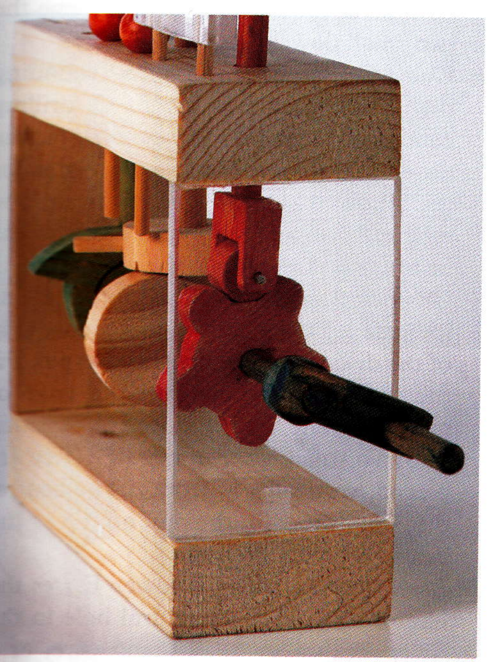
ergonomically in your design, so much the better.

Wood is an imprecise material, and the amount of 'play' in a wooden bearing is critical. Even after test-drilling, the dowel shaft of the follower in the bearing may not work 'on the night'. It is frustrating and you may be tempted to drill too wide a hole to allow ease of action. That can lead to problems, with the follower jamming on certain cams. Using a panel or bar, either openly or artfully concealed, can overcome these difficulties.

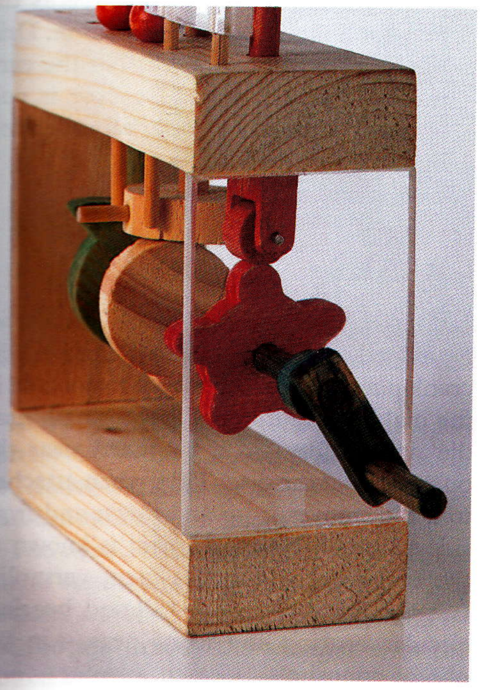
If your design does not allow for such problem-solving devices, remember that the deeper the follower's channel in the bearing, the better it will perform.



The roller follower is at the lowest point on the profile of the pentagonal cam. There are five events per revolution, or cycle.

The Roller Follower

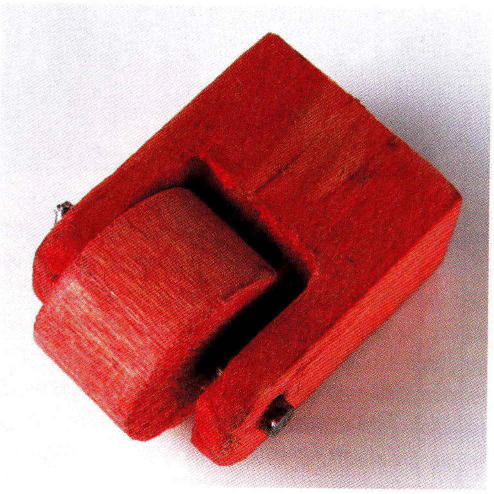
The free-running bearing or roller, fixed on the end of a pin follower, will facilitate tracking cams that have eventful profiles. An empirical approach will determine when and where you should use it. In most simple automata, it is rarely seen, because the cams are uncomplicated. It is only when the follower needs to track the cam's profile accurately that the device can play a useful role in relaying precisely the cam's message to the follower. It also reduces friction, which might be an important factor in the design of the piece.



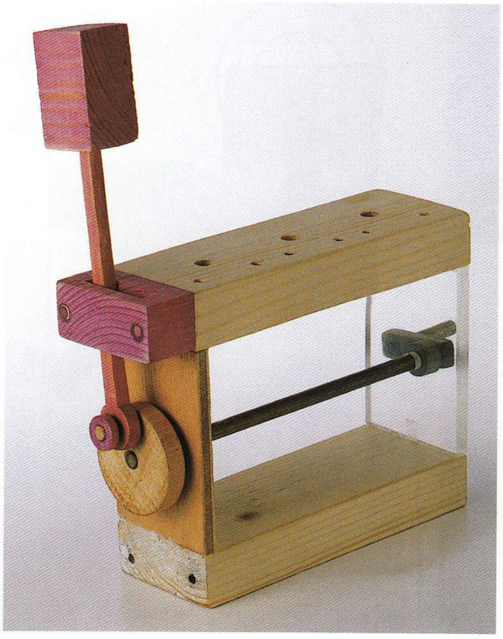
The roller is at the highest point on the profile of the pentagonal cam. The crank handle has moved from 20 to 25 past the hour, being one event in the cycle.

Making Cams and Followers

1. Cut five discs A, from 1⅛in (28mm) dowel. Drill holes as indicated, to fit tightly on dowel rods. The middle three

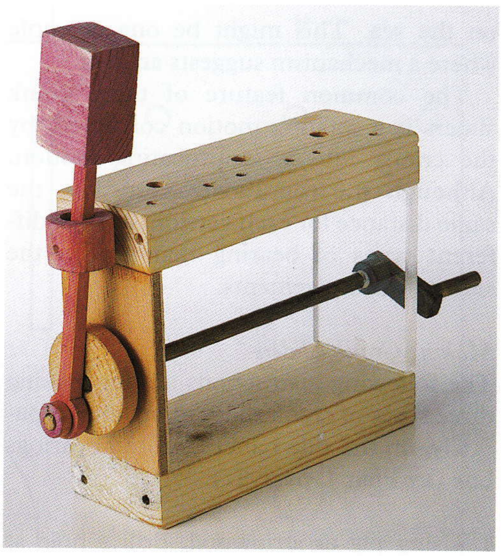


This roller is to be fixed to the end of a pin follower. It smoothes the path on a cam with an eventful profile.



FAR LEFT: The crankshaft turns the crank pin, which raises and lowers the weighted rod, backward and forward, within a fixed slotted bearing. This is called a crank slider.

The crank has converted rotating motion into reciprocating motion. The amount of vertical movement can be seen.



FAR LEFT: The rod at its highest point is moving within a fixed circular bearing.

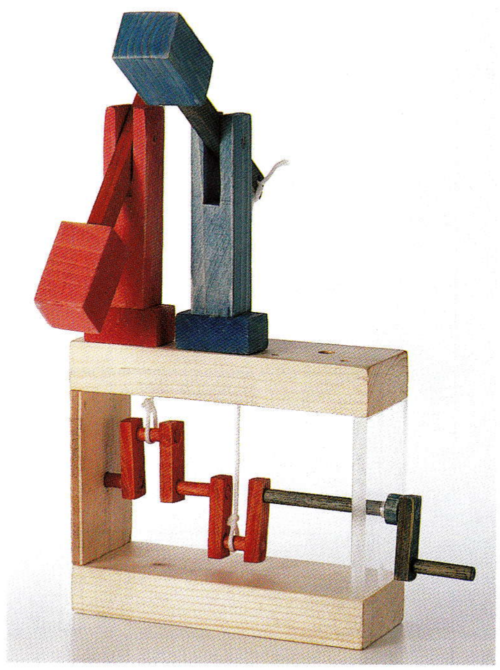
There is less lateral movement in the circular bearing than in the slotted bearing.

the slotted bearing version, in an open ow box without a base, the rod rides, up down, within the slot. It is a fairly vigor- hammering movement.

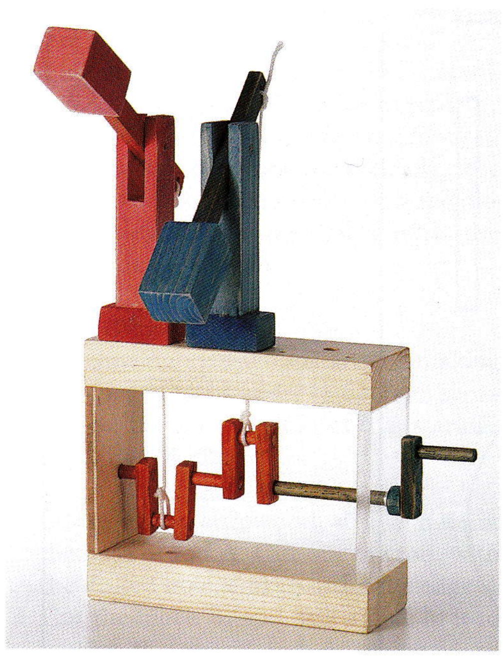
he circular bearing version confines the al motion to a gentle nodding. The nce travelled and the height gained by rod are exactly the same as with the ed bearing. The amount of play within the circular bearing determines the degree of lateral action.

The third version of the crank slider allows for experimentation with the use of pegs. The lower the pegs are placed on the peg board, the greater the side-to-side movement. This version combines the actions offered by the other two and, at its most active, evokes the image of a boat bobbing

As the red lever is down the crank beneath is up. While the blue lever is up, the crank below is down.



It can be seen that the crank merely follows the rotation of the handle. As the red lever is up the crank beneath is down. While the blue lever is down the crank below is up.

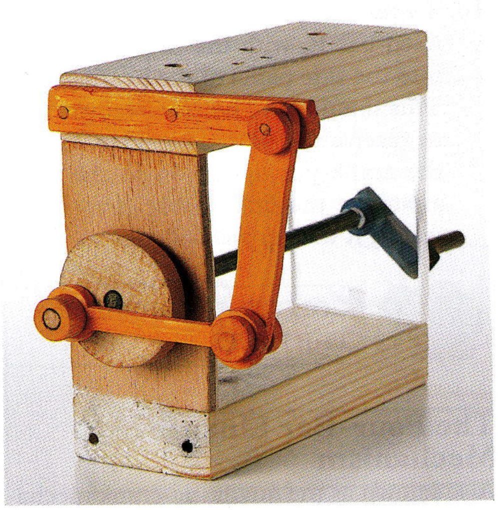


Strings or wires are looped loosely around the crank pins, to allow the pulling up and lowering of weighted levers. If the cranks are offset from each other they can operate in alternating rhythm.

The most important thing to remember in making crankshafts is that it is essential to determine the *throw* of a crank. This is the diameter of the path it travels in one revolution. Unless you allow for this, the mechanism may jam in the bearings box, or whatever device you employ to house the crankshaft. For example, the dimensions of the cranks in Plan 5 are not designed to work with front and back panels, since the box is open. With a closed box, the depth of the box would need to be wider, or the cranks smaller.

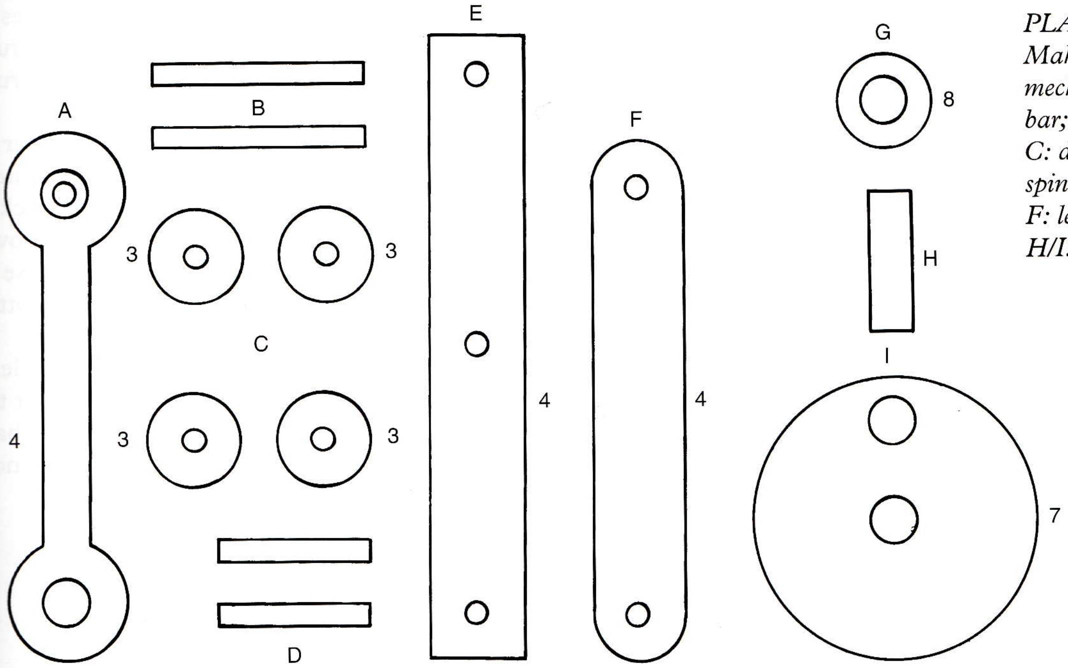
Making a Double Crankshaft

1. Cut a long dowel D, the complete length of the shaft on Plan 5. Cut two short dowels C, and one for the handle F.
2. Cut five lengths of 5 × 10mm (3/16 × 3/8in) stripwood, as indicated, for the cranks B. Drill holes in them to accommodate dowels C, D and F.
3. Position the two cranks, as on the plan, with the shaft, as yet uncut, running through them with a tight friction fit. This is best done working on a grid, graph paper or calibrated cutting mat. It is important to build the crankshaft as truly square as possible. Acetate or cellophane are good materials to work on. They allow both transparency and protection of the grid's surface from excess glue.
4. Glue and insert the crank pins C into the top and bottom of the two cranks B, and the dowel handle F, into the remaining crank B.
5. The left-hand part of the shaft D (coloured red) can be glued into the cranks B. The blue part, however, must be left unglued and detachable to fit into the bearings box. A tight friction fit is essential here, as otherwise slippage could occur.
6. The handle assembly B/F is now glued to the shaft D, square to the cranks. When the crankshaft is completely dry, the two redundant parts that have been holding



FAR LEFT: When the crank pin rotates, the linkage bar to which it is attached transfers movement to the vertical lever pivoting on the fixed bar.

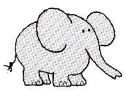
The rotary motion of the linkage bar turns into a side-to-side movement of the vertical lever. Half a turn will thrust it forward, and a complete turn will draw it back.



PLAN 7
Making a linkage mechanism. A: linkage bar; B: dowel pins; C: dowel collets; D: dowel spindles; E: fixed bar; F: lever; G: dowel collet; H/I: crank disc and pin.

5. Drill holes in, and cut out, the lever F.
6. Cut the crank pin disc I, from either dowel or ply. Drill holes as indicated, cut and glue the dowel pin H into the outer hole.
7. Cut the two short dowel spindles D, 3mm (⅛in), and insert one of them, freely, through the vacant hole in the fixed bar E. Secure this with a tight dowel collet C, adjacent to the two long, projecting dowel pins B, in the fixed bar E.
8. Place one end of the lever F on to the spindle D, and secure this joint with a tight dowel collet C.
9. Place the linkage bar A on top of the lever G, inserting a dowel spindle D through them both. Lock the spindle at either end with tight dowel collets C, ensuring that the parts move freely.

10. To assemble the mechanism, insert the fixed bar E, with the two dowel pins, into the side panel of the bearings box. This should have holes, already drilled, to receive the pins, as in Plan 1B. Fix the crank pin tightly on to the shaft, attaching the linkage bar A to it and sealing it with dowel collet G.



COLOUR AND NUMBER THE PARTS

The Four-Bar Linkage Mechanism

Also known as the quadratic-crank mechanism, the four-bar linkage mechanism is also sometimes referred to as the three-bar linkage, since only three bars are visible. The fourth is an invisible, stationary bar, which connects the lever in the pivot block to the crank.

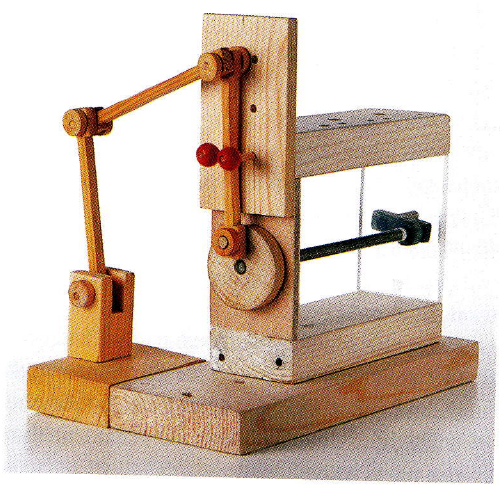
Whether three- or four-bar, the mechanism consists of four links connected by pin joints; the first link has already been mentioned; the second link is the crank; the third is the coupler, which connects the crank, or linkage bar, to the fourth link, which is the lever.

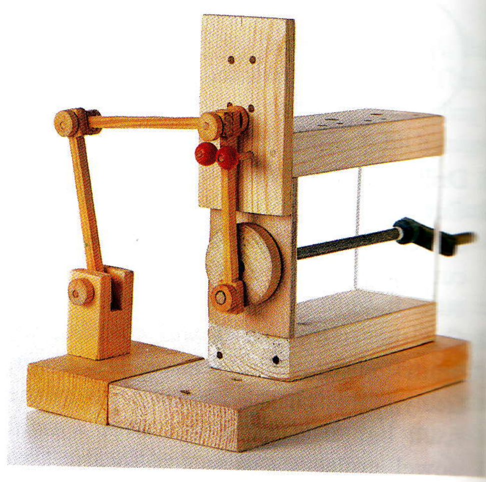
The linkage employs a crank slider device (*see* page 86), with pegs to contain the linkage bar. The bar can make a complete revolution while the lever moves from side to side, translating rotation into oscillation.

Making the Four-Bar Linkage Mechanism

Unlike the previous mechanisms, the four-bar linkage needs an extension of the dimensions afforded by the bearings box; in short, it requires a plinth.

1. Cut out the plinth A, as shown on Plan 8. Now refer to Plan 1C, which shows the location of peg holes in the base of the bearings box. Cut the four pegs to fit. Drill four corresponding holes in the plinth A. Glue and insert the pegs, so that the two nearest the large holes in the plinth, to be used later on, protrude 5mm ($^{3}/_{16}$in) and the other two protrude 14mm ($^{9}/_{16}$in).
2. Cut out the linkage bar B, the coupler C, and the lever D. Drill holes, as indicated.
3. Cut out the base E for the pivot block F. Locate and drill holes for the two dowel pegs, which are cut to length. These fit into plinth A, as shown by the dotted lines.
4. Cut out pivot block F, and drill a hole to receive the block pin I. Now cut out the recess in the block. Glue this to its base E, as shown on the plan. They can now be glued into the block E.





Four-bar linkage consists of four links connected by pin joints. Rotation of the crank is translated into an oscillating movement of the lever, by means of the coupler bar that connects them.

FAR RIGHT: *The crank's action turns into an ellipse where the linkage bar meets the coupler. It then turns into an arc, where the coupler joins the lever.*

5. Cut six dowel collets G and two dowel spindles H. Cut a longer dowel for the block pin I.
6. Cut the crank pin dowel J, the dowel collet K, and the wheel itself L.
7. To assemble the mechanism, slot the pivot block E/F into the plinth A, as shown, *with the two fixed pegs. Insert the crankshaft through the bearings box* and fix the crank pin J/L to its end. Press the bearings box on to the pegs in the plinth A.
8. Refer to Plan 4C. The crank slider peg board and pegs are essential to the operation of the four-bar linkage. This should have been cut and drilled already if you are working, in sequence, through the mechanisms. Fix the peg board, by the glued-in pegs, into the outer h in the side of the bearings box.
9. Assemble the three bars B, C and *The linkage bar B is fixed under* coupler D, loosely locked by a spindl and two collets G. The lever D attac likewise to the other end of the coup *C. Glue the collets to the spindles t* ensure that the three-pieced mechanis works freely within the joints.
10. Fix the free end of the linkage bar B c to the crank pin J/L. Place the tw headed dowel pins into the peg boa (made from Plan 4), to govern th linkage bar B.
11. Insert the free end of the lever D in the pivot block F, passing the block p I through and securing with dowel co lets K. Leave one of these unglued, s that the mechanism can be dismantle

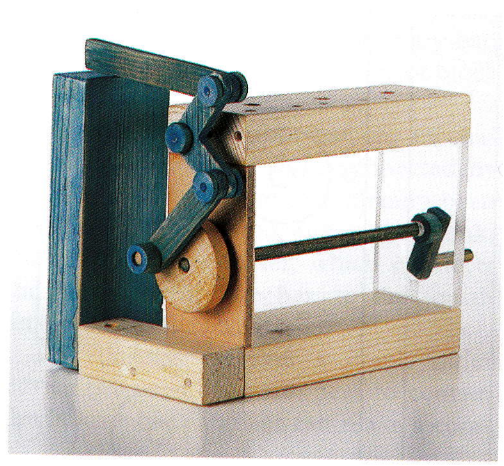
COLOUR AND NUMBER
THE PARTS

The Bell Crank

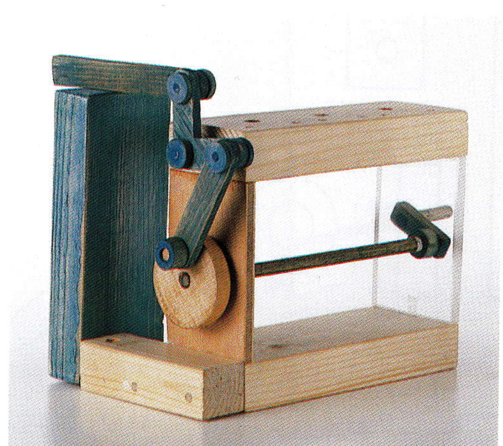
This linkage is actually a kind of lever. I the L-shaped component is extended, i either direction, the movement achieve gives greater leverage. This can also b done by moving the position of the ful crum; some patient experimentatio should bring about satisfying results whe incorporating this linkage into a piece One action the movement seems to evok is that of a woodpecker.

Making the Bell Crank

1. Cut the lever support block A, from $^{13}/_{16}$in (20mm) batten, and drill a hole, a indicated on Plan 9, to a depth o 16mm ($^{5}/_{8}$in).
2. Cut out the extension block D. Drill a hole to match the hole in the lever support block A, to a depth of 17mm ($^{11}/_{16}$in).
3. Cut the thick dowel pin C to fit into both these holes. Glue it into the lever support block A.

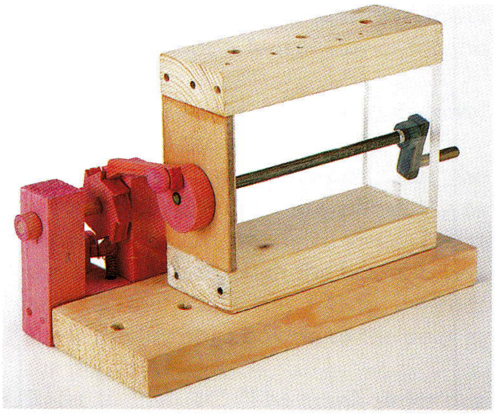


The bell crank linkage alters an up-and-down motion into a side-to-side motion. This is achieved by the L-shaped component joining the linkage bar to the lever, at the top.

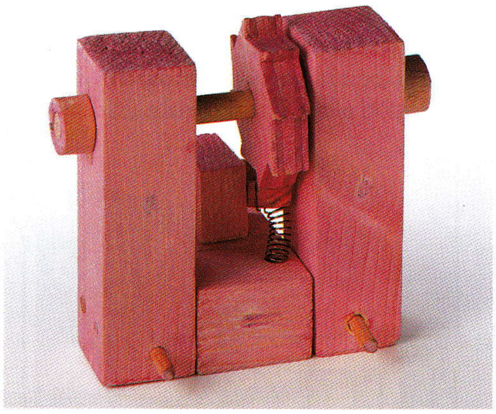


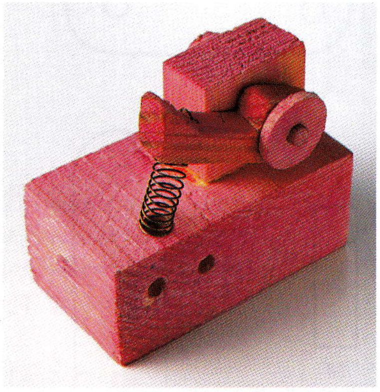
The horizontal, push-pull action of the lever, at the top, moves 25mm (1in) on this model.

The ratchet is a notched wheel, enabling movement to be effected in one direction only. This is achieved by a driving pawl pushing the ratchet wheel forward and a supplementary pawl checking it from slipping back.

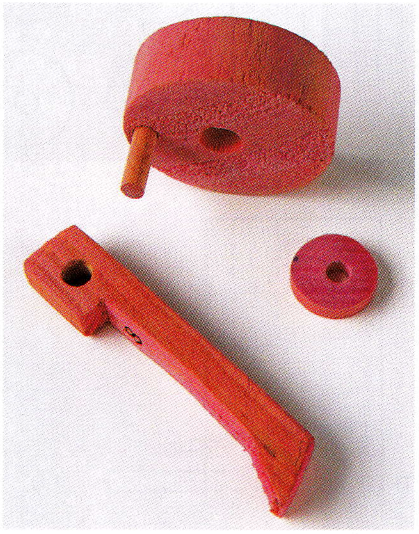


The ratchet block assembly shows the supplementary pawl, supported by a spring, engaging the ratchet wheel. This moves forward one notch per revolution.





ABOVE: *Detail showing how the supplementary pawl is positioned on the block. The spring is super-glued into holes in the block and the underside of the pawl.*



The driving pawl, the crank pin and the dowel collet, which locks it in position.

13. Insert the lever support block A, and its fixed dowel pin C, into the extension block D. Place the lever A on top and operate.

COLOUR AND NUMBER THE PARTS

RATCHETS

The ratchet supplies movement that is not continuous and can give a piece more time in which to complete a cycle. This intermittent, or stepped motion is governed by the number of teeth on the ratchet wheel.

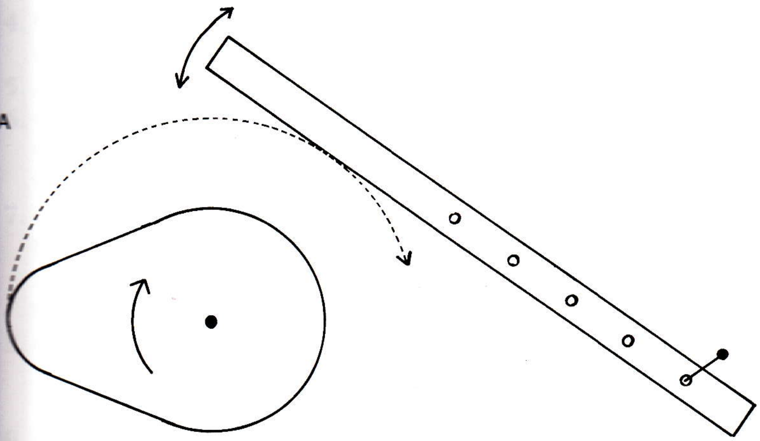
On this model there are eight teeth on the wheel. In order to complete the whole cycle, the crank needs to be turned eight times, with one revolution moving the ratchet wheel forward one notch. At, say, a second at a time, one cycle takes eight seconds.

The ratchet mechanism is governed by a long arm, the driving pawl, which turns on the crank pin, pushing the notched wheel forward. Below the wheel is a shorter arm, the supplementary pawl, which ensures that the wheel stops at the right place, correctly positioned for each push of the driving pawl.

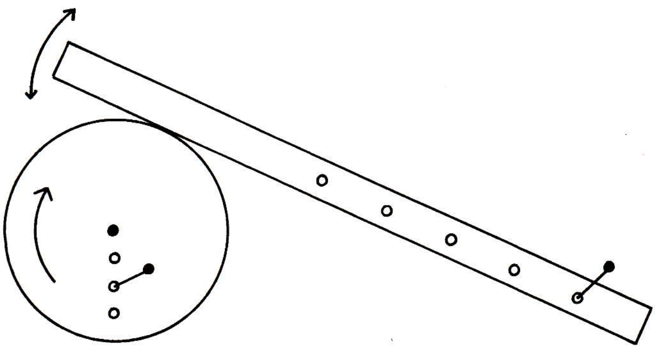
Making the Ratchet Assembly

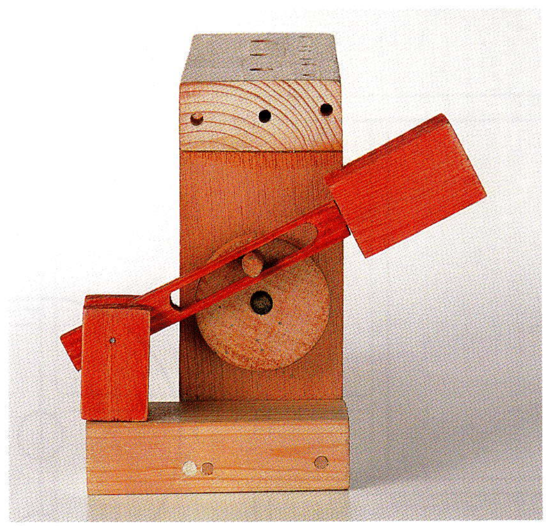
1. Cut out two pillars A, and drill holes in them, as indicated on Plan 10. Drill holes in their sides, centrally positioned, to receive two cut 3mm (⅛in) dowels. Glue these in.
2. Cut out the ratchet block B/C. Drill a shallow – 3mm (⅛in) – hole in block B, for the spring D. The exact diameter must be determined by the size of spring inserted.
3. Drill holes in the sides of block B to match the holes you cut in the pillars A. Cut and insert 3mm (⅛in) dowel pins to fit them.

A



B





ABOVE: Testing levers can be simply done by using cut-out card and pins. A shows a pear-shaped cam, which produces much the same performance for the lever as B, the eccentric disc, does for its lever. By experimenting with the pin holes, you can quickly and cheaply test the best positions for your mechanism.

ABOVE RIGHT: The slotted lever's positive contact with the crank pin does not depend on gravity, but moves within its restricted channel.

Restricted and Unrestricted Levers

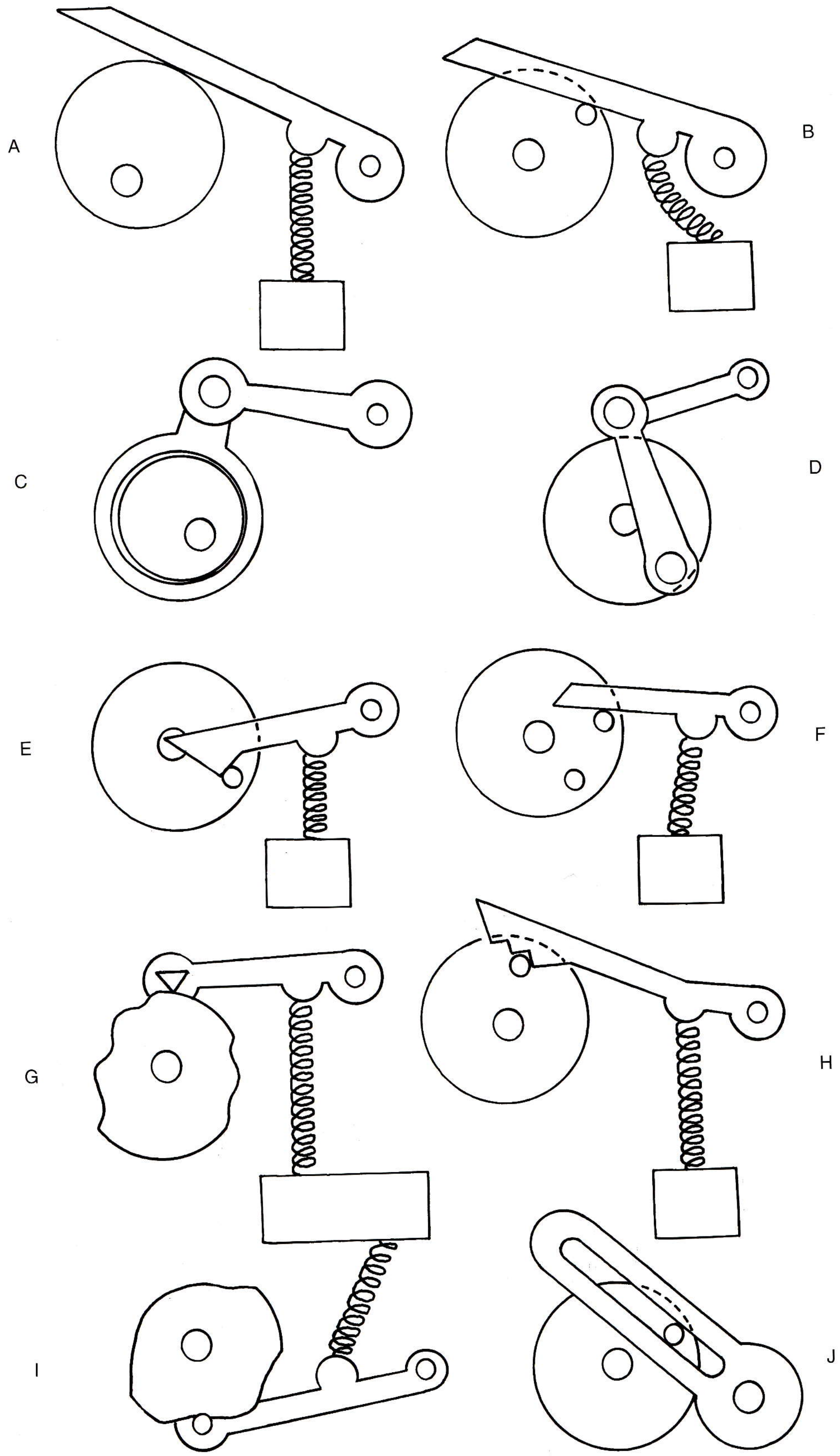
The essential thing to remember when making levers is to construct their pivot points so that when the piece is moved or handled, the levers do not fall out of position. If you are using a pivot block in which to house the lever, ensure that the slot is deep enough to allow freedom of action, but not so deep that it does not act as a stop to prevent the lever from flying off the crank pin.

The advantage of the restricted, slotted lever is that, with or without a pivot block, the path of the lever is always controlled within its channel.

Making Slotted and Plain Levers

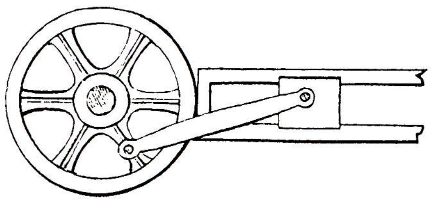
1. Cut out the lever support block A, from 20mm ($^{13}/_{16}$in) batten, and drill holes as indicated on Plan 15.
2. Cut two thin dowel pins and glue these into the two small holes in the lever support block A.
3. Cut out the short pivot block B. Drill holes for the support peg and spindle I. Cut out the slot for the lever.

The performance is similar to the crankshaft's string-operated 'nodding donkey', although here it is driven within its restricted limit.



PLAN 16
Miniature Mechanisms
A: eccentric disc with continuous movement; B: eccentric crank pin with continuous movement; C: eccentric disc with follower giving continuous movement; D: eccentric crank with connecting rod, giving continuous movement; E: eccentric crank pin with slow and sudden release of runner, giving intermittent movement; F: eccentric double crank pin with stepped and sudden release of the runner, giving intermittent movement; G: cam and runner with knife edge; H: crank pin and shaped runner giving a slow and 'nodding' release of the runner; I: cam and runner with pin; J: crank pin and slotted runner.

1



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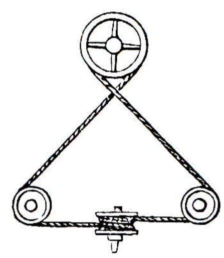

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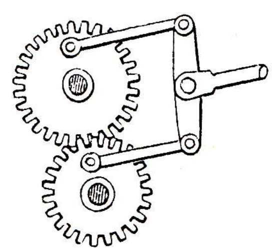

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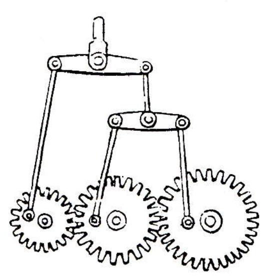

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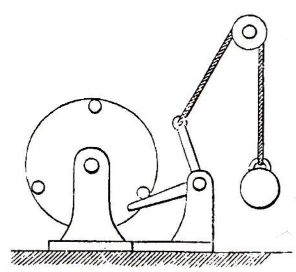

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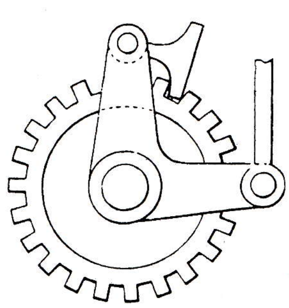

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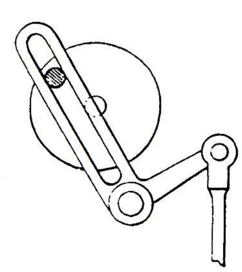

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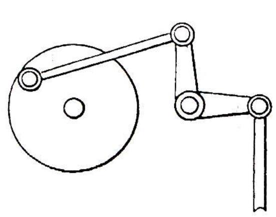

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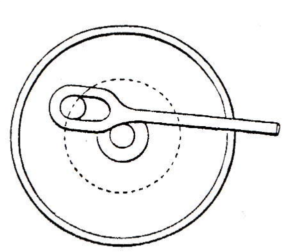

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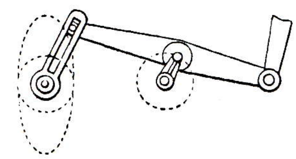

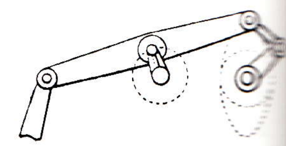

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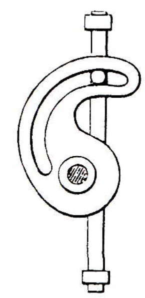

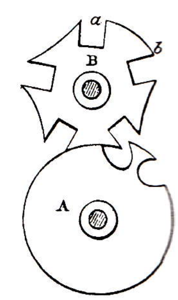

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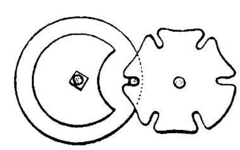

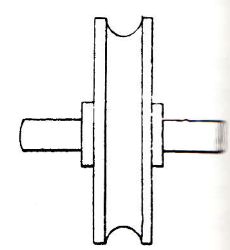

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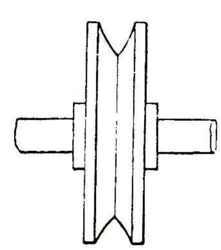

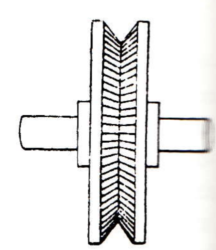

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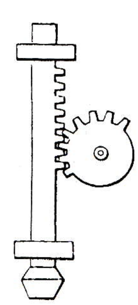

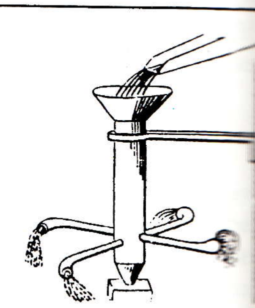

ie flat without touching the bead knobs. The lid must also be able to close without ouching the mechanisms.

The dimensions of the box, made from 8mm (5/16in) pine, are 254 × 146 × 47mm (10 × 5¾ × 1⅞in) with the lid closed. The plan shows the actual size of the inside area. Fix two brass latches and screws to he lid at the front, and brass hinges at the back, to secure the lid to the box. The back s left open for easy operation of the knobs.

ADDITIONAL MECHANISMS

The nineteen mechanisms listed opposite and below, which are especially useful to the automatist, are taken from Henry T. Brown's *Five Hundred and Seven Mechanical Movements* published in 1868.

1. Ordinary crank motion.
2. A method of transmitting motion from a shaft at right-angles to another whose axis is in the same plane.
3. The rotation of the two spur gears, with crank pins attached, produces a variable alternating traverse of the horizontal bar.
4. A more complex modification of No.3.
5. Circular motion into alternating rectilinear motion, by the action of the studs on the rotary disc upon one end of the bell crank, the other end of which has attached to it a weighted cord passing over the pulley.
6. Reciprocating rectilinear motion into intermittent circular motion by means of the pawl attached to the bell crank, and operating in the toothed wheel.
7. Circular motion into variable alternating rectilinear motion, by the crank pin on the rotating disc working in the slot of the bell crank.
8. A modification of No.7, a connecting rod being substituted for the slot in the bell crank.
9. The rotation of the disc carrying the crank pin gives a to-and-fro motion to the connecting rod. The slot allows the rod to remain at rest at the termination of each stroke.
10. The slotted crank on the left is attached to the shaft, and the connecting rod that connects it with the reciprocating moving power has a pin that works in the slot of the crank. Between the first crank and the moving power is a shaft carrying a second crank, attached to the same connecting rod. While the first crank moves in a circular orbit, the pin at the end of the rod moves in an elliptical orbit, increasing the leverage of the main crank at those points most favourable for the transmission of power.
11. A modification of No.10, in which a link is used to attach the connecting rod to the main crank, dispensing with the slot shown in No.10.
12. By turning the shaft carrying the curved slotted arm, a rectilinear motion of variable velocity is given to the vertical bar.
13. The Geneva Stop, used in watches to limit the number of revolutions in winding up. The convex curved part a, b of the wheel B serves as the stop.
14. Another modification of the Geneva Stop.
15. A concave-grooved pulley for a round band.
16. A smooth-surfaced V-grooved pulley for a round band.
17. A V-grooved pulley with its groove notched to improve adhesion of the band.
18. Stamp. Vertical percussive falls derived from horizontal rotating shaft. The mutilated toothed pinion moves up the rack to raise the rod until its teeth leave the track and let the rod fall.
19. Barker's or reaction mill. Rotary motion of the central hollow shaft is obtained by the reaction of the water escaping at the ends of its arms. The rotation is in the reverse direction of the escape.

OPPOSITE PAGE: Nineteen mechanisms especially useful to the automatist.