Reference Frames

Q: Newton's law: $\vec{F} = m\vec{a} = m\frac{d\vec{v}}{dt} = m\frac{d^2\vec{r}}{dt^2}$

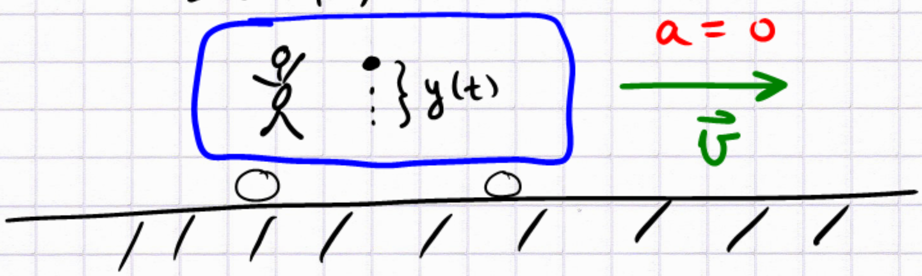
IS IT ALWAYS VALID ?

A: ONLY IN AN INERTIAL REFERENCE FRAME!

non-accelerated

why? study example of a passenger in a braking (accelerating) vehicle (bus, airplane)

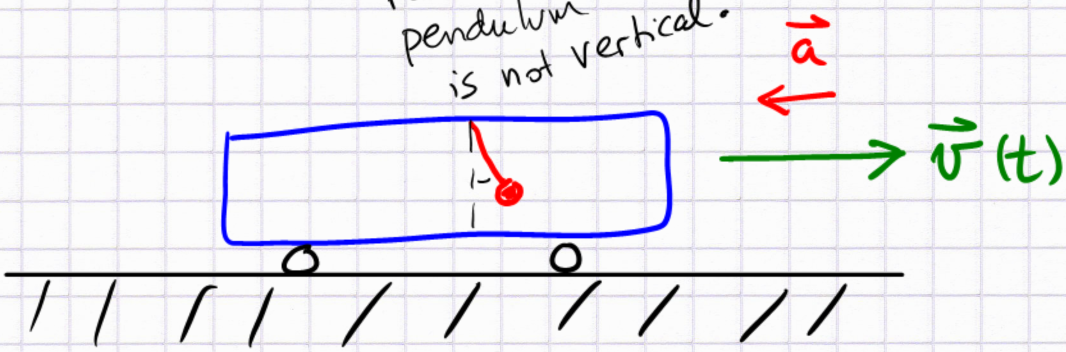
BUS = physics lab



physics laws (Newton) are the same as on stationary ground

NOW repeat with:

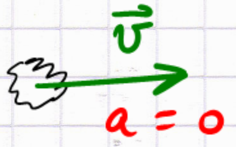
resting pendulum is not vertical!



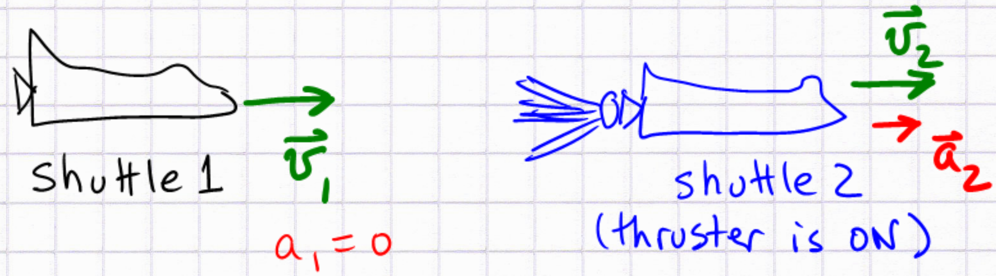
The only physical force on the pendulum is the vertical, downward gravitational pull. YET it tilts forward. In an airplane accelerating forward on the runway (before take-off) it tilts backward

WHY ?

One motion, two observers :



space rock



Assume we are in free space, far away from gravitational fields (shuttle → space ship)

What does S1 observe ? → one-dimensional (x) motion only

Rock moves with constant relative velocity :

$$\vec{v}_{rock} = \vec{v} - \vec{v}_1$$

It is force-free , $a_{Rock} = 0$ with respect to free space and also wrt S_1

∴ Newton 2 → $\vec{F}_{net\ on\ rock} = \vec{0}$

However, S2 will make a different observation :

Due to its own acceleration, the rock as observed appears to be accelerating away! The relative velocity $\vec{v}_{Rock} - \vec{v}_{S2}$ changes with time.

Now, suppose S2 isn't aware of its own acceleration (forgot that his thruster is ON)

S2 believes in Newton 2 ($\vec{F} = m\vec{a}$).

S2 observes the rock $\{ \vec{r}_j \, , j \hat{=} t_1, t_2, t_3 \dots \}$

makes a position graph vs time $\rightarrow \sim t^2$

"takes the derivative" $\rightarrow \{ \vec{v}_j \, , j \hat{=} t_1, t_2, \dots \}$

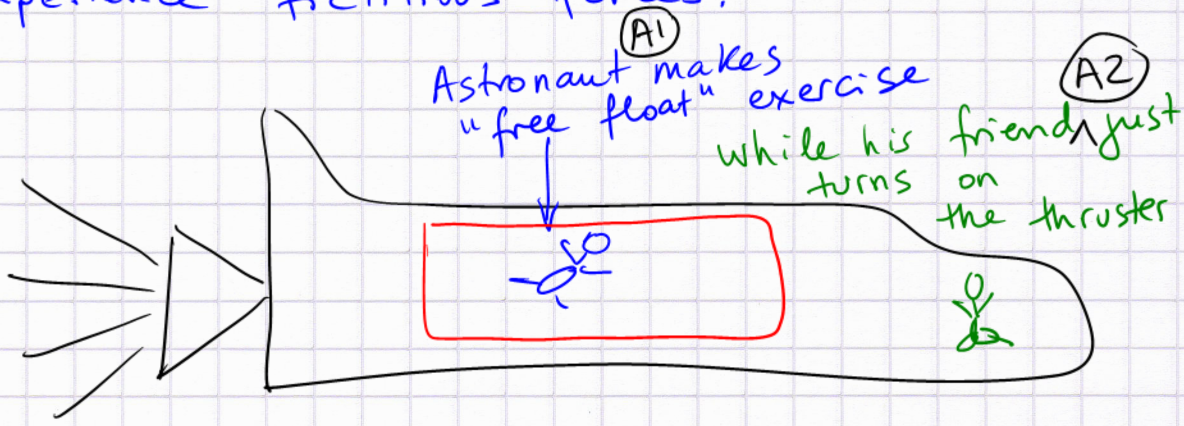
observes an acceleration $-\vec{a}_2$ for $j \hat{=} t_1, t_2, \dots$

Now observer S2 postulates $m \, \vec{a}^{(S2)}_{Rock} = \vec{F}_{net}$

We can invent the fictitious force $-m\vec{a}_2$

to "fix up" Newton's 2^{nd} law.

We even "experience" fictitious forces.



Before (A2) fires the thruster, (A1) floats freely; has the same $\vec{v}$ as the shuttle wrt free space.

(A1) is not in contact with the shuttle body, continues with $\vec{v}$, while the shuttle goes $\vec{v} + \vec{a}\,\Delta t$

(A1) will be jammed (accelerated) against the back wall

When we ride vehicles that undergo accelerations:

we have contact → normal forces act →

static friction will try to make us change our motion to adjust to the accelerating frame

→ sometimes we need to grab a handle, use our balance, seat belt, etc.

Message: Newton 2 $m\vec{a} = \vec{F}_{net}$

holds "as is" (using true forces in $\vec{F}_{net}$) in reference frames that do not accelerate themselves.

[If the frame does accelerate, invent names: fictitious forces $= -m\vec{a}_F$, centrifugal, coriolis.] 2nd yr PHYS

Philosophical question: aren't all reference frames accelerated at some level?

- earth spins about its axis
- earth rotates about the sun
- sun orbits the centre of the Milky Way
- Milky Way accelerates within its local galactic neighbourhood

These accelerations are small, but some do have observable effects → free fall is truly vertical only at the geographic poles

- this is not due to the surface speed, it is an acceleration effect

constant velocity vectors between frames don't change the physics.