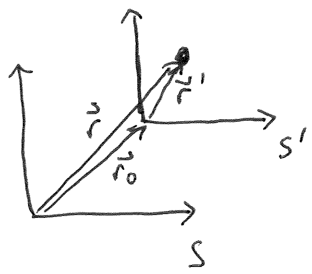
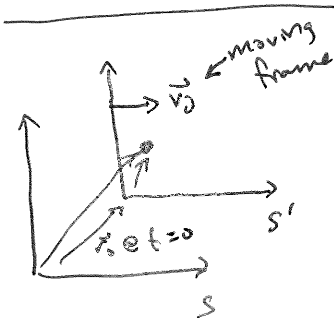
Physics 1a Lecture 8 10/21/11

Different reference frames
"Inertial" forces
Gravity as inertial force
Centrifugal force
Coriolis force



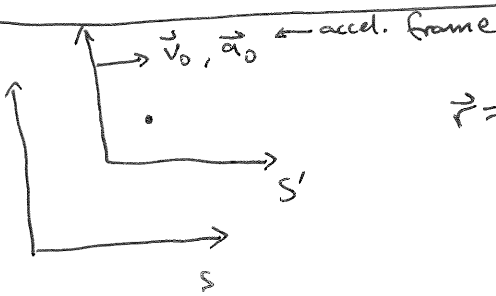
	position of object	velocity	accel.
	in S : $\vec{r}$ in S' : $\vec{r}'$		
	$\vec{r} = \vec{r}' + \vec{r}_0$	$\frac{d\vec{r}}{dt} = \frac{d\vec{r}'}{dt} + 0$	$\frac{d^2\vec{r}}{dt^2} = \frac{d^2\vec{r}'}{dt^2}$
	$(\vec{r} \neq \vec{r}')$	$\vec{v} = \vec{v}'$	$\vec{a} = \vec{a}'$



$$\vec{r} = \vec{r}' + \vec{r}_0 + \vec{v}_0 t$$
$$(\vec{r} \neq \vec{r}')$$

$$\frac{d\vec{r}}{dt} = \frac{d\vec{r}'}{dt} + 0 + \vec{v}_0$$
$$\vec{v} = \vec{v}' + \vec{v}_0$$
$$(\vec{v} \neq \vec{v}')$$

$$\frac{d^2\vec{r}}{dt^2} = \frac{d^2\vec{r}'}{dt^2} + 0 + 0$$
$$\vec{a} = \vec{a}'$$



$$\vec{r} = \vec{r}' + \vec{r}_0 + \vec{v}_0 t + \tfrac{1}{2}\vec{a}_0 t^2$$

$$\vec{v} = \vec{v}' + \vec{v}_0 + \vec{a}_0 t$$

$$\vec{a} = \vec{a}' + \vec{a}_0$$

$$a \neq \vec{a}'$$

In accel. frame : $\vec{a}'$
In inertial frame : $\vec{a}$ $\Rightarrow$

inertial frame	accel. frame
$\vec{F} = m\vec{a}$	$\vec{F}' = m\vec{a}'$
	$= m(\vec{a} - \vec{a}_0)$
	$\boxed{\vec{F}' = \vec{F} - m\vec{a}_0}$

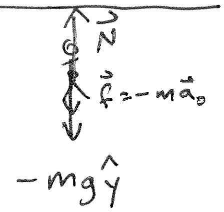
$$\boxed{\vec{f} = -m\vec{a}_0}$$

$\Bigg\{$ "inertial" force
pseudo-force
fictitious force

Examples

elevator:

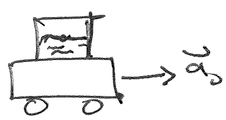
in elevator frame



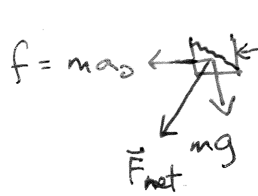
$$\vec{F}_{net} = 0 = (-mg\hat{y} - ma_0\hat{y} + N\hat{y})$$

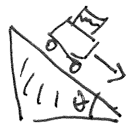
$$\Rightarrow N = m(g + a_0)$$

↳ scale reads more than mg

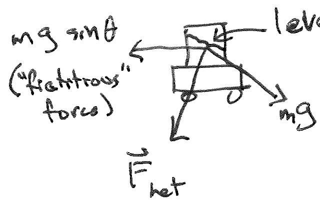


in car frame



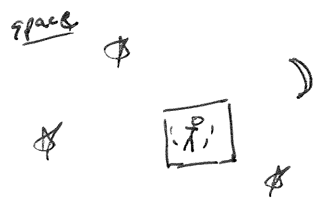


in car frame

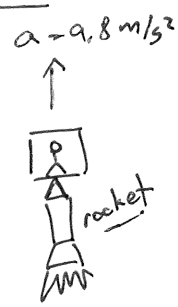


Demo: ramp & pendulum

Aside: gravity as inertial force



$\vec{F} = 0$

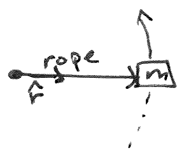


in box frame

gravity?

SAME situation

Centrifugal force



inertial frame

$\vec{a}_0 = -m\omega^2 \vec{r}$

&

$\vec{F}_{net} = \vec{T} \neq 0$ explains this accel.

$\vec{T} \leftarrow \boxed{m}$

frame of object

$a = 0$

&

$\vec{F}_{net} = \vec{T} + \vec{f}_c = 0$

$\downarrow$

$\vec{f}_c = m\omega^2 \vec{r}$

$\vec{T} \leftarrow \boxed{m} \rightarrow \vec{f}_c$

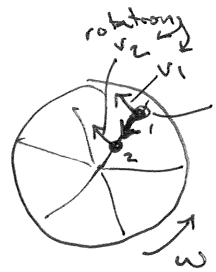
"centrifugal force" present; explains $a = 0$ by balancing T.

experience in cars, merry-go-rounds, etc.

Coriolis force

[Qualitative treatment]

→ Due to motion within a rotating frame.



bug walks inward along a radial line

$v_1 = \omega r_1$

$v_2 = \omega r_2 \neq v_1$

⇒ needs to accelerate himself to stay along line.

Explains this as due to a force pushing him to the right (of his motion)

$\boxed{\text{Demo}}$

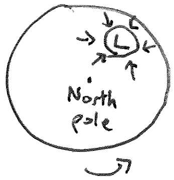
$$\vec{F}_{coriolis} = 2\,\vec{v} \times \vec{\Omega}$$

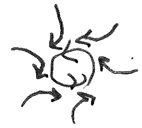
$\vec{F}_{coriolis}$: (pseudo-) force he feels

$\vec{v}$: bug's velocity in his frame

$\vec{\Omega}$: ω ($\overrightarrow{\text{axis of rotation}}$)

– storms:





like the bug:

$$\delta v \sim \frac{2\pi}{1\,\text{day}} (\delta r)$$

$$\sim \frac{2\pi}{1\,\text{day}} \big(\underbrace{R_{storm}}_{500\,mi} \sin \underbrace{\theta}_{\text{latitude}} \big)$$

$$\sim 60 \text{ mph}$$

significant compared to air speed (wind) inward

– sinks: ?

$$\delta v \sim \frac{2\pi}{1a} (30 \text{ cm} \sin\theta)$$

$$\sim 10^{-3} \text{ cm/s}$$

nominal velocity of water draining $v \sim \frac{30 \text{ cm}}{10 \text{ s}} \sim \boxed{\frac{3 \text{ cm}}{s} \gg 10^{-3} \text{ cm/s}}$

$\Rightarrow$ Coriolis effect is very tiny for your sink.

Drainage direction governed by initial angular momentum imparted during filling, etc.