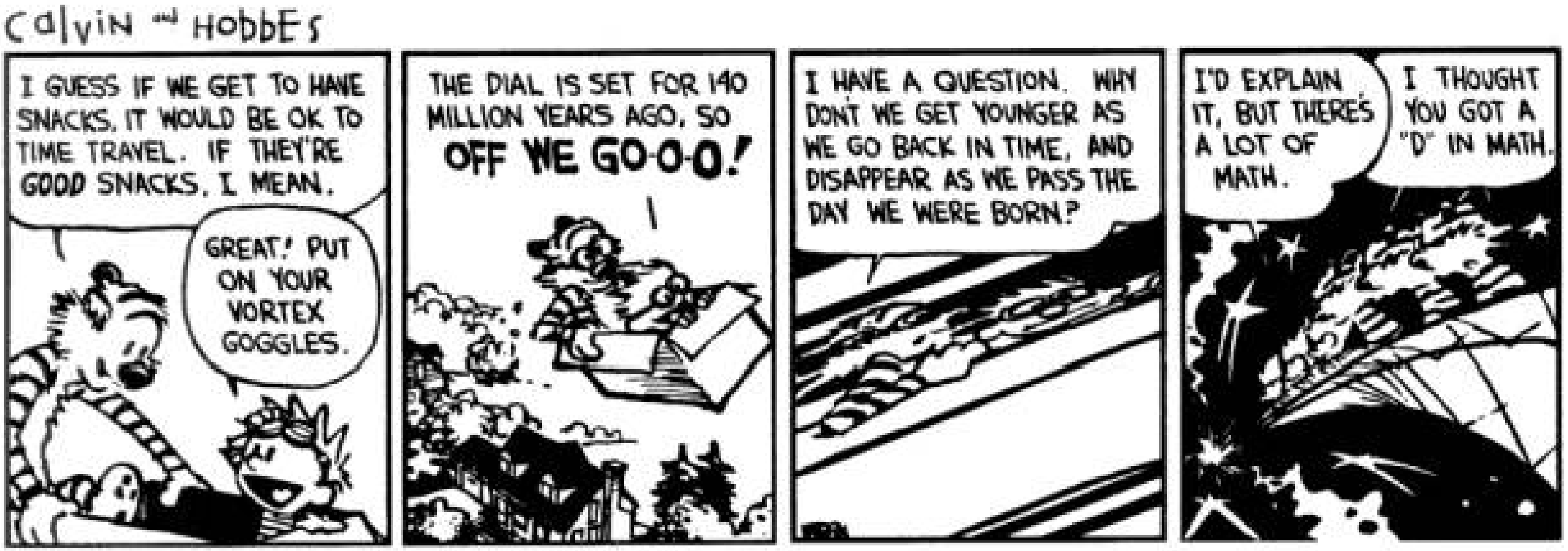
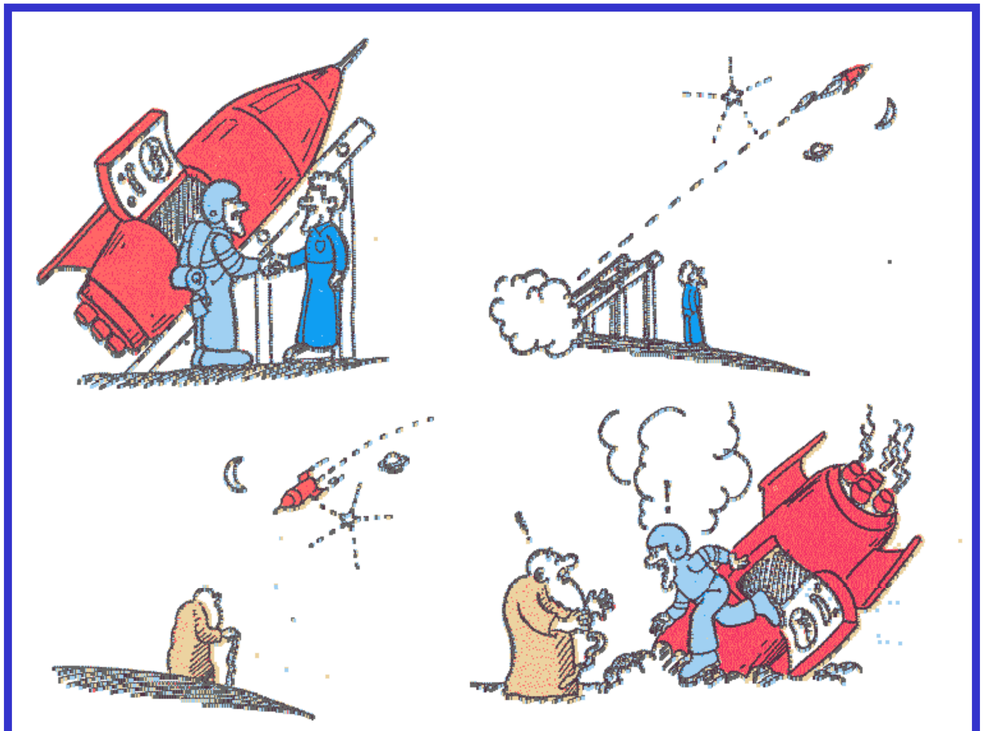


http://www.zamandayolculuk.com/cetinbal/timetravelscience.htm



http://www.zamandayolculuk.com/cetinbal/htmldosya1/TwinParadox-2.htm

PHY100S
Lecture 15

Current Assignments ...

Office hours:
3-4 Tuesdays
& Thursdays

For today

- Read Sections 10.6 - 10.7

For Lecture 16

- Read Sections 10.8, 11.1

Homework #3 (new due date)

- Handed out February 14, due **FRIDAY, MARCH 8**

Writing Assignment #2

- Handed out Feb. 28. Due 11:00 AM, Thurs., April 4

Suggested Conceptual Exercises

- Chapter 10: 21,25,27,31,35,37,39,41,43,47,49,51

Tutorial #7

Review of Lecture 14

Textbook, Sections 10.5 - 10.6

- More on the speed of light
- The relativity of time - time dilation
- Time travel

Rule: Moving clocks run slow.

- Time is relative – it depends on the relative speed of the clock and the observer.

$$T = \frac{T_o}{\sqrt{(1 - v^2/c^2)}} \qquad T = \gamma T_o \qquad \text{so } T > T_o$$

Plan for Lecture 15

Textbook, Sections 10.6 - 10.7

- Time travel
- The relativity of space – length contraction
- The relativity of mass

From L14: How fast do Mort and Velma age?

- If Velma passes Mort at 75% of lightspeed, then
  - → Mort and his descendants see Velma age 120 years during his 80-year lifetime.
    - She lives for 120 years as measured by Mort’s clock.
    - He sees her age slowly, by 1 yr for each of his 1.5 yrs.
    - He dies after 80 of his years and she dies after 120 of Mort’s years, but she looks like an 80-year-old.
  - → Velma and her descendants see Mort age 120 years during her 80-year lifetime.
  - → And both are correct!
- Each will see the other age more slowly.

The Twin "Paradox" **

** actually it is NOT a paradox

Now, suppose Mort stays on Earth while Velma takes a long trip in space at close to the speed of light.

When Velma returns to Earth, she is

(A) older than Mort (B) younger than Mort

(C) the same age as Mort

What happened to special relativity?!

It only applies to <u>unaccelerated</u> motion.

In order for Velma to go away and come back, she had to accelerate (three times).

The Twin "Paradox"

- How is this different from the previous example?
  - → Velma has accelerated.
  - → Velma and Mort begin and end in the same reference frame (Earth).
- When they are back together, they must agree on who is older because there is only a single time in that reference frame.
- Mort does not accelerate, so the Special Theory of Relativity does apply to his observations:
  - → If Velma's trip takes 60 years measured in Mort's reference frame, he sees only 40 of her years pass. When she returns, he is 60 and she is 40.
  - → He sees her age slowly, by 1 yr for each of his 1.5 yrs.

Time Travel

- Velma has traveled into the future – at least, into Mort's future.
- It's a one way trip, though – there's no way to go back.

- So time dilation allows time travel.
- But only time travel <u>into the future</u> is possible.

Concept Check 8

It is physically possible for your mother to leave Earth after you were born and return:

(A) before you were born

(B) before she was born

(C) younger than you

(D) older than you

(E) younger than she was when she left

(F) older than she was when she left

What Is Space?

- Space is something we measure with rulers.
- How can we measure the length of a moving object?

There are two ways.

(1) Measure the position of both ends of the object simultaneously, i.e., with two clocks.

→ Otherwise the object will move while measured

(2) Measure the time it takes for the object to pass a certain point, and use the speed to find the length.

Measuring Length

Velma is again in the spaceship moving relative to Mort.

Again, the situation is symmetric: Mort's window is shorter as measured by Velma.

Textbook Figure 10.10

The window in Velma's spaceship as measured by Velma.

The window in Velma's spaceship as measured by Mort.

Length Contraction

No matter how we measure length, we find the same result: lengths in the direction of motion are contracted.

$$L = L_o\sqrt{(1 - v^2/c^2)} = L_o/\gamma < L_o$$

so $L < L_o$

where
L_o = object's rest length,
L = object's length when moving at v

Textbook Figure 10.11

Length Contraction Animations

Try these at home yourself:

Relativistic length contraction

- http://www.physicsclassroom.com/mmedia/specrel/lc.cfm
- http://www.upscale.utoronto.ca/PVB/Harrison/SpecRel/Flash/LengthContract.html

Online tutorial showing time dilation and length contraction

- http://physics.ucsc.edu/~snof/Tutorial/index.html

The Relativity of Space

Suppose that Velma observes Mort's car as she passes it at 60% of lightspeed. She passes lengthwise over the car.

Mort's car is 4 meters long as measured by Mort. How long is it as measured by Velma?

(A) 0.8 meters

(B) 3.2 meters

(C) 4 meters

The length contraction factor is 0.8 for 60% of lightspeed.

Back to Newton's Second Law

- a = F/m predicts that a constant force will give a constant acceleration
- This implies that there is no maximum speed. This cannot be correct!
- Relativity alters Newton's Law of Motion.
- The relativity of time means that accelerations differ from one frame to another.
  - → Moving objects are observed to accelerate more slowly for the same force.

More Mort and Velma

- Imagine that Mort and Velma each have a 1 kg book, and that Velma is moving past Mort.
- If Mort pushes his book with a 1 N force,
  - → it will accelerate at 1 m/s^2.
- If Mort pushes on Velma's moving book with a 1 N force,
  - → Newton's Second Law predicts that it will accelerate at 1 m/s^2.
  - → Relativity predicts that it will accelerate at less than 1 m/s^2 (as seen by Mort).

The Relativity of Mass

- If the same force yields a smaller acceleration, the mass must be larger.
- Therefore, mass is also relative.
  - → Moving masses appear to heavier than those at rest.
- We call the mass of an object in its own reference frame (not moving) its <u>rest mass</u>.
  - → This is a constant for any particular object.

$$m = \frac{m_o}{\sqrt{(1 - v^2/c^2)}} = \gamma m_o$$

so $m > m_o$

m_o = object's rest mass,
m = object's mass when moving at v

This diagram shows time dilation, mass increase, and length contraction as the speed approaches the speed of light:

- duration of 1 sec on a moving clock
- length of a moving meter stick
- mass of a moving standard kilogram

Time dilation and mass increase

Textbook Figure 10.12

Length contraction

Our last Mort and Velma question

As measured by Velma, her spaceship has a mass of 10,000 kg and a length of 100 m. She moves at 80% of lightspeed relative to Mort. According to Mort's measurements, the mass and length of her spaceship are:

(A) 16,500 kg, 165 m

(B) 6000 kg, 60 m

(C) 6000 kg, 165 m

(D) 16,500 kg, 60 m

(E) This question cannot be answered without knowing which observer is really at rest.

For 80% of lightspeed, the mass increase factor is 1.65 and the length contraction factor is 0.60.