

Modern Physics - Philosophy of the Natural World

Special Relativity Class Work

1. You're on the deck of an enormous cruise liner in perfectly calm seas with absolutely clear skies in the middle of a positively beautiful, pitch black night (i.e., it's a new moon.) Immediately, your mind turns to physics! You feel a 5 knot wind coming from 45° starboard of the bow. Is it possible to tell whether the ship is moving forward or backward? Assume that you can't throw anything overboard, use a GPS unit, or otherwise "communicate" with the environment outside the ship. If it is possible, then describe how you could tell which way you're moving. If not, explain why it's impossible to determine from your perspective.
2. Describe the **frame of reference** you used to study the motion of the ship in **Question #1**. Begin your answer with "We were trying to determine the motion of the ship *with respect to*..." Explain why this is (or is not) an **inertial reference frame**.
3. Describe the **frame of reference** in which you are ultimately forced to conduct all possible onboard "experiments" designed to answer **Question #1**. Begin your answer with "The motions of all objects in all possible experiments would ultimately be measured *with respect to*..." Explain why this is (or is not) an **inertial reference frame**.
4. Why is **uniform motion** so rare in our everyday experience, even if we ignore the turning of the Earth?
5. Suppose that you are the passenger in a car traveling north at 55 MPH. Suddenly, a Porsche whizzes by you, traveling at 77 MPH in the same direction. What is the velocity (speed and direction) of the Porsche with respect to you?
6. If two protons are at rest and separated by 1mm, will there be an electric force between them? How about a magnetic force?
7. If two protons are separated by 1mm and both are moving to the left at 5 meters/second, will there be an electric force between them? How about a magnetic force?
8. If there is no "fixed" electromagnetic field for protons to move across, then what determines whether there is any magnetic attractive force between them? (**Hint**: The correct answer has not yet been covered, so *speculate*. It took a genius to resolve this paradox.)
9. What is the speed of light?
10. Describe the frame of reference for your answer to **Question #9** (e.g., "Light moves at a speed of 55 mph *with respect to the Sun*.")
11. Would light moving back & forth perpendicular to the "ether flow" take any longer to reach its destination than it would if the experiment was conducted at rest with respect to the ether?
12. Would light moving back & forth parallel to the "ether flow" take any longer to reach its destination than it would if the experiment was conducted at rest with respect to the ether?
13. Which path would be delayed more by the "ether flow", the perpendicular one or the parallel one?
14. If light moved at speed c with respect to its **source** (e.g., a flashlight), would this be consistent with the results of the Michelson-Morley experiment?
15. If light moved at speed c with respect to its source, would this be consistent with Maxwell's Equations?
16. Suppose that your rocket blasts off from the Earth at $\frac{1}{2}c$. Once you reach this speed, you launch a missile in the same direction that you're moving. The missile is moving at $\frac{1}{2}c$ with respect to you. Assume that the missile accelerates itself, so it doesn't affect your own motion. At what speed is the missile now moving with respect to the Earth?
17. Suppose that after firing your missile in **Question #16**, you now fire a laser in the same direction. How fast is the laser beam moving with respect to you? How fast is it moving with respect to the Earth? How fast is it moving with respect to the missile?
18. Suppose that an ambulance with a loud siren approaches you at 60 mph. Assume that the speed of sound is 760 mph. At what speed is the ambulance's sound moving with respect to you? At what speed is this sound moving with respect to the ambulance itself? Answer the same questions about the warning lights produced by the ambulance.
19. Explain how the result of the Michelson-Morley experiment supports Einstein's first postulate.
20. Did Einstein base his first postulate on the result of the Michelson-Morley experiment? If not, what did he base it on?

21. Suppose that the star ship Enterprise whizzes by you (noiselessly, of course) at $\frac{4}{5}c$. In whose reference frame will the light in the Enterprise's light clock have to travel **further**, yours or Captain Picard's (or will it be the same for both)?
22. In whose reference frame will the light in the Enterprise's light clock travel **faster** (or will it be the same for both)?
23. In whose reference frame will **more time** pass between ticks of the Enterprise's light clock (or will it be the same for both)?
24. Suppose that it takes Captain Picard 15 minutes to drink a cup of tea. How much time will pass in **your** frame of reference while he's drinking?
25. Suppose that you also take 15 minutes to finish your tea, and that you both started drinking at the instant the Enterprise passed the Earth. Who finishes their tea first?
26. Alpha Centauri is so far from Earth that it takes light 4.4 years to reach us from there (and vice versa). Suppose you're in a rocket ship traveling from Earth to Alpha Centauri at $\frac{4}{5}c$. How much time will pass on Earth during your journey? How long does the trip take in **your** frame of reference?
27. How much distance will **you** measure between Earth and Alpha Centauri?
28. As you zoom past the Earth at the start of your journey, how does the length of your ruler appear to earthbound observers?
29. Who considers the distance between Earth and Alpha Centauri longer?
30. There should be an apparent inconsistency between your answers to **Questions #28 and #29**. Describe this inconsistency, and then explain why your answers really **aren't** inconsistent.
31. Suppose that mission control on Earth sends a signal to the Mars rover during its descent, and that this signal reaches the rover 10 minutes later, just at the instant it touches down on the surface. If it lands safely, it responds immediately with an "I'm OK!" message. How much time passes on Earth between sending the message to the rover and getting a response?
32. Suppose a baby is born on Earth exactly 10 minutes after mission control sends its signal. Come up with three **different** possible orderings of the following events: your birth, your death, mission control sending its message, the rover landing, mission control receiving the rover's message, and the birth of the baby.
33. How long is the period of "elsewhere" on Earth for an event that occurs on Alpha Centauri (4.4 light years away)?
34. Are there any observers who consider World War II happening before World War I? If so, describe their frame of reference. If not, explain why this is impossible.
35. What property must two events have in order to be considered simultaneous to all observers?
36. Consider the message sent by mission control in **Question #31**. Who would measure a greater space-time interval between mission control sending this message and the rover receiving it, an observer on Earth, an observer on Mars, or an alien traveling at $\frac{4}{5}c$ between Earth and Mars?
37. Calculate the distance between Earth and Mars, as measured by the alien. Assume NASA thinks the distance between Earth and Mars is approximately 1.8×10^{11} meters.
38. Calculate the amount of time that passes on the alien's watch between the two events in question #36.
39. Check your answer to **Question #36** by calculating the space-time interval for each observer.
40. Do these two events have a definite time order that **all** possible observers will agree about? Do they have a definite position order that **all** possible observers will agree about? What is special about this pair of events that results in this relatively unusual pair of answers?
41. Suppose you continuously apply one newton of force to a 1-kilogram object that was initially at rest. Compare its motion after 10,000 years to its motion after 20,000 years. Will it have twice the velocity? Will it have twice the momentum?
42. Which has more mass, a baseball in a pitcher's glove as he checks the runner on first base, or the same baseball on its way from the pitcher's mound to home plate?
43. Which has more mass, a man standing on the first floor of the Empire State Building or the same man standing on the 100th floor?
44. Which has more mass, the reagents or the products of a chemical reaction? Assume no heat or radiation enters or escapes.
45. Come up with a formula for the total energy of a roller coaster at a particular instant on its way down a steep incline. Your answer should incorporate its velocity, its height, and some new form of energy that we just learned about.