Today

- What is science?

- What it time?

- Motion

- Special Relativity

- Motion – rates of change

- Time Travel – Introduction
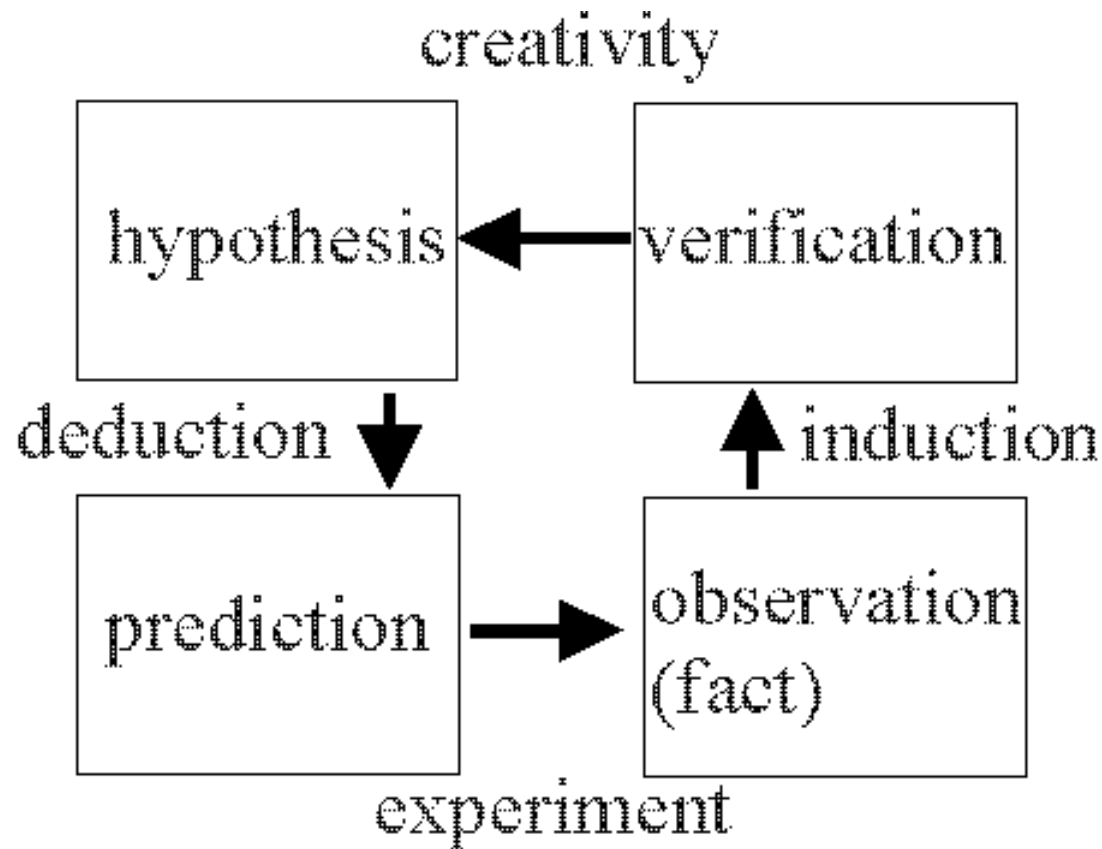
The Scientific Method

- ## Characteristics of Science (Scientific Method)
  - A hypothesis can become a theory if it successfully predicts and describes nature. A model is a combination of theories to describe how something works, e.g. how a supernova explosion occurs.
  - Theories can be proven wrong.
  - Theories are testable.
- ## Pseudoscience (not bad, just not science) Characteristics
  - The hypothesis is not at risk. If data does not agree with the hypothesis, then the data is assumed to be wrong or explanations are found to explain why the test failed.
  - Some facts are ignored.
  - Exploit the controversies and inadequacies in a competing theory.
  - Portrayed as an underdog being punished by the scientific establishment.
  - Reliance on fear and other emotions, or reliance on a lack of knowledge
  - People who do pseudoscience usually do not publish in normal scientific journals.
- ## Two Examples: ONE   TWO

The Scientific Method

creativity

hypothesis ← verification

deduction ↓ ↑ induction

prediction → observation (fact)

experiment

Keep an open mind

- "Heavier-than-air flying machines are impossible." (*Lord Kelvin, president, Royal Society, 1895*)

- "Professor Goddard does not know the relation between action and reaction and the need to have something better than a vacuum against which to react. He seems to lack the basic knowledge ladled out daily in high schools." (*New York Times editorial about Robert Goddard's revolutionary rocket work, 1921*)

- In 1912 Alfred Wegener (1880-1930) proposed that the continents were once compressed into a single protocontinent which he called Pangaea (meaning "all lands"), and over time they have drifted apart into their current distribution.
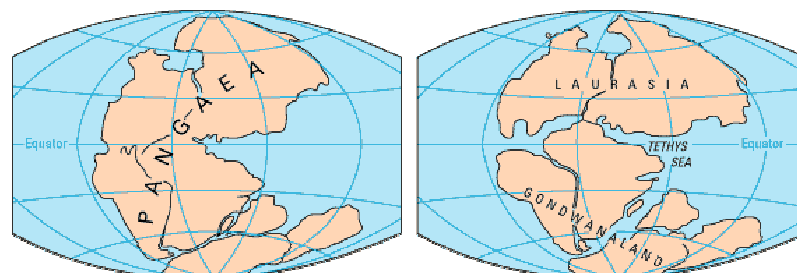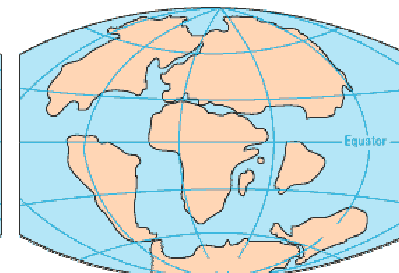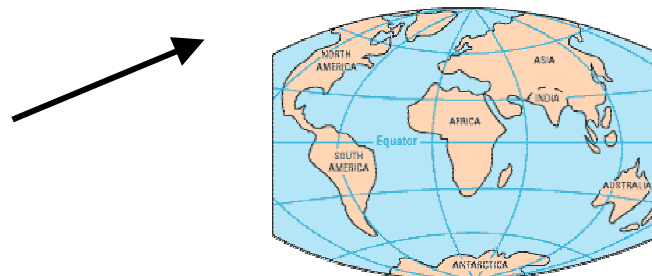

PERMIAN
225 million years ago

TRIASSIC
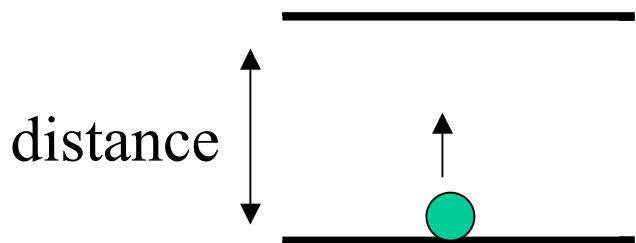200 million years ago
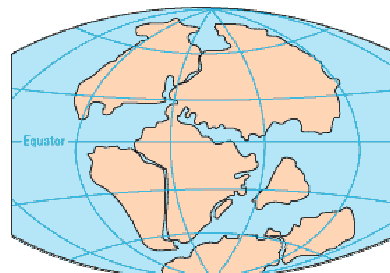
JURASSIC
135 million years ago

CRETACEOUS
65 million years ago

PRESENT DAY

What is time?

- ## What is time?

  - Time is the thing that is measured by clocks. What is a clock?

  - We can describe how to make a clock.
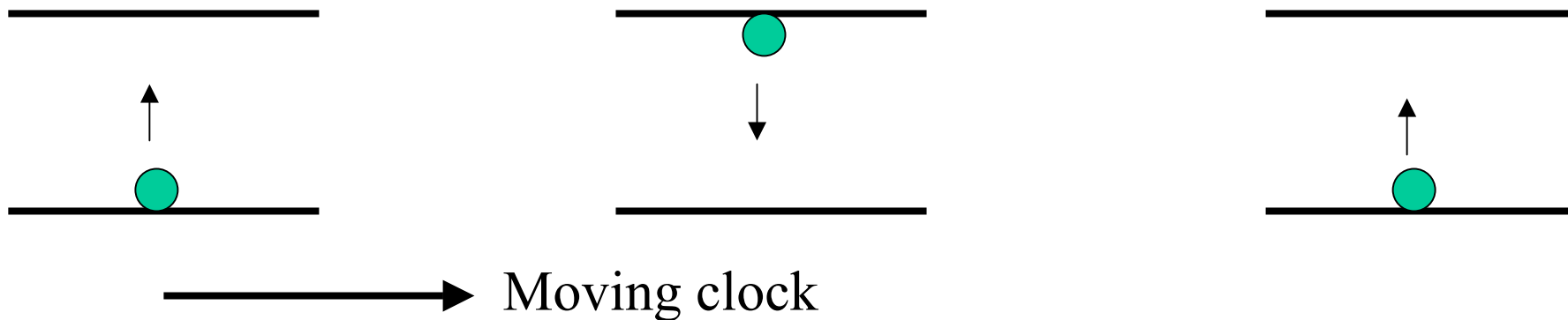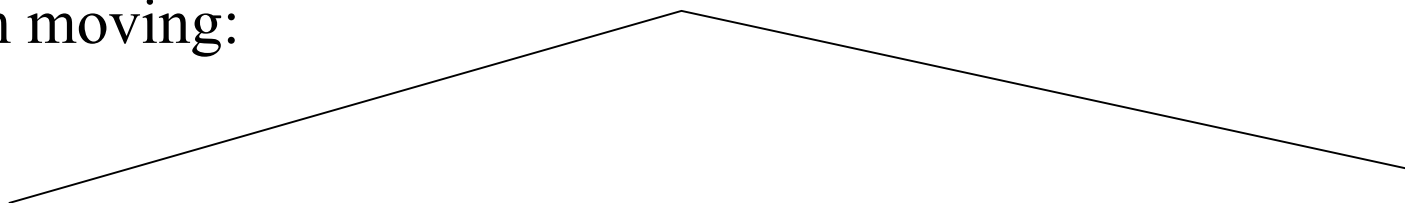
  - Example:

One bounce
is one click.

$$click = \frac{2 \times \text{distance}}{\text{speed}}$$

$$click = 1s = \frac{2 \times 1m}{2m/s}$$

distance

What happens if the clock is moving?

Moving clock

Path moving:

Path not moving:

H-iTT Clicker Question

If a clock is moving at a modest speed of 1 m/s, what can we say about the length of a click for a clock in motion relative to one at rest? Choose the best answer:

A). They are the same.

B). A click in the moving clock takes longer because the distance traveled is longer.

C). A click in the moving clock is faster because the velocity of the ball is greater.

Not to be answered by the clicker system: Why?

Motion

- **Position** – location in space relative to an origin.

- **Velocity** – rate of change of position

$$v = \frac{\text{change in position}}{\text{corresponding change in time}} = \frac{x_f - x_i}{t_f - t_i} = \frac{\Delta x}{\Delta t}$$

- **Acceleration** – rate of change of velocity

$$a = \frac{\text{change in velocity}}{\text{corresponding change in time}}$$

Example – Position of a ball at different times

x (m)	t (s)
0	0
1	1
2	2
2.5	2.5
3.0	3
3.0	4
2.0	5

What is the average velocity between 1 and 2 s?

$$v = \frac{\Delta x}{\Delta t} = \frac{2m - 1m}{2s - 1s} = \frac{1m}{1s} = 1\,m/s$$

What is the average velocity between 2 and 2.5 s?

$$v = \frac{\Delta x}{\Delta t} = \frac{0.5\,m}{0.5\,s} = 1\,m/s$$

Example

x (m)	t (s)
0	0
1	1
2	2
2.5	2.5
3.0	3
3.0	4
2.0	5

v (*m/s)*
1
1
1
1
0
-1

What is the average acceleration at 1 s?

$$a = \frac{\Delta v}{\Delta t} = \frac{1 m/s - 1 m/s}{1 s} = 0 \ m/s^2$$

What is the average acceleration at 4 s?

$$a = \frac{\Delta v}{\Delta t} = \frac{-1 m/s - 0 m/s}{1 s} = -1 \ m/s^2$$

Special Relativity

- Suppose we use a photon of light as the "ball" in our clock.

- The laws of electromagnetism require that the speed of light be a constant, independent of the motion of the clock.

- Einstein's two postulates of special relativity: 1). The speed of light is a constant in all inertial reference frames. 2). The laws of physics are the same in all inertial reference frames

- Special relativity deals with non-accelerating frames of reference (General Relativity deals will all cases)
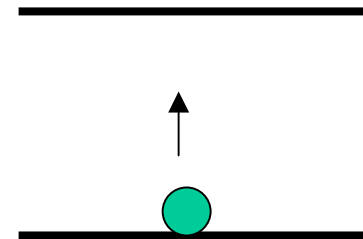
Consequences of Special Relativity

- Clocks in moving systems run more slowly.
  $$t = \gamma\, t_0 \quad \gamma = \sqrt{\dfrac{1}{1 - \left(\dfrac{v^2}{c^2}\right)}} = \sqrt{\dfrac{1}{1 - \beta^2}}$$
  - Equations: $\beta = v/c$

  - t_0 is called the "proper" time it is the time measure in the inertial reference frame.
  - c = speed of light = 299 792 458 m / s
- The length of moving objects is smaller
  - 1_0 is the "proper" length
  $$l = \dfrac{l_0}{\gamma} \quad \gamma = \sqrt{\dfrac{1}{1 - \left(\dfrac{v^2}{c^2}\right)}} = \sqrt{\dfrac{1}{1 - \beta^2}}$$
- How do we know?
  - Clock in airplanes
  - Lifetime of fundamental particles

Time Dilation

v/c	γ
.1	1.00504
.2	1.02062
.3	1.04828
.4	1.09109
.5	1.1547
.6	1.25
.7	1.40028
.8	1.6667
.9	2.29416
1	∞
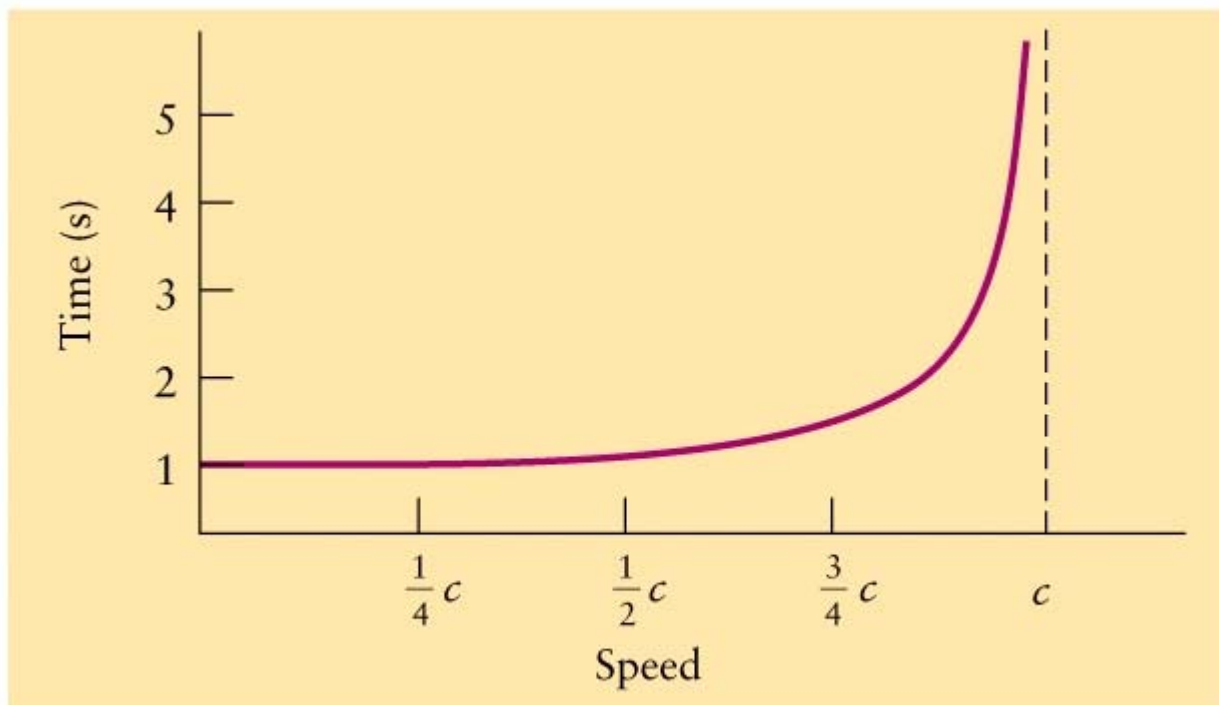
World record v/c (for electrons) is from SLAC in California: 0.999999875
γ = 20,000

What is time?

- Time is the thing that is measured by clocks.

- The more modern view is that time is one of the dimensions in space time (general relativity).

- If time is a dimension, is it possible to move back and forth in time?

Time Travel

- Moving at high speed is a way to travel into the future. No problem here; this is correct.
- The speed of light is fast, but distances in space are large.
  - We see the Sun as it was 8 minutes ago
  - We see nearby stars as they were 4-10 years ago
  - The distance light travels in one year is called a light year
  - We see nearby galaxies as they were 1 million years ago
  - Looking out at the stars is like looking back in time.
- Can we move backward in time? Maybe