

## Conceptual Questions

### 28.1 Einstein's Postulates

1.

Which of Einstein's postulates of special relativity includes a concept that does not fit with the ideas of classical physics? Explain.

2.

Is Earth an inertial frame of reference? Is the Sun? Justify your response.

3.

When you are flying in a commercial jet, it may appear to you that the airplane is stationary and the Earth is moving beneath you. Is this point of view valid? Discuss briefly.

### 28.2 Simultaneity And Time Dilation

4.

Does motion affect the rate of a clock as measured by an observer moving with it? Does motion affect how an observer moving relative to a clock measures its rate?

5.

To whom does the elapsed time for a process seem to be longer, an observer moving relative to the process or an observer moving with the process? Which observer measures proper time?

6.

How could you travel far into the future without aging significantly? Could this method also allow you to travel into the past?

### 28.3 Length Contraction

7.

To whom does an object seem greater in length, an observer moving with the object or an observer moving relative to the object? Which observer measures the object's proper length?

8.

Relativistic effects such as time dilation and length contraction are present for cars and airplanes. Why do these effects seem strange to us?

9.

Suppose an astronaut is moving relative to the Earth at a significant fraction of the speed of light. (a) Does he observe the rate of his clocks to have slowed? (b)

What change in the rate of Earth-bound clocks does he see? (c) Does his ship seem to him to shorten? (d) What about the distance between stars that lie on lines parallel to his motion? (e) Do he and an Earth-bound observer agree on his velocity relative to the Earth?

#### 28.4 Relativistic Addition of Velocities

10.

Explain the meaning of the terms “red shift” and “blue shift” as they relate to the relativistic Doppler effect.

11.

What happens to the relativistic Doppler effect when relative velocity is zero? Is this the expected result?

12.

Is the relativistic Doppler effect consistent with the classical Doppler effect in the respect that  $\lambda_{\text{obs}}$  is larger for motion away?

13.

All galaxies farther away than about  $50 \times 10^6$  ly exhibit a red shift in their emitted light that is proportional to distance, with those farther and farther away having progressively greater red shifts. What does this imply, assuming that the only source of red shift is relative motion? (Hint: At these large distances, it is space itself that is expanding, but the effect on light is the same.)

#### 28.5 Relativistic Momentum

14.

How does modern relativity modify the law of conservation of momentum?

15.

Is it possible for an external force to be acting on a system and relativistic momentum to be conserved? Explain.

#### 28.6 Relativistic Energy

16.

How are the classical laws of conservation of energy and conservation of mass modified by modern relativity?

17.

What happens to the mass of water in a pot when it cools, assuming no molecules escape or are added? Is this observable in practice? Explain.

18.

Consider a thought experiment. You place an expanded balloon of air on weighing scales outside in the early morning. The balloon stays on the scales and you are able to measure changes in its mass. Does the mass of the balloon change as the day progresses? Discuss the difficulties in carrying out this experiment.

19.

The mass of the fuel in a nuclear reactor decreases by an observable amount as it puts out energy. Is the same true for the coal and oxygen combined in a conventional power plant? If so, is this observable in practice for the coal and oxygen? Explain.

20.

We know that the velocity of an object with mass has an upper limit of  $c$ . Is there an upper limit on its momentum? Its energy? Explain.

21.

Given the fact that light travels at  $c$ , can it have mass? Explain.

22.

If you use an Earth-based telescope to project a laser beam onto the Moon, you can move the spot across the Moon's surface at a velocity greater than the speed of light. Does this violate modern relativity? (Note that light is being sent from the Earth to the Moon, not across the surface of the Moon.)