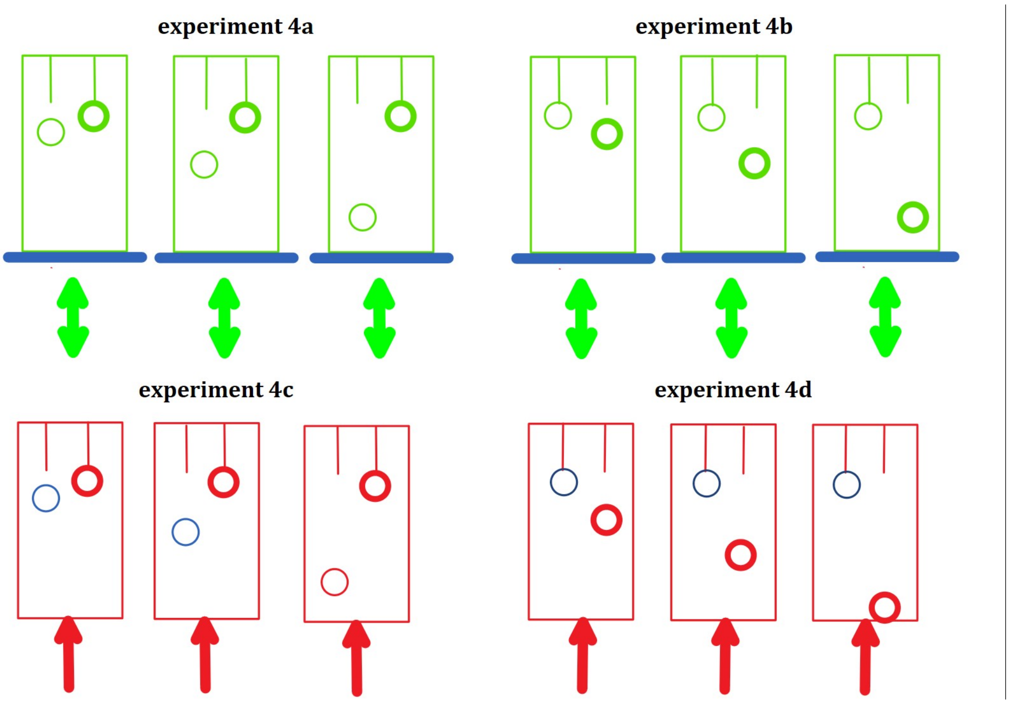
The Weak Equivalence Principle

According to QGD, there is only one definition of mass: the intrinsic mass of an object being simply the number of $preons^{(+)}$ it contains. The intrinsic mass determines not only the effect of gravity but all non-gravitational effect.

The gravitational mass is that property which determines the magnitude of gravitational acceleration while the inertial mass determines the magnitude of non-gravitational acceleration. It is important in describing a dynamic system that we understand that the distinction made between the gravitational and inertial masses are actually distinctions between gravitational and non-gravitational effects. Doing so, we will show that the intrinsic mass determines both gravitational and non-gravitational effects and that these effects are very distinct, thus distinguishable.

The acceleration of an object is given by $\Delta v_a = \frac{\left\|\Delta\vec{P}_a\right\|}{m_a}$ where $\left\|\Delta\vec{P}_a\right\| = \left\|\Delta\vec{G}\right\|$ for gravitational acceleration and $\left\|\Delta\vec{P}_a\right\| = \left\|\vec{F}\right\|$ for non-gravitational force $\vec{F}$ imparting momentum to a. From $\Delta v_a = \frac{\left\|\Delta\vec{G}\right\|}{m_a} = \frac{1}{m_a} m_a m_b \left(k - \frac{d^2+d}{2}\right) = m_b \left(k - \frac{d^2+d}{2}\right)$ we know that gravitational acceleration is independent of the mass of the accelerated body, while $\Delta v_a = \frac{\left\|\vec{F}\right\|}{m_a}$ tells us that non-gravitational acceleration is inversely proportional to the mass of the accelerated body.

Let us consider the experiments represented in the figure below which based on Einstein's famous thought experiment.



The green rectangles represent a room at rest relative to Earth's gravitational field.

The Earth and green room dynamics is described by the equation $\vec{v}_{\boxed{g}} = \frac{\vec{P}_{\boxed{g}}}{m_{\boxed{g}}} = \frac{\vec{P}_{\boxed{\varepsilon}}}{m_{\boxed{\varepsilon}}} = \vec{v}_{\boxed{\varepsilon}}$

where $\boxed{g}$ represents the green room and $\boxed{\varepsilon}$ the Earth. Applying the laws of momentum discussed earlier, we know that green room and the Earth are moving at the same speed hence, since $\left(v_{\boxed{g}} - v_{\boxed{\varepsilon}}\right) m_{\boxed{g}} = 0$ and $\left(v_{\boxed{\varepsilon}} - v_{\boxed{g}}\right) m_{\boxed{\varepsilon}} = 0$ there is no momentum transfer between the Earth and the green room, consequently no non-gravitational acceleration. And since there is no change in distance between $\boxed{g}$ and $\boxed{\varepsilon}$, there is no variation in the gravity, so no gravitational acceleration either.

The red room is in region of space where the effect of gravity is negligible. A non-gravitational force imparts momentum $\vec{F}$ to the red room from the floor up.

Einstein's thought experiment assumes that it is possible to apply a force which will accelerate the red room so that, to an observer within the room, the acceleration will be indistinguishable from that of gravity. That is, He assumes that $\vec{F} = \Delta\vec{G}$.

Before going into a full description of the experiment, we need to keep in mind the distinctions between gravitational acceleration and non-gravitational acceleration. For one, gravitational acceleration of body is independent of its mass while non-gravitational acceleration of a body is inversely proportional to its mass. That is: $\Delta\vec{v}_a = \frac{\left(\vec{v}_F - \vec{v}_a\right) m_{\vec{F}}}{m_a}$ where $\vec{v}_F$ is the speed of the particles carrying the momentum $\vec{F}$ (in the case of a rocket engine, this is the speed of the molecules of gas produced by the engine which interact with the room) and v_a the speed of the room. It follows that we can set $\vec{F} = \Delta\vec{G}$ for a given m_a but for an object of mass $m_b \neq m_a$, we can have $\vec{F} = \Delta\vec{G}$ but $\vec{F} \neq \vec{F}'$ and $\Delta\vec{v}_a = \frac{\left(\vec{v}_F - \vec{v}_a\right) m_{\vec{F}}}{m_a} \neq \frac{\left(\vec{v}_F - \vec{v}_b\right) m_{\vec{F}}}{m_b} = \Delta\vec{v}_b$. Which means that, to maintain an acceleration equivalent to gravitational acceleration, $\vec{F}$ must be adjusted to take into account the mass of the accelerated to compensate for its speed since the imparted momentum of a rocket engine (or any other form of propulsion) decreases as the speed increases.

Returning to experiment 4, the green and red rooms will have the same mass and composition. In each room, there will be a set of two spheres of mass m_a and m_b where $m_a < m_b$. In the rooms initial state the spheres are suspended from rods fixed to the ceilings. The spheres can be released on command. In each of the room is an observer that is cut off from the outside world.

They have no clue as to which of the two rooms they are in. The observers however, being experiment physicists, are trusted to measure the accelerations of the spheres in the two experiments and see if they can determine whether the room each is in is at rest in a gravitational field or uniformly accelerated.

In the first experiment, the spheres with mass m_a will be dropped in each room. In the second experiment, from the same initial state, spheres with mass m_b will be dropped. The observers will compare the results.

The green room observer finds that both spheres have the same rate of acceleration relative to the room despite having different masses. He finds this to be consistent with gravitational acceleration, but cannot exclude on these two experiments alone that he may be in a uniformly accelerated room.

The red room observer however finds that rate of acceleration of the a sphere is lower than the rate of acceleration of the more massive b sphere. His observations of the accelerations of the spheres being inconsistent with gravitational acceleration he must conclude that the room is accelerated by an external non-gravitational force $\vec{F}$.

Furthermore, being a physicist, the red room observer knows that at the moment a sphere is released, the momentum imparted by $\vec{F}$ is no longer transferred to the sphere. The sphere stops accelerating instantly and will move at the speed it had at the moment of its. Therefore, it is the room that is accelerated and not the sphere. The acceleration of the red room in its initial sate is $\Delta v_{\boxed{r}} = \dfrac{\left\|\Delta\vec{F}\right\|}{m_{\boxed{r}} + m_a + m_b}$. At the moment the a sphere is released, there is a sudden change in the rate of acceleration of the room given by $\Delta\Delta v'_{\boxed{r}} = \dfrac{\left\|\vec{F}\right\|}{m_{\boxed{r}} + m_b} - \dfrac{\left\|\vec{F}\right\|}{m_{\boxed{r}} + m_a + m_b}$.

The change the rate of acceleration after the release of sphere b is $\Delta\Delta v'_{\boxed{r}} = \dfrac{\left\|\vec{F}\right\|}{m_{\boxed{r}} + m_a} - \dfrac{\left\|\vec{F}\right\|}{m_{\boxed{r}} + m_a + m_b}$. The higher variation the in the rate of acceleration after the release of b is seen from within the room as a larger acceleration of b relative to the room.

So, it appears that observers can easily distinguish between being in a room at rest in a gravitational field from being in a uniformly accelerated room away from any significant gravitational field. This appears to invalidate the weak equivalence principle. Being an experimental physicist, the observer in the red room requires confirmation of his observation. He decides to repeat the experiment. After all, one experiment is not enough and one has to be able to reproduce the results before doing something so drastic as to refute the weak equivalence principle.

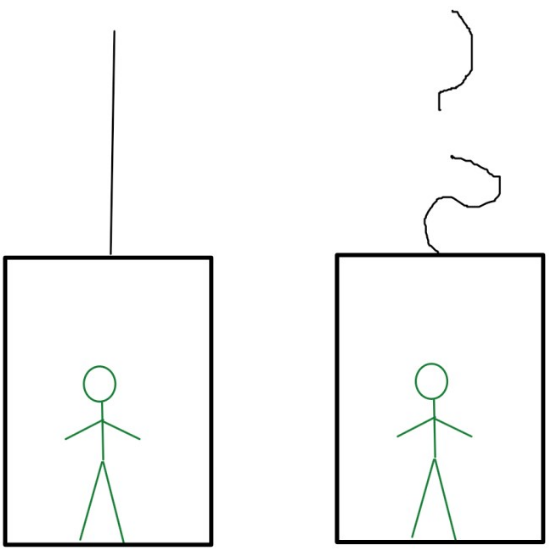
Again the more massive sphere accelerates faster than the lighter sphere, but something is different. The acceleration rates of sphere a and sphere b in the second set of experiments are slower than the accelerations of the same spheres in the first set of experiments. After conducting a few more experiments he finds the observations to be consistent with $\Delta\vec{P}_{\boxed{r}} = \left(v_{\vec{F}} - v_{\boxed{r}}\right)m_{\vec{F}}$ and concludes that the momentum imparted by the non-gravitational force decreases as speed of the room increases which allows him to predict that the maximum possible speed the red room can achieve is $\vec{v}_{\boxed{r}} = \vec{v}_{\vec{F}}$ at which speed $\Delta\vec{P}_{\boxed{r}} = \left(v_{\vec{F}} - v_{\boxed{r}}\right)m_{\vec{F}} = 0$ and $\Delta v_{\boxed{r}} = \dfrac{\Delta\vec{P}_{\boxed{r}}}{m_{\boxed{r}}} = 0$.

If experiments confirm QGD predictions that:

- Gravitational acceleration and non-gravitational acceleration are not equivalent then
    - The weak equivalence principle is falsified
- The outcome of an experiment may be affected by the speed of the laboratory then
    - The strong equivalence principle is falsified

Weightlessness in Einstein's thought Experiment

Consider a man standing in an elevator when suddenly the elevator cable breaks. After the rupture of the cable the elevator and the passenger and elevator are in free fall and, as if gravity had been turned off, they are weightless.



experiment 3

There is, it seems, no acceleration; an interpretation that is supported by the fact that if we were to put an accelerometer on the floor of the elevator, it would measure no acceleration. In fact, an accelerometer alone in free fall measures no acceleration. In the absence of other forces (assumed to be inexistent for the experiment) zero acceleration implies that zero force and a logical interpretation would be that gravity is not a force. This interpretation leads to the idea that gravity is the effect of curvature of space-time.

Let us describe the dynamics of the elevator and its passenger from Einstein's thought experiment of 1907. If the elevator is at rest before the rupture of the cable, then the dynamics is $\vec{v}_{\boxed{g}} = \frac{\vec{P}_{\boxed{g}}}{m_{\boxed{g}}} = \frac{\vec{P}_{\boxed{\varepsilon}}}{m_{\boxed{\varepsilon}}} = \vec{v}_{\boxed{\varepsilon}}$ where $\boxed{g}$ represents the elevator with the passenger and $\boxed{\varepsilon}$. In order to correctly describe the system, we need to use the intrinsic speed and momentum since the relative speed is misleading. Even though the speed of the passenger relative to the elevator is equal to zero, we know that it, along with the Earth, the solar system, and the entire galaxy, is speeding through space. Using conventional definitions of speed and momentum, which have null values, does not describe the system.

Before the cable ruptures

If the passenger were to jump in the elevator, that is, increase its speed by bending its legs and suddenly extending them, then, assuming that Δv_{pass} of extension from his the center of gravity, $\Delta\vec{P}_{\boxed{\varepsilon}} = \Delta v_{pass} m_{pass}$ and $\Delta\vec{P}_{pass} = -\Delta v_{pass} m_{pass}$. The momentum of the passenger after the jump is $\vec{P}'_{pass} = \vec{P}_{pass} - \Delta v_{pass} m_{pass}$ and its speed is $v'_{pass} = v_{pass} - \Delta v_{pass}$ where $-\Delta v_{pass}$ is the passenger's speed relative to the Earth. [7]

Now, applying the gravitational interaction equation, we know that after the jump the passenger will lose momentum proportionally to ΔG , that is $\Delta\vec{v}_{pass} = \frac{\Delta\vec{P}_{pass} - \Delta\vec{G}}{m_{pass}}$ so that when $\Delta\vec{G} = \Delta\vec{P}_{pass}$ the passenger speed will be back to its initial speed (zero relative to Earth) and the passenger will be gravitationally accelerated towards the Earth.

When the passenger lands back on the floor, the momentum of passenger will be $\vec{P}''_{pass} = \vec{P}_{pass} + \Delta\vec{G}$ resulting in a transfer of momentum from the passenger to the Earth (mediated by the elevator) and equal to $\Delta\vec{G}$ and since $\Delta\vec{G} = \Delta\vec{P}_{pass}$ the initial state is and conserving the momentum of the system.

We can now focus our attention on the thought experiment 3.

After the cable ruptures

When the cable is ruptured, $\vec{H} = \vec{P}_{\boxed{g}}$, the force that prevented the elevator from accelerating towards the Earth and which is transmitted via the cable is cut off. The elevator and passenger will move at their initial speed towards the Earth that is $\vec{v}_{\boxed{g}} = \frac{\vec{P}_{\boxed{g}}}{m_{\boxed{g}}}$. What the passenger

[7] We ignore here the negligible acceleration of the Earth from the jump which is $\Delta v_{\boxed{\varepsilon}} = \frac{\Delta v_{pass} m_{pass}}{m_{\boxed{\varepsilon}}}$

perceives as weightlessness is correct. Since the weight is simply the measurement of $\vec{H}$, when the cable is cut off, $\vec{H}$ is no longer imparted to the passenger and thus he is weightless. The removal of the effect of weight is not the removal gravity but the removal of the force that opposes gravity. There is increase in momentum, hence acceleration, which the passenger will be transferred to the Earth when the elevator hits the ground.

Since all components of an accelerometer are accelerated uniformly and at the same rate (see universality of free fall) it cannot measure gravitational acceleration. What an accelerometer measures is the effect of weight. That is: it measures $\vec{H}$. And $\vec{H}$ ceases to be transferred to the elevator and content after rupture of the cable so it will measure zero weight.

However, though the accelerometer (denoted acc below), cannot measure gravitational acceleration, it can inform of its momentum, its gravitational acceleration and its speed if we record and correctly interpret the measurement α it makes before release, the null reading during free fall, the measurement α' at impact and α'' after impact since:

$$\vec{H} = \vec{P}_{acc} \rightarrow \vec{P}_{acc} = \alpha \text{ ,}$$

$$\Delta G = \alpha' - \alpha'' \text{ and } \Delta v_{acc} = \frac{\Delta G}{m_{acc}} \text{, and}$$

$$\vec{H} = \vec{P}_{acc} \rightarrow \vec{P}''_{acc} = \Delta\alpha'' \text{.}$$

If there were a second elevator cabin was in space and moving at uniform speed, as describe in another one of Einstein thought experiment, it would be in a state of weightlessness and without gravity, so that $\alpha = \alpha' = \alpha'' = 0$. That would allow an observer to easily distinguish the experience of being in a cabin in space from being in a cabin free falling in a gravitational field.

What we have shown that though there is only one kind of mass, the effects of gravity and non-gravitational force can never be equivalent. And even when cut off from the outside world, as is imagined in Einstein's thought experiments, observers can correctly describe and distinguish between the forces acting on their environment through experiments as long as measurements are made of the initial, transitory and final states of the experiments and a minimum of two distinct experiments are conducted for each measured property.