## Overviev

#### Chapter 1

- Simulation #1
- C:----1/2
- Jillidiation #3

#### Chapter

- C: 1.1: 11A
- Simulation #
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Chapter 5

onclusion

# Mechanics Simulations With JavaScript

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# Overview - Why Did I Choose This Topic?

## Overview

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  Simulation #2
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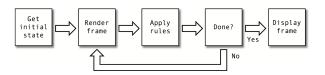
- I hope to use programming as a lens to view physics
- Examine mechanics in more detail
- Solve physics problems through simulations
- JavaScript high level language viewable easily in web browser

## What is a simulation?

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- Animation vs. Simulation
- Frames per second
- File size



## Method of Basic Simulation

## Overview

## Chantar 1

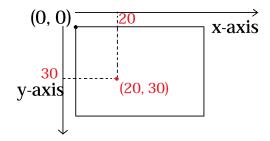
Simulation #1 Simulation #2

## Chapter 2

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- HTML5 canvas application programming interface (API)
- Timer for each frame



## Overview

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Conclusion

# Chapter 1: Basic kinematics and aerodynamic drag

## Overviev

## Chapter 1

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- Three simulations
- Simulation #1: Basic bouncing ball
- Simulation #2: Bouncing ball with aerodynamic drag
- Simulation #3: Multiple bouncing balls

# Simulation #1: Basic Bouncing Ball

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Realistic g value

• 9.81 
$$\frac{px}{s^2} = .1635 \frac{\frac{px}{s}}{frame} \times \frac{60 frame}{s}$$

- Coefficient of restitution  $(C_r)$
- $\bullet \ \ \textit{$C_r$} = \sqrt{\frac{\textit{$KE_f$}}{\textit{$KE_i$}}} = \sqrt{\frac{\frac{1}{2}\textit{$mv_f^2$}}{\frac{1}{2}\textit{$mv_i^2$}}} = \frac{\textit{$v_f$}}{\textit{$v_i$}}$
- $v_f = v_i * C_r$

# Simulation #2: Bouncing Ball With Aerodynamic Drag

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• 
$$f_{drag} = -\frac{1}{2}C_d\rho Av^2$$

- $F_D$  = force of drag
- $\rho = \text{density of fluid}$
- v =speed of object relative to fluid
- $C_d$  = drag coefficient (affected by texture, shape, viscosity, lift, etc)
- $\bullet$  A = cross-sectional area of object

# Simulation #3: Multiple Balls Bouncing

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- ullet Same physics as simulation #1
- Array of ball objects
- Each object has properties
- Each frame cycles through array, updating properties of each object

# Chapter 2: Planetary Motion

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3 Simulations

Simulation #4: Orbits

Simulation #5: Escape velocity

Simulation #6: Kepler's 2nd law

## Simulation #4: Orbits

## Overview

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Simulation #:

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Newton's Law of universal gravitation

$$\bullet \ F_g = G \frac{m_1 m_2}{r^2}$$

- Euler's Method to update velocity
- $x(t + dt) = x(t) + \frac{dx}{dt}(t) dt$

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$$\bullet \ K_i + U_{g_i} = K_f + U_{g_f}$$

$$\bullet \ \ \frac{1}{2}mv_{esc}^2 - \frac{\mathit{GMm}}{\mathit{r}} = 0 + 0$$

• 
$$v_{esc} = \sqrt{\frac{2GM}{r}}$$

• 
$$v_{esc} = \sqrt{\frac{2*1\frac{px^3}{s^2}*1000000}{410px}} \approx 69.843\frac{px}{s}$$

 Used bigger canvas, and plotted velocities during planet's travel

## Overviev

## Chapter 1

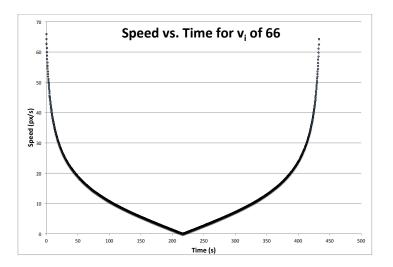
Simulation #1 Simulation #2

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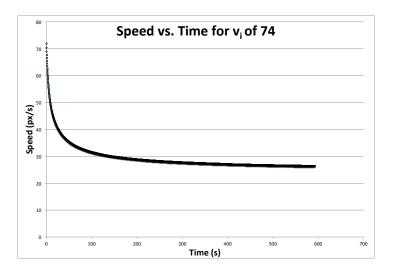
Simulation #1 Simulation #2

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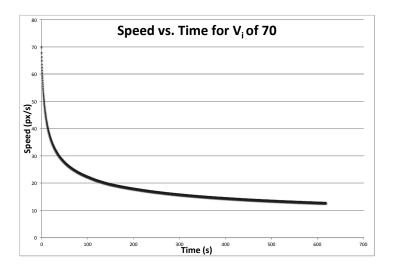
Simulation #1

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# Simulation #6: Kepler's 2nd law

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- Early 1600's Johannes Kepler proposed laws explaining how planets orbit the sun
- Law #2: "The radius vector drawn from the Sun to a planet sweeps out equal areas in equal time intervals"
- Simulation shows constant  $\frac{dA}{dt}$

## Derivation of Kepler's 2nd Law

## Overview

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• Gravity force is central force

$$\bullet \ \vec{\tau} = \vec{r} \times \vec{F_g} = \frac{d\vec{L}}{dt}$$

$$\bullet \ \vec{L} = \vec{r} \times \vec{p} = M_p \vec{r} \times \vec{v}$$

• 
$$L = M_p |\vec{r} \times \vec{v}|$$

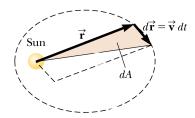


Figure : Relationship between  $\vec{r}$  and  $d\vec{r}$ 

# Derivation of Kepler's 2nd Law (Continued)

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$$ullet$$
  $|ec{r} imes dec{r}|$  area of parallelogram

• 
$$dA = \frac{1}{2}|\vec{r} \times d\vec{r}| = \frac{1}{2}|\vec{r} \times \vec{v}dt| = \frac{1}{2}|\vec{r} \times \vec{v}|dt$$

• 
$$dA = \frac{1}{2} \left( \frac{L}{M_p} \right) dt$$

• From before, 
$$|\vec{r} \times \vec{v}| = \frac{L}{M_p}$$

• L and  $M_p$  are constants

# Chapter 3: Rotational Motion

## Overview

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## Simulation #3

## Simulation #4

Simulation #4 Simulation #5

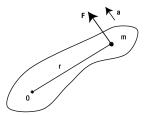
Simulation #6

Simulation #3

$$\vec{\tau} = \vec{r} \times \vec{F}$$

• 
$$I = \int r^2 dm$$

• 
$$\vec{L} = I\vec{\omega}$$



# Chapter 3: Rotational Motion

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Newton's 2nd law for rotation

•  $\vec{T} = I\vec{\alpha}$ 

• Program updates  $\omega$  by calculating  $\alpha$  from T and I.

## Conclusion

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Conclusion

- Simulations can be made very accurate with JavaScript
- Advantages of simulations involve sending instructions
- Future improvements could involve 3D

## Overviev

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#### Chapter

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Simulation #!

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Simulation #3

Conclusion

# Thank You