

**Problems**

1. **SMM, Chapter 1, Problem 6.**
2. **SMM, Chapter 1, Problem 7.**
3. Muons are elementary particles with a (proper) lifetime of 2.2  $\mu\text{s}$ . They are produced with very high speeds in the upper atmosphere when cosmic rays (high-energy particles from space) collide with air molecules. Take the height  $L_0$  of the atmosphere to be 100 km in the reference frame of the Earth. (a) What is the minimum speed that enables the muons to survive the journey to the surface of the Earth? (b) In the reference frame of the muon, what is the apparent thickness of the Earth's atmosphere?
4. The mean proper lifetime of  $\pi^+$  mesons (other elementary particles) is  $2.5 \times 10^{-8}$  s. In a beam of  $\pi^+$  mesons of speed  $0.99c$ , what is the average distance a meson travels before it decays? What would this value be if the relativistic time dilation did not exist?
5. **SMM, Chapter 1, Problem 24.**
6. As a follow up to problem 2 from the previous homework assignment, show that the scalar wave equation,  $\frac{\partial^2 \varphi}{\partial x^2} + \frac{\partial^2 \varphi}{\partial y^2} + \frac{\partial^2 \varphi}{\partial z^2} = \frac{1}{c^2} \frac{\partial^2 \varphi}{\partial t^2}$ , is invariant under Lorentz transformations.
7. Estimate the number of jellybeans needed to fill a one-liter jar.