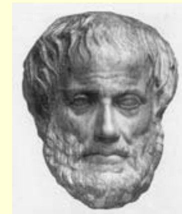
29:006 L-2
Mechanics: Why do things move?

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 objects was to be at rest



Galileo (Feb 15)1564-1642-Pisa

- To understand Nature, you must observe it
- Father of Modern Science
- Imprisoned by Pope Urban VIII in 1633 for advocating the Copernican theory, also know as the heliocentric theory, that the earth was a planet revolving around the sun.

Galileo, continued

- Previous thinking accepted for 15 centuries, held that the earth was the center of the universe (Ptolemaic theory)
- Invented the first useful telescope in 1609.
- First experimental studies of the laws of motion
- 350 years after his death, Pope John Paul II declared that the Church was in error in Galileo's case.

Tycho Brahe(1546-1601) & Johannes Kelper (1571-1630)

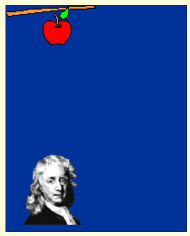
- Brahe compiled the first detailed observational data on planetary motion (*without a telescope*!)
- Kepler analyzed Brahe's data and discovered important regularities in the motion of the planets which supported the Heliocentric theory.
- These regularities are known as Kepler's Laws of planetary motion

Newton

- Born Jan 4, 1642
- Published *Principia* in 1687, considered the greatest scientific book ever written
- 3 Laws of mechanics (following on Galileo)
- Law of gravity (Following Kepler)
- Invented calculus

Newton, continued

- Showed that the same laws that govern the fall of objects on earth also govern the motion of the planets.
- *"If I have seen further than others it is by standing on the shoulders of giants."*



Einstein

- Born: 14 March 1879 in Germany
- Showed in 1905 that Newton's laws were not valid for objects moving with speeds near the speed of light → 186,000 miles/sec.
- Developed the special theory of relativity $E = mc^2$

Quantum Mechanics

- At the end of the 18th century and beginning of the 19th century it became clear that Newton's laws of mechanics failed to explain behavior at the atomic level
- A new theory – Quantum Mechanics was developed by Max Planck, Neils Bohr, Albert Einstein, Werner Heisenberg, Erwin Schroedinger, P. Dirac, M. Born.

Why does something move?

➔ Because nothing stops it!

The laws of motion – Why things move

- Galileo's principle of inertia (Newton's 1st law
- Newton's 2nd law - law of dynamics
  - → $F = m a$
- Newton's 3rd law - "for every action there is an equal and opposite reaction"

Inertia examples

- Pull the tablecloth out from under the dishes
- Knock the card out from under the marble
- Shake the water off of your hands
- The car on the air rack keeps going
- Homer not wearing his seatbelt

Galileo's principle of Inertia

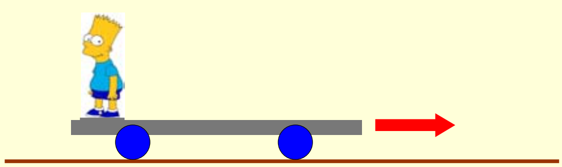
- A body at rest tends to remain at rest
- A body in motion tends to remain in motion

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

What is inertia?

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



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.

Other examples

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

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 and no turning

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

Concepts: speed and velocity

Speed: How fast am I going?

measured in miles per hour (mph)

feet per second (ft/s), etc.

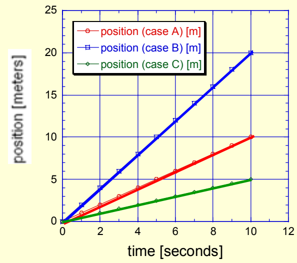
$$\text{speed} = \frac{\text{distance}}{\text{time}} = \text{distance} \div \text{time}$$

Velocity is a vector quantity

- Velocity conveys 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

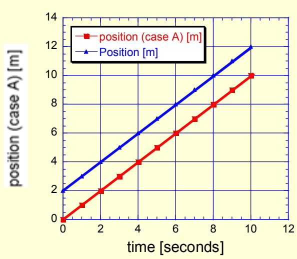
$$v = \frac{d}{t} = d \div t$$

Position vs. time plots



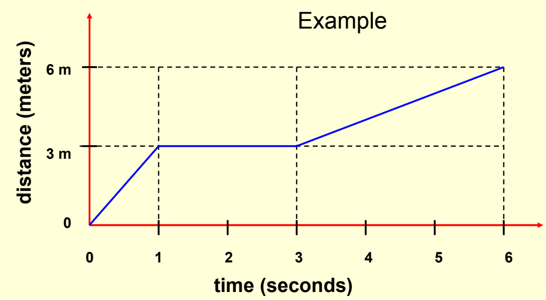
- Case A: speed is 10 m/10 s = 10 m/s
- Case B: speed is 20 m/10 s = 2 m/s
- Case C: speed is 5 m/10 s = 0.5 m/s

Two objects starting at different places



- The speed in case A and B are both 1 m/s
- In case A, the object starts at position 0 m
- In case B, the object starts at position 2 m

Example



- **from t = 0 to t = 1 s the object moves at a velocity of 3m / 1s = 3 m/s**
- **from t = 1 s to t = 3 s, the object is not moving, so v = 0 m/s**
- **from t = 3 s to t = 6 s the object moves at 3 m / 3 s = 1 m/s**

Problem for today

- At an average speed of 5 ft/s how long would it take to walk around the world? (How would you measure your average walking speed?)
- The diameter of the earth is about 7800 miles
- The circumference is the diameter x pi (π = 3.14)
  Circum = diam X 3.14 = 24,500 miles
- In feet, this is Circum = 24,500 miles x 5280 miles per foot = 129,360,000 feet

Problem, continued

- Velocity (v) = d / t → time t = d / v (d ÷ v)
- time = 129,360,000 feet / 5 ft/s
  = 25,872,000 sec
- Divide by 60 to give time in minutes, time = 431,200 minutes
- Divide by 60 again to get t in hours t = 7,187 hours, divide by 24 to get days
- time = 299 days – almost 1 year!

We need a better way to deal with big numbers