Sample Final Exam — Einstein and Relativity

Multiple Choice

1. A passenger train travels east at high speed. One passenger is located at the east side of one car, another is located in the west side of that car. In the train's frame, these two passengers glance up at the same time. In the earth's frame,

a. they glance up simultaneously.
b. the passenger at the east side glances up first.
c. the passenger at the west side glances up first.
d. the passengers glance sideways.

Answer: c — relativity of simultaneity (rear event happens first).

2. An earthworm has eight hearts located at different parts of its body. The eight hearts must all beat at the same time in order to produce effective blood circulation. If an earthworm flies past us in a rocket ship traveling at 3/5th the speed of light, it front hearts will be out of synch with its rear hearts. Nevertheless, the earthworm remains alive because

a. the worm is so short (due to length contraction) that it no longer requires effective blood circulation.
b. the worm is not perfectly rigid.
c. the hearts remain synchronized in the worm's own frame.
d. both the heartbeats and the respiration rate slow down.

Answer: c — the phenomena mentioned in a, b, and d occur, but do not explain why the earthworm remains alive.

3. James travels at high speed from the Earth to the star Alpha Centauri, four light years away. In James's frame

a. the trip takes more time than it does in the Earth's frame.
b. James travels to Alpha Centauri over a length that is shorter than four light years.
c. clocks on Earth and on Alpha Centauri are synchronized.
d. Alpha Centauri travels to James over a length that is shorter than four light years.

Answer: d — length contraction.

4. A train is 200 feet long in its own frame, and a railroad platform is 160 feet long in *its* own frame. The train rushes past the platform so fast that, in the platform's frame, the train and platform are the same length. How fast was the train moving?

a. $\frac{4}{5}c$ b. $\frac{5}{4}c$ c. $\frac{3}{5}c$ d. $\frac{4}{3}c$ e. $\frac{5}{3}c$

Answer: c.

5. Ignore the rotation of the earth. Which clock ticks more slowly?

a. The one on the top of a mountain.

b. The one at the bottom of that same mountain.

c. They tick at the same rate.

d. Cannot be determined from the information given.

Answer: b — gravitational time dilation.

Short Answer

A train is 900 feet long in its own frame, and a tunnel is 1500 feet long in its own frame. Ivan sits at the very front of the train and Veronica sits at the very rear. The train speeds from west to east through the tunnel at $V = \frac{4}{5}c$ (so that $\sqrt{1-(V/c)^2} = \frac{3}{5}$).

In the train's frame: The moving tunnel is length contracted to be exactly 900 feet long [900 feet = $\frac{3}{5} \times$ (1500 feet)]. Ivan and Veronica both stick out their heads and glance up at the instant that the train exactly fits within the tunnel, so Veronica sees the west portal of the tunnel and Ivan sees the east portal of the tunnel. All of these questions deal with the situation **in the tunnel's frame.**

Explain your answers briefly but cogently in the space provided. Sketches might be helpful.

1. In the tunnel's frame, how long is the train?

2. In the tunnel's frame, Veronica glances before Ivan does because her clock is set ahead of his. By how much is Veronica's clock set ahead?

3. While Ivan's watch ticks off 720 nans, how much time elapses in the tunnel's frame? (In other words, how much time elapses between Veronica's glance and Ivan's glance?)

4. During the time between glances, how far does the train move (in the tunnel's frame)?

5. Sum your answer to question 1 and your answer to question 4 to find Ivan's position when he glances up. How does this compare to the situation as found in the train's frame?