PHYS 201 Winter 2010

Recitation Problems (Week 9)

All problems taken from *University Physics,* Young and Freedman, 12th Ed.

37.3. **IDENTIFY and SET UP:** The problem asks for u such that $\Delta t_0 / \Delta t = \frac{1}{2}$.

EXECUTE: $\Delta t = \frac{\Delta t_0}{\sqrt{1-u^2/c^2}}$ gives $u = c\sqrt{1-(\Delta t_0/\Delta t)^2} = (3.00\times10^8 \text{ m/s})\sqrt{1-\left(\frac{1}{2}\right)^2} = 2.60\times10^8 \text{ m/s}$; $\frac{u}{c} = 0.867$

Jet planes fly at less than ten times the speed of sound, less than about 3000 m/s. Jet planes fly at much lower speeds than we calculated for u.

37.9. **IDENTIFY and SET UP:** $l = l_0\sqrt{1-u^2/c^2}$. The length measured when the spacecraft is moving is $l = 74.0$ m; l_0 is the length measured in a frame at rest relative to the spacecraft.

EXECUTE: $l_0 = \frac{l}{\sqrt{1-u^2/c^2}} = \frac{74.0 \text{ m}}{\sqrt{1-(0.600c/c)^2}} = 92.5 \text{ m}$.

EVALUATE: $l_0 > l$. The moving spacecraft appears to an observer on the planet to be shortened along the direction of motion.

37.11. **IDENTIFY and SET UP:** The 2.2 μs lifetime is Δt_0 and the observer on earth measures Δt. The atmosphere is moving relative to the muon so in its frame the height of the atmosphere is l and l_0 is 10 km.

EXECUTE: **(a)** The greatest speed the muon can have is c, so the greatest distance it can travel in 2.2×10^{-6} s is $d = vt = (3.00\times10^8 \text{ m/s})(2.2\times10^{-6} \text{ s}) = 660 \text{ m} = 0.66 \text{ km}$.

(b) $\Delta t = \frac{\Delta t_0}{\sqrt{1-u^2/c^2}} = \frac{2.2\times10^{-6} \text{ s}}{\sqrt{1-(0.999)^2}} = 4.9\times10^{-5} \text{ s}$

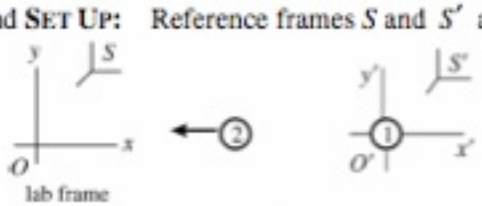
$d = vt = (0.999)(3.00\times10^8 \text{ m/s})(4.9\times10^{-5} \text{ s}) = 15 \text{ km}$

In the frame of the earth the muon can travel 15 km in the atmosphere during its lifetime.

(c) $l = l_0\sqrt{1-u^2/c^2} = (10 \text{ km})\sqrt{1-(0.999)^2} = 0.45 \text{ km}$

In the frame of the muon the height of the atmosphere is less than the distance it moves during its lifetime.

37.19. **IDENTIFY and SET UP:** Reference frames S and S' are shown in Figure 37.19.



Frame S is at rest in the laboratory. Frame S' is attached to particle 1.

Figure 37.19

u is the speed of S' relative to S; this is the speed of particle 1 as measured in the laboratory. Thus $u = +0.650c$. The speed of particle 2 in S' is $0.950c$. Also, since the two particles move in opposite directions, 2 moves in the $-x'$ direction and $v'_x = -0.950c$. We want to calculate v_x, the speed of particle 2 in frame S; use Eq.(37.23).

EXECUTE: $v_x = \frac{v'_x + u}{1 + uv'_x/c^2} = \frac{-0.950c + 0.650c}{1 + (0.950c)(-0.650c)/c^2} = \frac{-0.300c}{1 - 0.6175} = -0.784c$. The speed of the second particle, as measured in the laboratory, is $0.784c$.

EVALUATE: The incorrect Galilean expression for the relative velocity gives that the speed of the second particle in the lab frame is $0.300c$. The correct relativistic calculation gives a result more than twice this.

37.30. The force is found from Eq.(37.32) or Eq.(37.33).

(a) Indistinguishable from $F = ma = 0.145$ N.

(b) $\gamma^3 ma = 1.75$ N.

(c) $\gamma^3 ma = 51.7$ N.

(d) $\gamma ma = 0.145$ N, 0.333 N, 1.03 N.

37.53. **(a)** $E = \gamma mc^2$ and $\gamma = 10 = \frac{1}{\sqrt{1-(v/c)^2}} \Rightarrow \frac{v}{c} = \sqrt{\frac{\gamma^2 - 1}{\gamma^2}} \Rightarrow \frac{v}{c} = \sqrt{\frac{99}{100}} = 0.995.$

(b) $(pc)^2 = m^2 v^2 \gamma^2 c^2, E^2 = m^2 c^4 \left(\left(\frac{v}{c}\right)^2 \gamma^2 + 1\right)$

$$\Rightarrow \frac{E^2 - (pc)^2}{E^2} = \frac{1}{1 + \gamma^2 \left(\frac{v}{c}\right)^2} = \frac{1}{1 + (10/(0.995))^2} = 0.01 = 1\%.$$