Physics 142 - October 11, 2005

Relativity

Exam Results
Troubleshooting guide

Last Time -

**RC circuits**

\[ E - iR - \frac{q}{C} = 0 \]

\[ E - \frac{dq}{dt} R - \frac{q}{C} = 0 \Rightarrow q(t) = CE \left( 1 - e^{-t/RC} \right) \]
Introduction to the Special Theory of Relativity

1. Physics is the same in all inertial reference frames. No acceleration moving at const. V.
(2) The velocity of light (in vacuum) is observed to be the same in all inertial reference frames (c).

\[ \Delta t' = \Delta t \gamma \]

\[ \gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} > 1 \]

Time dilation

measured time is shortest in proper frame of reference

frame where event is at rest
Length Contraction

\[ \Delta x' = \frac{\Delta x}{\lambda} \]

Length is greatest when measured in Proper Frame of Reference.
at $t=0$, $t'=0$

two systems overlap

$0=0'$

classical physics:

Galilean Transforming

\[
\begin{aligned}
x' &= x - \nu t \\
y' &= \eta \\
z' &= z \\
t' &= t
\end{aligned}
\]
\[
\begin{align*}
    d &= \frac{x'}{\gamma} \\
    x' &= \gamma d \quad \text{as measured in } S' \\
    d &= x - vt \\
    \frac{x'}{\gamma} &= x - vt \\
    x' &= \gamma(x - vt) \\
    y' &= y \\
    \beta' &= \beta \\
    t' &= \gamma \left( t - \frac{v}{c^2}x \right)
\end{align*}
\]
Galilean trans. 

\[ x' = d' - vt' \]
\[ d' = x \quad t' = t \]
\[ x' = x - vt \]

\[ x = \text{dist from } 0 \rightarrow A \text{ in } S \]
\[ d' = \frac{x}{y} \]

\[ x' = d' - vt' \]
\[ x' = \frac{x}{y} - vt' \]
\[ x = \delta(x' + vt') \]

\[ x = \gamma(x' + vt') \]
Sub in \[ x' = \gamma(x - vt) \]
\[ x = \gamma[\gamma(x - vt) + vt'] \]
\[ \beta \text{ Algebra} \]
\[
\begin{align*}
t &= \gamma(t' + \frac{v}{c^2}x) \\
t' &= \gamma(t - \frac{v}{c^2}x)
\end{align*}
\]

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

\[
\gamma = 1.40
\]

Event 1: \(t=0, t'=0\) origins coincide

Spaceship passes by asteroid

Event 2: Laser flashed on \(S\) at \(x = 3\) km, \(t = 5\) \(\mu s\)

What does event 2 look like in frame \(S'\)?

\[
x'_2 = \gamma(x - vt) = 1.4 \left[ 3 - (0.7) \frac{3 \times 10^5 \text{ km}}{3} \frac{5 \times 10^{-6} \text{s}} \right]
\]

\[
= 2.73 \text{ km}
\]

\[
t'_2 = \gamma(t - \frac{v}{c^2}x) = 1.4 \left[ 5 \times 10^{-6} \text{s} - \frac{0.7}{3 \times 10^5 \text{ km/s}} \frac{3 \text{ km}}{2} \right] = -2.8 \mu s
\]
\( s' \rightarrow v \)

\( \vec{u} = \text{velocity in } s \)

\( \begin{align*}
\text{in } s: & \quad u_x = \frac{dx}{dt} \\
& \quad u_y = \frac{dy}{dt} \\
& \quad u_3 = \frac{dz}{dt}
\end{align*} \)

\( \text{in } s': \)

\( \begin{align*}
\dot{u}_x &= \frac{dx'}{dt'} = \frac{\gamma(dx - vdt)}{\gamma(dt - \frac{v}{c^2}dx)} = \frac{\gamma \left( \frac{dx}{dt} - v \right)}{\gamma \left( 1 - \frac{v}{c^2} \frac{dx}{dt} \right)} \\
\dot{u}_y &= \frac{dy'}{dt'} = \frac{\gamma \frac{dy}{dt}}{\gamma(dt - \frac{v}{c^2}dx)} = \frac{\gamma \frac{dy}{dt}}{\gamma \left( 1 - \frac{v}{c^2} \frac{dx}{dt} \right)} \\
\dot{u}_3 &= \frac{dz'}{dt'} = \frac{\gamma \frac{dz}{dt}}{\gamma \left( 1 - \frac{v}{c^2} \frac{dx}{dt} \right)}
\end{align*} \)
2 wires

\[ + + + + + + + + + + \rightarrow \nu \]

\[ \lambda_+ \quad \text{at rest} \quad \lambda_- \]

\[ g_0 \text{ at rest} \]

\[ \lambda_- = \lambda_+ \]

Electrostatic force on \( g_0 = 0 \)

Switch to frame of reference where \( g_0 \) is moving

\[ \circ \quad U \quad g_0 \]

Now \( \lambda_- \neq \lambda_+ \) - so there is now a force

Force or not? depends on frame of reference

Resolution of this lies in Relativistic theory of \( E+M \)