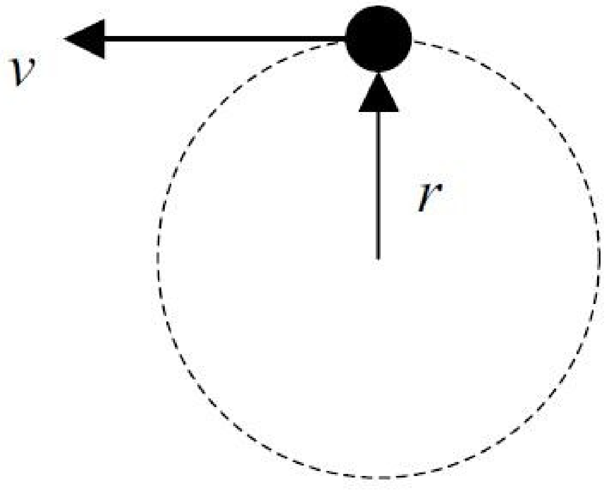
Types of Forces

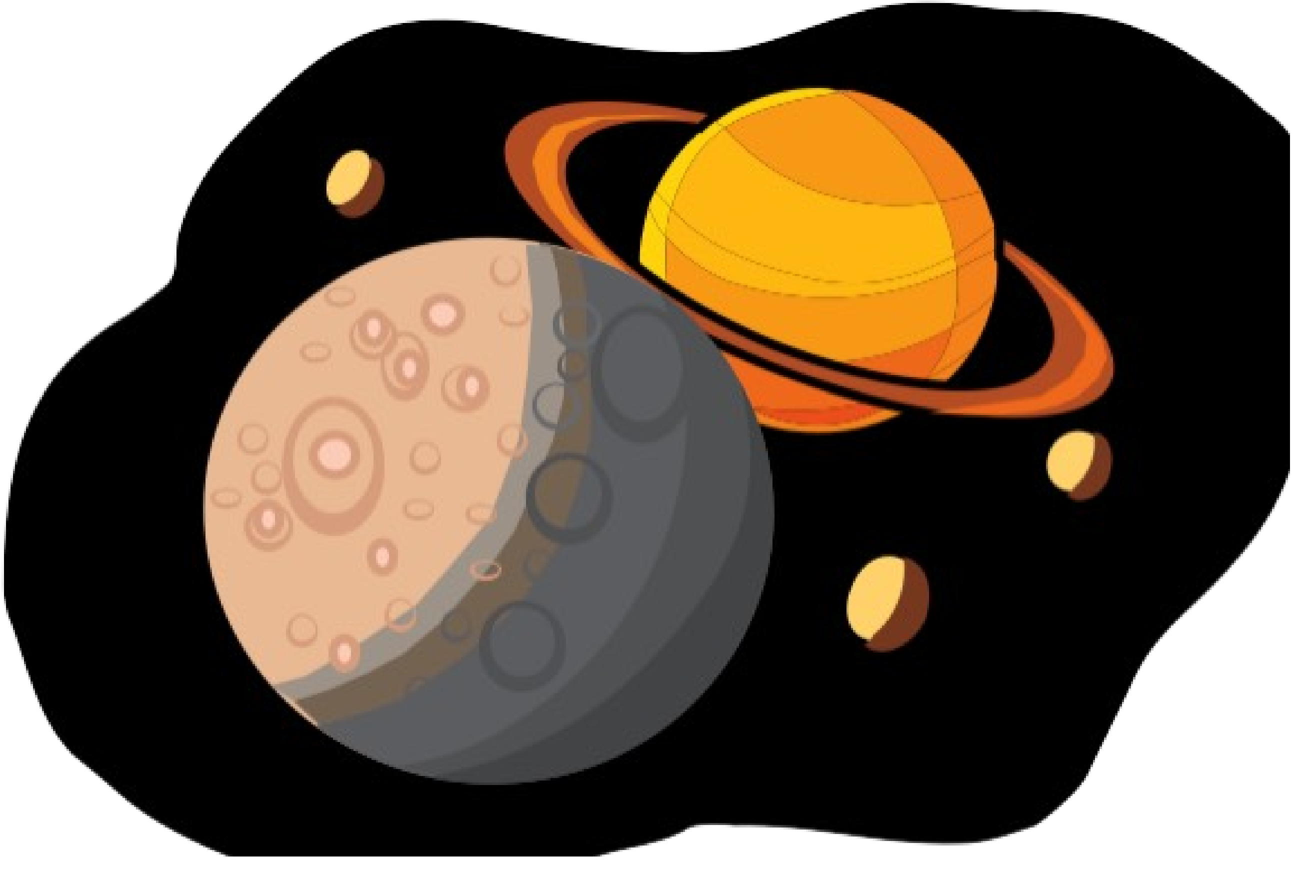
- **Centripetal Force**



$$F = \frac{mv^2}{r}$$

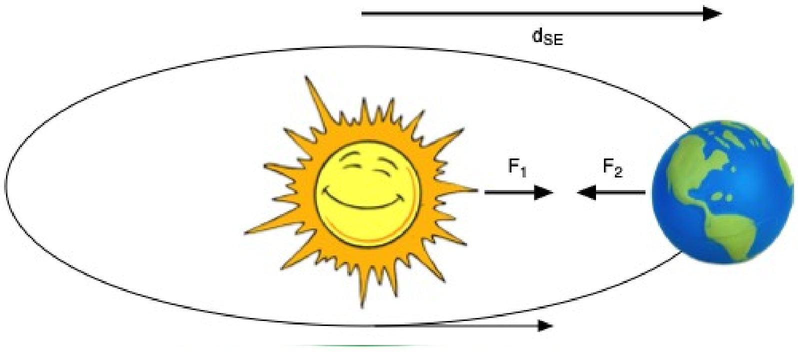
Types of Forces

- **Gravitational Force**



Types of Forces

- **Gravitational Force**



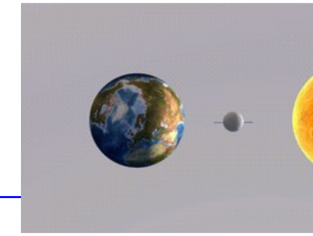
$$F = F_1 = F_2 = \frac{M_s \cdot M_E}{d_{sE}^2} = 3.5 \times 10^{22}\ N$$

$$\vec{F} = G\frac{M_1 M_2}{|\vec{R}_{12}|^3}\vec{R}_{12} = M_2 g$$

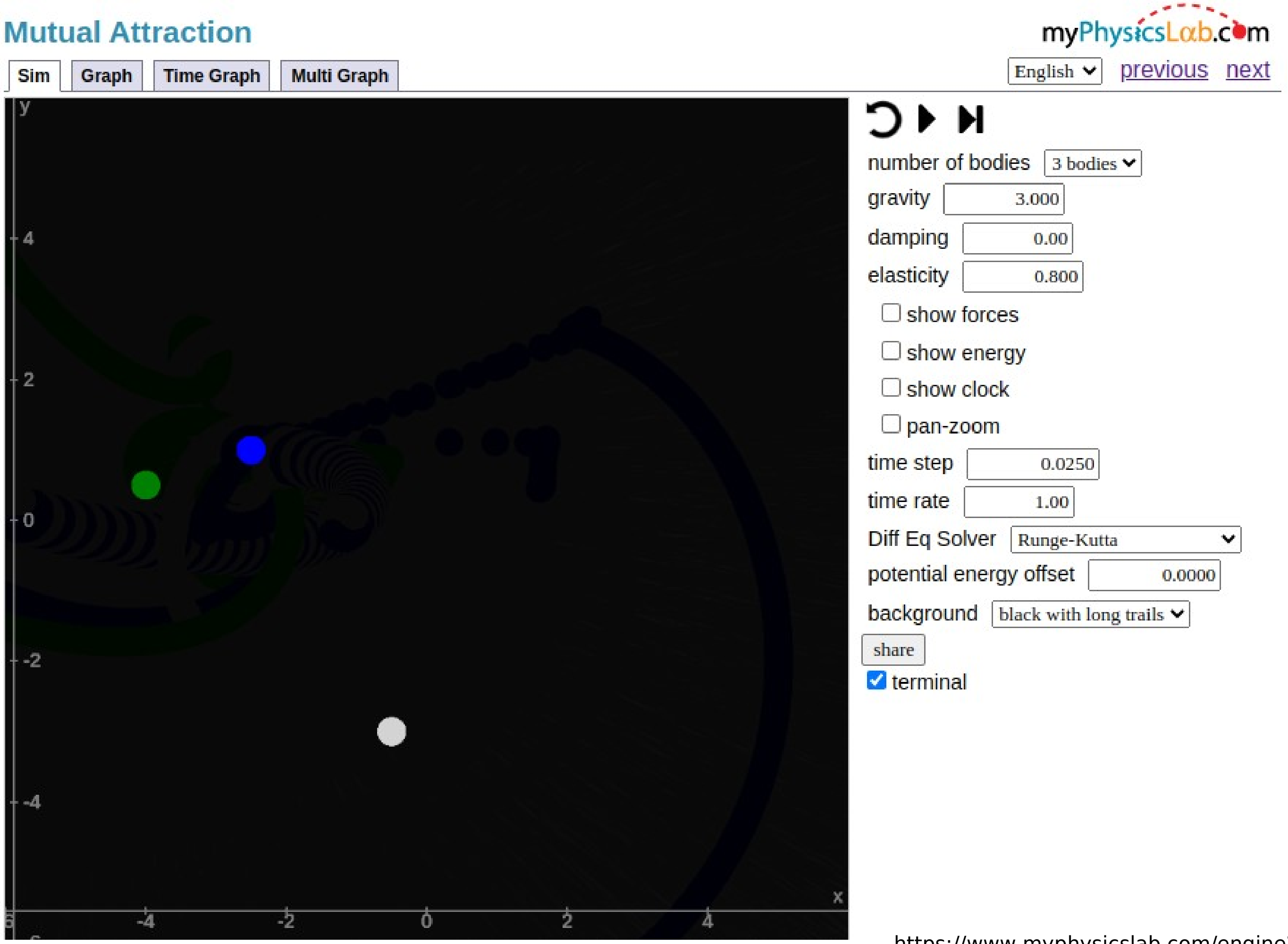
$$G = 6.674 \cdot 10^{-11}\frac{Nm^2}{kg^2}$$

$$g = 6.674 \cdot 10^{-11}\frac{Nm^2}{kg^2}\frac{5.9736 \cdot 10^{24} kg}{(6,375 \cdot 10^6 m)^2} = 9.81\frac{N}{kg}$$

Types of Forces



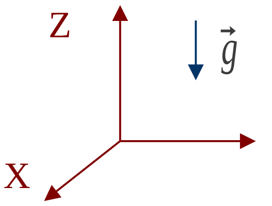
- ## Gravitational Force



https://www.myphysicslab.com/engine2D/mutual-attract-en.html

Gravitation Force

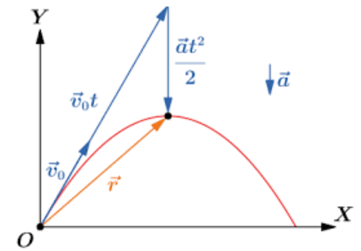
- **Equations of motion for projections**



Quantity	Differential Equation	Solution
Acceleration	None	$a_z = -g$, $a_x = 0$, $a_y = 0$
Velocity	$\frac{dv_z}{dt} = a_z = -g$	$v_z = v_{z0} - gt$, $v_x = v_{x0}$, $v_y = v_{y0}$
Location	$\frac{d^2 z}{dt^2} = a_z = -g$; $\frac{dz}{dt} = v_z = v_{z0} - gt$	$z = z_o + v_{z0} t - \frac{1}{2} g t^2$, $x = x_o + v_{x0} t$, $y = y_o + v_{y0} t$

Gravitation Force

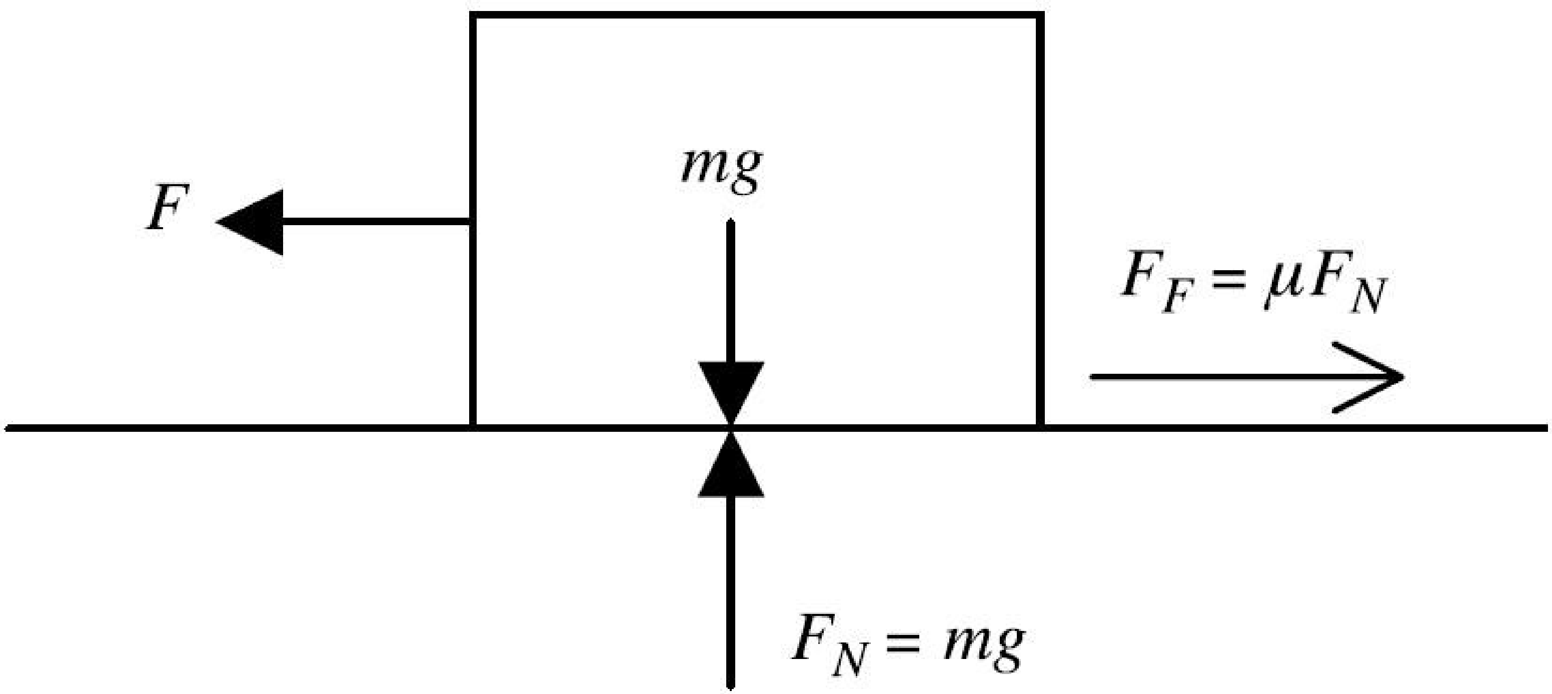
- **Equations of motion in vector form**



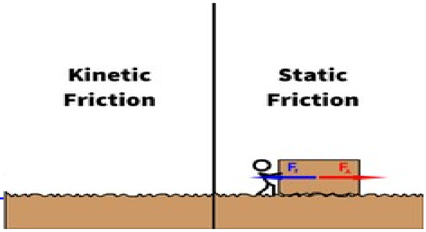
Quantity	Differential Equation	Solution
Acceleration	None	$\vec{a} = \vec{g}$
Velocity	$\frac{d\vec{v}}{dt} = \vec{a} = \vec{g}$	$\vec{v} = \vec{v}_o + \vec{g}t$
Location	$\frac{d^2\vec{r}}{dt^2} = \vec{a} = \vec{g}$ $\frac{d\vec{r}}{dt} = \vec{v} = \vec{v}_o + \vec{g}t$	$\vec{r} = \vec{r}_o + \vec{v}_o t + \frac{1}{2}\vec{g}t^2$

Friction

$$F_F = \mu F_N$$



Friction



- *Friction Coefficients for Some Common Surface Interactions*

Materials	μ_s	μ_k
Steel—steel	0.7–0.74	0.57–0.6
Steel—steel (lubricated)	0.12	0.07
Aluminum—steel	0.61	0.47
Copper—steel	0.53	0.36
Cast iron—cast iron	1.1	0.15
Teflon—Teflon	0.04	0.04
Glass—glass	0.94	0.4
Wood—wood	0.25–0.5	0.2–0.3
Rubber—concrete	1.0	0.8
Rubber—concrete (wet)	0.7	0.5
Ice—ice	0.1	0.03
Waxed ski—snow	0.1–0.14	0.05–0.1

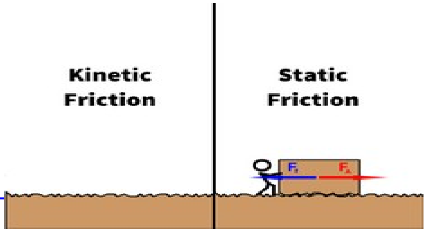
* *Source: RoyMech,* `www.roymech.co.uk`

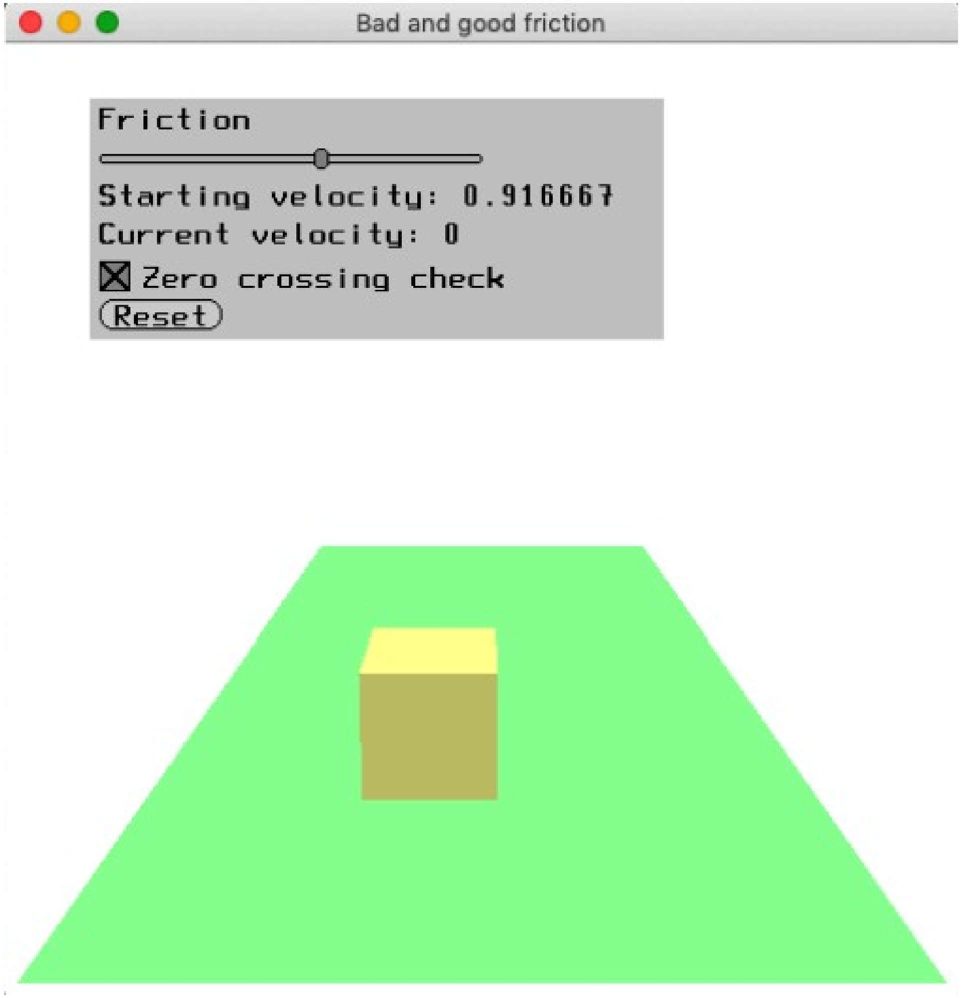
* *Raymond Serway and John Jewitt,* Physics for Scientists and Engineers, Sixth Edition *(Brooks-Cole, 2003)*

* `www.physlink.com/Reference/FrictionCoefficients.cfm`

* *Encarta.msn.com*

Friction

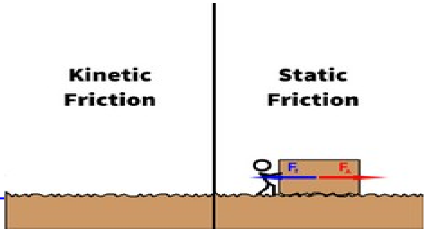


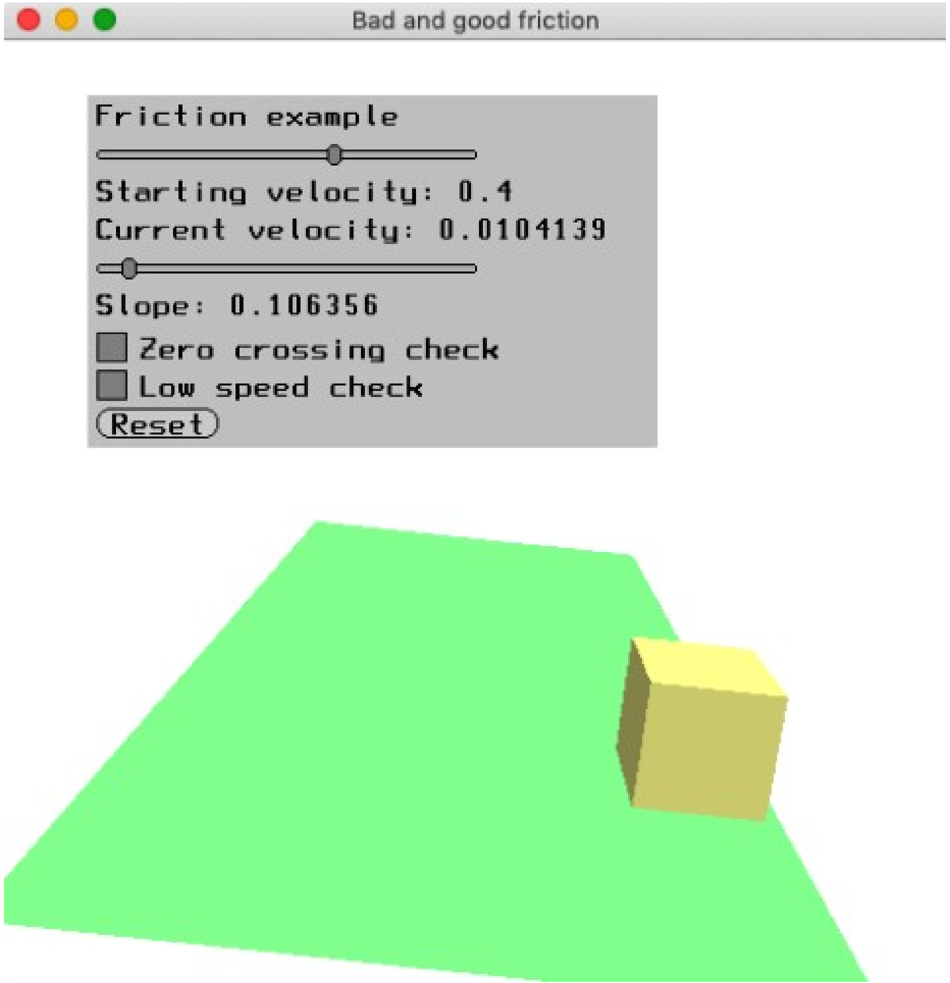


The sliding block demo

https://www.computer-graphics.se/demos/files03/Beachball-demos.zip

Friction



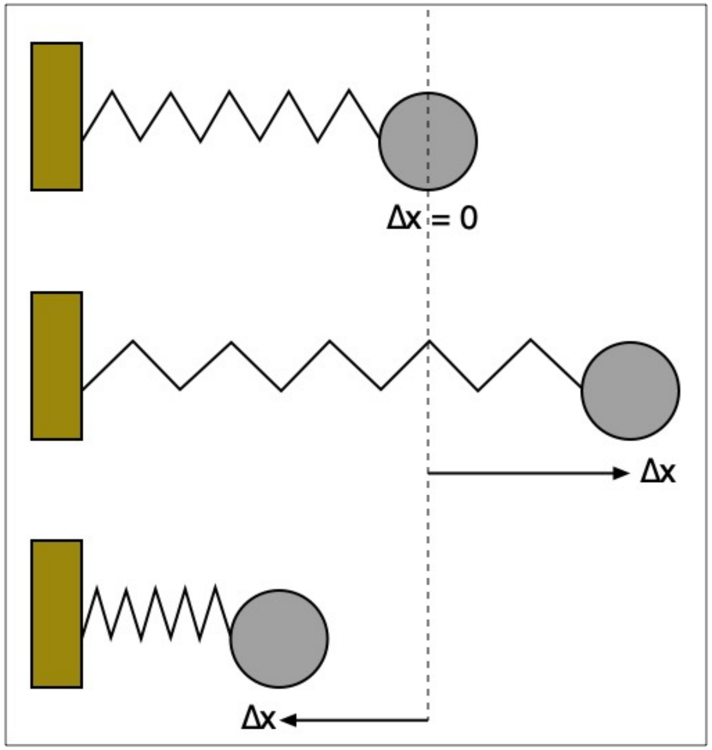


The sliding block demo 2

https://www.computer-graphics.se/demos/files03/Beachball-demos.zip

Vibration

- **Deformation**
  - **Springs**



Hooke's Law

$$\vec{F} = -k\Delta\vec{x}$$

Equation of motion: $m\ddot{x} = -kx$

$$\ddot{x} + \varpi^2 x = 0 \qquad \varpi^2 = \frac{k}{m}$$

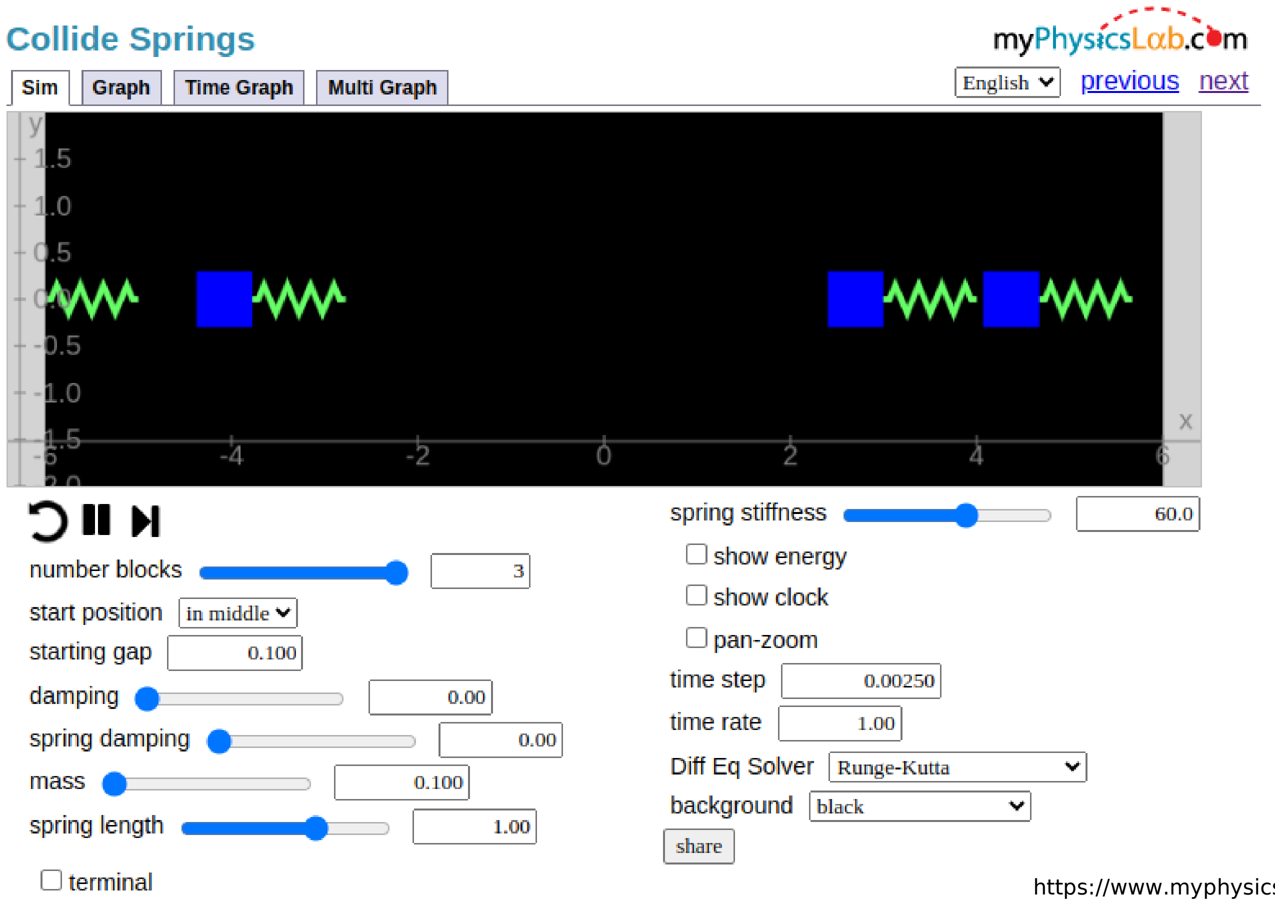
Solution: $x(t) = A\sin(\varpi t + \phi_o)$

$$T = \frac{2\pi}{\varpi} = 2\pi\sqrt{\frac{m}{k}}$$

Vibration

Deformation

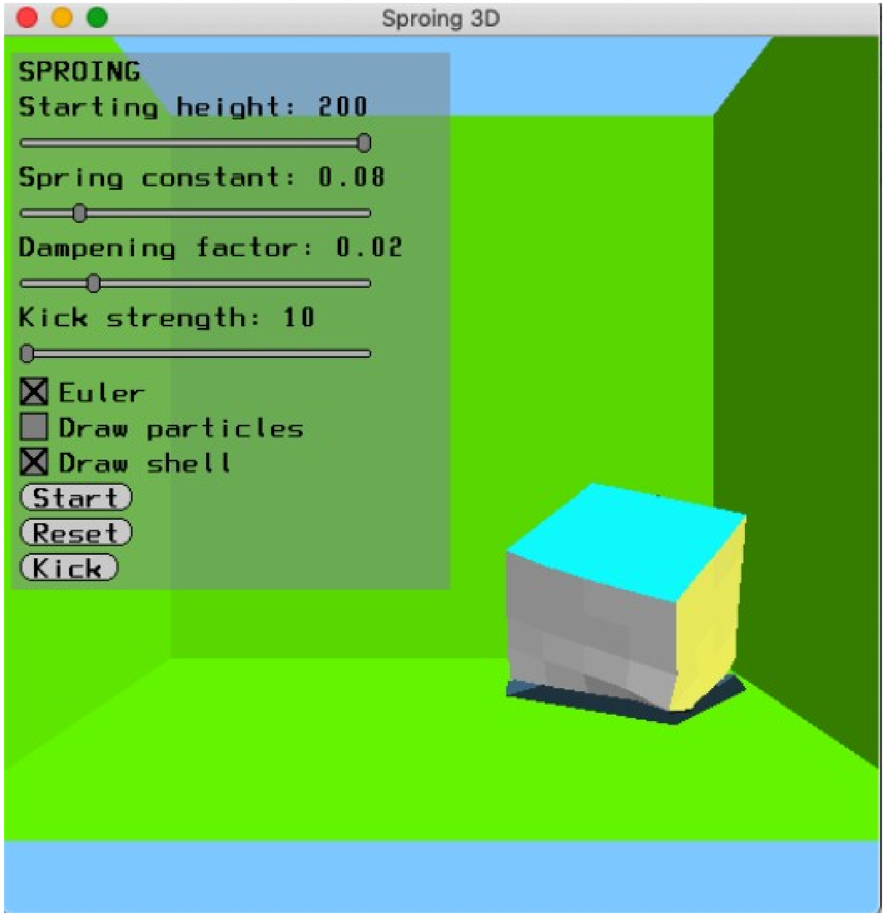
Springs



https://www.myphysicslab.com/springs/collide-spring-en.html

Vibration

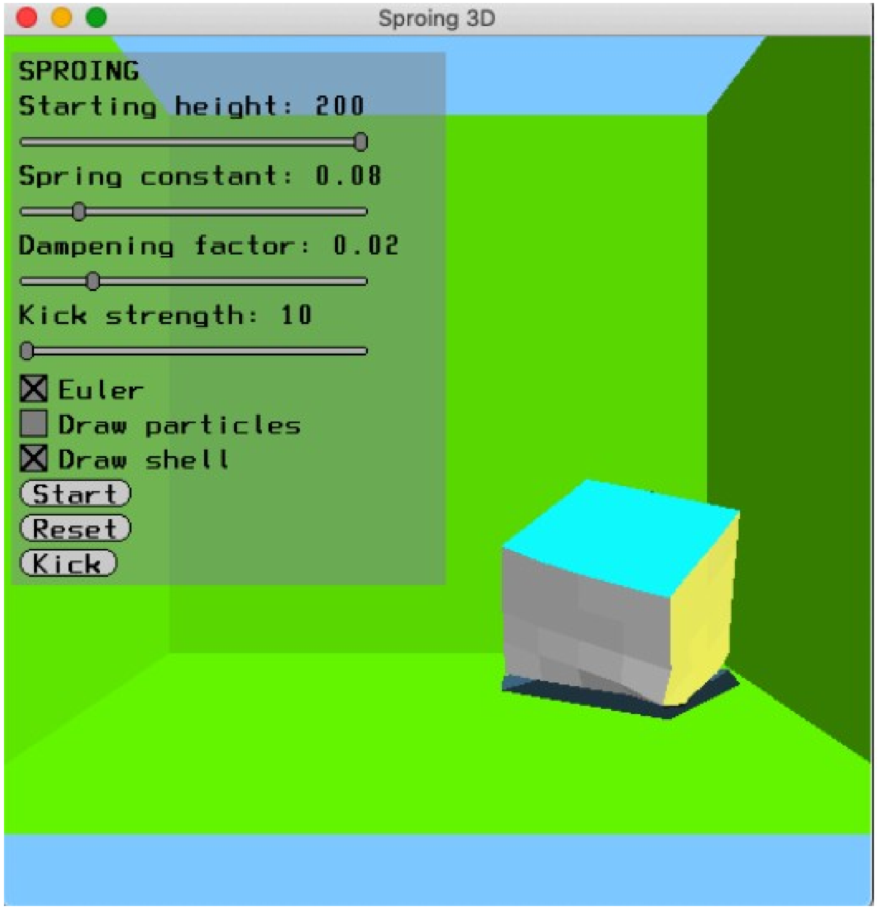
Deformation

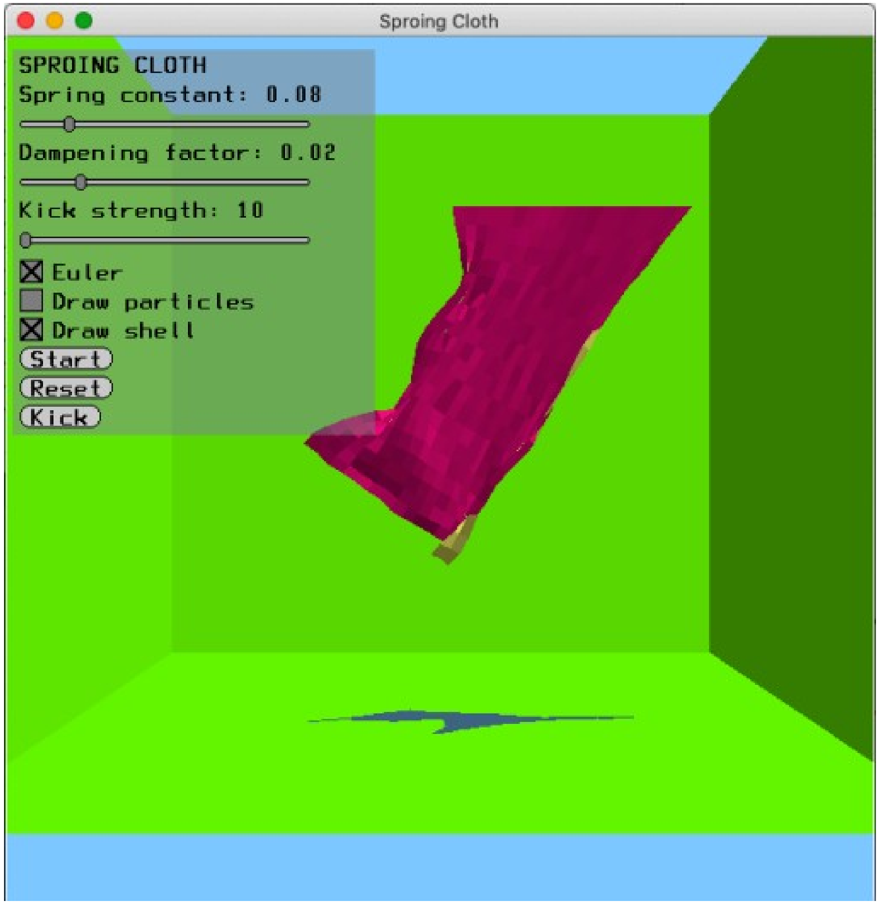


https://www.computer-graphics.se/demos/files03/Beachball-demos.zip

Vibration

Deformation

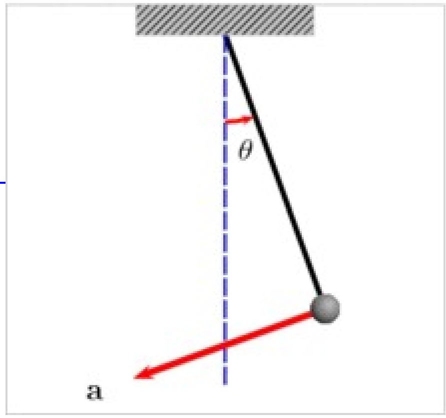




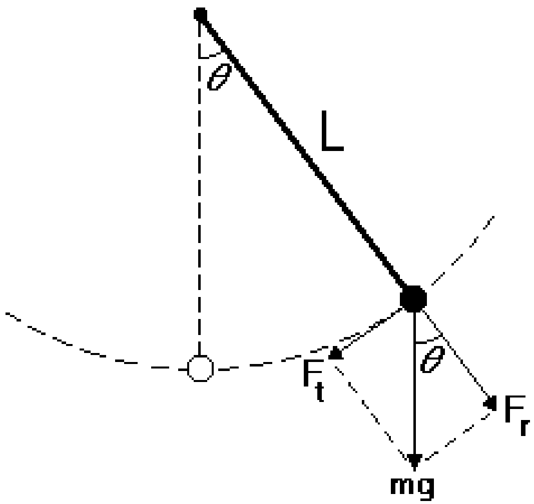
https://www.computer-graphics.se/demos/files03/Beachball-demos.zip

Vibration

- **Pendulum**



$$\vec{F} = -mg\sin\theta = -\frac{mg}{L}\Delta\vec{x}$$



$$\vec{F} = -k\Delta\vec{x}$$

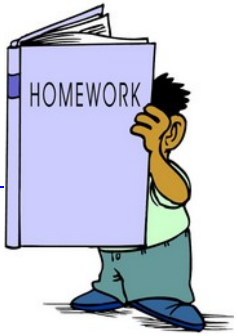
Equation of motion: $m\ddot{x} = -kx$

$$\ddot{x} + \varpi^2 x = 0 \qquad \varpi^2 = \frac{g}{L}$$

Solution: $x(t) = A\sin(\varpi t + \phi_o)$

$$T = \frac{2\pi}{\varpi} = 2\pi\sqrt{\frac{L}{g}}$$

Vibration



- **Boat**

Write the equation of motion for a boat in water.

What is the period of the vibration?