26.1 Classical Relativity and the Michelson–Morley Experiment

1. (d). 2. (c). 3. (b)

7. (a) The speed of sound relative to you is $v = 345\text{ m/s} + 10.0\text{ m/s} = 355\text{ m/s}$.

So $t = \dfrac{d}{v} = \dfrac{1.20 \times 10^3\text{ m}}{355\text{ m/s}} = \boxed{3.38\text{ s}}$.

(b) The speed of sound relative to you is $v = 345\text{ m/s} + (-10.0\text{ m/s}) = 335\text{ m/s}$.

So $t = \dfrac{1.20 \times 10^3\text{ m}}{335\text{ m/s}} = \boxed{3.58\text{ s}}$.

$\boxed{8}$. (a) The velocity relative to ground is $200\text{ km/h} + (-35\text{ km/h}) = \boxed{165\text{ km/h}}$.

(b) The velocity relative to ground is $200\text{ km} + 25\text{ km/h} = \boxed{225\text{ km/h}}$.

$\boxed{10}$. (a) The time it takes is $\boxed{\text{(1) longer}}$. Although it takes less time on the trip in the direction of the current, it takes more time on the trip in the direction opposite the current. The extra time in the opposite direction more than offsets the lesser time in the direction of the current.

(b) When there is no current, the time is $t_1 = \dfrac{1000\text{ m}}{20\text{ m/s}} + \dfrac{1000\text{ m}}{20\text{ m/s}} = 100\text{ s} = \boxed{1.7\text{ min}}$.

In the direction of current: the relative velocity is $20\text{ m/s} + 5.0\text{ m/s} = 25\text{ m/s}$.

In the direction opposite the current: the relative velocity is $20\text{ m/s} - 5.0\text{ m/s} = 15\text{ m/s}$.

So the time is $t_2 = \dfrac{1000\text{ m}}{25\text{ m/s}} + \dfrac{1000\text{ m}}{15\text{ m/s}} = 107\text{ s} = \boxed{1.8\text{ min}}$

26.2 The Postulates of Special Relativity and the Relativity of Simultaneity

12. (c). 13. (a). 14. (d).

17. In frame *O*, the bullet takes 1 s to hit target. Light takes 10^{-6} s to get to the target (the time for light of speed 3.00×10^8 m/s to travel 300 m). Frame *O*' would have to travel to the right. The light flashes from the gun reach the target in 10^{-6} s. The observer in frame *O*' would have to cover the 300 m in less than 10^{-6} s to intercept the signals at the same time, which means $v > c$. Since $v > c$ is not possible, all observers agree that the gun fires before the bullet hits the target.

26.3 The Relativity of Length and Time: Time Dilation and Length Contraction

19. (c), her friend does appear the same height, because the height is perpendicular to their relative velocity.

20. (b), a moving clock appears to run slowly.

21. (a).

23. $\boxed{\text{No}}$, this is not possible. From the boy's view, the barn is moving at the same speed, so it would appear to contract and be even shorter than 4.0 m.

29. $\Delta t = \dfrac{\Delta t_o}{\sqrt{1 - v^2/c^2}}$, ☞ $v = \sqrt{1 - \Delta t_o^{\,2}/\Delta t^2}\; c = \sqrt{1 - 2.20^2/34.8^2}\; c = \boxed{0.998c}$.

31. (a) Compared with the spaceship clock, an Earth-based clock will measure $\boxed{\text{(1) a longer time}}$ due to time dilation.

(b) The time on the spaceship is the proper time.

The time observed on Earth is $\Delta t = \dfrac{4.30 \text{ light-years}}{0.60c} = 7.17 \text{ years} = \boxed{7.2 \text{ years}}$.

$$\Delta t = \frac{\Delta t_o}{\sqrt{1 - v^2/c^2}}, \quad ☛ \quad \Delta t_o = \Delta t\sqrt{1 - v^2/c^2} = (7.17 \text{ y})\sqrt{1 - 0.60^2} = \boxed{5.7 \text{ years}}.$$

36. The time observed by an Earth-bound observer is $t = \dfrac{1.00 \text{ light-year}}{0.700c} = 1.429$ years.

The proper time is the one according to the pilot of the spaceship.

$$\Delta t = \frac{\Delta t_o}{\sqrt{1 - v^2/c^2}}, \quad ☛ \quad \Delta t_o = \Delta t\sqrt{1 - v^2/c^2} = (1.429 \text{ years})\sqrt{1 - 0.700^2} = \boxed{1.02 \text{ years}}$$

26.4 Relativistic Kinetic Energy, Momentum, Total Energy, and Mass–Energy Equivalence

40. (a). 41. (b). 42. (b).

59. (a) $E_o = mc^2 = (9.11 \times 10^{-31} \text{ kg})(3.00 \times 10^8 \text{ m/s})^2 = 8.20 \times 10^{-14} \text{ J} \approx 0.511 \text{ MeV}$.

$$K = E - E_o = E_o(\gamma - 1) = E_o\left[\frac{1}{\sqrt{1-(v/c)^2}} - 1\right] = (0.511 \text{ MeV})\left[\frac{1}{\sqrt{1-0.950^2}} - 1\right] = \boxed{1.13 \text{ MeV}}.$$

(b) $E = K + E_o = 1.13 \text{ MeV} + 0.511 \text{ MeV} = \boxed{1.64 \text{ MeV}}$.

26.5 The General Theory of Relativity

63. (a). 64. (d).

65. (c), because the Schwarzschild radius defines the event horizon.

69. $\rho = \dfrac{m}{V} = \dfrac{2.0 \times 10^{30} \text{ kg}}{4\pi(3.0 \times 10^3)^3/3} = \boxed{1.8 \times 10^{19} \text{ kg/m}^3}$.

*26.6 Relativistic Velocity Addition

71. $v = 7.5 \times 10^7 \text{ m/s} = 0.25c$. $u = \dfrac{v + u'}{1 + vu'/c^2} = \dfrac{0.25c + 0.20c}{1 + (0.25)(0.20)} = \boxed{0.43c}$.

Comprehensive Exercises

$\boxed{76}$. (a) The answer is $\boxed{\text{(1) the astronaut in the ship}}$.

(b) $\Delta t = \dfrac{\Delta t_o}{\sqrt{1 - v^2/c^2}}, \quad ☛ \quad \Delta t_o = \sqrt{1 - v^2/c^2}\,\Delta t.$

So the time difference is $\Delta t - \Delta t_o = \left(1 - \sqrt{1 - v^2/c^2}\right)t = \left(1 - \sqrt{1 - 0.60^2}\right)(24 \text{ h}) = \boxed{4.8 \text{ h}}$.

(c) $L = L_o\sqrt{1 - v^2/c^2}, \quad ☛ \quad L_o = \dfrac{L}{\sqrt{1 - v^2/c^2}} = \dfrac{110 \text{ m}}{\sqrt{1 - 0.60^2}} = \boxed{1.4 \times 10^2 \text{ m}}$.