Introduction to Mechanics
Uniform Circular Motion

Lana Sheridan

De Anza College

Mar 17, 2020

Last time

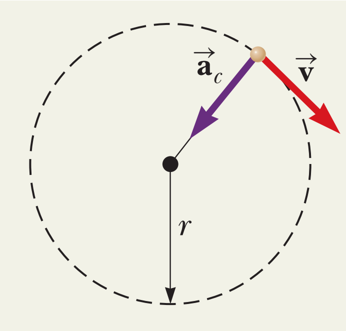
- acceleration and uniform circular motion

Overview

- circular motion
    - force and uniform circular motion
    - banked turns

Uniform Circular Motion

The velocity vector points along a tangent to the circle



For uniform circular motion:

- the radius is constant
- the speed is constant
- the *magnitude* of the acceleration is constant

Circular Motion

Centripetal acceleration

The acceleration of an object in uniform circular motion of radius, r, at constant speed v. Its magnitude is

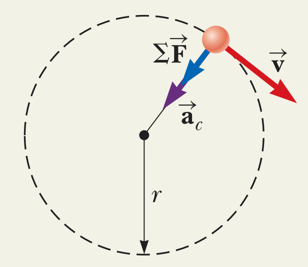
$$a_{cp} = \frac{v^2}{r}$$

Uniform Circular Motion - Now with Force

Net force:

$$F_{\text{net}} = \frac{mv^2}{r}$$

Directed toward the center of the turn.



[1]Figures from Serway & Jewett.

Force and Circular Motion Example

Page 169, # 4

4. A curve in a road forms part of a horizontal circle. As a car goes around it at constant speed 14.0 m/s, the total horizontal force on the driver has magnitude 130 N. What is the total horizontal force on the driver if the speed on the same curve is 18.0 m/s instead?

UCM and Force Example

Page 169, # 4

$$F_{\text{net}} = \frac{mv^2}{r}$$

and

$$F'_{\text{net}} = \frac{m(v')^2}{r}$$

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UCM and Force Example

Page 169, # 4

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$$F_{\text{net}'} = \frac{F_{\text{net}}(v')^2}{v^2}$$

UCM and Force Example

Page 169, # 4

$$F_{\text{net}} = \frac{mv^2}{r}$$

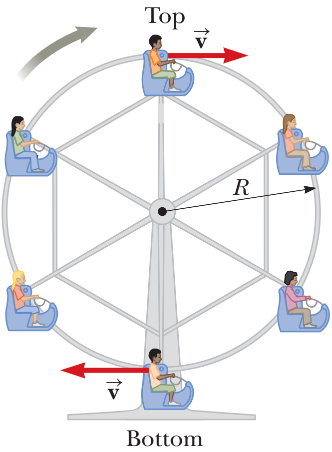
and

$$F'_{\text{net}} = \frac{m(v')^2}{r}$$

$$\begin{aligned}
\frac{m}{r} &= \frac{F_{\text{net}}}{v^2} = \frac{F_{\text{net}'}}{(v')^2} \\
F_{\text{net}'} &= \frac{F_{\text{net}}(v')^2}{v^2} \\
&= \frac{130\ \text{N}(18.0\text{m/s})^2}{(14.0\text{m/s})^2} \\
&= 215\ \text{N}
\end{aligned}$$

Ferris Wheel Forces

A Ferris wheel is a ride you often see at fairs and theme parks.



During the ride the speed, v, is constant.

Ferris Wheel Forces

Quick Quiz 6.1[1] You are riding on a Ferris wheel that is rotating with constant speed. The car in which you are riding always maintains its correct upward orientation; it does not invert.

(i) What is the direction of the normal force on you from the seat when you are at the top of the wheel?

(A) upward

(B) downward

(C) impossible to determine

[1] Page 153, Serway & Jewett

Ferris Wheel Forces

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[1] Page 153, Serway & Jewett

Ferris Wheel Forces

Quick Quiz 6.1[1] You are riding on a Ferris wheel that is rotating with constant speed. The car in which you are riding always maintains its correct upward orientation; it does not invert.

(ii) From the same choices, what is the direction of the net force on you when you are at the top of the wheel?

(A) upward

(B) downward

(C) impossible to determine

[1] Page 153, Serway & Jewett

Ferris Wheel Forces

Quick Quiz 6.1[1] You are riding on a Ferris wheel that is rotating with constant speed. The car in which you are riding always maintains its correct upward orientation; it does not invert.

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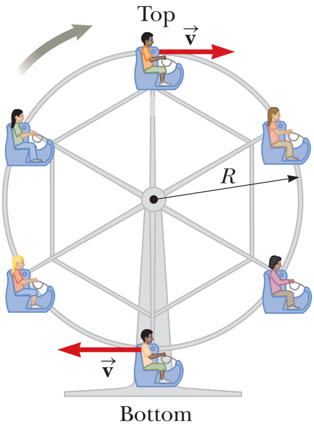
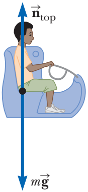
[1] Page 153, Serway & Jewett

Ferris Wheel

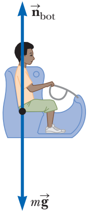
Assume the speed, v, is constant.



$n_{\text{top}} < mg$: $\vec{F}_{\text{net}}$ points down

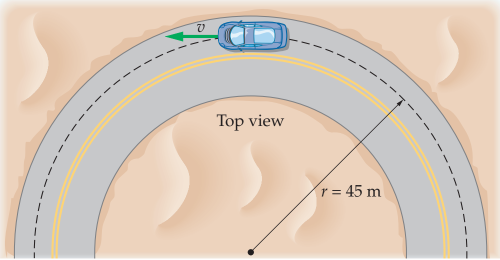


$n_{\text{bot}} > mg$: $\vec{F}_{\text{net}}$ points up



Speed, friction, & circular motion example, Ex 6-8

A 1200-kg car rounds a corner of radius $r = 45$ m. If the coefficient of static friction between the tires and the road is $\mu_s = 0.82$, what is the greatest speed the car can have in the corner without skidding?



Sketch free body diagram for car.

Hypothesis: The faster the car goes, the larger the centripetal force needed to stay in the turn. The centripetal force will come from static friction, which cannot take a larger value than $\mu_s N$. It is a tight turn. Guess: 30 m/s.

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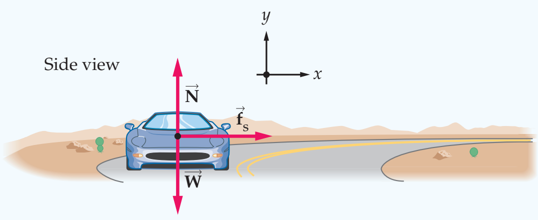
Sketch:



Strategy:

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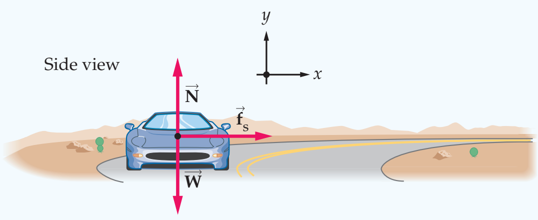

Strategy: $F_{\text{net}} = ma_{cp}$ and $F_{cp} = f_s$.
y-direction:

$$\begin{aligned} F_{\text{net},y} = N - mg &= 0 \\ N &= mg \end{aligned}$$

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x-direction:

$$
\begin{aligned}
F_{\text{net},x} = f_s &= \frac{mv^2}{r} \\
\mu_s N &= \frac{mv^2}{r} \\
\mu_s (mg) &= \frac{mv^2}{r} \\
v &= \sqrt{\mu_s g r} \\
&= \underline{19 \text{ m/s}}
\end{aligned}
$$

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A 1200-kg car rounds a corner of radius $r = 45$ m. If the coefficient of static friction between the tires and the road is $\mu_s = 0.82$, what is the greatest speed the car can have in the corner without skidding?

$$v = \underline{19 \text{ m/s}}$$

Reasonable?: This is much less than my guess (30 m/s), however, 30 m/s $\approx$ 65 mi/h, which would be an insane speed to take such a sharp turn. Usually the speed limit signs say 35 mi/h on such tight turns. So, I think my answer is right and hypothesis is too big.

Summary

- uniform circular motion
- banked turns

Final Exam, Thursday, Mar 26, by Canvas & Zoom, be ready at 9am.

Homework

- Quiz 7 (take home quiz, due today, **3pm**)
- Forces sand Motion worksheet (due Thursday, **10am**)

Walker Physics:

- Ch 6, onward from page 177. Problems: 110 (vertical circle)