

THE

**HORNBY
SYSTEM**

OF MECHANICAL DEMONSTRATION

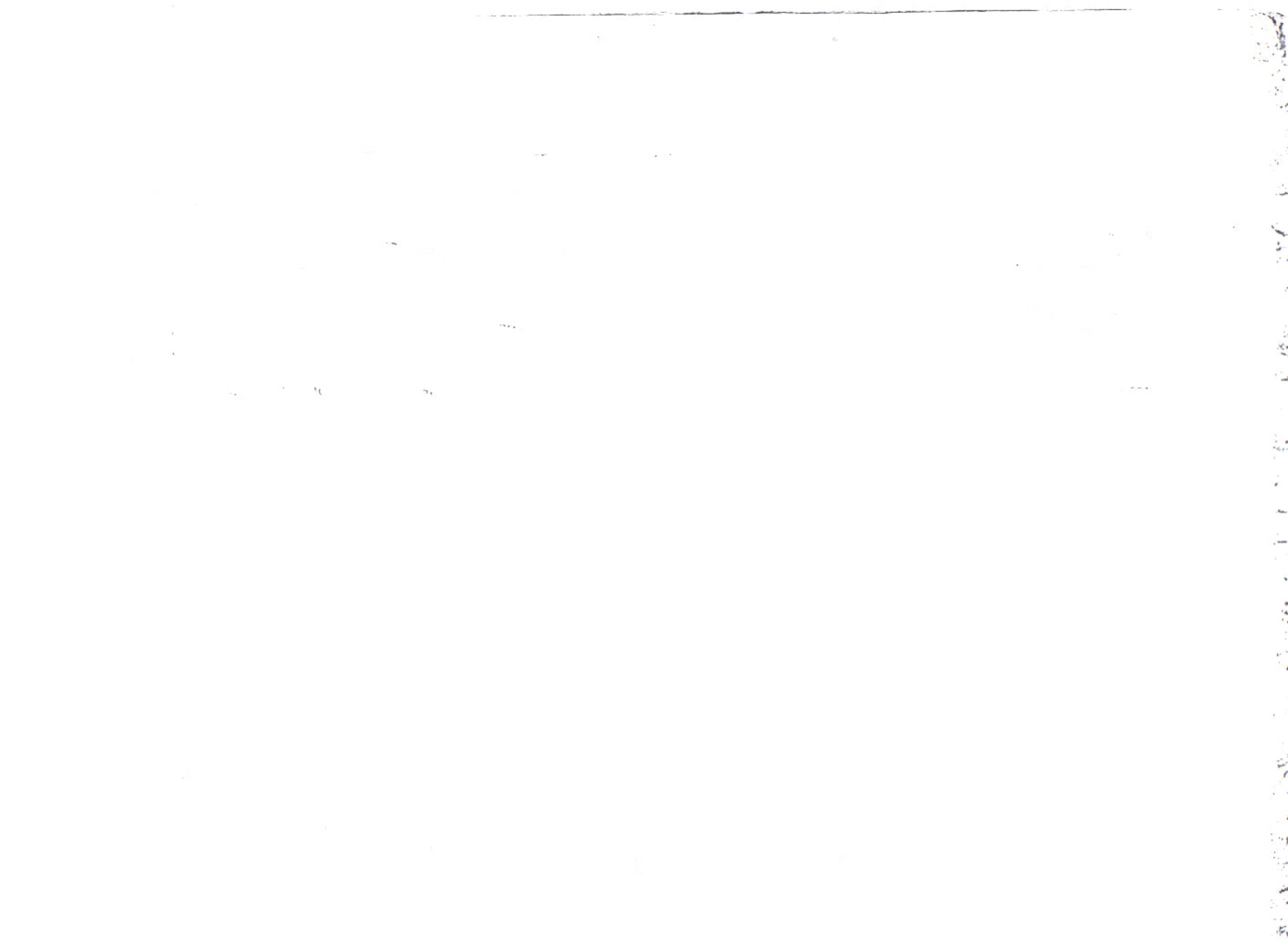
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Introduction.

IN introducing the "HORNBY" SYSTEM OF MECHANICAL DEMONSTRATION, we have endeavoured to provide an economical and yet very effective series of apparatus for demonstrating the main elementary fundamentals of mechanics and mechanical science. The scheme is intended to cover the requirements of ordinary elementary schools, though it is by no means limited to such an application. The present models used in the teaching of mechanical science such as those in use in Evening and Secondary Schools are very costly. In such models one piece of apparatus is employed to teach a given lesson, and that one only, the consequence being that to cover anything like a proper ground, the cost of the apparatus required is very heavy.

With the "HORNBY" SYSTEM a model may be taken to pieces, and the parts utilised to construct other models; again, the student by making his own model develops his constructive faculties, and instead of merely using an already highly finished piece of apparatus, he makes his apparatus from standard parts, his skill in the putting together of the parts being to some extent a measure of the success of his subsequent experiments with the apparatus. Experimental models constructed from "HORNBY" SYSTEM parts will be found to be of quite as high a degree of accuracy as apparatus costing many times as much.

Every care has been taken in designing these models to make each one both simple in construction and effective as a demonstration of some important principle. We hope to further develop the scheme by the introduction of additional models from time to time, and by improving our present ones. We need hardly say that suggestions from teachers and others will be welcomed by us, and are invited.

We have introduced three separate Outfits to meet the requirements of the three higher standards of elementary day schools. "A" section relates mainly to constructional work, and is designed to bring out such ideas as bracing, girder construction, the building up of roof trusses, the joining of plates, and so on. "B" section embodies a series of simple movable parts in engines; whilst the "C" section is designed to afford scope for the teaching of the elementary laws of mechanics. The perforated bed plate supplied with each "HORNBY" SYSTEM OUTFIT will be found of great utility as a base upon which to build up many of the models.

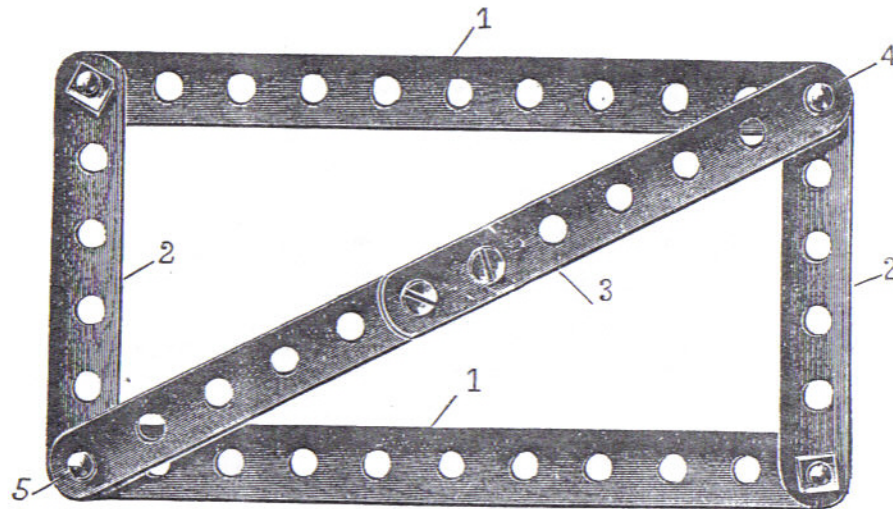
A short description is appended to the illustration of each model, which will enable the models to be built up. It is hoped that the illustrations will be full enough, taken in conjunction with these descriptions, to prevent any difficulties arising in the construction of the various examples.

All the parts in these Outfits have been standardised—and new ones can be purchased at any time, to replace any which have been lost or damaged. The strips are perforated with holes equidistant; the axles fit any of the holes, and their position in the various models can always be ascertained by counting the holes.

Each part has been specially made, selected, and tested for scientific use, and a high degree of accuracy and finish has been arrived at. We undertake to replace any part which from any cause is not found satisfactory when purchased from us.

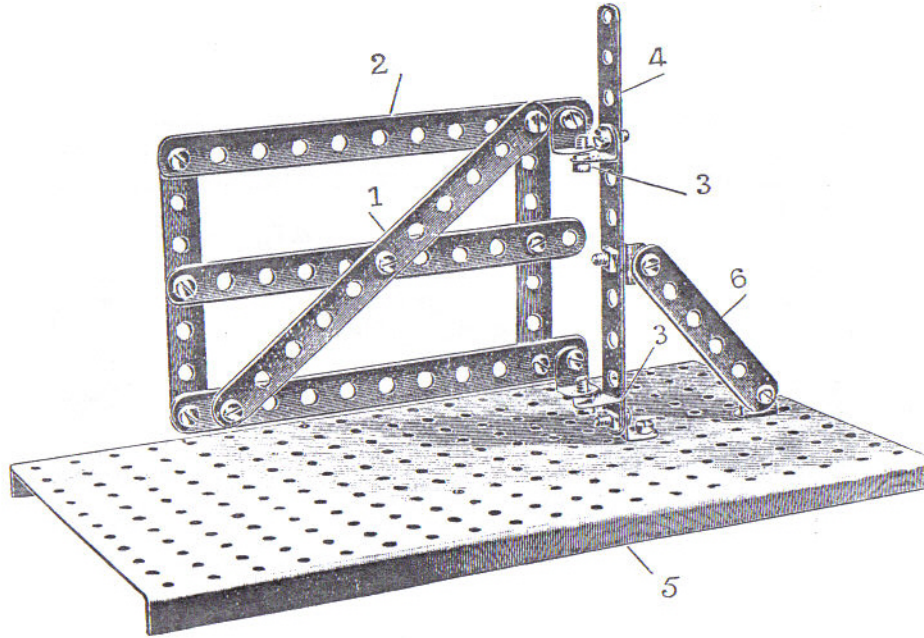
When ordering additional parts, it should always be specified that they are for use with a "HORNBY" SYSTEM OUTFIT.

Diagonal Tie Bar for Frame.



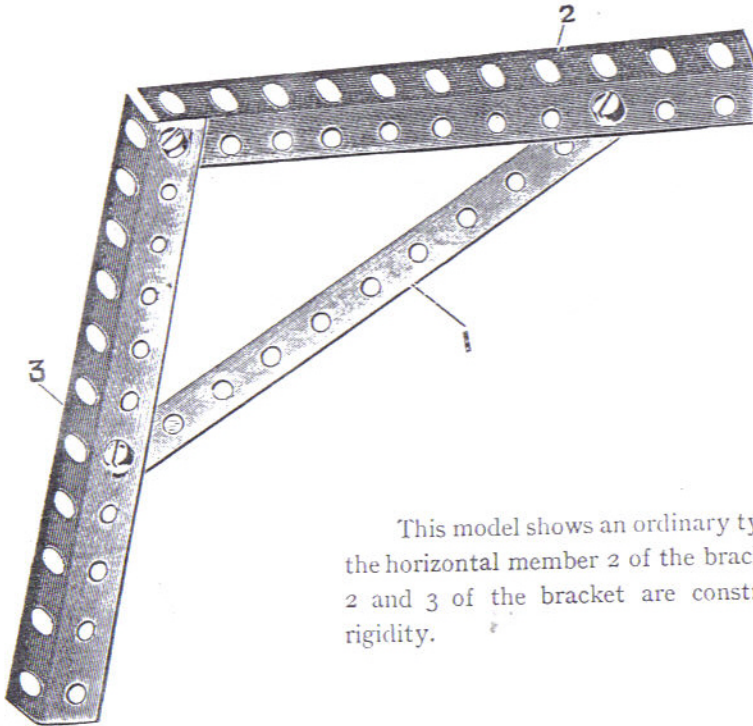
The object of this model is to point out the value of a diagonal tie piece in preventing racking of a built-up framework. The frame model should first be constructed from the four strips 1 and 2 bolted at the corners. It should then be noted how this constructure will easily collapse or close up if left in the simple framework form. A composite strip 3 should now be constructed from two smaller perforated strips of just sufficient length to fit from the upper corner bolt 4 of the framework to the opposite corner bolt 5. On placing this strip 3 diagonally across the framework and over the ends of the bolts 4 and 5, it will be found that the frame has become quite rigid and is secure against any possibility of racking or closing up.

Application of Diagonal Tie to Gate.



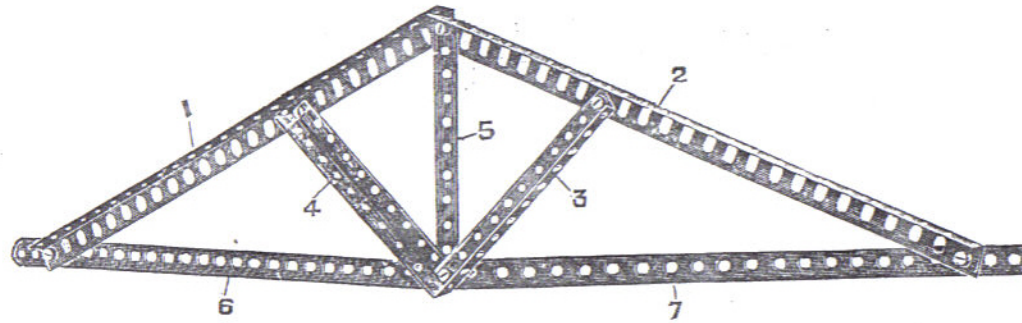
This shows the application of the principle brought out in the previous model, the diagonal strip 1 in the swinging gate 2 being so disposed to prevent racking. In this instance also the diagonal tie acts as a support to the outer overhanging weight of the gate. The gate is pivoted on the bolts 3 in the brackets carried from the upright strip 4 and secured to the perforated plate 5. A stay 6 should be bolted to the upright 4 and the base.

Angle Bracket.



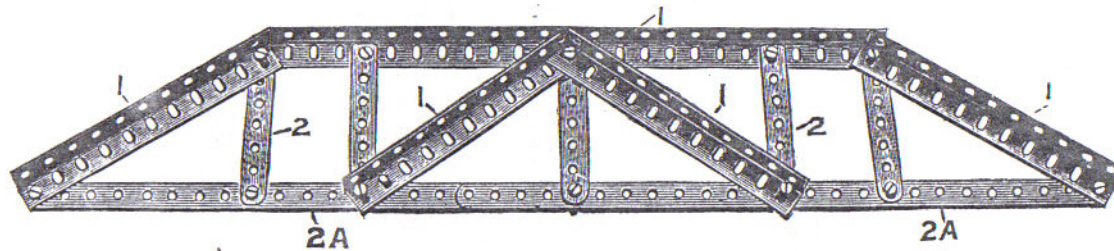
This model shows an ordinary type of angle bracket. The stay 1 supports the horizontal member 2 of the bracket from the vertical member 3. The parts 2 and 3 of the bracket are constructed from angle strips as shown to give rigidity.

Simple Roof Truss.



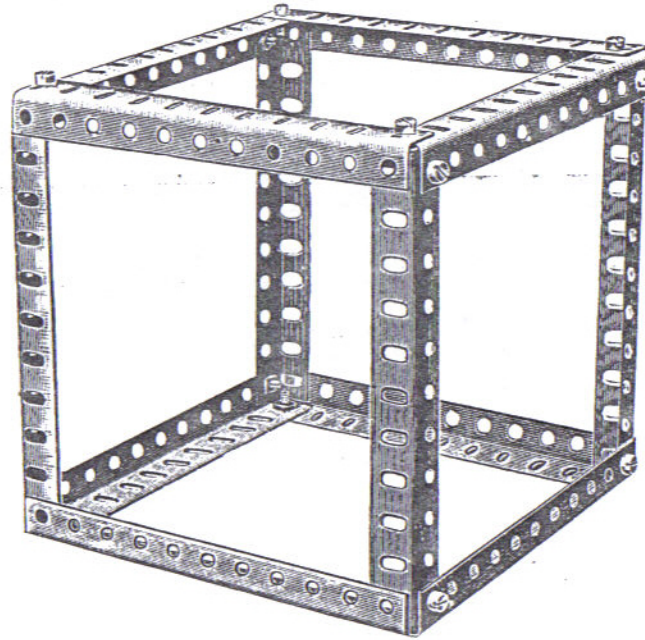
This model represents a simple roof truss. In constructing this example, it should be noted that the parts 1, 2, 3, and 4, which are used to meet the compression or thrusting forces on the girder, are made from angle strips, while parts 5, 6, and 7, which are merely in tension, are made from ordinary flat strips. This construction of angle irons for the members in thrust, and flat bar irons or rods for those in tension, is always followed in constructional iron work.

Built-up Girder.

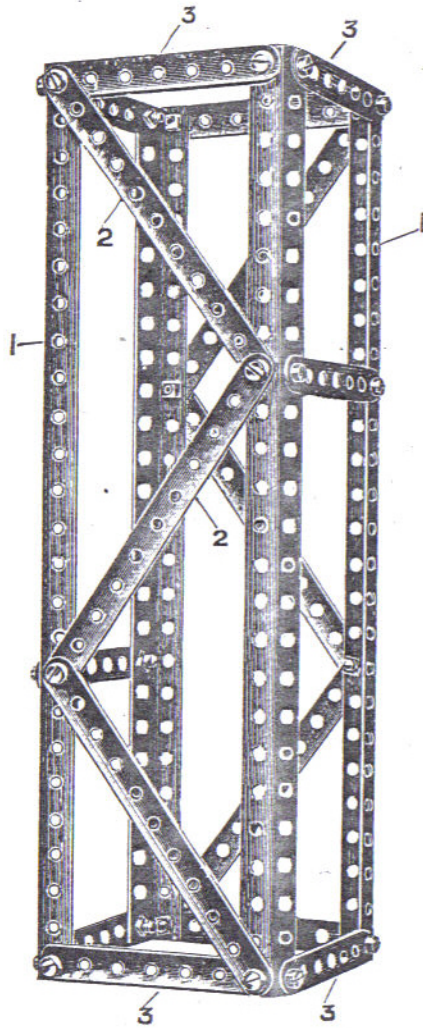


This example shows a simple type of built-up girder. The diagonal parts of the girder and the top element being constructed of angle girders 1, while the vertical members 2 and the lower horizontal parts 2a are constructed of flat strips. In this respect it should be noted that the upper boom of a girder such as 1 is always in compression, and therefore needs to be rigid, and the lower boom such as 2a is in tension, and therefore needs only a flat tie.

Rectangular Angle Iron Framing.



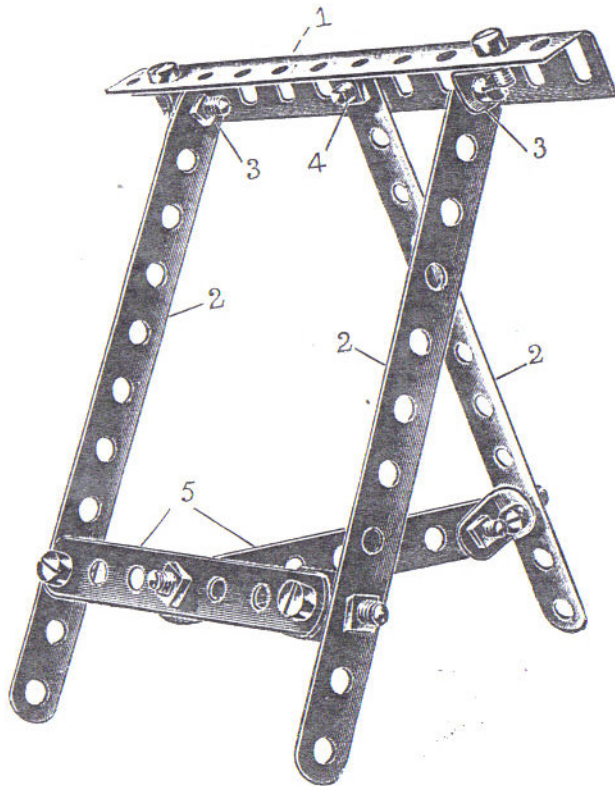
This example is meant to illustrate the construction of the skeleton work of a tank, the corner frames being throughout of angle girders, to which the side plates are subsequently bolted. In actual engineering practice, of course, the angle irons and sides are all riveted together.



Braced Tower.

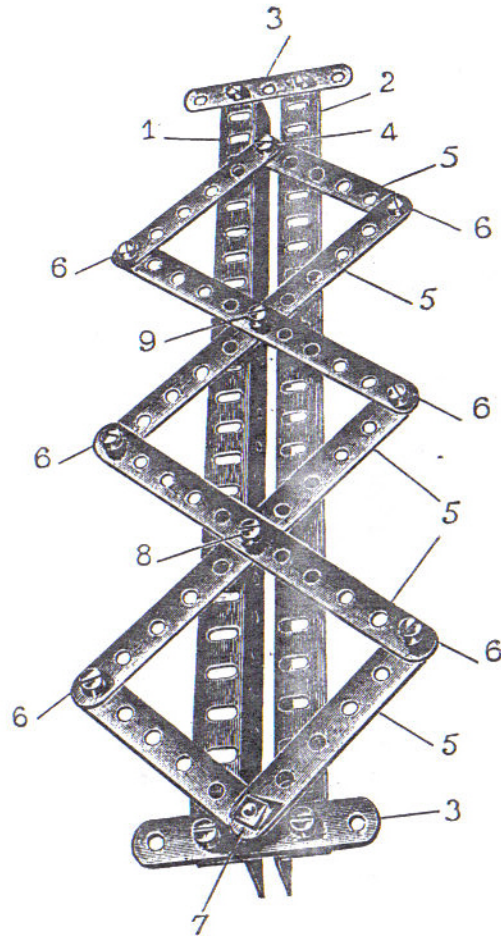
In this example, which might represent one of the supporting towers of a building crane, the corner members 1, which meet the compression of the dead weight upon the structure and requiring to be rigid against any liability of bending, are made of angle girders, while the diagonal strips bracing the corner members together need only be made of flat strips 2, the upper and lower ends of the corner girders 1 being bolted together by the strips 3. It is to be noted that the diagonal braces 2 used to prevent racking are staggered or alternated on the opposite sides.

SECTION A. MODEL 8



Trestle.

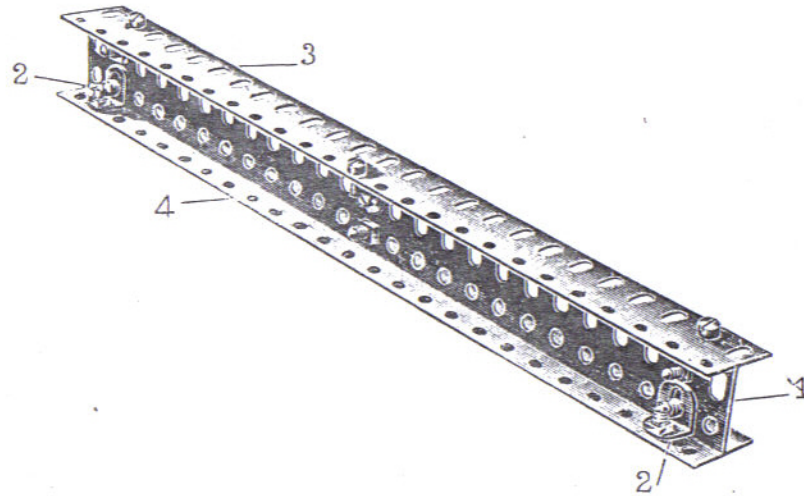
This model represents a trestle such as is usually adopted for temporarily supporting a bench or the like. The upper angle girder 1 is supported by the three legs 2 which are bolted to the upper girder by the angle brackets 3 or direct as at 4, the lower strips 5 being disposed to form a tee rail holding the legs rigidly in position. It should be noted that this type of structure is very firm.



Lazy Tong.

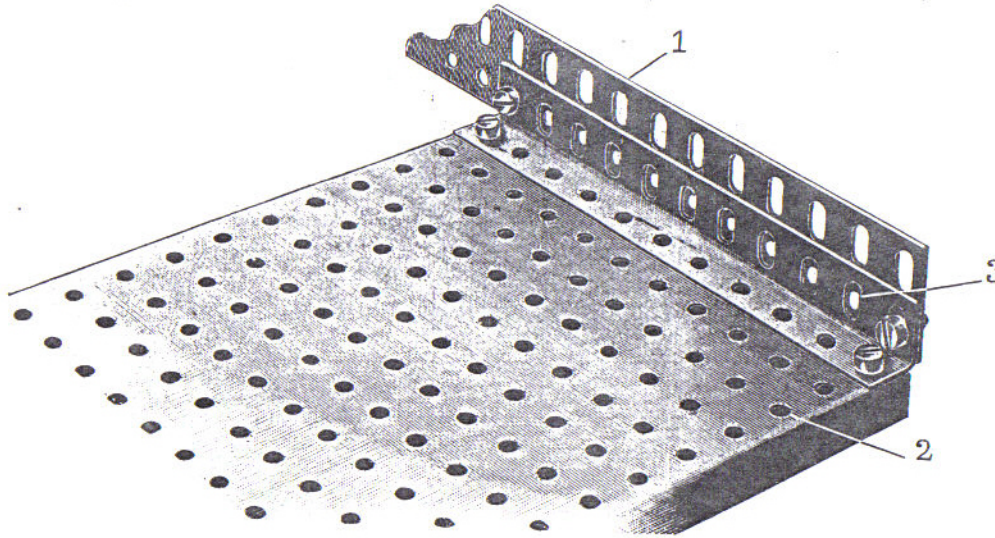
This model will serve to illustrate the principle of a lazy tong. The two angle girders 1 and 2 tied at the ends by the short strips 3 form a guide race for the freely moving shank of the bolt 4. The tong is constructed from a series of diagonally disposed strips 5 bolted together at their outer tips 6, the end bolt 7 of the tongs being secured to the lower cross strips 3, thus anchoring the tongs thereto. Spacing nuts are fitted beneath the strips at 7. It is to be carefully noted that the first centre bolt 8 does not move so rapidly along the slot as the second centre bolt 9, while the movement of this latter bolt is again exceeded by that of the extreme bolt 4. This can be tested by counting the number of holes in the guide strips passed by each of the bolts in question. Lock nuts are required at all the bolts 6, 8, 9, and 4.

H Girder.



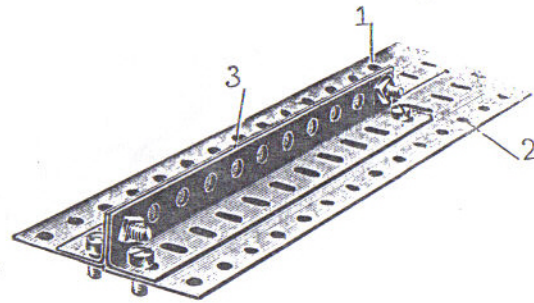
This example shows the construction of an H Girder from "HORNBY" SYSTEM parts consisting of flat double strips. The vertical web 1 of the girder is bolted by means of the angle brackets 2 to the upper and lower booms 3 and 4. It would be desirable before proceeding to make this model to place the three double strips 1, 3, and 4 flat together and one upon another. Then support them at each end. By pressing the strips in the centre attention will be directed to the weakness of a girder made from three strips superimposed in this way. After the girder has been built up, it should be tested in a similar way to that just described by supporting at the ends, when the increased rigidity and strength of the same amount of material will immediately be noticed when disposed in the correct girder form.

Joining Plates at Right Angles.



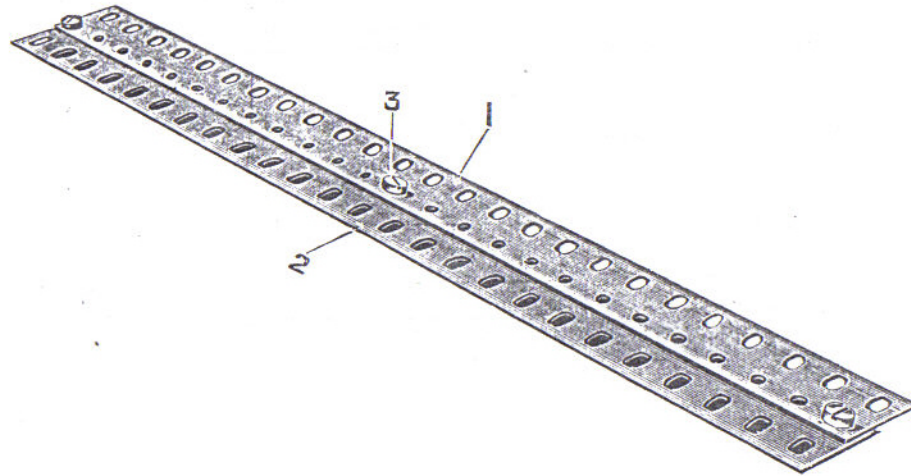
This model illustrates a method of connecting two plates 1 and 2 at right angles by means of an angle girder 3; of course, in actual engineering the plates 1 and 2 are, as a matter of fact, riveted to the angle iron 3. Such a method of joining plates is frequently used in tank work and the like situations, and forms a very satisfactory joint.

Butt Joint with Tee Iron.



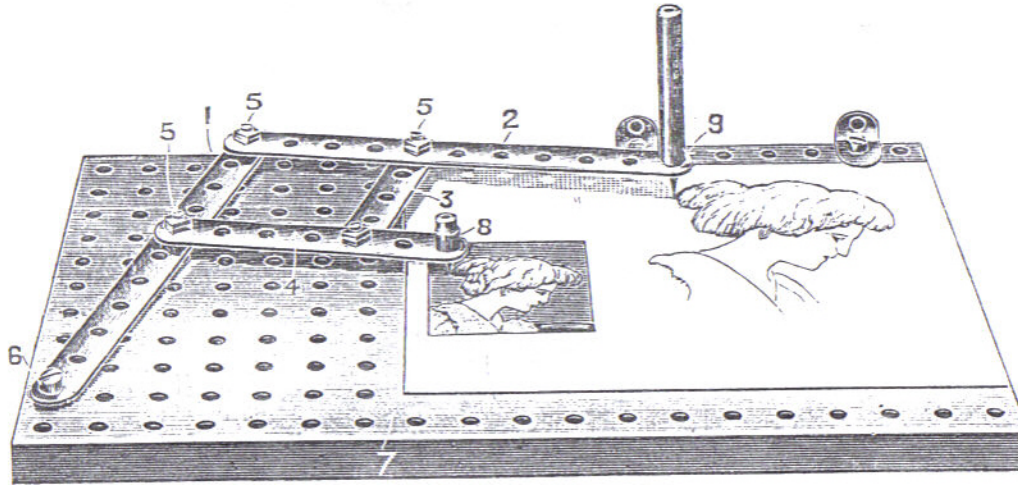
This shows a method of butt jointing two plates 1 and 2 by means of a tee iron 3. This form of junction is utilised where rigidity is required at the joint, such as in many classes of boiler joints.

Lap Joint of Plates.



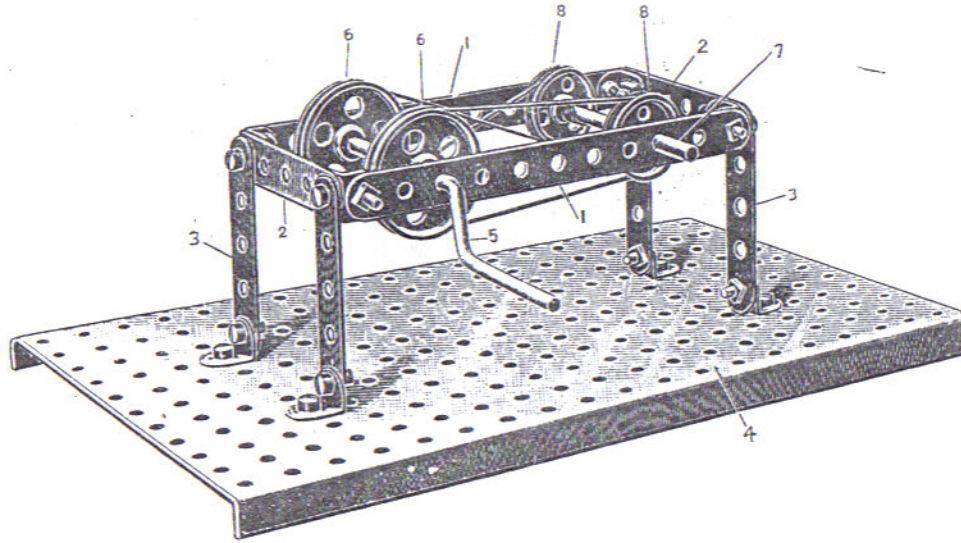
This represents an ordinary form of lap joint, the plates 1 and 2 being merely lapped together and bolted at 3. This is the form usually adopted in the simpler joints of boiler construction, the bolts 3 being of course replaced by rivets. The circumferential joints in a boiler are lap joints, the longitudinal joints usually butt joints.

Pantograph.



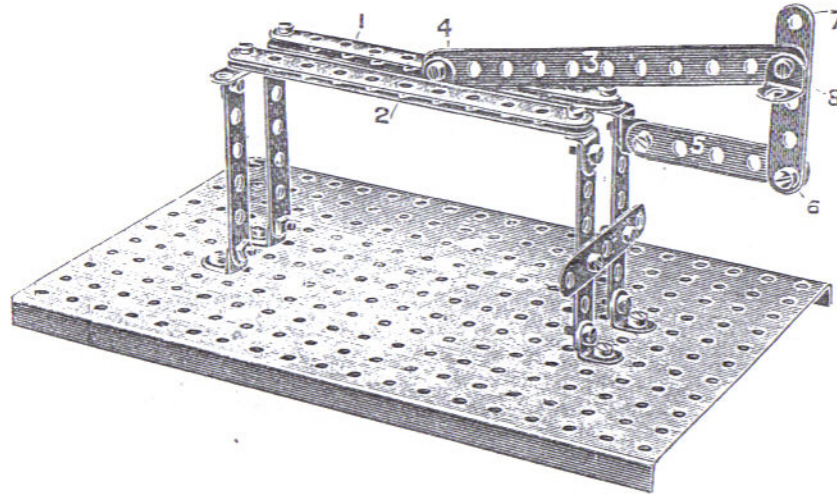
This model shows how the well-known pantograph may be constructed from "HORNBY" SYSTEM parts. As will be seen from the illustration the example is made up of the longer flat strips 1 and 2, coupled together at the angle by means of a short strip 3 and a slightly longer strip 4. Care should be taken that all the pivoted connections 5 of the strips should be provided with double lock nuts as shown, to prevent their working loose. The device is then bolted at 6 to the perforated plate 7, a distance nut being inserted on the bolt 6 beneath the strip 1 to give clearance, as shown in the illustration. The bolt has double lock nuts beneath. If a piece of paper be placed on the perforated plate and lead pencils be inserted in the end holes 8 and 9 of the strips, it will be found that the outer pencil 9 enlarges any original drawing over which the inner pencil 8 may be passed. By inserting the pencil 9 in one of the inner holes of the strip 2, the outer drawing is reproduced to a different scale. The operation may be reversed, and the inner piece 8 used to trace out the new drawing, while the outer pencil goes over the copy.

Open and Crossed Belt Drives.



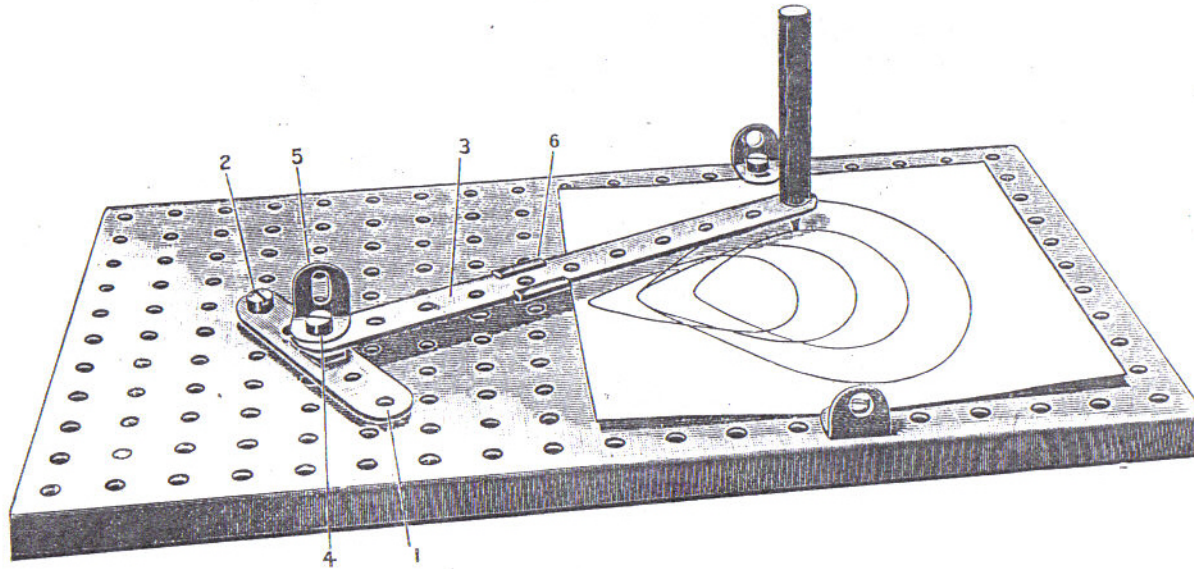
The features of an open and a crossed belt drive are shown in this example. The main frame is constructed of two long strips 1 and two shorter strips 2, carried from the uprights 3 bolted to the perforated plate 4. The crank shaft 5 rotatably supported in the side strips 1 has rigidly keyed upon it two pulley wheels 6. At the opposite ends of these strips is supported a second shaft 7, upon which are loosely mounted the two pulleys 8. These pulleys are connected to the larger pulleys 6 by india-rubber bands, the nearer one being shown as an open drive, and the further one as a crossed belt drive. By rotating the crank handle 5 and the wheels 6 in one direction, it will be seen that the directions of rotation of the pulleys 8 are not the same in each case. In the case of the crossed belt drive the directions of the driving and driven pulleys are opposite, while in the open drive they are the same. This fact is taken advantage of in engineering in those cases where machines need to be driven forward and reversed, a loose pulley being employed to receive the idle belt.

Crank and Connecting Rod.



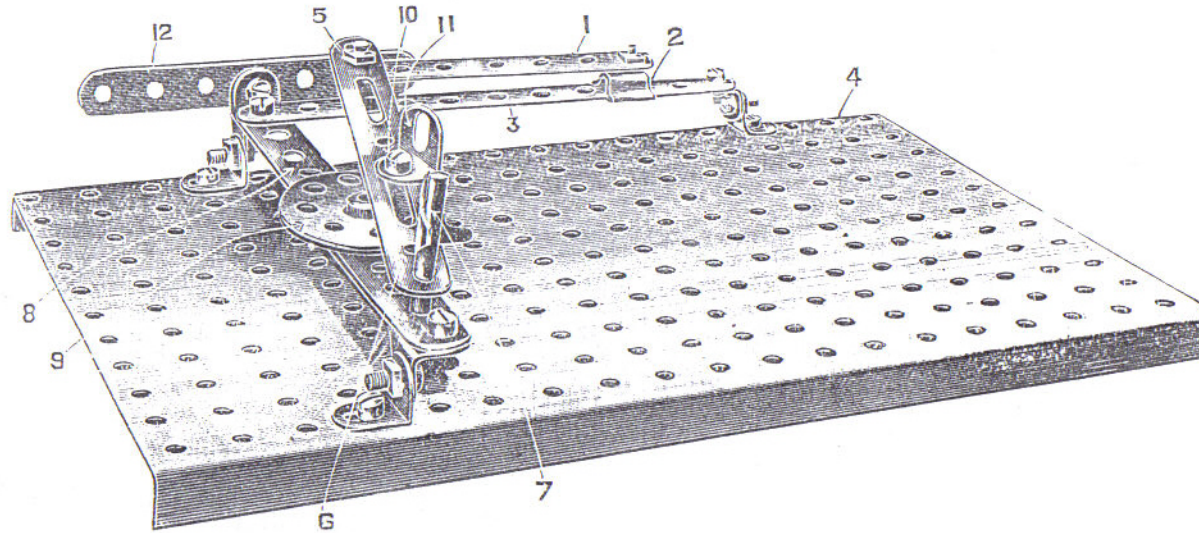
This model illustrates the action of a crank and connecting rod of an engine, one of the simple methods of changing a to-and-fro motion into a rotary motion. The guide strips 1 and 2 are made duplicate, and on either side of the connecting rod 3 is bolted an angle bracket 4, the projecting flanges of which slide along between the double guide strips 1 and 2. This allows a guided reciprocating or to-and-fro motion to the angle brackets 4, which here correspond to the guided crosshead of an engine. The short strip 5 acts as a bracket to support the bolt 6, which corresponds to the crank shaft of the engine, and to which the crank 7 is connected so as to easily rotate. Two distance nuts are fitted between strips 3 and 7 so as to clear bolt head 6 and a lock nut behind. The angle bracket 8 may be utilised to rotate the crank 7. This apparatus shows how the reciprocating motion of a piston in a cylinder is converted through the agency of the connecting rod, such as 3, and the crank 7, into a rotary movement of the main shaft such as 6 of the engine. It will be noticed that while the crank 7 moves round uniformly, the crosshead 4 gradually increases its velocity from the end towards the middle of the stroke, and then decreases towards the opposite end.

Tracing a Locus.



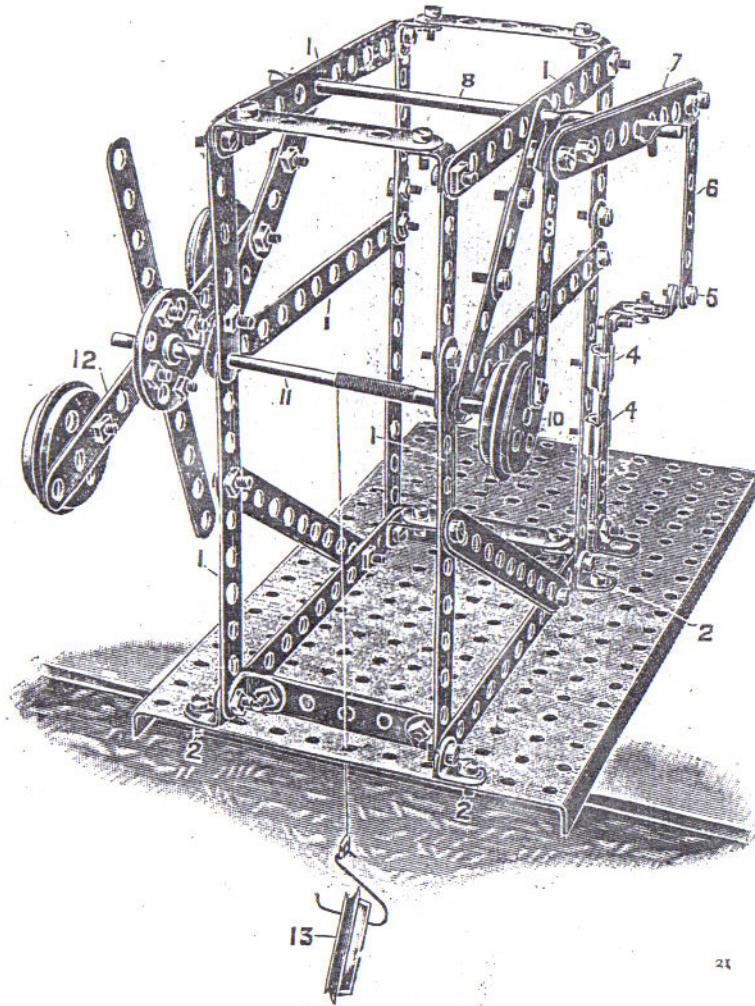
By the aid of this model it will be seen how several loci are traced. The short strip 1 is bolted at 2 to the perforated bed-plate in such a manner that the strip 1 may be revolved round the bolt 2, distance nuts being fitted under the strip for this purpose, and a lock nut on the opposite side of the plate. A long strip 3 is bolted to the strip 1 at 4, an angle bracket 5 being also secured by the same bolt; a swivelling eye piece 6 is pivoted to the bed-plate in such a manner that the strip 3, as the crank 1 rotates, may slide to and fro through this eye piece. As the crank 1 rotates the strip 3 is drawn in and out of the swivelling guide. If a pencil be inserted in any of the outer holes of the strip 3 it will trace a series of loci on a piece of paper as shown; the peculiar shape of these loci should be carefully noted for the different positions of the pencil. In a similar way the loci of various points on a connecting rod may be traced. These curves are of advantage in assisting in the design of connecting rods.

Quick-return Motion.



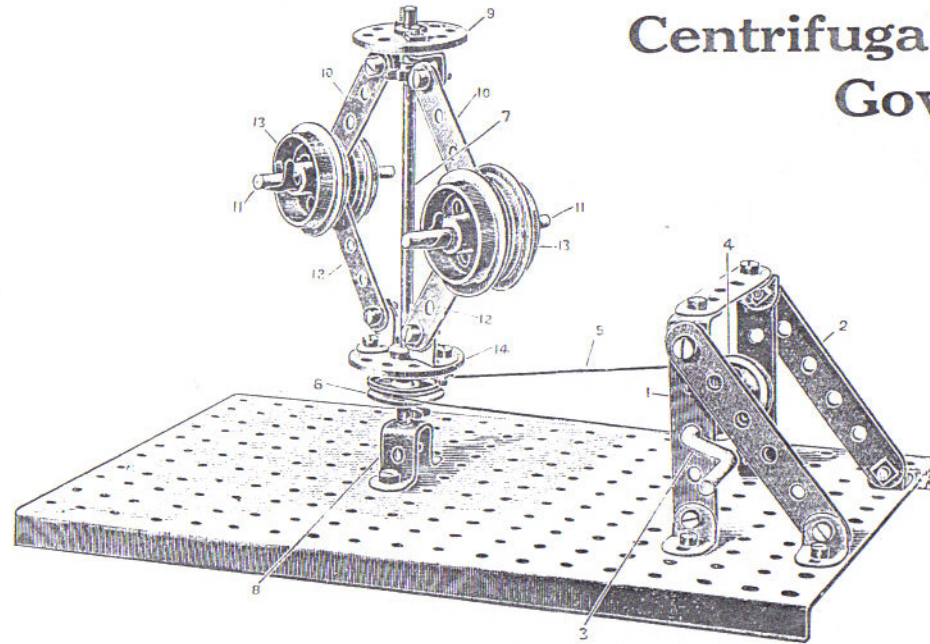
This is a construction for showing the method adopted for obtaining a quick-return motion in various machines, such as slotting or shaping machines. It is desirable in such machines that the cutting stroke of the tool should be much slower than the return stroke, during which no work is being done. In the model shown the strip 1 represents the arm of the machine carrying the cutting tool, which is guided by means of the eye piece 2 on the strip 3, which is supported from the bed-plate 4. The nearer end of the strip 1 is connected at 5 to an oscillating strip 6, which pivots about the short rod 7 carried in the flat strip 8. Pivoted on the shank of a bolt locked by a nut on this flat strip is a wheel 9 in which is screwed a bolt 10 with lock nuts above and below the wheel. The bolt 10 passes through the slot in the strip 6. As the wheel 9 is rotated by the angle bracket 11 the bolt 10 slides to and fro along the slot in the strip 6, which also oscillates about its pivot. A slotted strip will be found in the "HORNBY" SYSTEM OUTFIT. By noting how far the end 5 of the strip 6 travels to and fro along the supporting gauge, strip 12, it will be seen that when the wheel 9 is rotating through one half, the nearer part of its travels, the end 5 of the strip 6 moves through a very much longer space than when the wheel 9 is passing through the other or outer half of its travels. As the rotation of the wheel 9 in a slotting or shaping machine is constant, it follows that the speed of the cutting tool arm 1 varies on the forward and the return strokes, that is, the arm is quicker on the return or non-cutting stroke.

Beam Engine.



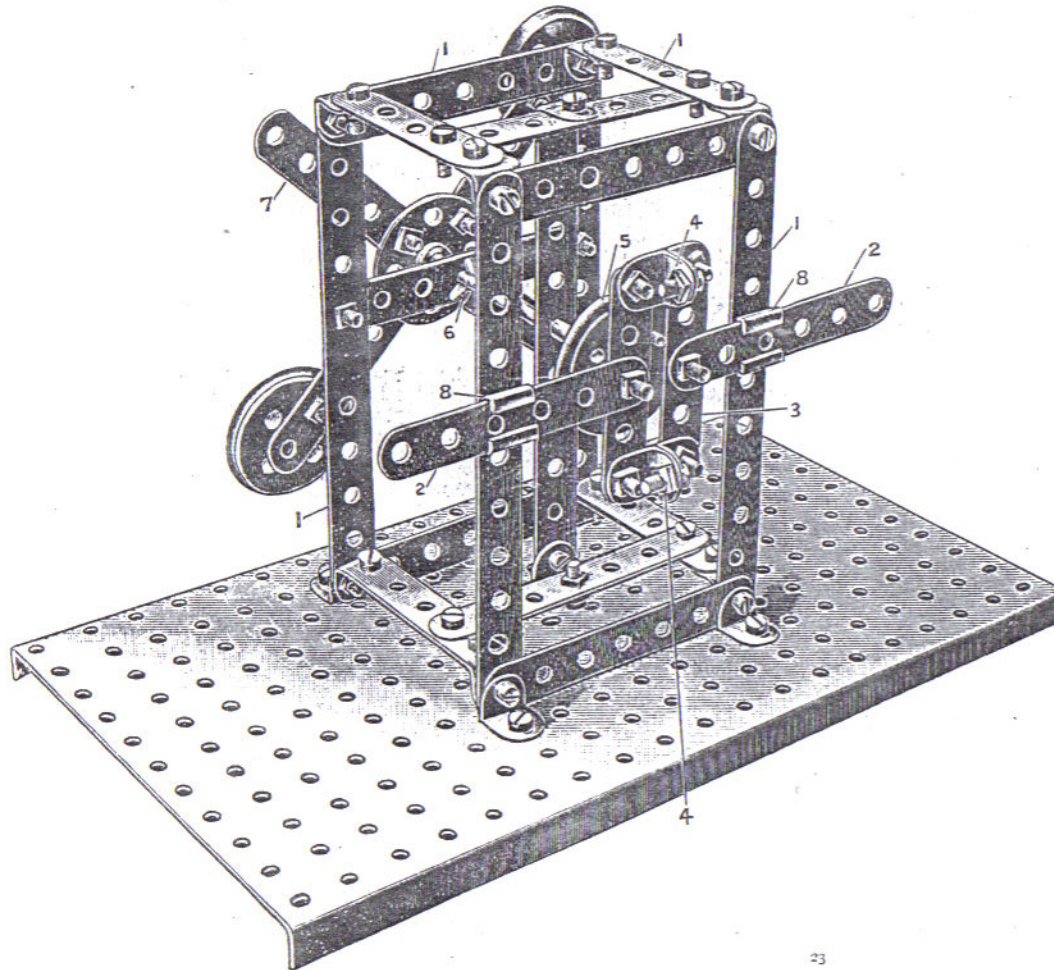
This model illustrates the arrangement of the old type of beam engine. The main frame work 1 should not present any difficulty in construction, and this is bolted to the bed-plate by the brackets 2. The strip 3 is arranged to be vertically guided in the eye pieces 4, and is pivotally bolted at 5 to the connecting rod 6, which is in turn bolted to the end of the double strip beam, provided with distance nuts, oscillating about the shaft 8. The other end of the beam is connected by the strip 9 to the flanged wheel 10 keyed on the winding shaft 11. At the other end of the shaft 11 is keyed the fly-wheel 12 made up of strips, to which are bolted outer weights in the form of flanged wheels. On reciprocating the vertical moving strip 3, the beam 7 is oscillated by the connecting rod 6, thereby rotating the wheel 10 and winding up the weight 13. This was the early form of the steam engine in the pioneer types of single-acting engines used in mines and similar situations, the strip 3 corresponding to the piston rod.

Centrifugal Governor.



This model shows the fundamental principle of a centrifugal type of governor. The winding bracket is constructed from a series of flat strips 1 and supports the operating handle 3, on which is keyed a pulley 4. This pulley is connected by a belt drive 5 to a similar pulley 6, is keyed fast to the vertical spindle 7, supported in the footstep bearing 8 formed from a double bent strip. At the top of the spindle 7 is keyed a bush wheel 9, connected to which are two angle brackets, and on these angle brackets are pivoted the upper links 10. Short spindles 11 pass through the ends of these links 10 and through the ends of the lower links 12, the wheels 13, which correspond to the ball weights of an ordinary governor, and are held on the spindles 11 by keys. The lower ends of the links 12 are bolted to brackets on the lower bush wheel 14, this lower wheel 14 being capable of riding loosely up the spindle 7. On rotating the crank 3 it will be found that the tendency of the weights 13 to fly outwards causes the bush wheel 14 to rise up the spindle. This principle is taken advantage of to govern the engine; the greater the speed of the engine when under steam a corresponding rise is developed in the wheel 14, and this wheel 14 is arranged by means of suitable gear to shut off the steam from the engine, and thus control it.

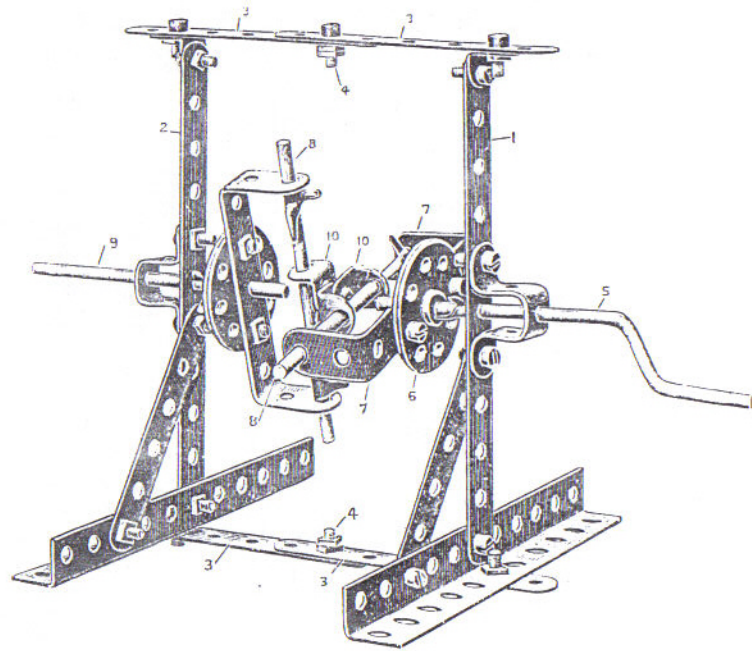
Universal Crosshead.



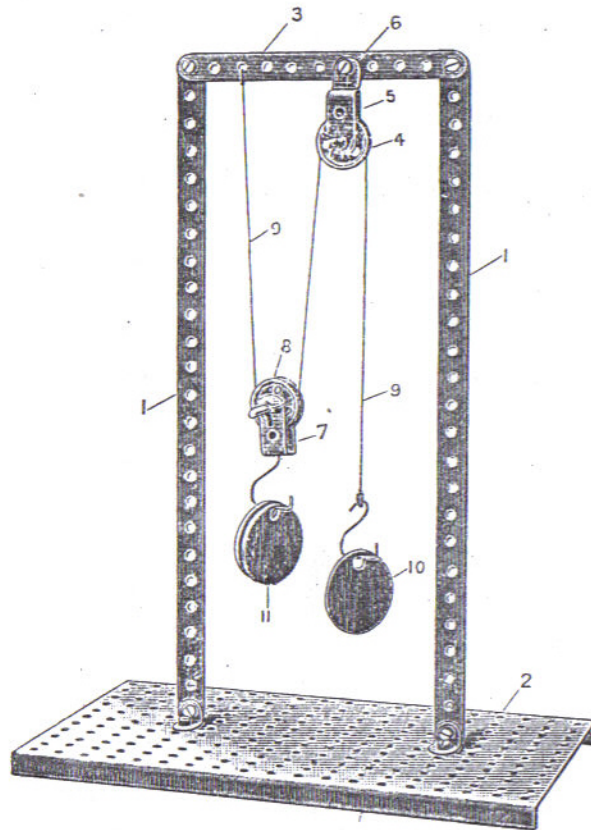
This model shows a construction which is frequently adopted in pumps and similar mechanism. It is known as a universal crosshead. The framework 1 is of the usual type built up from flat strips. At the nearest side is mounted a moving frame constructed of two straight strips 2 connected to another pair of cross strips 3, bolted at their ends by angle brackets 4 to form a slot. This slot engages the projecting shank of a bolt screwed in a flanged wheel 5, which is keyed upon a short spindle 6, passing through a middle vertical strip and the back framework. Four strips 7 bolted to a bush wheel keyed on the outer end of the spindle 6 act as a fly wheel. The front strips 2 are guided in the eye pieces 8. By reciprocating the front frame by one or other of the strips 2 in the guides 8, it will be seen that the slotted guides 3 operate on the projecting bolt of the wheel 5 and rotate the shaft 6. This is another instance of the methods adopted in engineering for converting reciprocating motion into rotating motion. This movement is a very advantageous one as it is equivalent to a connecting rod of infinite length.

Hooke's Coupling.

This shows an apparatus known as Hooke's coupling, which is designed for use in situations where it is required to connect together two rotating shafts which are not in line. It will be found that this model will convey a thorough understanding of what is otherwise a very complicated and elusive movement. The two side frames 1 and 2 are constructed from a vertical flat strip and a base angle girder. They are provided at the top and bottom with rigid projecting strips 3, which are pivoted together at 4 in such manner that the frames 1 and 2 may be relatively obliquely disposed. On the crank shaft 5 is keyed the wheel 6, to which is bolted the bent armed strip 7. Across the ends of this bent strip 7 is fitted the short spindle 8, and exactly similar duplicate formation is provided for the shaft 9 in the side frame 2. The cross shafts 8 are coupled by pairs of angle brackets 10, arranged back to back. It would be advisable to construct these angle brackets first, and then thread the shafts 8 through them when placed between the bent jaws of the strips 7. The shafts 5 and 9 are now coupled together in such a manner that even if the side frames 1 and 2 are pivoted about the bolts 4 to a position such that the shafts 5 and 9 are inclined to each other, the coupling will still rotatively connect the one shaft to the other. Such a type of coupling is of extreme utility in many situations in mill work.



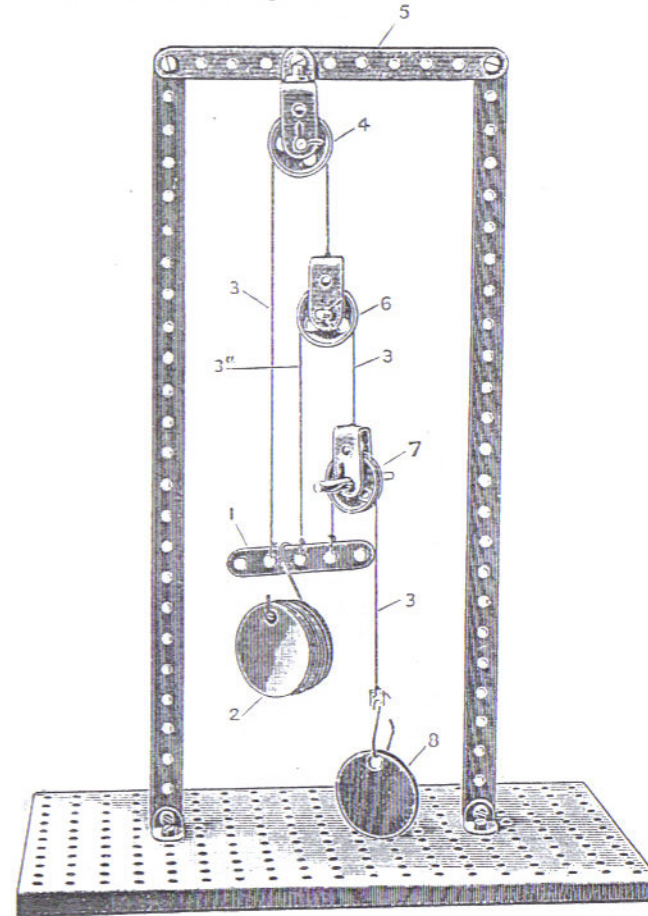
First Order of Pulleys.



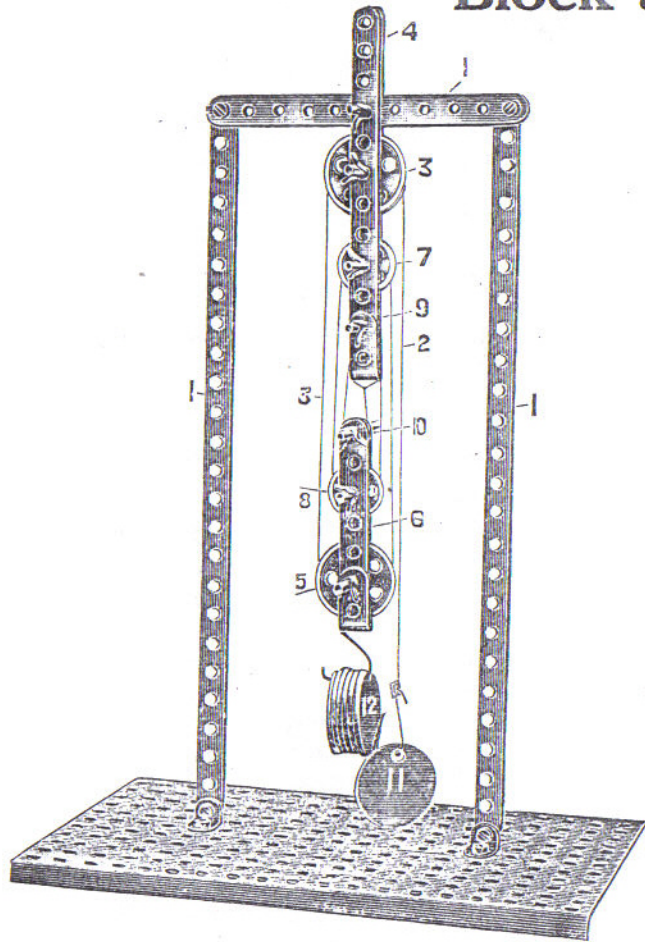
This model is a simple system of pulleys of the first order. The frame work 1 is bolted to the perforated plate 2 by angle brackets, and is provided with an upper cross strip 3. On this cross strip 3 is carried a fixed pulley 4, which is pivotally mounted on a short spindle passing through a single bent strip 5, which forms bearings for the spindle. This bent strip 5 is secured to the cross strip 3; a similar bent strip 7 carries a movable pulley 8. The continuous actuating cord 9 is attached to the cross strip, and threaded beneath the pulley 8 and over the pulley 4, weights 10 and 11 being suspended from the end of the cord and the bent strip 7 respectively. With models such as this, and the succeeding one C 2, it is to be noted that a pulley when mounted in such a way that it can only turn about a fixed axis, as the pulley 4, confers no mechanical advantage; it is merely an endless lever having two equal arms, and its use is to enable the direction of a force to be changed. When the pulley is movable, however, the weight raised will always be greater than the force applied, and then the advantage depends upon the number of cords by which the load is suspended. In this apparatus, the pulley 4 being fixed and the pulley 8 movable, it will be found that the force, which in this case is the weight 10, required to lift the pulley 8, is just one half of the load 11, there being two cords supporting the lower pulley block carrying the load.

Second Order of Pulleys.

This model is a system of pulleys of the second order. In the model C 1 of the previous example, the system has only one continuous cord; in the present apparatus there are several separate cords, all attached to a cross bar 1 supporting the load 2. The outermost one of the cords 3 passes over a pulley 4 fixed to the upper member 5 of the framework; the other end of this cord is fixed to the supporting single bent strip of the movable pulley 6, the next cord 3a passing from the strip 1 round the movable pulley 6 to the strip of the second movable pulley 7. In this example it will be found that the load 2 which can be lifted by the force 8 is equal to eight times the force. The cords are secured to nuts beneath the bent strips of the pulleys 6 and 7. Of course, in all these apparatus there is a certain amount of friction which has to be overcome in the bearings of the pulleys. As regards this second system of pulleys, it may be mentioned that such an arrangement with more than one cord, while more powerful than the single-cord system and though interesting from a mechanical point of view, is, with few exceptions, rarely employed in practice. The systems with a single continuous cord are more convenient in fixing and management. In this arrangement the mechanical advantage would depend upon the relative values of the force 8 and the weight 2 to be lifted.



Block and Tackle.

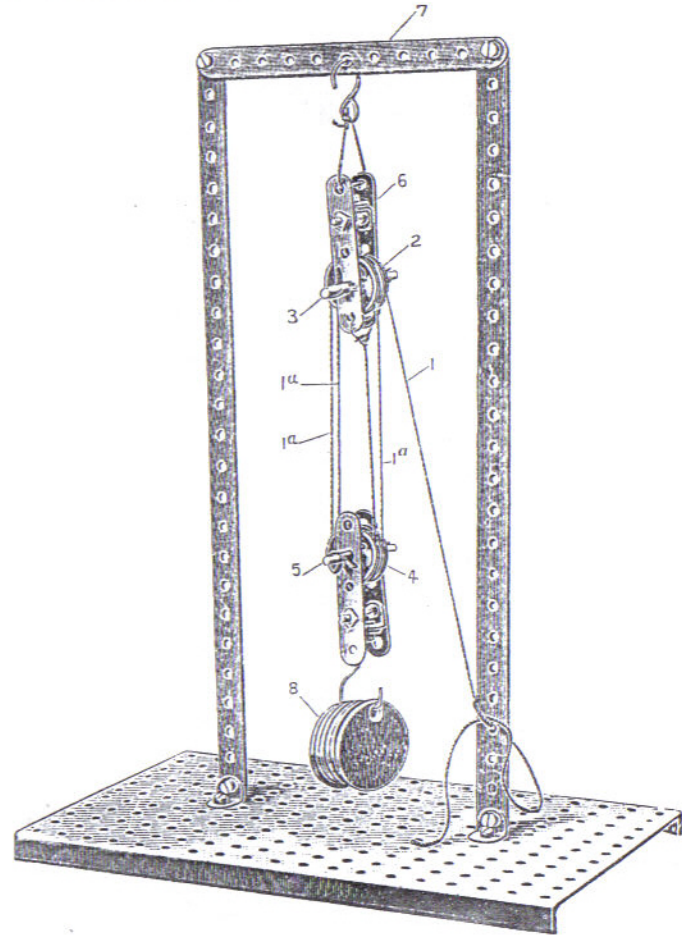


This is an arrangement showing the more usual application of a pulley system in the case of a block and tackle. There is only one continuous cord 2 in this case, which passes round the top pulley 3, pivotally mounted in the strips 4 which are fixed to the frame work 1. The cord then passes round the lower pulley 5, also pivotally mounted in the movable frame work 6, then over the next top fixed pulley 7, and then to the lower movable pulley 8; from thence to the small upper pulley 9, and finally round the corresponding lower pulley 10, and is fixed to the end of the bent strip attached to 4. The effect of the force 11 in raising the weight 12 is found by counting the number of cords which spring from the lower movable pulley block 6 to the fixed block 4. In the case given this will be seen to be 7. The mechanical advantage in such a system, therefore, neglecting friction, would be 7. In actual practice the various pulleys in the fixed and movable set are each mounted on the same axis as in the next example C 3a, thereby giving a more compact arrangement.

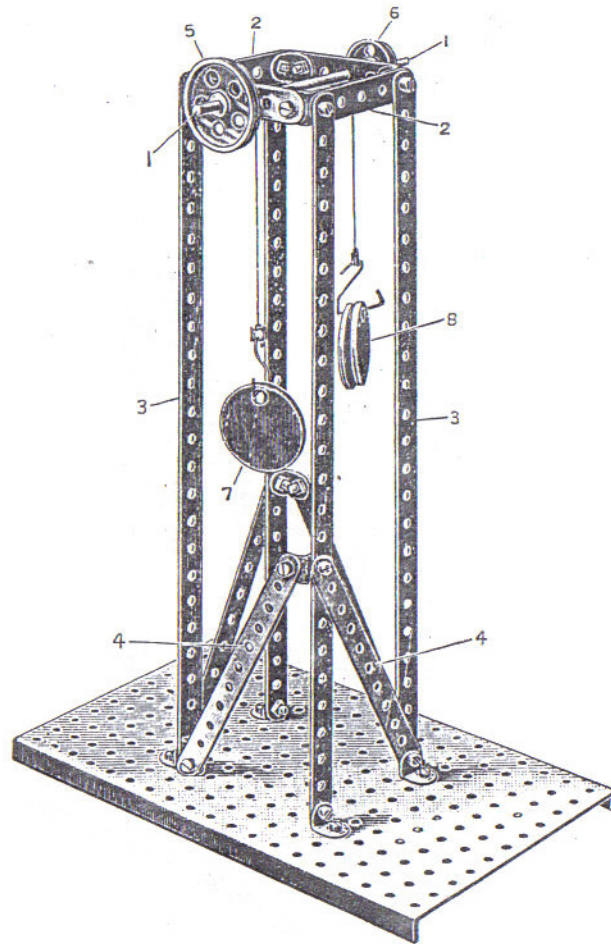
Block and Tackle.

This example shows the more usual arrangement of the pulleys in actual practice of the block and tackle shown in the two preceding examples. In this case the cord 1 is a continuous one, passing over the upper pulleys 2, which are loose on the spindle 3, and over the loose pulleys 4 on the lower spindle 5, being finally secured to the upper block. The upper pulleys 2 and also the lower ones 4 are carried in the side strips 6, connected by angle brackets to form jaws, the upper set of pulleys being fixedly supported from the cross bar 7 by the hook, the lower set of pulleys 4 being movable. Here again it will be found that the amount of the load 8 which can be lifted by the operating cord 1 is dependent upon the number of cords 1a which arise from the lower block. In the arrangement shown, for instance, the force necessary to lift the weight 8 would be one quarter of this weight, neglecting friction, because of the four cords passing from the lower block to the upper one. There may be any number of pulleys in each block, the arrangement belonging to the "second system of pulleys." It is one of the most convenient and generally adopted systems in use.

The principle of the apparatus may be readily understood by considering what happens if the lower set of pulleys carrying the weight be raised, say, one inch. This will result in each of the four cords 1a being slackened or shortened by one inch, the consequence being that the pulling cord 1 will need to move through four times one inch in order to take up this slack; consequently the operating force pulling on this cord 1 moves through four times the space that the weight is lifted. Neglecting friction the operating force should thus be one quarter of the weight that is lifted.



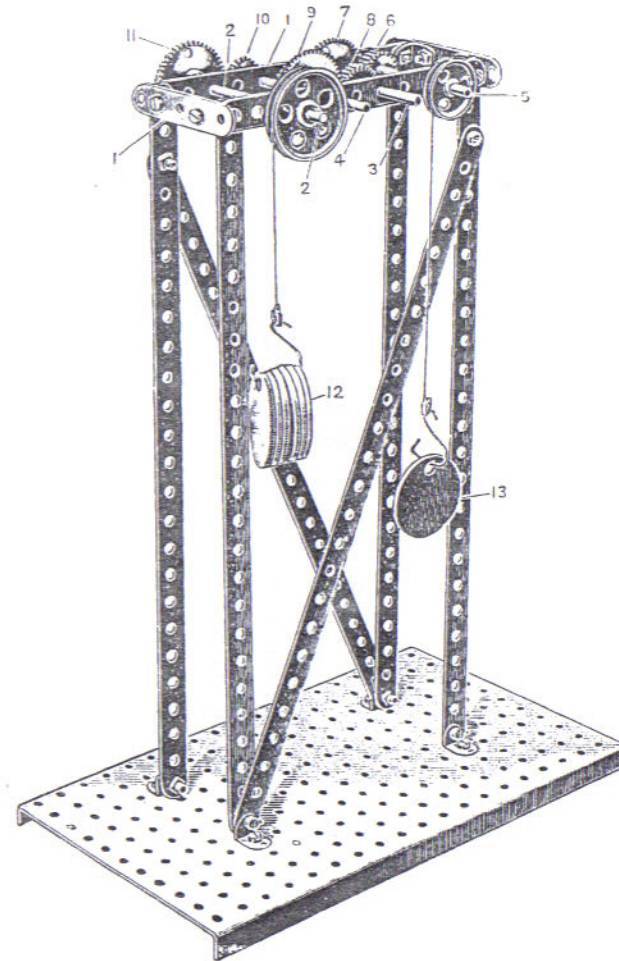
Wheel and Axle.



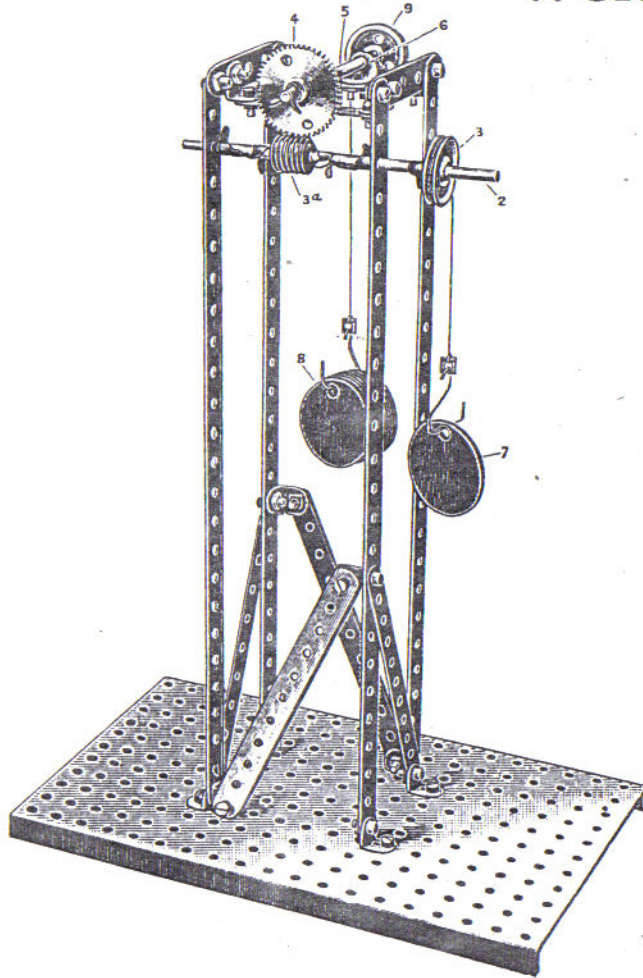
This example is usually known as the wheel and axle. There is also another apparatus somewhat similar to this—it is known as a compound wheel and axle; the present example is known as a simple wheel and axle. As regards the construction of the model the upper shaft 1 is supported in the frame work 2 carried from the uprights 3, which are braced to the bed-plates by the diagonal strips 4. A 38 mm. pulley wheel 5 is keyed at one end of the spindle, and a 25 mm. pulley 6 at the other end. The principle embodied in this apparatus is that of a continuous lever, the larger pulley 5 to which the force 7 is being applied overcoming the heavier weight 8, which becomes wound up by its supporting cord about the smaller pulley 6. Such an arrangement is used for many purposes, as in a marine steering gear, or elevating goods in a store or mill. Neglecting friction in the apparatus the weight 7 multiplied by the revolutions of the pulley 5 should always equal the load 8 multiplied by the revolutions of the pulley 6. By referring to the description of the lever, model C 7, it will be seen that the same principle applies here as in that case, namely, that the force multiplied into the arm or radius of the large pulley 5 equals the load multiplied into its arm—in other words, the moments of both forces 7 and 8 about the axle 1 are equal.

Gear Train.

This model shows a usual type of wheel train used in engineering where it is required to reduce the velocity of a shaft geared up to the driving shaft. The frame work 1 is of the usual description, the shafts 2, 3, 4, and 5 being mounted in the side strips. The small pinion 6 keyed on the shaft 5 gears with the toothed wheel 7, and the pinion 8 on the opposite side of the shaft 3 also gears with the toothed wheel 9, the outside pinion 10 on the same shaft gearing with the toothed wheel 11. It will be found on rotating the shaft 5 at a definite speed, that the rotation of the spindle 2 is very much slower; the exact relative proportion of speed of these two shafts is obtained by multiplying the number of teeth in the large spur wheels 7, 9, and 11, and dividing this product by the number of teeth multiplied together in the pinions 6, 8, and 10. A 38 mm. pulley is keyed on the end of the shaft 2, and a smaller pulley on the shaft 5, as shown in the illustration, weights 12 and 13 being supported on these pulleys from cords. From this it will be found that the force 13 hung on the pulley wheels keyed on the shaft will be always approximately a certain proportion of that on the shaft 2, and will correspond to the relative rates of rotation of the shafts 2 and 5—in other words, the force acting on the shaft 5 multiplied by its speed of revolution will equal the weight lifted by the shaft 2 multiplied by its own rate of revolution. This is, of course, not absolutely the case, as in all these machines there is a certain correction to be made for the friction of the machine. Supposing, however, that we could have a machine absolutely without friction, then this result would be actually obtained.



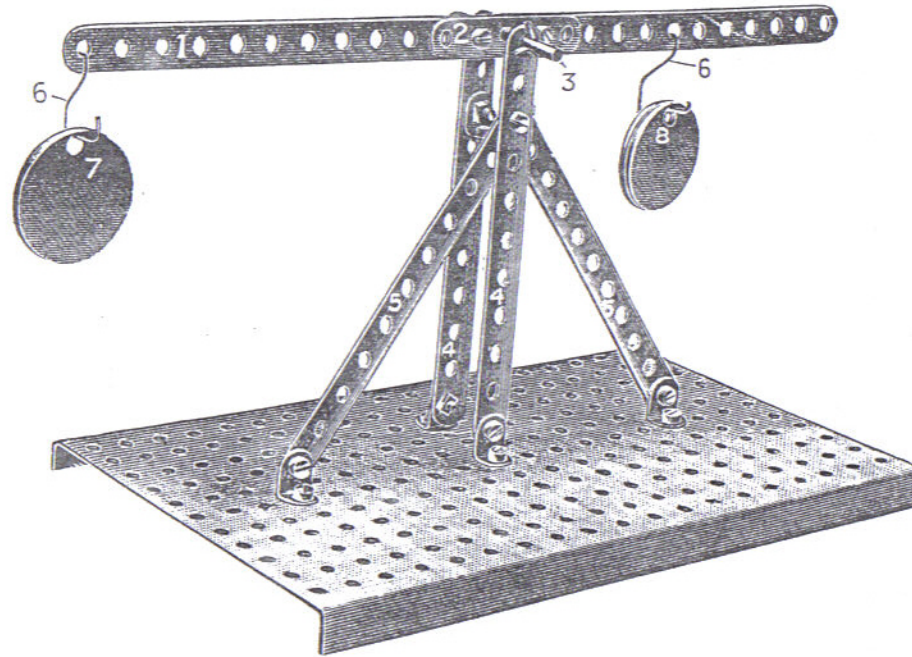
Worm and Worm Wheel.



This shows a very well-known arrangement of the worm and the worm wheel. In the last example an arrangement is shown whereby a shaft rotating at a high speed is gradually stepped down to a much lower speed, thus converting a quickly rotating shaft of small power into a slowly rotating shaft of high power, but this method is uneconomical and also inconvenient, and to obviate this, recourse is had to the arrangement shown in the present illustration. In constructing this model the usual type of frame work is provided in which is supported the crank shaft 2 carrying the worm 3a. This worm gears with the wheel 4 keyed upon the transverse shaft 5 supported in the angle brackets 6 from the frame work. By rotating the shaft 2 at a high speed, it will be noticed that the tooth wheel 4 only rotates very slowly; as a matter of fact, one rotation of the shaft 2 will only move the wheel 4 round a distance equal to one tooth. This is always the case when the worm 3a is what is known as a single-threaded worm. In this case, therefore, it will be seen that the relative velocities of the shaft 2 and the toothed wheel 4 depend upon the number of teeth in the latter. In the model as shown there are 50 teeth in this wheel; the shaft 2 will need to rotate 50 times in order to give one complete rotation to the shaft 5. Such an arrangement, fulfilling as it does the same principle as the complicated wheel train of the previous example, is of great advantage in engineering. It is often used to step down the high speed on an electric motor shaft.

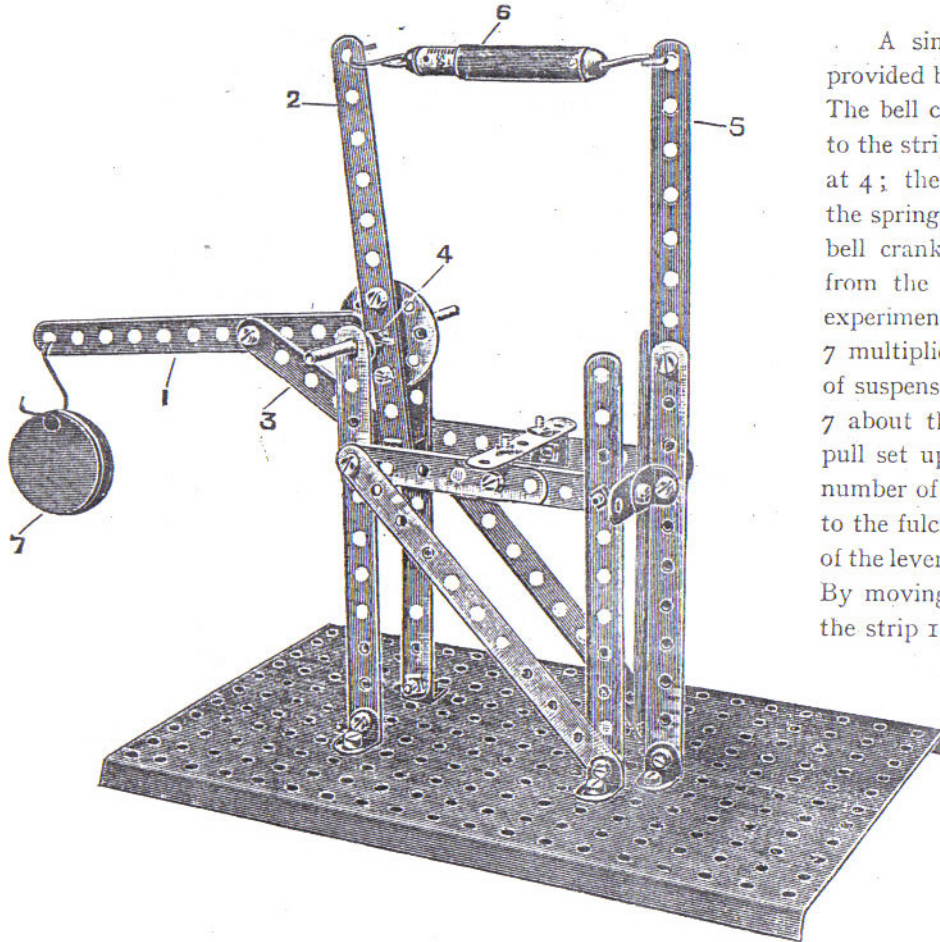
In order to test the efficiency of the example, the worm shaft 2 is provided with a pulley 3, and the gear-wheel-shaft 5 is likewise fitted with a pulley 9. Supposing now there were no friction in this machine, the force 7 necessary to raise the load 8 carried from the pulley 9 would only need to be one-fiftieth of the load 8, that is, supposing that there are 50 teeth in the gear wheel 4 (which in this case acts as a worm wheel), that the worm 3a is a single-threaded worm, and that there is no friction in the machine. An actual experiment of this should be made, first of all finding out what force is required to be hung on the pulley 3 in order to just rotate the shaft 5 when there is no load on the pulley 9. This will make the necessary correction for friction in the apparatus, after which proceed to determine the relative values of the force 7 necessary to lift any given weight 8.

✓ Lever.



This example serves to determine the principle of equilibrium of an ordinary lever. The main lever 1 is constructed from a 25-unit strip, reinforced at the centre by a short strip 2, between which and the long strip are distance nuts. Through this strengthening strip 2 is passed the short shaft 3, which is supported in the uprights 4 carried from the bed-plate and braced thereto by the diagonal strips 5. The hooks 6 are for supporting the weights. By selecting a certain number of disc weights and suspending them in various holes on each side of the spindle 3, it will be found that any weight 7 on one side of the spindle multiplied by the arm or distance—that is, the number of holes—from the spindle 3, will be equal to the weight 8 multiplied by its arm or distance, or number of holes, from the spindle 3. The weight at any side multiplied by its arm or distance from the spindle 3 is called the moment of the force, or weight, about the fulcrum 3, and it is necessary in order that the lever should balance that the moments on each side of the fulcrum should be equal. The perforated strip forms a convenient means of reckoning the distance of the weights from the fulcrum 3.

Bell Crank.



A simple form of lever for experimental purposes is provided by the example of the bell-crank lever as illustrated. The bell crank itself is made up of the longer strip 1 braced to the strip 2 by the diagonal tie 3. These strips are pivoted at 4; the rear bracket 5 is also carried from the plate, and the spring balance 6 is connected to the shorter arm 2 of the bell crank and the upright 5. The weights 7 are carried from the longer arm 1 of the crank. In conducting the experiment with this model, it is to be noted that the weight 7 multiplied by the number of perforations from the point of suspension to the fulcrum 4 is the moment of the weight 7 about the fulcrum. The spring balance will register the pull set up by this weight, and this pull multiplied by the number of holes from the point of attachment of the balance to the fulcrum gives the balancing moment on the short arm of the lever. These two moments should of course correspond. By moving the suspended weight 7 to various places along the strip 1, it will be seen that the pull on the spring balance

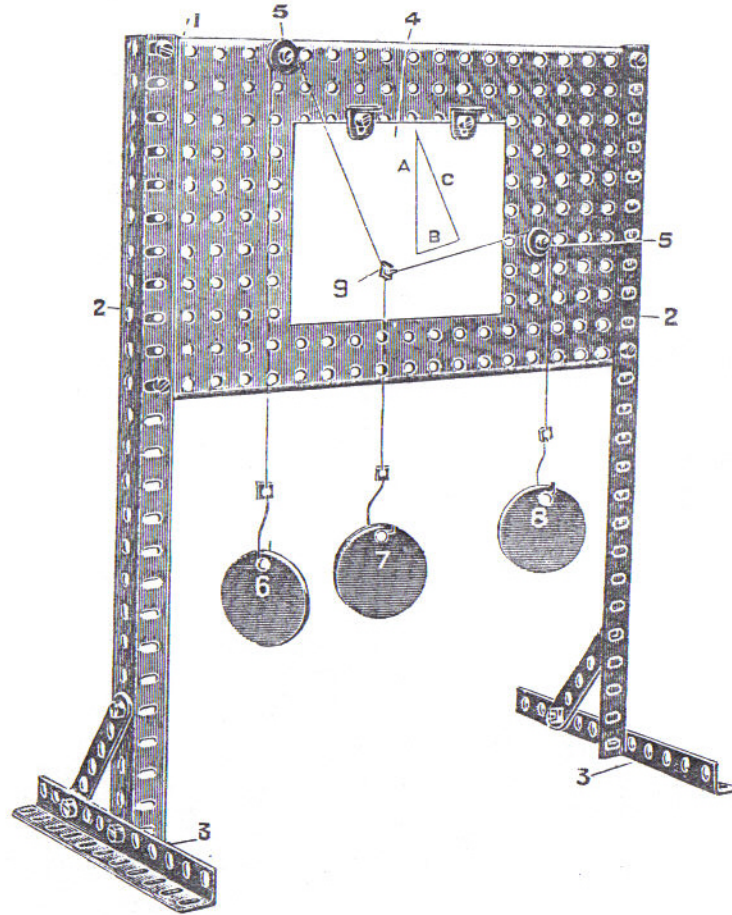
continually changes in proportion to the varying distances at which the weight is suspended. Experiments should be made to prove that the law of moments holds good for every position of the weight 7.

Triangle of Forces.

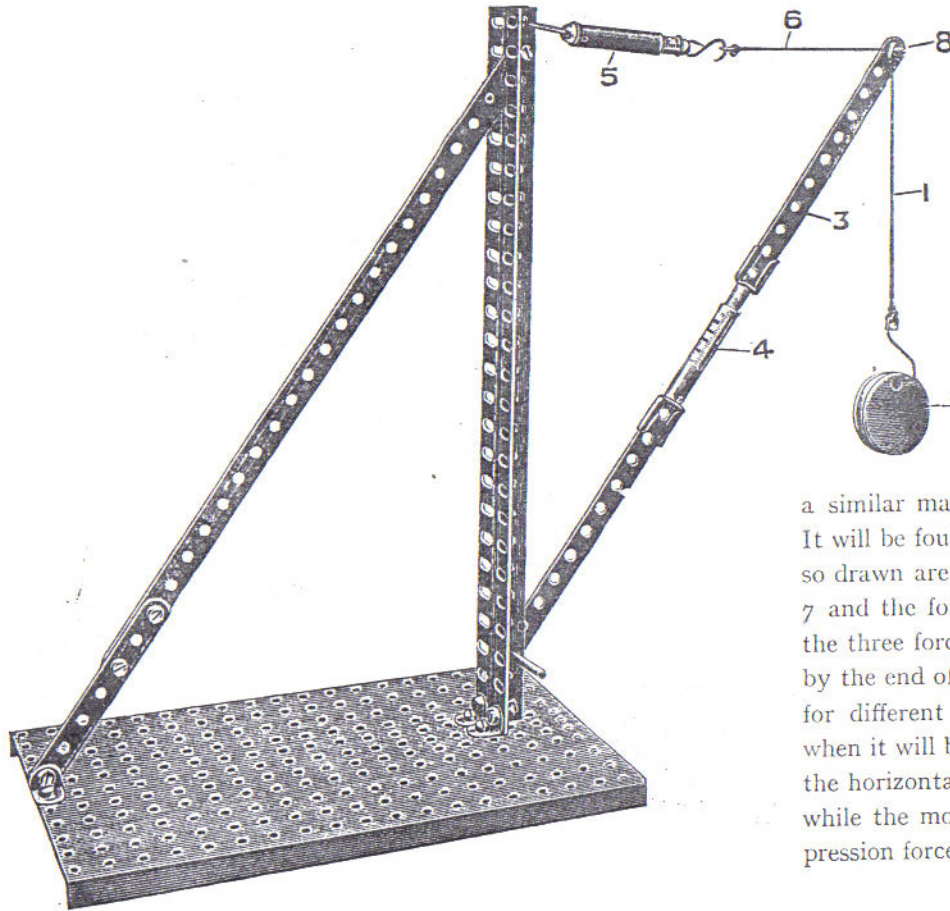
This model illustrates the well-known principle of the triangle of forces. This may be briefly stated as follows: If any three forces meet at a point and are in equilibrium, then if the directions of all three forces are known and the magnitude of any one of them be known, the magnitude of the other two may be determined by drawing a triangle, such as designated in the sides A, B, and C in the smaller diagram, whose sides are parallel to the direction of all three forces.

In drawing the triangle, begin by drawing a line corresponding to the direction of the force the magnitude of which is known. Supposing this force to be five units. A line should be drawn parallel to the direction of this force, and set off to a length of five units to some suitable scale. From the ends of this line, the remaining sides of the triangle should be completed, these sides being drawn parallel to the direction of the force, the magnitude of which it is required to find. These magnitudes may be determined by scaling the length of the two sides, and counting the number of units contained in these sides to the same unit scale as that to which the original side was set off.

In constructing the model the perforated plate 1 is bolted to side angle girders 2. A sheet of paper 4 is attached to the perforated plate 1, the two small pulleys 5 being bolted and locked at the rear with nuts so as to allow the pulleys to freely rotate at different positions near the side of the paper 4, and the cords supporting the three weights 6, 7, and 8 are all attached to a nut 9. Various weights should now be tried attached at the end of the cords, and as near as possible lines drawn to the positions in which the parts of the cords lie over the paper. If the paper be removed and a triangle be drawn, as shown in the smaller diagram, with its sides parallel to the directions of the three lines so traced on the paper, it will be found that the sides of the triangle are in direct proportion to the three suspended weights. This experiment should be repeated for different series of weights; the law will be found to hold good in every case.



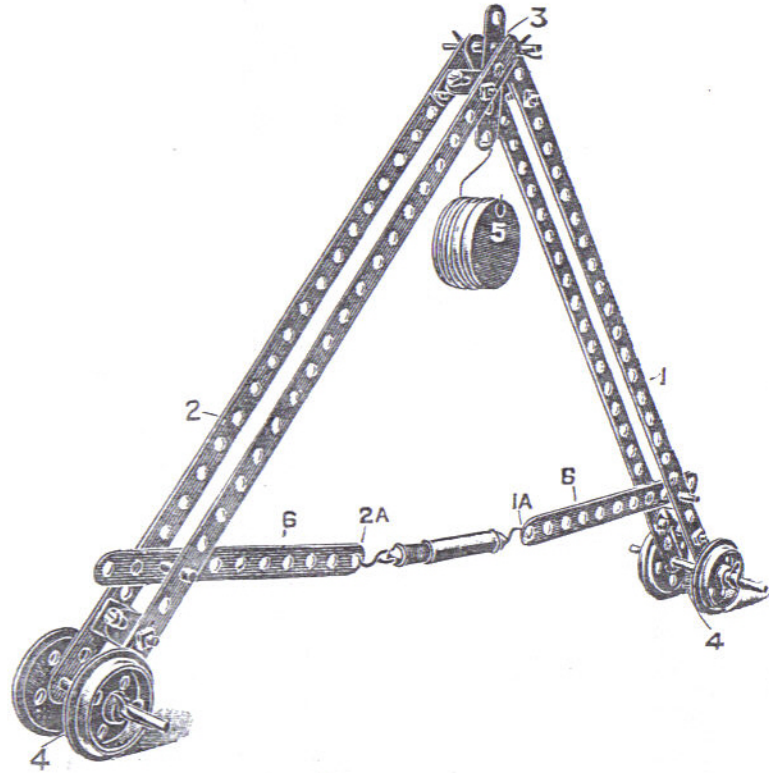
Jib Crane.



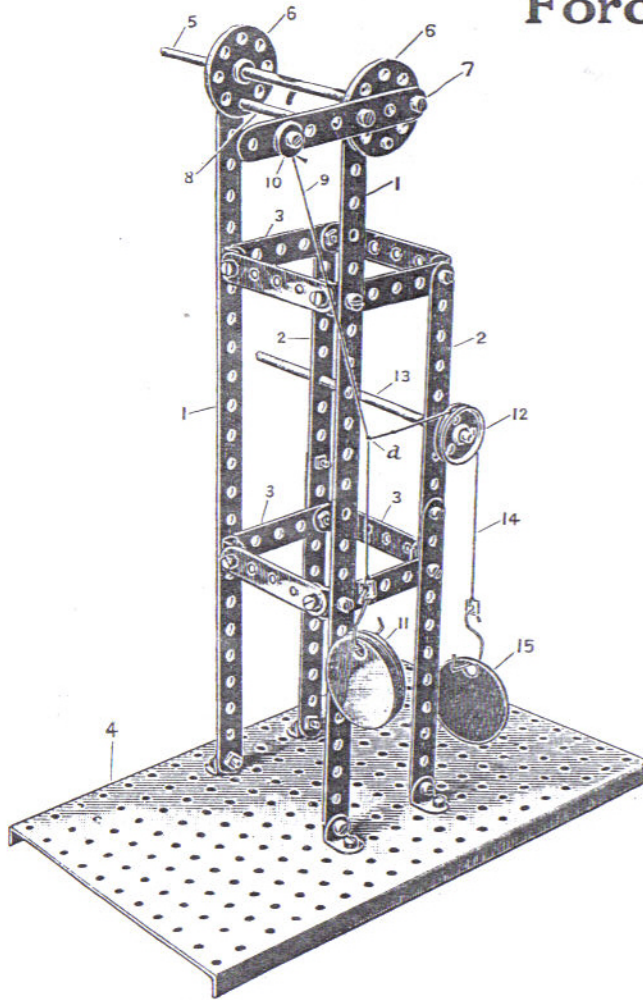
This model serves to illustrate how the forces in the tie and jib of a simple crane may be determined. If any weights be suspended by the cord 1 from the extremity of the jib 3, it will be found that the compression spring balance 4 and the tension spring balance 5 register various forces. The angles formed by the jib 3 and the tie 6 should be carefully noted, and a triangle then drawn with its sides parallel respectively to the vertical cord 1, the jib 3, and the tie 6, in a similar manner to that explained in the previous model. It will be found that in this case also the sides of the triangle so drawn are in direct proportion to the values of the weight 7 and the forces on the jib 3, and the tie rod 6. These are the three forces in this device meeting at a point represented by the end of the jib 8. This experiment should be repeated for different angular positions of the jib and the tie rod, when it will be found that the more nearly the jib approaches the horizontal position the greater will be the thrust upon it, while the more vertically it is disposed the nearer the compression force on it will approximate to the suspended weight.

Simple Roof Truss.

This apparatus serves to determine the forces acting in the different members of a simple triangular roof truss. The two main side members 1 and 2 are pivoted together at 3, and are furnished at their lower ends with wheels 4, so that when the weight 5 is suspended from the top pivot 3 the pulleys 4 allow of the members 1 and 2 expanding freely when resting on a flat support. The ends 1a and 2a are connected to the tension spring balance before the load 5 is applied, and shows the actual force set up on the tie rod 6 by the mere weight of the structure itself, due to the sloping rafters 1 and 2. If the load 5 be then hung from the pivot 3 it will be found that a considerable force is set up in the spring balance; this force is a tension force, because of the two ends 4 of the sloping rafters tending to move away from each other. The sloping rafters 1 and 2, however, are in compression, and therefore in a proper constructional iron-work framing, they should be made of angle irons, while the tie rod 6 being in tension need only be constructed of bar or flat iron. In constructional work where there is a pull or tension, flat bars are used, where there is a thrust or compression, angle irons are generally employed.

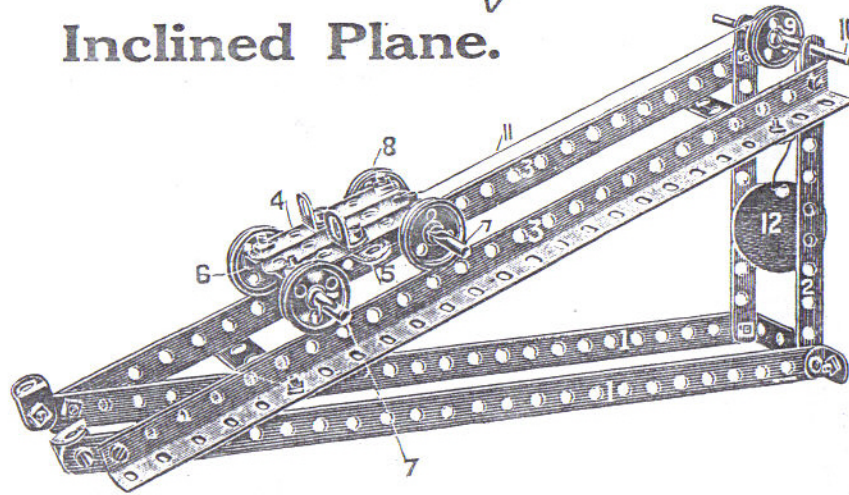


Forces Acting at the Cross Head.



This is an example for determining the forces in an engine which act at the cross head, such as the pressure on the slides of the engine. The frame work is constructed of long strips 1 tied to shorter strips 2 by short cross pieces 3. These are all carried from the perforated plate 4. In the upper perforations of the upright strips 1 is mounted the shaft 5, upon which are keyed the bush wheels 6. To the nearer bush wheel is bolted a strip 7 which corresponds to the engine crank, a locking bar 8 being provided which is adapted to be inserted through the perforations in the strips 1 and the perforations in the bush wheels 6, thereby locking these bush wheels and consequently the crank 7 at any desired angle. A cord 9 is now connected to the small wheel 10, rotatably mounted on the crank, this cord carrying at its lower extremity a weight 11. A pulley 12 mounted upon a spindle 13 receives a second cord 14, at the end of which weights 15 are suspended. The junction *a* of the cord 14 and 9 corresponds to the cross head of an engine, the lower portion of the cord 9 representing the piston rod, and the upper inclined portion the connecting rod. The pull of the cord 14 will be a measure of the pressure exerted on the slides due to the angularity of the connecting rod. The junction *a* of the cords 14 and 9 should be kept in line with the centre of the perforations in the nearer strip 1 by adding weights at 15, and the crank 7 should be set at different angular positions round its path. The different weights required to be hung on the cord 14 to keep the point *a* central on the nearer strip 1 for a given weight 11 should be noted for the various positions of the crank 7, and it will be seen by so doing that the greater weight 15 is required when the crank 7 is at right angles to the direction of the piston, and decreases as the crank becomes more in line with the piston. From this it should be noted that the thrust on the slides of an engine increases from a minimum when the engine is at the end of the stroke to a maximum when it is in the middle of this stroke, the weight 15 being a measure of the thrust exerted by the cross head on the slides.

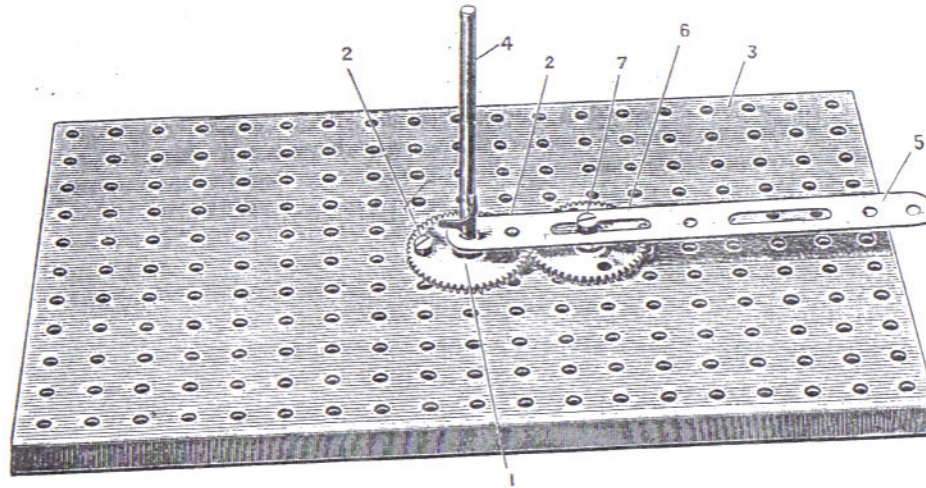
Inclined Plane. ✓



This is an example to illustrate the principle of the inclined plane. The main frame work is constructed of the horizontal strips 1 carrying the vertical strips 2. A pair of inclined angle girders 3 are bolted to the lower strips 1 and the uprights 2. A carriage, consisting of a series of strips 4 bolted to a cross strip 5 and to angle brackets 6, which carry the shafts 7, is adapted to roll on its wheels 8 along the upper edges of the angle girders 3. A pulley 9 mounted on a short shaft 10 rotates in the top perforations of the uprights 2, a cord 11 is passed over this pulley 9 to the carriage 4, and is provided at its lower end with a hook, upon which a series of weights 12 may be suspended. In the form of the apparatus shown, which is suitable for finding the conditions of equilibrium of a smooth body on a smooth inclined plane when the line of action is parallel to the plane, the weight 12 should first be found which is just necessary to maintain the carriage 4 still upon the plane. Then by placing a weight upon the carriage the additional force 12 should be noted which is now necessary to maintain the carriage in equilibrium. By the aid of the triangle of forces previously

referred to the results may now be checked, the three forces and their directions being obtainable from the following data. The force 12 acts on the carriage in a direction along the cord 11 and parallel to the plane, while the weight of the carriage is to be resolved into two forces, one acting vertically downward, and the other at right angles to the direction of the plane. A triangle drawn with its sides parallel to these three directions will give the proportionate values of the three forces. By withdrawing the spindle 10 and inserting it with its pulley at a lower position in the upright strips 2, the cord 11 may be arranged to act horizontally on the carriage 4. This arrangement gives the second condition of the inclined plane where the line of direction of the force maintaining equilibrium acts horizontally. The procedure should be exactly as in the previous experiment, by first correcting for the weight of the carriage, when it will be learned from this experiment that if the weight on the plane be represented by the length of its base, the reaction of the plane will be represented by the length of the plane, and the force which maintains equilibrium by the height of the plane.

Epicycloidal Gear.



This model serves to illustrate the principle of an epicycloidal type of gearing. The main gear wheel 1 is bolted at 2 to the perforated plate 3, so that it is fixed to this plate; a short spindle 4 is loosely fitted in the bush of the fixed wheel 1, and a slotted strip 5 is mounted upon the spindle 4 and held in position axially on the strip by a key. At a suitable distance radially outward on the strip 5 a bolt 7 is fixed in one of the slots of the strip on the shank of which a gear wheel 6 is capable of rotating. As the arm 5 is rotated round the spindle 4 it will be noticed that the loose gear wheel 6, though of the same diameter as the fixed wheel 1, will make two complete revolutions about its axis 7 for every one complete revolution of the arm 5 about the fixed spindle 4.

This type of gear in which one wheel rotates outside another is called epicycloidal gear. Where a gear wheel or pinion rotates round a gear wheel, the teeth of which are formed on the inner face of the wheel, the gearing is called hypocycloidal.

Explanation of the Metric System.

Units.

- The Metre** is the basis of the whole "METRIC SYSTEM." It is the unit for measures of length, and is the one ten-millionth part ($\frac{1}{10,000,000}$ th) of a quadrant of the meridian, or distance from the pole to the equator.
- The Square Metre** is the unit for measures of surface, and is a square having sides each one metre in length.
- The Cubic Metre** is the unit for measures of volume or solids, and is a cube having edges each one metre in length.
- The Litre** is the unit for measures of capacity, is a "cubic decimetre"—that is, the capacity of a cubic vessel measuring one decimetre or ten centimetres on all its inside edges.
- The Gramme** is the unit for measures of weight, and is the weight of a cubic centimetre of pure cold water.



One Decimetre.



Conversion Table.

One Metre = 39.371 inches.

One Litre = 1.76 pints.

One Gramme = .0352 oz.

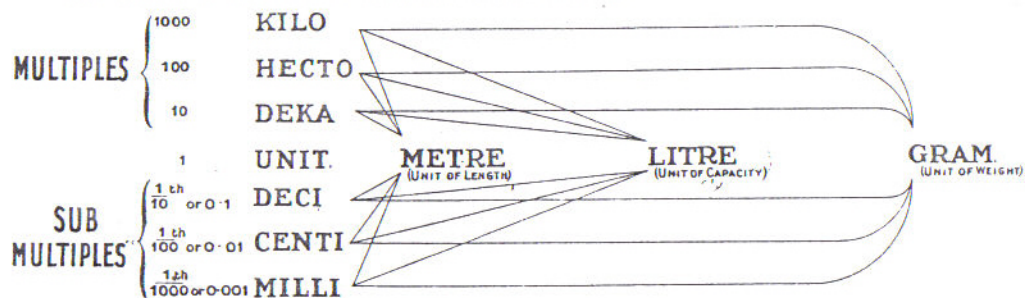
One of the greatest advantages of the "METRIC SYSTEM" is the direct relation between weights and measures.

Explanation of the Metric System.

Multiples and Sub-Multiples.

The Multiples in the "METRIC SYSTEM" are indicated by the Greek prefixes indicating "Deka," ten times, "Hecto," one hundred times, "Kilo," one thousand times.

The Sub-Multiples are indicated by the Latin prefixes—"Deci," one tenth, "Centi," one hundredth, "Milli," one thousandth. It is therefore evident that the Multiples and sub-Multiples always bear to one another the relation of ten or a multiple of ten, and it is merely necessary to move the decimal point to read the figures in any desired Multiple or Sub-Multiple.



Anyone constructing the above diagram intelligently will understand the Metric System.

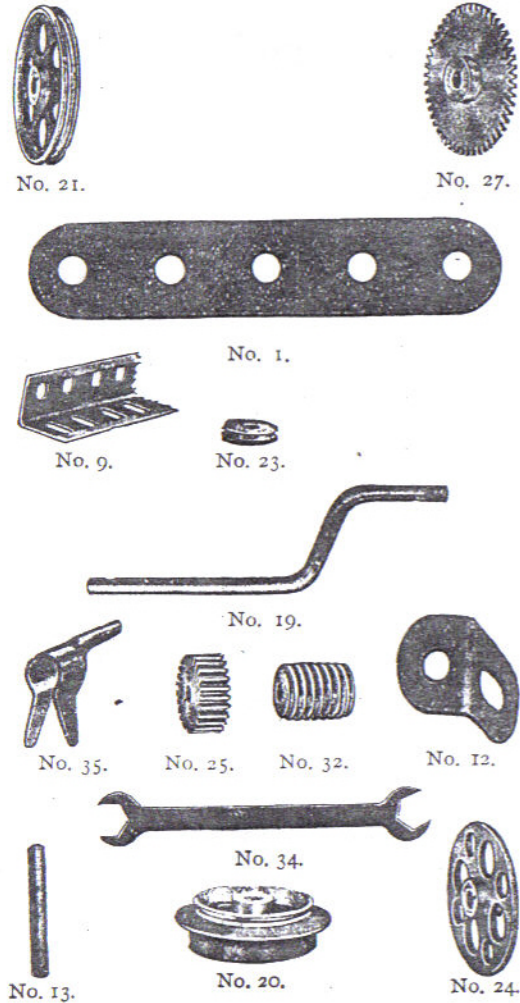
The Multiples of the Metre are	{ The Dekametre = 10 Metres „ Hectometre = 100 „ „ Kilometre = 1,000 „	The Sub-Multiples of the Metre are	{ The Decimetre = $\frac{1}{10}$ th of a Metre. „ Centimetre = $\frac{1}{100}$ th „ „ „ Millimetre = $\frac{1}{1000}$ th „ „
The Multiples of the Litre are	{ The Dekalitre = 10 Litres „ Hectolitre = 100 „ „ Kilolitre = 1,000 „	The Sub-Multiples of the Litre are	{ The Decilitre = $\frac{1}{10}$ th of a Litre. „ Centilitre = $\frac{1}{100}$ th „ „ „ Millilitre = $\frac{1}{1000}$ th „ „
The Multiples of the Gramme are	{ The Dekagramme = 10 Grammes „ Hectogramme = 100 „ „ Kilogramme = 1,000 „	The Sub-Multiples of the Gramme are...	{ The Decigramme = $\frac{1}{10}$ th of a Gramme „ Centigramme = $\frac{1}{100}$ th „ „ „ Milligramme = $\frac{1}{1000}$ th „ „

This information is given by the courtesy of the Decimal Association, Finsbury Court, Finsbury Pavement, London, E.C.

Contents of Outfits.

Description of Parts.	A.	AA.	B.	BA.	C.
Perforated Strips, 32 cm. long	2	—	2	2	4
" " 14 " "	6	8	14	—	14
" " 9 " "	10	—	10	—	10
" " 7½ " "	4	4	8	—	8
" " 6 " "	2	8	10	—	10
" " 14 " " (slotted)	—	—	1	—	1
" " 32 " " (double)	3	—	3	—	3
Angle Girder 32 " "	4	—	4	—	4
" " 14 " "	12	—	12	—	12
Angle Brackets	7	11	18	—	18
Axle Rod 13 cm. long	—	2	2	—	2
" " 9 " "	—	3	3	—	3
" " 5 " "	—	2	2	—	2
" " 4 " "	—	—	—	7	7
Crank Handle	—	1	1	—	1
Flanged Wheel 38 mm. dia	—	4	4	—	4
Pulley	—	2	2	—	2
" " 25 " "	—	2	2	3	5
" " 12 " "	—	—	—	2	2
Bush	—	2	2	—	2
Pinion	—	—	—	3	3
Gear	—	—	—	3	3
Worm	—	—	—	1	1
Spanner	2	—	2	—	2
Keys	—	9	9	5	14
Screwdriver	1	—	1	—	1
Nuts and Bolts	24	32	56	—	56
Balls, Cord	—	1	1	1	2
Spring Balance (tension)	—	—	—	1	1
" " (compression)	—	—	—	1	1
Weights, 20 grammes	—	—	—	10	10
Stand	1	—	1	—	1
Single Bent Strip	—	—	—	3	3
Double	—	2	2	—	2
Large	—	2	2	—	2
Eye Piece	—	2	2	—	2
Rubber Bands	—	2	2	—	2
Hook	—	—	—	4	4

Separate Parts.



Price List of Additional Parts.

			s.	d.
1.—Perforated Strips	32 cm. long	.. .. each	0	3
2.—	" " 14 " "	.. .. "	0	2
3.—	" " 9 " "	.. .. "	0	1
4.—	" " 7½ " "	.. .. "	0	1
5.—	" " 6 " "	.. .. "	0	1
7.—Perforated Strip (slotted),	14 cm. long	.. .. "	0	3
8.—	" " (flat, double), 32 cm. long	.. .. "	0	4
9.—Angle Girder,	32 cm. long	.. .. "	0	4
10.—	" " 14 " "	.. .. "	0	3
12.—Angle Brackets	.. ..	per 12	0	6
15.—Axle Rod,	13 cm. long	.. .. each	0	2
16.—	" " 9 " "	.. .. "	0	2
17.—	" " 5 " "	.. .. "	0	1
19.—Crank Handle	.. ..	.. ..	0	3
20.—Flanged and Grooved Wheel,	38 mm. dia.	.. ..	0	9
21.—Pulley Wheel,	38 " "	.. ..	0	6
22.—	" " 25 " "	.. ..	0	4
23.—	" " 12 " "	.. ..	0	2
24.—Bush Wheel	38 " "	.. ..	0	6
25.—Pinion Wheel	19 " "	.. ..	0	9
27.—Gear Wheel	38 " "	.. ..	0	10
32.—Worm	.. ..	.. ..	0	9
34.—Spanner	.. ..	.. ..	0	3
35.—Keys	.. ..	per 12	0	6
36.—Screwdrivers	.. ..	.. each	0	3
37.—Nuts and Bolts	.. ..	per 24	1	0
39.—Ball Cord (Special)	.. ..	.. each	0	2
47.—Spring Balance (tension)	.. ..	.. ..	2	6
48.—	" " (compression)	.. ..	2	6
49.—Disc Weights,	20 grammes	.. ..	0	4
50.—Perforated Stand	.. ..	.. ..	1	6
51.—Eye Piece	.. ..	.. ..	0	2

Price List of "Hornby" System Scientific Series.

No. A. "Hornby" System Outfit - - - - 10/-

No. B. Do. do. - - - - 35/-

Packed in well made walnut stained box.

No. C. Do. do. - - - - 70/-

Packed in well made walnut stained box.

No. AA "Hornby" System Accessory Outfit - - 27/6

Containing sufficient parts to convert a No. A into a No. B Outfit.

No. BA Do. do. do. - - 37/6

Containing sufficient parts to convert a No. B into a No. C Outfit.

