1. Einstein’s special theory of relativity is based in part on which one of the following postulates?

   *Mass and energy are equivalent*

   *Space and time are absolutes*

   *Energy is always conserved*

   *The speed of light is constant*

2. An inertial frame of reference is one that:

   *moves at constant velocity*

   *moves at constant speed*

   *is stationary*

   *moves at constant acceleration*
3. An astronaut moves at a constant velocity of 0.5c relative to an Earth observer. Both astronaut and Earth observer measure the interval between heartbeats of the astronaut. Who measures the proper time?

   The Earth observer

   The astronaut

   Neither

   Both

4. In Einstein's thought experiments of lighting striking the front and rear of a train carrying one observer past a second stationary observer, who measures the proper time between the lightning strikes?

   The train observer

   The stationary observer

   Neither

   Both
5. A spaceship is flying past an Earth observer as the Earth observer measures it's length. How is this measured length different for a larger velocity of the spaceship.

   It is smaller

   It is larger

   It remains the same

   It cannot be measured.

6. A 30-year old astronaut leaves Earth, travels at speeds close to that of light, and then returns to earth after 20 years as measured on earth. What would be the astronaut's biological age upon returning?

   Less than 50 years.

   50 years.

   More than 50 years.

   100 years.
7. A space probe has an 18.0-m length when measured at rest. What length does an observer at rest measure when the probe is going by at a speed of 0.700 c?

- 25.2 m
- 12.9 m
- 12.6 m
- 9.18 m

8. The period of a pendulum is 2.0 s in a stationary inertial frame of reference. What is its period when measured by an observer moving at a speed of 0.60 c with respect to the inertial frame of reference?

- 1.2 s
- 1.6 s
- 2.5 s
- 3.3 s
9. In a one-dimensional system like our train example, two events separated by 1 m are observed to be simultaneous by a stationary observer. To an observer moving at nonzero velocity these events are observed to be
   also simultaneous

   not simultaneous

   depends on velocity

   depends on type of event

10. A boxcar moves the right. One light flash moves from back to front, another moves from front to back. A passenger records how long it takes each flash to pass from one end of the boxcar to the other end. Which took longer?
   The flash going from back to front.

   The flash going from front to back.

   They both took the same time.

   Depends on position of passenger.
11. The observed relativistic length of a super rocket moving by the observer at 0.70 c will be what factor times that of the measured rocket length if it were at rest?

- 0.45
- 0.71
- 0.82
- 1.4
Answers:

1) Einstein concluded that all physical laws held in inertial reference frames. One of these is Maxwell's laws of electromagnetism, which concludes that light propagates at a particular speed c.

2) An inertial frame of reference moves at constant velocity. A frame moving at constant speed could still be accelerating - it could be moving in a circle.

3) The proper time is the time interval measured in a frame where the events occur at the same spatial location. The heartbeats occur in the astronaut's body, which is at rest in the frame of the ship. So the astronaut measures the proper time.

4) Neither measure the proper time. For both observers, the lighting strikes hitting the front and rear of the train occur at different spatial locations.
5) The proper length is measured in a frame in which the object is at rest. This is the spaceship frame. All other measured lengths are shorter by a factor gamma. Gamma increases with increasing velocity.

6) Time dilation says that the Earth observer observes clocks to run slow on the ship. This means that the Earth observer sees that biological processes on the ship have slowed down, and the astronaut ages less than the Earth observer, who has aged 20 years.

7) The gamma factor is determined by the relative velocity: \( \gamma = \frac{1}{\sqrt{1-(v/c)^2}} \)

\[
= \frac{1}{\sqrt{1-0.7^2}} = \frac{1}{\sqrt{1-0.49}} = 1.4
\]

The observed length is contracted by this factor, so observed length = 18m/1.4 = 12.9m

8) The gamma factor is determined by the relative velocity: \( \gamma = \frac{1}{\sqrt{1-(v/c)^2}} \)

\[
= \frac{1}{\sqrt{1-0.6^2}} = \frac{1}{\sqrt{1-0.36}} = 1.25
\]

The proper time is measured in the frame where the pendulum is at rest. The time measured by the moving observer is longer by a factor \( \gamma = 1.25 \), so measured time = (2.0s) x 1.25 = 2.5s
9) Since the events are not at the same spatial location, the proper time is not measured, and we cannot use the time dilation result (gamma factor). But we saw in class from the train example that the train observer sees these events as not simultaneous, as long as he is moving at some nonzero velocity.

10) It is a principle of special relativity that the speed of light is observed to have the same value, c, in all inertial reference frames. Since the speed is the same, and the distance traveled by the two flashes is the same, the time taken by each is the same.

11) The length measured by the stationary observer is a factor gamma shorter than the length measured when it is at rest. This is length contraction. The gamma factor is determined by the relative velocity: gamma = 1/sqrt(1-(v/c)^2) = 1/sqrt(1-0.7^2)=1/sqrt(1-0.49)=1.40m