M.8 Special Relativity

M.8.1 Frames of Reference

Imagine, as Einstein did in many of his thought (Gedanken - German) experiments, that you are on a train which is travelling at 60 km/h. You run towards the front of the train at 5 km/h. Your speed relative to the train is 5 km/h.
Your speed relative to an observer, stationary beside the track, is something different. They see you as travelling 60 + 5 = 65 km/h

The train and the tracks can be considered as frames of reference. Your speed is different depending on which of these frames of reference is used.
Frames of reference which is stationary or moving with constant velocity is referred to as inertial frames of reference.

In general if a body *A* and an observer *B* are moving with velocities $\boldsymbol{v}_a$ and $\boldsymbol{v}_b$ respectively, then the velocity of body *A* relative to observer *B* ($\boldsymbol{v}_{ab}$) is the velocity the body *A* appears to have to observer *B*, when *B* is unaware of their own motion, i.e., when the observer has apparent zero velocity. We require a frame of reference in which the observer's velocity is zero. To obtain this we need to subtract the velocity of the observer.

$$\text{velocity}_{\text{A relative to B}} = \boldsymbol{v}_{ab} = \boldsymbol{v}_a - \boldsymbol{v}_b.$$

Here is a 1960's video on frames of reference, it is from PSSC Physics. The first nine minutes is all you need. https://www.youtube.com/watch?v=PhVy1WG_lKQ

Example 1 (2009 Q13, 2 marks)

Which one of the following statements is the best statement about inertial frames of reference?

A. Inertial frames must be stationary.

B. Inertial frames must be accelerating.

C. The laws of physics have the same form in all inertial frames.

D. Inertial frames cannot be moving at close to the speed of light.

If you threw the same ball, with the same speed, while standing on the back of a truck, you must take into account the speed of the truck and also the direction in which you throw the ball.

Consider the issue of a person standing still on the roadside. What speed will the observer see the ball travel at? The truck travels forwards at 40 m s^{-1}, the ball backwards (*relative to the truck*) at 10 m s^{-1}, so we add the velocities (remember vector addition!):

= 40 m s^{-1} forwards + 10 m s^{-1} backwards

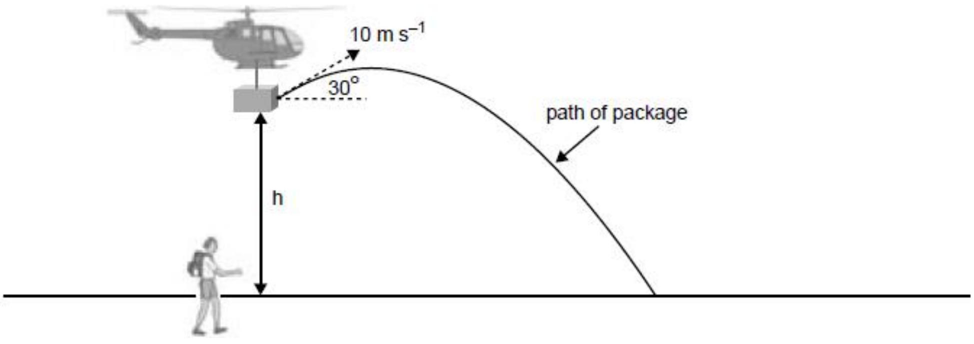
= 30 m s^{-1} forwards.

So the ball travels at a velocity less than the truck, in the same direction of the truck, according to the observer at the roadside. According to the thrower on top of the truck, the ball is travelling backwards at 10 m s^{-1}. Both are correct, but each is in a different frame of reference.

A bushwalker is stranded while walking. Search and rescue officers drop an emergency package from a helicopter to the bushwalker. They release the package when the helicopter is a height (h) above the ground, and directly above the bushwalker.

The helicopter is moving with a velocity of 10 m s^{-1} at an angle of 30° to the horizontal, as shown below. The package lands on the ground 3.0 s after its release.

Ignore air resistance in your calculations.



Example 2 (2004 Pilot Q2, 2 marks)

Assuming that the helicopter continues to fly with its initial velocity, where is it when the package lands? Which one of the statements below is most correct?

A. It is directly above the package.

B. It is directly above a point that is 15 m beyond the package.

C. It is directly above a point that is 26 m beyond the package.

D. It is directly above a point that is 30 m from the bushwalker.