Relative Velocities- Inertial Observers

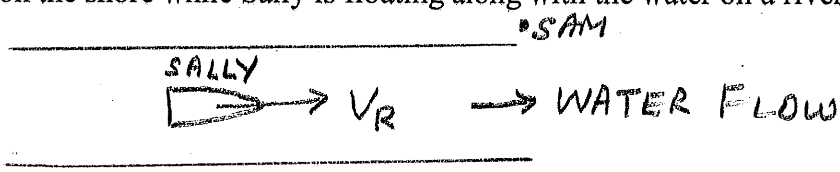
Now that we have developed the kinematic Equs.

$$\vec{a} = a\hat{x}$$
$$\vec{V} = (V_o + at)\hat{x}$$
$$\vec{x} = (x_0 + V_0 t + \tfrac{1}{2}at^2)\hat{x}$$

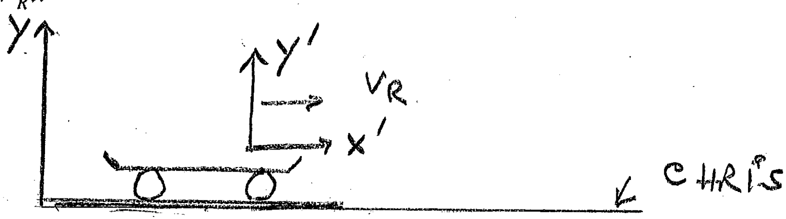
we know that given a clock (to measure t) and two meter scales (to measure x and y) we can describe any constant acceleration motion precisely. Since there are many, many observers, the question arises, how do two observers relate their observations of the same motion if the observers are not at rest with respect to one another.

For example, Sam is standing on the shore while Sally is floating along with the water on a river. With a velocity.

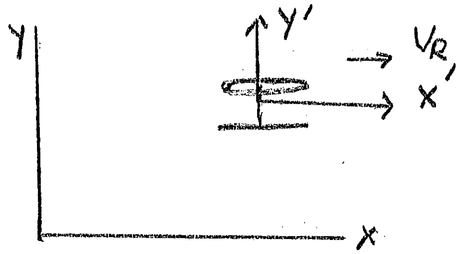
$\vec{V}_R = V_R\hat{x}$



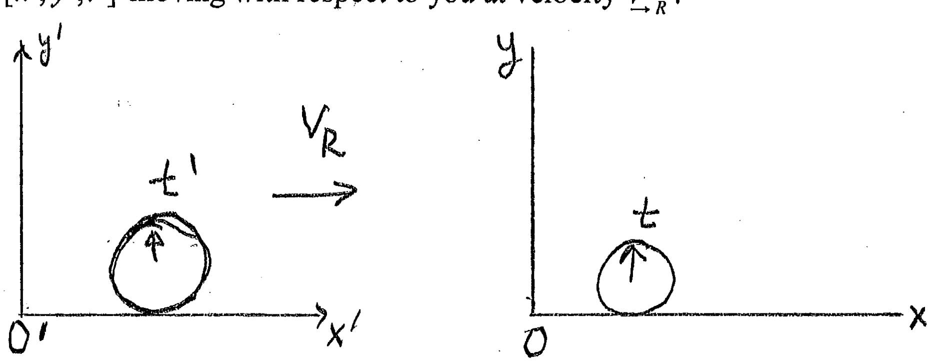
OR Chris is standing on the ground and Crystal comes along on a roller skate travelling at $\vec{V}_R = V_R\hat{x}$



or you are standing on the ground and a helicopter hovers overhead while the wind is blowing at vel. $\vec{V}_R = V_R\hat{x}$

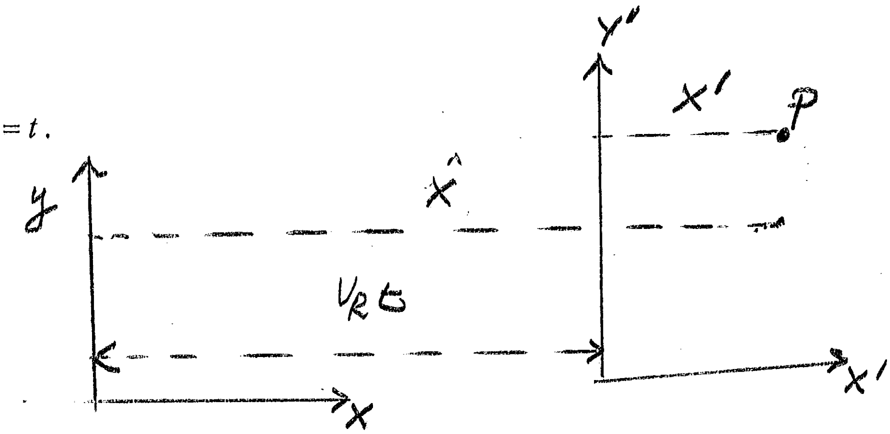


We must learn how to relate observations made by you [x,y,t] with observations made by an observer $[x', y', t']$ moving with respect to you at velocity $\vec{V}_R$.



Step 1: We arrange that at the instant your origins coincide (0 and $0'$ same), both start your

clocks, that will ensure that $t' = t$.
Now consider a time t later



At t an event occurs at p:

You measure x, y, t — She measures x', y', t'

and you can see that

$$t' = t.$$
$$y' = t$$
$$x' = x - V_R t$$

If now P has a displacement you measure Δx, Δt she measures $\Delta x'$, $\Delta t' = \Delta t$

so

$$\Delta x' = \Delta x - V_R \Delta t$$

and dividing by Δt and making it small we see that

$$\vec{V}^1 = \vec{V} - \vec{V}_R \qquad \text{\_\_\_\_\_\_ I}$$

This equation is very useful fo solving all the "relative velocity" problems:

<u>EX1: Boat in River</u>

$\vec{V}_R = \vec{V}_{WS}$ velocity of water with respect to shore

$\vec{V}' = \vec{V}_{BW}$ Velocity of Boat with respect to water

$\vec{V} = \vec{B}_{BS}$ Velocity of Boat with respect to shore

$$\vec{V}_{BS} = \vec{V}_{BW} + \vec{V}_{WS}$$

<u>EX2:</u> Airplane

$\vec{V}' = \vec{V}_{PA}$ [Velocity of plane wrt air]

$\vec{V}_R = \vec{V}_{AG}$ [Velocity of air wrt ground]

$\vec{V} = \vec{V}_{PG}$ [Velocity of plane wrt ground]

$$\vec{V}_{PG} = \vec{V}_{PA} + \vec{V}_{AG}$$

<u>EX3:</u> Velocity observed by person standing on ground

$$\underrightarrow{V} = \underrightarrow{V'} + \underrightarrow{V}_R$$

However, Eq I has more profound consequences.
Suppose that P also has an acceleration.

Since $\underrightarrow{V}_R = \cancel{\text{Const}}$ constant

$$\Delta\underrightarrow{V'} = \Delta\underrightarrow{V}$$

so $\underrightarrow{a'} = \underrightarrow{a}$

This allows us to define an Inertial observer as one whose coordinate system moves at a constant velocity (vector) = constant. Magnitude, no change in direction.

This has two major consequences:
<u>A:</u> Principle of Relativity: LAWS OF PHYSICS ARE THE SAME FOR ALL INERTAIL OBSERVERS. (FULL SIGNIFICANCE OF THIS BECOMES CLEAR AFTER WE INTRODUCE NEWTON'S LAW WHICH MANDATES THAT IF $\underrightarrow{a} \neq 0$ THERE MUST BE A FORCE PRESENT AT THAT POINT AT THAT TIME.

<u>B:</u> No experiment done <u>within</u> a SYSTEM CAN DISCOVER THAT THE SYSTEM IS MOVING AT A UNIFORM VELOCITY. (This is the basis for the popular statement, all motion is relative. Now we know that the more precise statement should be all uniform motion ($\underrightarrow{V}_R =$ const.) is relative.)