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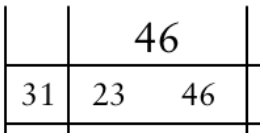
Reconstruction of
Sebastian Theodoricus: *Canon Sexagenarum* (1564)

The usefulness of the sexagesimal numbering system depends on the existence of numerical tables, in Babylonia as well as in the ancient Islamic and in Western World of mathematics.
In 1564 Sebastian Theodoricus[1], (about 1520 – 1574), a German mathematician and physician, published his *canon sexagenarum et scrupulorum sexagesimorum* ("Canon of sixties and of sixtieth parts"). In this small booklet[2] with only 32 unnumbered pages, a complete unabridged 24 page multiplication table is given. The table ranges from (1 × 1) to (60 × 60).



The figure on the left, a section of the canon (fig. 3, upper left corner), shows an example for usage:
$31 \times 46 = 23 \times 60 + 46 \equiv 23.46$. Factors and products are given without any place-identifier. In his *Canon* Theodoricus only uses names for identifiers in calculating examples (fig. 1). In several rules he tries to explain generally how to deduce them during multiplication or division.

60^3	*sexagenae tertiae* ("third sixties")
60^2	*sexagenae secundae* ("second sixties")
60^1	*sexagenae primae* ("first sixties")
60^0	*integrum* ("unit")
60^{-1}	*scrupula prima* ("first parts")
60^{-2}	*scrupula secunda* ("second parts")
60^{-3}	*scrupula tertia* ("third parts")

Fig. 1: Place-identifiers used by Theodoricus

1 For the many variants of his name see Deutsche National Bibliothek, http://d-nb.info/gnd/100635415
For bibliographical data see Wikipedia http://de.wikipedia.org/wiki/Sebastian_Theodoricus
His place of birth, Windsheim, now Bad Windsheim, is a small town in the northern part of Bavaria, Germany.

2 Digitalized editions are available from Bayerische Staatsbibliothek Muenchen (ed. 1564) and Saechsische Landesbibliothek Dresden (ed. 1609). They equal in text.

Portrait of Sebastian Dietrich or Sebastianus Theodoricus Winshemius. Drawing probably from school of Lucas Cranach. Reproduced with kind permission of 'Reichsstadtmuseum', 91438 Bad Windsheim, Germany

One year before his *Canon* he published another booklet[3] on how to calculate in sexagesimal system. Here he explains and uses signs to mark the places (fig. 2) and here he gives the same rules as later in C*anon,* expressed in sentences and in the form of modern looking decision trees.

3 Sebastian Theodoricus *Breve, perspicuum, et facile compendium logisticae astronomiae*. 1563 (digitalized copy Bayerische Staatsbibliothek Muenchen).

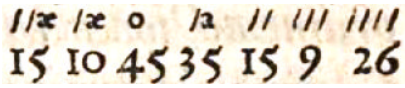


Fig. 2: Sexagesimal number with identifiers,
(from left to right 60^2 down to 60^{-4})

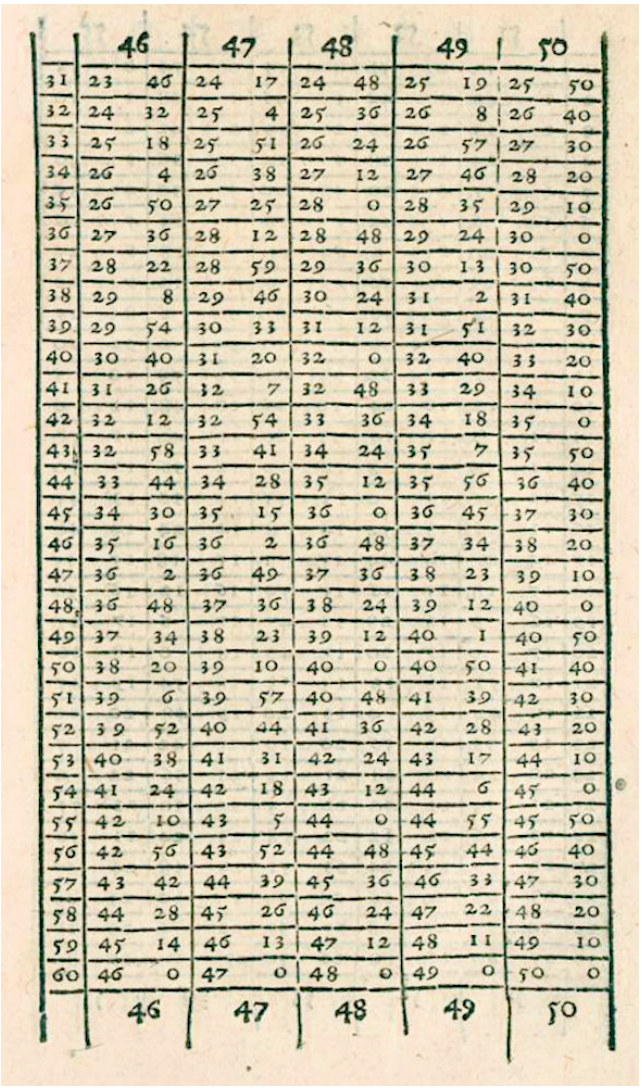


Fig. 3: Theodoricus' *canon sexagenarum* 1564, p. 20

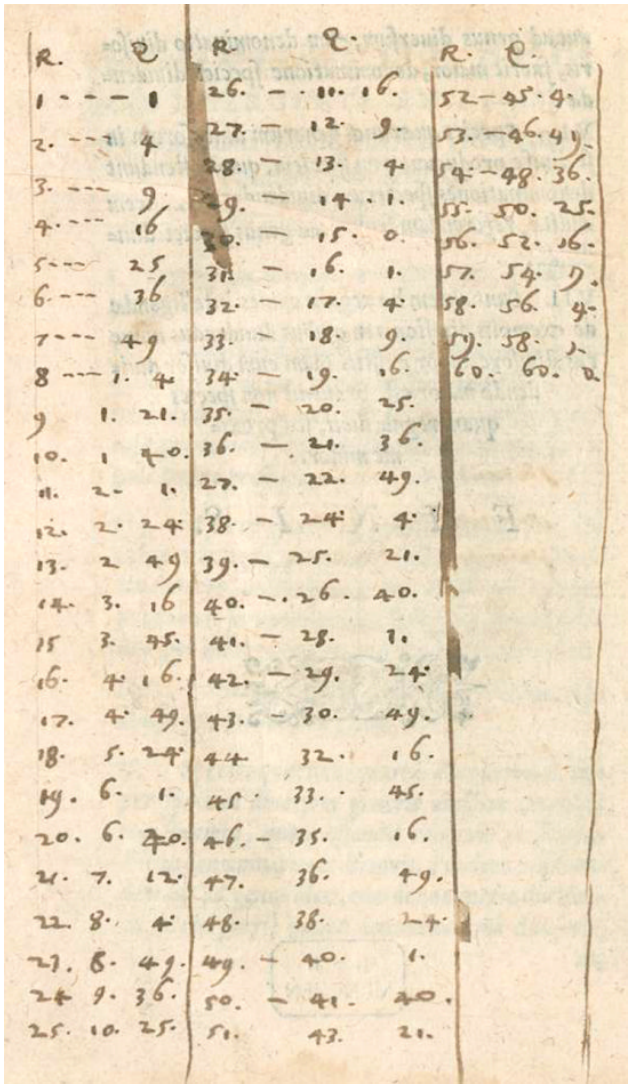


Fig. 4: Hand written table of squares

It looks like *Canon* was thought to be an addition to *Compendium* and he implicitly refers to it.
Remarkable is that he doesn't explicitly speak of powers of sixty, in *Compendium* he only speaks of sixtieth parts and of bundled sixties, that lead to the next higher or lower place. On the other hand he uses place-identifiers as if they have an order to calculate with, otherwise he couldn't add, subtract and reverse them. The given rules are nothing else but verbally expressed complicated formulas on how to multiply and divide with exponents.
Both rules and table ease the labour of multiplication and division. In *Compen-*

dium he gives examples. For a multiplication (fig. 5) he writes both factors and their partial products in a grid with columns, sorted by place-identifiers. To get all partial products he starts with 26" × 35" = 15"' 10"" (rule III) placed into the rightmost columns. All results are easily obtained with help of the *Canon* and his rules.

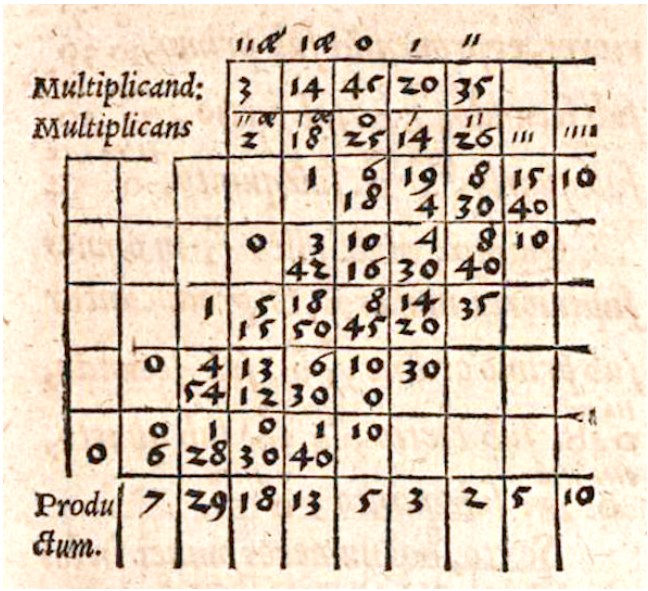


Fig. 5: An example for multiplication, taken from *Compendium*

Division is a more complicated basic arithmetic operation. Theodoricus teaches to subtract multiples of the divisor from the dividend and for this purpose rules and *Canon* serve as well as in multiplication.

In the digitalized copy 1564 from Bayerische Staatsbibliothek Muenchen one of the owners added a *Tabula Denominatio* to quantify place-identifiers together with a hand written table of squares from 1^2 to 60^2, shown in fig. 4.

The appended reconstruction of Theodoricus' sexagesimal multiplication table gives a free translation of the latin text in the booklet. The table itself was calculated and redrawn with the graphical programming environment *Processing*[4].

Nov. 2011, enlarged vers. May 2012
http://www.mechrech.info

4 http://processing.org

(Title Page)

Canon Sexagenarvm et Scrvpvlorvm Sexagesimorum,
Vtilis ad multiplicationem & Diuisionem Logisticæ Astronomicæ,
Editus opera M. Sebastiani Theodorici Vuinshemij.
Vvittebergæ excvdebat Ioannes Crato. Anno M.D.LXIIII.

(Text)

(The following text is printed before the table.)

Regvlae de specie emergente ex mvltiplicatione duorum numerorum Astronomicorum cuiuscunq; speciei.
Rules for emerging an order from multiplication of two astronomic numbers with their orders whatever.[5]

I. Integra multiplicata per integra producunt integra, (et) sexagenas si numeri suffecerint.
Units multiplied by units give units and *sexagenas*[6] if the numbers will be sufficient[7].

II. Integra multiplicata in quamcunq; speciem generis alterutrius, producunt eiusdem generis speciem eandem, (et) proximè maiorem, si numeri suffecerint.
Units multiplied with whatever other order give that particular order and the next higher one if the numbers will be sufficient.

III. Species alterutrius generis quæcunq; in se multiplicatæ, eam producunt eiusdem generis speciem, quam denominationes specierum multiplicatarum inuicem iunctæ ostendunt.
Whatever orders multiplied with themselves give an order that turns out, when the designations[8] of the orders to be multiplied on both sides are combined.

IIII. Species quæcunq; diuersorum generum in se ductæ, producunt eius generis, cuius speciei denominatio maior est, speciem eam, quam ostendit relictum, denominationum inuicem subtractarum, ut sexagenæ tertiæ, per scrupula prima multiplicatæ, producunt sexagenas secundas, scrupula quarta, per sexagenas tertias multiplicata, producunt scrupula prima.
Whatever different orders multiplied give an order, that remains, when from the order of higher designation the other order is subtracted, so that *sexagenae*

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5 With *species* resp. *genus speciei* Theodoricus names the value of the place itself where a figure stands within a number. For translation I use the word „order“, because from a modern point of view he works with exponents. His rules may be understood easily with help of fig. 1 and the equations
$(a\times60^m)\times(b\times60^n) = a\times b\times60^{m+n}$ or $(a\times60^m)/(b\times60^n) = a/b\times60^{m-n}$.

6 He means the place value s*exagenae primae*, 60^1.

7 If the result will be higher than 59°.

8 With *denominatio (*designation) he names a place-identifier and its symbol (fig. 2). From this rule III one can derive " × " ≡ "" resp. 2æ × 2æ ≡ 4æ.

tertiae, multiplied with *scrupula prima*, give *sexagenas secundas* (and) *scrupula quarta*, multiplied with *sexagenae tertiae*, give *scrupula prima.*

(The following text is printed after the table.)
Regvlae de specie emergente ex divisione duorum numerorum Astronomicorum cuiuscunq; speciei.
Rules about emerging an order by division of two astronomic numbers with their order whatever.

I. Integrum diuisum per integrum, producit integrum.
Unit divided by unit gives unit.

II. Integrum diuisum per speciem quamcunq; generis alterutrius, producit speciem eandem generis diuersi, ut partes per sexagenas primas diuisae, producunt scrupula prima: Diuisæ per scrupula prima producunt sexagenas primas.
Unit divided by another different order gives that very order inverted, so that parts (units) divided by *sexagenae primae* give *scrupula prima*, (units) divided by *scrupula prima* give *sexagenas primas*.

III. Species quæcunq; generis alterutrius, diuisa per integra, producit eiusdem generis speciem eandem, ut scrupula prima diuisa per integra producunt scrupula prima, sexagenæ secundæ, diuisæ per integra, producunt sexagenas secundas.
An order whatever divided by units gives the same order, so that *scrupula prima* divided by units give *scrupula prima*, *sexagenae secundae* divided by units give *sexagenas primas*.

IIII. Species eædem generis alterutrius in se diuisæ producunt integrum.
An order divided by the same give a unit.

V. Species quæcunq; generis alterutrius, diuisa per speciem diuersam generis eiusdem producit eam speciem, quam ostendit relictum ex subtractione denominationis minoris, à maiore, referendam aut ad genus idem, cum denominatio diuidendæ speciei fuerit maior denominatione diuisoris, aut ad genus diuersum, cum denominatio diuisoris, fuerit maior, denominatione speciei diuidendæ.
An order whatever divided by a different order gives an order, that turns out remaining, when the smaller designation is subtracted from the bigger one, distinguishing either with this order if the designation of the dividend will be bigger than the designation of the divisor, or with a reverse[9] (order) if the designation of divisor will be bigger than the designation of the divisor.

VI. Species quæcunq; generum diuersorum in se diuisæ producunt eam speciem, quam ostendunt denominationes specierum diuidendarum inuicem additæ, referendam semper ad genus speciei diuidendæ.

9 Reciprocal value.

Reversed orders whatever divided[10] give an order, that turns out when the division designations on both sides are added, its sort[11] resembles that of the dividend.

VII. Sunt autem hæ regulæ omnes intelligendæ de exemplis diuisionis in quibus diuidendus numerus, diuisore maior existit. Nam cum diuisor diuidendo maior est, prouenit non species quam regula dicit, sed proxime minor.
But all these rules are to be understood for a division, in which the number of dividendus is bigger than the divisor. If the divisor is bigger than the dividendus, that order, the rule says, doesn't show, but the nearest smaller one.[12]

F I N I S.

10 This phrase means $60^{n} / 60^{-n}$

11 *Sexagenae* or *scrupula*.

12 At a first glance this rule doesn't fit to the context of the others. In my opinion Theodoricus' intention is to express $(a \times 60^{m}) / (b \times 60^{n}) = a/b \times 60^{m-n}$ for $a>b$ and $= a/b \times 60^{m-n-1}$ for $a<b$.

	1		2		3		4		5	
1	0	1	0	2	0	3	0	4	0	5
2	0	2	0	4	0	6	0	8	0	10
3	0	3	0	6	0	9	0	12	0	15
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7	0	7	0	14	0	21	0	28	0	35
8	0	8	0	16	0	24	0	32	0	40
9	0	9	0	18	0	27	0	36	0	45
10	0	10	0	20	0	30	0	40	0	50
11	0	11	0	22	0	33	0	44	0	55
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14	0	14	0	28	0	42	0	56	1	10
15	0	15	0	30	0	45	1	0	1	15
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23	0	23	0	46	1	9	1	32	1	55
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57	10	27	11	24	12	21	13	18	14	15
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59	10	49	11	48	12	47	13	46	14	45
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	11		12		13		14		15	

	16		17		18		19		20	
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2	0	32	0	34	0	36	0	38	0	40
3	0	48	0	51	0	54	0	57	1	0
4	1	4	1	8	1	12	1	16	1	20
5	1	20	1	25	1	30	1	35	1	40
6	1	36	1	42	1	48	1	54	2	0
7	1	52	1	59	2	6	2	13	2	20
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