1. a) Peter is in the reference frame "airplane" (observer in motion, moving *with* the airplane): $5.00\ \frac{m}{s}$

   b) The velocity of the ball is extremely small compared to the velocity of light. Thus, we can add the (nonrelativistic) velocities

   $v_{airplane} + v_{ball} = 250\ \frac{m}{s} + 5.00\ \frac{m}{s} = 255\ \frac{m}{s}$

   c) $v_{airplane} - v_{ball} = 250\ \frac{m}{s} - 5.00\ \frac{m}{s} = 245\ \frac{m}{s}$

   d) The speed of light does not depend on the reference frame in which it is measured: $c = 299'792'458\ \frac{m}{s}$

   e) The speed of light is a constant, regardless of the reference frame in which it is measured: $c = 299'792'458\ \frac{m}{s}$

   f) The speed of light has the same value, regardless of the velocity of the source of light or the observer: $c = 299'792'458\ \frac{m}{s}$

2. a) slower: time passes more slowly in a reference frame in motion (from the perspective of an “observer at rest”, *not* moving with the spacecraft).

   b) $$\Delta t = \frac{\Delta t_0}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{12.00\ h}{\sqrt{1 - \frac{\left(\frac{100.00 \cdot 10^6\ \frac{m}{s}}{3.6}\right)^2}{\left(299'792'458\ \frac{m}{s}\right)^2}}} = 12.05\ h = \underline{\underline{12\ h\ 3\ min\ 7\ s}}$$

3. $$v = c \cdot \sqrt{1 - \left(\frac{\Delta t_0}{\Delta t}\right)^2} = 299'792'458\ \frac{m}{s} \cdot \sqrt{1 - \left(\frac{27'933\ s}{27'945\ s}\right)^2} = \underline{\underline{8784714\ \frac{m}{s}}} = \underline{\underline{31'624'970\ \frac{km}{h}}}$$

4. $\Delta t = 2 \cdot \Delta t_0$ $$v = 299'792'458\ \frac{m}{s} \cdot \sqrt{1 - \left(\frac{1}{2}\right)^2} = 259'627'884\ \frac{m}{s} = \underline{\underline{9.35 \cdot 10^8\ \frac{km}{h}}}$$

5. $$\Delta t = \frac{\Delta t_0}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{2.2\ \mu s}{\sqrt{1 - (0.9994)^2}} = \underline{\underline{63.5\ \mu s}}$$

6. a) shorter

b) $\Delta\ell_{\text{bewegt}} = \Delta\ell_{\text{ruhend}} \cdot \sqrt{1-\frac{v^2}{c^2}} = 1.000\text{ m}\cdot\sqrt{1-\frac{\left(\frac{100.00\cdot 10^6}{3.6}\ \frac{\text{m}}{\text{s}}\right)^2}{\left(299'792'458\ \frac{\text{m}}{\text{s}}\right)^2}} = 0.9957\text{ m} = \underline{\underline{996\text{ mm}}}$

c) same length: $\underline{996\text{ mm}}$

7. $\frac{\Delta\ell_{\text{bewegt}}}{\Delta\ell_{\text{ruhend}}} = \sqrt{1-\frac{v^2}{c^2}}$ $\quad \left(\frac{\Delta\ell_{\text{bewegt}}}{\Delta\ell_{\text{ruhend}}}\right)^2 = 1-\frac{v^2}{c^2}$ $\quad \frac{v^2}{c^2} = 1-\left(\frac{\Delta\ell_{\text{bewegt}}}{\Delta\ell_{\text{ruhend}}}\right)^2$ $\quad v^2 = c^2\cdot\left[1-\left(\frac{\Delta\ell_{\text{bewegt}}}{\Delta\ell_{\text{ruhend}}}\right)^2\right]$

$$v = c\cdot\sqrt{1-\left(\frac{\Delta\ell_{\text{bewegt}}}{\Delta\ell_{\text{ruhend}}}\right)^2} = 299'792'458\ \frac{\text{m}}{\text{s}}\cdot\sqrt{1-\left(\frac{999.9\text{ mm}}{1000.0\text{ mm}}\right)^2} = 4'239'599.6\ \frac{\text{m}}{\text{s}} = \underline{\underline{4.240\cdot 10^6\ \frac{\text{m}}{\text{s}}}}$$

$$= \underline{\underline{1.526\cdot 10^7\ \frac{\text{km}}{\text{h}}}}$$

8. $\Delta\ell_{\text{ruhend}} = \frac{\Delta\ell_{\text{bewegt}}}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{568\text{ m}}{\sqrt{1-\frac{\left(\frac{1.50\cdot 10^8}{3.6}\ \frac{\text{m}}{\text{s}}\right)^2}{\left(299'792'458\ \frac{\text{m}}{\text{s}}\right)^2}}} = \underline{\underline{574\text{ m}}}$

9. a) $s_{\text{Myon}} = v\cdot t_{\text{Myon}} = 0.9994\cdot 299'792'458\ \frac{\text{m}}{\text{s}}\cdot 2.2\cdot 10^{-6}\text{ s} = \underline{\underline{659\text{ m}}}$

b) From the Myon’s perspective, the reference frame „Earth“ is the reference frame in motion, while the ”Myon” is at rest. That is, the Earth is passing by the Myon at almost the speed of light. Thus, from the Myon’s perspective, the Earth’s length is shorter: $s_{\text{Myon}} = \Delta\ell_{\text{in motion}}$

$$\Delta\ell_{\text{ruhend}} = \frac{\Delta\ell_{\text{bewegt}}}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{\Delta\ell_{\text{bewegt}}}{\sqrt{1-\left(\frac{0.9994\cdot c}{c}\right)^2}} = \frac{659\text{ m}}{\sqrt{1-(0.9994)^2}} = 19'027\text{ m} = \underline{\underline{19\text{ km}}}$$