<u>Einstein's special Relativity</u>

Classic physics relates motion and mass using Newton's Law: Fnet = ma.

This assumes that mass stays constant…..and it does for all practical purposes at speeds that we travel at during everyday life. But Einstein determined that at speeds approaching the speed of light, mass does change!

Classic physics says that time is a constant.

This assumes that the steady 'tick tock' of time is always the same…and it is for all practical purposes during everyday life. But Einstein once again determined that at speeds approaching the speed of light, times slows down!

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Reference frame – is where the observer is standing and 'seeing'. There is no stationary frame of reference as everything in the universe is moving.

<u>Einstein's First Postulate of Special Relativity</u>: The laws of physics are the same for observers in all inertial frames of reference. (13.1)

'inertial frame' – means a frame of reference moving at constant speed (where inertia holds)

So…If I measure the length of my textbook here in the classroom or riding on a bus going 40 km/h, I will get the same result. As well, the textbook will remain at rest unless there is an unbalanced force…here in the classroom or on the bus going 40 km/h. So far…so good.

<u>Einstein's Second Postulate of Special Relativity:</u> The speed of light is the same in all inertial systems. It is absolute! (13.2)

Consider being able to throw a baseball at 6 m/s. And consider that you can run at 7 m/s. If you throw the ball forward while running, a stationary observer would see the ball moving at 13 m/s (6 + 7 = 13). You, the runner, would observe the ball moving away from you at 7 m/s. The difference is explained by which frame of reference you are using.

Now..light! Light travels at 3×10^8 m/s. If you ran at 7 m/s and shone the flashlight, you would observe the light leaving you at 300, 000, 000 m/s. However, a stationary observer also sees the light leaving you at 300, 000, 000 m/s **<u>NOT</u>** 300,000,007 m/s. Light always travels at a constant speed regardless of the point of reference - regardless of where the observer is.

Einstein says the speed of light is the constant in the universe, not time!

Moving Clocks Run Slow: Time dilation

Refer to Fig. 13.11 on page 640 for a full sketch. Basically, there is an observer on a moving car and an observer standing still as the car passes. Light from the floor of the car travel sup and then reflects off a ceiling mirror and back to the floor. Each observer can measure the distance light travels and the speed of light is a constant (2^{nd} postulate). Each observer then can calculate correctly how much time passed for the light to travel (1^{st} postulate). The times calculated will be different!

The observer on the moving car saw light travelling a shorter distance at 3×10^8 m/s . Time calculated is smaller.

The observer standing on the side saw light travelling a longer distance at 3×10^8 m/s. Time calculated is longer.

The time calculated in each case is correct, but different!

t = relativistic time = is the time calculated by standing observer – experiment begins and ends in two different spots according to this observer.

t_o = proper time = is the time calculated by the moving observer – experiment begins and ends in the same location according to this observer.

Time dilation = the time interval measured by an observer in relative motion to an event is longer than proper time. Time is relative. Absolute time does not exist.

Copy the relative time formula into your notes – pg. 641

You Try:

What is the mean lifetime of a muon, measured by scientists on Earth, if it is moving at a speed of v = 0.70 c through our atmosphere? Assume that it's lifetime at rest is 2.2 μs. *Note we use a percentage of 'c' and leave 'c' in the equation. It will cancel out. (confused? See pg. 642)

Why don't we see time dilation in everyday life? For the answer…consider velocity <<<< c and work through the equation.

Moving Objects Appear Shorter: Length Contraction

Consider Tanya on earth and Katrina on a fast moving spaceship travelling from Earth to Mars.

Tanya's time calculation is

$t = L_o/v$ where **L_o is proper length** in which observed object is at rest. (object is distance)

F or Katrina, proper time (t_o) is less because the she and spaceship are travelling very fast. So her relativistic length of trip is $L = vt_o$. Follow the formula substitutions in text 9pg. 643.

Copy the relative length formula into your notes – pg. 644

Remember: **L_o is proper length** – object is at rest, not moving

L is relativistic length – object is moving

<u>Length Contraction</u> – the length of a moving object in the direction of travel is shortened. Length is a relative, not an absolute, concept. Absolute length does not exist!

Why don't we see length contraction in everyday life? For the answer…consider <u>velocity <<<< c</u> and work through the equation.

You Try:

Another muon, travelling 12 km through Earth's atmosphere, travels downward at a speed of 0.98c. Determine the contracted relativistic length the muon experiences as it hurtles towards us. You should find that the muon 'feels' like the 12 km as a much shorter length. Confused? Refer to page 644.