

Solutions

Chapter S2

13. Special relativity has been tested many times. For example, mass increase and time dilation have been observed with particles that move near the speed of light in particle accelerators. Accelerators have also shown that we cannot get particles to move faster than the speed of light. The Michelson-Morley experiment showed that the speed of light really is absolute. Other experiments include observations of time dilation with precise clocks on moving airplanes and nuclear energy, demonstrating Einstein's equation $E = mc^2$.

43. a) As you observe a spaceship moving past, you will see their clocks running slow. That is, everything on the spaceship would appear to be taking place in slow motion.
b) The spaceship would be shortened in the direction of its motion. Its height and width would be unchanged.
c) The mass of the spaceship would be increased compared to its rest mass.
d) A passenger on the spaceship would say that your clocks are slow, your length is contracted, and your mass is increased. Because all inertial frames are equivalent, the situations seen by you and by passengers on the spaceship must be symmetric.

Chapter S3

4. The equivalence principle states that the effects of gravity are equivalent to the effects of uniform acceleration. This means, for example, that a person in an enclosed box cannot tell if she is sitting on the surface of the Earth or accelerating at $1g$ 9.8 m/sec^2 in space.

11. You can tell if you are following the straightest possible path in your spacetime if you feel no weight. If you feel weight, you are not on the straightest possible path.

18. Because time travels more slowly on the surface of the Sun (where the acceleration of gravity is higher), the time it takes for a trillion cycles to occur for a photon is longer. So on Earth, we will see fewer cycles in each second, making the light appear to have a lower frequency or a longer wavelength. This shifts the photon's wavelength in the "red" direction, and we call the effect "gravitational redshift."