G-L-1

Review

The Modelling Team
Department of Design Engineering
Faculty of Industrial Design Engineering
Delft University of Technology

Aim

To pick-up knowledge learned before

To be able to interpret this knowledge in the Modelling Framework

To be better prepared for Modelling

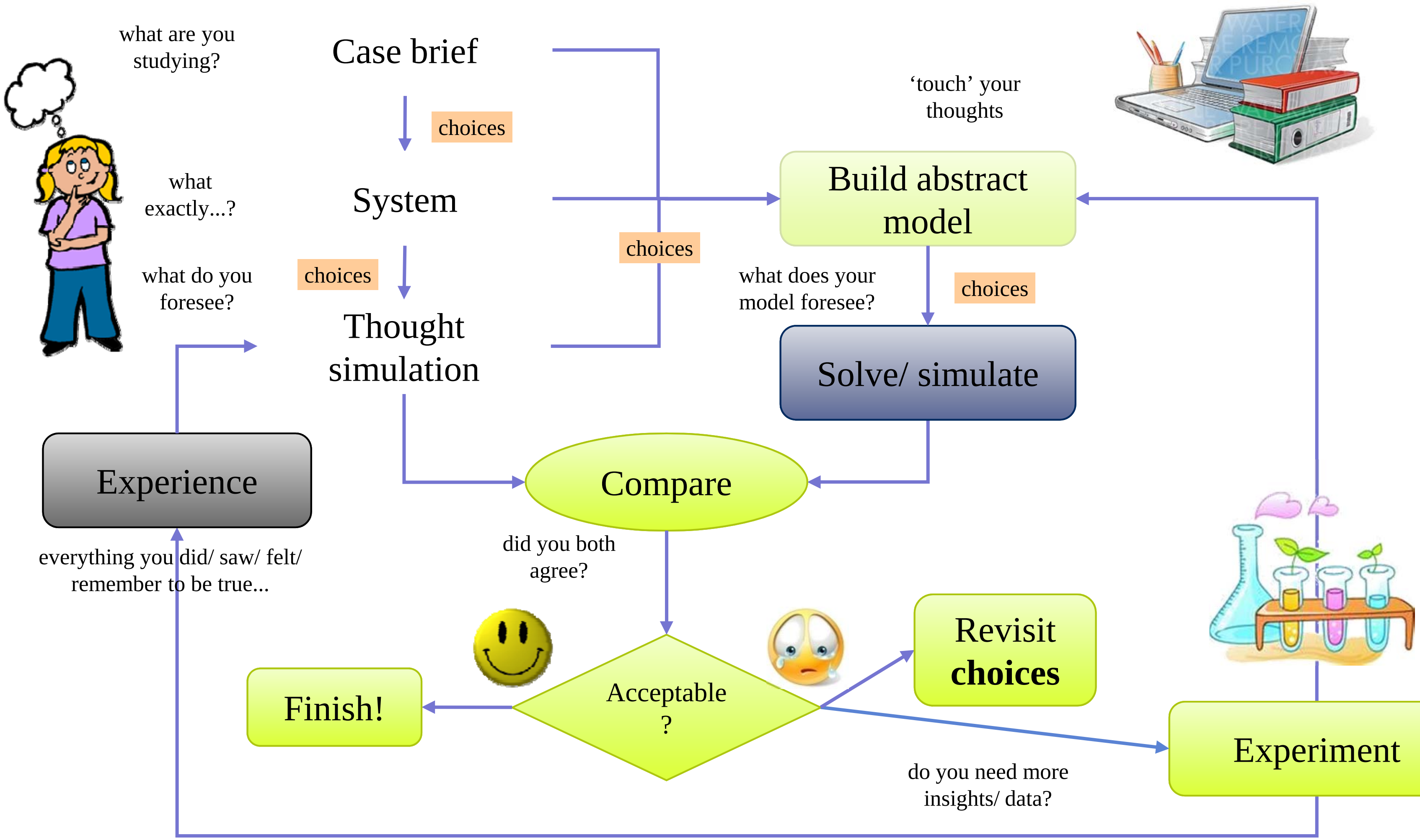
Contents

IO2081: G-L-1 Review

- Our vision
- Statics – Product in Action
- Dynamics – Product in Motion
- Summary
- The workshop

Our vision

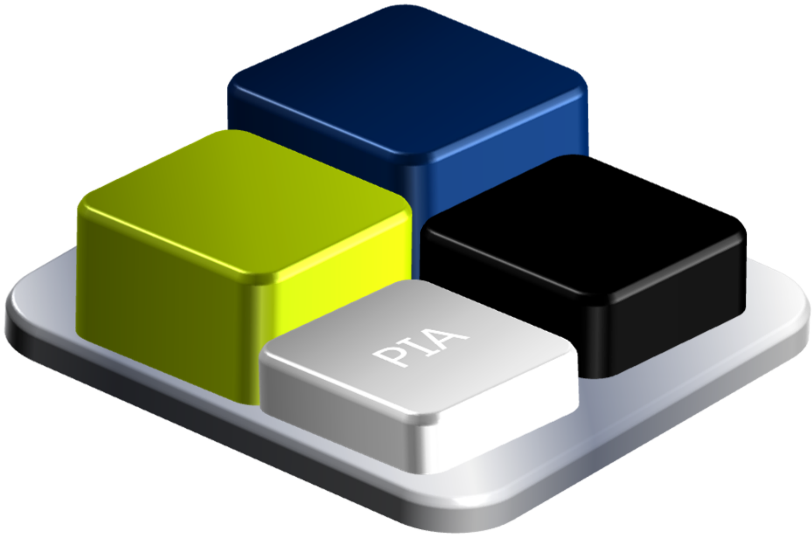
The Modeling Framework



Courtesy of centech.com.pl and http://www.clipsahoy.com/webgraphics4/as5814.htm

Statics Case study: Nut Cracker

Special Thanks to ir. Ernest van Breemen



Design Brief

A portable nut cracker

- **Crack nuts by hand force**
- **Adapt to different sizes of nuts**

Ref. http://www.lizandlaura.com/fun-and-games/fortune/?read=1301456242

The basic thought

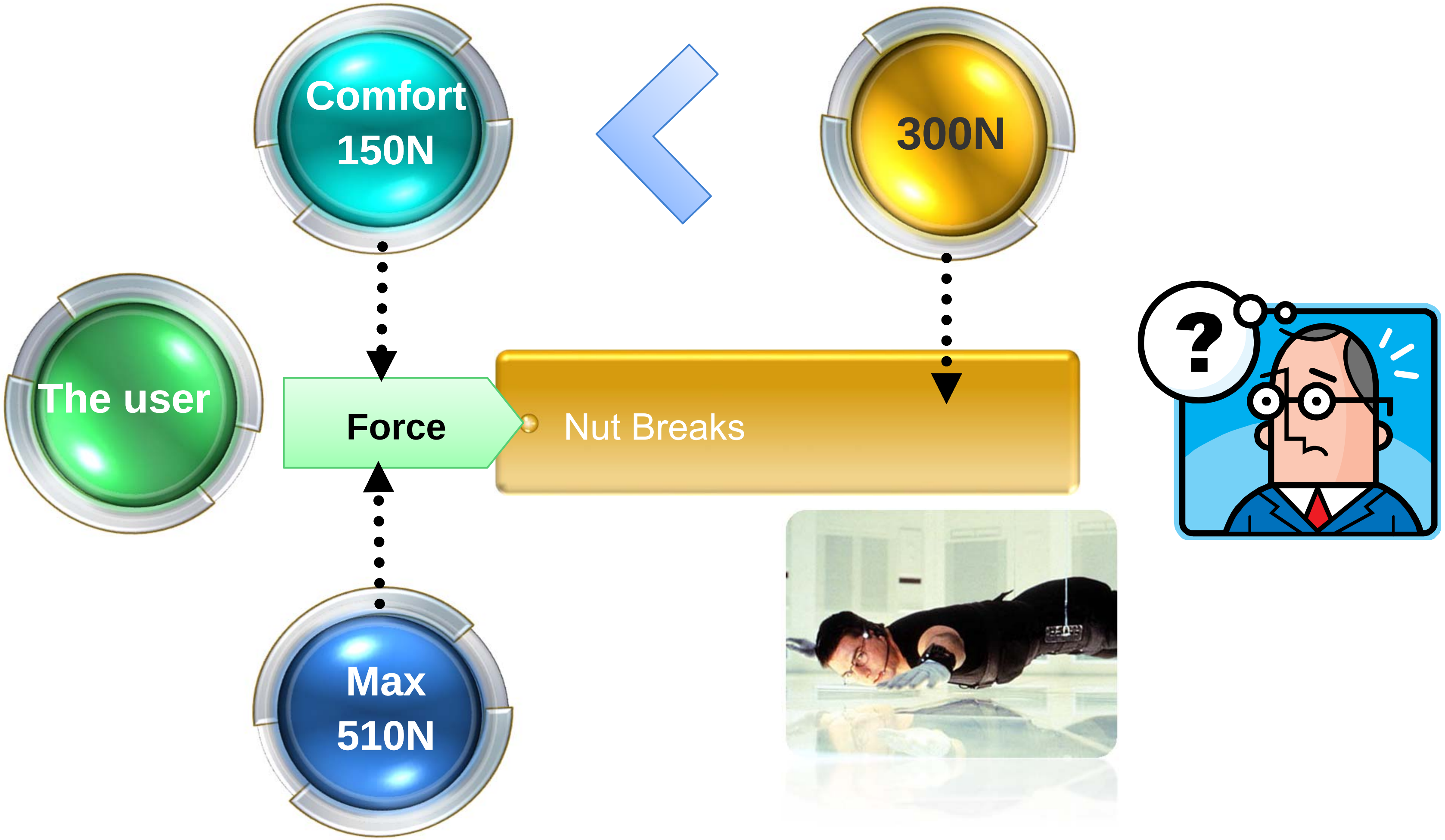
We use

- Force

to

- Break nuts

How about the force?



Courtesy of http://unrealitymag.com/index.php/2009/03/19/tom-cruise-working-on-mi-4/

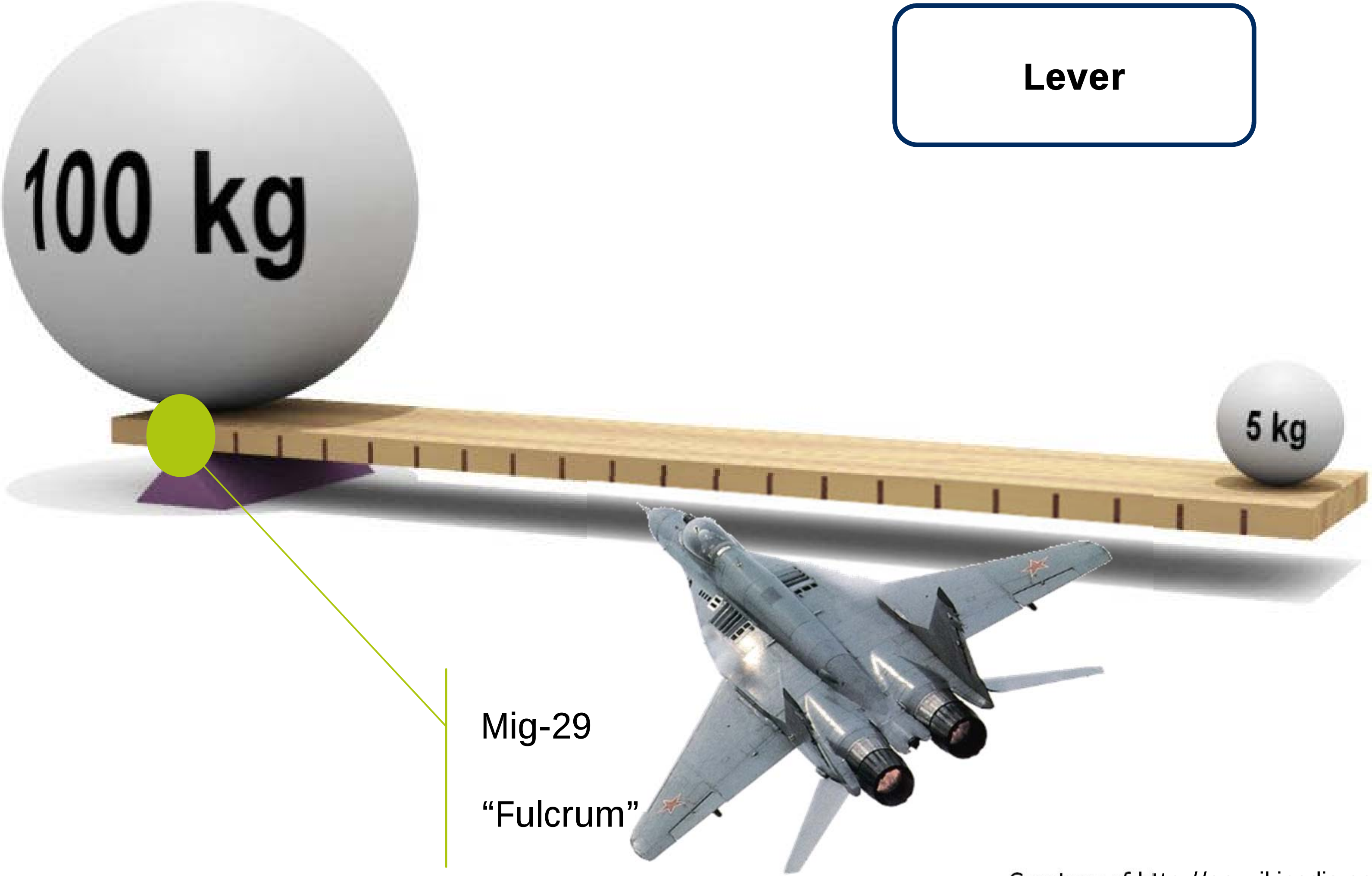
What shall we do?

Give me a place to stand,
and I shall move the earth.

Archimedes of Syracuse

Courtesy of http://en.wikipedia.org/wiki/Archimedes

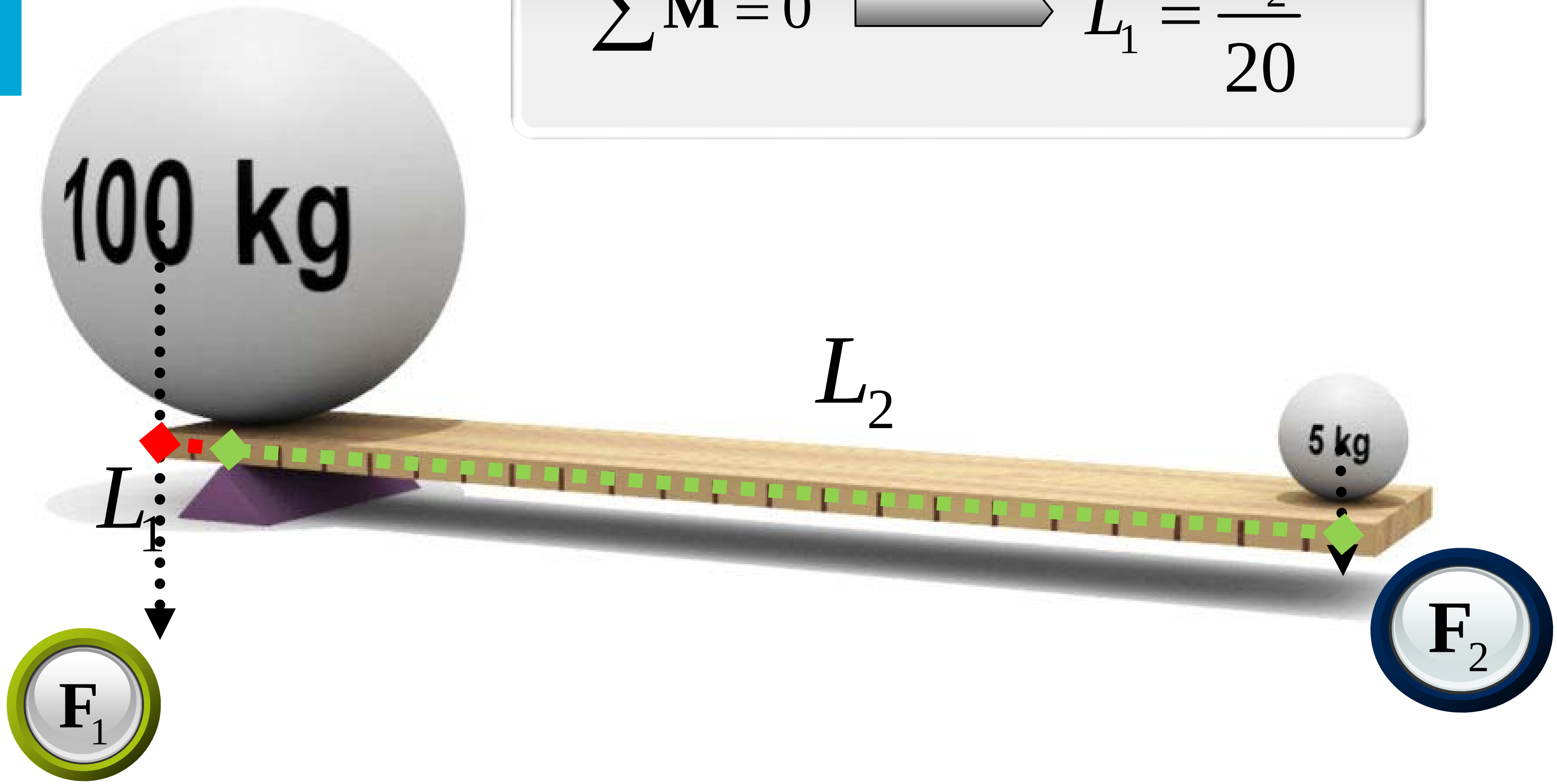
The lever



Courtesy of http://en.wikipedia.org/wiki/Lever

Physics behind

$$\sum \mathbf{M} = 0 \longrightarrow L_1 = \frac{L_2}{20}$$



Courtesy of http://en.wikipedia.org/wiki/Lever

The Experience

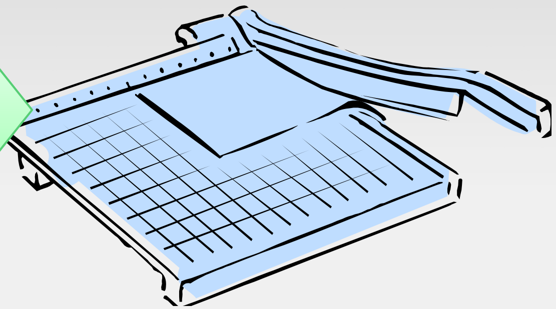
1. Use the theory of the lever

To zoom force at least two times larger

2. Design a place to stand

The first idea

Something similar



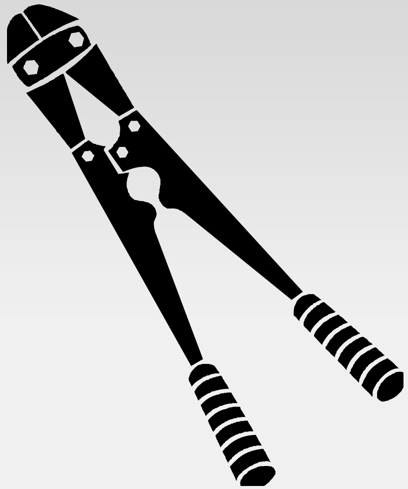
- **It should work**

But

- **Too large**
- **Not potable**

Then

Something similar



- **It should work**
- **Portable**

But

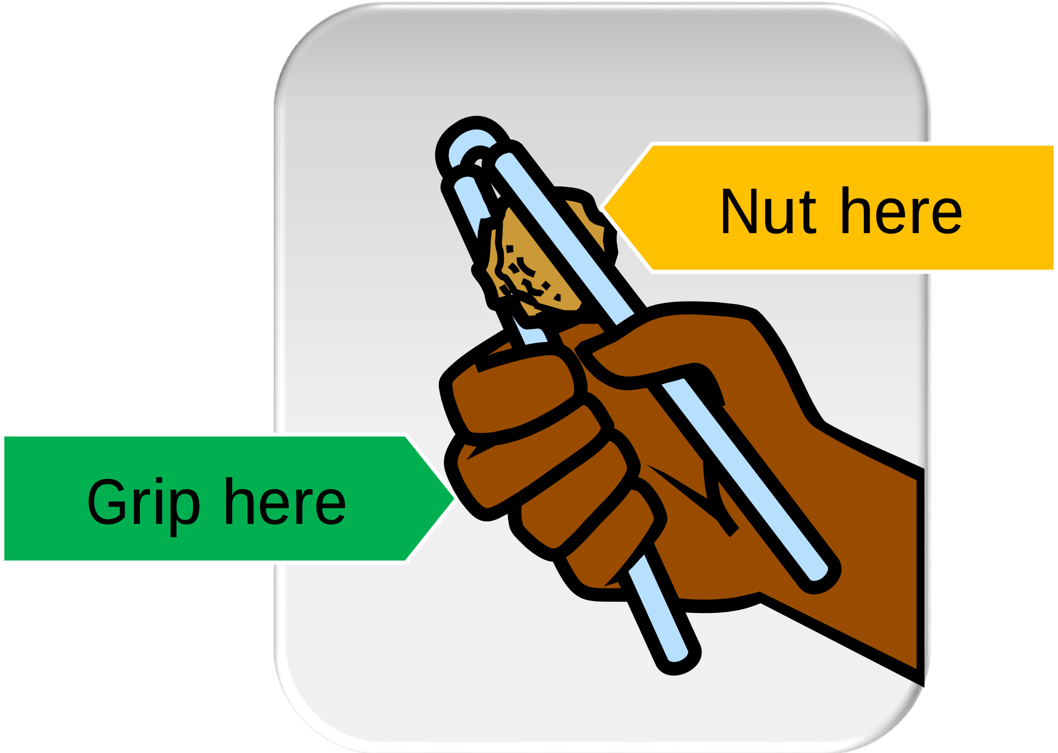
- **Too large**

The breakthrough

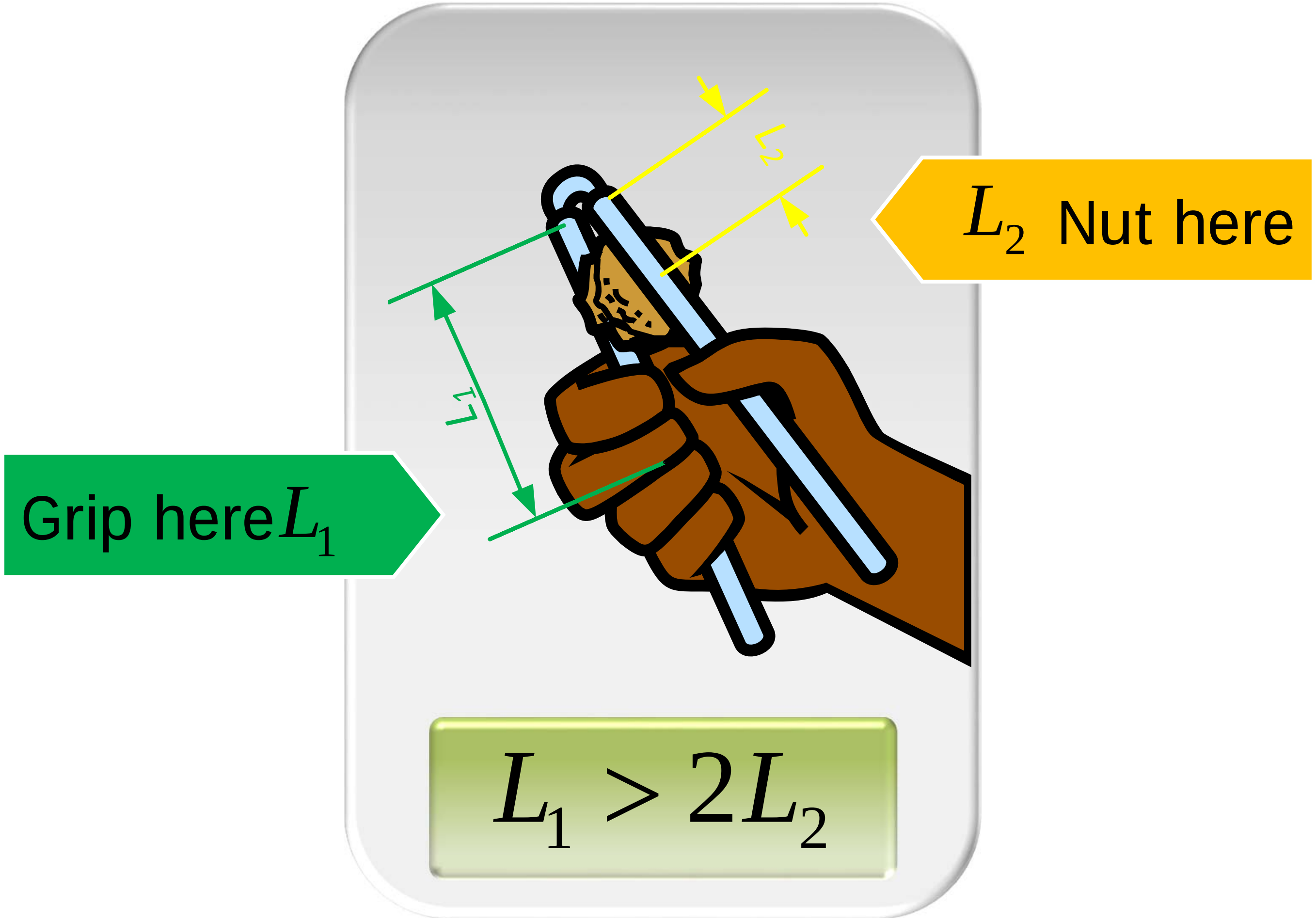
Something similar

- It should work
- Potable
- Small

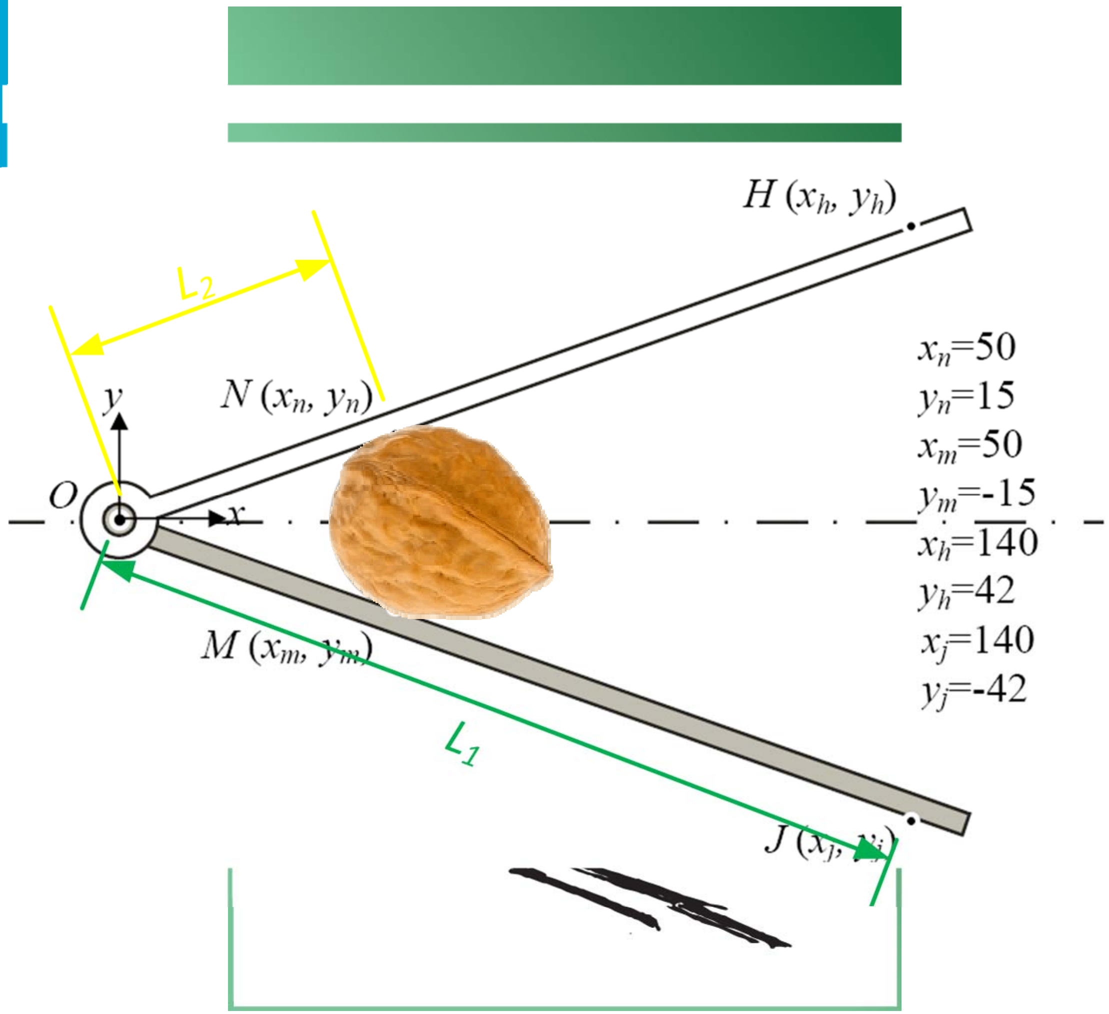
Thought simulation



Thought simulation



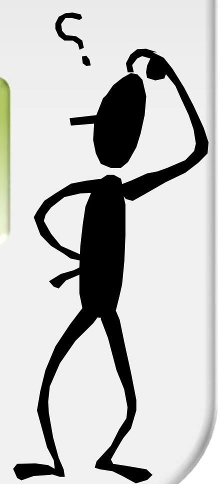
First design with polished stainless steel



$$L_1 = \sqrt{140^2 + 42^2} \approx 146$$

$$L_2 = \sqrt{50^2 + 15^2} \approx 52$$

$$L_1 > 2L_2$$

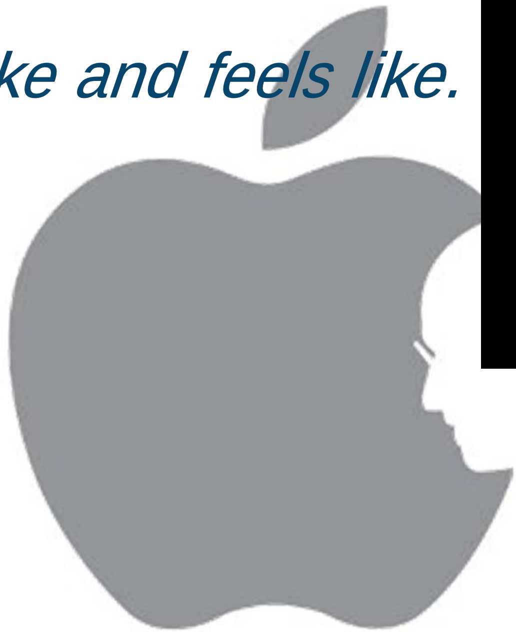


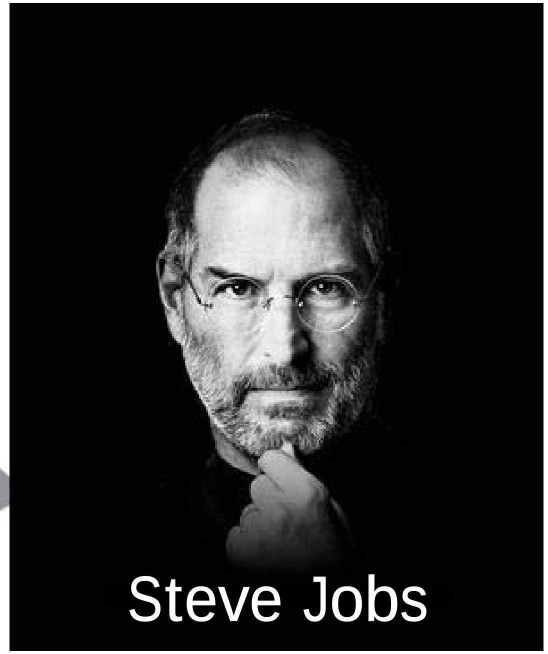
Design is how it works

"Make it look good!' That's not what we think design is.

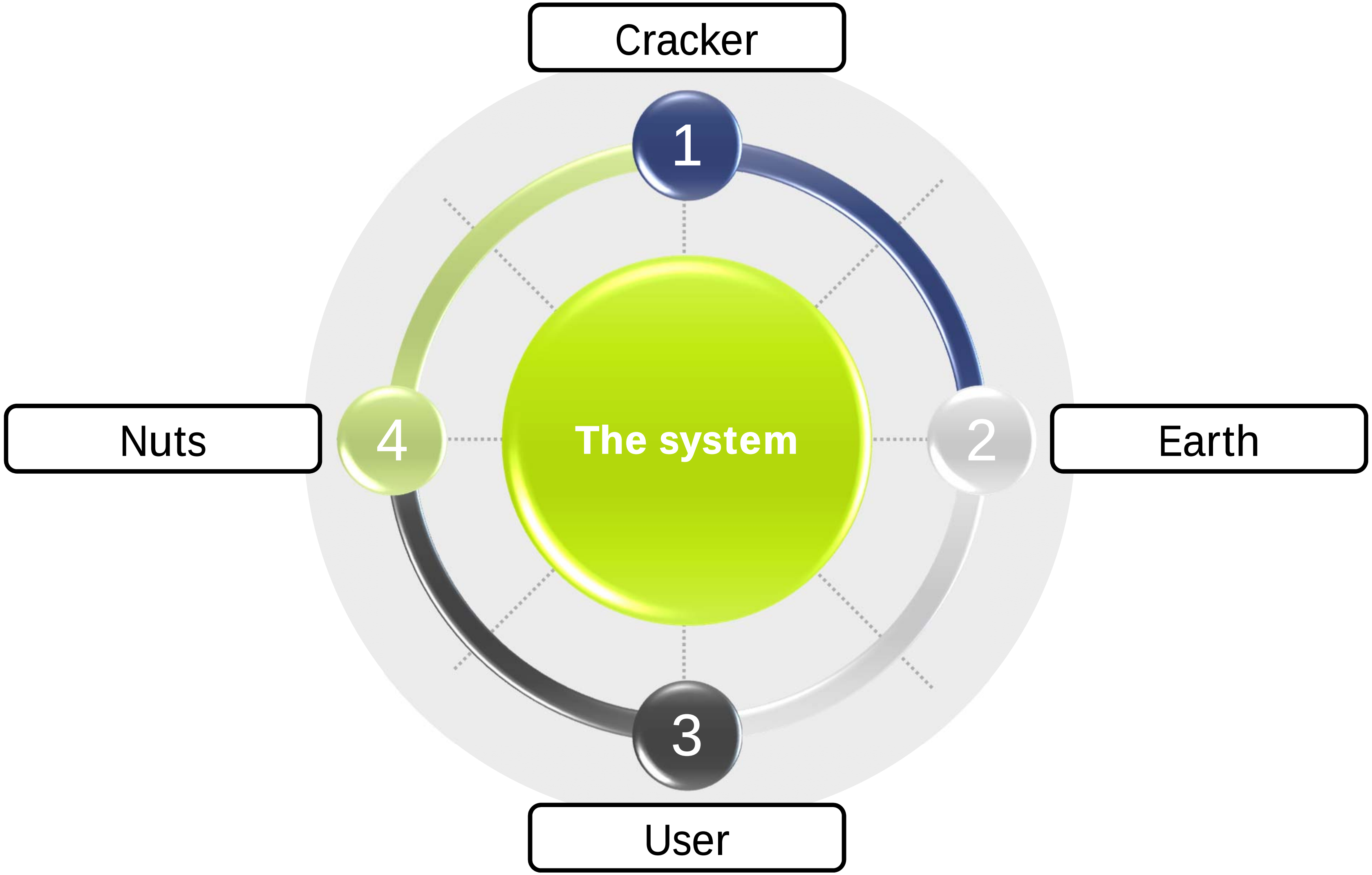
It's not just what it looks like and feels like.

Design is how it works.





Components in the system?

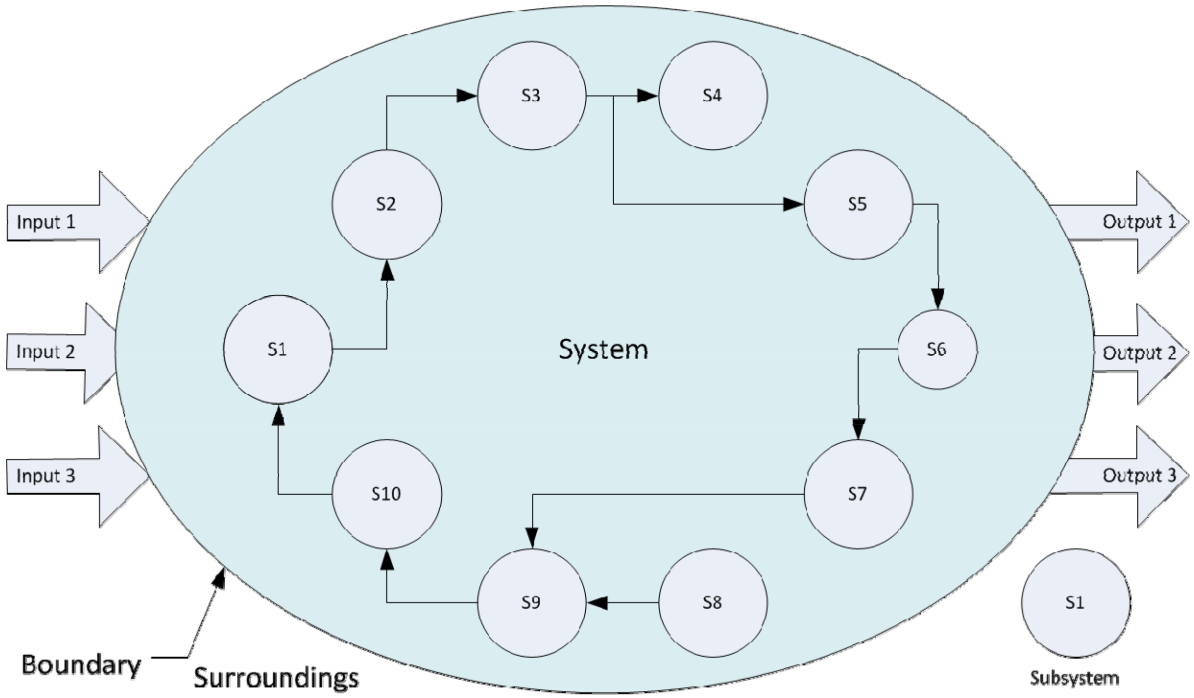


What is a system?

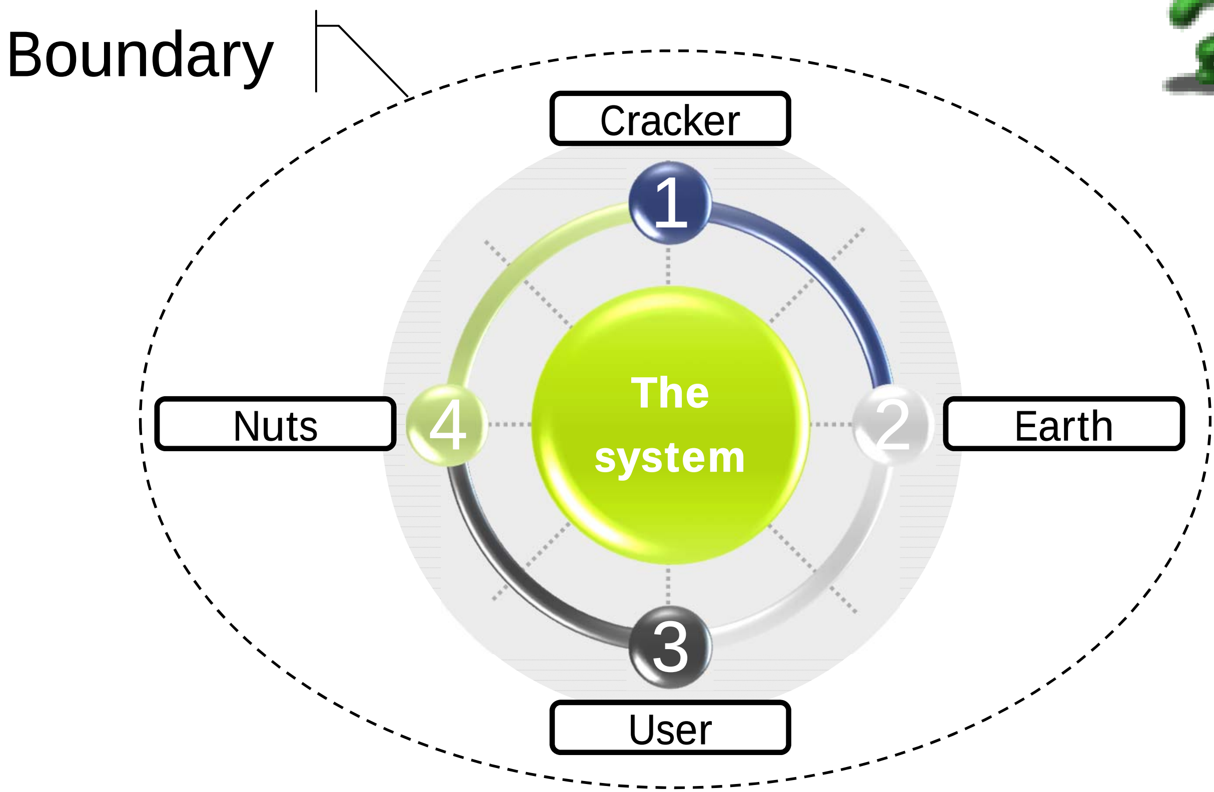
System

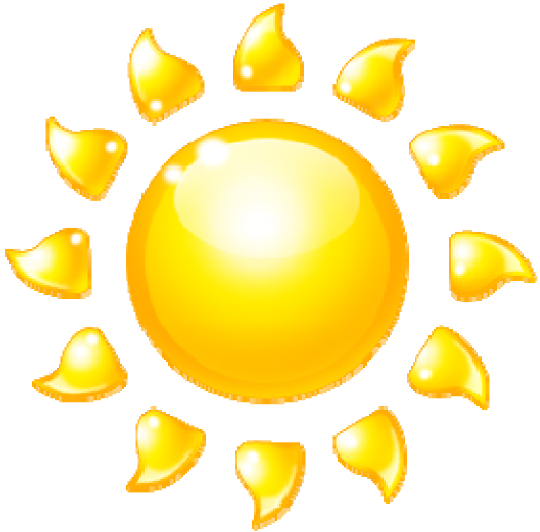
System consists of a set of interacting or interdependent system components (or sub-systems)

- Structure & interconnectivity
- Boundary
- Input & Output
- Surroundings



Components in the system?



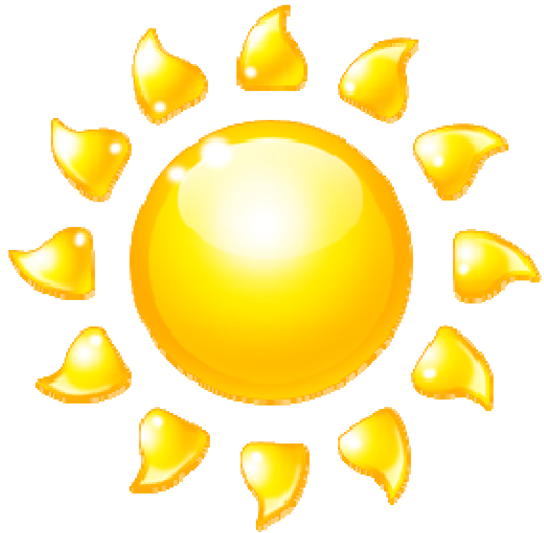


Your experiences?

Physics behind:
Newton's law of universal gravitation

$$F_s = G\frac{m_{sun} m_{nut}}{r_{sun}^2}$$

$$F_e = G\frac{m_{earth} m_{nut}}{r_{earth}^2}$$



Gravity

> $restart;\ G := 6.67259 \cdot 1e-11 : m_{nut} := 0.02 :$

> $W_{earth} := \frac{G \cdot m_{earth} \cdot m_{nut}}{r_{earth}^2} : m_{earth} := 5.9736 \cdot 1e24 : r_{earth} := 6.371 \cdot 1e6 :$

> $evalf(W_{earth});$

0.1964017550 **(1.1)**

> $W_{sun} := \frac{G \cdot m_{sun} \cdot m_{nut}}{d^2} : m_{sun} := 1.9891 \cdot 1e30 : d := 1.496 \cdot 1e11 :$

> $evalf(W_{sun});$

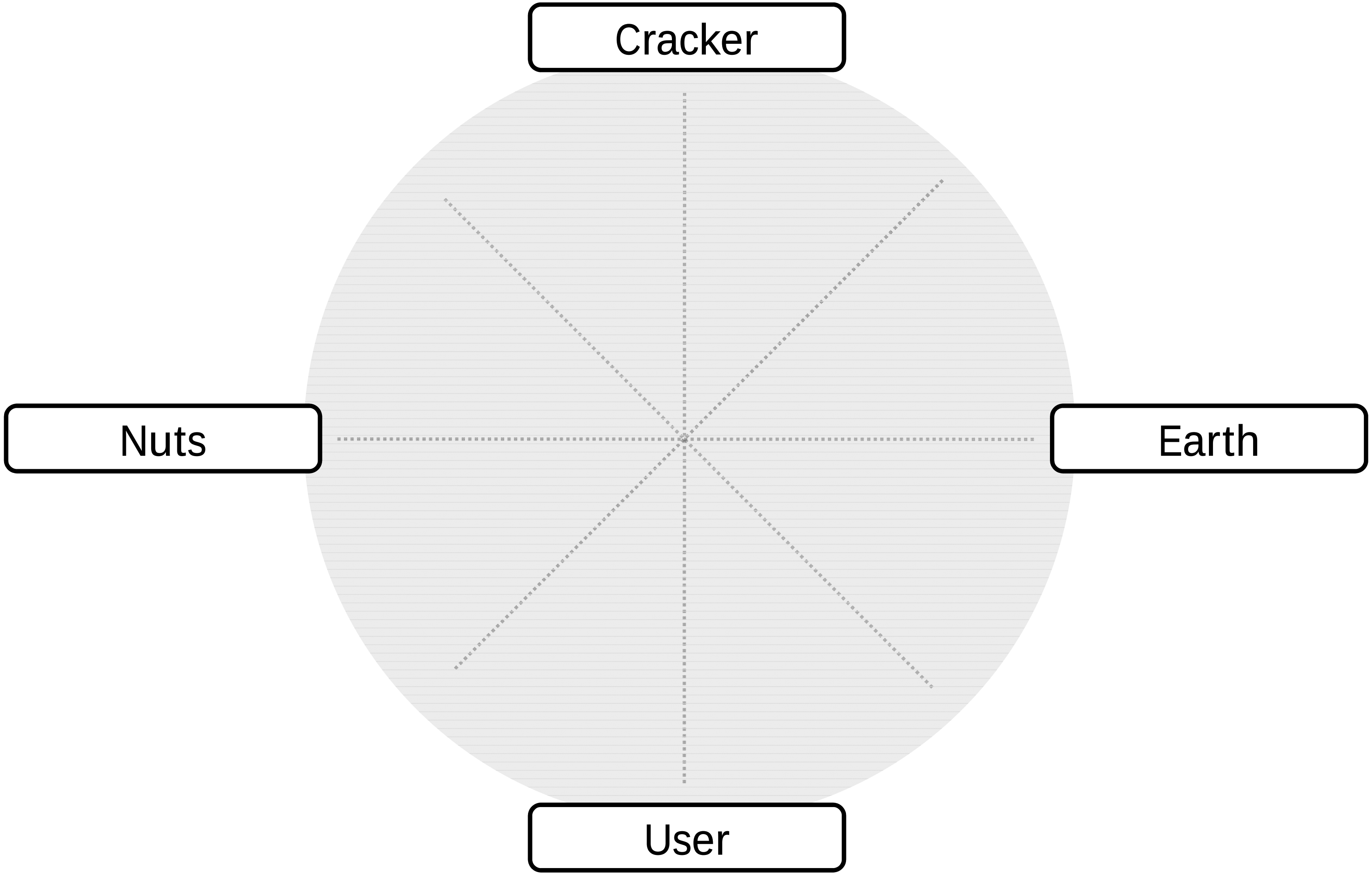
0.0001186090606 **(1.2)**

> $\frac{evalf(W_{sun})}{evalf(W_{earth})}$

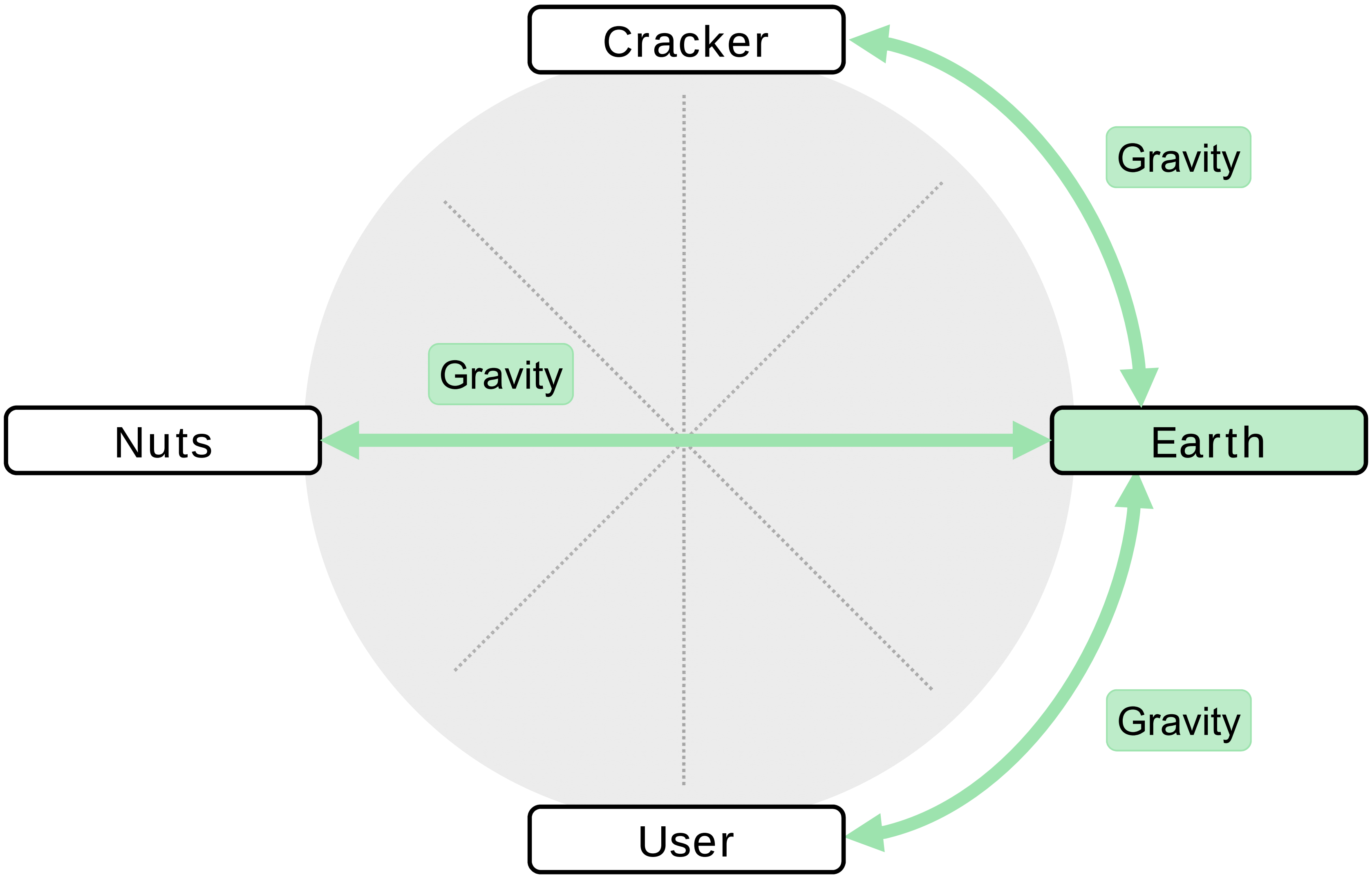
0.0006039103907 **(1.3)**

$$Gravity_{sun} = 0.06\% Gravity_{earth}$$

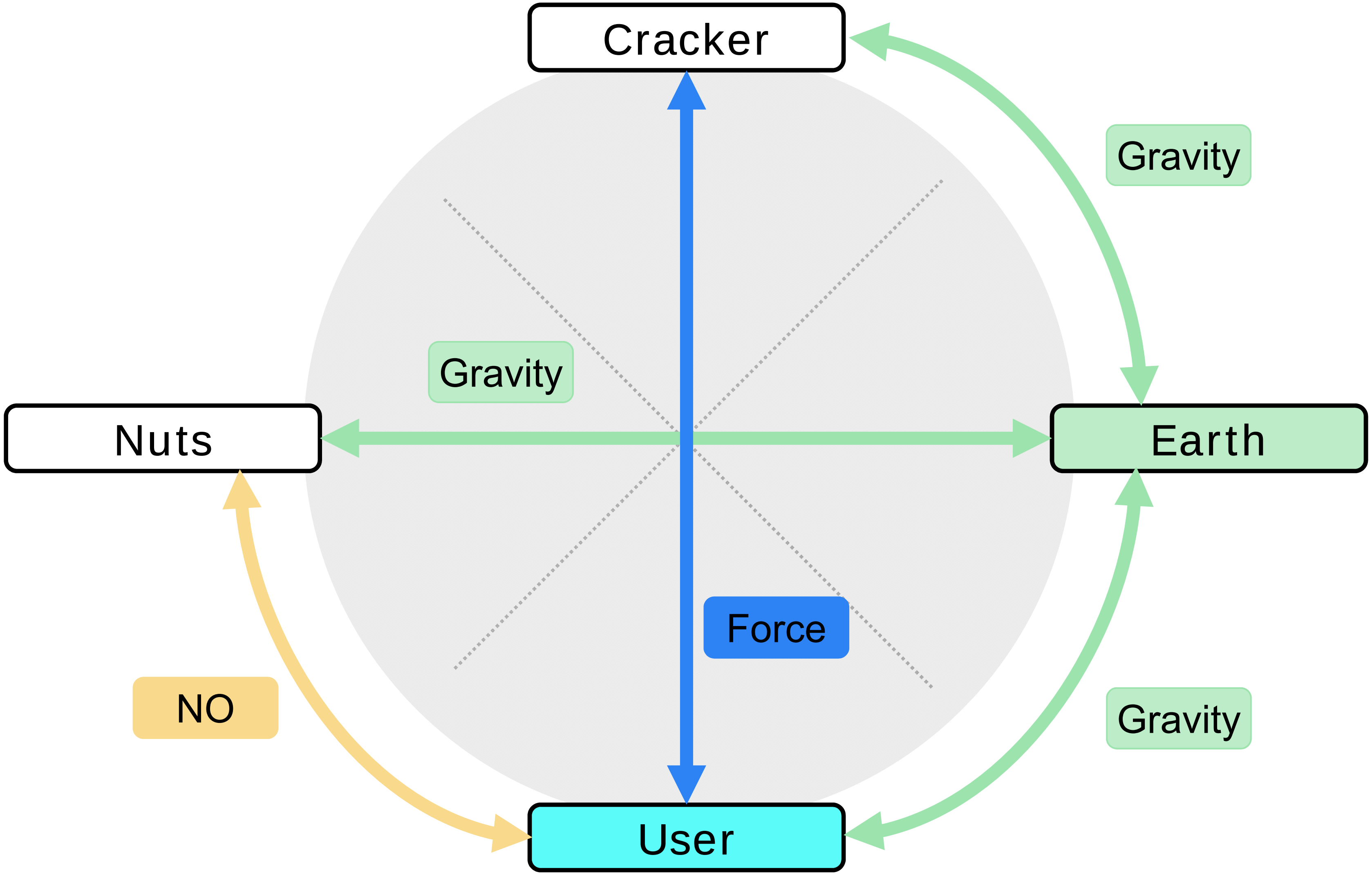
Explore the relations



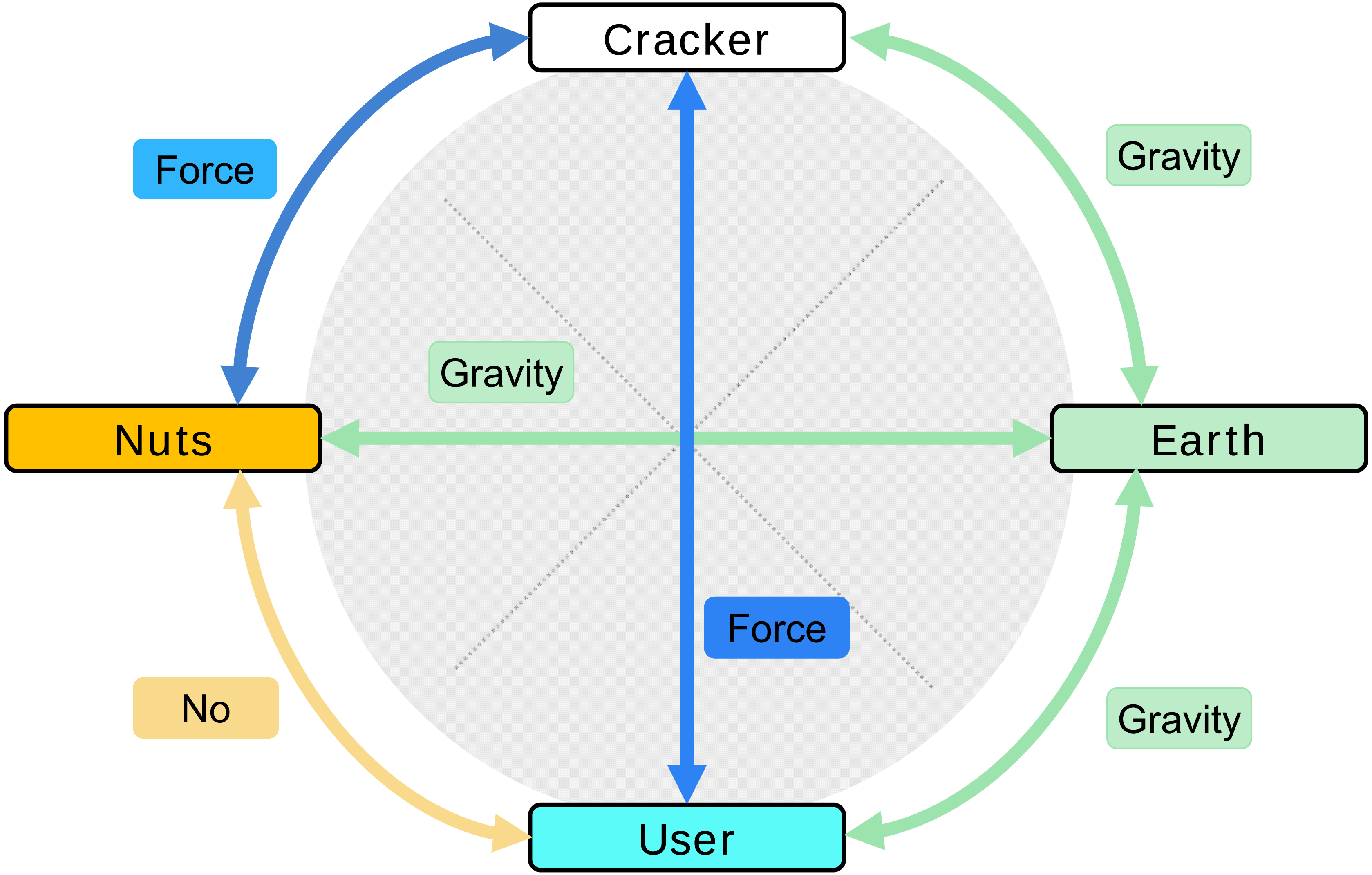
Explore the relations



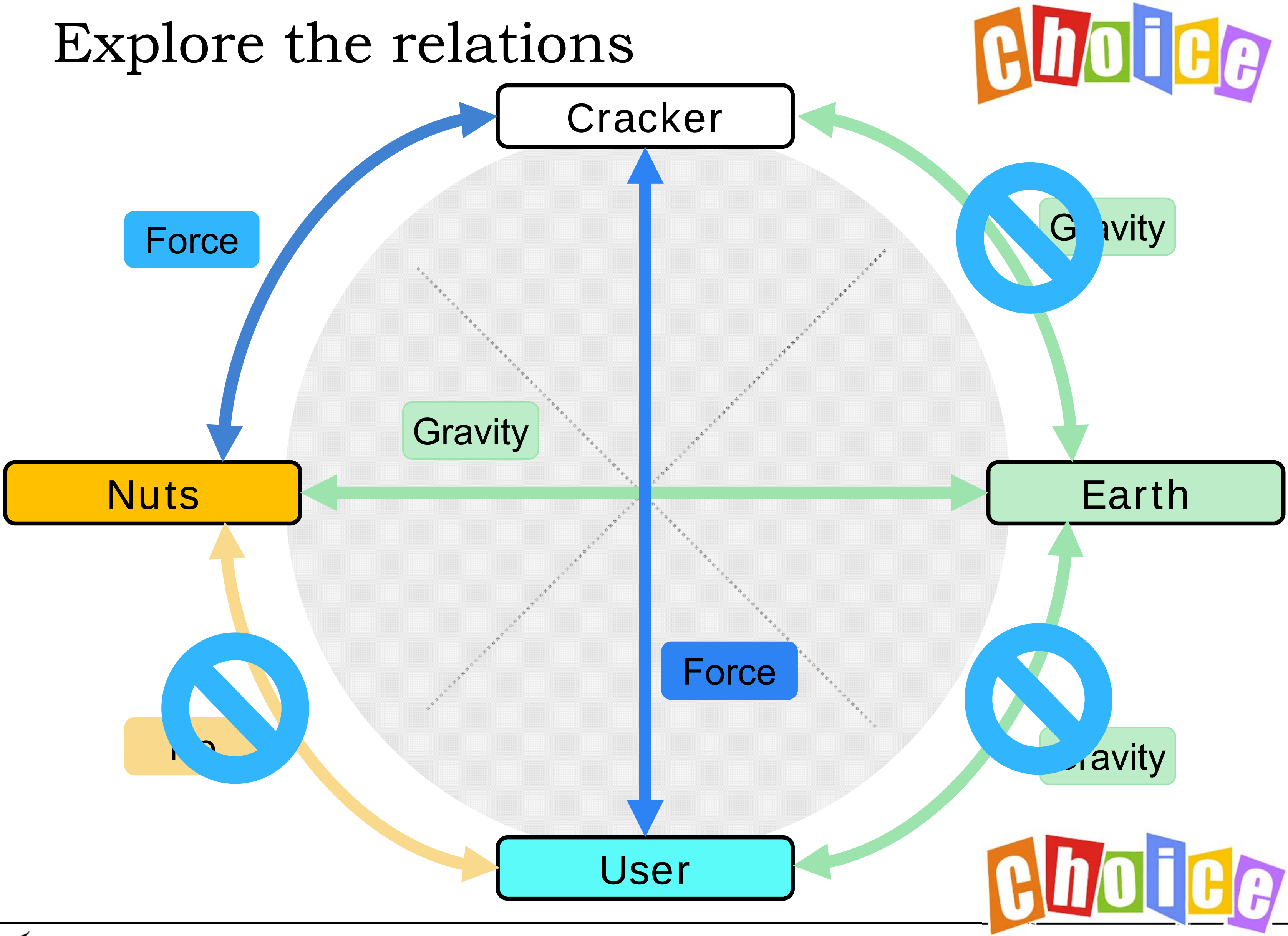
Explore the relations



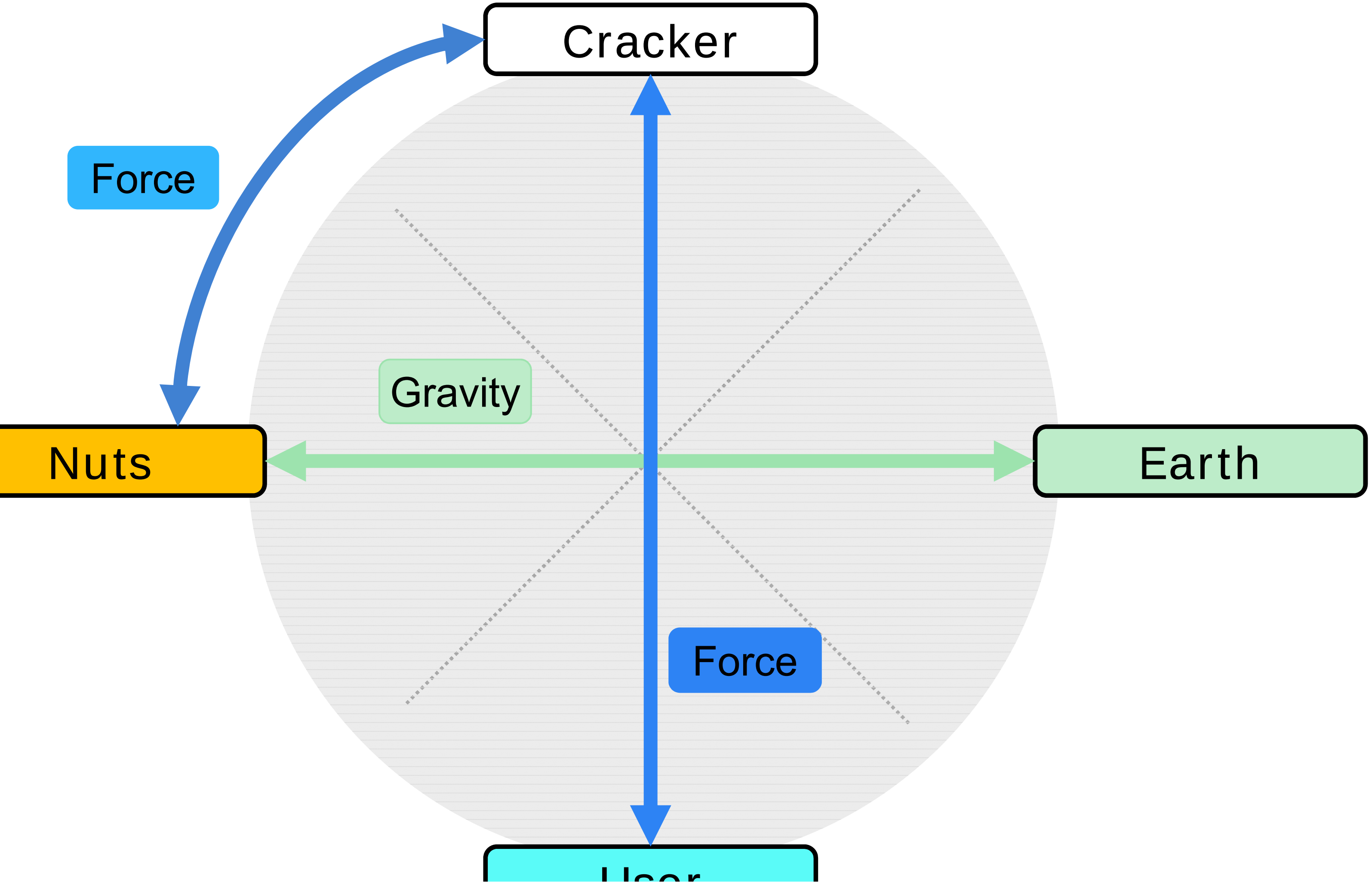
Explore the relations



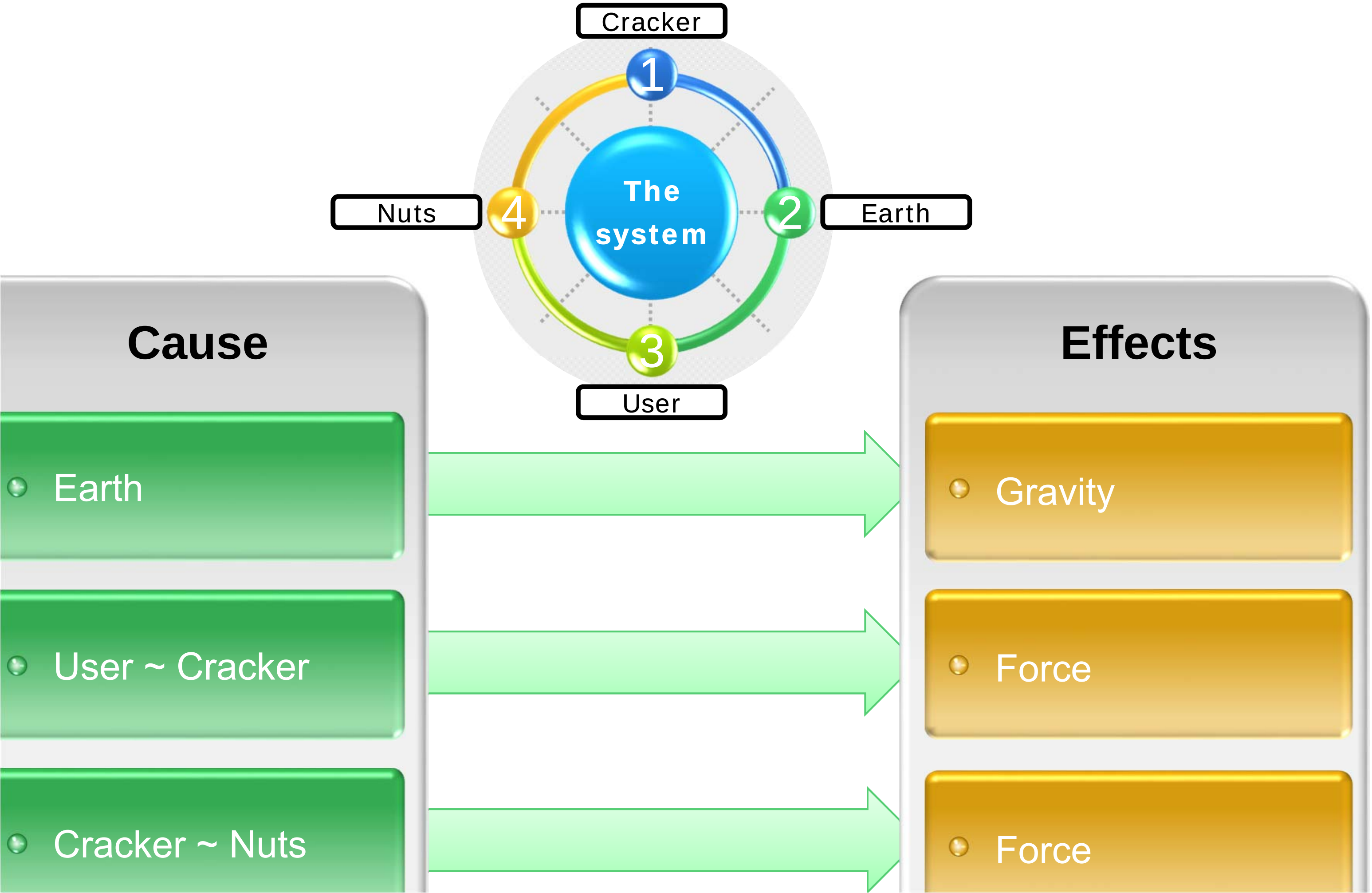
Explore the relations



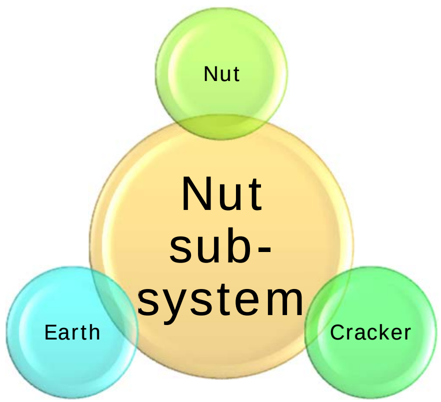
Explore the relations

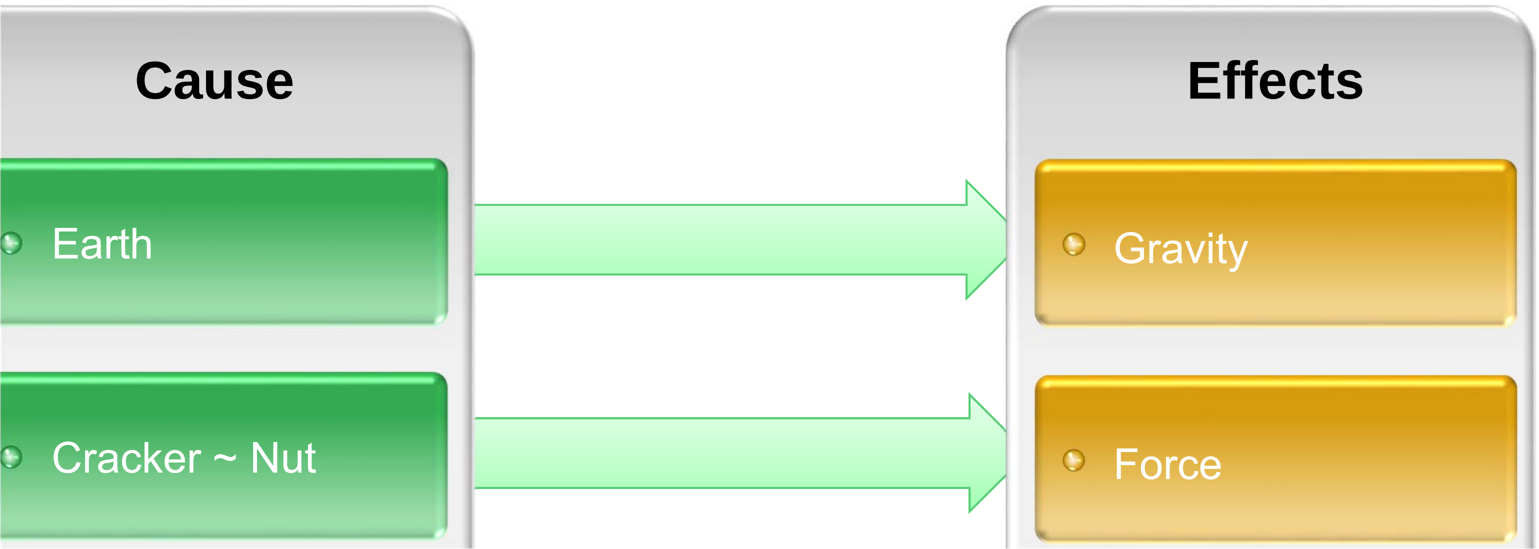


The thought simulation

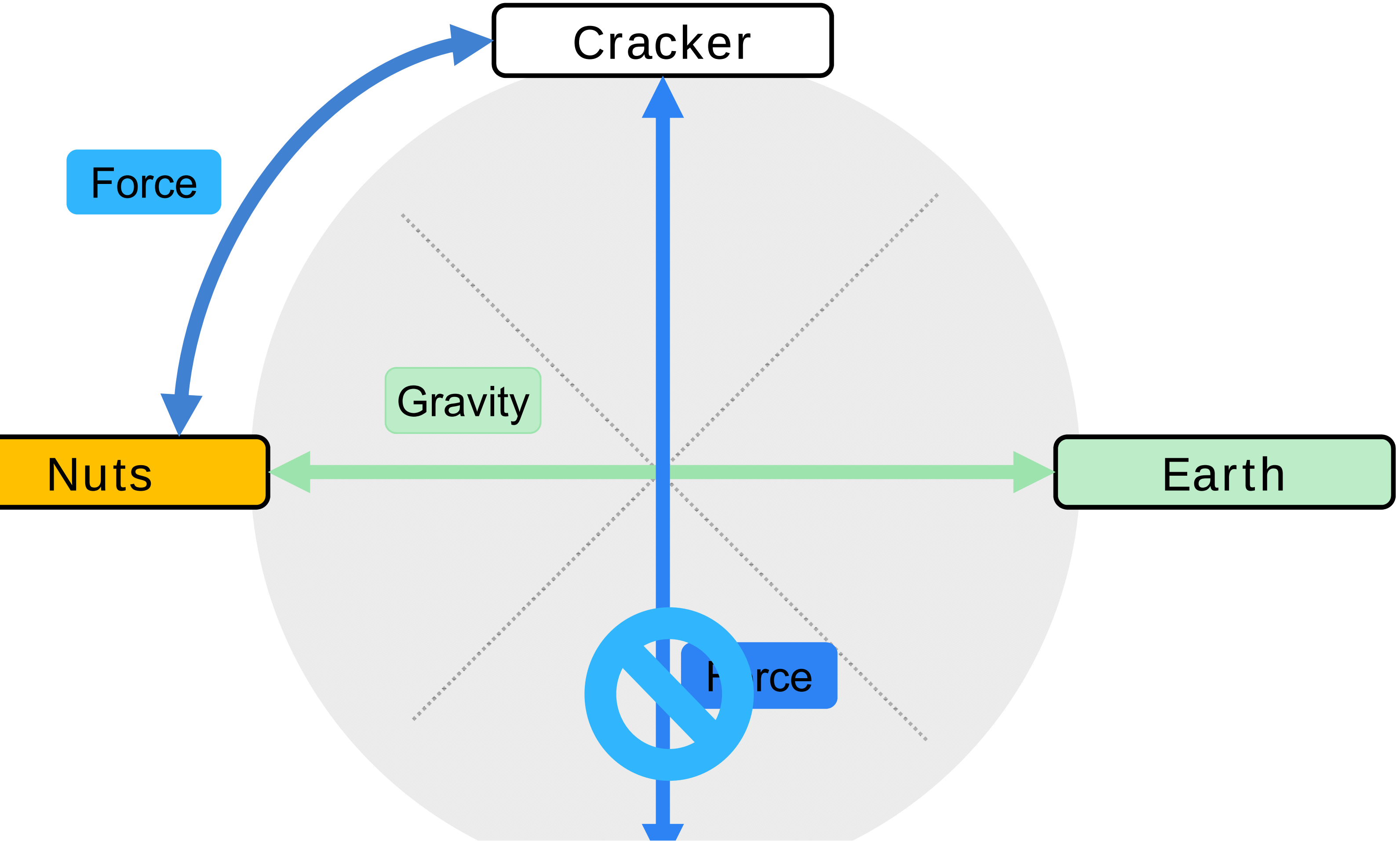


Further focus on the nut

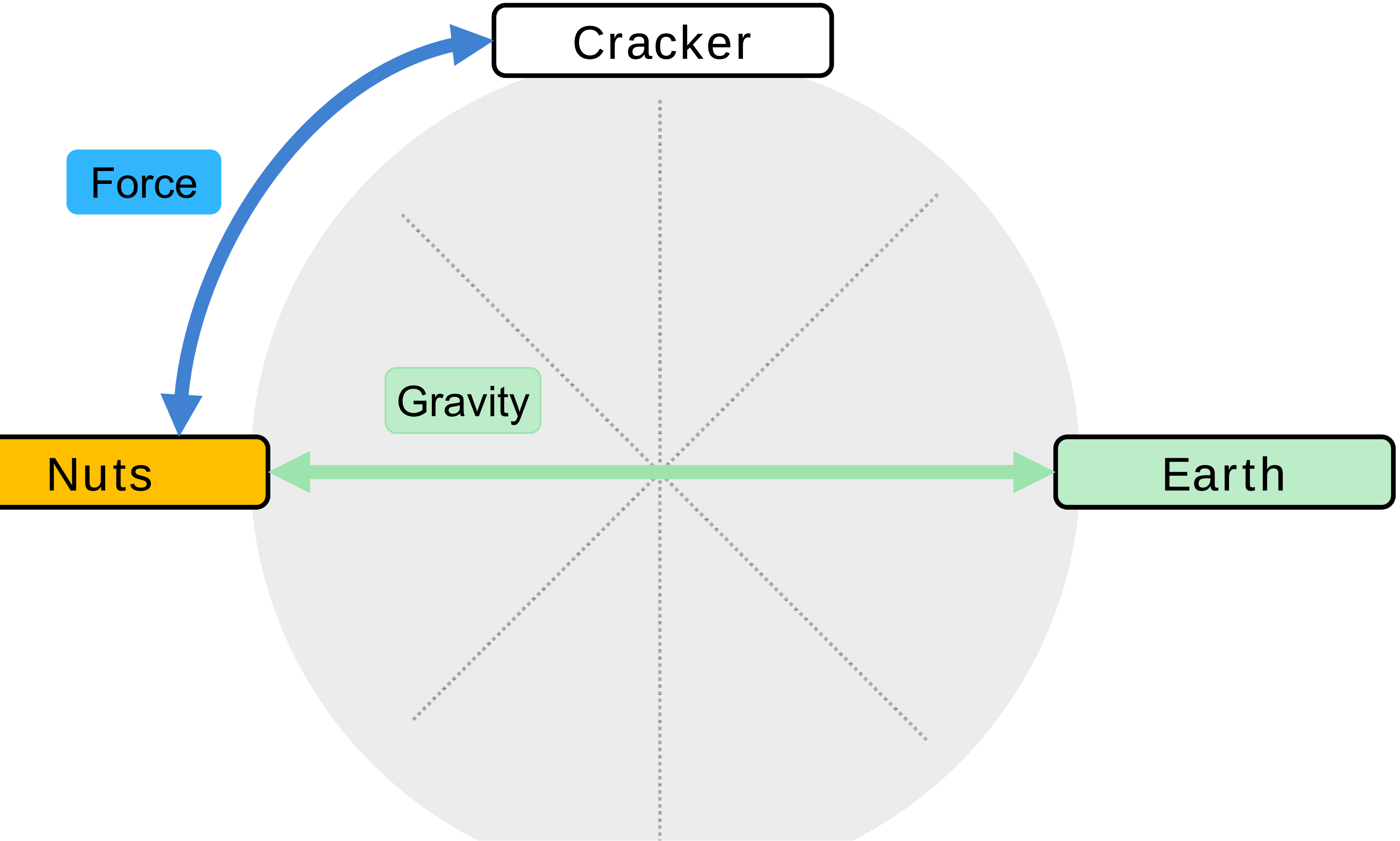




Explore the relations



Explore the relations

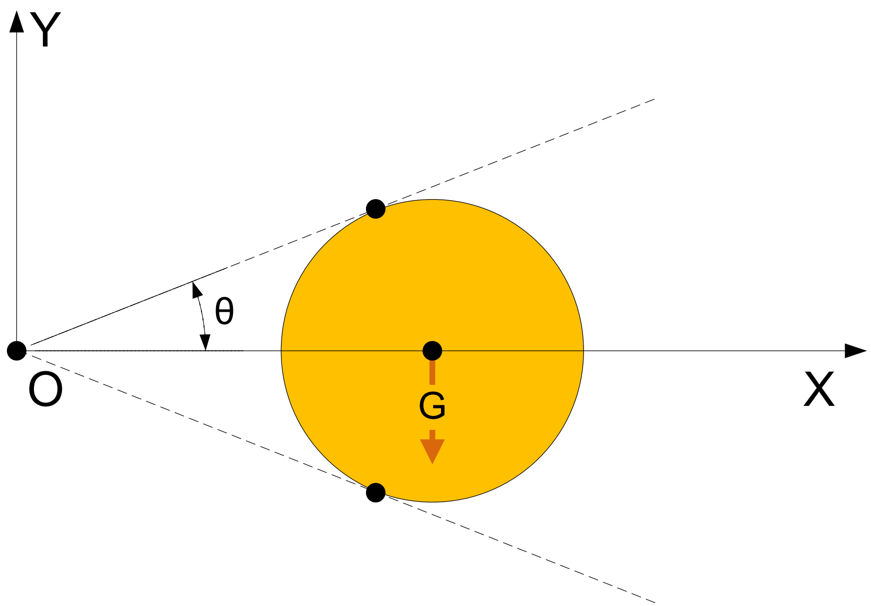


Modelling - The Nut – Analysis

Earth - Gravity

vity

• Earth Gravity



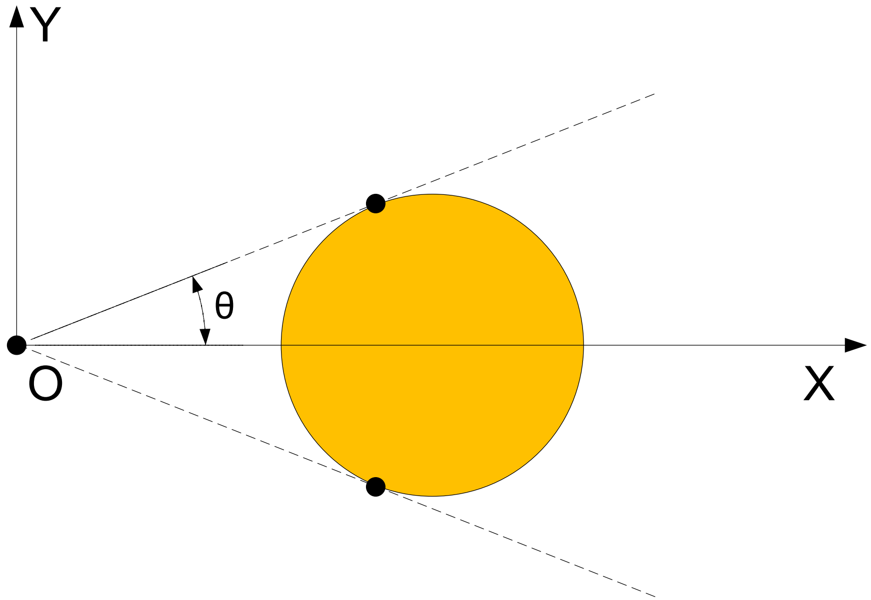
Modelling - The Nut – Analysis

Cracker ~ Nuts

vity

• Earth Gravity

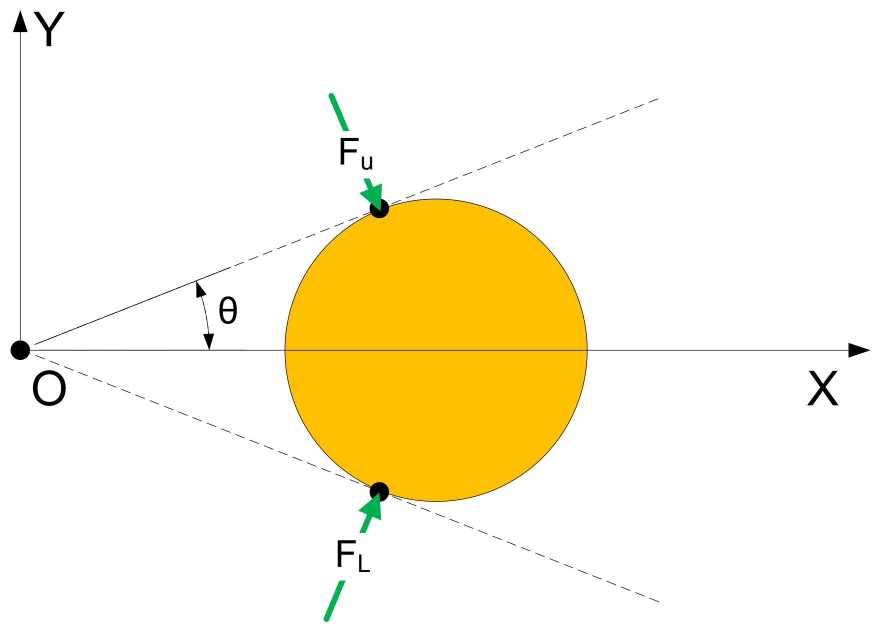
ndary



Modelling - The Nut – Analysis

Cracker ~ Nuts

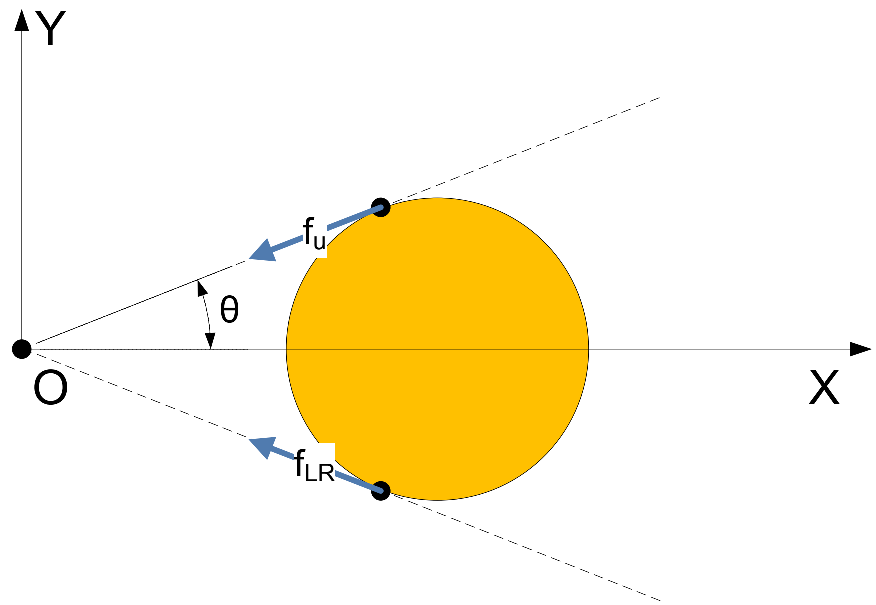
- vity — •Earth Gravity
- ndary
- Input — •From the grips
- Reaction
- Friction



Modelling - The Nut – Analysis

Cracker ~ Nuts

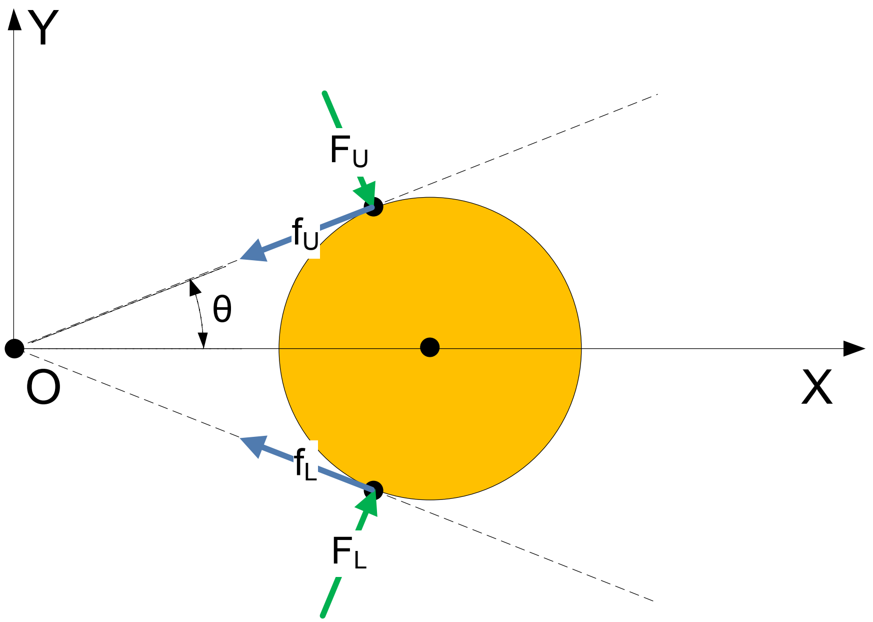
vity	•Earth Gravity
ndary	
Input	•From the grips
Reaction	
Friction	•From the grips



The attribute of friction force

coefficient of friction

$$f_u \le fF_u$$

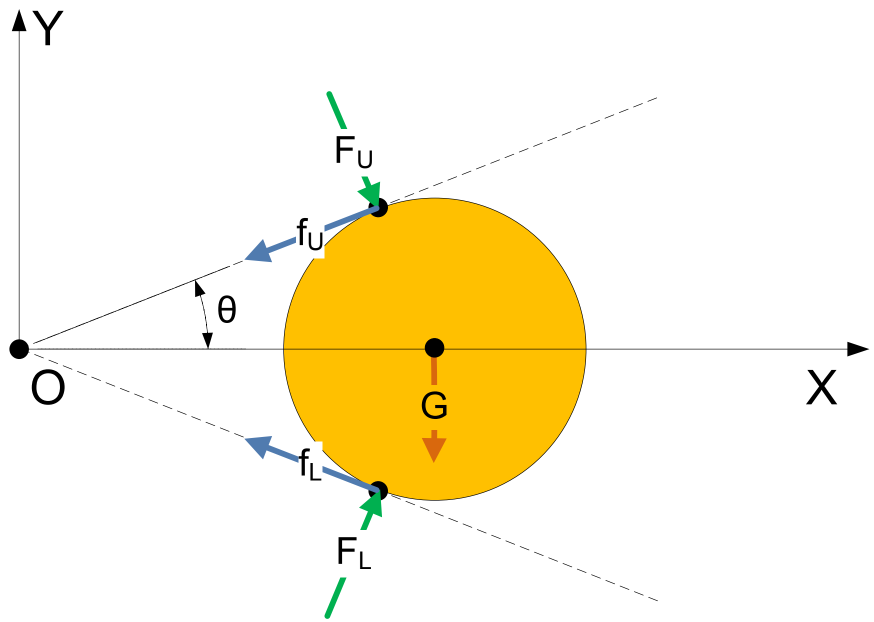


Modelling - The Nut – Equilibrium

Cause ~ effect

vity	•Earth Gravity
ndary	
Input	•From the grips
Reaction	
Friction	•From the grips

$$\sum \mathbf{F} = 0, \sum \mathbf{M} = 0$$



Modelling - The Nut – Equilibrium

Cause ~ effect

vity
- Earth Gravity

ndary

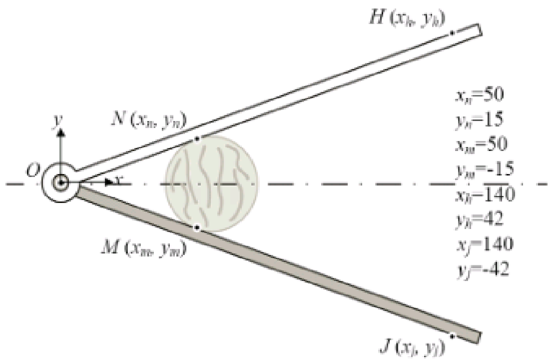
Input
- From the grips

Reaction

Friction
- From the grips

- Diameter = 30mm

Modeling G-L-1



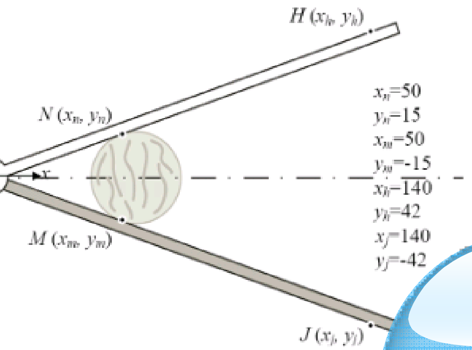
Sum of all force is zero

```
> restart : with(VectorCalculus) :
> theta := arctan(15/50) :
> F_U := 300 · ⟨sin(theta), −cos(theta)⟩ :
> F_L := F_LNorm ⟨sin(theta), cos(theta)⟩ :
> f_U := (f·Norm(F_U)) · ⟨−cos(theta), −sin(theta)⟩ :
> f_L := (f·Norm(F_L)−B) · ⟨−cos(theta), sin(theta)⟩ :
> G := 0.2 · 9.8 · ⟨0, −1⟩ :
> SUMF := F_L + F_U + f_U + f_L + G = ⟨0, 0⟩
> SUMM := (f·Norm(F_U)) − (f·Norm(F_L) − B) = 0 :
> solve({SUMF(1), SUMF(2), SUMM}, {f, F_LNorm, B})
```

Modelling - The Nut – Large & Small nut

- Diameter = 40mm

deling G-L-1



f = 0.4

f all force is zero

$estart : with(VectorCalculus) :$

$eta := \arctan\left(\frac{20}{50}\right) :$

$_U := 300 \cdot \langle \sin(theta), -\cos(theta) \rangle :$

$_L := F_{LNorm} \langle \sin(theta), \cos(theta) \rangle :$

$_U := (f \cdot Norm(F_U)) \cdot \langle -\cos(theta), -\sin(theta) \rangle :$

$_L := (f \cdot Norm(F_L) - B) \cdot \langle -\cos(theta), \sin(theta) \rangle :$

$:= 0.2 \cdot 9.8 \cdot \langle 0, -1 \rangle :$

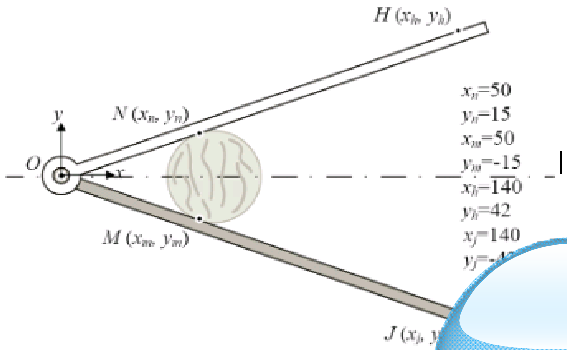
$UMF := F_L + F_U + f_U + f_L + G = \langle 0, 0 \rangle :$

$UMM := (f \cdot Norm(F_U)) - (f \cdot Norm(F_L) - B) = 0 :$

$olve(\{SUMF(1), SUMF(2), SUMM\}, \{f, F_{LNorm}, B\})$

- Diameter = 20mm

Modeling G-L-1



f = 0.2

Sum of all force is zero

$> restart : with(VectorCalculus) :$

$> theta := \arctan\left(\frac{10}{50}\right) :$

$> F_U := 300 \cdot \langle \sin(theta), -\cos(theta) \rangle :$

$> F_L := F_{LNorm} \langle \sin(theta), \cos(theta) \rangle :$

$> f_U := (f \cdot Norm(F_U)) \cdot \langle -\cos(theta), -\sin(theta) \rangle :$

$> f_L := (f \cdot Norm(F_L) - B) \cdot \langle -\cos(theta), \sin(theta) \rangle :$

$> G := 0.2 \cdot 9.8 \cdot \langle 0, -1 \rangle :$

$> SUMF := F_L + F_U + f_U + f_L + G = \langle 0, 0 \rangle :$

$> SUMM := (f \cdot Norm(F_U)) - (f \cdot Norm(F_L) - B) = 0 :$

$> solve(\{SUMF(1), SUMF(2), SUMM\}, \{f, F_{LNorm}, B\})$

Evaluation

Approximate coefficients of friction

Materials		Static friction, μ_s	
		Dry & clean	Lubricated
Aluminum	Steel	0.61	
Copper	Steel	0.53	
Brass	Steel	0.51	
Cast iron	Copper	1.05	
Cast iron	Zinc	0.85	
Concrete (wet)	Rubber	0.30	
Concrete (dry)	Rubber	1.0	
Concrete	Wood	0.62[10]	
Copper	Glass	0.68	
Glass	Glass	0.94	
Metal	Wood	0.2-0.6[10]	0.2 (wet)[10]
Polythene	Steel	0.2[11]	0.2[11]
Steel	Steel	0.80[11]	0.16[11]
Steel	Teflon	0.04[11]	0.04[11]
Teflon	Teflon	0.04[11]	0.04[11]
Wood	Wood	0.25-0.5[10]	0.2 (wet)[10]

cannot guarantee that it will work.

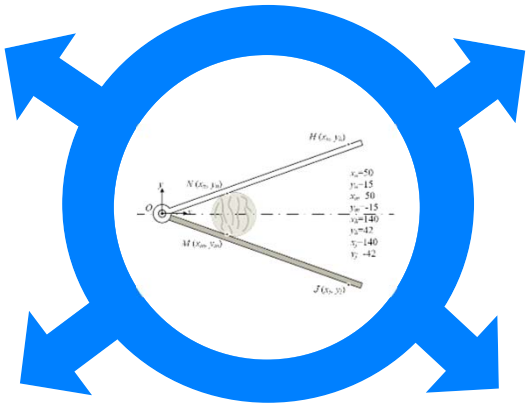
f this is an acceptable design

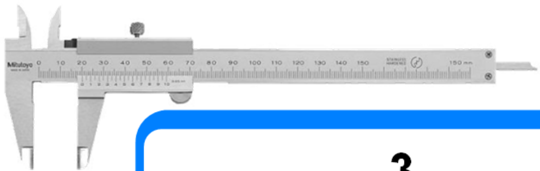
1

e developed a
rtable nut cracker

2

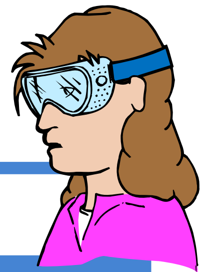
normal conditions, it can
ck nuts till 20mm in
meter. (Small nuts)





3

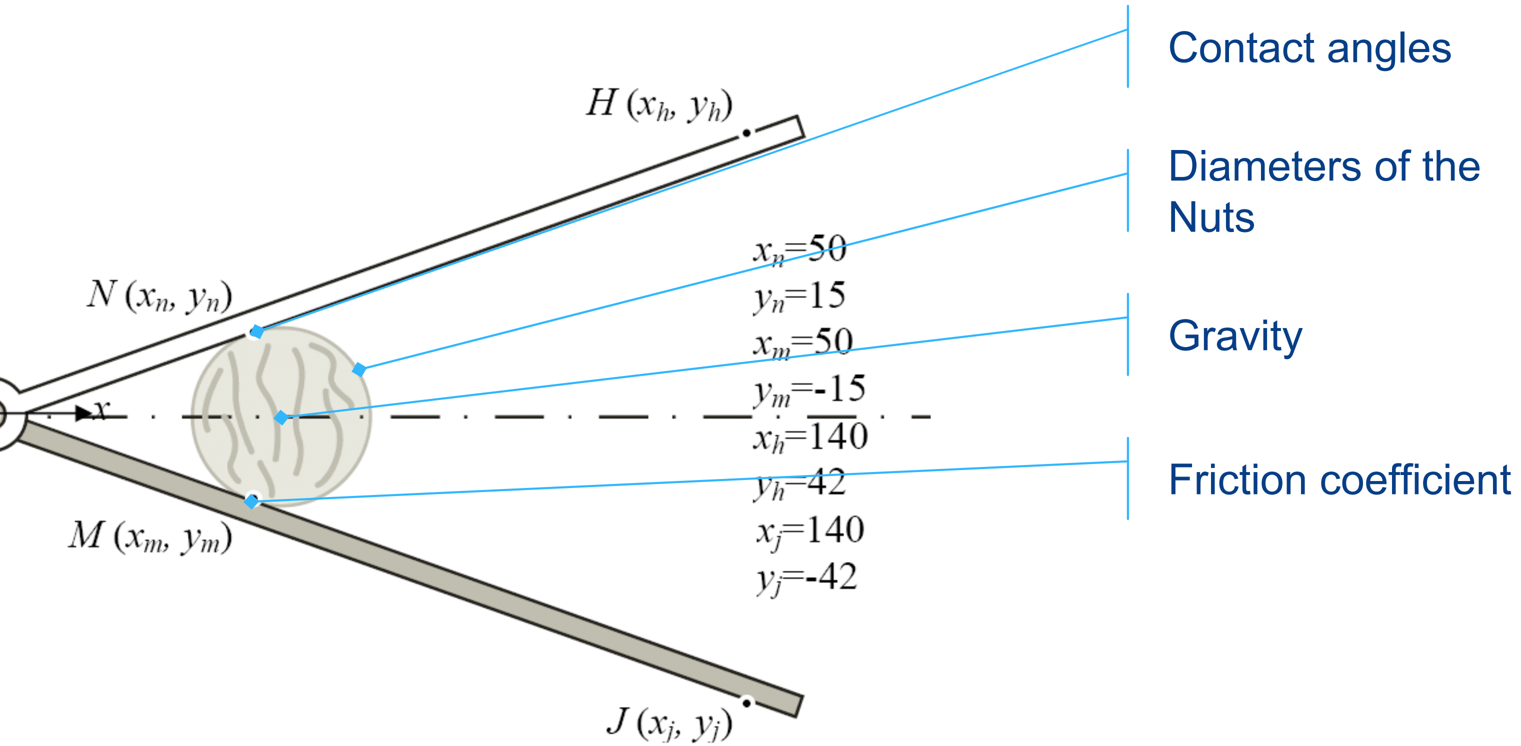
We advice the user to purchase a caliper to make a precise measurement of the nut before usage



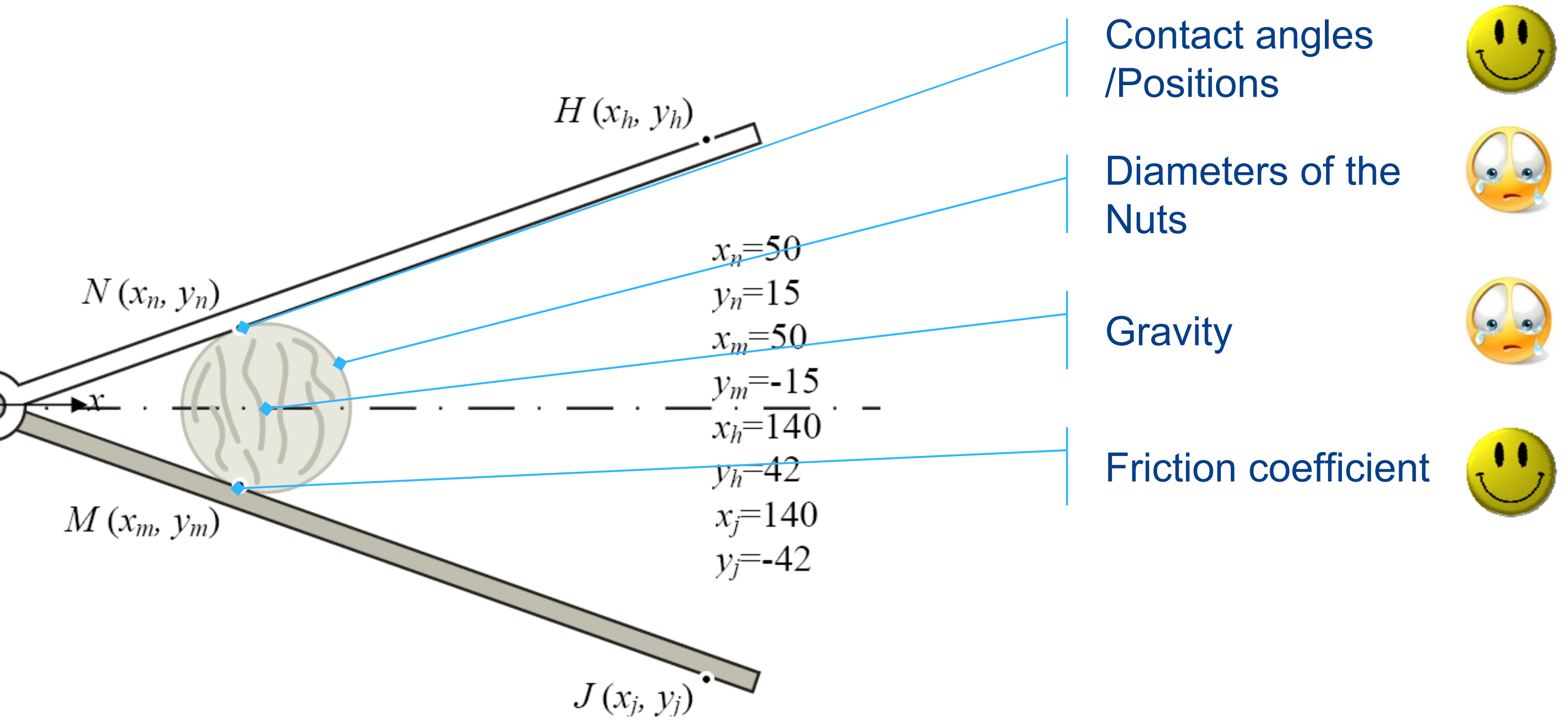
4

We also advice the user to dress a safety glasses in the case of trying to crack large nuts

Evaluation: Revisit choices in the system



Which parameter can be changed?



Evaluation: Friction coefficient

We may try to use rubber in the contact area, but rubber is not durable?

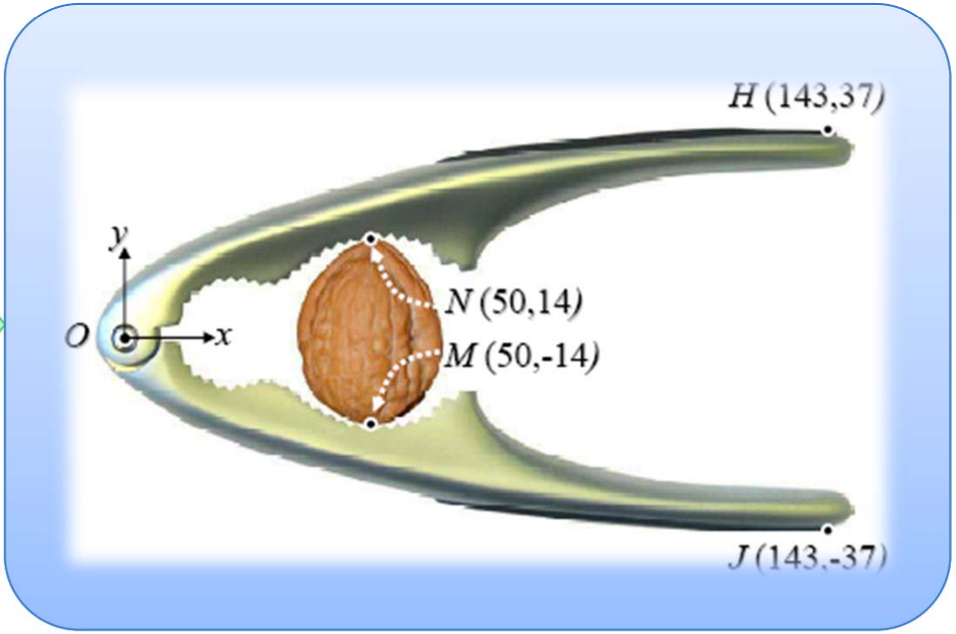
What else can we do?

Approximate coefficients of friction

Materials		Static friction, μ_s	
		Dry & clean	Lubricated
Aluminum	Steel	0.61	
Copper	Steel	0.53	
Brass	Steel	0.51	
Cast iron	Copper	1.05	
Cast iron	Zinc	0.85	
Concrete (wet)	Rubber	0.30	
Concrete (dry)	Rubber	1.0	
Concrete	Wood	0.62[10]	
Copper	Glass	0.68	
Glass	Glass	0.94	
Metal	Wood	0.2-0.6[10]	0.2 (wet)[10]
Polythene	Steel	0.2[11]	0.2[11]
Steel	Steel	0.80[11]	0.16[11]
Steel	Teflon	0.04[11]	0.04[11]
Teflon	Teflon	0.04[11]	0.04[11]
Wood	Wood	0.25-0.5[10]	0.2 (wet)[10]

A new idea – Change the contact angle

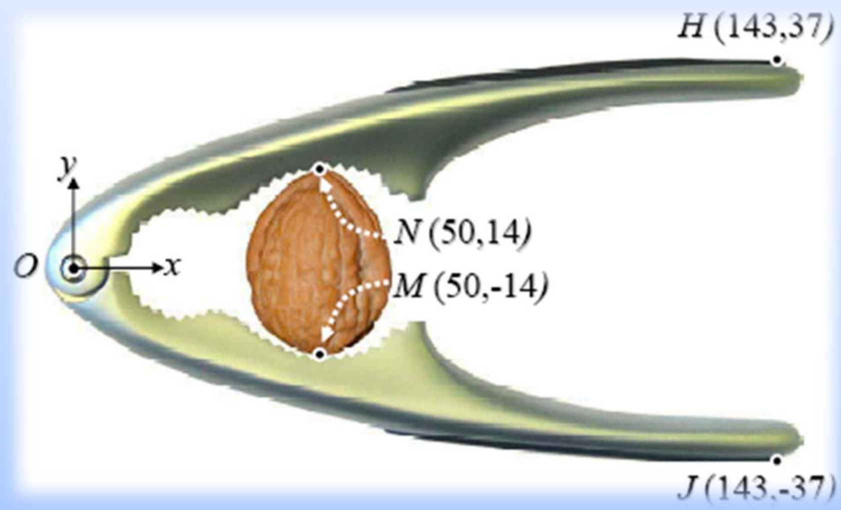
A new idea



A new cycle of modelling

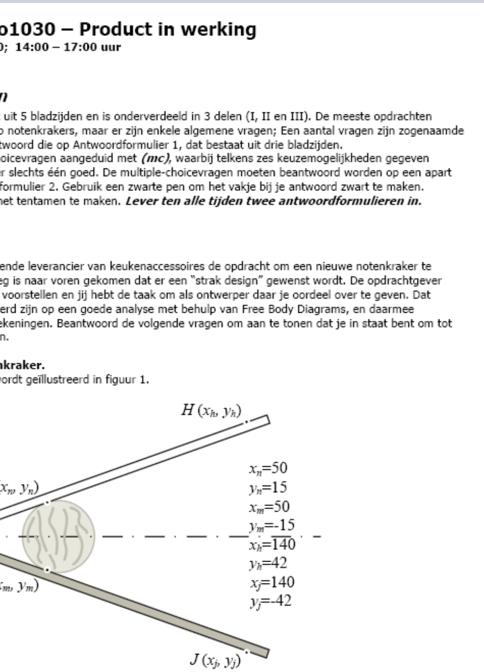
Cause ~ effect

ty	• Earth Gravity
dary	
nput	• From the grips
eaction	
riction	• From the grips



DIY it, Please

The origin of this case study



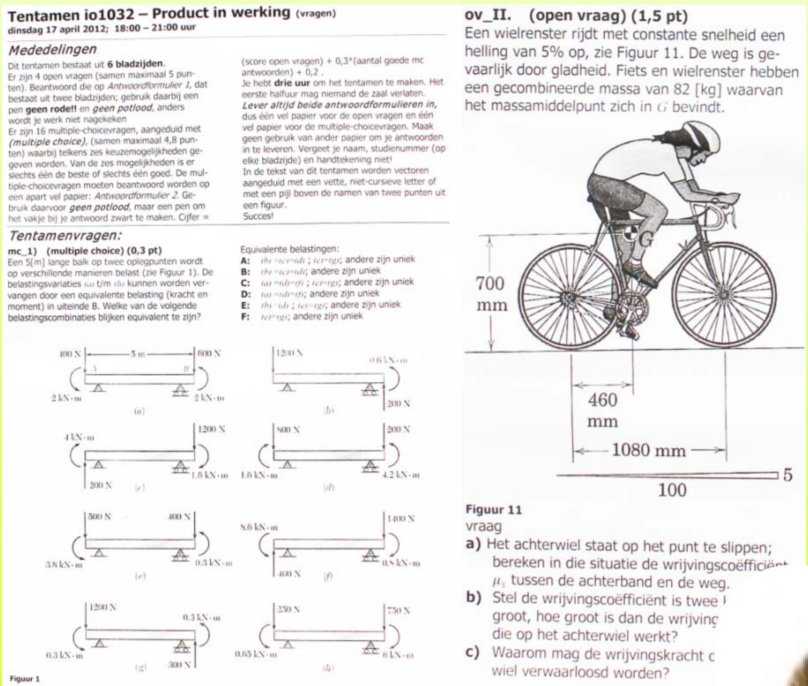
o1030 – Product in werking
0; 14:00 – 17:00 uur

n

uit 5 bladzijden en is onderverdeeld in 3 delen (I, II en III). De meeste opdrachten
o notenkrakers, maar er zijn enkele algemene vragen; Een aantal vragen zijn zogenaamde
twoord die op Antwoordformulier 1, dat bestaat uit drie bladzijden.
oicevragen aangeduid met *(mc)*, waarbij telkens zes keuzemogelijkheden gegeven
r slechts één goed. De multiple-choicevragen moeten beantwoord worden op een apart
formulier 2. Gebruik een zwarte pen om het vakje bij je antwoord zwart te maken.
het tentamen te maken. ***Lever ten alle tijden twee antwoordformulieren in.***

ende leverancier van keukenaccessoires de opdracht om een nieuwe notenkraker te
eg is naar voren gekomen dat er een "strak design" gewenst wordt. De opdrachtgever
voorstellen en jij hebt de taak om als ontwerper daar je oordeel over te geven. Dat
erd zijn op een goede analyse met behulp van Free Body Diagrams, en daarmee
ekeningen. Beantwoord de volgende vragen om aan te tonen dat je in staat bent om tot
n.

nkraker.
ordt geïllustreerd in figuur 1.



Tentamen io1032 – Product in werking (vragen)
dinsdag 17 april 2012; 18:00 – 21:00 uur

Mededelingen

Dit tentamen bestaat uit **6 bladzijden**.
Er zijn 4 open vragen (samen maximaal 5 punten). Beantwoord die op *Antwoordformulier 1*, dat bestaat uit twee bladzijden; gebruik daarbij een pen **geen rode!!** en *geen potlood*, anders wordt je werk niet nagekeken.
Er zijn 16 multiple-choicevragen, aangeduid met *(multiple choice)*, (samen maximaal 4,8 punten) waarbij telkens zes keuzemogelijkheden gegeven worden. Van de zes mogelijkheden is er slechts één de beste of slechts één goed. De multiple-choicevragen moeten beantwoord worden op een apart vel papier: *Antwoordformulier 2*. Gebruik daarvoor *geen potlood*, maar een pen om het vakje bij je antwoord zwart te maken. Cijfer = (score open vragen) + 0,3*(aantal goede mc antwoorden) + 0,2 .
Je hebt **drie uur** om het tentamen te maken. Het eerste halfuur mag niemand de zaal verlaten.
Lever altijd beide antwoordformulieren in, dus één vel papier voor de open vragen en één vel papier voor de multiple-choicevragen. Maak geen gebruik van ander papier om je antwoorden in te leveren. Vergeet je naam, studienummer (op elke bladzijde) en handtekening niet!
In de tekst van dit tentamen worden vectoren aangeduid met een vette, niet-cursieve letter of met een pijl boven de namen van twee punten uit een figuur.
Succes!

Tentamenvragen:

mc_1) (multiple choice) (0,3 pt)
Een 5[m] lange balk op twee oplegpunten wordt op verschillende manieren belast (zie Figuur 1). De belastingsvariaties (a) t/m (h) kunnen worden vervangen door een equivalente belasting (kracht en moment) in uiteinde B. Welke van de volgende belastingscombinaties blijken equivalent te zijn?

Equivalente belastingen:
A: (b) (c) (d) ; (e) (g); andere zijn uniek
B: (b) (c) (d); andere zijn uniek
C: (a) (d) (f) ; (e) (g); andere zijn uniek
D: (a) (d) (f); andere zijn uniek
E: (b) (d) ; (e) (g); andere zijn uniek
F: (e) (g); andere zijn uniek

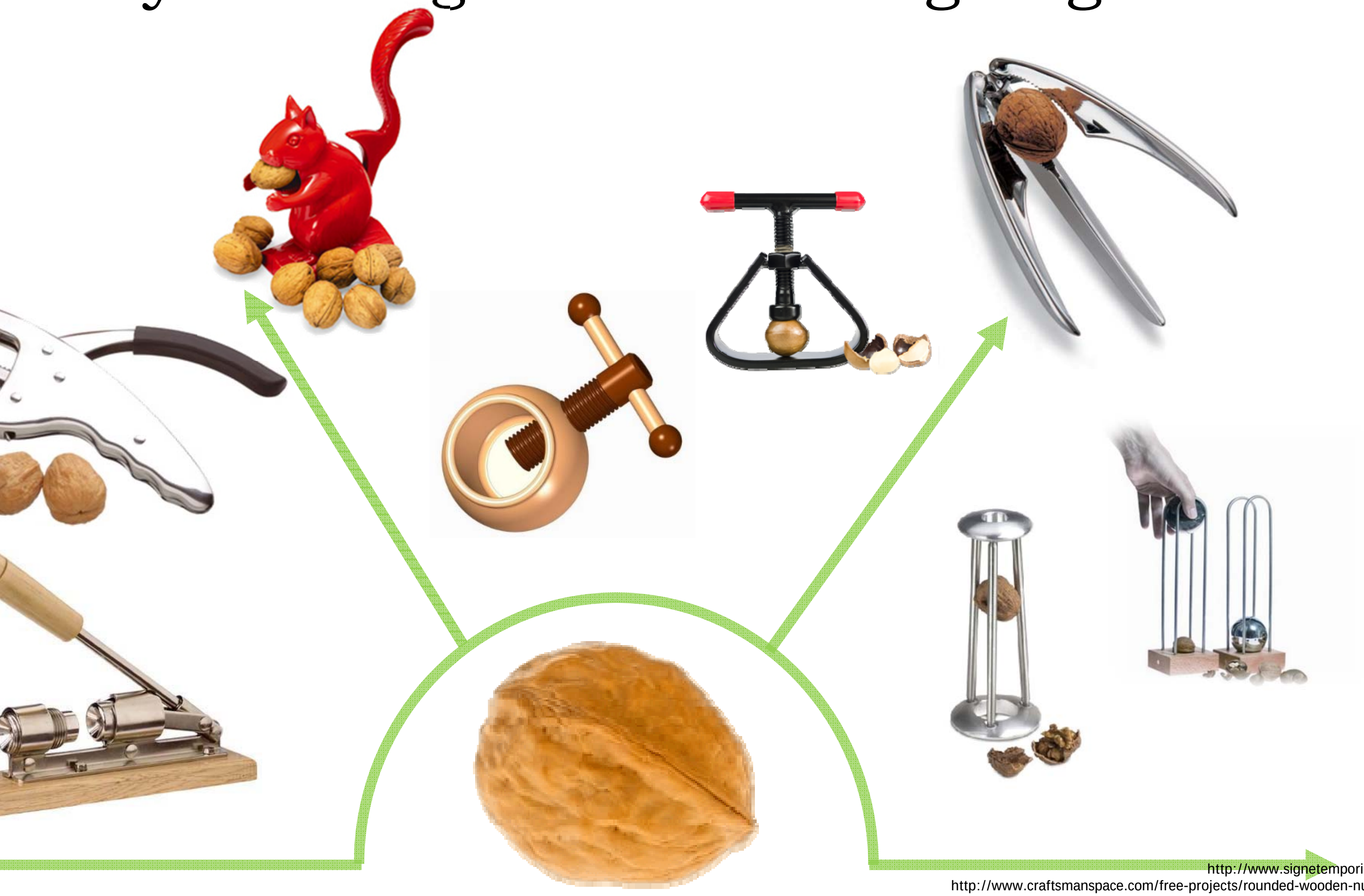
Figuur 1

ov_II. (open vraag) (1,5 pt)
Een wielrenster rijdt met constante snelheid een helling van 5% op, zie Figuur 11. De weg is gevaarlijk door gladheid. Fiets en wielrenster hebben een gecombineerde massa van 82 [kg] waarvan het massamiddelpunt zich in G bevindt.

Figuur 11
vraag
a) Het achterwiel staat op het punt te slippen; bereken in die situatie de wrijvingscoëfficiënt μ_s tussen de achterband en de weg.
b) Stel de wrijvingscoëfficiënt is twee ... groot, hoe groot is dan de wrijving... die op het achterwiel werkt?
c) Waarom mag de wrijvingskracht o... wiel verwaarloosd worden?

Thank you: Ir. Ernest van Breemen

Free your imagination in designing



Courtesy of
http://www.signetemporium.com/promo.php
http://www.craftsmanspace.com/free-projects/rounded-wooden-nut-cracker-plan.html
http://www.ohgizmo.com/2009/12/02/northern-industrial-tools-nut-cracker-is-one-serious-piece-of-holiday-kit/

igid body dynamics

pecial Thanks to Dr. Bas Flipsen

The Modelling Team
Department of Design Engineering
Faculty of Industrial Design Engineering

Everything starts from here

Law of Motion

Observed from an inertial reference frame, the net force on a particle is equal to the time rate of change of its linear momentum:

$$\mathbf{F} = \frac{d}{dt} m\mathbf{v}$$

He never wrote

$$\mathbf{F} = m\mathbf{a}$$

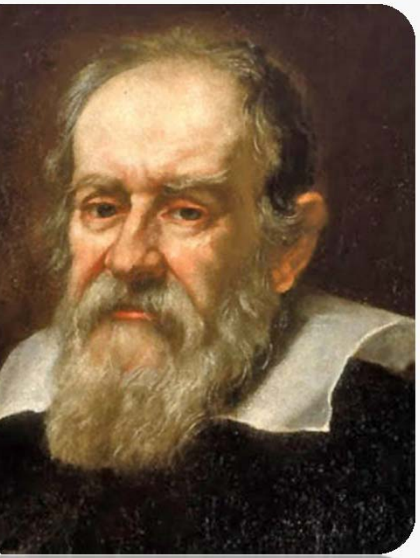
Dynamics – Equilibrium

$$\sum \mathbf{F} = 0, \sum \mathbf{M} = 0$$

orces related to Cause ~ effect

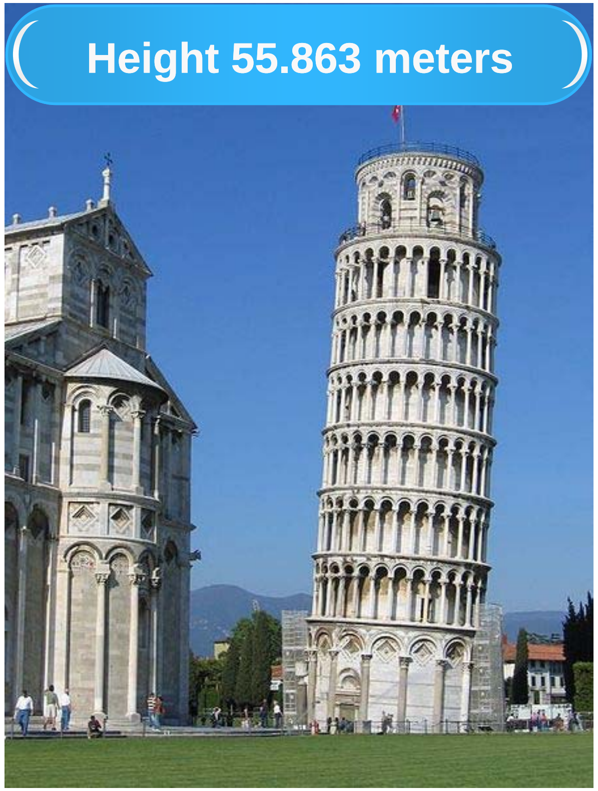
- ertia force: $-\frac{d}{dt} m\mathbf{v}$
- avity: •Earth Gravity
- undary
- Input
- Reaction
- Friction

Case study: Galileo's Leaning Tower of Pisa experiment



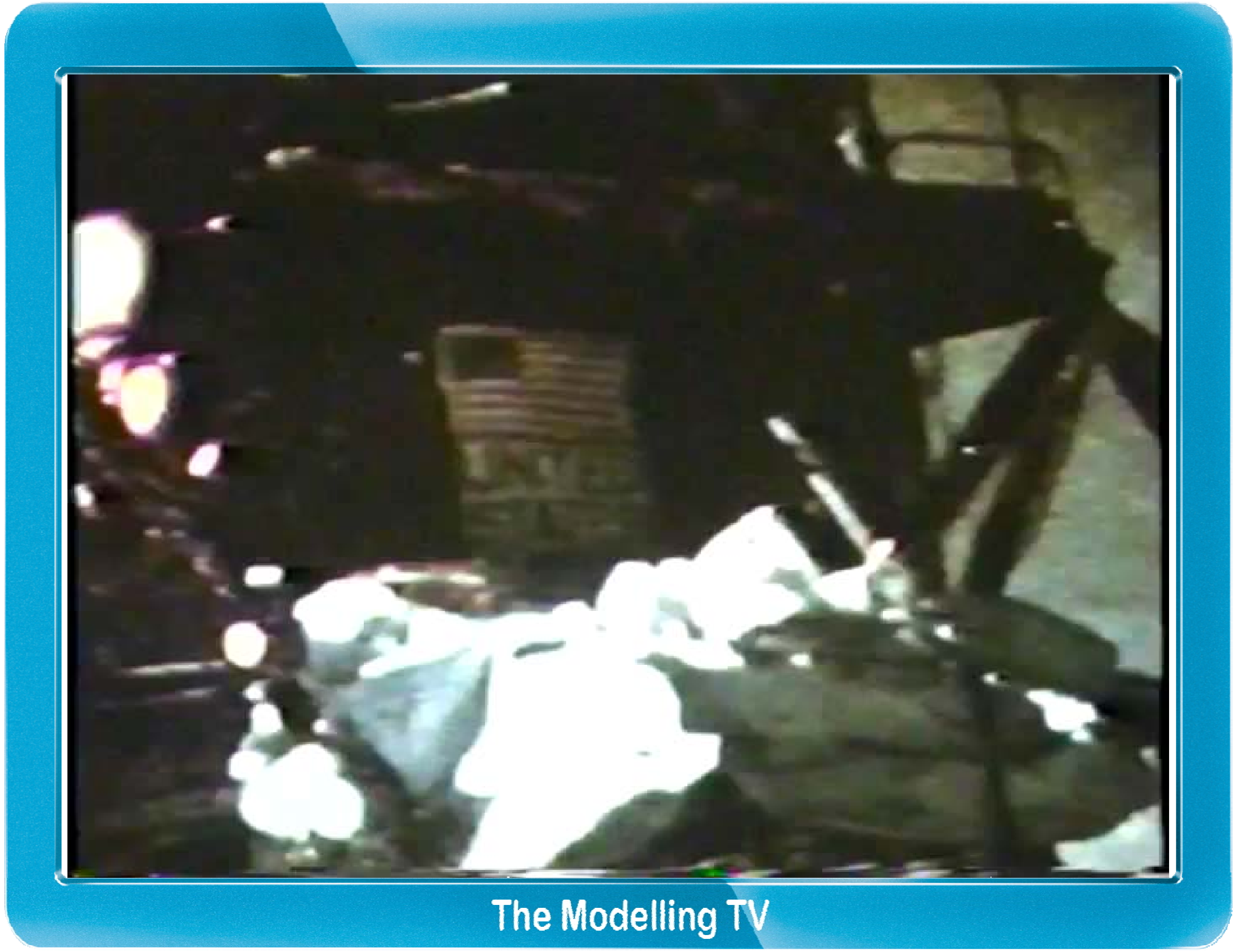
Physicist
Mathematician
Astronomer

Is it really true?



Hammer & Feather drop: Apollo 15

ref. http://nssdc.gsfc.nasa.gov/planetary/lunar/apollo_15_feather_drop.html



It seems true on the moon, how about earth?

NASA “*metric mixup*” -Mars Climate Orbiter

sci-tech > space > story page

exploringmars

in-depth specials

MAIN PAGE
WORLD
U.S.
LOCAL
POLITICS
WEATHER
BUSINESS
SPORTS
TECHNOLOGY
SPACE
HEALTH
ENTERTAINMENT
BOOKS
TRAVEL
FOOD
ARTS & STYLE
NATURE
IN-DEPTH
ANALYSIS
myCNN

Headline News brief
news quiz
daily almanac

NASA's metric confusion caused Mars orbiter loss

September 30, 1999
Web posted at: 1:46 p.m. EDT (1746 GMT)

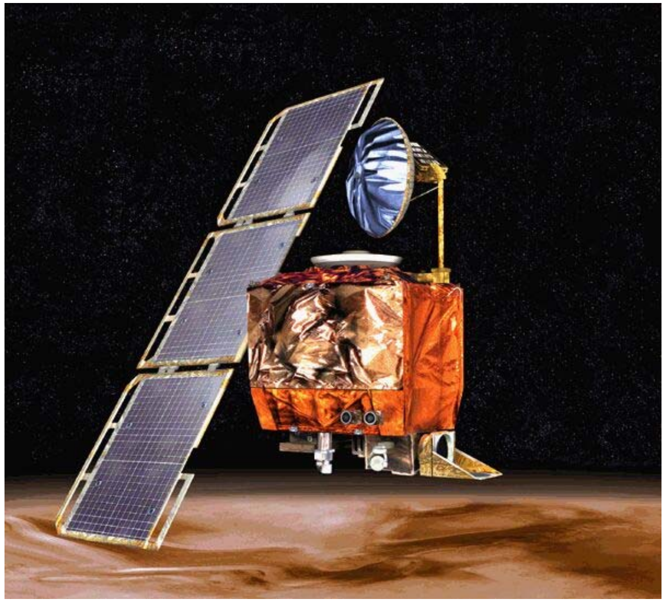
(CNN) -- NASA lost a $125 million Mars orbiter because one engineering team used metric units while another used English units for a key spacecraft operation, according to a review finding released Thursday.

NASA's Climate Orbiter was lost September 23, 1999

For that reason, information failed to transfer between the Mars Climate Orbiter spacecraft team at Lockheed Martin in Colorado and the mission navigation team in California. Lockheed Martin built the

Courtesy of http://en.wikipedia.org/wiki/Mars_Climate_Orbiter, www.cnn.com

NASA “*metric mixup*” - The tution fees



$327.6 million: Orbiter and Lander
$193.1 million: Spacecraft development
$91.7 million: Launch
$42.8 million: Mission operations

$655.3 Million

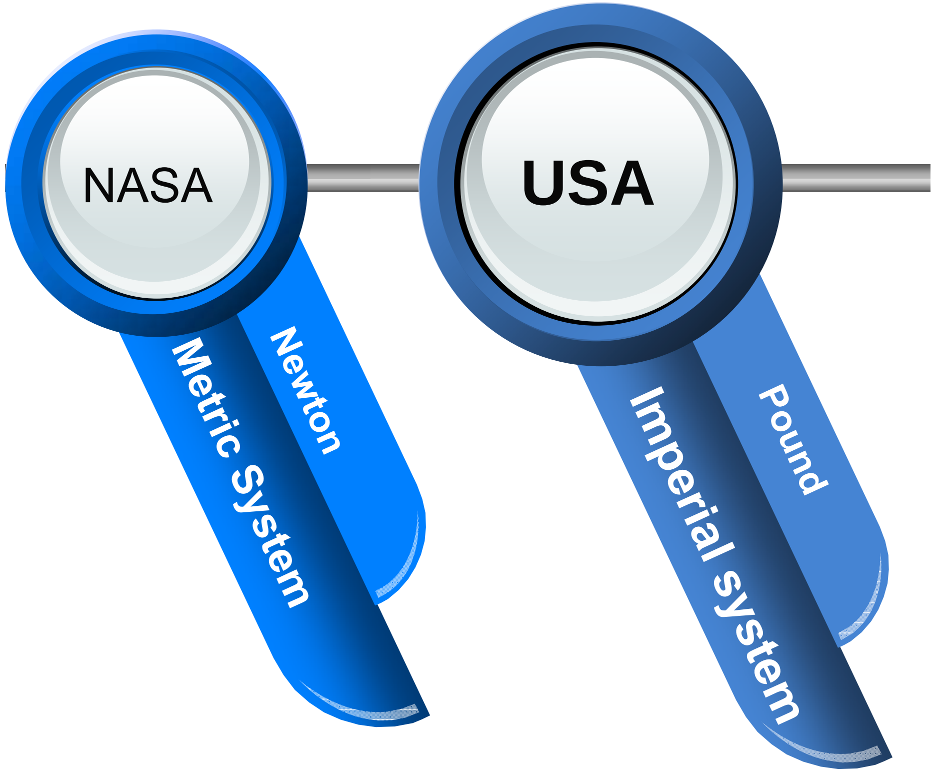
Ref. http://en.wikipedia.org/wiki/Mars_Climate_Orbiter

Dimension problems

Metric system
+
Imperial Units

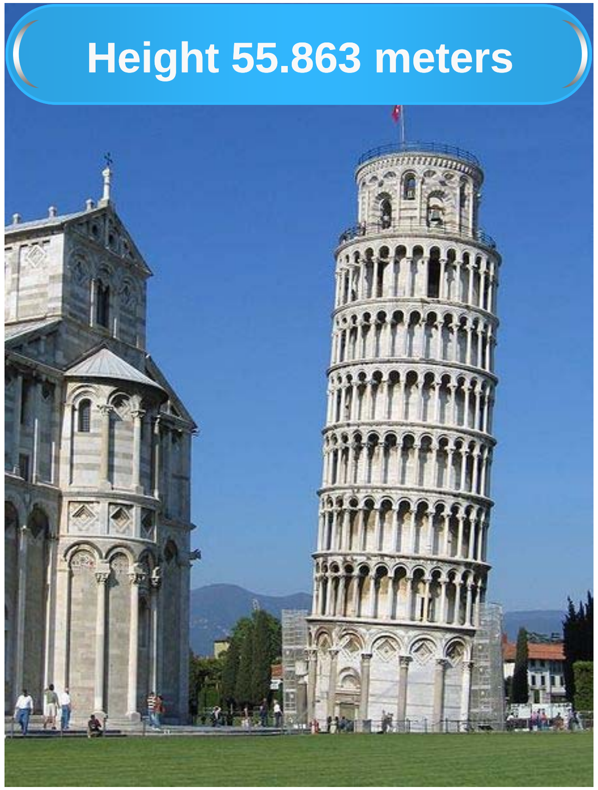
Imperial units

$655.3 Million
+
Time



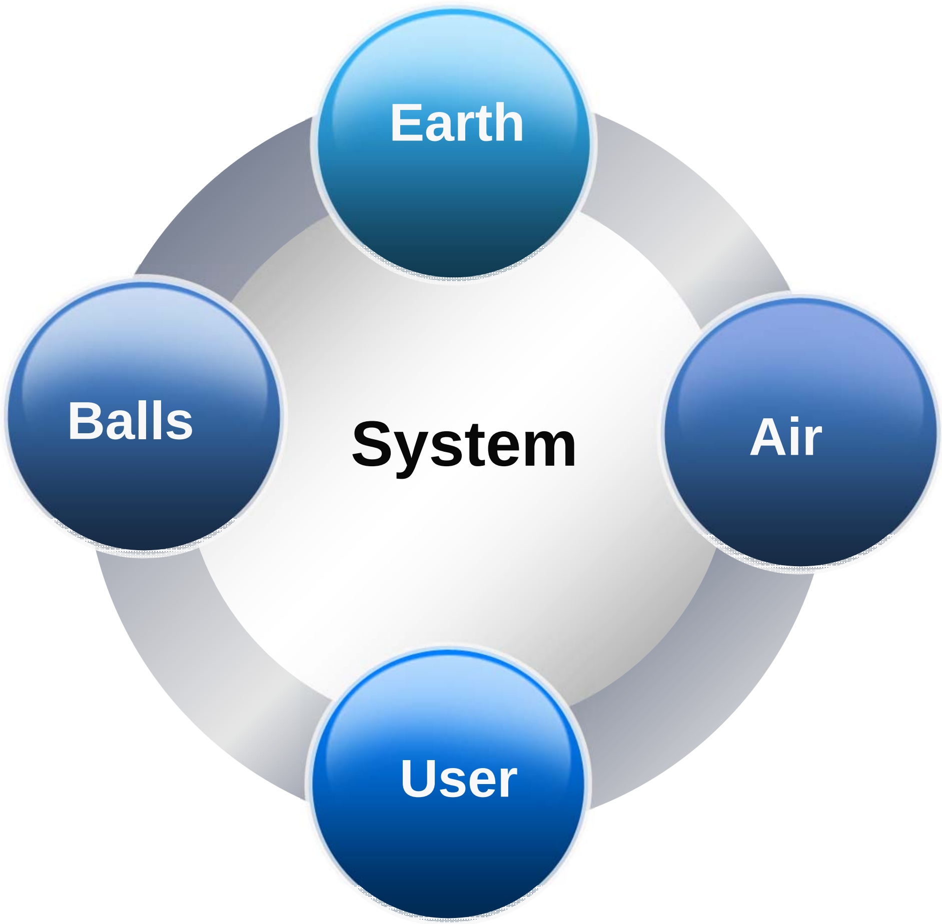
Ref. http://en.wikipedia.org/wiki/Mars_Climate_Orbiter

Is it really true?

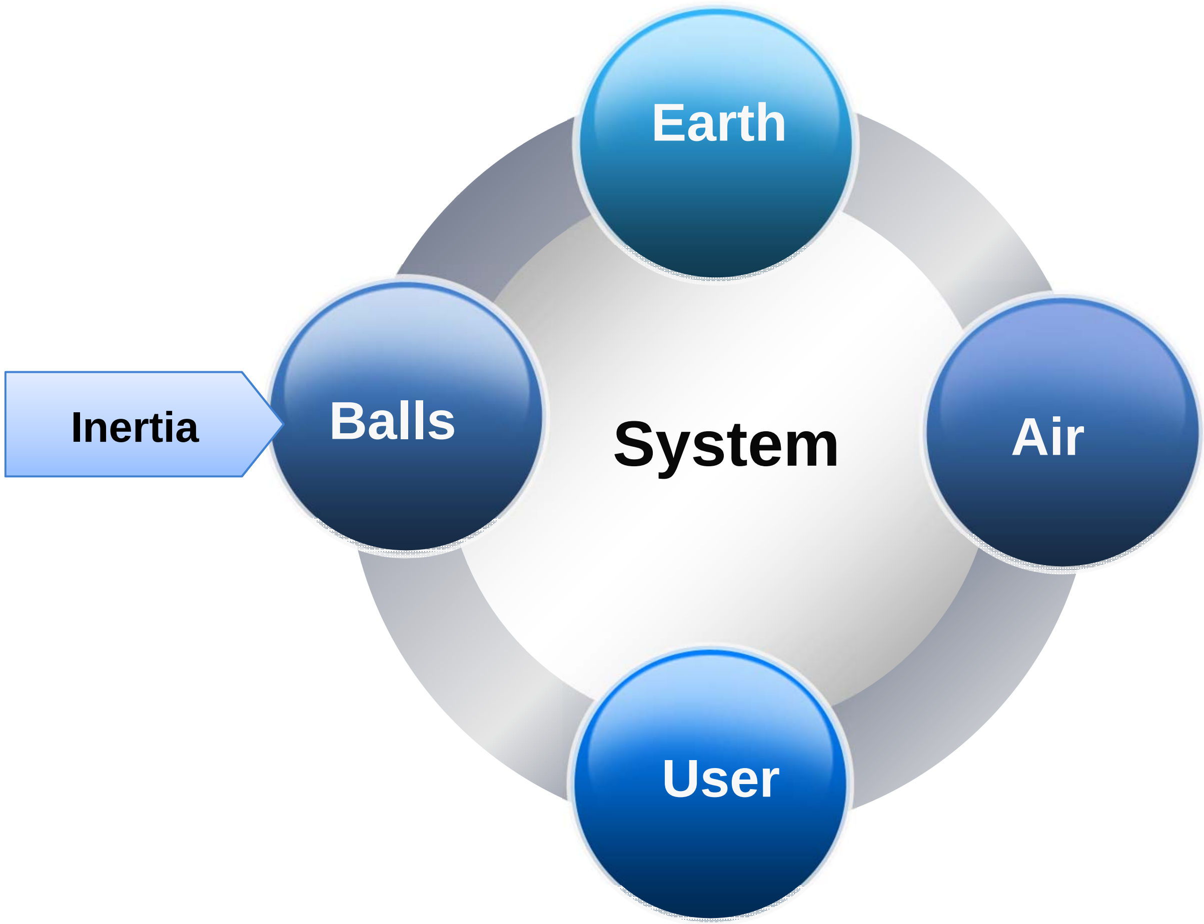


Courtesy of http://en.wikipedia.org/wiki/Leaning_Tower_of_Pisa, http://www.bluffton.edu/~bergerd/classes/NSC109/Handouts/answers2-3.html

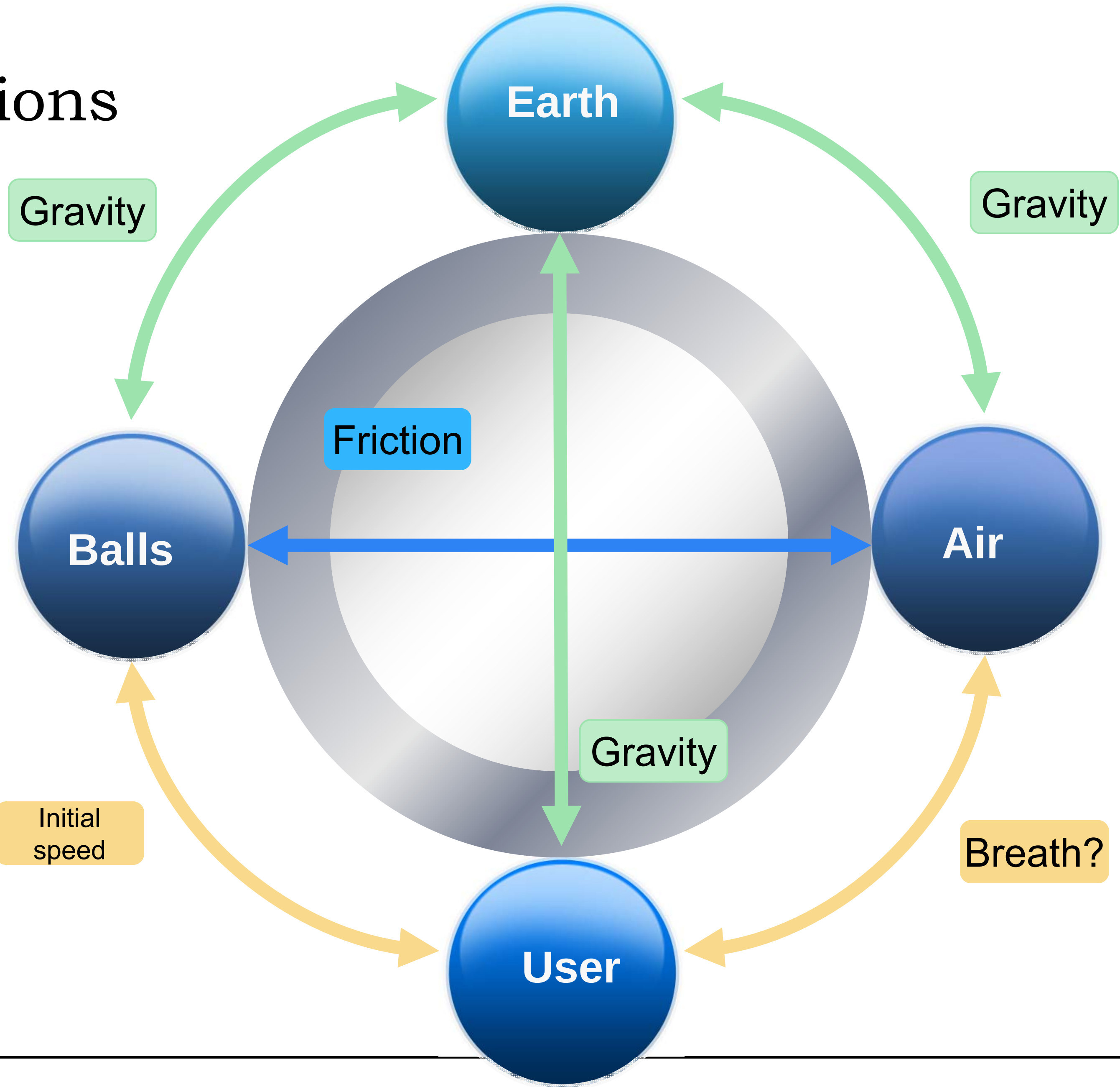
Inside the system?



Reasoning about components: Which one is moving?

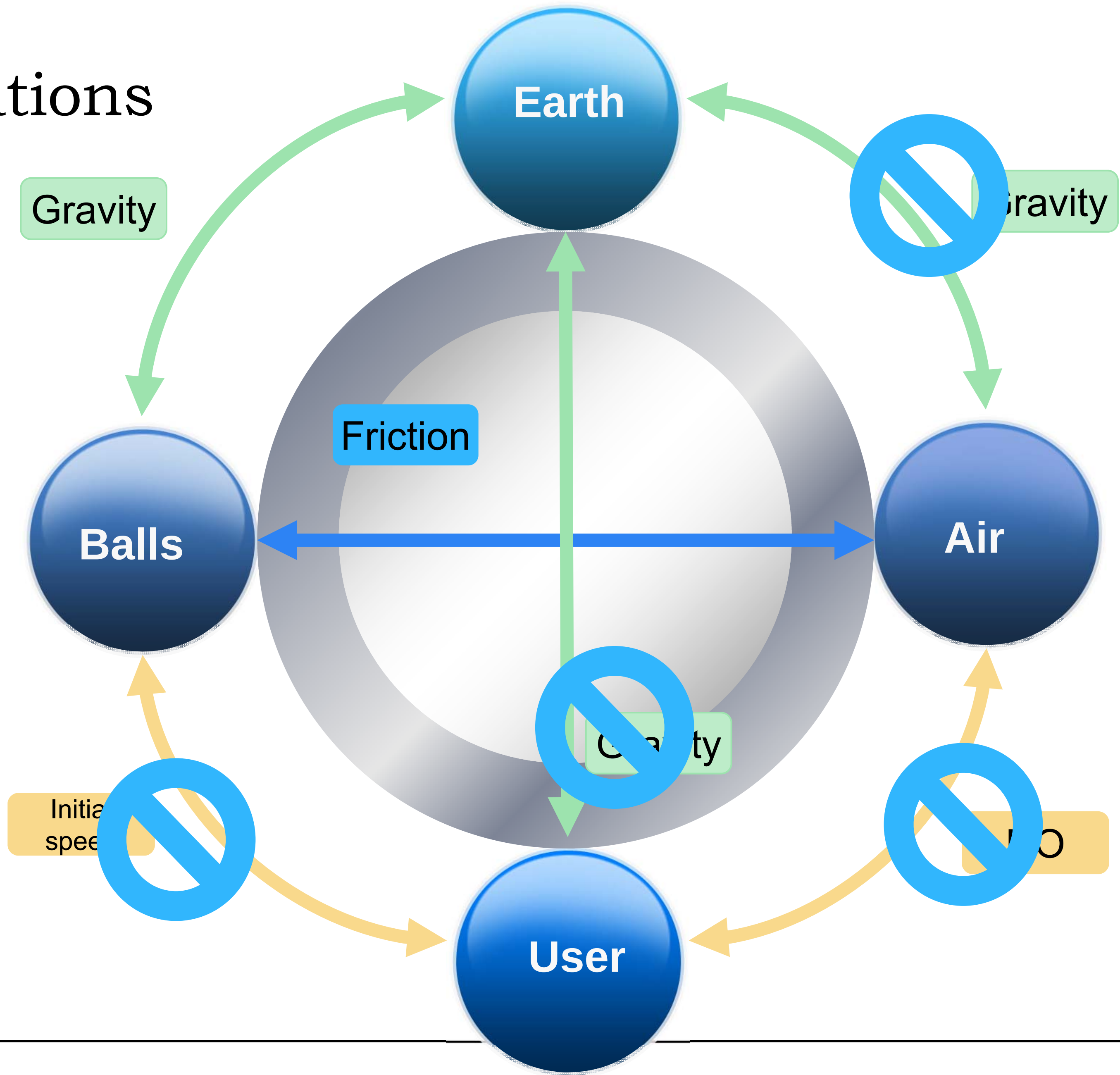


Relations

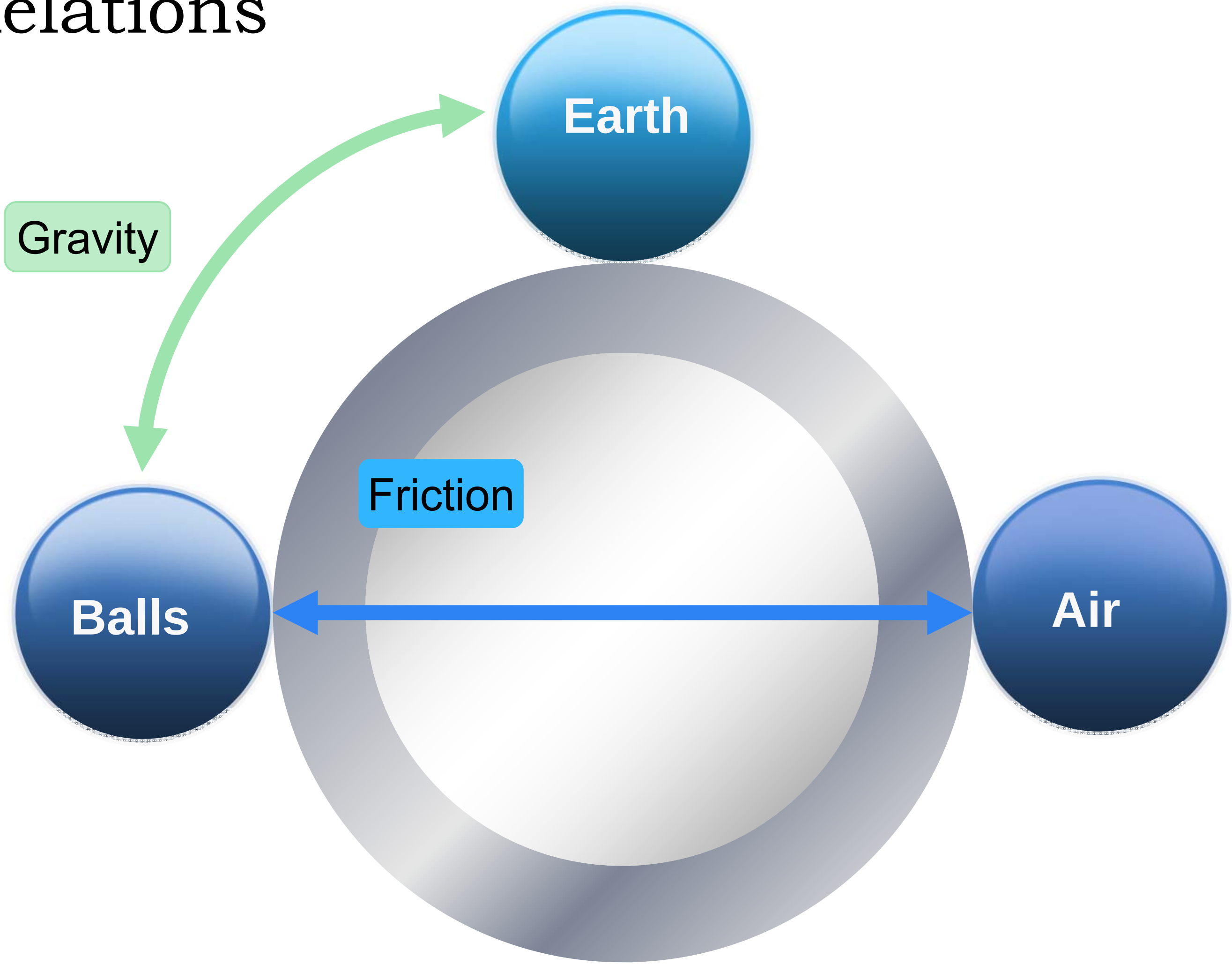


Earth
Gravity
Gravity
Friction
Balls
Air
Gravity
Initial speed
Breath?
User

Relations

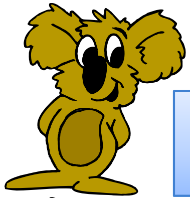


Relations



Cause-Effect

Cause



Inertia
- **Resist to change**

Gravity
- **Ball drops**

Air drag
- **Ball slows down**

Effect

Physics behind – The air drag

The Air drag (scalar form)

$$F_D = \frac{1}{2}\rho A C_d V^2$$

Ref. http://en.wikipedia.org/wiki/Drag_(physics)

Physics behind – The air drag

Density
Unit(kg/m^3)

The Air drag (scalar form)

$$F_D = \frac{1}{2}\rho A C_d V^2$$

The density of air

1.204 kg/m^3

Ref. http://en.wikipedia.org/wiki/Drag_(physics)

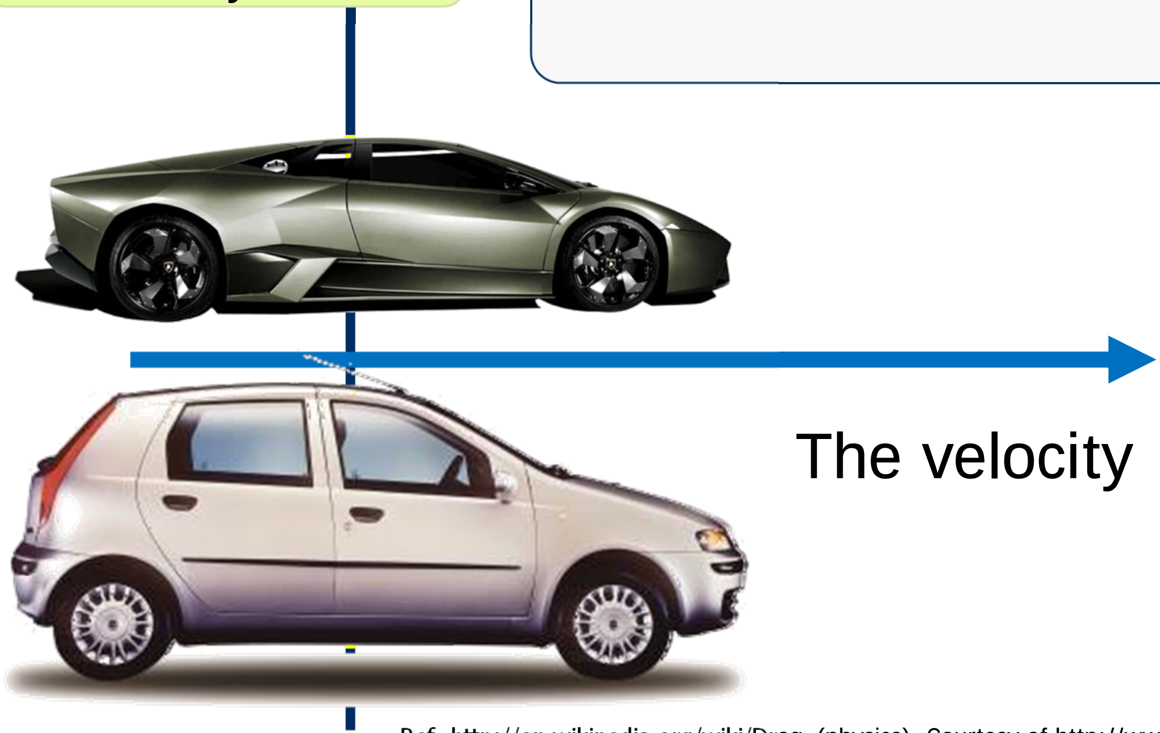
Physics behind – The air drag

Reference Area
Unit(m^2)

The Air drag (scalar form)

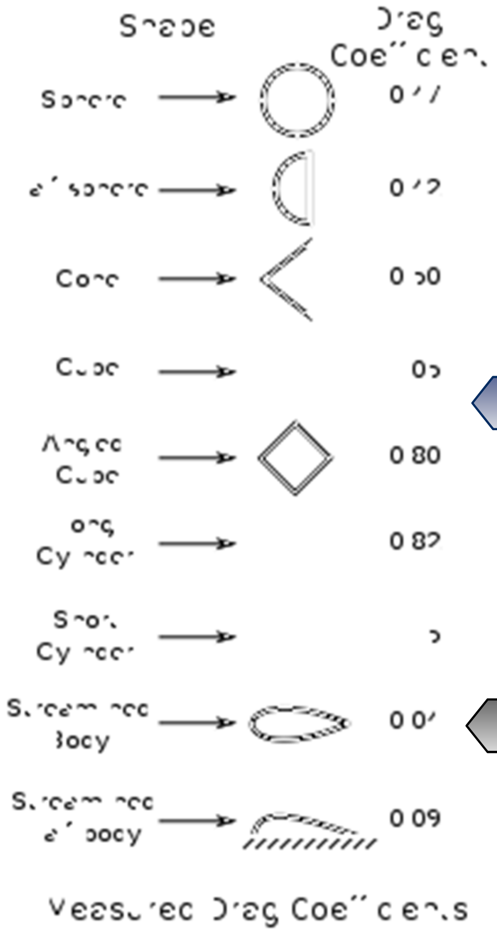
$$F_D = \frac{1}{2} \rho A C_d V^2$$

Cross section area
Perpendicular to
the velocity



Ref. http://en.wikipedia.org/wiki/Drag_(physics), Courtesy of http://www.redlineblog.com/reventon-lambos-ruthless-new-bull/

Physics behind – The air drag



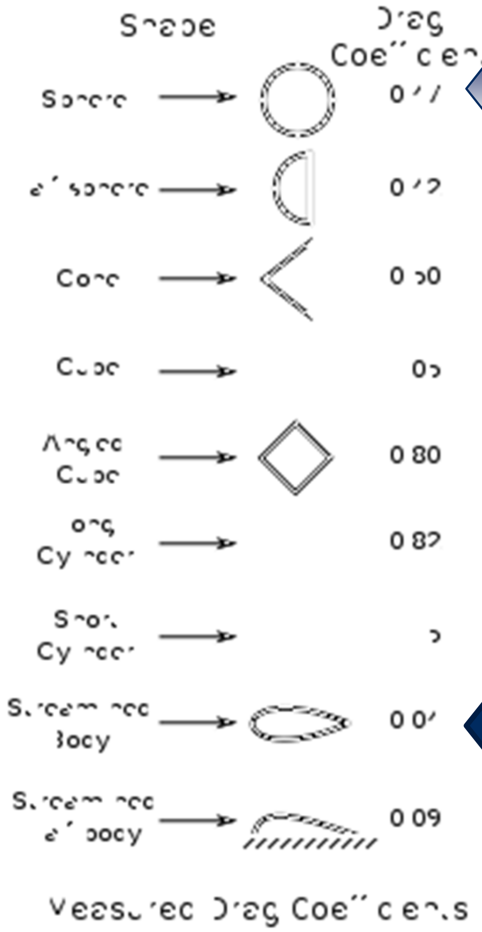
The Air drag (scalar form)

$$F_D = \frac{1}{2}\rho A C_d V^2$$

Drag coefficient (dimensionless)

Courtesy of http://en.wikipedia.org/wiki/Drag_(physics), http://www.cyclingweekly.co.uk/archive/348018/how-to-improve-your-aero-position.html

Why?



Courtesy of http://en.wikipedia.org/wiki/Drag_(physics), http://www.cyclingweekly.co.uk/archive/348018/how-to-improve-your-aero-position.html

Physics behind – The air drag

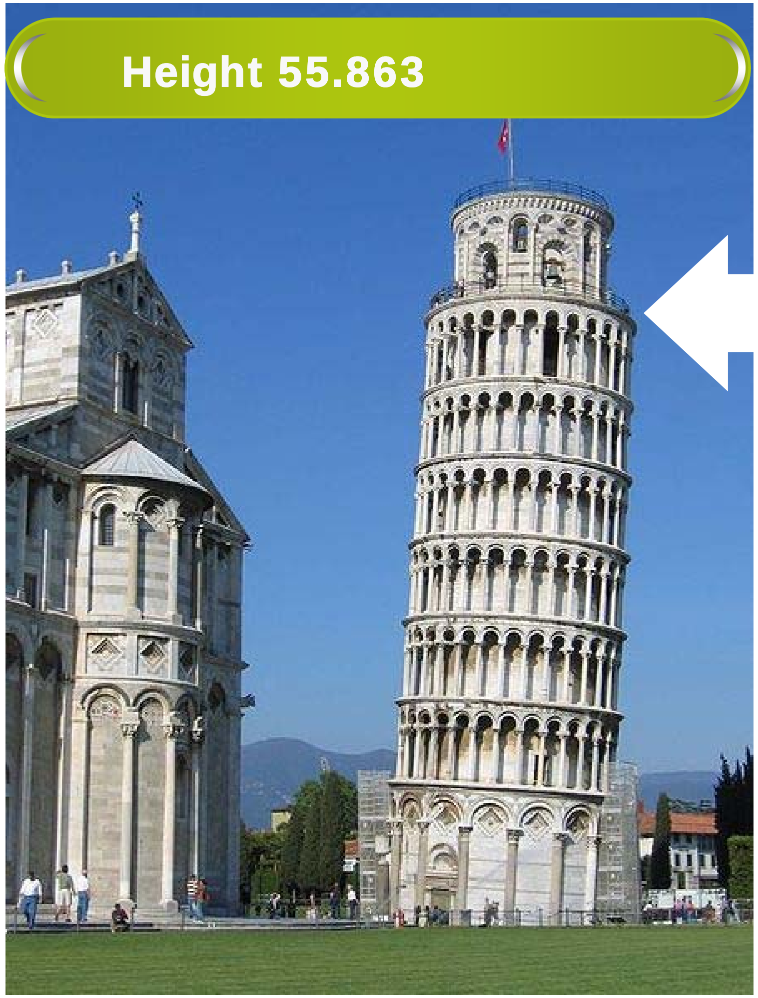
The Air drag (scalar form)

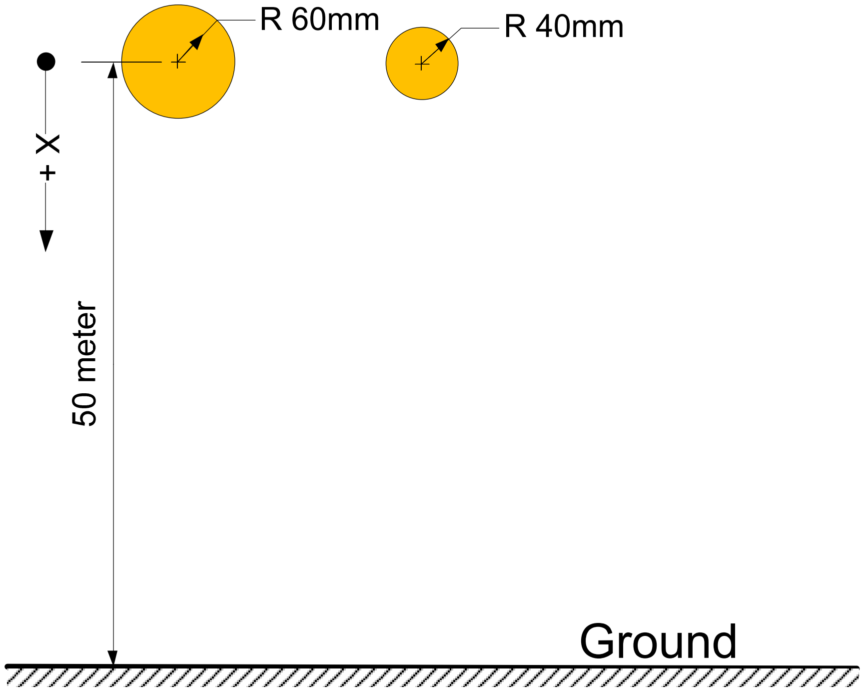
$$F_D = \frac{1}{2}\rho A C_d V^2$$

- Density Unit(kg/m^3)
- Reference Area Unit(m^2)
- Velocity Unit(m/s)
- Drag coefficient (dimensionless)

Ref. http://en.wikipedia.org/wiki/Drag_(physics)

Modeling





Courtesy of http://en.wikipedia.org/wiki/Leaning_Tower_of_Pisa

Dynamics – Equilibrium (Scalar)

Forces related to Cause ~ effect

- **Inertia force**: $-\frac{d}{dt}m\mathbf{v}$ → $-m\frac{d^2x(t)}{dt^2}$
- **Gravity**: •Earth Gravity → mg
- **Boundary**
  - **Input**
  - **Reaction**
  - **Friction**: •From the air → $-\frac{1}{2}\rho A C_d\left(\frac{dx(t)}{dt}\right)^2$

$$\sum F_x = 0$$

$x(t)$ - travel along X-axis

Dynamics – The model

Forces related to Cause ~ effect

- **Inertia force**: $-\frac{d}{dt}m\mathbf{v}$
- \+ **Gravity**: •Earth Gravity
- \+ **Boundary**
  - **Input**
  - \+ **Reaction**
  - \+ **Friction**: •From the air

$$\sum F_x = 0$$

$$-m\frac{d^2x(t)}{dt^2} + mg - \frac{1}{2}\rho A C_d \left(\frac{dx(t)}{dt}\right)^2 = 0$$

$x(t)$ - travel along X-axis

Dynamics – The model

Forces related to Cause ~ effect

- Inertia force: $-\frac{d}{dt} m\mathbf{v}$
- \+ Gravity: • Earth Gravity
- \+ Boundary
  - Input
  - \+ Reaction
  - \+ Friction: • From the air

$$\sum F_x = 0$$

$$-m\frac{d^2x(t)}{dt^2} + mg - \frac{1}{2}\rho A C_d \left(\frac{dx(t)}{dt}\right)^2 = 0$$

$x(t)$ - travel along X-axis

Dynamics – Equilibrium

$$-m\frac{d^2x(t)}{dt^2}+mg-\frac{1}{2}\rho AC_d\left(\frac{dx(t)}{dt}\right)^2=0$$

We choose

- The ball radiuses are 60mm and 40mm, respectively
- The balls are made from Iron, density is 7800kg/m^3
- The travel distances is 50 meters
- The density of air is 1.204kg/m^3
- The reference area is πr^2
- The drag coefficient is 0.47

Dynamics – Equilibrium

$$-m\frac{d^2x(t)}{dt^2}+mg-\frac{1}{2}\rho AC_d\left(\frac{dx(t)}{dt}\right)^2=0$$

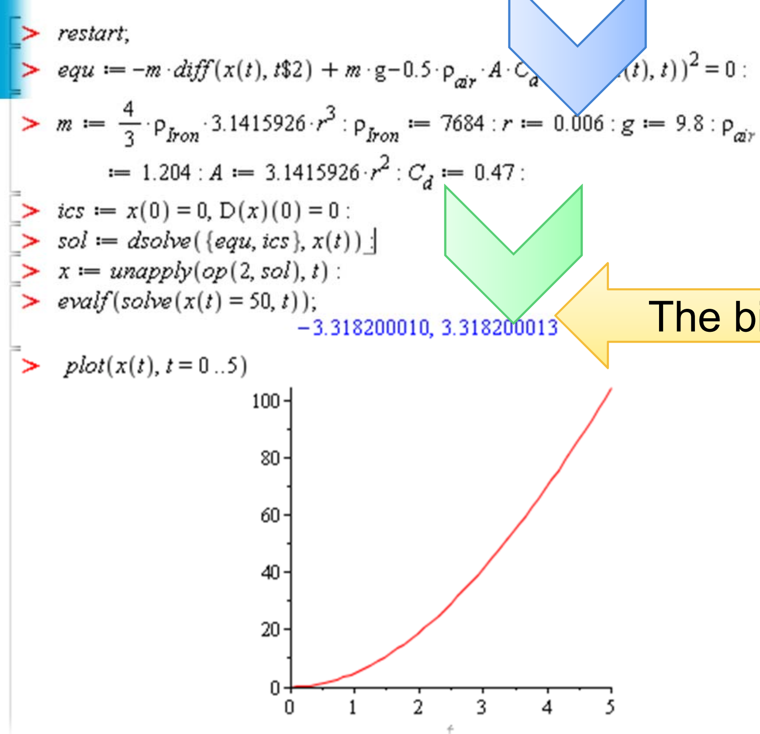
$$\rho_{Iron}V = \rho_{Iron}\frac{4}{3}\pi r^3$$

We choose

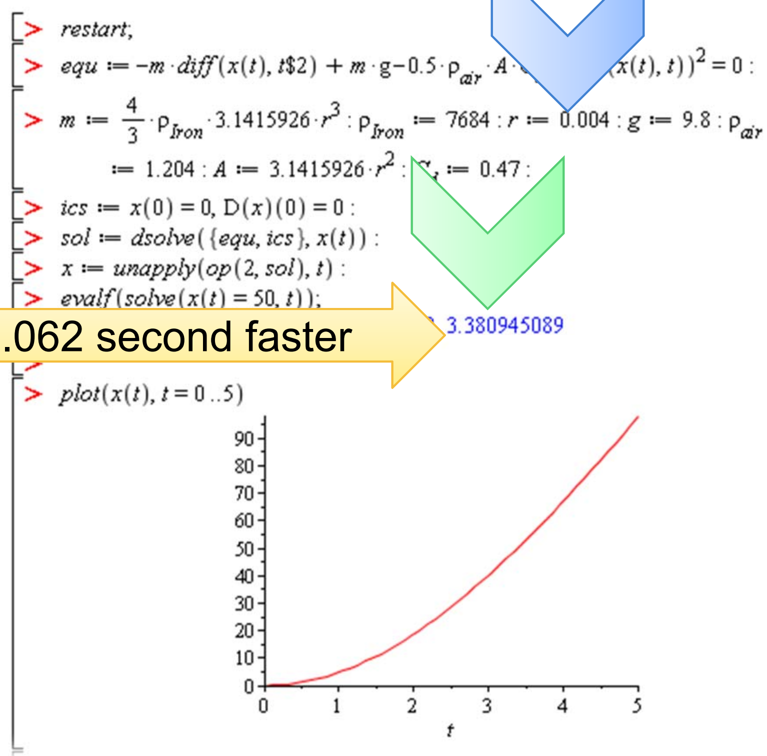
- The ball radiuses are 60mm and 40mm, respectively
- The balls are made from Iron, density is 7874kg/m^3
- The travel distances is 50 meters
- The density of air is 1.204kg/m^3
- The reference area is πr^2
- The drag coefficient is 0.47

Dynamics – Solve

Big



Small



The big ball is 0.062 second faster

Indeed, our experience is right, the big ball is faster.
It is just hardly noticeable in this case (Human average reaction time: 0.215 second)

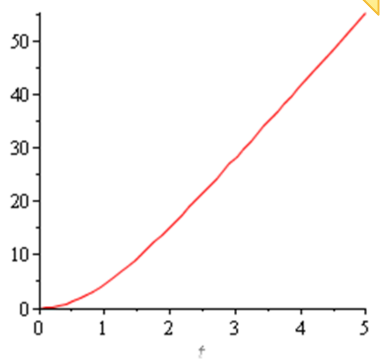
Ref. http://www.humanbenchmark.com/tests/reactiontime/index.php

Evaluations – Wooden ball

Big

Galileo - Wood

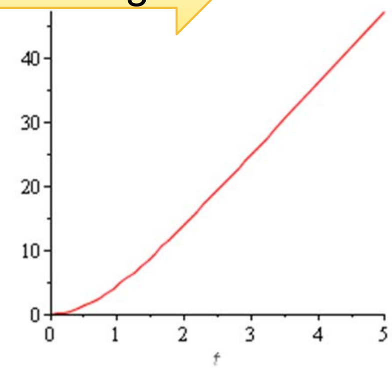
```
> restart;
> equ := −m·diff(x(t), t$2) + m·g−0.5 ... C_d·(diff(x(t), t))^2 = 0 :
> m := 4/3·ρ_Wood·3.1415926·r^3 : ρ_Wood := 684 : r := 0.006 : g := 9.8 : ρ_air
    := 1.204 : A := 3.1415926·r^2 : C_d := 0.47 :
> ics := x(0) = 0, D(x)(0) = 0 :
> sol := dsolve({equ, ics}, x(t)) :
> x := unapply(op(2, sol), t) :
> evalf(solve(x(t) = 50, t));
                                  −4.603606891, 4.603606822
> plot(x(t), t = 0..5)
```



Small

- Wood

```
> restart;
> equ := −m·diff(x(t), t$2) + m·g ... A·C_d·(diff(x(t), t))^2 = 0 :
> m := 4/3·ρ_Wood·3.1415926·r^3 : ρ_Wood := 684 : r := 0.004 : g := 9.8 : ρ_air
    := 1.204 : A := 3.1415926·r^2 : C_d := 0.47 :
> ics := x(0) = 0, D(x)(0) = 0 :
> sol := dsolve({equ, ics}, x(t)) :
> x := unapply(op(2, sol), t) :
> evalf(solve(x(t) = 50, t));
                                  −5.2430466..., 5.243046320
```



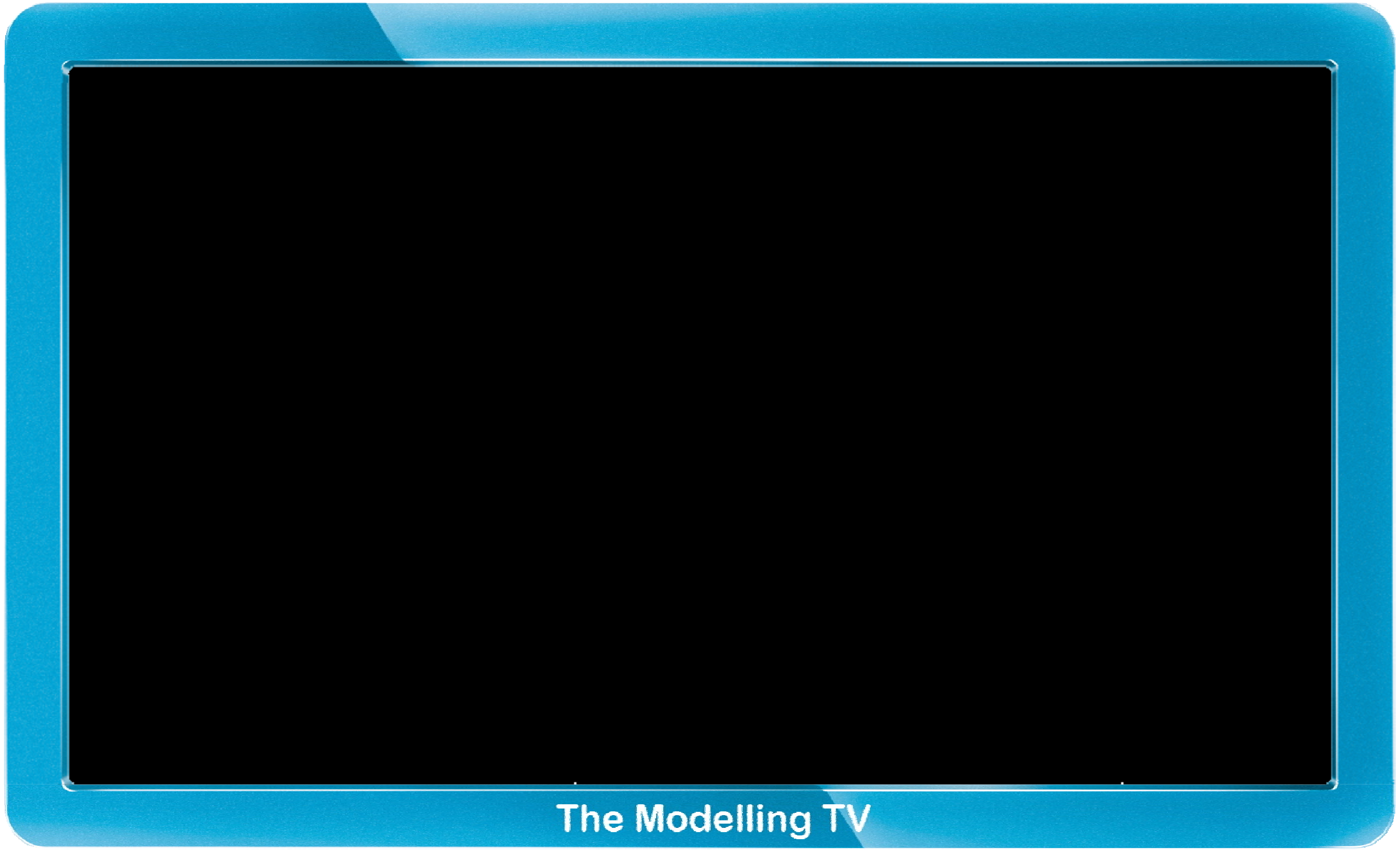
0.64 second, which is 10 times larger

Now we know how smart Galileo Galilei is

Safety regarding Wooden ball

Courtesy of http://www.theage.com.au/news/world/deadly-storms-lash-europe/2007/01/12/1168105153228.html, http://www.bluffton.edu/~bergerd/classes/NSC109/Handouts/answers2-3.html

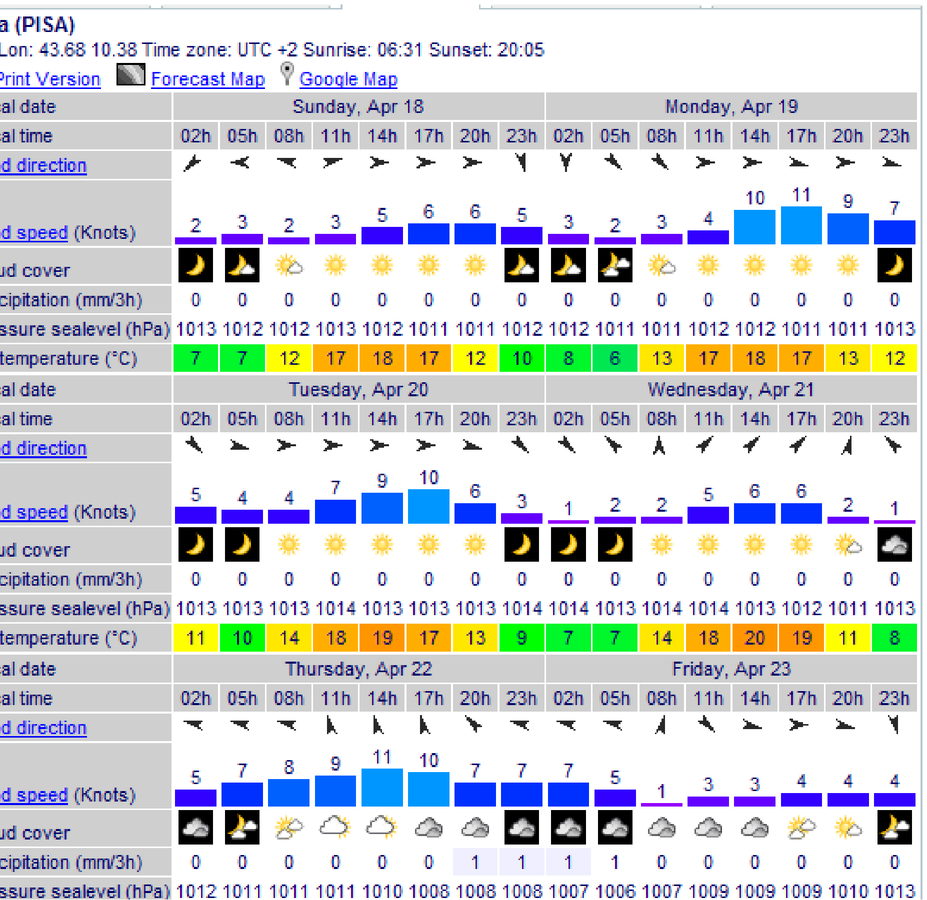
The power of wind



April 18, 2013

Wind speed in Pisa

Data from http://www.windfinder.com/forecast/pisa



a (PISA)
Lon: 43.68 10.38 Time zone: UTC +2 Sunrise: 06:31 Sunset: 20:05
Print Version Forecast Map Google Map

al date	Sunday, Apr 18								Monday, Apr 19							
al time	02h	05h	08h	11h	14h	17h	20h	23h	02h	05h	08h	11h	14h	17h	20h	23h
d direction																
d speed (Knots)	2	3	2	3	5	6	6	5	3	2	3	4	10	11	9	7
ud cover																
cipitation (mm/3h)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ssure sealevel (hPa)	1013	1012	1012	1013	1012	1011	1011	1012	1012	1011	1011	1012	1012	1011	1011	1013
temperature (°C)	7	7	12	17	18	17	12	10	8	6	13	17	18	17	13	12
al date	Tuesday, Apr 20								Wednesday, Apr 21							
al time	02h	05h	08h	11h	14h	17h	20h	23h	02h	05h	08h	11h	14h	17h	20h	23h
d direction																
d speed (Knots)	5	4	4	7	9	10	6	3	1	2	2	5	6	6	2	1
ud cover																
cipitation (mm/3h)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ssure sealevel (hPa)	1013	1013	1013	1014	1013	1013	1013	1014	1014	1013	1014	1014	1013	1012	1011	1013
temperature (°C)	11	10	14	18	19	17	13	9	7	7	14	18	20	19	11	8
al date	Thursday, Apr 22								Friday, Apr 23							
al time	02h	05h	08h	11h	14h	17h	20h	23h	02h	05h	08h	11h	14h	17h	20h	23h
d direction																
d speed (Knots)	5	7	8	9	11	10	7	7	7	5	1	3	3	4	4	4
ud cover																
cipitation (mm/3h)	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0
ssure sealevel (hPa)	1012	1011	1011	1011	1010	1008	1008	1008	1007	1006	1007	1009	1009	1009	1010	1013

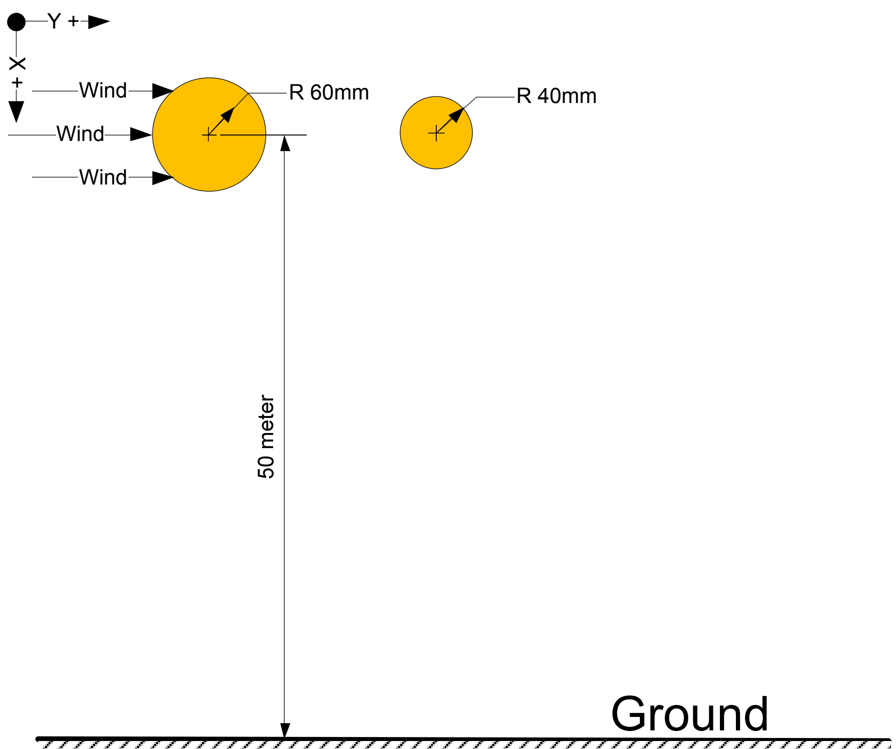
11 Knots = 5.66 meter/s

Dynamics – Equilibrium

$$\sum F_y = 0$$

es related to Cause ~ effect

force	$-\frac{d}{dt}m\mathbf{v}$
y	•Earth Gravity
ary	
put	
eaction	
iction	•From the air



Dynamics – Equilibrium along Y

es related to Cause ~ effect

force $-\frac{d}{dt}m\mathbf{v}$

•Earth Gravity

ry

ut •From the air

action

ction

$$-m\frac{d^2y(t)}{dt^2}$$

$$\frac{1}{2}\rho AC_d\left(V_{wind}-\frac{dy(t)}{dt}\right)^2$$

$$\sum F_y = 0$$

Dynamics – Equilibrium along Y

ces related to Cause ~ effect

a force	$-\frac{d}{dt}m\mathbf{v}$
y	•Earth Gravity
dary	
nput	•From the air
eaction	
riction	

$$\sum F_y = 0$$

$$-m\frac{d^2y(t)}{dt} + \frac{1}{2}\rho A C_d \left(V_{wind} - \frac{dy(t)}{dt}\right)^2 = 0$$

Dynamics – Equilibrium

$$-m\frac{d^2y(t)}{dt}+\frac{1}{2}\rho AC_d\left(V_{wind}-\frac{dy(t)}{dt}\right)^2=0$$

We choose

- The ball radiuses are 60mm and 40mm, respectively
- The balls are made from Wood, the density is 684kg/m^3
- The wind speed is 5.66 m/s
- The density of air is 1.204kg/m^3
- The reference area is πr^2
- The drag coefficient is 0.47

Dynamics – Equilibrium

eo - Fly - Wood

tart;

u := −m·diff(y(t), t$2) + 0.5·ρ_air·A·C_d·(... (y(t), t))^2 = 0 :

= 4/3·ρ_Wood·3.1415926·r^3 : ρ_Wood := 684 : r := 0.006 : g := 9.8 : ρ_air

:= 1.204 : A := 3.1415926·r^2 : C_d := 0.47 :

:= y(0) = 0, D(y)(0) = 0 :

:= dsolve({equ, ics}, y(... numeric, ... tput = listprocedure) :

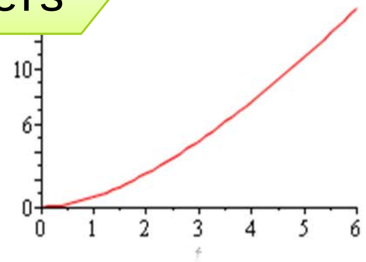
= rhs(sol[2]);

y := p ... end proc

.6)

9.54275497985485721

.5 meters



Small

... - Fly - Wood

> restart;

> equ := −m·diff(y(t), t$2) + 0.5·ρ_air·A·C_d·(... iff(y(t), t))^2 = 0 :

> m := 4/3·ρ_Wood·3.1415926·r^3 : ρ_Wood := 684 : r := 0.004 : g := 9.8 : ρ_air := 1.204 : A := 3.1415926·r^2 : C_d := 0.47 :

> ics := y(0) = 0, D(y)(0) = 0 :

> sol := dsolve({equ, ics}, y ...), numeri ... output = listprocedure) :

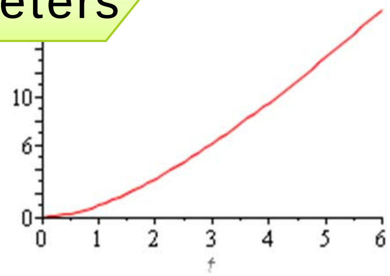
> y := rhs(sol[2]);

y := ... end proc

> y(5.243)

14.2755336349381388

14.28 meters



Safety region – Wooden ball

Safety region – Wooden ball

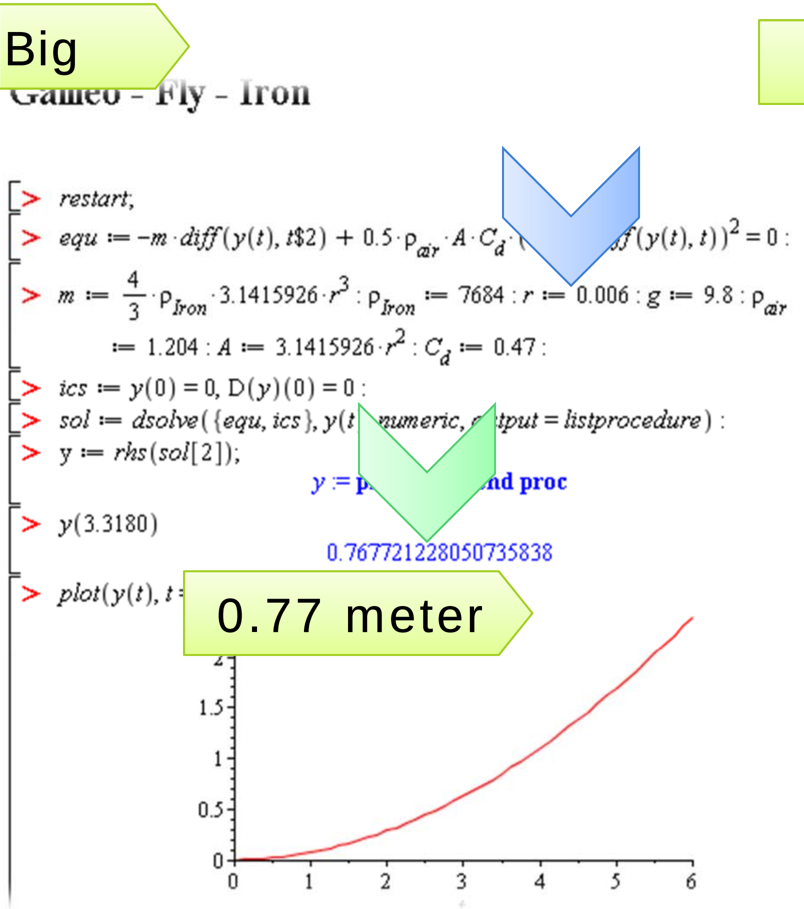
Lean angle 5.5 degree

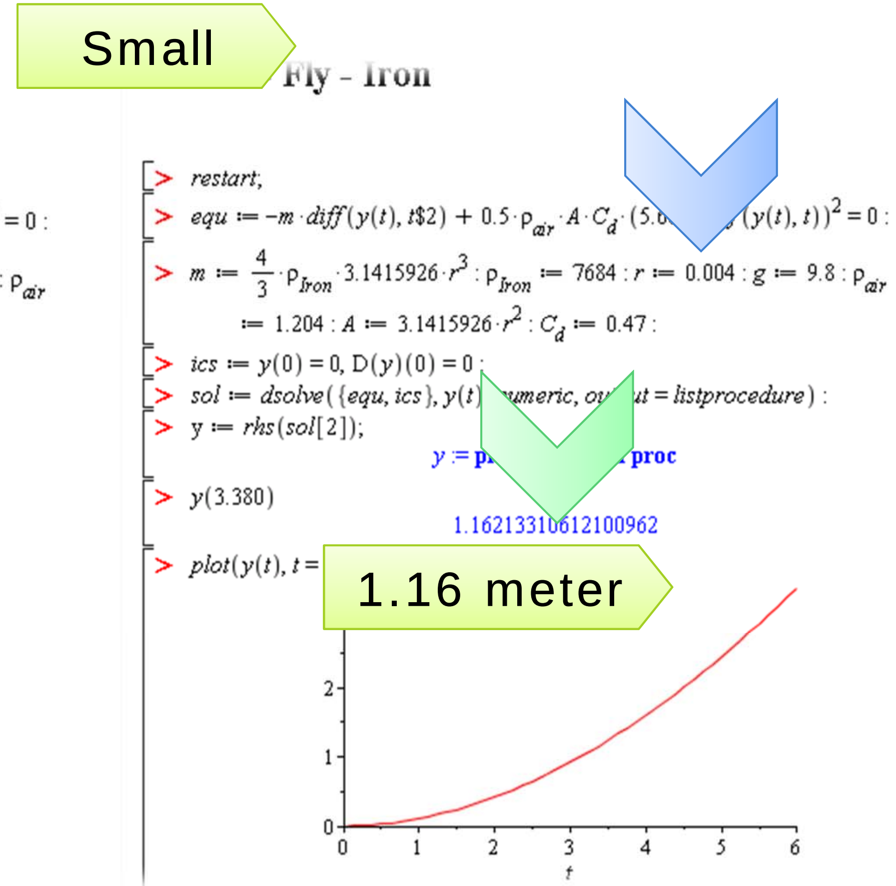
Height 50 meters

D = Height*tan(Lean angle)= 4.2 meters

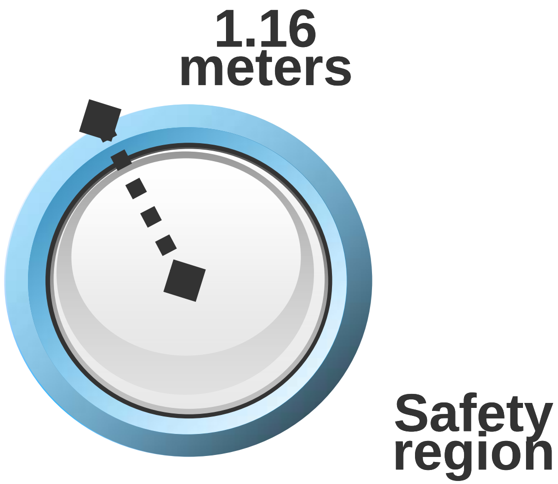
Small wooden ball 14.28 meters

How about an iron ball?





Safety region – Iron ball



Safety region – Iron ball

Lean angle
5.5 degree

Height 50 meter

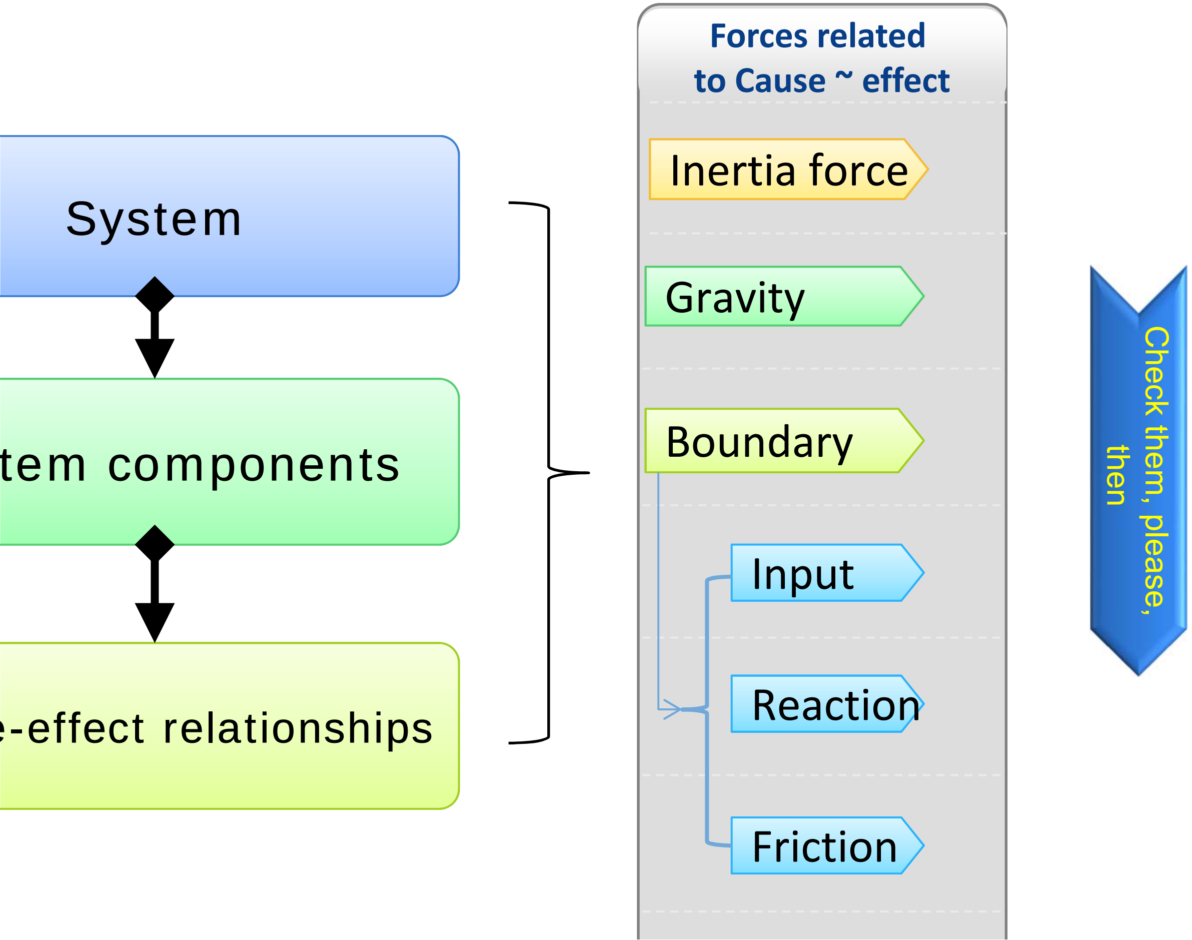
D = 4.2 meters

Small iron ball 1.16 meter

Now we know more about Galileo Galilei.
He is sure that the ball will reach the ground.

ummary

What did we learn



$$\sum F = 0$$
$$\sum M = 0$$

Workshop

IO2081 Modeling

Workshop P-W-2: The seesaw (wipwap)

Attention: Fiction case study, for education only

Design brief	A seesaw (also known as a teeter-totter or teeter board) is a long, narrow board pivoted in the middle so that, as one end goes up, the other goes down. (ref. http://en.wikipedia.org/wiki/Seesaw) Question: Ergonomics study indicates that when child starts to swing by kicking the ground, the force is about 100N force, the time is about 0.2 second. Specify the constant of the torsion spring to make sure the children can swing more than 5 times.
We choose	1. Two children (20kg) sit on each side, respectively; 2. We suppose the child is sit at the end of the board and the gravity center is on the board; 2. To simplify the question, we choose all rotation is around the center of the board; 3. The board is made by pinewood, the density is 700kg/m3 ; 4. The total length of the board is 4 meters, the width is 0.2 m and the thickness is 0.1 m; 5. At the center of the seesaw, there is friction torque 15Nm, and it always applied in the direction against the rotation; 6. Neglect the weight of the handle 7. Neglect the air friction

Courtesy of http://www.falco.nl/producten/spel-sport/

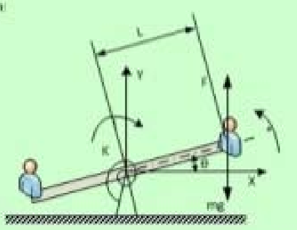
System

Board

Children System Spring

Earth Friction

Sketch:



ΣM=0

Cause	Mass of child	Mass of Board	Spring	Friction force	Input
Effect	Inertia force	Child goes down	Drags the board back	Slows the motion	Slows the motion

$$-2I_{child}\frac{d^2\theta(t)}{dt^2} - 2I_{board}\frac{d^2\theta(t)}{dt^2} - k\theta(t) - \begin{cases} f & \frac{d\theta(t)}{dt} > 0 \\ -f & \frac{d\theta(t)}{dt} \le 0 \end{cases} + F(t)L = 0$$

Solution
See Maple file P-W-2

Green line

Your choices?

Workshops: Questions & Coaching

Workshops: A sample question

Workshop G-W-0: The silde - Self-study

Courtesy of http://www.kidsplanetu

A child slides down from the top of a slide:

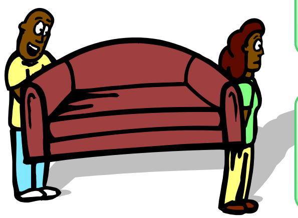
1. What is his speed at the bottom of the slide?

2. To guarantee the safety of the child, the maximum velocity of the child should b
degree)

We Choose

Slide:
The slide is straight, 5 meters long, leaning angle 30 degrees.
The slide is fixed on the ground, it surface friction coefficient 0.2.

Child:
Weight 20kg, He keeps still in the process.



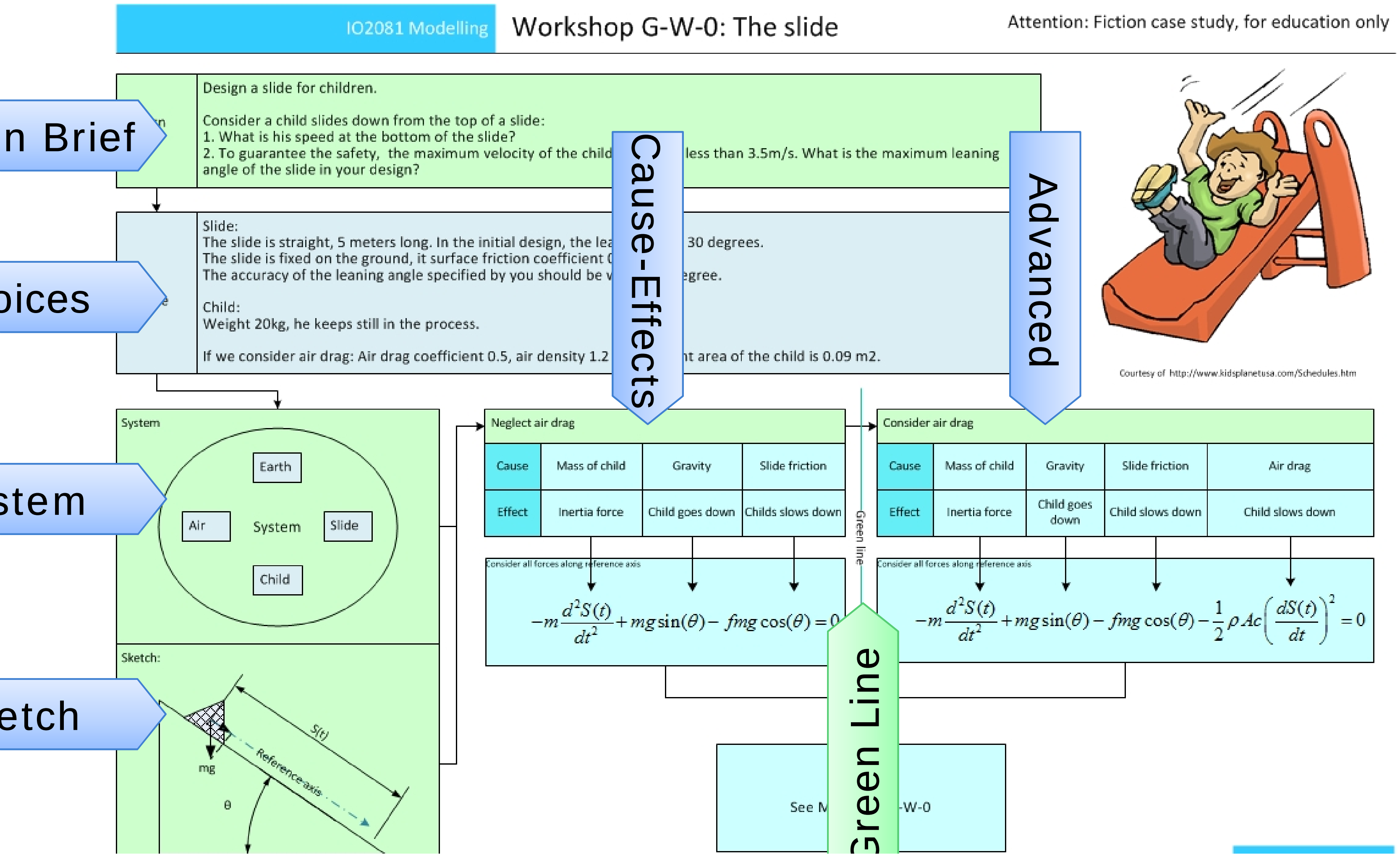
1 coach

1~2 TA(s)

Grading

0	•Not presented
0.5	•No progress
1	•Progressing

How to do it?



IO2081 Modelling
Workshop G-W-0: The slide
Attention: Fiction case study, for education only
n Brief
Design a slide for children.
Consider a child slides down from the top of a slide:
1. What is his speed at the bottom of the slide?
2. To guarantee the safety, the maximum velocity of the child
less than 3.5m/s. What is the maximum leaning
angle of the slide in your design?
oices
Slide:
The slide is straight, 5 meters long. In the initial design, the lea
30 degrees.
The slide is fixed on the ground, it surface friction coefficient
The accuracy of the leaning angle specified by you should be v
egree.
Child:
Weight 20kg, he keeps still in the process.
If we consider air drag: Air drag coefficient 0.5, air density 1.2
nt area of the child is 0.09 m2.
Cause-Effects
Advanced
Courtesy of http://www.kidsplanetusa.com/Schedules.htm
stem
System
Earth
Air
System
Slide
Child
Neglect air drag
Cause
Mass of child
Gravity
Slide friction
Effect
Inertia force
Child goes down
Childs slows down
Consider all forces along reference axis
$-m\frac{d^2S(t)}{dt^2}+mg\sin(\theta)-fmg\cos(\theta)=0$
Green line
Consider air drag
Cause
Mass of child
Gravity
Slide friction
Air drag
Effect
Inertia force
Child goes down
Child slows down
Child slows down
Consider all forces along reference axis
$-m\frac{d^2S(t)}{dt^2}+mg\sin(\theta)-fmg\cos(\theta)-\frac{1}{2}\rho Ac\left(\frac{dS(t)}{dt}\right)^2=0$
etch
Sketch:
S(t)
Reference axis
mg
θ
Green Line
See M
-W-0

G-W-0

Courtesy of http://www.kidsplanetusa.com/Schedules.htm

Design a slide for children.

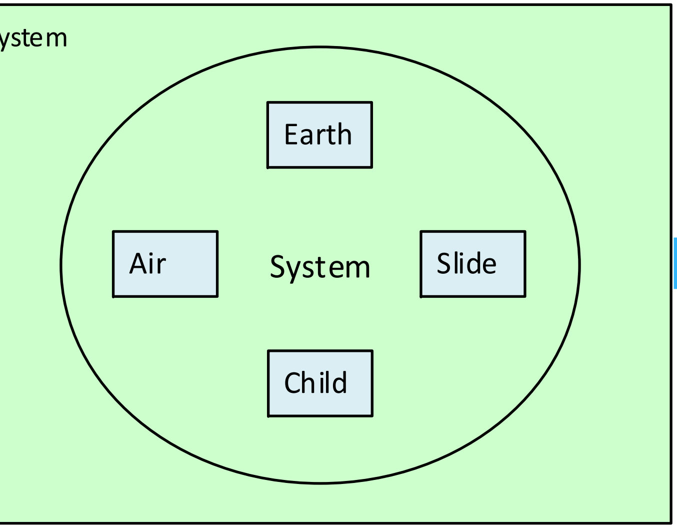
Consider a child slides down from the top of a slide:
1. What is his speed at the bottom of the slide?
2. To guarantee the safety, the maximum velocity of the child should be less than 3.5m/s. What is the maximum leaning angle of the slide in your design?

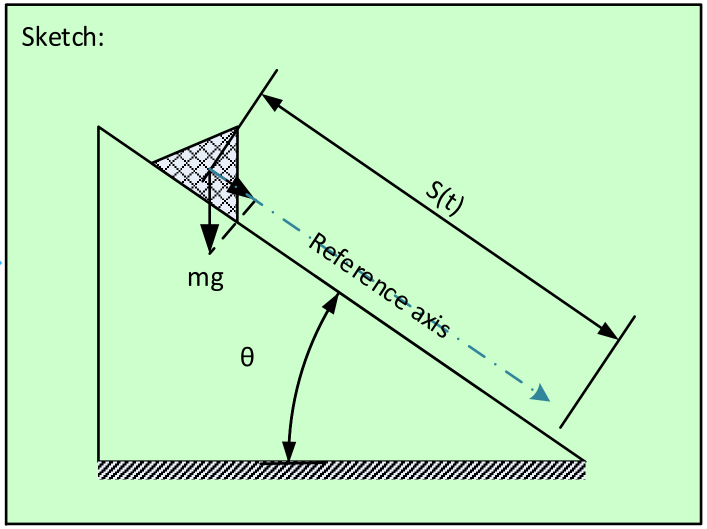
lide:
he slide is straight, 5 meters long. In the initial design, the leaning angle 30 degrees.
he slide is fixed on the ground, it surface friction coefficient 0.2.
he accuracy of the leaning angle specified by you should be within ±1 degree.

hild:
Veight 20kg, he keeps still in the process.

f we consider air drag: Air drag coefficient 0.5, air density 1.2 kg/m^3, front area of the child is 0.09 m2

G-W-0



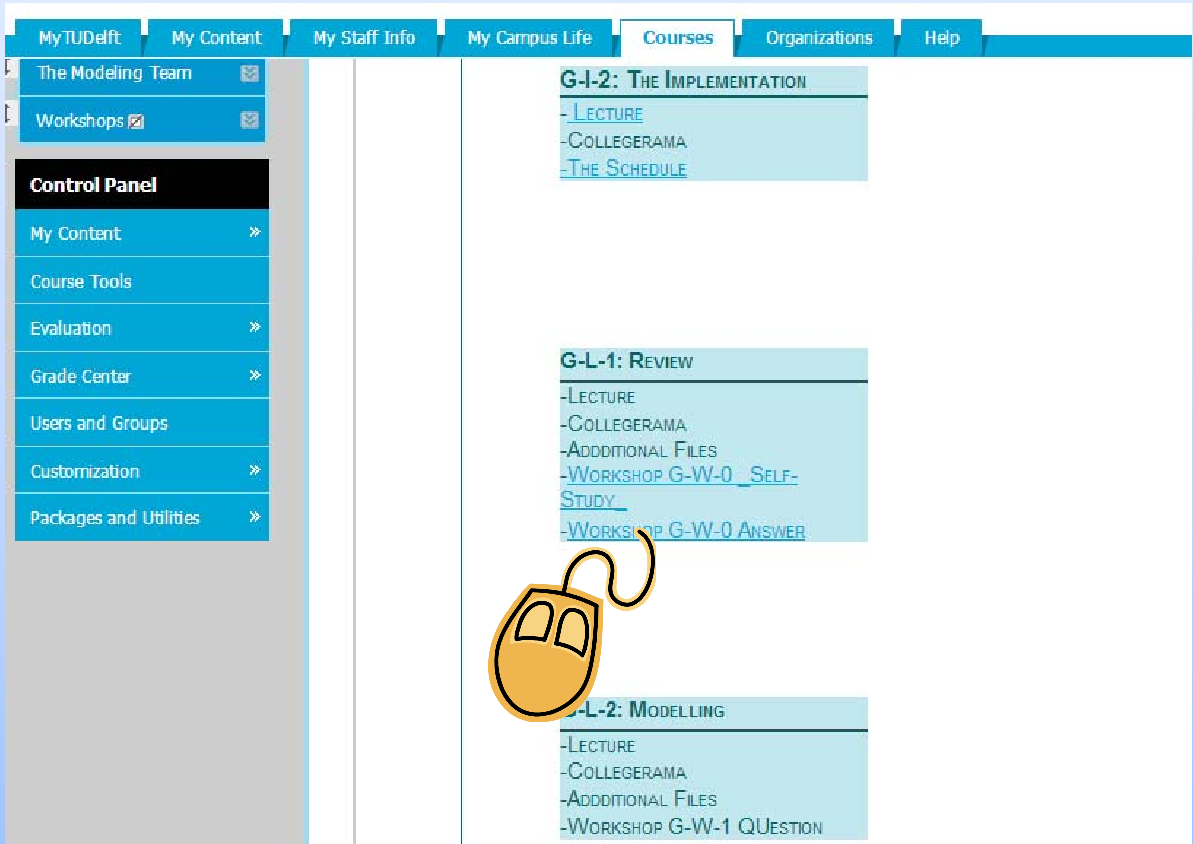


Consider air drag

Cause	Mass of child	Gravity	Slide friction	Air drag
Effect	Inertia force	Child goes down	Child slows down	Child slows down

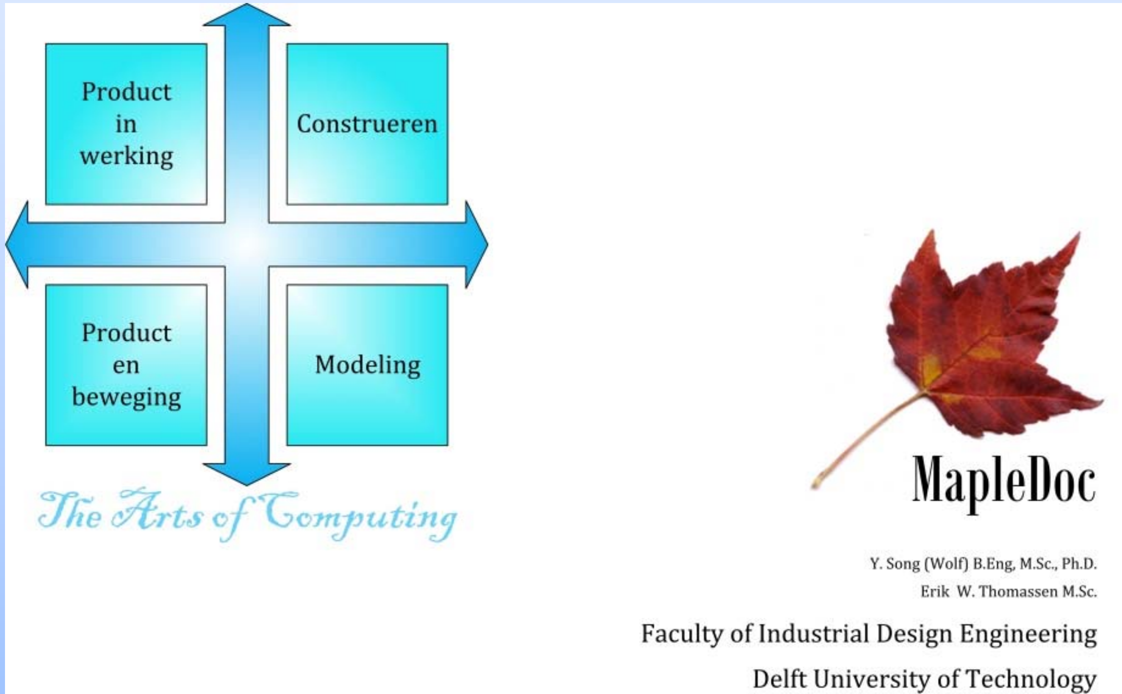
Consider all forces along reference axis

The Maple solution will be online after the workshop



Please check MapleDoc

The MapleDoc



Demo

Maple Demo

Do and Don't

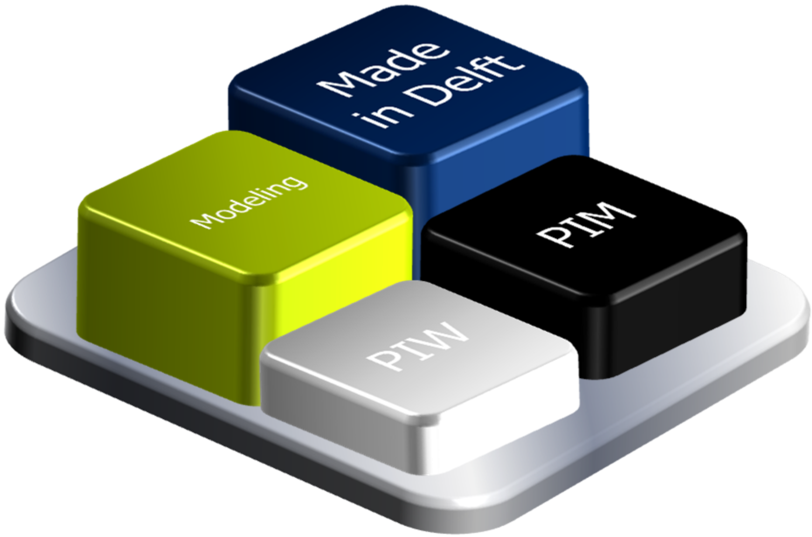
Maple Demo

Workshop G-W-0

G-W-0

Practice G-W-0 by yourself, please

Thank You!



The Modelling Team
Department of Design Engineering
Faculty of Industrial Design Engineering

njoy Sunshine, Enjoy Modelling

hen the spring is coming, Modelling is coming