



2.8 I.2.4 Equivalence principle of Einstein

MH Consider the simplest possible case of an accelerated frame:

K-H 6.2  $\vec{\omega} = 0, \dot{\vec{\omega}} = 0, \vec{R}_0 \neq 0, \ddot{\vec{R}}_0 = \vec{a} = (a, 0, 0)$

In  $(S)$ , the accelerated frame

Newton's eqn becomes:

$$m \frac{d^2 \vec{r}}{dt^2} = \vec{F} - m \vec{a} = \vec{F} - m \ddot{\vec{R}}_0$$

Now look at the case of a free particle, i.e., no real forces  $\vec{F} = 0$ :

$$m \frac{d^2 \vec{r}}{dt^2} = -m \vec{a} = -m \ddot{\vec{R}}_0$$

Compare this to gravity at the surface of a planet, where a real gravitational force acts:  $\vec{F} = m \vec{g}$

Due to the equivalence of inertial and gravitational mass the fictitious force due to constant acceleration acts like a uniform gravitational field.

Acceleration of  $S$  to the right  $\Leftrightarrow$  uniform gravitational field to the left

Illustration: 2 closed railroad cars (no windows).

(A) is stationary (or moves with constant speed)

(B) is accelerated with  $\vec{a}$ . Both experience gravity.

Use a pendulum to measure (i) equilibrium orientation

(ii) period of oscillation

(i) For (B) the pendulum is in equilibrium at  $\tan \vartheta = \frac{a}{g}$  w.r.t. vertical

(ii) A pendulum of equal length  $L$  has a shorter period in (B):

$$T = 2\pi \sqrt{\frac{L}{g_{\text{eff}}}} = 2\pi \sqrt{\frac{L}{g^2 + a^2}}$$


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