Lecture 6- Uniform circular motion
Chapter 6

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PHY-123 ANALYTICAL PHYSICS IA

Phys- 123
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Objectives

- Drag Force
- Uniform circular motion
Frictional Force vs time

![Graph showing frictional force over time with static and kinetic friction regions highlighted.](image-url)
A block with a gravitational force of $F_g = 10$ N is sitting on a table that has a coefficient of friction $\mu_s = 0.5$, the block is tapped with a force of 2 N in the horizontal direction, will the block slide?

A.) Yes, it will slide.
B.) No, the horizontal force would need to be 2 N’s larger to make it slide.
C.) No, the horizontal force would need to be more than 3 N’s larger to make it slide.
D.) No, it would bounce.
E.) Yes, just barely.
Will the block slide?

A block with a gravitational force of $F_g = 10 \text{ N}$ is sitting on a table that has a coefficient of friction $\mu_s = 0.5$, the block is tapped with a force of 2 N in the horizontal direction, will the block slide?

A.) Yes, it will slide.

B.) No, the horizontal force would need to be 2 N’s larger to make it slide.

C.) No, the horizontal force would need to be more than 3 N’s larger to make it slide.

D.) No, it would bounce.

E.) Yes, just barely.
What is a fluid?

Anything that flows, could be a liquid or a gas.
Drag Force

Drag Force $\vec{D}$

Opposition to the relative motion of a body as it passes through a fluid (or the fluid moves past the body).

Can you think of examples?
Drag Coefficient

\[ D = \frac{1}{2} C \rho A v^2 \]

where

- \( \rho \) is air density (mass per volume)
- \( A \) is the effective cross-sectional area
- \( v \) is the velocity
Falling objects

\[ D - F_g = ma \]
Terminal velocity

Eventually the $D = F_g$ and the acceleration goes to zero $a = 0$, this is known as terminal velocity

$$D - F_g = ma$$
Terminal velocity

\[ D - F_g = ma \]

\[ \frac{1}{2} C_\rho A v_t^2 - F_g = 0 \]

\[ v_t = \sqrt{\frac{2F_g}{c_\rho A}} \]  \hspace{1cm} (1)
Table 6.2.1 Some Terminal Speeds in Air

The 95% distance is the distance through which a body must fall from rest to reach 95% of its terminal speed, based on Peter J. Brancazio, *Sport Science*, 1984, Simon & Schuster, New York.

<table>
<thead>
<tr>
<th>Object</th>
<th>$v_t$ (m/s)</th>
<th>95% Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shot (from shot put)</td>
<td>145</td>
<td>2500</td>
</tr>
<tr>
<td>Sky diver (typical)</td>
<td>60</td>
<td>430</td>
</tr>
<tr>
<td>Baseball</td>
<td>42</td>
<td>210</td>
</tr>
<tr>
<td>Tennis ball</td>
<td>31</td>
<td>115</td>
</tr>
<tr>
<td>Basketball</td>
<td>20</td>
<td>47</td>
</tr>
<tr>
<td>Ping-Pong ball</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Raindrop (radius 1.5 mm)</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Parachutist (typical)</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>
Uniform Circular Motion

What is Uniform Circular Motion?
Uniform Circular Motion

- Speed = const
- Velocity is tangent to the circle (path)
- Acceleration points inward
- $|\vec{v}| = const$ and $|\vec{a}| = const$
Centripetal acceleration and period

Centripetal = “center seeking”

**Acceleration**

\[ a = \frac{v^2}{r} \]

**Period**

Time to travel around entire circle (distance of \(2\pi r\))

\[ T = \frac{2\pi r}{v} \]
Vector Components

### Velocity

\[ \vec{v} = v_x \hat{i} + v_y \hat{j} \]

\[ = -v \sin \theta \hat{i} + v \cos \theta \hat{j} \]

### Acceleration

\[ \vec{a} = a_x \hat{i} + a_y \hat{j} \]

\[ = -\frac{v^2}{r} \cos \theta \hat{i} + -\frac{v^2}{r} \sin \theta \hat{j} \]
Merry-go-round

Centripetal acceleration

A merry-go-round is has an initial velocity of \( \vec{v} = 3.0\hat{i} + 1.0\hat{j} \) m/s with a radius of 3.0 meters. What is its centripetal acceleration?

First, we find the magnitude of the velocity

\[
|\vec{v}| = \sqrt{3^2 + 1^2} m/s = \sqrt{10} m/s
\]

Then we solve for the acceleration

\[
a = \frac{v^2}{r} = \frac{10.}{3.0} = 3.3 m/s^2
\]
Merry-go-round

acceleration

What direction is the acceleration pointing in?

- At the sky
- Into the ground
- Towards the center of the merry-go-round
- Away from the center of the merry-go-round
- Tangent to the edge of the merry-go-round
Merry-go-round

**acceleration**

What direction is the acceleration pointing in?

- At the sky
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Merry-go-round

Centripetal acceleration

A merry-go-round is has an initial velocity of \( \vec{v} = 3.0 \hat{i} + 1.0 \hat{j} \text{ m/s} \) with a radius of 3.0 meters. What is its period?

\[
T = \frac{2\pi r}{v} = \frac{2\pi 3.0 \text{m}}{\sqrt{10 \text{m/s}}} = 6.0 \text{ seconds}
\]
Centripetal Force

Newton’s 2nd Law
A force *must* cause an acceleration

- Car going round a curve. There is a centripetal force (towards the center) that is a friction force on the tires (makes the turn possible)
- Satellite orbiting Earth → gravitation force pointed towards Earth
Hammer throw
Hammer throw

What is the main type of centripetal force acting on a hammer throw?

- Gravitational
- Frictional
- Normal
- Magnetic
- Tension
Hammer throw

What is the **main** type of centripetal force acting on a hammer throw?

- Gravitational
- Frictional
- Normal
- Magnetic
- **Tension**
Centripetal Force

Magnitude of Centripetal Force

\[ F = m \frac{v^2}{R} \]

Direction of force varies continuously, magnitude is constant.
Bike loop-the-opp

Dirt bike loop-the-loop
Bike loop-the-opp

Minimum velocity

What is the minimum velocity the biker needs to remain in contact with the loop at the top?
Minimum velocity

What is the minimum velocity the biker needs to remain in contact with the loop at the top?

\[-F_N - F_g = m(-a)\]
\[-F_N - mg = m\left(-\frac{v^2}{R}\right)\]
Minimum velocity

What is the minimum velocity the biker needs to remain in contact with the loop at the top?

But it’s the minimum velocity so $F_N \rightarrow 0$. Thus,

$$-mg = m\left(-\frac{v^2}{R}\right)$$

$$g = \frac{v^2}{R}$$

$$v = \sqrt{gR}$$
Chance of succes for different loops

Does the biker have a better chance for a loop of radius $R = 10$ m or $R = 20$ m

- $R = 10$ m because his minimum velocity is $v \sim 10$ m/s
- $R = 20$ m because his minimum velocity is $v \sim 10$ m/s
- $R = 20$ m because his minimum velocity is $v \sim 20$ m/s
- They have the same chance of success
- $R = 10$ m because his minimum velocity is $v \sim 20$ m/s
Does the biker have a better chance for a loop of radius $R = 10$ m or $R = 20$ m

- $R = 10$ m because his minimum velocity is $v \sim 10$ m/s
- $R = 20$ m because his minimum velocity is $v \sim 20$ m/s
- They have the same chance of success
- $R = 10$ m because his minimum velocity is $v \sim 20$ m/s
Jumping off a merry-go-round

With centripetal force the object moves in a circular path with speed $v$. When centripetal force is removed, the object moves along a tangent to the circular path with speed $v$. 
Next Week

- Energy and Work