Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Making things look shorter and slower.*

There's a thing called the principle of relativity that dates back to Galileo who (when he wasn't mucking about with telescopes) used to roll balls down ramps to develop a understanding of motion and velocity.

Essentially, the principle of relativity acknowledges that if you are say on a train travelling at sixty kilometers an hour and you throw a ball forward at a speed of 10 kilometres an hour - then for you on the train, the ball measurably travels at 10 kilometres an hour. But, for someone on the train station platform, as the train is passing by, the ball measurably travels past with its own speed of 10 kilometers an hour plus the 60 kilometers an hour speed of the train – that is, the ball is measurably moving at 70 kilometres an hour.

Both observers, either on and off the train, make pefectly correct but totally different measurements of the ball's speed. This means that you always have to be careful to refer your measurements to a particular frame of reference – which means we have to say that the same ball moves at 10 kilometres an hour relative to the train but also moves at 70 kilometres an hour relative to the platform.

That all sounds pretty straight forward Steve.

Well, yes. But things went a bit pear-shaped when Einstein considered James Clark Maxwell's finding that the speed of light was absolute – that is, it didn't matter what your frame of reference was – you would always measure the speed of light as the speed of light – which is around 300,000 kilometres a second.

So shine a torch beam forward on the train and it will move at the speed of light. But amazingly, it will also move at the speed of light for someone watching it from the platform. It doesn't gain that extra 60 kilometres an hour that represents the velocity of the train.

Well, that's a little unusual Steve.

Indeed. One way to explain it is to consider that speed is a measure of distance over time. So the missing 60 kilometres an hour in the torch beam scenario could be accounted for if the observer on the platform is observing a train in which kilometers are a bit shorter and time runs a bit slower that it does on the platform.

Oh I don't know laddie - let's just back up a bit. So I'm standing on the platform and there's a guy on the train throwing a ball at 10 kilometers an hour. So since he's on the train, I actually measure it going at 70 kilometers an hour.

Yes.

But if I see a torch beam on that train it still just goes at the same speed – is that right?

Exactly.

Well, I don't think I quite get it then.

Well the answer to that is that the ball isn't going at quite 70 kilometers. We already know from the fact that light speed is always constant that there must be a degree of length contraction and time dilation on the train - so that light speed still works out to be light speed.

But it's a tiny effect which is just ensuring that the 300,000 kilometers a second light beam doesn't gain an additional 60 kilometers an hour. So that tiny effect does have a tiny influence of the ball's motion – but it's a really, really tiny effect.

Length contraction and time dilation effects become a lot more obvious if we imagine something moving really, really fast relative to the platform. So say we fly the starship Enterprise past the platform at 90% of the speed of light. Then if you're on the platform watching someone on the starship shining a torch beam, there has to be a huge amount of length contraction and time dilation on the starship to ensure that torch beam on the starship that you can see from the platform still moves at exactly the speed of light. And with all that length contraction and time dilation going on, a 10 kilometer an hour ball will look more like it's only moving a 5 kilometers an hour on the starship – which is a substantial 50% effect.

OK Steve - so on train there's a tiny bit of length shortening and time dilation (which are hardly noticeable) but on the starship there's really big effects. Yeah?

Yes. Everything else changes in a way that ensures that light will always be seen to move at the speed of light.

Aye, well OK – I mean I've heard this sort of thing before, Steve. It's not what you'd call intuitive, is it?

That's probably true. I think understanding special relativity is largely about remembering a set of rules. So, it's enough to know that if something is moving fast relative to you – its lengths are measurably shorter and its clocks run slower. That's about it really.

What people don't always get is that nothing strange happens within your own frame of reference. So when you throw a ball at 10 kilometers an hour on the platform, or on the train or on the Starship Enterprise – as far as you are concerned, the ball just goes at 10 kilometers an hour. It's only when you look out at someone else's frame of reference that you see strange things happening.

Aye well, fair enough Steve.

And we can take this frame of reference idea back to Galileo. In his book *The Dialogue Concerning Two Chief World Systems*...

And this dialogue Steve – I believe it was Galileo creating a sort of imaginary conversation between different people - even though it was just him all the time. Is that right?

Well, that is right. Anyway, in this dialogue he had a Ptolemaic proponent of the geocentric model of the universe saying that the Earth couldn't possibly be in motion because all the people on the Earth would feel that motion. Galileo then had his proponent of the heliocentric model of the universe respond with a thought experiment which was about a ship – although a sailing ship rather than a star ship. In this thought experiment, you imagine dropping a stone from the top of the ship's mast, so that it falls towards the deck.

If the Ptolemaic view of the world was right, then the stone should fall diagonally towards the back of the ship – because the ship is moving forward. But in reality, if the ship is moving at a constant velocity, the stone already posseses that velocity. So, it's just going to fall straight down, parallel to the mast - just like it would do if the ship was docked at port – as long as that motion is a constant velocity rather than an acceleration or deceleration.

Oh aye – and what happens if you accelerate or decelerate Steve?

Well, the rules have to change a bit and you need to call on general relativity – and that probably needs another podcast.

Fair enough Steve. Well let's hear you summarise the whole special relativity story then.

The mathematics of Einsteinian physics, ensures that an observer in any frame of reference will observe that distances and time in another frame of reference may change in a totally predictable and calculable way that will always ensure that light speed (measured as distance over time) always works out to be the same (around 300,000 kilometers a second in a vacuum).

And that will always happen regardless of who you are, where you are or how fast you are moving.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website with no ads, no profit, just good science at least in a relative sense. Bye.