# PHYS 135: ST and the QW Info

Fall 2010 v1.0

## 1. Instructions

## 2. Some of our favorite expressions:

Please use the speed of light $c = 3.0 \times 10^8$ m/s.

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}.$$

$v/c$ in terms of $\gamma$ is

$$\frac{v}{c} = \sqrt{1 - \frac{1}{\gamma^2}}$$

"**Moving objects shrink**" or length contraction. Moving object of length $L'$ contracts from its proper length $L$ by

$$L = \gamma L'$$

"**Moving clocks run slow**" or time dilation. Moving clock $t'$ runs slow relative to its proper time $t$ by

$$t = \gamma t'$$

"**Simultaneity slips**" The time in a moving frame between simultaneous events in another frame is

$$T = \frac{vD}{c^2}$$

The details: If events $E_1$ and $E_2$ are simultaneous in one frame then in a frame moving with speed $v$ in the direction from $E_1$ to $E_2$, the event $E_2$ occurs earlier than $E_1$ by the time interval $Dv/c^2$, where $D$ is the distance between the events in the second frame.

"**Velocity addition is modified**". An object moves at $u$ in a frame. In another frame moving at $v$ with respect to this frame, the object moves at $w$ given by

$$w = \frac{v + u}{1 + uv/c^2}$$

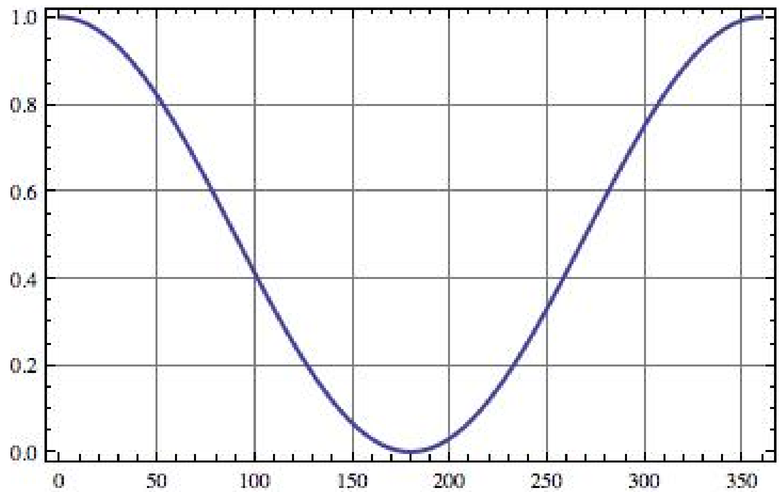
"**Light changes color**" For observers with relative velocity $v$

$$K = \frac{T'}{T} = \sqrt{\frac{1 + \frac{v}{c}}{1 - \frac{v}{c}}} = \gamma + \sqrt{\gamma^2 - 1} = z + 1$$

where $T'$ is in the frame that receives the light, $T$ is in the frame that emits light. For receding observers $v > 0$, for approaching observers $v < 0$. The speed in terms of $K$ is given by

$$\frac{v}{c} = \frac{K^2 - 1}{K^2 + 1}$$

The probability chart $P(m_\theta = +m_B | m_z = +m_B)$ vs. $\theta$




**Quantum Mechanics** The probability for a system to transition from state $A$ to state $B$ is found by

(1) **Find the paths** List the exclusive, exhaustive ways or paths to transition from $A$ to $B$.
(2) **Assign amplitudes** Determine the amplitudes for each path.
(3) **Add amplitudes** Add the amplitudes for all possible paths "tip to tail".
(4) **Square to probability** Then the square of the length of the total amplitude is the probability for the transition.

"**Gravity slows clocks**" Alice and Bob are near a massive object that accelerates objects at $g$. If Alice is a height $h$ above Bob then when Alice's clock clicks off $T_A$ then Bob's clock ticks off $T_B$

$$T_B = T_A \left(1 - \frac{gh}{c^2}\right)$$

(to leading order).

The Schwarschild radius of a black hole of mass $M$ is

$$r_s = \frac{2GM}{c^2}$$

where is Newton's gravitational constant.

The Hawking temperature of a black hole of mass $M$ is, in degrees Kelvin,

$$T_H = 6 \times 10^{-8} \frac{M_\odot}{M}$$

where $M_\odot$ is the mass of the sun.

## 3. Questions: Please answer and explain your answer

(1) Briefly explain the characteristic feature(s) of a black hole.
(2) The mass of a black holes has a large impact on their behavior. Compare the environment near the horizon of a very massive black hole, say with a mass of a million times the mass of the sun so that $\frac{M}{M_{\odot}} = 10^6$, to the environment near the horizon of a black hole with the mass of Tethys, a satellite of Saturn, so that $\frac{M}{M_{\odot}} = 3 \times 10^{-10}$.