Motion

Newton’s First Law

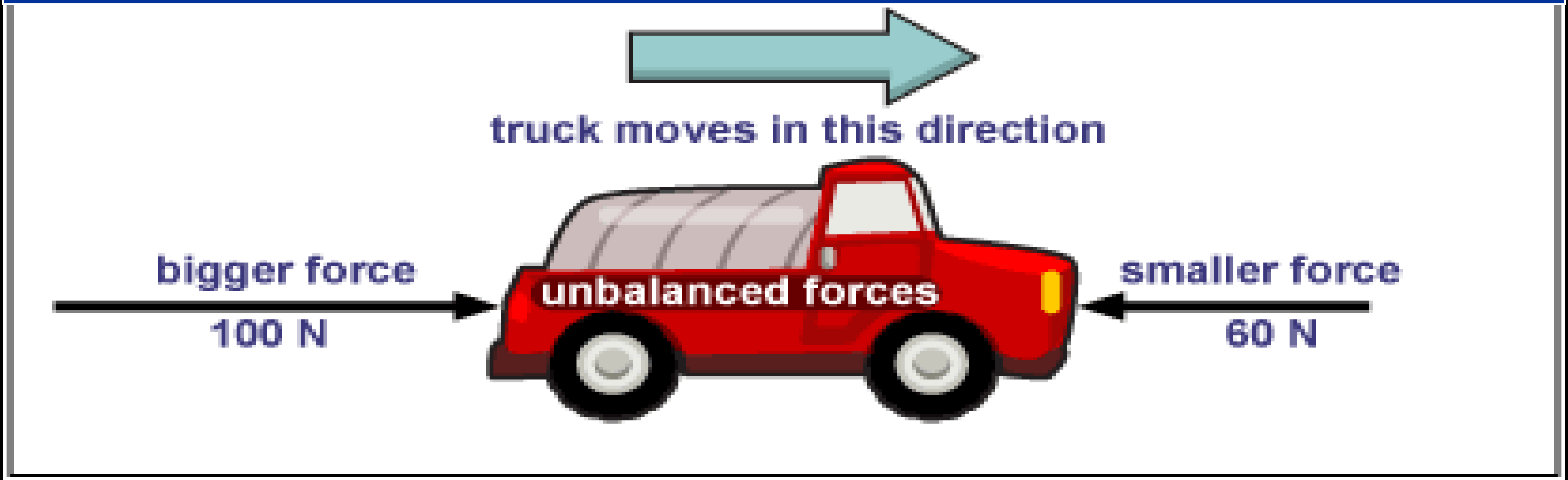
An object at rest tends to stay at rest and object in motion tends to stay in motion unless acted upon by an unbalanced force.

Balanced Force

Equal forces in opposite directions produce no motion

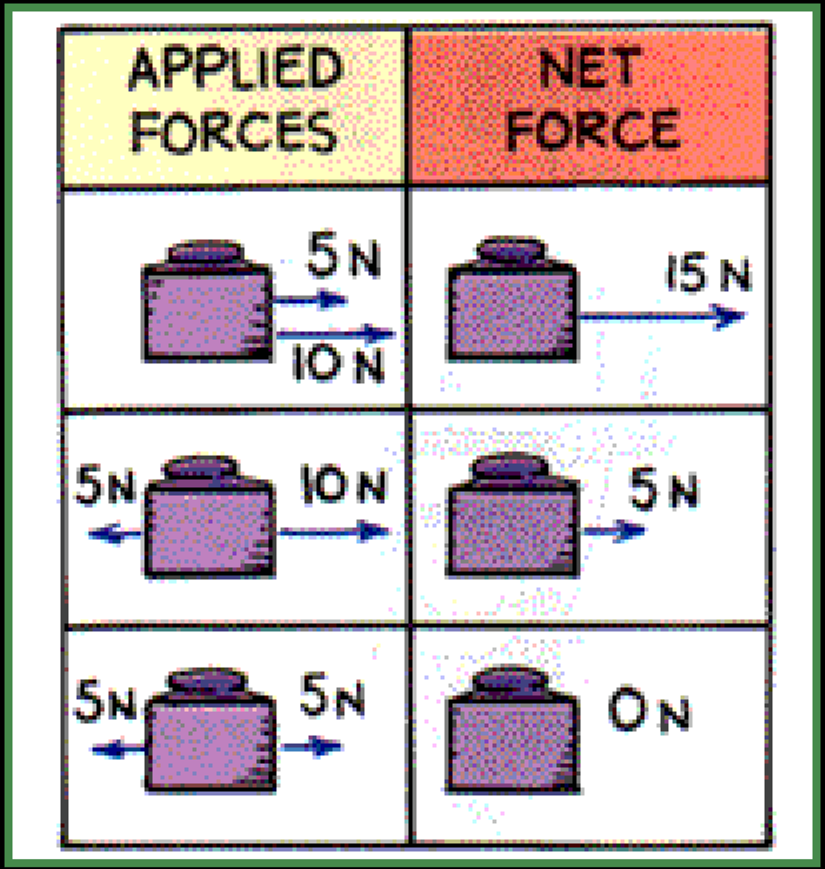
Unbalanced Forces

Unequal opposing forces produce an unbalanced force causing motion



Net Force

Net Force = all the forces acting on an object.



If objects in motion tend to stay in motion, why don’t moving objects keep moving forever?

Things don’t keep moving forever because there’s almost always an unbalanced force acting upon them.

A book sliding across a table slows down and stops because of the force of *friction*.

If you throw a ball upwards it will eventually slow down and fall because of the force of *gravity*.

Newton's First Law is also called the *Law of Inertia*

Inertia: the tendency of an object to resist changes in its state of motion

The First Law states that *all objects have inertia*. The more mass an object has, the more inertia it has (and the harder it is to change its motion).

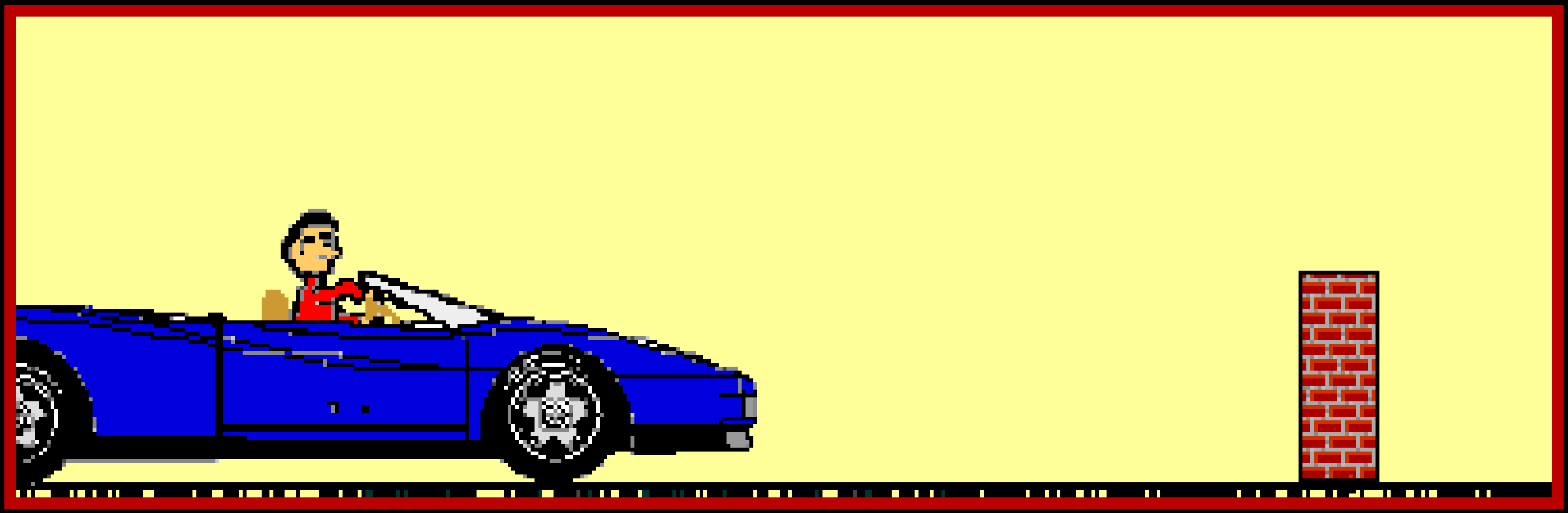
1st Law

Unless acted upon by an unbalanced force, this golf ball would sit on the tee forever.

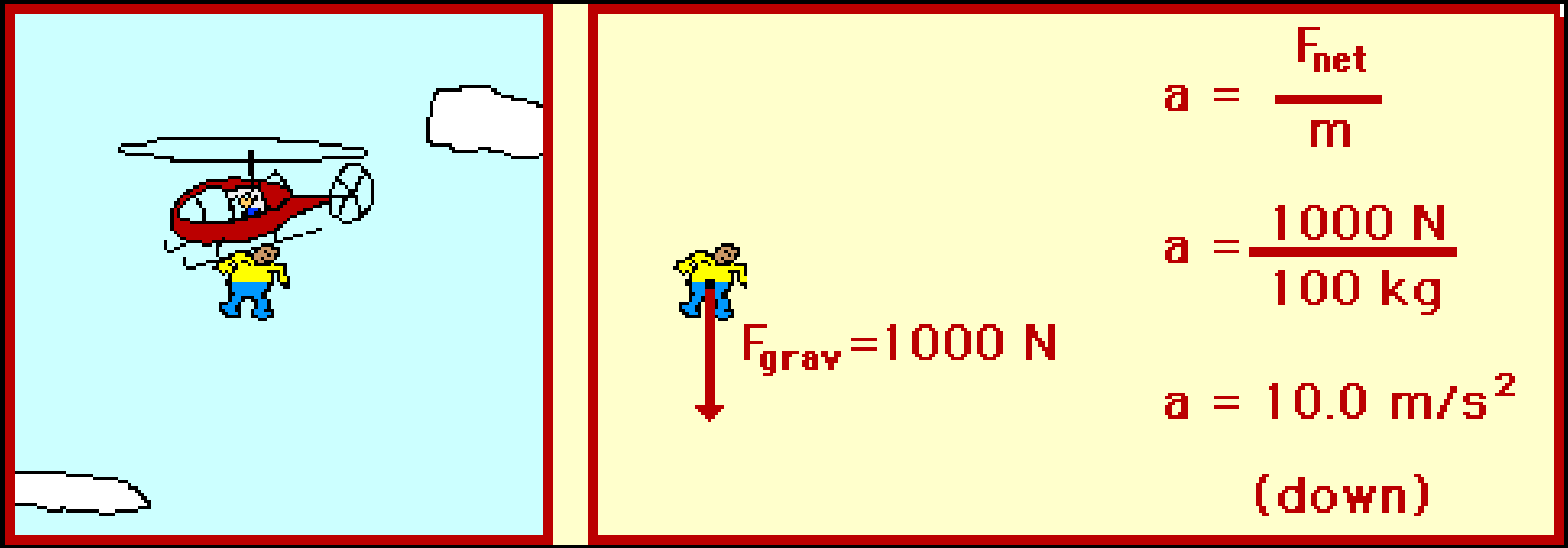
1st Law

Once airborne, unless acted on by an unbalanced force (gravity and air) it would never stop!

Inertia



Terminal Velocity



Newton's Second Law

Force equals mass times acceleration.

$$F = ma$$

Acceleration: a measurement of how quickly an object is changing speed

More about $\boldsymbol{F = ma}$

If you *double* the mass, you *double* the force. If you *double* the acceleration, you *double* the force.

What if you double the mass *and* the acceleration?

$(2m)(2a) = 4F$

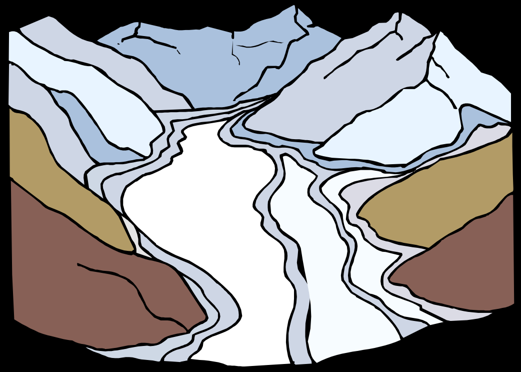
Doubling the mass *and* the acceleration *quadruples* the force.

So . . . what if you *decrease the mass by half*? How much force would the object have now?

What does ***F* = *ma*** mean?

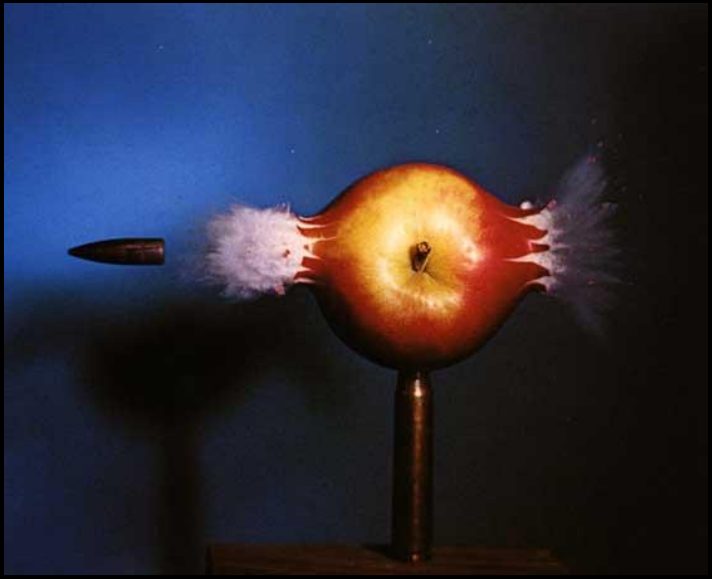
F* = *ma basically means that the force of an object comes from its mass and its acceleration.

Something very massive (high mass) that's changing speed very slowly (low acceleration), like a glacier, can still have great force.



What does $F = ma$ mean?

Something very small (low mass) that's changing speed very quickly (high acceleration), like a bullet, can still have great force.



Newton's Second Law

One rock weighs 5 Newtons. The other rock weighs 0.5 Newtons. How much more force will be required to accelerate the first rock at the same rate as the second rock?

Ten times as much

Newton’s Third Law

For every action there is an equal and opposite reaction.

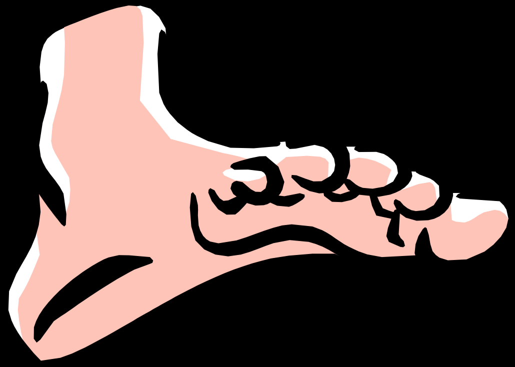
What does this mean?

For every force acting on an object, there is an equal force acting in the opposite direction. Right now, gravity is pulling you *down* in your seat, but Newton's Third Law says your seat is pushing *up* against you with *equal force*. This is why you are not moving. There is a *balanced force* acting on you– gravity pulling down, your seat pushing up.

Think about it . . .

What happens if you are standing on a skateboard or a slippery floor and push against a wall? You slide in the opposite direction (away from the wall), because you pushed on the wall but the wall pushed back on you with equal and opposite force.

Why does it hurt so much when you stub your toe? When your toe exerts a force on a rock, the rock exerts an equal force back on your toe. The harder you hit your toe against it, the more force the rock exerts back on your toe (and the more your toe hurts).

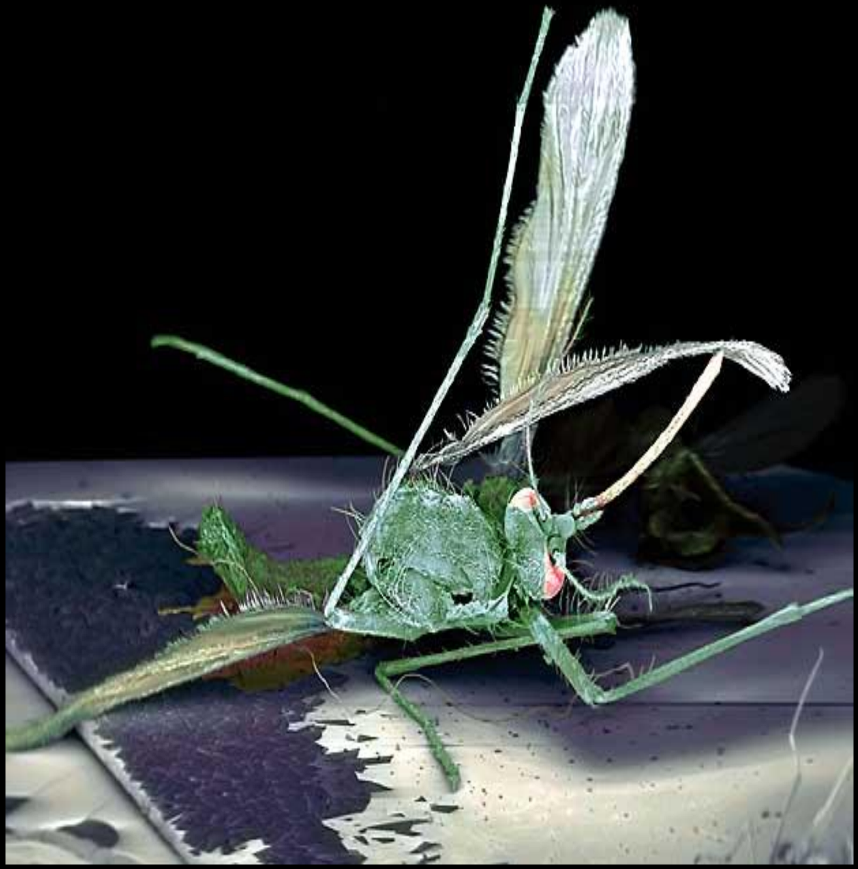


Newton's Third Law

- A bug with a mass of 5 grams flies into the windshield of a moving 1000kg bus.
- Which will have the most force?
  - The bug on the bus
  - The bus on the bug

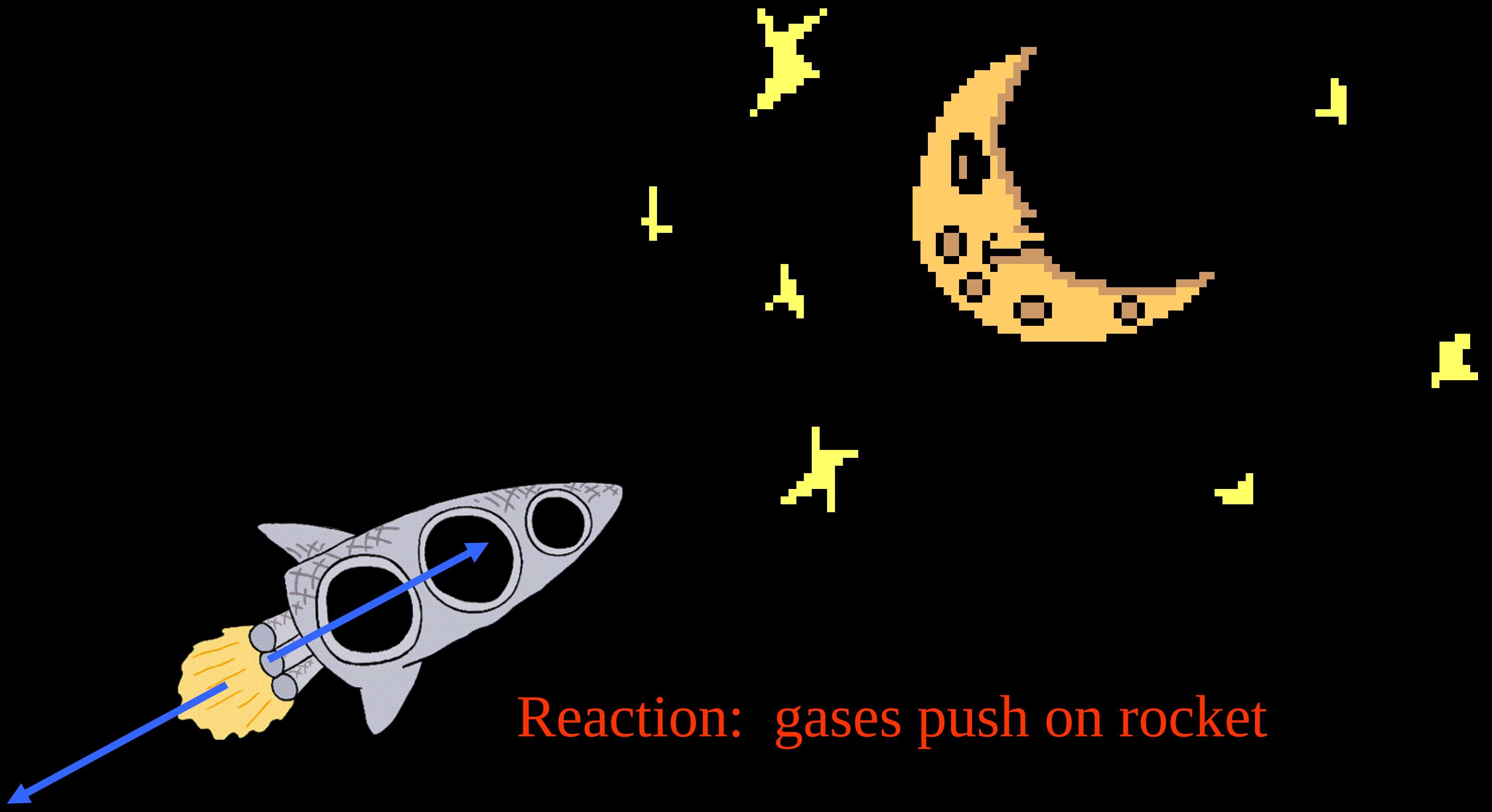
Newton's Third Law

- The force would be the same.
- Force (bug)= $m \times A$
- Force (bus)= $M \times a$



Reaction: road pushes on tire

Action: tire pushes on road


Reaction: gases push on rocket
Action: rocket pushes on gases

Consider hitting a baseball with a bat. If we call the force applied to the ball by the bat the *action force*, identify the *reaction force*.

(a) the force applied to the bat by the hands

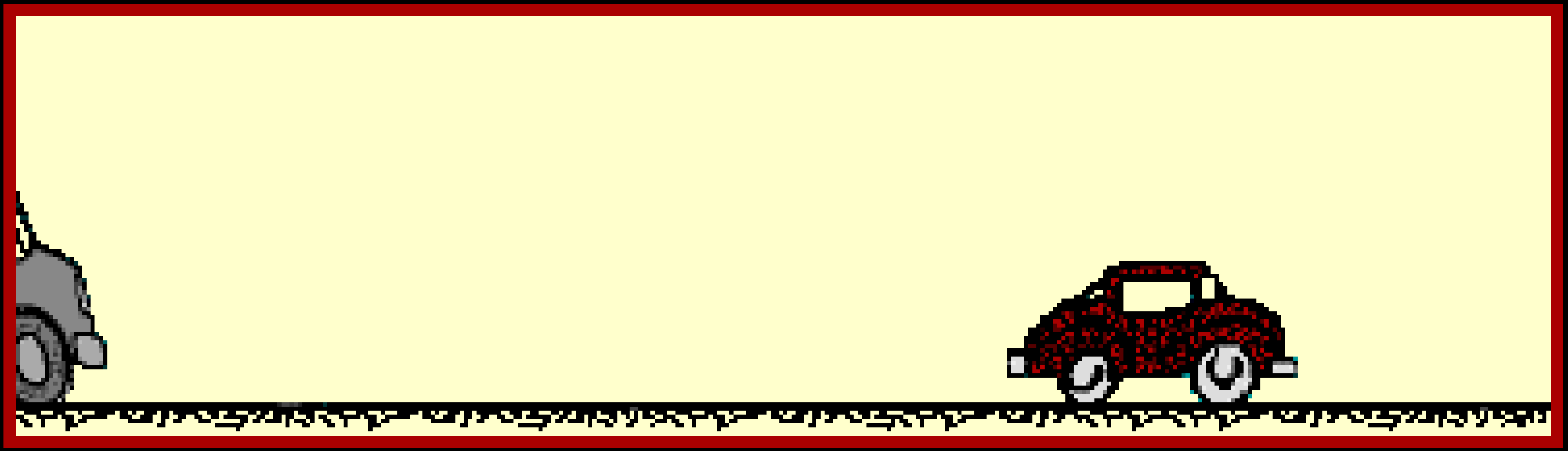
(b) the force applied to the bat by the ball

(c) the force the ball carries with it in flight

(d) the centrifugal force in the swing

Suppose you are taking a space walk near the space shuttle, and your safety line breaks. How would you get back to the shuttle?

What laws are represented?



Review

Newton's First Law:

Objects in motion tend to stay in motion and objects at rest tend to stay at rest unless acted upon by an unbalanced force.

Newton's Second Law:

Force equals mass times acceleration ($F = ma$).

Newton's Third Law:

For every action there is an equal and opposite reaction.

Vocabulary

Inertia:

the tendency of an object to resist changes in its state of motion

Acceleration:

- a change in velocity
- a measurement of how quickly an object is changing speed, direction or both

Velocity:

The rate of change of a position along a straight line with respect to time

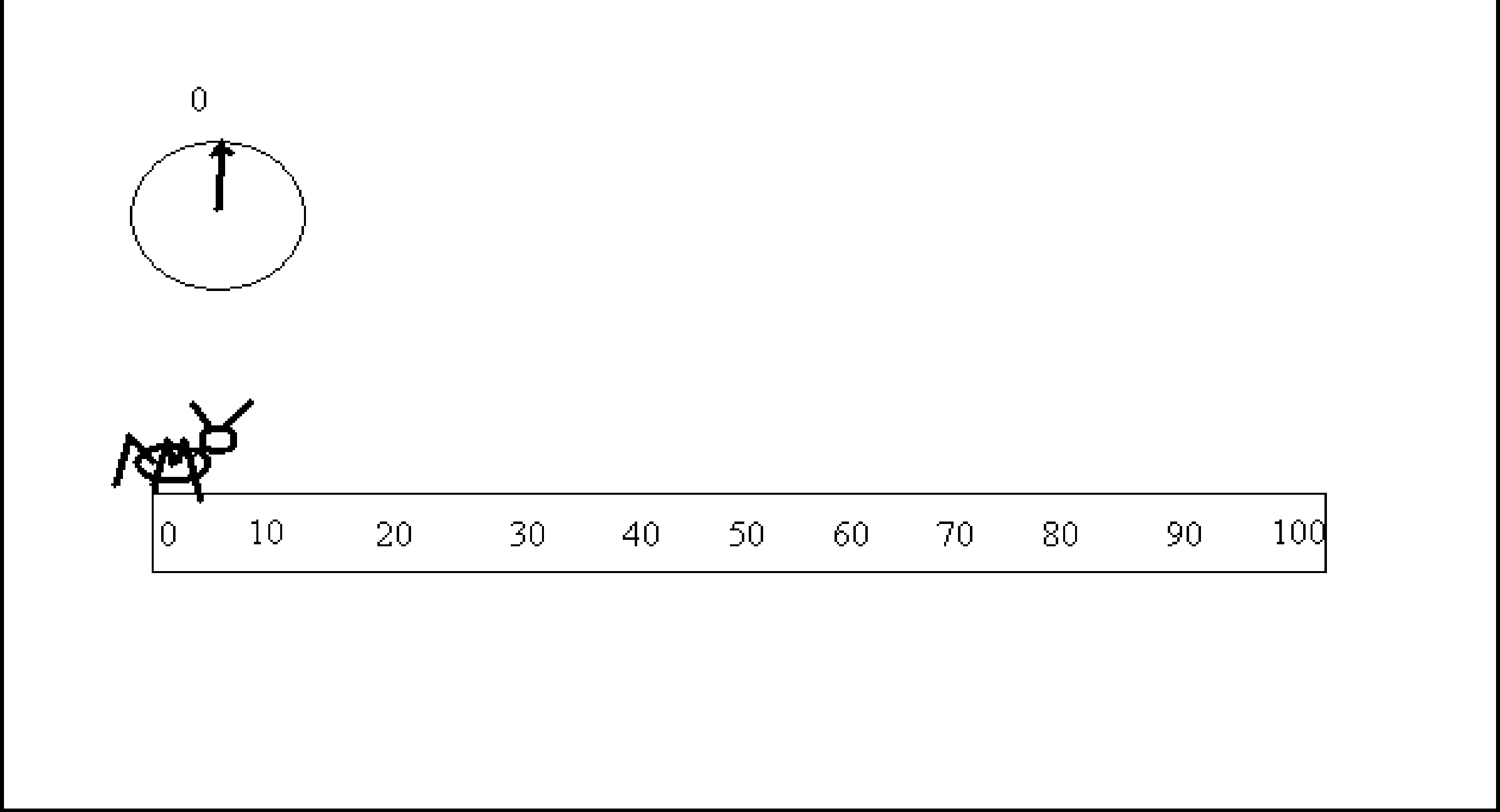
Force:

strength or energy

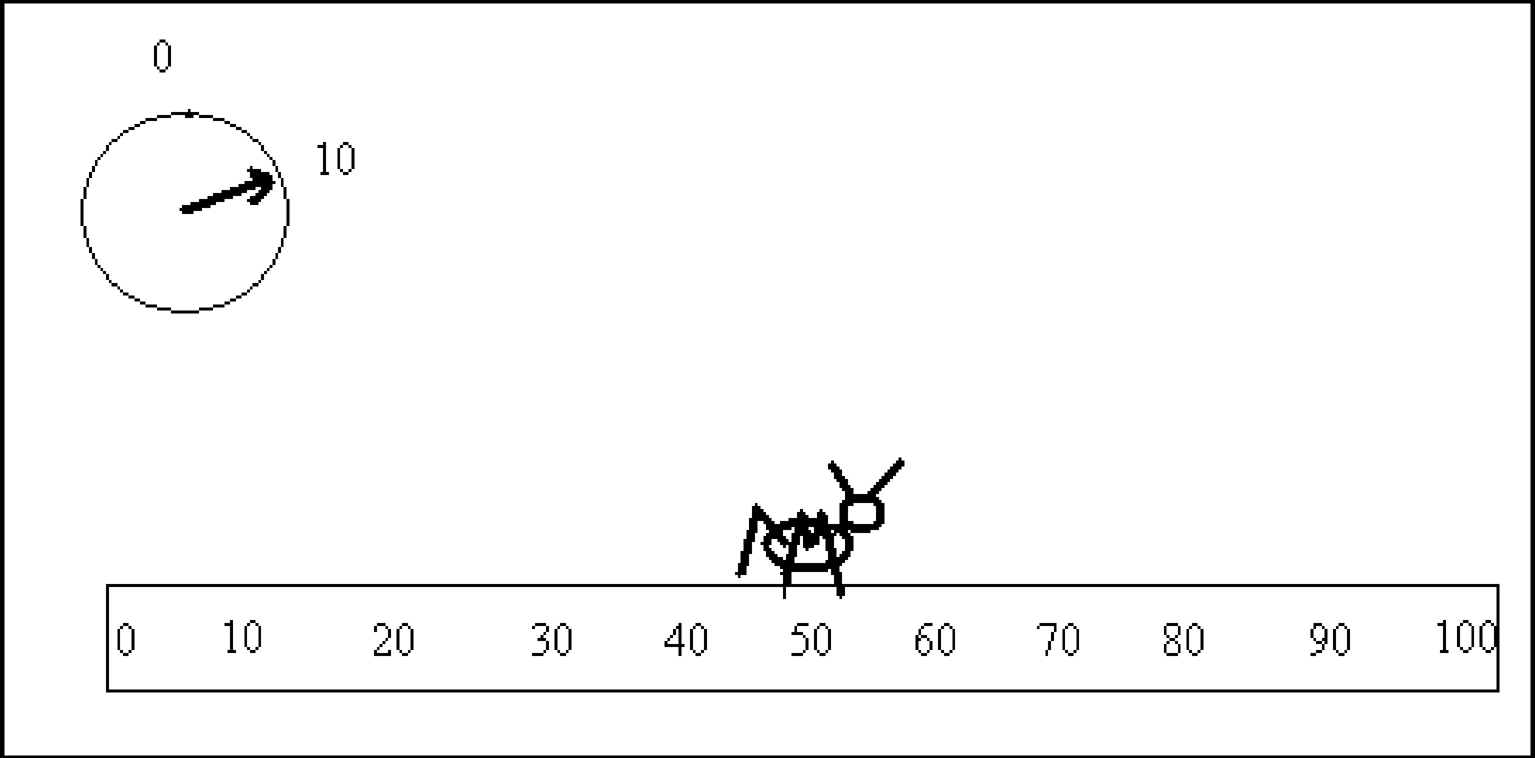
Speed
Velocity
and
Acceleration

SPEED

- The speed of an object is the distance traveled divided by how long it took.
- Speed = distance/time



Here is a little bug located at 0 cm at 0 seconds.



10 seconds later he is at 50 cm.

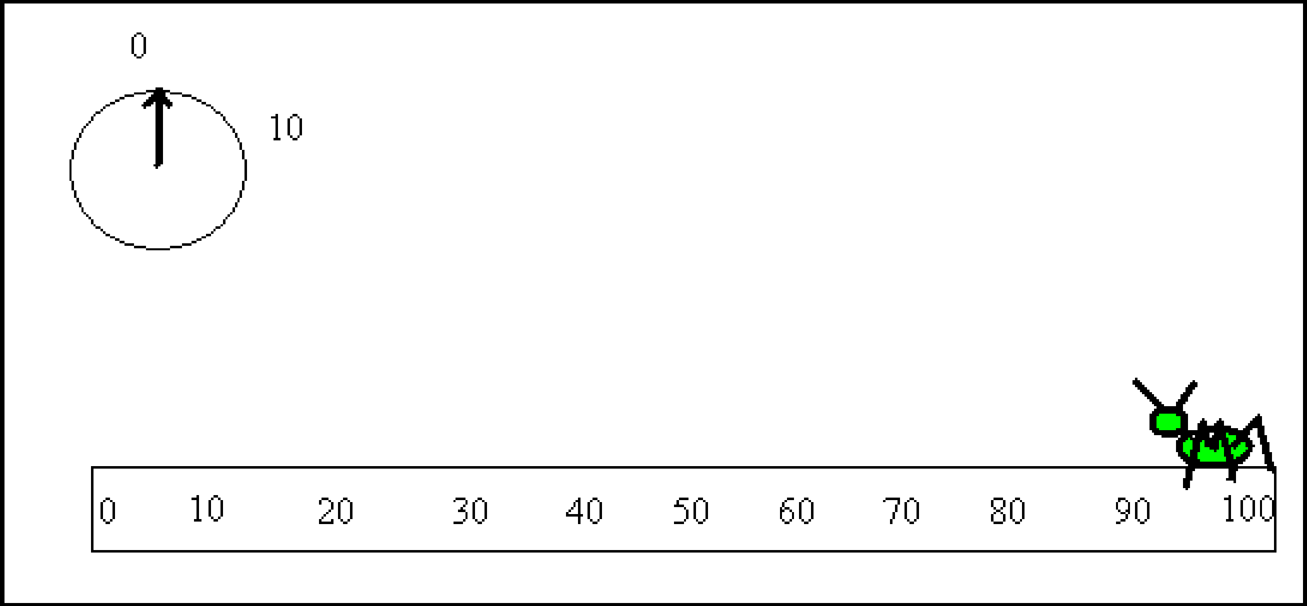
What was the bug's speed?

- Speed = 50 cm/10 s = 5 cm/s

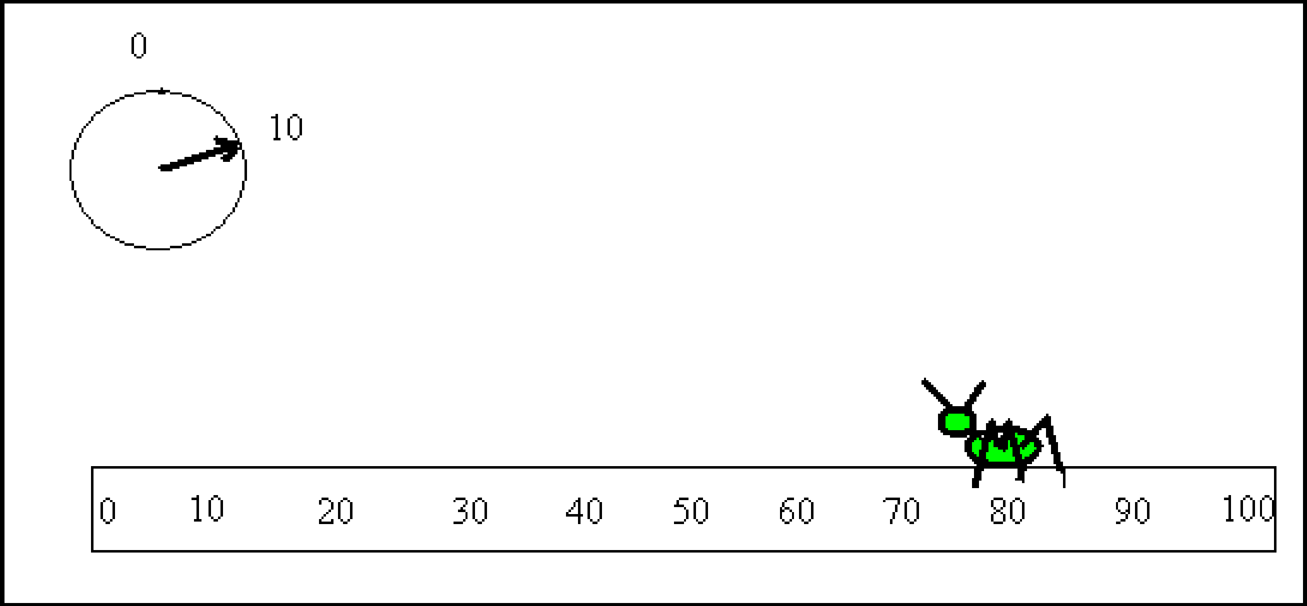
- Speed is just how fast something is moving.
- Speed is always a positive number.

VELOCITY

- Velocity is *speed* and *direction.*
- Velocity is *how fast* and *which way*.
- Quantities that have direction are called *vectors.*



- Suppose our bug stars off at 100 cm.



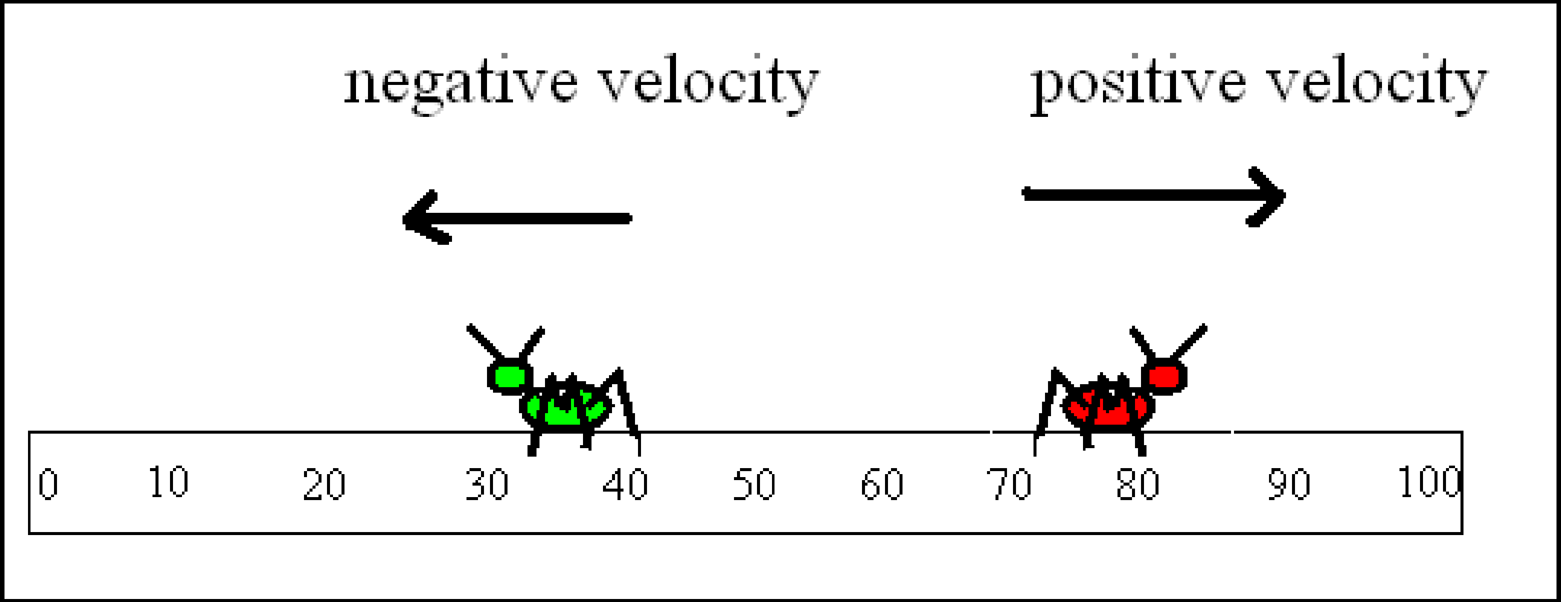
- And ends up at 80 cm 10 seconds later.

- Calculating velocity is a little more complicated than calculating speed.
- Velocity = change in position/time
  - Velocity = (final position - initial position)/time

Velocity of Bug?

- Velocity = (80cm – 100cm)/10 seconds
- Velocity = - 2 cm/s

- A positive velocity means moving right.
- A negative means moving left.
  - A negative velocity does not mean an object is moving slower than zero.
  - It just means an object is moving in a certain direction.


negative velocity
positive velocity
0
10
20
30
40
50
60
70
80
90
100

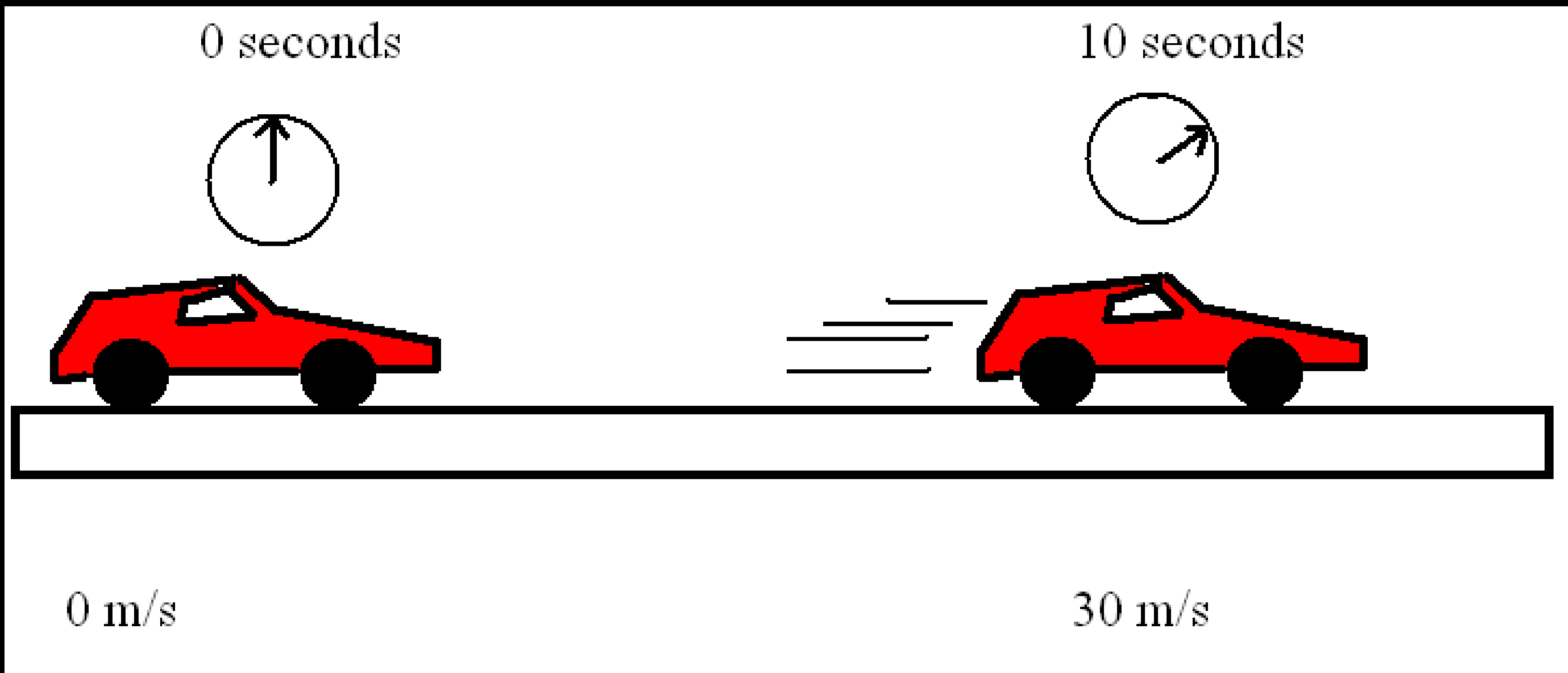
ACCELERATION

Acceleration is a change in velocity.

So an object accelerates if it:

- Speeds up
- Slows down
- Or changes the direction it is moving,

- Acceleration = change in velocity/time
- Acceleration = (final velocity – initial velocity)/time

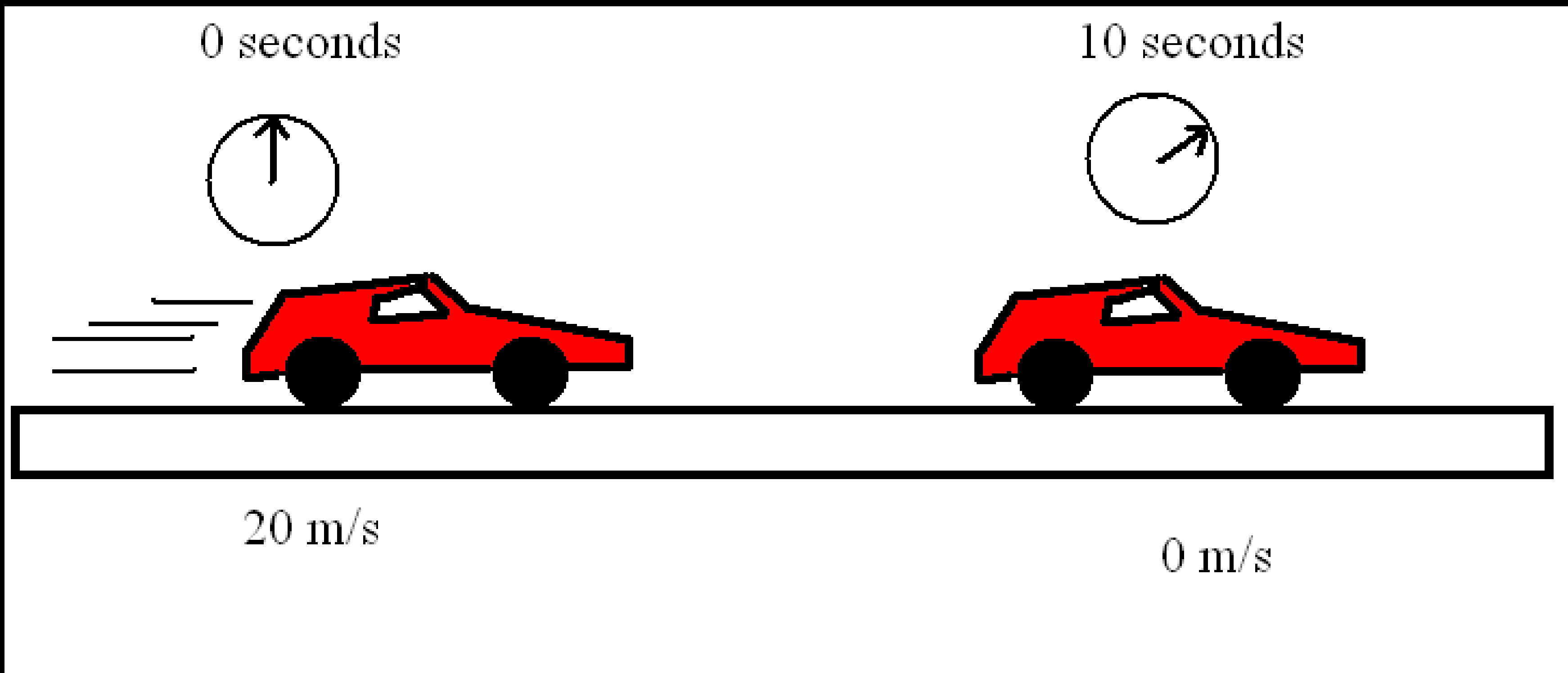

0 seconds
10 seconds
0 m/s
30 m/s

- Acceleration = (30 m/s – 0 m/s)/10 s

  a = 3 m/s/s

- The car's velocity is increasing 3 m/s per second.

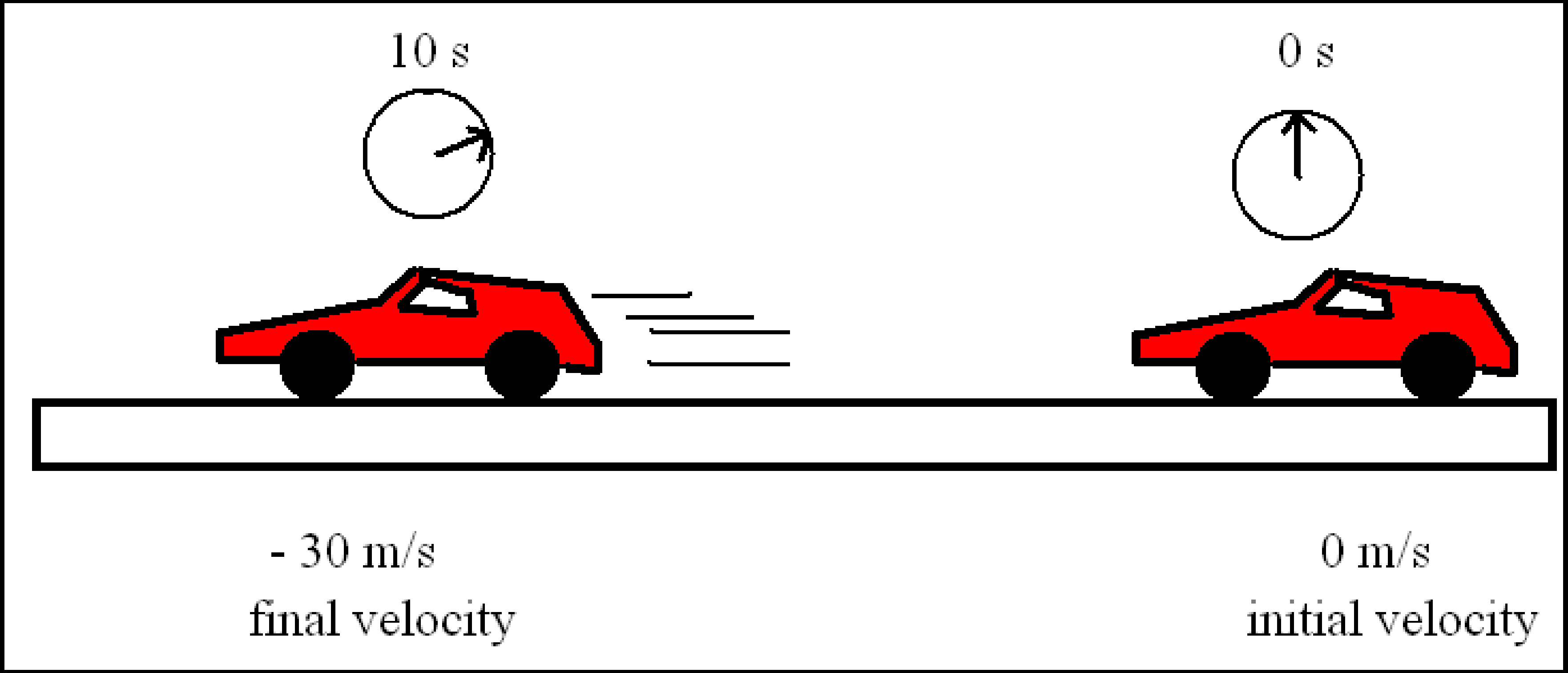
- Positive acceleration means moving to the right.
- Negative acceleration means moving to the left.


0 seconds
10 seconds
20 m/s
0 m/s

- Acceleration = (0m/s – 20 m/s)/10 s

  a = - 2 m/s/s

- Although the car is *moving* to the right it is *accelerating* to the left!

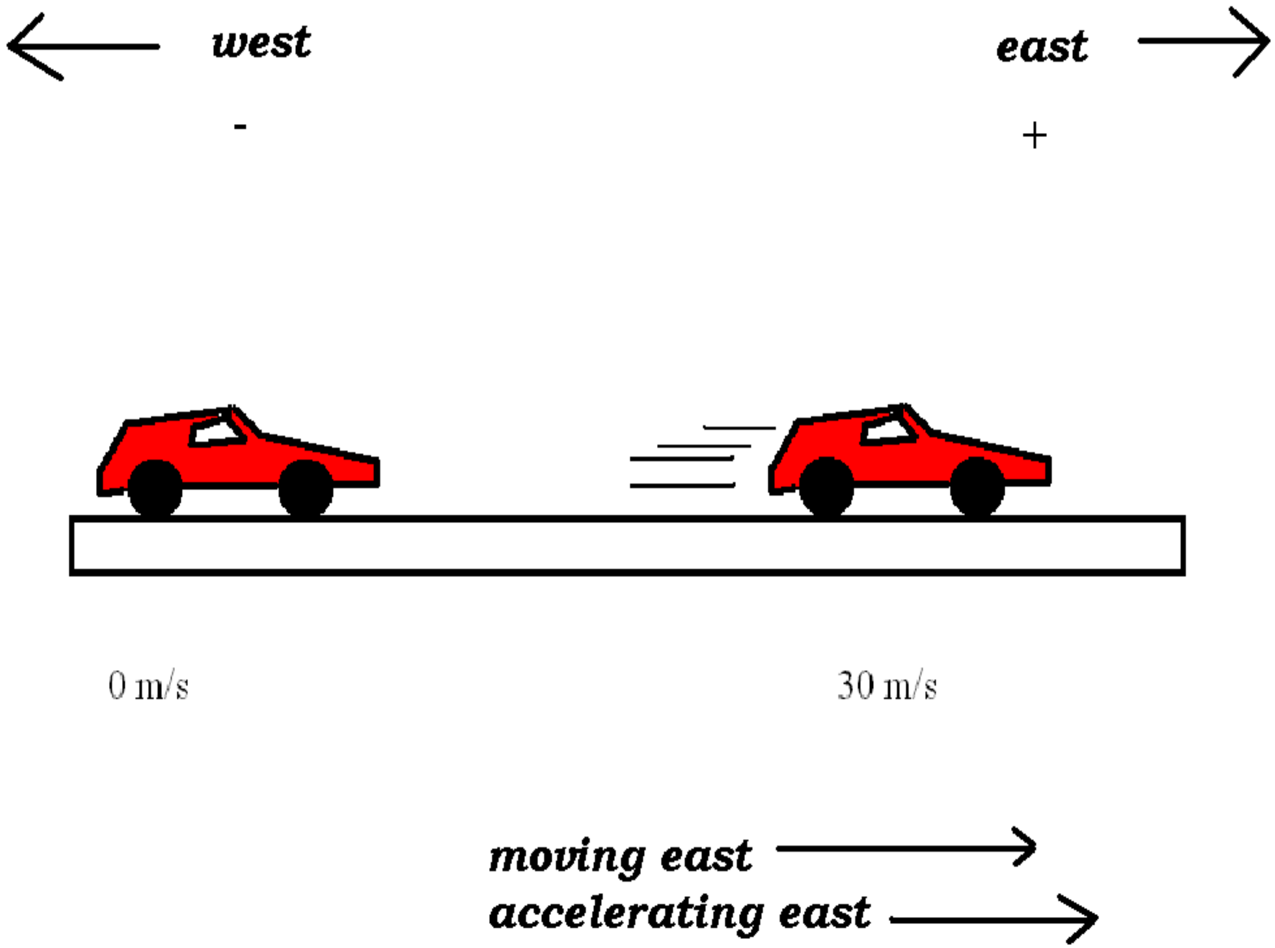

10 s
0 s
- 30 m/s
final velocity
0 m/s
initial velocity

- Acceleration = (final velocity – initial velocity)/time

  a = (-30 m/s – 0 m/s)/ 10 s

  a = - 3 m/s/s

- The car is both moving to the left and accelerating to the left.
- Negative acceleration does not always mean an object is slowing down!



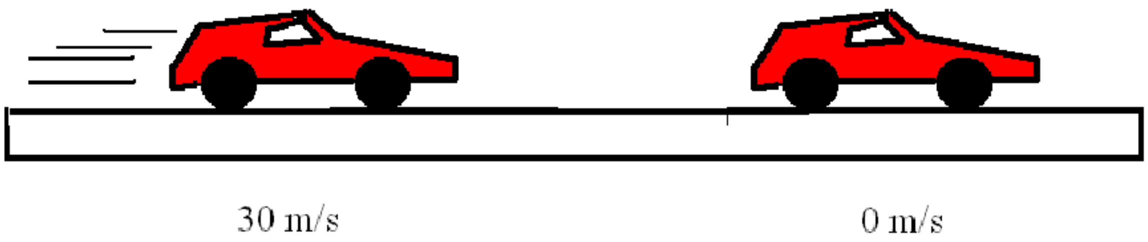
positive velocity and positive acceleration

← *west*

-

east →

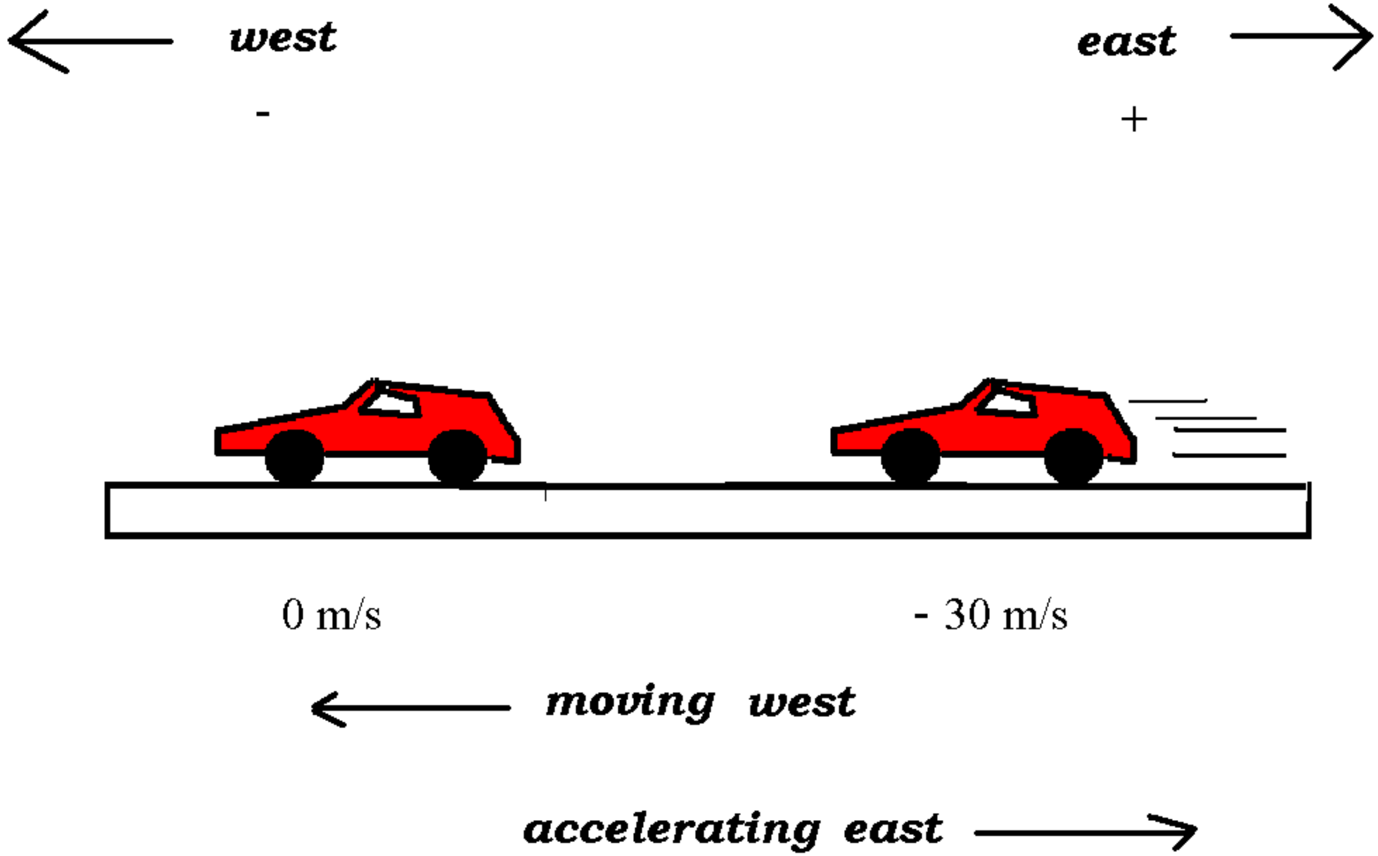
+



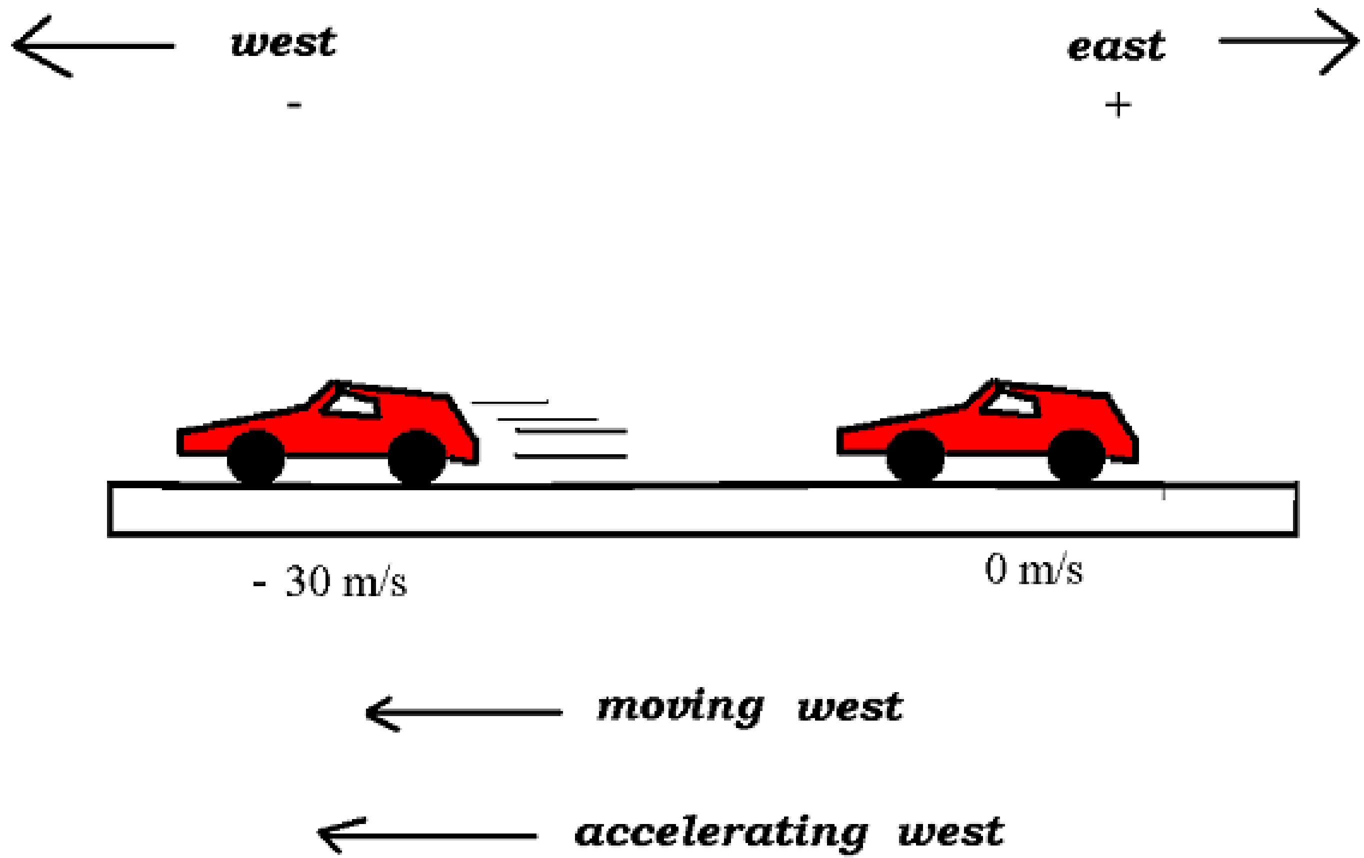
moving east →

← *accelerating west*

positive velocity and negative acceleration



negative velocity and positive acceleration



negative velocity and negative acceleration