

# Non-Inertial Frames of Reference. Forces of Inertia

- Non-Inertial Frames of Reference
- Forces of Inertia
- Principle of Equivalence of Force of Gravity and Force of Inertia
- Forces of Inertia in Rotating Frame of Reference
- Centrifugal Force
- Coriolis Force

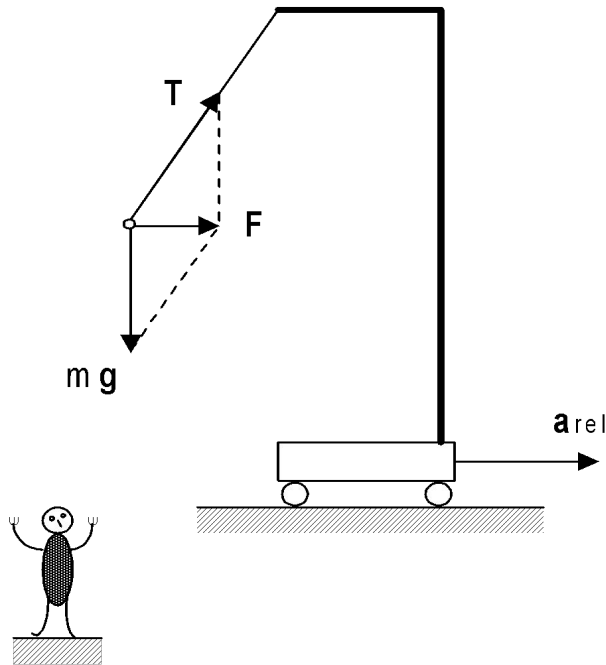
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# Non-inertial Frames of Reference

The frame is called *non-inertial* one if it moves with acceleration relative to an inertial frame of reference.

# Observer is in the Inertial Frame of Reference

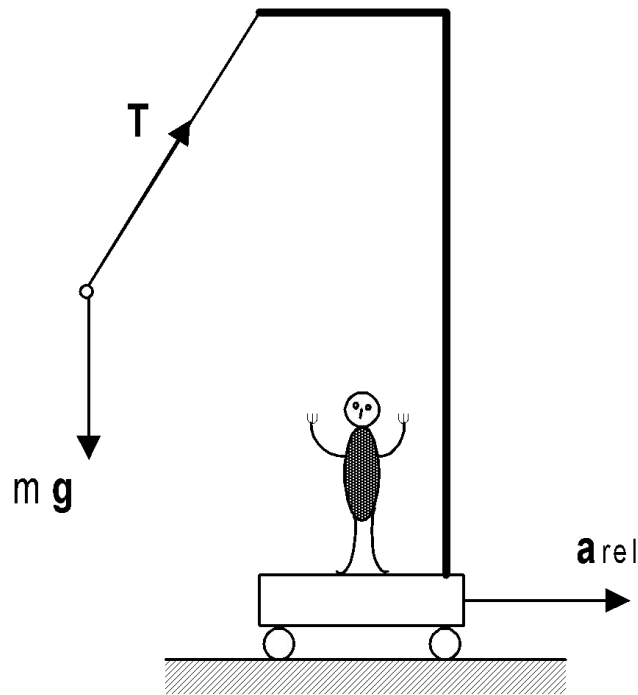


2 forces: the of gravity,  $mg$ , and the tension of a thread,  $T$ .

The motion is described by the fundamental law of motion,

$$\mathbf{T} + m\mathbf{g} = \mathbf{F} = m\mathbf{a}_{rel}.$$

# Observer is in the Non-Inertial Frame of Reference



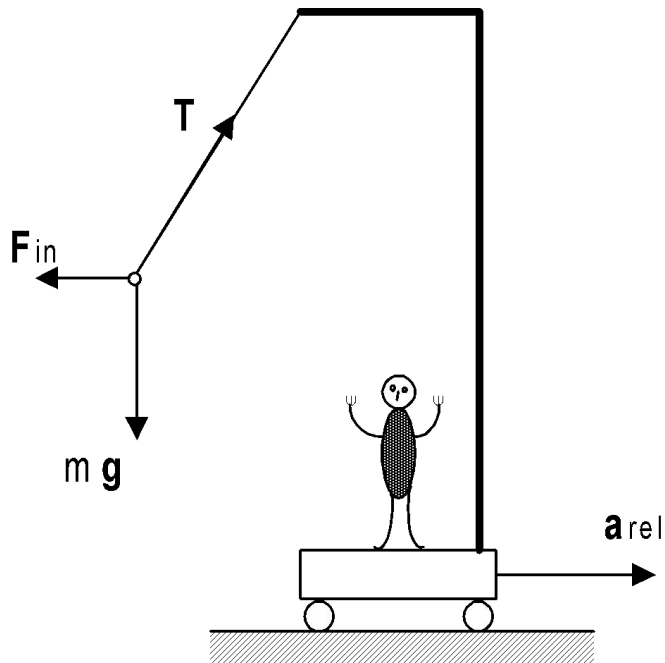
The ball is in state of rest!

Newton's law of motion seems to be *not* correct now!?

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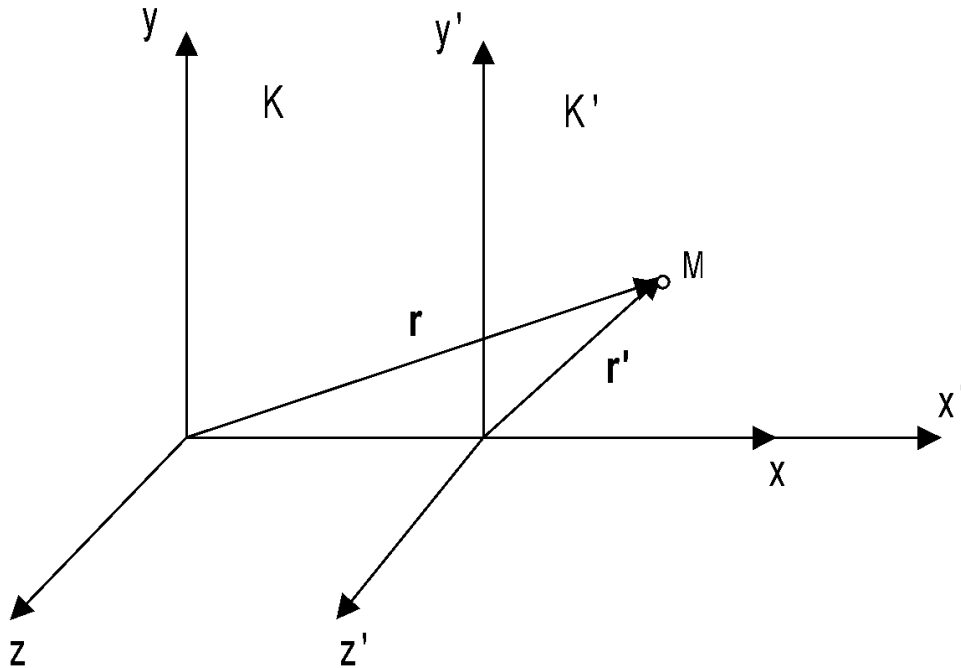
# Observer is in the Non-Inertial Frame of Reference (cont.)



$$\mathbf{T} + m\mathbf{g} + \mathbf{F}_{in.} = \mathbf{0}$$

The force  $\mathbf{F}_{in.}$  we call the *force of inertia*. But where does this force come from?

# Frame Moves with Acceleration



$$\mathbf{r} = \mathbf{r}' + \Delta \mathbf{r}$$

$$\mathbf{a} = \mathbf{a}' + \mathbf{a}_{rel}$$

$$m\mathbf{a} = m\mathbf{a}' + m\mathbf{a}_{rel}$$

$$\mathbf{F} = \mathbf{F}' + m\mathbf{a}_{rel}$$

In non-inertial system of reference an additional force - force of inertia - appears. Its magnitude is proportional to the acceleration of the moving frame of reference with respect to the inertial frame.



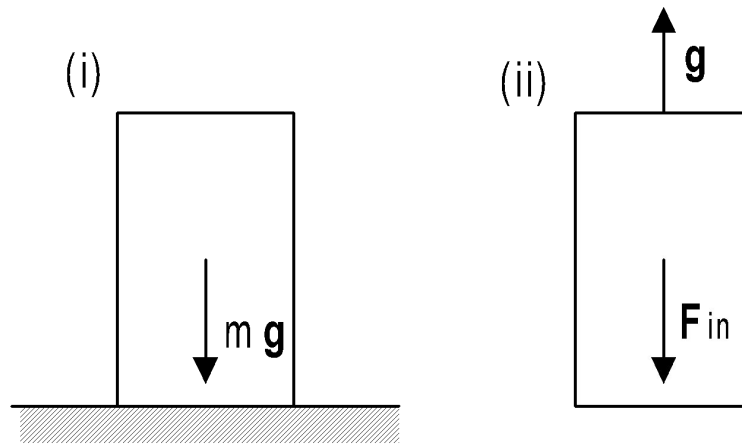
# Forces of Inertia

- **Forces of inertia exist in non-inertial frames of reference only**, never forget it.
- As the forces of inertia are not the result of interaction of objects, **the 3<sup>rd</sup> Newton's law is not applicable to them**.
- **The magnitude of the force of inertia is proportional to the mass of the object.**

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# Principle of equivalence of force of gravity and force of inertia

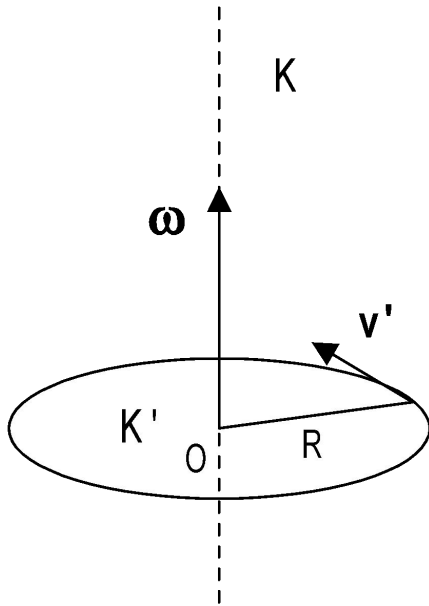


The principle of equivalence of gravitational and inertial mass lies at the heart of Einstein's general theory of relativity.

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# Forces of Inertia in Rotating Frame of Reference



In  $K'$  frame the motion of the ball is uniform circular motion with  $v' = const$ . In  $K$  frame the motion of the ball is uniform circular motion, its velocity is  $v = v' + \omega R$ .

The centripetal acceleration of the ball in  $K$  is

$$\mathbf{a}_{cp} = \frac{v^2}{R} \mathbf{n} = \frac{(v' + \omega R)^2}{R} \mathbf{n} = \frac{(v')^2}{R} \mathbf{n} + \omega^2 R \mathbf{n} + 2v' \omega \mathbf{n}$$

Multiplying by mass of the ball,

$$m \mathbf{a}_{cp} = m \mathbf{a}'_{cp} + m \omega^2 R \mathbf{n} + 2m v' \omega \mathbf{n}$$

# Centrifugal and Coriolis Forces

$$m\mathbf{a}'_{cp} = \mathbf{F} - m\omega^2 R\mathbf{n} - 2m\mathbf{v}'\omega\mathbf{n}$$

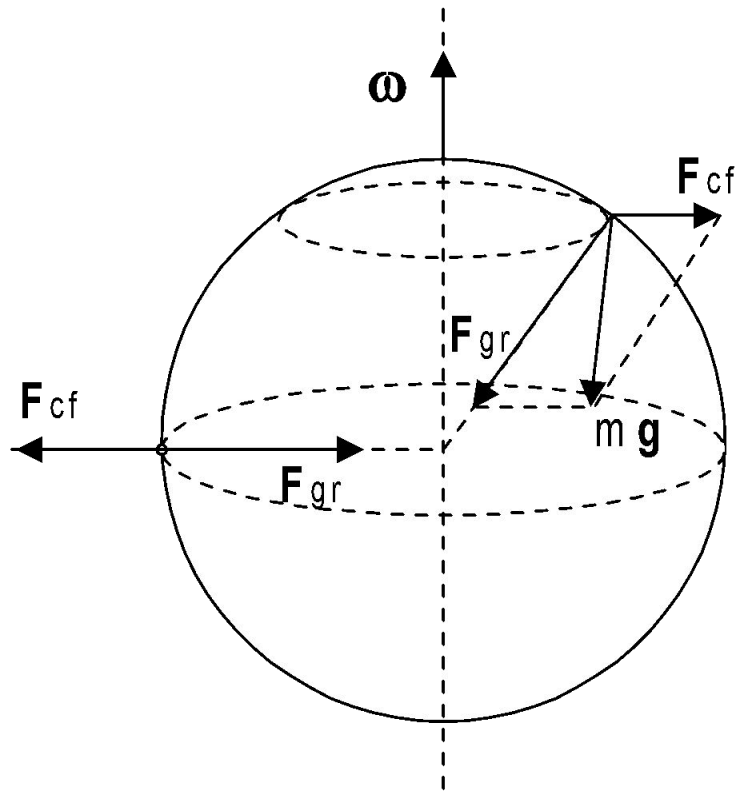
*centrifugal force*       $\mathbf{F}_{cf} = m\omega^2 \mathbf{R}$        $\mathbf{F}_{cf} = m[\boldsymbol{\omega}[\boldsymbol{\omega}, \mathbf{R}] ]$

*force of Coriolis*       $\mathbf{F}_{cor} = 2m[\mathbf{v}', \boldsymbol{\omega}]$

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# Centrifugal Force

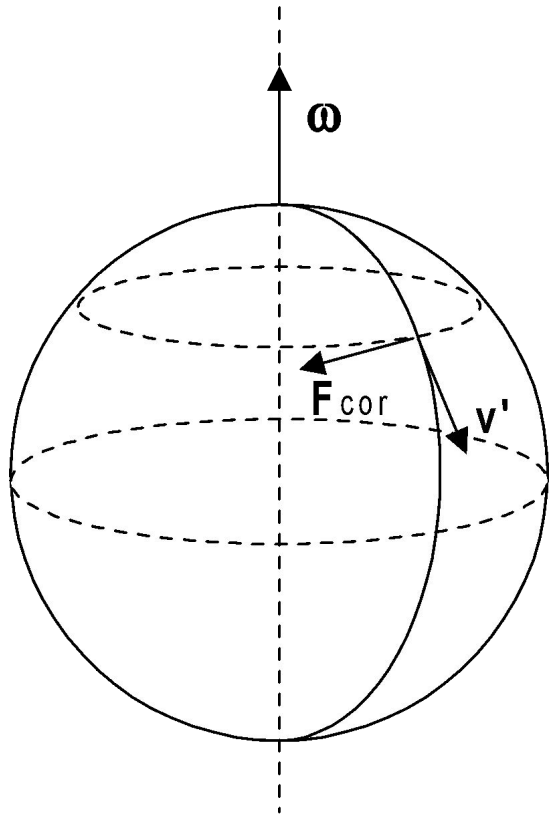


$$m\mathbf{g} = \mathbf{F}_{gr} + \mathbf{F}_{cf}$$

The centrifugal force of inertia causes difference in acceleration due to gravity in different latitudes.



# Coriolis Force



The rivers in the northern hemisphere destroy their right banks.

A trajectory of a free falling body deviates to the east.