PHYS 2211 K

Week 6, Lecture 2

2022/02/17

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4 clicker questions today

On today's class…

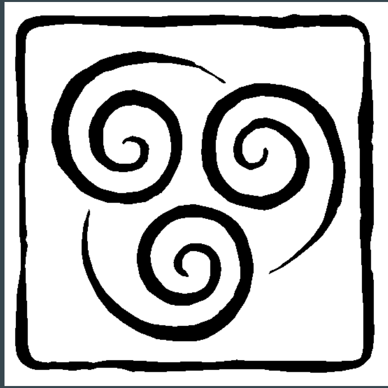
1. Curving motion problems (in 2D and 3D)
2. Kinesthetic sensations (feeling weightless, feeling heavier)

CLICKER 1: Favorite element-bending

A. Waterbending

B. Earthbending

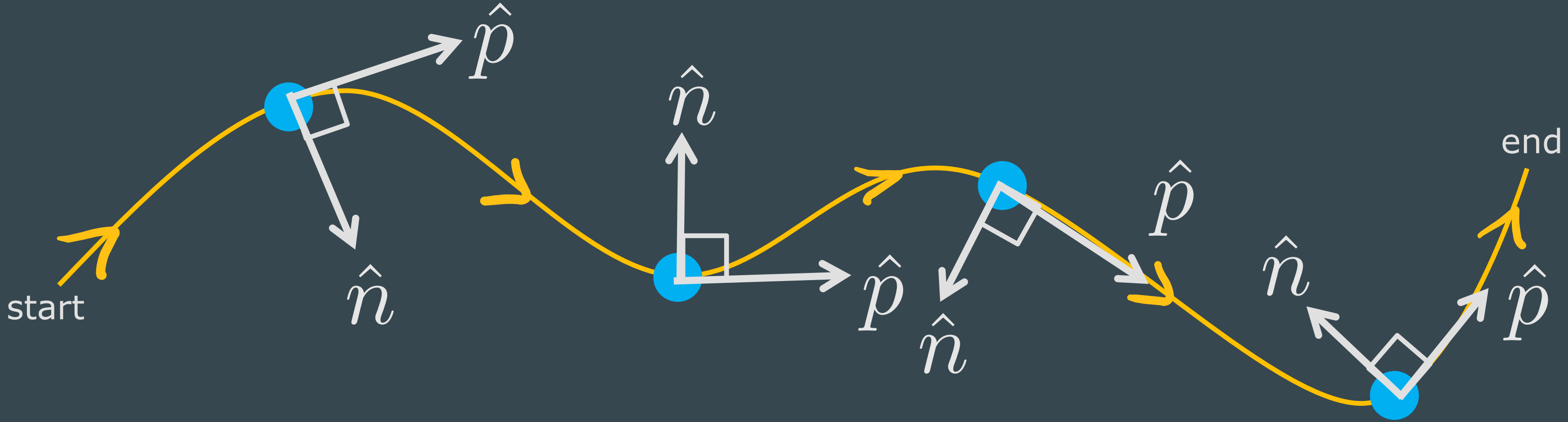
C. Firebending



D. Airbending

From Tuesday

- $\hat{p}$ axis is parallel to the direction of the motion
- $\hat{n}$ axis is perpendicular to the direction of the motion and positive towards the center of the turning circle
- The coordinates move and change with the object’s motion!



Also from Tuesday

Changes the **speed** of the object

$$\vec{F}_{\text{net}||} = \left(\frac{d\vec{p}}{dt}\right)_{||} = \frac{d|\vec{p}|}{dt}\hat{p} = \left(\frac{|\vec{p}_f| - |\vec{p}_i|}{\Delta t}\right)\hat{p}$$

Changes the **direction** of motion

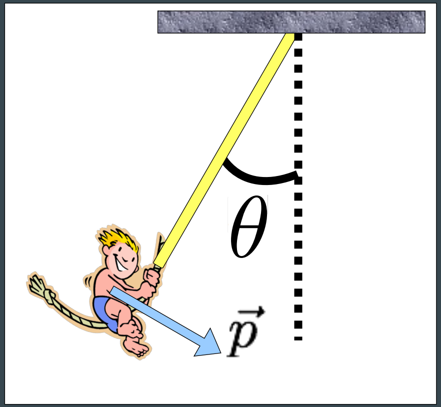
$$\vec{F}_{\text{net}\perp} = \left(\frac{d\vec{p}}{dt}\right)_{\perp} = |\vec{p}|\frac{d\hat{p}}{dt} = \frac{mv^2}{R}\hat{n}$$

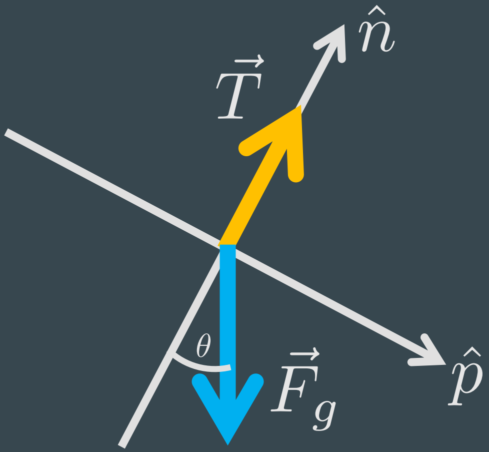
$$\vec{F}_{\text{net}} = \vec{F}_{\text{net}||} + \vec{F}_{\text{net}\perp}$$

Solving curving motion problems

- Similar to equilibrium problems, but Fnet is not equal to zero
- Components of Fnet are not Fnet,x and Fnet,y, but rather Fnet_parallel and Fnet_perp
- Draw FBD
  - p-hat axis points in direction of motion
  - n-hat axis points towards center of turning circle
  - Draw forces as arrows and place angles as needed
- Find the components of Fnet
  - Fnet_parallel = sum of all parallel components
  - Fnet_perp = sum of all perpendicular components
  - Remember that Fnet_perp = mv^2/R (n-hat)
- Solve for the unknowns

Example: A man of **mass m** swings from a rope of **length L**. At one particular moment, the rope makes an angle **theta** with the vertical and the man moves with **speed v**. What is the tension in the rope?





CLICKER 2: The orbit (radius R = 3.8e8 m) of the Moon (mass m = 7.3e22 kg) is in uniform circular motion (constant speed) around the Earth (mass M = 6e24 kg). What is the orbital speed of the moon?

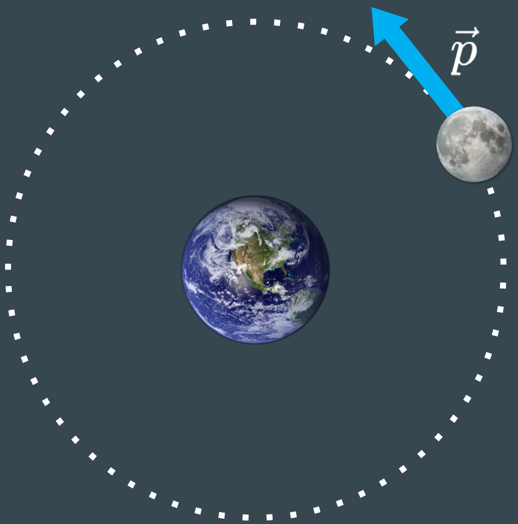
A. 1 km/s

B. 5 km/s

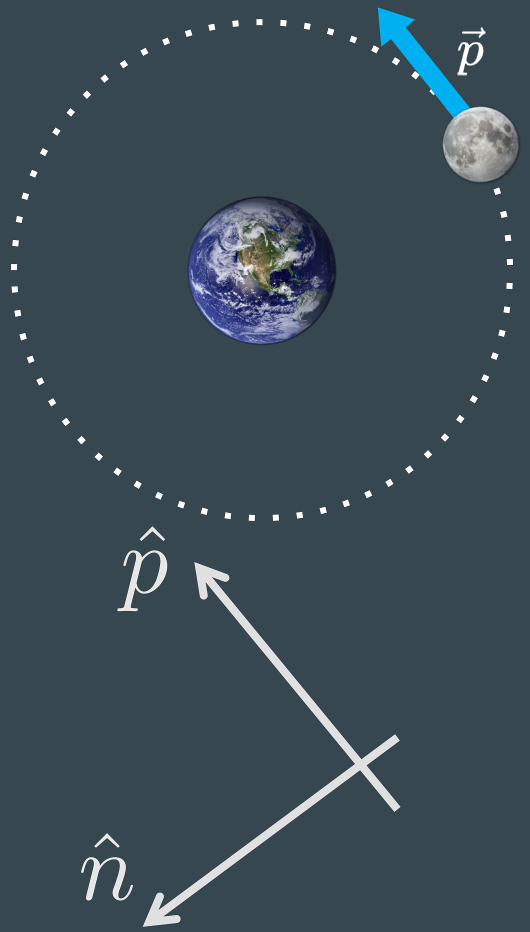
C. 10 km/s

D. 20 km/s

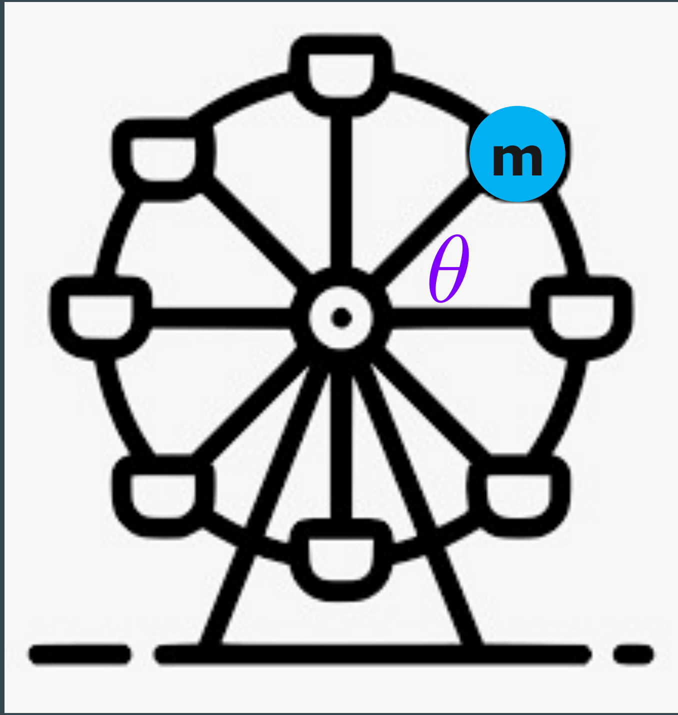
E. 30 km/s



SOLUTION: The orbit (radius R = 3.8e8 m) of the Moon (mass m = 7.3e22 kg) is in uniform circular motion around the Earth (mass M = 6e24 kg). What is the orbital speed of the moon?



Example: A Ferris wheel of radius R rotates clockwise at constant speed v. You have mass m and are currently in the location shown, at an angle θ from the horizontal. Find the parallel and perpendicular components of the contact force you feel from the seat.



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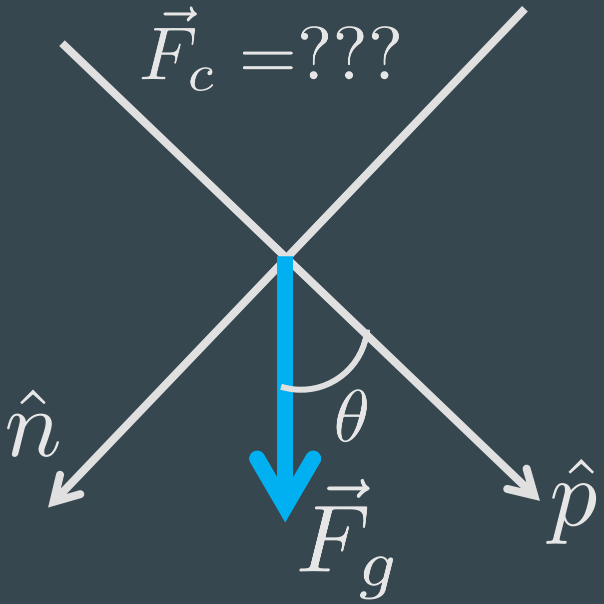
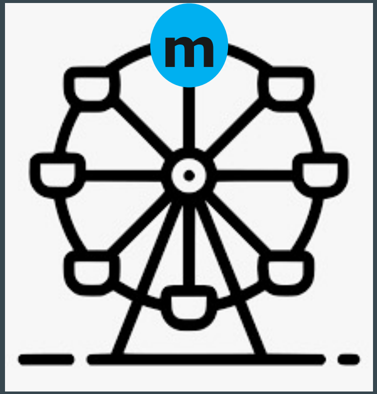
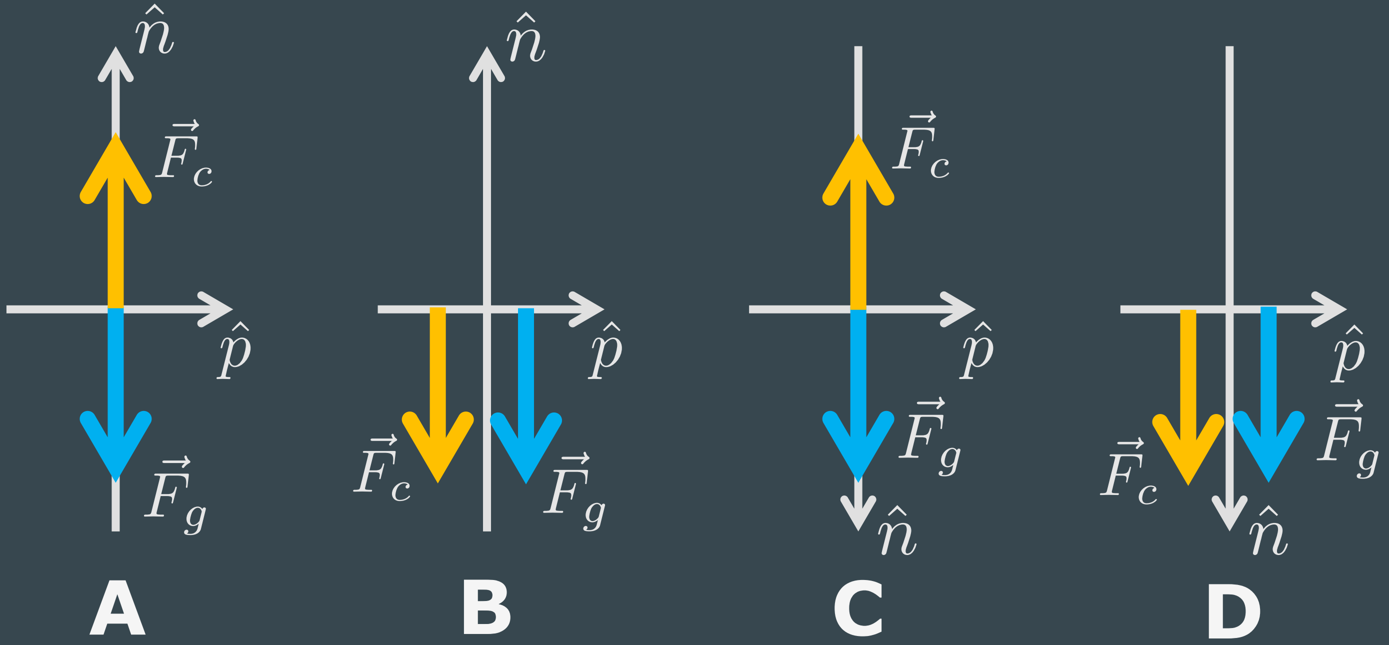
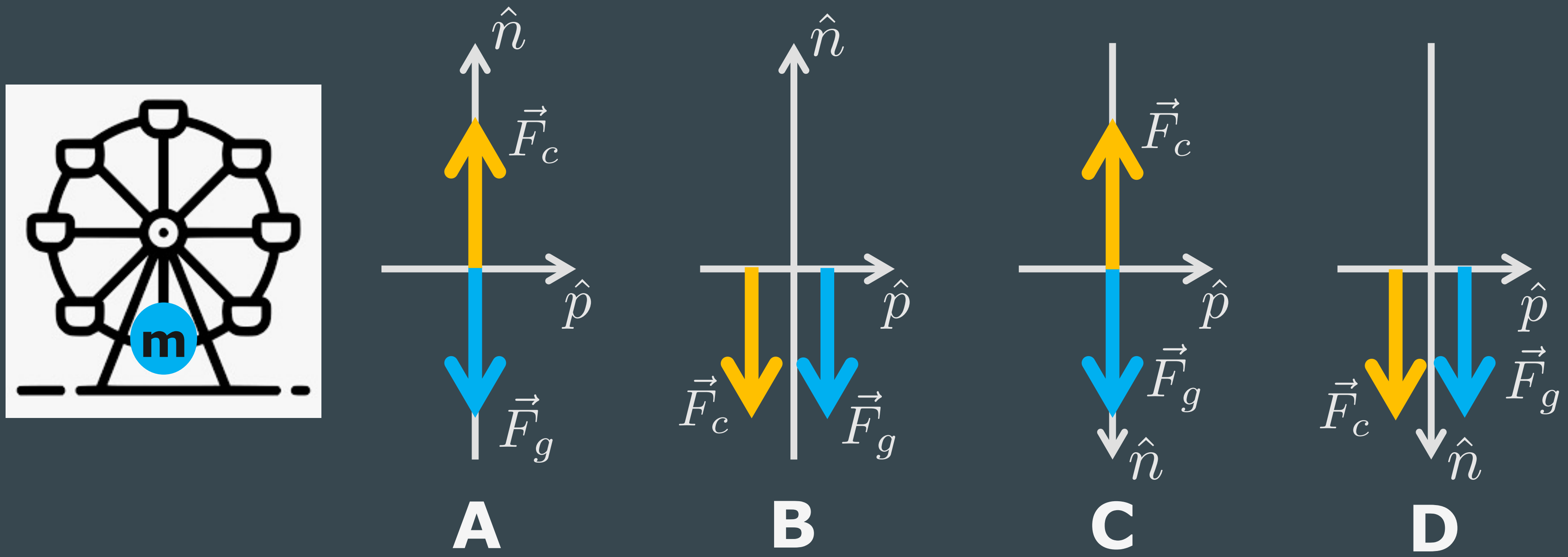


CLICKER 3: What does your FBD look like when you're at the TOP of the Ferris wheel? (ignore the size of the arrows)





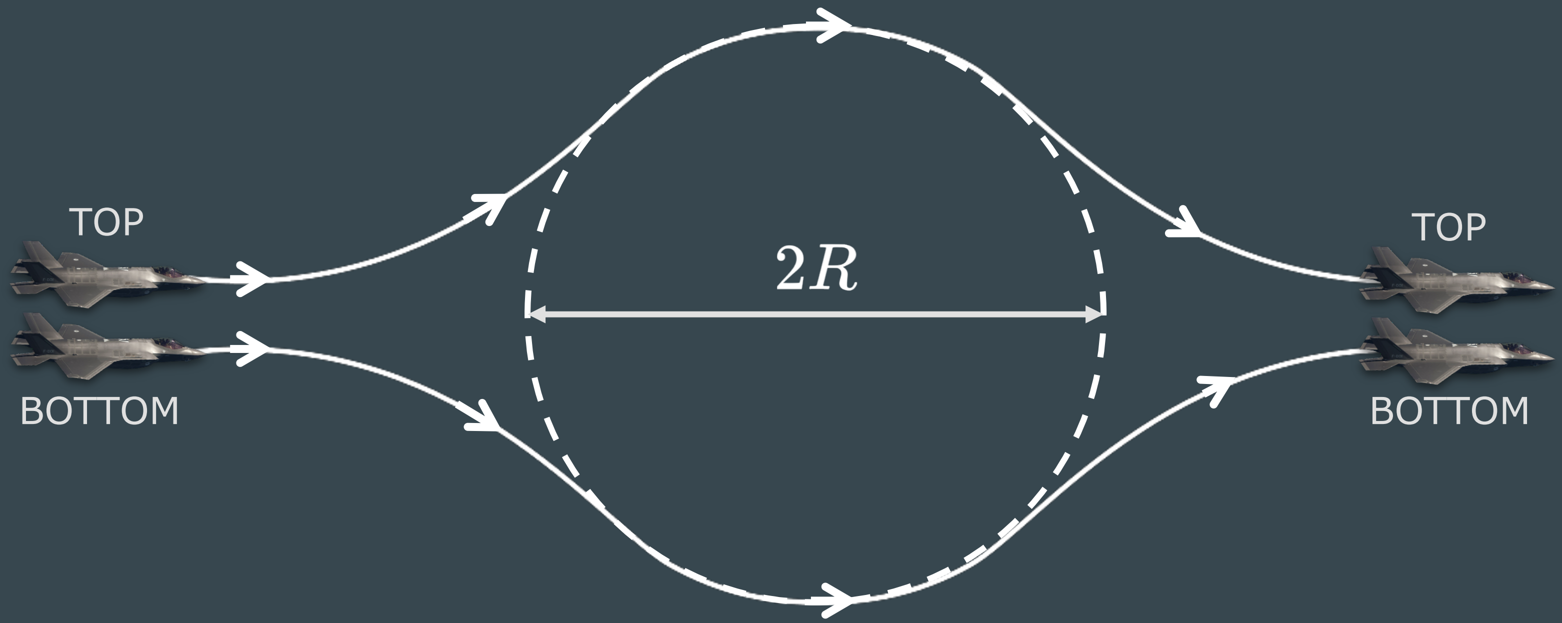
CLICKER 4: What does your FBD look like when you're at the BOTTOM of the Ferris wheel? (ignore the size of the arrows)



Weightlessness

- Your weight is caused by Earth’s gravity, weight = $|F_g| = mg$
- You FEEL your weight when you’re in contact with the ground, $|F_c| = |F_g|$
- If $|F_c| < |F_g|$, then you feel lighter
- Similarly, if $|F_c| > |F_g|$, then you feel heavier
- If there’s no contact force, $|F_c| = 0$, pushing back on you, then you’ll feel weightless, even though you still have weight!

Example: Two planes fly **parallel to each other** with **speed v** when they see a blip in the radar up ahead. They split and fly around the whatever-it-is in **vertical half-circles**. **Which pilot feels heavier** in the middle of their half-circle - meaning, at the top for the top plane, or at the bottom for the bottom plane?



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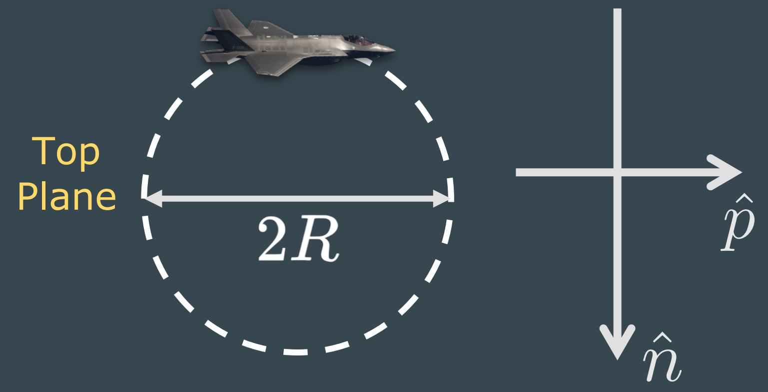
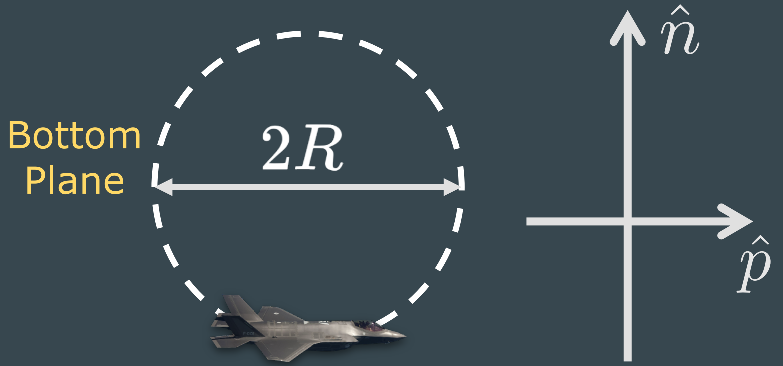
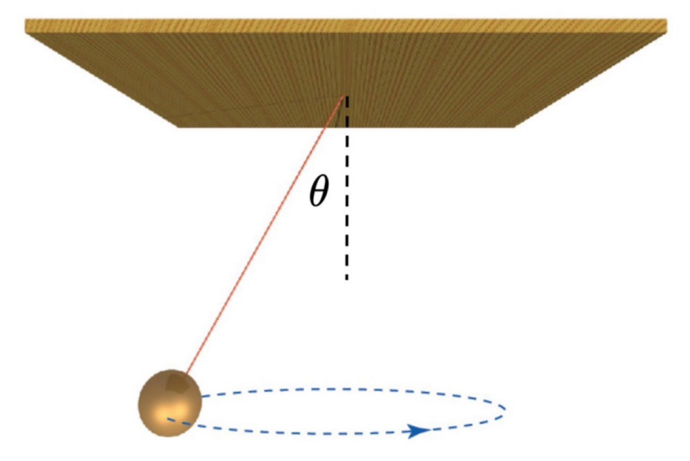




Curving motion in 3D

- Sometimes you need more than just p-hat and n-hat to describe the motion of an object
- In these situations, you need to use xyz coordinates in addition to p-hat n-hat coordinates

Example ("conical pendulum") A ball of mass m is attached to a string and moves in a horizontal circular path. The string has length L and makes an angle theta with the vertical. The ball moves with constant speed, but you don't know what this speed is. What is the tension in the string? What is the speed of the ball?



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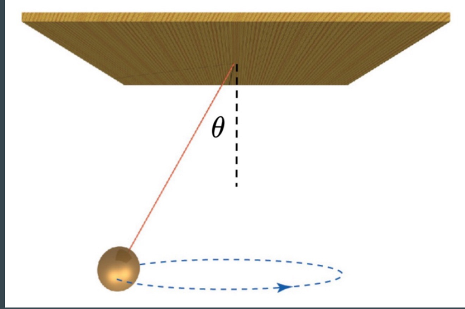
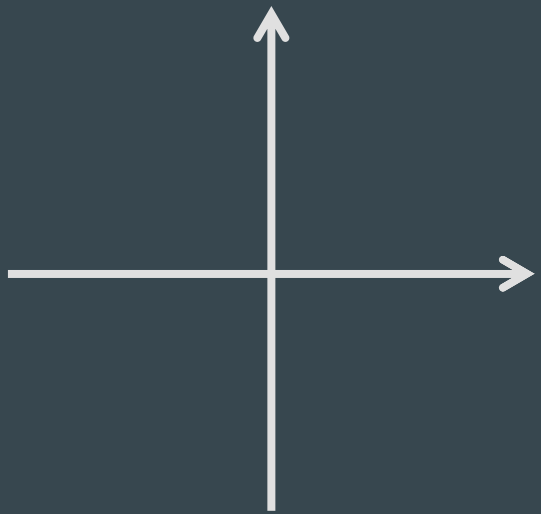


What is the tension in the string?



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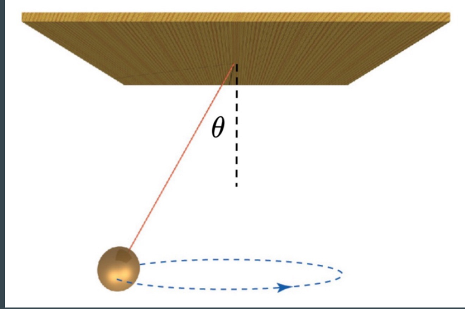
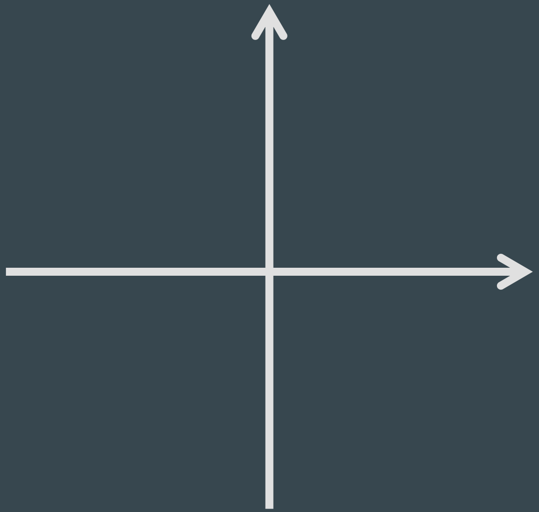
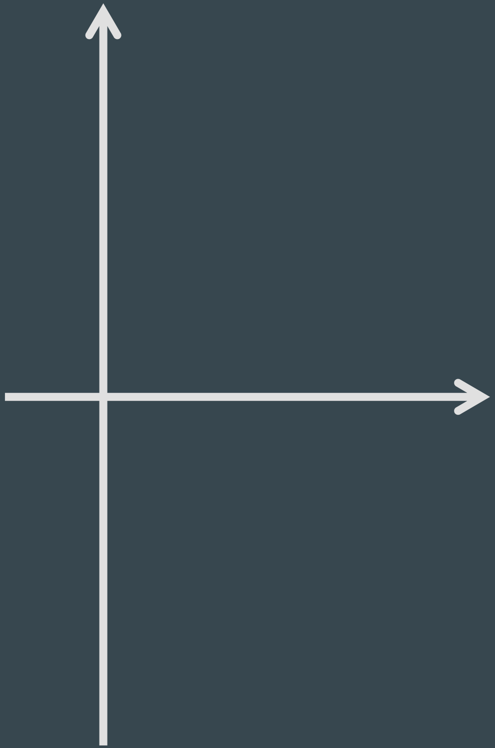


What is the speed of the ball?



Example: An amusement park ride is shaped like a cylinder of radius R that spins. People stand against the inner wall of the cylinder, which has coefficient of friction μ. When the cylinder spins, the floor drops, but yet the people are still "stuck" to the wall. How fast does the cylinder have to spin to avoid having people slipping and falling off the wall?



Things we will assume here:

- μ is the same for every person and corresponds to $f_{s,max}$
- The cylinder stays horizontal (no tilt) and spins at a constant rate

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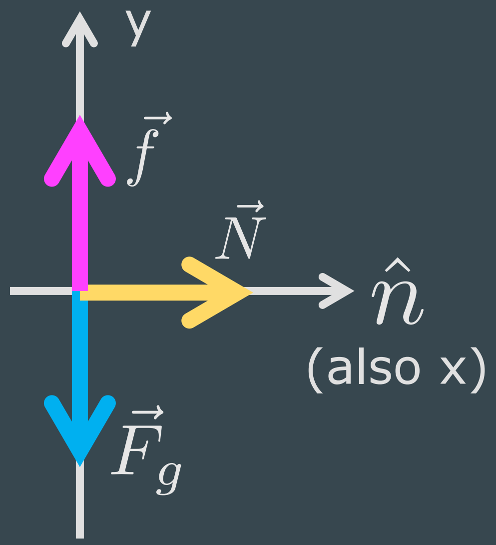
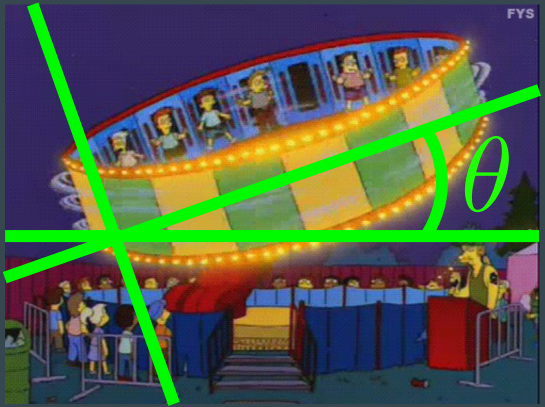
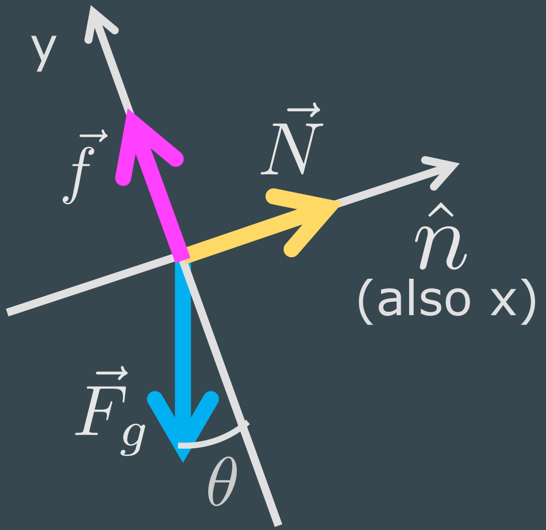


What about when the cylinder is tilted?





Old problems with video solutions

- From Dr Greco!
  - An object moving in a circle along an angled surface
    - https://vimeo.com/208202487
  - Riding a sleigh over a hill
    - https://vimeo.com/158651602
  - A bug slides off a sphere
    - https://vimeo.com/158393644
  - A student riding a ferris wheel
    - https://vimeo.com/30277476
  - The three body problem
    - https://vimeo.com/30277550