Philipps Universität Marburg

The Collection of Mathematical Models of Marburg University

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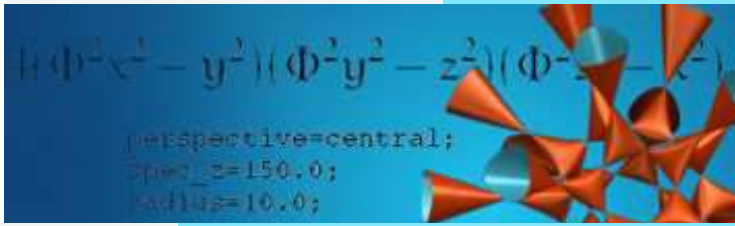


May 2017, Universität Hannover

Marburg: An old traditional university. . .

- Founded in 1527 by Philip I, Landgrave of Hesse (he embraced Protestantism in 1524 after a personal meeting with Philipp Melanchthon)

- oldest protestant university in the world

- hosted the 'Marburg Colloquy' ('Marburger Religionsgespräch') in 1529, attended by: Luther, Zwingli, Melanchthon, Agricola, Brenz, Bucer, Osiander. . .

The university owns 6 museums, 2 botanical gardens, and 26 scientific collections, including

- Deutscher Sprachatlas
- Dt. Dokumentationszentrum für Kunstgeschichte – Bildarchiv Foto Marburg
- Hessisches Staatsarchiv Marburg, Lichtbildarchiv älterer Originalurkunden
- Emil-von-Behring-Archiv

Museum für Kunst und Kulturgeschichte

Antikelsammlung

Karzer

Museum Anatonicum

Problems & questions :

- the university lacks staff, budget, PR (compared to a state museum)
- huge amount of valuable exhibits, some in very poor condition, scattered all around the city in ‘Faculty Collections’
- what is the purpose of each scientific collection?
- how to achieve visibility & legitimacy?

An old Faculty. . . in an ugly new building

Gallery of former professors
of mathematics

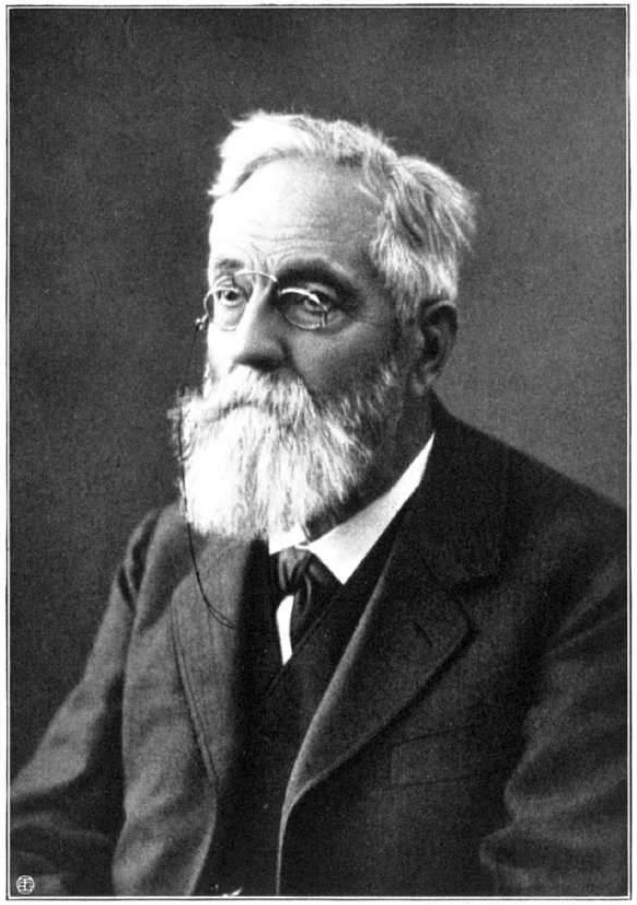
'Mehrzweckgebäude', domicile of Faculty
and Collection on Lahnberge since 1970

Moves are the most important natural enemy of any collection!

Das ‘Mathematische Seminar’

Mathematics was taught in Marburg since the foundation of the university 1527 (Papin, Wolff. . .).

- 1817: Foundation of the ‘Mathematisch-physikalisches Institut’ by Christian Gerling
- 1885: Foudation of the Faculty by H. Weber (‘normal subgroups’, thm of Kronecker-Weber on algebraic number fields)
- The Collection of Mathematical Models was founded (or rather, separated from the Physical Collection) and slowly enlarged
- The university had then about 1 000 students, mathematics: 10–30 students. Summer 1904: approx. 75 students.
- A few plaster and cardboard models are still preserved from this time
- With Bourbaki, the Collection was dissolved and partially destroyed around 1960



After decades of decline: A new start in 2008

The decision to revive the Collection and its first 'budget' were part of my negotiations for the appointment of full professor in 2008.

Situation:

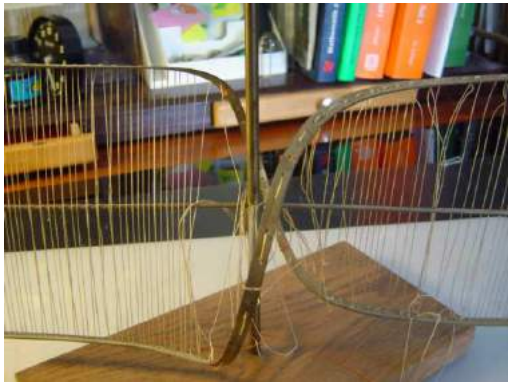
- no inventory, no show cases
- a few models scattered around in the library, storerooms, offices, homes. . .
- some experience from my reconstruction of the Collection of Humboldt University

Quotes from 2008:

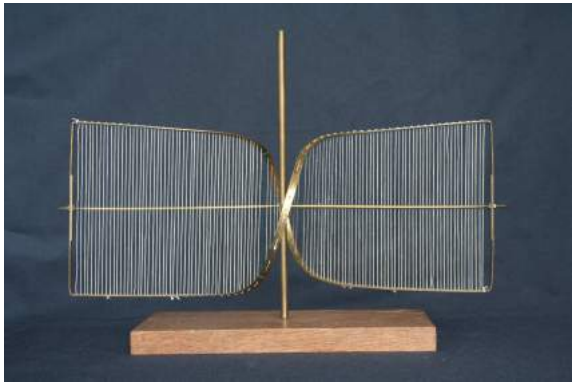
„What Collection are you talking about?“ — „You mean the old dust catchers in the library, what do you want with them?“ — „Yes, we used to have a lot, but I think it got lost.“

First steps: Gathering together & executing small repairs

A ruled surface



before



after

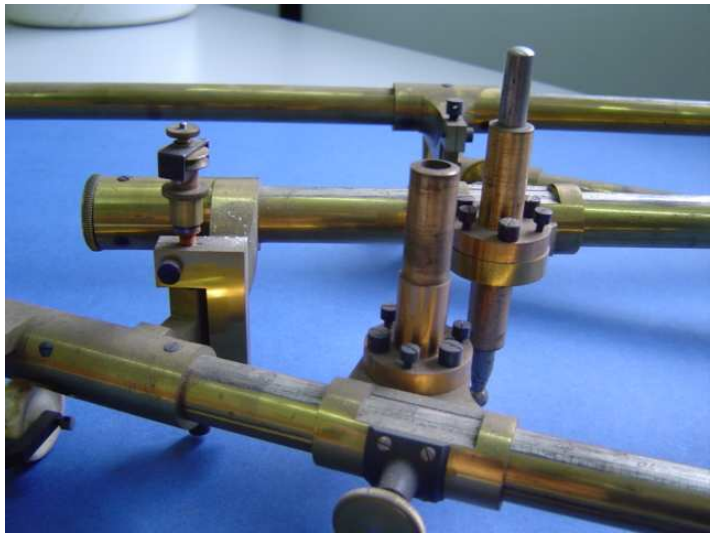
Schilling models from around 1880

quadrics

cubic surface with
four double points A1

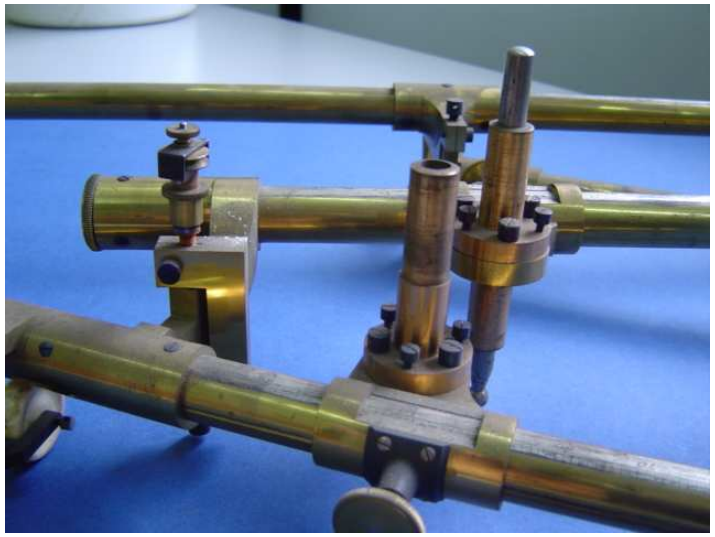
helicoidal surface
of a tractrix

An example: The story of a an exhibit



What is this and does it still work?

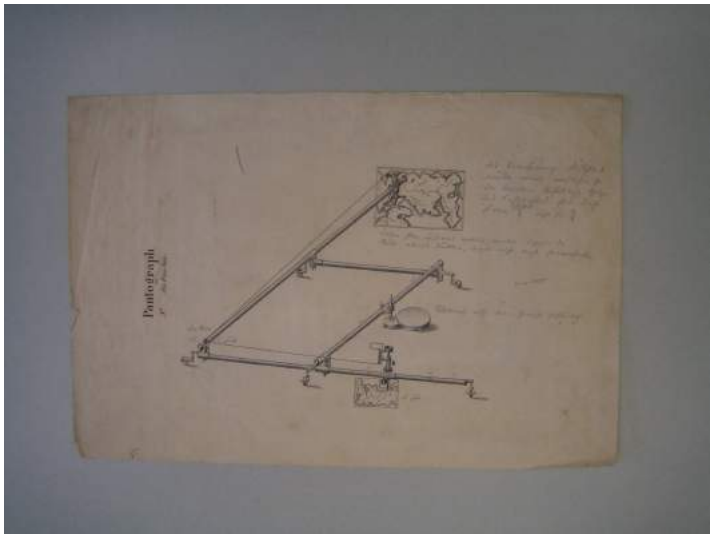
An example: The story of a an exhibit

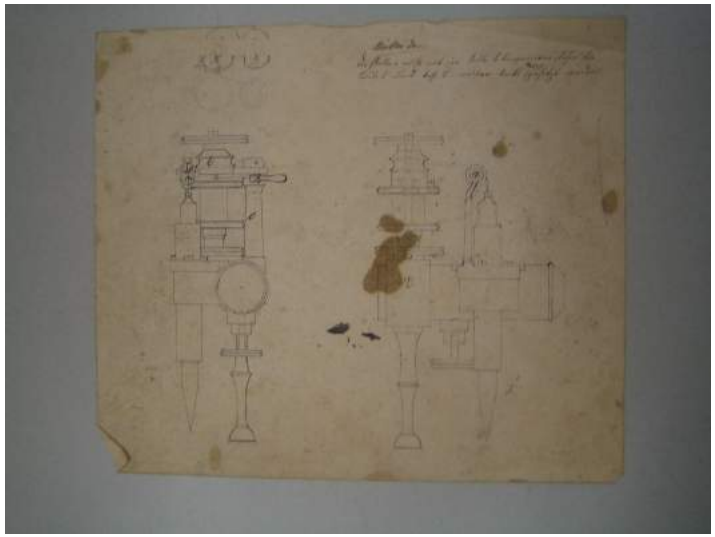


- This is a pantograph („Storchenschnabel“, „Allesschreiber“)
- yes, it looks complete but it needs serious restoration
- a tiny inscription says „Klebe 1866“:
- 1866 – this is before the foundation of the Faculty?
- and before the introduction of the „Deutsche Industrie-Norm DIN“ (1917), hence the screws are not standardized

Excursion I: The archive of the 'Astronomisch-Physikalisches Kabinett' in Kassel

Here, we found several construction drawings showing an identical instrument:





$\Rightarrow$ the manufacturer was Firma Breithaupt in Kassel, still a small, but world leading company of precision measurement instruments (founded 1762), furnisher of Gauß, Gerling et. al. The date 1866 is confirmed, and Breithaupt had indeed a constructing engineer of the name Klebe in that time.

The instrument turns out to be rather valuable, hence a professional restoration is indicated – how did it join the Faculty of Mathematics?

Excursion II: The archive of Marburg University

In order to find out more about the history of all old exhibits, an assistant digs through the old account books of the Faculty, and finds:

- 1932: Purchase of a few used instruments from the Faculty of Physics and the Faculty of Geography, amongst others, a Breithaupt pantograph and two Breithaupt theodolites.

In his account on the 100th birthday of the Faculty, Prof. Karl-Bernhard Gundlach writes:

„Die Ära Hensel war zwar mit seiner Emeritierung im Wintersemester 1928/29 zu Ende gegangen, er erhielt aber in seinem Schüler Helmut Hasse einen würdigen Nachfolger. Hasse, der sein Amt zum 1.4.1930 antrat, konnte die Einrichtung einer zweiten Assistentenstelle durchsetzen. Auch 400 Mark für die Beschaffung einer Schreibmaschine wurden ihm zugesagt. Die räumlichen Verhältnisse blieben jedoch weiter beengt. Hasse mußte sein Arbeitszimmer offensichtlich mit dem Assistenten teilen, denn in dem Schriftwechsel mit dem Kurator über die Renovierung wird ausdrücklich ein zweiter Steckkontakt für den Arbeitsplatz des Assistenten in diesem Zimmer erwähnt.

Die allgemeine Dürftigkeit der Ausstattung wird auch durch einen Antrag von Maximilian Krafft vom 6. Juli 1932 beleuchtet. Krafft führte aus, es gäbe keine Ausbildungsmöglichkeit in geodätischen und astronomischen Beobachtungsmethoden. Das physikalische und das geographische Institut hätten jedoch Instrumente, die zwar größtenteils aus kurhessischer Zeit stammten, aber nach Instandsetzung noch brauchbar seien. Für die Instandsetzung und einige Neuanschaffungen beantragte er 535 Mark. In der Tat erhielt das Seminar eine Reihe älterer Instrumente, von denen besonders ein Breithauptscher Pantograph erwähnt wurde. Durch die Hilfe des Universitätsbundes konnten ein Sextant und ein Theodolith beschafft werden.“

K.-B. Gundlach, *100 Jahre Mathematisches Seminar – Ein Rückblick auf die Entwicklung der Mathematik in Marburg*

- Maximilian Krafft: professor of ‘applied’ math in Marburg 1926–1956 – meaning geodesy, theoretical astronomy, ‘practical’ calculus (‘praktische Analysis’); for further anecdotes, see:

`https://www.uni-marburg.de/fb12/historie/zeitzeugen/mathe-profs`

After restoration: Again in use in 2011

About the mathematics (how does it work?): later. Actually, it's an easy application of the incidende theorems ('Strahlensätze')

What is the purpose of the Collection?

One can have many wishes. . . but only limited time and money, and the purpose should also convince those who don't like to play.

- Our Collection is **not** a museum, although it has a few valuable exhibits

- It's main purpose is to **support teaching** for students of mathematics, computer science, and physics (bachelor, teaching degree for secondary schools)

Remarks on teaching:

- Mathematics and Computer Science differ from all other natural sciences by not being laboratory based — after all, the main advantage of mathematics is its abstraction!

$\Rightarrow$ What can models teach that is not part of normal courses?

- The Collection should be perceived as being an integral part of the Faculty; in particular, no changes of curricula should be necessary

Therefore, the Collection consists mainly of:

- An exhibition in the Faculty — for raising awareness, for a few hands on activities, and also for having more space in the workshop
- a workshop ('Werkstatt') where t.a.'s can work, make repairs, and where models are stored / can be loaned for courses
- Purchase / construction of exhibits mainly **for teaching purposes**
- An ever growing online catalogue — for the general public and for our own lecturers
- the **'Mathematical Model Seminar'** – this is the most important pillar of the Collection, with many follow-up activities
- Outreach activities of many kinds

Remarks:

– The Collection is never static, but undergoes permanent changes!

– Involve students as much as possible! It's for them. . . and you don't achieve much without them

The exhibition

What are the most valuable pieces of the exhibition, and those requiring the largest amount of work?

The exhibition

the showcases!

Standard showcases are often not solid and large enough; ‘museum level’ show cases are usually unaffordable

$\Rightarrow$ need to rely on donations!

RHS: From the Hessisches Landesmuseum Kassel.

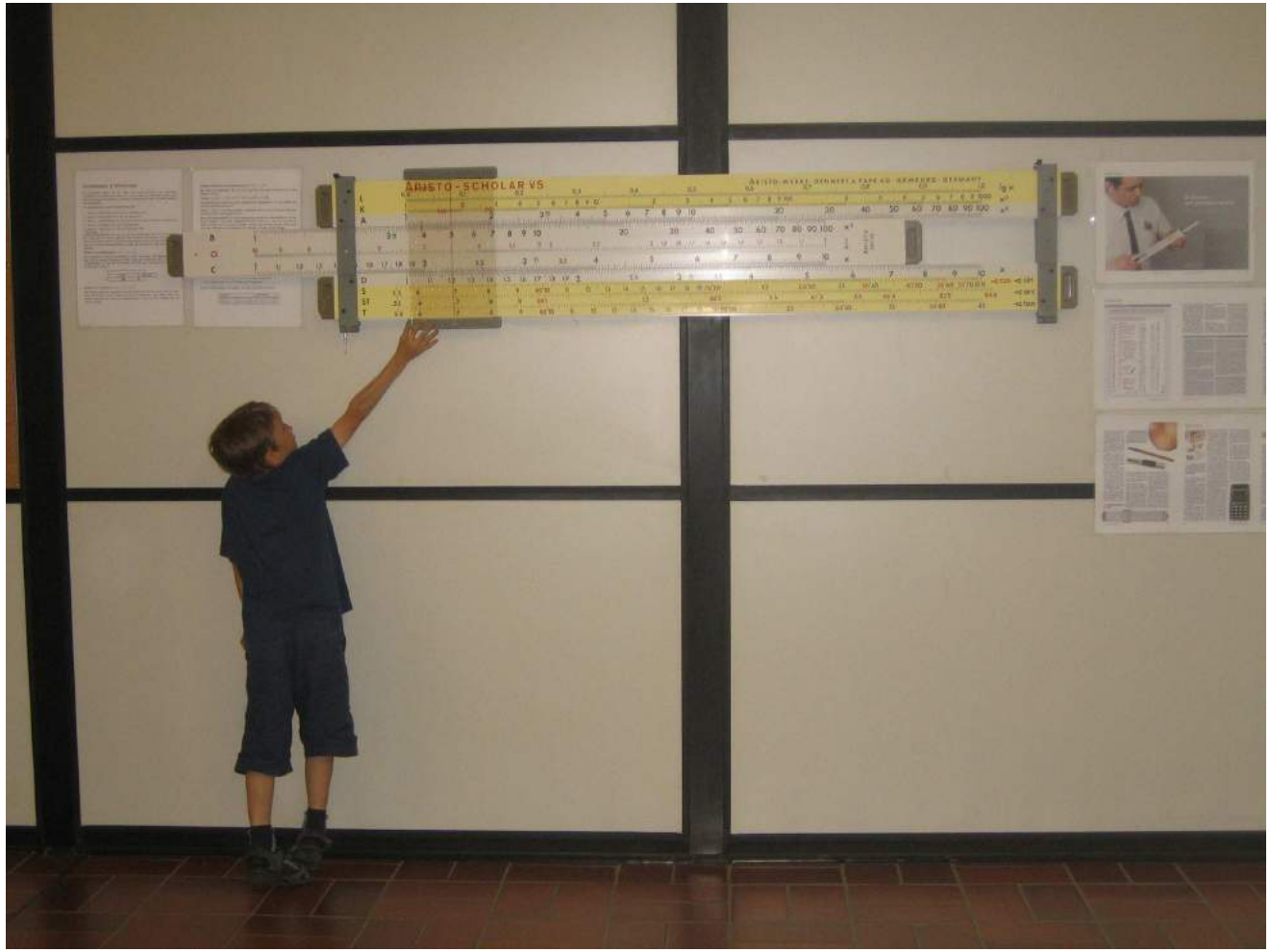
Together with 3 other showcases, transportation, repairs (support platform) and new shelves costed approx. 1 500,- EUR

Six people were necesssary to lift this showcase (without the glas) from the truck!

Foyer of the Faculty

This showcase is now the ‘business card’ of the Faculty:

Foyer: Hands on the slide rule – Calculating, part 1



Perfect exhibit: Students and visitors can try out themselves (. . . and they do it). A reference leads them from the entrance showcase to this object!

Foyer: Calculating, part 2

Mechanical computing machines — great for learning: How can one realize the ‘carry over’ (*Zehnerübertrag*)? → Seminar!

Foyer: Calculating, part 3

LHS: Friden 130 (1966)

earliest all-electronic desktop calculator, and generally regarded as the first transistorized electronic calculator

20 kg, price: 6 750 DM

Was repaired by the pc lab of the Hochschulrechenzentrum in February 2017

RHS: Diehl Combitron S (1970), plus tape puncher / punch tape reader

25 kg, 10.334,40 DM (incl. software)

- How to explain these in a course?
- took years to get a suitable show case

First floor: Calculating, part 4

Some exhibits are so large that they actually don't need showcases. . .

Telefunken TR 440 (1969), IBM sorter 083 (1958), IBM puncher 129 (1970)

Observe the poster on the wall, made by students in the **Model Seminar**

Library I

Assorted exhibits from geometry and topology

Library II

Breithaupt theodolites and a diopter. The diopter transfers horizontal angles (roughly) to a map without measuring them, the theodolite gives a a high precision measurement of angles in any direction

The Model Seminar

Idea: Each group of students selects an exhibit (or something which doesn't yet exist). Then, imagination is required: Each 90 minutes presentation is required to

- explain the mathematics behind the model / instrument, how it works, its history. . .
- include a practical part in which the fellow students should be doing something suitable on their own.

After the talk, some kind of elaboration is required, for example:

- a classical essay on the object (these are becoming rare)
- a poster presenting the exhibit; if well done, it will be put on display
- a video explaining the mode of operation of the exhibit
- construction and documentation of a new exhibit

Hence, participating in the Seminar does mean work for students!

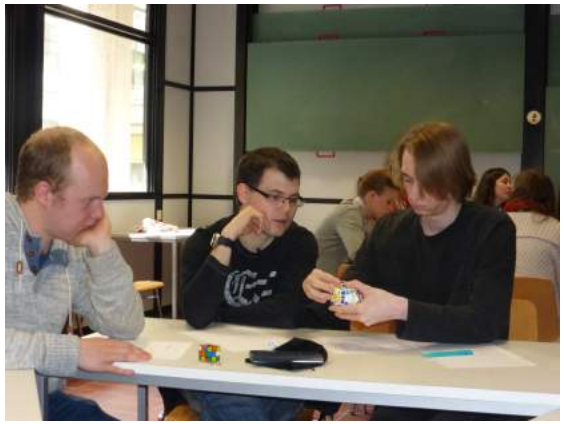
Goals of the Model Seminar

- to reintroduce some haptic experience into the teaching of mathematics; this usually increases understanding and intrinsic motivation.
- to teach elements of the history of mathematics and computer science (not always covered in separate courses)
- to discuss and suggest possible uses of models in secondary schools
- to establish cross connections to other topics: physics (Slinky), chemistry (crystals, bucky ball), architecture ('geodesic domes', quadrics or minimal surfaces used for roofs. . .)
- to establish the deep link between math and art (Escher, Dürer, da Vinci. . .)
- to appreciate the achievements of 'mathematical precision mechanics', and to learn about analogue measurement techniques (what is a nonius?)
- to make full use of the 3rd dimension or other features not available on a blackboard / computer screen
- to interact with students from other topics in a very intensive way
- to learn about topics one might not have encountered otherwise

Snapshots from the Model Seminar I

pantographs in action

polyhedra



how to solve Rubik's cube

'Rechentuch'

soap bubbles

Slinky walking down stairs

Snapshots from the Model Seminar II

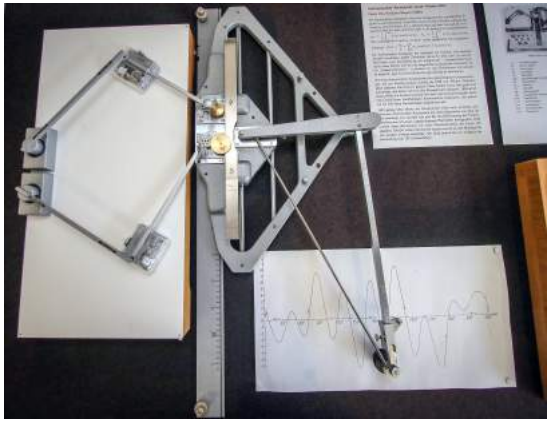
Mechanical integration machines are another large part of the collection:

Planimeter

(application of Stokes' thm)

integraph

(draws the primitive)

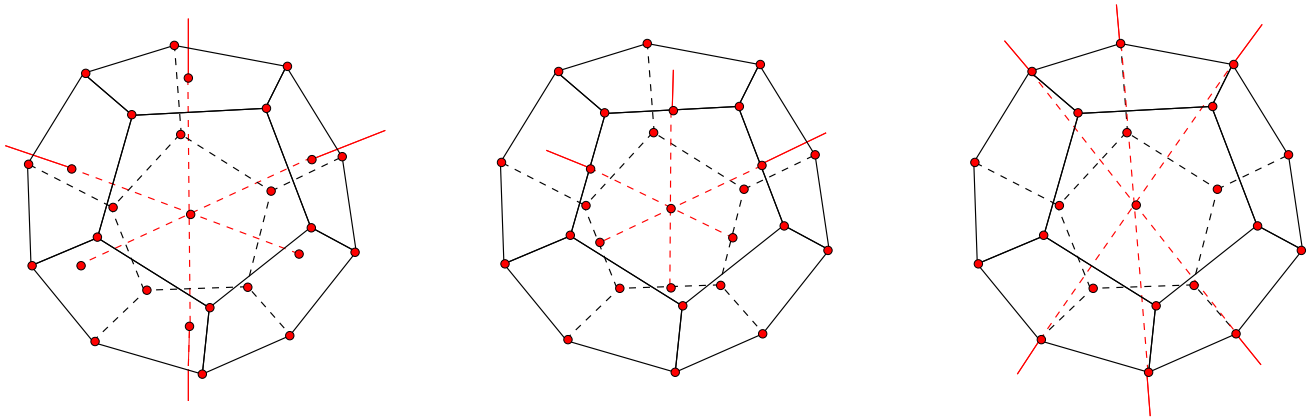


harmonic analyzer

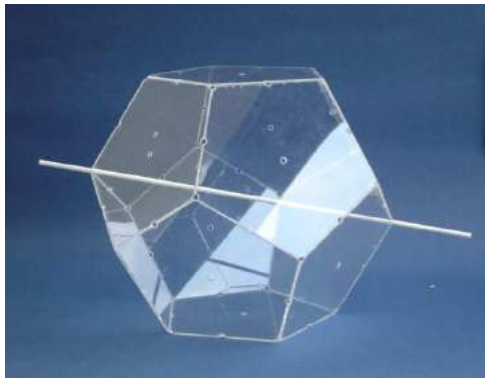
(computes Fourier coefficients)

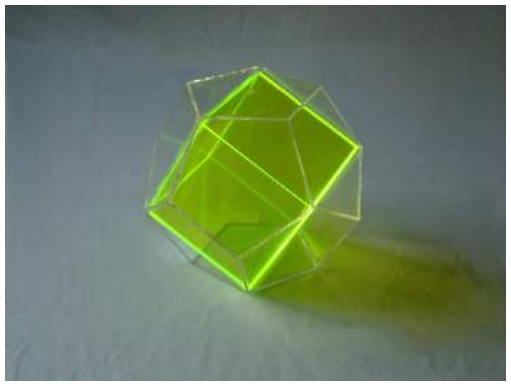
Instances where the 3rd dimension is valuable

Thm. The group of rotation symmetries of a regular dodecahedron (or icosahedron) is isomorphic to $\mathcal{A}_5$.



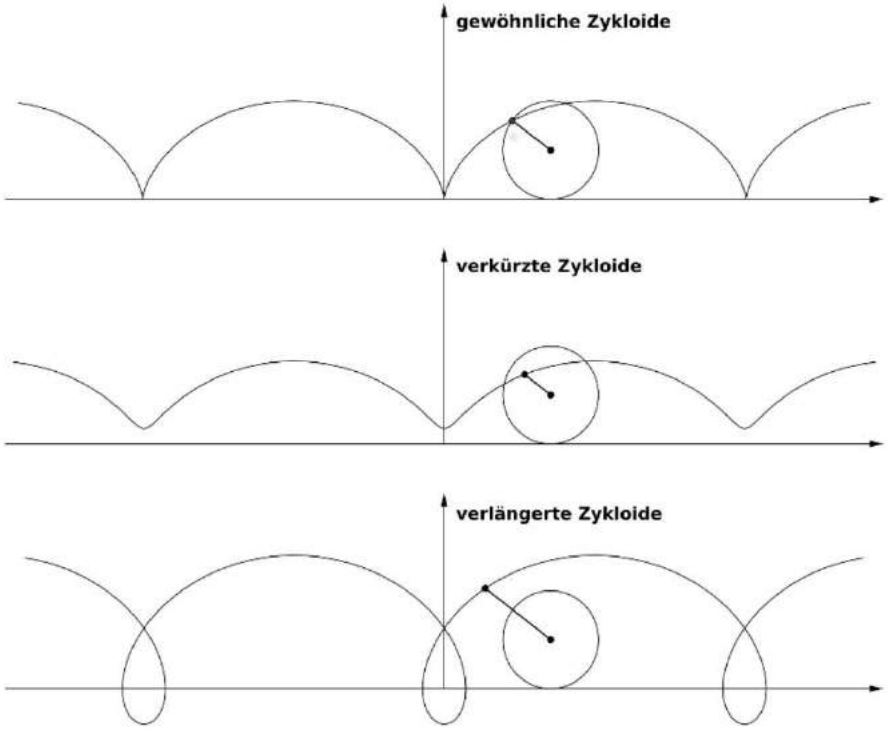
These drawings are almost impossible on a blackboard! With two suitable models, the students can find the solution in less than 10 minutes.

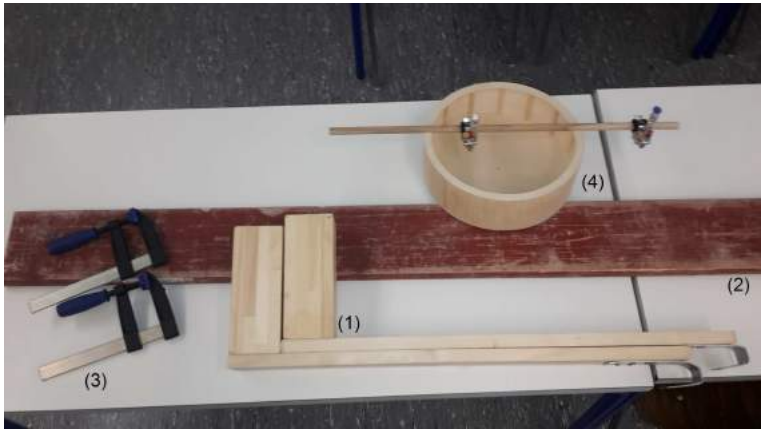




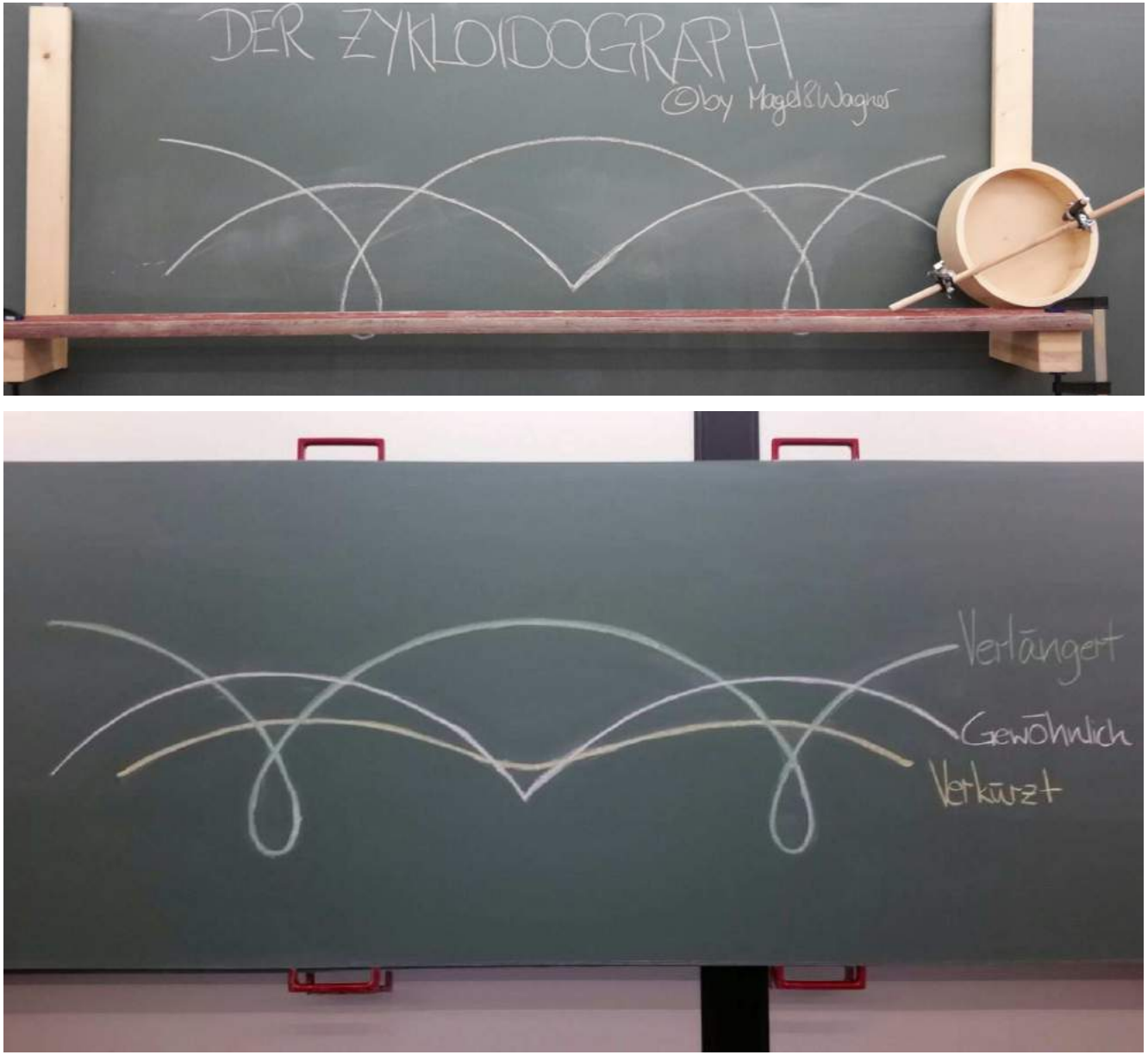
Self-built models I

Exercise: Construct a device drawing cycloids





Result: perhaps not yet ripe for mass production, but great fun!

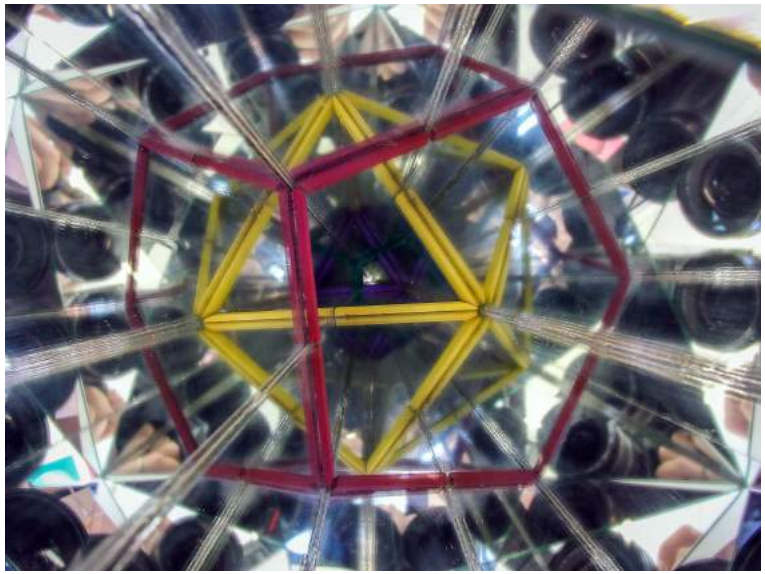


Self-built models II

Topic: 3-dim. caleidoscopes, mathematically: Weyl chambers of root systems

Challenge: Explain concepts without a course on Lie algebras

Starting point: One prototype. . .



The new models and their labels are ready (some on the table, with ‘zome tool’), a show case has been found.

To do: take neat pictures of models, prepare & set up show case. . . under way

This is a typical picture of the workshop.

Self-built models III

Topic: The IBM punch tape machines seen before. What could be the practical part for the fellow students?

Idea: Build a binary adding machine!

Write integers in binary representation:
$1101_2 = 1 \cdot 2^3 + 1 \cdot 2^2 + 0 \cdot 2^1 + 1 \cdot 2^0 = 13_{10}$

Addition works like in base 10:

$$\begin{array}{r} 10110 \\ +\ 10011 \\ \hline 101001 \end{array}$$
$$\begin{array}{r} \\ 1\ 11 \\ \end{array}$$

. . . corresponding to $22 + 19 = 41$

In their tutorial, the students explain the piecewise addition and give the work flow of a computation:

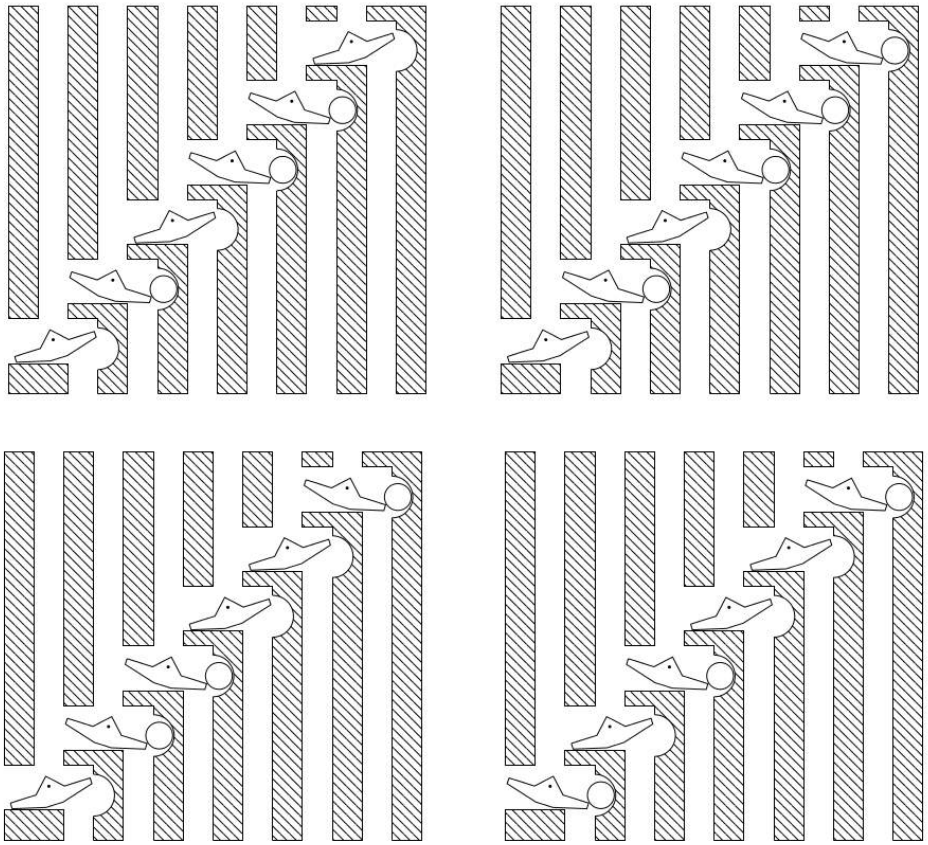


Abbildung 3: Schrittweise Addition von 10011_2 auf 10110_2

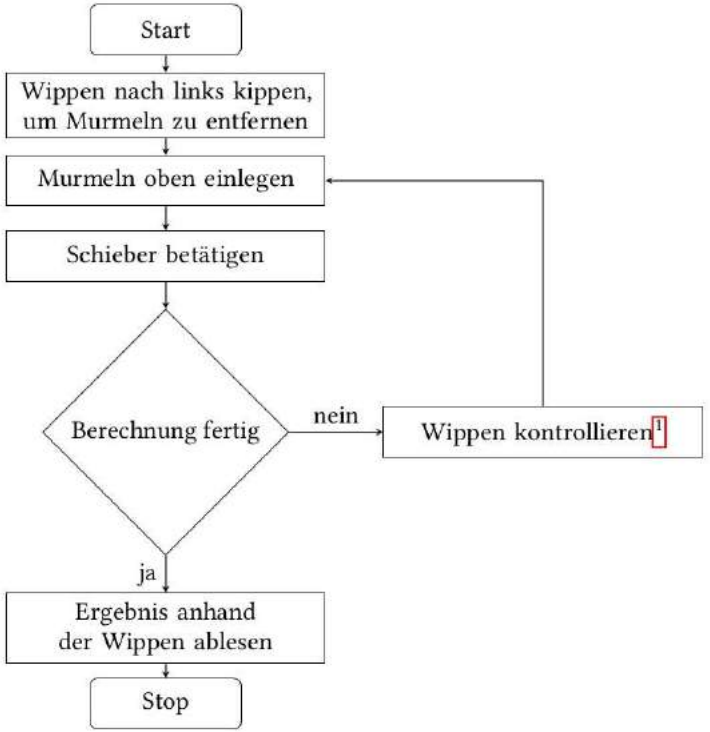


Abbildung 4: Bedienung des Murmeladdierers

[1]Eine Wippe besitzt nur zwei gültige Zustände:

- Keine Murmel und nach links geneigt
- Eine Murmel und nach rechts geneigt

Video on the pantograph

By now, the Collection owns about 8 pantographs of different sizes.

Latest arrivals: Several donations of the *Amt für Bodenmanagement Marburg*:

It takes some practice and time to set them up. This led to the idea of having an explanatory video!

Outlook: The mathematical city tour

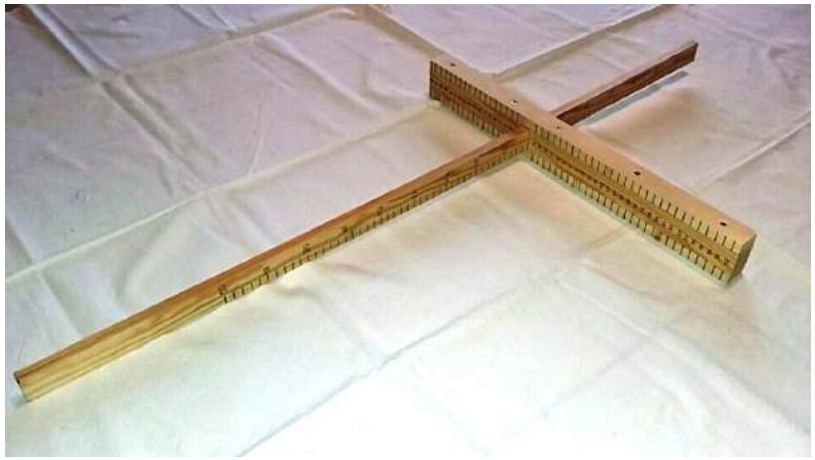


Originally designed by future math teachers for outdoor school activities, variable in length and topics, usually offered by future math teachers

Guiding idea: There's mathematics everywhere!

Self-built models V

A Jacob's staff is a simple device for measuring the height, already mentioned in the Bible:



It consists of two pieces:

- the main staff is marked with graduations for length
- the cross-piece (also marked) slides up and down on the main staff

. . . Nevertheless, it takes a half dozen math students at least 20 minutes to come up with a realistic height of the Math building

Digital resources

- Collection Homepage: permanently under construction, but getting better. . .

`http://www.uni-marburg.de/fb12/modellsammlung/`

- Online catalogues: The Hermann von Helmholtz-Zentrum für Kulturtechnik at Humboldt-Universität zu Berlin understands itself as an Information Resource on Collections and Museums at Universities in Germany. It offers a database that anybody can use for its models:

`http://www.universitaetssammlungen.de/modelle/suche/sam/1203`

Unfortunately, it doesn't cover machines and instruments

- Use DAMM, the database of Dresden (compatible with the Berlin database):

`https://mathematical-models.org/models/`

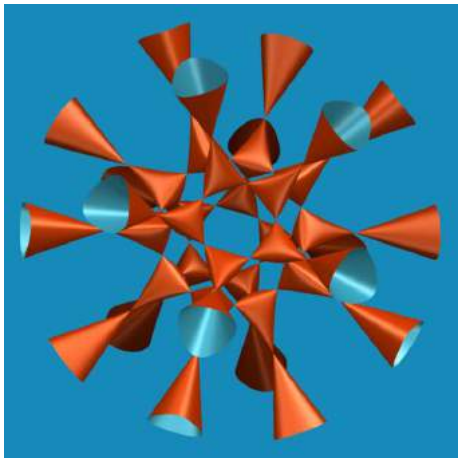
My warmest thanks go to:

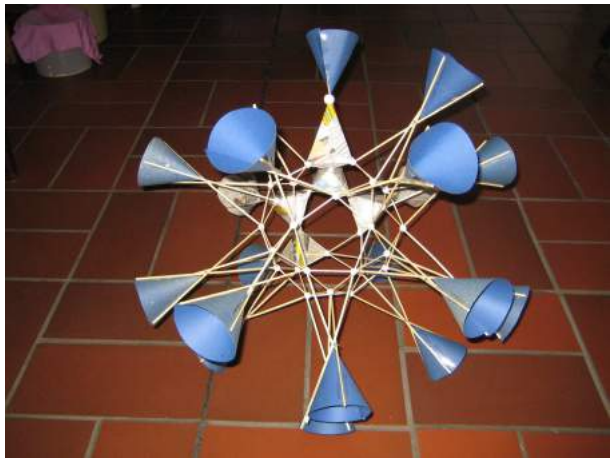
- Ramona Trusheim and Jens Winkler – teaching assistants (stud. HK) working for the Collection for many years,
- all students who participated in the 'Model Seminar' over the past years,
- all janitors, electricians, mechanics. . . of the university who helped many many times,
- the members of my research group who helped moving heavy stuff around,
- all museums and private persons who made donations – be it exhibits, showcases, and, sometimes, even money,
- all University Faculties / institutions who entrusted some of their valuable exhibits to our Exhibition,
- Volker Nienhaus, president of Marburg University in 2008, who was willing to invest a lot of money into an invisible and almost inexistent collection,
- the Marburger Universitätsbund for its ongoing financial support,
- the 'Oberhessische Presse' whose kind articles on the collection greatly contributed to its popularity

The logo of the Faculty

A Barth sextic (1996) with 65 singularities ($\Phi := (1+\sqrt{5})/2$):

$$4(\Phi^2x^2-y^2)(\Phi^2y^2-z^2)(\Phi^2z^2-x^2)-(1+2\Phi)(x^2+x^2+z^2-w^2)^2w^2=0$$





THANK YOU FOR LISTENING!