19.2: The Elevator

An elevator is a large box (called a car) that is used to lift and lower passengers or cargo, typically operated by a pulley arrangement.

Suppose an elevator contains a passenger of mass m, standing on a scale. The scale will then measure the total force on the passenger. If the elevator is stationary, the scale measures the passenger's weight, mg. If the elevator is moving up or down with a constant velocity, then the scale still measures only the passenger's weight, mg. But if the elevator is accelerating upward with acceleration a, then the passenger will feel heavier; the elevator's upward acceleration will be added to the acceleration due to gravity, and the scale will read $m(g+a)$. If the elevator is accelerating downward with acceleration a, then the passenger will feel lighter; the elevator's downward acceleration will be subtracted from the acceleration due to gravity, and the scale will read $m(g-a)$. If the cable holding the elevator breaks, the elevator will fall downward with an acceleration $a=g$, and the scale will read zero; in other words, there will be no force on the passenger, who will begin floating inside the elevator car, similar to the way astronauts float inside a spacecraft. [1]

Suppose you fall asleep, and wake up in a closed, windowless elevator car in which you have your normal weight. How do you know whether you're sitting stationary on the surface of the Earth, or if you're in space, being accelerated by rockets at $9.8\ \mathrm{m/s^2}$? A remarkable consequence of Einstein's General Theory of Relativity (Section 51.8) is: you can't tell. There is no experiment you can do that would enable you to distinguish gravity from an acceleration of the elevator car. Gravity and acceleration are equivalent. This result has been proposed as a means for providing artificial gravity to astronauts during a long space voyage: the spacecraft can accelerate at $9.8\ \mathrm{m/s^2}$ to provide artificial gravity for the astronauts up to the half-way point of their trip; then the ship can rotate 180° and de-accelerate at $9.8\ \mathrm{m/s^2}$ for the last half of the trip.

[1] In real life, elevators are built with several levels of safety devices to prevent this kind of free fall. If the power goes out, the brakes automatically engage, since the power holds the brakes open. If the car goes too far inside the shaft, another independent set of brakes engages. Also, there is a large spring at the bottom of the shaft to catch the passengers just in case everything else fails.