Lesson 21

Tuesday, June 01, 2010
1:42 PM

Lesson 1

Saturday, February 20, 2010
4:27 PM

Special Relativity

The theory of special relativity deals with a kind of reference frame called an inertial reference frame.

Fancy way of saying

1) laws of physics are the same in every inertial frame of reference

- all the laws of physics ex) $F_{net} = ma$ is true

- This means when you are seated in a chair on the ground you can be considered @ rest or you are seated in a chair on a moving plane, you could be considered at rest while objects are moving to or away from you in the plane

- it is not possible to single out "1" absolute inertial reference frame that is absolute since we are truly moving in space as we apply the laws

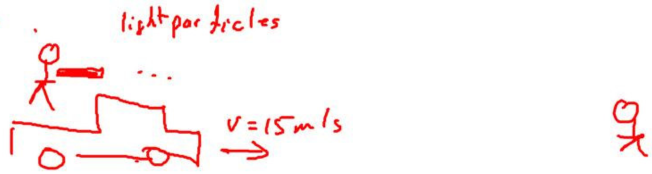
2) The speed of light in a vacuum measured in any inertial reference frame is "c" no matter how fast the source of light and the observer are moving relative to each other

This is a difficult concept to grasp.

ex) you are holding a flashlight. The speed of light from a stationary source is "c"

light from a stationary source is "c"
Now imagine that person is standing on a flatbed truck and the truck is moving

15 m/s .



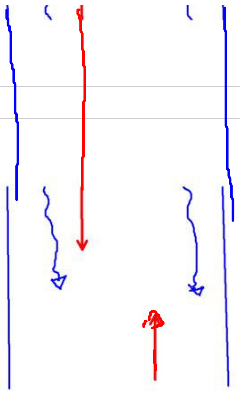
There is a stationary observer who measures the speed of light. As it turns out, the speed of light w.r.t the person on the truck is "c", light is travelling away from him at that speed.

w.r.t the stationary observer in front of the truck, light is Not approaching him at the speed of light "c" + 15 m/s, but only at "c" { keep in mind all reference frames are valid }

It was once assumed that light energy travelled through "ether" and travelled @ the speed of light w.r.t. the ether. em waves

If a boat travels down strean

of a speed of 7m/s and



~~at a speed of 7m/s and~~
can only travel upstream @ a speed of 3m/s, we can easily calculate the speed of the boat

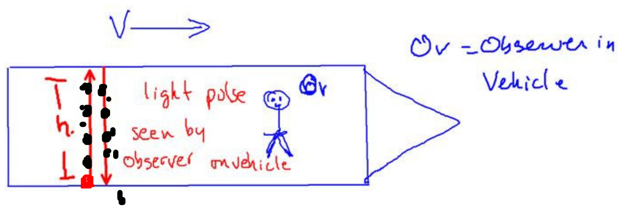
$V_{Boat} + V_{water} = 7m/s$

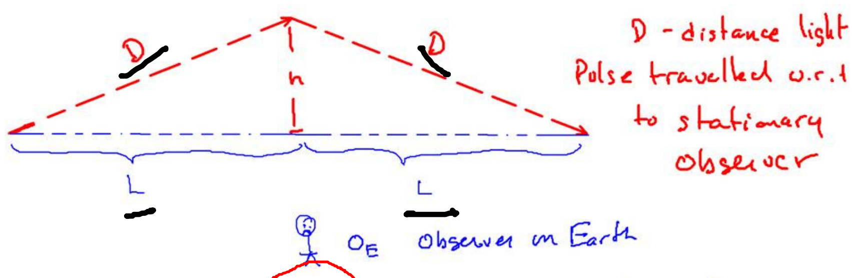
$V_{Boat} - V_{water} = 3m/s$

using Algebra it can be determined that $V_{Boat} = 5m/s$ and $V_{water} = 2m/s$

This same type of idea was used in conducting experiments to determine the speed of light in "ether"

Time Dialation





We have 2 diagrams to help us explain time dialation, The first diagram is of a space ship travelling near the speed of light. If

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there is a light source on the ship and a pulse is sent straight up and reflected down, it appears to the observer that light travels straight up and then down but if we look at that same pulse as the space ship travels overhead from a stationary observer light actually travels a greater distance and ∴ takes longer.

Things we know $d = v \cdot t$ ⇒ kinematics formula

light travels a total distance of $2D$ w.r.t O_E

speed of light particle = "c"

$$\therefore \quad t = \frac{d}{v} \text{ or } \frac{2D}{c} \Rightarrow 2D = ct$$

we know that the space ship travels a distance of $2L$ in the same time the light particle travels $2D$

$$v = \frac{d}{t} \text{ but the ship travels } 2L$$

$$\Rightarrow \quad v = \frac{2L}{t} \text{ or } 2L = vt \Rightarrow L = \boxed{\frac{vt}{2}}$$

Notice triangles ∴ we can help explain using pythagorus

"h" the height that the pulse travels

$$D^2 = L^2 + h^2$$

$$D = \sqrt{L^2 + h^2} = \sqrt{\left(\frac{vt}{2}\right)^2 + (h)^2}$$

$$\Rightarrow \quad 2D = 2\sqrt{\frac{v^2t^2}{4} + h^2} \Rightarrow$$

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$$\Rightarrow (ct)^2 = \left(2\sqrt{\frac{v^2t^2}{4} + h^2}\right)^2$$

square both sides to get rid of square root

$$= \quad c^2t^2 = 4\cdot\left(\frac{v^2t^2}{4} + h^2\right)$$

$$\Rightarrow \boxed{\frac{c^2t^2}{c^2t^2}} = \frac{v^2\cancel{t^2}}{c^2\cancel{t^2}} + \frac{4h^2}{c^2t^2}$$

$$\Rightarrow \boxed{1 = \frac{v^2}{c^2} + \boxed{\frac{4h^2}{c^2t^2}} \qquad eq\ \#1}$$

we know that from the observer in the spaceship that light travels a distance of 2h in t_0 {time wrt to observer in the ship}

$$d = r\,t$$

$$\frac{2h}{c} = \frac{\cancel{c}\cdot t_0}{\cancel{c}} \quad \Rightarrow \quad (t_0)^2 = \left(\frac{2h}{c}\right)^2 \qquad (t_0)^2 = \left(\frac{2h}{c}\right)^2$$

$$t_0^2 = \frac{4h^2}{c^2} \qquad\qquad t_0^2 = \frac{4h^2}{c^2}$$

$$\Rightarrow \underbrace{4h^2}_{\text{sub into Eq 1}} = c^2 t_0^2$$

$$1 - \frac{v^2}{c^2} = \frac{\cancel{c^2}\,t_0^2}{\cancel{c^2}\,t^2} \Rightarrow \boxed{1 - \frac{v^2}{c^2} = \frac{t_0^2}{t^2}}$$

$$\Rightarrow t^2 = \frac{t_0^2}{1 - \frac{v^2}{c^2}} \Rightarrow t = \frac{t_0}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$$

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t = is time experienced by external observer
t_0 = " " " " internal observer in ship travelling @ near the speed of light

ex) An astronaut is travelling at a constant speed of 2.95×10^8 m/s relative to the speed of light. According to the timing device on the space vehicle the trip lasted 0.500 years. How much time relative to earth did the trip last?

$$t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{0.500\text{ yrs}}{\sqrt{1-\left(\frac{2.95\times\cancel{10^8\text{ m/s}}}{3.00\times\cancel{10^8\text{ m/s}}}\right)^2}}$$

$= 2.75$ years

ex An astronaut is travelling @ a constant speed of 2.7×10^8 m/s relative to earth. If this takes 25 years measured to earth, how much did the astronaut age?

$$t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}} \qquad t_0 = t\sqrt{1-\frac{v^2}{c^2}}$$

$$= 25\text{ yrs}\sqrt{1-\left(\frac{2.7\times10^8\text{ m/s}}{3.00\times10^8\text{ m/s}}\right)^2}$$

$\doteq$ 11 yrs The astronaut aged

ex3) If an astronaut's trip through space takes 2.50 yrs relative to earth and 1.50 years measured by timing devices aboard the ship, determine the speed of the ship.

$$t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}} \Rightarrow \left(\sqrt{1-\frac{v^2}{c^2}}\right)^2 = \left(\frac{t_0}{t}\right)^2$$

$$1 - \frac{v^2}{c^2} = \frac{t_0^2}{t^2}$$

$$1 - \frac{v^2}{(3.00 \cdot 10^8 m/s)^2} = \left(\frac{1.50}{25.0}\right)^2$$

$$1 - \frac{(1.50)^2}{(25.0)^2} = \frac{v^2}{(3.00 \cdot 10^8 m/s)^2}$$

$v = 2.99 \times 10^8 m/s$ or $\frac{2.99}{3.00} \times 100\% = .99c$

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Quiz Thurs.