Chapter 28

Problems & Exercises

1.

(a) 1.0328

(b) 1.15

3.

5.96×10^{-8} s

5.

$0.800c$

7.

$0.140c$

9.

(a) $0.745c$

(b) $0.99995c$ (to five digits to show effect)

11.

(a) 0.996

(b) γ cannot be less than 1.

(c) Assumption that time is longer in moving ship is unreasonable.

12.

48.6 m

14.

(a) 1.387 km = 1.39 km

(b) 0.433 km

(c) $L = \frac{L_0}{\gamma} = \frac{1.387 \times 10^3 \text{ m}}{3.20} = 433.4 \text{ m} = 0.433 \text{ km}$

Thus, the distances in parts (a) and (b) are related when $\gamma = 3.20$.

16.

(a) 4.303 y (to four digits to show any effect)

(b) 0.1434 y

(c) $\Delta \mathrm{t} = \Delta \mathrm{t}_0 \Rightarrow \gamma = \frac{\Delta \mathrm{t}}{\Delta \mathrm{t}_0} = \frac{4.303 \text{ y}}{0.1434 \text{ y}} = 30.0$

Thus, the two times are related when =30.00.

18.

(a) 0.250

(b) γ must be 1

(c) The Earth-bound observer must measure a shorter length, so it is unreasonable to assume a longer length.

20.

(a) 0.909c

(b) 0.400c

22.

0.198c

24.

a) 658 nm

b) red

c) $v/\mathrm{c} = 9.92 \times 10^{-5}$ (negligible)

26.

0.991c

28.

$-0.696c$

30.

0.01324c

32.

$u' = c$, so

$$\begin{aligned} \boldsymbol{u} &= \frac{v+u\prime}{1+(vu\prime/c^2)} = \frac{v+c}{1+(vc/c^2)} = \frac{v+c}{1+(v/c)} \\ &= \frac{c(v+c)}{c+v} = \boldsymbol{c} \end{aligned}$$

34.

a) 0.99947c

b) 1.2064×10^{11} y

c) 1.2058×10^{11} y (all to sufficient digits to show effects)

35.

$4.09 \times 10^{-19}\ \mathrm{kg \cdot m/s}$

37.

(a) $3.000000015 \times 10^{13}$ kg $\cdot$ m/s.

(b) Ratio of relativistic to classical momenta equals 1.000000005 (extra digits to show small effects)

39.

2.9957×10^{8} m/s

41.

(a) 1.121×10^{-8} m/s

(b) The small speed tells us that the mass of a proton is substantially smaller than that of even a tiny amount of macroscopic matter!

43.

8.20×10^{-14} J

0.512 MeV

45.

2.3×10^{-30} kg

47.

(a) 1.11×10^{27} kg

(b) 5.56×10^{-5}

49.

7.1×10^{-3} kg

7.1×10^{-3}

The ratio is greater for hydrogen.

51.

208

$0.999988c$

53.

6.92×10^{5} J

1.54

55.

(a) $0.914c$

(b) The rest mass energy of an electron is 0.511 MeV, so the kinetic energy is approximately 150% of the rest mass energy. The electron should be traveling close to the speed of light.

57.

90.0 MeV

59.

$$E^2 = p^2c^2 + m^2c^4 = \gamma^2 m^2 c^4 \text{, so that}$$

$$p^2c^2 = \left(\gamma^2 - 1\right)m^2c^4 \text{ , and therefore}$$

(a) $\frac{(pc)^2}{(mc^2)^2} = \gamma^2 - 1$

(b) yes

61.

1.07×10^3

63.

6.56×10^{-8} kg

4.37×10^{-10}

65.

$0.314c$

$0.99995c$

67.

(a) 1.00 kg

(b) This much mass would be measurable, but probably not observable just by looking because it is 0.01% of the total mass.

69.

(a) 6.3×10^{11} kg/s

(b) 4.5×10^{10} y

(c) 4.44×10^9 kg

(d) 0.32%

73.

(a) $L = 1000.0\sqrt{1 - \frac{(0.6c)^2}{c^2}} = 800.00$ m

(b) $L = 1000.0\sqrt{1 - \frac{(0.6c)^2}{c^2}} = 800.00$ m

(c) No.

(d) Yes.