Made in Oxford: John Prujean's 1701 Catalogue of Mathematical Instruments

By D.J. BRYDEN

SUMMARY

The London-trained mathematical instrument maker John Prujean settled in Oxford in 1664, where he worked until his death in 1706. The few surviving examples of his work indicate that he was a competent workman. A 1701 advertisement lists over 20 different instruments that he made and sold; outside London, it is the earliest recorded example of the genre. The text is reprinted. There are a high proportion of instruments designed by Oxford men. The catalogue reflects a growing interest in practical mathematics outside the undergraduate teaching programme.

BIOGRAPHICAL NOTE

John Prujean (*c.* 1630–1706) matriculated 'privilegiatus', that is as a non-academic member of the University of Oxford, permitted to trade as a 'mathematical instrument maker' in the City, on 11 March 1663/4.[1] He had learnt his trade under the doyen of the London instrument making fraternity, Elias Allen, to whom he was apprenticed in the Clockmakers' Company in May 1646.[2] Many of Allen's apprentices served for at least ten years before taking their Freedom.[3] Withers Cheney, booked as one of Allen's apprentices almost a month before Prujean, did not take his Freedom until 1657, some four years after their master had died. Possibly he completed his term with another master, perhaps Ralph Greatorex, booked to Allen in 1639 but not Free until six months after his master's death, and then as 'formerly servant unto Mr. Allen', rather than as an apprentice.[4]

No Freedom is recorded for John Prujean, who may have worked as a journeyman until moving to Oxford to trade on his own account. He was not the first of Elias Allen's apprentices to leave the metropolis. Robert Davenport (booked 1623, Free 1635) had settled

[1] J. Foster, *Alumni Oxoniensis 1500–1714* (1891–2), iii, 1217.

[2] C.E. Atkins, *Register of Apprentices of the Worshipful Company of Clockmakers* (1931), 232; B. Loomes, *The Early Clockmakers of Great Britain* (1981), 50. This apprenticeship is not recorded in the best study of Allen, J. Brown, *Mathematical Instrument Makers in the Grocers' Company 1688–1800* (1979), 24–5, 62–5. For variations of the spelling of the surname, *D[ictionary of] N[ational] B[iography]*, ed. L. Stephens et al., entry for Sir Francis Prujean MD; below notes 10 and 12.

[3] Brown, op. cit. note 2, 25. Allen, though Free of the Grocers' Company (in which he booked 10 apprentices over the years) joined the Clockmakers' Company as a Brother shortly after its foundation in 1631. His apprentices in that Company were initially booked to a Free Clockmaker before being 'turned over' to him: J. Brown, 'Guild Organisation and the Instrument-making Trade, 1550–1830; the Grocers' and the Clockmakers' Companies', *Annals of Science*, xxxvi (1979), 27; Prujean was first booked to Thomas Alcock: Atkins, op. cit. note 2, 232.

[4] Brown, op. cit. note 2, 27–8 for Cheney, 25 for Allen's death, 64 for the record of Greatorex's Freedom.

in Edinburgh in 1647.[5] Christopher Brookes (booked 1629, Free 1639, died 1665), married to a daughter of Allen's patron William Oughtred, had settled in Oxford during the Protectorate under the patronage of John Wilkins, intruded by the Parliamentary Visitors as Warden of Wadham in 1648. Anthony Wood records that Wilkins gave Brookes a servant's post in the college with a salary of £30 a year 'purposely to encourage his ingenuity'.[6] It seems reasonable to speculate that Prujean was alerted to the business opportunity offered by a move to Oxford by Greatorex, with whom Oxford savants, including those who had returned to London at the Restoration, were acquainted.[7]

What little evidence there is of Prujean's activities in Oxford point to his making no more than a marginal living. The 1667 poll tax returns list him as living at Short's Coffee House in New College Lane. He paid the minimum tax of one shilling.[8] Three decades later, the 1696 window tax returns note him as resident in a property in New College Lane, paying tax for only three windows.[9] It was presumably this same small house, 'a tenement of [New] College in the tenure of John Pridgeon', that is noted in a lease of 1702.[10] Prujean died in 1706 and was buried in the church of St. Peter in the East on 10 September, the parish register describing him as 'mathematical instrument maker'.[11] An earlier reference in the parish accounts, relating to the construction and repair of a mural sundial on the church, notes that in 1689 'Mr John Prigon and Mr Henry Wyldgoose nue drawed and painted the Dial gratis'.[12] That irrascible observer of the Oxford scene, the antiquary Thomas Hearne, recorded in a diary jotting of May 1712 that the heads of Houses, as trustees to Crosse's Hospital at Ampthill, Bedfordshire, gave a place to

> the Daughter of one Clark an Oxford Scriviner, a rich but empty fellow, great with Charlett. This was done by the Interest and at the Sollicitation of Will. Sherwin. This is a damnable Shame, & the more so, because they denied to put in the Widow of one Mr John Prujean a Mathematical Instrument Maker, who was an ingenious Man, and had done a great deal of service for the University for several Years, & died very poor, wanting bread. Interest was made for this Poor woman by Dr. Halley & others but to no purpose.[13]

[5] D.J. Bryden, *Scottish Scientific Instrument Makers 1600–1900* (Royal Scottish Museum Edinburgh, 1972), 3–6; D.J. Bryden, 'Scotland's Earliest Calculating Device; Robert Davenport's Circles of Proportion', *Scottish Hist. Rev.* lv (1976), 54–60.

[6] A. Wood, *Athenae Oxonienses*, ed. P. Bliss (1813–20), ii, *Fasti* i, 403; Brown, op. cit. note 2, 63; F. Cajori, *William Oughtred, a Great 17th-century Teacher of Mathematics* (Chicago and London, 1916), 7; see also [W. Oughtred], *The Solution of all Sphaerical Triangles . . . published with the consent of the author by Christopher Brookes mathematique instrument-maker and Manciple of Wadham College* (Oxford 1650), tp; there is no reference to Brookes in R.B. Gardiner, *The Registers of Wadham College Oxford 1613–1719* (London, 1889). This move presumably took place after the 1649 publication of C. B[rookes], *A New Quadrant of more Naturall, Easie, and Manifold Performance* (London, 1649). For a comment on the enthusiasm for mechanical contrivances shown by Wilkins at Wadham, see A.V. Simcock's 'Introduction' to C.F.C. Beeson, *Clockmaking in Oxfordshire 1400–1850* (3rd edn. 1989), 6.

[7] For a study of Oxford science during the Commonwealth, with some references to both Brookes and Greatorex, C. Webster, *The Great Insturation* (1975), 153–78; see also J.A. Bennett, *The Mathematical Science of Christopher Wren* (1982), 17, 40.

[8] H.E. Salter (ed.), *Surveys and Tokens* (Oxf. Hist. Soc. lxxv, 1920), 296. He does not appear in the 1665 hearth tax or in other surveys of householders of the time. A.V. Simcock, *The Ashmolean Museum and Oxford Science 1683–1983* (1984), note 34, 28 and personal communication May 1992, notes that academically related craftsmen had settled in this area of Oxford from the 13th century.

[9] M.G. Hobson (ed.), *Oxford Council Acts 1665–1701* (Oxf. Hist. Soc. n.s. ii, 1939), 372.

[10] H.E. Salter (ed.), *A Cartulary of the Hospital of St. John the Baptist*, i, (Oxf. Hist. Soc. lxvi, 1914), 389.

[11] I am greatly indebted to A.V. Simcock, Librarian of the Museum of the History of Science, University of Oxford, for this reference, and for directing me to the references to Prujean in notes 8 to 10.

[12] A.D. Tyssen, 'On the Old Churchwardens' Account-Books of St. Peter's in the East, at Oxford', *Proc. Oxf. Archit. and Hist. Soc.* n.s. i (1860–64), 298. In 1688/9 the churchwardens of St. Mary the Virgin paid Prujean for making drawings of Kratzer's celebrated pillar dial: see Beeson, op. cit. note 6, 80.

[13] C.E. Doble et al. (ed.), *Remarks and Collections of Thomas Hearne*, iii (Oxf. Hist. Soc. 1889), 347.

Following the pattern of the London mathematical instrument makers, Prujean advertised his presence in a number of books published in Oxford.[14] However the brief phrase 'All Mathematical Instruments are Made and Sold by John Prujean living near New College in Oxford', is quite opaque about what he actually made and sold. In a 1701 publication, however, a full page advertisement listed his wares. Though brief, this catalogue is of particular value as an indication of the nature of his output. In addition, it is the earliest known catalogue of a provincial British mathematical instrument maker. It was reprinted many years ago by Gunther, but the typography of the original was not maintained, introducing errors into the text.[15] The catalogue is printed here in the format in which it originally appeared on the final page of the 1701 edition of Richard Holland's *Globe Notes*.[16] The marginal reference figures are editorial.

A Catalogue of Instruments, *Made and Sold by* John Prujean, *near* New-College, *in* Oxford. *With Notes of the Use.of them.*

[1] *Holland's* Universal Quadrant.
[2] His Altrimetrick Quadrant, serving to take Hights by inspection.
[3] *Oughtred's* Quadrant.
[4] His double Horizontal Dial.
[5] *Gunter's* Quadrant.
[6] His Analemma.
[7] His Nocturnal.
[8] *Collins's* Quadrant.
[9] Mr. *Halton's* Universal Quadrat for all Latitudes, with Mr. *Haley's* Notes.
[10] *Orontia's* Sinical Universal Quadrant.
[11] *Napier's* Rods.
[12] Mr. *Caswel's* Nocturnal.
[13] Mr. *Haley's* Nocturnal.
[14] Mr. *Thomson's* Pantometron.
[15] Mr. *Pound's* Cylinder-Dial.
[16] Mr. *Edward's* Astrolobe.
[17] Mr. *Hooper's* Dialing Scales.
[18] Scales for Fortification.
[19] Scales for Surveying, Dialing, *&c.*

[20] *And most other mathematical Instruments.*

14 R. H[olland], *Globe Notes* ([Oxford] 1666), 32; R. Holland, *Globe Notes* ([2nd edn.] Oxford, printed by L. Lichfield for R. Davies, 1678), 32, Madan 3178; R. Holland, *Globe Notes* ([3rd edn.] London, printed for a friend of the Authors [16]84), 32 – despite the imprint, this edition appears to be an Oxford printing, the cornucopia-type ornament on the title page being identical to that used in the 1701 edition (below note 16); R. Holland, *An Explanation of Mr Gunter's Quadrant as it is Enlarged with an Analemma* (Oxford, 1676), tp, Madan 3108; T. E[dwards], *Dialling Made Easy; or Tables Calculated for the Latitude of Oxford* (Oxford, 1692), 20; F. Madan, *Oxford Books; Oxford Literature 1651–1680* (1931).

15 R.T. Gunther, *Early Science in Oxford* (1922–45), i, 180. Gunther also unearthed but infuriatingly failed fully to cite many scattered references to Prujean: ibid. ii, 116, 180; see also his *Astrolabes of the World*, ii (1932), 519–20. These were used as the basis of the entry in E.G.R. Taylor, *The Mathematical Practitioners of Tudor and Stuart England* (1954), 256; Taylor's identification of the various designers listed by Prujean fails to cite sources. R.G.W. Anderson, J. Burnett and B. Gee, *Handlist of Scientific-Instrument Makers' Trade Catalogues 1600–1914* (National Museums of Scotland, Edinburgh, 1990), p. i, cite this catalogue as the earliest of the genre that they have located. It certainly appears to be the earliest known British catalogue of instruments produced outside London, but there are several far more extensive London listings dating from the latter decades of the 17th century: D.J. Bryden, 'Evidence from Advertising for Mathematical Instrument Making in London, 1556–1714', *Annals of Science*, xxxxix (1992), 329–30.

16 R. Holland, *Globe Notes* ([4th edn.] Oxford, for Henry Clements, 1701), 40.

RELATED PUBLICATIONS

At the head of the catalogue, Prujean refers to 'Notes of the Use of them', that is instruction sheets for the instruments that he sold. These ephemeral explanatory *Notes* have been inadequately recorded by bibliographers.[17] To date I have located four distinct broadsheet instruction leaflets, describing the use of six instruments.

PRUJEAN A+B: *The* Analemma QUADRANT, *serving for all* LATITUDES.
These Notes, with all Mathematical Instruments, are Made and Sold by JOHN PRUJEAN.
with *The* Altimetrick QUADRANT, *serving to take Hights by Inspection.*
These Notes, with all Mathematical Instruments, are Made and Sold by JOHN PRUJEAN in *OXON.*
[copy in Chethams Library, Manchester; Wing P.3884]

PRUJEAN C+D: *A short description of a Quadrant of the particular Astrolabe inverted.*
These Notes with all Mathematical Instruments, are Made and Sold by *JOHN PRUJEAN* in *OXON.*
with *Oughtred's Quadrant.*
These Notes, with all Mathematical Instruments, are Made and Sold by *JOHN PRUJEAN* in *OXON.*
[copy in Christ Church Library, Oxford; Wing P.3884, Press Mark Hyp.B.225]

PRUJEAN E: *A DESCRIPTION OF GUNTER'S QUADRANT.*
These Notes with all Mathematical Instruments are Made and Sold by JOHN PRUJEAN in Oxford.
[copy in British Library, London; Press mark 1850.c.10(70)]

PRUJEAN F: *The description of the* Horological Ring-Dial, *which showeth the* Hour of the Day in any part of the World.
This DIAL, *or any other Instrument for the* Mathematicks are made exactly by *John Prujean* living neer *new College* in *Oxford.*
[copy in Science Museum, London; Calvert 308][18]
This sheet has two rows of type ornaments at the head and is printed on paper with a foolscap watermark – similar but not identical to Heawood 1981.[19]

THE CATALOGUE ENTRIES

Of the 19 items listed in John Prujean's 1701 catalogue, 17 are attributed to 13 named designers. These designers fall into two groups, those no longer alive, who are referred to by their surname alone, and those still living, distinguished by the designation: 'Mr'. With the exception of Richard Holland, the deceased designers were responsible for instruments that

[17] D. Wing, *A Short Title Catalogue of Books Printed in England . . . 1641–1700* (New York, 1945–51), entry P. 3884, is misleading in reading: 'PRUJEAN, Jean (sic), Notes of mathematical instruments made and sold by Jean (sic) Prujean in Oxon. [London, 1653?]', referring to a single copy at Chethams Library, Manchester. The second edition (New York 1972–1988), entry P. 3884, merely adds an additional location: Christ Church, Oxford. In an unpublished paper of February 1970, *Ephemera issued by the Early Lecturers in Experimental Science*, P.J. Wallis of the University of Newcastle-upon-Tyne noted the differences between the Chethams and Christ Church *Notes*.

[18] H.R. Calvert, *Scientific Trade Cards in the Science Museum Collection* (1971), item 308.

[19] E. Heawood, *Watermarks Mainly of the 17th and 18th Centuries* (The Paper Publications Society, Hilversum, 1950), plate 281.

were well known in the 17th century. Holland, in contrast, owes his place in Prujean's repertoire to the fact that he had taught mathematics in Oxford for many years. Most of the living designers were Oxford men, though their designs are largely unknown except through this catalogue. An exception in this group is Immanuel Halton, whose Oxford connections were indirect, through two brothers and a son, all Queen's men. However, in referring to *Mr*. Halton, Prujean does not appear to have been aware of the former's death in 1699.

For a mathematical instrument maker operating in the year 1701, the content of Prujean's catalogue appears anachronistic, notably in the concentration on designs related to dialling, the art and science of the sundial. Certainly the contents shows no anticipation of the 18th century; there are no measuring instruments of the type used by practitioners of astronomy, navigation or surveying, and none of the philosophical apparatus then exciting interest among both savants and the gentry alike. However, the reflection of a previous era is not unique. For example, in the later years of the 17th century a handful of London instrument makers kept in circulation designs for horary quadrants, marketing paper pulls from copper plates of instruments designed many decades earlier.[20] Whilst Prujean's catalogue is essentially firmly rooted in the 17th century, it provides an interesting insight into mathematical education in post-Commonwealth Oxford. It indicates an expectation that mathematical tyros would want to buy instruments of this sort. Indeed, the nature of the items listed suggests that Prujean was primarily selling inexpensive paper instruments, the sort of thing that an undergraduate could readily afford to buy.

Another factor which the catalogue brings out is the youthful competence in the mathematical astronomy of dialling demonstrated by men like Edmund Halley, James Pound and Thomas Edwards; the latter two designing a cylinder dial and an astrolabe, instruments whose history dates from the Middle Ages and classical antiquity respectively. During the second half of the 17th century, the value of such devices was not as research tools, but as educational aids, introducing students to the mathematical geometry of solar and stellar motions. To produce one's own design was to demonstrate a mastery of practical mathematics, a competence which was a useful foundation for more advanced studies.

What Prujean's catalogue also suggests is that in his little workshop in New College Lane, Oxford savants did not have access to the advanced technical skills that were required by those wanting instrumental aids for investigations in the new natural philosophy of the age. Despite Prujean's presence in the City, the Savilian professor of astronomy Edward Bernard could complain 'we lack a corporation, a set of grinders of glass, instrument-makers, operators and the like, that experiments may be well managed in this place'.[21] Equally, although he was known to at least one of their number, Prujean's name does not appear in the records of the activities of the Oxford Philosophical Society.[22] What little survives of his

[20] The most notable was Philip Lea: see P. Lea, *A Catalogue of Globes, Spheres, Maps, Mathematical Projections, Books and some Instruments* (London [1698/1700]). The section headed 'Mathematical Projections, one sheet' (p. 14) includes quadrants made to the designs of Gunter, Sutton and Delamain; under the general head of 'Mathematical Instruments' (pp. 20–1) the sub-heading of '*Quadrants of several sorts*' lists designs by Gunter, Sutton, Collins, Foster, Thompson, Serle, Dary and Leybourn. In an *Advertisement of Globes, Maps &c sold by Philip Lea* [London *c.* 1690] (British Library, Harl. 5947, ff. 18 and 26A) the 'Mathematical Projections on paper' include: 'Prints of Quadrants, Gunter, Collins, Sutton, Leybourne, . . . Delamain'. Lea had a well developed penchant for re-working old map plates: see I.M. Evans and H. Lawrence, *Christopher Saxton Elizabethan Map-Maker* (1979), 50–53, and R.A. Skelton, *The County Atlases of the British Isles 1579–1850* (1970), 172, 237, 246; with just one exception, the quadrants listed can be identified and related to books illustrated with a copper plate of the instrument.

[21] Letter, E. Bernard to J. Collins, 3 April 1671, printed in *Correspondence of Scientific Men of the Seventeenth Century*, ed. S.J. Rigaud, i (1841), 159.

[22] Gunter, op. cit. note 15, iv (1925) and xii (1936). The contact was John Caswell (below, entry 12).

work suggests that Prujean did not develop beyond being a competent maker of a limited range of the small mathematical instruments that were the conventional products of London workshops of the mid-17th century. In addition, he made similar instruments to the particular designs of Oxford men, devices whose sales outside the City were unlikely. There is no evidence to suggest that he possessed the more demanding and innovative mechanical skills sought by that small number of discriminating customers wanting to emulate the experimental work exemplified by the activities of Robert Hooke and the Royal Society.

[1] Holland's universal quadrant
[2] Holland's altimetrick quadrant, serving to take heights by inspection

Richard Holland (1596–1677), though reputedly educated in Oxford, took no degree. Anthony Wood reports that he taught young students geography and mathematics in the town for over half a century, and 'being always sedulous in his employment, several afterwards became eminent by his instruction'.[23] As has been noted, his *Globe Notes* was reprinted three times after his death, with the final (1701) edition having addended to it not only the catalogue here discussed, but also instructions for 'THE Anelemma QUADRANT, serving for all LATITUDES by R. HOLLAND' and 'His Altimetrick QUADRANT, serving to take Hights by Inspection'.[24] The text of these sections is identical to that in Prujean A+B, so that authorship of the latter can be firmly attributed to Holland.

I have been unable to locate examples of either of these two instruments. The descriptions of use are sufficient to permit identification. Readers are urged to compare unidentified quadrant projections, especially any printed on paper, with the texts.

[3] Oughtred's quadrant
[4] Oughtred's double horizontal dial

William Oughtred (1575–1660) was one of the leading mathematicians of his day.[25] He was of the opinion that instruments should only be used by those who had first mastered the mathematical theory on which they were based. Consequently, he gave little priority to publishing his own designs for instruments. Indeed, Oughtred's most important contribution to the corpus of mathematical instruments, the logarithmic slide rule, was published only as a response to outright plagiarism by a former pupil, Richard Delamain.[26] The design for a 'Horizontal Instrument' incorporating a stereographic projection, was similarly plagiarised. In this instance, both parties to the dispute acknowledged that the projection had antecedents.[27] In listing 'Oughtred's Quadrant', Prujean was in fact referring to Delamain's version, which took account of the symmetrical nature of the projection to insert it within an arc of 90 degrees. There is a paper example by Prujean in the apex of the quadrant illustrated in Figure 1 (top).

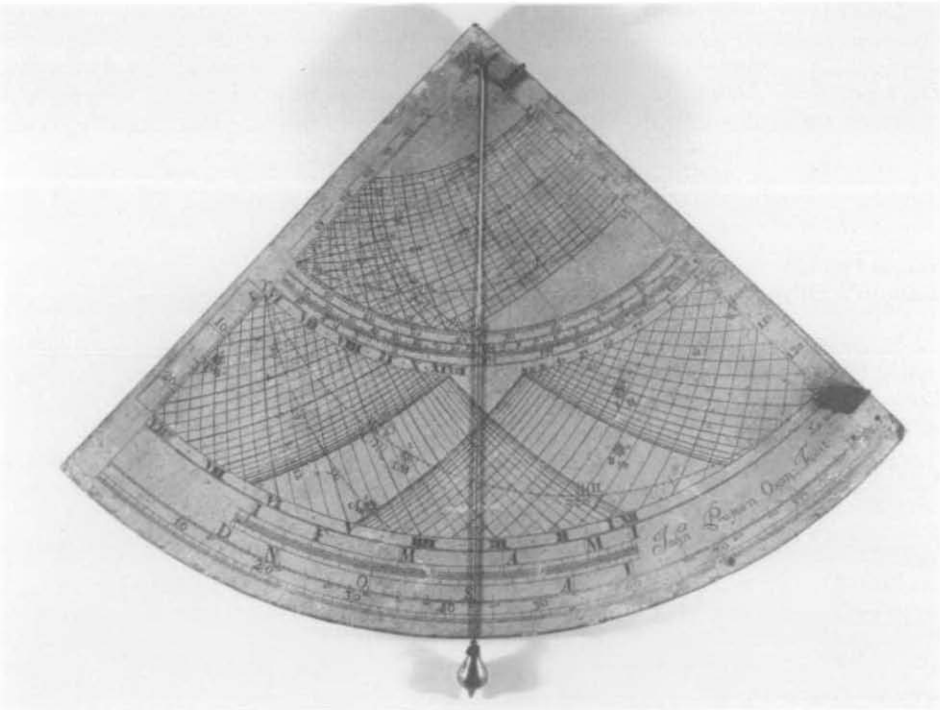
[23] Wood, op. cit. note 6, iv, 690. See also *DNB*, art. Richard Holland.

[24] Holland, op. cit. note 16, 33–9. See note 14 for other editions.

[25] Cajori, op. cit. note 6, passim; J.F. Scott, 'William Oughtred', in *D[ictionary of] S[cientific] B[iography]*, ed. C.C. Gillispie (1970–80), x, 254–5.

[26] D. J. Bryden. 'A Patchery and Confusion of Disjointed Stuffe; Richard Delamain's *Grammelogia* of 1631/3', *Trans. Camb. Bibliographical Soc.* vi (1974), 158–66; P.J. Wallis, 'William Oughtred's "Circles of Proportion" and "Trigonometries"', *Trans. Camb. Bib. Soc.* iv (1968), 372–82. On Oughtred's view of the role of instruments see Cajori, op. cit. note 6, 84–95; for the wider educational context see D.J. Bryden, 'A Didactic Introduction to Arithmetic; Sir Charles Cotterell's 'Instrument for Arithmeticke' of 1667', *History of Education*, ii (1973), 14–15, and A.J. Turner, 'Mathematical Instruments and the Education of Gentlemen', *Annals of Science*, xxx (1973), 58–61.

[27] Compare W. Oughtred, *The Circles of Proportion and the Horizontal Instrument* (London, 1632) with R. Delamain, *The Making, Description, and Use of a . . . Horizontal Quadrant* (London, 1632). See also A.J. Turner, 'William Oughtred, Richard Delamain and the Horizontal Instrument in 17th-Century England' *Annali Dell'Istituto E Museo Di Storia Della Scienza Di Firenze*, iv (1981), 99–124.



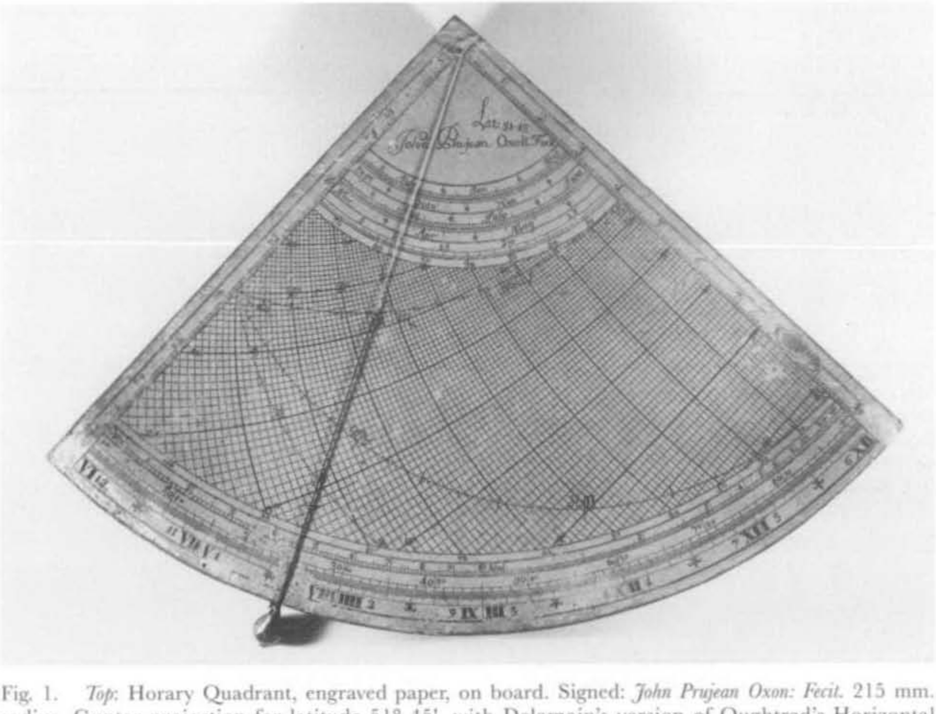


Fig. 1. *Top*: Horary Quadrant, engraved paper, on board. Signed: *John Prujean Oxon: Fecit*. 215 mm. radius. Gunter projection for latitude 51° 45', with Delamain's version of Oughtred's Horizontal Instrument in the apex.
Bottom: Horary Quadrant, engraved paper, on board. Signed: *John Prujean Oxoñ Fecit*. 215 mm. radius. Harvie/Collins/Sutton projection for latitude 51° 45'. Museum of the History of Science, Oxford, Newdegate Collection.

Oughtred's double horizontal dial combined the horizontal instrument with a horizontal sundial. It enjoyed some popularity among London mathematical instrument makers, more especially those whose training came directly or indirectly from Elias Allen. It slipped out of the repertoire during the early decades of the 18th century.[28] No example by Prujean is known. In the context of his manufacture of paper instruments, it is noted that the London instrument maker Thomas Tuttell cut a printing plate for the double horizontal dial which is contemporary with the listing in Prujean's *Catalogue*.[29]

[5] Gunter's quadrant
[6] Gunter's analemma
[7] Gunter's nocturnal

Edmund Gunter (1581–1626) matriculated at Christ Church in 1600, (BA 1603, MA 1606). His Licence to Preach and BD degree were granted in 1615 when he moved to London to become vicar of St. George's, Southwark. He was appointed to read the Astronomy Lectures at Gresham College in 1619.[30] On the authority of the instrument maker Ralph Greatorex, John Aubrey wrote of him:

> He was the first that brought Mathematical Instruments to perfection. His *Booke of the Quadrant, Sector, and Crosse-staffe* did open men's understandings and made young men in love with that Studie. Before, the Mathematicall Sciences were lock'd up in the Greek and Latin tongues; and so lay untocht, kept safe in some Libraries. After Mr Gunter published his Booke, these Sciences sprang up amain, more and more to that height it is at now (1690).[31]

Gunter was by no means the first to make practical mathematics accessible by writing in the vernacular. Furthermore, his text is certainly not written for the beginner. In particular, some of the suggestions for instrument applications are buried deep in the text. Nevertheless, Gunter's work had a lasting influence on contemporaries. The book was reprinted, with additions, regularly during the 17th century.[32] At the time, Gunter's approach was perceived as essentially practical. Aubrey's anecdote relating to Sir Henry Savile's filling of the first Savilian chairs epitomises a dichotomy between practical application and theoretical comprehension that still causes debate among educationalists:

> He first sent for Mr Gunter from London (being of Oxford University) to have been his Professor of Geometrie: so he came and brought with him his Sector and Quadrant, and fell to resolving of Triangles and doeing a great many fine things. Said the grave Knight, *Doe you call this reading of geometrie? This is shewing of tricks, man!* and so dismisst him with scorne, and sent for Henry Briggs, from Cambridge.[33]

Gunter was responsible for the most popular 17th-century design for an horary quadrant. Surviving 17th- and 18th-century instruments indicate that the London instrument makers frequently made the instrument with a planispheric nocturnal and a superimposed analemma on the reverse face, designs also described in Gunter's 1624 text, though not as integral parts of one instrument.[34] Prujean's paper version of the Gunter quadrant, made for the latitude of Oxford, is illustrated in Figure 1 (top). The

[28] W. O[ughtred], *The Description and Use of the Double Horizontal Dyall* (London, 1636); Turner, op. cit. note 27, 120–2.

[29] Turner, op. cit. note 27, 123. Henry Sutton had cut a plate in or before 1660, ibid. 123.

[30] J. Ward, *The Lives of the Professors of Gresham College* (1740), 77–81; Foster, op. cit. note 1, ii, 620; J.V. Pepper, 'Edmund Gunter', in *DSB*, v, 593–4.

[31] *Aubrey's Brief Lives*, ed. O.L. Dick (1949). I have used the Penguin English Library Edition (1972), 275–6.

[32] E. Gunter, *The Description and Use of the Sector* (London, 1624). From the 3rd edn. (1653), ed. Henry Bond, the book appeared with the title *The Works of Edmund Gunter*; the 5th (1673) and 6th (1680) edns. ed. William Leybourn. Taylor, op. cit. note 15, 60–4, and D.W. Waters, *The Art of Navigation in England in Elizabethan and Early Stuart times* (1958), 358–92, stress the importance of Gunter's contribution to popularising the new mathematical navigation, both by written and instrumental methods.

[33] Dick, op. cit. note 31, 431.

[34] Gunter, op. cit. note 32, bk 3, 188 (for the quadrant) and bk 1, 55 and 60 (for the analemma and the nocturnal). For surviving examples, see D.J. Bryden, *Sundials and Related Instruments*, The Whipple Museum of the History of Science, Catalogue 6 (Cambridge 1988), items 279–288.

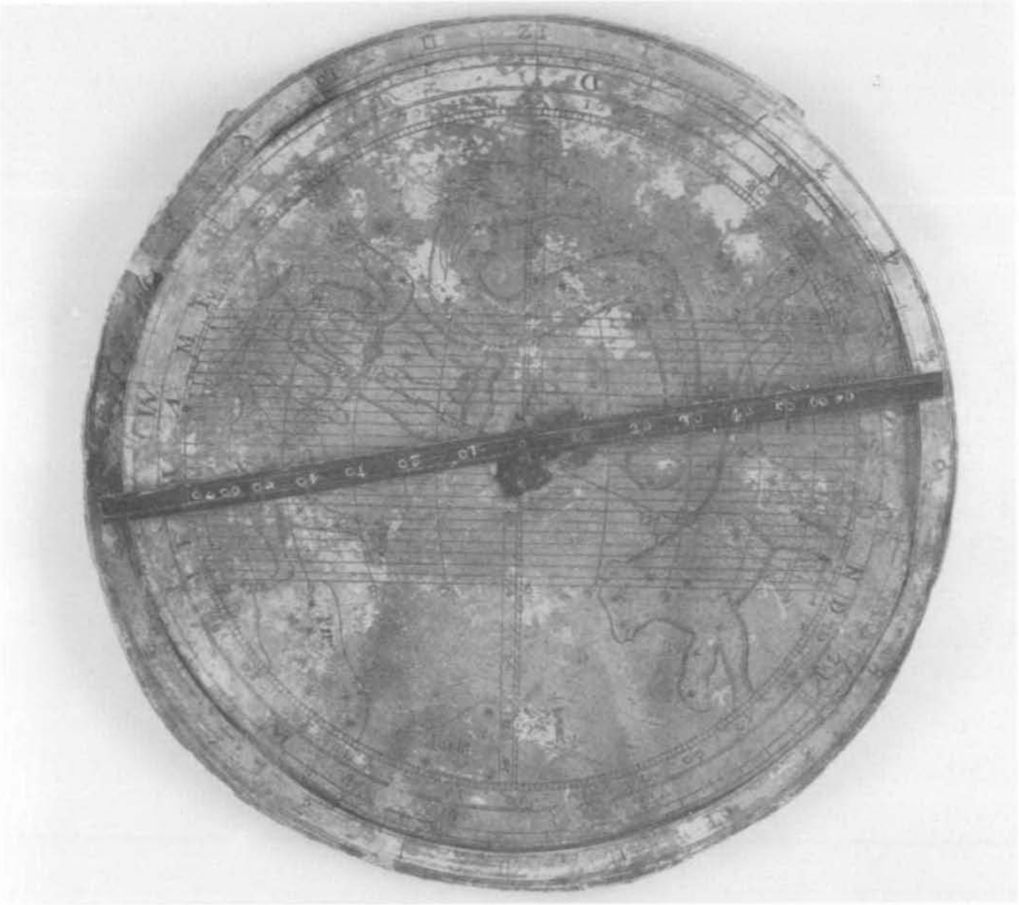


Fig. 2. Planispheric Nocturnal and Analemma, engraved paper on card, with copper/bronze index arm. 157 mm. diamter. To the design of Edmund Gunter. Unsigned, but on stylistic grounds attributed to John Prujean of Oxford. Museum of the History of Science, Oxford, Newdegate Collection.

use of the instrument is described in Prujean E. An unsigned paper volvelle comprising Gunter's planispheric nocturnal and the associated analemma is illustrated – (Fig. 2). On the basis of the orthography this has been attributed to Prujean.[35] The combined instrument is described in a text written by Richard Holland and published the year before his death.[36] Comparison with the broadsheet indicates that the latter is derived from the former, though whether it was actually written by Holland, or abstracted and reordered by Prujean at a later date, is a matter of conjecture.

It is indicative of the popularity of the Gunter quadrant that the surviving examples of Prujean's work in metal are all small Gunter quadrants, each with the analemma and planispheric nocturnal on the reverse face – (Fig. 3).[37]

[35] Museum of the History of Science, Oxford, Newdegate Collection, 26–90/1. Professor G.L.E. Turner (personal communication, May 1992) has confirmed the attribution.

[36] R. Holland (1676), op. cit. note 14.

[37] Examples are known signed: *Iohã Prujean Fecit Oxo.* – Hull Museums 936.1986.1 (M4.503); *I.P. Fecit Oxõ* – National Maritime Museum Q.12/48–288; *I. * P. Fecit Oxõ.* – Museum of the History of Science, Oxford 86–8, purchased Christie's, *[sale of] Scientific Instruments,* 17 April 1986, lot 309.

[8] Collins' quadrant

John Collins (1625–83) served three years of an apprenticeship to an Oxford bookseller. On his master ceasing to trade, Collins went to London, becoming a kitchen clerk at the Court of Charles I. During the Civil War he served as a seaman in the Venetian navy. On returning to the metropolis he set up as teacher of accounts and mathematics. After the restoration Collins held a succession of minor Government offices, and was able to use the consequent privilege of free postage to conduct a vigorous correspondence with mathematicians in Britain and Europe.[38]

The instrument which Prujean attributed to Collins was one of a group of designs first published in 1658. In the forward to his account of these horary quadrants, Collins indicates that the originator of the key design was one Thomas Harvie, but that he himself had made some additions as a result of being asked to write instructions for their use. He also noted that the instrument maker Henry Sutton, commissioned by Harvie to construct examples, had also made changes to the designs. Collins apologised to readers for the consequent mismatch between text and illustrations, explaining that he had written it 'before the instruments were cut, wherefore the description given of them, may not so nearly agree with the instruments'.[39] Writing to mathematician John Wallis in 1665, he distanced himself from the whole project:

> At the request of Mr. Sutton I wrote a despicable treatise of quadrants. His design was to demonstrate himself to be a good workman in cutting the prints of those quadrants. Mine to improve the prints by varnish, which I was certain I could accomplish'.[40]

Purchasers of Collins' text were informed that they could have it 'with large Cuts of each Quadrant, printed from the original Plates graved by *Henry Sutton*, either loose, or pasted upon Boards'.[41] Henry Oldenburg, as editor of the Royal Society's *Philosophical Transactions*, told his readers that horary quadrants, specifically including those described by Collins,

> *printed may very conveniently be pasted on* Copper-Plates *and varnisht; which done, they will be not only very cheap and portable (to be had at* John Marks *at the* Sign *of the* Golden Ball, *near* Somerset House) *but also serviceable enough, being preserv'd by the Varnish from the accidental injuries of Ink and Dirt*'.[42]

Varnished paper examples of the 10-inch quadrant, mounted on a wooden core, are in a number of collections, as are examples of Collins' four-inch model pasted on brass.[43] Though signed by Henry Sutton and dated 1658, they remained on sale long after Sutton's death.[44] Indeed the original copper

[38] *DNB*, art John Collins; D.T. Whiteside, 'John Collins', *DSB*, iii, 348–9.

[39] J. Collins, *The Sector on a Quadrant, or a Treatise Containing the Description and Uses of Three Several Quadrants* (London, 1658), sig.A2^{r}. The latter part of the book deals with Collins' own design: *The Description and Uses of a Great Universal Quadrant*, 205–75 is distinguished by a subsidiary title page, whilst 'the description and use of an universal small pocket quadrant' runs from 277–84. Separately paginated and with its own title page is *The Description and Uses of a General Quadrant* (London, 1658). The work was re-issued with a new title page the next year as *The Sector on a Quadrant, or a Treatise Containing the Description and Uses of Four Several Quadrants.*

[40] Rigaud, op. cit. note 21, ii, 462.

[41] Collins, op. cit. note 39, tp; in the 1659 re-issue the phrase is 'With Paper Prints of each Quadrant, either loose or pasted upon boards'.

[42] H. Oldenburg, [review of A. Tacquet, *Opera Mathematica* (Antwerp 1669)], *Philosophical Trans. Royal Soc. of London*, iii (1668–9), 873.

[43] Bryden op. cit. note 34, item 288A; Science Museum, London, Inv. No. 1937.117; Museum of the History of Science, Oxford, Orrery Collection 37; National Maritime Museum Q.15 NA.60–13/12c. Science Museum, London Inv. No. 1889.50 and British Museum 88 12–1 277 are Collins' 4-inch model pasted on one side of a piece of brass, both with original fitted leather case.

[44] Oldenburg, op. cit. note 42, 873 notes that John Mark (who succeeded to Henry Sutton's business, see Rigaud, op. cit. note 21, ii, 459) continued to sell them. Robert Morden published a brief account, *A description and use of a large quadrant contrived and made by Henry Sutton* (London, 1669); his successor Philip Lea advertised them: see Lea [1690] and [1698/1700], op. cit. note 20. An abridged version of the 1658 text, illustrated by the 10-inch plate, was printed in the early 18th century: J. Collins, *The Description and Use of Four Several Quadrants* (new edn. ed. J. Good, London, 1710), re-issued in 1723 and 1750.

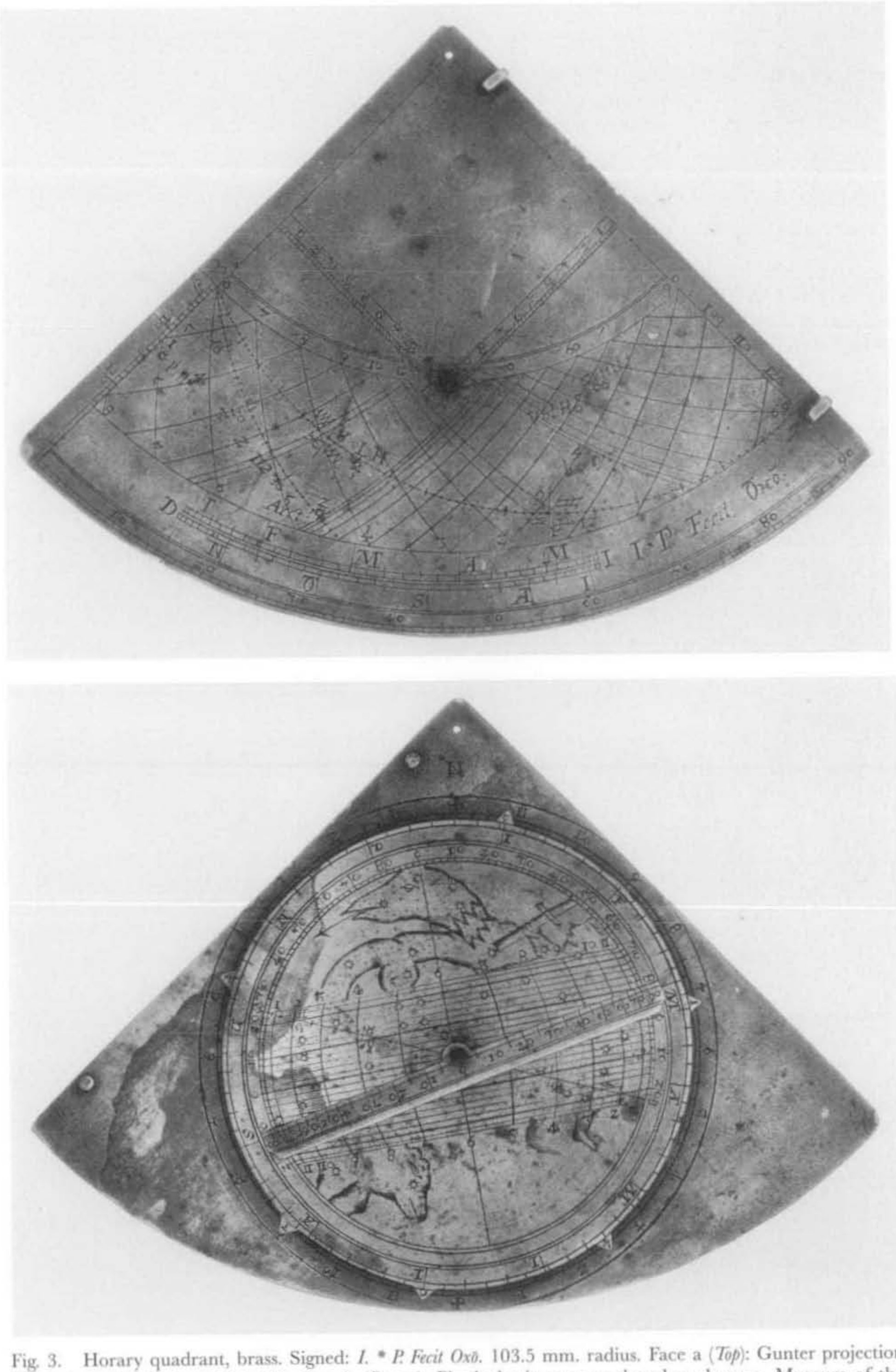


Fig. 3. Horary quadrant, brass. Signed: *I. * P. Fecit Oxō.* 103.5 mm. radius. Face a (*Top*): Gunter projection [for a latitude of about 51° 45']. Face b (*Bottom*): Planispheric nocturnal and analemma. Museum of the History of Science, Oxford, 86–8.

plate for the 10-inch instrument was reworked to take account of the introduction of the Gregorian Calendar in Britain in 1752.[45] It is probably the long availability of pulls from the excellent plates that ensured the literary survival of the so-called Sutton or Collins quadrant, well into the 19th century.[46]

Prujean cut his copper plate of the Harvie-Sutton-Collins quadrant for the latitude of Oxford. An example is illustrated (Fig. 1, bottom). The varnish has provided some protection from nearly three centuries of wear. The first part of Prujean C+D describes the instrument, under the title 'particular astrolabe inverted'.

[9] Halton's universal quadrat for all latitudes, with Halley's notes

Immanuel Halton (1628–99) came from a Cumberland family. His interests and proficiency in the mathematics of practical astronomy and dialling are indicated by letters written in the early 1650s when at Gray's Inn.[47] He purchased an estate in Derbyshire, and early encouraged the mathematical and astronomical interests of John Flamsteed, subsequently the first Astronomer Royal. In a 1673 letter, Flamsteed recorded Halton's continuing interest in matters relating to dialling:

> Lately, in discourse with Mr. Halton, he was pleased to shew me a straight-lined projection for finding the hour by inspection, the sun's declination and height being given; but concealing the proportion from which it was derived, gave me occasion to vary it.[48]

Halton's brothers Timothy and John matriculated and graduated at Queen's. Timothy Halton was Provost of the college from 1677 until his death in 1704 and John a Proctor in 1681 during his brother's first period as Vice-Chancellor. Immanuel's son John matriculated in 1680.[49] Lacking other information, it seems appropriate to identify Immanuel Halton as the designer of the universal quadrat that is listed in Prujean's catalogue. Edmund Halley went up to Queen's the very year that Flamsteed learned of Halton's quadrant design. Given his early talent for dialling, he would have been an ideal person for either Timothy or John Halton to have invited to write instructions for the use of their brother's instrument. No copies are known and this aspect of Halley's activities has not been recorded by biographers.[50]

[10] Fine's sinical quadrant

Oronce Fine (1494–1555) held the chair of Mathematics at the Collège Royal in Paris from 1531 until his death. Through his work as a translator, editor and compiler of a whole range of texts in astronomy, geometry and other mathematical subjects, university mathematical science became available to a wider public. His books, often featuring instruments, were frequently reprinted.[51] Little that Fine wrote was original and his account of the sine quadrant is no exception. The instrument is thought to be Islamic in origin, dating from the mid-10th century and the Iberian Peninsula. By the

[45] Science Museum, London Inv. No. 1918.257.

[46] E. Chambers, *Cyclopaedia* (2nd edn. 1738), ii, art. 'quadrant' and plate 'astronomy' fig 56; M. Hinde et al, *The New Royal and Universal Dictionary of Arts and Sciences* (1771), ii, art. 'quadrant' and plate 78; J.M. Good et al, *Pantologia* (1813), x, art 'quadrant' and plate 147; *The Edinburgh Encyclopaedia*, ed. D. Brewster (Edinburgh, 1830), xvii, 287–8 and plate 476.

[47] *DNB*, art. Immanuel Halton; see also S. Foster, *Miscellanea sive Lucubrationes Mathematicae* (trans. and ed. J. Twysden, London, 1659), with appendix ed. W. Leybourn, appendix pp. 7–10.

[48] Rigaud, op. cit. note 21, ii, 171. Rigaud published Flamsteed's design, but not Halton's.

[49] Foster, op. cit. note 1, ii, 637–8; *DNB*, art. Timothy Halton; Wood, op. cit. note 6, iv, *Fasti* ii, 238, 345, 371, 395, 379; and below entry 13.

[50] E.F. MacPike, *Correspondence and Papers of Edmond Halley* (1932); A. Armitage, *Edmund Halley* (1966); C.A. Ronan, *Edmond Halley, Genius in Eclipse* (1970); *Standing on the Shoulders of Giants: A larger view of Newton and Halley*, ed. N.J.W. Thrower (Berkeley, 1990).

[51] E. Poulle, 'Oronce Fine', *DSB*, xv, 153–7.

14th century it was a common instrument among both Islamic and western European astronomers, frequently appearing on the reverse face of astrolabes.[52] Fine published his description in 1542 and it was presumably a direct or indirect awareness of this source that caused Prujean to add the appellation 'Orontia's'.[53]

In Prujean's lifetime, English writers considered the sinical quadrant to be of use in dialling in performing analogue computations like the horary quadrant, or more often for use in navigational computation.[54] Earlier in the century, Rathborne had included it in the vertical axis of his alt-azimuth surveying instrument, the 'peractor'.[55] For both surveyor and navigator alike, the supposed advantage of the instrument was that it removed a computational stage; an observation of an angle could be recorded directly as a trigonometrical ratio. In practice, the principal became less and less valid as the design of angle-measuring instruments improved. Once angles were routinely being read to fractions of a degree, a small sinical quadrant could not compete on accuracy with trigonometrical tables. Nevertheless, the instrument remained in the general repertoire of London workshops into the 18th century, presumably because it had a value in teaching practical trigonometry.[56]

[11] Napier's rods

The calculating rods designed by John Napier (1550–1617) were published in Edinburgh a few months after the death of the Scots mathematician famed as the inventor of logarithms.[57] In the 17th century, beginners in mathematics were more familiar with Napier's rods than with his logarithms. The little calculating rods were widely exploited as a teaching aid. 'These little moveables doth so facilitate, that the meanest capacity may in 2 houres learne to multiply and divide', claimed John Dansie in 1627.[58] Similarly, Jonas Moore boasted:

> *Multiplication and Division* being the only hinderances to many in their progresse Mathematicall, because indeed to such Gentlemen and others who make it their pleasure it is very troublesome; I have for their sakes made the same very easie and facile many ways, among which I commend unto them one way I insist upon, by certain rods invented by the *L. Nepair*, called *Nepair's bones* of such expedition and ease that to any one that knows how to adde and subtract, I dare affirm that in 2 hours time to shew them how to multiply and divide and extract the square and cube roots.[59]

[52] D. King, 'Ibn al-shatrir' and 'Al-Zarqali', *DSB*, xii, 361, and xiv, 594. Gunther (1932), op. cit. note 15, passim.

[53] O. Fine, *De Universali Quadrante Sinuumve Organo*, in the folio edition only of O. Fine, *De Mundi Sphaera* (Paris, 1542), 104v.–112r. The Bodleian Library had copies of Fine's works from an early date: M. Feingold, *The Mathematicians' Apprenticeship; Science, Universities and Society in England, 1560–1640* (1984), 118; Savile Bb4 contains three of them, including the 1550 Paris edition of *De Universali Quadrante Sinuumve Organo*, though this does not have the large woodcut that appears in the 1542 folio version – compare M4.14(5) Art.

[54] T. Stirrup, *The Description of the Universal Quadrant* (London, 1655); S. Sturmy, *The Mariner's Magazine* (London, 1669), 64–72; J. Seller, *Practical navigation* (London, 1669), 254–261; D. Newhouse, *The whole Art of Navigation* (London, 1685), 210–250.

[55] A. Rathborne, *The Surveyor* (London, 1616), 129–131.

[56] O. Brown, *Surveying*, Whipple Museum of the History of Science, Catalogue 1 (Cambridge 1982), item 42, is an example dating from about 1700. See also P. Hoste, *A Compendious Course of Practical Mathematicks* (trans. and augmented by W. Webster, London, 1730), 3, p. 56 et seq and plate 3. The plate of the instrument cut by Jonathan Sisson (plate 3), bearing the legend 'The true form of the Sinical Quadrant when perfected according to the English method of Projection', is often found (uncalled for in the text!) in editions of W. Webster, *The Description and Use of a Complete Sett or Case of Pocket-instruments* (2nd edn. 1739). This first appeared as an appendix to the 1730 translation of Hoste, 3, p. 179 et seq. See also J. Adams, *The Description and Use of a New Much Improved Sinical Quadrant* (1781).

[57] J. Napier, *Rabdologiae, seu Numerationes per Virgulas* (Edinburgh, 1617); see also the modern translation of the text by W.F. Richardson, with an introduction by R.E. Rider, in the Charles Babbage Institute reprint series, No. 15 (Cambridge, Mass. 1990).

[58] J. Dansie, *A Mathematicall Manuel* (London, 1627), 2.

[59] J. Moore, *Arithmeticke* (2nd edn. London, 1660), 28.

Though there were some circumstances in which a competent mathematician would want to use Napier's rods, they were primarily an initial teaching aid, giving a clear and simple visual indication of the importance of place when undertaking simple multiplication. In contrast the mysterious rote method to be followed when extracting a square or a cube root has no educational value at all.[60]

Napier recommended that the rods be made of boxwood, ivory or silver, or any other similar material. One early commentator also suggested that users could make their own from paste board,[61] whilst Seth Partridge said that the most economical mode of construction was to use the plate illustrating his book:

> These rods being printed on a clean paper may be cut out into so many fine slips, and pasted on little four square pieces of wood, or on little slips of fine Past-board, or on little slips of good thicke vellome, and so will save the cost, or labour of making them.[62]

Prujean could have made and sold quite inexpensive sets by using such a method, with the rods printed either from letterpress or from an engraved plate. I am not aware of any examples; indeed the only surviving paper-on-wood Napierian rods known to me are more or less contemporary sets from the Lusuerg workshop in Rome.[63]

[12] Caswell's nocturnal

John Caswell (1656–1712) matriculated at Wadham in 1671, working his way as a Servitor (1670–8) (BA 1674, MA 1677). He succeeded Richard Holland as an instructor in mathematics to young scholars, and became Vice Principal of Hart Hall.[64] As an active member of the Oxford Philosophical Society, Caswell was known to the wider scientific community. He had a particular interest in the barometer, taking an instrument on a tour of Snowdonia to ascertain the altitude of various mountains.[65] Caswell's tenure of the Savilian chair of astronomy (1709–12) falls outside the period of this study, but indicates that Oxford contemporaries judged him to be more than merely one who 'taught the grounds of mathematics to young scholars'.[66]

A very early form of nocturnal, an instrument used to tell the time at night from observations of the apparent circumpolar rotation of particular stars, is described in a late 13th-century manuscript. Surviving early 16th-century instruments indicate that by that date the instrument had become well established. In the Mediterranean region the bright star in the constellation of the Little Bear, ß Ursae Minoris, was commonly used, whilst navigators in northern waters preferred the Guards of the Great Bear.[67] During Prujean's working life a design appeared that was to predominate in England. Invariably made in wood, with pointers for use with either the Great or Little Bear, it incorporated

[60] D.J. Bryden, *Napier's Bones: A History and Instruction Manual* (1992), 22.

[61] W. Barton, *Arithmeticke Breviated* (London, 1634), 19–20.

[62] S. Partridge, *Rabdologia, or the Art of Numbering by Rods* (London, 1648), sig.A2v, 2–3, and plate.

[63] There are examples in large sets of geometrical and mathematical instruments of the late 17th and early 18th century by Iacabo and Dominicus Lusuerg respectively in the Science Museum, London, Inv. No. 1976.637 and the Whipple Museum, Cambridge, Inv. No. 1621.A6. The Museum of the History of Science, Oxford, 2370, has a set of these paper rods on wooden cores in a brass case, which is clearly from the same workshop.

[64] Foster, op. cit. note 1, 249; Wood, op. cit. note 6, iv, 737 and 1109.

[65] Gunther, op. cit. note 15, iv (1925), 78, 81, 112–3, 180–1; xii (1939), 200, 322; E. Halley, 'Concerning the Torricellian experiment tryed on the top of Snowdon Hill and the success of it', *Phil. Trans. Roy. Soc. London*, xix (1695–7), 583; J. Caswell, 'An Account of a new invented Barascope', *Phil. Trans. Roy. Soc. London*, xxiv (1704–5), 1597–1603); R. Plot, *The Natural History of Oxfordshire* (2nd ed. London, 1705), 313–4.

[66] Wood, op. cit. note 6, iv, 737. I have been unable to locate an account of Caswell's method of gauging casks, referred to *en passent* in J. Lightbody, *The new art of Gauging and Measuring* (London, 1713), 52.

[67] C. Vincent and B. Chandler, 'Nighttime and Easter Time: the Rotations of the Sun, Moon and the Little Bear in Renaissance Time Reckoning', *The Metropolitan Museum of Art, Bulletin* (1969), 375–9; F.R. Maddison, *Medieval Scientific Instruments and the Development of Navigational Instruments in the XVth and XVIth Centuries*, Agrupamento de Estudos de Cartografia Antiga série separatas xxx (Coimbra, 1969), 30–5.

calendrical scales for finding the age of the moon and the state of the tide.[68] This reference in Prujean's catalogue is all that is known of Caswell's design.

[13] Halley's nocturnal

Wood records that when Edmund Halley (1656–1742) went up to Queen's in 1673, he had 'not only good skill in the Latin, Greek and Hebrew tongues, but so much knowledge in geometry as to make a compleat dial'.[69] This comment was intended to underline the precocious ability which Halley manifested as an undergraduate. It also suggests that Wood, like so many of his contemporaries, had suffered from an education that virtually ignored mathematics, thus the fact that a young matriculand had mastered the practical geometry required to construct a sundial was worthy of special note. Halley left Oxford in 1676 without taking a degree. His MA was awarded in 1678 *per literas regias*, following the publication of his mapping of the stars of the southern hemisphere, his first major contribution to science. He certainly lived up to his early promise. A long scientific career, which included tenure of the Savilian chair of geometry (1704) and appointment as Astronomer Royal (1720), has been well documented.[70]

Wood apart, biographers have not noted Halley's youthful endeavours in dialling, though his techniques for constructing mural dials were recorded and illustrated by one contemporary.[71] However, nothing is known of his design for a nocturnal. Halley's subsequent action in pressing for support for Prujean's widow suggests that he remembered and retained a degree of respect for the instrument maker.[72]

[14] Thomson's Pantometron

Identification of Thomson has not been possible. There is, however, no doubt that he is *not* the London instrument maker Anthony Thompson who published a design for an horary quadrant in 1652.[73] Paper copies of that instrument were still being sold by Philip Lea almost half a century later, the designer having died during the Great Plague.[74] But Anthony Thompson did not call his instrument 'Pantometron' – and Prujean's use of the title 'Mr' indicates that this Thomson was still alive in the late 17th century. The somewhat pretentious name suggests a universal and all-embracing instrument, which given the rest of Prujean's list, was probably a dialling device of some sort.[75]

Among the many Oxford men surnamed Thom[p]son in this period, it is difficult to pick out one whose career suggests that he was likely to have demonstrated new-found mathematical proficiency by designing an instrument for use in dialling.[76]

68 Sturmey, op. cit. note 54, Bk II, 73–8; Seller, op. cit. note 54, 233–8; J. Moore, *A New System of the Mathematicks* (London, 1681), i, 253–7.

69 Wood, op. cit. note 6, iv, 536.

70 See above, note 50.

71 J. Holwell, *Clavis Horologiae* (London, 1686), 285–7: '*How to draw the Paralleles of the Signs or Declination, or Parallels of the Length of the Day, or any other Parallel that doth depend upn the Declination of the Sun, without having respect to the Hour-lines, and that three several ways Geometrically, which Ways have never been Published in any Language* . . . . These three Ways I had given me by my very Loving Friend Mr. *Edmond Halley* of *Queens-Colledge* in *Oxford*.'

72 See above, and note 13.

73 A. Thompson, *The Uses of a Quadrant* (London, 1652). Compare Taylor, op. cit. note 15, 221.

74 Lea [1690] and Lea [1698/1700], op. cit. note 20; see Rigaud, op. cit. note 21, ii, 459, for Thompson's death.

75 The name may have been inspired by L. Digges, *A Geometrical Practise named Pantometria* (London, 1571). For two similarly named universal surveying instruments see G. Atwell, *The Faithfull Surveyor . . . shewing likewise the making of a new instrument, called a Pandoran; which supplies the use of the Plain Table, Theodolite, Quadrant, Quadrat, Circumferentor and any other surveying instrument* (Cambridge, 1658), 58–76, and G. Schott, *Pantometrum Kircherianum* (Wurzburg, 1660), 1–5 and plates 1 & 2. It is most unlikely that Prujean confused both the name of the instrument and the designer with a universal horary quadrant' see W. Leybourne, *Panorganon, or a Universal Instrument* (London, 1672).

76 Foster, op. cit. note 1, passim.

[15] Pound's cylinder dial

James Pound (1669–1724) matriculated at St. Mary Hall in 1687 (BA Hart Hall 1694, MA Gloucester Hall 1694, MB 1697). He went out to Madras in 1699 serving as chaplain at Fort St. George for seven years.[77] From 1709, as rector of Wanstead, he established a private observatory where he undertook valuable astronomical work. The support given to his nephew James Bradley, discoverer of the phenomenon of the aberration of light (1729), Savilian professor of astronomy from 1718 and Astronomer Royal from 1742, has assured Pound's place in the history of astronomy.[78]

As an undergraduate, Pound was probably taught by John Caswell, Vice Principal at Hart Hall, and it is well within the context of such early mathematical teaching that he would have gone through the exercise of designing a cylinder dial for the latitude of Oxford. The instrument itself dates from the late Middle Ages and accounts are found in manuscripts composed in England from the 13th century.[79] Surviving examples indicate that the cylinder or pillar dial remained in the repertoire of European instrument makers well into the 19th century,[80] but despite its appearance in some English text books, there is no surviving material evidence that it was a conventional item of manufacture in London workshops during Prujean's working life or later.[81] No detail of Pound's design is known.

[16] Edwards' astrolabe

Thomas Edwards matriculated at Jesus College in 1686, migrated to Trinity and did not proceed to a degree because he was unwilling to take the oath. He is identified by Wood as the T.E. who wrote *Dialling made easy: or, Tables calculated for the latitude of Oxford*, published in 1692 and in which Prujean briefly advertised that '*All Instruments for the Mathematicks are Made*'.[82] It is presumably an example of Edwards' astrolabe made from engraved paper plates and signed by John Prujean that is in the Museum of the History of Science (Fig. 4).[83] That a copy of the pull from the plate used for the projection for the latitude of 51° 45' was found in a binding in the Bodleian by Mr. Paul Morgan as recently as 1980[84] (Fig. 5) suggests that examples of Prujean's ephemeral paper instruments may still be found in unlikely places.

The planispheric astrolabe has roots that go back to classical antiquity. It was the archetypal scientific instrument of the later Middle Ages, retaining a place in conservative Islamic astronomy into the present century. This is in stark contrast to the position in western Europe, for during the early decades of the 17th century the planispheric astrolabe rapidly became an instrument associated with an outmoded astronomy.[85] Nevertheless, the 1658 revival of John Blagrave's 1585 universal astrolabe, the 'Mathematical Jewel', indicates that Joseph Moxon envisaged a market for a paper astrolabe at this

[77] Wood, op. cit. note 6, iii, 1189; *DNB*, art James Pound.

[78] A.F. O'D. Alexander, 'James Bradley', *DSB*, ii, 387–9.

[79] C. Kren, 'Herman the Lame', *DSB*, vi, 301–2 notes that the mid 11th-century text by Herman, 'De Utilitatibus', is the first Latin account of the cylinder dial. Gunther, op. cit. note 15, ii (1923), 123 cites two pre-1350 manuscripts in the Bodleian, citing also E. Brock, *A Latin Treatise on the Chilindre, XIII Cent Practica Chilindri* (reprinted and translated for the Chaucer Society [London 1868]). K. Vogel, 'John of Gmunden', *DSB*, vii, 119, notes that there are extant 19 versions of Gmunden's manuscript text on the cylinder dial, written between 1430 and 1438.

[80] Bryden, op. cit. note 34, items 253–65.

[81] The inclusion of the cylinder dial in E. Stone, *The construction and principal uses of mathematical instruments* (1723), 240–1, is not evidence of manufacture in England. This work is a translation of N. Bion, *Traité de la construction et des principaux usages des instrumens mathématiques* (Paris, 1709), with additions by Stone of English instruments. The cylinder dial is part of the original French text: see Bion (1709), 313–6.

[82] Foster, op. cit. note 1, ii, 450; Wood, op. cit. note 6, iv, 690; Edwards, op. cit. note 14, 20.

[83] Lewis Evans Collection 2094, IC 314: See Gunther, op. cit. note 15, ii (1923), 220–1, and ii (1932), 519–20.

[84] Bodleian Library, Mathematical Fragment, Savile, Mm.d.141*, f.16. I am indebted to Professor G. L'E Turner for drawing this item to my attention.

[85] D.J. Price, 'An International Checklist of Astrolabes', *Archives Internationales d'Histoire des Sciences*, xxxiv (1955), 381; Gunther, op. cit. note 15, (1932), passim.

Fig. 4. Astrolabe to the design of Thomas Edwards, engraved paper, on wood and card. Signed on the latitude plate for 51° 45': *Johā. Prujean Fecit Oxōn* 203 mm. diameter. Museum of the History of Science, Oxford, Lewis Evans Collection 2094, IC 314.

date.[86] In designing a conventional astrolabe for the latitude of Oxford, Edwards undertook a demanding academic exercise in the stereographic geometry required for a projection which provides an analogue device with considerable didactic potential as an initial teaching aid. However, the sort of astronomy which leading contemporaries were undertaking required a sophistication both in observational techniques and in mathematical analysis which left the astrolabe as at best no more than

[86] J. Blagrave, *The Mathematicall Jewell* (London, 1585), especially sigs.A1r, 12v and 13–19; J. Palmer, *The Catholique Planisphere which Mr Blagrave calleth the Mathematicall Jewell* (London, 1658). Blagrave's original text was illustrated with woodcuts made by the author, and which he advised could be cut out and pasted on board to make an instrument. The text published by Moxon was intended to compliment a 17-inch diameter paper instrument made from pulls from newly engraved plates. Moxon continued to list this paper instrument in his catalogues almost to the end of his life: J. Moxon, *A Tutor to Astronomy and Geography* (4th edn. London, 1686), sig.2M4v. When James Moxon took over his late father's business in 1692, he was selling only copies of the book: J. Moxon, *Mechanick Exercises or the Doctrine of Hand-Works* (2nd edn. London, 1693), sig.2L2r.

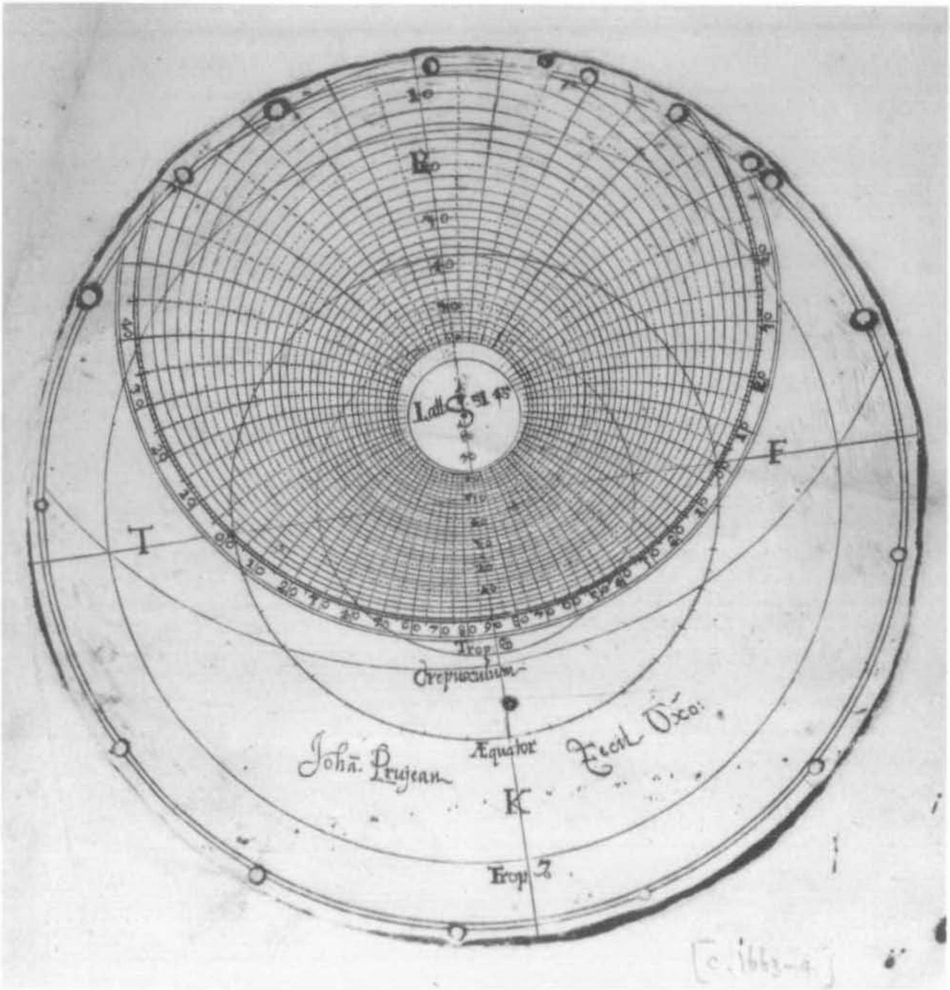


Fig. 5. Engraving of latitude plate 51° 45' for Thomas Edwards' astrolabe. Signed: *Johā. Prujean Fecit Oxō.*: 175 mm. diameter engraved surface, sheet, 305 × 200+ mm. Bodleian Library, Savile Mm.d.141*, f. 16r.

a tool of the school room, and at worst an impressive calculating device used for an astrology whose credibility was increasingly doubted by educated men. It is the reflection of the achievements of the Merton School of the late Middle Ages that provides the context for Edwards' design and Prujean's cutting of the plates to make an inexpensive paper replica. Paradoxically, today's school and college students frequently repeat the classic experiments of modern physics with equipment that would have made the pioneers they strive to emulate green with envy.

[17] Hooper's dialling scales

Library catalogues describe George Hooper (1640–1727) as 'Bishop of Bath and Wells', the appointment that marked the zenith of his distinguished ecclesiastical career. Hooper matriculated at Christ Church in 1657 (BA 1660, MA 1663). Bachelor and Doctor of Divinity degrees were awarded in 1673 and 1677 respectively. The *Dictionary of National Biography* records his insatiable thirst for knowledge of all sorts, adding to the list of conventional disciplines of the period the comment 'a mathematician of quite the first rank in his day', though there are no contemporary publications to support this claim. Nomination to lecture as deputy to Thomas Willis, Sedleian professor of natural philosophy, and to John Wallis, Savilian professor of geometry, indicate contemporary recognition of his scientific interests.[87] Hooper's daughter recorded that a short mathematical treatise written in 1669 had once been considered for publication by Nicholas Mercator, but in 1737 it remained in manuscript, and is now lost.[88]

An unfinished brass Gunter Quadrant signed '*G H Fecit: 1665*' has been tentatively attributed to Hooper's hand,[89] possibly made whilst he was a tutor at Christ Church, an appointment held until 1672 when he became chaplain to the bishop of Winchester. The quadrant is certainly the work of a gentleman amateur rather than the product of a London workshop. The dialling scale itself appears to have been the subject of a manuscript account written in or before 1669, but presently unlocated.[90]

[18] Scales for Fortification

The factional fighting of the Civil War apart, 17th-century England was a relatively peaceful country. On continental Europe, warfare between the states remained endemic with Englishmen fighting both as mercenaries and with expeditionary forces. Here, the inevitable cycle of building, remodelling, sieging and destruction of the defence works of castles, fortresses and towns provided specialist employment for military engineers. As a consequence fortification was practiced as a geometrical art.[91] Instrumental aids to fortification design were also available. The Bristol mathematician Philip Stanyred designed one,[92] whilst Sir Jonas Moore's fortification sector included scales embodying the design features of the leading European military engineers, together with an improvement on Pagan credited to Charles II.[93] It is likely that Oxford students interested in practical mathematics would undertake studies in fortification. In particular, the subject provided experience in protraction and a practical application for the construction of the regular polygons, a useful contrast to the academic sterility of much Euclidian geometry. For such students, Prujean offered 'Scales for Fortification'. In the absence of surviving examples, the designs are a matter of conjecture.

[87] Foster, op. cit. note 1, ii, 741; *DNB*, art. George Hooper; British Library Add. MS. 4222.201 (I am indebted to Dr W.M. Marshall for bringing this reference to my attention). [G. Hooper], 'A Calculation of the Credibility of Human Testimony', *Phil. Trans. Roy. Soc. London*, xxi (1699), 359, is the one paper that hints at his mathematical skills.

[88] W.M. Marshall, *George Hooper 1640–1727, Bishop of Bath and Wells* (Sherborne, 1976), 6, 170.

[89] F.A.B. Ward, *A Catalogue of European Scientific Instruments* (British Museum, London, 1981), 95, states that the instrument is made for latitude 52° 30' – in fact the design latitude is not marked and examination indicates about 52° – Oxford conventionally 51° 45'.

[90] Taylor, op. cit. note 15, 291 – without any indication of the location.

[91] The classic texts of the period were those describing the work of Jean Errard, Antoine de Ville, Blaise Françoise Comte de Pagan and Sébastien Le Prestre de Vauban. English readers could turn to such works as H. Ruse, *The Strengthening of Strongholds* (translated from the 1654 Amsterdam edition, London 1668); J.S., *Fortification and Military Discipline* (London, 1688); A. Tacquett, *Military Architecture, or the Art of Fortifying Towns* (trans. J. Lacy), which appears with *The Count of Pagan's method of delineating all manner of Fortifications, reduced to English Measure* (by S. Morland) as the second book of *Military and Maritine Discipline* (London, 1672). J. Moore, *Modern Fortification* (London, 1673); S. Le Prestre de Vauban, *The New Method of Fortification* (trans. A. Swall London, 1691), from the 3rd (1702) edn. with additional material collected by the editor W. Allingham. W. Leybourn, *Cursus Mathematicus* (London, 1690), 586–601 is an English example of the formal application of practical geometry to the design of fortifications.

[92] P. Staynred, *A Compendium of Fortification, both Geometrically and Instrumentally by a Scale* (London, 1669), which appeared only as a separately paginated appendix to Sturmey, op. cit. note 54.

[93] J. Moore, op. cit. note 91.

[19] Scales for Surveying, Dialling, *&c.*

This entry is an equally uninformative catch-all. Engraved plates of a variety of scales appear in contemporary text books. In the context of the rest of the items in the catalogue, Prujean might have been expected to cite particular dialling scales, such as those of Samuel Foster or George Serle,[94] to say nothing of the many more general dialling scales appearing in other texts.[95] For surveying the plain scale was firmly established.[96] Like dialling and fortification scales, it could be reproduced cheaply as a paper pull from a copper plate. Only the location of signed examples will show whether Prujean cut such plates himself, or was acting as a retailer selling paper pulls purchased from London. In the context of this catalogue, that he did not detail the exact form of such devices is suggestive. Perhaps those teaching practical mathematics in Oxford only covered these subjects in general terms, without explicit reference to particular designs which students might wish to purchase and use to demonstrate their mathematical competence.

[20] Most other mathematical instruments

In echoing the all embracing phrase of his advertising in earlier printings of *Globe Notes* and elsewhere, Prujean was following the general practice of London mathematical instrument makers. In the 17th century the normal practice was for a particular maker to advertise that he made and sold mathematical instruments, without any further specification, on the basis that the reader knew what he wanted to buy. The advertisement merely served to inform of the whereabouts of a suitable supplier.[97] Catalogues and lists of instruments were atypical, and for that very reason worthy of study since they indicate the range of production of a particular workshop.

Broadsheet Prujean F indicates that the 1701 catalogue is not a complete list of the potential output of the New College Lane workshop, for it does not include the 'horological ring-dial'. This instrument, now known as the universal equinoctial ring dial, is a simplified form of the astronomical ring, a design which appears in many European publications from the mid-16th century.[98] First published in 1652, the design is attributed to William Oughtred.[99] Because it is self-orientating and adjustable for use in any latitude, this form of ring dial had particular attractions. It remained in the repertoire of English instrument makers until the late 19th century, and the large number of surviving examples is strong testimony to its popularity.[100] The authorship of the broadsheet Prujean F has not been ascertained. Accounts of the instrument are commonplace in the literature of the time[101] so that producing a short text would have been quite simple. Indeed in the last two decades of the 17th

[94] S. Foster, *Posthuma Fosteri: the Description of a Ruler* (London, 1654); G. S[erle], *Dialling Universal . . . by Certain Scales on a Small Portable ruler* (London, 1657), in T. Stirrup, *Horometria, or the Compleat Dialist* (2nd edn. London, 1659), the latter was certainly still in vogue at the turn of the century, see J. Moxon and T. Tuttell, *The Description and Explanation of Mathematical Instruments* (London, 1701), 18, in J. Moxon, *Mathematicks made Easie* (3rd edn., London, 1700). Mr A.V. Simcock has drawn my attention to the fact that the Lewis Evans copy of Stirrup/Serle in the Museum of the History of Science Oxford is annotated and interleaved with an early 18th-century manuscript on dialling written by the nonconformist Divine Isaac Watts, teacher of mathematics and writer of hymns.

[95] Sturmey, op. cit. note 54, Bk II, 47–50 and Bk VII, 1–2; J. Collins, *Geometricall Dyalling, or Dyalling Performed by . . . the Plain Scale* (London, 1659); W. Leybourn, *The Art of Dialling* (London, 1669), sig.A4v, 147–70; W. Leybourn, *Dialling* (London, 1682), 24–7 and 99–110.

[96] Leybourn, op. cit. note 91, 396–8, 548–9.

[97] Bryden, op. cit. note 15, 303, 326–7.

[98] Maddison, op. cit. note 67, 43–6.

[99] W. Oughtred, *The Description and Use of the Double Horizontal Dyall . . . Whereunto is Added the Description of the Generall Horological Ring* (London, 1652), which also appears as an integral appendix to H. van Etten = J. Leurechon, *Mathematical Recreations . . . Whereunto is added the Description and use of the Generall Horological Ring and the Double Horizontal Dial* (London, 1653). The critical design feature of this two ring instrument is the pin hole gnomon, adjustable for declination and set against a calendrical scale on a diametrical bridge, in place of the pin hole sights set on the third ring of the astronomical ring dial.

[100] Bryden, op. cit. note 34, items 220–42.

[101] Leybourn, op. cit. note 91, 613–5; Seller, op. cit. note 54, 196–9; T. Tuttell, *The Description and Uses of a New Contriv'd Eliptical Double Dial, as also of the Universal Aequinoctial Dial* (London, 1698).

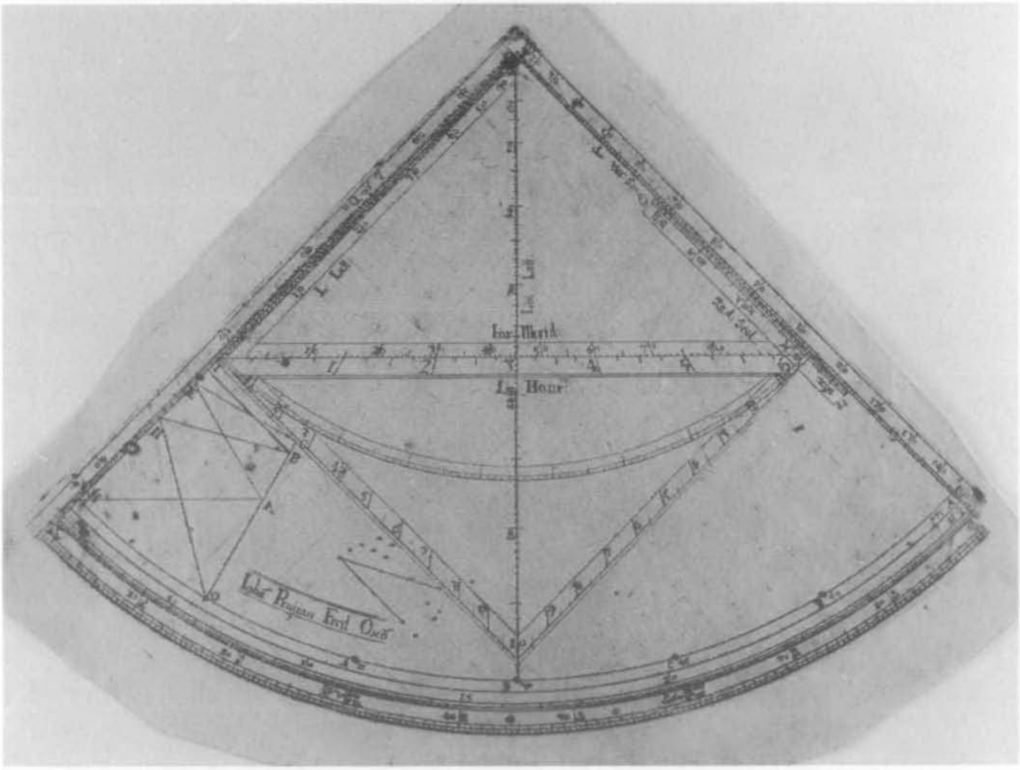


Fig. 6. Universal Horary Quadrant, engraved paper, 175 mm. radius engraved surface, sheet cut unevenly to about 208 mm. radius. To the design of Leybourn's version of Foster's quadrant, with additions. Signed: *Iohā: Prujean Fecit Oxō*: Museum of the History of Science, Oxford, Radcliffe Collection, part of 32-11.

century at least three London instrument makers issued their own instruction sheets for the universal equinoctial ring dial.[102]

Another omission from the catalogue is any reference to horary quadrants designed by either Samuel Foster or William Leybourn. In itself this is not surprising. There are numerous English 17th-century designs for quadrants which functioned as analogue devices for a variety of astronomical calendrical computations, as sundials, or were intended for use in laying out mural dials; and there is no reason at all to suppose that Prujean was claiming to make a comprehensive range of such instruments. However, a surviving paper quadrant by Prujean in the Museum of the History of Science at Oxford (Fig. 6) is to a design that originated with Foster in 1638 and was republished in a modified form by Leybourn in 1675 'with several *Additions* and *Variations* of the Authors, deduced from his [i.e. Foster's] own manuscripts'. What Leybourn did was to delete from Foster's original design what he considered to be superfluous lines and scales and re-arrange the remainder on one rather than two faces of a quadrant.[103] The Prujean quadrant contains all the lines and lettering of the

[102] Bryden, op. cit. note 15, 314, note 68.

[103] Compare S. Foster, *The Art of Dialling* (London, 1638), with S. Foster, *The Art of Dialling* (2nd edn. with supplement by W. Leybourn, London, 1675), where the plate has the legend: 'Mr Samuel Fosters QUADRANT for the Making of Sun-Dialls In all Latitudes'. Science Museum, Inv. no. 1918.256, is an unsigned London-made example in brass of the Foster-Leybourn design. Foster's second version of an horary quadrant appeared in E. Gunter, *The Works of Edmund Gunter . . . whereunto is now added the further use of a quadrant . . . by S. Foster* (3rd edn., ed. H. Bond, London, 1653), 270 et seq, and its separately published version, S. Foster, *The Uses of a Quadrant* (London, 1652).

Foster/Leybourn quadrant of 1675 with the addition of a shadow square and associated degree scale, plus meridian and hour scales for time-telling. The only other addition, with respect to the 1675 instrument, is the placing of asterisms for *Ursa Major* and *Ursa Minor*, the Great and Little Bear. The diagram was provided by Foster to familiarise readers with these constellations, and the location of the Pole Star, a first step in ascertaining local latitude. The same diagram is used in Leybourn's account of Foster's quadrant. The shadow square and the related degree scale merely make the instrument applicable for use in basic surveying and triangulation exercises. In this form, it has all the attributions called for in the as yet unlocated Universal Quadrat of Immanuel Holton. However, the implication of a 1694 comment by Edward Llywd, second Keeper of the Ashmolean Museum, is that Prujean was well aware of what was and what was not an original design for an horary quadrant.[104] He is, therefore, unlikely to have included in his catalogue an incorrectly attributed design.

POSTSCRIPT

Given the poor survival rate of both the ephemeral *Notes* and the paper instruments themselves, the identification of two instruments over and above those explicitly listed in the 1701 catalogue suggests that in claiming to make 'most other mathematical instruments', John Prujean was not indulging in empty rhetoric. The location of other examples of his work, and of further broadsheet instruction leaflets, will show whether or not the conclusion of an essentially conservative and technically restricted production capacity in the New College Lane workshop is sound. Yet, even within those limitations, John Prujean clearly provided a service to Oxford teachers and students in the forty years that he worked in the City.

As the nature and extent of the extra-curricular teaching of practical mathematics in 17th-century Oxford is more fully investigated, the significance of the role of the instrument maker will be clarified.[105] At the turn of the century, John Arbuthnot harangued his Oxford peers, arguing for an increase in mathematical education in the University. He stressed that the theoretical foundations of the applied mathematical arts must be erected, maintained and enlarged by a core of university-trained mathematicians.[106] By 1700 David Gregory, professor of mathematics at Edinburgh prior to his appointment to the Savilian chair of astronomy in 1691, was intending to offer a whole range of mathematics courses. The practical geometry course was extendable with a 'lecture on fortification, so far as 'tis necessary for understanding it without actually serving in an army or fortifying a town or camp', and similarly the principles of astronomy might be supplemented with a class on 'the doctrine of the Sphear projected in plano or of the Analemma and Astrolabes, and Dyalling'. By 1707, if not before, these extra-curricular courses were formally advertised.[107]

[104] Gunther, op. cit. note 15, xiv (1945), 216.

[105] R.G. Frank, 'Science, Medicine and the Universities of Early Modern England', *History of Science*, xi (1973), especially 202–3, 245.

[106] [J. Arbuthnot], *An Essay on the Usefulness of Mathematical Learning* (Oxford, 1701), especially 28, 35 and 50. S. Halkett and J. Laing, *Dictionary of Anonymous and Pseudonymous English Literature* (1926), ii, 202 cite a contemporary MS. note attributing the authorship, and indicating that the intended recipient was John Keill. The text is dated 25 Nov. 1700.

[107] *Private Correspondence and Miscellaneous Papers of Samuel Pepys 1679–1703*, ed. J.R. Tanner (1926), ii, 91–4, prints Gregory's schema for a series of mathematics lectures to be given in English, and sent to Pepys on 15 Oct. 1700 for his comments. M. G[illiflower], *Mercurius Oxoniensis or the Oxford Intelligencer for . . . 1707* (London 1707), 26–9, prints the syllabus offered by Gregory, which offered classes identical to those proposed in 1700; for Keill's 'College or Course of Mechanical and Experimental Philosophy', see ibid. 30–31. For the 18th-century history of such teaching in Oxford, G.L'E Turner, 'The Physical Sciences', in *The History of the University of Oxford*, v, ed. L.S. Sutherland and L.G. Mitchell (1986), 659–81.

However, by Michaelmas term 1701 Gregory's Edinburgh pupil John Keill, who had followed him to Oxford, was lecturing on dialling to a class which included a number of Christ Church undergraduates.[108]

Whether the 1701 re-issue of the enlarged *Globe Notes* and the inclusion of a list of instruments made by Prujean was a response to or a part of the new programme of teaching which Gregory and Keill brought to Oxford is a matter of conjecture. There is evidence that interest in the instruments made and sold by John Prujean continued after his death. A folio broadsheet reprinting the instruction sheets for the Gunter, Collins and Oughtred quadrants is recorded, bearing the legend: *These and other mathematical Instruments are Sold by* THO. COOKEOW *near* New College *in* OXFORD.[109] Cookeow is known as a joiner rather than as an instrument-maker.[110] Presumably he acquired Prujean's stock and had the instruction leaflet printed to sell with mounted engravings of the double-sided horary quadrant illustrated in Figure 1. In this way Prujean's work continued to be available to Oxford students after his death. It is, however, symptomatic of the nature of the contrasting rewards which the academic community gave and gives to those who work with their hands rather than their heads, that Hearne recorded his sense of injustice to the memory of 'an ingenious Man, [who] had done a great deal of service to the University for several Years, & died very poor, wanting bread'.

ACKNOWLEDGEMENTS

Mr A.V. Simcock, Librarian of the Museum of the History of Science, University of Oxford, has willingly shared his wide knowledge of Oxford craftsmen.

[108] Tanner, op. cit. note 107, ii, 240; in a letter to Pepys, John Evelyn proudly copies a letter from his grandson at Oxford, '. . . Dominus Keil praeter publicam lecturam, alternis diebus explicat Gnomicam et Hydrostaticam, qui nuper etiam cursum Experimentatis Philosophiae instituit, et me cum pluribus aliis ex Aede Christi auditorem habet.'

[109] ['A description of GUNTER'S QUADRANT'] with on the verso: ['Collins's Quadrant'] and 'OUGHTRED's *Quadrant*. R.V. and P.J. Wallis, *Biobibliography of British mathematics and its Applications*, part II, 1701–1760 (Newcastle, 1986), 68, record copies in the libraries of Lincoln College and Queen's College. The former cannot presently be located; I have examined the latter (Press Mark NNd.100^{2}), which is cropped at the head, hence the conjectural titles; there are minor changes to the text – the last two examples of Prujean C are deleted and another inserted; propositions 7 and 11 and the final three paragraphs of Prujean E are deleted. It may be significant that the Queen's copy came to the College with the books of Theopholus Metcalf, who matriculated at Hart Hall in 1706 whilst John Caswell was vice Principal; on Metcalf see Foster, op. cit. note 1, iii, 1005.

[110] Salter, op. cit. note 10, i, 389, records a lease issued to Thomas Cockeow, joiner, in 1714; see also iii, 341. See also M.G. Hobson (ed.), *Oxford Council Acts, 1701–1752* (Oxf. Hist. Soc. n.s. x, 1954), 133, 155, noting the death of Thomas Cuckoe early in 1727.