Answer to Essential Question 26.5: According to Isabelle, she and the relevant observer in her reference frame are separated by 24 light-years, the distance between Earth and Zorg in her reference frame. The fastest the message could be sent would be at light speed, in which case the message would take 24 years to reach Isabelle.

Chapter Summary

Essential Idea: Special Relativity.

The closer relative speeds get to the speed of light, the more time and space exhibit unusual behaviors. This includes (but is not limited to) clocks in different reference frames running at different rates, lengths measured to be different by different observers, and events that are simultaneous for one observer taking place at different times for other observers.

The Postulates of Special Relativity

Relativity is based on two simple ideas, or postulates. One implication of these postulates is that nothing can travel faster than the speed of light in vacuum, which is $c = 3.00\times10^8$ m/s.

1. The speed of light in vacuum is the same for all observers.
2. There is no preferred reference frame. The laws of physics apply equally in all reference frames.

The Spacetime Interval

Observers in different constant-velocity reference frames always agree on the value of the spacetime interval between two events, as defined by

$$(c\Delta t)^2 - (\Delta x)^2 = (c\Delta t')^2 - (\Delta x')^2 = (\text{spacetime interval})^2 ,$$ (Eq. 26.1: **the spacetime interval**)

where $c\,\Delta t$ and $c\,\Delta t'$ are the time intervals, converted to distance units, between the two events as measured from two different frames of reference, and Δx and $\Delta x'$ are the spatial separations between the two events in the same two reference frames. If the left-hand side of the equation gives a negative number, it is appropriate to reverse the order of the terms.

Proper time and time dilation

An observer measures the proper time interval Δt_{proper} between two events when that observer is present at the location of both events. Observers for whom the events take place in different locations measure a longer time interval Δt between the events.

$$\Delta t = \frac{\Delta t_{proper}}{\sqrt{1-\frac{v^2}{c^2}}} = \gamma\ \Delta t_{proper} ,$$ (Equation 26.2: **Time dilation**)

where v is the relative speed between the observers.

Length contraction

An observer measures the proper length L_{proper} between two points when the points are at rest with respect to that observer (that is, the observer is in the same frame of reference as the points). For an observer in a different reference frame, the observer measures a contracted length L between the points along the direction of motion. v is the relative speed between the observers.

$$L = \sqrt{1-\frac{v^2}{c^2}}\ L_{proper} = \frac{L_{proper}}{\gamma} .$$ (Equation 26.3: **Length contraction**)