PHYSICS

BOOKS - RESNICK AND HALLIDAY PHYSICS (HINGLISH)

RELATIVITY

Sample Problem

1. Your starship passes Earth with a relative speed of 0.9990c. After traveling 10.0 y (your

(time), you stop at lookout post LP13, turn, and then travel back to Earth with the same relative speed. The trip back takes another 10.0y (your time). How long does the round trip take according to measurements made on Earth? (Neglect any effects due to the accelerations involved with stopping, turning, and getting back up to speed.)

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2. The elementary particle known as the positive kaon (K^+) is unstable in that it can decay (transform) into other particles. Although the decay occurs randomly, we find that, on average, a positive kaon has a lifetime of 0.1237 μs when stationary-that is, when the lifetime is measured in the rest frame of the kaon. If a positive kaon has a speed of 0.990c relative to a laboratory reference frame when the kaon is produced, how far can it travel in that frame during its lifetime according to classical physics (which is a reasonable approximation for speeds much less than c) and according to special relativity (which is correct for all physically possible speeds)?

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3. In Fig. 36-10, Sally (at point A) and Sam's spaceship (of proper length $L_0 = 230m$) pass each other with constant relative speed v. Sally measures a time interval of 3.57 μs for the ship to pass her (from the passage of point B in Fig. 36-10a to the passage of point C in Fig.

36-10b). In terms of c, what is the relative speed v between Sally and the ship?

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4. Caught by surprise near a supernova, you race away from the explosion in your spaceship, hoping to outrun the high-speed material ejected toward you. Your Lorentz factor γ relative to the inertial reference frame of the local stars is 22.4.

To reach a safe distance, you figure you need to cover 9.00×10^{16}m as measured in the reference frame of the local stars. How long will the flight take, as measured in that frame?

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5. Caught by surprise near a supernova, you race away from the explosion in your spaceship, hoping to outrun the high-speed material ejected toward you. Your Lorentz factor γ relative to the inertial reference frame of the local stars is 22.4.

How long does that trip take according to you (in your reference frame)?

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6. An Earth starship has been sent to check an Earth outpost on the planet P1407, whose moon houses a battle group of the often hostile Reptulians. As the ship follows a straightline course first past the planet and then past the moon, it detects a high-energy microwave burst at the Reptulian moon base and then, 1.10 s later, an explosion at the Earth outpost, which is 4.00×10^8 m from the Reptulian base as measured from the ship's reference frame. The Reptulians have obviously attacked the Earth outpost, and so the starship begins to prepare for a confrontation with them.

The speed of the ship relative to the planet and its moon is 0.980c. What are the distance and time interval between the burst and the explosion as measured in the planet-moon frame (and thus according to the occupants of the stations)?

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7. An Earth starship has been sent to check an Earth outpost on the planet P1407, whose moon houses a battle group of the often hostile Reptulians. As the ship follows a straightline course first past the planet and then past the moon, it detects a high-energy microwave burst at the Reptulian moon base and then, 1.10 s later, an explosion at the Earth outpost, which is 4.00×10^8 m from the Reptulian base as measured from the ship's reference frame. The Reptulians have obviously attacked the Earth outpost, and so the starship begins to prepare for a confrontation with them.

What is the meaning of the minus sign in the value for $\Delta t'$?

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8. An Earth starship has been sent to check an Earth outpost on the planet P1407, whose moon houses a battle group of the often hostile Reptulians. As the ship follows a straightline course first past the planet and then past the moon, it detects a high-energy microwave burst at the Reptulian moon base and then, 1.10 s later, an explosion at the Earth outpost, which is 4.00×10^8 m from the Reptulian base as measured from the ship's reference frame. The Reptulians have obviously attacked the Earth outpost, and so the starship begins to prepare for a confrontation with them.

Did the burst cause the explosion, or vice versa?

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9. What is the total energy E of a 2.53 MeV electron?

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10. What is the magnitude p of the electron's momentum, in the unit MeV/c? (Note that c is the symbol for the speed of light and not itself a unit.)

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11. The most energetic proton ever detected in the cosmic rays coming to Earth from space had an astounding kinetic energy of 3.0×10^{20}eV (enough energy to warm a teaspoon of water by a few degrees).

What were the proton's Lorentz factor γ and speed v (both relative to the ground-based detector)?

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12. The most energetic proton ever detected in the cosmic rays coming to Earth from space had an astounding kinetic energy of 3.0×10^{20}eV (enough energy to warm a teaspoon of water by a few degrees).

Suppose that the proton travels along a diameter of the Milky Way galaxy $(9.8 \times 10^4 ly)$. Approximately how long does the proton take to travel that diameter as measured from the common reference frame of Earth and the Galaxy?

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13. The most energetic proton ever detected in the cosmic rays coming to Earth from space had an astounding kinetic energy of

3.0×10^{20}eV (enough energy to warm a teaspoon of water by a few degrees).

How long does the trip take as measured in the reference frame of the proton?

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Checkpoint

1. In Fig frame S' has velocity 0.90c relative to frame S. An observer in frame S' measures two events as occurring at the following spacetime coordinates: event Yellow at (5.0m, 20ns) and event Green at (-2.0m, 4.5 ns). An observer in frame S wants to find the temporal separation $\Delta t_{GY} = t_G - t_Y$ between the events. (a) Which equation in Table 36-2 should be used? (b) Should +0.90c or -0.90c be substituted for v in the parentheses on the equation's right side and in the Lorentz factor γ? What value should be substituted into the (c) first and (d) second term in the parentheses?

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2. Are (a) the kinetic energy and (b) the total energy of a 1GeV electron more than, less than, or equal to those of a 1 GeV proton?

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Problems

1. Ovserver S detects two flashes of light. A big flash occurs at $x_1 = 1200m$ and , $5.00\mu s$ later, a small flash occurs at $x_2 = 700m$. As detected by observer S', the two flashes occur at a single coordinate x'. (a) What is the speed parameter of S', and (b) is S' moving in the positive or negative direction of the x axis? To S', (c) which flash occurs first and (d) what is the time interval between the flashes?

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2. Apply the binomial theorem (Appendix E) for the kinetic energy of a particle. (a) Retain the first two terms of the expansion to show the kinetic energy in the form

K = (first term) + (second term).

The first term is the classical expression for kinetic energy. The second term is the first-order correction to the classical expression. Assume the particle is an electron. If its speed v is c/20, what is the value of (b) the classical exopression and (c) the first-order correction? If the electron's speed is 0.85c, what is the value of (d) the classical expression and (e) the first-order correction? (f) At what speed parameter β does the first-order correction become 10% on greater of the classical expression?

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3. How much work must be done to increase the speed of an electron (a) from 0.18c to 0.20c and (b) from 0.97c to 0.99c? Note that the speed increase is 0.01c in both cases.

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4. (a) If m is a particle's mass, p is its momentum magnitude, and K is its kinetic energy, show that

$$m = \frac{(pc)^2 - K^2}{2Kc^2}$$

(b) For low particle speeds, show that the right side of the equation reduces to m. (c) If a particle has K = 55.0 MeV when p = 121 MeV/c, what is the ratio m / m_e of its mass to the electron mass?

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5. (a) Assuming that Eq. holds, find how last you would have to go through a red light to have it appear green. Take 620 nm as the wavelength of red light and 540 nm as the eavelength of green light. (b) What would the emission wavelength be if you went twice that speed?

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6. A sodium light source moves in a horizontal circle at a constant speed of 0.100c while emitting light at the proper wavelength of $\lambda_0 = 589.00 nm$. Wavelength λ is measured for that light by a detector fixed at the center of the circle. What is the wavelength shift $\lambda - \lambda_0$?

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7. The mass of an electron is 9.190 381 88×10^{-31} kg. To six significant figures, find (a) γ and (b) β for an electron with kinetic energy K = 300.000 MeV.

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8. A spaceship whose rest length is 280 m has a speed of 0.94c with respect to a certain reference frame. A micrometeorite, also with a speed of 0.94c in this frame, passes the sapceship on an antiparallel track. How long does it take this object to pass the ship as measured on the ship?

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9. What is the minimum energy that is required to break a nucleus of ^{12}C (of mass

11.996 71 u) into three nuclei of ^4He (of mass 4.001 51 u each)?

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10. An armada of spaceships that is 1.00 ly long (as measured in its rest frame) moves with speed 0.850c relative to a ground station is frame S. A messenger travels from the rear of the armada to the front with a speed of 0.950 relative to S. How long does the trip take as measured (a) in the rest frame of the messenger, (b) in the rest frame of the armada. and (c) by an observer in the ground frame S?

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11. The mass of an electron is 9.109 381 88 $\times 10^{-31}$ kg. To eight significant figures, find the following for the given electron kinetic energy: (a) γ and (b) β for K = 1.000 000 0 keV, $(c)\gamma$ and $(d)\beta$ for K = 1.000 000 0 MeV, and then (e) γ and $(f)\beta$ for K = 1.000 000 0 GeV.

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12. A spaceship is moving away from Earth at speed 0.333c. A source on the rear of the ship light at wave length 450 nm according to someone on the ship. What (a) wavelength and (b) color (blue, green, yellow, or red) are detected by someone on Earth watching the ship?

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13. Stellar system Q_1 moves away from us at a speed of 0.800c. Stellar system Q_2, which lies in the same direction in space but is closer to us, moves away from us at speed 0.400c. What multiple of c gives the speed of Q_2 as measured by an observer in the reference frame of Q_1?

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14. As you read this page (on paper or manitor screen), a cosmic ray proton passes along the left-right width of the page with relative speed v and a total energy of 23.16 nJ. According to your measurements, that left-right width is 21.0 cm. (a) What is the width according to the proton's reference frame? How much time did the passage take according to (b) your frame and (c) the proton's frame?

15. The mass of a muon is 207 times the electron mass, the average lifetime of muons at rest is 2.20 μs. In a certain experiment, muons moving through a laboratory are measured to have an average lifetime of 6.90 μs. For the moving muons, what are (a) β, (b) K, and (c) p (in MeV/c)?

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16. Galaxy A is reported to be receding from us with a speed of 0.45c. Galaxy B, located in precisely the opposite direction, is also found to be receding from us at this same speed. What multiple of c gives the recessional speed an observer on Galaxy A would find for (a) our galaxy and (b) Galaxy B?

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17. How much work must be done to increase the speed of an electron from rest to (a) 0.500c, (b) 0.990c, and (c)0.99990c?

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18. We showed that a particle of charge q and mass m will move in a circle of radius r = mv/|q|B when its velocity $\vec{v}$ is perpendicular to a uniform magnetic field $\vec{B}$. We also found that the period T of the motion is independent of speed v. These two results are approximately correct it v << c. For relativistic speeds, we must use the correct equation for the radius:

$$r = \frac{p}{|q|B} = \frac{\gamma m v}{|q|B}$$

(a) Using this equation and the definition of period $(T = 2\pi / v)$, find the correct expression for the period.

(b) Is T independent of v? If a 20.0 MeV electron moves in a circular path in a uniform magnetic field of magnitude 2.20 T, what are (c) the radius according to , (d) the correct radius, (e) the period according to, and (f) the correct period?

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19. Observer S reports that an event occurred on the x axis of his reference frame at $x = 3.00 \times 10^8$m at time t = 1.50 s. Observer S' and her frame are moving in the positive direction of the x axis at a speed of 0.400c. Further, x = x' = 0 at t = t' = 0. What are the (a) spatial and (b) temporal coordinate of the event according to S'? If S' were, instead, moving in the negative direction of the x axis, what would be the (c) spatial and (d) temporal coordinate of the event according to S' ?

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20. An experimenter arranges to trigger two flashbulbs simultaneously, producing a big flash located at the origin of his reference frame and a small flash at x = 30.0 km. An observer moving at a speed of 0.450c in the positive direction of x also views the flashes. (a) What is the time interval between them according to her? (b) Which flash does she says occurs first?

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21. (Come) back to the future. Suppose that a father is 25.0 y older than his daughter. He wants to travel outward from Earth for 2.000 y and then back for another 2.000 y (both intervals as he measures them) such that he is then 25.0 y younger than his daughter. What constant speed parameter β(relative to Earth) is required ?

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22. A clock moves along an x axis at a speed of 0.700c and reads zero as it passes the origin of the axis. (a) Calculate the clock's Lorentz factor. (b) What time does the clock read as it passes x = 180m ?

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23. To four significant figures, find the following when the kinetic energy is 12.00 MeV: (a) γ and $(b)\beta$ for an electron $(E_0 = 0.510$ 998 MeV), $(c)\gamma$ and $(d)\beta$ for a proton

$(E_0 = 9.38.272 MeV)$, and $(e)\gamma$ and $(f)\beta$

for an α particle $(E_0 = 3727.40 MeV)$.

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24. The premise of the planet of the Apes movies and book is that hibernating astronauts travel far into Earth's future, to a time when human civilization has been replaced by an ape civilization. Considering only special relativity, determine how far into

Earth's future the astronauts would travel if they slept for 120.0 y while traveling relative to Earth with a speed of 0.999 90c, first outward from Earth and then back again.

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25. In the reaction $p + {}^{19}F \rightarrow \alpha + {}^{16}O$, the massesare

$m(p) = 1.007825u, \quad m(\alpha) = 4.002603u,$

$m(F) = 18.998405u, \quad m(O) = 15.994915u$

.

Calculate the Q of the reaction from these data.

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26. A rod lies parallel to the x axis of reference frame S, moving along this axis at a speed of 0.892c. Its rest length is 1.70m. What will be its measured length in frame S?

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27. frame S' moves relative to frame S with velocity $0.620c\hat{\imath}$ while a particle moves parallel to the common x and x' axes. An observer attached to frame S' measures the particle's velocity to be 0.47 c$\hat{\imath}$. In terms of c, what is the particle's velocity as measured by an observer attached to frame S according to the (a) relativistic and (b) classsical velocity ransformation? Suppose, instead, that the S' measure of the particle's velocity is $-0.47c\hat{\imath}$. What velocity does the observer in S now measure according to the (c) relativistic and (d) classical velocity transformation?

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28. The center of our Milky Way galaxy is about 23 000 ly away. (a) To eight significant figures, at what constant speed parameter would you need to travel exactly 23 000 ly (measured in the Galaxy frame) in exactly 40 y (measured in your frame)? (b) Measured in your frame and in lightyears, what length of the Galaxy would pass by you during the trip?

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29. (a) The energy released in the explosion of 1.00 mol of TNT is 3.40 MJ. The molar mass of TNT is 0.227 kg/mol. What weight of TNT is needed for an explosive release of $1.80 \times 10^{14} J$? (b) Can you carry that weight in a back-pack, or is a truck or train required? (c) Suppose that in an explosion of a fission bomb, 0.080% of the fissionable mass is converted to released energy. What weight of fissionable material is needed for an explosive release of $1.80 \times 10^{14} J$? (d) Can you carry that weight in a backpack, or is a truck or train required?

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30. A 7.00-grain aspirin tablent has a mass of 448 mg. For how many kilometers would the energy equivalent of this mass power an automogbile? Assume 12.75 km/L and heat of combustion of $3.65 \times 10^7 J/L$ for the gasoline used in the automobile.

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31. What is β for a particle with (a) $K = 3.00E_0$ and (b) $E = 3.00E_0$?

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32. Quasars are thought to be the nuclei of active galaxies in the early stages of their formation. If a quasar radiates energy at the rate of $2.00 \times 10^{41} W$, at what rate is the mass of this quasar being reduced to supply this energy? Express your answer in solar mass units per year, where one solar mass unit (1 smu $= 2.0 \times 10^{30}$kg) is the mass of our Sun.

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33. A spaceship of rest length 270 m races past a timing station at a speed of 0.600c. (a) What is the length of the spaceship as measured by the timing station? (b) What time interval will the station clock record between the passage of the front and back ends of the ship?

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34. Certain characteristic wavelength in the light from a galaxy in the constellation virgo are observed to be increased in wavelength, as compared with terrestrial sources, by about 0.4%. What is the radial speed of this galaxy with respect to earth ? Is it approacing or receding ?

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35. What must be the momentum of a particle with mass m so that the total energy of the particle is 4.00 times its rest energy?

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36. A space traveler takes off from Earth and moves at speed 0.9950c toward the star Vega, which is 26.00 ly distant. How much time will have elapsed by Earth clocks (a) when the traveller reaches Vega and (b) when Earth observers receive word from the traveler that she has arrived? (c) How much older will Earth observers calculate the traveler to be (measured from her frame) when she reaches Vega than she was when she started the trip?

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37. Bullwinkle in reference frame S' passes you in reference frame S along the common direction of the x' and x axes, as in Fig. 36-9. He carries three meter sticks: meter stick 1 is parallel to the x' axis, meter stick 2 is parallel to the y' axis, and meter stick 3 is parallel to the z' axis. On his wristwatchhe counts off 10.0 s, which takes 30.0 s according to you. Two events occur during his passage. According to you, event 1 occurs at $x_1 = 33.0\text{m}$ and $t_1 = 22.0$ ns, and event 2 occurs at $x_2 = 53.0$

and $t_2 = 62.0$ ns. According to your measurements, what is the length of (a) meter stick 1, (b) meter stick 2, and (c) meter stick 3? According to Bullwinkle, what are (d) the spatial separation and (e) the temporal separation between events 1 and 2, and (f) which event occurs first?

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38. An alpha particle with kinetic energy 7.70 MeV collides with an ^{14}N nucleus at rest, and the two transform into an ^{17}O nucleus and a proton. The proton is emitted at 90° to the direction of the incident alpha particle and has a kinetic energy of 4.44 MeV. The masses of the various particles are alpha particle, 4.002 60u, ^{14}N, 14.003 07 u, proton, 1.007 875 u, and ^{17}O, 16.999 14 u. In MeV, what are (a) the kinetic energy of the oxygen nucleus and (b) the Q of the reaction? (Hint: The speeds of the particles are much less than c.)

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39. the origins of the two frames coincide at $t = t' = 0$ and the relative speed is 0.980c. Two micrometeorites collide at coordinates x = 100 km and t = 200 μs according to an observer in frame S. What are the (a) spatial and (b) temporal coordinate of the collision according to an observer in frame S'?

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40. observer S detects two flashes of light. A big flash occurs at $x_1 = 1000$ m and, slightly later, a small flash occurs at $x_2 = 480\text{m}$. The time interval between the flashes is $\Delta t = t_2 - t_1$. What is the smallest value of Δt for which observer S' will determine that the two flashes occur at the same x' coordinate?

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41. A certain particle of mass m has momentum of magnitude 2.00mc. What are (a) β, (b) γ and (c) the ratio K / E_0?

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42. The mean lifetime of stationary muons is measured to be 2.2000 μs. The mean lifetime of high-speed muons in a burst of cosmic rays observed from Earth is measured to be 20.000 μs. To five significant figures, what is the speed parameter β of these cosmic-ray muons relative to Earth?

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43. The length of a spaceship is measured to be 25% of its rest length. (a) To three significant figures, what is the speed parameter β of the spaceship relative to the observer's frame? (b) By what factor do the spaceship's clocks run slow relative to clocks in the observer's frame?

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44. In a high-energy collision between a dcosmic-oray particle and a particle near the top of Earth's atmosphere, 120 km above sea level, a pion is created. The pion has a total energy E of 4.00×10^5 MeV and is traveling vertically downward. In the pion's rest frame, the pion decays 35.0 ns after its creation. At what altitude above sea level, as measured from Earth's reference frame, does the decay occur? The rest energy of a pion is 139.6 MeV.

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45. A meter stick in frame S' makes an angle of 30° with the x' axis. If that frame moves parallel to the x axis of frame S with speed 0.95c relative to frame S, what is the length of the stick as measured from S?

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46. A spaceship, moving away from Earth at a speed of 0.850c, reports back by transmitting at a frequency (measured in the spaceship frame) of 100 MHz. To what frequency must Earth receivers be tuned to receive the report?

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47. Inertial frame S' moves at a speed of 0.65c with respect to frame S (Fig. 36-11). Further, $x = x' = 0$ at $t = t' = 0$. Two events are recorded. In frame S, event 1 occurs at the origin at t = 0 and event 2 occurs on the x axis at x = 3.0 km at t = 4.0 μs. According to observer S', what is the time of (a) event 1 and

(b) event 2? (c) Do the two observers see the same sequence or the reverse?

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48. A particle moves along the x' axis of frame S' with velocity 0.50c. Frame S' moves with velocity 0.80c with respect to frame S. What is the velocity of the particle with respect to frame S?

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49. An unstable high-energy particle enters a detector and leaves a track of length 0.856 mm before it decays. Its speed relative to the detector was 0.992c. What is its proper lifetime? That is, how long would the particle have lasted before decay had it been at rest with respect to the detector?

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Practice Questions Single Corrrect Choice Type

1. At time t = 2.3 s, a 4 kg block that initially moves with a constant speed of 6 m/s undergoes an inelastic collision with another block. Any two inertial observers must agree that

A. The event took place at t = 2.3 s

B. The initial speed of the block is 6 m/s

C. The initial momentum of the block has magnitude 24 kg m/s

D. The momentum of the two block system is conserved during the collision

Answer: D

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2. Which one of the following is a consequence of the postulates of special relativity?

A. There is no such thing as an inertial reference frame.

B. Newton's laws of motion apply in every reference frame.

C. Coulomb's law of electrostatics applies in any reference frame.

D. The question of whether an object is at rest in the universe is meaningless.

Answer: D

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3. Which one of the following statements is a consequence of Special Relativity?

A. Clocks that are moving run slower than when they are at rest.

B. The length of a moving object is larger than it was at rest.

C. Events occur at the same coordinates for observers in all inertial reference frames.

D. Events occur at the same time for observers in all inertial reference frames.

Answer: A

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4. In the year 2100, an astronaut wears an antique, but accurate, quartz wristwatch on a journey at a speed of $2.0 \times 10^8 m/s$. According to mission control in Houston, the trip lasts 12 hours. How long was the trip as measured on the watch?

A. 6.7 hr

B. 12.0 hr

C. 8.9 hr

D. 16.1 hr

Answer: C

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5. In a science fiction novel, a starship takes three days to travel between two distant space stations according to its own clocks. Instruments on one of the space stations indicate that the trip took four days. How fast did the starship travel, relative to the space station?

A. $1.98 \times 10^8 m/s$

B. $2.51 \times 10^8 m/s$

C. $2.24 \times 10^8 m/s$

D. $2.83 \times 10^8 m / s$

Answer: A

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6. The proper mean lifetime of a muon is 2.2×10^{-6}s. A beam of muons is moving with speed 0.6c relative to an inertial observer. How far will a muon in the beam travel, on average, before it decays?

A. 288m

B. 500m

C. 360m

D. 600m

Answer: B

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7. Which one of the following statements concerning the proper length of a meter stick is true?

A. The proper length is always one meter.

B. The proper length depends upon the speed of the observer.

C. The proper length depends upon the acceleration of the observer.

D. The proper length depends upon the reference frame in which it is measured.

Answer: A

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8. A meter stick is observed to be only 0.900 meters long to an inertial observer. At what speed, relative to the observer, must the meter stick be moving?

A. $0.44 \times 10^{8} m/s$

B. $0.95 \times 10^{8} m/s$

C. $0.57 \times 10^{8} m/s$

D. $1.31 \times 10^{8} m/s$

Answer: D

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9. A UFO flies directly over a football stadium at a speed of 0.50c. If the proper length of the field is 100 yards, what field length is measured by the crew of the UFO?

A. 59 yards

B. 87 yards

C. 75 yards

D. 113 yards

Answer: B

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10. A proton has a mass of $1.673 \times 10^{-27} kg$. If the proton is accelerated to a speed of 0.93c , what is the magnitude of the relativistic momentum of the proton?

A. $6.2 \times 10^{-17} kg \cdot m / s$

B. $4.7 \times 10^{-19} kg \cdot m / s$

C. $1.3 \times 10^{-18} kg \cdot m / s$

D. $5.9 \times 10^{-24} kg \cdot m / s$

Answer: C

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11. An electron gun inside a computer monitor sends an electron toward the screen at a speed of $1.20 \times 10^8 m/s$. If the mass of the electron is 9.190×10^{-31}kg, what is the magnitude of its relativistic momentum?

A. $9.88 \times 10^{-23} kg \cdot m/s$

B. $1.19 \times 10^{-22} kg \cdot m/s$

C. $1.09 \times 10^{-22} kg \cdot m / s$

D. $1.41 \times 10^{-22} kg \cdot m / s$

Answer: B

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12. In the distant future, a $5.40 \times 10^5 - kg$ intergalactic ship leaves Earth orbit and accelerates to a constant speed of 0.92c. Determine the difference, $p - p_0$, between the relativistic and classical momenta of the ship.

A. $3.9 \times 10^{14} kg \cdot m / s$

B. $8.0 \times 10^{13} kg \cdot m / s$

C. $2.3 \times 10^{14} kg \cdot m / s$

D. $5.8 \times 10^{13} kg \cdot m / s$

Answer: C

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13. Determine the speed at which the kinetic energy of an electron is equal to twice its rest energy.

A. 0.45c

B. 0.87c

C. 0.63c

D. 0.94c

Answer: C

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14. A muon has rest energy 105 MeV. What is its kinetic energy when its speed is 0.95c?

A. 37 MeV

B. 231 MeV

C. 47 MeV

D. 441 MeV

Answer: B

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15. A space ship at rest on a launching pad has a mass of 1.00×10^5 kg. How much will its energy have increased when the ship is moving at 0.600c?

A. $1.12 \times 10^{21} J$

B. $2.25 \times 10^{21} J$

C. $1.62 \times 10^{21} J$

D. $6.00 \times 10^{21} J$

Answer: C

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16. Two spaceships are observed from Earth to be approaching each other along a straight line. Ship A moves at 0.40c relative to the Earth observer, while ship B moves at 0.50c relative to the same observer. What speed does the captain of ship A report for the speed of ship B?

A. 0.10c

B. 0.85c

C. 0.75c

D. 0.95c

Answer: C

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17. Spaceship A travels at 0.400c relative to an Earth observer. According to the same observer, spaceship A overtakes a slower moving spaceship B that moves in the same direction. The captain of B sees A pass her ship at 0.114c. Determine the speed of B relative to the Earth observer.

A. 0.100c

B. 0.300c

C. 0.214c

D. 0.625c

Answer: B

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18. A passenger train travels east at high speed. One passenger is located at the east side of one car, another is located in the west side of the car. In the train's frame, these two passengers glance up at the same time. In the earth's frame,

A. The glance up simultaneously

B. The passenger at the east side glances up first

C. The passenger at the west side glances up first

D. The passengers glance sideways

Answer: C

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19. Two events occur simultaneously on the x axis of reference frame S, one at x = 0 and the other at x = +1. According to an observer moving in the positive x direction

A. The event at x = +1 occurs first

B. The event at x = 0 occurs first

C. Either event might occur first, depending on the value of (a) and the observer's speed

D. The events are simultaneous

Answer: A

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20. Two events occur simultaneously at separated points on the y axis of reference frame S. According to an observer moving in the positive x direction

A. The event with the greater y coordinate occurs first

B. The event with the greater y coordinate occurs last

C. Either event might occur first, depending on the observer's speed

D. The events are simultaneous

Answer: D

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21. Two events occur on the x axis separated in time by Δt and in space by Δx. A reference frame, traveling at less than the speed of light, in which the two events occur at the same time

A. Exists no matter what the values of Δx and Δt

B. Exists only if $\Delta x / \Delta t < c$

C. Exists only if $\Delta x / \Delta t > c$

D. Does not exist under any condition

Answer: D

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22. An astronaut aged 3 years when traveling at 99% of the speed of light to the Andromeda galaxy and back. The space officials who greeted her on her return have aged less than

A. 3 years

B. More than 2.5 years and less than 3 years

C. More then 3 years

D. 2.5 years

Answer: C

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23. The spaceship Enterprise, traveling through the galaxy, sends out a smaller explorer craft that travels to a nearby planet and signals its findings back. The proper time for the trip to the planet is measured by clocks

A. On board the Enterprise

B. On board the explorer craft

C. On Earth

D. At the center of the galaxy

Answer: B

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24. A meson when at rest decays 2 μs after it is created. If moving in the laboratory at 0.99c, its lifetime according to laboratory clocks would be

A. the same

B. 0.28 s

C. 14 μs

D. 4.6 s

Answer: C

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25. A certain automobile is 6 m long if rest. If it is measured to be $4/5$ as long, its speed is

A. 0.1c

B. 0.3c

C. 0.6c

D. 0.8c

Answer: C

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26. If your were in a spaceship traveling at a speed close to the speed of light (with respect to Earth) you would notice that

A. Your pulse rate is different than normal

B. Some of your physical dimensions where smaller than normal

C. Your mass is different than normal

D. None of these effects occur

Answer: D

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27. Frame S_1 moves in the positive x direction at 0.6c with respect to frame S_2. A particle moves in the positive x direction at 0.4c as measured by an observer in S_1. The speed of the particle as measured by an observer in S_2 is

A. $c/5$

B. $5c/19$

C. $8c/25$

D. $25c/31$

Answer: D

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28. A spectral line of a certain star is observed to be "red shifted" from a wavelength of 500 nm to a wavelength of 1500 nm. Interpreting this as a Doppler effect, the speed of recession of this star is

A. 0.33c

B. 0.50c

C. 0.71c

D. 0.8c

Answer: D

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29. The special theory of relativity predicts that there is an upper limit to the speed of the speed of a particle. It thus follows that there is also an upper limit on the following property of a particle

A. The linear momentum

B. The total energy

C. The kinetic energy

D. None of these

Answer: D

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30. If the kinetic energy of a free particle is much greater than its rest energy then its kinetic energy is proportional to

A. The magnitude of its momentum

B. The square of the magnitude of its momentum

C. The square root of the magnitude of its momentum

D. The reciprocal of the magnitude of its momentum

Answer: A

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31. If the kinetic energy of a free particle is much less than its rest energy then its kinetic energy is proprotional to

A. The magnitude of its momentum

B. The square of the magnitude of its momentum

C. The square root of the magnitude of its momentum

D. The reciprocal of the magnitude of its momentum

Answer: B

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Practice Questions Linked Comprehension

1. Paragraph: A subatomic particle X spontaneously decays into two particles, A and B, each of rest energy 1.40×10^2 MeV. The particles fly off in opposite directions, each with speed 0.827c relative to an inertial reference frame S.

Determine the total energy of particle A.

A. 109 MeV

B. 200 MeV

C. 140 MeV

D. 249 MeV

Answer: D

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2. Paragraph: A subatomic particle X spontaneously decays into two particles, A and B, each of rest energy 1.40×10^2 MeV. The particles fly off in opposite directions, each with speed 0.827c relative to an inertial reference frame S.

Determine the kinetic energy of particle B (relative to frame S).

A. 109 MeV

B. 206 MeV

C. 140 MeV

D. 249 MeV

Answer: A

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3. Paragraph: A subatomic particle X spontaneously decays into two particles, A and B, each of rest energy 1.40×10^2 MeV. The particles fly off in opposite directions, each with speed 0.827c relative to an inertial reference frame S.

Which one of the following statements concerning particle X is true?

A. Momentum conservation requires that it was moving in frame S.

B. Energy conservation requires that it must have been at rest in frame S.

C. Momentum conservation requires that it must have been at rest in frame S.

D. Energy conservation requires that its total energy was 280 MeV in frame S.

Answer: C

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4. Paragraph: A subatomic particle X spontaneously decays into two particles, A and B, each of rest energy 1.40×10^2MeV. The particles fly off in opposite directions, each with speed 0.827c relative to an inertial reference frame S.

Which expression gives the momentum of particle A (relative to frame S)?

A. 109 MeV/c

B. 206 MeV/c

C. 140 MeV/c

D. 249 MeV/c

Answer: B

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5. Paragraph: A subatomic particle X spontaneously decays into two particles, A and B, each of rest energy 1.40×10^2MeV. The particles fly off in opposite directions, each with speed 0.827c relative to an inertial reference frame S.

Use energy conservation to determine the rest energy of particle X.

A. 206 MeV

B. 498 MeV

C. 249 MeV

D. 392 MeV

Answer: B

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6. Paragraph: The rest energy of a block is E_0.

Relative to inertial observer O, the block is moving with speed v so that $\sqrt{1 - v^2 / c^2} = 1/4$.

Observer O finds that the block takes 12s to go from A to B. How long would this time interval appear to be to an observer riding on the block?

A. 3s

B. 12s

C. 6s

D. 24s

Answer: A

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7. Paragraph : A spaceship traveling east flies directly over the head of an inertial observer who is at rest on the Earth's surface. The speed of the spaceship can be found from this relationship: $\sqrt{1 - v^2 / c^2} = 1/2.$

The observer is 5 feet fall. According to the navigator of the space ship, how tall is the observer?

A. 2.5 ft

B. 5 ft

C. 3.6 ft

D. 8 ft

Answer: B

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8. Paragraph : A spaceship traveling east flies directly over the head of an inertial observer who is at rest on the Earth's surface. The speed of the spaceship can be found from this relationship: $\sqrt{1 - v^2 / c^2} = 1 / 2.$

The navigator of the space ship observes a neon sign on a storefront. If he measures the speed of light emitted from the sign as he approaches the sign, what value will he obtain?

A. $1.5 \times 10^8 m / s$

B. $3.0 \times 10^8 m / s$

C. $1.8 \times 10^8 m / s$

D. $2.8 \times 10^8 m / s$

Answer: B

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9. Paragraph : A spaceship traveling east flies directly over the head of an inertial observer who is at rest on the Earth's surface. The speed of the spaceship can be found from this relationship: $\sqrt{1-v^2/c^2}=1/2$.

The navigator's on-board instruments indicate that the length of the spaceship is 20m. If the length of the ship is measured by the inertial Earth-bound observer, what value will be obtained?

A. 5m

B. 20m

C. 10m

D. 40m

Answer: C

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10. Paragraph : A spaceship traveling east flies directly over the head of an inertial observer who is at rest on the Earth's surface. The speed of the spaceship can be found from this relationship: $\sqrt{1 - v^2 / c^2} = 1/2.$

The pilot fires an ion gun that propels ions from the space ship at $1.0 \times 10^8 m/s$ relative to the ship. What is the speed of the ions as measured by the Earth observer?

A. $1.0 \times 10^8 m / s$

B. $2.4 \times 10^8 m / s$

C. $2.0 \times 10^8 m / s$

D. $2.8 \times 10^8 m / s$

Answer: D

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11. Paragraph : A spaceship traveling east flies directly over the head of an inertial observer who is at rest on the Earth's surface. The speed of the spaceship can be found from this relationship: $\sqrt{1 - v^2 / c^2} = 1/2$.

An apple falls from a tree and takes 4 s to reach the ground as reported by the Earth-bound observer. According to the navigator's instruments, how long did it take the apple to fall?

A. 1s

B. 4s

C. 8s

D. 6s

Answer: C

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Practice Questions Integer Type

1. A bomb is designed to explode 2.00 s after it is armed. The bomb is launched from Earth and accelerated to an unknown final speed. After reaching its final speed, however, the bomb is observed by people on Earth to explode 4.25 s after it is armed. What is the final speed of the bomb just before it explodes (in terms of c)?

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2. Mars rotates about its axis once every 88 642 s. A space-craft comes into the solar system and heads directly toward Mars at a speed of 0.800c. What is the rotational period of Mars (in $\times 10^3 s$) according to the beings on the spaceship?

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3. The Milky Way galaxy is a part of a group of galaxies called the Local Group. The proper distance from the Milky Way, on one side of the Local Group, to the M31 galaxy on the other side is approximately 2.4×10^6 light-years. How long (in $\times 10^5$ years) would it take a spaceship traveling at 0.999c to travel this distance according to travelers onboard?

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4. The momentum of an electron is 1.60 times larger than the value computed non-relativistically. What is the speed (in $\times 10^8$ m/s) of the electron?

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5. During each hour of flight, a large jet airplane consumes 3330 gallons of fuel via combustion. Combustion releases 1.25×10^6 joules/gallon. One gallon of fuel has a mass of

2.84kg. Calculate the energy equivalent of 3330 gallons of fuel and determine the ratio (in $\times 10^{-10}$ percent) of this energy equivalent to the amount of energy released by combustion in one hour of flight.

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