107 Answer Key HW #7- Chapter 11 assignment

Conceptual: 2, 6, 14, 20, 32, 34
Problems: 4, 6

October 26, 2005

1 Conceptual Exercises

2.) "Mort's swimming pool is 20 m long and 10 m wide. If Velma flies lengthwise over the pool at 60% of light-speed, how long and wide will she observe it to be?"

We are asked to consider the situation from Velma's frame - i.e how long and wide she sees the pool - so this means that the pool is moving at 60% of light-speed relative to her. Because the pool is moving, she will observe length contraction of the length (not width!) of the pool: $L_{Velma} = L_{Mort} * \sqrt{1 - s^2/c^2} = 20m * \sqrt{1 - .6^2} = 16m$. Since the width is not going to be contracted (perpendicular to the motion), Velma observes the pool to be $\boxed{\text{16m long by 10 m wide.}}$

6.) "Velma's spaceship is 100 m long and 10 m high as measured by Velma. Roughly how fast must she be moving past Mort in order for him to measure her spaceship to be 50 m long?"

Velma's the proper one, since she's in the spaceship, so $L_{Mort} = L_{Velma} * \sqrt{1 - s^2/c^2}$, with $L_{Mort} = 50m$ and $L_{Velma} = 100m$. This gives us: $1/2 = \sqrt{1 - s^2/c^2}$; solving gives us $\boxed{s = \sqrt{3/4}c \simeq .866c.}$

14.) "Velma, passing Mort at 0.25c, launches a rocket forward at 0.5c. According to Galilean relativity, how fast does the rocket move relative to Mort? How fast according to Einstein? Which answer is correct?"

According to Galilean relativity, we just add the velocities: $\boxed{s_{Galileo} = 0.5c + 0.25c = 0.75c.}$

According to Einstein, we need to take into account time dilation and length contraction. Looking at Table 11.1 on pg. 292, we see that the observed relative speed is $\boxed{s_{Einstein}.667c.}$ A better way is to use the relativity addition of speeds equation: $s_{Einstein} = \frac{0.5c+0.25c}{1+(.5c)(.25c)/c^2} = 2/3c$.

The answer according to Einstein is the "correct" one because it takes the effects of special relativity into account.

20.) "You are in a spaceship moving past Earth at nearly light-speed. You measure your own mass, pulse rate, and size. How have they changed?"

$\boxed{\text{They have not changed!}}$ According to you, you're at rest and everything else is moving at nearly light speed, thus you will measure all lengths, times, and masses in your own frame as normal. Only when someone else not moving with you makes observations will special relativity become apparent.

32.) "If you were in a rocket ship in space accelerating at 2g and you dropped a ball, how would it move as observed by you? What if your acceleration were instead 0.5g? What if you were not accelerating at all?"

If you were $\boxed{\text{not accelerating at all, the ball would not move}}$ relative to you because there is no way to tell the difference between a frame moving at constant velocity and a frame in free fall!

The principle of General Relativity says that you cannot tell the difference between being accelerated in the absence of gravity or not accelerating in the presence of gravity. If you were accelerating at 2g, then, you would not be able to tell the difference between this and being at rest on a planet with gravitational acceleration 2g - thus, you observe the ball to $\boxed{\text{fall}}$ at an $\boxed{\text{acceleration of 2g}}$ relative to you! Similarly, if you were accelerating at 0.5g, then you observe the ball to $\boxed{\text{fall}}$ at an $\boxed{\text{acceleration of 0.5g}}$ relative to you.

34.) "Is a circle (meaning the perimeter of a flat circular area) a space? How many dimensions does it have? Is it a curved space, or is it flat?"

The definition of a space given in the text is an <u>extended region that has no edges or boundaries.</u> The perimeter of a circle does not have any edges or boundaries, since one can continue moving along the perimeter forever, so it $\boxed{\text{is a space.}}$ There is only one choice of direction along the perimeter: forward or backward. The perimeter, then, $\boxed{\text{has dimension 1.}}$ You can determine that the space $\boxed{\text{is curved}}$ by sending two people opposite directions along the perimeter - eventually they will meet, implying that the space has some curvature! In flat spaces, people moving in parallel directions never cross paths.

2 Problems

4.) "Show that, if all the energy released (transformed) in fissioning 1 kg of uranium were used to heat water, about 2 billion kg of water could be heated from freezing to boiling. [Assume that the uranium's rest-mass is reduced by about 1%. Roughly 4 J of thermal energy is needed to raise the temperature of 1 gram of water by 1°.] How many tonnes of water is this (a tonne is 1000 kg). How many large highway trucks, each loaded to about 30 tonnes, would be needed to carry this much water?"

We first start by noting that all the energy released by fissioning the uranium will go to heating the water: $Energy\, from\, Uranium = Energy\, to\, heat\, water$.

Because only 1 % of the 1 kg rest-mass of the uranium is converted to energy, the energy released by uranium is: $Energy\ from\ Uranium = m * c^2 = .01kg * c^2$, where $c = 3 * 10^8\ m/s$.

We are told that it takes 4 J to raise 1 gram of water 1°, so it takes 400 J to heat 1 gram of water from freezing (0°) to boiling (100°), or $\frac{400J}{g} = \frac{400{,}000J}{kg}$. The total amount of heat energy needed to raise some amount of water M_{water} from freezing to boiling is then $Energy\ to\ heat\ water = 400,000J/kg *\ M_{water}$.

We now have both sides of our energy equation:

$$.01kg{*}c^2 = 400,000J/kg{*}M_{water} \Rightarrow M_{water} = 2.25{*}10^9\ kg = \boxed{\text{2.25 billion kg}} \tag{1}$$

If there are 1000 kg for every tonne, the amount of water that can be heated is $2.25{*}10^9\ kg/(1000\ kg/tonne) = 2.25{*}10^6\ tonnes$, and $\boxed{2.25 * 10^6\ tonnes}$ can fit on $\boxed{7.5 * 10^4\ trucks = 74,000\ trucks!}$

6.) "Use the answer to the preceding question to find how many kilograms of sunlight hit Earth every second."

From the back of the book, the answer to the previous question was that $1.8{*}10^{17}J$ hit the Earth every second. Using $E = mc^2$, we can convert Joules into kilograms to find that $\boxed{1.8 * 10^{17}J/c^2 = 2\ kg}$ hit the Earth every second due to sunlight.