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# The *Large Glass* Seen Anew: Reflections of Contemporary Science and Technology in Marcel Duchamp's "Hilarious Picture"

Linda Dalrymple Henderson

## INTRODUCTION

The following text is drawn from the conclusion of Linda Dalrymple Henderson's recent book *Duchamp in Context: Science and Technology in the Large Glass and Related Works* (Princeton, NJ: Princeton University Press, 1998). This section of the book presents an overview of new readings of Duchamp's *The Bride Stripped Bare by Her Bachelors, Even* (*The Large Glass*) (1915–1923) suggested by a study of early twentieth-century science and technology, two of several fields to which Duchamp responded so creatively in this project. Determined to restore to art an emphasis on the mind of the artist (rather than on the hand), Duchamp spent three years making copious notes for the work before he began its execution in 1915. Not only did he experiment with a variety of unorthodox alternatives to the painter's oil on canvas, he also considered his notes to be as important as the work's visual form, publishing three collections of notes during his lifetime: the *Box* of 1914; the *Green Box* (1934); and *A l'infinifit* (1966). After Duchamp's death, however, another 289 unpublished notes were found, at least 100 of which date to the period of his intense work during the 1910s on the *Large Glass* project. *Duchamp in Context* provides the first systematic study of the *Glass* in relation to the entire corpus of Duchamp's notes as well as to the science and technology that captured the imagination of the public during this period—from X-rays and wireless telegraphy to radioactivity and Brownian motion.

The *Large Glass* is a humorous allegory of sexual quest cast in scientific/technological language: a four-dimensional, biomechanical *Bride* hangs in the upper half of the *Glass* ever beyond the reach of the mechanical *Bachelors*, who are confined to the three-dimensional, gravity-bound realm below. Unlike his friend Francis Picabia, Duchamp almost never replicated specific images from science and technology. Rather, he used visual and verbal metonymy to encode his scientific content and usually layered one meaning over another in individual components of the *Glass*. Duchamp's models for his creative invention were the writers Alfred Jarry and Raymond Roussel, and, like them, he was ever alert to the possibilities for humor (especially wordplay and visual and verbal punning) as he ranged through the milieu of science and technology. In his "painting of precision" and its accompanying notes, Duchamp fashioned a new identity for himself as a detached artist/engineer operating in the realm of the intellect—in deliberate contrast to his former Cubist colleagues, who by 1912 had embraced the philosophy of Henri Bergson and now promoted an art based on intuition, profound self-expression and the sensitive touch of the artist [1].

## THE *LARGE GLASS* SEEN ANEW: REFLECTIONS OF CONTEMPORARY SCIENCE AND TECHNOLOGY IN MARCEL DUCHAMP'S "HILARIOUS PICTURE"

In the standard "litany" of Duchamp's *Large Glass*, or *The Bride Stripped Bare by Her Bachelors, Even* (Figs 1, 2), codified long before the appearance of his unpublished notes in 1980 and repeated again and again in the Duchamp literature, the main connections to science and technology are made through the *Bride's* identity as an automobile, the metamorphosis of a mysterious *Illuminating Gas* into a liquid *Splash*, and the suggestion of mechanics in the activities of the *Chariot/Glider* propelled by a falling *Weight* [2]. When his notion of "Playful Physics" has been treated at all in this literature, it is reduced to a brief mention of any or all of the "Laws, principles, phenomena" listed in the notes of the 1934 *Green Box*: the "stretching in the unit of length," "oscillating density," "emancipated metal," and "friction reintegrated" [3]. Studies of the notes on four-dimensional geometry in his 1966 collection, *A l'infinifit*, subsequently added Duchamp's engagement with geometry as another aspect of the "mental ideas" behind the *Large Glass* project [4]. Here, too, was the first demonstration of the way Duchamp could use a field, such as geometry, to embody the contrasts or collisions between the realms of the *Bride* and the *Bachelors*. Yet many questions about the *Large Glass* project remained unanswered or even unasked.

The publication of Duchamp's remaining 289 notes forces us to break out of the long-held attitude expressed, for example, by Arturo Schwarz that the two long *Green Box* notes on the *Bride* "give all the basic information on the theme of the *Large Glass* and the psychology of its protagonists" [5]. In fact, those two notes, the ten-page note and the one immediately

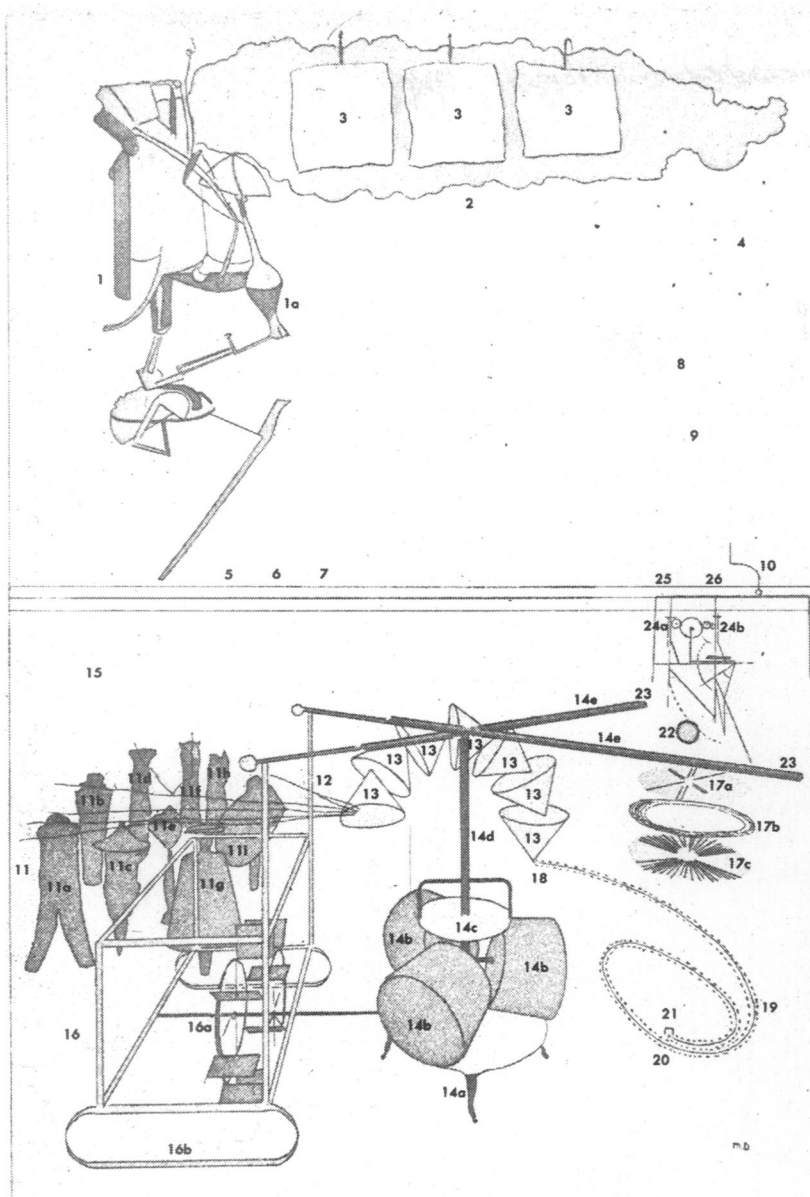
Marcel Duchamp's *The Bride Stripped Bare by Her Bachelors, Even* (*The Large Glass*) of 1915–1923 is a unique image-text system in which the physical object is complemented by hundreds of preparatory notes the artist considered to be as important as the object itself. Although Duchamp talked of "Playful Physics" in his notes for the *Glass*, much of his humor and the breadth of his creative invention was obscured for later audiences when, after 1919, the popularization of relativity theory eclipsed the late Victorian ether physics that had fascinated the public in the early years of the century. Indeed, drawing upon contemporary science and technology, among other fields, Duchamp had created in the *Large Glass* a witty, multivalent commentary on the age-old theme of sexual desire, presented in the very newest verbal and visual languages. These ideas are explored in this article, reprinted from the conclusion of the author's book *Duchamp in Context: Science and Technology in the Large Glass and Related Works*.

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**Fig. 1.** Marcel Duchamp, *The Bride Stripped Bare by Her Bachelors, Even (The Large Glass)*, oil, varnish, lead wire, lead foil, mirror silvering and dust on two glass panels (cracked), each mounted between two glass panels with five glass strips, foil and a wood and steel frame, 109  $\frac{1}{4}$   $\times$  69  $\frac{1}{8}$  in, 1915–1923. (Photo courtesy of Philadelphia Museum of Art, Bequest of Katherine S. Dreier. © 1998 ARS, New York/ADAGP, Paris. Reproduced by permission of the Marcel Duchamp Archive, Villiers-sous-Gréz, France.)



This diagram is based on Duchamp's etching *The Large Glass Completed*, 1965.

THE BRIDE'S DOMAIN (upper half of the glass):

1. The Bride (*Pendu femelle*, arbor-type)
  - a. Wasp or Sex Cylinder
2. Top Inscription or Milky Way (the cinematic blossoming)
3. Draft Pistons or Nets
4. Nine Shots
5. Bride's garment
6. Region of the Gilled Cooler (isolating plates)
7. Horizon
8. Region of the picture of cast shadows
9. Region of the mirror image of the sculpture of drops
10. Juggler of Gravity (also called the Trainer, Handler, or Tender of Gravity)

THE BACHELOR APPARATUS (lower half of the glass):

11. Nine Malic Molds (or Eros's Matrix) forming the Cemetery of Uniforms and Liveries
  - a. Priest
  - b. Delivery Boy
  - c. Gendarme
  - d. Cuirassier (cavalryman)
  - e. Policeman
  - f. Undertaker
  - g. Flunky (liveried servant)
  - h. Busboy
  - i. Stationmaster
12. Capillary Tubes
13. Sieves or Parasols (within are the Drainage Slopes)
14. Chocolate Grinder
  - a. Louis XV chassis
  - b. Rollers
  - c. Necktie
  - d. Bayonet
  - e. Scissors
15. Region of the Waterfall
16. Glider (Chariot or Sleigh)
  - a. Water Mill Wheel
  - b. Runners sliding in a groove
17. Oculist Witnesses
  - a. Oculist Charts
  - b. Oculist Charts
  - c. Oculist Charts
18. Region of the Butterfly Pump
19. Toboggan (or Corkscrew or Slopes of Flow)
20. Region of the Three Crashes (or Splashes)
21. Weight with nine holes
22. Mandala (a magnifying glass to focus the splashes)
23. Marbles
24. Boxing match
  - a. First ram
  - b. Second ram
25. Region of the sculpture of drops
26. Region of the "Wilson-Lincoln effect"

No. 10 and nos. 18-26 are elements that were not completed in the *Large Glass* (1915-23).

Fig. 2. Diagram of components of Duchamp's *Large Glass*. (Reprinted by permission from Marcel Duchamp [Philadelphia, PA: Philadelphia Museum of Art, 1973] p. 64.)

following it, were only an initial statement of the project, and Duchamp was to add many more layers of meaning by the time he stopped making notes for the work. Although the present book is just a beginning in the attempt to understand Duchamp's body of notes as a whole, the focus here on the theme of science and technology has made it possible to enlarge considerably previous ideas about the components and processes embodied in the *Glass*.

Turning first to the Bride, early twentieth-century automobile literature held the clue that Duchamp's *arbre type*, or tree type, is an automobile transmission

shaft (*arbre*) and that, like the drawing *Virgin (No. 1)* (Fig. 3), the painted *Bride* (Philadelphia Museum of Art) and the Bride of the *Large Glass* (Fig. 2, No. 1) are based loosely on the structure of an automobile (Fig. 4) [6]. In the Bride, Duchamp cleverly conflated his interest in internal bodily organs and skeletal structures, revealed by X-rays of the body, to create the combination of spinal column, transmission shaft, and blossoming tree that serves as the Bride's basic persona. The Bride as *arbre* (organic or mechanical) also offered an iconoclastic allusion to the Virgin Mary as well as to the goddess Persephone—

creating another level of allegorical meaning in the *Glass* beyond its basic sexual content [7]. Duchamp's original conception of the form and structure of the Bride, which also took on associations with chemical apparatus, remained largely unchanged from the painting of summer 1912 through her initial incarnation in the *Glass*. Gradually, however, he developed additional identities for her in his notes, humorously augmenting the Bride's personality and sexual functions as well as her links to other areas of science. Although the names of many of the Bride's constituent parts were known from Duchamp's published

notes, his posthumously published notes now make it possible to propose locations for most of those components [8].

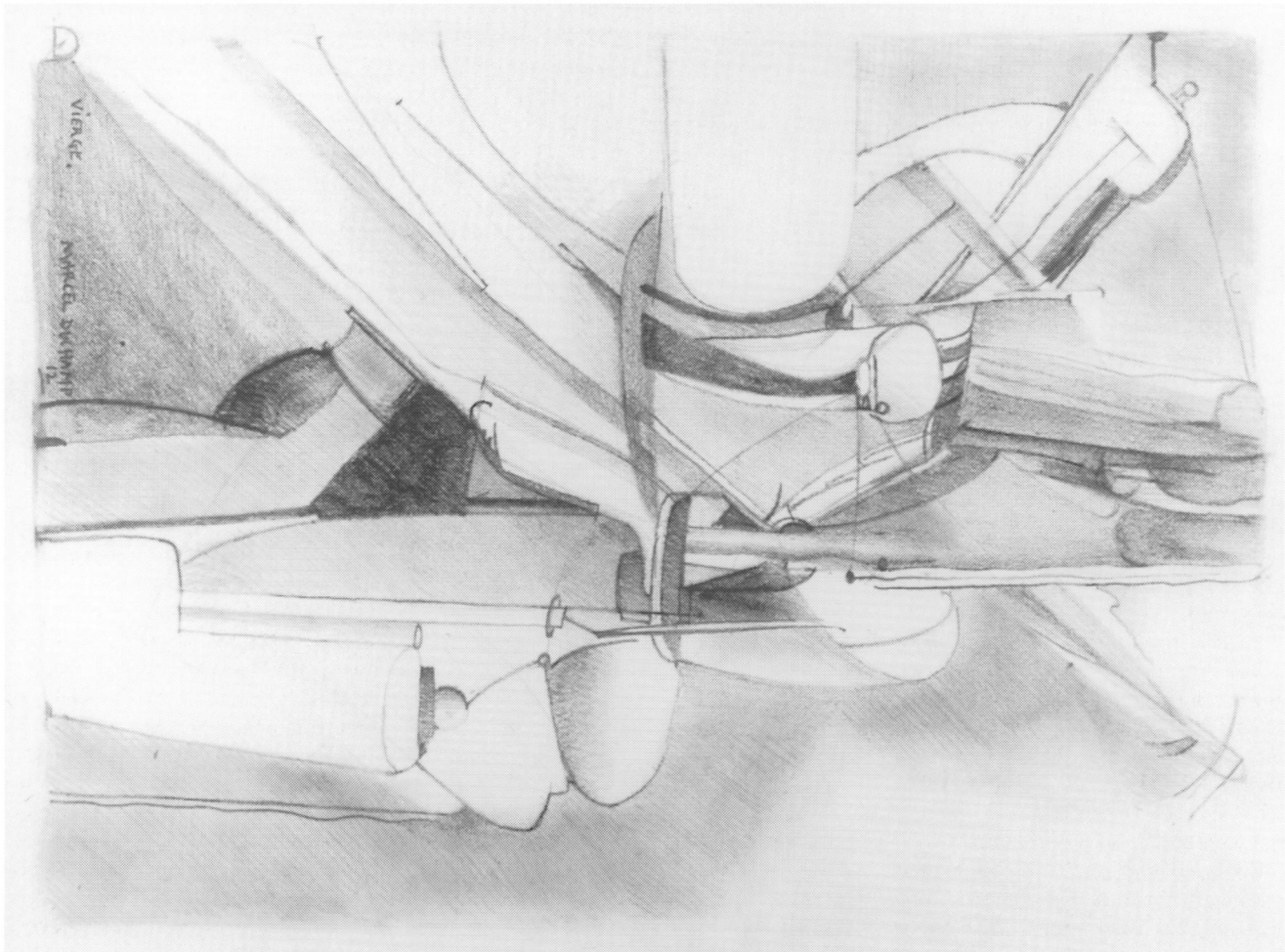
There is a delicate blend of the organic and the mechanical in the Bride, a quality that distinguishes her markedly from the comically mechanical Bachelors. Several of the Bride's identities reinforce this organic-mechanical quality. Specifically, her associations with the "organic" automaton envisioned by Villiers de l'Isle-Adam in his 1886 novel *L'Ève future* brought together the type of clockwork mechanism seen in the Bachelors and in traditional automata and Villiers's descriptions of the flesh and organs of Hadaly that evoke the "visceral" quality of the Bride, whom Duchamp described as "half-robot, half four-dimensional" [9]. In addition to her all-important associations with wireless telegraphy, Duchamp gave her three other identities: her functioning as various meteorological instruments (barometer, weather vane), her association with

incandescent lightbulbs, and her persona as Wasp. Cleverly linking all three was the concept of the Bride's "filaments," which take on specific meanings in each of these contexts. As a Barometer, the Bride registers her own "storms and fine weathers" by means of the "meteorological extension" of her filaments—as if she were a hygrometer with hair stretching in response to moisture. As Weather Vane, she swings freely in those "air currents" and randomly "horse kicks" a "circle of cardinal points," determining (by the "principle of subsidized symmetries") the displacement she will communicate to the never-executed Juggler/Handler of Gravity (Figs 5, 6) by the extension of her filaments [10].

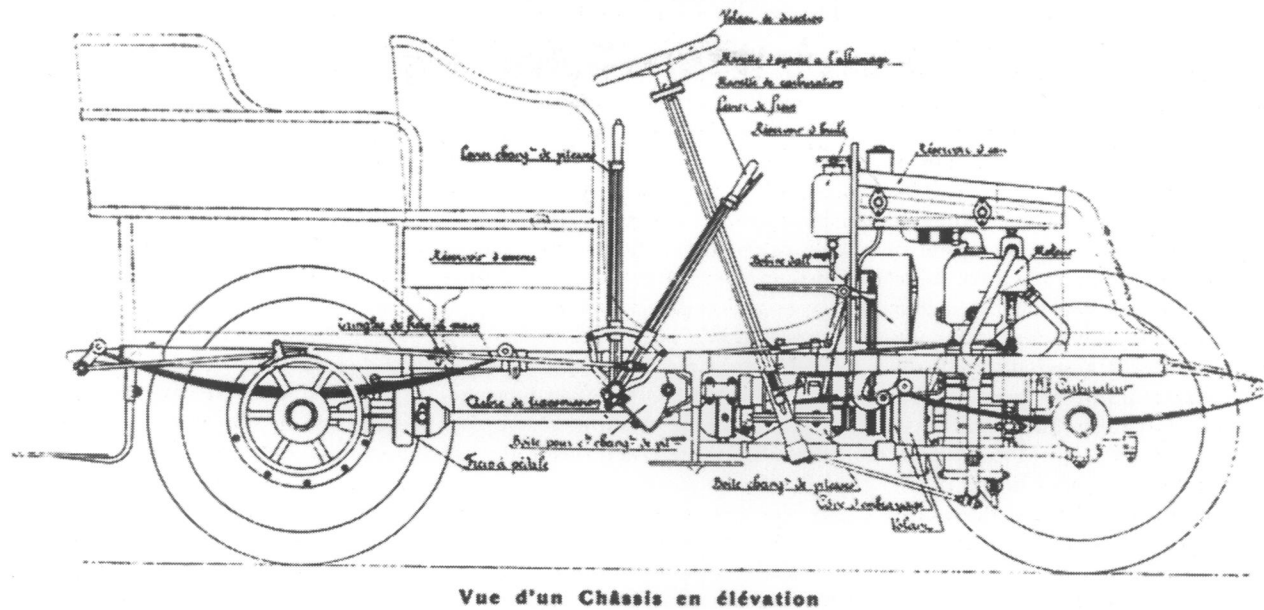
Duchamp's use of the term "filament" and of seemingly organic notions such as "nourishing the filament paste" relates directly to contemporary technology for making incandescent lightbulbs, in which extruded paste filaments were

"nourished" with carbon. Like the *arbre*, as we have seen, both the glass bulb and the notion of "put[ting] the whole Bride under a glass cover" have strong overtones of religious and mythological figures associated with sealed glass vessels, such as the Virgin Mary, and with torches (Persephone) and their modern electrical counterparts. In addition, the idea of putting a figure under glass suggests that the Bride as Wasp relates to the observations of the popular entomologist J.-H. Fabre and their use in Remy de Gourmont's 1903 *Physique de l'amour: Essai sur l'instinct sexuel*, which abounds with organic-mechanical analogies. Indeed, Gourmont's treatment of human sexuality in terms of the animal kingdom and mechanical processes must now be recognized as a crucial prototype not only for Duchamp but for any artist interpreting sexuality in mechanical terms in this period. In giving her the guise of highly intelligent Wasp, Duchamp reasserted the organic side of

Fig. 3. Duchamp, *Virgin [No. 1]*, pencil on paper, 428 × 220 mm, 1912. (Reproduced turned 90° to the right.) (Philadelphia Museum of Art, The A. E. Gallatin Collection. © 1998 ARS, New York/ADAGP, Paris. Reproduced by permission of the Marcel Duchamp Archive, Villiers-sous-Gréz, France.)



## Voiture légère RENAULT Frères



Vue d'un Châssis en élévation

Fig. 4. Renault Frères, "light car" chassis in elevation, ca. 1901. (Reprinted from Yves Richard, *Renault 1898, Renault 1965* [Paris, 1965] p. 25. Reprinted by permission of Service Histoire et Collection, Renault, Boulogne Billancourt, France.)

the Bride and linked her filaments to the "vascularized paste" produced not only in the lightbulb industry but by paper wasps [11].

The Bride's filaments were primarily a physical sign for what he termed the "horizontal" aspect of her "cinematic blossoming" or imagined orgasm, a process to which he gave visual form in several drawings (e.g., Fig. 5) [12]. In his ten-page note in the *Green Box*, in *Salt Seller*, Duchamp had already distinguished between the Bride's "vertical" and "horizontal" blossomings, associating them, respectively, with the "stripping" or tugging on her garment by the Bachelors' Boxing Match mechanism (Fig. 2, No. 24) and with her "voluntary-imaginative" stripping or her "self blossoming." Although he talked in that first note about the "collision" and subsequent "conciliation" of these two blossomings, Duchamp had not yet developed the Juggler/Handler of Gravity to serve as the locus of the meeting of the two blossomings (Fig. 6). Indeed, the Juggler was to become the crucial intermediary between the Bride in the upper level of the *Glass* and the Bachelors below, carrying on a wave-borne dialogue with the Bride (identified with her horizontal "self blossoming") and, at the same time, registering the physical movement of her Clothing (Fig. 2, No. 5; never executed) as he balances on it above the tugging Boxing Match (the

vertical blossoming/stripping). While Duchamp never added the Juggler/Handler to the *Glass* before he abandoned work on it in 1923, he remained committed to this central figure, celebrating his role in a 1947 tableau, *The Altar of the Handler of Gravity*, created for the Paris exhibition *Le Surréalisme en 1947*.

In his first, automobile-oriented notes on the Bride, Duchamp treated her sexual response metaphorically in terms of the firing of a gasoline combustion engine in an automobile. While the Bride's sexual functions center around a motor, for which she secretes "love gasoline" and for which her Desire-magneto produces the "sparks of her constant life," the notes also stress the role of electricity, including references to "electrical stripping," "electrical control" of the stripping, and the fact that between the Bride and the Bachelor Machine "the connections. will be. *electrical*." In conjunction with Duchamp's description of the Bride's "cinematic blossoming" as the "sum total of her splendid vibrations" and the prominent role of sparks in Duchamp's scenario (including the "artificial sparks" that both control the Bachelors' Boxing Match and provide a second "stroke" to the Bride's motor), the suggestion of the theme of communication via electromagnetic waves (i.e., wireless or spark telegraphy) is unmistakable. Indeed, Duchamp further confirmed such an interest in the

notes of the *Box of 1914*, which include references to "Electricity at large" as the "only possible utilization of electricity 'in the arts'" and to his intention to "make a painting of frequency" [13].

In this period, words such as *vibration* and *frequency* would have called to mind the electromagnetic waves that were revolutionizing the field of communication, just as X-rays earlier had produced a radically new way of seeing (and with it a distrust of human perception) and had popularized the notion of space as filled with vibrating waves of varying frequencies. Both Frantisek Kupka, Duchamp's informal mentor, and the avant-garde poets of the prewar years, including his friend Guillaume Apollinaire, responded enthusiastically to wireless telegraphy and its implications for contemporary culture [14]. For Duchamp the realms of electricity and electromagnetism must have been particularly appealing because of their sexually suggestive language—from excitation to sparks and vibration. Further, Edouard Branly's (and earlier Nikola Tesla's [15]) development of what we now term "radio control" of objects by means of wave signals offered an even more specific model for the interaction of Duchamp's Bride with her Bachelors—whose mechanical activities she stimulates by her actions.

Duchamp's allusions to electromagnetic communication, however, could

only be indirect—that is, by means of the apparatus, materials, and functions relating to the emission and detection of Hertzian or wireless telegraphy waves. The mid-section dividing the upper and lower halves of the *Large Glass*, for example, with its three stacked glass strips, strongly suggests the construction of an electrical condenser (Fig. 7), a vital element in the production of sparks for wireless, spark telegraphy. The primary source of sparks in the *Glass* is the Bride, and located at her “life-center,” according to Duchamp, is a “spherical, empty emanating ball,” or the kind of ball associated with a spark gap in wireless telegraphy [16]. He also refers to the Bride as an “isolated cage,” and as she hangs at the top of the *Large Glass*, her form and functions suggest the insulated, cagelike emitting antennae for wireless telegraphy atop the Eiffel Tower [17]. Moreover, the Bride sends commands to the Bachelors in the form of code-like “alphabetic units” through the Air Current

Pistons of the Top Inscription and Milky Way, the cloudlike form of the Bride’s “blossoming” actually executed on the *Glass* (Fig. 2, nos. 2 and 3) [18].

The other emitter of waves or signals in the *Glass* is the Juggler of the Center of Gravity or Handler of Gravity, whose “ball in black metal” projects “waves of disequilibrium” toward the Bride (Figs 6, 8) [19]. Here Duchamp cleverly combines the fields of mechanics and electromagnetism using the theme of equilibrium and its displacement: in statics, the disruption of equilibrium means loss of balance, whereas in an oscillating electrical circuit such a disruption accompanies the production or detection of Hertzian waves. Both the Bride and the Juggler are capable not only of emitting signals but also of detecting and receiving wave-borne messages. Among the Bride’s properties are a “Flair or sense receiving the waves of disequilibrium” and a “Vibratory property determining the pulsations of the needle,” seemingly

a reference to wave detectors using magnetized needles [20]. Duchamp specifically suggests the Juggler’s identity as an electrical wave detector in the sketch he included in the *Green Box* (Fig. 8): here the Juggler’s base closely resembles the popular Branly tripod coherer (Fig. 9), a detector that would “dance” at the passage of a wave, just as the Juggler dances on the Bride’s Clothing (albeit registering the mechanical tugging of the Boxing Match). This, then, was the wave-borne interchange between the Bride and the Juggler embodied in her filaments (Figs 5, 6). With their “movement . . . rooted in the Desire-magneto” (and its sparks) these filaments/waves of her horizontal “self blossoming” move back and forth, like the unrolling and rerolling of “certain party whistles from the fair in Neuilly” [21].

In a typical Duchampian overlay, the interaction between the Bride and the Juggler operates both as etherial wave communication and as the physical ma-

Fig. 5. Marcel Duchamp, *Bride and Juggler of the Center of Gravity*, from Duchamp’s four-page note on the *Bride*, 1913–1914. (Reprinted from Paul Matisse, ed., *Marcel Duchamp: Notes*, note 152, p. 2 [62]. © 1998 ARS, New York/ADAGP, Paris. Reproduced by permission of the Marcel Duchamp Archive, Villiers-sous-Grez, France.)

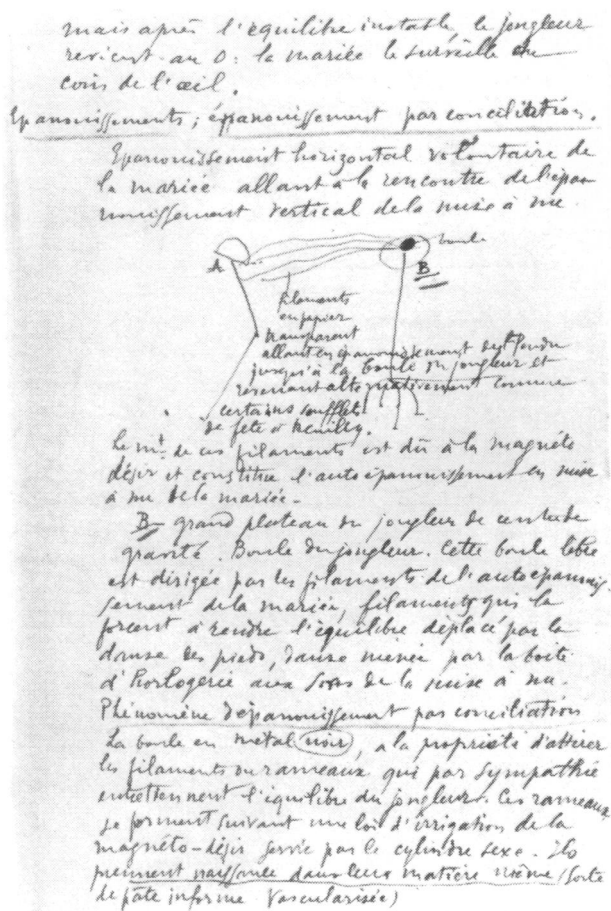
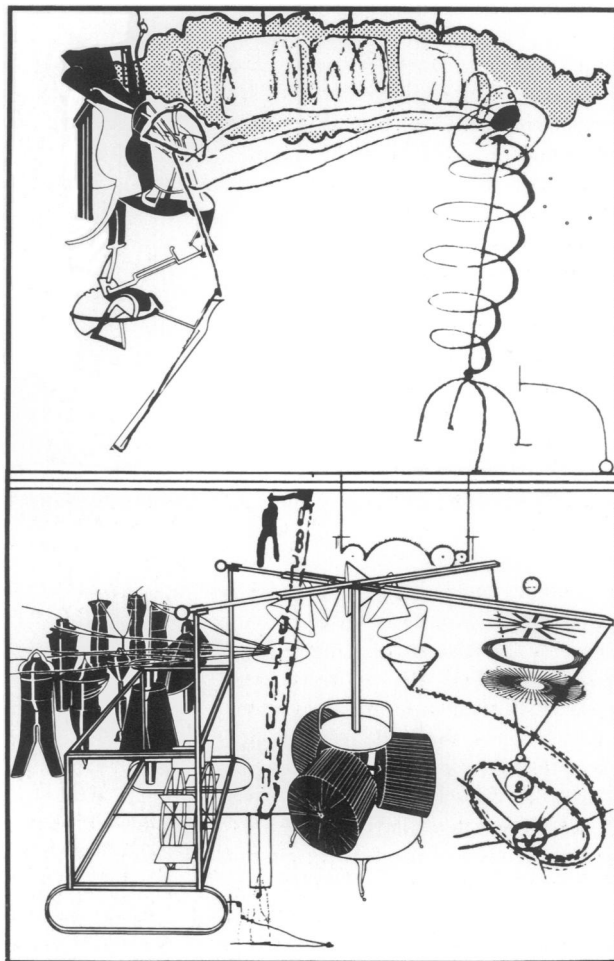


Fig. 6. Diagram of Duchamp’s *Large Glass* with overlay of various components by Jean Suquet. (Reprinted by permission of Jean Suquet)



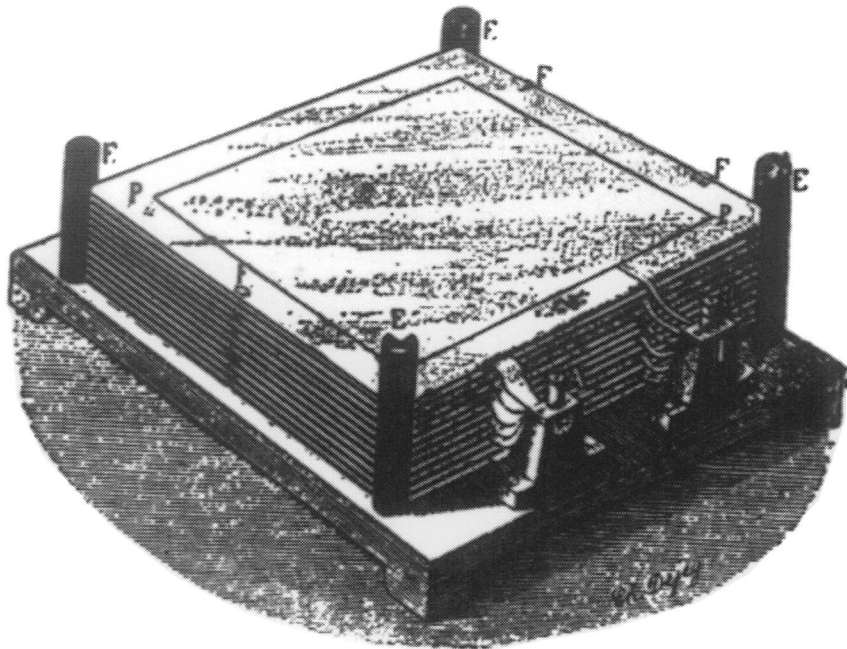


Fig. 7. Electrical condenser. (Reprinted from Georges Claude, *L'Électricité à la portée de tout le monde*, 5th Ed. [Paris, 1905] p. 284.)

nipulation by the Bride's filaments of the Juggler's black ball/stabilizer as he seeks to recover his lost equilibrium—suggesting another metaphor for sexual experience as equilibrium lost and regained [22]. In this interplay of messages and movement, Duchamp had described the Bride's "Inscription" with its "alphabetic units" as able to "displace a [stabilizer]" [23]. Yet, those "commands, orders, authorizations" sent through the Air Current Pistons of the Top Inscription were destined for the Bachelors [24]. Indeed, a more direct form of "broadcasting" to the lower half of the *Glass* is basic to the Bride's interaction with the Bachelors and the inauguration of the sexual/technological activities of the Bachelor Apparatus that culminate in the "vertical stripping" by the Boxing Match. Unlike the Bride and Juggler, who, as denizens of the etherial realm Duchamp conceived as four-dimensional, can both emit and detect waves, the three-dimensional Bachelors can communicate only mechanically with the Juggler (via the Boxing Match) and function solely as receivers of commands. Given Duchamp's interest in indexical registering procedures and the prevalence of scientific apparatus for detecting invisible phenomena in this period, the theme of wireless telegraphy and wave detection offers a number of new identities and functions for familiar components of the Bachelor Apparatus.

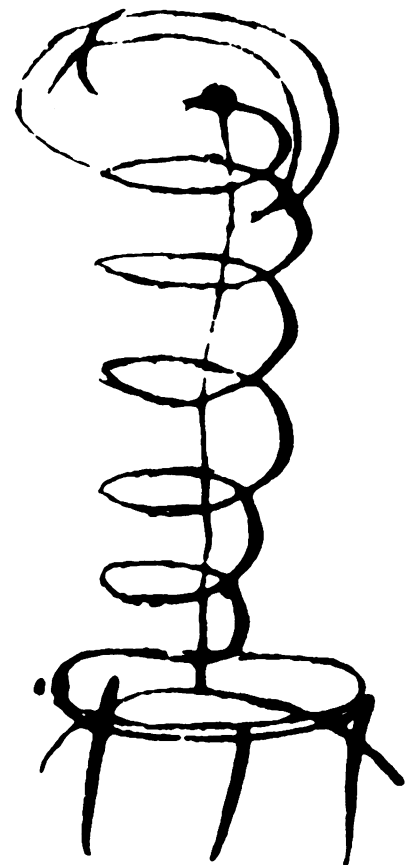
Duchamp's Chocolate Grinder (Fig. 2,

No. 14) with its sexually suggestive grinding of chocolate, would seem to be a hybrid object based equally on the idea of an actual chocolate grinder, with the requisite basin to hold ground chocolate, and a type of wave detector utilizing electromagnets (Fig. 10). Having wound thread through the canvas to produce the grinder ridges in his painting *Chocolate Grinder (No. 2)* (Philadelphia Museum of Art), as if he were winding an electromagnet (Fig. 11), Duchamp approximated the look of that procedure in the *Large Glass* using lead wire. Outlining the forms of the Grinder and the rest of the components of the *Glass* with such wire, which was used to create electrical fuses in France in this period, Duchamp effectively "wired" his "painting of frequency" [25]. If the Bayonet atop the Chocolate Grinder (Fig. 2, No. 14d) suggests a single "aerial" or antenna, the conical Sieves or Umbrellas/Parasols above it (Fig. 2, No. 13) evoke even more directly the experimental forms of early "umbrella" antennae used for gathering waves [26]. Most important, however, in this rethinking of functions in the Bachelor Apparatus is the clarification that the Bachelors/Malic Molds are filled, according to Duchamp, with an "inert illuminating gas"—not the natural gas-like substance meant to be burned, to which he would later allude in a gas lamp held by the nude in his 1946-66 assemblage *Étant donnés* (Philadelphia Museum of Art) [27]. Indeed, the appearance of the

Malic Molds (Fig. 2, No. 11) calls to mind the variously shaped electrical discharge tubes, such as Geissler or Crookes tubes, that could be filled with inert gases at low pressures for use in both scientific and popular contexts (Fig. 12). Because such gases, including the newly popular neon, would fluoresce when electrified or "excited," the tubes could also be used to demonstrate the presence of an electromagnetic wave—and thus came into use as wave detectors in wireless telegraphy practice.

Nikola Tesla was the most dramatic demonstrator of the spectacular effects that could be achieved with such gas-filled tubes in conjunction with the high-frequency alternating current produced by a Tesla coil. George Claude's *L'Électricité à la portée de tout le monde* had illustrated a re-creation of such a Tesla performance (Fig. 13), as well as a photograph of a waterfall (Fig. 14). These two images in a book on electricity point up that theme as a unifying factor behind Duchamp's "Notice" or "Preface"

Fig. 8. Marcel Duchamp, *Juggler of the Center of Gravity/Handler of Gravity*, 1914-1915, drawing on note from the *Green Box*. (© 1998 ARS, New York/ADAGP, Paris. Reproduced by permission of the Marcel Duchamp Archive, Villiers-sous-Grez, France.)





for the *Large Glass* project: “Given: 1. the waterfall/2. the illuminating gas, in *the dark*” [28]. Duchamp’s specification that the events occur “in the dark” reinforces the connection of the *Glass* to Tesla-like demonstrations of illuminated tubes as well as to the nighttime spectacle of an “electric fete,” such as that at Luna Park or the Pier Pavilion at Herne Bay, which Duchamp cited in another note [29]. Here, as in so many other aspects of the *Large Glass*, popular culture added another layer of significance to the scientific events Duchamp was exploring.

Following its “Given” terms, Duchamp’s “Notice” announced that the subject to be considered in the *Large Glass* was the “extra-rapid exposition (= allegorical appearance) of several collisions seeming strictly to succeed each other according to certain laws. . . .” [30] The term “extra-rapid” in conjunction with Duchamp’s use of “instantaneous” in the “Preface” version of this note strongly suggests photography in the dark—specifically the new “instantaneous spark photography” that was being explored by such figures as A.M. Worthington and, subsequently, C.T.R. Wilson. Wilson had photographed subatomic collisions for Ernest Rutherford in his radioactivity research, and his work stands at the infinitesimal pole of the range of collisions Duchamp was to explore in the *Large Glass* [31]. Duchamp later cited booths at county fairs with balls “that you throw at the heads of the bride, the bridegroom, and the guests” as one of the roots of the *Glass* [32]. Indeed, it was to be filled with ballistic events at all scales—from subatomic and molecular collisions to the “blows” of the Combat Marble of the never-executed Boxing Match (Fig. 2, No. 24) and the impact of the Nine Shots targeted at the Bride’s realm (Fig. 2, No. 4). All these events were metaphors, in a sense, for the overarching collision between the goals of the Bachelors and the position of the Bride, high above them and forever beyond their reach. With overtones of a religious and philosophical quest for the beyond, the incommensurability of the relationship of the Bride to the Bachelors is represented most overtly in terms of dimension—her ethereal four-dimensionality versus their confinement in a three-dimensional, perspective construction. Yet science and technology offered crucial means to augment the distinction between the upper and lower halves of the *Glass*, just as it had offered a vehicle for the communication between the Bride and Bachelors via electromagnetic waves.

Fig. 9. Branly’s tripod coherer. (Reprinted from J.A. Fleming, *The Principles of Electric Wave Telegraphy* [London, 1906] p. 366.)

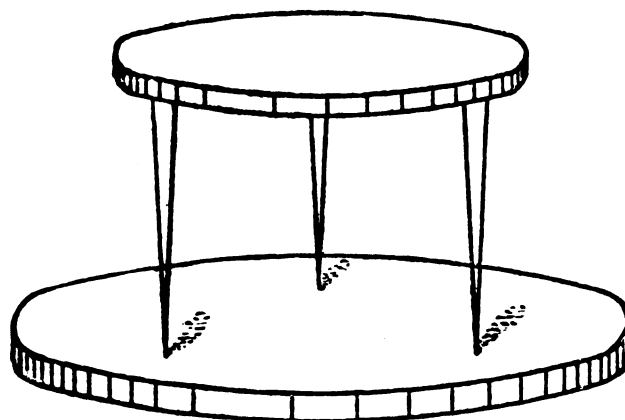


Fig. 10. Arnò’s magnetic wave detector. (Reprinted from Riccardo Arnò, “Rivelatore di onde hertzienne a campo Ferraris,” *Atti Electrotecnica Italiana* 8 [1904] p. 355.)

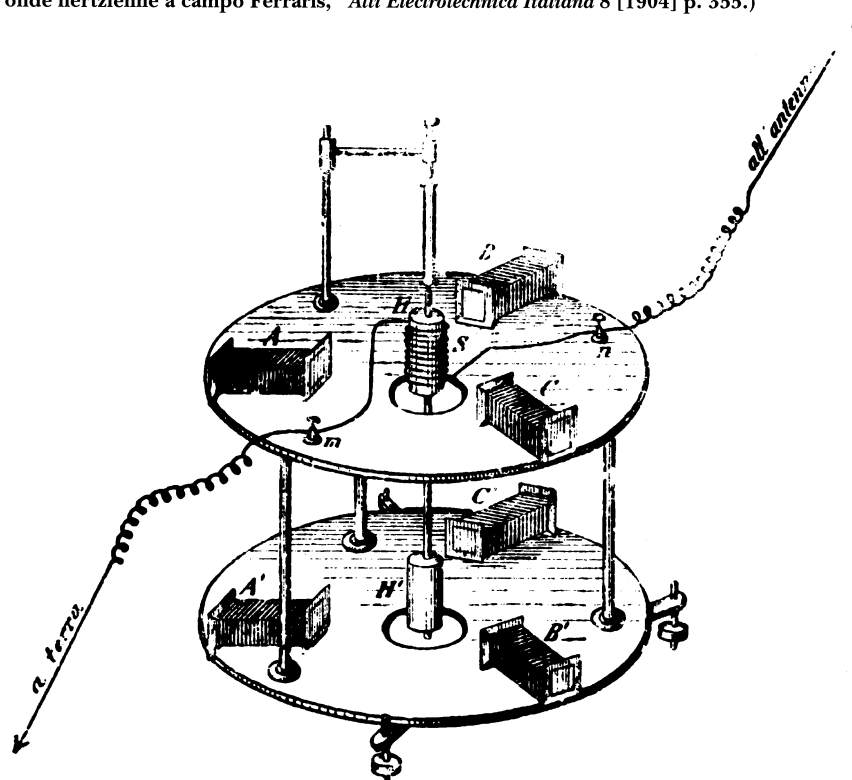
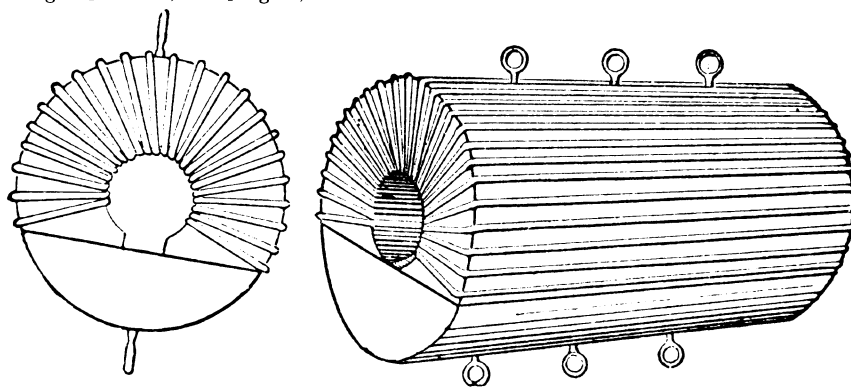


Fig. 11. Joule’s electromagnet. (Reprinted from Silvanus P. Thompson, *Lectures on the Electromagnet* [London, 1891] Fig. 7.)



Duchamp described the *Large Glass* as a “series of variations on ‘the law of gravity’” [33]. Although the Bride’s various identities are modeled on familiar objects, she is nonetheless meant to transcend their three-dimensionality, as she hangs, free of gravity, in her ethereal realm of antigravity. The Bachelors, by contrast, are forever subject to the effects of gravity, and various “falls” as well as collisions dominate the operations of the Bachelor Apparatus. The world of the Bachelors—who “live on coal or other raw material drawn not from them but from their not them”—is purely mechanical; there is none of the smooth blending of organic and mechanical present in the Bride, with her “life center” and internal energy [34]. The actions of the Bachelor Apparatus are jerky, and any element that exhibits anthropomorphic qualities invariably produces a comical effect. Even so, the lower half of the *Glass* was Duchamp’s richest area of scientific and technological invention—the one in which he created a complex and humorous layering of events. From his commentary on male sexual physiology in the thrusting Chariot/Glider (Fig. 2, No. 16) and the exploding Desire Dynamo (never executed) to his exploration of chance and free will at the molecular level, Duchamp in the Bachelor Apparatus responded creatively to aspects of chemistry, physical chemistry (including the kinetic theory of gases), thermodynamics, and mechanics.

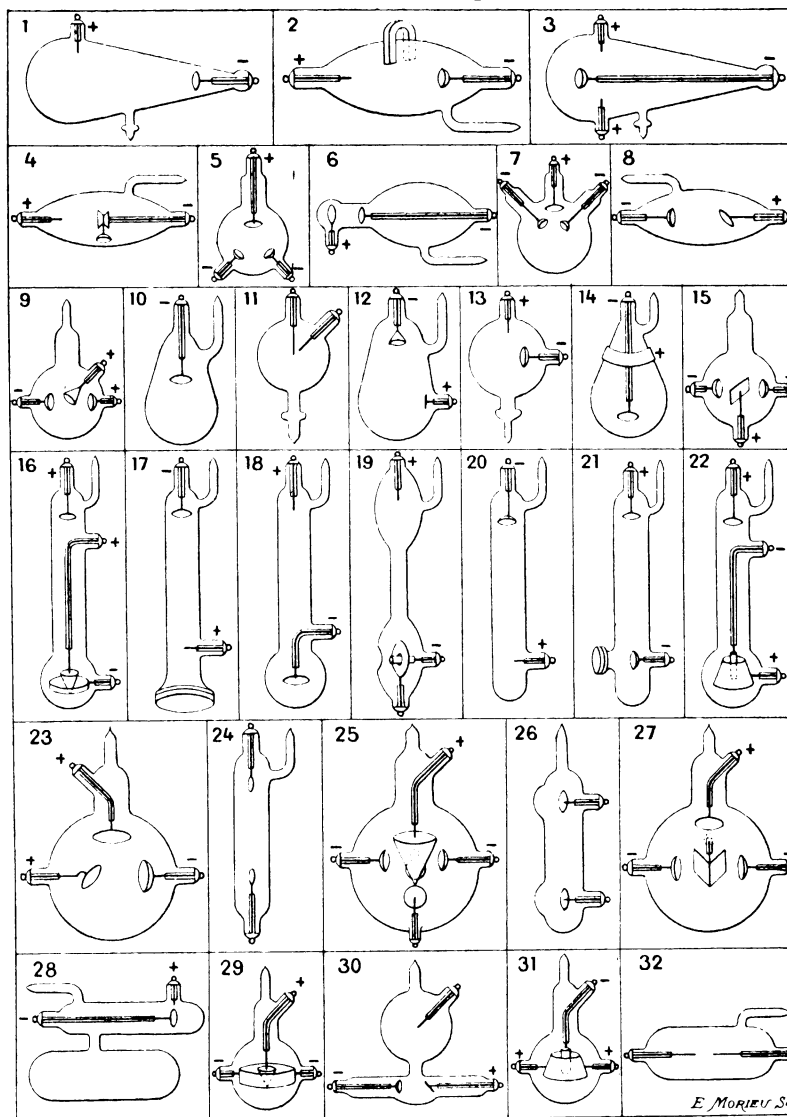
The Juggler/Handler of Gravity was the crucial component never added to the upper half of the *Large Glass*, but the Bachelors’ realm as executed is missing much more of Duchamp’s original conception, as revealed in his posthumously published notes. As he described the operations of the *Glass* in a 1953 interview, “Oh yes, it was very well connected, there was no splashing and no disconnection. It could almost work” [35]. Duchamp’s “First breakdown” note had indicated that, in addition to the Chariot, Chocolate Grinder, and “Tubes of erotic concentration” (the liquefaction apparatus leading from the Malic Molds), there were to be “4. Desire Dynamo—/combustion chamber/Desire centers/Sources of the stripping” and “5. Horizontal column” [36]. Although Duchamp finally substituted an optical Splash mechanism, involving the mirror image of the drops of liquefied Illuminating Gas, as the final stage of the Bachelor operations (i.e., the Oculist Witnesses, Fig. 2, No. 17), his earlier inventions continued to interest

him decades later. In lists of note phrases he made in the later 1950s, seemingly contemplating publishing another set of writings, Duchamp included notes dealing with the crucial Desire Dynamo and fully functioning Horizontal Column or Scissors (Fig. 2, No. 14e) [37]. These notes also address the Mobile, the mechanism that was to have dropped from the end of the Scissors, producing the physical Splash of the gas (see Fig. 6,

right side), and that was a central vehicle for his exploration of chance and the “liberty of indifference” [38].

The central operation in the Bachelor Apparatus is the liquefaction of the inert Illuminating Gas, from its origins in the Bachelors/Malic Molds (and associations with gas-filled vacuum tubes) through successive changes of state until it becomes a semenlike “erotic liquid” [39]. The *gouttes*, or drops, of that liquid

Fig. 12. Crookes tubes and other types of cathode ray tubes for X-ray production. (Reprinted from J.L., “Étude expérimentale des ampoules utilisées en radiographie et fluoroscopie,” *La Nature* 24 [21 November 1896] p. 585.)



N° 1 à 32. — Divers modèles d'ampoules pour radiographie et fluoroscopie. — N° 1 et 2. Ampoules de Crookes. — N° 3. Ampoule Séguy. — N° 4. Ampoule Wood. — N° 5. Ampoule Séguy. — N° 6. Ampoule Chabaud et Hurmuzescu. — N° 7. Ampoule Séguy. — N° 8. Ampoule Tompson. — N° 9. Ampoule Séguy. — N° 10. Ampoule d'Arsonval. — N° 11. Ampoule Séguy. — N° 12. Ampoule Puluj. — N° 13. Ampoule Séguy. — N° 14. Ampoule d'Arsonval. — N° 15. Ampoule Le Roux. — N° 16, 17 et 18. Ampoules Séguy. — N° 19. Ampoule de Rulfz. — N° 20. Ampoule Crookes. — N° 21, 22, et 23. Ampoules Séguy. — N° 24. Ampoule Röntgen. — N° 25. Ampoule Brunet-Séguy. — N° 26, 27. Ampoules Le Roux. — N° 28. Ampoule Colardeau. — N° 29. Ampoule Séguy. — N° 30. Ampoule Colardeau. — N° 31. Ampoule Séguy. — N° 32. Ampoule Röntgen.

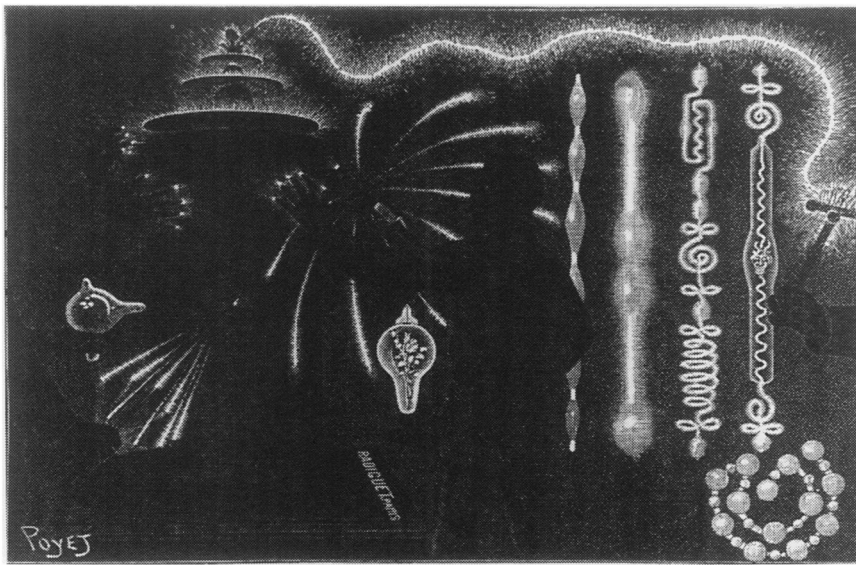


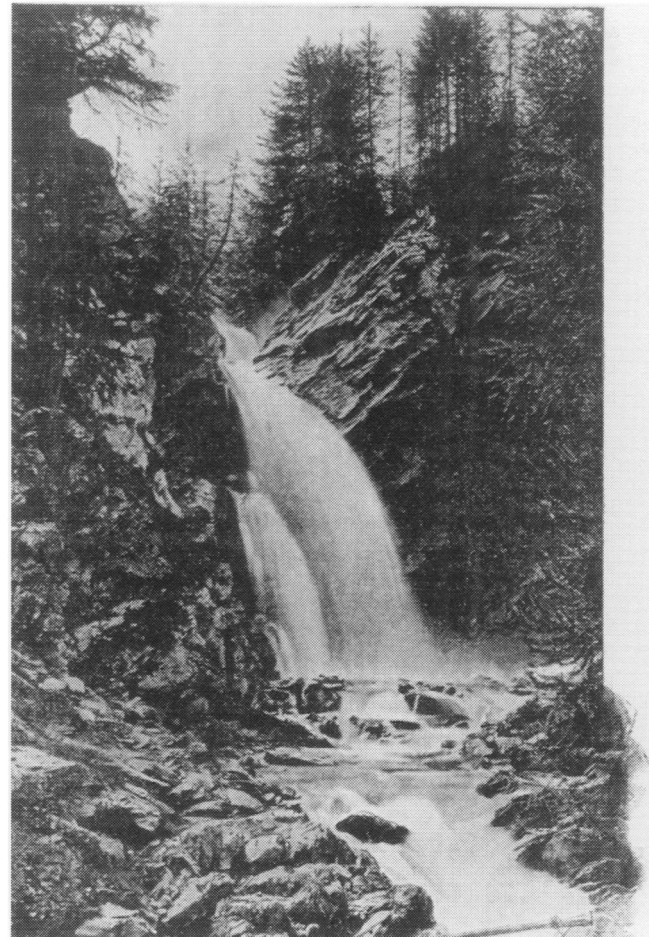
Fig. 13. "Luminous Effects of High Frequency." (Reprinted from Claude, *L'Électricité à la portée de tout le monde*, 5th Ed. [Paris, 1905] Fig. 174.)

play a critical role in Duchamp's various scenarios for the final phase of the Bachelor operations, allowing him to develop the Raymond Roussel-like wordplay on *goût*, or taste, that underlies his Readymade *Bottle Rack* (*égouttoir*) as well [40]. Responding to the important work being done on the liquefaction of gases in this period by figures such as Heike Kamerlingh Onnes (Fig. 15) and Georges Claude, Duchamp originally designed a more complex series of procedures for the liquefaction process. Ultimately, he simplified that laboratorylike approach into the anthropomorphic "journey" of the Illuminating Gas and its solidified Spangles as they emerge from the Capillary Tubes linking the Molds, having experienced Duchamp's humorous "stretching in the unit of length" [41]. Duchamp played with a number of ideas borrowed from the physics of changing states of matter and contemporary discussions of liquefaction, including the intense cold required for the liquefaction (and solidification) of gases. This phenomenon is the root of his references to "frosty gas" and "snow," as well as the connecting link to the wintry landscape in the 1914 Readymade *Pharmacy*, which Duchamp associated specifically with the liquefaction in the *Glass* and which seems to have stood as a surrogate landscape for the Bachelors' surroundings [42]. In Duchamp's *Pharmacy* his addition of red and green dots converted the pre-printed landscape into a chemist's shop; in the *Large Glass* a chemist's laboratory becomes a landscape, complete with in-

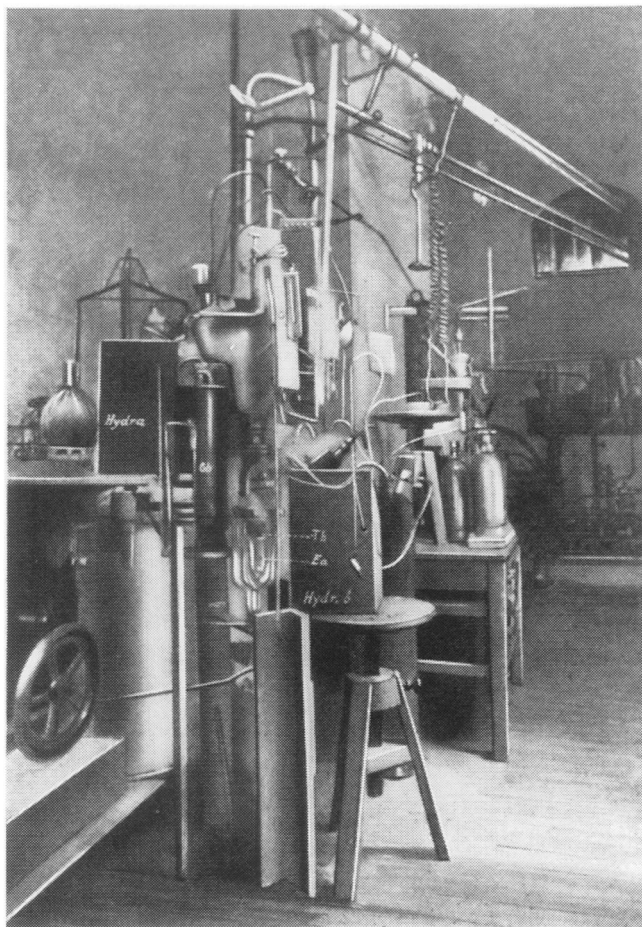
visible waterfall and a Water Mill Wheel (Fig. 2, No. 16a).

Because of Duchamp's interest in "slightly distending the laws of [both] physics and chemistry," many of his notes relate to traditional chemistry

Fig. 14. "The Waterfall of Chadoulin." (Reprinted from Claude, *L'Électricité à la portée de tout le monde*, 5th Ed. [Paris, 1905] Fig. 28.)



[43]. Yet his notes for the Bachelor Apparatus also contain references to molecules or molecular activity that reflect a concern with the newly developed field of physical chemistry and its study of the physical and chemical properties of matter. More specifically, certain notes point to the work of the pioneering physical chemist Perrin on Brownian movement as a source for a general methodological precision, noted earlier, and for information on molecules, atoms, and subatomic particles [44]. Perrin's best-selling *Les Atomes* of 1913 summarized his research on Brownian movement, which had revealed the incessant motion of granules in a suspension to be the indexical buffeting of those granules by colliding molecules. By 1909, in fact, Perrin's publication of his research had provided the first visual confirmation of the very existence of molecules and atoms, a topic still in debate. Perrin's writings, along with many other scientific and popular sources of the time, presented the world of molecules, like that of the speeding electrons Duchamp had evoked in the works of his 1912 *King and Queen Surrounded by Swift Nudes* series (Philadelphia Museum of Art), as domi-



**Fig. 15. Apparatus used to liquefy helium in the laboratory of Kamerlingh Onnes in Leyden. (Reprinted from G. Bresch, "Les Gaz liquifiés [l'air, l'hélium]," *La Nature* 39 [10 December 1910] Fig. 7.)**

nated by continuous collisions among ballistic projectiles. Now, however, instead of the images of Rutherford's subatomic collisions captured by Wilson's instantaneous spark photographs of ionized drops in his cloud chamber, which Perrin illustrated in the 1914 edition of *Les Atomes*, Duchamp evoked such a realm by terminology and procedures associated with this research and by the large-scale collisions enacted in the Bachelor Apparatus.

Among these collisions, which include the blows in the Boxing Match, the Nine Shots projected into the Bride's realm (Fig. 2, No. 4) suggest a particular parallel to Perrin. Duchamp discusses the displacement of the Shots from a single four-dimensional target or point in much the same way that Perrin used the image of a target and displacements from its center to graph the molecular deviations resulting from random collisions [45]. There are numerous other examples of Duchamp's language or procedures that seem to echo Perrin and even Rutherford. The theme of "scattering," for example, was central to the work of both Perrin and Rutherford, and Duchamp refers to the liquefied il-

luminating Gas as a "liquid elemental scattering" and a "scattered suspension" [46]. Perrin also frequently used the term "concordance"; at the end of *Les Atomes* he celebrated the "miracle of concordance" among his findings and those of numerous other researchers concerning the number of molecules that exist in a cubic centimeter of gas (Avogadro's number). In Duchamp's "Preface" and "Notice" notes, which approximate the scientific style of Rutherford or Perrin, it is the "sign of the accordance" (*signe de la concordance*) between the "extra rapid exposition . . . of several collisions" and the "choice of possibilities" that is to be sought [47].

Thermodynamics and the kinetic-molecular theory of gases, two independent but interrelated fields, formed the backdrop for Perrin's work and provided Duchamp with themes that deeply interested him—namely, energy and chance [48]. The issue of energy in the *Large Glass* extends from the large-scale generation of power to the molecular and subatomic levels where, for example, Henri Poincaré discussed radioactivity and Brownian movement as seeming violations of the first and second laws of

thermodynamics. Poincaré also wrote extensively on chance, and the random molecular movements studied by the kinetic theory of gases were a central focus for discussions of chance—as well as of determinism and free will—in this period [49]. Atom theory had also been associated with the question of free will since the time of Lucretius and Epicurus, who interpreted the unexpected swerve (*écart*) of a falling atom as a sign of the possibility of free will. In a note addressing "molecular construction" and "phosphorescence," with its links to radioactivity and "excited" luminescent gases, Duchamp quoted the phrase "écarts de molécules," encoding the age-old debate on free will versus determinism, newly current in the context of kinetic-molecular theory, into the *Large Glass* [50]. Thus, although the tragicomical Bachelors will never achieve their goal of the Bride, they nonetheless do possess free will. Similarly, Duchamp embodied his quest for the "liberty of indifference" and free will versus determinism in his experiments with chance at a visible scale.

The three primary exemplars of chance in the *Large Glass*, as finally executed, were the ballistic Nine Shots, whose positions were determined by shooting paint-dipped matchsticks from a toy cannon; the *Air Current Pistons*, which Duchamp photographed fluttering in a breeze to establish their shapes in the Top Inscription (Fig. 2, No. 3); and the Capillary Tubes connecting the Malic Molds (Fig. 2, No. 12), which were based on his experiments with falling strings in the *3 Standard Stoppages* (Museum of Modern Art, New York). Yet Duchamp's primary agent for his exploration of chance and the "liberty of indifference" was the never-executed Mobile (Fig. 6, right side). It was to have hung from the ends of the Horizontal Column/Scissors and to have fallen in a Splash-producing "crash" as a result of the jerky opening of the Scissors as the Chariot/Glider moved toward the Chocolate Grinder, responding to the erratic fall of the Benedictine Bottle(s) with their "oscillating density" [51]. (In Fig. 6, Duchamp's two conceptions of a falling weight as motive force are simultaneously overlaid onto the *Glass* to the left of the Chocolate Grinder.) With the recovery of the Mobile and its functions, Duchamp's assertions that "it is by this oscillating density that the choice is made between the 3 crashes," and that "it is truly this oscillating density that expresses the liberty of indiff.," can now be

understood. In fact, only the successful fall of the Mobile in the center of its three possible positions would splash the liquefied gas upward. Some portion of the Splash would set off the Boxing Match's clockwork-like tugging on the Bride's Clothing, while the remainder would be projected through a never-executed Weight with Holes and produce the Nine Shots in the Bride's domain.

The Splash remained in Duchamp's final scenario, although it was ultimately as light (a mirror reflection through the later Oculist Witnesses [Fig. 2, No. 17]) that a Sculpture of Drops would ascend "to meet the 9 shots" [52]. Just as electromagnetic waves had provided the communication from the Bride, such waves, now in the form of reflected visible light, would transcend the Bachelors' gravity-bound existence. Initially, however, before there was ever a Splash

and long before the Oculist Witnesses, the Illuminating Gas was to have exploded in one of Duchamp's most unique creations, the Desire Dynamo, which was originally to have triggered the Boxing Match alone. Shown encased in a cubic box to the right of the Sieves in early drawings, the Desire Dynamo included three rods or "desire centers," each composed of "desire," "intention," and "fear," in varying proportions (Fig. 16) [53]. As these rods received an electrical current, they would glow and ultimately ignite a pool of liquefied gas that had been channeled upward. The electrical connection for these igniters was provided by the Precision Brushes, flat plates visible above the Sieves on the left-hand extension of the Scissors (see Fig. 1). That contact would occur when the "little wheels" Duchamp considered for the Chariot's upward extensions slid

along the Horizontal Column/Scissors. The result of that contact would be both the transmission of current and the "double displacement" of the Scissors, which could now shorten and produce a quicker ignition of the Gas.

Finally, the Chariot/Glider, like the Juggler of the Center of Gravity, was a centerpoint for Duchamp's play in the field of mechanics [54]. Here, however, his focus was dynamics or the motion of the Chariot, which slides on runners in the *gouttières*, or grooves, that extended his wordplay on *goût* and *gouttes*. Countering the second law of thermodynamics by "emancipating" the runners of the Chariot/Glider from friction (or "reintegrating" any frictional heat as useful energy), Duchamp created a sexual perpetual-motion machine for the Bachelor Apparatus. Yet the Chariot/Glider hardly glides smoothly: its pace is the characteristic irregular lurching of the Bachelors' demeanor—produced by the "oscillating density" of the Weight in the form of Benedictine Bottle(s) as they fall and pull the Chariot toward the Chocolate Grinder. Those Bottles were raised to their height by energy from the Water Mill Wheel at the center of the Glider, itself a multilayered sign for power and energy, seemingly ranging from water mill wheels and electrical dynamos down to the "mill wheel" used by William Crookes to demonstrate the flow of cathode rays (i.e., electrons) in a vacuum tube [55].

The Chariot/Glider is a superb example of the multiple layers of meaning and humor Duchamp could develop on a specific theme, such as back-and-forth motion and the lifting and falling of weights. The most important alternative identity for the Chariot/Glider derives from the cable-drawn plow, encoded in Duchamp's notes in the Rousselian homophone *buttoir/butoir* (plow/buffer) and providing, at last, a specific locus for his references to an "agricultural instrument" in the *Large Glass* [56]. Duchamp also wrote of a crane or "mobile go-between," surely another contemporary parallel to the Chariot's tracking motion and the rising and falling weights carried on huge hooks [57]. Eugen Sandow, the highly popular weight lifter of the period, is also included metonymically in Duchamp's Chariot mechanism in the form of the elastic band or "Sandow," which is meant to pull the Chariot back into place [58]. Finally, if Duchamp's Chariot took on historic, mythological dimensions with its plowing theme, its reflection of Gustave

Fig. 16. Marcel Duchamp, *Desire Dynamo*, 1913–1914. (Reprinted from Paul Matisse, ed., *Marcel Duchamp: Notes*, note 163 [63]. © 1998 ARS, New York/ADAGP, Paris. Reproduced by permission of the Marcel Duchamp Archive, Villiers-sous-Gréz, France.)

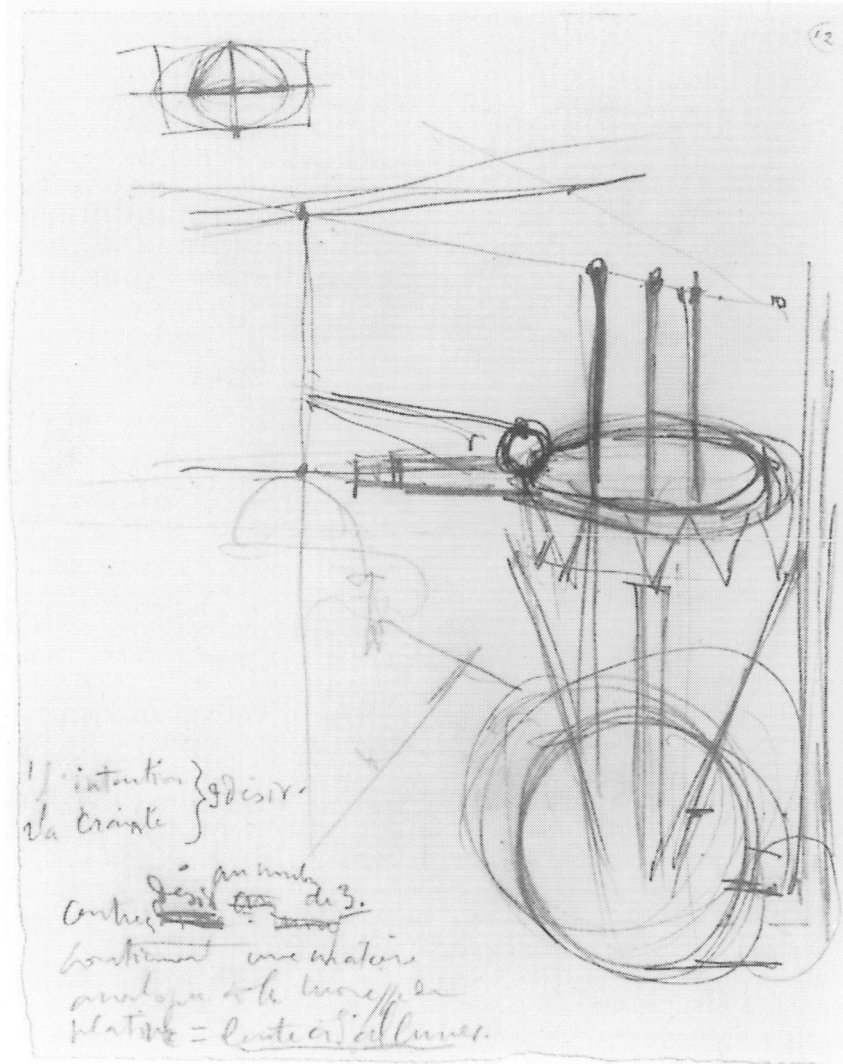




Fig. 17. Apparatus for measuring the air resistance of falling objects. (Reprinted from Gustave Eiffel, *Recherches expérimentales sur la résistance de l'air exécutées à la Tour Eiffel* [Paris, 1907] facing p. 12.)

Eiffel's contemporary aerodynamic experiments with falling objects at the Eiffel Tower made it up-to-the-minute technologically (Fig. 17). Spanning the past and the present and encompassing science and technology as well as popular culture, the Chariot/Glider epitomizes Duchamp's sophisticated and humorous invention in the *Large Glass* in general.

It was in the area of mechanics that Duchamp formulated his most extensive "Laws, principles, and phenomena." His creative invention and challenge to accepted principles of mechanics reflect not only the rich history of this field—including the contributions of Leonardo—but also the fer-

ment in contemporary physics, chronicled by Henri Poincaré and others, in which, for example, anomalies in the area of electrodynamics were challenging the traditional interpretation of basic concepts such as mass and inertia. Although Einstein's 1905 special theory of relativity had addressed those anomalies, his formulation of relativity, which would come to dominate physics after World War I, was not acknowledged in scientific sources in Paris until late 1912–13. Instead, what Duchamp knew of this ferment would have come from general comments in the writings of figures like Henri and Lucien Poincaré, who made no mention of Einstein. Indeed, if Duchamp knew the name of

Einstein, it would have been through *Les Atomes*, in which Perrin cites a different aspect of Einstein's work—his theoretical calculations of molecular displacements in relation to Brownian movement—to support his own experimental findings [59].

Duchamp's *Large Glass* was a work deeply rooted in the culture of pre-World War I Paris, and when he abandoned his execution of the work in 1923, it may have been not only because, as he said, "it became so monotonous" and "there was no invention" [60]. By 1923, the new paradigms of relativity theory and quantum physics and new technologies such as radio had supplanted the earlier science and technology—from X-rays and radioactivity to wireless telegraphy—that he had explored so extensively in the prewar years. It is little wonder that Duchamp's later comments on the subject downplayed his scientific knowledge; he asserted, for example, that "every fifty years or so a new 'law' is discovered that changes everything. . . ." [61] He was right—it had happened to him. And yet, when we are willing to go beyond Duchamp's later disclaimers about his knowledge of science and recover that cultural moment as best we can, the rewards are extremely rich. Illuminated in this manner, the *Large Glass* and its notes can be recognized as a remarkable synthesis of contemporary ideas and as one of the great monuments of early twentieth-century art and culture.

## References and Notes

1. For "painting of precision," see Marcel Duchamp, *Green Box*, in *Salt Seller: The Writings of Marcel Duchamp*, Michel Sanouillet and Elmer Peterson, eds. (New York: Oxford Univ. Press, 1973) p. 30. (Reprinted as *The Writings of Marcel Duchamp* [New York: Da Capo Press, 1989].) See also Paul Matisse, ed. and trans., *Marcel Duchamp: Notes* (Boston, MA: G.K. Hall, 1983) notes 68 and 77. The latter collection of notes found after Duchamp's death was first published in 1980 in a deluxe edition by the Centre Georges Pompidou, Paris. All of the issues raised in the introductory paragraphs and in the chapter excerpt that follows are discussed and documented in full in Linda Dalrymple Henderson, *Duchamp in Context: Science and Technology in the Large Glass and Related Works* (Princeton, NJ: Princeton Univ. Press, 1998). All works by Marcel Duchamp have been reproduced with the permission of the Marcel Duchamp Archive, Villiers-sous-Grez, France.
2. For Duchamp's phrase "hilarious picture" in the title of the chapter, see Duchamp [1] *Green Box*, in *Salt Seller*, p. 30; Matisse [1] notes 68, 77.
3. Duchamp [1] *Green Box*, in *Salt Seller*, p. 30; for "Playful Physics," see Duchamp [1] *Green Box*, in *Salt Seller*, p. 49.
4. For "mental ideas," see Katherine Kuh, *The Artist's Voice: Talks with Seventeen Artists* (New York: Harper & Row, 1962) p. 83. On Duchamp and geometry,

- see Linda Dalrymple Henderson, *The Fourth Dimension and Non-Euclidean Geometry in Modern Art* (Princeton, NJ: Princeton Univ. Press, 1983); and Craig Adcock, *Marcel Duchamp's Notes from the "Large Glass": An N-Dimensional Analysis* (Ann Arbor, MI: UMI Research Press, 1983).
5. Arturo Schwarz, ed., *Notes and Projects for the Large Glass* (London: Thames and Hudson, 1969) p. 1.
  6. For the automobile-oriented notes in the *Green Box* noted in this paragraph, see Duchamp [1] *Green Box*, in *Salt Seller*, pp. 39–44.
  7. On the *Large Glass* and allegory, see Linda Dalrymple Henderson, "Etherial Bride and Mechanical Bachelors: Science and Allegory in Marcel Duchamp's 'Large Glass,'" *Configurations* 4 (Winter 1996) pp. 91–120; and Henderson [1] Chapter 12. On Duchamp and X rays, see Linda Dalrymple Henderson, "X Rays and the Quest for Invisible Reality in the Art of Kupka, Duchamp, and the Cubists," *Art Journal* 47 (Winter 1988) pp. 323–340; and Henderson [1] Chapter 1.
  8. See Henderson [1] Fig. 82 and the related text.
  9. Duchamp, in Richard Hamilton and George Heard Hamilton, 1959 BBC (British Broadcasting Company) interview (*Audio Arts Magazine* 2 [1975]); for Duchamp's reference to "visceral," see "Apropos of Myself" (unpublished manuscript) p. 9. On Villiers's Hadaly and the Bride as automaton, see Henderson [1] Chapter 7.
  10. For Duchamp's weather-related terminology, see Duchamp [1] *Green Box*, in *Salt Seller*, pp. 45–48; Matisse [1] notes 105, 106, 108, 137, 144, 149, 152.
  11. For Duchamp's references to filaments and to the Wasp's "vascularized paste" in this paragraph, see Duchamp [1] *Green Box*, in *Salt Seller*, pp. 45, 47–48; Matisse [1] notes 105, 108, 137, 146, 152. For "nourishing" of filaments in lightbulb manufacture, see Georges Claude, *L'Électricité à la portée de tout le monde*, 5th Ed. (Paris: Ch. Dunod, 1905) p. 114. For the "Bride under a glass cover," see Duchamp [1] *Green Box*, in *Salt Seller*, p. 30; Matisse [1] notes 68, 77. Along with the themes of meteorology, lightbulbs, and biology, Fabre and Gourmont are discussed in Henderson [1] Chapter 9. The Bride's links to the Virgin Mary and Persephone are treated in Chapters 11 and 12.
  12. All quotations in this and the following paragraph, unless otherwise noted, are taken from Duchamp [1] *Green Box*, in *Salt Seller*, pp. 39–44, the 10-page, automobile-oriented note and its sequel. For the phrase "self blossoming," as well as Duchamp's actual use of the terms "horizontal" and "vertical," see Matisse [1] note 152 (p. 2).
  13. Duchamp [1] *Box of 1914*, in *Salt Seller*, pp. 23, 25.
  14. The material on wireless telegraphy summarized here, including the interest of Kupka and Apollinaire, is discussed in detail in Henderson [1] Chapter 8.
  15. On Tesla's activities in this area, see "Nikola Tesla (1856–1943): Science as Spectacle," in Henderson [1] Chapter 4.
  16. Matisse [1] notes 143, 153 (p. 4).
  17. Duchamp [1] *Green Box*, in *Salt Seller*, p. 48, for "isolated cage"; for such an emitting antenna, see Henderson [1] Fig. 103.
  18. Duchamp [1] *Green Box*, in *Salt Seller*, for "alphabetic units."
  19. See Matisse [1] notes 137, 152 (p. 2) for the Juggler's "ball"; see the following note for the "waves" reference.
  20. Duchamp [1] *Green Box*, in *Salt Seller*, p. 45.
  21. Matisse [1] note 152 (p. 2).
  22. The interaction of the Juggler/Handler of Gravity with the Bride is discussed in the context of wireless telegraphy in Henderson [1] Chapter 8, and in the context of mechanics in Henderson [1] Chapter 11.
  23. Duchamp [1] *Green Box*, in *Salt Seller*, p. 38.
  24. Duchamp [1] *Green Box*, in *Salt Seller*, p. 36.
  25. Duchamp [1] *Box of 1914*, in *Salt Seller*, p. 25.
  26. Typically, Duchamp's multivalent Sieves/Parasols also play a central role in the chemical liquefaction occurring in the Bachelors' realm.
  27. Duchamp [1] *Green Box*, in *Salt Seller*, p. 50, for "inert illuminating gas."
  28. Duchamp [1] *Green Box*, in *Salt Seller*, pp. 27–28.
  29. Matisse [1] notes 74, 80.
  30. Duchamp [1] *Green Box*, in *Salt Seller*, p. 28.
  31. On the relevance of the work of Worthington and Wilson to the *Large Glass*, see Henderson [1] Chapter 10 (pp. 146–148).
  32. Duchamp, in 1959 BBC interview [9].
  33. Matisse [1] note 104. For Duchamp's "principle of antigravity," see the section of Henderson [1] Chapter 11 on the "Playful Mechanics" of the Juggler of Gravity.
  34. Duchamp [1] *Green Box*, in *Salt Seller*, p. 45.
  35. Unpublished typescript of interview with Sidney, Harriet, and Carroll Janis (1953) sec. 5, p. 10.
  36. Matisse [1] note 98.
  37. For Duchamp's lists, see Matisse [1] notes 250, 251; see also Henderson [1] Chapter 14 and Appendix B, where the possible collection of notes is first proposed and the listed notes are brought together for the first time.
  38. Duchamp [1] *Green Box*, in *Salt Seller*, p. 62.
  39. Matisse [1] note 133. For Duchamp's various liquefaction schemes and contemporary interest in the subject, see the sub-section "The Liquefaction of Gases as Model for the Journey of the Illuminating Gas," in Henderson [1] Chapter 10.
  40. For Duchamp's use of gouttes (drops), see, e.g. Duchamp [1] *Green Box*, in *Salt Seller*, p. 65; Matisse [1] notes 91, 132, 133. On the thematic connections between Duchamp's Readymades and the *Large Glass*, see the sub-section "Thematic Collisions, Duchamp's Anti-Bergsonism, and New Unities in the *Large Glass* and Early Readymades," in Henderson [1] Chapter 13. On Roussel's homophones and Duchamp's response to them, see, for example, "Raymond Roussel (1877–1933): Scientific Machines in *Impressions d'Afrique*," in Henderson [1] Chapter 4; see also p. 175.
  41. For this process, see Duchamp [1] *Green Box*, in *Salt Seller*, pp. 48–53.
  42. See Duchamp [1] *A l'infinifitif*, in *Salt Seller*, pp. 76–77 (note at bottom and top of following page) for the connection of *Pharmacy* to the liquefaction process in the *Glass*; for "frosty gas" and "snow," see Duchamp [1] *Green Box*, in *Salt Seller*, pp. 50, 53.
  43. Duchamp [1] *Green Box*, in *Salt Seller*, p. 71. For a sampling of Duchamp's chemistry-related notes, see Henderson [1] pp. 132–133.
  44. On Perrin and Duchamp's interest in physical chemistry, see the sub-section "Molecular and Atomic Reality in the *Large Glass*," in Henderson [1] Chapter 10.
  45. See Henderson [1] Figs 143, 144.
  46. Duchamp [1] *Green Box*, in *Salt Seller*, p. 50. See, e.g., Jean Perrin, "La Réalité des molécules," *Revue Scientifique* 49 (16 December 1911) p. 779; and Ernest Rutherford, "The Scattering of  $\alpha$  and  $\beta$  Particles by Matter and the Structure of the Atom," *Philosophical Magazine and Journal of Science* 21, 6th Ser. (May 1911) pp. 670–671.
  47. Duchamp [1] *Green Box*, in *Salt Seller*, p. 28. See also Perrin [46] pp. 776, 782, 784; and Jean Perrin, *Les Atomes* (Paris: Félix Alcan, 1913) p. 289.
  48. For further discussion of the issues raised in this paragraph, see the sub-section "Duchamp, Thermodynamics, and the Kinetic-Molecular Theory of Gases," in Henderson [1] Chapter 10.
  49. For Poincaré on chance, see *Science et méthode* (Paris: Flammarion, 1908) Chapter 4. He discusses seeming violations of the laws of thermodynamics in *La Valeur de la science* (Paris: Flammarion, 1904) Chapter 8.
  50. For Duchamp's use of "écarts de molécules," specifically, see Michel Sanouillet, ed., *Duchamp du signe* (Paris: Flammarion, 1975); the phrase is mistranslated in Duchamp [1] *Green Box*, in *Salt Seller*, p. 71, where the remaining terms in this sentence occur.
  51. For the Duchamp phrases in this paragraph, see Duchamp [1] *Green Box*, in *Salt Seller*, pp. 62–63. For the Mobile, see Duchamp [1] *Green Box*, in *Salt Seller*, p. 66; Matisse [1] notes 101, 153.
  52. Duchamp [1] *Green Box*, in *Salt Seller*, p. 65. Duchamp, however, never clarifies how the Nine Shots would be produced, once the Splash was transformed into a light-borne mirror reflection instead of a ballistic Splash/Shot.
  53. In addition to Matisse [1] note 163, which is illustrated as Fig. 16, see Matisse [1] note 153 (pp. 1, 4) for the description of the operation of the Desire Dynamo that follows.
  54. For Duchamp's terminology in this paragraph, see Duchamp [1] *Green Box*, in *Salt Seller*, pp. 56–57, 60–62. For further discussion of the mechanics of the Chariot/Glider, as well as its relation to the themes of plowing, Sandow, and Eiffel's experiments (discussed below), see "Playful Mechanics in the Chariot and Juggler/Handler of Gravity," in Henderson [1] Chapter 11.
  55. See Henderson [1] Figs 151, 152.
  56. For "agricultural instrument," see Duchamp [1] *Green Box*, in *Salt Seller*, p. 44; and Matisse [1] note 80. For *buttoir*, mistranscribed by Sanouillet as *butoir* (buffer), see Schwarz [5] pp. 193, 195; see also Sanouillet [50] p. 82.
  57. See Matisse [1] notes 100, 104.
  58. Duchamp [1] *Green Box*, in *Salt Seller*, p. 57.
  59. Lucien Poincaré was the author of *La Physique moderne* (Paris: Flammarion, 1906), among other texts. On Duchamp and the history of mechanics (including Leonardo) as well as contemporary challenges to mechanics, see Henderson [1] Chapter 11.
  60. Duchamp, as quoted in Pierre Cabanne, *Dialogues with Marcel Duchamp* (1967), Ron Padgett, trans. (New York: Viking, 1971) p. 61.
  61. Duchamp, as quoted in Calvin Tomkins, *The Bride and the Bachelors* (New York: Viking, 1965) p. 34. Duchamp's later comments on science, including Einstein, are discussed in Henderson [1] Chapter 14.
  62. Matisse [1].
  63. Matisse [1].