Quiz 3 - Solutions

Physics for Pedestrians

6th August, 2019

From the Reading on Quantum Mechanics

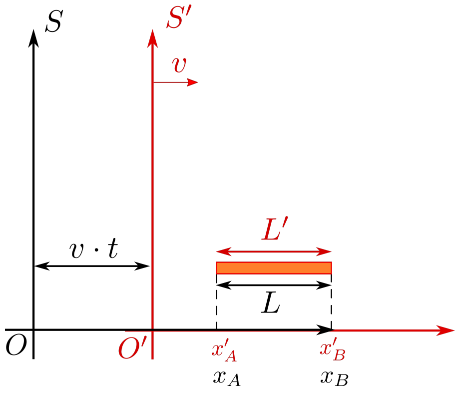
1. How do electrons behave in the experiment Feynman proposes?
   (a) They behave exactly as waves do.
   (b) They behave exactly as particles do.
   (c) They sometimes behave as particles, and sometimes as waves, but never both at the same time.
   (d) **They behave both as particles and waves at the same time.**
2. How do photons behave like electrons?
   (a) **They both come in lumps.**
   (b) They both have a definite position in space and time.
   (c) Their momenta are related to their (De Broglie) wavelengths: $p = \frac{h}{\lambda}$
   (d) Photons do not behave like electrons.

The Special Theory of Relativity

1. Galilean or "common-sense" relativity is
   (a) Theoretically inconsistent.
   (b) **Experimentally inconsistent.**
   (c) Both theoretically and experimentally inconsistent.
   (d) Neither theoretically nor experimentally inconsistent.

   Solution: It is important to realise that our common sense theory of relativity is perfectly acceptable and consistent, but *everything hinges upon the velocity-addition law.* **If** the velocity addition law happens to be different from $u' = u - v$, then two observers *would not agree* on simultaneous events. If two observers do not agree upon simultaneous events, then they will not agree upon lengths of objects in different frames. It turns out that there is a frame independent speed (the speed of light c). However, this cannot be reconciled with the velocity addition law. Thus, it is **experiment** that has decided that Galilean Relativity is wrong, not theory.

2. Consider two frames, S and S' as discussed in class. S' is moving with respect to S with velocity v as shown in the figure.



An observer in S wishes to measure the length of a table in S' (moving with respect to him at velocity v, see the figure). In order for the difference of the coordinates to indeed be the length, we require that:

(a) **Correct:** $\Delta t = 0$.

(b) $\Delta t' = 0$.

(c) $\Delta t = 0$ and $\Delta t' = 0$.

(d) $\Delta x = 0$.

(e) $\Delta x' = 0$.

(f) $\Delta t = 0$ or $\Delta t' = 0$.

Solution: Since the table is moving with respect to the observer standing in S, he would need to measure it's end coordinates simultaneously in order for their difference to be the length of the table. (This is not really a difficult concept to understand, despite being something that everyone seems to be struggling with. If you're still unclear, come and meet me or watch the video I sent out.)

What about $\Delta t' = 0$? In "common-sense" relativity, simultaneity was agreed upon. In other words, $\Delta t = 0 \implies \Delta t' = 0$. However, it must be appreciated that $\Delta t'$ **need not be** (and in fact, Special Relativity tells us that it *isn't*) zero!

3. The faster a spaceship is flying, the shorter it will appear to people on board the ship.

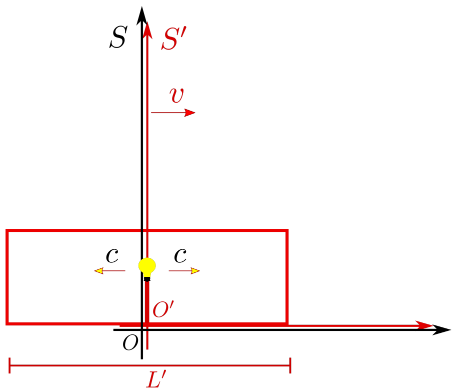
(a) True.

(b) **False.**

Solution: If you're in S, and the spaceship is S', it might look to you that the lengths of objects in S' (the ship) have "shrunk". However, that is just how things appear to you! Length measurements are relative: an observer on S' would not see his lengths contract, as he is at respect with respect to the ship. He *will*, however, look at you zooming backwards and think that *your* lengths are contracted. Both your views are **symmetric**.

Another solution: If what was proposed were true, it would be possible to measure how much shorter the spaceship appears, and thereby figure out how fast you are moving. But the Principle of Relativity tells us that *this cannot be done!*

4. In the train thought experiment, two beams of light are fired from the centre of a moving train car (in S'): one beam of light towards the front of the train and one towards the back. From the perspective of a person in S (on the platform watching the train), which beam of light strikes the wall of the train car first?



(a) Neither, they both arrive at the same time.

(b) The beam going towards the front of the train.

(c) **The beam going towards the back of the train.**

(d) Neither: the light just stays where it is.

Solution: The fundamental thing about Special Relativity that you need to understand is this: **the speed of light is a quantity that all observers will agree upon, irrespective of their motion with respect to each other.** We have two observers: one in S' who sees the train car as being stationary. As the signal is emitted at the centre of the train, she sees both of them strike the wall simultaneously.[1]

With respect to someone standing in S, the light rays are *still* travelling at c. However, in this frame the "back" wall is moving towards the light, while the front wall is moving away from

[1]From our discussion in class you should already realise that this means that it **cannot** be simultaneous for an observer in S, since for these observers to agree on simultaneous events, we'd need the Galilean Transformations which are *wrong*.

it. Obviously the light will strike the back wall first!

Remember: You don't get to choose when to use Galilean (or common-sense) Relativity. It is a nice and consistent theory, but nevertheless **wrong**. While it might seem to you that if the speed of S' with respect to S were small, these effects are negligible, that does not mean that they are non-existent. Special Relativity is **always** true; Galilean Relativity is a good approximation at small values of v/c, but it is still intrinsically wrong.