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Let us now praise famous physicists, and the apparatus named after them, with apologies to the writer of Ecclesiastes. I once compiled a list of about 300 pieces of apparatus known to us as X’s Apparatus. Some of the values of X are familiar, like Wheatstone and Kelvin and Faraday, but have you heard of Pickering or Ruhmkorff or Barlow? In an earlier article about Packard’s apparatus, I paid homage to an early-20th-century high school teacher, and other articles have mentioned apparatus by a number of other physicists and physics teachers. In many cases the apparatus came directly out of research being done by the physicist, or from the need to show the phenomena of physics in the classroom and lecture hall. Here are more stories about apparatus and their makers, starting with three pieces of apparatus that are related to the development of electron physics in the latter half of the 19th century.

1. Ruhmkorff’s Coil. (Fig. 1) Readers of Jules Verne’s 1870 novel, *Twenty Thousand Leagues under the Sea*, have encountered Ruhmkorff’s coil. Led by Captain Nemo, the party explores the bottom of the sea with the aid of lamps powered by Ruhmkorff’s coils. The coils provide a high voltage that is applied across two electrodes in an evacuated glass bulb into which a small amount of carbon dioxide gas has been introduced. Verne wrote, “When the apparatus is at work this gas becomes luminous, giving out a white and continuous light.”

Physicists are more likely to call this an induction coil. At its heart is a step-up transformer, with many turns of fine wire surrounding a coil made of a relatively few turns of thick wire; both are wound around a core of iron wires, insulated from each other to prevent eddy currents. The alternating current to drive the coil is derived from the mechanism on the right side as follows: the dc through the primary sets up a magnetic field that pulls in the upright iron reed at the end. This breaks the contact on the reed’s lower end that supplies the primary, the electric field collapses, and the current through the primary is reestablished. The resulting waveform is roughly square, and the Fourier components drive the transformer.

The Parisian apparatus manufacturer Heinrich Daniel Ruhmkorff (1803-1877) is responsible for putting together the elements of the coil, including the use of the condenser connected across the primary to moderate the back emf of the collapsing magnetic field of the secondary. In Europe the device is usually called a Ruhmkorff coil. Today it is used for exciting Crooke’s and other discharge tubes, though in the early part of the 20th century a compact version was used in the ignition system of the Model T Ford automobile. These “Ford” coils and their modern versions are still used in physics demonstrations.

2. Crookes Tubes. (Fig. 2) William Crookes (1832-1919) straddled the fields of physics and chemistry in the second half of the 19th century. At various times he was president of the (British) Chemical Society, the Institution of Electrical Engineers, and the Royal Society. He used the new technique of spectrum analysis introduced by Robert Bunsen to discover a new element, thallium, in 1861. In the course of this research he discovered the radiometer effect in which thermal radiation, falling on blackened vanes in a reasonably good vacuum, causes the vanes to be repelled. The Crookes Radiometer, with its vanes rotating in sunlight, is a popular scientific toy to this day.

Crookes and others devised a series of evacuated tubes that can be used to elucidate the properties of cathode rays. In the four tubes in Fig. 2, a Ruhmkorff coil, connected to the two electrodes, is used to provide a high potential difference. In the vicinity of the cathode a large electric field exists that removes an outer electron from a residual gas atom. The resulting positive ion is attracted to the cathode, strikes it, and ejects an electron (or a cathode ray). This is emitted perpen-
dicular to the surface of the cathode and travels in a straight line to the other end, where it strikes the glass, producing a green glow—and x-rays. The Maltese Cross Tube in the upper left-hand corner has a metal cross that blocks out the beam of electrons, and the shadow of the cross appears on the end of the tube, thus showing that the rays travel in straight lines. The Railway Tube on the lower left-hand corner has a pinwheel that runs on glass rails; when the beam hits it, the pinwheel rotates, thus showing that the cathode rays carry momentum. The Heating Tube on the upper right-hand side has a curved cathode and a sheet of thin platinum at the focus of the cathode. The sheet will glow red from the impingement of the cathode rays; they carry kinetic energy. The rays coming from the flat cathode on the remaining tube pass through a thin slit, forming a beam that strikes the phosphorescent plate, producing a line across it. Electric and magnetic fields can move the beam up and down, thus showing that the cathode rays have a negative charge. And, in 1905, J.J. Thomson showed that all cathode rays have the same e/m value.

Are these tubes safe? In 1895 Wilhelm Roentgen was using one when he discovered that it emitted radiation that he named x-rays. This is not an optimal way of producing x-rays, however, and I have never seen a warning about their use.

3. Wimshurst’s Machine. (Fig. 3) James Wimshurst (1832-1903) had two parallel careers. His professional life was spent as an expert on commercial shipping affairs, serving as a consulting engineer for the British Board of Trade and working as a surveyor and evaluator of ships. His spare time he devoted to experimental work, starting with reproductions of existing influence-type electrostatic machines that he built in his own shop.

Unlike the original electrostatic machines, in which a rotating glass shape (a sphere, a cylinder, or a disk) is rubbed with another body to achieve a separation of charge, the influence machine involves no contact. Instead, charges that initially exist on the foil sectors on one of the contra-rotating disks induce charges on the sectors on the facing plate; these charges are then picked off with metal brushes and stored in the Leiden jars. This Wimshurst machine is in the Greenslade Collection. It was made by the L.E. Knott Apparatus Co. of Boston and is pre-1916. The plates have been replaced; when I rescued it a two-by-four had just fallen across it. Despite being nearly 100 years old, it still gives a good spark.

Let me conclude this article with two contributions to physics apparatus made by professors at Harvard University at the end of the 19th century and the start of the 20th.

4. Pickering’s Polariscope. (Fig. 4) Edward Pickering (1846-1919) graduated from the Sheffield Scientific School of Harvard in 1865. At the age of 23 he was appointed to the Thayer Chair of Physics at M.I.T., where he established the first undergraduate laboratory in the United States in 1869. Seven years later he was appointed to the directorship of the Harvard Observatory, and did research on stellar photometry and spectroscopy until his death. Pickering published Elements of Physical Manipulation in 1873, and this may be regarded as the first useful laboratory manual in this country. For the first time graphical methods were used for data analysis by undergraduates.

Experiment No. 92 on polarized light uses the apparatus in Fig. 4. Light reflected from the horizontal glass plate at the left-hand side of the apparatus at Brewster’s angle (about 56º) is plane-polarized from side to side. The reflected beam passes through the Nicol prism at the top of the apparatus. This device uses crystals of the naturally occurring mineral Iceland spar, suitably cut and cemented together, to produce light that is polarized up and down. The sample, placed in the holder in the middle of the polariscope, is thus between crossed polarizing devices. Thin sheets of mica, split into various thicknesses and arranged in patterns, produces striking images of butterflies and other objects in red and green as the different thicknesses of mica rotate the plane of polarization by differing amounts.

You can do the same thing today with layers of inexpensive cellophane tape placed on a plate of glass that is held between crossed polarizing filters. A number of years ago an art major in my natural philosophy course for non-science majors used this technique to build up a picture that looked as if it were made of stained glass.
The entry about this apparatus in the 1916 catalogue of the L.E. Knott Apparatus Co. of Boston is: "Improved Sabine's Torsion Pendulum for determining the moment of torsion of a wire and the moment of inertia of a ring. Two methods of reading torsional vibrations are possible—by direct observation of consecutive transits of the index past the zero point of the graduated arc; by observing through a telescope the consecutive flashes from the illuminated mirror. The disc is 10½ inches in diameter, and is clamped to the wire by means of a small chuck fixed at its middle point. This disc is then supported from the frame by a similar chuck having the additional features of an adjusting thumb screw and a set-screw. The index dial is cast from metal and has large raised figures. A ring [whose] moment of inertia is to be determined has the same diameter and mass as the disk... $15.60."

Part II of this paper will consider apparatus named after 'sGravesande, Nicholson, Barlow, Sturgeon, and Savart.

References
2. These include Argand, Callender and Barnes, D'Arsonval, Duff, Gassiot, Hare, Helmholtz, Hero, Koenig, Kohlrausch, Lissajous, Lloyd, Page, Roget, von Nardroff, Weston, and Wheatstone.

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