Einstein's Equivalence Principle

Gravitational forces are locally equivalent to inertial forces[1] which are equivalent to non-inertial frames which are equivalent to curvilinear coordinates.

Inertial forces

Consider the motion of a free test body in an inertial frame K with Cartesian coordinates: its equation of motion is $\ddot{\vec{x}} = 0$ which is an equation for a straight line.

Now, consider the same body from a frame K' that accelerates with respect to K with acceleration $\vec{a}$. In this frame the equation of motion for a free body is $\ddot{\vec{x}} = -\vec{a}$ (not an equation for a straight line). This equation can be written with the help of a fictitious inertial force $\vec{F}_I = -m\vec{a}$ as the Newton's law: $m\ddot{\vec{x}} = \vec{F}_I$, where m is the mass of the body.

Inertial forces have the following properties:

1. Inertial forces are proportional to the masses of bodies, or, in other words, under inertial forces all bodies move with the same acceleration.

2. Inertial forces completely disappear after a coordinate transformation to an inertial (flat) frame.

3. Inertial forces appear in the equations of motions not due to some real physical fields affecting the body but as additional (geometrical) terms because the frame is not-inertial (curved).

Einstein's equivalence principle

Galileo's "Pisa experiment" showed that all bodies move in a gravitational field with the same acceleration, which is the first property of inertial forces. Einstein has postulated that all three properties of inertial forces are fulfilled for gravitational forces. In other words, gravitational forces are unlike other physical forces but much like fictitious inertial forces. This is called the Einstein's equivalence principle. It can also be formulated as:

1. In free fall the effects of gravity disappear in all possible local experiments and general relativity reduces locally to special relativity.

2. An accelerated frame is locally equivalent to a frame in a gravitation field.

3. Gravitation field is locally equivalent to a non-inertial frame.

4. Gravitation forces are equivalent to inertial forces.

[1] Inertial forces are fictitious forces which are thought to affect the bodies when looking at their motion from an non-inertial frame. Examples: centrifugal, Coriolis and elevator forces.