**Space and Time**

S2.1 Multiple-Choice Questions

1) Each of the following lists two statements. Which two are the basic *premises* for the special theory of relativity?

A) 1. The laws of nature are the same for everyone.

2. The speed of light is the same for everyone.

B) 1. Everything is relative.

2. You can never really tell who is moving.

C) 1. You can't go faster than the speed of light.

2. Time is different for different people.

D) 1. The laws of nature are the same for everyone.

2. Everything is relative.

E) 1. The speed of light is the same for everyone.

2. You can't go faster than the speed of light.

Answer: A

2) Which of the following statements best describes what is "relative" in the theory of relativity?

A) The theory says that everything is relative.

B) The theory says that truth can never be established in any absolute sense.

C) The theory says that measurements of motion make sense only when we state what they are measured relative to.

D) The theory says that the speed of light is relative and depends on who is measuring it.

E) The theory says that all scientific results must be considered within the context of the scientists' individual viewpoints.

Answer: C

3) Which of the following *is not* a prediction made by the theory of relativity?

A) No material object sent outward from Earth can reach or exceed the speed of light.

B) Observers in different reference frames may disagree about whether two events in two different places occur simultaneously.

C) Observers in different reference frames may disagree about the time and distance between two events.

D) Observers in different reference frames may disagree about the basic laws of nature.

E) *E = mc*2

Answer: D

4) According to the authors of the text, the theory of relativity

A) does not violate our common sense.

B) violates common sense because it contradicts logic.

C) violates common sense because it is counterintuitive.

D) violates common sense because the theory contradicts itself in many cases.

E) violates common sense because it is full of paradoxes.

Answer: A

5) In relativity, two people share the same frame of reference only if

A) they are not moving relative to each other.

B) they are both located in the same place.

C) they are both located in the same place and are traveling at the same speed.

D) they are both located in the same place and are stationary.

E) they agree on the laws of nature.

Answer: A

6) You and Al are both floating freely in your spaceships. Suppose Al is moving away from you at 85 km/hr. You throw a ball in his direction at a speed of 75 km/hr. According to Al, which of the following is going on?

A) He agrees that he is moving at 85 km/hr and the ball is moving at 75 km/hr while you are standing still.

B) He sees you moving away from him at 85 km/hr and the ball moving toward him at 75 km/hr.

C) He sees you moving away from him at 85 km/hr and the ball moving toward him at 10 km/hr.

D) He sees you moving away from him at 85 km/hr and the ball moving away from him at 10 km/hr.

E) He sees you moving toward him at 85 km/hr and the ball moving toward him at 75 km/hr.

Answer: D

7) Bob is coming toward you at a speed of 75 km/hr. You throw a baseball in his direction at 75 km/hr. What does he see the ball doing?

A) He sees the ball coming at him at 75 km/hr.

B) He sees the ball going away from him at 75 km/hr.

C) He sees the ball coming at him at 150 km/hr.

D) He sees the ball going away from him at 150 km/hr.

E) He sees the ball remaining stationary.

Answer: C

8) Shawn is traveling away from you at a speed of 120 km/hr. He throws a baseball that, according to him, is going at 100 km/hr in your direction. What do you see the ball doing?

A) You see the ball traveling away from you at 120 km/hr.

B) You see the ball traveling away from you at 100 km/hr.

C) You see the ball traveling away from you at 220 km/hr.

D) You see the ball traveling toward you at 20 km/hr.

E) You see the ball traveling away from you at 20 km/hr.

Answer: E

9) Sue is traveling toward you at 90 km/hr. She throws a baseball that, according to her, is going at 90 km/hr in the opposite direction. What do you see the ball doing?

A) You see the ball traveling away from you at 90 km/hr.

B) You see the ball remaining stationary.

C) You see the ball traveling away from you at 180 km/hr.

D) You see the ball traveling toward you at 90 km/hr.

E) You see the ball traveling toward you at 180 km/hr.

Answer: B

10) Carol is going away from you at 75 km/hr, and Sam is going in the opposite direction away from you at 90 km/hr. According to Carol, how fast is Sam going?

A) Carol sees Sam going away from her at 75 km/hr.

B) Carol sees Sam going away from her at 90 km/hr.

C) Carol sees Sam going away from her at 15 km/hr.

D) Carol sees Sam going away from her at 165 km/hr.

E) Carol sees Sam coming toward her at 15 km/hr.

Answer: D

11) You are racing away from Earth in a super spaceship in which you can continually increase your speed. Which of the following best explains how people on Earth will perceive your speed?

A) They will know you are going very fast but will have no way of knowing whether you ever exceed the speed of light.

B) You will see any beam of light from Earth coming toward you at the speed of light, which means it will catch you. Thus, the people on Earth must conclude that you are going slower than the speed of light.

C) An imaginary spaceship can go as fast as it wants, so the folks on Earth soon will see you going faster than the speed of light.

D) You may soon be racing away from Earth faster than the speed of light, but, if so, people on Earth will no longer be able to see you.

E) Without more information, it is impossible to know how fast you would see a light beam from Earth coming toward you. If it happens that you are going fast enough so that the light can't catch you, then people on Earth would find you to be going faster than light.

Answer: B

12) If you see Al going to your left at exactly 0.99*c* and Bob going to your right at exactly 0.99*c*, Al will say that Bob is

A) going away from her at 1.98*c*.

B) going away from her at exactly 0.99*c*.

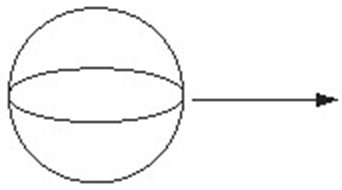
C) going away from her at exactly *c*.

D) going away from her at about 0.98*c*.

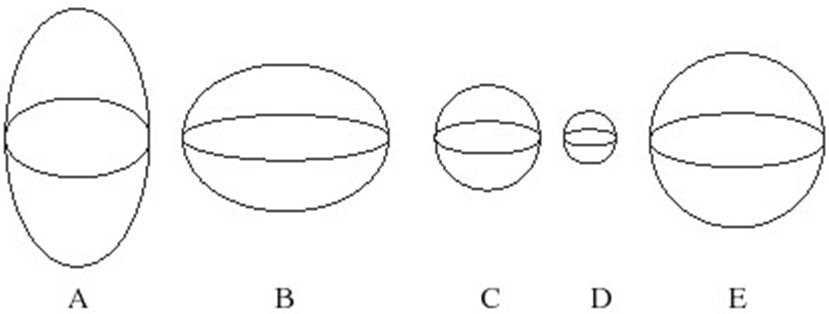
E) going away from her faster than 0.99*c*, but slower than *c*.

Answer: E

13) The picture below shows a sphere as it looks at rest. Suppose the sphere is moving to the right at about 90 percent of the speed of light.



Which figure below correctly shows the shape of the sphere as you would measure it?



A) Figure A

B) Figure B

C) Figure C

D) Figure D

E) Figure E

Answer: A

14) A spaceship is headed toward Alpha Centauri at 0.999*c*. According to us, the distance to Alpha Centauri is about 4 light-years. How far away is Alpha Centauri according to the travelers in the ship?

A) also about 4 light-years

B) very slightly more than 4 light-years

C) very slightly less than 4 light-years

D) quite a bit less than 4 light-years

E) quite a bit more than 4 light-years

Answer: D

A spaceship is moving past us at a speed close to the speed of light.

15) How would we view time (clocks) on the spaceship as it goes by?

A) Time is the same for everyone.

B) Their clocks are going at the same rate as ours.

C) Their clocks are going exactly half as fast as ours.

D) Their clocks are going faster than ours.

E) Their clocks are going slower than ours.

Answer: E

16) If we could measure the mass of the spaceship as it goes by, what would it be?

A) Its mass is infinite.

B) Its mass is greater than its rest mass.

C) Its mass is the same as it would be if it were not moving.

D) Its mass is less than its rest mass.

Answer: B

17) How would the passengers on the spaceship view our clocks?

A) Time is the same for everyone.

B) Our clocks are going fast.

C) Our clocks are going slow.

D) Our clocks are going at the same rate as theirs.

E) They can't see our clocks, but we can see theirs.

Answer: C

18) Al is moving by you at a very high speed (close to the speed of light). You get out a clock and measure 10 seconds going by. If you also watch a clock in Al's ship, how much time will you see it record during your 10 seconds?

A) Al's clock will record less than 10 seconds.

B) Al's clock will record more than 10 seconds.

C) Al's clock will agree that 10 seconds go by.

Answer: A

Twin sisters, Gwen and Jackie, were both 20 years old in the year 2000. Jackie took off on a round trip to Vega, 25 light-years away. She traveled at an average speed very close to the speed of light—say, 0.9999*c*.

19) According to Gwen back on Earth, about how long does it take Jackie to reach Vega?

A) about a month

B) about 10 years

C) about 25 years

D) about 100 years

E) about 1,000 years

Answer: C

20) Which of the following best describes the situation according to Jackie?

A) She stays still, while Earth rushes away from her at 0.9999*c* and Vega rushes toward her at 0.9999*c*. Since Vega is 25 light-years away, she says it takes Vega about 25 years to reach her.

B) She stays still, while Earth rushes away from her at 0.9999*c* and Vega rushes toward her at 0.9999*c*. She sees the distance from Earth to Vega shortened considerably from 25 light-years, and therefore it takes far less than 25 years for Vega to reach her.

C) She says that the 25-light-year trip takes only a few months and therefore concludes that she is traveling faster than the speed of light.

D) She's taking a trip that takes 25 years from Earth to Vega.

Answer: B

21) Which of the following correctly describes the situation when Jackie returns to Earth? (Ages in this problem refer to *biological* ages–that is, how much time has passed for each sister since she was born.)

A) It's the year 2050, and both twin sisters are 70 years old.

B) It's the year 2050. Gwen (who stayed home) is 70 years old, but Jackie is only a little older than her age of 20 when she left.

C) It's the year 2050. Gwen is 70 years old. Jackie is 19.

D) It's the year 2100. Gwen and Jackie are both 120 years old.

E) According to Gwen, Jackie returns to Earth in the year 2050, but according to Jackie, she returns in the year 2001.

Answer: B

Ben is racing a light beam in a 100-meter dash. Ben bursts out of the starting blocks at 99 percent of the speed of light (0.99*c*). At the same instant, a flashlight beam is turned on from the starting blocks.

22) Refer to the race described above. According to the spectators watching in the stands, what happens?

A) The light beam wins the race, but barely–it is going 1 percent of the speed of light faster than Ben.

B) The light beam instantly finishes the race, before Ben even has a chance to start.

C) The light beam wins the race by a large margin because it is going faster than Ben by the full speed of light.

D) Ben beats the light beam to the finish line, becoming a hero.

Answer: A

23) Refer to the race described above. According to Ben, what happens?

A) The light beam gradually pulls ahead of him and wins the race because it is going 1 percent of the speed of light faster than him.

B) The light beam instantly finishes the race, before Ben even has a chance to start.

C) The light beam moves out ahead of him at the full speed of light, winning the race easily.

D) Ben wins the race and becomes a hero.

Answer: C

24) How does the explosion of a nuclear bomb provide evidence of the theory of relativity?

A) The bomb causes things in its vicinity to move at very high speeds, allowing scientists to measure effects of time dilation.

B) The mass of the bomb when it explodes is much greater than its normal mass.

C) The bomb shortens the lifetimes of all people who happen to be near it when it detonates.

D) The bomb produces energy in accord with *E = mc*2, which is part of the theory of relativity.

Answer: D

25) The lifetime of a π+ meson normally is 18 nanoseconds. In a large particle accelerator, scientists can create π+ mesons moving at speeds very close to the speed of light. What do the scientists observe when they measure the lifetime of a π+ meson that is created at very high speed?

A) The π+ meson lasts 18 nanoseconds.

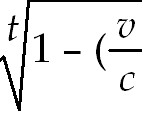
B) The π+ meson lasts much more than 18 nanoseconds.

C) The π+ meson lasts much less than 18 nanoseconds.

D) The π+ meson no longer decays and remains as a stable particle.

Answer: B

You take a trip to a star located 1,000 light-years away and return. You travel at an average speed of 0.99*c*.

*HINT*: The time dilation formula is: *t*' =  *.*

26) About how long will the trip take, according to you?

A) 2.8 years

B) 10 years

C) 28 years

D) 280 years

E) 2,000 years

Answer: D

27) About how many years will pass on Earth while you are gone?

A) 2.8 years

B) 10 years

C) 28 years

D) 2,000 years

E) 280 years

Answer: D

28) Which of the following is not *predicted* by Einstein's special theory of relativity?

A) the constancy of the speed of light

B) no material object can reach or exceed the speed of light

C) time dilation

D) the equivalence of mass and energy

E) length contraction

Answer: A

29) The predictions of special relativity can sound implausible at first. What observational evidence do scientists have that the theory is correct?

A) Subatomic particles in accelerators exhibit effects of time dilation and mass increase at high speeds.

B) Light is always observed to travel at the same speed.

C) Time dilation can be observed in airplanes.

D) All of the above

Answer: D

S2.2 True/False Questions

1) Suppose that, as you sit in your classroom, you see two balls fall to the floor and hit at exactly the same time. According to the theory of relativity, other people sitting in the classroom with you will not agree that the balls hit the floor at the same time.

Answer: FALSE

2) The general theory of relativity deals with the effects of gravity, but the special theory of relativity does not take gravity into account.

Answer: TRUE

3) If you could measure the mass of a moving object, you would find that it was greater than its value when stationary.

Answer: TRUE

4) The surface of Earth is an example of a free-float reference frame.

Answer: FALSE

5) According to the theory of relativity, the speed of light is absolute (meaning that everyone always measures it to have the same value).

Answer: TRUE

6) Different observers can disagree about the speed of a baseball, but they cannot disagree about the speed of a light beam.

Answer: TRUE

7) Different observers always agree about the order of events that occur at the same place.

Answer: TRUE

8) Scientists believe in the theory of relativity because it was invented by Einstein, even though very little experimental evidence supports it.

Answer: FALSE

9) The idea that the speed of light is absolute is supported by experimental evidence.

Answer: TRUE

10) The fact that we cannot travel faster than the speed of light means that it is theoretically impossible for us to make trips to distant stars within our lifetimes.

Answer: FALSE

11) *Process of Science:* The theory of special relativity is one of the most tested theories in physics and has now been completely proven beyond all doubt.

Answer: FALSE

S2.3 Short Answer Questions

1) Suppose a supersonic airplane flies at a speed of 1,650 km/hr from Nairobi, Kenya, to Quito, Ecuador; note that this is the same speed that Earth rotates, but in the opposite direction. Describe how this flight would look to an observer on the Moon.

Answer: The airplane would essentially appear to lift straight off the ground and then remain stationary while Earth rotated. The rotation would carry Nairobi away from the airplane and Quito toward it. When Quito arrived, the airplane would drop back down to the ground, completing the trip.

2) Describe at least three pieces of evidence supporting the special theory of relativity.

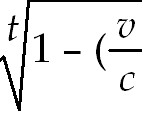
Answer: Many possibilities; some include: Michelson-Morley experiment supporting absoluteness of *c*; particle accelerator experiments finding that particles have longer lifetimes at higher speeds; airplane experiments testing time dilation; the fact that binary stars are seen distinctly supports absoluteness of *c*; nuclear bombs and nuclear energy support *E = mc*2and hence relativity.

3) Recall that a π+ meson produced at rest has a lifetime of 18 billionths of a second. Thus, in its own reference frame, a π+ meson will always "think" it is at rest and therefore decay after 18 billionths of a second

(1.8 × 10-8 s). Suppose a π+ meson is produced in a particle accelerator traveling at 0.998*c*.

a. According to scientists in the lab, how long will the π+ meson last compared to its normal lifetime of 18 billionths of a second (e.g., shorter, the same, or longer)?

b. Recall that the time dilation formula is:

*t*' = 

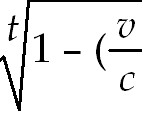
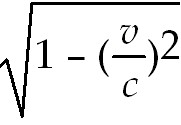
where *t* is the time in the laboratory and is the time for the moving particle. Use the time dilation formula to calculate how long scientists will see the π+ meson last before it decays.

Answer:

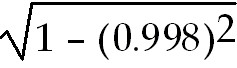
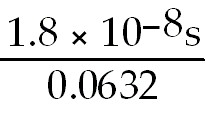
a. In the lab reference frame, the π+ meson's high speed will make it last longer than its "normal" lifetime of 18 billionths of a second.

b. When produced at 0.998*c*, the π+ meson is expected to last about 280 billionths of a second, rather than its "normal" lifetime of 18 billionths of a second. Calculation:



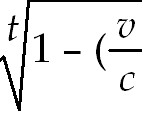
*t*' = ⇒ *t*' = 

1.8 × s

=  =  = 2.8 × 10-7 s

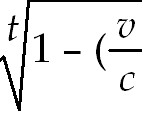
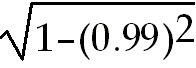
4) Suppose you stay home on Earth while your twin sister takes a trip to a distant star and back in a spaceship that travels at 99 percent of the speed of light. If both of you are 25 years old when she leaves and you are 45 years old when she returns, how old is your sister when she gets back?

*Hint*: Recall that the time dilation formula is:

*t*' = 

where *t* is the time according to the person at home and is the time for the traveler.

Answer: Your sister's speed is *v* = 0.99*c*, or *v/c* = 0.99. The time that passes for you is *t* = 20 years (you age from 25 to 45). The time that passes for your sister is:

*t*' = = (20 yr) 

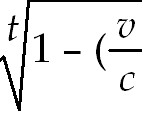
= (20 yr) 

= (20 yr)  = 2.8 yr

While 20 years pass for you, only 2.8 years pass for your traveling sister.

5) A clever student decides to spend time cruising around the local solar neighborhood at a speed of 0.95*c* (95 percent of the speed of light). How much time will pass on her spacecraft during a period in which 70 years pass on Earth?

Answer: Plugging into the time dilation formula, we find:

*t*' =  =(70 yr)  = (70 yr) 

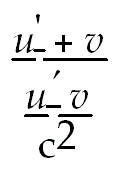
= (70 yr) (0.312) ≈ 21.9 yr

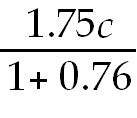
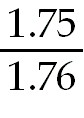
For the traveler at 95 percent of the speed of light, only a little less than 22 years passes while 70 years pass for those of us left behind on Earth.

6) Julia is traveling away from you at 0.95*c* when she shoots a probe forward from her spacecraft. According to her, the probe travels at 0.8*c*. How fast do you see the probe going?

Answer: This problem is simply velocity addition. Let *u*' be the speed of the probe according to Julia

(*u*' = 0.8*c*), and let *v* be the speed of her ship according to you (*v* = 0.95*c*). We can then find the velocity we measure, *u*, by use of the addition formula:

1 + ** = 1 + **

u = = =  = *c =* 0.994*c*

We will see the probe traveling at 99.4 percent of the speed of light–less than the speed of light, but faster than either the spacecraft or the probe independently.

7) Explain why relativity allows us to travel, in principle, to the center of the Milky Way, but we would never be able to tell our friends back home about it.

Answer: If we could build a very fast spacecraft that traveled within a tenth of a percent of the speed of light, then time dilation and length contraction allow us to travel the 28,000 light-years to the center of the Milky Way in what would seem like just a few years to us. However, back home on Earth, the trip would take about 28,000 years to go and another 28,000 years to come back: none of your friends would be around to listen to your tales of adventure when you returned. Note that even if you sent a radio message while you were at the center of the Galaxy, it would still take 28,000 years to arrive at Earth because the radio waves barely move faster than the spacecraft.

8) *Process of Science*: Devise an experiment you could conduct (using any technology you can dream up—it doesn't have to already exist) to test a prediction of special relativity.

Answer: Many are possible. One may be to test the twin paradox by sending an astronaut away for a long time at relativistic speeds to observe their aging compared to those remaining on Earth.

9) *Process of Science:* Explain how "thought experiments" were so important to Einstein as he made his theory of special relativity.

Answer: The experiments that Einstein made were imaginary situations that showed paradoxes in what was then conventional views about relative motion and time at speeds close to the speed of light. This helped him realize the need for a new theory and guided him as he developed it.

S2.4 Mastering Astronomy Reading Quiz

1) The primary difference between the special theory of relativity and the general theory of relativity is that the general theory also describes

A) length contraction.

B) the nature of gravity.

C) time dilation.

D) the constancy of the speed of light.

Answer: B

2) Which of the following statements best describes what is "relative" in the theory of relativity?

A) The theory says that everything is relative.

B) The theory says that the speed of light is relative, and depends on who is measuring it.

C) The theory says that truth can never be established in any absolute sense.

D) The theory says that measurements of motion make sense only when we state what they are measured relative to.

Answer: D

3) In relativity, two people share the same *reference frame* only if what is true?

A) They are not moving relative to one another.

B) They are both located in the same place.

C) They are both located in the same place and are stationary.

D) They agree on the laws of nature.

Answer: A

4) You are in an airplane, traveling relative to the ground at 500 km/hr. You throw a baseball toward the front of the plane at a speed of 50 km/hr. How fast would someone on the ground say the baseball is moving?

A) 550 km/hr

B) 50 km/hr

C) 500 km/hr

D) 450 km/hr.

Answer: A

5) You and Mae are in free-float frames. Mae has just passed you, traveling at a speed of 60 km/hr. You throw a ball toward her at a speed of 60 km/hr. What will Mae see the ball doing?

A) She'll see the ball coming toward her at 60 km/hr.

B) The ball will be stationary, floating freely in her own reference frame.

C) She'll see the ball moving away from her at 60 km/hr.

D) She'll see the ball coming toward her at 120 km/hr.

Answer: B

6) The measured value of the speed of light is about 300,000 km/s. Suppose a futuristic space train is traveling at 200,000 km/s with its headlights on. If you could measure the speed of the light from the headlights, you would find it to be

A) 200,000 km/s.

B) 100,000 km/s.

C) 300,000 km/s.

D) 500,000 km/s.

Answer: C

7) What do we mean by *time dilation* in relativity?

A) It is the idea that time *seems* to run slower in reference frames moving relative to you, but time really is the same for everyone.

B) It is the idea that relativity makes time dilate, or expand, for people who study it.

C) It is a hallucinogenic effect experienced by people who take too much of something.

D) It is the idea that time really runs slower in reference frames moving relative to you.

Answer: D

8) You can see a clock in a spaceship moving past you at 90% of the speed of light. According to you, how much time would pass while the clock in the spaceship ticked through one minute?

A) more than one minute

B) less than one minute

C) A minute is the same on the ship as it is for you.

D) A minute on the ship is exactly two minutes for you.

Answer: A

9) What do we mean by *length contraction* in relativity?

A) It is the idea that if you measure the size of an object moving relative to you, you will find that it is shorter in every direction than it would be at rest. That is, length, width, and height are all shorter for an object when it is moving by you.

B) It is the idea that moving objects *look* smaller than nonmoving objects, but their sizes have not really changed.

C) It is the idea that if you measure the size of an object moving relative to you, you will find that in the direction of motion it is shorter than it would be at rest, while its size in other directions is unchanged.

D) It is the idea that if you travel very fast, you'll notice yourself getting shorter.

Answer: C

10) A man is moving by you at a speed close to the speed of light. Which of the following correctly summarizes the effects you would notice on his mass, size, and time?

A) His mass would be increased from its value at rest, his length would be decreased from its rest value but only in the direction in which he is moving, and his time would be running slower than yours.

B) His mass would be increased from its value at rest, his length, width, and height would all be decreased no matter what direction he is moving, and his time would be running slower than yours.

C) His mass would be decreased from its value at rest, his length would be decreased from its rest value but only in the direction in which he is moving, and his time would be running slower than yours.

D) His mass would be increased from its value at rest, his size would be increased, and his time would be running slower than yours.

Answer: A

11) A super train is moving along a track at a speed close to the speed of light. You are watching the train from the ground. You observe lightning to strike in two places along the track, a mile apart, at precisely the same time. What would someone on the train say?

A) The two bolts of lightning struck at different times, and they struck at places that are more than a mile apart.

B) The two bolts of lightning struck at the same time, and they struck at places that are less than a mile apart.

C) The two bolts of lightning struck at different times, and they struck at places that are precisely a mile apart.

D) The two bolts of lightning struck at different times, and they struck at places that are less than a mile apart.

Answer: D

12) Kim is in a spaceship moving past you at half the speed of light. Which of the following correctly describes how you will perceive each other's time?

A) You will say that Kim's time is running slow, and she will say that your time is running fast.

B) You will say that Kim's time is running slow, and she will say that your time is running slow.

C) You will say that Kim's time is running fast, and she will say that your time is running slow.

D) You will both agree that time runs at the same rate for both of you.

Answer: B

13) The lifetime of a *Π*+ meson normally is 18 nanoseconds. In a large particle accelerator, scientists can create p+ mesons moving at speeds very close to the speed of light. What do the scientists observe when they measure the lifetime of a *Π*+ meson that is created at very high speed?

A) The *Π*+ meson lasts 18 nanoseconds.

B) The *Π*+ meson lasts much less than 18 nanoseconds.

C) The *Π*+ meson lasts much more than 18 nanoseconds.

D) The *Π*+ meson no longer decays, and remains as a stable particle.

Answer: C

14) Two twin sisters, Gwen and Jackie, are both 20 years old in the year 2020. Jackie takes off on a round-trip to Vega, 25 light-years away. She travels at an average speed very close to the speed of light—say, 0.9999*c*. According to Gwen back on Earth, about how long does it take Jackie to reach Vega?

A) about a month

B) about 10 years

C) about 25 years

D) about 100 years

Answer: C

15) Consider the same scenario as in the previous problem: Two twin sisters, Gwen and Jackie, are both 20 years old in the year 2020. Jackie takes off on a round-trip to Vega, 25 light-years away. She travels at an average speed of 0.9999*c*. Which of the following best describes the situation according to Jackie?

A) She stays still, while Earth rushes away from her at 0.9999*c* and Vega rushes toward her at 0.9999*c*. Since Vega is 25 light-years away, she says it takes Vega about 25 years to reach her.

B) She says that the 25 light-year trip takes only a few months, and therefore concludes that she is traveling faster than the speed of light.

C) It takes her 25 years to reach Vega.

D) She stays still, while Earth rushes away from her at 0.9999*c* and Vega rushes toward her at 0.9999*c*. She sees the distance from Earth to Vega shortened considerably from 25 light-years, and therefore it takes far less than 25 years for Vega to reach her.

Answer: D

16) Again consider two twin sisters, Gwen and Jackie, who are both 20 years old in the year 2020. This time, assume that Jackie makes the *round-trip* to Vega, which is 25 light-years away, at an average speed of 0.9999*c*. Which of the following correctly describes the situation when Jackie returns to Earth? (Ages in this problem refer to *biological* ages—that is, how much time has passed for each sister since she was born.)

A) It's the year 2070. Gwen (who stayed home) is 70 years old, but Jackie is only a little older than her age of 20 when she left.

B) It's the year 2070 and both twin sisters are 70 years old.

C) It's the year 2070. Gwen is 70 years old. Jackie is 19.

D) According to Gwen, Jackie returns to Earth in the year 2070, but according to Jackie, she returns in the year 2021.

Answer: A

17) Which of the following is *not* true of the special theory of relativity?

A) The special theory does not apply to situations that involve substantial acceleration or gravity; for that, you need the general theory of relativity.

B) For low speeds, the theory predicts effects that are so small that they cannot be noticed without extremely precise, high-tech measurement.

C) The theory is valid only at speeds close to the speed of light.

D) The theory tells us that there is no such thing as absolute time or space, because measurements of time and space depend on your reference frame.

Answer: C

S2.5 Mastering Astronomy Concept Quiz

1) Each of the following lists two statements. Which two are the basic premises for the special theory of relativity?

A) (1) The laws of nature are relative. (2) The speed of light depends on your viewpoint.

B) (1) You can't go faster than the speed of light. (2) Time is different for different people.

C) (1) Everything is relative. (2) You can never really tell who is moving.

D) (1) The laws of nature are the same for everyone. (2) The speed of light is the same for everyone.

Answer: D

2) Which of the following is *not* a prediction made by the theory of relativity?

A) Observers in different reference frames may disagree about the basic laws of nature.

B) No material object sent outward from Earth can reach or exceed the speed of light.

C) *E = mc*2.

D) Observers in different reference frames may disagree about whether two events in two different places occur simultaneously.

Answer: A

3) Why do the predicted consequences of the special theory of relativity seem so strange to most of us?

A) because they are self-contradictory, making it impossible to make any sense of them

B) because they are obvious only at speeds that we never experience in our daily lives

C) because they contradict the well-tested ideas of Newton's laws of motion

D) because they affect only subatomic particles and not big things like people

Answer: B

4) What is the primary reason why scientists accept the idea that the speed of light is the same for everyone?

A) because it makes sense when you think about it as Einstein did

B) because it has been verified by many observations and experiments

C) because no one has come up with a better idea about the speed of light

D) because the theory is just so darn cool, it can't be wrong

Answer: B

5) You and Al are both floating freely in your spaceships. Suppose that Al is moving away from you at 85 km/hr. You throw a ball in his direction at a speed of 75 km/hr. According to Al, which of the following is going on?

A) He sees you moving toward him at 85 km/hr and the ball moving toward him at 75 km/hr.

B) He sees you moving away from him at 85 km/hr and the ball moving toward him at 10 km/hr.

C) He agrees that he is moving at 85 km/hr and the ball is moving at 75 km/hr while you are standing still.

D) He sees you moving away from him at 85 km/hr and the ball moving away from him at 10 km/hr.

Answer: D

6) You are racing away from Earth in a super space ship in which you can continually increase your speed by firing engines that never quit. Which of the following best explains how people on Earth will perceive your speed?

A) They will see your speed getting closer and closer to the speed of light, but never reaching it.

B) They will know you are going very fast, but will have no way to know if you ever exceed the speed of light.

C) They will see you speed up until you reach the speed of light, and then your speed will remain constant after that.

D) They will see you going faster and faster until you reach the speed of light, and after that they won't be able to see you any more.

Answer: A

7) A spaceship is moving past you at a speed very close to the speed of light. If you could somehow watch the people inside it over a long period of time, what would you conclude?

A) They are aging more rapidly than you.

B) Their mechanical clocks go slower than yours, but the people are aging at the same rate as you.

C) Their time is the same as your time.

D) They are aging more slowly than you.

Answer: D

8) Suppose your normal resting heart rate is 60 beats per minute. Now, suppose you board a spaceship that travels away from Earth at 90% of the speed of light. While on the ship, you measure your heart rate. What will it be?

A) It will be 46 beats per minute.

B) It will be 74 beats per minute.

C) It will still be 60 beats per minute.

D) It will be 12 beats per minute.

Answer: C

9) Bob is in a spaceship going by you at 90% of the speed of light, but in an upright standing position. Bob measures his mass to be 50 kg, his height to be 2.0 meters, and his waist size to be 80 cm. What would *you* say about his measurements?

A) His mass is more than 50 kg, his height is still 2.0 meters, and his waist size is less than 80 cm.

B) His mass is more than 50 kg, his height is less than 2.0 meters, and his waist size is less than 80 cm.

C) His mass is less than 50 kg, his height is more 2.0 meters, and his waist size is less than 80 cm.

D) You would measure the same mass and size as he does.

Answer: A

10) Suppose you measure the density (mass per volume) of an object moving by you at very high speed. How will its density compare to the density it would have at rest in your reference frame?

A) Its density would be lower.

B) Its density would be higher.

C) Its density would be the same.

D) There is no way to know, because relativity doesn't tell us anything about density.

Answer: B

11) Tom is going to your left at 90% of the speed of light and Joan is going to your right at 90% of the speed of light. What will Tom say about you and Joan?

A) You are moving away from him at 90% the speed of light. Joan is moving away from him at 180% of the speed of light.

B) You are moving away from him at 90% the speed of light. Joan is moving away from him at as speed that is faster than 90% of the speed of light, but slower than the whole speed of light.

C) You are moving away from him at 90% the speed of light. Joan is moving away from him at as speed of light.

D) You and Joan are both moving away from him at 90% the speed of light.

Answer: B

12) How does the explosion of a nuclear bomb provide evidence for the theory of relativity?

A) The mass of the bomb when it explodes is much greater than its normal mass.

B) bomb causes things in its vicinity to move at very high speeds, allowing scientists to measure effects of time dilation.

C) The bomb shortens the lifetimes of all people who happen to be near it when it detonates.

D) The bomb converts rest-mass energy into thermal energy in accord with *E = mc*2, which is part of the theory of relativity.

Answer: D

13) In what way do observations of binary star systems support the special theory of relativity?

A) Stars in binary systems often orbit at speeds close to the speed of light, allowing us to check whether time dilation really occurs.

B) Stars in binary systems are moving, so we can compare their moving masses to their rest masses.

C) The fact that the stars appear distinct supports the idea that the speed of light is unaffected by the motion of the stars.

D) Binary systems have two stars, and therefore give us twice the opportunity to test the theory than single star systems.

Answer: C

14) A sprinter named Ben has challenged a beam of light to a race in the 100-meter dash. The race is held in a stadium full of spectators. At the start signal, a laser beam is turned on at the start line, pointed down the track. At the same instant, Ben bursts out of the starting blocks at 99% of the speed of light (0.99*c*). According to the spectators watching in the stands, what happens? (Assume they could somehow watch a slow-motion replay to see what occurred.)

A) The light beam wins the race, but barely—it is going 1% of the speed of light faster than him.

B) The light beam instantly finishes the race, before Ben even has a chance to start.

C) The light beam wins the race by a large margin because it is going faster than him by the full speed of light.

D) Ben beats the light beam to the finish line, becoming a hero.

Answer: A

15) Again consider the scenario from the previous problem: A sprinter named Ben has challenged a beam of light to a race in the 100-meter dash. The race is held in a stadium full of spectators. At the start signal, a laser beam is turned on at the start line, pointed down the track. At the same instant, Ben bursts out of the starting blocks at 99% of the speed of light (0.99c). According to Ben, what happens?

A) The light beam gradually pulls ahead of him and wins the race because it is going 1% of the speed of light faster than him.

B) The light beam instantly finishes the race, before Ben even has a chance to start.

C) The light beam moves out ahead of him at the full speed of light, winning the race easily.

D) Ben wins the race and becomes a hero.

Answer: C

16) Which statement below is true?

A) If we could build a spaceship capable of traveling at a speed very near the speed of light, passengers on the ship could make a journey to a star that is 500 light-years away within their lifetimes.

B) If we could build a spaceship capable of traveling at a speed very near the speed of light, we could send a ship to a star that is 500 light-years away and it would return just a few years after we launched it.

C) Thanks to effects of special relativity, we could build a spaceship that could go close to the speed of light with much less fuel than we would have guessed from Newton's laws of motion.

D) Because special relativity tells us that we cannot reach or exceed the speed of light, it means that distant stars will never be within our reach because the time required to reach them will always be quite long, even with very fast spaceships.

Answer: A

17) Use the appropriate relativity formula given in the text to answer the following: Isabella is moving by you at a speed of 0.8c. While 1 minute passes on your watch, how much time will you see pass on her watch?

A) 36 seconds

B) 1 minute

C) 48 seconds

D) 100 seconds

Answer: A