Physics 101H

General Physics 1 – Honors

Lecture 13 – 9/21/23

Forces and Noninertial Reference Frames

Summary

Topics

Yesterday: Newton's laws [chapter 5]

- First law
- Second law
- Third law

Today is the **last** day to **opt out** (by emailing me) of having quizzes count as part of your final grade. Remember, everyone receives participation credit for taking the quizzes.

Today:

- Noninertial reference frames
- "Fictitious" forces

Announcements

Yesterday: **Problem set 2 due**
Problem set 3 assigned

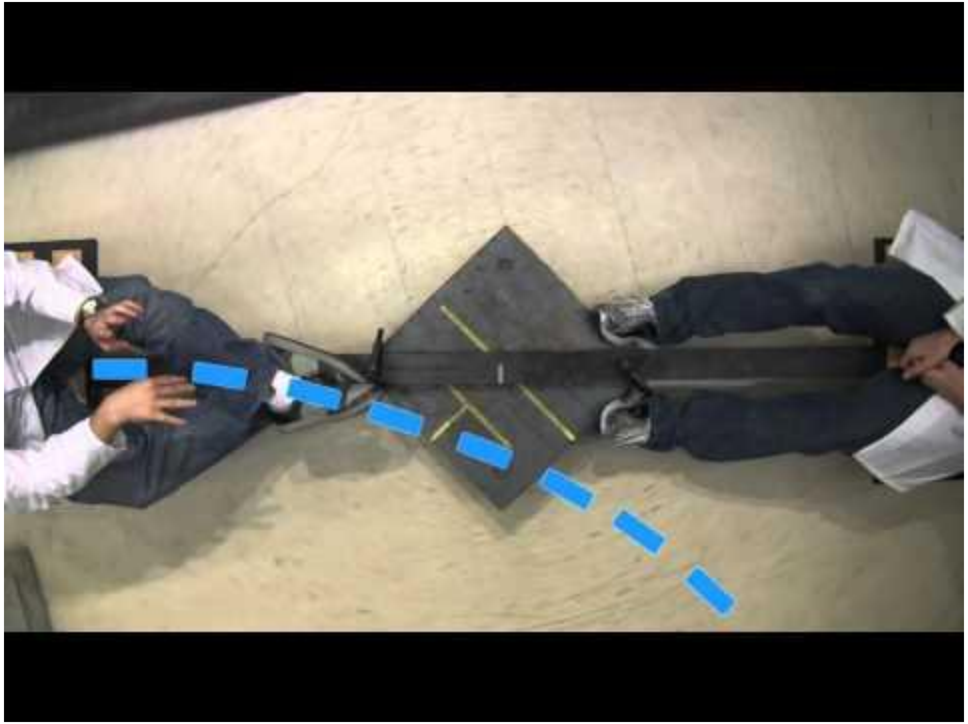
Today: **Quiz 3**

What causes the force that you feel when cornering (especially too fast) in a car?

Noninertial reference frames

So far we have considered **inertial reference frames**.

What happens if our reference frame is accelerating?



Fictitious forces

In noninertial reference frames, there appear to be unexplained accelerations

Introduce **fictitious forces** (or **pseudo forces**) to explain these accelerations

- **Not** real forces
- Useful construct to "explain" what we observe in a noninertial frame
- Observers in an inertial frame would not call this a force, but would see that the other observer is in an accelerating frame

Centrifugal “force”

Apparent force in a non-inertial frame that seems to oppose **centripetal force**

“Explains” your feeling of being thrown outwards when cornering too fast

DON’T CONFUSE *CENTRIPETAL* FORCES (REAL!) WITH *CENTRIFUGAL* FORCES (NOT REALLY REAL!)

Coriolis “force”

Some more details here: https://apps.dtic.mil/dtic/tr/fulltext/u2/a010816.pdf

Another fun (15 minute) video here: https://www.youtube.com/watch?v=okaxKzoyMK0

Example 13.1: How fast do we need to rotate a ball on a string to ensure that it completes a vertical circle?

Recall question from Lecture 9: Is motion in a vertical circle uniform circular motion or nonuniform circular motion?

Quiz 3

You got this!

Put your name on the sheet.

Do not turn over the sheet until I tell you to.

You have ten minutes to answer four questions.

You may not use notes, slides, textbook or any other resources.

Calculators are allowed, but no phones, laptops, tablets or other devices.

Summary

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Topics

Today:

- Noninertial reference frames
- "Fictitious" forces

Tomorrow: Newton's laws [chapter 5]

- Solving problems
  (AKA a flipped classroom)

Announcements

Yesterday:	**Problem set 2 due**
	Problem set 3 assigned
Today:	**Quiz 3**

PHYSICS 101 - HONORS

Lecture 13 9/21/23

Centrifugal "force" (slide 6)

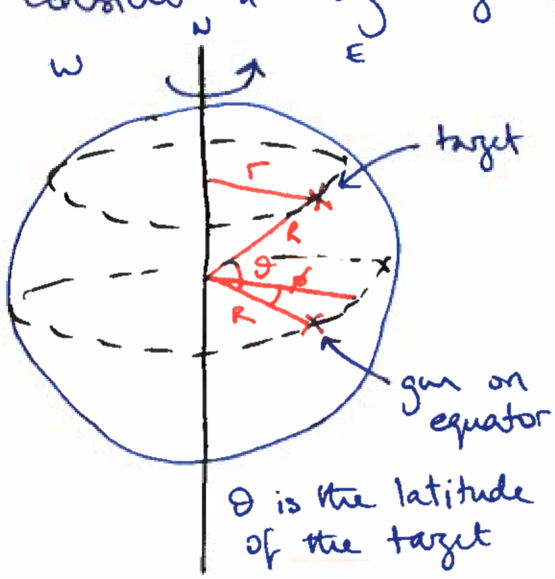
Pseudo force – an apparent force in a non inertial frame that seems to oppose the centripetal force (real force!)

– "explains" feeling of being thrown outwards when cornering too fast in a car

Coriolis "force" (slide 7)

Earth is rotating ⇒ we are in a noninertial frame

Consider a long range projectile



The gun is moving (in an inertial frame

$$v_{gun} = R\omega = R\frac{d\phi}{dt}$$

The target is also moving

$$v_{target} = r\omega = r\frac{d\phi}{dt}$$

But $r = R\cos\theta \Rightarrow r < R$

Target moves less quickly than gun!

To an external observer in an inertial frame, looking down from above the gun moves faster than the target, so projectile appears to move to the east (!!). ← the "coriolis effect" (↑ amount depends on latitude)

Coriolis "force"

around low pressure region ↓ — around high pressure region ↓

Coriolis effect responsible for cyclones and anticyclone

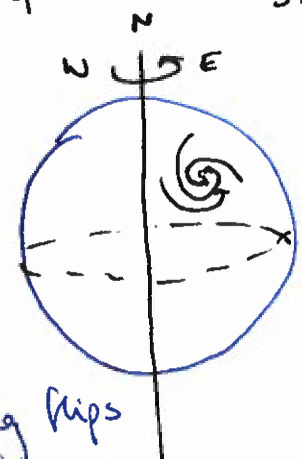
- cyclones ↑ anticlockwise in N. hemisphere, clockwise in S. hemisphere
- anticyclone ↑ clockwise in N. Hemisphere, anticlockwise in S. hemisphere

Consider a low pressure region

⇒ air is "sucked in"

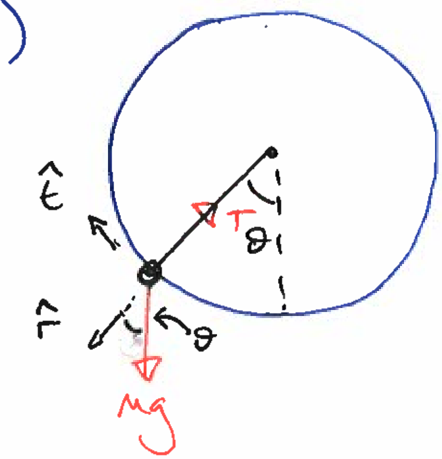
Without Earth's rotation, the air flows straight in

In presence of Earth's rotation, air starts to follow curved path and circulates



Everything flips in the southern hemisphere!

Vertical circle example (slide 8)



- Pick a reference frame
- Draw a diagram
- Identify forces
  - ⇒ $\overline{T} = -T\hat{r}$
  - ⇒ $\overline{F}_g = mg\cos\theta\,\hat{r} - mg\sin\theta\,\hat{t}$
- Identify acceleration
  - accelerating in radial direction (and maybe tangential?)
    ↳ $\overline{a} = -a_r\hat{r} + a_t\hat{t}$
- Equate forces $\overline{F}_{net} = \overline{T} + \overline{F}_g$

$$\sum_i \bar{F}_i = m\bar{a}$$

$\Rightarrow \hat{r}$: $-T + mg\cos\vartheta = -ma_r$

so $T = m(g\cos\vartheta + a_r)$

$\hat{t}$: $-mg\sin\vartheta = ma_t$

so $a_t = -g\sin\vartheta$

We know that the centripetal acceleration is

$a_r = v^2/r \Rightarrow T = m(g\cos\vartheta + v^2/r)$

At the top, we want the case where the tension just vanishes $|\bar{T}_{top}| = 0$

$$\Rightarrow T_{top} = m(g\cos\pi + v^2/r) = 0$$

$$\Rightarrow -g + v^2/r = 0$$

$$v^2 = gr \Rightarrow \boxed{v = \sqrt{gr}}$$