Winterim Short Course Proposal
Thayer School of Engineering
September 10, 2019

Title: Computing Before Electronics

Dates: December 9–12, 2019 (preferred) or December 3-6, 2019

Instructor: H. J. Frost

Intended Audience: Students of science and engineering, from Thayer and other departments.

Prerequisites: Multivariable calculus (Math 8 or equivalent).

Objectives:

- Learn a little about the history of technology.
- Gain an appreciation of the trade-offs among precision, accuracy, and ease of computation.
- Reinforce appreciation of natural distributions of experimental data: Logarithmic scales; Normal distributions; Weibull distributions; and so forth.
- Have some fun with some interesting old gadgets.

Synopsis:

How did mankind survive and thrive before the advent of the integrated circuit and the handheld electronic calculator? The need for numerical calculations originated with the commerce of the first early civilizations and intensified throughout the industrial revolution into the modern age. The answer lies in the large variety of mechanical gadgets and graphical techniques invented since the enlightenment and widely used until well after the middle of the 20th century. (Some of them are occasionally used to this day.) In this course we will study the development of a few of these, so as to understand the mechanics and mathematics upon which they are based, concentrating on four types:

- Slide rules.
- Planimeters and Integrators.
- Mechanical digital calculators.
- Nomograms and specialized graphical charts.

Hands-On Experience.

Each class will have a lecture with demonstrations, followed by a hands-on or experimental project by the students. Class will last from 9:00 AM until noon, with appropriate breaks. In the slide rule class there will be a competition between different types of slide rules for speed and accuracy for a given set of calculations. For the class on planimeters there could be an exploration of the accuracy and repeatability of different designs of planimeter. Something similar could be created for adding machines. The project for nomograms would be the creation of a new nomogram for a specific problem. For each class meeting there will be assigned reading. For demonstrations in the two classes on slide rules and planimeters, we may rely on the instructor's personal collection, with possible additions from Dartmouth College collections. For the class on mechanical digital arithmetic, we will need to acquire or discover a few more demonstration models. For the class on graphical methods, we will use paper demonstrations.

Facilities: Cummings Room 105. The students will be given printed circular slide rules, and possibly used linear slide-rules if numbers permit.

Maximum Class Size: 15.

Course Outline.

A. The Slide Rule.
   1. Napier and Logarithms. (Log Tables)
   2. Oughtred and the first slide rules.
   3. The Sector and Gunter's Rule (single logarithmic scales).
   4. Mannheim Rule; Trigonometric Scales; Log-Log scales *etc*. .
   5. Precision and Accuracy.
   6. Geometric Schemes to extend the Length of the Scales:
      Linear, Circular, Spiral, Helical, Cylindrical, Segmented-Divided, Segmented-Gridiron
   7. Demise of the Slide Rule: H.P. 35 Scientific Calculator (~1972).
   8. Benford's Law and the prevalence of the logarithmic scale in nature.
   9. Internet Virtual Slide Rule.

B. Mechanical Arithmetic.
   1. Abacus.
   2. Napier's Rods.
   3. Genaille Rulers.
   4. Digital Logic of addition.
   5. Troncet-style machines for addition; Addiator.
   6. Early Connected-Wheel Adding Machines:
      Calculating Clock of Wilhelm Schickard (1623)
      Machine of Blaise Pascal (1642); Calculator of Philip Matthäus Hahn (1773); *etc*.
   7. Leibnitz Calculator.
   8. Industrial Age Adding Machines:
   9. Millionaire (from Dartmouth College collection)
   10. Curta Calculator (~1947).
   11. Mechanical Programmable Computation.
      Charles Babbage and the Difference Engine.
      Dawn of Electronic Computing; Electro-mechanical systems.

C. Planimeters and Integrators.
   1. Measurement of area; mathematics of the linear planimeter.
   2. Inventions Prior to Amsler: Johann Martin Hermann; Wettli-Starke; Maxwell; Hatchet.
   3. Jacob Amsler's invention of the basic slip-and-roll polar planimeter.
   4. Polar Variants: *e.g*. Willis, Coradi Radial Disk.
   5. Linear Variants: *e.g*. Coradi Rolling Disc, Coradi Rolling Sphere.
   6. Planimeters for Steam Indicators.
   7. Radial planimeters and square-root planimeters. *e.g*. for flow meters.
   8. Amsler Integrators and Naval Architecture: 2-Dial; 3-Dial; 4-Dial.
   9. Integraph by Abakanowicz.
   10. Harmonic Analyzers.

D. Graphical Methods.
   1. Special Graph Papers:
      Log-Linear; Log-Log; Log-Inverse; Normal distribution probability paper;
      Weibull distribution probability paper.
   2. Nomograms/Nomographs.
   3. Special Graphical Systems.
      Smith Impedance Charts; Stereographic Projection and Wulff Plots;
      Thermodynamic and psychrometric charts.