NRW-FAIR Netzwerk

NETZWERK TEILCHENWELT

Theory Masterclass

About Newton, simulations and undetectable planets.

The original idea

- Original is from an extracurricular programme offered by Forschungsinstitut Jülich
- Target group: Secondary school pupils interested in physics
- Embedded in an intensive examination of physics
- Paper (English): https://arxiv.org/pdf/1803.01678.pdf (Note: code has a small bug with vector multiplication)

What we want to achieve

- Differentiation from school lessons
- Insights into the work of theoretical physics
- Develop an understanding of models
- Develop an understanding of physics simulations

Challenges

- Python and programming (and IT)
- Mathematics
- Prior knowledge for nationwide heterogeneous groups
- Infrastructure in schools

Necessary infrastructure

- Room with projector (for presentations)
- At least one laptop for every two participants...
  - ... with Python, Vpython and material pre-installed, or...
  - ... with internet and admin rights.
- A tablet or smartphone is not enough!
- Optionally, if there is no internet on the laptops, a smartphone or tablet with internet access.

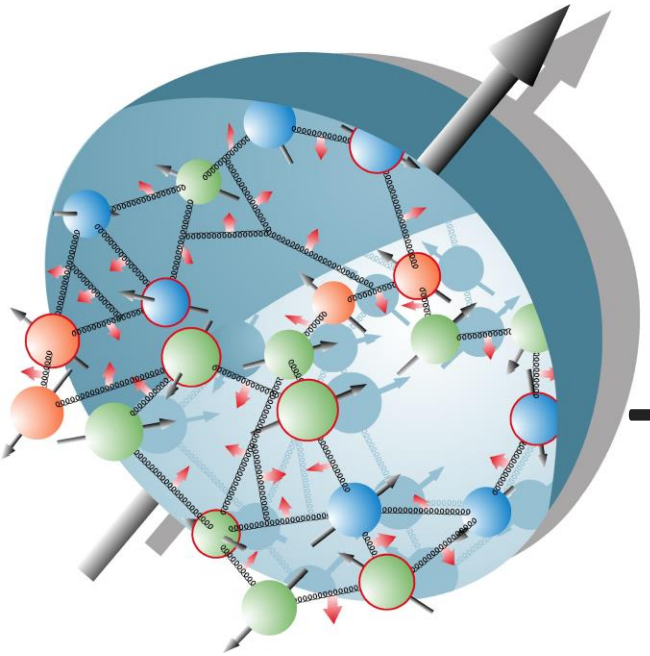
How does the Masterclass proceed?

Part 1 - Morning (approx. 3h)

- Introductory lecture
- Python crash course
- Why actually... numerics?

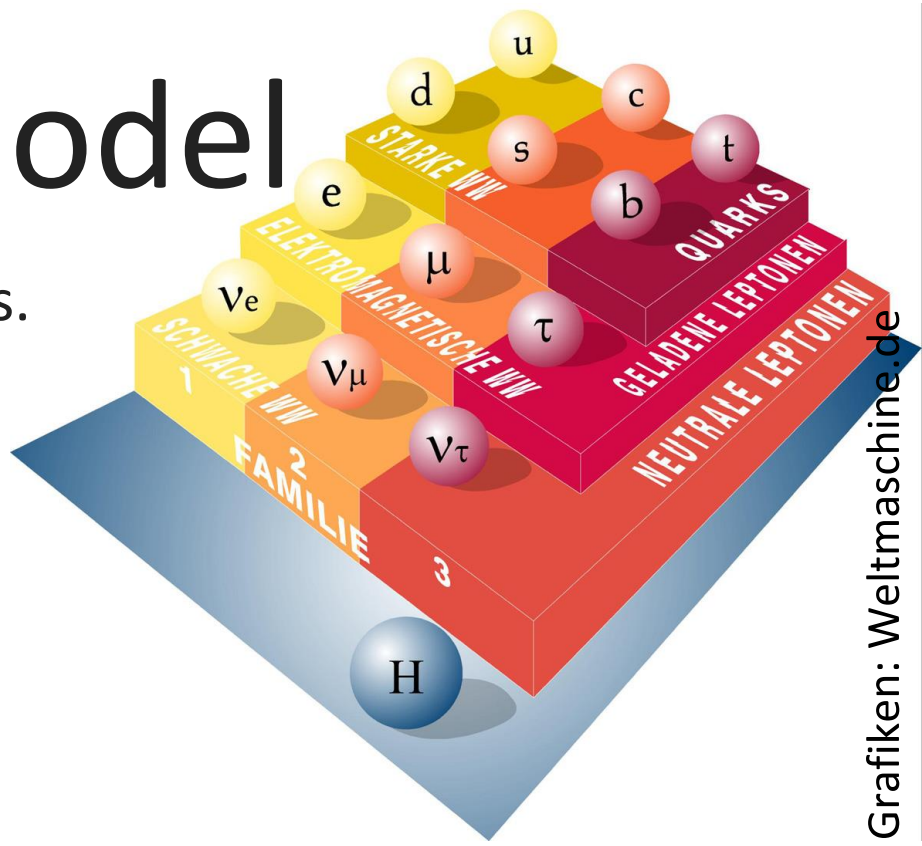
Part 2 - Afternoon (about 3h)

- First simulation with Python
- Prediction vs. reality
- And now comes Einstein!



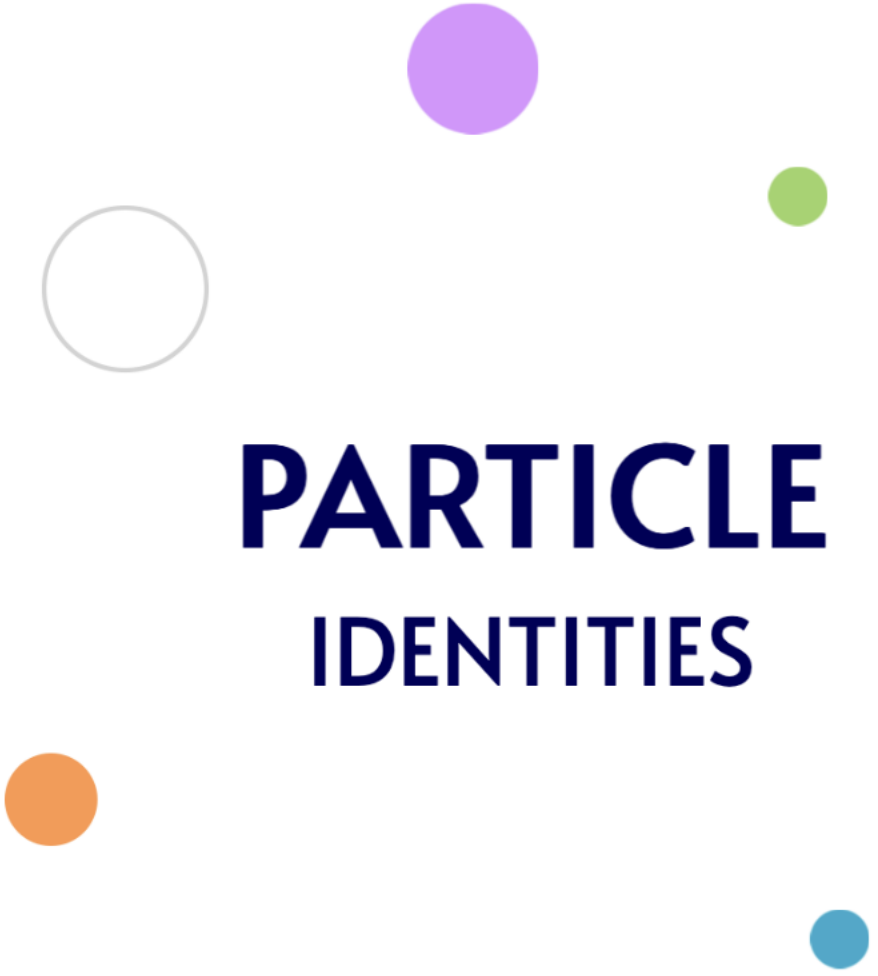
The standard model

The centre of particle physics.



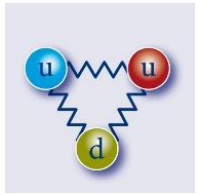
Grafiken: Weltmaschine.de

Teilchen Persönlichkeitstest!

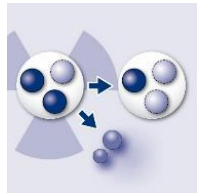


Wechselwirkungen im Überblick

- Electromagnetic interaction



- Strong interaction



- Weak interaction

Interactions are used as a transition to gravity.

PAUSE (for the pupils)

Research

and how it (doesn't) work.

Scientific models

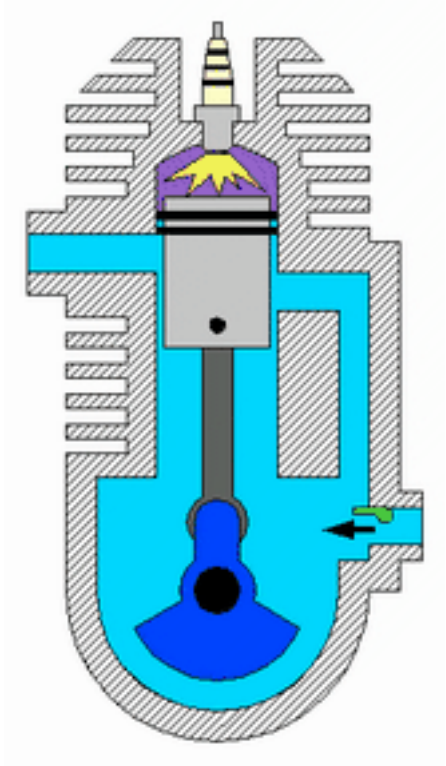
Model level I (GROSSLIGHT et al. (1991))

Model of Frankfurt's Old Town 1926

- Typically for entertainment
- Copy of reality or an action
- Difference between reality and model not to be explicitly named

Scientific models

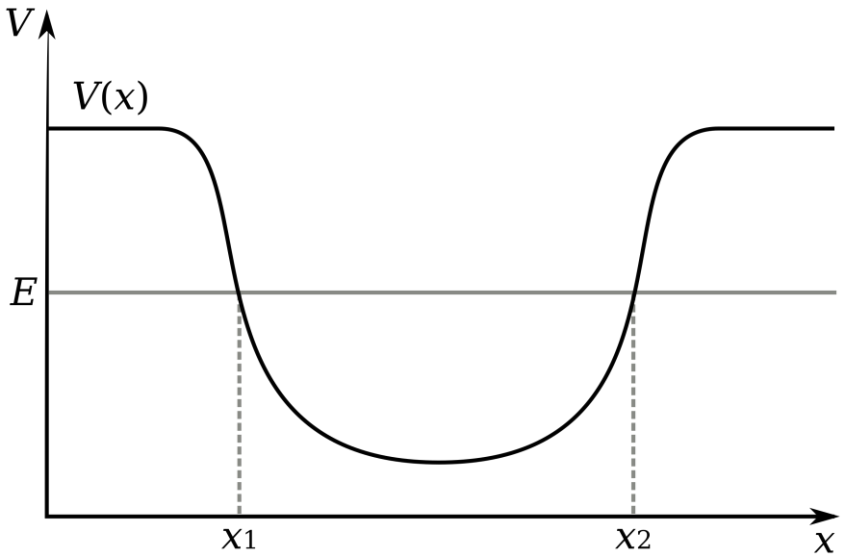
Model level II (nach GROSSLIGHT et al. (1991))



- Typically for teaching purposes
- Model serves a specific purpose
- Adding symbols, simplifications, etc.
- Still recognisable representation of reality

Scientific models

Model level III (nach GROSSLIGHT et al. (1991))



Potential pot in one dimension

- Typically scientific
- Represents idea and can be tested
- was created for a specific purpose
- can be adapted or extended
- allows predictions

Other examples are numerical models, formulae or axioms.

Scientific models

Model level I

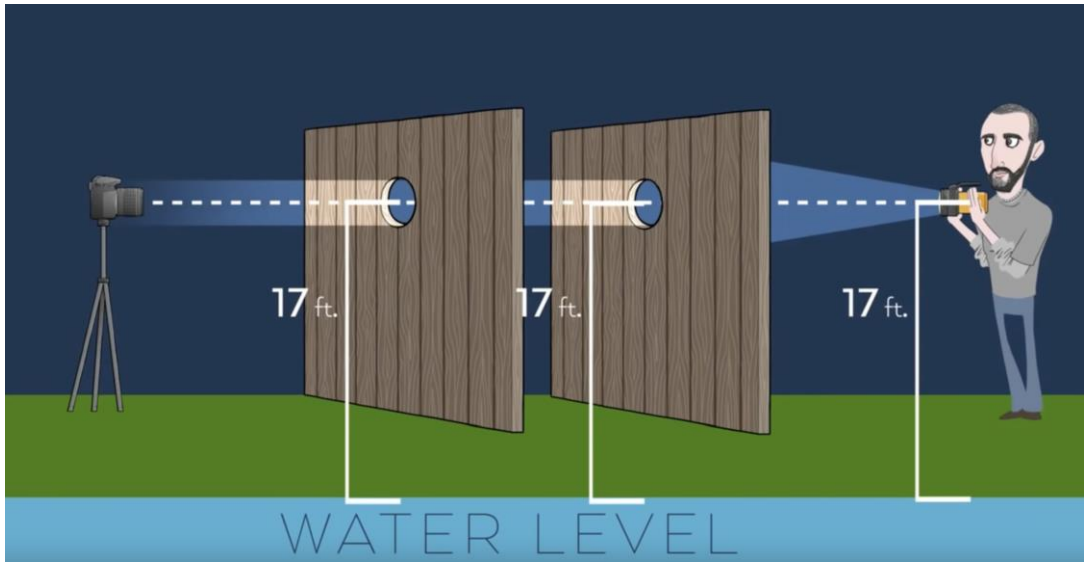
Model level II

Model level III

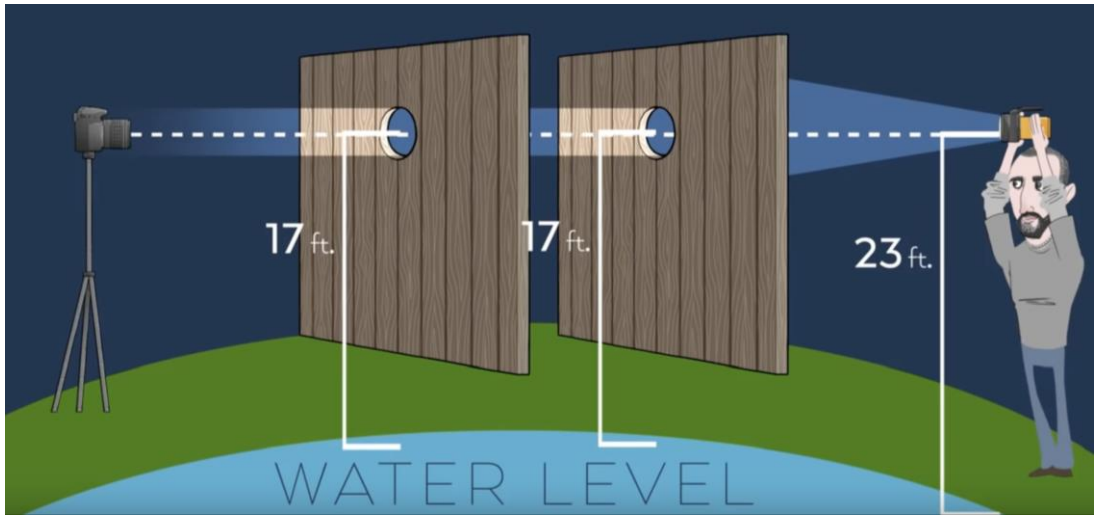
Tangible, easy to visualise, entertaining

Abstract, suitable for science

Example of good science



Predictions using models (Flat Earth vs. Globe)



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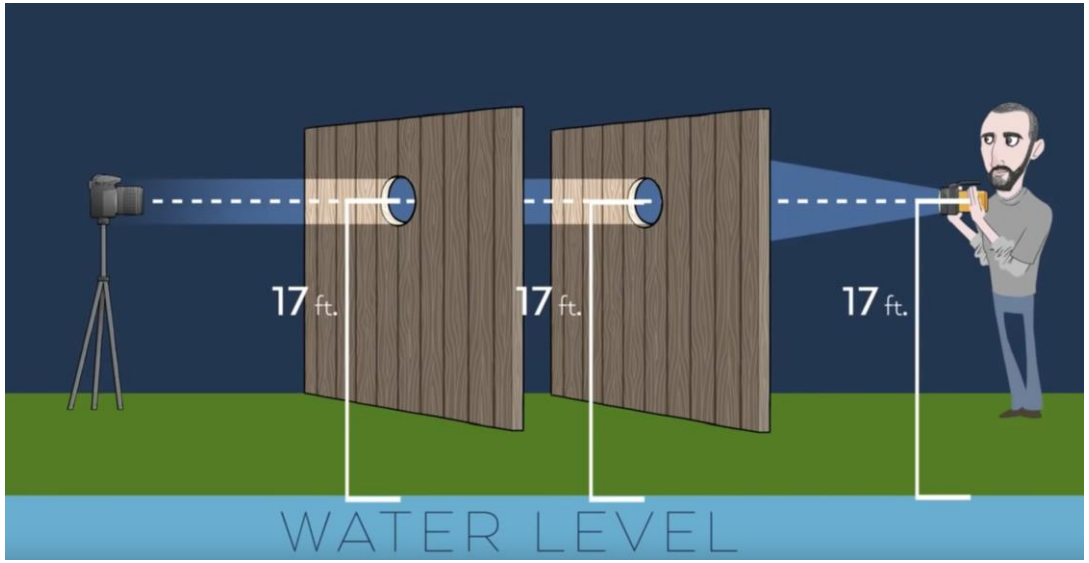

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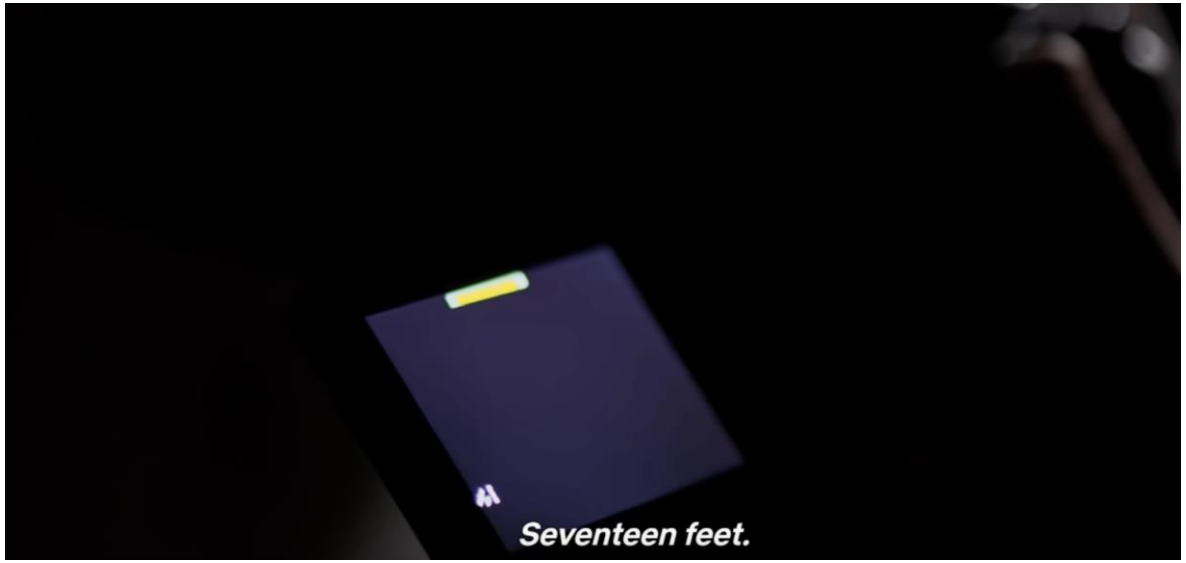
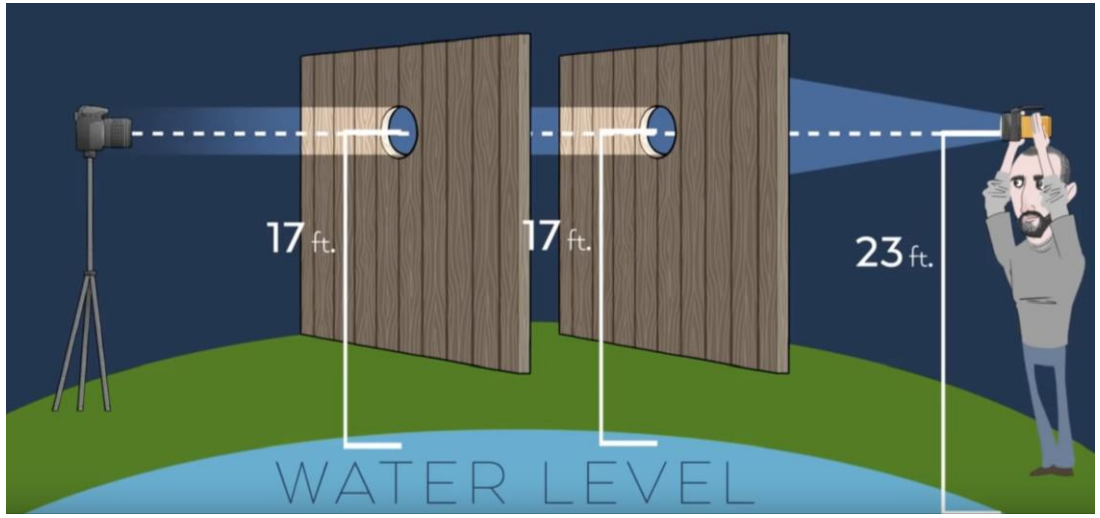
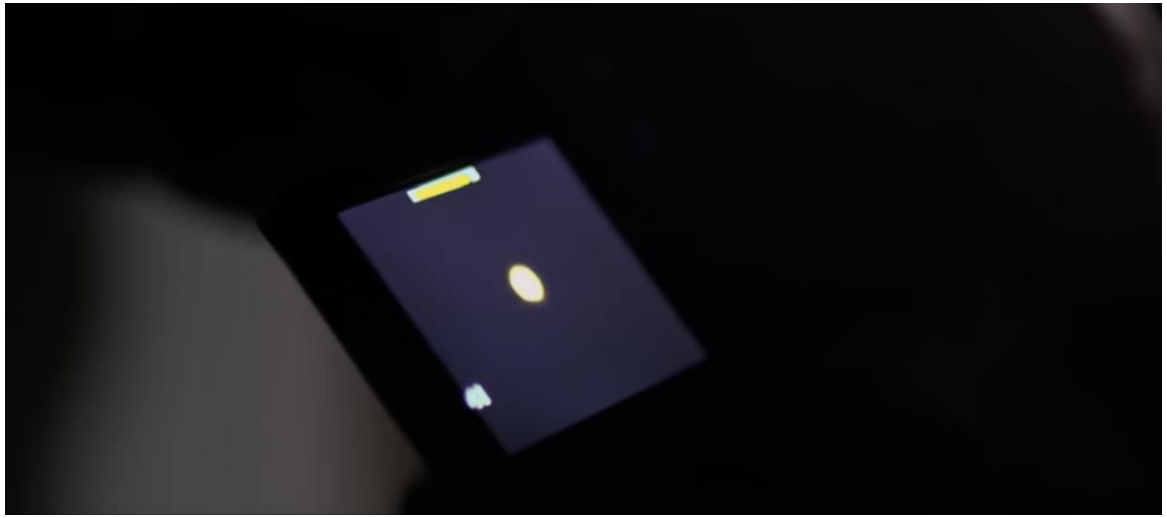
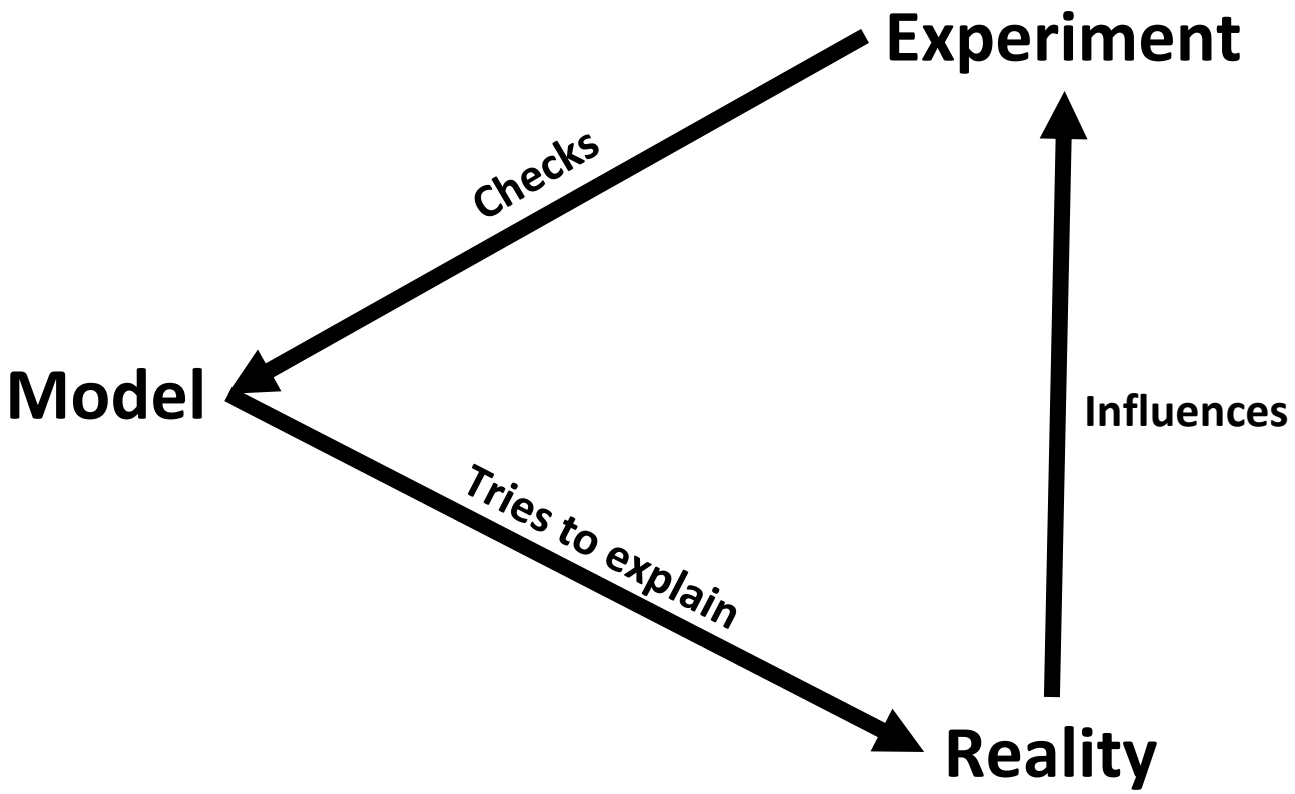


Carrying out experiments to test the model





Simplified …


Experiment
Checks
Model
Influences
Tries to explain
Reality

Who is Isaac Newton?

- Lived from 1642-1726
- Worked in England
- Studied physics, astronomy and mathematics
- Laid the foundations for classical mechanics

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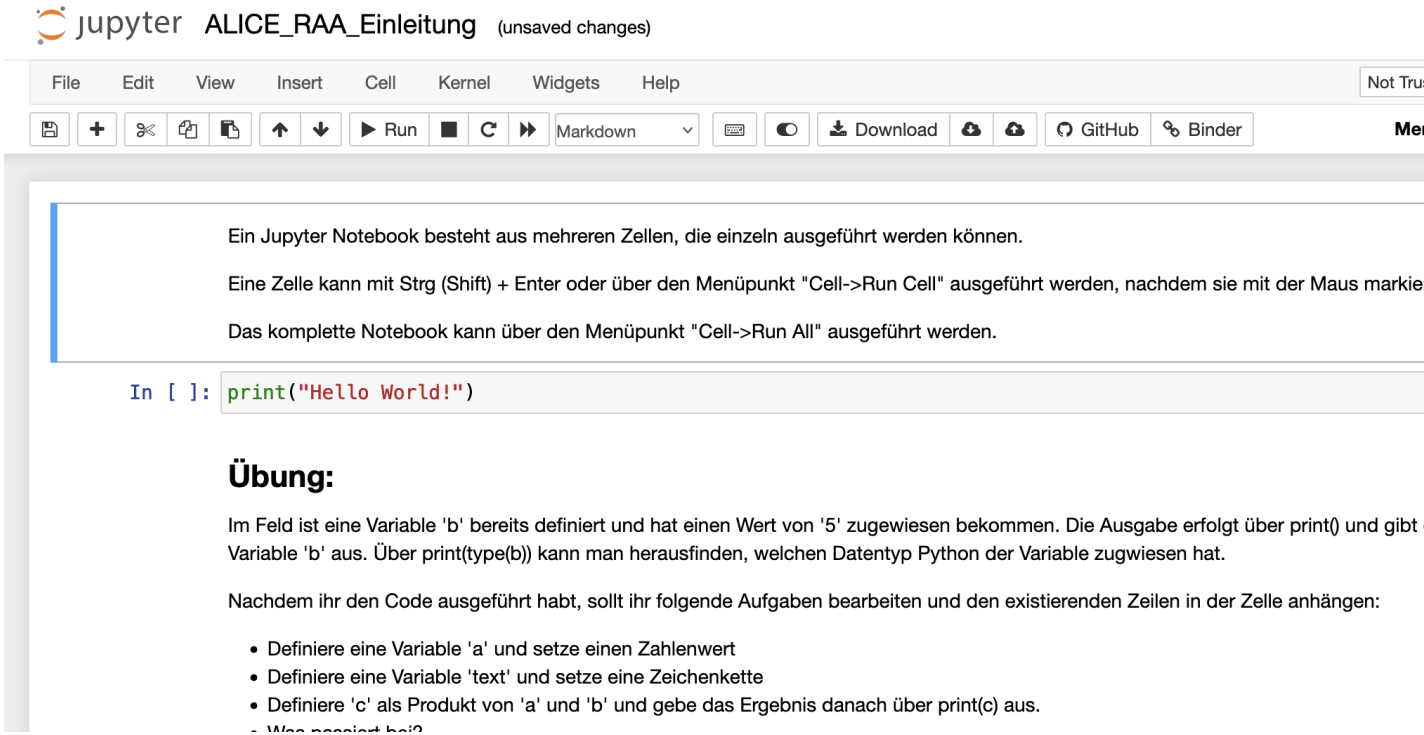
Python 101 (German)



tinyurl.com/mrcwbubx

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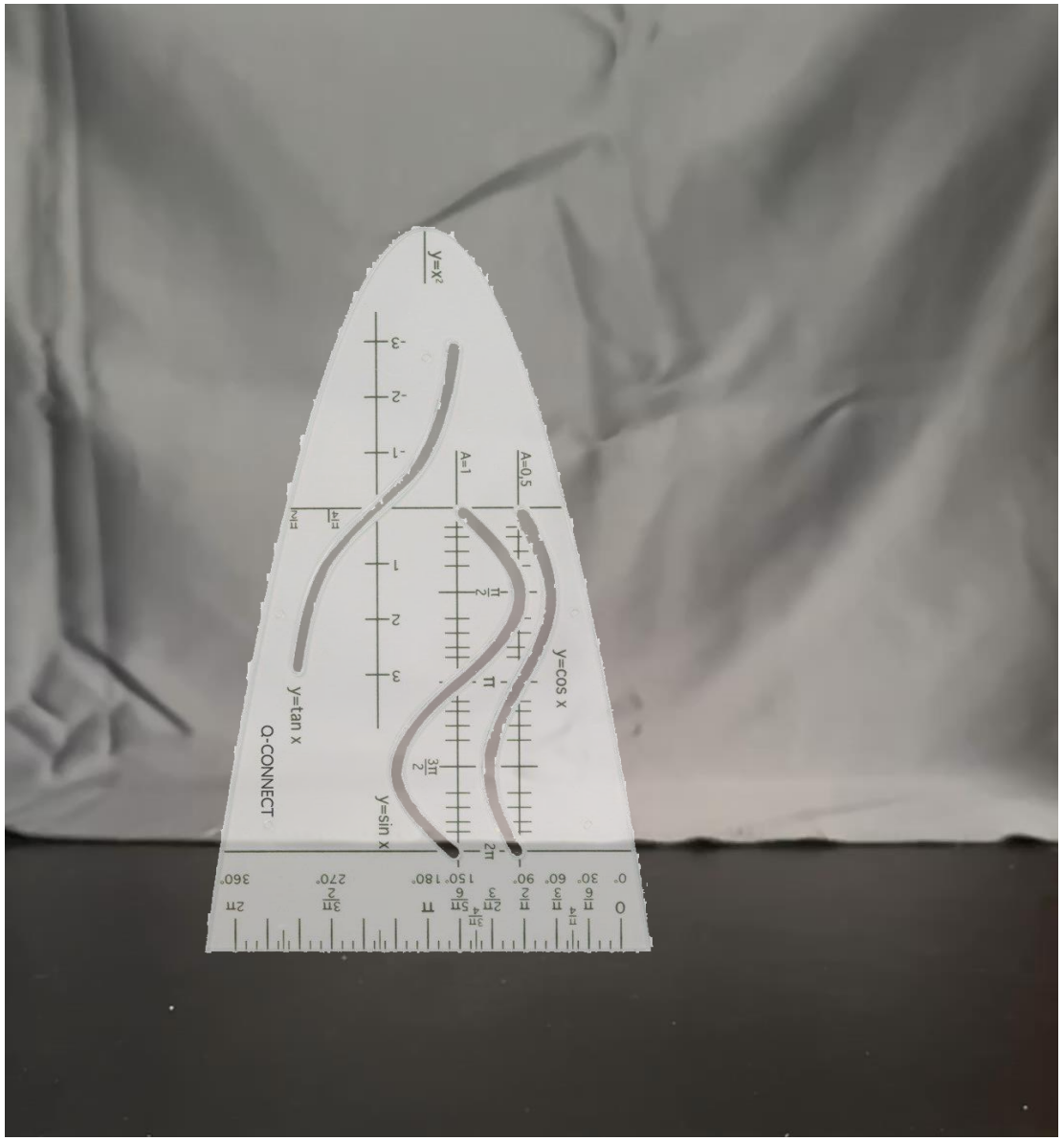
Example throwing parabola



Repetition:

$$x(t) = v_0 \cdot t + x_0$$

$$\mathrm{v}(t) = a_0 \cdot t + v_0$$

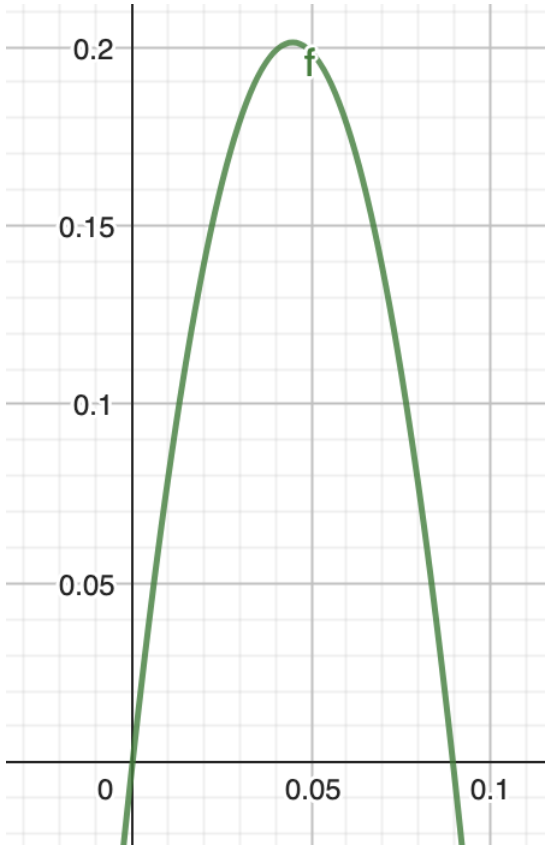
and

$$F = m \cdot a$$

Deliberate avoidance of derivations, but this connection can be added (if course has prior knowledge).

Two ways to the same solution

Closed solution

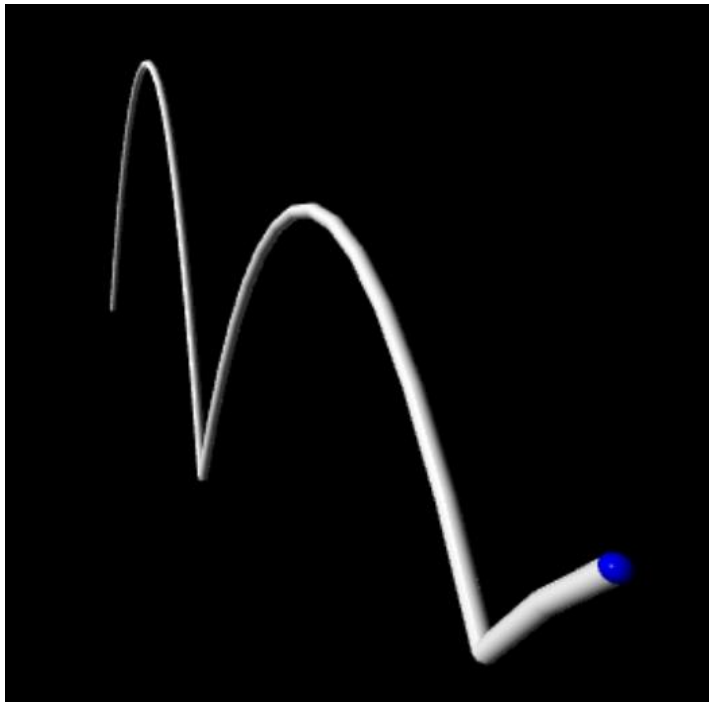


$$f\colon y = -\frac{1}{2} \cdot \frac{g}{(2 \cdot \cos(60°))^2} \cdot x^2 + \tan(60°) \cdot x + 0$$

In this example, both methods are

methods are equivalent!

Numerical solution

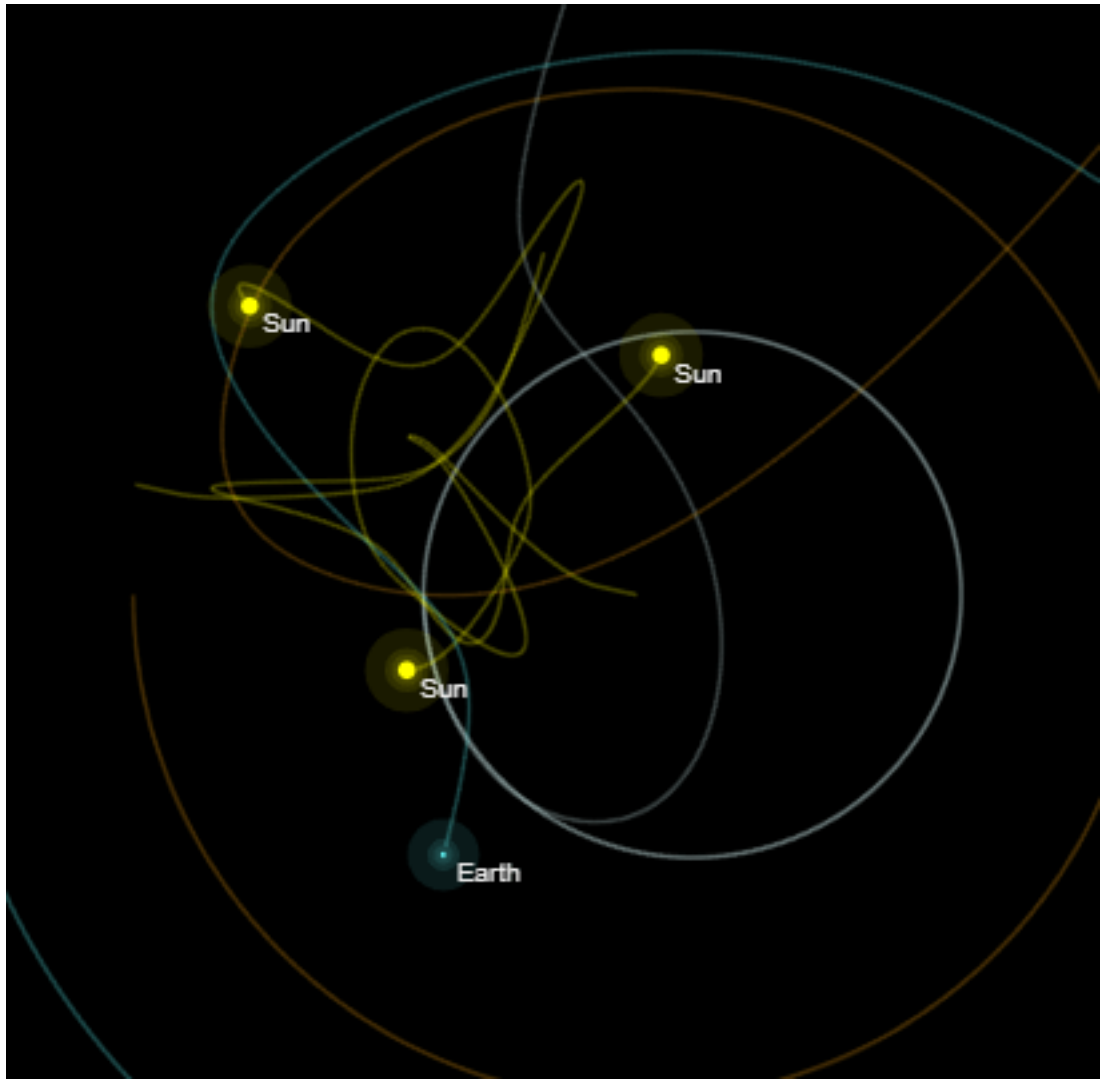


```
30      Ball.velocity = Erdbeschleunigung * Zeit + Ball.velocity
31      Ball.pos = Ball.velocity * Zeit + Ball.pos
```

Two ways to the same solution

Closed formula for a star system with three suns
does not have a closed formula as a (general) solution!

Only a numerical simulation (even a simple one) is possible here.



Reddit: svdh000

In particle physics

Typically ‘Monte Carlo’ simulations

- Random numbers are chosen as the basis for the calculations.
- Good example: ‘Pi dice’

$$A_{Circle} = \pi * r^2$$

$$A_{Square} = a^2$$

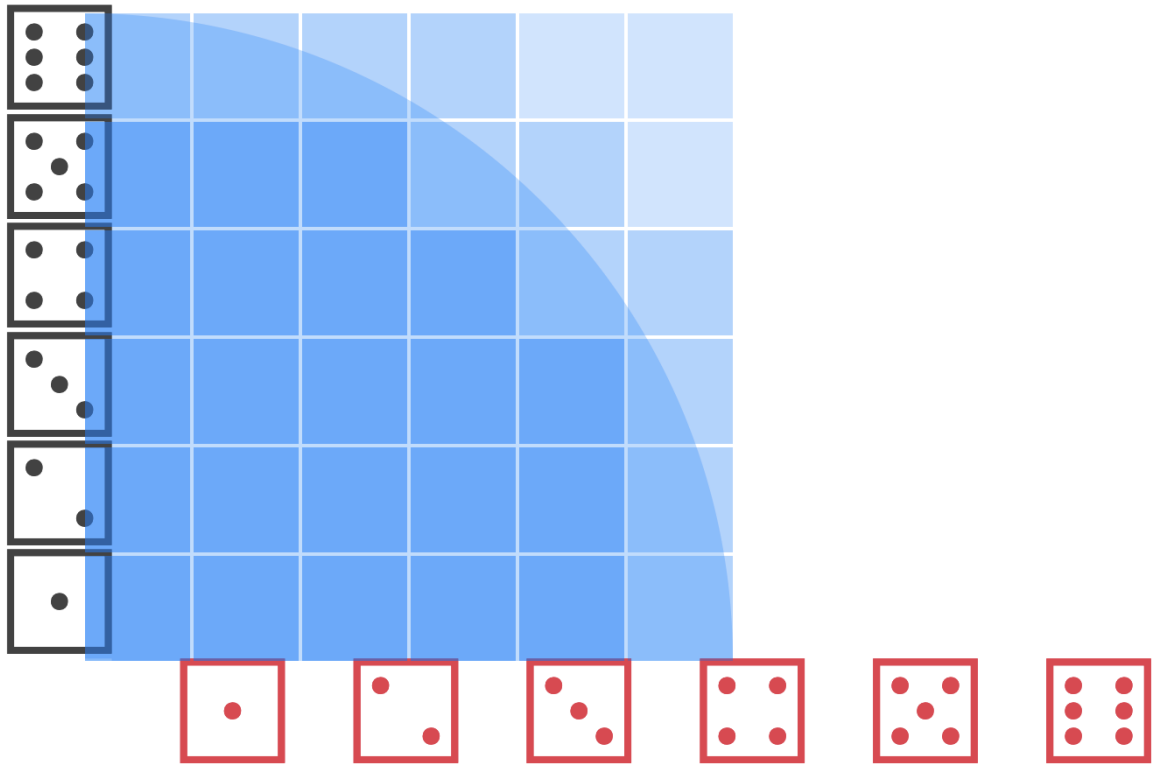
With $a = r = 1$:

$$A_{Circle} = \pi$$

$$A_{Square} = 1$$

Here it is a quarter square, hence:

$$\frac{A_{Quarter\_Circle} \cdot 4}{A_{Quadrat}} = \pi$$



http://www.dorfuchs.de/pi-wuerfeln

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