RELATIVITY, PARADOXES, KINETICS

Prof. Stephen Sekula
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Supplementary Material for
PHY 3305 (Modern Physics)

Associated Reading:
Harris Ch. 2.4-2.6
TABLE OF CONTENTS

- Review
- Muons from cosmic rays
  - questions to be answered
- “The Incident” (the twins paradox)
  - questions to be answered
- The Doppler Effect
  - beat the ticket!
- High speeds: supernova 1987A
We learned about Einstein’s postulates
  - preserve measurements and the laws of physics, but abandon absolute notions of space and time
We discussed the consequences of those postulates
We learned how to relate events in two frames of reference
  - The Lorentz Transformation
We started applying the Lorentz Transformation
Lorentz Transformation

Frame $S$ ("at rest")

\[
\begin{align*}
    dx' &= \gamma_v \left( dx - \nu \, dt \right) \\
    dt' &= \gamma_v \left( -\frac{\nu}{c^2} \, dx + dt \right)
\end{align*}
\]

Frame $S'$ ("in motion relative to $S$")

\[
\begin{align*}
    dx &= \gamma_v \left( dx' + \nu \, dt' \right) \\
    dt &= \gamma_v \left( \frac{\nu}{c^2} \, dx' + dt' \right)
\end{align*}
\]

\[
\begin{align*}
    dx \equiv \Delta x &= x_2 - x_1 \\
    dt \equiv \Delta t &= t_2 - t_1
\end{align*}
\]
MUONS FROM COSMIC RAYS

Illustration representing size and depth of cosmic ray shower
MUONS FROM GUADALUPE PEAK

3.0km

muon travels at 0.98c
Muons: Questions

- What is a “muon”?

- Thinking classically
  - what is the distance to the earth?
  - how far does the muon travel in 2.2μs?
  - does the muon reach the earth?

- Thinking modern(ly)
  - Frame S: how long does the muon live?
  - Frame S: how far does the muon go?
  - Frame S': how long does it take to reach earth?
"THE INCIDENT"

40 light-years

Earth

\[ v = 0.8c \]

Planet X
QUESTIONS

● Which is frame $S$ and $S'$?

● What is the gamma factor?

● Bob’s frame:
  
  ● how old is he when Anna arrives at Planet X?
  
  ● how old is Anna when she arrives?

● Anna’s frame:
  
  ● how old is she when she arrives?
  
  ● how old is Bob when she arrives?
MORE QUESTIONS

- Crisis abated after 10 years
  - Bob’s frame: how long does a signal to Planet X take to arrive?
  - Anna’s frame: how long does that signal travel before it arrives?
- Carla’s perspective
  - How long did it take the signal to arrive?
  - How old is Bob when the signal arrives?
  - How long is the journey to Earth?
THE DOPPLER EFFECT
BEAT THE TICKET!
SUPERNNOVA 1987A
NEXT TIME

- Harris, Ch. 2.7, 3.1-3.2
- Revisit Energy and Momentum
  - stunning revelations about the nature of energy and matter
- Begin to discuss light
  - is light really a wave?