

A Mystery of Ancient China

The Riddle of the South-seeking Chariot

By F. W. Cousins, A.M.I.E.E., A.C.I.P.A., F.R.A.S.

AN interesting model is inconspicuously displayed in the Science Museum's exhibition that treats of the art and principles of navigation. It represents the South-seeking Chariot, which was possibly used by the Yellow Emperor Huang Ti in the 64th year of his reign. The Yellow Emperor was one of three great Chinese Emperors of an almost legendary period and his reign is dated in Chinese story at about 2634 B.C. He is said to have used this famous navigational device to guide his armies over the vast steppes leading to the south. To the Chinese the south was more important than the north, because to them where the Sun stood highest there was the centre of life and light.

The South-seeking chariot is seen in the illustration on this page. It commands our attention for a variety of reasons. Firstly, it contains a differential gear that is used ingeniously so to direct a pointer that the true south point of the compass is indicated, irrespective of the way in which the chariot is manoeuvred.

Secondly, it discredits the story, presented in so many books and encyclopædia, that the Chinese invented the *magnetic compass* over 4,500 years ago.

Thirdly, it suggests that the Chinese artificers at Huang Ti's court were uncommonly well versed in the art of mechanisms, and that they had usefully employed the differential gear 4,500 years before it was *re-invented* in the West.

Meccano enthusiasts will be familiar with the differential gear, which has its most common use in the back axles of

motor vehicles, in which it allows the inner and outer wheels to make a different number of rotations as the vehicle follows a curve in the road. This is necessary to prevent wheel-slip, since the outer wheel has to travel farther than the inner wheel in the same time.

The differential gear used in the rear axle of a car would be of little use to direct a pointer in the South-seeking chariot. If, however, we modify the gear and provide a differential gear of the type seen in Fig. 1, which shows the chariot in diagram form, we shall have the mechanism we want. In it the wheels A and B rotate in opposite directions.

An interesting feature of the

differential gear shown in Fig. 1, one that can be verified from a model, is that the axle C makes *one half turn* or revolution for a *full turn* of the wheel A

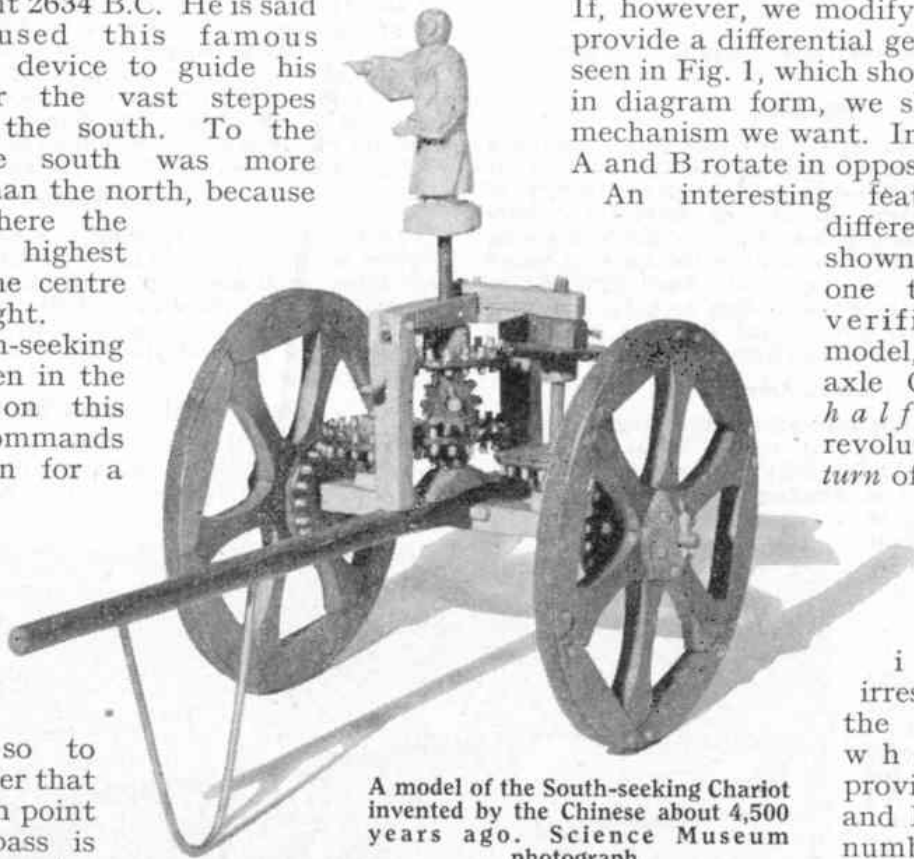
when wheel B is kept stationary. This

is true irrespective of the size of the wheels D, provided wheels A and B have equal numbers of teeth.

It is important to keep this in mind

to appreciate fully the working of the chariot.

The layout of the gears used in the South-seeking chariot is made clear in Figs. 1 and 2, the illustrations on the opposite page. Let us consider these in a little more detail. It will be seen that the pointer P is controlled by the axle C, to which it is rigidly connected by way of a vertical shaft. The differential gear consists of the wheels A and B, and the axle C, with its pair of small wheels, D and D1. The wheels A and B are free running on the axle F. The gear wheels lettered H in



A model of the South-seeking Chariot invented by the Chinese about 4,500 years ago. Science Museum photograph.

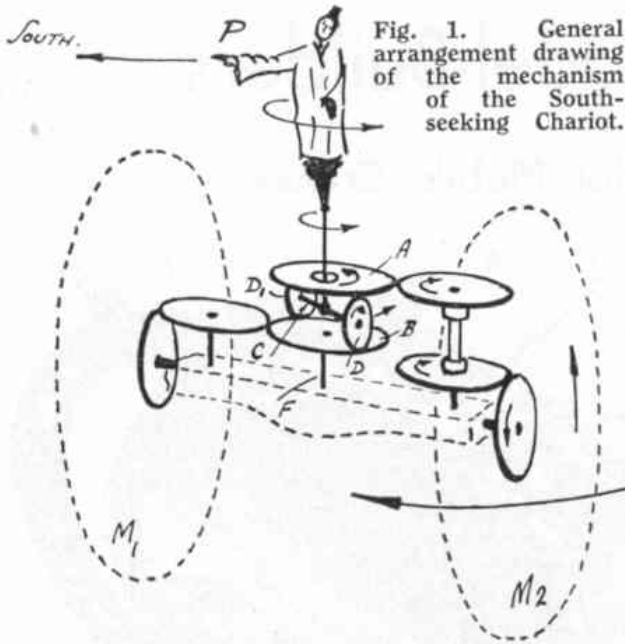


Fig. 1. General arrangement drawing of the mechanism of the South-seeking Chariot.

Fig. 2 have identical numbers of teeth, and this number is the same as the number of teeth of the wheels A and B.

The main road wheels of the chariot, M1 and M2, are spaced apart a distance x , which is made equal to the diameter of the road wheels, as is clearly seen in Fig. 2.

The reason for this equality of the lengths d and x will be obvious if we consider the main road wheel M1 to be fixed, that is stationary, as indicated in the lettering of Fig. 2, while the chariot is bodily revolved clockwise as seen from above. The chariot's outer wheel M2 then sweeps out a circular track, and will make two complete rotations on its axle for one revolution of the chariot in space.

Now the two rotations of main road wheel M2 will cause wheel A to make two rotations and the axle C one revolution, or turn, in a direction opposite to the chariot's direction of turn. In this example the axle C moves counter clockwise as seen from above. Now axle C and pointer P are rigidly connected and pointer P therefore remains fixed in space as the chariot is turned.

It will be appreciated that if the chariot moves forward or backward in a straight line, the main road wheels M1 and M2 will rotate at equal speeds and consequently the wheels A and B of the differential gear will also turn at equal speeds but in opposite directions. In these conditions the axle C and the

pointer P remain stationary, while the small wheels D and D1 rotate on the axle C. Any turning of the chariot will bring about a difference in the speeds of the two wheels A and B, and thereby will cause axle C to revolve the pointer P in a direction opposite to the direction of the chariot's turn. This will keep the pointer fixed in space on the point to which it was originally set—in this case the south point.

Now a word about the oft repeated legend of the invention of the magnetic compass by the Chinese.

Mr. George Lanchester, whose solution of the problem of the South-seeking chariot I have presented, delivered a learned address to the China Society on 3rd February 1947. In this he directed the attention of his listeners to a lecture by Dr. J. B. Kramer, an eminent electrical engineer, on the history of magnetism. Dr. Kramer makes this very forceful statement. "Where are the manuscripts in which the Chinese lay claim to the honour of having discovered the magnet? There are none, and there never existed any writings by the Chinese claiming for themselves that discovery."

In the course of Dr. Kramer's researches he visited the British Museum and in the Oriental Library there he studied Dr. Herbert A. Giles' historic work *Adversaria Sinica* (Book 11853s) in which he found evidence that the South-seeking chariot was a mechanical device and not magnetic.

I think you will agree that the model by Mr. George Lanchester and the researches of Dr. Kramer provide a lesson of absorbing interest in the fields of mechanical engineering and the history of science.

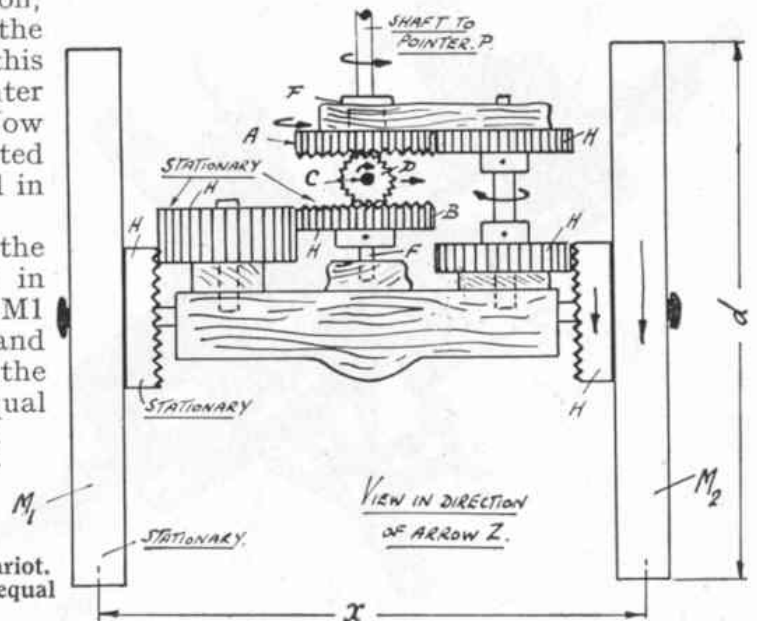


Fig. 2. The gearing of the South-seeking Chariot. The road wheels are spaced apart a distance equal to their diameter.

Among the Model-Builders

By "Spanner"

A Meccano South-seeking Chariot

Regular readers will remember the interesting article by Mr. F. W. Cousins, A.M.I.E.E. in the September 1955 *M.M.* describing a South-seeking Chariot said to have been used by the Chinese about 2634 B.C. This article described in detail the mechanical arrangement and the method of operation of the Chariot, the main feature of which was a form of differential mechanism.

I fully expected Meccano model-builders to be intrigued by the ingenious mechanism of the Chariot, and I was sure that sooner or later I would receive details of a Meccano model of the device. My expectations were realised some time ago when I heard from Mr. M. J. Oliver, Morpeth, a keen model-builder who succeeded in reproducing the mechanism of the South-seeking Chariot neatly and efficiently. Mr. Oliver's model is illustrated in Fig. 1.

The frame of the Chariot consists of a $2\frac{1}{2}'' \times \frac{1}{2}''$ Double Angle Strip 1 and a $2\frac{1}{2}''$ Strip 2 connected by two $\frac{3}{4}''$ Bolts. These Bolts secure also two $5\frac{1}{2}''$ Strips that form a towing bar. The road wheels are 3" Pulleys with Tyres and they are mounted freely on $1\frac{1}{8}''$ Bolts. A $1\frac{1}{2}''$ Contrate 3 is connected to each Pulley by $\frac{1}{2}''$ Bolts, and the

$1\frac{1}{8}''$ Bolts are attached by two nuts each to the

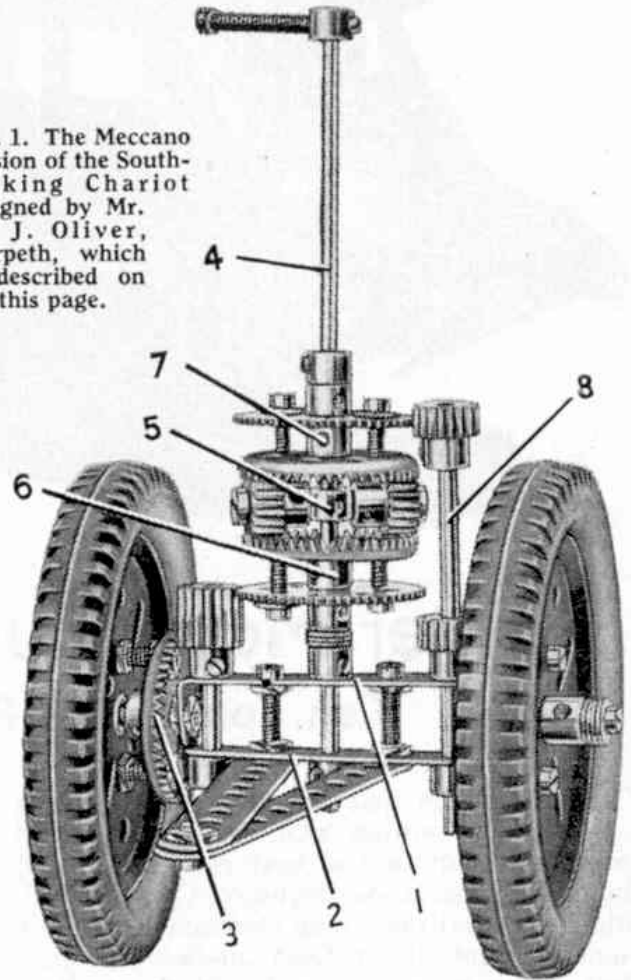


Fig. 1. The Meccano version of the South-seeking Chariot designed by Mr. M. J. Oliver, Morpeth, which is described on this page.

lugs of Double Angle Strip 1. It is important to make sure that the distance between the centres of the road wheels is exactly the same as the diameter of the Tyres on the wheels, and the wheels should be spaced on the Bolts by Washers until the two measurements are identical.

The centre shaft of the mechanism is a $6\frac{1}{2}''$ Rod 4. This carries a "spider" 5 from a Swivel Bearing and two gear assemblies 6 and 7, each of which consists of a $1\frac{1}{2}''$ Contrate and a 57-tooth Gear connected

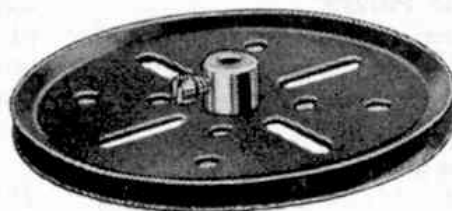
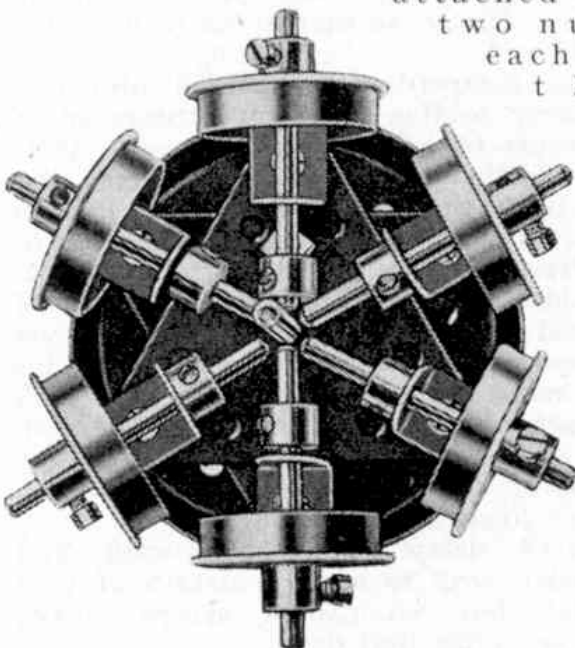
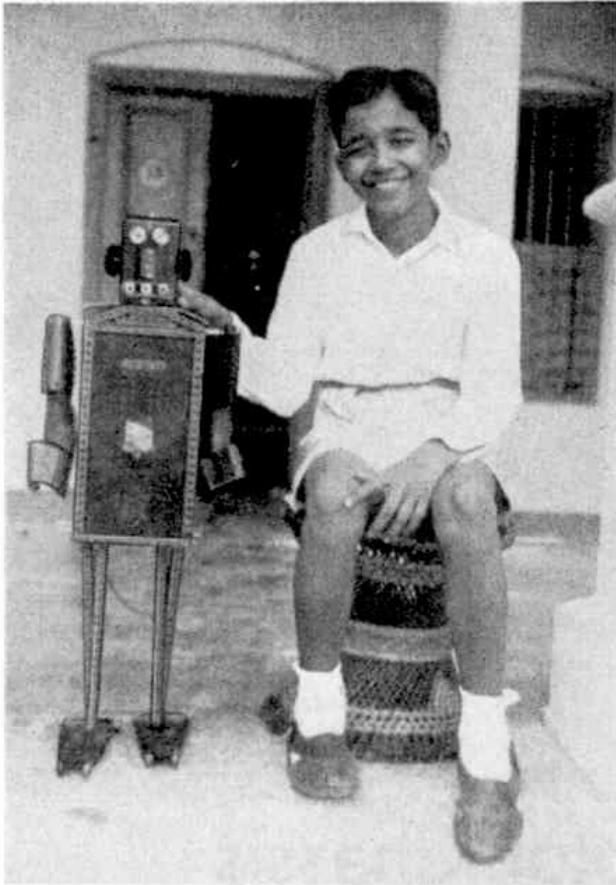


Fig. 2. A good use for the Meccano large Triangular Plate is shown in this six-roller bearing designed by E. H. L. Roden, Truro. Details are given on the next page.



This cheerful Indian boy is Chandrashekar Murthi, Vellore, India, and he is obviously very proud of the model mechanical man seen in the picture, which he built with his No. 8 Outfit.

by $\frac{3}{8}$ " Bolts. The gear assemblies are loose on Rod 4, but the "spider" is fixed on the Rod and carries two Pivot Bolts, each of which is fitted with a $\frac{1}{2}$ " Pinion. These Pinions mesh with the $1\frac{1}{2}$ " Contrates of the gear assemblies. A $\frac{1}{2}$ " diameter, $\frac{1}{2}$ " face Pinion connects the assembly 6 to one of the Contrates 3, while the assembly 7 is connected to the other Contrate 3 by two $\frac{1}{2}$ " Pinions on a Rod 8.

The indicating pointer fixed to the upper end of shaft 4, will be found to point always in the same direction no matter how the Chariot turns as it is towed along the ground.

A Novel Six-Roller Bearing for Cranes

Every model-builder knows that an outstanding feature of the Meccano System is the adaptability of the parts included in it. Practically every part

has many uses, and from time to time my correspondence includes details of yet another example of a new use that has been found for one of the parts in the range. An example of this occurred recently when I received a letter from Mr. E. H. L. Roden, Truro, describing a compact roller bearing unit he has found very useful. This roller bearing is shown in Fig. 2.

The part for which a novel use has been found in this bearing is No. 76, $2\frac{1}{2}$ " Triangular Plate. Two of these Triangular Plates are overlapped and bolted together in such a way that they form a six pointed star-shaped member. A Double Bracket is bolted to each point, with Washers under three of the Double Brackets to ensure that all six parts are at exactly the same level. A 2" Rod is passed through each Double Bracket, is fitted with a $1\frac{1}{4}$ " Flanged Wheel and is held in place by a Collar.

The fixed member of the roller bearing is a 3" Pulley. This is bolted to the base of the crane and a Rod of suitable length is held in its boss. The Rod is passed through the centre holes of the Triangular Plates, a second 3" Pulley is placed on it and the assembly is held together by a Collar fixed on the Rod.

When this bearing is used in a crane the model can be slewed or rotated by passing a Driving Band round the fixed 3" Pulley and round a small Pulley held on a Rod mounted in the rotating superstructure.

Meccano in the Laboratory

An interesting application of Meccano outside the run of ordinary model-building was brought to my (Continued on page 50)

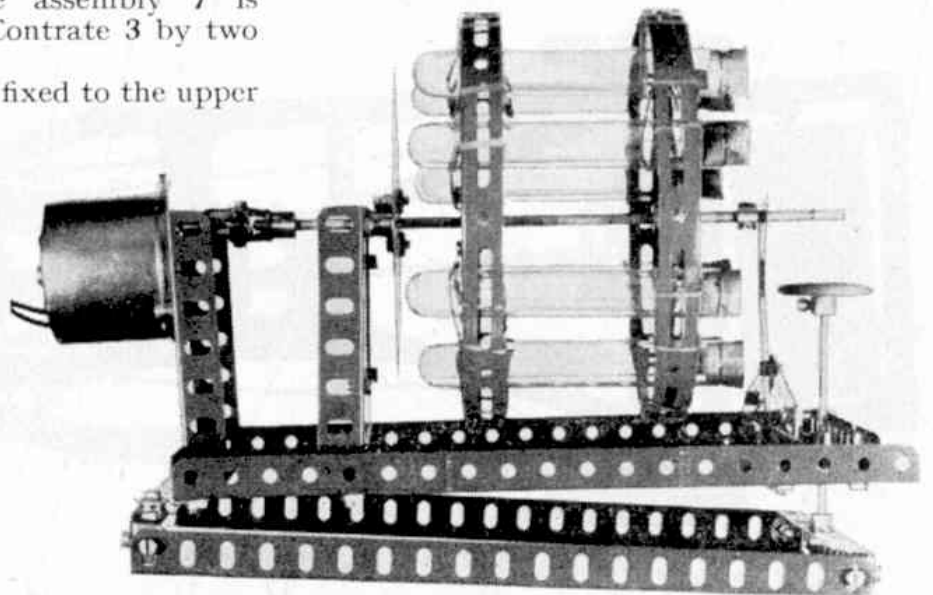


Fig. 4. Laboratory apparatus built in Meccano for use in tissue-culture processes. It is referred to on this page.

**WELLINGBOROUGH & DISTRICT
MECCANO CLUB**

Since our last club report, we have been to several exhibitions. The annual Meccano Exhibition at Henley-on-Thames, which all members thoroughly enjoyed, was the Club's first visit, and incidentally, our first outing together. The following members exhibited models: Richard Fisher, a Dragster; Michael Lawrence, a Motor Bike and an Army Jeep; Paul Dickin, a Dockyard Crane; Stephen Burgess, a Strongman with Dumbbells.

In early October, we were invited to display our models at Irchester Model Railway Exhibition. This, our first local event, proved very successful and created much interest. My father and I had built the Ship Coaler from the 1928 SML, a most fascinating model to operate. Our club chairman, Ivor Dickin, replaced the grab with an electro-magnet, and little eyes watched spellbound as Meccano Strips were hoisted aloft, then dropped into the truck, which in turn despatched them through the hopper. A Tower Crane with automatic grab by Paul Gautry was also on show, as was a Drop Hammer and Grinding Wheel by Matthew Traxton.

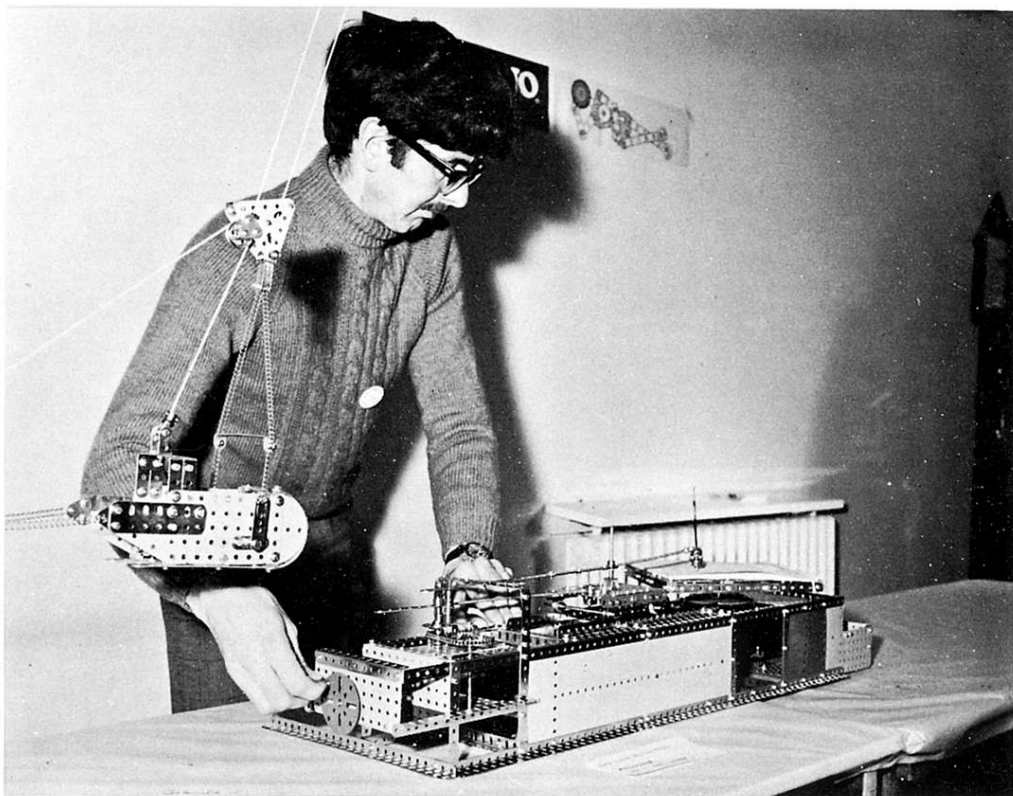
Later in October, we responded to an invitation from the '92 Squadron' to join in their exhibition at Letchworth. Here I displayed my own models, the Beyer-Garratt Locomotive, and the Double Decker Bus with complete working chassis. Various small models from our younger members made up the display.

One new member has been enrolled, and we welcome David Lack of Wollaston.

Terry Pope
16, Princess Way, Wellingborough,
Northants, NN8 2HJ, England.

MECCANO IN TASMANIA

An enthusiast in Tasmania has written to us in the hope of contacting Meccano enthusiasts in his part of the world. He writes: "I would like



to join a Meccano Club in Australia, but I do not know of the whereabouts. I am anxious to get in touch with other enthusiasts, as Meccano is nowhere near as big a hobby here as in England, with parts hard to get, and no exhibitions held". Meccano enthusiasts able to contact our correspondent are urged to do so; his name and address are as follows: G E Duncan 42 Lavender Grove, Launceston, Tasmania, Australia, 7250.

JOHN LYTHGOE demonstrated his freelance Meccanograph at the NEMS Darlington exhibition

POSSIBLE NEW MECCANO CLUB
P Tonges of Emmastraat 3, Trommenie, in the Netherlands would like to hear from any of his countrymen interested in forming a Meccano Club.

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All Meccano Clubs are invited to submit reports (and photographs if possible) for these pages. Reports should be approximately 350 words long, and should reach us by the end of the second month before publication. Ed

# South-Seeking Chariot · by Terry Morris

**MANY ENCYCLOPAEDIAS** attribute the discovery of the magnetic compass to the Ancient Chinese, but there is a school of thought which says that the navigational aid used by the Chinese was not magnetic, but mechanical!

The South-Seeking Chariot is interesting because it contains a differential gear, the same concept as that found in the back axles of motor vehicles, but used in a rather different way so as to direct a pointer to the true South point of the compass irrespective of the way in which the chariot is maneuvered. I baulk at the difficulty of explaining how it works. Build it and find out!

The model is not difficult to build, but care must be taken at each stage to ensure that bolt holes are in line so that all Axle Rods revolve smoothly.

**BUILDING INSTRUCTIONS**

**THE FRAMEWORK**

The framework is commenced by building two rectangular sections, each constructed by bolting two 1½" Strips 1 to two ½"×½" Double Brackets 2. Two of the sides of the Nuts used should be parallel to the edges of the 1½" Strips to give the maximum space between them. The two rectangular segments are joined by two further 1½" Strips 3, the Bolts also securing 1" Corner Brackets 4, only one of which can be seen in the photographs. The centre holes of each of these latter 1½" Strips carries a 3½" Strip 5 on a ¾" Bolt. The 3½" Strips are separated from the 1½" Strips by three Washers. The 3½" Strips are also bolted by ¾" Bolts to the remaining holes in the Corner Brackets and separated by three Washers, the

Bolts also carrying 1½"×½" Double Angle Strip 6 separated from each corner Bracket by a Washer.

A 3½"×½" Double Angle Strip is fixed as shown, and carries a Rod Socket containing a 2" Rod which forms the stand.

**THE WHEELS**

The Spoked Wheels are mounted with Grub Screws on 1½" Axle Rods journaled in the 1½" Strips 1. These Rods are held in place by ¾" Pinions. One Pinion, 7, has its boss outwards, and the other, 8, inwards. Each Pinion is prevented from excessive lateral movement by a Washer on the Rods. Sufficient room at the inside ends of the 1½" Rods should be allowed for another Rod to pass between them.

**THE DIFFERENTIAL**

At this point, the differential should be built. A Bush Wheel and

a 1½"Contrate Wheel 9 are joined by two 1½"×½"Double Angle Strips which are each separated from the Contrate Wheel by a Collar. A ¾"Contrate, 10, is fixed on a 2"Rod mounted in Contrate Wheel 9. The Contrate Wheels are separated by a Washer. A further ¾"Contrate 11 is mounted on a 1½"Rod journalled in the Bush Wheel, and is separated from it by a Washer. A further 1½" Rod carries two ½"Pinions and a Collar. These Pinions mesh with Contrates 10 and 11. One Pinion is fixed on the Rod, the other is loose, but held in place by the Collar.

Three Washers are now placed on the 2"Rod which is inserted into the centre hole of Double Angle Strip 6. The Washers rest on the inner Strips 1, and raise the Contrate Wheel 9 above them slightly. This Rod also carries a ¾"Contrate 12, which meshes with Pinion 7. The Contrate Wheel 9 meshes with Pinion 8.

The other end of the differential mechanism is journalled in a 2½"×½" Double Angle Strip 13, bolted to the top ends of Strip 5, and separated from them by four Washers. The 1½"Rod carries a ¾" Pinion 14, which meshes with a 1¼"Gear Wheel 15, mounted loose on a Threaded Pin attached to Double Angle Strip 13, and raised from it by two Washers.

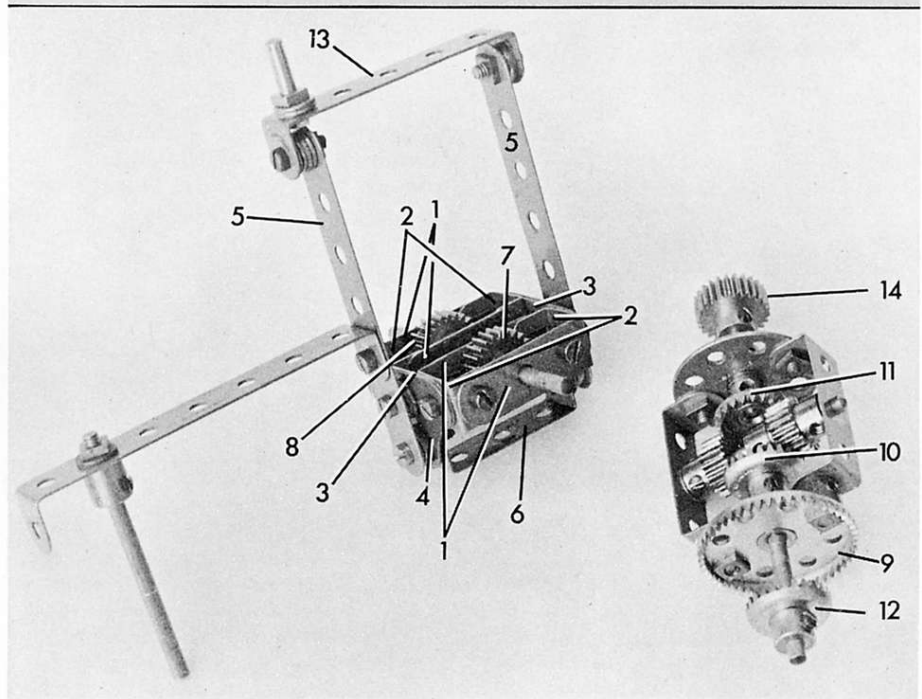
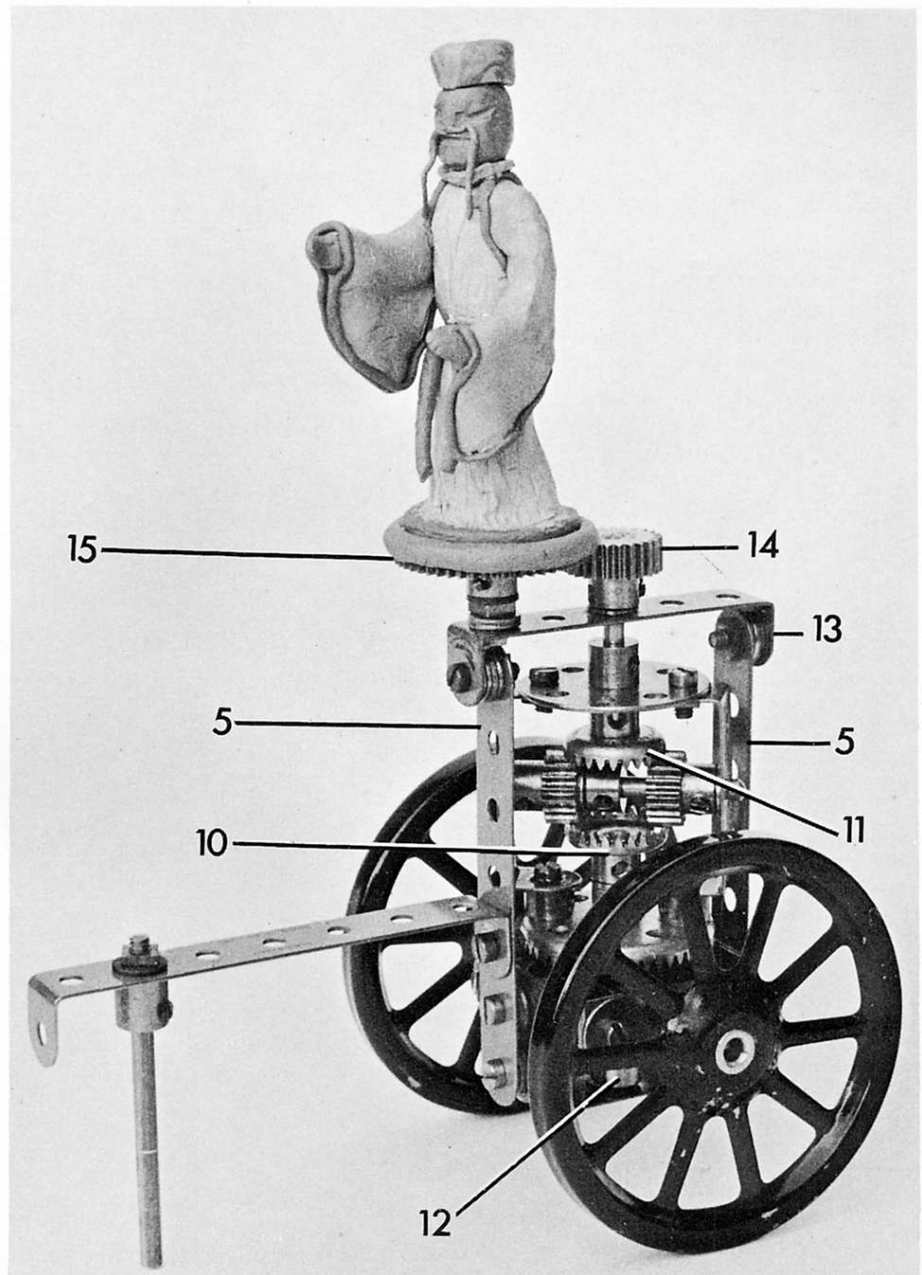
**COMPLETION AND OPERATION**

The Spoked Wheels should now be adjusted so that they are *exactly* the same distance from the centre of the model, and spaced apart a distance *exactly* equal to their diameter.

All that now remains is to attach a 'Chinaman', made of 'Plasticine' or card (or Meccano), to Gear Wheel 15. When the model is correctly adjusted, he will point in the same direction regardless of whether the chariot is moved forwards, backwards, or round in circles.

Dashed clever these Chinese!

|             |              |              |
|-------------|--------------|--------------|
| PARTS LIST  | · · · · ·    | 3 of No 48   |
| 2 of No 3   | 2 of No 26   | 1 of No 48a  |
| 6 of No 6a  | 1 of No 27   | 1 of No 48b  |
| 4 of No 11  | 1 of No 28   | 2 of No 111a |
| 2 of No 17  | 3 of No 29   | 6 of No 111c |
| 4 of No 18a | 15 of No 37b | 1 of No 115  |
| 2 of No 19a | 24 of No 37c | 2 of No 133a |
| 3 of No 25  | 35 of No 38  | 1 of No 179  |



ABOVE RIGHT: The completed model of the South-Seeking Chariot, complete with 'Plasticine' Chinaman on top!

RIGHT: A close-up of the mechanism of the Chariot, showing the construction of the differential and the axle unit.



# M M ★ COMPETITION ★ PAGE

In the M.M. for January 1977 (writes Alan Partridge), pages 30 and 31, Terry Morris gave us an excellent account of the so-called Chinese Self-seeking Chariot. I do not wish at this stage to enter into the controversy as to whether or not it was in fact an ancient Chinese invention, but I must say that it is a very entertaining device. In letters in the last M.M. page 67, two writers refer to the article by Frank Cousins in M.M. September 1955, pages 498/499, and Dr. Keith Cameron claims that no one has followed exactly the design by Mr. George Lanchester which appears in Mr. Cousins' article.

So that everyone will start level, fig. 1 shows Mr. Cousins' sketch re-drawn. The vertical central shafts carry wheels which appear to function both as spur gears and as bevels or contrates! No wonder the design has not been copied exactly! If each of these is made from a Meccano Gear and a Contrate bolted together as done by M.J. Oliver, M.M. January 1957, page 36, a total of eleven gears is needed. Terry Morris used only 10 gears, but could the number be reduced still further?

Clearly we could omit one Pinion from the differential in either version, or we might use one of the differentials I described on page 70 of the last M.M. However, further economies are possible. Indeed, I'm not saying whether or not any differential is needed at all, but if it is, it is not in the internal details of this that the chief saving is to be made.

The exact object of this month's problem, then, is this: design a chariot or hand cart running on two equal wheels. The line joining the centres of the wheels is to be at right-angles to the plane of rotation of each wheel (this is to distinguish a chariot from a bicycle). The body of the chariot is to carry a horizontal pointer rotating about a vertical axis. The two wheels and the pointer are to be connected by gearing in such a way that, however the chariot is moved, with its wheels remaining in rolling contact with a smooth horizontal surface, the pointer continues to point in the same direction. The smallest possible number of toothed parts is to be used and, as usual, the mechanism is to consist of standard Meccano Parts without mutilation and non-conventional alignments, with no cord or belt drive or other frictional device.

Solutions to the problem should be addressed to Chariot Competition, Meccano Magazine, Binns Road, Liverpool L13 1DA. The designer who we feel produces the best solution will receive a token prize in the form of a Crane Kit motor.

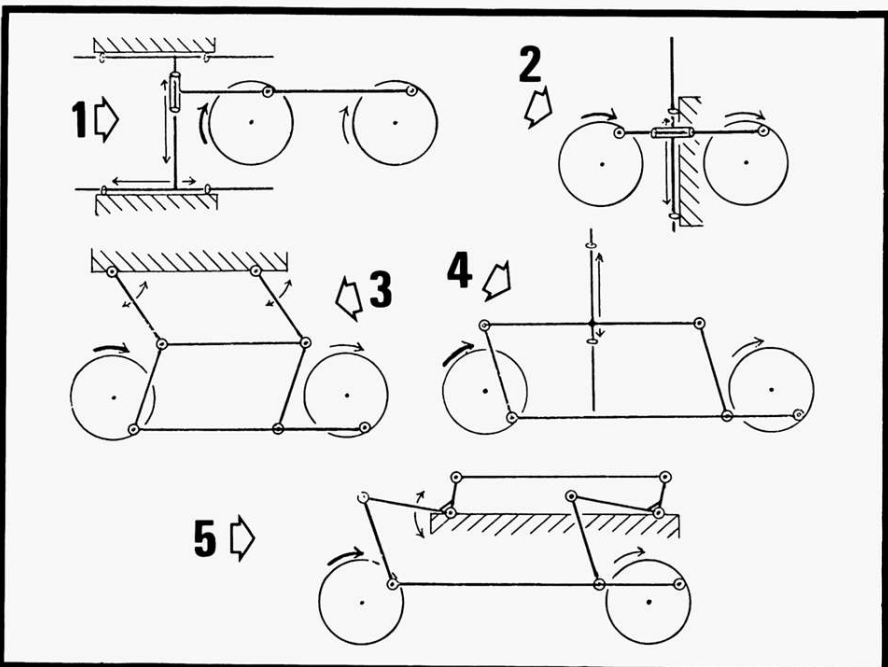
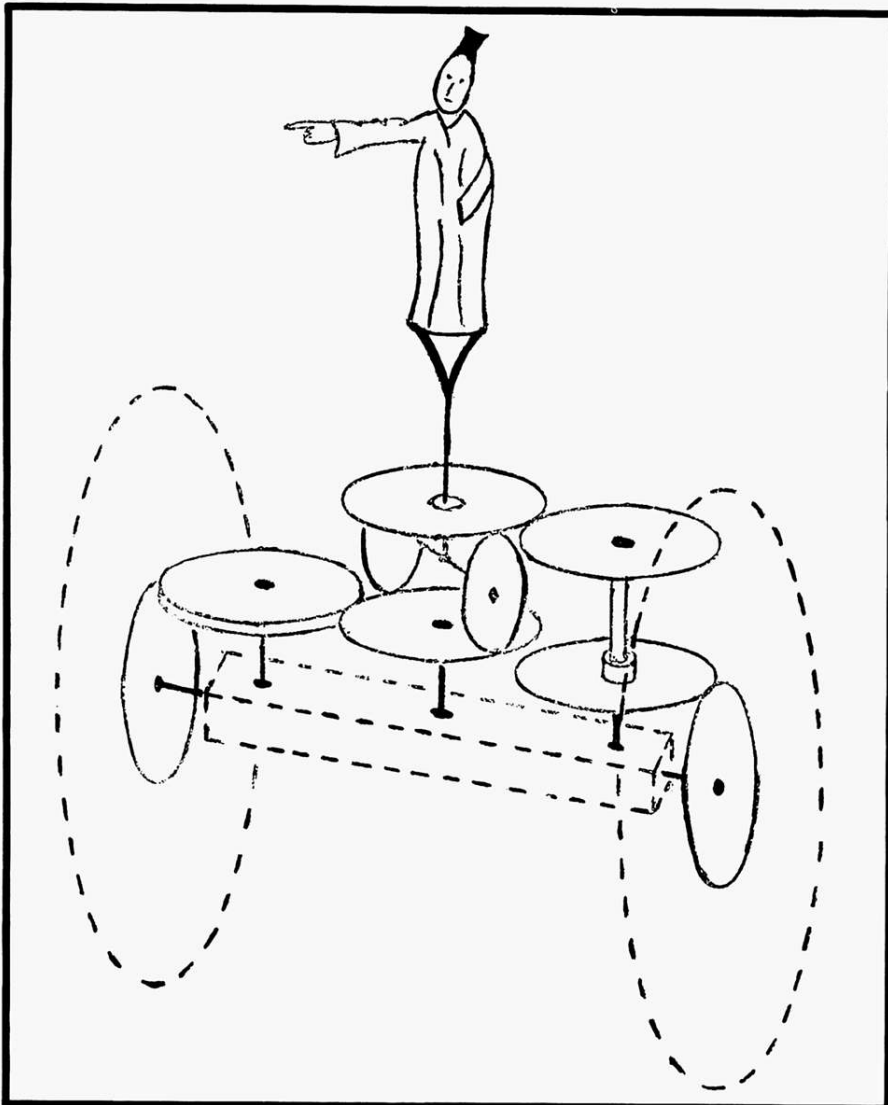
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## "CHUFF-CHUFF" COMPETITION

(Alan Partridge's solution to his contest in the last M.M.)

I promised I had ten different solutions to this. I have since found four more, but dropped two of my earlier ones which were rather dodgy. So here in sketch form are a dozen which all work well. To keep things simple I have not shown the fixed bearings for the driving and driven wheels, but I have shown, by blocks of shading, fixed supports for the link-work.

I have shown the driver by a heavy arrow and the driven wheel by a lighter one. There are also, in some cases, arrows to show relative motions between different parts of the link-



# MM ★ COMPETITION ★ PAGE

## CHINESE CHARIOT – ECONOMY DRIVE (Alan Partridge's solution to his competition set in the last MM)

The Chinese South-Seeking Chariot can be made with only 5 gears! Although I tried to raise a doubt in competitors' minds, the use of a differential is essential. The main saving of gears comes from placing this transversely, as in a motor car. Now if a car is pushed along, with the clutch out, the movement transferred to the drive shaft is the *sum* of the rotations of the road wheels (halved and usually then stepped up). The *difference* produced by cornering is absorbed in the mechanism. We want the opposite effect – to absorb the *sum* and transfer the *difference* to a pointer. This is achieved extremely simply by putting a reversal in one half-shaft. Then the differential adds the rotation of one road wheel to minus that of the other – which is the difference as required.

In Figs 1 and 2, the Pinion furthest to the left is a reversing pinion. The other two Pinions, the large Contrate, and the 50-toothed Gear constitute a 1:1 epicyclic, or minimum, gear differential, as I described in Meccano Magazine 1977 No. 2, page 70. The chief difference is that the Pinions are outside the cage formed from the Contrate and a Wheel Disc, overhanging to the left. This allows the central one to mesh with the reversing pinion. The Rod which passes through the centre of the cage is stationary, held in two Collars suspended from the chariot by 1" Screwed Rods. One hangs from the centre of a 1½" Strip, the other from a pair of Fishplates, the angle of which must be carefully set to keep the Contrate in mesh with the 50-toothed Gear. The Contrate, with its cage, and the Pinion next to it are both loose on this Rod. Fixed to the Rod is a Coupling which provides a bearing for a 1" Rod which

carries the reversing pinion, connected to the Road Wheel on the left by Universal Couplings.

The length of the whole mechanism is 9½", so wheels 9½" diameter are needed. Each is made from 8 – 4" Stepped Curved Strips, No. 89b, connected to a Face Plate by various Strips. It is, however, not essential to have wheels the same diameter as their distance apart. A smaller Pinion in place of the 50-toothed Gear would require larger wheels, and a larger Gear would allow smaller wheels.

While we use a lower pointer, instead of a tall Chinaman, the chariot can be turned upside down within its wheels. What does the pointer do then? If, after a bit of running about like that, the chariot is brought right way up again, can one say where the pointer will be? If you can't work out the answers (or even if you think you can!) built it and see!



The above was written when the puzzle was set. I have since been in correspondence with Prof. Sleswyk, Groningen, Holland, who has made a fresh study of the ancient Chinese documents. He has shown that there were two different designs. One was a crude affair using ratchets. The other was a beautiful symmetrical mechanism using two differentials. I hope to write a separate article about this. Prof. Sleswyk showed that my mechanism (Figs. 1–3) can be re-arranged so that the output of the cage goes to the pointer by universal joints instead of gears, see Fig. 4. That gets the number of gears down to three.

This set me thinking about the device I showed in MM January 1978, page 35, No. 12.

If the input and output shafts are in line with each other on opposite sides of the oscillating rod, this produces a gearless reversing mechanism. Fig. 5 shows this and other applications. Fig. 6 shows how this could be used to produce a differential with only two gears – an improvement on my previous solution to that problem. Now, if this is used in the Chinese Chariot, and another such device for the reversal of one half-shaft, we would have a solution with only two gears. This is the best solution to the problem in the way I worded it. But, if instead of "The two wheels and the pointer are to be connected by gearing...." I had put ".....are to be connected with a minimum of gears....." then the solution is no gears at all! When using the oscillating devices one cannot use Prof. Sleswyk's re-arrangement to extract the motion of the cage, but Fig. 7 shows how it can be done using two pairs of eccentrics.

### ADDENDUM

The above was written before solutions were received. Sr. R. G. Torrent of Madrid hit on the principle of using only two gears in the last paragraph of above, but his design was not fully worked out in Meccano. Fig. 8 shows the Meccano version.

Mr. Noel C. Ta' Bois found a different two-gear solution from the above and a photograph of his model is shown in Fig. 9. This is the winning entry.

*Please note:* – Fig. 4 is incomplete. The pointer rotates in the wrong direction. Above the body of the chariot there should be, instead of two Universal Couplings, a gearless reversing mechanism, such as "Chuff-Chuff" competition solution No. 8. (January MM).

Fig. 1: an underneath view of a 5-gear Meccano mechanism for a South-Seeking Chariot developed by the Author.

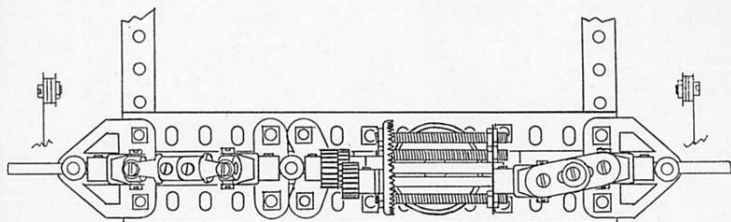


Fig. 2: a front view of Alan Partridge's 5-gear version of the Mechanism.

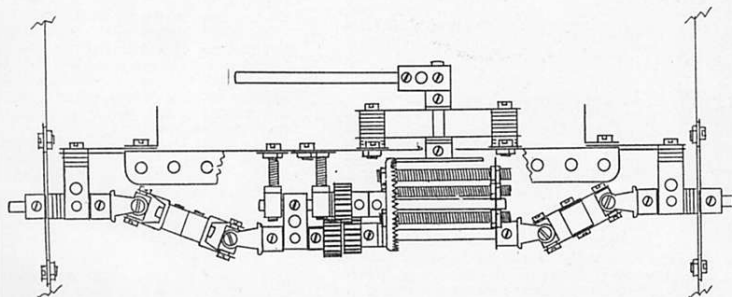
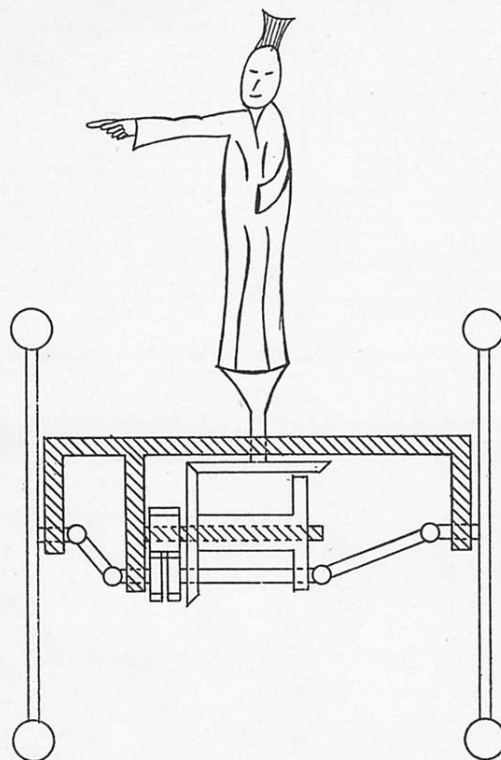
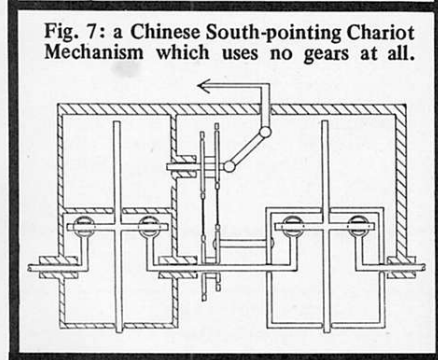
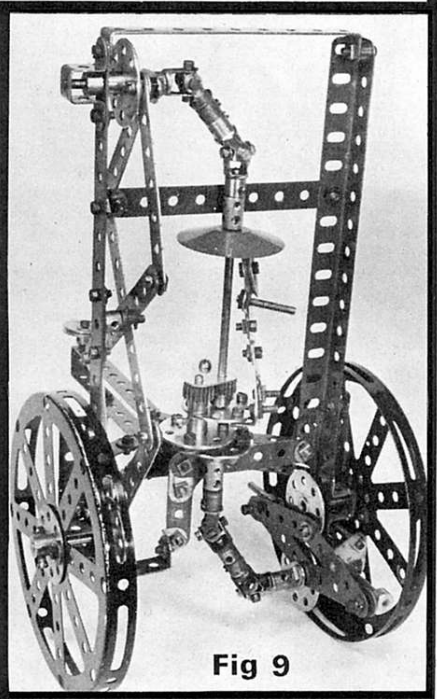
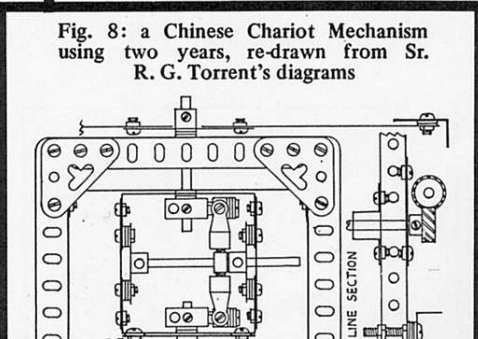
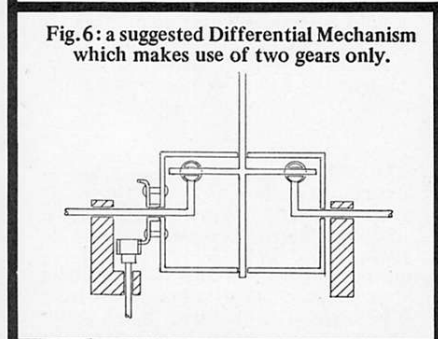
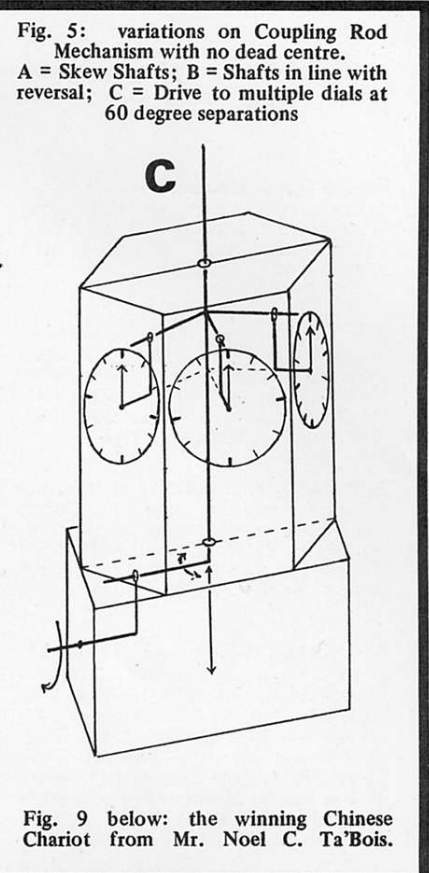
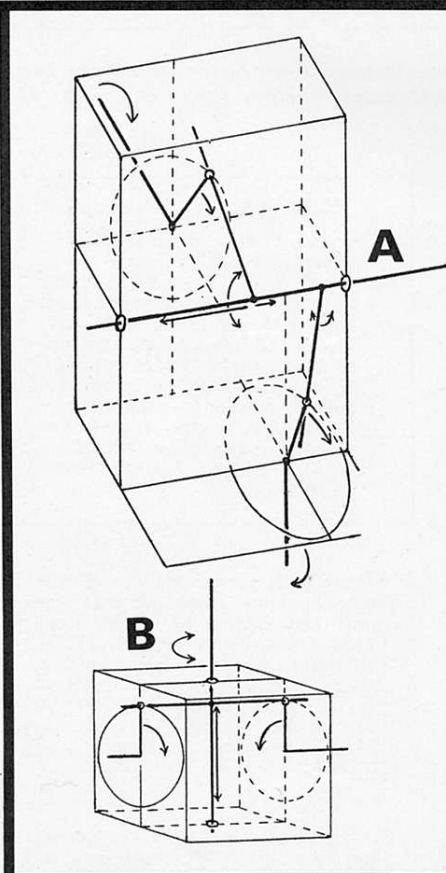
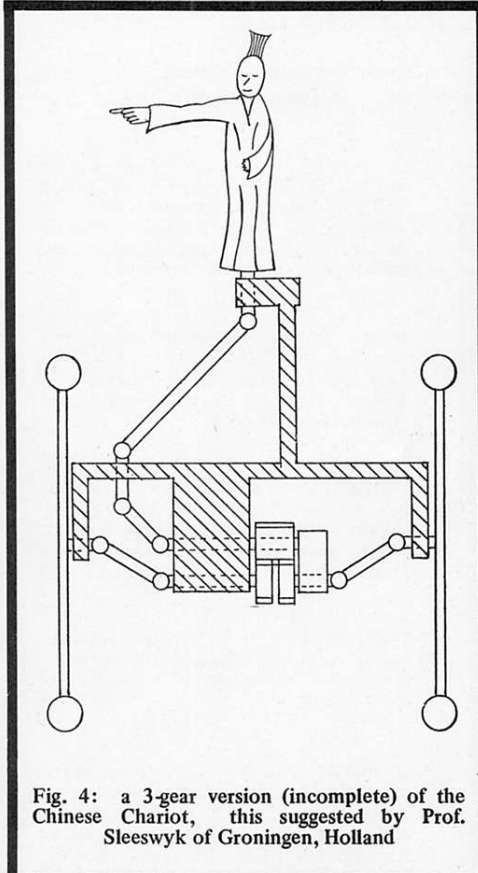


Fig. 3: a sketch of the Author's complete version of a South-Seeking Chinese Chariot







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# MECCANO MOUSE CONTEST

devised by Alan Partridge

A competition, which stood open for many years, to make a man-powered aeroplane was recently won by a very light, but large craft, appropriately named Gossamer Condor. The pilot drove the propeller by cycle pedals. To prove it was fully controllable, and not helped by wind, it had to fly a figure-of-eight course. Now what about making a Meccano Mouse which would run a figure-of-eight?

The problem is to make a model which, when suitably prepared, set down on a smooth surface, and released, will move along a figure-of-eight course and return to the starting point. The model is to consist entirely of standard

(not plastic) Meccano. Any clockwork or electric motor sold by Meccano Limited in the last ten years may be used if required. Any battery (non-Meccano) needed must be carried on the model, so that it moves without any external power supply or guidance.

The prize will go to the maker of the lightest model. Do not send the actual model, but send enough details for the Editor to be able to make a copy. State the all-up weight and this must include battery if used, but not winding key of clockwork motor if used. You haven't a great deal of time, so please get busy. Entries must reach us by 13th June 1978.

# CHINESE SOUTH-SEEKING CHARIOTS

by Noel C Ta'Bois

TO enable the Chinese to navigate to the sunny south before the invention of the compass it is thought that they used south-seeking chariots. These are vehicles having two wheels connected by gearing to a vertical rod on top of which is a pointing figure set to indicate south and remaining so no matter in what direction the chariot is driven, providing the wheels remain in rolling contact with the ground. Articles on the subject appeared in the MMs for September 1955, January 1957 and January 1977 describing models using ten or eleven gears.

It is not essential to use as many, and in January 1978 the MM offered a prize for the chariot using the lowest possible number. The writer submitted an entry consisting of a treatise on south-seeking chariots, in which the theoretical principles were illustrated by models using progressively fewer gears, the final two gear version being the winner. It is possible to build a gearless chariot but the wording of the competition would have disallowed it as an entry. This article is a shortened and modified version of the treatise and also includes with permission some gratefully acknowledged additional material from John Nuttall and Alan Partridge.

## THEORETICAL PRINCIPLES

Fig. 1 shows the plan view of a chariot, the body being represented by a rectangle. Two wheels 1 and 2 of diameter  $D_1$  and  $D_2$ , spaced apart by distance  $X$ , are mounted on diametrically opposite axles and independently drive the pointer  $P$ , fixed to a vertical rod, through gearing of ratios  $R_1$  and  $R_2$  respectively.

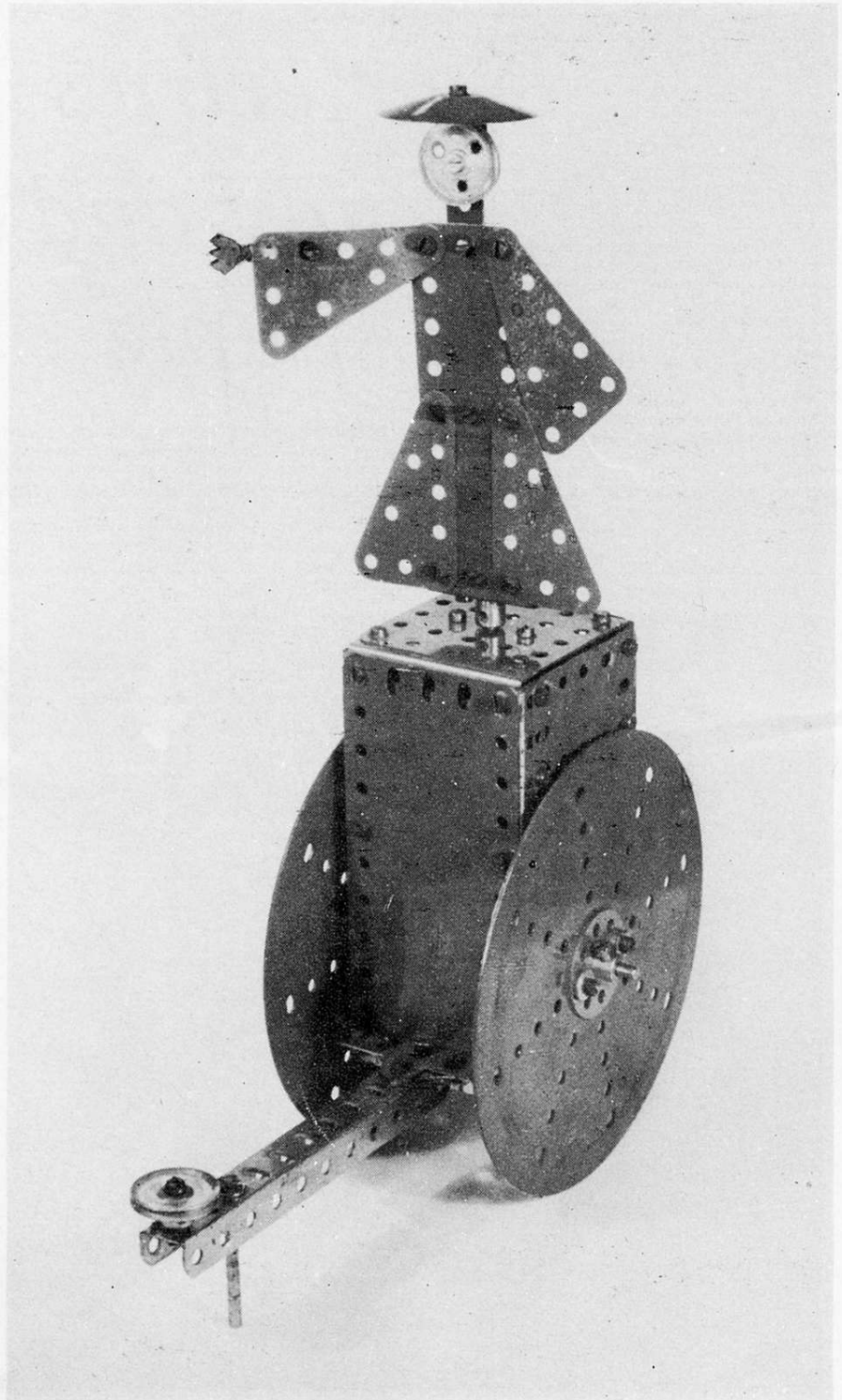
The gearing must be such that the pointer rotates in the opposite direction to that in which the chariot turns ... (1). For example, if wheel 1 turns in the direction shown by the arrow and wheel 2 is stationary the chariot will pivot about point  $C$  in a clockwise direction, so the gearing must turn the pointer in an anti-clockwise direction.

Wheel 1 follows the path shown by the dotted circle, and if the spacing between the wheels is made equal to  $D_1$  then, because the radius of the dotted circle equals the diameter of the wheel, the circumference of the dotted circle will be twice the circumference of the wheel which will therefore rotate twice for a 360 degree turn of the chariot. So  $R_1$  must be 2:1 step down if the pointer is to appear stationary.

If  $X$  is less than  $D_1$  the wheel will turn less than twice, and  $R_1$  must be proportionately less than 2. Similarly if  $X$  is greater than  $D_1$ ,  $R_1$  must be proportionately greater than 2. The same argument applies to  $D_2$  and  $R_2$ . It is not essential that the wheels are the same size or that  $X$  equals  $D_1$ . The chariot will function correctly provided that condition (1) is satisfied and that  $D_1 \times R_1 = D_2 \times R_2 = 2X \dots (2)$ .

This is confirmed by the model shown in Fig 2 which has unequal wheels (for use on hill-sides?). The 2" Pulley with Tyre (3" diameter) transmits the drive through a 4:1 ratio and the 3" Pulley with Tyre (4" diameter) through a 3:1 ratio. As  $4 \times 3 = 3 \times 4 = 2 \times 6$  the chariot functions correctly with the wheels 6" apart. Further constructional details of this model are given later.

Fig. 6.





Note that there is nothing in equation (2) to relate the distances of the two wheels from the centre of the chariot. It is not necessary, just as it is not necessary to specify the position of a differential gear in the driving axle of a road vehicle.

If the wheels are the same size, as they normally will be, then  $R_1$  and  $R_2$  must be made equal and (2) can be modified to give the very simple formula, which can be used to check the wheel spacing of any model,  $X = D \times R \div 2$ . (3) where  $X$  is the wheel spacing,  $D$  is the wheel diameter and  $R$  is the ratio of the gearing between either wheel and the pointer.

Fig 3 shows a fascinating little seven gear chariot to a design by John Nuttall in which  $R = 4$  and therefore the wheel spacing is twice the wheel diameter. The only components fixed to the  $5\frac{1}{2}$ " Rod on which the model is built are four Collars, one at each end to hold the vehicle together, and the two which carry the Pivot Bolts for the  $\frac{3}{4}$ " Contrates. By turning this model upside down one can demonstrate the effect produced by not complying with condition (1).

**DESIGN PRINCIPLES**

If  $X = D$  formula (3) shows that  $R$  must be 2:1. This ratio can be obtained either from a differential gear which needs four or three bevels or, more economically, from an epicyclic gear with two pinions of equal size as in Fig 4. Rod A turning in the boss of Bush Wheel C carries a  $\frac{1}{2}$ " Pinion meshing with a similar Pinion on Rod B which passes through one of the outer holes of the Bush Wheel. Hold A and rotate B and Pinion B will ride round Pinion A and turn C at half the speed of the rotation of B. Hold B and rotate A and C will again turn at half speed.

By connecting A to wheel 1 of the chariot, B to wheel 2 and C to the pointer, independent drives to the pointer will be satisfied as also will be equation (3) but not condition (1) because the wheels rotate in opposite directions. Furthermore the pointer, connected to wheel C will not be rotating on a vertical axis. Therefore to make a workable chariot modification is necessary and the following would seem to be the essential gear requirements:

- (i) Two epicyclic pinions 1:1 ratio.
- (ii) Two pinions 1:1 ratio to reverse the direction of rotation of one of the wheels, which one being determined by condition (1).
- (iii) Two bevels, or a contrate and pinion 1:1 ratio for a right-angle drive to the pointer.

Total six gears. By using a contrate for (iii) the pinion meshing with it can be one of the pinions of (i) thus reducing the total to five. A chariot using this number is shown in Fig 5. Because A and B (Fig 4) are not in line it is more practical to up-end the epicyclic mechanism and provide two right-angle drives to the wheels as in Fig 5 where the axle of the right-hand wheel has a  $\frac{3}{4}$ " Contrate meshing with

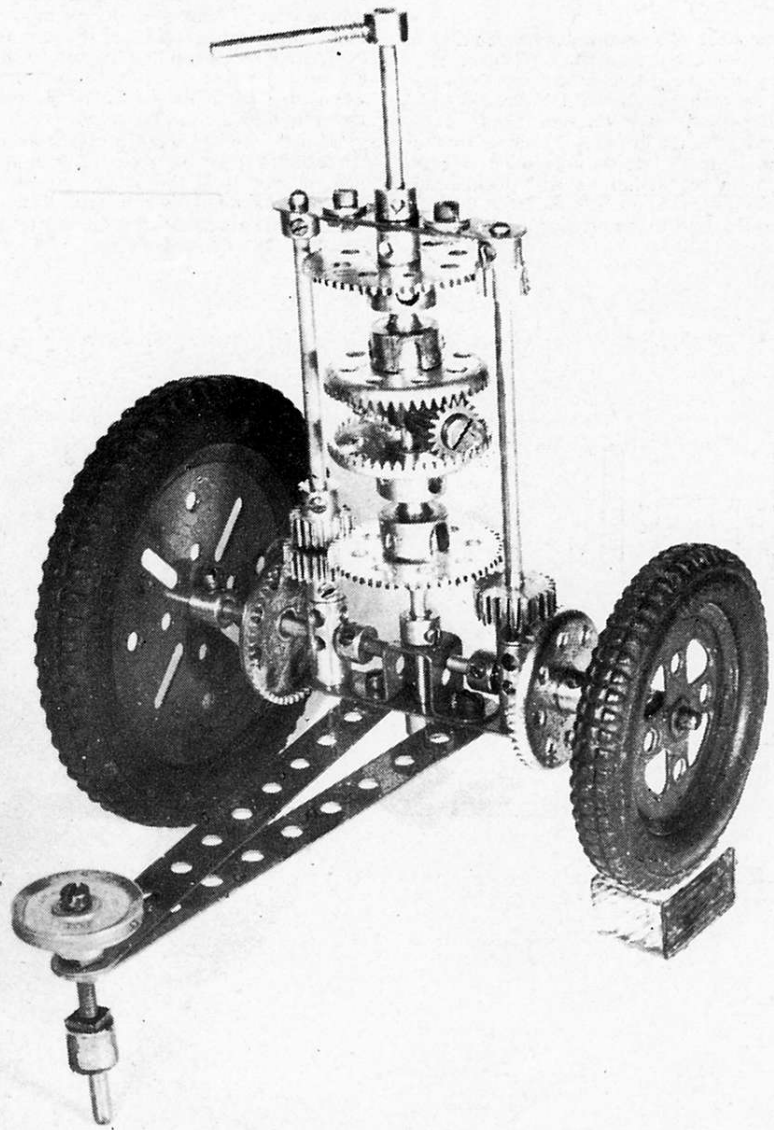


Fig. 2.

the first  $\frac{3}{4}$ " Pinion of the epicyclic gear (this Pinion is free on the Rod) making a ratio of 1:1 i.e.  $R = 1$ . Applying this to formula (3) gives

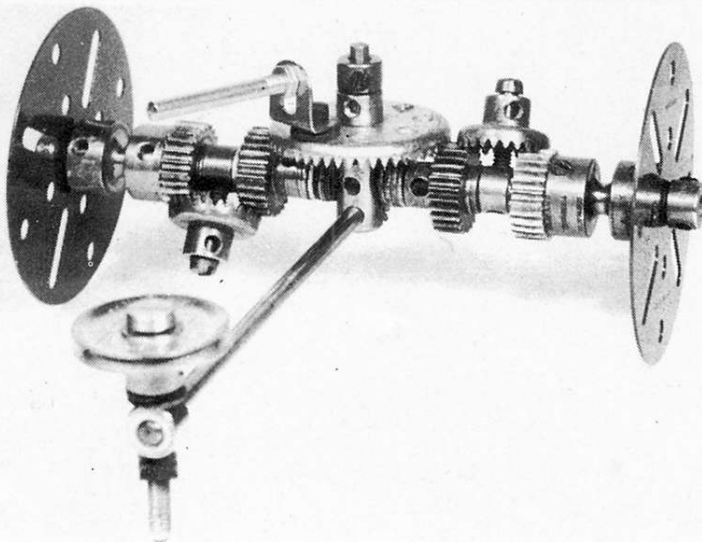
$X = D \div 2$ , so the spacing between the wheels must be half their diameter, and as they are 6" Circular Plates they must be 3" apart.

The drive from the left-hand wheel is 2:1 step down through a  $\frac{3}{4}$ " Pinion and a  $1\frac{1}{2}$ " Contrate on a centrally placed vertical 3" Rod to the top of which a Collar is anchored by its Grub Screw. A Handrail Support, fixed to the Collar by a Nut, forms the bearing for a 1" Rod carrying the second  $\frac{3}{4}$ " Pinion of the epicyclic pair, which give a step-up ratio of 2:1 resulting in the required overall 1:1 ratio to match the drive from the right-hand wheel. The orbital motion of the outer epicyclic Pinion is transmitted to the pointer through a linkage consisting of two  $\frac{1}{2}$ " Reversed Angle Brackets connected by locknotted Bolts to two 1" Corner Brackets secured to Rod Sockets on the driving and driven shafts.

Alan Partridge has designed an enclosed version of this chariot with a delightful Meccano Chinaman perched on top. The model shown in Fig 6 is similar.

Is it possible to use less than five gears? Study of the gear requirements mentioned above suggests that (ii) can be replaced by crossed connecting rods (and the 'Chuff-chuff' competition results, MM January 1978 page 35 Fig 8, show how to do this with only one pair of cranks) and as Meccano Universal Couplings work quite nicely at 45 degrees, two in tandem can be used to replace (iii) Thus only two gears are

Fig. 3.





required. Fig. 7 is a photograph of such a model, with up-ended epicyclic gear and two right-angle drives. Another view was shown in the MM for April 1978 page 75.

A miniature Meccano Chinaman holding a pointer is mounted on a Bush Wheel corresponding to C in Fig 4, and the drives from the wheels are taken via pairs of Universal Couplings above and below through 'Chuff-chuff' competition result linkages 7 and 8 to the epicyclic Pinions. Two six-hole Bush Wheels united by three Fishplates with locknutted Bolts pivoting in the holes of the Bush Wheels transmit the drive to the orbiting epicyclic Pinion.

**IN CONCLUSION**

A 1" Pulley pivoted on a Bolt on the tow-bar of each model facilitates testing by running the vehicle round in circles in one direction only, when small errors add up and are readily detected. If it is found that the pointer drifts in the same direction as the chariot is turning, the wheels are too close, and if in the opposite direction they are too far apart.

Of all the models, apart from the competition viewpoint, Fig 2 is probably the most interesting because it is the most versatile. Two Threaded Couplings bolted vertically to a 2½" Strip provide the bearings for the vertical Rods carrying the required Pinions, and also the

bearings for the wheel stub axles which can be made any required length. Fixed to the middle of the 2½" Strip is a Double Bent Strip providing support for a vertical 6½" Rod carrying the pointer.

All components on this Rod are free to rotate except for the retaining Collars and the 'Spider' carrying the two Pivot Bolts for the Pinions of the differential gear, the Contrates of which are joined by Socket Couplings to the Gear Wheel so that other sizes can be easily substituted as required. Gear ratios, wheel sizes and wheel spacing can all be readily varied to enable the principles of south-seeking chariots to be studied in detail.

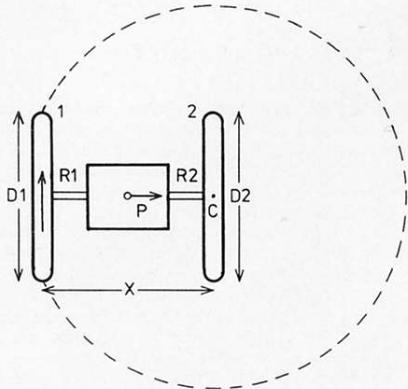


Fig. 1.

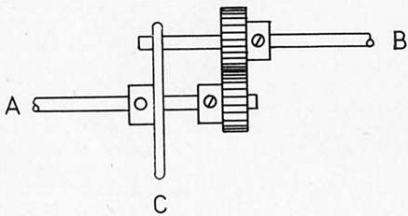


Fig. 4.

Fig. 5.

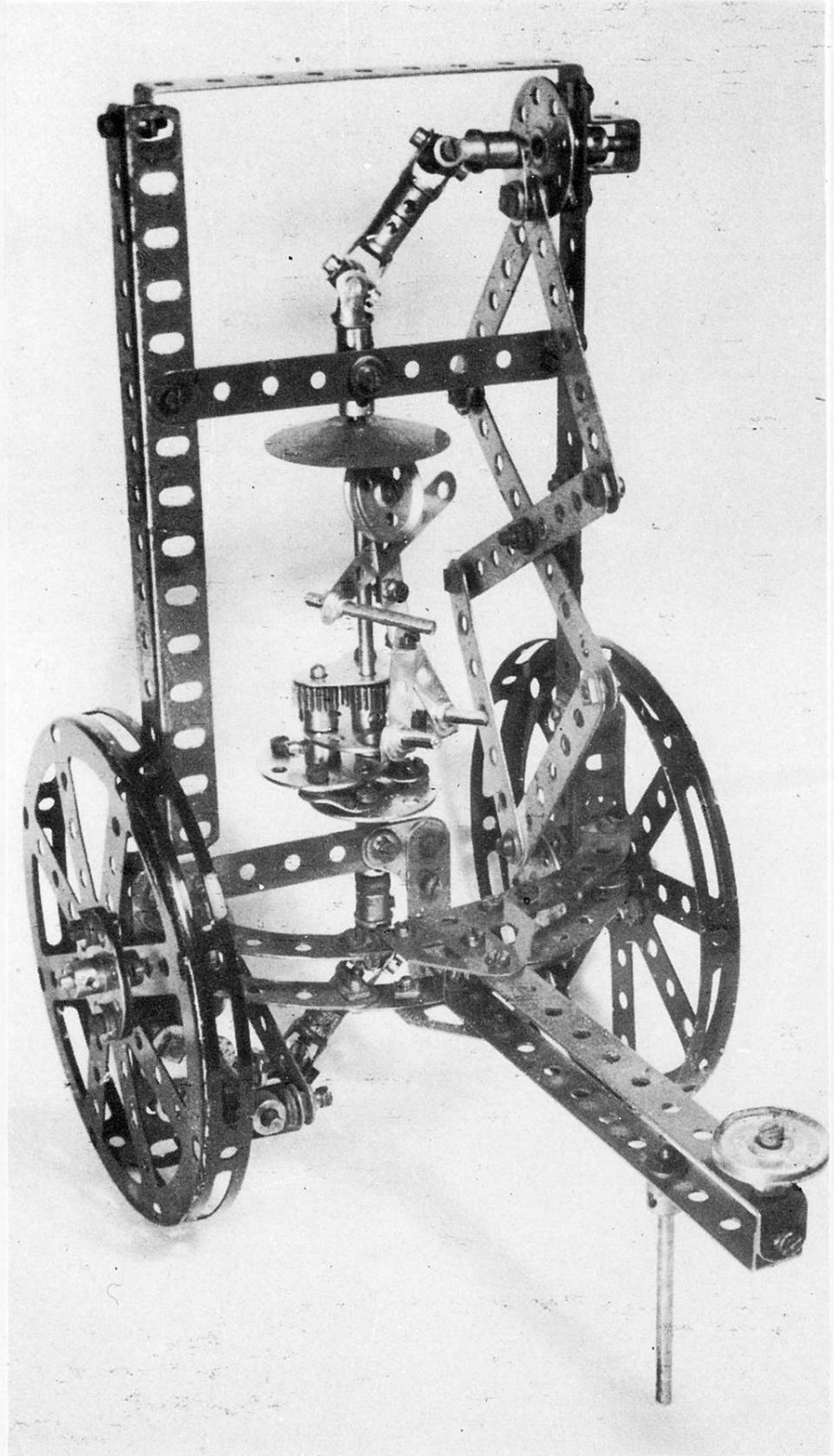
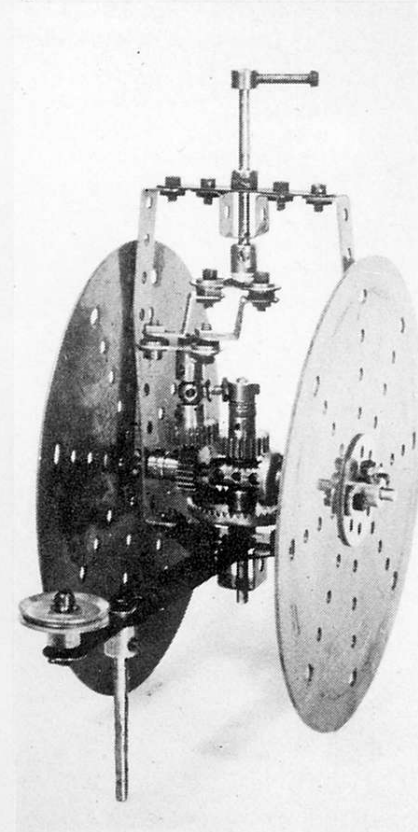


Fig. 7.