# Orrery Developments: The Use of Meccano in Constructing Planetaria

Michael Whiting

## Introduction – Nomenclature

An early 18th century model depicting the Sun and Planets was commissioned by the fourth Earl of Orrery and hence the name 'orrery' was derived. In this article I shall use the term more generally to include all mechanical depictions of heavenly bodies revolving around others although specific terms such as 'Jovilabe' – an orrery of Jupiter and some of its satellites – are used. 'Planetarium' is the term used for the Sun and objects revolving around it: Planets, Dwarf Planets, Asteroids, and/or Kuiper Belt bodies.

## The Use of Meccano

Most Readers will be familiar with Meccano – a constructional system invented in 1901 by Frank Hornby and later marketed as 'Engineering in Miniature'. It provides an ideal medium for trying out engineering ideas although obviously lacking the precision of most scientific instruments. At first sight the number of gears and sprockets available in the Meccano system would seem to preclude accurate clocks, orreries etc; for example, simple primes such as 17 and 23 are not available. However even Meccano enthusiasts have surprised themselves by what can be achieved.

The earliest Meccano orrery can be traced to a model in the June 1918 *Meccano Manual* (no. 391, a 'Special Model'). Although it was described as 'an excellent educational model' and indeed it did have the merit of showing the Earth's axis fixed towards the stars, its year was only about 3 days and the illustrated season was about 3 months out!

About 20-25 years ago serious Meccano orrery building began; from that date until now continuous development has taken place and this has fortunately coincided with rapid advances in Astronomy such that completely novel orreries are being made e.g. Pluto plus its 3 moons, 55 Cancri A plus 4 planets and Mu Arae plus 4 planets, the latter two being Extra – solar systems.

Foremost among the Meccano orrery builders have been Alan Partridge (Fig. 1), John Nuttall, Pat Briggs and myself. Our efforts have been recorded for the most part in *The Meccano Newsmag*[1] and *Meccano Model Plans*.[2]

## Types of Orrery

Meccano builders have identified six methods of building orreries:

Fig. 1 *Alan Partridge with his prize-winning Jovilabe built in 1984, showing close-up of the complex gearing.*

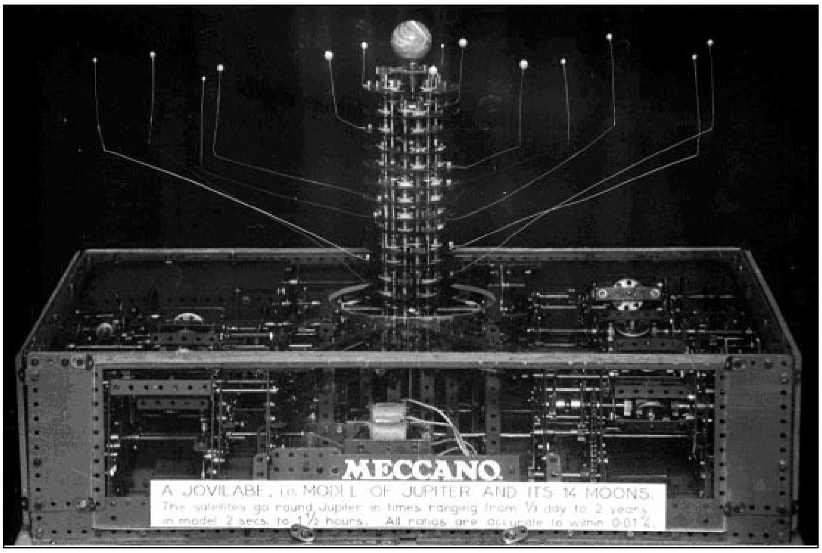


Fig. 2 *Jovilabe (method 2).*

### *Method 1 – Telescopic Tubing*

This is the traditional method, exemplified in the *Bulletin* previously by Peter Grimwood.[3] The innermost body (e.g. the Sun) rotates on a long rod surrounded by close fitting concentric tubes of decreasing lengths. Each tube and rod project below and are fitted with gearing which can be as simple or as complicated as necessary to achieve the desired accuracy. In a Planetarium showing the Sun plus 9 planets (more correctly 8 planets plus Pluto, a dwarf planet), with the planets rotating and revolving, there are 19 motions needing 1 rod and 18 concentric tubes.

No such tubing is available with Meccano although purely for illustrative purposes I have built a Jovilabe – Jupiter plus the 4 Galilean moons – using concentric tubes made from an indoor television aerial!

### *Method 2 – Nesting Hollow Turntables*

This is exemplified by a Meccano model (Fig. 2) built in 1984 by Alan Partridge. The model represents Jupiter and the 14 known moons at that date (it's now 63 and counting!) The central rod supports Jupiter and below 14 rings each support one moon. The rings are toothed internally and are supported on a nest of 14 rods. Each rod journals support pulleys for the rings and a single gear which engages with one geared ring. The 14 rods project below and each is driven from a single drive by complex gearing to an accuracy of plus/minus 0·01%. Most of the gear trains contain differentials and 324 gears were used in all.

This method has the advantage that almost unlimited accuracy is available but it is not easily adapted to show the rotation of any revolving bodies.

### *Method 3 – Fixed Central Rod, Epicyclic (Sun and Planet!) Gearing, Top Drive*

With most planetary systems that we wish to model, the innermost object (e.g. the

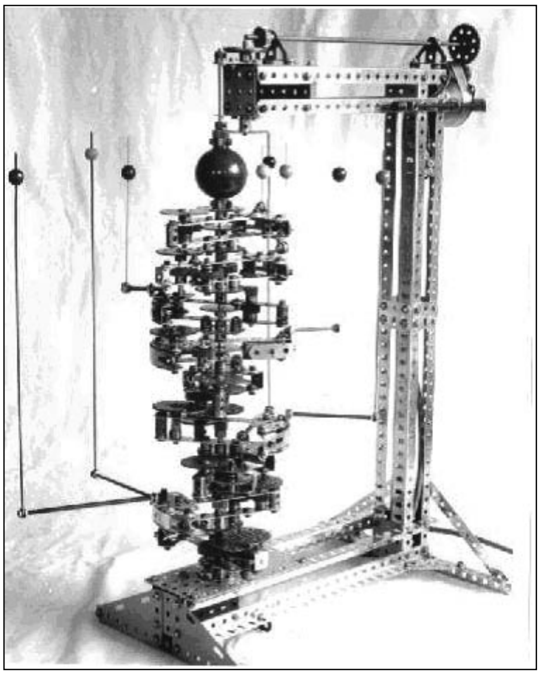

Fig. 3 *Planetarium (method 3) P. Briggs.*

SUN AND NINE PLANETS. (Briggs' compact)

| | True | Calculation | | Model | Error% |
|---|---|---|---|---|---|
| SUN (Rot.) | 25.38 | B / (1 + (50/20 x 56/57)) | | 25.53 | +0.60 |
| MERCURY | 87.97 | C / (1 + (38/25 x 57/56)) | = B | 88.25 | +0.31 |
| VENUS | 224.7 | D / (1 + (50/20 x 15/60)) | = C | 224.77 | +0.03 |
| EARTH | 365.256 | Datum | = D | | |
| MARS | 686.98 | D x (1 + 50/57) | = E | 685.66 | -0.19 |
| JUPITER | 4332.59 | E x (1 + (60/11 x 56/57)) | = F | 4359.98 | +0.63 |
| SATURN | 10759.2 | F x (1 + 56/38) | = G | 10785.23 | +0.24 |
| URANUS | 30684.7 | G x (1 + (38/20 x 56/57)) | = H | 30917.65 | +0.76 |
| NEPTUNE | 60190.8 | H x (1 + 19/20) | = J | 60289.41 | +0.16 |
| PLUTO | 90795 | J x (1 + (25/50 x 57/56)) | | 90972.41 | +0.20 |

Fig. 5 *Planetarium - Period Table.*

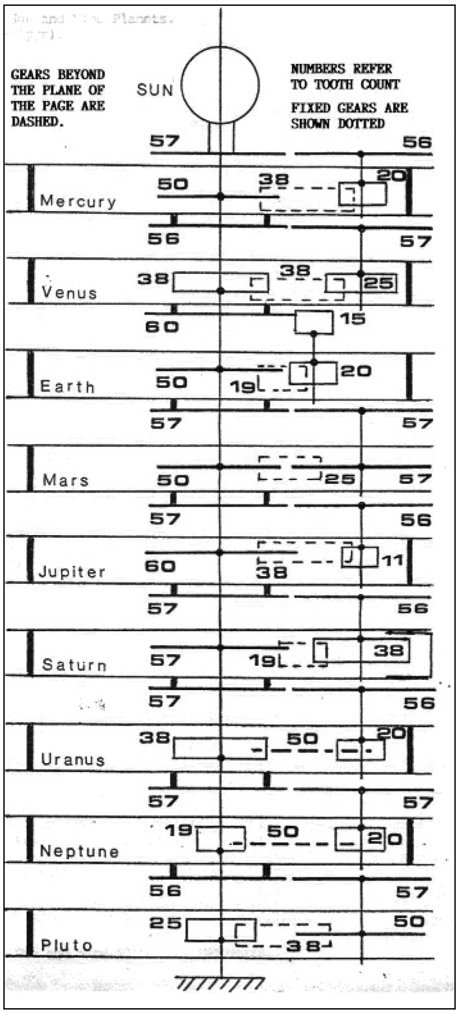


Fig. 4 *Planetarium - gear layout.*

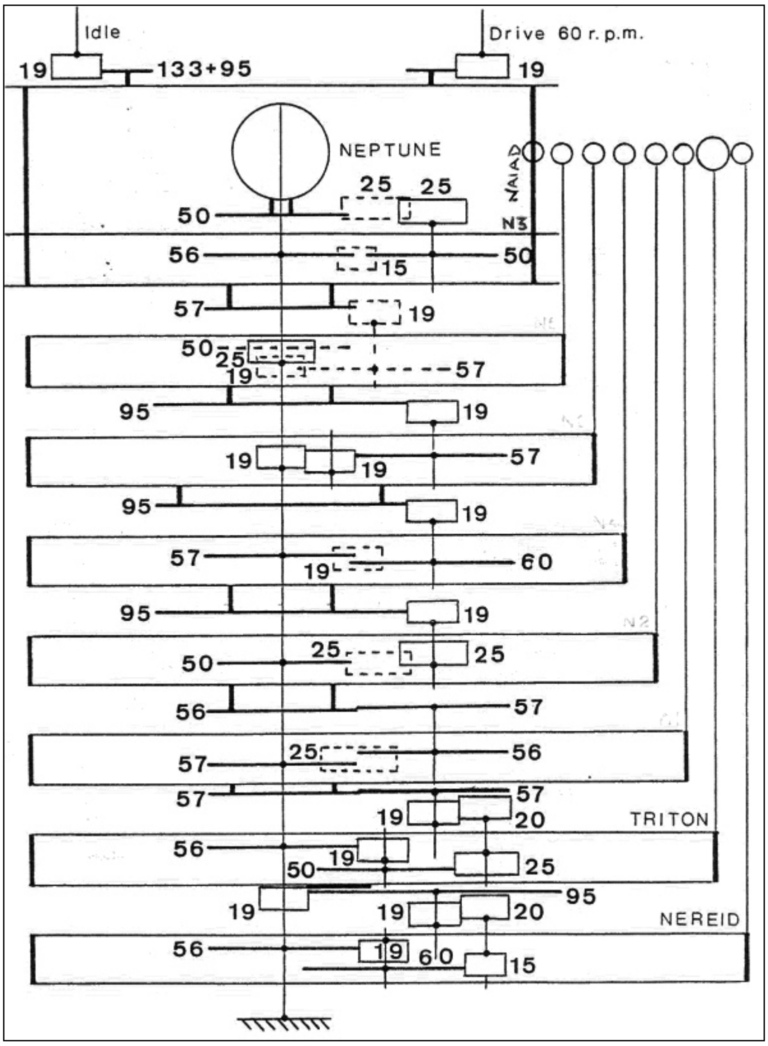


Fig. 6 *Neptunilabe - gear layout.*

Sun) rotates fastest and outer objects (e.g. the Planets) successively revolve around more slowly. From this I formulated the idea that if the Sun is driven first, it can be used to drive the first planet arm (Mercury); this arm then drives the next (Venus) and so on to the slowest moving (Pluto, say). Thus, if we drive the Sun first, each arm is successively geared down and friction is largely avoided. An early example of this technique is shown in a Planetarium by Pat Briggs (Fig. 3); the gear layout and a table showing accuracies are shown as Figs 4 and 5. In this model, rotation of the planets is not shown. Note that with extra gearing, or indeed non-Meccano gearing, improved accuracy can be achieved e.g. the ratio between Mars/Jupiter is 4332·59/686·98 = 6·30672. This model uses a ratio of (1 + 60/11 × 56/57) = 6·35885 – an error of +0·83%. A later modification uses (1 + 57/19 × 57/19 × 56/95) = 6·30526 – an error of only -0·02%. Note, however, that each calculation is related to the others, e.g. if the improved Mars/Jupiter gearing were used in Pat Briggs' model, *all* of the periods from Jupiter through to

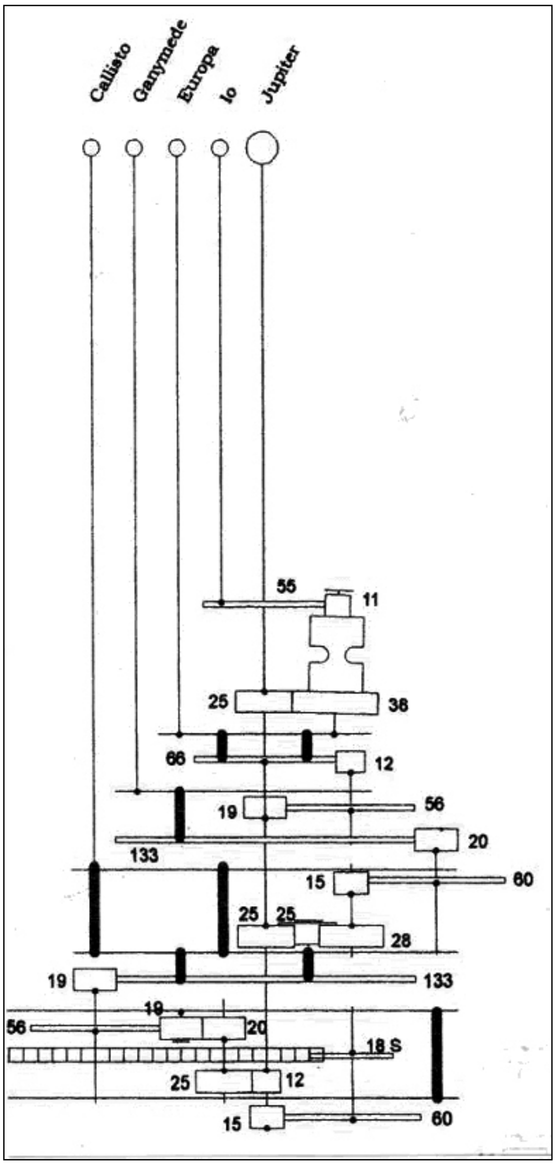


Fig. 7 *Jovilabe - gear layout (method 5).*

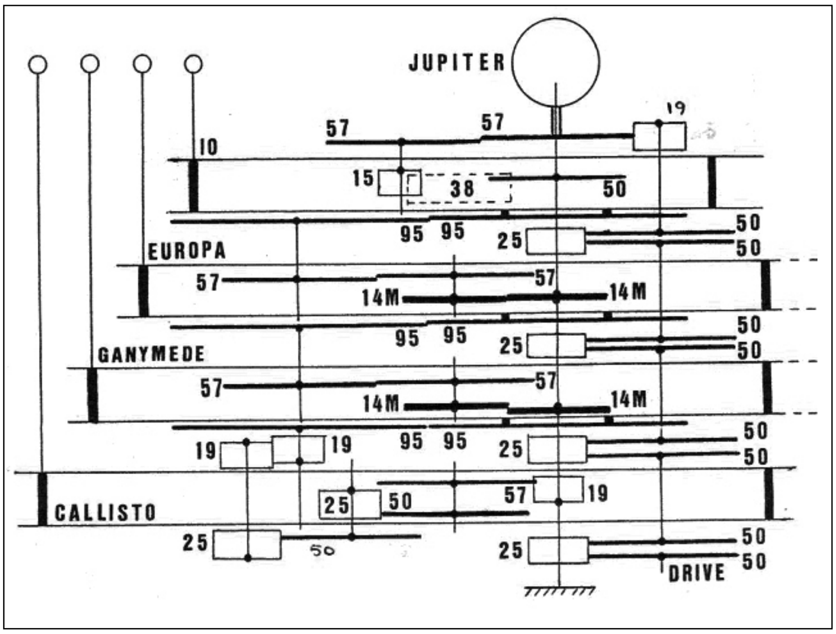


Fig. 8 *Jovilabe - gear layout (method 6).*

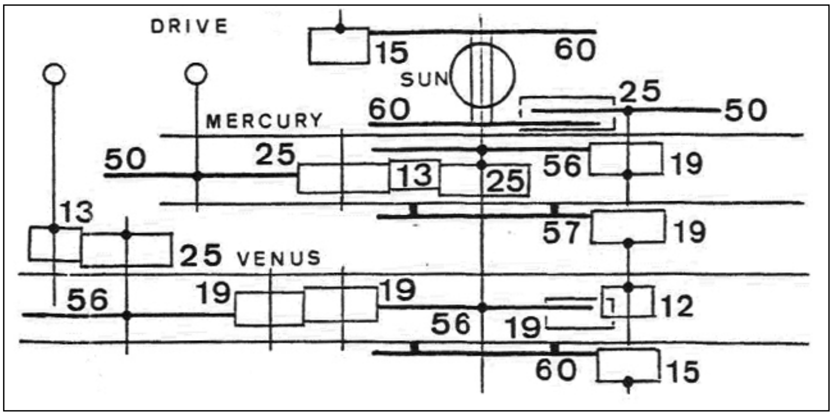


Fig. 9 *Planet rotation - slow moving - gear layout.*

Pluto would be altered.

A further point of interest is that each gear train is an odd number of gear/gear combinations typically three e.g. Mars/Jupiter is 57/56, 11/idler38 and idler38/60. This maintains the direction of each arm the same as that of its driver. If the number of gear/gear combinations is even, the direction is reversed; this is used where the heavenly body moves in a retrograde fashion, e.g. with Neptune's moon Triton (gear layout Fig. 6). Note too that with this particular orrery (termed a 'Neptunilabe') the inner moon Naiad revolves faster than Neptune rotates; the drive is therefore taken to Naiad first and this arm drives both the arms below and Neptune above.

Quite a number of such orreries have been constructed with Meccano, the largest being Saturn plus 20 of its moons. The practical limit is that each arm requires about 4 cm in height and the central rod has a progressively heavy weight to support. With an alternative construction system (thinner gears, no nuts and bolts, a stronger central rod and lighter arms) it might be possible to construct even Jupiter plus 63 moons!

### *Method 4 – A Combination of Methods 1 and 3*

The basic construction is as method 3 but the central fixed rod is replaced by a (non-Meccano) fixed tube. A rod driven from below goes through the tube and drives a central body (e.g. the Sun) above. This then drives the (planet) arms as before. This method has the advantage that the overhead gantry introducing the drive to the central body is not necessary. The disadvantage is that the central tube is unsupported and therefore cannot carry as much weight. The method is ideal for small orreries, e.g. Pluto plus 3, or Jupiter plus 4, say. Meccano models require a central tube of about 4 mm diameter. With a much stronger (thicker) central tube, larger orreries could be constructed.

### *Method 5 – Two Component Rotating Epicyclic*

This method has been suggested by John Nuttall and is exemplified by a detail from a large orrery (Fig. 7). The central (Jupiter) rod is driven from below; this rod drives the Callisto arm above by simple gearing; successive arms are then driven by a combination of direct gearing from the central rod and epicyclic gearing from the arm below.

### *Method 6 – Fixed Central Rod. Epicyclic Gearing. Drive From Top via 'By-pass' Gearing From The Base*

This is best explained by reference to the Jovilabe depicted in Fig. 8. As in method 3,

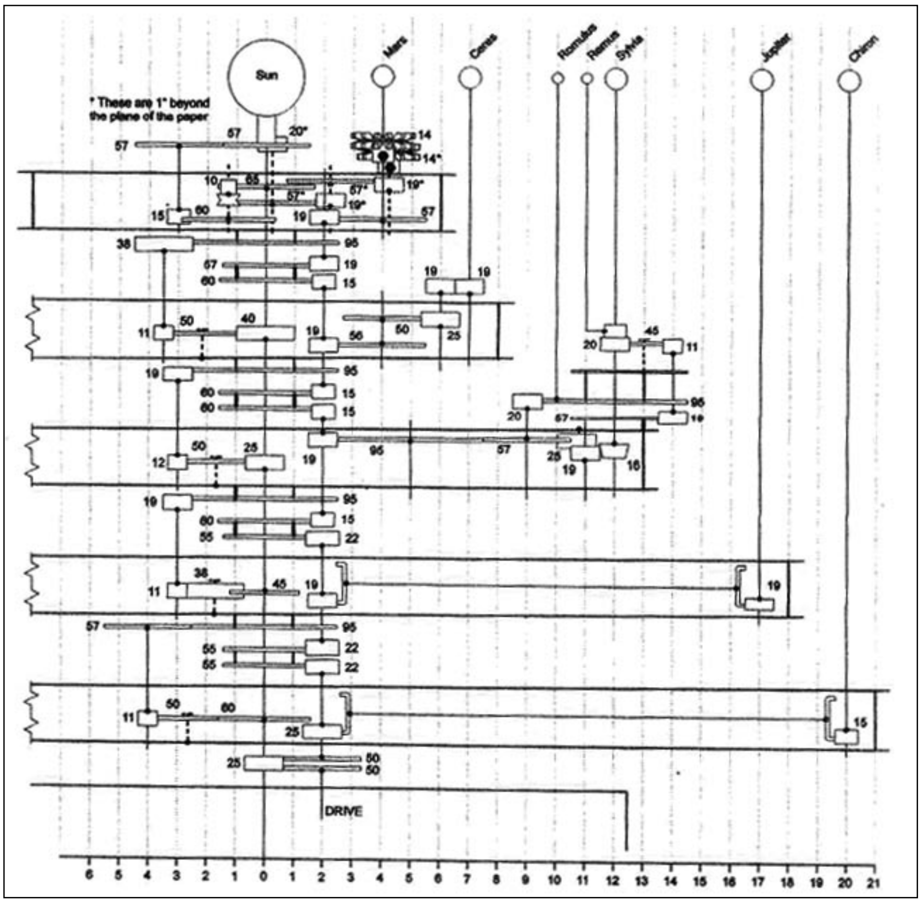


Fig. 10 *Fast rotating objects (asteroid) - gear layout.*

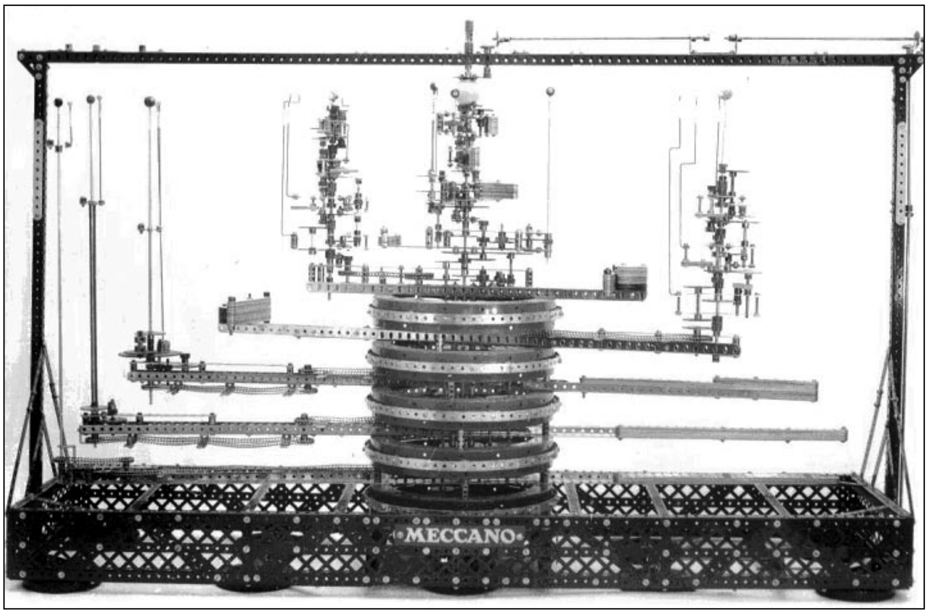


Fig. 11 *Grand Orrery (Planetarium, 12 moons).*

the drive is essentially from the top; central gears are chosen which are relatively small except for the large gears fixed to the underside of the arms. In the Meccano model these gears have holes 1 in. from the centre. This enables a zigzag drive from the bottom to pass through the driving gears from above and to engage with the main drive gear (attached to Jupiter in this example). The idea of such a 'by-pass' was first used by John Nuttall in a Mercury – Venus – Earth orrery[2] (Model Plan 73, sub-reference B). This orrery, incidentally, has the merit of showing the Earth's tilt and the nodal period of the Moon.

## More on By-pass Gearing

So far we have only touched on cases where the revolving body is shown rotating. Where the rotation is slow, e.g. for Mercury and Venus, the rotation can be simply achieved by gearing derived from the motion of the arms (see Fig. 9). For fast rotation, gearing up would be impractical.

My Asteroid orrery (layout Fig. 10) shows how the by-pass gearing from below can, during its ascent to the upper drive to the arms, be used to rotate Chiron, Jupiter, Sylvia, Ceres and Mars. By using Method 5 on the Sylvia arm, the revolution of moonlets Romulus and Remus around Sylvia are also shown. An alternative would be to use Method 6 for Romulus and Remus. The discerning reader might at this point realize that the mathematics of such a system is quite complex; such calculations are not to be found in the literature. John Nuttall must take much of the credit in this pioneering field.

In one of my largest orreries[2] (Model Plan 81 shown in Fig. 11) 2 drives are used, in a ratio of 10/1. The slower drive above turns the Sun and 9 planet arms, together with the rotations of Mercury and Venus. The faster drive turns a by-pass drive from below which rotates Pluto, Neptune, Uranus, Saturn, Jupiter, Mars and Earth. Further by-pass gearing on the Jupiter and Saturn arms give the revolution of 7 of their moons, method 5 is used for 2 of Uranus' moons whilst simple gearing takes care of Charon, Triton and Earth's Moon – in all Sun, 9 planets and 12 moons. The ratio of the fastest movement (Jupiter's spin) to the slowest (Pluto's revolution) is nearly a quarter of a million to one. The periods are accurate to 1·0%. A later modification (not yet built) by John Nuttall improves the accuracy to 0·1% (see[1], Issue 102).

Note also on this model the use of turntables on the lower arms, akin to Method 2. Here the turntables are not themselves driven but merely serve to support the weight of the long arms.

## Epilogue

In 1773, it was written that 'Knowledge of the orrery is of first consideration amongst those qualities forming the scholar and the gentleman'. I trust that you, dear reader, have thus been enriched!

## Notes and References

1. *The Meccano Newsmag* (formerly *The Meccanoman's Newsmag*), produced by The North Midlands Meccano Guild. Enquiries to The Editor, Anne Coles, tel. 01636 830 398.

Supplement No. 2 (1990) Planetarium;

Orrery of Uranus plus 15 moons

Issue No. 57, 61: Calculation of Gear Trains for use in Orreries

64: Grand Orrery – Photo (as featured in MP 81 vid.infra)

69: Geocentric Earth/Sun/Venus Orrery

78: Martian Lunarium

82: Sun-Mercury-Earth Orrery

95: Planetarium (Sun, 9 planets, Moon) accurate to 0·1%

96: Photograph showing the 6 types of Orrery Construction

99: Extra Solar Orrery – Upsilon Andromedae plus 3 planets

101: Planetarium with no overhead gantry

102: Grand Orrery accurate to 0·1%

104: Asteroid Orrery

105: The first Meccano Orrery

107: Dwarf Planets Orrery (Photograph)

2. Model Plans published by *The Meccanoman's Club*, P.O. Box, 38696, London, W13 8WD, tel. 02088108719.

MP 59: A Meccano Orrery

MP 73: Suite of Planetary Models (Planetarium plus 12 other Orreries)

MP 81: Grand Orrery

MP156: A Saturnilabe (for Meccano Set 10)

MP160: Planetarium plus Quaoar (for Meccano Set 10)

MP165: An Asteroid Orrery

MP173: Two Extra Solar Orreries (for Meccano Set 10)

3. Peter Grimwood, 'A Modern Planetarium and Orrery', *SIS Bulletin*, No. 43 (December 1994), pp. 24-26.

*Author's address:*
*'Pinegarth'*
*2 Old Hall*
*Castle Rising*
*Norfolk PE31 6AJ, UK*
*e-mail: annandmichael2@tiscali.co.uk*

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4. two confidential references (these can be sent directly by the referees)

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Andrea Walther Coordin tor of the
Research Institute Deutsches Museum
80306 Munich
Tel: 00 49 (0) 89 2179-280;
Fax: 00 49 (0) 89 2179-239
Email: a.walther@deutsches-museum.de

# Letters to the Editor

### Depression Rangefinder

Your correspondent's instrument in *SIS Bull.*, No. 93 (June 2007), p.7 is an 'Indian' Pattern Clinometer that was issued to the Army for field sketching purposes. It was to be used on a plane table and enabled a simple measure of heights and declinations to be made.

A description of the instrument and its use may be found in *Manual of Map Reading Photo Reading and Field Sketching*, 1929 (Reprinted with Amendments Nos1 to 4 1939) and was published by His Majesty's Stationary Office for the War Office.

*R.D. Howard*

### William Gilber*d* of Colcheter

Concerning your 'Cover Story' in the *SIS. Bull.*, No. 93 (June 2007), p. 1, I am pleased to enclose a copy of the booklet *Biography and Assessment of William Gilberd* by E.B. Gilber**d** and Lord Penny (1979).

William Gilber**d** attended the Colchester Royal Grammar School shortly after its first Royal Foundation (by Henry VIII).

In turn I attended classes at the CRGS, in 'Gilber**d** House', during 1942-1944. As you will see, your Figure 1 is a photograph of the painting presented to Colchester by the Institution of Electrical Engineers in 1903.

*Maurice J. Kenn*

### Pocket Spinthariscope Revisited

In my 'Favourite Instrument (*SIS. Bul.*, No. 92 (March 2007) I said that alpha particles emit from radium at about 0.75 the speed of light, well actually the figures for the three radiations from radium are:

Alpha: 0.2-0.3 the speed of light;

Beta (being electrons) 98% the speed of light;

Gamma (being the electromagnetic spectrum): the speed of light.

My apologies.

*Anthony Swift*