Art Review

Man Ray's Human Equations

E. Arthur Robinson Jr.

American artist and photographer Man Ray was living in Paris in the 1920s and 1930s, and was an active participant in the Dada and surrealist movements. Man Ray is probably best known for his 1921 readymade "The Gift," a flatiron with thumb tacks glued to the bottom; for his "Rayographs," darkroom-composed shadow images of household objects; and for his surrealistic photographs of the human body.

In 1934 Max Ernst suggested that Man Ray photograph the mathematical model collection at the Institut Henri Poincaré. At the institute Man Ray encountered a "dim hall, lined with glass cases containing hundreds of strange objects, covered with dust, objects in wood, plaster, paper-mache, metal, wire string, glass, glue, gelatin, paper." Many of the models were German in origin, dating back to the late nineteenth and early twentieth centuries. Man Ray spent "several days," ultimately photographing some thirty-four of the approximately three hundred models at the institute. Twelve of these photographs were published in 1936 in the journal *Cahiers d'Art* as illustrations to an article "Mathematique et Art Abstrait" by art critic Christian Zervos, which questioned whether mathematical objects could be considered art. Several photographs were featured in the 1938 Exposition Internationale du Surréalisme in Paris, and later the same year others were shown at MoMa, the Museum of Modern Art, in New York.

With the imminent arrival of Hitler's army in 1940, Man Ray was forced to flee Paris, leaving behind much of his work and eventually settling in Hollywood. Man Ray retrieved the photographs in 1948 and embarked on a new series of twenty-three oil paintings based on the models. Originally titled the "Human Equations," Man Ray emphasized the anthropomorphic qualities that he saw in the

Figure 1. Man Ray in his Hollywood studio in 1947. Behind him can be seen "Twelfth Night" (Figure 2), "As You Like It": showing a sphere in (Man Ray's) hand, and "As You Like It (Hands Free)": based on the model "Three helices with the same axis and pitch."

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Figure 2. Man Ray's "Twelfth Night" incorporates four different models from the Institute Henri Poincaré (Figure 3). The strange object, front right, with an "egg" sitting on it is actually the stand for a model of a cyclide. The spiral object behind it is a broken lampshade, one of Man Ray's favorite artifacts.

models. When the paintings were featured later that year in a show at the Copley Gallery in Beverly Hills, Man Ray had assigned each painting the name of a play by Shakespeare and had renamed the entire series the "Shakespearean Equations."

From February to May 2015, the Phillips Collection in Washington DC presented a major Man Ray exhibition. Titled "Man Ray—Human Equations: A journey from mathematics to Shakespeare," the exhibition brought together for the first time eighteen of Man Ray's Shakespearean Equations paintings, his 1936 mathematical model photographs, and some of the original models from the Institut Henri Poincaré. A significant selection of Man Ray's other work was also exhibited. The exhibition was curated by Wendy Grossman.

Running concurrently at the Phillips, in an adjacent room, was a second exhibition titled "Hiroshi Sugimoto: Conceptual forms and mathematical models." When contemporary Japanese photographer and sculptor Hiroshi Sugimoto saw the University of Tokyo's nineteenth-century German mathematical model collection in 2002, he recognized the models from Man Ray's work (see Figure 10). In addition to Sugimoto's large-format photographs of the University of Tokyo models, this exhibition featured several of the very large polished aluminum mathematical models that Sugimoto made himself using high-precision Japanese industrial milling technology.

Many readers of this review will undoubtedly also have seen models in glass cases like the ones Man Ray saw in Paris and Sugimoto saw sixty years later in Tokyo, since these types of models still exist in math departments throughout the world.[1] One of the most extensive and well-documented collections in the United States is at the University of Illinois (`www.mathmodels.illinois.edu/`). Another excellent collection, with a good website, is at Harvard (`www.math.harvard.edu/history/models/index.html`). These types of models cover many different mathematical topics. Beyond models of simple objects like spheres, ellipses, and cones, there are stellated polyhedra, space curves, and linkages.

The most popular topics for the models are surfaces. Among the models that Man Ray photographed at the Institut Henri Poincaré and then painted was a Meissner tetrahedron (Figure 4). This is a solid surface with a constant diameter that is made by intersecting four spheres, then modifying three of the edges. As a painting, the Meissner tetrahedron becomes Man Ray's "Hamlet."

Other surfaces found among the models come from differential and algebraic geometry or depict the graphs of functions. The Kummer surface is a quartic surface with eight real double points. The plaster model of the Kummer surface (Figure 5) that Man Ray photographed at the Institut Henri Poincaré consists of six sheets suspended by metal rods that touch at the double points. Man Ray transforms this surface into the painting "King Lear." One imagines the top sheet as Lear himself and the sheets below as Lear's long-suffering daughters. In a similar way, the poles of the derivative $\wp'$ of the Weierstrass $\wp$-function become, for Man Ray, "The Merry Wives of Windsor" (Figure 6).

Man Ray's "Julius Caesar" (Figure 7), which served as the poster for the Phillips exhibition, is based on the essential singularity in the graph of the real part of $w = e^{1/z}$ at $z = 0$. A mathematician would understand this in terms of Picard's great theorem, which says that in any neighborhood of $z = 0$, the variable w must take every complex value except one. However, it is certain that Man Ray was oblivious to this fact. He said, "The formulas accompanying [the models] had meant nothing to me." Yet we know from Picard that this function must have some sort of extremely complicated behavior in a neighborhood of $z = 0$. Any good model of the graph would have to reflect this complexity; the model would have to "look" interesting. Indeed, as Man Ray puts it, "The forms themselves were as varied and authentic as any in nature." In other words, the complexity of the mathematics comes through in the models, and this is why they captured Man Ray's imagination.

[1] *A list* `https://angelavc.wordpress.com/collections-of-mathematical-models/` *of locations of mathematical model collections is maintained by Angela Vierling-Claassen.*

Figure 3. Three of the Institut Henri Poincaré models in "Twelfth Night": the cubic surface $20x(3y^2 - x^2) - 24(x^2 + y^2) + 3z^2 = 0$, a wooden Enneper minimal surface by Joseph Caron, and Man Ray's photograph of the paper Brill-Schilling model "Curvature Circles at a Point of Negative Curvature."

Figure 4. The model of a Meissner tetrahedron from the Institut Henri Poincaré and Man Ray's "Hamlet." Man Ray says that he decorated the Meissner tetrahedron to resemble a breast.

The Institut Henri Poincaré models, and similar models found in other mathematics departments around the world, belong to a particular era in the history of mathematics education that lasted from around 1870 until the beginning of the First World War. Peggy Kidwell, curator of the Smithsonian Museum of American History's extensive model collection, refers to these as models by and for professional mathematicians [6]. Some of the earliest models of this type go back to collaborations between Alexander Brill, a mathematician with an interest in model making, and Felix Klein. Model design went on to become a standard exercise that Klein and other German mathematicians assigned to their students. The models were "published" by Brill's brother, Ludwig Brill, who manufactured and sold the models through a catalog (some of these catalogs can be seen on the University of Illinois website). Brill was later joined by mathematician Martin Schilling, who eventually took over the business. A nice book about these "Brill-Schilling" models is [2].

In addition to the Sorbonne (whose models later ended up in the Institut Henri Poincaré) and the University of Tokyo, many American universities also acquired models during this period. Despite their high prices, newly serious American mathematics departments were anxious to keep up with the latest German techniques in mathematics education. The German models, once acquired, often inspired local interest in model making. The Institut Henri Poincaré collection includes many models by the French mathematician Joseph Caron. Some of Caron's models ended up in Man Ray's work; for example, Caron's Enneper surface appears in "Twelfth Night" (see Figures 2 and 3). In the US, models were made and sold by Richard P. Baker[2] of Iowa State University until the 1930s (see [6]). But the golden age of mathematical models would essentially end with the beginning of the First World War as German products became increasingly unavailable. Also, mathematics was entering a more axiomatic and algebraic period that would ultimately be exemplified by the iconoclastic Bourbaki.

Visual mathematics, including model building, is something that goes in and out of style. There was not much interest in models of polyhedra when Magnus Wenninger began making them in 1958 (see [9]), but now one can buy a commercial polyhedral modeling system called Zometool (see

[2] *To see some of Baker's models, visit the Smithsonian webpage* `collections.si.edu/search/index.htm` *and search "Richard P. Baker."*

Figure 5. The Kummer surface from the Institut Henri Poincaré, Man Ray's 1936 photograph of it, and its transition in 1948 to "King Lear." The model was designed by Karl Rohn (see [7] for a history of models of Kummer surfaces).

Figure 6. The Weierstrass $\wp'$ function and Man Ray's "Merry Wives of Windsor."

[3]). Computer graphics started to become available in the late 1970s. As a student I remember being mesmerized by a Thomas Banchoff (see [1]) lecture about computer visualization of the 4-dimensional graphs of complex analytic functions. Computer graphics really took off in the 1980s, sixty years after the First World War, as inexpensive personal computers with previously unimaginable graphical capabilities became widely available. In the period immediately following the First World War, Pierre Fatou and Gaston Julia laid the foundations for what would ultimately become complex dynamics, but they were hindered by their inability to "see" a Julia set. No field was revolutionized by computer graphics more than complex dynamics, where pictures almost always preceded theorems. Pictures of Julia sets and Mandelbrot sets even became a sort of "folk art," appearing on posters and t-shirts. A picture of what is called "Douady's rabbit" (Figure 8) is a Julia set with an attracting periodic orbit of period 3. It is a rabbit in precisely the same sense that Man Ray's "Julius Caesar" is Julius Caesar.

Although Man Ray was not a mathematician, mathematical ideas figure frequently in his work. One of Man Ray's readymades, which appeared in the Phillips exhibition, is a coat hanger mobile called "Obstruction" (Figure 9). It arrives at a gallery as a suitcase full of coat hangers, with the following assembly instructions (in Man Ray's handwriting with a hand-drawn diagram): "You begin with one hanger attached to the ceiling. In the two holes at the extremity of the hanger introduce two more hangers. Into these you hook four more hangers. Into these you hook eight more hangers and so on until the sixth row has thirty two hangers. Of course if enough hangers are available, this mathematical progression may be carried on to infinity. The increasing confusion is apparent only to the eye and is to be desired. Man Ray." Downstairs at the Phillips was a contemporary coat hanger mobile made by a group of students from Kenmore Middle School in Arlington, Virginia, who had visited the Man Ray exhibition.[3]

Another example of Man Ray's interest in mathematics is his 1938 painting "La quadrature," which appeared in the Phillips exhibition. Man Ray painted it after having a dream about the impossibility of "squaring the circle." The painting looks like a mechanical device consisting of a cone that pushes down into a circle, stretching it out into a square. It was painted well before the Shakespearean Equations, but after Man Ray's visit to the Institut Henri Poincaré, and was clearly influenced by the models there. A study for the painting shows a second device that is obviously a

[3] *See the* Washington Post *article* `www.washingtonpost.com/local/education/at-arlingtons-kenmore-middle-school-teaching-math-really-is-an-art/2015/05/17/12342ae2-f8cd-11e4-9ef4-1bb7ce3b3fb7_story.html`.

Figure 7. The real part of $w = e^{1/z}$ near the origin, and Man Ray's "Julius Caesar." Caesar's scepter is a table leg with a caster. Behind Caesar is a blackboard with mathematical formulas, including $\sqrt{\text{Man Ray}}$ and $2 + 2 = 22$.

linkage, a common subject for the model makers. Man Ray's fascination with squaring the circle comes out again in the Shakespearean Equations "King Lear" (Figure 5), in which the square canvas is mounted on a board with a wooden circle.

Many of the surfaces that Man Ray would have seen modeled at the Institut Henri Poincaré are now easy to draw using software like `Mathematica`. Many of these surfaces are featured in the book *Modern Differential Geometry of Curves and Surfaces with* `Mathematica` by the late Alfred Gray [4]. `Mathematica` pictures of surfaces can be rotated on the screen, and controls can be added to animate the picture as the parameters change. The Phillips exhibition also featured a computer graphics demonstration, furnished by MoMath, the Museum of Mathematics in New York. The screen showed images of several algebraic surfaces, and there were knobs that visitors could turn to vary the parameters in real time. But even with this added motion, these pictures were pretty dull compared to the models, the photographs, and the paintings. The paintings, in particular, have a presence that is very poorly conveyed by anything in a book or on a computer screen. This is why we still go to museums.

Beyond computer graphics, there is 3D-printing, which is now fairly easily accomplished using `Mathematica` and an online printing company.

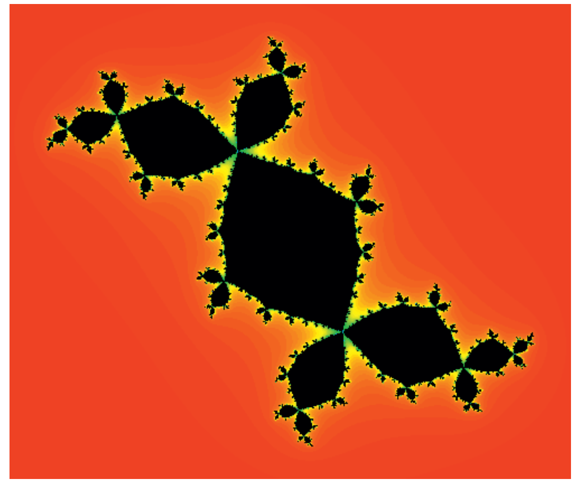

Figure 8. Douady's "rabbit."

Figure 9. Man Ray's "Obstruction": a binary tree made out of coat hangers.

One ends up with a physical model not unlike the models from the Institut Henri Poincaré or University of Tokyo. In fact, this is a less expensive version of the process Sugimoto used to make his gigantic models (Figure 10).

In my own attempt to draw some of the models with `Mathematica`, I rediscovered something I already knew from teaching calculus. The hardest thing is to find the right view. Choosing the view is a process akin to composing a photograph, something Man Ray and Hiroshi Sugimoto would be familiar with.

But using a computer to draw a picture of a surface, or even printing it in 3D, is not the same as drawing or painting it by hand or molding it out of a solid material. Drawing, painting, and sculpting are physical activities that demand a more intimate relationship with their subject. If you look carefully at Man Ray's Shakespearean Equations paintings you will see that they are drawn very accurately. So while Man Ray may have dressed up the mathematics in new Shakespearean costumes, the mathematics itself still shines through unscathed. A rose by any other name…

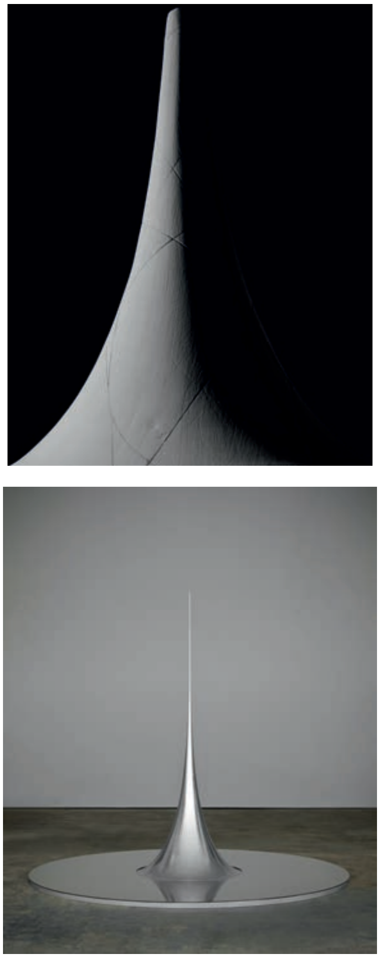

Figure 10. Sugimoto's photograph of a pseudosphere and his aluminum pseudosphere sculpture. The sculpture is about 2 meters tall, and the end of the cusp is about 0.5 millimeters in diameter.

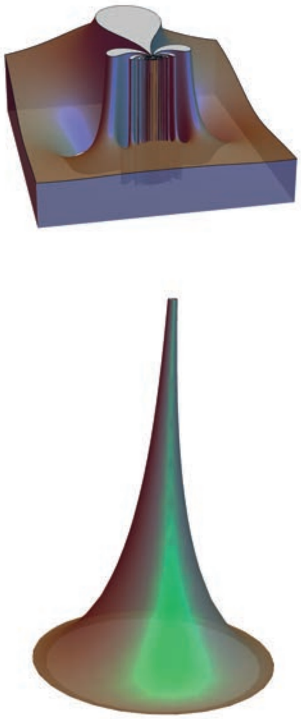

Figure 11. *Mathematica* **plots of $w = e^{1/z}$ near $z = 0$, and a pseudosphere.**

After the Phillips, the Man Ray Human Equations exhibition travels to the Ny Carlsberg Glyptotek in Copenhagen, where it runs June 11 to September 20, 2015. Then it moves to The Israel Museum in Jerusalem, where it runs October 20, 2015, to January 23, 2016.

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- Figure 10: Hiroshi Sugimoto, Surface of Revolution with Constant Negative Curvature *(Conceptual Form 0010)*, 2004. Gelatin-silver print, 58 3/4 × 47 in. Collection of the artist, New York. Hiroshi Sugimoto, Surface of Revolution with Constant Negative Curvature *(Mathematical Model 009)*, 2006. Aluminum and mirror, 76 × 27 1/2 in. diam. Pace Gallery, New York.