Abstract

When George Adams assembled a large collection of philosophical instruments for King George III in the early 1760s, he drew on a variety of printed books as sources of experiments and instrument designs. Most important of these was Mathematical Elements of Natural Philosophy by the Dutch mathematician and philosopher Willem ’s Gravesande, whose own collection of instruments is now in the Museum Boerhaave in Leiden. Papers in the Science Museum archives reveal the specific practices through which Adams used books such as Mathematical Elements in the course of his business. These techniques included commonplacing, a widespread method for organising information in the early-modern period; and physically cutting and pasting fragments from engraved illustrations into new drawings, as part of the process of design. These practices connected mobile print with local networks of production. They fundamentally shaped the group of instruments Adams made for George III, and constitute a material link between two important collections of 18th-century instruments: those of ’s Gravesande in Leiden, and those of George III at the Science Museum in London.

Keywords

commonplacing, cut and paste, George III, George Adams, imitation, philosophical instruments, print, Willem ’s Gravesande

Mobile knowledge, local skill

The prominent London instrument-makers of the mid-eighteenth century, such as George Adams (1709–72) of Fleet Street, were bridging figures, poised between disparate social worlds. As skilled tradesmen, they orchestrated, but also partially hid from
view, the efforts of the workmen they employed, and the networks of manufacturing trades, such as foundries and glass-makers, that crisscrossed the city (Millburn, 2000; McConnell, 2007; Baker, 2010; Bennett, 2007). As authors of books and designers of instruments, they participated in the production and consumption of print, and in a community of readers that tended to be elite, learned and international (Bennett, 2002). The materials they worked with, such as brass and mahogany, flowed into and through London with different tempos and geographical ranges; the books that for Adams proved most commercially useful had their own, distinctive trajectories as well (see Figure 1).

![Figure 1](https://example.com/image1.png)

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George Adams, ‘Instructions to the Illustrator’ of the mechanics manuscript, fol. 6, fig. 24, showing a fragment of engraving cut from the plates of ’s Gravesande’s Mathematical Elements

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The mobility of print and the situated nature of skilled, material production have both played pivotal roles in accounts of the development of experimental science (Eisenstein, 1979; Smith, 2004). Steven Shapin and Simon Schaffer (1985) have provided one influential model for thinking about how natural philosophers of the 17th century sought to extend the epistemic range of local, material processes of making instruments and experiments, through techniques of rhetoric and composition, and the circulation of printed books and periodicals. In a gentlemanly culture in which determining the truth about experience was profoundly linked to the testimony of reliable witnesses, Robert Boyle (1627–91) and other fellows of the early Royal Society developed ways of writing experimental accounts that recruited their readers as ‘virtual witnesses’ to new experimental phenomena (Shapin and Schaffer, 1985, p 60). The question of how reading and other ways of consuming print fed into practices of making – whether of experiments or of instruments – is of equal interest, though perhaps less well explored (Johns, 2003).

Collections held by the Science Museum shed important light on how, in the more commercial and socially diverse culture of 18th-century experimental philosophy, an instrument-maker such as Adams might use books in the conduct of his trade. Adams’s ways of exploiting print in the production of instruments were informed by widespread practices such as commonplacing (see section 'Instruments for The King, 1761-62', below) and physical cutting and pasting (see section...
Instruments for The King, 1761–62

The Science Museum’s 1993 catalogue of the George III collection (see Figure 2), Public & Private Science, details the group of instruments made by George Adams for a young King George III (1738–1820) in the early years of his reign – which, along with the demonstration apparatus of the lecturer Stephen Demainbray (1710–82), now form the core of the larger collection (Morton and Wess, 1993, pp 123–242).

Almost 200 individual catalogue entries are devoted to the philosophical instruments of George III, which comprise an air pump with a comprehensive array of attachments for experiments on the weight, pressure, spring and composition of the air; and a large-scale modular group of devices for demonstrating the principles of mechanics (Morton and Wess, 1993, pp 243–372) (see Figures 3 and 4). It has already been observed (Morton and Wess, 1993, pp 22, 245–6) that Adams drew many of the designs for these instruments from printed books, and by far the most important of these was Mathematical Elements of Natural Philosophy, Confirmed by Experiments: Or, an Introduction to Sir Isaac Newton’s Philosophy (6th English edition, 1747), by the Dutch mathematician and natural philosopher Willem’s Gravesande (1688–1742). The range of Adams’s reading in relation to
this collection, however, and the specific ways in which he drew from and transformed these printed sources, has not yet been fully explored.

Figure 3

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George Adams, Air-pump. Mahogany, brass, glass, leather and iron

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In the preface to his 1747 ‘A catalogue of mathematical, philosophical and optical instruments’, Adams publicised his use of books in compiling and designing a wide variety of instrument types. He wrote, ‘In the construction of all the Machines I have..."
ever made, my first and greatest Care hath been to procure good Models and Drawings, several of them I have imitated from the best Authors, as well Foreigners, as those of our own Country; I have alter’d and improv’d others, and have added many new ones of my own Invention’ (Adams, 1747a, p 244). This statement can be applied directly to the group of machines Adams designed and made for George III in 1761–62. As a guide to the construction and use of these instruments, Adams also provided two lengthy manuscripts (1762a), one on pneumatics and one on mechanics.[3] These manuscripts give descriptions and illustrations of the apparatus in the collection, and outline the experiments for which the instruments were designed. In each, minimal instructions are given for the use of the machines, along with citations to the printed texts from which the experiments were taken: predominantly Mathematical Elements, but including 18 other publications. In each manuscript, the order of the experiments mainly follows that given by ’s Gravesande. Experiments from other books were added subsequently in the pneumatics manuscript, and in the mechanics manuscript they were inserted at relevant points within ’s Gravesande’s sequence. Adams kept his explanations of the physical principles being demonstrated to a minimum, but provided references to printed works where further information was available (see Figure 5). Thus the collection, properly considered as an extended system of knowledge, incorporates the instruments, the manuscripts and the printed books to which they refer.
George Adams, ‘A description of an apparatus for explaining the principles of mechanics made for His Majesty George III ...’, 1762, f 1. Ink on paper, 420 x 260 mm

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The Science Museum’s copy of Adams’s ‘A description of an apparatus for explaining the principles of mechanics made for His Majesty King George III ...’ is fair but incomplete, accompanied not by finished plates of drawings, but instead by sketches known as Adams’s ‘Instructions to the illustrator’ of the mechanics manuscript (1762b) (see Figure 6). The composition of these sketches is telling in itself. They comprise 232 numbered figures, including 185 pen-and-ink drawings and 47 fragments cut from the engraved plates of the 1747 edition of ’s Gravesande’s Mathematical Elements. Of the drawings, some are directly based on further engravings in the same text; others are profiles and perspective drawings of Adams’s own machines.‘s
Gravesande’s *Mathematical Elements* is also by far the most frequently cited work in both manuscripts, accounting for 44 of 57 references to printed works in the pneumatics manuscript, and 138 of 188 in the mechanics manuscript.

**Figure 6**

George Adams, drawing of the mahogany pillar and attachments for making various experiments in mechanics, ‘Instructions to the illustrator’ of the mechanics manuscript, Plate 7. Ink on paper, 304 x 221 mm, 1761

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Translating *Mathematical Elements*: Leiden and London
Gravesande’s *Mathematical Elements*, written by him in Latin, was first published in Leiden in 1720–21. Two competing English editions appeared in London in the same years, both undertaken without the author’s knowledge or approval. It was the aggressive tactics of the booksellers John Senex (bapt. 1678, d. 1740) and William Taylor (d. 1724) on the one hand, and William Mears (bapt. 1686, d. 1739) on the other – rather than gentlemanly networks of correspondence – that first brought the book to London (*Allamand, 1774, pp xxix–xxx*). It is not clear how the Latin text reached London so quickly, but competition between the two English editions was so fierce that at one point John Theophilus Desaguliers (1683–1744), the translator engaged by Senex and Taylor, was forced to dictate to four scribes in turn, and he thrashed out the entire second volume in the space of 15 days (*Allamand, 1774, p xxix*). This arrangement was eventually regularised, establishing the channels through which subsequent English editions were produced, and thereby making the book available in English for Adams’s commercial use in later decades.

The production and movement of this text represents part of a reciprocal exchange between centres of knowledge and material production in London and Leiden. In 1715, ‘s Gravesande had come to London as secretary to a Dutch diplomatic mission, and it was there that he learned what he called the ‘English’ method of teaching natural philosophy with experiments performed on specially designed machines (*van Helden, 1999, p 450*; ‘s Gravesande, 1747, Vol. 1, p ix). In 1717 he became professor of mathematics and astronomy at the University of Leiden; he also began building up a collection of machines for a course of experimental philosophy, which he delivered to paying audiences at his home (*de Clercq, 1997a, p 11*). He conceived the first edition of *Mathematical Elements* as an *aide-mémoire* for those who had attended his course. In later editions, which became increasingly copious and detailed, he acknowledged that its readership had expanded, and the final edition included information on the scale on which each instrument was depicted in the plates, so that readers could have the devices remade if they wished to do so (*Allamand, 1774, p xxxii*).

Over the years that he delivered lectures on natural philosophy at his home, ‘s Gravesande and the instrument-maker Jan van Musschenbroek (1687–1748) worked closely together to design, produce and improve the machines depicted in successive editions of *Mathematical Elements* (*de Clercq, 1997b, p 85; Allamand, 1774, p xxviii*). Thus the three Latin editions of the book function as snapshots of a constantly evolving collection, which now resides at the Museum Boerhaave in Leiden (Figure 7).
Seventeen years passed between the second Latin edition (1725) and the third (1742), during which time ‘s Gravesande and van Musschenbroek made so many changes and additions that their mutual friend Jean Nicolas Sebastien Allamand considered the 1742 edition an entirely new work (Allamand, 1774, p xxix). Its expanded format and prolific, detailed engravings made it an ideal resource for Adams in London, who was one of the first generation of instrument-makers to bring the production and marketing of mathematical, philosophical and optical instruments under the same roof (Baker, 2010, p 45). Books such as Mathematical Elements, which doubled as exhaustive ‘magazines’ of instrument designs, were a crucial factor in this development[2].

Organising information with ‘commonplaces’

Not only the availability of Mathematical Elements, but also George Adams’s particular ways of exploiting it, made George III’s philosophical instruments what they are. For example, Adams used the widespread and long-established method of commonplacing to accumulate and manage large amounts of textual and visual information. Commonplacing was the practice of copying out passages from books, often over many years of a person’s reading life, under assorted headings or ‘places’ in a notebook. In the Renaissance, an established range of ‘moral’ and ‘general’ ‘places’ facilitated the accumulation of material for use in rhetorical composition and argumentation (Moss, 1996, p vii). While this set repertoire of headings gradually fell out of use in the second half of the 17th century, commonplacing continued to be used as a vital method for organising information and compiling ‘useful material for projected works’ (Moss, 1996, p 280)[3].
In the mechanics manuscript, Adams used the method in this way, adopting the section headings in 's Gravesande's *Mathematical Elements* as 'places'. This allowed his sequence of experiments predominantly to follow the structure of 's Gravesande's book which, as an elementary system of philosophy, progressed from simple definitions of concepts such as body and space, through the simple and compound machines, collisions and central forces, ultimately to the principle of universal gravitation and the motions of the planets around the Sun[^4]. This was an expedient way of compiling a comprehensive group of instruments for the royal commission. But the strategies that Adams pursued could also undermine the unity – and at some points the coherence – of 's Gravesande's elementary system of knowledge.

First, Adams used the various principles and phenomena covered in *Mathematical Elements* as 'places' under which to gather more instruments and experiments from other sources. For example, 's Gravesande provided only one experiment in his explanations of Newton's three laws of motion ('^s Gravesande, 1747, Vol. 1, pp 78–81'). Adams clearly regarded this as an oversight, and set about gathering experiments for this purpose from other publications, including his own pamphlet on an instrument called a 'whirling Speculum' (Adams, 1748); Desaguliers's *A Course of Experimental Philosophy* (1745); and *Leçons de physique expérimentale* (1754) by the French lecturer Jean Antoine Nollet (1700–70), described by historians variously as 'Cartesian' and 'anti-Newtonian' (Adams, 1762a, ff 88–100; Heilbron, 1993, p 7; Gascoigne, 2003, p 302[^5]). Adams thus used Newton's three laws of motion as conceptual 'places', bringing together the instruments themselves, their drawings and descriptions, and citations to 's Gravesande, Nollet, Desaguliers and his own work. While this method enabled him to provide an exhaustive repertoire of experiments, and a maximum number of instruments for George III's collection, it also interrupted the rigorous conceptual structure set out in *Mathematical Elements* – especially through the introduction of competing interpretations via references to Nollet's *Leçons*.

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**Cut and paste as a design technique**

Adams’s ‘Instructions to the illustrator’ of the mechanics manuscript contain 47 fragments cut from the engraved plates of the 1747 edition of *Mathematical Elements*, demonstrating the book's centrality, not just in identifying and organising experiments, but also in his process of designing instruments for George III (Adams, 1762b, figs. 6, 24, 40–2, 45, 49–51, 85–88, 96, 96 (2), 105–8, 112, 118 (4), 118 (5), 119, 123–4 (2), 137–9, 152A, 154–7, 158 (1), 158 (2), 159, 181–4, 194, 195, 207, 216–18). The ‘Instructions to the illustrator’ appear to have been intended to communicate the layout of the final plates of the mechanics manuscript to the draughtsman who worked on them. As such, they are not direct evidence of design practices in the workshop; but where a cutout engraving of 's Gravesande's instrument could stand in for a drawing of Adams's, the derivation of the design is very strongly indicated. Of these pasted-in fragments, 13 were altered by trimming off parts, drawing in alterations or written notes (Adams, 1762b, figs. 41, 45, 86–8, 106, 118 (4), 118 (5), 123, 124 (1), 181, 183, 194) (see Figures 8–10).
Jan van Musschenbroek and Willem ’s Gravesande, machine for experiments on a pendulum moved by a spring. Oak, iron, brass and steel, 1700 x 935 x 700 mm, c. 1733, Museum Boerhaave Inv. No. 9629 (de Clercq, 1997a, p 43).

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Physical cutting and pasting was a common practice among 18th-century designers and artisans in other trades; it has been argued that the reason why so few 18th-century pattern books survive is that they were cut up in the normal course of business (Heckscher, 1969, p 299). An interesting point of comparison is the scrapbook compiled by the wood-carver and furniture-maker Gideon Saint, who began trading for himself in 1763. Saint’s scrapbook (see Figure 11) was a personalised visual index to Rococo woodworking, which he divided up into sections according to various types of furniture and carved ornament. The 520 entries in Saint’s book can be sorted into categories that are directly equivalent to those in Adams’s ‘Instructions to the
The 'Instructions to the illustrator' also offer valuable evidence of the reasons why Adams altered the designs in *Mathematical Elements*. On 13 different occasions, he made significant alterations to these cutout engravings by cutting off parts and/or drawing in additions. Ten of these represent large-scale instruments that in the collection of the Museum Boerhaave are free-standing objects, but which Adams preferred to integrate into a complex, modular system structured by a central table and jointed pillar, ‘fitted for many Experiments and supporting Machines’ ([Adams, 1762b, ff 25, 26–39; Morton and Wess, 1993, pp 298–9][1]). For example, he integrated ’s Gravesande’s design for a machine for oblique and compound collisions into the ‘great Table’, while adopting formal aspects from Nollet (see Figures 12–15).
Jan van Musschenbroek and Willem 's Gravesande, machine for oblique and compound collisions. Oak and brass, 1285 x 600 x 300 mm, c. 1720, Museum Boerhaave Inv. No. 9631 (de Clercq, 1997a, p 45).

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Imitation, improvement and invention

Adams himself identified three related processes of design: imitation, improvement and invention (Adams, 1747a, p 244). For 18th-century thinkers about the arts, such as Joshua Reynolds, imitation was not just the simple, direct reproduction of an object, text or image. Rather, it was what we would think of as a creative process, through which an artist absorbed, considered, responded to and improved upon the works of others (Reynolds, 1992, p 160). By adopting the language of ‘imitation’, Adams asserted his participation in the cognitive processes of the liberal arts. Elsewhere in his writing, he also indicated some of the
qualities on which such improvements were based. His changes to 's Gravesande's free-standing machines, which remade them as components of a modular apparatus, represent an example of what Adams considered 'concise' design in instruments. Concision was a concept that preoccupied Adams throughout his working life, and it was one of several criteria that led him to alter the patterns he gathered through print. The differences between 's Gravesande's machines in Leiden and those of George III in London, as well as scattered remarks by Adams in the mechanics manuscript and his published writing, make it possible to build up a vocabulary of such criteria, and to observe them in action. For example, in his universal microscope (see Figure 16), advertised in the *London Evening Post* in 1743, as well as in George III’s philosophical machines, striving for concision meant giving basic, structural parts multiple functions, and making them support the substitution of smaller parts for different uses (*Millburn, 2000, p 32*). Adams’s improvements to the 'Machine whereby the Experiments on central forces are demonstrated' integrated a free-standing device from *Mathematical Elements* into the modular system of the 'great Table', and simplified the configuration of the cord that drove the mechanism (see Figures 17 and 18). As he wrote in the mechanics manuscript, this new machine 'was adapted to the great Table by which means we have a very concise apparatus, and have entirely thrown away that cumbersome frame used by 's Gravesande' (*Adams, 1762a, f 102*).
George Adams, universal double microscope. Brass, steel, glass and stained ivory, 245 x 64 mm, c. 1750, Oxford Museum of the History of Science Inv. No. 54497.

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Adams’s 1746 catalogue contained an extended discussion of the principles on which he designed his instruments, and from this and other sources it is possible to build up a list of positive and negative values of design in machines. Within this vocabulary, ‘simple’, ‘elegant’, ‘concise’, ‘conspicuous’, ‘neat’, ‘substantial’, ‘exact’ and ‘applicable to several Operations’ stand in opposition to ‘cumbersome’, ‘superfliously Ornamented’ and ‘multiplied without Necessity’ (Adams, 1747a, f 244). Some of these words, such as ‘elegant’ and ‘simple’, were used in a variety of evaluative contexts in the 18th century, and referred to pleasing qualities in natural objects, dress, deportment, prose and painting. This particular pair of qualities also emerged in discussions of design in nature, as evincing ‘the Almighty’s wisdom in [its] contrivance’ (Adams, 1747b, f 73). In the works that Adams used as he composed his manuscripts and *Micrographia illustrata* (1746), a book on microscopes and microscopic...
objects, he aligned himself with aesthetic qualities considered to demonstrate wisdom in contrivance and to contribute to the intelligibility of nature. In adopting these aesthetic criteria, Adams followed the precedent of 17th-century natural philosophers and inventors such as Robert Hooke (1635–1703), for whom the concept of mechanical ‘ingenuity’ spoke of similar, positive design qualities in instruments, as well as the intellectual and moral virtues of their designers (Bennett, 2006).

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**Material connections**

In the world of 18th-century instrument-making, the commercial tactics of the book trade facilitated the circulation of printed designs between distant workshops, each embedded in its own local networks of production. The availability of designs was one of many factors influencing the development of instruments in the 18th century. George Adams’s use of *Mathematical Elements* took place in a wider context of material production that cannot be addressed fully here. Designs were altered or improved according to local requirements, and executed in materials that had their own tempos and geographical patterns of movement. The ready availability of mahogany, from which many of George III’s instruments were made, was a direct result of British imperial expansion, the rapid development of British trading interests with an increasingly global reach, and the naval and fiscal policies that supported them. By the 1760s vast quantities of this exotic wood were arriving in London from Belize, and making their way into the joiners’ and cabinet-makers’ shops to the north of Covent Garden (Bowett, 1994; Finamore, 2004).

The fusibility of brass, another key material in this collection, gave it a distinctive pattern of movement around London, where foundries concentrated in clusters between Aldersgate Street, Moorfields and Bishopsgate to the east; north of Fleet Street in Snow Hill and Shoe Lane; and near the cabinet-makers of Covent Garden (Mortimer, 1763). Its circulation was only semi-regulated, with tradesmen settling their foundry bills in part through credit for old metal, while a brisk trade in stolen brass, often along the same routes, was fed by theft from workshops and storerooms.

Much work remains to be done on the practical aspects of how printed designs were put to use in the networks of trade that crisscrossed London in the mid-18th century. Between the printed image and the new version of any instrument that George Adams made, a whole range of other things, such as drawings, patterns, moulds, jigs and tools, intervened. These mundane but powerful objects have, in the main, been lost. But comparisons between related collections, such as Adams’s instruments, manuscripts and printed books; and ’s Gravesande and van Musschenbroek’s instruments at the Museum Boerhaave, can illustrate both the creative and material dynamics of the 18th-century instrument trade, as well as the historic links between the holdings of modern institutions.

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**Tags**

- History of science
- Museum collections
- Scientific instruments
- Instrument makers
- Eighteenth century
Footnotes

1. These manuscripts exist in multiple versions. The Science Museum holds a fair, complete copy of the pneumatics manuscript (Adams, 1761a), as well as a draft text (Adams, 1761b) and sketches for the illustrations (Adams, 1761c). The fair copy of the mechanics manuscript in the Science Museum archives (Adams, 1762a) lacks the finished illustrations, but is accompanied by sketches (Adams, 1762b); there are also additional sketches of George III’s instruments (Adams, n.d.). The Royal Library at Windsor Castle holds fair, bound copies of both manuscripts (Morton and Wess, 1993, pp 243–6; Millburn, 2000, pp 100–2).

2. In the 18th century the works of antiquity, or books representing them, were discussed as ‘magazines’ of designs for artists and artisans to imitate (Reynolds, 1992, p 167; Coltman, 2006, pp 70, 78).

3. Richard Yeo (2001, pp 101–19) has argued that the tradition of commonplaces profoundly informed early-18th-century encyclopaedic projects, such as Ephraim Chambers’s Cyclopaedia.

4. Adams’s manuscripts and instruments for George III cover Mathematical Elements, Books I and II on mechanics, and Book IV on pneumatics.

5. The ‘whirling Speculum’ was a form of artificial horizon, a device that provided the constantly level plane needed to make astronomical observations from the deck of a moving ship (Morton and Wess, 1993, pp 340–1).

6. The ten large-scale machines are: ‘A Machine whereby the properties of the Wedge are demonstrated’ (Adams, 1762b, fig. 111; Adams, 1762a, f 55; Morton and Wess, 1993, pp 322–3); ‘A Machine for Experiments concerning Oblique and Compound Collision’ (Adams, 1762b, fig. 150; Adams, 1762a, f 92; Morton and Wess, 1993, p 343); ‘A Machine to shew that a Weight thrown up from a body in motion, will fall down upon the same point that it falls upon when the body is at rest’ (Adams, 1762b, fig. 151; Adams, 1761a, f 93); ‘A Machine to compare the ascent of bodies with their descent’ (Adams, 1762b, fig. 152; Adams, 1762a, f 94); ‘A Machine to shew that a body thrown perpendicularly upwards through a tube as it is in motion altho’ it describes a curve will fall upon the same point that it falls upon when it is at rest’ (Adams, 1762b, fig. 160; Adams, 1762a, f 101; Morton and Wess, 1993, p 348); ‘A Machine whereby the Experiments on central forces are demonstrated’ (Adams, 1762b, fig. 163; Adams, 1762a, f 102; Morton and Wess, 1993, pp 350–1); ‘A Machine whereby Experiments are made on a Pendulum moved by the action of a spring’ (Adams, 1762b, fig. 181; Adams, 1762a, f 112; Morton and Wess, 1993, p 355); ‘A Machine whereby Experiments on innate forces and the collision of Bodies are made’ (Adams, 1762b, fig. 194; Adams, 1762a, f 116; Morton and Wess, 1993, p 357); ‘A Machine whereby the forces of bodies falling directly are compared’ (Adams, 1762b, fig. 205; Adams, 1762a, f 119; Morton and Wess, 1993, p 359); ‘A Machine Shewing that the velocity of Falling Bodies is accellerated every moment’ (Adams, 1762b, fig. 221; Adams, 1762a, f 193).

7. Adams was familiar with Hooke’s Micrographia (1665), which was one of the sources of both text and illustrations for Adams’s own Micrographia illustrata.


10. One useful source is the French lecturer Jean Antoine Nollet’s account of basic workshop tools and processes, intended to help experimenters in the provinces make and repair instruments (1770).

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