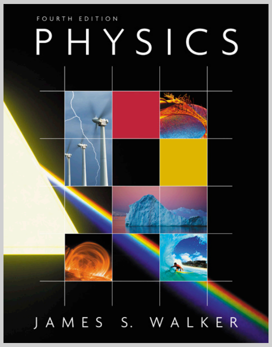

ConcepTest Clicker Questions

Chapter 29

Physics, 4th Edition

James S. Walker

Question 29.1 Playing Ball on the Train

You and your friend are playing catch in a train moving at 60 mph in an eastward direction. Your friend is at the front of the car and throws you the ball at 3 mph (according to you). What velocity does the ball have when you catch it, according to you?

a) 3 mph eastward
b) 3 mph westward
c) 57 mph eastward
d) 57 mph westward
e) 60 mph eastward

Question 29.1 Playing Ball on the Train

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a) 3 mph eastward
b) 3 mph westward
c) 57 mph eastward
d) 57 mph westward
e) 60 mph eastward

In the reference frame of the train car, you and your friend are both at rest. When he throws the ball to you at 3 mph, you will judge the ball to be moving at 3 mph. To you and your friend, it is just the same as if you were playing catch in a stationary room.

Follow-up: What velocity does the ball have, as measured by an observer at rest on the station platform?

Question 29.2 Running with an Electron

You hold an electron in your hand, thus you are at rest with respect to the electron. You can measure the electric field of the electron. Now what would your friend running past you measure?

a) an *E* field
b) a *B* field
c) both an *E* and a *B* field

Question 29.2 Running with an Electron

You hold an electron in your hand, thus you are at rest with respect to the electron. You can measure the electric field of the electron. Now what would your friend running past you measure?

a) an *E* field
b) a *B* field
c) both an *E* and a *B* field

An electron at rest produces only an *E* field.
A moving electron (current) produces a *B* field and also an *E* field.
So which is it?
Is there really a *B* field there or not?
It depends on your reference frame!!!

Question 29.3 Inertial Reference Frames

Which of the systems to the right are not *inertial reference frames*?

a) a person standing still
b) an airplane in mid-flight
c) a merry-go-round rotating at a constant rate
d) all of the above are IRFs
e) none of the above are IRFs

Question 29.3 Inertial Reference Frames

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d) all of the above are IRFs
e) none of the above are IRFs

An inertial reference frame is the same as a non-accelerating reference frame. Due to the circular motion of the merry-go-round, there is a centripetal acceleration, which means that the system is accelerating. Therefore it is not an inertial reference frame.

Question 29.4a Changing Reference Frames I

Which of these quantities change when you change your *reference frame*?

a) position
b) velocity
c) acceleration
d) all of the above
e) only a) and b)

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Which of these quantities change when you change your *reference frame*?

a) position
b) velocity
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d) all of the above
e) only a) and b)

Position depends on your reference frame – it also depends on your coordinate system. Velocity depends on the difference in position, which also relates to the frame of reference. However, since acceleration relates to the difference in velocity, this will actually be the same in all reference frames.

Question 29.4b Changing Reference Frames II

Which of these quantities change when you change your *reference frame*?

a) time
b) mass
c) force
d) all of the above
e) none of the above

Question 29.4b Changing Reference Frames II

Which of these quantities change when you change your *reference frame*?

a) time
b) mass
c) force
d) all of the above
e) none of the above

Mass is clearly independent of the reference frame. And time intervals are also not affected by which frame you are in. Since mass and acceleration are the same in all reference frames, due to Newton's second law ($F = ma$), force also will not change.

Question 29.5 Windowless Spaceship

You are in a spaceship with no windows, radios, or other means to check outside. How would you determine if the spaceship is at rest or moving at constant velocity?

a) By determining the apparent velocity of light in the spaceship.
b) By checking your precision watch. If it's running slow, then the ship is moving.
c) By measuring the lengths of objects. in the spaceship. If they are shorter, then the ship is moving.
d) You should give up because you've taken on a impossible task.

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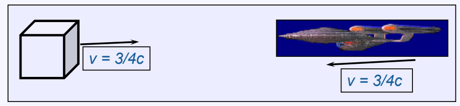
b) By checking your precision watch. If it's running slow, then the ship is moving
c) By measuring the lengths of objects. in the spaceship. If they are shorter, then the ship is moving.
d) You should give up because you've taken on a impossible task.

According to you (in the spaceship), your clock runs exactly the same as it did when you were at rest on Earth, all objects in your ship appear the same to you as they did before, and the speed of light is still *c*. There is nothing you can do to find out if you are actually moving.

Question 29.6a Borg Ship I

The *Enterprise* is traveling at 3/4*c* heading toward a Borg spaceship, which is approaching at 3/4*c*. Having never heard of the Special Theory of Relativity, with what relative speed would Sir Isaac Newton tell you the Borg ship is approaching the *Enterprise*?

a) 3/4c
b) *c*
c) 1.5c
d) more than 1.5c
e) more than 3/4c but less than *c*



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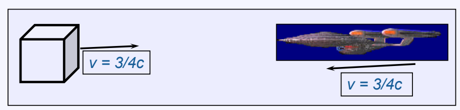
c) 1.5c
d) more than 1.5c
e) more than 3/4c but less than *c*

Newton would tell us that it should be 1.5*c* since each of their individual velocities is 3/4*c*. We have to add them up to get the relative velocity. However . . .

Question 29.6b Borg Ship II

The *Enterprise* is traveling at 3/4*c* heading toward a Borg spaceship, which is approaching at 3/4*c*. Since you understand the theory of relativity, you tell Sir Isaac Newton that he has no clue about physics and that you know the relative speed with which the two ships approach each other is:

a) 3/4c
b) *c*
c) 1.5c
d) more than 1.5c
e) more than 3/4c but less than *c*



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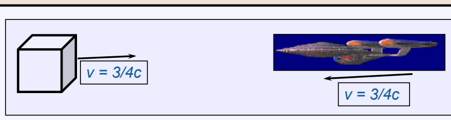


The speed of light is *c* and this is the ultimate speed. Nothing can go faster than this, not even light!

Question 29.6c Borg Ship III

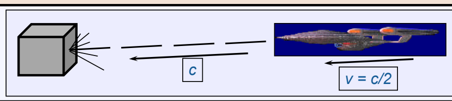
You are in the *Enterprise* traveling at half the speed of light ($v = 0.5c$), heading toward a Borg spaceship. You fire your phasers and you see the light waves leaving your ship at the speed of light $c = 3 \times 10^8$ m/s toward the Borg. With what speed do the Borg see the phaser blasts approaching their ship?

a) 0.5c
b) *c*
c) 1.5c
d) more than 2c
e) none of the above

Question 29.6c Borg Ship III

You are in the *Enterprise* traveling at half the speed of light ($v = 0.5c$), heading toward a Borg spaceship. You fire your phasers and you see the light waves leaving your ship at the speed of light $c = 3\times10^8$ m/s toward the Borg. With what speed do the Borg see the phaser blasts approaching their ship?

a) $0.5c$
b) c
c) $1.5c$
d) more than $2c$
e) none of the above



The speed of light is c in empty space, independent of the speed of the source or the observer. This is the ultimate speed. While the Borg measures the speed to be the same (the speed of light), the color of the light will appear blue shifted.

Question 29.7a Speed of Light I

It is said that Einstein, in his teenage years, asked the question: "What would I see in a mirror if I carried it in my hands and ran with the speed of light?" How would you answer this question?

a) the mirror would be totally black
b) you would see the same thing as if you were at rest
c) the image would be distorted
d) none of the above

Question 29.7a Speed of Light I

It is said that Einstein, in his teenage years, asked the question: "What would I see in a mirror if I carried it in my hands and ran with the speed of light?" How would you answer this question?

a) the mirror would be totally black
b) you would see the same thing as if you were at rest
c) the image would be distorted
d) none of the above

The speed of light is the same in all reference frames, independent of the speed of the source or the observer. Therefore, the light still travels at the speed c, and what you see in the mirror will be exactly the same as what you would see if you were at rest.

Question 29.7b Speed of Light II

Your roommate tells you that she has conducted an experiment under water and found some high-energy particles which move faster than light. She asks for your opinion. Based on your excellent preparation you received in your PHYS 2 course, what do you tell her?

a) that is impossible
b) that is quite possible
c) you have no clue
d) you don't care

Question 29.7b Speed of Light II

Your roommate tells you that she has conducted an experiment under water and found some high-energy particles which move faster than light. She asks for your opinion. Based on your excellent preparation you received in your PHYS 2 course, what do you tell her?

a) that is impossible
b) that is quite possible
c) you have no clue
d) you don't care

The speed of light travels at the speed c in vacuum! We know from optics that light under water will move slower because it gets refracted. Thus, particles can move faster than light in water – but is still less than c.

Question 29.8 Foghorns

All of the boats on the bay have foghorns of equal intensity. One night on the shore, you hear two horns at exactly the same time – one is loud and the other is softer. What do you conclude from this?

a) softer one sounded first
b) louder one sounded first
c) both sounded at the same time
d) unable to conclude anything

Question 29.8 Foghorns

All of the boats on the bay have foghorns of equal intensity. One night on the shore, you hear two horns at exactly the same time – one is loud and the other is softer. What do you conclude from this?

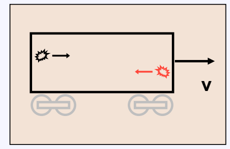
a) softer one sounded first
b) louder one sounded first
c) both sounded at the same time
d) unable to conclude anything

Since all boats sound their foghorns at the same intensity but you hear them at different intensities, the softer one must have traveled a greater distance. That means the softer one sounded first.

Question 29.9 Balls in Boxcar

A boxcar moves right at a very high speed. A green ball is thrown from left to right, and a blue ball is thrown from right to left with the same speed. According to an observer on the ground, which ball takes longer to go from one end to the other?

a) the blue ball
b) the green ball
c) both the same



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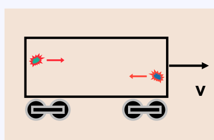
a) the blue ball
b) the green ball
c) both the same

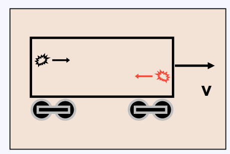
For an observer on the ground, the green ball moves with $v_{ball} + v_{car}$ while the blue ball moves with $v_{ball} - v_{car}$. But the green ball has to move a longer distance than the blue ball. In the end, both balls take the same amount of time.



Question 29.10a Light Flashes in Boxcar I

A boxcar moves right at a very high speed. A green flash of light moves from left to right, and a blue flash from right to left. For someone with sophisticated measuring equipment in the boxcar, which flash takes longer to go from one end to the other?

a) the blue flash
b) the green flash
c) both the same



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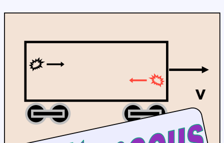
a) the blue flash
b) the green flash
c) both the same

The speed of light is c inside the boxcar, and the distance that each flash must travel is L (length of boxcar). So each flash will take $t = L/c$, which will be the same for each one.

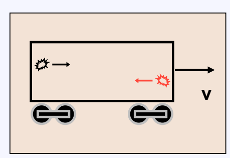


Simultaneous

Question 29.10b Light Flashes in Boxcar II

A boxcar moves right at a very high speed. A green flash of light moves from left to right, and a blue flash from right to left. According to an observer on the ground, which flash takes longer to go from one end to the other?

a) the blue flash
b) the green flash
c) both the same



Question 29.10b Light Flashes in Boxcar II

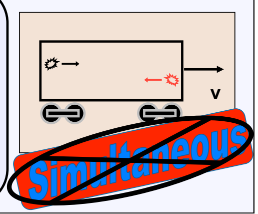
A boxcar moves right at a very high speed. A green flash of light moves from left to right, and a blue flash from right to left. According to an observer on the ground, which flash takes longer to go from one end to the other?

a) the blue flash

b) the green flash

c) both the same

The ground observer still sees the light moving at speed *c*. But while the light is going, the boxcar has actually *advanced*. The back wall is moving toward the blue flash, and the front wall is moving away from the green flash. Thus, the green flash has a longer distance to travel and takes a longer time.

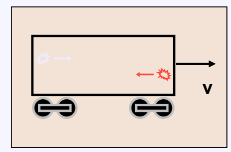


Question 29.11 Causality

A boxcar moves right at a very high speed. A *green* flash of light moves from left to right, and a *blue* flash from right to left. Is there a reference frame in which the blue flash hits the back wall *before* it was sent out?

a) yes

b) no



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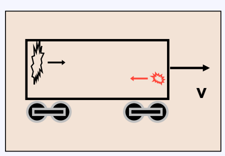
a) yes

b) no

This is called the *principle of causality*. If event A causes event B, then in all reference frames, event A must occur *before* event B. But, if your reference frame traveled past with speed $v > c$, then you could theoretically see the tree split "before" the lightning. However, faster-than-light travel is not possible.



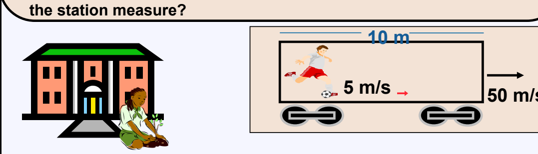
Question 29.12a Boxcar I

A boxcar moves right at 50 m/s. A physics professor kicks a soccer ball at 5 m/s toward the front of the car. Since the boxcar is 10 m long, he measures the time it takes for the ball to reach the front wall to be t = 10 m / 5 m/s = 2 seconds. What time does the girl at the station measure?

a) 2 seconds

b) more than 2 seconds

c) less than 2 seconds



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A boxcar moves right at 50 m/s. A physics professor kicks a soccer ball at 5 m/s toward the front of the car. Since the boxcar is 10 m long, he measures the time it takes for the ball to reach the front wall to be t = 10 m / 5 m/s = 2 seconds. What time does the girl at the station measure?

a) 2 seconds

b) more than 2 seconds

c) less than 2 seconds

For her, the soccer ball flies with a speed of v = 5 + 50 = 55 m/s. But the soccer ball must cross the distance of 10 + 2 x 50 m = 110 m. This means the girl at the station measures t = 110 m / 55 m/s = 2 seconds.

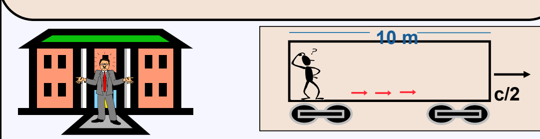
Question 29.12b Boxcar II

A boxcar moves right at v=c/2. A physics student sends a light flash toward the front of the car and measures how long it takes for the light flash to get there (t_{boxcar}). What time ($t_{station}$) will the physics professor at the station measure for the trip of the light flash?

a) $t_{boxcar} = t_{station}$

b) $t_{boxcar} < t_{station}$

c) $t_{boxcar} > t_{station}$



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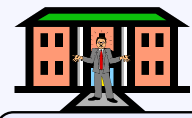
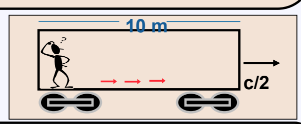




In contrast to the soccer ball, the light flash does *not* move with a speed of $v = c + c/2$ m/s, but only with c! While the light is going, the boxcar has actually *advanced*! Therefore, the light will need *longer* according to the prof on the station compared to the student in the boxcar.

Question 29.13a Time Dilation I

An astronaut moves away from Earth at close to the speed of light. How would an observer on Earth measure the astronaut's pulse rate?

a) it would be faster

b) it would be slower

c) it wouldn't change

d) no pulse - the astronaut died a long time ago

Question 29.13a Time Dilation I

An astronaut moves away from Earth at close to the speed of light. How would an observer on Earth measure the astronaut's pulse rate?

a) it would be faster

b) it would be slower

c) it wouldn't change

d) no pulse - the astronaut died a long time ago

The astronaut's pulse would function like a clock. Since time moves slower in a moving reference frame, the observer on Earth would measure a slower pulse.

Question 29.13b Time Dilation II

The period of a pendulum attached in a spaceship is 2 seconds while the spaceship is parked on Earth. What is its period for an observer on Earth when the spaceship moves at 0.6c with respect to Earth?

a) less than 2 seconds

b) more than 2 seconds

c) 2 seconds

Question 29.13b Time Dilation II

The period of a pendulum attached in a spaceship is 2 seconds while the spaceship is parked on Earth. What is its period for an observer on Earth when the spaceship moves at 0.6c with respect to Earth?

a) less than 2 seconds

b) more than 2 seconds

c) 2 seconds

To the Earth observer, the pendulum is moving relative to him and so it takes longer to swing (moving clocks run slow) due to the effect of time dilation.

Follow-up: What would the astronaut in the spaceship measure?

Question 29.13c Time Dilation III

A simple way to understand time dilation is to imagine moving away from a clock. Since it takes longer for the light from the clock to reach you, you conclude that time is slowing down. Is this way of thinking correct?

a) yes

b) no

Question 29.13c Time Dilation III

A simple way to understand time dilation is to imagine moving away from a clock. Since it takes longer for the light from the clock to reach you, you conclude that time is slowing down. Is this way of thinking correct?

a) yes

b) no

This is not how to think about it. In this way of thinking, moving toward the clock would seem to speed up time. But this is not what happens. Time itself flows more slowly, whether we measure it (with clocks) or not!

Question 29.14 Length Contraction

A spaceship moves faster and faster, approaching the speed of light. How would an observer on Earth see the spaceship?

a) it becomes shorter and shorter

b) it becomes longer and longer

c) there is no change

Question 29.14 Length Contraction

A spaceship moves faster and faster, approaching the speed of light. How would an observer on Earth see the spaceship?

a) it becomes shorter and shorter

b) it becomes longer and longer

c) there is no change

Due to length contraction, an observer would see the spaceship become shorter and shorter.

Follow-up: What would the astronaut measure about his spaceship?

Question 29.15 Pancake or Cigar?

A spaceship in the shape of a sphere moves past an observer on Earth at a speed of 0.9c. What shape *should* the observer on Earth see as the spaceship moves by?

a) unchanged

b) cigar-like

c) pancake-like

Question 29.15 Pancake or Cigar?

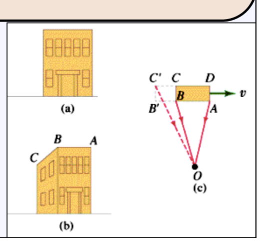
A spaceship in the shape of a sphere moves past an observer on Earth at a speed of 0.9c. What shape *should* the observer on Earth see as the spaceship moves by?

a) unchanged

b) cigar-like

c) pancake-like

Due to length contraction, the round spaceship should appear *as a pancake*. However, due to the finite speed of light, we see not only the front but also the side of the space ship, making it appear *round* again.



Question 29.16a The Tunnel I

A spacecraft has a length of 100 m when parked on Earth. It is now moving toward a tunnel with a speed of 0.8c (γ =1.66). The lady living near the tunnel can control doors that open and shut at each end of the tunnel, which is 65 m long. The doors are open as the spaceship approaches, but in the very moment that she sees the back of the spaceship in the tunnel, she closes both doors and then immediately opens them again.

- *According to the lady living near the tunnel:*

a) no door hit the spaceship because for her the doors weren't closed simultaneously

b) no door hit the spacecraft because length contraction makes the spaceship only 60 m long

c) no door hits the spaceship because length contraction has made the tunnel 109 m long

d) a door hits the spaceship

Question 29.16a — The Tunnel I

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b) no door hit the spacecraft because length contraction makes the spaceship only 60 m long

c) no door hits the spaceship because length contraction has made the tunnel 109 m long

d) a door hits the spaceship

The rocket is in the moving reference frame and therefore length is contracted by the amount γ.

Question 29.16b — The Tunnel II

A spacecraft has a length of 100 m when parked on Earth. It is now moving toward a tunnel with a speed of 0.8c. The lady living near the tunnel can control doors that open and shut at each end of the tunnel, which is 65 m long. The doors are open as the spaceship approaches, but in the very moment that she sees the back of the spaceship in the tunnel, she closes both doors and then immediately opens them again.

- According to the captain in the spaceship:

a) no door hit the spaceship because for her the doors weren't closed simultaneously

b) no door hit the spacecraft because length con- traction shortens the spaceship to 60 m long

c) no door hits the spaceship because length contraction has made the tunnel 109 m long

d) a door hits the spaceship

Question 29.16b — The Tunnel II

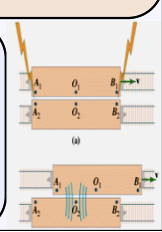
a) no door hit the spaceship because for her the doors weren't closed simultaneously

b) no door hit the spacecraft because length contraction shortens the spaceship to 60 m long

c) no door hits the spaceship because length contraction has made the tunnel 109 m long

d) a door hits the spaceship

Remember the flashes hitting the box cars; here the doors of the tunnel work like the flashes. Just as the *moving* boxcar sees the front flash first, before the back flash, the captain sees the *front door close (and open!)* while the back of the space ship is still sticking out the end of the tunnel. Then he sees the back doors close while the front of the spaceship is already out of the tunnel.



Question 29.17 — Relativistic Mass

A spear is thrown at a very high speed. As it passes, you measure its length at one-half its normal length. From this measurement, you conclude that the relativistic mass of the moving spear must be:

a) equal to its rest mass

b) one-half its rest mass

c) one-quarter its rest mass

d) twice its rest mass

e) four times its rest mass

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Since you measured the length of the moving spear to be half its proper length (and since $L = L_0/\gamma$), you know that $\gamma = 2$. Therefore, since $m = \gamma m_0$, you can conclude that the relativistic mass is ***double*** the rest mass.

Question 29.18 — Muon Decay

The short lifetime of particles called muons (created in Earth's upper atmosphere) would not allow them to reach the surface of Earth unless their lifetime increased by time dilation.

- From the reference system of the muons, they can reach the surface of Earth because:

a) time dilation increases their velocity

b) time dilation increases their energy

c) length contraction decreases the distance to the surface of Earth

d) the creation and decay of muons is simultaneous

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In the muon frame of reference, they see the distance to the surface of Earth "moving toward them" and therefore this length is relativistically contracted. Thus, according to the muons, they are able to traverse this shorter distance in their proper lifetime, which is how long they live in their frame.