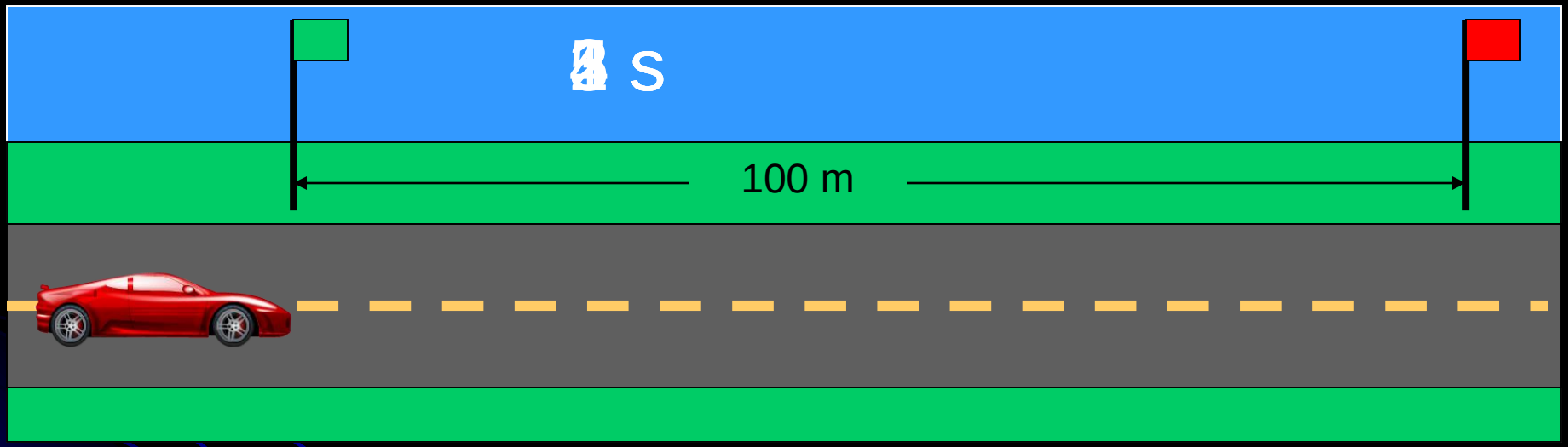
- Distance = 300 m
- Displacement = 0 m
- Why?

Speed

- Speed (s) – Rate at which an object is moving.
- speed = distance / time
- s = d/t
- Like distance, speed *does not* depend on direction.

Speed

- A car drives 100 meters in 5 seconds.



- What is the car's average speed?
  - s = d/t
  - s = (100 m) / (5 s) = 20 m/s

Speed

- A rocket is traveling at 10 km/s. How long does it take the rocket to travel 30 km?

Speed

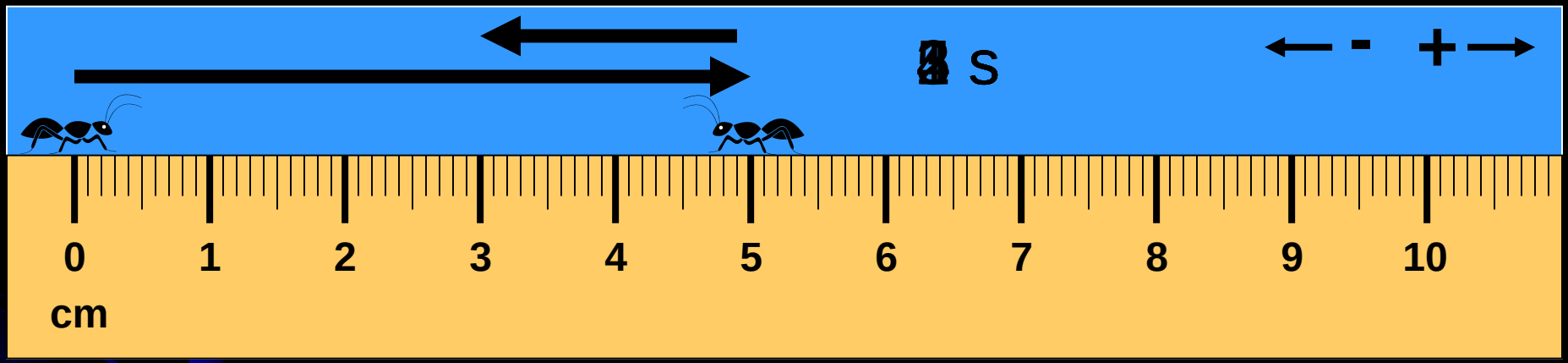
- A racecar is traveling at 85.0 m/s. How far does the car travel in 30.0 s?

Velocity

- Velocity (v) – speed with direction.
- velocity = displacement / time
- $v = \Delta x / t$

Pulling It All Together

- Back to our ant explorer!



  - Distance traveled: 7 cm
  - Displacement: +3 cm
  - Average speed: (7 cm) / (5 s) = 1.4 cm/s
  - Average velocity: (+3 cm) / (5 s) = +0.6 cm/s

Scalar and Vector Quantities

- Scalar Quantity – has magnitude but not direction.
  - Distance and speed are scalar quantities.
- Vector Quantity – has magnitude *and* direction.
  - Displacement and velocity are vector quantities.