Group Problems #1
Solutions

Tuesday, August 23

**Problem 1  \textit{Galilean Transformation}**

You are driving at a steady 100 km/h. At noon you pass a parked police car. At twenty minutes past noon, the police car passes you, traveling at 120 km/h.

(a) How fast is the police car moving relative to you? \( v_d = 100 \text{ km/h} \) and \( v_p = 120 \text{ km/h} \) \( \Rightarrow \Delta v = 20 \text{ km/h} \).

(b) When did the police car start driving, assuming that it accelerated from rest to 120 km/h instantaneously? In 20 minutes (1/3 hour), the driver goes \( 100 \cdot \frac{1}{3} \text{ km} \). Traveling at 120 km/h, it takes the police car \( \Delta t_p = \frac{100/3 \text{ km}}{120 \text{ km/h}} = \frac{5}{18} \text{ hour} \). So the police car starts \( 1/3 - 5/18 = 1/18 \text{ hour} \) after the car passes.

(c) How far away from you was the police car when it started? After 1/18 h, the car has traveled \( 1/18 \text{ h} \cdot 100 \text{ km/h} = 50/9 \text{ km} \).

(d) Plot the trajectories of the driver and police car on a graph \((x \text{ vs. } t)\). Now plot the trajectories as \(t \text{ vs. } x\).

(e) Plot the trajectories \((t \text{ vs. } x)\) from the driver’s perspective: the rest frame of the driver.

(f) Plot the trajectories \((t \text{ vs. } x)\) in the police car’s rest frame.

(g) Label the event coordinates in all three reference frames: Earth, Driver, Police. Use convention \((t, x)\) for coordinates:

In Earth frame: \(A(0, 0); B(1/18 \text{ hour}, 0); C(1/3 \text{ hour}, 100/3 \text{ km})\).

In Driver frame: \(A(0, 0); B(1/18 \text{ hour}, -50/9 \text{ km}); C(1/3 \text{ hour}, 0)\).

In Police frame: \(A(0, 0); B(1/18 \text{ hour}, 0); C(1/3 \text{ hour}, 0)\).
Figure 1: Space-time diagrams in the Earth frame. The left panel shows $x$ vs. $t$, while the right panel shows $t$ vs. $x$.

Figure 2: Space-time diagram in the driver frame.

Figure 3: Space-time diagram in the police frame.