Gravity

Living on Earth we are used to accounting for gravity. Einstein thought a lot about how to eliminate the effects of gravity and what the implications are of doing that.

In each situation below you are enclosed in an elevator. You have a super-ball that you throw toward one wall of the elevator. You release the ball so its initial velocity is horizontal with respect to you. The super-ball experiences elastic collisions with the walls of the elevator.

Describe the path of the ball from your perspective inside the elevator, and from Superman's perspective outside the elevator. Superman is at rest relative to the Earth, and he is using his x-ray vision to see through the wall of the elevator.

The elevator is at rest. What do you see the ball doing? What does Superman see?

The elevator is moving upward with a constant velocity of 2.0 m/s. What do you see the ball doing? What does Superman see?

The elevator is accelerating upward with a constant acceleration of 2.0 m/s^2. You release the ball when the elevator is moving upward at 2.0 m/s. What do you see the ball doing? What does Superman see?

The cable supporting the elevator breaks, and the elevator is in free-fall. What do you see the ball doing? What does Superman see?

The elevator is projected straight up into the air. You release the ball when the elevator is moving upward. What do you see the ball doing? What does Superman see? Can you tell when the elevator reaches its highest point? Can Superman?

Now we'll move the elevator to outer space, far from any gravitational influences. Find a situation in which the elevator's motion, from your perspective inside the elevator, produces motion of the super-ball that is indistinguishable from the motion you observed when the elevator was at rest on Earth.

Find a situation in which the elevator's motion, from your perspective inside the elevator, produces motion of the super-ball that is indistinguishable from the motion you observed when the elevator was in free-fall on Earth.

Einstein was the first to realize that accelerated motion in a frame of reference free from all gravitational influences is equivalent to motion in a frame of reference moving at constant velocity (or at rest) in a uniform gravitational field, and that motion with constant velocity in a frame of reference free from all gravitational influences is equivalent to free-fall in a frame of reference in a uniform gravitational field.

What happens in a non-uniform gravitational field? In this case, from our perspective inside the elevator, we observe the effects of tidal forces – essentially the difference between gravitational forces at different locations.

Let's say we have a very very tall elevator, and we're in free-fall above the Earth. Release a ball from rest near the floor of the elevator, then release a ball from rest near the ceiling of the elevator. Do the balls move with respect to one another? If so, how? Why?

Instead we have a very wide elevator. Release a ball from rest near one side of the elevator, and then release a ball from rest near the other side. Do the balls move with respect to one another? If so, how? Why?
