Overviev

Chapter 1

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

Chapter

- C: 1.1: 11A
- Simulation #
- Simulation #6

Chapter 5

onclusion

Mechanics Simulations With JavaScript

Peter Krieg

Physics Fall Semester Thesis

December 3, 2014

Overview - Why Did I Choose This Topic?

Overview

- Chapter 1
 Simulation #1
 Simulation #2
- Chapter 2
 Simulation #4
 Simulation #5
- Chapter 3 Simulation #3

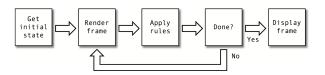
- Use programming as a lens to view physics
- Examine mechanics in more detail
- Solve physics problems through simulations
- JavaScript high level language viewable easily in web browser

What is a simulation?

Overview

- Chapter 1
- Simulation #1
 Simulation #2
 Simulation #3
- Chapter 2
- Simulation #4
- Simulation #! Simulation #6
- Chapter 3 Simulation #3
- onclusio

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



Method of Basic Simulation

Overview

Chapter 1

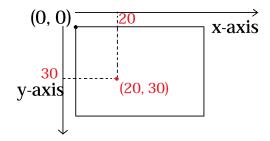
Simulation #1 Simulation #2

Chapter 2

Simulation #4 Simulation #5

Chapter 3

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



Chapter 1: Basic Kinematics and Aerodynamic Drag

Overviev

Chapter 1 Simulation #1

Simulation #1 Simulation #2 Simulation #3

Chapter 2 Simulation #4 Simulation #5

imulation #5

Simulation #3

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

Simulation #1: Basic Bouncing Ball

Overview

- Chapter 1
- Simulation #1 Simulation #2
- Simulation #2 Simulation #3

Chapter 2

- Simulation #
- Simulation #5
- Chapter 3
 Simulation #3
- Conclusi

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

Overview

Chapter 1
Simulation #1
Simulation #2

Chapter 2
Simulation #4
Simulation #5
Simulation #6

Chapter 3 Simulation #3

•
$$f_d = -\frac{1}{2}C_d\rho Av^2$$

- 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

Overviev

- Simulation #2
 Simulation #3
 Chapter 2
- Simulation #4 Simulation #5 Simulation #6
- Chapter 3 Simulation #3

- 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

Overviev

Chapter 1
Simulation #1
Simulation #2
Simulation #3

Chapter 2
Simulation #4
Simulation #5
Simulation #6

Chapter 3 Simulation #3

onclusio

3 Simulations

Simulation #4: Orbits

Simulation #5: Escape velocity

Simulation #6: Kepler's 2nd law

Simulation #4: Orbits

Overview

Chapter :

Simulation #2

ulation #3

Chapter 2

Simulation #4

Simulation #5 Simulation #6

Chapter 3
Simulation #:

Conclusio

Newton's Law of universal gravitation

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

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

Overviev

Chapter 1
Simulation #1
Simulation #2
Simulation #3

Chapter 2
Simulation #4
Simulation #5
Simulation #6

Chapter 3 Simulation #3

onclusio

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

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

•
$$v_{esc} = \sqrt{\frac{2GM}{r}}$$

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

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

Overviev

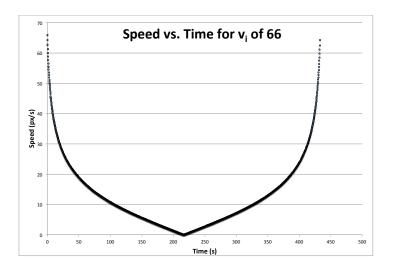
Chamban 1

Simulation #1 Simulation #2

Chapter 2

Simulation #4
Simulation #5

Chapter 3



Overviev

Chapter 1

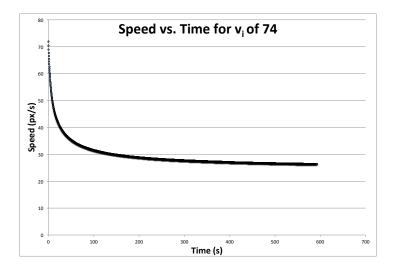
Simulation #1 Simulation #2

Simulation #3

Chapter 2 Simulation

Simulation #5
Simulation #6

Chapter 3
Simulation #3



Overviev

nanter 1

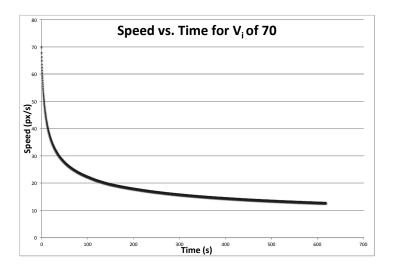
Simulation #1 Simulation #2

Chapter 2

Simulation #4
Simulation #5

Simulation #5

Simulation #3



Simulation #6: Kepler's 2nd law

Overviev

- Chapter 1
 Simulation #1
 Simulation #2
- Chapter 2 Simulation #4 Simulation #5 Simulation #6
- Chapter 3
 Simulation #3

- 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

Chapter 1 Simulation #1 Simulation #2 Simulation #3

Chapter 2
Simulation #4

Simulation #5
Simulation #6

Chapter 3
Simulation #3

Conclusio

• Gravity force is central force

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

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

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

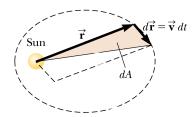


Figure : Relationship between \vec{r} and $d\vec{r}$

Derivation of Kepler's 2nd Law (Continued)

Overview

- Chapter 1
 Simulation #1
 Simulation #2
- Chapter 2 Simulation #4 Simulation #5
- Simulation #6
 Chapter 3

Conclusio

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

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

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

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

• L and M_p are constants

Kepler's 2nd Law

Overview

Chapter 1
Simulation #1
Simulation #2
Simulation #3
Chapter 2

Simulation #4 Simulation #5

Simulation #6

Simulation #3

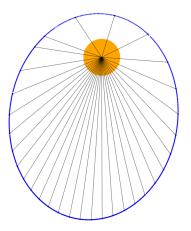


Figure : Screenshot of Kepler Law test simulation

Chapter 3: Rotational Motion

Overview

Chapter 1

Simulation #1 Simulation #2

5111tilation #-

Simulation #4

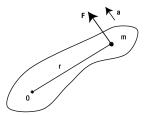
Simulation #6

Simulation #3

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

•
$$I = \int r^2 dm$$

$$\vec{L} = I\vec{\omega}$$



Chapter 3: Rotational Motion

Overview

Chapter :

Simulation #1

Simulation #2 Simulation #3

Chapter 2

Simulation #4

Simulation #

Chapter 3
Simulation #3

Conclusio

Newton's 2nd law for rotation

• $\vec{T} = I\vec{\alpha}$

• Program updates ω by calculating α from T and I.

Conclusion

Overviev

- Chapter 1
 Simulation #1
 Simulation #2
 Simulation #3
- Chapter 2
 Simulation #4
 Simulation #5
 Simulation #6
- Chapter 3
 Simulation #3

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

Overviev

Chapter 1

Simulation #1

mulation #3

Chapter

nulation #4

Simulation #!

_. .

Simulation #3

Conclusion

Thank You