Newton’s Laws Of Motion

Chapter 9

Unit 2: Motion and Force in One Dimension

Chapter 5: Newton's Laws: Force and Motion

- 5.1 The First Law: Force and Inertia
- 5.2 The Second Law: Force, Mass, and Acceleration
- 5.3 The Third Law: Action and Reaction

Chapter 5 Objectives

1. Describe how the law of inertia affects the motion of an object.
2. Give an example of a system or invention designed to overcome inertia.
3. Measure and describe force in newtons (N) and pounds (lbs).
4. Calculate the net force for two or more forces acting along the same line.
5. Calculate the acceleration of an object from the net force acting on it.
6. Determine whether an object is in equilibrium by analyzing the forces acting on it.
7. Draw a diagram showing an action-reaction pair of forces.
8. Determine the reaction force when given an action force.

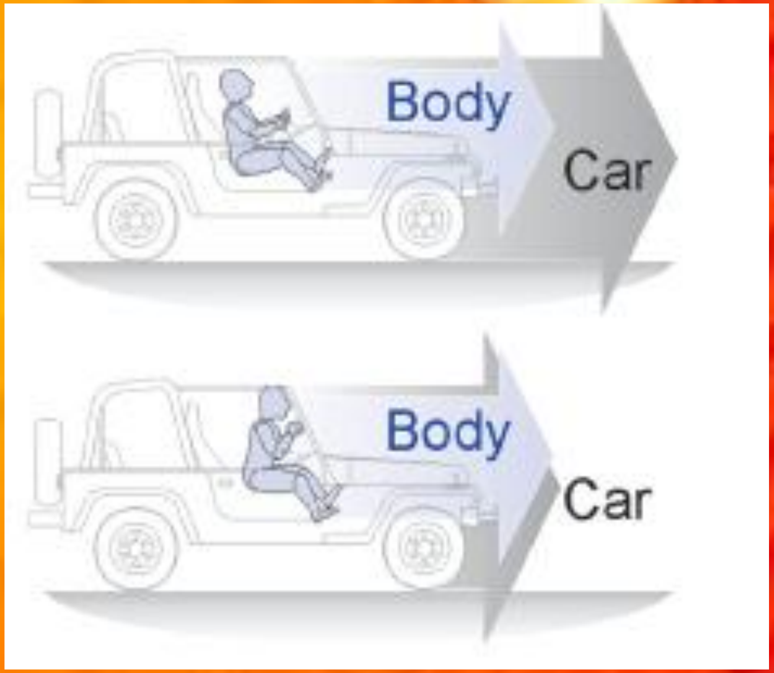
Chapter 5 Vocabulary Terms

- force
- inertia
- law of inertia
- Newton's first law
- net force
- dynamic equilibrium
- static
- Newton's second law
- locomotion
- newton (N)
- action
- reaction
- Newton's third law

5.1 The First Law: Force and Inertia

Key Question:

How does the first law apply to objects at rest and in motion?

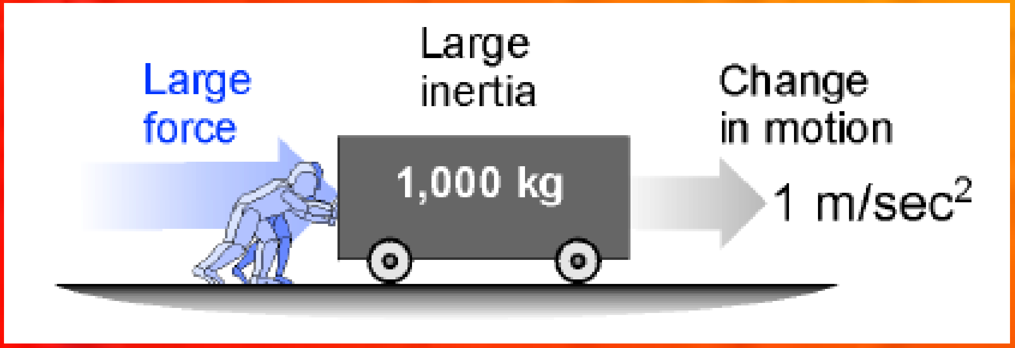


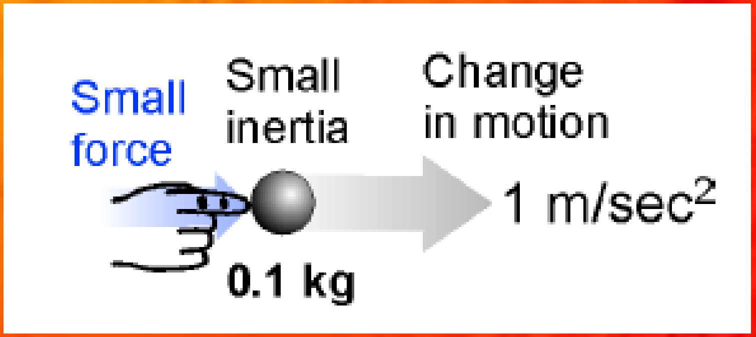
5.1 Force

- Force is an action that can change motion.
  - A force is what we call a push or a pull, or any action that has the ability to change an object's motion.
  - Forces can be used to increase the speed of an object, decrease the speed of an object, or change the direction in which an object is moving.

5.1 Inertia

- Inertia is a term used to measure the ability of an object to resist a change in its state of motion.
- An object with a lot of inertia takes a lot of force to start or stop; an object with a small amount of inertia requires a small amount of force to start or stop.
- The word “inertia” comes from the Latin word *inertus*, which can be translated to mean “lazy.”

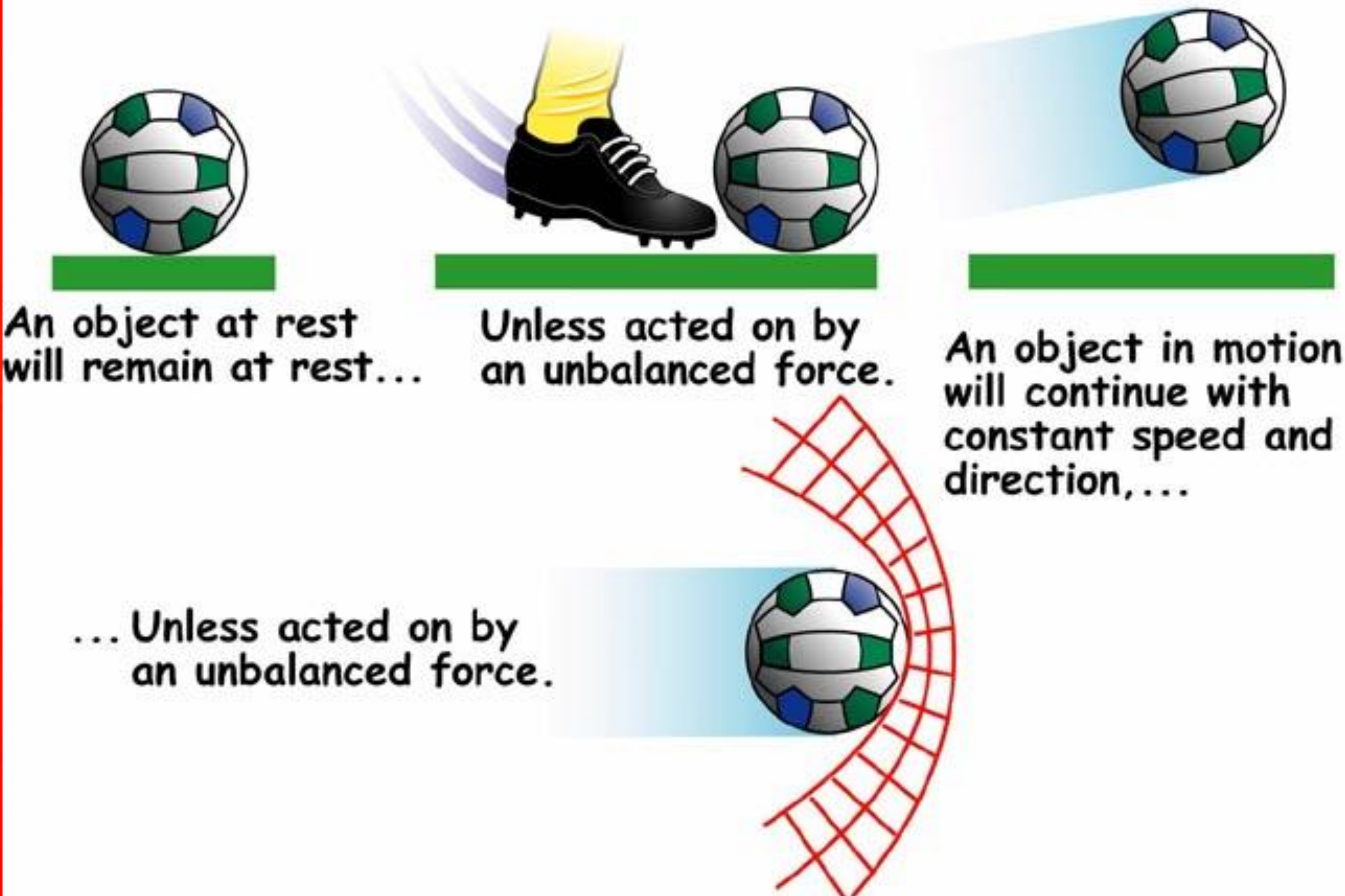




5.1 Newton's First Law

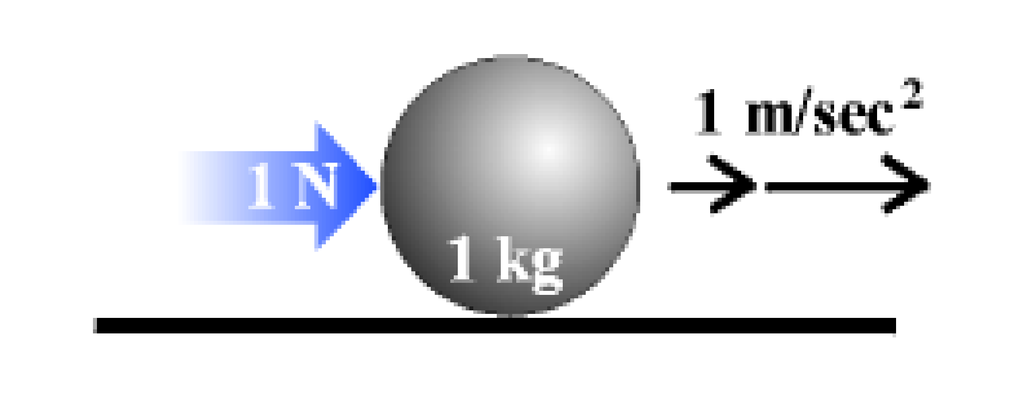
- Can you explain why the long table would make the trick hard to do?

Newton's First Law of Motion



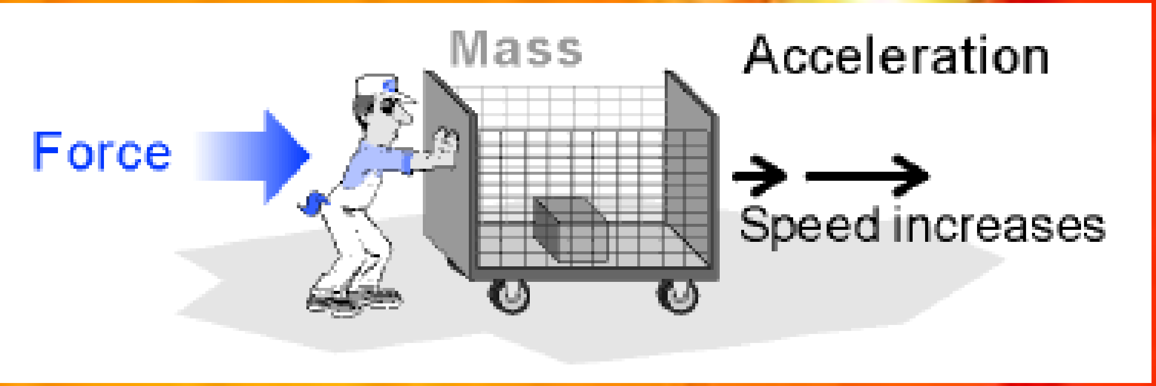
5.2 Newton's Second Law

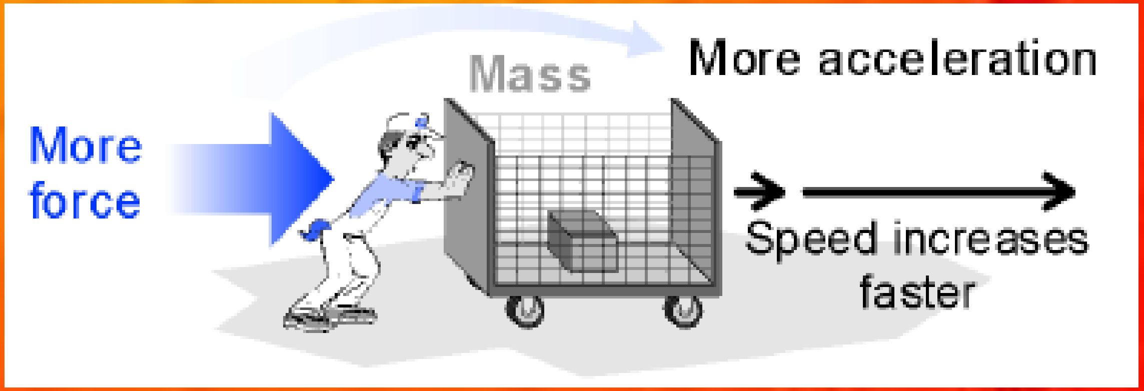
- The acceleration of an object is equal to the force you apply divided by the mass of the object.



5.2 Newton's Second Law

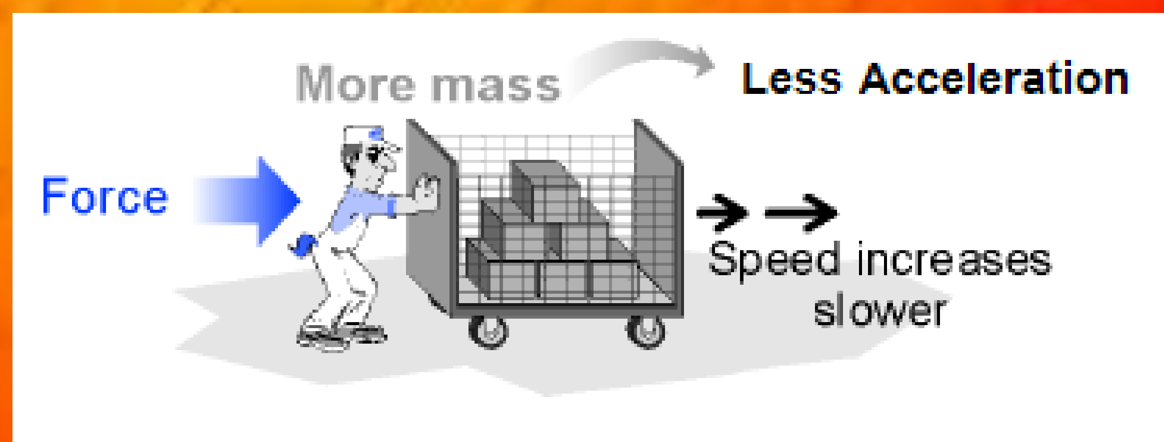
- If you apply <u>more</u> force to an object, it accelerates at a higher rate.





5.2 Newton's Second Law

- If an object has <u>more</u> mass it accelerates at a lower rate because mass has inertia.



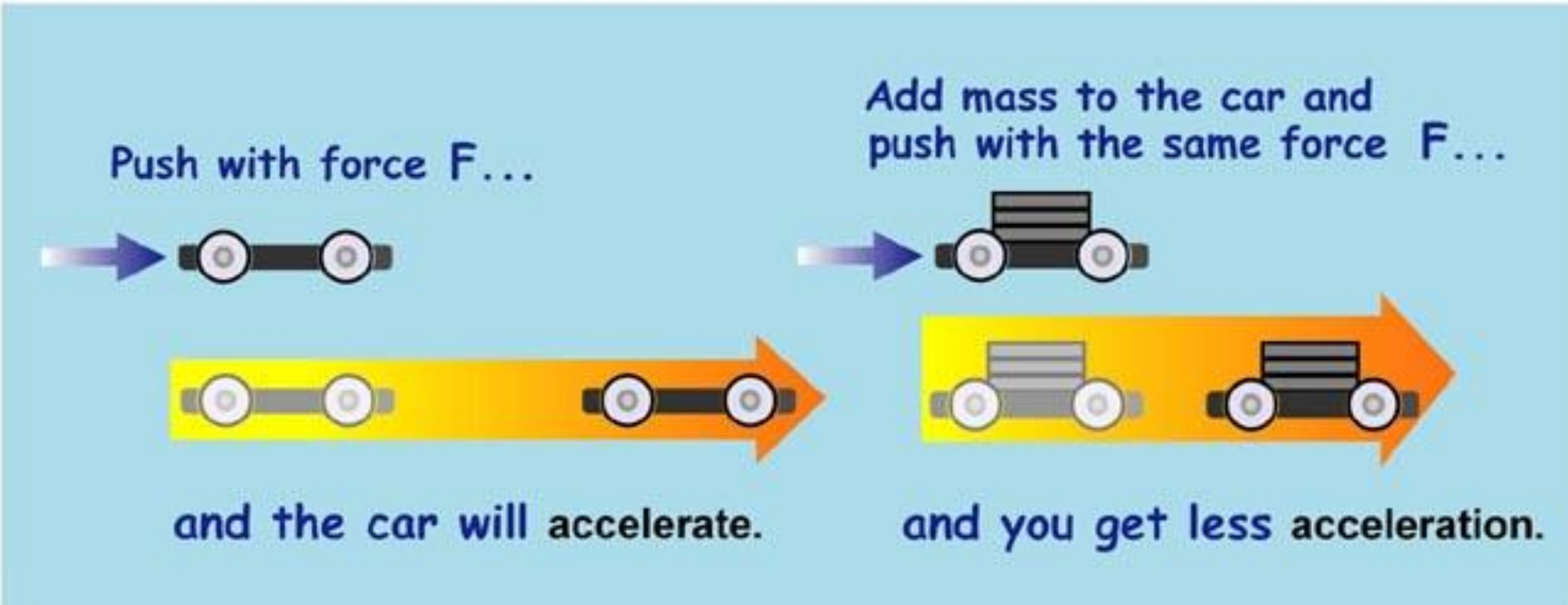
5.2 Newton's Second Law

Acceleration (m/sec^2) $\longrightarrow$ $a = \dfrac{F}{m}$

Force (newtons, N)

Mass (kg)

Newton's Second Law of Motion



Acceleration (m/sec^2) — $$a = \frac{F}{m}$$

F — Force (newtons, N)

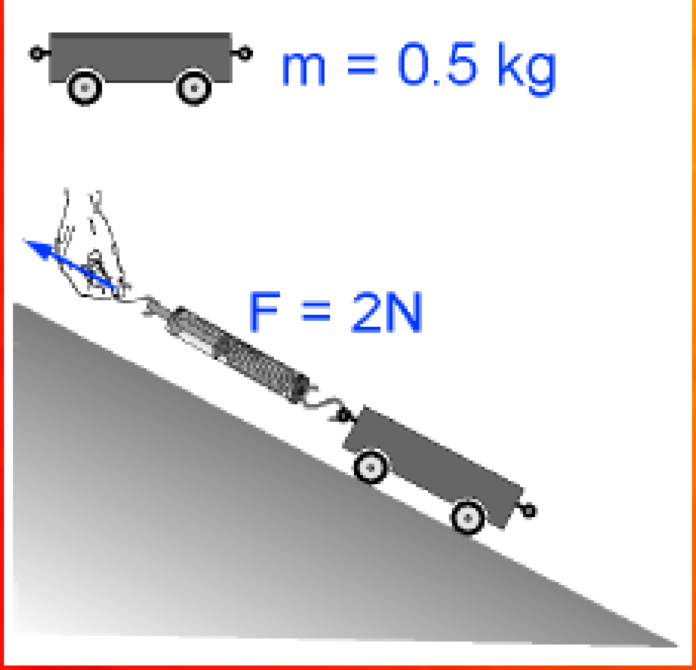
m — Mass (kg)

5.2 Newton's Second Law

Three forms of the second law:

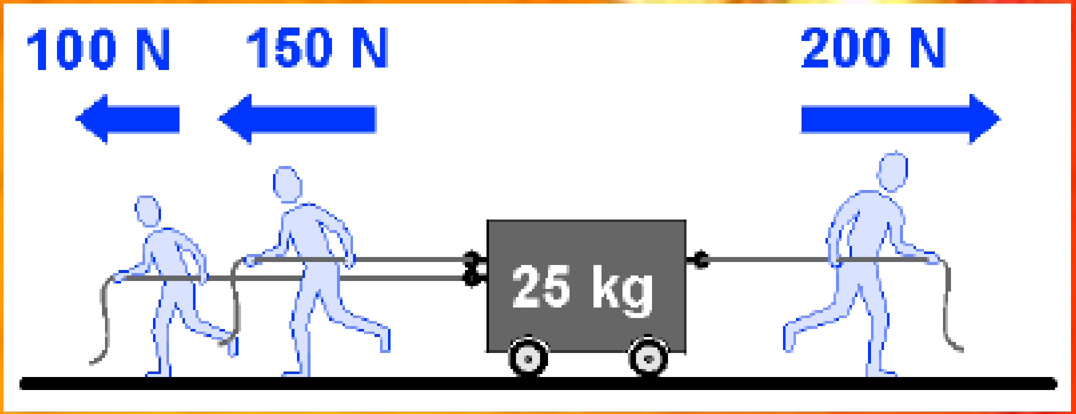
Use . . .	if you want to find . . .	and you know . . .
$a = \frac{F}{m}$	The acceleration (a)	The net force (F) and the mass (m)
$F = ma$	The net force (F)	The acceleration (a) and the mass (m)
$m = \frac{F}{a}$	The mass (m)	The acceleration (a) and the net force (F)

5.2 Calculate acceleration



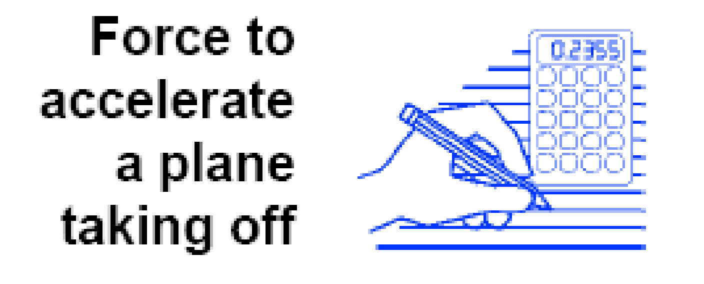
- A cart rolls down a ramp.
- The cart has a mass of 500 grams (0.5 kg).
- Using a spring scale, you measure a net force of 2 newtons pulling the car down.
- Calculate the acceleration of the cart.

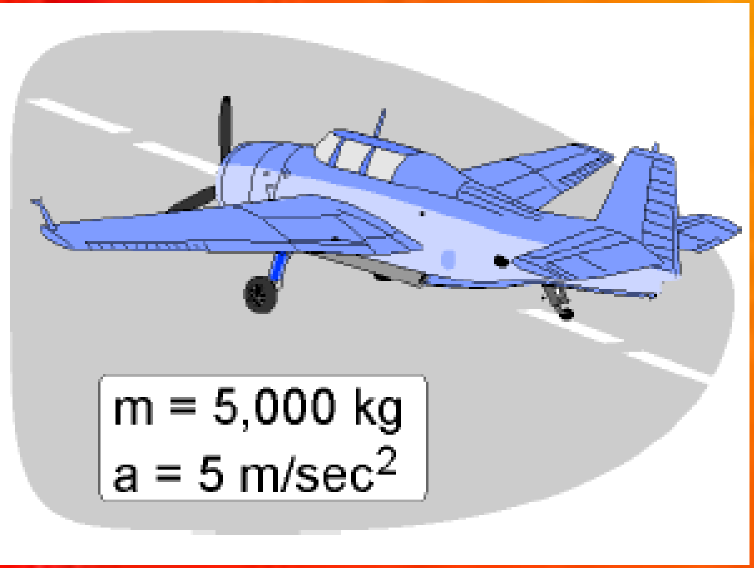
5.2 Calculate acceleration



- Three people are pulling on a wagon applying forces of 100 N,150 N, and 200 N.
- The wagon has a mass of 25 kilograms.
- Determine the acceleration and the direction the wagon moves.

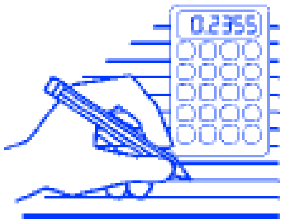
5.2 Calculate force





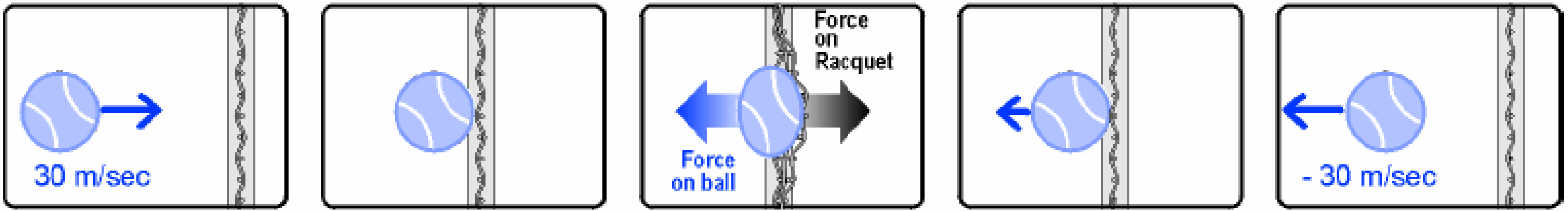
- **An airplane needs to accelerate at 5 m/sec2 to reach take-off speed before reaching the end of the runway.**
- **The mass of the airplane is 5,000 kilograms.**
- **How much force is needed from the engine?**

5.2 Calculate force



Force on a tennis ball striking a racquet

- A tennis ball contacts the racquet for much less than one second.
- High-speed photographs show that the speed of the ball changes from -30 to +30 m/sec in 0.006 seconds.
- If the mass of the ball is 0.2 kg, how much force is applied by the racquet?



Newton's Second Law of Motion

How fast does it go?

Acceleration

- An unbalanced force causes something to accelerate.

Acceleration

- **Acceleration is directly related to the size of the force and the direction of the force.**

- **It accelerates in the direction you push or pull it.**

In other words….

Large Force = Large Acceleration

F

a

In other words….

Small Force = Small Acceleration

So….if you push twice as hard, it accelerates twice as much.

But there is a twist….

- Acceleration is INVERSELY related to the mass of the object.

In other words…..using the same amount of force….

F

Small acceleration

a

Large Mass

F

Large acceleration

a

Small Mass

Newton’s Second Law

- Newton, that brilliant genius, observed those “rules” of acceleration and came up with his second law of motion. It is both a formula & a law.

Newton's Second Law

- The acceleration of an object is directly proportional to the net force & inversely proportional to it's mass.
- F = ma
- Force = Mass x Acceleration

Calculating Acceleration

- **Acceleration Equation**

Acceleration = (final speed (in m/s) – initial speed (in m/s)) / Time (in seconds)

$$A = \frac{(s_f - s_i)}{t}$$

Okay then…

- **First, you need to know the units of Force, Mass & Acceleration.**
  - The units used for force are Newtons (N)
  - The units used for mass are kilograms (kg)
  - The acceleration units are meters per second squared (m/sec2).

Next, what is speed?

Average Speed
Speed

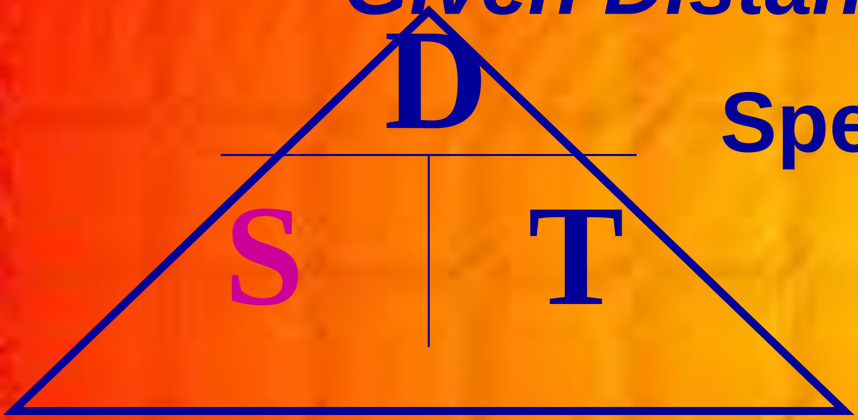
- **Comparison of *time* and *distance***
  - Distance traveled per unit time

Acceleration

- **A change in velocity**
  - Speeding up
    - Positive acceleration
  - Slowing down
    - Negative acceleration
    - Deceleration
  - Changing direction

Calculating Speed

Given Distance & Time



$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

Speed = Distance ÷ Time

Let’s Practice

- **Riley chucks a water balloon at a big, mean looking guy at the park. Running for his life, he travels 100m in 9.83s. What was his average speed?**

S= Distance/time

S= d/t

S= 100m/9.83s

S=10.17 mps (meters per second)

Calculating Distance
Given Speed & Time

Distance = Speed • Time

Multiply Speed and Time

Distance = Speed X Time

Speed X Time = Distance

Let’s Practice

1. If you ran 15 km/h for 20 min, how much distance would you cover?

Distance = Speed x time

D=ST

D=15 km/h x (20 min/60)

D =

Calculating Time

Given Distance and Speed

$$\textbf{Time} = \frac{\textbf{Distance}}{\textbf{Speed}}$$

Divide Distance by Time

Distance ÷ Speed = Time

Time = Distance ÷ Speed

Let’s Practice

- Marcy doesn't want to be late for class so she rushes to McDonald’s at lunch. How much time would it take Marcy to walk 2 km to McDonalds for a Big Mac if she walked at a rate of 4.5 km/h?

Time = distance/speed

T=DS

T = 2km / 4.5 km/h

T= .44 hours or 26.4 minutes

Calculating Acceleration

- **Acceleration Equation**

Acceleration = (final speed (in m/s) – initial speed (in m/s)) / Time (in seconds)

$$A = \frac{(s_f - s_i)}{t}$$

Oh... I get it now!

Let's practice…

- Rob is really bored one Saturday night and goes outside to study the nocturnal habits of mice in the hayfield. He sees a mouse sniffing along at 0.1 m/s. but it hears and starts to scurry for safety. In just 3.7 s it accelerates to 0.9 m/s. Find its acceleration.

Let’s Practice

Acceleration = (final speed (in m/s) – initial speed (in m/s)) / Time (in seconds)

A= $\dfrac{(s_f - s_i)}{t}$

A= $\dfrac{0.9\,m/s - 0.1\,m/s}{3.7s}$

A= $\dfrac{0.8\,m/s}{3.7s}$

A= 0.22 m/s^2

Let’s Practice

- A roach moves down the hall at 1.2 m/s. When he sees the janitor coming down the hall, he begins to run. After 3.2 s, he is moving at 3.6 m/s. What is his acceleration?

Let’s Practice

- While waiting for his Mom to come out of the hairdresser's, Sean accidentally puts the car in gear and it begins to roll forward. How far would the vehicle travel if it moved at 34 m/s for 2.5 s?

Let’s Practice

- While showing off for some girls at the skate park, Josh D crashes.. After the crash he tumbled 30 m in 4.2 s, what was his speed in m/s

Let’s Practice

- Colin skateboards down the sidewalk in front of the school, traveling at 24 km/h. How much time would it take him to travel 6.0 km?