Charles Babbage: Part 1

A brief introduction about the life of Charles Babbage and his machines: The Difference Engine

James Tam

Charles Babbage (1791 – 1871)

- Considered by many to be the grandfather of the computer age (Williams).
- The technology of the day was primitive.
- But his ideas were advanced (~1940s).
  - The speed of his devices matched technology decades into the future.
    - The second machine (the Analytic engine) ~1830- 1871 took 1 second to complete an addition
    - A machine from around the time of World War II (machine was around ~1939-1945) took 0.3 seconds to complete an addition operation.
  - Howard Aitken's Harvard Mark I will be covered in the "Mechanical Monsters" section of the course.

James Tam

Background

- Born into a wealthy banking family
  - He had time to be productive researcher
- He excelled at his work
  - Primarily known for his work in computation/devices
    - But he excelled at other areas:

    - Member of the Royal Astronomical society, founder of the Royal Statistical Society.

Image: colourbox.com

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Research

- Babbage was a very active (and eclectic!) researcher and he published papers in the following fields:
  - Optics
  - Atmospheric observations
  - Electricity and magnetism
  - The operation of life insurance companies
  - Cryptography
  - Geology
  - Metal working
  - Taxation systems
  - The design of light houses
  - The operation of light houses

James Tam

An Inquisitive Child

- Even as a young child Babbage had an intense curiosity about how mechanical devices worked.

Images:
colourbox.com

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An Inquisitive Adult

- Babbage's interests and curiosity was not just limited to mechanical devices.

Image:
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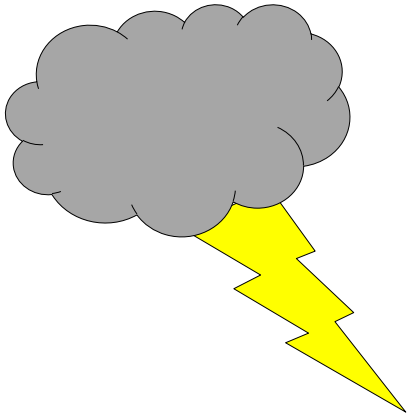
An Inquisitive Adult (2)

- New ‘experiment’



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An Inquisitive Adult (2)

Yea

Nay

“I remember well the observation was made, but I have no recollection as to the state of the door” - Passages from the Life of a Philosopher (Charles Babbage)

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Budding Mathematician

- Boarding school days

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Preparation For College

- Babbage's father decided that his son should attend Cambridge.
- The father hired a tutor to prepare Babbage for what to expect in college.

Cambridge

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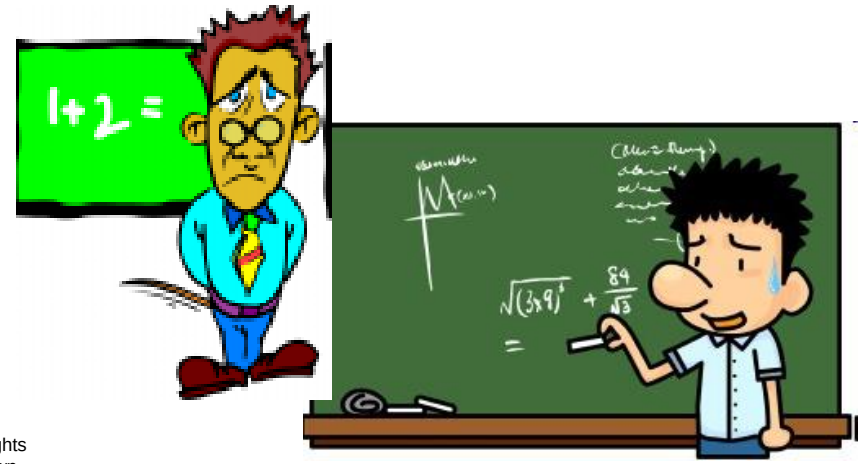
Life At Cambridge

- Babbage quickly discovered he had a deeper knowledge of mathematics than his tutors



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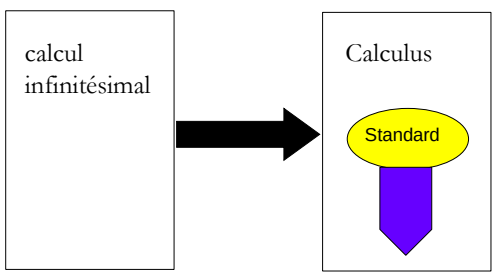
Life At Cambridge (2)

- Babbage then spent most of his time at college reading the papers of great mathematicians and meeting with other advanced students:
  - George Peacock
  - John Herschel
  - Together they translated and added substantially to a text by LaCroix



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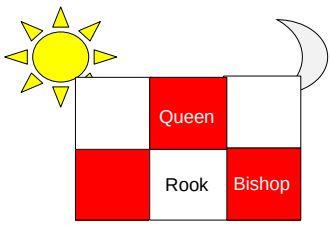
Cambridge: Recreational Activities

- However Babbage didn't spend all his time studying and had an active social life, "…in fact, his social life was so active that it is a wonder that he had time for any studies at all." (Williams)
- Chess club



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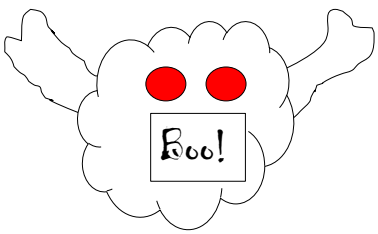
Cambridge: Recreational Activities (2)

- Cambridge ghost club



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Cambridge: Recreational Activities (3)

- Extractors club

Rules from "History of Computing Technology" (Williams)

- *Every member must communicate his address to the Secretary at lest once every six months.*
- *If this communication was delayed beyond 12 months, it would be taken for granted that his relatives had shut him up as insane.*
- *Every effort legal and illegal shall be made to get him out of the madhouse (hence the name "extractors").*
- *Every candidate for admission shall produce six certificates to be kept on file – three that he is sane and three that he is not.*

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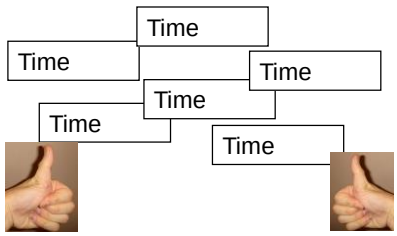
Cambridge: Recreational Activities (4)

- Why these social clubs?



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Post College: England

- Although brilliant Babbage did not receive recognition when studying at Cambridge.
- He unsuccessfully sought lectureship appointments at universities (it's who you know rather than what you know or what you can do).
- Later in life Babbage was elected as the Lucasian Professor of Mathematics in Cambridge
  - (Outstanding chair holders)
    - Isaac Newton: 1669
    - Charles Babbage: 1828
    - Stephen Hawking: 1979

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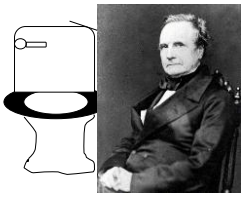
Post College: England (2)

- Although the research chair is quite prestigious Babbage's initial reaction was neither enthusiastic nor was it positive.



Images:
Babbage: http://www.mhs.ox.ac.uk/
Research chair ("the Throne": Tam

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Post College: Continental Europe

- Babbage was well known and respected in the rest of Europe.
- Elected as a member to at least 15 European scientific societies
- He was even named commander of the Italian Order of: Saint Maurice and Saint Lazarus.

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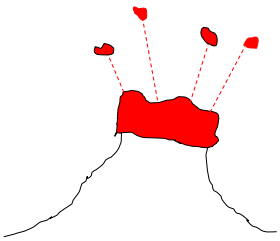
A Very Dedicated Researcher

- While in Italy Babbage wanted to study the volcano at Mount Vesuvius



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Contributions To Logarithms

- In 1826 he published his own set of logarithms (by far the most accurate published up to that date).
- He improved on the accuracy but he was a perfectionist and wanted to reduce the chances of misreading the information so he experimented with different:
  - Tried many typefaces to improve readability and to decrease the probability of an error.
  - Paper colors (151!)
  - Colors of ink (13)
  - Babbage was beyond thorough!

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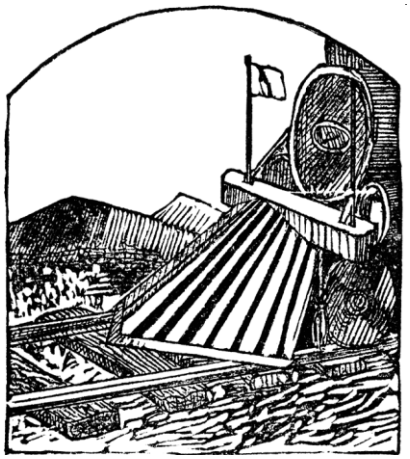
Contributions To The British Rail System

- Invented the cow catcher



http://etc.usf.edu (last accessed 2016)

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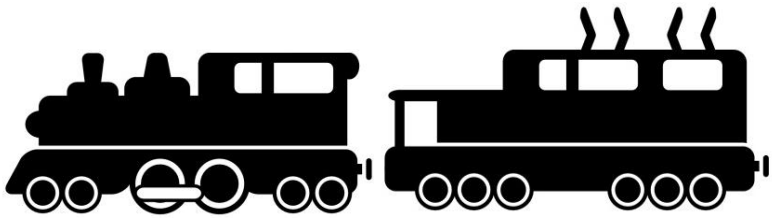
Contributions To The British Rail System (2)

- Recovery of lost rail cars.
  - Source: “Charles Babbage, Passages from the Life of a Philosopher” pp. 325 –326.



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Contributions To The British Rail System (2)

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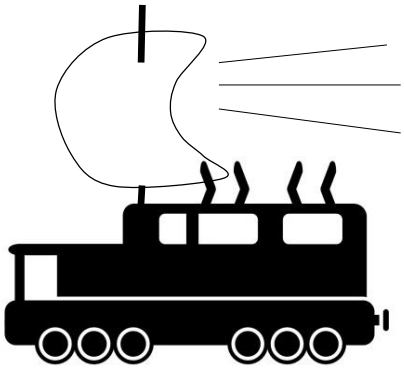
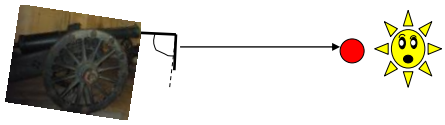


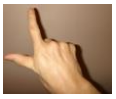
Obviously a very resourceful person!

James Tam

Social Life Beyond College

- He still maintained an active social life.
- Babbage was a well known member of London society (he was eagerly sought after by the London elite).
- He often had to turn down invitations (multiple).
- Guests were always treated displays of scientific or technical terms.





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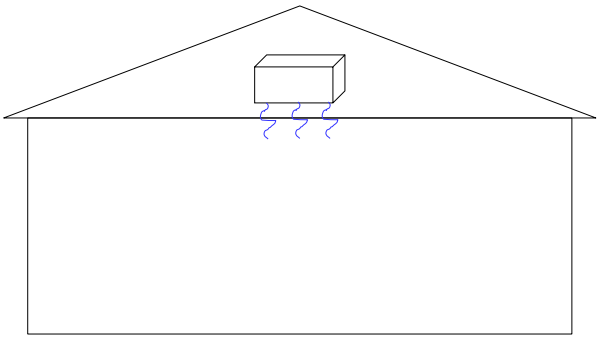
Social Life Beyond College (2)

- He designed the first "environmental control" for a residential dwelling in London.



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Social Life: Later Years

- As Babbage got older his social agenda diminished and he developed a cantankerous attitude towards life.

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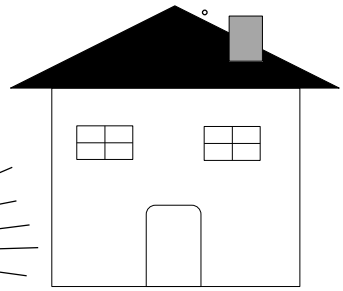

Groupies!

"Elastic virtue!" - from Williams

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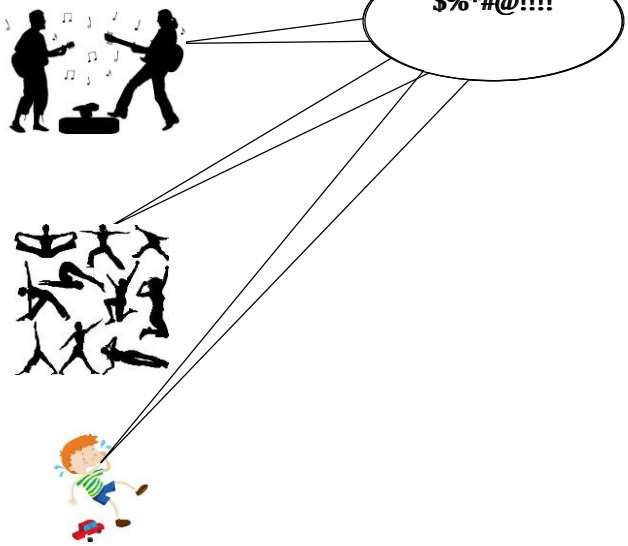
Social Life: Later Years (2)



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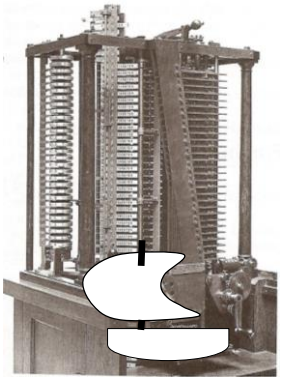
International Connections

- Although he was not appreciated by the common people of England Babbage had a strong reputation in the academic community on both sides of the Atlantic.



All images from Tam

James Tam

The Need For Accuracy

```
(csx3 lectures 126 )> python MyMath.py
 1   2   3   4   5   6   7   8   9
 2   4   6   8  10  12  14  16  18
 3   6   9  12  15  18  21  24  27
 4   8  12  16  20  24  28  32  36
 5  10  15  20  25  30  35  40  45
 6  12  18  24  30  36  42  48  54
 7  14  21  28  35  42  49  56  63
 8  16  24  32  40  48  56  64  72
 9  18  27  36  45  54  63  72  81
```

- During the late 1700s publication of mathematical tables began to be common place.
- They ranged calculating the results of simple operations (e.g., addition, subtraction) to something more complex (e.g., logarithms, trigonometric tables).
- Although the creation of tables were intended to reduce the labor of performing a calculation they were always full of errors.
- Example (survey of one scientist's [Babbage?] library: Williams):
  - 140 volumes of arithmetic and trigonometric tables
  - 40 volumes were sampled and the contained 3,700 known errors.

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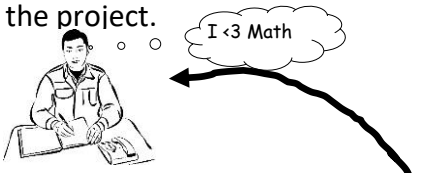
Computing New Tables

- After the French revolution (late 1700s) the new French government decided it would publish a new set of mathematical tables (prestige).
- The best French mathematicians were brought on to oversee the project.



- The work of performing the actual calculations were filled with the unemployed

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Images: Colourbox.com

Computing New Tables (2)

- To ensure accuracy numbers were computed at least twice.
- To prevent collaboration between the groups performing the calculations, each group was located in different locations scattered across France.
- But even with all of the time and effort employed the tables still contained errors.
- Sometimes tables of errata were published afterwards.
  - However sometimes the second table contained more errors than the original table it was intended to correct! (Williams)

James Tam

Computing New Tables (3)

- Some of the errors were introduced during type setting.
  - To a large extend this is why Babbage was so meticulous
    - Tried many typefaces to improve readability and to decrease the probability of an error.
    - Paper colors (151!)
    - Colors of ink (13)
  - The tables completed by Babbage in 1827 were the most accurate set of tables produced up to that time.
    - Only 40 errors (out of ? Volumes)

James Tam

Computing New Tables (4)

- Other sets of tables published around that time were not nearly as accurate:
  - Dr. Hutton's famous tables 1781 contained 40 errors on a single page.
  - The Nautical Ephemeris for Finding Latitude and Longitude at Sea contained over 1,000 errors.
- The only fool-proof method of preventing errors was to remove people entirely from the task of producing the calculations and substitute them with some sort of mechanical device.

James Tam

Using Differences

- It was once the main tool used by the makers of mathematical tables.
- Replaces more complex operations such as multiplication with additions and subtractions.
- Example (from Williams): Evaluating `f(x) = 2X + 3`

x	=	1		2		3
F(x)	=	5		7		9
Differences	=		2		2	

- Computing the constant sum results in less complex machinery than evaluating the function.
  - Functions with higher powers could be computed using constant differences.
- The property of constant differences was the technological basis of the Difference Engine.

James Tam

Using Differences: 2ND Difference

- $f(x) = x^2$

x	=	1		2		3		4
F(x)	=	1		4		9		16
1st diff	=		3		5		7	
2nd diff	=			2		2		

James Tam

Difference Engine

- A computing device that is able to employ the property of differences to compute a series of numbers.
- Mr. E. Klipstein (Frankfurt 1786 "*Description of a Newly Invented Calculating Machine [Translated title]*") included the first reference to such a device.
  - Klipstein (write about it) described a computing device in the book.
  - In the appendix written by the (Hessian) Engineering Captain J.H. Muller, Muller (invented one) describes an even more ambitious computing device if only $$$ were available.
  - "The first reference to such a device [Difference Engine]…" was made by Klipstein.
  - Muller is credited the first publication describing such a device.
    - His credit for 'publishing' is ambiguous (Williams)

James Tam

Babbage's Difference Engine: Motivations

- As noted Babbage had an intense obsession for completeness and accuracy.
- One of his goals was to produce a more accurate series of mathematical tables.
- (Recall: even with a great deal of care and duplication taken to produce the tables that errors would inevitably occur so the goal was to remove the person – the source of the errors – entirely from the process).
- The idea of a Difference Engine first came to Babbage in 1812 or 1813 (student at Cambridge).

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Babbage's Difference Engine: Motivations (2)

- In the early 1820s after his experience at publishing tables of logarithms Babbage was again spurred to design a machine that would automatically produce these values.
- "Being of moderate independent means" (Williams) Babbage managed to produce a working model by 1822.
  - It could work with 6 figure numbers.
  - It could evaluate any function having a constant second difference.
  - 44 calculations per minute
- To generate additional funding and support Babbage wrote the president of the Royal Society
  - The Royal Society of London for Improving Natural Knowledge ("Royal Society")

Royalsociety.org

James Tam

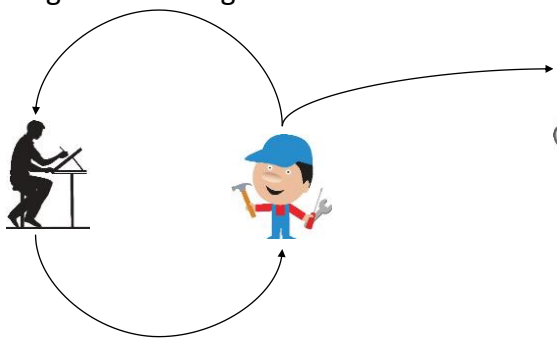
Babbage's Difference Engine: Motivations (3)

- The Royal Society supported Babbage's project and sent a letter of support to the Lords of the Treasury.
  - Note: the support was not unanimous (Dr. Young: felt that the money would be better spent on investments and using the proceeds to fund more human calculators).
  - The government provided some start up funds 1,500 pounds (~$7,500).
  - Babbage made up the difference ~3,400 pounds himself ("I'll get it back!")
- Unfortunately Babbage soon discovered that there can be a significant difference between making a demonstration prototype and a fully working model.
- Fortunately Babbage was able to obtain the services of Samuel Clement.

James Tam

Samuel Clement And Charles Babbage: Early Years

- Clement
  - Not formally educated
  - "Good with his hands"
  - One of the best of his day
- Together Babbage and Clement went through many iterations



e.g., Whitworth standards for nuts and bolts

Clipart: Colourbox.com

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Charles Babbage: Life During The Design Process

- While Babbage and Clements were working on different parts of the Difference Engine Babbage suffered from a number of personal tragedies.
- All within the span of four years:
  - Babbage's wife, new born baby daughter and father passed away.
- These events (along with hard work on the project) result in Babbage's health breakdown and problems with the project.
  - Babbage took a break at warmer climate.
  - While there he checked his accounts and remembered the personal funds he put into the project;
  - Unfortunately there were problems when he tried to get a reimbursement from the government.
    - Where's your contract???

James Tam

Charles Babbage: Life During The Design Process (2)

- Finally after personal appeals from Babbage's friends the project was advanced an additional 1,500 pounds.
- After another personal appeal from a *very influential* friend (*The Duke of Wellington*) the project was advanced another 3,000 pounds with a suggestion that Babbage show evidence of his progress.
- Unfortunately the financial and health problems would often significantly delay work on the project.

James Tam

Samuel Clement And Charles Babbage: Later Years

- Babbage would normally travel across London when he needed to visit Clement's workshop.
- To facilitate work on the project Babbage built a new (fire proof) house that was closer.
- He expected Clement to join him at the new location but Clement refused and eventually the two had a falling out.
  - Unfortunately British law favored Clemet's position
- During this dispute work on the Difference Machine was halted
- The one positive: Babbage conceived of another machine (Analytical Engine: more later) during this time

James Tam

Babbage: Later Years

- Finally Babbage determined that it would be more efficient (i.e., cheaper) to start building a new machine with a different design than complete the original design.
- This announcement was not well received by the government.
- While the officials deliberated the current government lost it's majority position.
  - Babbage had to start dealing a whole new group of officials.
- Finally Babbage tired of the process and asked the Prime Minister to make a decision on the fate the project.
  - Unfortunately the decision (1842) wasn't favorable for Babbage
  - Maybe the Difference Engine should be used to compute the cost of producing the Difference Engine. – Paraphrasing a member of Parliament

James Tam

Babbage: Later Years (2)

- Eventually the machine itself was donated to a museum.
- Ironically after abandoning Babbage's work:
  - Only a few years later the British government financed the production of a Difference Engine designed in Sweden.

James Tam

Difference Engine (Cost)

- Government portion:
  - 17,000 pounds ($84,000) 1842 currency values
- Babbage's portion:
  - 20,000 pounds ($100,000) 1842 currency values

James Tam

Difference Engine: Final Design

- The final machine wasn't complete (parts of it now at South Kensington Science Museum).
- "Baggage's description of the machine are difficult to follow" (Williams).
- Also the descriptions were extensive (1000 square feet of paper).

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Difference Engine: Final Design (2)

- Dr. Dionysus Lardner

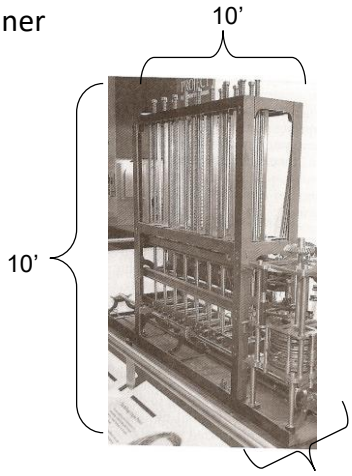

Image: “A history of Computing Technology” (Williams)

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Optional External Video:

- Demonstrating the operation of the Difference Engine and stories about the life of Babbage
  - If you don’t want to watch the whole video at least check it out 1:38 to see the intricate and complex mechanisms in operation.
  - https://www.youtube.com/watch?v=BlbQsKpq3Ak

James Tam

After This Section You Should Know

- Who was considered to be the grandfather of the computer age and why
- Details about the background life of Babbage (early years, time at Cambridge and after)
- What was Babbage's contribution to calculus and who were the co-contributors
- Babbage's contribution to the production of logarithmic tables
- Babbage's other contributions and inventions: British Rail system
- The motivator for Babbage to produce a calculating machine
- How/when mathematical differences were used to generate results with the Difference Engine

James Tam

After This Section You Should Know (2)

- Details about pre-Babbage Difference Engines and details in the development of the Babbage Difference Engine
- Some of the challenges experienced by Babbage when producing his Difference Engine

James Tam