From Last Time...

- **position**: coordinates of a body
- **velocity**: rate of change of position
  - average: \( \frac{\text{change in position}}{\text{change in time}} \)
  - instantaneous: average velocity over a very small time interval
- **acceleration**: rate of change of velocity
  - average: \( \frac{\text{change in velocity}}{\text{change in time}} \)
  - instantaneous: average acceleration over a very small time interval

Just to check...

A car’s position on a highway is plotted versus time. It turns out to be a straight line. Which of these statements is true?

A. Its acceleration is negative  
B. Its acceleration is positive  
C. Its acceleration is zero  
D. Its velocity is zero

What about constant acceleration?

- Acceleration = \( \frac{\text{change in velocity}}{\text{change in time}} \)
- **Constant acceleration**:
  - For every time interval (say, 1 second), the velocity increases by the same amount.
  - Gives a uniformly increasing velocity:

Position with constant accel.

- Velocity increases uniformly with time.
- Velocity = \( \frac{\text{change in position}}{\text{change in time}} \)
- So each equal time increment results in increasing distance increments.
- Can find \( x = \frac{1}{2} at^2 \)

Review question

An object has a constant acceleration. If the object has speed \( v \) at time \( t \), then what is the speed at time \( 2t \) ?

A. \( v/4 \)  
B. \( v/2 \)  
C. \( v \)  
D. \( 2v \)  
E. \( 4v \)
But what causes accel? Back to inertia

- The motion of an object does not change unless it is acted upon by a net force.
  - If \( v = 0 \), it remains 0
  - If \( v \) is some value, it stays at that value

- Another way to say the same thing:
  - No net force ⇔
    - velocity is constant
    - acceleration is zero

Force causes acceleration

- A body will accelerate (change its velocity) when another body exerts a force on it.
- But what is a force?
  - Push
  - Pull
  - Jet thrust

More than one force...

- Total force determines acceleration
- If \( F_1 \) and \( F_2 \) balance, acceleration is zero.

The Four Forces

1. Strong nuclear force
2. Electromagnetic force
3. Weak nuclear force
4. Gravity
   - Only gravity and electromagnetic forces are relevant in classical mechanics (motion of macroscopic objects).

Types of forces

Force and acceleration

- Larger force gives larger acceleration
- Directly proportional: \( a \propto F \)
- But clearly different bodies accelerate differently under the same force.
  - Heavier objects are harder to push.
  - Proportionality constant may depend on weight?
Inertia again

- But we already said that **inertia** characterizes a body’s tendency to retain its motion (i.e. to not change its velocity), We say a heavier object has more inertia.

- But inertia and weight are different
  - A body in space is weightless, but it still resists a push

Mass

- Define **mass** to be ‘the amount of inertia of an object’.
- Symbol for mass usually $m$
- Unit of mass is the kilogram (kg).

- Said before that $a \propto F$
- Find experimentally that

<table>
<thead>
<tr>
<th>Acceleration</th>
<th>Force</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a \propto \frac{F}{m}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Constant force $\Rightarrow$ constant accel

- Car is 0.73 kg
- After adding 1 kg, it is 1.73 kg

\[ x = \frac{1}{2}at^2 \]
\[ a = \frac{2x}{t^2} \]

Force, weight, and mass

\[ F = ma \Rightarrow F = (kg) \times (m/s^2) \]
\[ = kg \times m/s^2 = \text{Newton} \]

- 1 Newton = force required to accelerate a 1 kg mass at 1 m/s$^2$.

But then what is weight?
- Weight is a force, measured in Newton’s
- It is the net force of gravity on a body.
- $F = mg$, $g=F/m$

What do you think?

Suppose you are on the moon instead of on earth

A. Your weight is less but your mass is the same.
B. Both your weight and mass are less than on earth.
C. Your weight is less and your mass is zero.

Mass is an intrinsic characteristic of a body. The force of gravity on the body (weight) will depend on the other bodies around it.

Is ‘pounds’ really weight?

- In the English system (feet, pounds, seconds), pounds are a measure of **force**.
- So it is correct to say my weight is 170 pounds.
- Then what is my mass?

\[ m = \frac{F}{g} = \frac{170 \text{lbs}}{32 \text{ ft/s}^2} = 5.3 \text{ slugs}!! \]
Examples

- A force $F$ acting on a mass $m_1$, results in an acceleration $a_1$. The same force acting on a different mass $m_2$ results in an acceleration $a_2 = 2a_1$. What is the mass $m_2$?

\[ m_2 = \frac{1}{2} m_1 \]

Or in words... *twice the acceleration means half the mass*