029:006 — Lecture 2

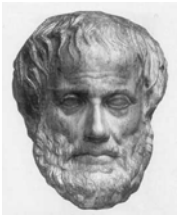
Mechanics (M1)

Why do things move?

Historical Perspective

Aristotle

- 350 BC
- Was the final word on any scientific question
- Influenced scientific thought until the end of the 17th century
- ***Believed that the natural state of an object was to be at rest—He was WRONG!***



Galileo 1564-1642

- To understand nature, you must first observe it
- *He is considered the "Father of Modern Science"*
- Imprisoned by Pope Urban VIII in 1633 for advocating that the earth was a planet revolving around the sun (heliocentric hypothesis)
- Pope John Paul II in 1992 declared that the Church was in error regarding Galileo.

Galileo, continued

- Previous thinking, accepted for 15 centuries, held that the earth was the center of the universe (geocentric hypothesis)
- Invented the first useful telescope in 1609
- Discovered the rings of Saturn
- He performed the first experimental studies of motion

Tycho *Brahe* (1546-1601) and Johannes *Kepler* (1571-1630)

T. Brahe

Tycho Brahe compiled the first detailed observational data on planetary motion (Mars), *without a telescope*! No one had previously attempted to make so many planetary observations.

J. Kepler

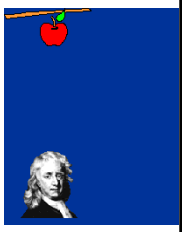
Johannes Kepler derived the laws of planetary motion using the data obtained by Brahe.

Isaac Newton

- Born Jan 4, 1642
- Published *The Principia* in 1687, considered the *greatest scientific book* ever written
- Discovered the 3 laws of mechanics, known as *Newton's Laws*
- Based on the work of Kepler, he discovered the *Law of Gravity*

Newton, continued

- Showed that the same laws that govern the fall of objects on earth also govern the motion of the planets.
- Newton's work followed directly from the experimental work of Galileo and Kepler's analysis of the observations of Brahe
- Scientific progress:
  Brahe→ Galileo & Kepler→ Newton



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Why does something move?

Because nothing stops it!

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Newton's laws of motion

- Newton's 1st law (Galileo's principle of inertia)
  "A body at rest tends to remain at rest; a body in motion tends to remain in motion."
- Newton's 2nd law (law of dynamics)
  "The rate of change of the velocity of an object (i.e., its acceleration), is the net force exerted on it divided by its mass."
- Newton's 3rd law
  "For every action (force) there is an equal and opposite reaction."

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Law of Inertia - examples

- Pull the tablecloth out from under the dishes
- Knock the card out from under the marble
- Hoop and Pen
- Knock the plate out under the egg
- Hammer head
- Shake the water off of your hands
- The car on the air track keeps going
- Homer not wearing his seatbelt

If you are at rest, you tend to stay at rest; if you are moving, you tend to keep moving, unless something stops you.

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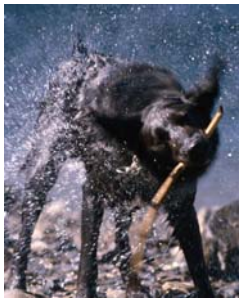
Dogs use the principle of inertia!



- When a dog is wet, he twists his body back and forth to shake off the water.
- When the dog rotates his body in one direction, the water is set into motion.
- When the dog twists the other way, the water drops keep moving in the original direction and fly off of him.
- We do the same thing when we shake our hands after washing them.

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Galileo's principle of Inertia

- A body at rest tends to remain at rest
- A body in motion tends to remain in motion

Or stated in another way:

- You do not have to keep pushing on an object to keep it moving
- If you give an object a push, and if nothing tries to stop it, (like friction) it will keep going
- *The "natural state" of an object is not rest*

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Ice Hockey

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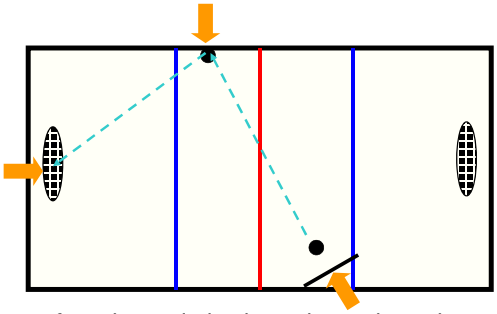
Physics and Ice Hockey



No force is needed to keep the puck moving forward after it leaves the player's stick.

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What is inertia?

- All objects have it
- It is the tendency to resist *changes in velocity*
  - if an object is at rest, it stays at rest
  - if an object is moving, it keeps moving
- *Mass* is a measure of the inertia of a body, in units of *kilograms (kg)= 1000 grams*
- Mass is **NOT** the same as *weight* !

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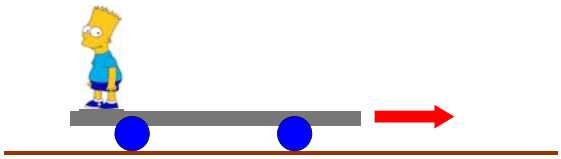

Bart is on the moving train and then jumps straight up on the moving train

will he land:

1) on the ground, or
2) on the train?

Bart maintains his forward motion even as he jumps up. *He lands on the train.*

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Other examples

- Having a catch on a plane, bus or train
- Throwing a ball up and down while walking
- Dribbling a basketball while running

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Refined Law of Inertia

- No force (push or pull) is needed to keep an object moving with *constant velocity*
- *Constant velocity-* moving in a straight line with constant *speed*

No stopping or turning

Note that a body at rest has a constant velocity of zero

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Concepts: speed and velocity

- Speed: How fast am I going?
  measured in miles per hour (mph), kilometers per hour (km/h), feet per second (ft/s), meters per second (m/s), . . .

$$\text{speed} = \frac{\text{distance}}{\text{time}} = \text{distance} \div \text{time}$$

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Velocity includes *speed* and *direction*

- Velocity includes information both about the speed (magnitude) and direction, not only *how fast*, but also *in what direction*
- It is what we call a *vector* quantity – one having both magnitude and direction
- Formula to calculate the magnitude

$$v = \frac{d}{t}$$

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Example

The average human can walk at 5 km/hr [1 kilometer (km) = 1000 m]. If a person walks at this rate for *half a day*, how far would he or she travel?

Answer

Since v = d / t, then d = v × t

d = v × t = 5 km/hr × 12 hr = 60 km

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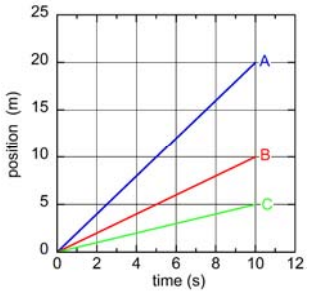
Position vs. time plots



v = d / t

- Case A: speed is 20 m/10 s = 2.0 m/s
- Case B: speed is 10 m/10 s = 1.0 m/s
- Case C: speed is 5 m/10 s = 0.5 m/s

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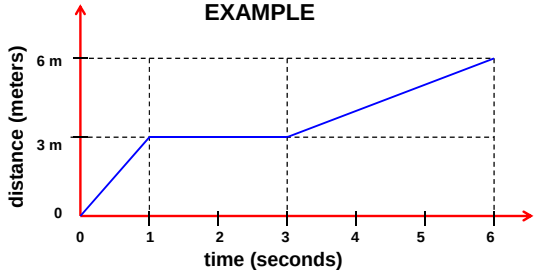
EXAMPLE



- **t = 0 to t = 1 s → velocity = 3 m / 1s = 3 m/s**
- **t = 1 s to t = 3 s → velocity = 0 m/s (at rest)**
- **t = 3 s to t = 6 s → velocity = 3 m / 3 s = 1 m/s**

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