

## Applied Physics – Problem set #10

1. A fast train approaches a bridge with length  $d_0 = 400\text{m}$  along a straight track. The length of the train when stationary is  $l_0 = 2d_0$ . Two men are standing on the two ends of the bridge with brushes, and they put a mark on the front end and rear end of the train at the same time, as measured by them. What is the speed of the train? How much time passes between marking the front of the train and the end of the train, as observed by the passengers on the moving train?
2. When high energy cosmic particles (mostly protons) hit the upper atmosphere,  $\pi$ -mesons are created at about 100km altitude. These particles decay very quickly (their half-time is:  $T_{1/2} = 2\mu\text{s}$ ), thus even traveling at the speed of light, they would not have enough time to reach the ground. However, these particles are still observed at the surface, and this fact proves the relativistic time dilation. What percentage of the speed of light should the  $\pi$ -mesons travel with respect to the Earth, so that they cover the 100km distance in  $2\mu\text{s}$  proper time? (Thus, half of the  $\pi$ -mesons will reach the ground.)
3. The surface temperature of the Sun is about 5800K, and the peak of its thermal radiation spectrum is at the  $\lambda_{max} = 0.5\mu\text{m}$  wavelength (green color).
  - a) Using these data, calculate  $\lambda_{max}$  for the following objects:
    - (i) 10000 K welding arc light (ii) 37°C human (iii) 2.7 K cosmic background radiation of space.
  - b) Calculate how much mass the Sun loses due to this radiated energy every second. Use the formulas for black body radiation!
  - c) What is the energy flow density at the distance of the Earth? (This is called solar constant, and its standard value is 1390 Joules over 1 square meter in 1 sec.)
  - d) Calculate the equilibrium temperature of the Earth if it can be considered as a perfect black body with homogeneous temperature on its surface.
4. A laser beam in vacuum has a diameter of 1.2mm, and its average power is 5mW. What is the intensity of this beam, and how much pressure does it create on a reflecting surface?
5. In the atmosphere of the Earth, for every  $8.6 \cdot 10^{11}$  of  $^{12}\text{C}$  nuclei there is one  $^{14}\text{C}$  radioactive isotope with a half-life of 5730 years.
  - a) Calculate the activity of 1mol atmospheric  $\text{CO}_2$  due to the  $^{14}\text{C}$ !
  - b) How many years does it take for the activity to decrease by 20%?

### Homework 10

1. One of two identical twins goes for an interstellar space travel. His spaceship travels at  $4c/5$  speed and reaches an exoplanet 20 lightyears away, then comes back at the same speed. How much younger will he be than his brother when he arrives back?
2. A furnace with internal temperature 800°C has a door with dimensions 0.2 x 0.25 m<sup>2</sup>. The temperature of the outer environment is 30°C. How much heating power is needed to keep the internal temperature constant if the door of the furnace is open?
3. How many years ago was the tree chopped down if the specific activity of the  $^{14}\text{C}$  in its remainder is 70% of the freshly chopped down trees? The half-life of  $^{14}\text{C}$  is 5730 years.