GAME2016
Mathematical Foundation of Game Design and Animation

Lecture 9
Circular, Harmonic, and Pendulum Motion

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Agenda

- Understanding Circular Motion
- Exploring Harmonic Motion
- Analyzing Pendulum Motion
- Integrating Motion Types in Game Design

Circular, Harmonic, and Pendulum Motion in Game Design and Animation

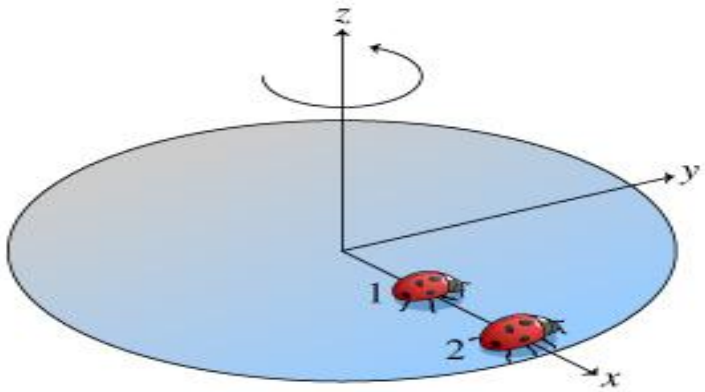
Understanding Circular Motion

Understanding Circular Motion

- Realism
  - Accurate physical motions create immersive game worlds. Players expect objects to behave naturally, enhancing their experience.
- Gameplay Mechanics
  - Understanding these motions allows designers to create innovative gameplay elements. Circular platforms and pendulum obstacles challenge players in unique ways.
- Visual Appeal
  - Smooth, natural animations based on these motions captivate players. They add life and dynamism to game environments and characters.

Vocabulary for Circular Motion

- Period(T): the time it takes for one rotation or revolution. Measured in seconds.
- Rotation: spinning about an internal axis, an ice skater spinning
- Revolution: traveling about an external axis, kid on merry-go-round
- Centripetal force: a center-seeking force, causes circular motion
- Linear Speed: a point on the outer edge of an object moves a greater distance in one rotation than a point closer to the center of the object.



Circular Motion Fundamentals

- Centripetal Force
  - The force that keeps an object moving in a circular path. It's always directed towards the center of the circle.
  - Centrifugal force is just a sensation
- Angular Velocity
  - The rate of change of angular position. It's measured in radians per second.
- Angular Acceleration
  - The rate of change of angular velocity. It causes objects to speed up or slow down in circular motion.

Circular Motion in Games

Rotating Platforms

Circular motion creates challenging gameplay elements. Players must time jumps and movements to navigate rotating platforms.

Orbiting Objects

Planets and satellites in space-themed games use circular motion. This creates realistic celestial mechanics for players to interact with.

Spinning Gears

Puzzle games often feature interlocking gears. Understanding circular motion is crucial for creating these intricate mechanisms.

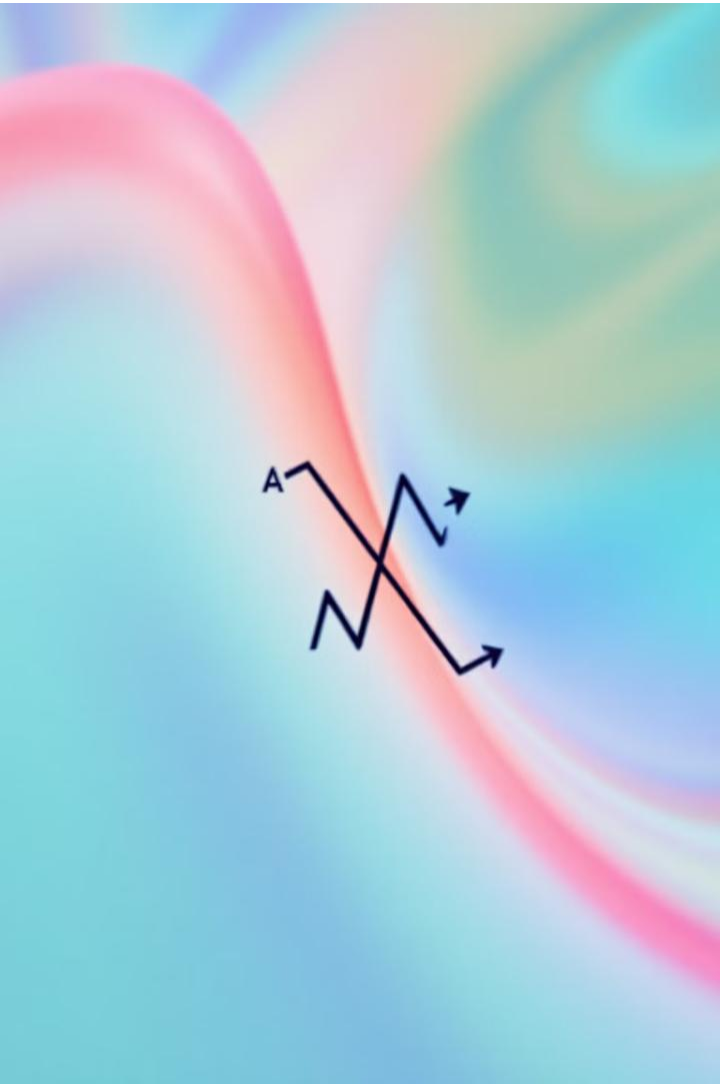
- Examples: Fall Guys

Animation Techniques for Circular Motion

- **Keyframe Animation Precision**
  - Precise control over an object's position along a circular path
  - Enable animators to define critical points and create smooth transitions
  - Enhance the visual flow of motion in animations and games
- **Path Animation Consistency**
  - Objects follow a defined circular trajectory, maintaining consistent speed and direction
  - Essential for achieving realistic motion and improving the overall aesthetic of animated scenes
- **Physics-Based Simulation Realism**
  - Allows for the incorporation of real-world dynamics, such as inertia and friction
  - More believable circular movements that enhance player immersion and interaction in game environments

Exploring Harmonic Motion

Harmonic Motion Basics



Amplitude

The maximum displacement from equilibrium. It determines how far an object moves in each direction.

Period

The time taken for one complete oscillation. It affects the speed of repetitive motions.

Frequency

The number of oscillations per unit time. It's the inverse of the period.

Phase

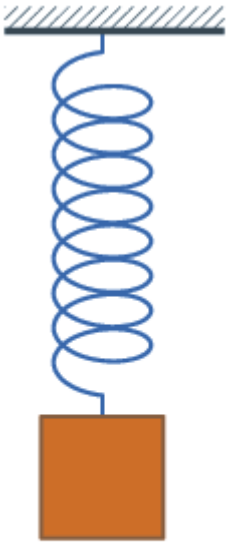
The position of an oscillating object at a specific time. It determines the starting point of motion.

Simple Harmonic Motion (SHM)

- Definition
  - SHM is a periodic motion where the restoring force is proportional to displacement.
  - Think of it as nature's smoothest way to repeat a motion.
  - It's driven by a “desire” to return to a center point, like a stretched rubber band. The further you pull it, the harder it pulls back. We can create this motion easily using a sine wave.
- Examples
  - Springs and pendulums exhibit SHM. These principles are used to create realistic object behaviors in games.

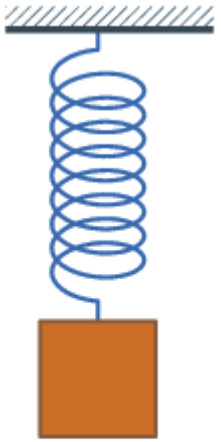
Simple Harmonic Motion (SHM)

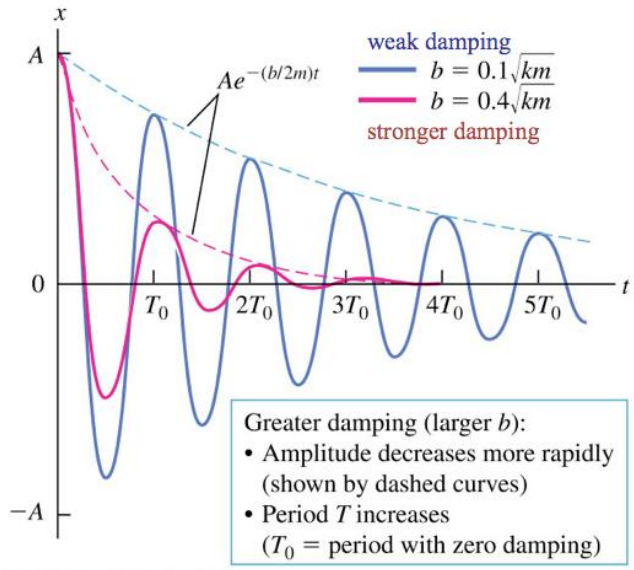
- Springs oscillate in simple harmonic motion
- **Undamped** springs will continue to oscillate
- Simple harmonic motion is a type of periodic motion where the restoring force is directly proportional to the displacement.



Simple Harmonic Motion (SHM)

- Springs oscillate in simple harmonic motion
- **Damped springs** will eventually come to rest
- Damping is an influence within or upon an oscillatory system that has the effect of reducing, restricting or preventing its oscillations.
- Calculator: LINK





Periodic Motion vs Simple Harmonic Motion

- **Periodic Motion**: something that repeats the same motion over and over, like the earth going around the sun or a ball bouncing.

- **Simple Harmonic Motion**: a special type of periodic motion that has a restorative force that varies directly with the distance from the equilibrium position or rest position, like a mass on a spring or a pendulum bob.

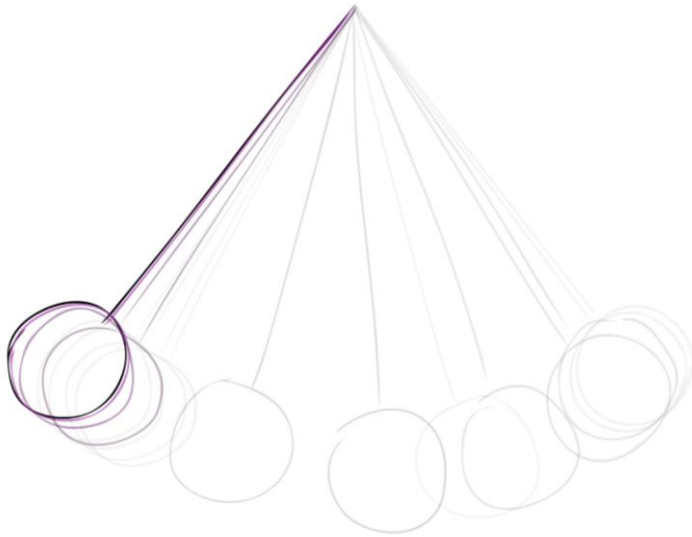
Harmonic Motion in Game Design

- Character Movement
  - Harmonic motion creates natural-looking jumps and landings. It adds a sense of weight and realism to character animations.
- Environmental Effects
  - Swaying trees and rippling water use harmonic principles. These details bring game worlds to life.
- Enemy Patterns
  - Oscillating enemies move in predictable yet challenging patterns. This creates engaging gameplay mechanics for players to master.

Analyzing Pendulum Motion

Principles of Pendulum Motion

- Oscillation Dynamics
  - Pendulum motion is an example of simple harmonic motion
  - The restoring force is proportional to the displacement
  - This leads to predictable oscillations that can be modeled mathematically



- Energy Conservation
  - The pendulum's motion illustrates the conversion between potential and kinetic energy
  - Maximum potential energy at the highest points
  - Maximum kinetic energy at the lowest point

Pendulum Motion Essentials

Component	Description	Game Application
Bob	Mass at the end of the pendulum	Swinging obstacles or collectibles
String/Rod	Connects bob to pivot point	Grappling hooks, swing mechanics
Amplitude	Maximum swing angle	Difficulty adjustment in pendulum puzzles
Period	Time for one complete swing	Timing challenges in platformers

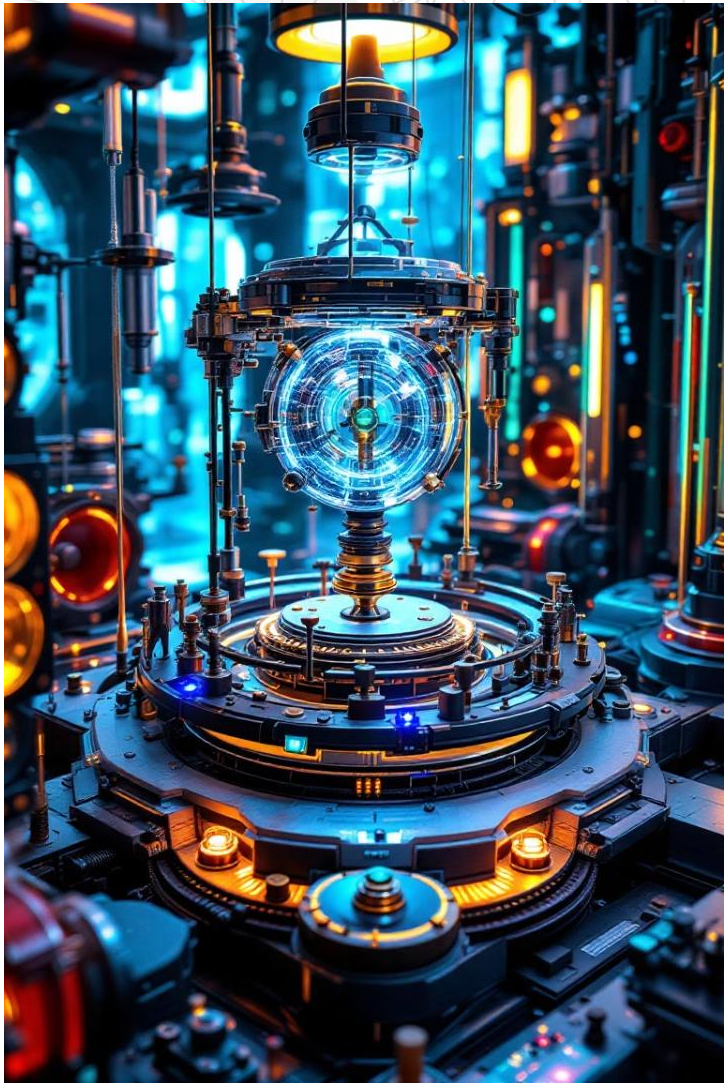
Pendulums in Games and Animation

- Puzzle Elements
  - Pendulums create timing-based puzzles.
  - Players navigate swinging obstacles or use pendulums to reach new areas.
  - Example: Cut the rope, Tomb Raider, God of War
- Traps and Hazards
  - Swinging blades or hammers use pendulum motion.
  - Create timing-based challenges for players to overcome.
- Character Animations
  - Pendulum enhance character movements.
  - Used for realistic swinging actions, like grappling hooks or vines.

Integrating Motion Types in Game Design

Integrating Motions in Game Design

- Layered Mechanics
  - Combine different motions to create complex, engaging gameplay. For example, pendulums on rotating platforms add multiple challenges.
- Physics Engines
  - Modern game engines simulate these motions accurately. They provide tools for designers to easily implement realistic physics.
- Balancing Realism and Fun
  - While accuracy is important, gameplay should remain enjoyable. Designers must find the right balance between realism and playability.



Combining Circular, Harmonic, and Pendulum

- Pro
  - **Enhanced Realism in Gameplay**
    - The integration of these motion types creates a more immersive experience with lifelike interactions and dynamic environments.
  - **Innovative Gameplay Mechanics**
    - Timed jumps and synchronized movements can increase player engagement and challenge.
- Cons
  - **Complexity in Design Challenges**
    - Requires careful calibration to ensure smooth and realistic animations that enhance gameplay.
  - **Potential for Technical Limitations**
    - The complexity of simulating these motions may lead to performance issues that may affect fluidity.