Physics 100 HW 11 (Due 4/11/07 **Wednesday**) Name S. Olsen

1. In a universe where the speed of light is only 50 km/hr, a football player scores an apparently game-winning touchdown just as the final gun is fired. The coach of the opposing team demands that Albert Einstein, who is moonlighting as the referee, review the play on instant replay. The replay from a camera on the football field shows that the pass was completed before the gun was fired, while the replay from a camera on the Goodyear Blimp, flying overhead at a speed of 40 km/hr, shows the gun being fired before the ball was caught. Could both replays be correct? Explain.

Yes. According to Einstein, the time interval between events can be different for different observers, depending on their state of motion.

2. How much mass is converted into energy in a 1000 Megawatt nuclear power plant during one year of operation? (1 Megawatt = 1 million watts = 10^6 watts = 10^6 joules/sec)

Energy = Power × time $\qquad E_{1yr} = 1.0\times10^{9}$ watts $\times 3.15\times10^{7}$ s $= 3.15\times10^{16}$ J/yr

$mc^2 = E$

$\Rightarrow m = \frac{E}{c^2} \Rightarrow m_{1yr} = \frac{E_{1yr}}{c^2} = \frac{3.15\times10^{16}\ \text{J/yr}}{9\times10^{16}\ \text{m}^2/\text{s}^2} = 0.35$ kg/yr

3. The Sun's mass is 2×10^{30}kg and its total power output is 4×10^{26} Watts. a) What fraction of the Sun's mass is converted to energy each second? b) each year?

a) $E = P\times t = 4\times10^{26}\,\text{W}\cdot 1\text{s} = 4\times10^{26}\,\text{J} \quad m = E/c^2 = \frac{4\times10^{26}\,\text{J}}{9\times10^{16}\,\text{m}^2/\text{s}^2} = 4.4\times10^{9}$ kg

$m^{1s}/m_{\odot} = \frac{4.4\times10^{9}\,\text{kg}}{2\times10^{30}\,\text{kg}} = 2.2\times10^{-21}$

b) multiply ans in a) by 3.15×10^{7} s $\Rightarrow \frac{m^{1yr}}{m_{\odot}} = 7\times10^{-14}$

4. What type of star would you guess to be cooler, *red* giants or *white* dwarfs? Why?

red giants would be cooler

long wave lengths = cooler

5. When paper burns, the flame is orange. When natural gas burns the flame is blue. What does this tell us about the differences in temperature between a burning paper and burning natural gas?

natural gas must burn much hotter than Paper

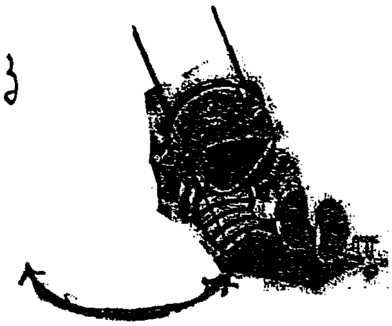
6. When soldiers use infrared-sensitive glasses during nighttime battles, what infrared light are they looking for?

black body IR radiation emitted from the bodies of enemy soldiers

7. A 15 kg child plays on a swing has a natural frequency of 0.3Hz. She swings with an amplitude such that her maximum vertical displacement is 1 m.

a) What is the quantum of energy for this swing?

$E_{quant} = h \cdot f = 6.6 \times 10^{-34} Js \times 0.3 Hz$
$= 2.0 \times 10^{-34} J$



b) What is her total energy?

$E_{tot} = mg\, h_{max}$
$= 15kg \cdot 10 m/s^2 \cdot 1m = 150 J$ $\quad h_{max} = 1m$

c) What is the value of her quantum number n for her motion?

$E_{TOT} = n\, E_{quant} \Rightarrow n = \frac{E_{TOT}}{E_{quanta}} = \frac{150J}{2.0 \times 10^{-34} J} = 75 \times 10^{34}$

number of quanta

8. Consider the previous problem except now imagine that the child lives in a universe where Planck's constant is $h = 100Js$ (as opposed to its value in our universe of $h = 6.6 \times 10^{-34} Js$).

a) What would her quantum of energy be?

$E_{quant} = hf = 100 Js \cdot 0.3 Hz = 30 J$

b) What would the quantum number n of her motion be?

$n = \frac{E_{TOT}}{E_{quant}} = \frac{150J}{30J} = 5$

c) Describe what the girl's motion on the swing would look in the this $h = 100\ Js$ universe.

She would only swing at certain quantized max. heights, & not in between. If you push her, but not hard enough to increase her energy by 30J, she won't swing higher

9. Even though people studied the laws of nature throughout history, quantum effects were not realized until the twentieth century. Why were they so easy to overlook?

since, in fact, h is a very small number, quanta are tiny compared to energies people experience & are aware of in daily life, & therefore not noticeable