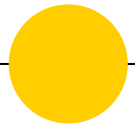
Physics 101H

General Physics 1 – Honors



Lecture 12 – 9/21/22

Forces and Noninertial Reference Frames

Problem sets

Problem Set 3 has been posted

Due by the **start of class** on **Wednesday 28 September**

Remember

- I will **drop the lowest grade** on your weekly Problem Sets

MAKING SURE YOUR WORK IS LEGIBLE IS *YOUR* RESPONSIBILITY

Summary

Topics

Monday: Newton's laws
- First law
- Second law
- Third law
- Forces in action

Today: Noninertial frames
- Noninertial reference frames
- Fictitious/pseudo forces
  - Centrifugal "force"
  - Coriolis "force"

Announcements

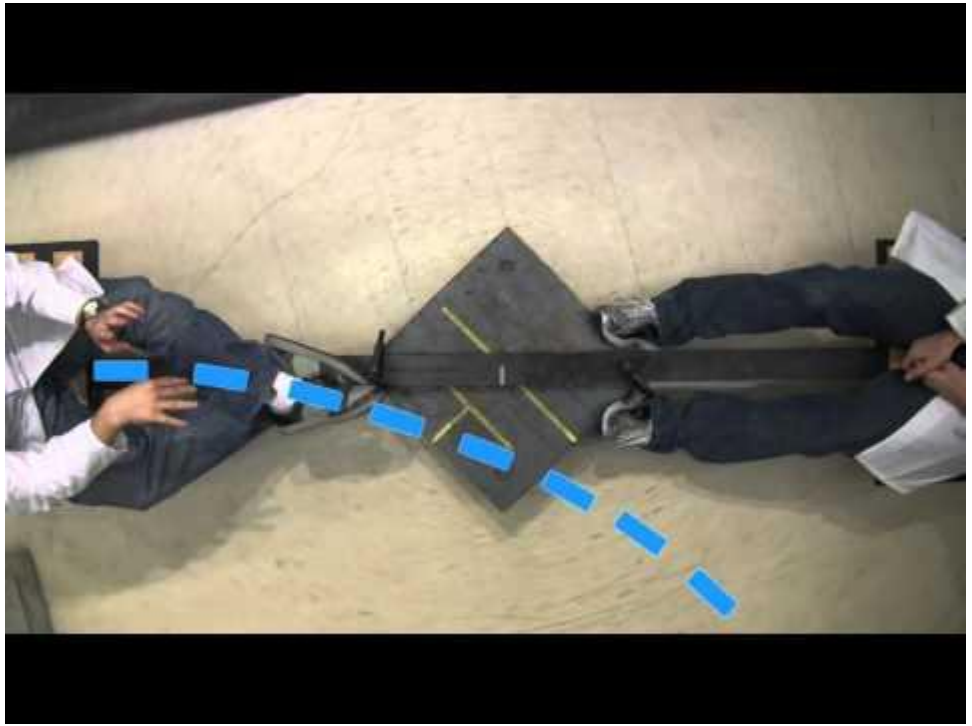
This week: **Problem Set 2 due today**
Problem Set 3 posted
No class tomorrow or Friday!

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: 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?

Practice in pairs

Instructions: Discuss the following question with a neighbour. Your answers will not be graded; your discussion is for your own learning*.

Question: A block is at rest on a plane inclined at angle θ. The forces on it are the Gravitational, normal, and friction forces act on the block (not drawn to scale!). Which of the following statements is *always* true, for any θ?

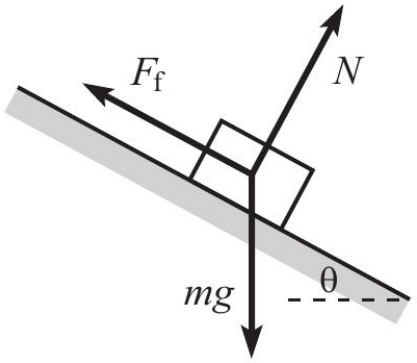
(a) $mg \leq N$ and $mg \leq F_f$

(b) $mg \geq N$ and $mg \geq F_f$

(c) $F_f = N$

(d) $F_f + N = mg$

(e) $F_f > N$ if $\mu_s > 1$



Summary

Topics

Today: Noninertial frames

- Noninertial reference frames
- Fictitious/pseudo forces

Monday: in-medium motion [chap.6]

- Motion through a medium
- Models of resistance:
  - Linear and quadratic

Next week

- Work
- Energy
- Power

Announcements

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Problem Set 3 posted
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THIS WEEK:
THERE IS NO CLASS ON THURSDAY OR FRIDAY

PHYSICS 101 - HONORS

Lecture 12 9/21/22

Centrifugal "force" (slide 8)

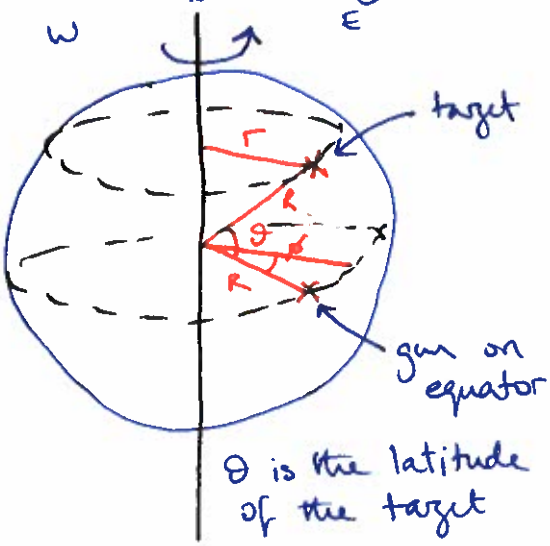
Pseudo force - an apparent force in a non inertial frame that seems to oppose the centripetal force (real force!)

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

Coriolis "force" (slide 9)

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 → cyclones and around high pressure region → anticyclone

Coriolis effect responsible for

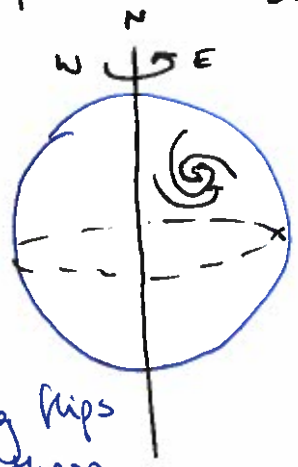
anticlockwise in N. hemisphere, clockwise in S. hemisphere

clockwise in N. hemisphere, anticlockwise in S. hemisphere

Consider a low pressure region
⇒ air is "sucked in"

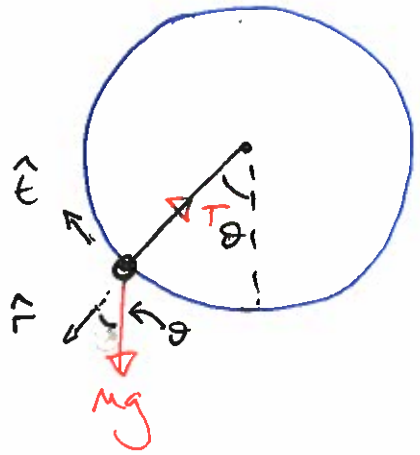
Without Earth's rotation, the air flows straight in

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



Everything flips in the southern hemisphere!

Vertical circle example



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

$$\bar{F}_{net} = \bar{T} + \bar{F}_g$$

$$\bar{F}_{net} = m\bar{a}_{net}$$

$$\Rightarrow \quad \hat{r}: \quad -T + mg\cos\theta = -ma_r \quad \Rightarrow T = m(g\cos\theta + a_r)$$

$$\hat{t}: \quad -mg\sin\theta = ma_t \quad \Rightarrow \quad a_t = -g\sin\theta$$

We know that the centripetal acceleration is

$$a_r = v^2/r \quad \Rightarrow \quad T = m\left(g\cos\theta + v^2/r\right)$$

To continue at the top, we want the case where the tension just vanishes ($|\bar{T}_{top}| = 0$)

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

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

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

Extra problem

Total acceleration is zero $\Rightarrow$ net force = 0

$\Rightarrow$ perpendicular to plane $N = mg\cos\theta \Rightarrow N \leq mg$

parallel to plane $F_f = mg\sin\theta \Rightarrow F_f \leq mg$ } b)

Note if $\theta = 0$ $F_f \to 0$ so a), c), and e) are wrong

d) implies $mg\sin\theta + mg\cos\theta = mg \Rightarrow \sin\theta + \cos\theta = 1$ which is wrong!!

$\Rightarrow$ d) cannot be correct (should be $\sin^2\theta + \cos^2\theta = 1$)