



MACHINATIONS: Mechanisms

It is the business of all four presenters of Channel 4's *Machinations* programmes to make things happen. The happenings themselves might be quite diverse, but the underlying intention is to produce some kind of show. It might be theatre, it might be sculpture, philosophy or education, or it could be just a joke. My work is a hellish brew of all those things. All four of us handle machinery, and in that respect we are all subject to the same physical laws and constraints. The idea of the programmes was to use the making of our work as an opportunity to point out some aspects of engineering design.

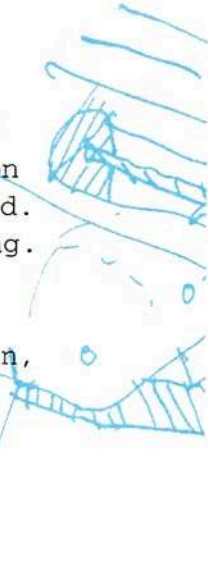
In his film *Vibrations*, Johnny White, who fled a real engineering career at Bird's Eye Foods, chose to make machines that were embodiments of the principles he wanted to deal with. His 'Sillyscope' illustrated the generation of wave forms by being a wave form. In the other three shows the connection between theory and practice is less intimate.

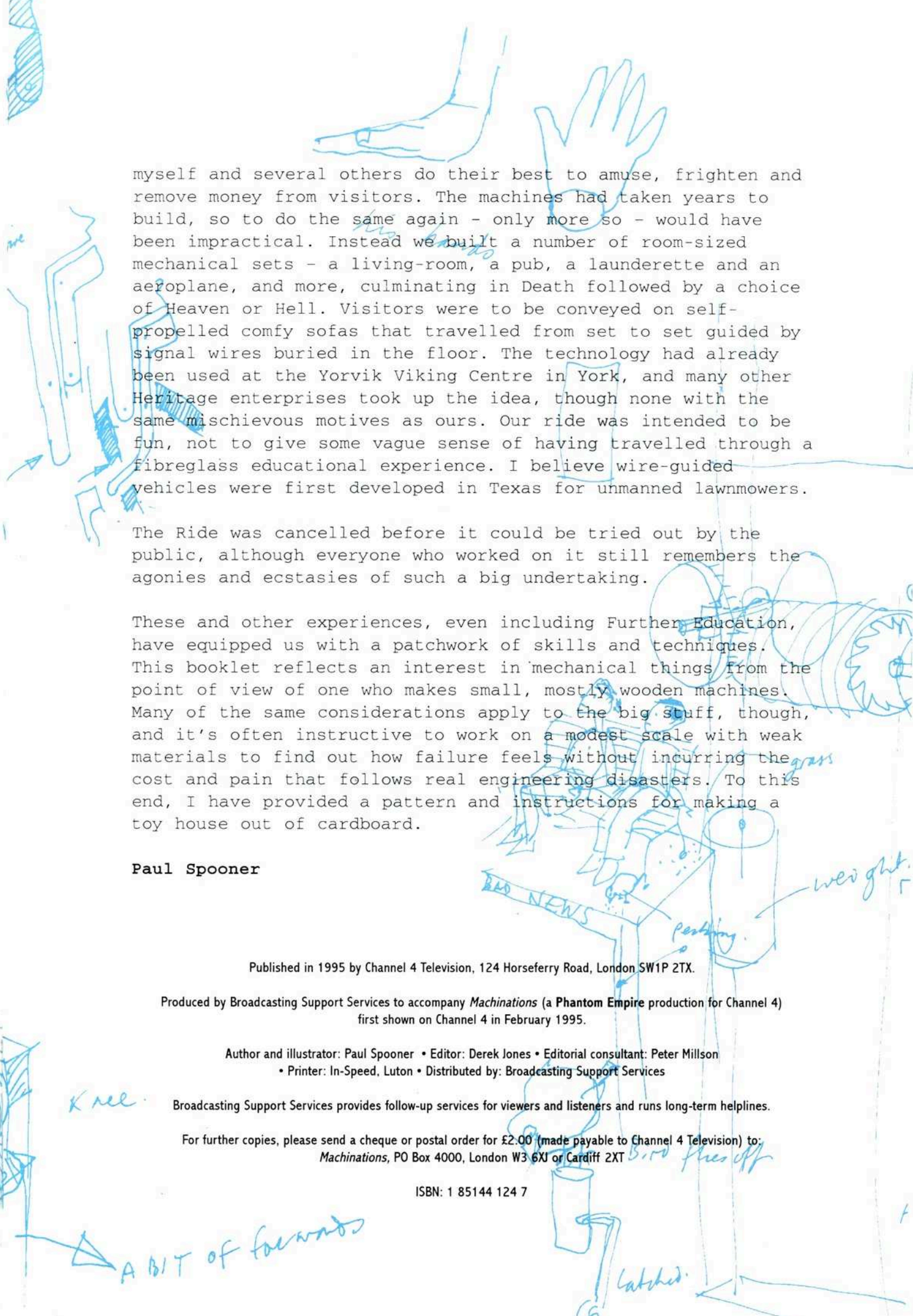
Andy Plant is driven by mysterious psychological forces in his film, *Driving Forces*, to construct a huge aluminium angel clinging to the back of a lorry. It combines a number of means of producing motion so that Andy can demonstrate the different qualities of electricity, compressed air and hydraulics, as well as making an out-and-out piece of street theatre.

Tim Hunkin shows that, in part, both he and Messrs Black & Decker use the same design methods (known to the vulgar as 'suck it and see'). At the same time he managed to make another exhibit for his new Domestic Machines gallery at the Science Museum.

My programme is partly a reinvention of clockwork, partly an obscure revenge on several women who had, in the distant past, obliged me never again to darken their doors.

An experience we all shared was the building of the 'Ride of Life'. Under the auspices of Cabaret Mechanical Theatre, some 20 of us were commissioned to design and build an installation for the Meadowhall shopping mall on the outskirts of Sheffield. This was at the time in the 1980s when consumerism was booming. The developers had originally asked for an extended version of Cabaret itself, which is a small museum and shop in a cellar in old Covent Garden market. There machines made by Tim Hunkin,





myself and several others do their best to amuse, frighten and remove money from visitors. The machines had taken years to build, so to do the same again - only more so - would have been impractical. Instead we built a number of room-sized mechanical sets - a living-room, a pub, a launderette and an aeroplane, and more, culminating in Death followed by a choice of Heaven or Hell. Visitors were to be conveyed on self-propelled comfy sofas that travelled from set to set guided by signal wires buried in the floor. The technology had already been used at the Yorvik Viking Centre in York, and many other Heritage enterprises took up the idea, though none with the same mischievous motives as ours. Our ride was intended to be fun, not to give some vague sense of having travelled through a fibreglass educational experience. I believe wire-guided vehicles were first developed in Texas for unmanned lawnmowers.

The Ride was cancelled before it could be tried out by the public, although everyone who worked on it still remembers the agonies and ecstasies of such a big undertaking.

These and other experiences, even including Further Education, have equipped us with a patchwork of skills and techniques. This booklet reflects an interest in mechanical things from the point of view of one who makes small, mostly wooden machines. Many of the same considerations apply to the big stuff, though, and it's often instructive to work on a modest scale with weak materials to find out how failure feels without incurring the cost and pain that follows real engineering disasters. To this end, I have provided a pattern and instructions for making a toy house out of cardboard.

Paul Spooner

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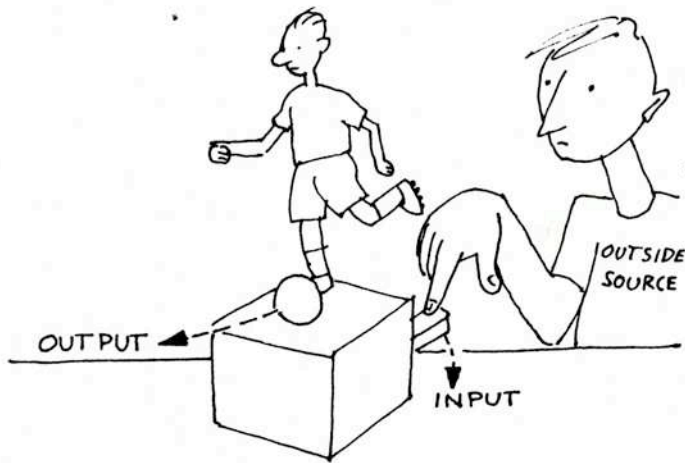
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A BIT of forwards

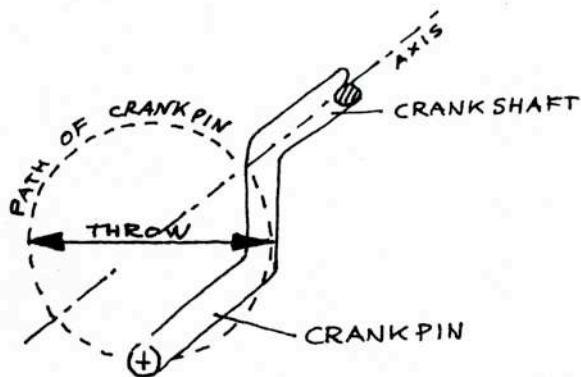
MECHANISMS

JUST AS ALL HUMOUR IS SAID TO DERIVE FROM A HANDFUL OF BASIC JOKES, THE NUMBER OF MECHANISMS ON WHICH ALL MACHINES ARE BASED IS VERY SMALL. HERE ARE SOME THAT I FIND HANDY.



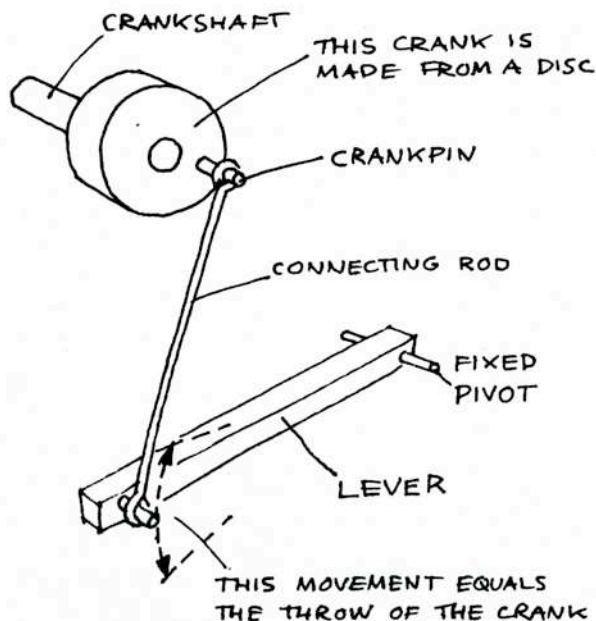
MACHINE: AN APPLIANCE THAT MODIFIES WORK FROM AN OUTSIDE SOURCE (INPUT) TO SUIT SOME DESIRED PURPOSE (OUTPUT).

THE INPUTS TO MY MACHINES ARE USUALLY EITHER HANDLES OR ELECTRIC MOTORS.



CRANKS: THE CRANKSHAFT IN A TRUCK ENGINE IS A GREAT HUNK OF STEEL, BUT I OFTEN USE A BENT PIECE OF WIRE.

THE DIAMETER OF THE PATH TRAVELLED BY THE CENTRE OF THE CRANKPIN IS CALLED THE **THROW** OF THE CRANK.

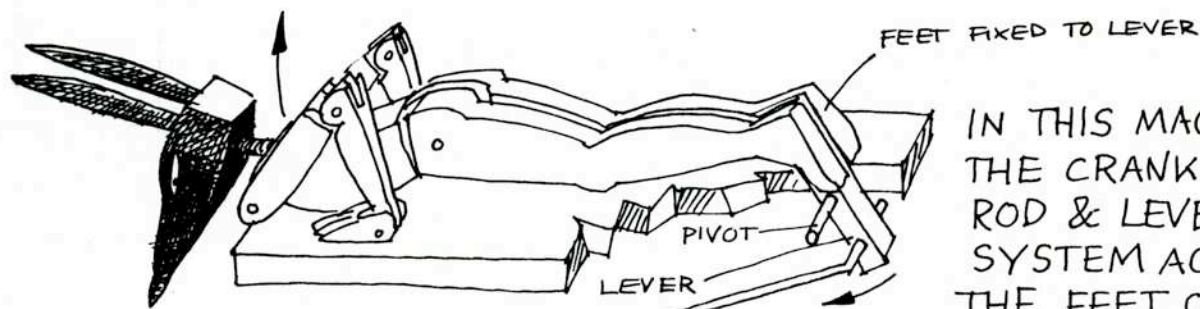


CRANKS CONVERT **ROTARY** INTO **RECIPROCATING** MOTION AND VICE VERSA.

A **CONNECTING ROD** TRANSFERS THE MOTION OF THE CRANKPIN TO THE NEXT PART OF THE MACHINE. IN THIS CASE IT IS A **LEVER**. THE DISTANCE TRAVELLED BY THE FREE END OF THE LEVER IS EQUAL TO THE **THROW** OF THE CRANK.

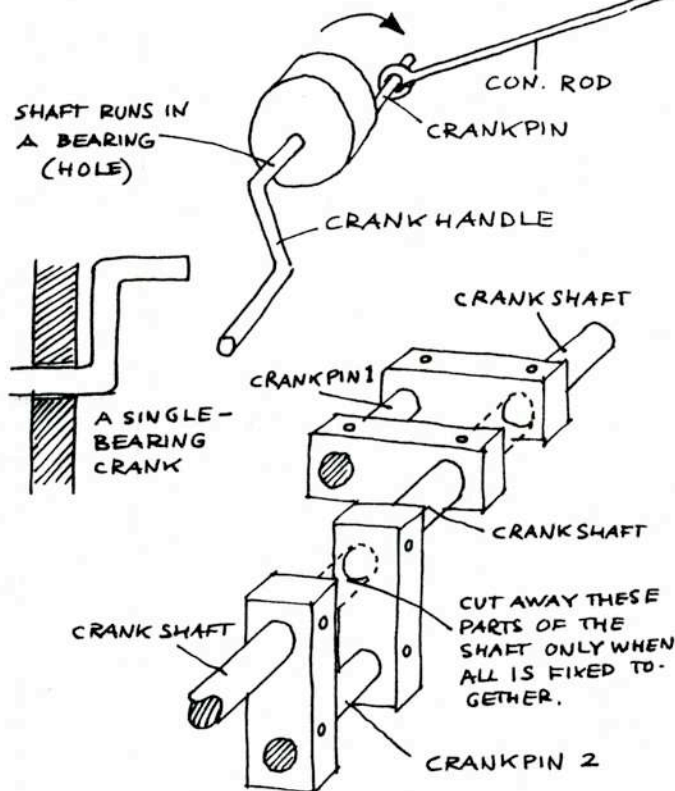
THE END OF THE LEVER COMES & GOES OR **RECIPROCATES**.

A **REGULAR RECIPROCATING** MOVEMENT IS CALLED AN **OSCILLATION** OR **VIBRATION**.



IN THIS MACHINE THE CRANK, CON. ROD & LEVER SYSTEM ACTS ON THE FEET OF THE

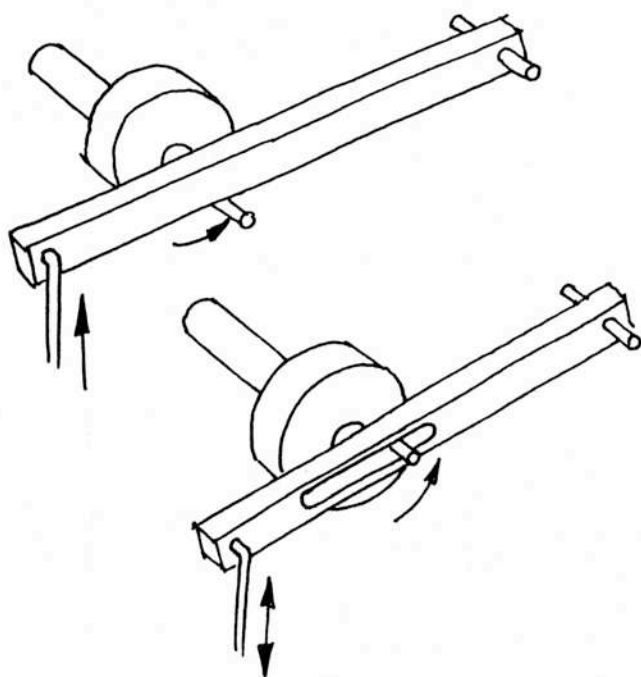
FIGURE TO RAISE HIS BODY. BECAUSE HIS HANDS ARE FIXED TO THE FLOOR, IT SEEMS AS IF HE IS DOING THE WORK HIMSELF.



SINGLE-BEARING CRANKS, LIKE ALL OF THE ABOVE, CAN BE WOBBLY. A STRONGER DESIGN - BUT HARDER TO MAKE, ESPECIALLY IN BENT WIRE - HAS EACH CRANKPIN SUPPORTED ON BOTH SIDES BY A SHAFT RUNNING IN A BEARING. ALSO, A SINGLE SHAFT CAN DRIVE MORE THAN ONE PIN. HERE TWO ARE FIXED AT 90° TO EACH OTHER.

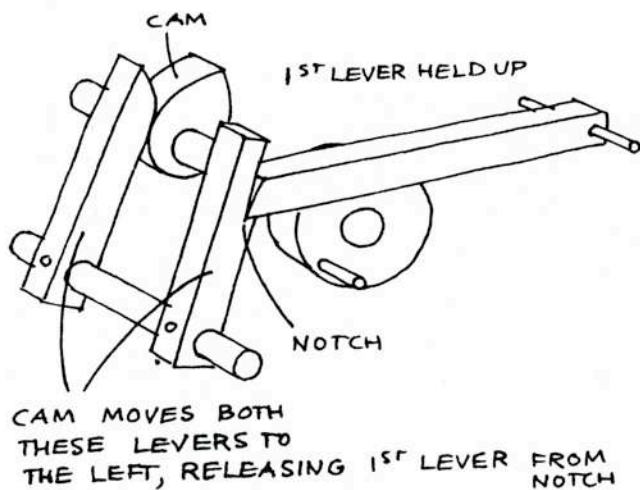
SOME MORE CRANKS

THIS CRANK LIFTS A LEVER WHICH MUST FALL BACK UNDER ITS OWN WEIGHT.

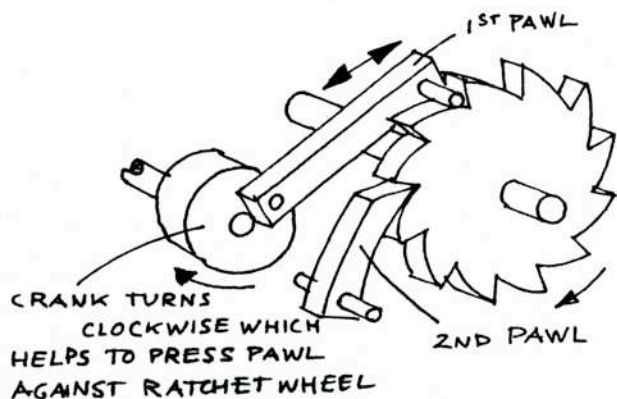


HERE THE LEVER IS DRIVEN POSITIVELY BOTH UP AND DOWN.

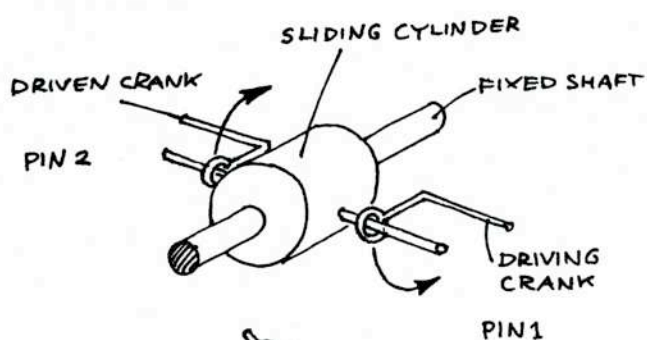
CRANKS PRODUCE A SMOOTH MOVEMENT, WHICH IS NOT ALWAYS DESIRABLE. UNEVENNESS CAN SOMETIMES ADD TO ANY CHARM A MECHANICAL TOY MIGHT POSSESS.



THIS CRANK LIFTS THE LEVER WHICH CATCHES IN A NOTCH IN A SECOND LEVER UNTIL IT IS RELEASED BY THE CAM MECHANISM.



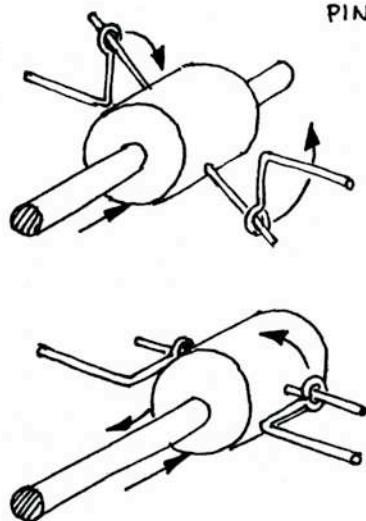
THE NOTCHED WHEEL OR RATCHET IS STEPPED ROUND BY THE CATCH OR PAWL WHICH IS VIBRATED BY THE CRANK. A SECOND PAWL STOPS THE RATCHET FROM TURNING ANTICLOCKWISE. IT TAKES TWELVE TURNS OF THE CRANK TO PRODUCE ONE TURN OF THE RATCHET



THE CYLINDER IN THE MIDDLE OF THIS STRANGE CRANK MECHANISM CAN SLIDE ALONG AND ROTATE AROUND THE FIXED SHAFT.

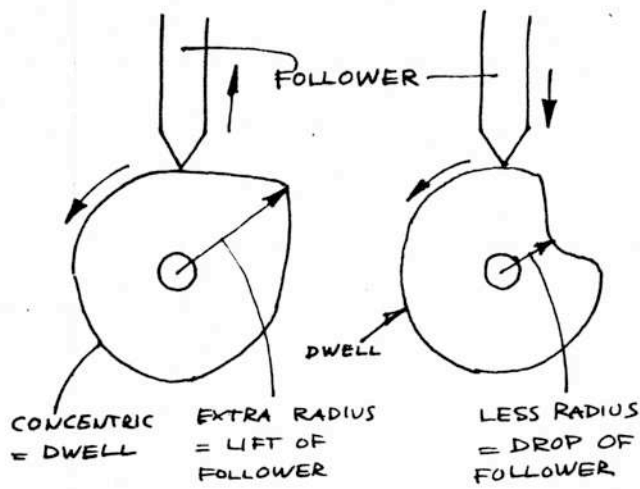
THE DRIVING CRANK FORCES PIN1 TO FOLLOW A NEARLY CIRCULAR PATH.

WHEN PIN 1 IS TILTED DOWN, PIN 2 IS TILTED UP, BUT WHEN PIN 1 SLIDES TO THE RIGHT, PIN 2 ALSO SLIDES TO THE RIGHT. THE RESULT IS THAT AN ANTICLOCKWISE MOVEMENT OF THE DRIVING CRANK PRODUCES A CLOCKWISE MOVEMENT OF THE DRIVEN CRANK.

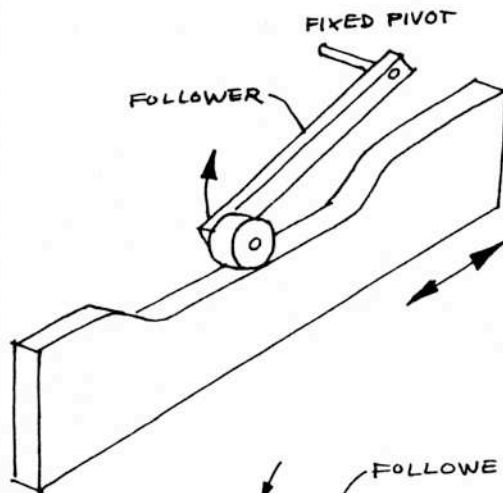


I SAW A DIAGRAM OF THIS IN A BOOK & HAD TO MAKE A MODEL BEFORE I COULD COMPREHEND IT.

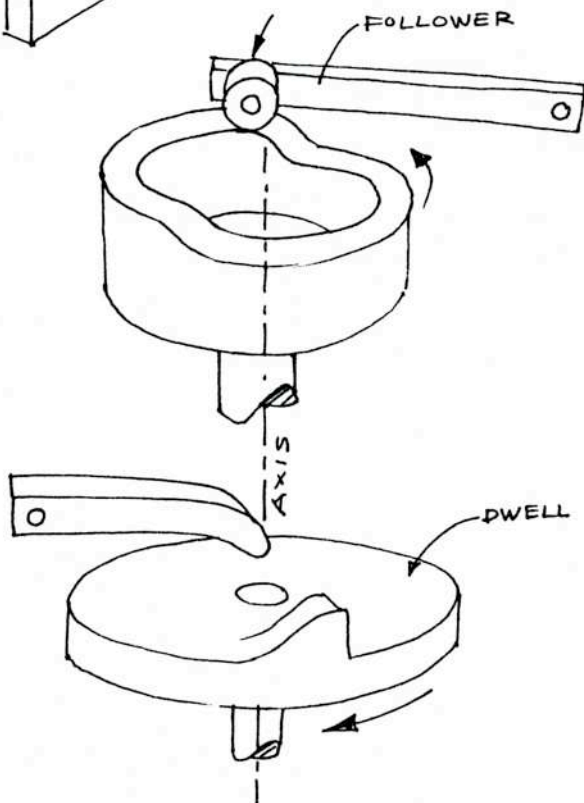
I USE IT A LOT NOW.



CAMS WORK BY A SLIDING OR RUBBING ACTION. THE COMMONEST FORM IS THE ROTARY RADIAL TYPE. A VARIATION IN DISTANCE OF THE CAM SURFACE FROM THE CENTRE OF ROTATION WILL CAUSE MOVEMENT OF THE FOLLOWER. CONCENTRIC SURFACES PRODUCE A DWELL OR PAUSE.



THIS IS A FLAT CAM, WHICH SLIDES BACK & FORTH TO FORCE THE FOLLOWER TO RIDE UP & DOWN. THE WHEEL REDUCES FRICTION.

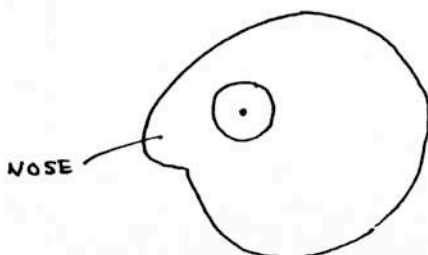


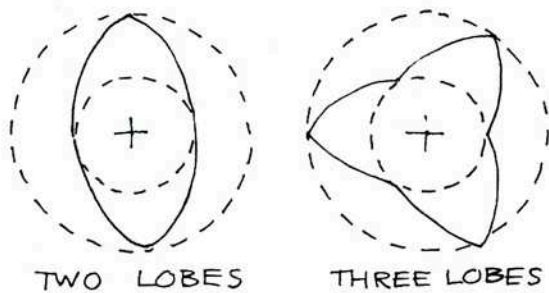
IF THE SAME SHAPE WERE ROLLED UP IT WOULD BECOME A CYLINDRICAL ROTARY CAM

THIS IS AN AXIAL CAM - THE MOVEMENT IT CAUSES IS IN LINE WITH THE AXIS OF ROTATION.

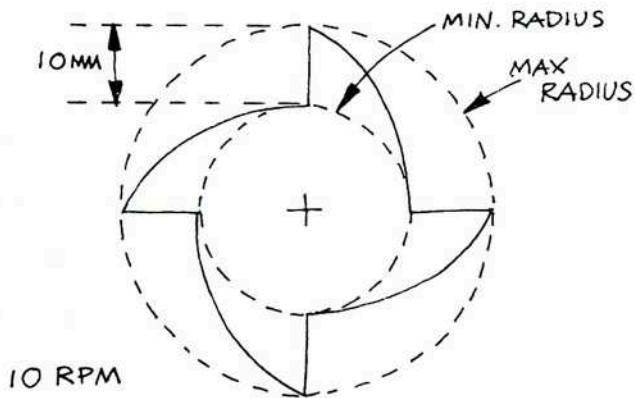
THIS AXIAL CAM CAN ONLY RUN ONE WAY CONTINUOUSLY. IT'S LIKE A ONE-TOOTHED RATCHET & THE FOLLOWER IS LIKE A PAWL. THE ACTIVE SURFACE IS ON THE FACE OF THE DISC SO IT IS KNOWN AS A FACE CAM.

ANOTHER TYPE OF FACE CAM.





THESE CAMS PRODUCE TWO AND THREE EVENTS PER REVOLUTION RESPECTIVELY.

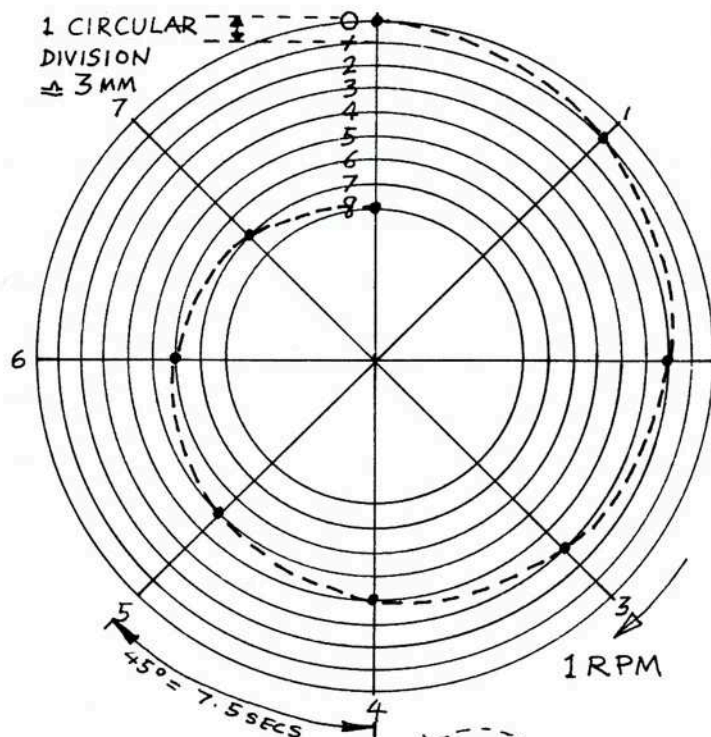


10 RPM

= 1 REV PER 6 SECONDS

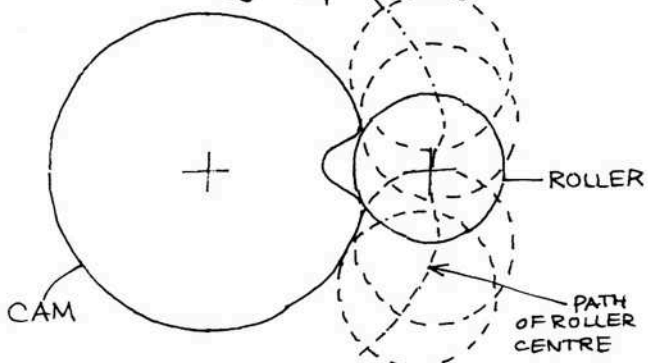
4 EVENTS PER REV OR 1 EVENT PER $6 \div 4 = 1\frac{1}{2}$ SECS

CAMS ARE DESIGNED IN RESPECT OF MOTION AND TIME. THE RANGE OF MOVEMENT OR 'THROW' IN THIS RADIAL CAM IS THE DIFFERENCE BETWEEN THE MAXIMUM & MINIMUM RADII, WHICH IS 10mm. THE TIME IS DETERMINED BY THE SPEED OF ROTATION - 10 REVS PER MIN IN THIS CASE. THE FOLLOWER WILL RISE & FALL 10mm EVERY

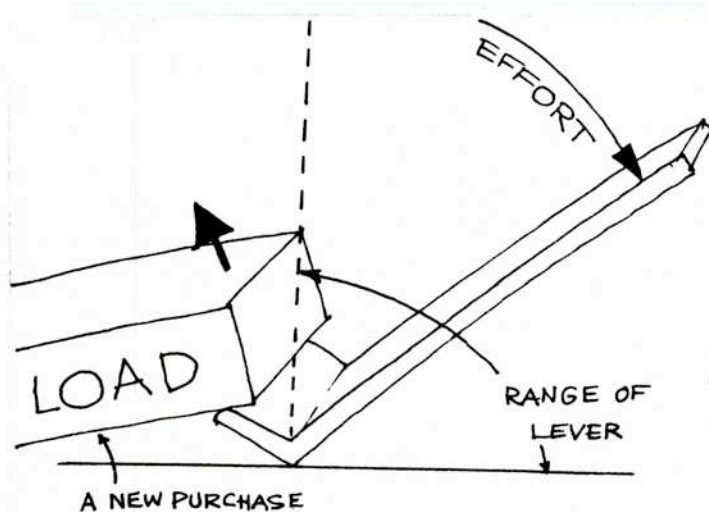


IF A CAM IS NEEDED TO SUIT SOME EXACT REQUIREMENTS, IT WILL HAVE TO BE PLOTTED. THIS CAM IS TO TURN CLOCKWISE WITH A THROW OF 25mm. IT IS TO LIFT THE FOLLOWER THROUGHOUT THE ENTIRE ROTATION, THEN LET IT DROP SUDDENLY.

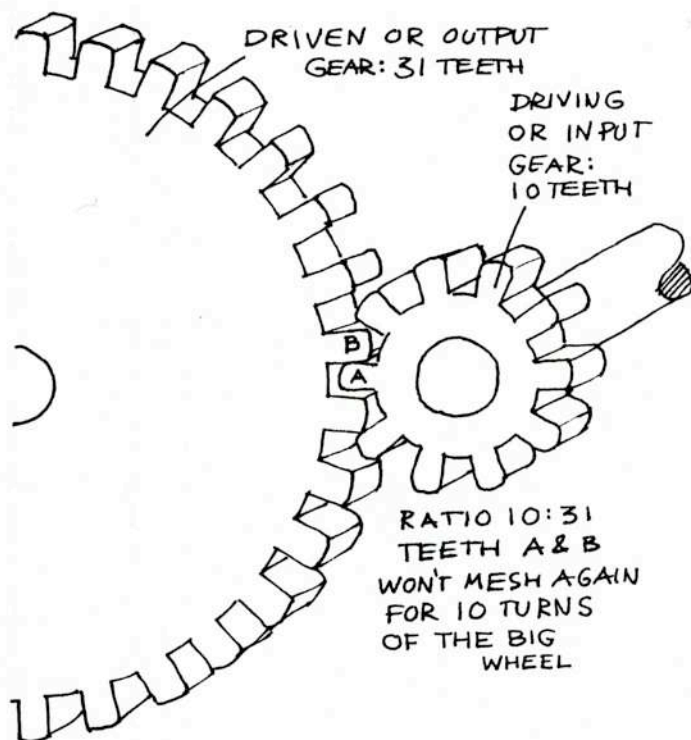
THE RESULT IS A SNAIL-SHAPED CAM. IT IS NOT A TERRIBLY PRACTICAL MECHANISM: IF IT RAN FAST, THE FOLLOWER WOULD NOT HAVE TIME TO DROP ONTO THE LOWEST POINT. ALSO THE SHAPE OF THE FOLLOWER MUST BE CONSIDERED.



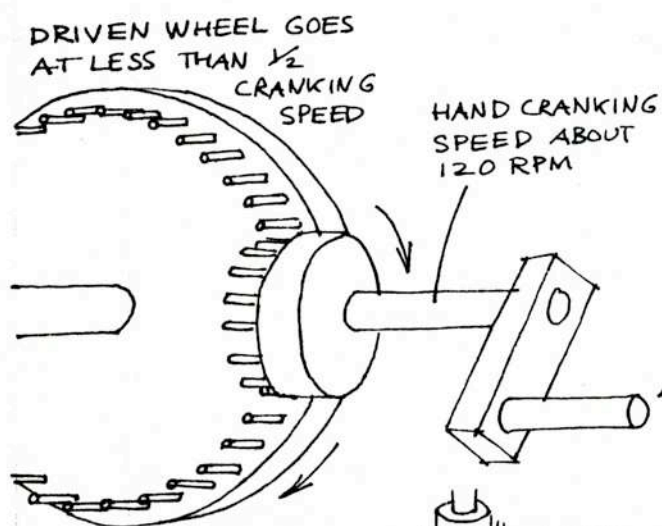
A LARGE ROLLER CUTS DOWN FRICTION BUT MAY NOT FOLLOW THE SURFACE OF THE CAM. THE PATH OF THE CENTRE OF THE ROLLER GIVES THE TRUE PICTURE.



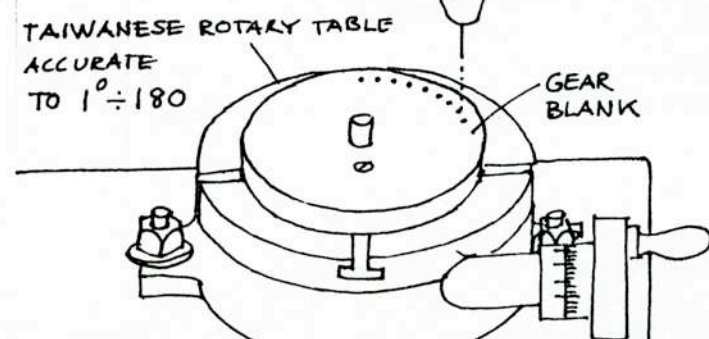
LEVERS: A HEAVY LOAD IS LIFTED A SHORT DISTANCE BY A LESSER EFFORT TRAVELLING A GREATER DISTANCE. THE ACTION IS DISCONTINUOUS: YOU MUST STOP & TAKE A NEW PURCHASE IF YOU WANT TO MOVE THE LOAD FURTHER THAN THE RANGE OF THE LEVER.



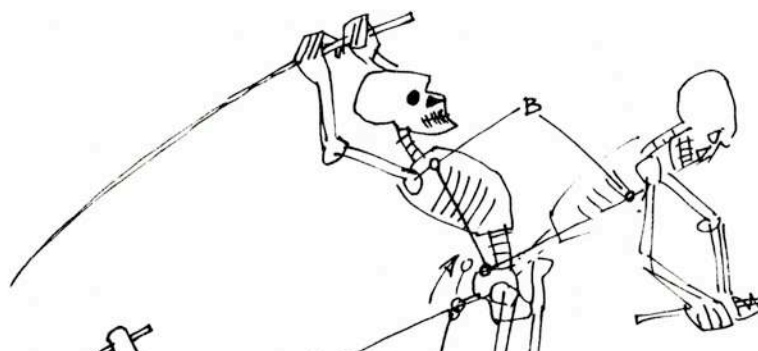
GEAR TEETH ARE CONTINUOUSLY APPLIED LEVERS. AS ONE PAIR OF TEETH DISENGAGES, ANOTHER PAIR IS ENGAGING. GEARS OF UNEQUAL NUMBERS OF TEETH ALTER THE RATIO OF SPEED BETWEEN INPUT & OUTPUT. THIS PAIR OF GEARS PRODUCES A REDUCTION OF ABOUT 3:1 AND A REVERSAL OF DIRECTION. THE RATIO IS NOT EXACTLY 3:1 BECAUSE THE DRIVEN WHEEL HAS 31 TEETH. AN EXTRA TOOTH MEANS THAT THE SAME PAIRS OF GEARS MEET LESS FREQUENTLY & EVEN OUT THE WEAR.



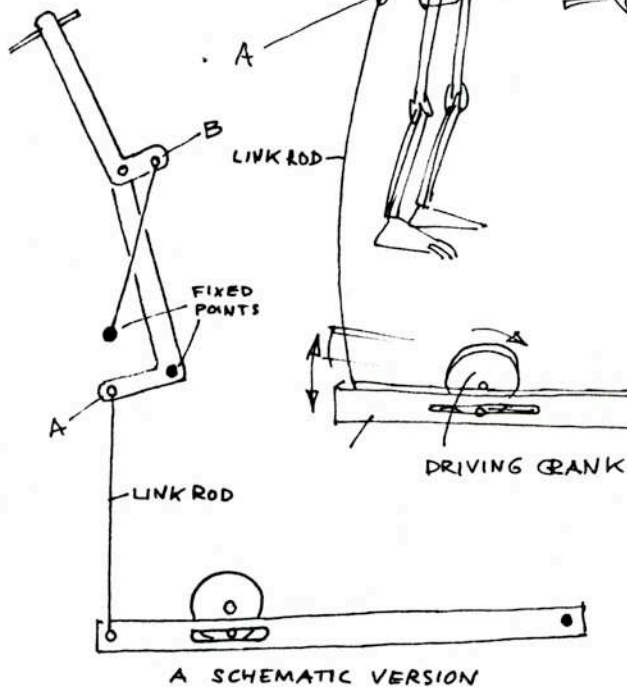
THE GEARS I MAKE FOR MY MACHINES ARE VERY CRUDE & WOULD BE USELESS AT HIGH SPEEDS OR LOADINGS. THEY ARE MADE BY DRILLING A ROW OF HOLES IN THE FACES OF PLYWOOD DISCS & DRIVING IN STEEL PINS. THE GEARS MESH AT RIGHT ANGLES, WHICH CREATES A LOT OF FRICTION AND TAKES UP SPACE.



I USE A ROTARY TABLE TO SPACE THE PIN HOLES ACCURATELY. EVEN A CHEAP ONE IS TOO GOOD FOR THIS KIND OF WORK.



THIS SKELETON IS PART OF A MACHINE CALLED "FLOGGING A DEAD HORSE".

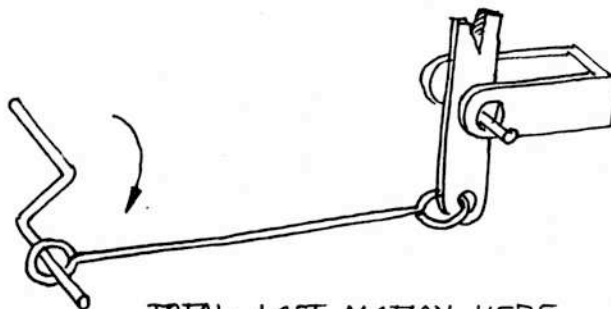


THE TIP OF THE WHIP HAS MOVED A MUCH GREATER DISTANCE THAN THE THROW OF THE DRIVING CRANK. THIS IS ACHIEVED BY A SYSTEM OF LEVERS. THE FIGURE BENDS OVER WHEN THE LINK ROD PUSHES UP THE END OF THE SHORT LEVER AT 'A'.

ANOTHER ROD LINKS A FIXED POINT ON THE PELVIS TO A SHORT LEVER AT THE SHOULDER CAUSING THE ARMS TO STRIKE DOWNWARDS. THE TIP OF THE WHIP TRAVELS AT 16 TIMES THE SPEED OF THE POINT A.

LOOK IN A PIANO FOR MORE COMPOUND LEVERS.

'L' SHAPED LEVERS ARE CALLED 'BELL CRANKS'.



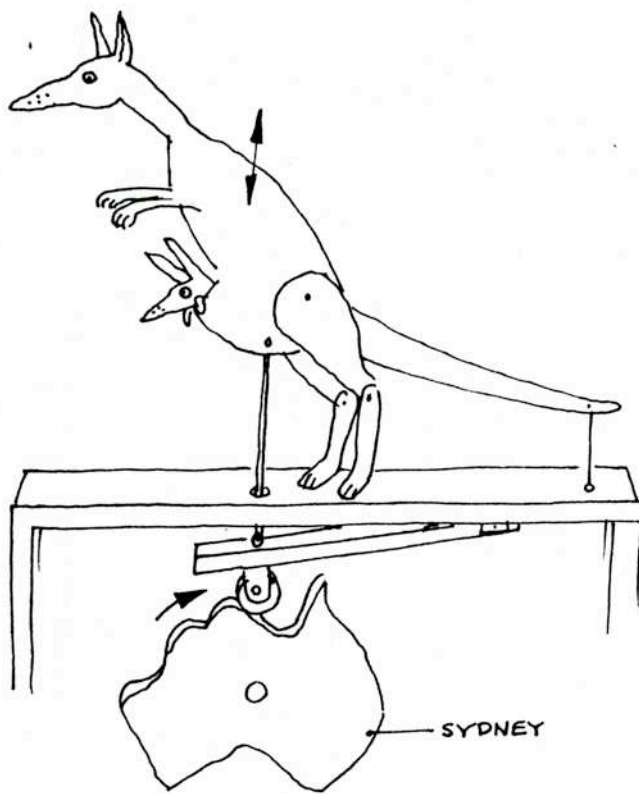
TOTAL LOST MOTION HERE MIGHT BE HALF THE INPUT

LOST MOTION: ALL MECHANICAL PARTS MUST BE FREE TO MOVE BUT CONSTRAINED TO MOVE IN THE PATHS ORDAINED BY THEIR DESIGNERS. IT'S GENERALLY BETTER TO ERR ON THE SIDE OF LOOSENESS. BUT FOR EACH LOOSE JOINT THERE IS A LOSS OF INPUT MOTION. IT'S POSSIBLE TO MAKE A MACHINE WITH SO MANY SLACK PARTS THAT $OUTPUT = 0$.

YOU CAN GET REPRINTS OF OLD BOOKS ON MECHANISMS FROM CAMDEN STEAM SERVICES, BARROW FARM, RODE, NR. BATH, SOMERSET BA3 6PS. TEL. 01373 830151.

CABARET MECHANICAL THEATRE IS AT :
33/34 THE MARKET, COVENT GARDEN, LONDON WC2E8RE
0171 379 7961

ENTHUSIASTS' CORNER



A MECHANICAL JOKE

I LIKE TO SHOW THE ALLIANCE BETWEEN A MECHANISM AND THE SCENE IT ACTIVATES.

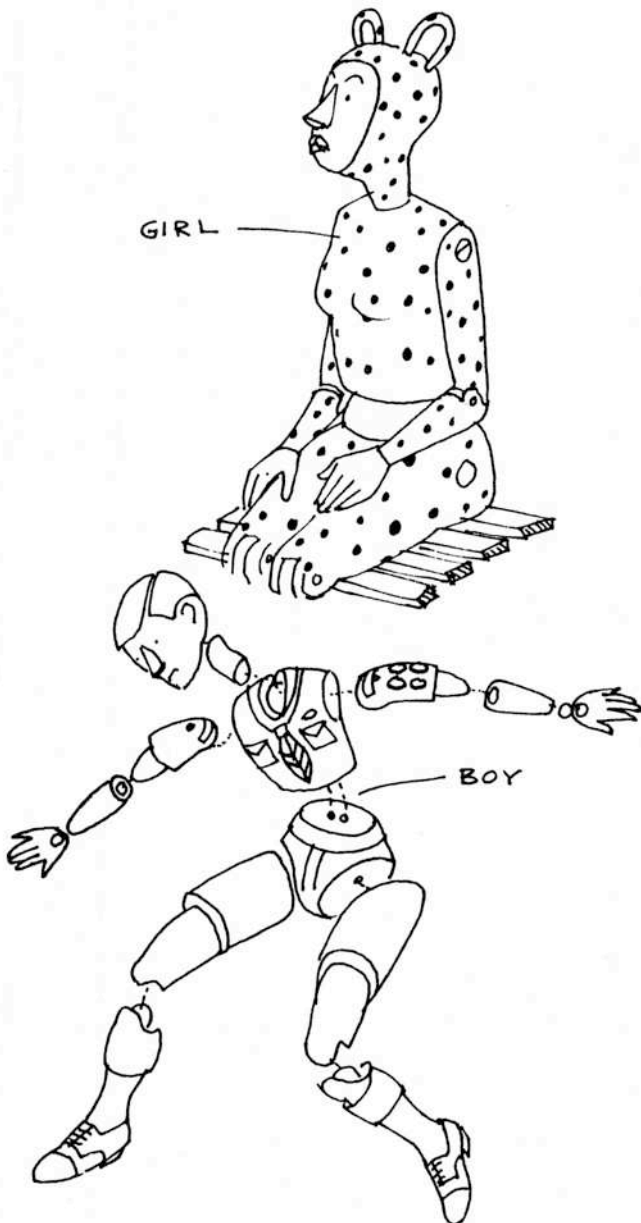
BAD NEWS

IN MY 'BAD NEWS' PIECE, A GIRL TELLS A BOY THAT SHE NO LONGER LOVES HIM. SHE IS DETERMINED ON A COURSE OF ACTION. THIS IS REFLECTED IN THE BOX OF MACHINERY. HER ACTIONS ARE DRIVEN BY A WOUND-UP SPRING THAT IMPARTS A POWERFUL DRIVING FORCE TO THE CAMSHAFT, MAKING HER MOUTH THE DREADED WORDS THEN GET UP TO LEAVE.

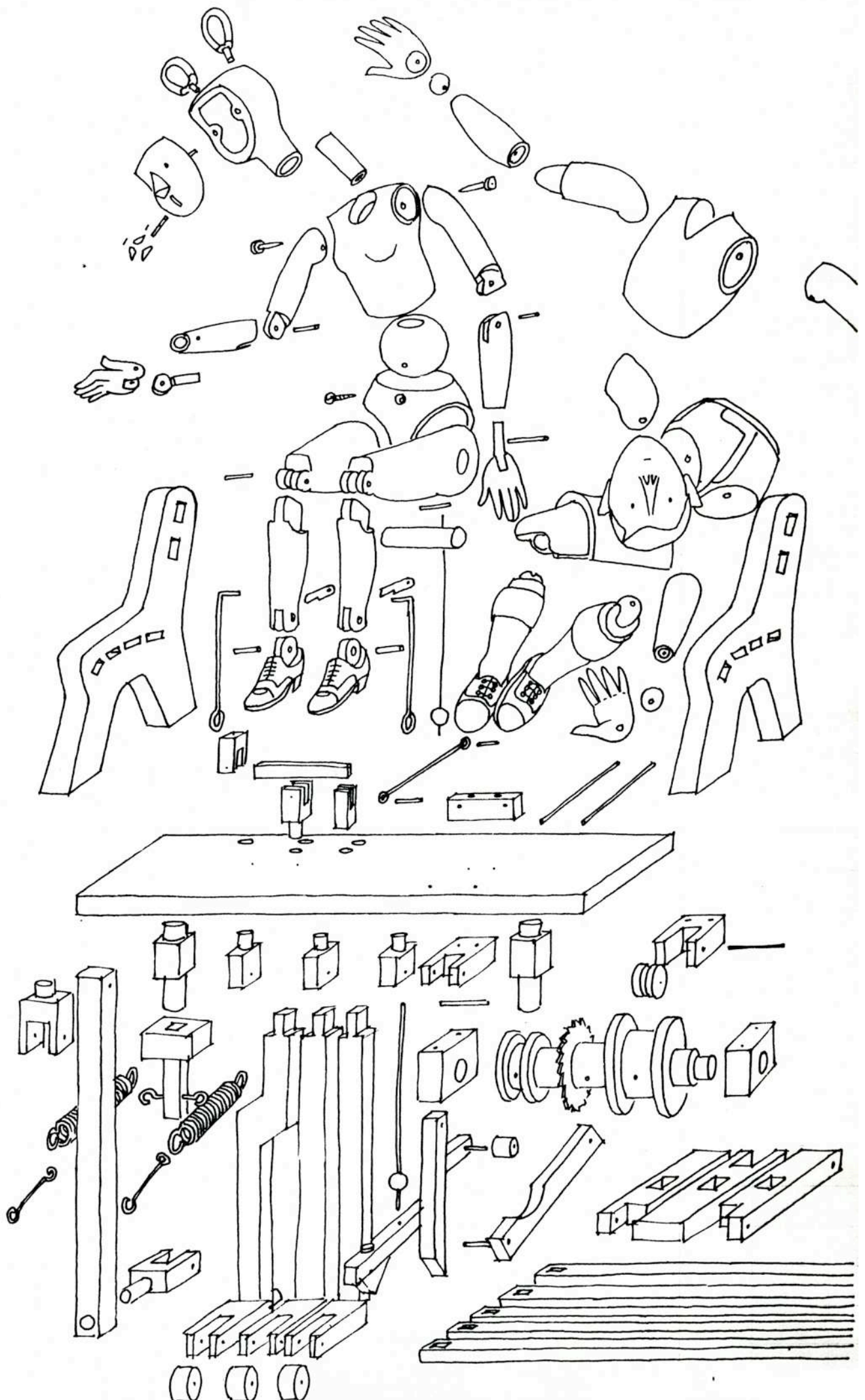
HE IS A BAG OF NERVES, DREADING THE BAD NEWS AND READY TO FALL TO PIECES. HIS MECHANISM, TRIGGERED BY HERS, SIMPLY ALLOWS HIM TO COLLAPSE.

THEIR COSTUMES - HERS A YELLOW JAGUAR OUTFIT, HIS A SCOUT UNIFORM - ARE JUST FOR FUN.

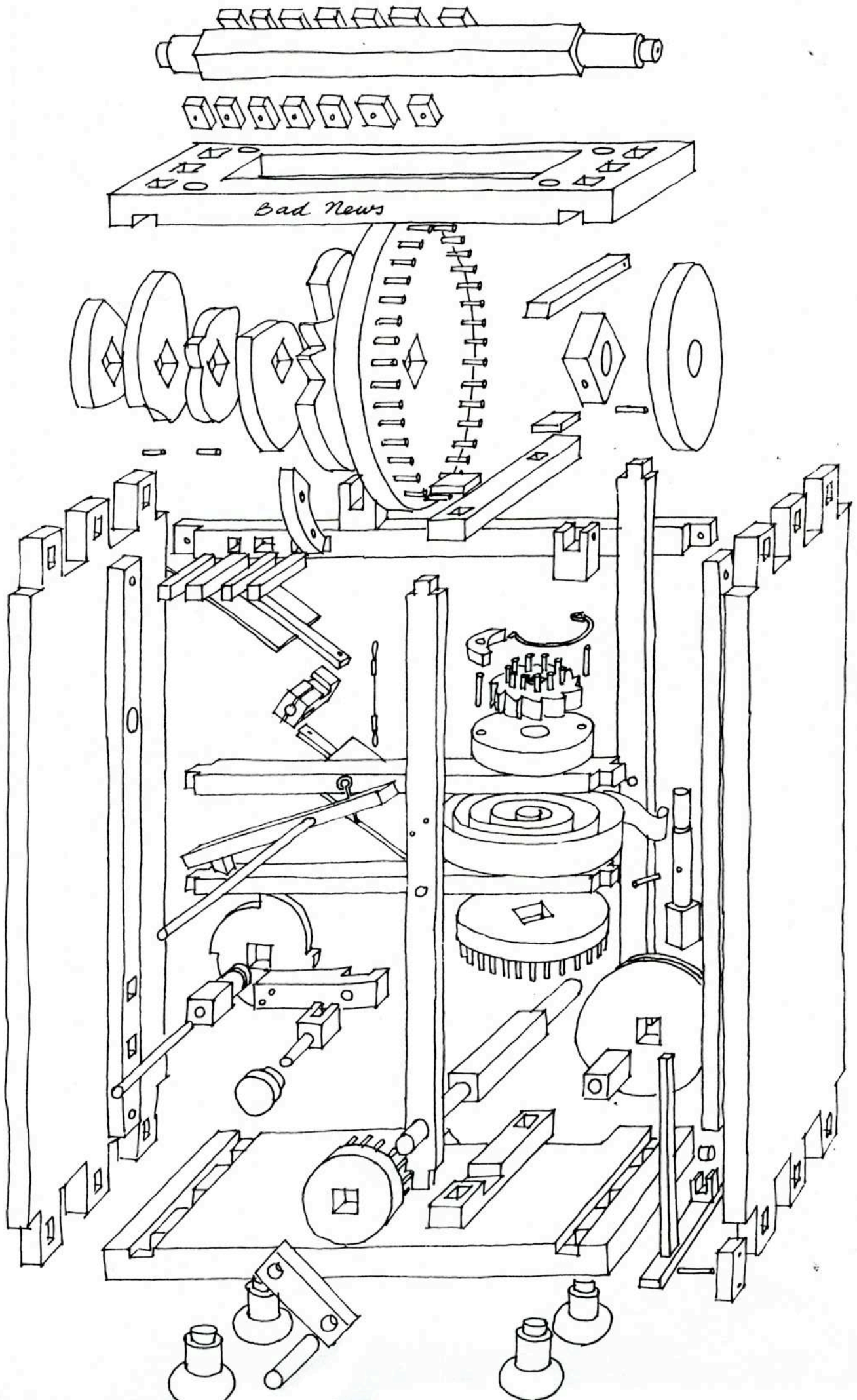
WHEN ONE OF MY MACHINES LOOKS A LITTLE DULL TO ME, I LIKE TO DRESS IT UP WITH EXTRA BITS. I'VE USED A LOT OF MODEL WATER-MELONS LATELY.



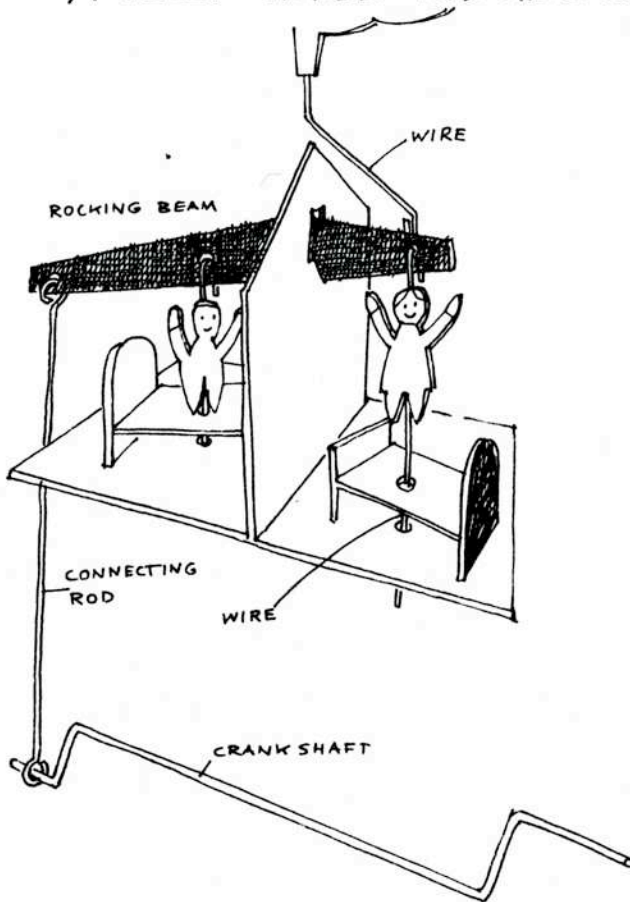
'BAD NEWS': AN EXPLODED VIEW



MORE EXPLODED BAD NEWS



HERE ARE PLANS & INSTRUCTIONS FOR MAKING A LITTLE MECHANICAL HOUSE IN WHICH A BABYSITTER WATCHES A TELLY WHILE THE KIDS JUMP ON THEIR BEDS UPSTAIRS.



THE BAD BABYSITTER

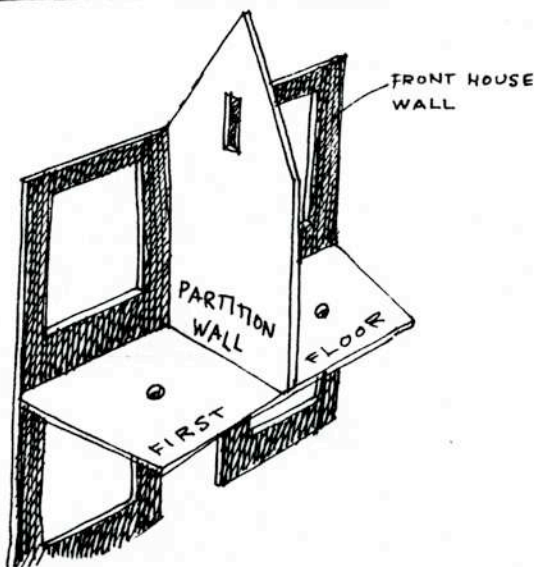
THE WORKING PARTS: A CRANK-SHAFT IS LINKED TO A ROCKING BEAM BY A CONNECTING ROD. THE BEAM RAISES & LOWERS WIRES TO WHICH ARE ATTACHED THE NAUGHTY CHILDREN. ANOTHER WIRE IS CONNECTED TO A PUFF OF SMOKE FROM THE CHIMNEY.

THE MACHINE LOOKS GOOD WHEN MADE OF THICK MOUNTING CARD, WHITE ONE SIDE, COLOURED THE OTHER.

TOOLS: A SHARP CRAFT KNIFE OR SCALPEL, STEEL RULE, LONG & ROUND-NOSED PLIERS, PAPER PUNCH FOR PIVOT HOLES.

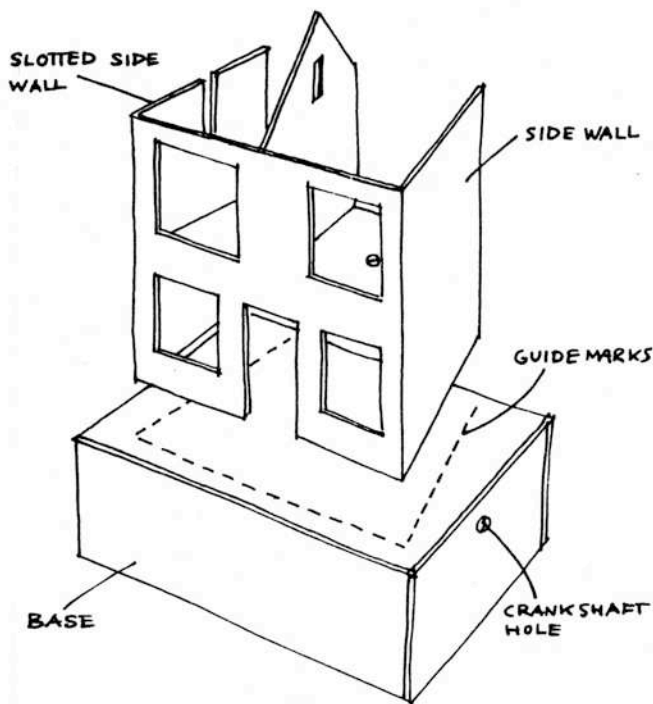
MATERIALS: MASKING TAPE, P.V.A. WOOD GLUE. THIN & THICK WIRE—SEE PLAN FOR DETAILS. CARD.

YOU CAN USE THE PLANS AS A GUIDE & MAKE YOUR OWN VERSION OF THE MACHINE OR COPY THE PLAN BY TAPING IT ONTO YOUR CARD. PRICK THROUGH WITH COMPASS POINT (E.G.) TO TRANSFER.



INSTRUCTIONS: CUT OUT ALL THE PARTS. PUNCH ALL THE HOLES—TRY TO MAKE THEM BETWEEN THESE SIZES $\frac{1}{8}$ " & $\frac{1}{4}$ ". GLUE TOGETHER THE PARTITION WALL AND THE FIRST FLOOR. AN EDGE-TO-FACE JOINT WILL BE QUITE STRONG IF YOU USE WOODWORKER'S P.V.A. GLUE.

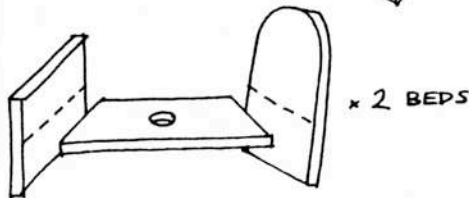
DOTTED LINES ON THE PLAN INDICATE STICKING PLACES. NOW GLUE FLOOR & WALL BEHIND THE FRONT HOUSE WALL.



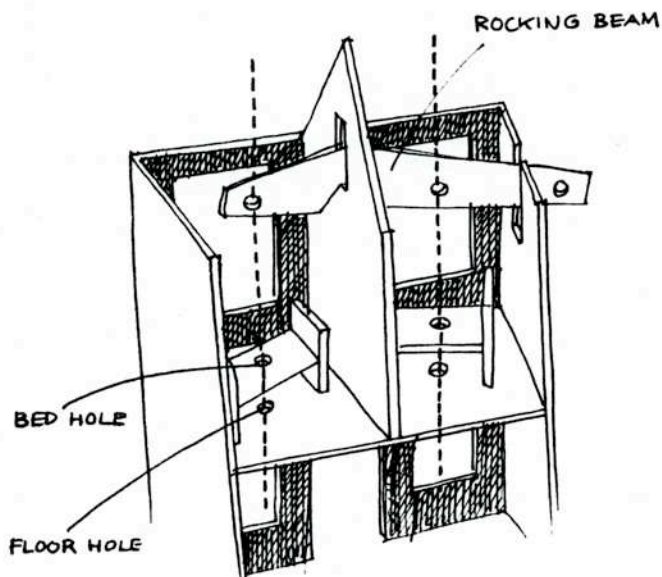
ADD THE SIDE WALLS TO THE HOUSE - NOTE SLOTTED WALL ON LEFT.

MAKE THE BASE. THE PLAN SHOWS IT AS IF FLATTENED OUT. THE TWO CRANKSHAFT HOLES ARE NEAR THE TOP SURFACE. YOU HAVE TO CUT IT INTO FIVE SEPARATE PIECES BECAUSE THE THICK CARD WON'T FOLD.

GLUE THE HOUSE SHELL ONTO THE BASE.

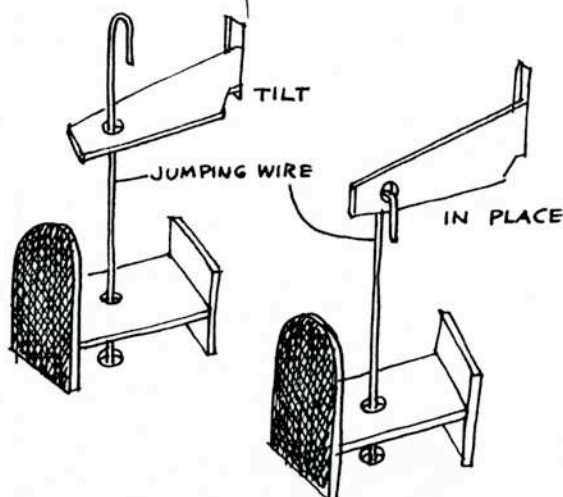


MAKE THE TWO BEDS.



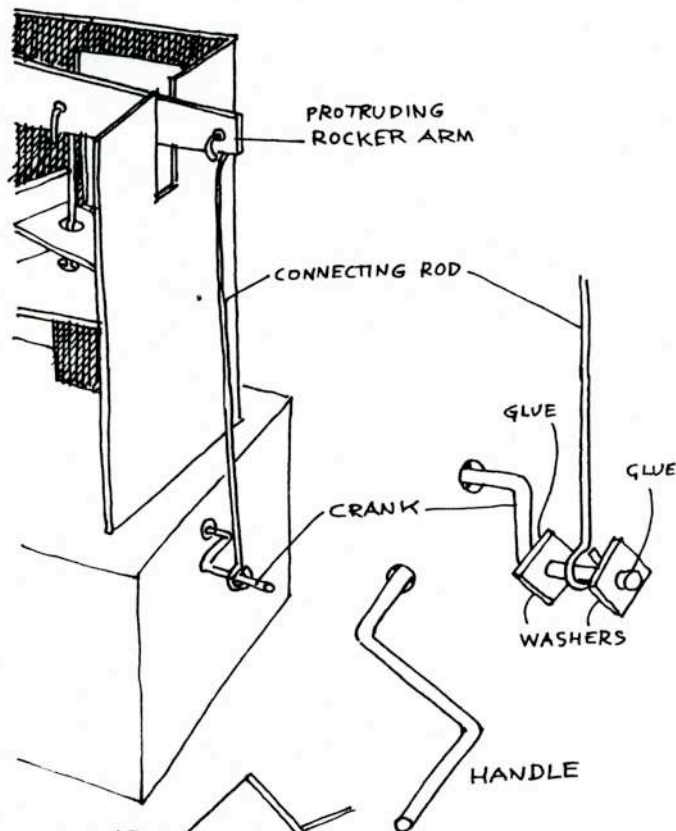
FIT THE ROCKING BEAM.

GLUE THE BEDS TO THE FIRST FLOOR. THE BED HOLES SHOULD ALIGN VERTICALLY WITH THEIR RESPECTIVE HOLES IN ROCKING BEAM & FLOOR.



PASS THE JUMPING WIRES THROUGH THE ROCKING BEAM - TILT IT AS SHOWN - AND DOWN INTO THE BED & FLOOR HOLES.

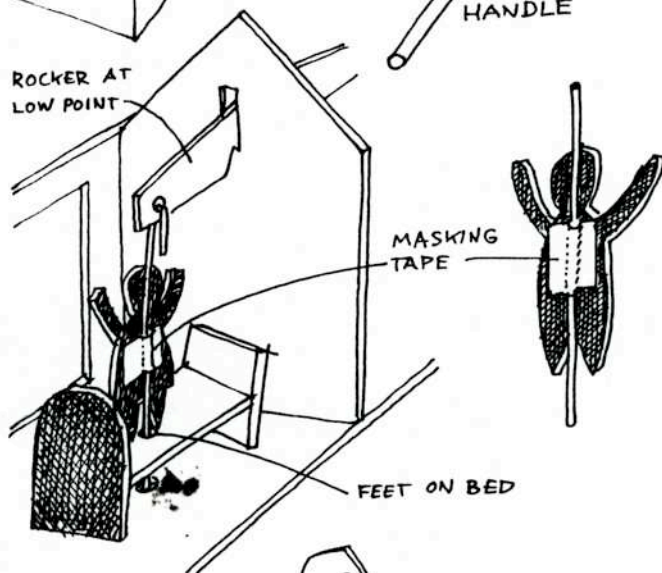
THE BEAM SHOULD ROCK FREELY AND THE WIRES SHOULD PASS EASILY THROUGH BEDS & FLOOR.



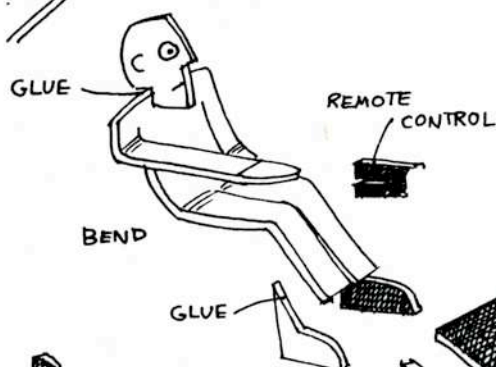
MAKE THE CRANK BY BENDING THICKER WIRE WITH PLIERS. LEAVE HANDLE END (DOTTED ON PATTERN AT END). INSTALL IT WITH CRANK UNDER PROTRUDING ROCKER ARM. MAKE CONNECTING ROD FROM THIN WIRE. TRY IT IN PLACE. WHEN CRANK IS HORIZONTAL, ROCKER SHOULD ALSO BE HORIZONTAL. MAKE ANY NECESSARY ALTERATIONS.

WHEN ALL IS WELL, PUT WASHERS ON CRANK & FIX WITH GLUE TO KEEP CON. ROD IN PLACE.

BEND OTHER END OF CRANK-SHAFT TO FORM HANDLE.

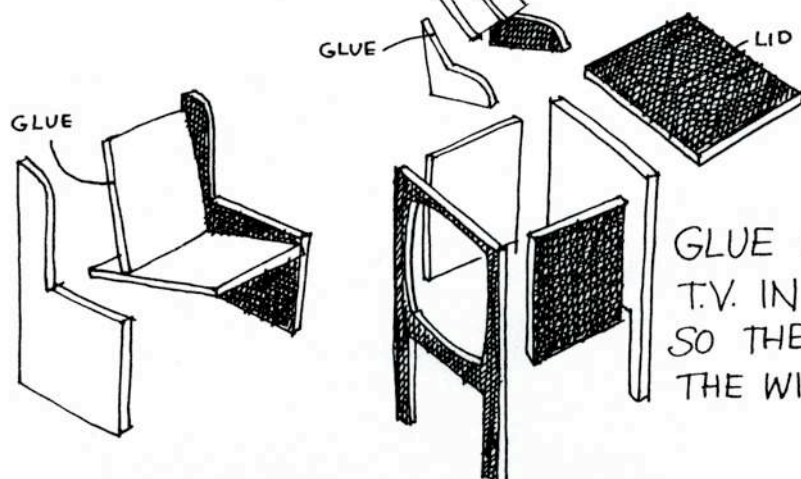


FASTEN THE CHILDREN TO THE JUMPING WIRES WITH LITTLE TABS OF MASKING TAPE. THEIR FEET SHOULD JUST TOUCH THEIR BEDS AT THE LOWEST PART OF THE ROCKER'S STROKE. ADJUST TILL OK.

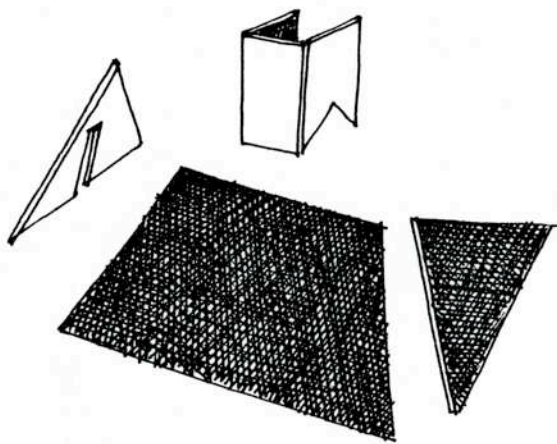


BEND THE BABYSITTER INTO A SEATED POSITION AND GLUE ON HIS HEAD, BOOTS & REMOTE CONTROL.

MAKE THE SEAT & T.V.

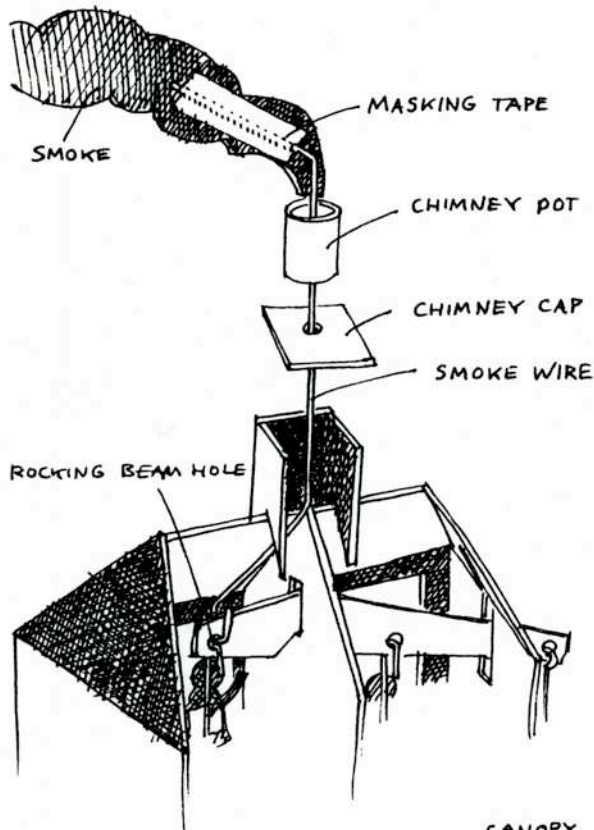


GLUE BABYSITTER, CHAIR & T.V. IN THE DOWNSTAIRS ROOM SO THEY CAN BE SEEN THROUGH THE WINDOWS.



GLUE THE FRONT & SIDES OF THE ROOF ONTO THE HOUSE. THE SLOTTED PART IS FITTED OVER THE ROCKING BEAM.

GLUE TOGETHER THE FRONT & SIDES OF THE CHIMNEY & GLUE IT ONTO THE MIDDLE OF THE ROOF.

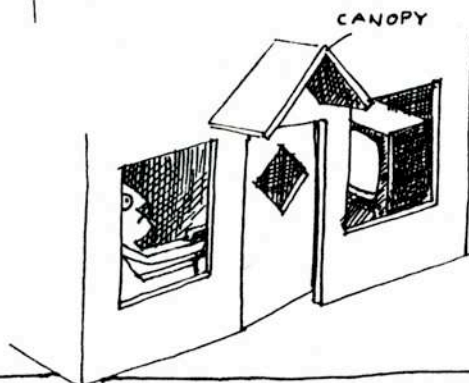


FIT HOOK OF SMOKE WIRE INTO ROCKING BEAM HOLE, THEN BEND THE WIRE SO IT TRAVELS UP THE CHIMNEY. THREAD ON CHIMNEY CAP & GLUE IT ON.

ROLL UP THIN CARD OR THICK PAPER TO MAKE CHIMNEY POT. STICK IT ONTO THE CAP.

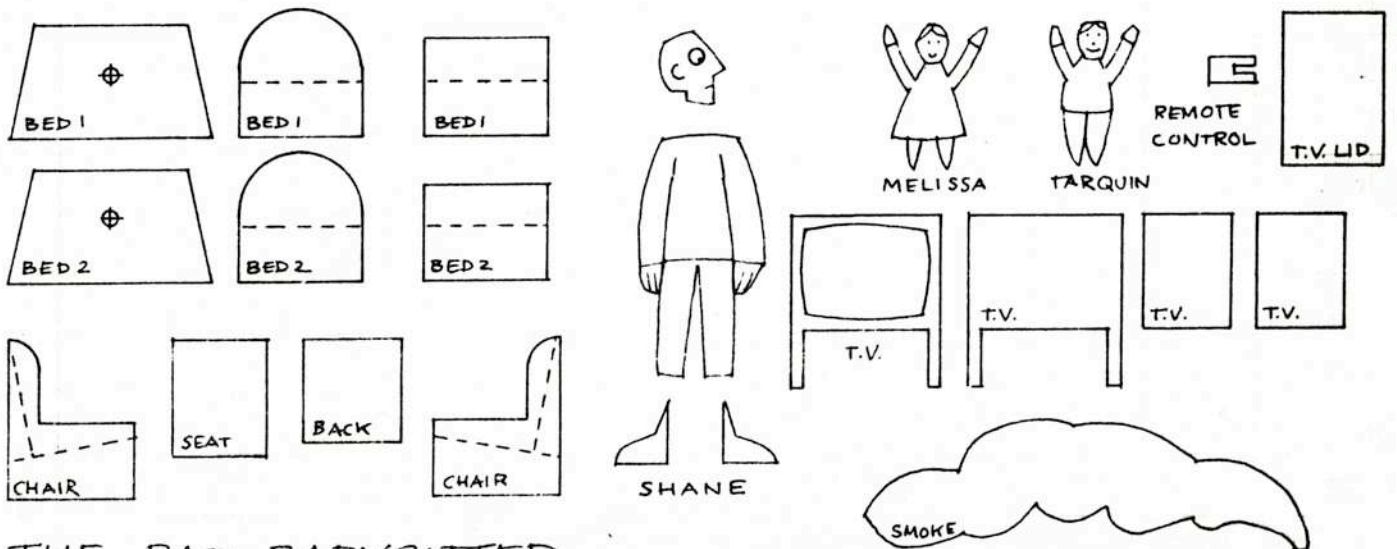
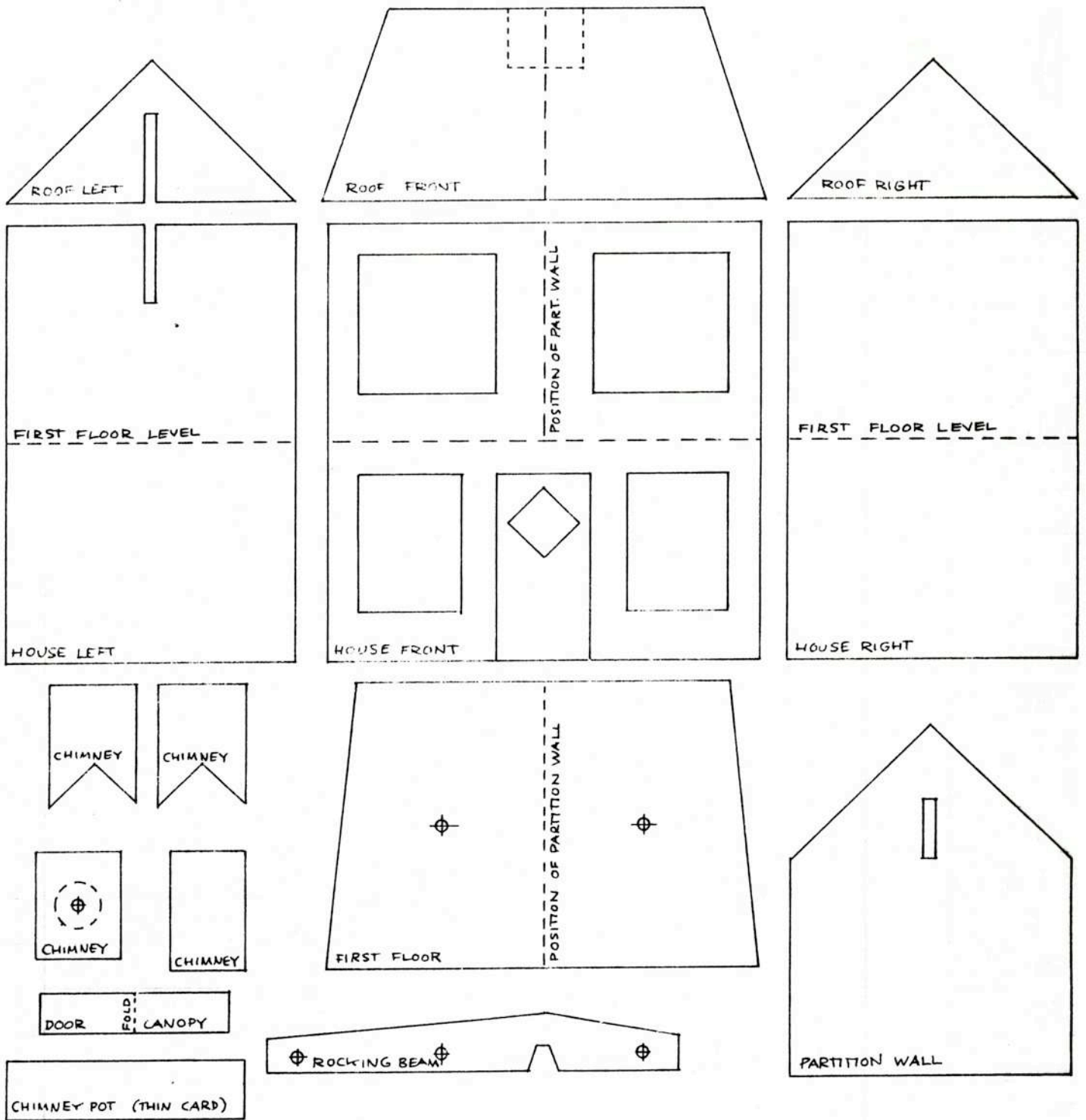
TEST ACTION OF SMOKE WIRE. IT SHOULD RISE & FALL FREELY.

ATTACH SMOKE WITH MASKING TAPE TO WIRE & BEND TO TASTE.



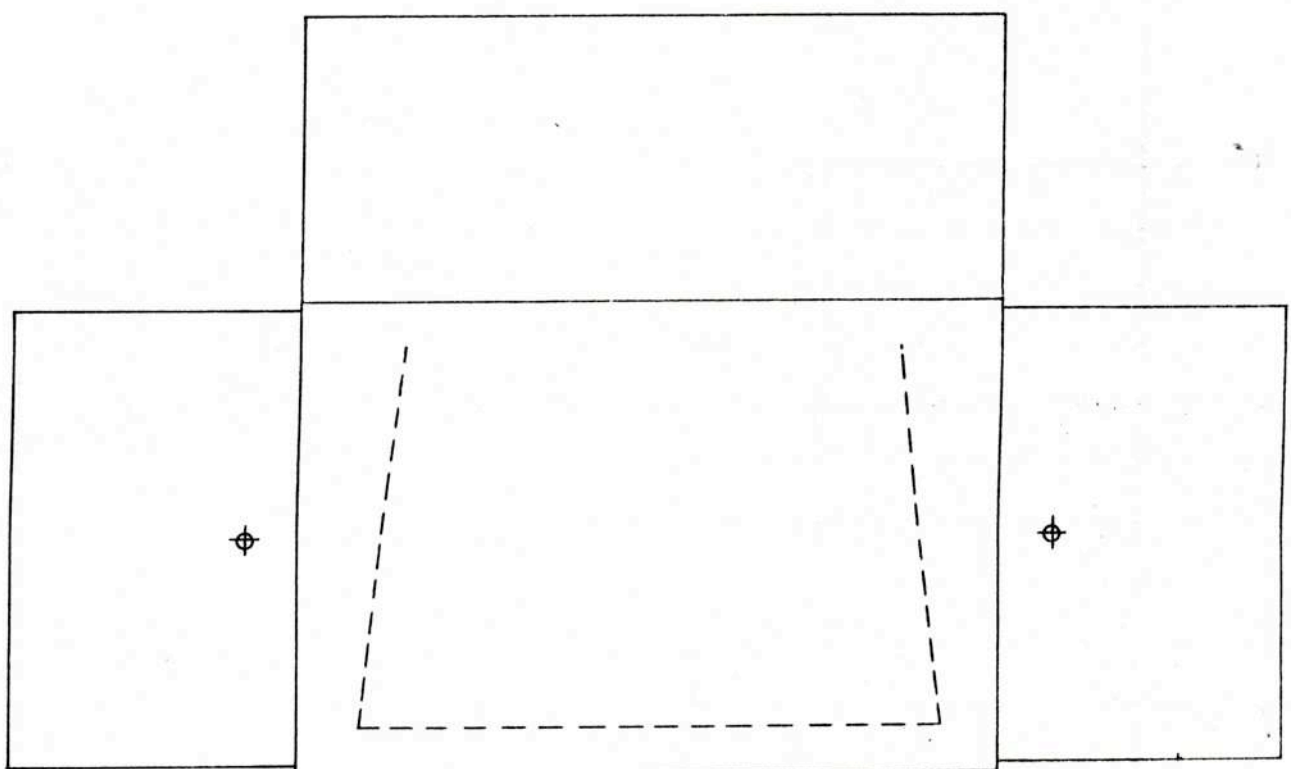
BEND & GLUE ON DOOR CANOPY. MAKE THE FRONT DOOR A LITTLE AJAR IF YOU LIKE. MAKE A LABEL SAYING "THE BAD BABYSITTER" AND STICK IT ONTO THE FRONT OF THE BASE.

THIS IS ONLY A START: MUCH MORE COULD BE DONE TO COMPLICATE THINGS. THE T.V. IS IN A HANDY PLACE OVER THE CAM SHAFT TO TEMPT YOU TO MAKE AN ANIMATED PICTURE APPEAR ON THE SCREEN. THE T.V. COULD CONTAIN AN L.E.D. WHICH WOULD CAST A COSY GLOW ROUND THE DOWNSTAIRS ROOM. YOU MIGHT ENJOY DOING SOME MINIATURE INTERIOR DECORATING. I PUT A REVERSED BASEBALL CAP ON MY BABYSITTER TO ADD A TOUCH OF AUTHENTICITY.



THE BAD BABYSITTER

MAKE FROM 1mm THICK MOUNTING CARD EXCEPT CHIMNEY POT.



MAKE CON. ROD,
JUMPING WIRES &
SMOKE WIRE FROM
1.0 MM DIA. WIRE
(ABOUT PAPER CLIP
SIZE)

THE BAD BABYSITTER

BASE - MAKE FROM MOUNTING CARD



HOLES IN WASHERS
TO FIT CAMSHAFT

