Table of Contents

[Math dictionary 2](#_Toc45179030)

[Integration methods 3](#_Toc45179031)

[Examples 3](#_Toc45179032)

[Requirements 3](#_Toc45179033)

[Friction models 4](#_Toc45179034)

[Requirements 4](#_Toc45179035)

[Examples 4](#_Toc45179036)

[References 5](#_Toc45179037)

# Math dictionary

|  |  |  |
| --- | --- | --- |
|  | Full Name | Description |
|  | Old Position | The position before integration |
|  | New Position | The position after integration |
|  | Old Velocity | The velocity before integration |
|  | New Velocity | The velocity after integration |
|  | Delta Time | Reciprocal timestep |
|  | Force | 3D force vector |
|  | Mass | Mass |
|  | Acceleration | Second derivative of motion |
|  | Coeff of Friction | Square root of the combined coefficients |
|  | Coeff of Static Friction | Resting friction between two surfaces |
|  | Coeff of Kinematic Friction |  |
|  | Friction | 3D friction force vector |
|  | Normal force | 3D force that keeps objects from intersecting |
|  | Coeff of Restitution |  |

# Integration methods

|  |  |  |  |
| --- | --- | --- | --- |
|  | Order | Pros | Cons |
| Explicit Euler | 1st | Simple | Inaccurate with variable acceleration  Unstable in edge cases |
| Semi-implicit Euler | 1st | Simple  Accurate with small timesteps | Slightly less accurate then explicit |
| Implicit Euler | 1st | Solves most edge cases | Expensive |
| Verlet | 2nd | Accurate  Lower memory usage | No explicit velocity |
| Runge-Kutta 4 | 4th | Very accurate  Better at big timesteps | Complicated  Needs custom acceleration functions  Can lose energy |

## Examples

Explicit Euler:

Semi-implicit Euler:

Verlet:

## Requirements

* Objects should not gain energy without a force being applied.
* Timestep is fixed, but it should handle big timesteps to keep performance.
* Should be easily integrated into a SIMD vectorized system.
* Should not need additions if other systems get upgraded.

# Friction models

|  |  |  |
| --- | --- | --- |
|  | Pros | Cons |
| Constant Force | Very cheap | Not physically based |
| Coulomb | Pretty cheap | No distinction between static and kinetic friction.  Linear, not physically accurate. |
| Viscous | Cheap  Good approximation of kinetic friction | No static friction.  Not accurate at low velocity. |
| Combination  Coulomb + Viscous + Stribeck | Good approximation of static and kinetic friction  Handles lubrication | Expensive |

## Requirements

* Dry friction should not violate Coulomb’s law .
* Should be able to handle traction.
* Surface roughness should affect the friction   
  (more roughness = more friction).
* Friction should generate heat.
* Velocity should be independent.

## Examples

Constant force:

Coulomb:

# Impulses

|  |  |
| --- | --- |
| Symbols | Meaning |
|  | Position relative to the contact point |
|  | Contact point / Collision point |
|  | Object position |
|  | Relative velocity |
|  | Object velocity |
|  | Object angular velocity |
|  | Object coefficient of restitution |
|  | Contact normal / Collision normal |
|  | Object inverse mass |
|  | Object inverse moment of inertia tensor |
|  | Impulse magnitude |

# References

Fiedler, G. (2013, Febuary 24). *Collision Response and Coulomb Friction*. Retrieved from Gaffer on Games: https://gafferongames.com/post/collision\_response\_and\_coulomb\_friction/

Nave, C. R. (2017). *Friction*. Retrieved from HyperPhysics: http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html

Szauer, G. (2017). *Game Phyics Cookbook.* Packt.

Various Authors. (2020, June 7). *Friction*. Retrieved from Wikipedia: https://en.wikipedia.org/wiki/Friction