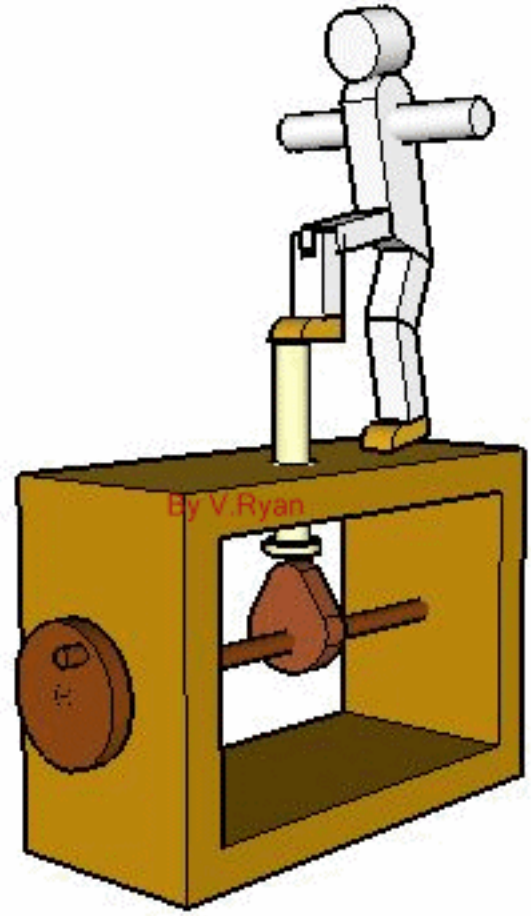
Cams

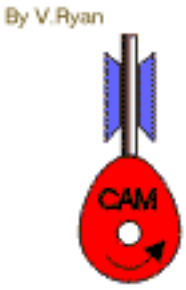
http://www.lizarum.com/assignments/physical_computing/2008/mechanisms/cams.html



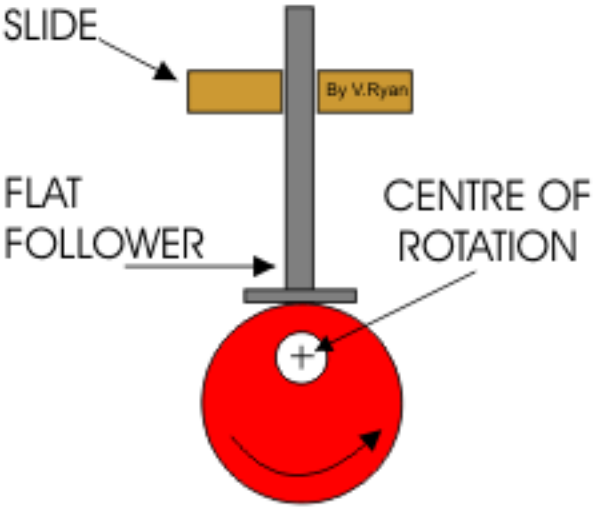
The basic principle of the cam is to turn a circular motion into a linear one. This is referred to as reciprocating movement. In it's simplest form you turn a handle to make something move up and down.

The cam-follower is connected to, and part off, a shaft known as the ***Push-Rod***. The push-rod controls the direction of motion and transfers the cam's movement. The cam-follower should be designed with a smooth end that can easily follow the cam's contours and movement. This is very important as the cam and follower will jam if not properly designed.

They are found in many machines and toys.



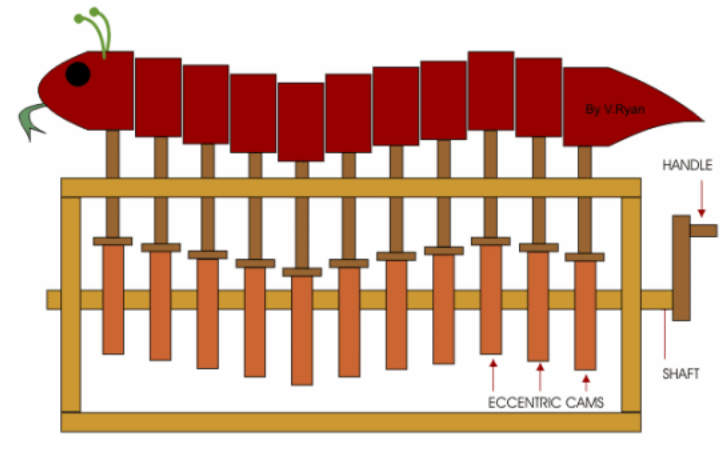
Concentric Cams

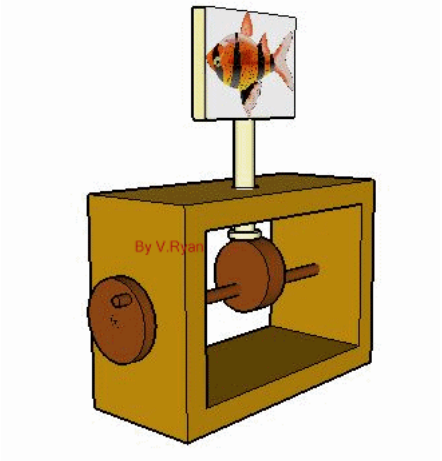


An ***concentric cam*** is a disc with its centre of rotation positioned 'off centre'. This means as the cam rotates the flat follower rises and falls at a constant rate. This type of cam is the easiest to make and yet it is one of the most useful.

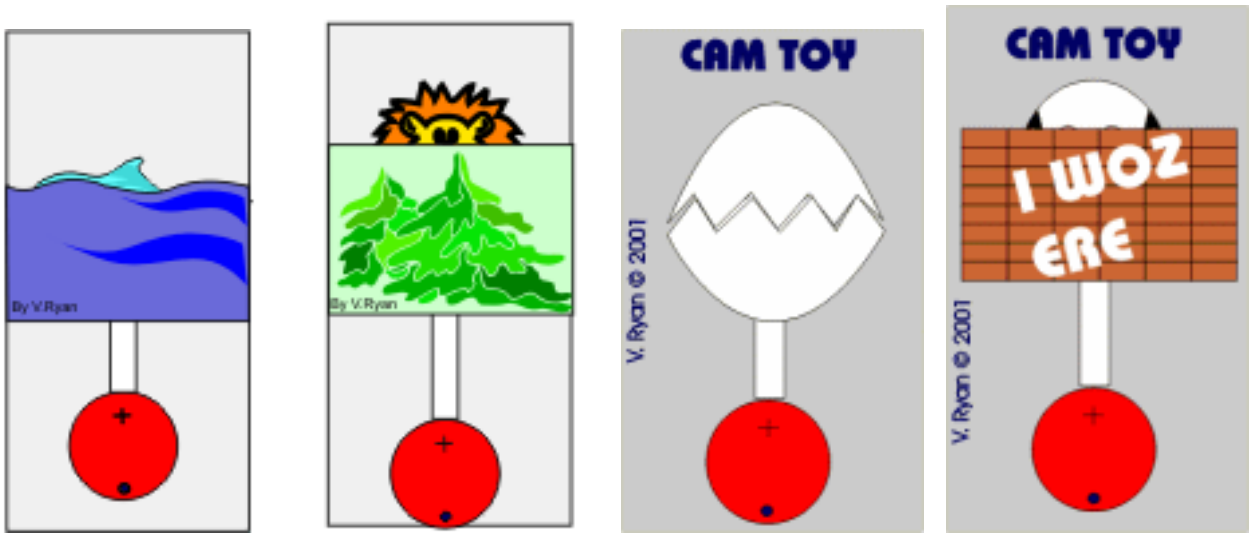
As it rotates it pushes the flat follower upwards and then allows it to drop downwards. The movement is smooth and at a constant speed.

A mechanical toy based on a series of concentric cams is seen below. As the handle is turned the shaft and the cams fixed to it rotate. Placed above the cams are a number of segments representing a 'snake'. As the cams rotate some of the flat followers are pushed upwards while others drop down. This gives the impression that the snake is moving.

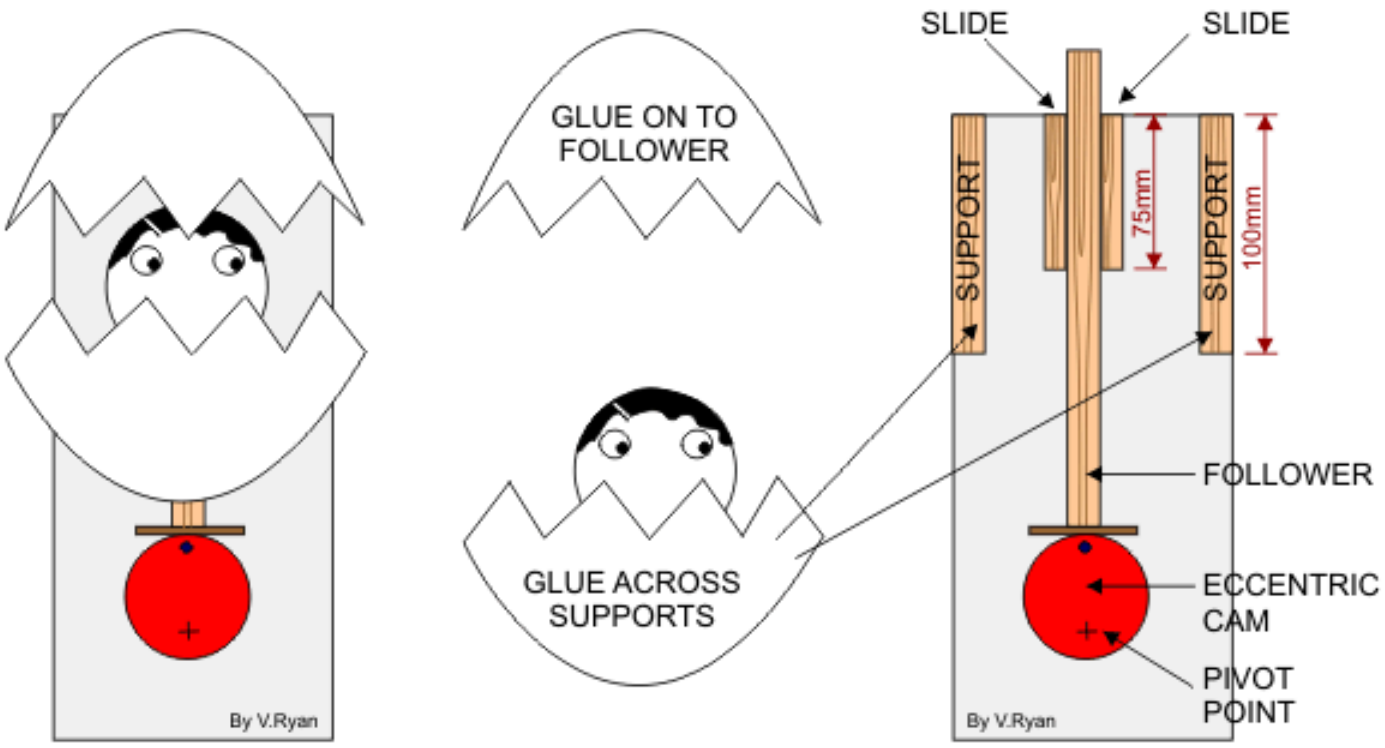


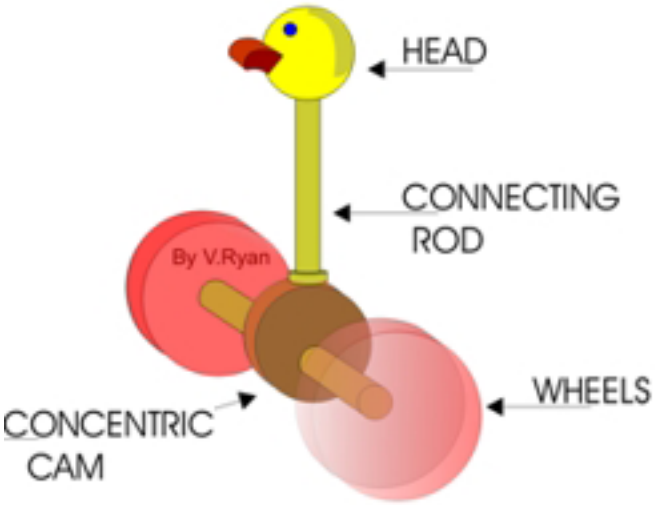


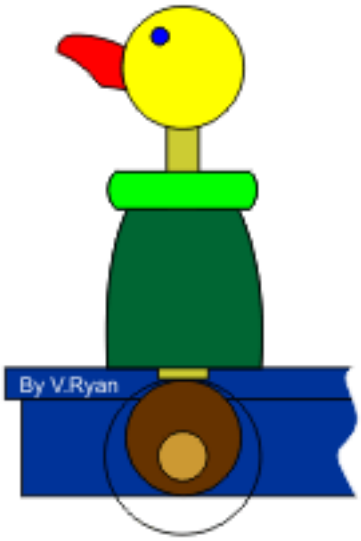
More Examples



Below is a mechanical toy based on a CAM mechanism. As the handle on the concentric cam is turned the top part of the egg shell lifts to reveal a face. The basic construction of the toy is also shown below. The 'flat' follower moves upwards and downwards as the cam rotates. Although the design is simple it must be made accurately or the mechanism will stick.

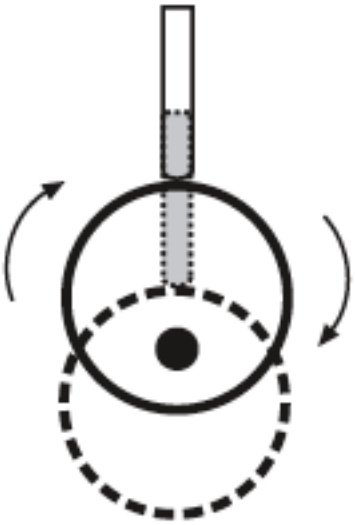






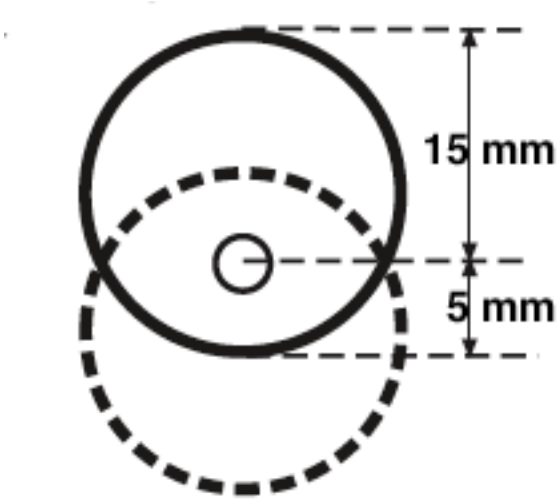
Designing Cams

In order to design a cam you need to know what you want it to do. It may have just one or several movements per revolution. Cams turn on a shaft and so need to be offset to create movement. If you have a circle with the shaft running through the center then nothing happens. However, if you offset it you can create a mechanism that can lift.



The cam-follower has lifted by this amount. So the more you offset the cam, the greater the amount of lift you produce.

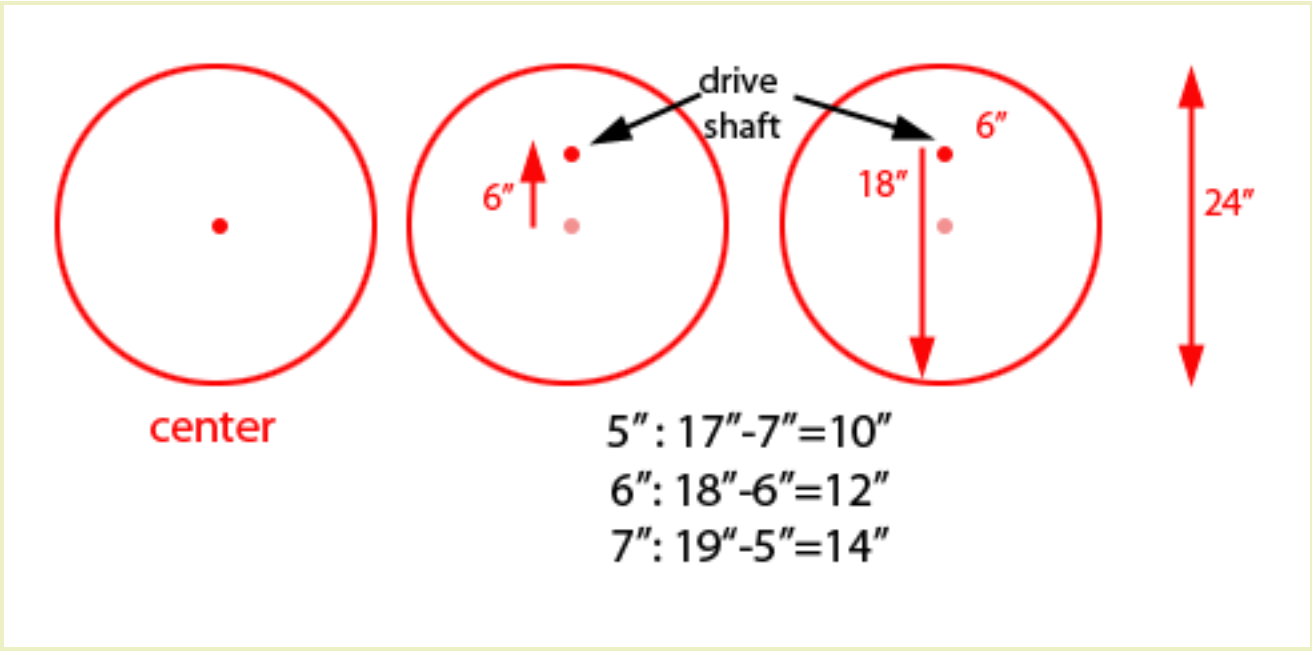
Calculating Lift



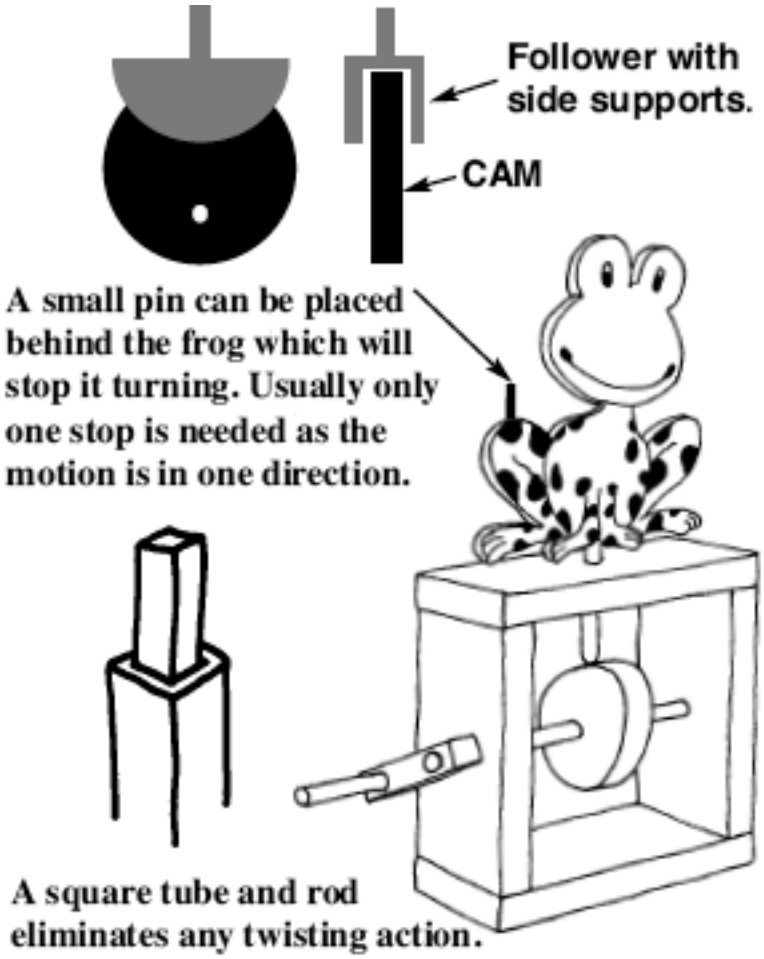
It is very easy to calculate the amount of lift by simply taking the measurement from the center of the drive shaft to the lowest point of the cam and subtracting this from the measurement to the highest point. This calculation will give the amount of lift the cam will produce.

The concentric cam, is a circle with an offset center. By offsetting the center you produce the lift. The further you move away from the center point the greater the amount of lift you will produce. Don't overdo it. It is better to make a larger cam that rises gently than a small one that rises rapidly. They will both do the same job but the smaller cam is more likely to jam.

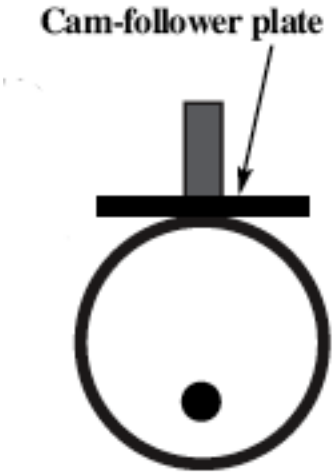
If you need to produce lift to a specific height, the following formula is simple and shows you how to work out the fixing point for the drive shaft:
Every millimeter that you move away from the cam's center point, you must double, in order to calculate the amount of lift generated by the cam.



To eliminate the turning affect you can either build stops to prevent turning, (this can affect the overall look of your automata) or put guides either side of the cam.



Cam-follower Plate

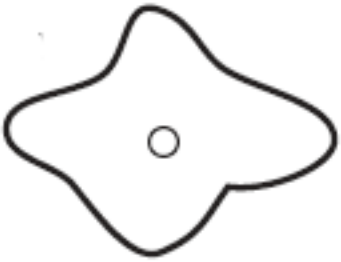


A thin, card cam when used with a wooden dowel camfollower may jam. To avoid this a circular cam-follower known as a ***Plate*** should be used. Because of it's large, flat contact area, it is less likely to jam. This type of follower works best with concentric and some lobed cams. It will not work on cams with complicated shapes.

Cam Shapes

This cam produces a smooth uplift which suddenly drops down. It is often referred to as a ***snail cam*** because of its shape or contour. This cam can only work in one direction. If you turn it the other way the cam-follower would jam. You need to bear this in mind when you are designing cams.

To ensure the rotation is smooth, the vertical centre line of the snail/drop cam is positioned slightly to the left of the slide.

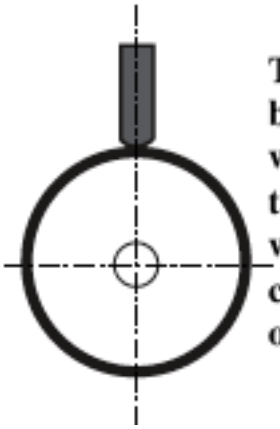


This cam produces several short up and down movements from one revolution.

This cam produces three very distinct movements from one revolution. You can combine as many movements as your cam will allow.

Remember that the cam-follower has to work smoothly. If you try to make it do too much or make the contours too steep, such as this one on the right, it will jam. The cam-followers can only move on gentle curves, make them too tight and you will have problems!

Lobed and Droped

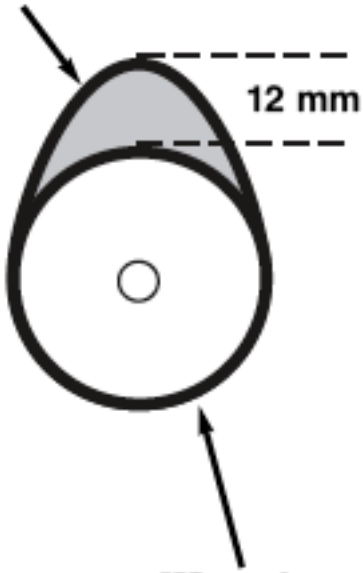


The lobed and drop cams are based on a concentric circle with the drive shaft running through the centre. Obviously, without a lobe or drop, this cam will not produce any effect on the cam follower.

From the basic round cam you can increase the diameter across one axis, to produce an egg-shaped, or ***Lobed*** cam. Alternatively, you can create a recessed area that drops below the circumference of the circle, producing a ***Drop***cam. You can combine these two elements in a single cam.

Lobed Cam

A lobe refers to any part of the circumference raised above the base diameter of the cam.

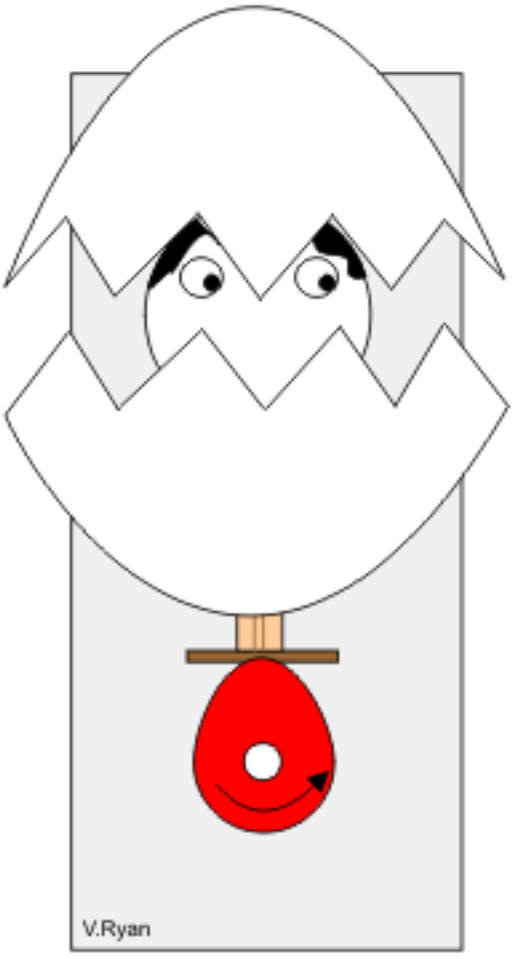


The distance from the circumference of the cam to the highest point of the lobe will determine how much lift it will produce. In this example the cam-follower will smoothly rise to 12mm before dropping.

When the cam-follower is not being lifted, that part of the cam is referred to as the dwell angle. This will produce a pause in the action.

If you raise part of the circumference, you produce a lobe, hence the name lobed cam. This will lift the cam follower by the maximum height from the tip of the lobe to the

circumference of the circle. When the camfollower returns to the circle it will pause and this is referred to as the dwell angle. You can produce a pause or dwell angle on top of the lobe if you design it properly.



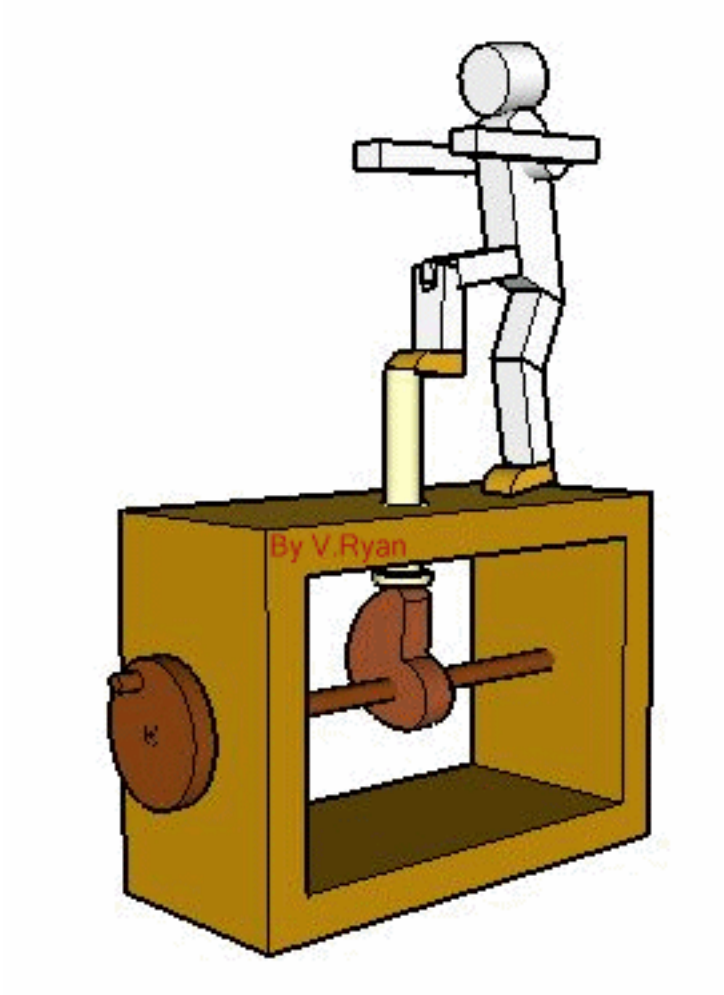
PEAR SHAPED CAM

Droped Cam

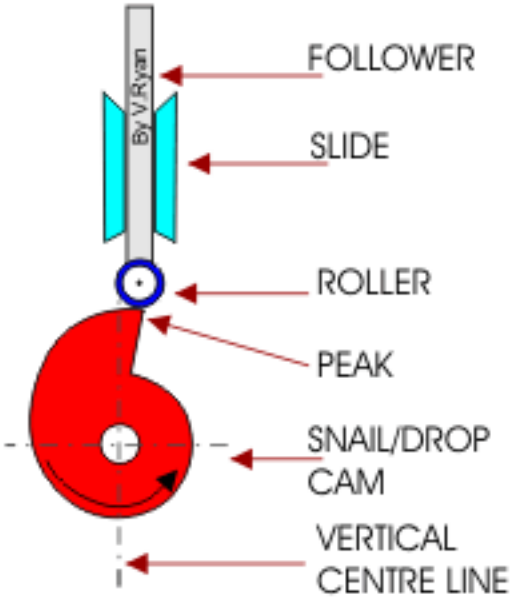
A "Drop" refers to any surface that goes below the circumference of the cam.

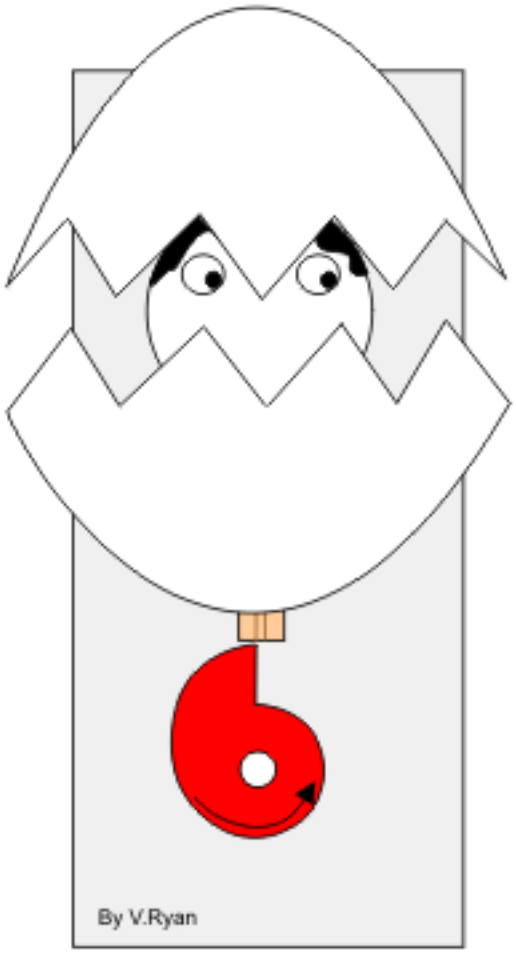
The distance from the circumference of the cam to the lowest point of the drop will determine the amount of travel. In this example the cam-follower will smoothly drop to 12mm, before rising.

This snail cam both drops and lifts. You could even add some extra lobes and drops on the cam face.



If you dip below the circumference of the circle then the cam follower drops, hence the term drop cam. You can calculate the drop of the cam by measuring from the lowest point of the drop to the circumference. A very popular form of drop cam is called the snail cam. This has a sudden drop that slowly rises to the next drop point. This cam is used a lot in automata and is a blend of both drop and lobe cam.


By V Ryan
FOLLOWER
SLIDE
ROLLER
PEAK
SNAIL/DROP
CAM
VERTICAL
CENTRE LINE

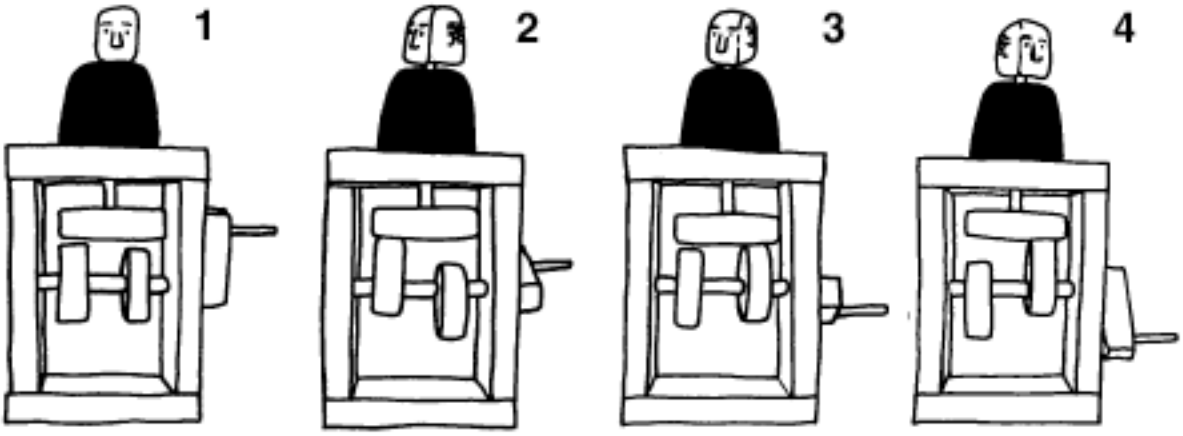


DROP CAM

Offset Cams

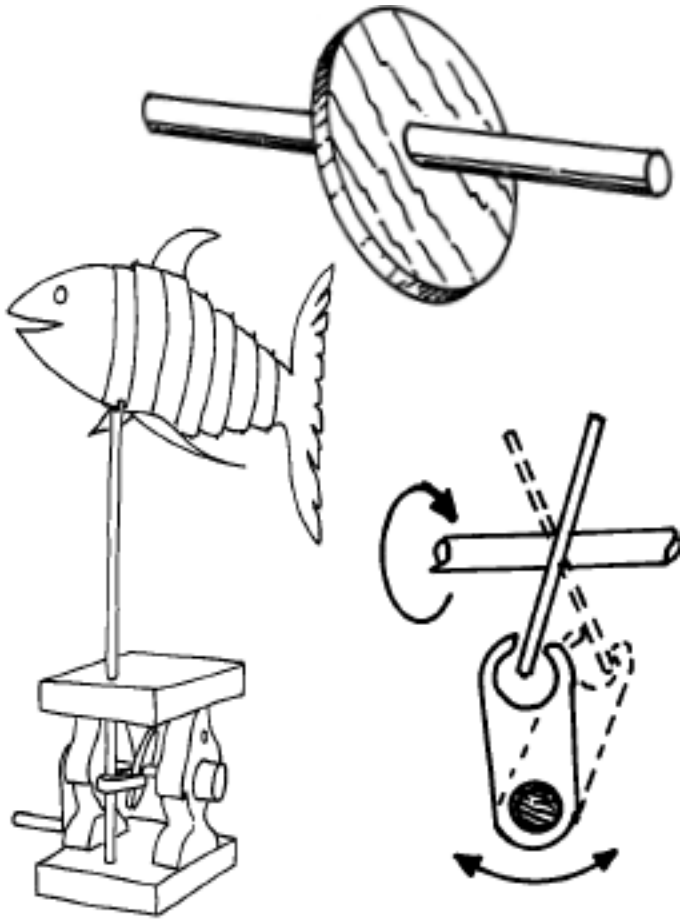
The single cam, lifts and turns the cat in a circle with an intermittent motion.

The man in this automata shakes his head from side to side. There is a small amount of lift but it is not really noticeable.



An offset cam not only moves things up and down but also in a circular motion. You must make sure that the cam contacts the cam-follower plate either side of the cam shaft. If it contacts directly underneath then it will only lift. Offsetting two cams either side produces movement in opposite directions, giving you both up and down as well as a side to side movement.

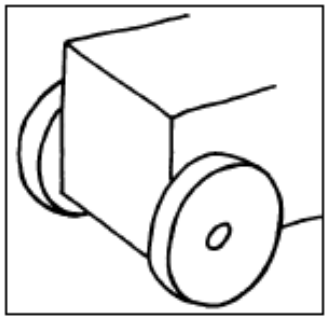
Note that the closer the cam is to the center of the follower the faster and further it will rotate, moving away from the center has the opposite effect.



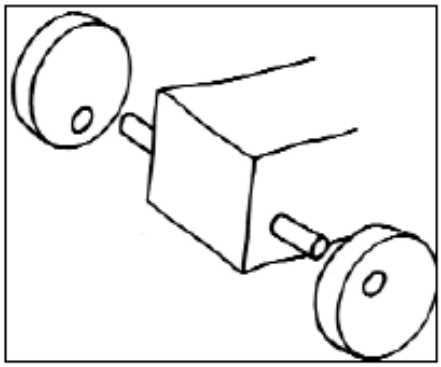
The skew cam has a thin plate which is attached to the drive shaft at an angle. As it turns, it contacts a forked lever which it turns from side to side. This twists a vertical rod and so transfers the movement.

The skew cam is like a wobbly plate and turns a circular motion into a side to side one. This can be adapted to form the axle of a pull along toy.

The Pull-along Toy

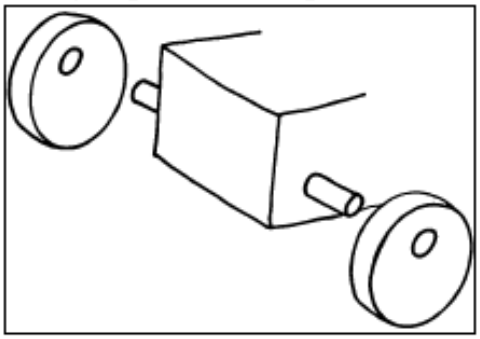


If the wheels are set level and centred on the axle you should have a smooth rolling action. This is the simplest mechanism.

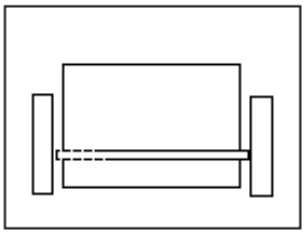


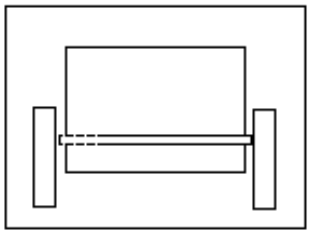
If you offset the centre of the wheels on the axle and synchronise the high and low points to be opposed you will produce and up and down as well as a pronounced side to side wobble.

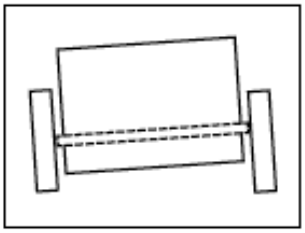
By offsetting the wheels from the middle of the axle you produce an up and down motion as the toy moves backwards or forwards.

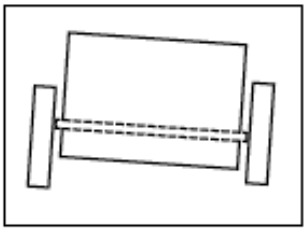


The wheels below are offset by the same amount, this gives a very definite but smooth movement. The more you offset the wheels on the axle the greater the up and down movement you will produce.



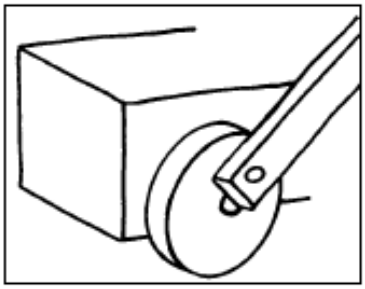


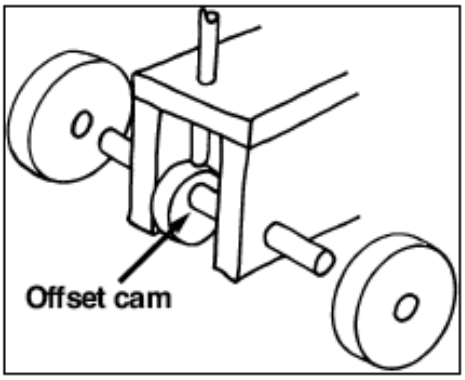




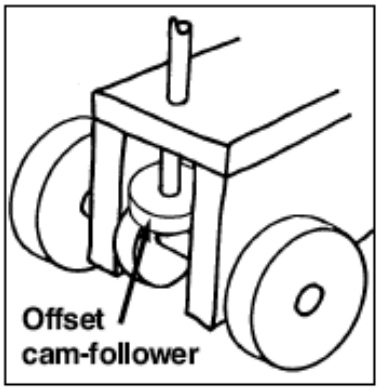
The more you offset the wheels on the axle the greater the wobble you will produce. This simple mechanism produces a very exciting movement when pulled along, yet is very easy to make.

The wheel is centred on the axle and a con-rod is attached to an offset peg. This produces a back and forth, or up and down motion. You can use this to mimic legs.

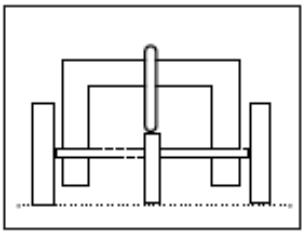


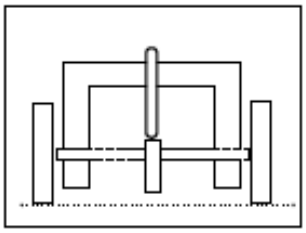


You can have an offset cam on the axle which produces an up and down movement.

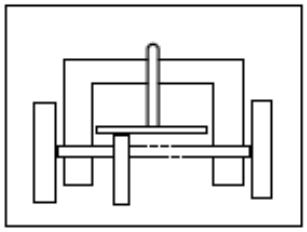


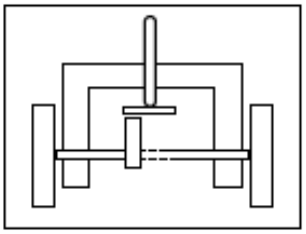
This example employs an offset cam. The cam follower is also offset. This produces both rotary and up and down movement.



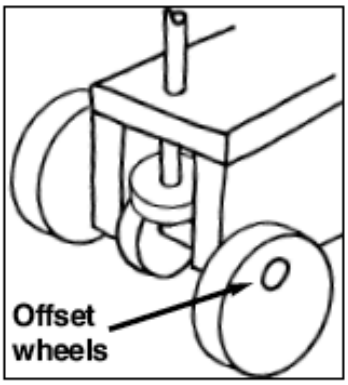


The offset cam should not make contact with the ground, allow room for it not to “stick” if used on a thick carpet. Bear in mind that the larger you make the cam the better and more smoothly it will work.



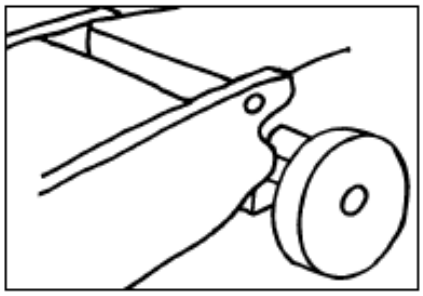


The offset cam must clear the ground and the cam follower plate must not touch the sides.



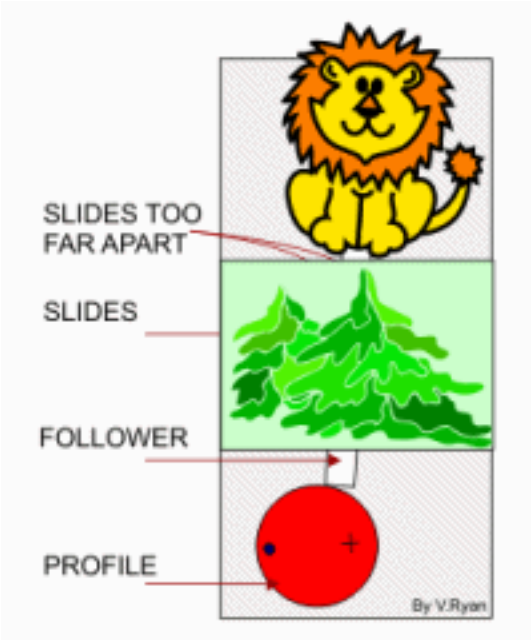
You can build up on the mechanisms for the axle. The example on the left not only has an offset cam-follower but the wheels are also offset and will create a wobble.

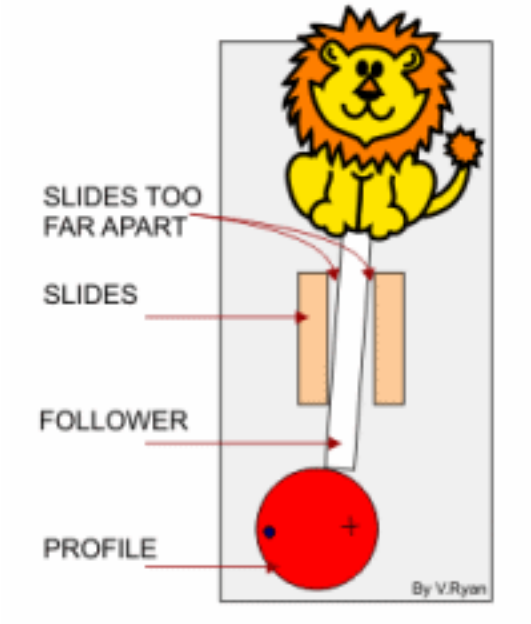
The example below uses a peg attached to the inside of the wheel. As the peg is rotated it contacts a pivoted part and lifts it up. When cleared, the part drops down. The art is to make sure that you don’t lift too high and that the part being is lifted is made out of light material such as balsa wood.



Troubleshooting

Cam mechanisms work well if they are made accurately. However, any inaccuracy in making the device can lead to the mechanism 'jamming' during rotation. Also, inaccuracy can lead to the movement of the follower being less than smooth when rotating.

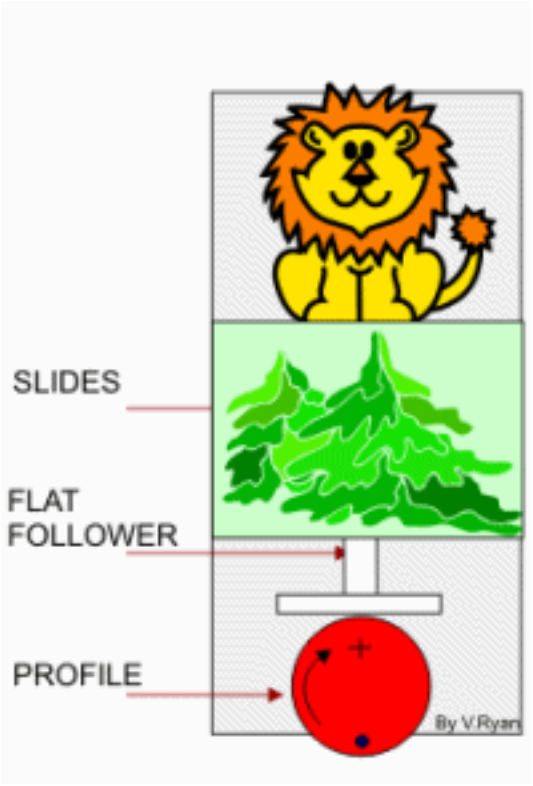


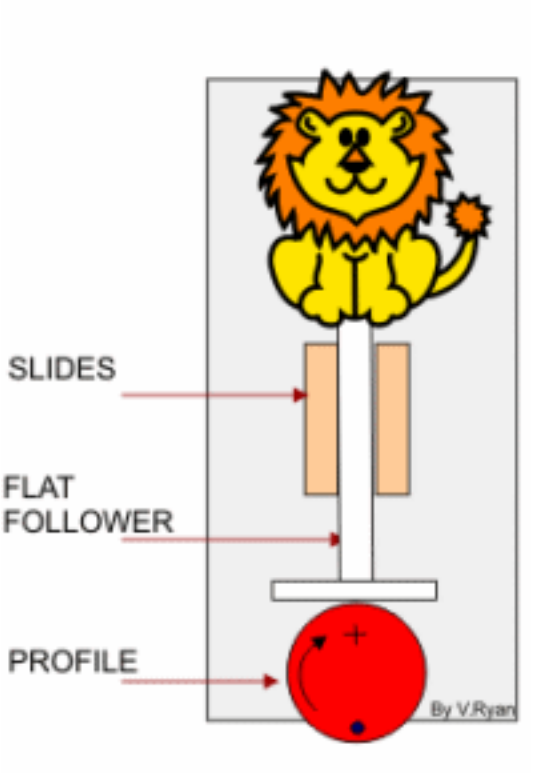


The diagrams show a typical CAM, mechanical toy. The follower has jammed as the profile rotates in a clockwise direction. There are possible reasons/faults that lead to this problem;

1. The slides are too far apart, allowing the follower to jam as the profile rotates.
2.
3.
4. The shape of the follower means that the movement of the mechanism is likely to jam or at best, move roughly rather than smoothly.
5.
6.
7. The Shape of the cam is too extreme

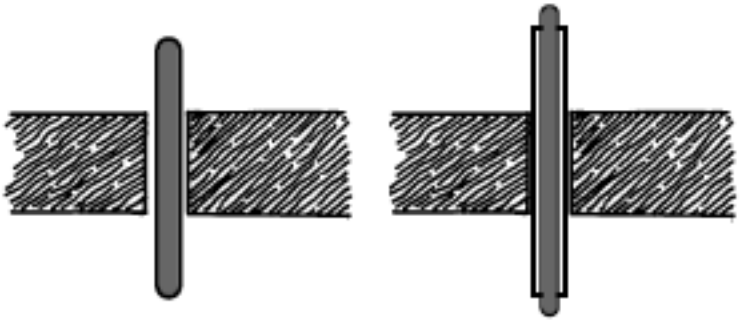
8.





The mistakes can be corrected easily by altering;

1. The shape of the follower. A 'flat' follower is used. This means that the movement of the profile and follower is more likely to be smooth and efficient. Alternatively, you can provide support for the follower:

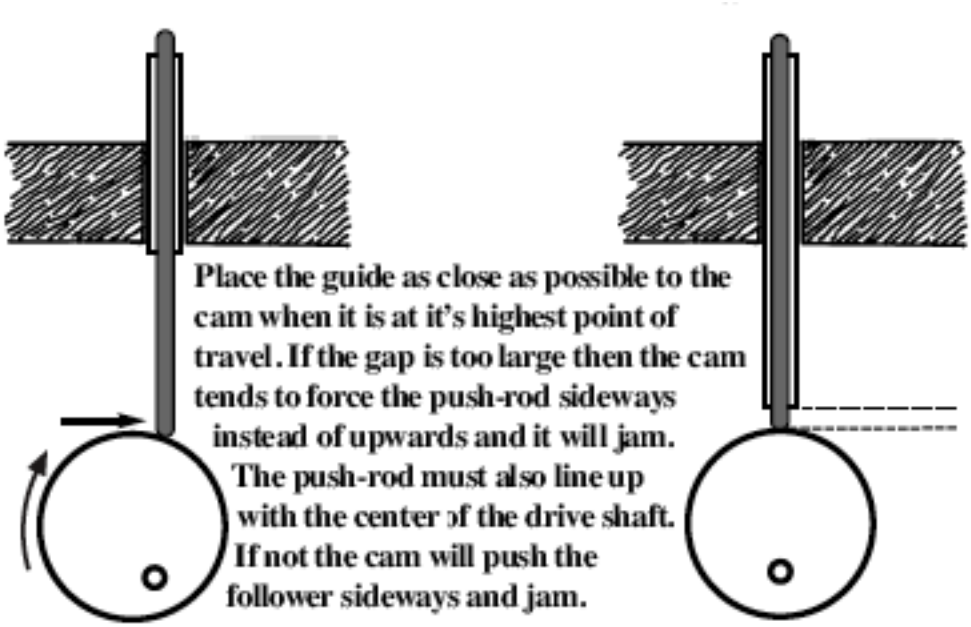


In most cases the push-rod will benefit from extra support. In the above example a straw is used for the guide. This gives much better support.

2.
3.
4.
5. The slides have been moved close together so that the follower is forced to move vertically, without 'jamming'.
6.
7.
8. A larger, more subtle shape creates several events with smoother motion

9.

Aligning the follower with the cam

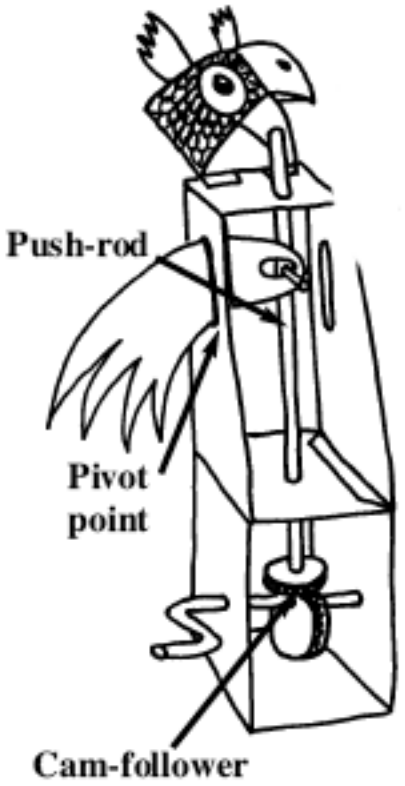


Materials

When you have designed your cam, you will have to think about what to use to make it. The ideal material should be soft enough to cut easily but strong enough not to break or wear out too quickly. Cardboard, for example, can be a useful material. Several thin sheets can be cut to size and then stuck together (or ***laminated***) using wood glue or PVA. This produces a very strong and durable cam. Alternatively you can use thick corrugated cardboard. The cams don't have to be ***industrial*** strength, very often a single 2mm or 3mm thick card one will work adequately.

MDF (medium density fibre board or craftboard) can be bought in various thicknesses. 4-6 mm works best and it is fairly easy to cut and can be shaped with sand paper.

Thin pine wood (again 4-6 mm) is another effective material to work with. It takes a little more time to cut and shape but is very durable, works well and looks good.



This entire automaton is made from paper and card. The ***lobed cam*** is constructed from thick corrugated card. The ***cranks*** (supporting shafts, cranks and push-rods) can be made out of pencils, straws or wooden dowels. Wood glue or PVA can be used to stick all the parts together. The base can be made out or a cereal or other box.

This illustration shows you how the mechanisms are constructed. The head is hinged at the back and is pushed up by the pushrod. The wings are slotted through the body (which acts as a pivot) and are attached to a rod that is in turn connected to the pushrod. This provides the lift for the wings. Both the head, wings and cam follower are assisted by gravity which provides the downward force.