

INTRODUCTION

Have you ever wondered how simple things you use time and again work ? Don't think we are going to speechify something , but we will give you an account of the mechanism of a thing that is not as simple as it looks. If you have got a discerning eye then you will be able to see our point.

We are talking about your constant companion in the hot summers and when it rains. Yes you are right if you have guessed it to be the umbrella.

So next time when you hold it just observe its mechanism and check whether we have given you a true account of its mechanism.

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HISTORY OF THE UMBRELLA



Umbrellas in ancient Egypt, Mesopotamia, China, and India were used to protect important persons from the sun. They were often large and held by bearers, and they served as marks of honour and authority for the wearer. The ancient Greeks helped introduce **umbrellas** into Europe as sunshades, and the Romans used them to protect against rain. The use of **umbrellas** disappeared in Europe during the Middle Ages but had reappeared in Italy by the late 16th century, where they were regarded as marks of distinction for the pope and clergy. By the 17th century the use of the **umbrella** had spread to France, and by the 18th century **umbrellas** were common throughout Europe. A small, dainty **umbrella** used for shading women's faces from the sun became known as a **parasol** and was a standard element of fashionable women's outdoor attire in the 18th and 19th centuries. The traditional construction of **umbrellas** using cane ribs was replaced in the 1850s by modern **umbrellas** using a very light but strong steel frame. Men in the West began carrying **umbrellas** for personal use in the mid-19th century. Men's **umbrellas** were generally black, but in the 20th century men's as well as women's **umbrellas** were made in a variety of bright and colourful designs.

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GENERAL MECHANISM OF THE COMMON UMBRELLA

An umbrella consists of

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All you have to do to open an umbrella is to press a button on the handle that releases a hollow shaft, held against a catch. A compressed spring between the hollow shaft and the base shaft causes the hollow shaft to move up. The movement of the hollow shaft is restricted by another catch on the base shaft. Amidst all this the umbrella does not open up. This is to ensure that you don't get hurt by the spokes of the main framework. After the hollow shaft gets engaged, the relative motion between this shaft and main spring responsible for the opening mechanism is allowed. Now this spring applies an upward force on linkages attached to it which results in the opening of the umbrella.

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SPRINGS

THE MAIN TYPES OF SPRINGS ARE :--

- *button spring*

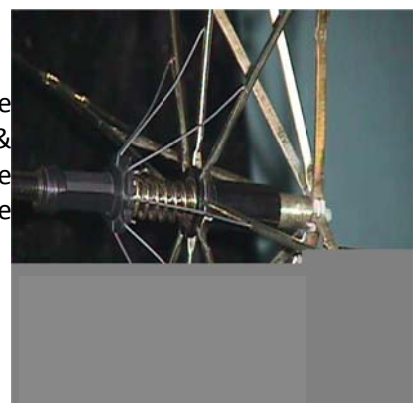
Button springs are used to achieve an auto push back mechanism for the button.

- *inner shaft spring*

Inner shaft spring is used to enable the hollow shaft move above the base shaft automatically as soon as the catch is released.

- **main spring**

The main spring acts as a connection between the two prismatic pairs of the five bar linkage (3R & 2P) . The function of the spring is to open up the umbrella as soon as the maximum length of the



umbrella is achieved. It is seen that when you close the umbrella initially the force required is more because of the component of the force used in the compression of the spring is less initially. A detailed description of this mechanism can be studied in the linkage part.

- **shock absorber spring**

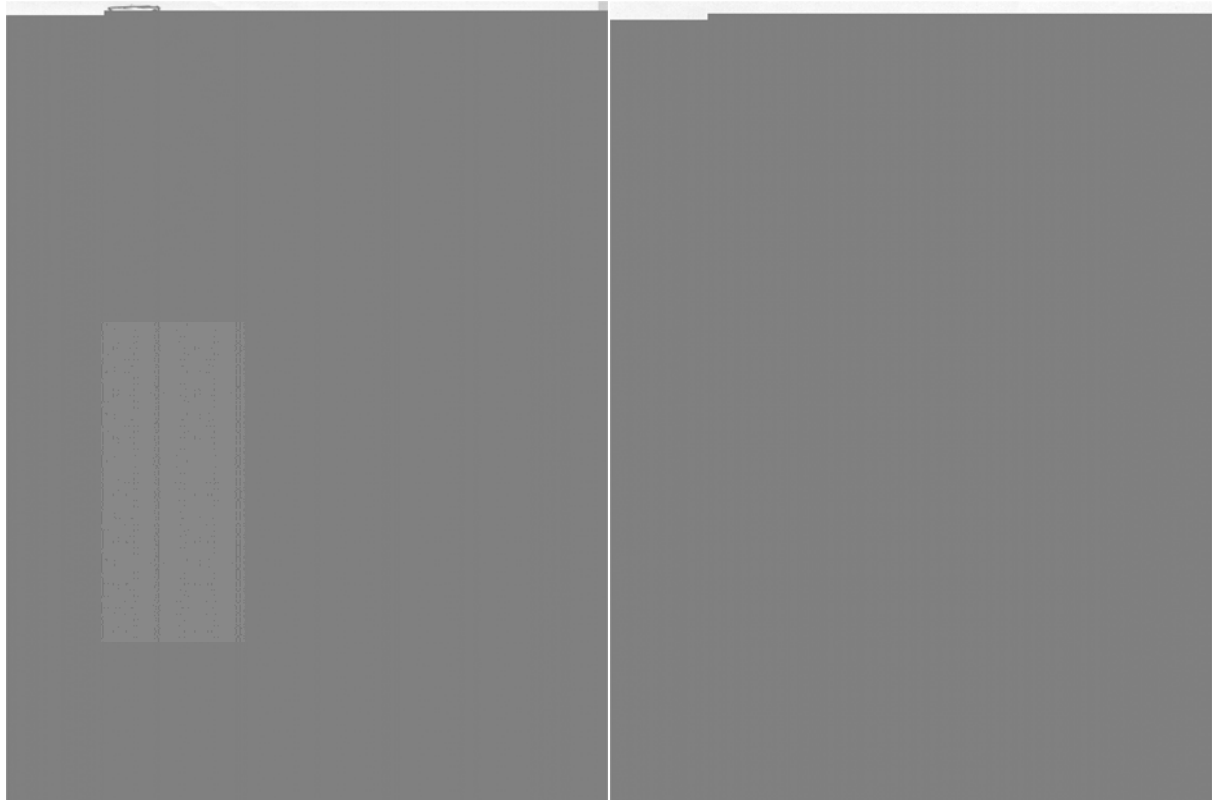
This spring is attached to the topmost portion of the umbrella and bears the shock while the umbrella is opening.



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LINKAGES

THE MAIN FRAME AND THE LINKAGES

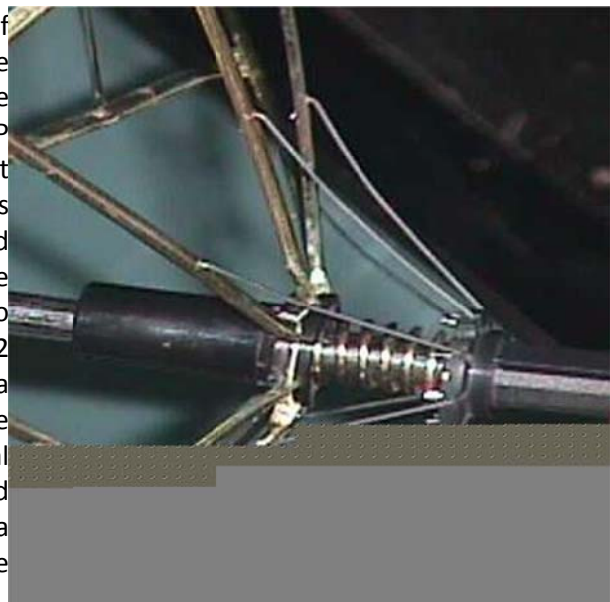


As a whole umbrella consists of eight linkages, six revolute pairs and two prismatic pairs. Therefore the degree of freedom is $\{3 \cdot (8-1) - 2 \cdot 8\} = 1$ and so for a given input there is a unique output. Here we further subdivide its linkages into two.

THERE ARE TWO MAIN LINKAGES :--

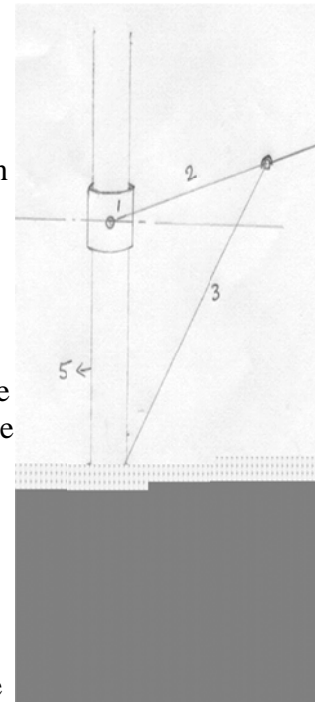
- *5 bar linkage (3R & 2P)*

The five bar linkage consists of two prismatic pairs and three revolute pairs. Although the degree of freedom of 3R and 2P linkage is 2 $\{3(5-1) - 2 \cdot 5 = 2\}$ but here one degree of freedom is lost because of the restricted motion of link 2 (because the other end of link 2 is restricted to move in a circular path). The 2 prismatic pairs are connected by a spring so that while closing the umbrella we store potential energy in the spring which could be used to open the umbrella automatically. Here we study the



closing of the umbrella, what happens in the opening is just the reverse the only difference being that since no external force is applied so there is acceleration of the umbrella parts.

To close the umbrella we apply force on the link 4. Initially the angle made by link 2 with horizontal is approximately Zero (slightly >0). So the force transmitted from link 4 to link 1 through link 2 is less because the component of force in downward direction is less, but as the umbrella is further closed this angle increases and so the component of the applied force in the downward direction increases (Although the spring gets more compressed still the force required is less because the increase in component of force due to variation of angle is more than sufficient to balance the spring force). So finally when the umbrella is closed, the two prismatic pairs move a certain distance (fixed $=D$) from their other extreme positions (In fact they now come above the base shaft). This fixed distance is less than the total usable length of the shafts put together. Now suppose you fold the umbrella (without allowing relative motion between the two shafts), what you will find is that one of the prismatic pair has come on the base shaft this implies that $D >$ the length of the hollow shaft and so you have to have a part of the base shaft to completely fold the umbrella. Now since the required force to fold the umbrella was decreasing as it was folded we know that the force required to hold umbrella in folded position is less. When you completely close the umbrella you have to apply a force for two purposes 1. To keep the umbrella in folded position. 2. The spring force between the two shafts.



In the folded position the umbrella is stable (force required to hold the umbrella in folded position is less), so if we leave umbrella in this position it would open slowly. What is done to open the umbrella quickly is that a relative velocity is imparted to the prismatic pairs w.r.t the hollow shaft in the upward direction, this is done by the spring between the hollow and base shafts. When you open the umbrella (from completely closed position) the spring between the shafts pushes the hollow shaft upward and thus imparts velocity to both the prismatic pair and the hollow shaft, but the movement of the hollow shaft is limited by a catch and so it stops suddenly at a point but the prismatic pairs keep on moving and thus a relative velocity is imparted to prismatic pairs w.r.t the hollow shaft and the umbrella opens. Above mechanism also gives an account of why the umbrella first extends and then opens up.

- **4 bar linkage**

This is a parallelogram linkage consisting of four revolute pairs. The function of this linkage is to achieve the final and initial configuration of the umbrella i.e it acts as a guide way for the cloth from opened condition to the closed one.

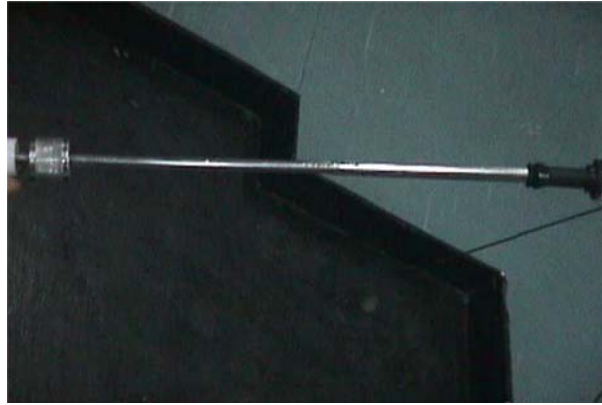


The link 1 moves in a circular motion about the fixed point O. Since the link 3 is parallel to link 1 its motion is exactly governed by the motion of link 1. In the opened position the angle made by the link 1 with the vertical axis is more than in the closed one therefore the link 3 makes more angle with the vertical axis in the opened position and enhances the spreading of the cloth, while in closed position it makes less angle and so enhances folding of the cloth.

Another peculiarity of the four bar linkage is that the joint between the link 2 and link 3 is made smoother as visible in the photograph. It is done so that the cloth tied to this linkage does not tear off if some roughness is present.

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SHAFTS



THERE ARE TWO TYPES OF SHAFTS :--

- *hollow shaft*

This shaft is the main shaft carrying all the linkages including two prismatic pairs in the open position of the umbrella. Initially in the closed position this shaft is held against the lower catch. When this catch is released, the shaft moves up relative to the base shaft due to force applied on this shaft by an inner shaft spring which is in a compressed position initially. During this movement of the shaft, the umbrella doesn't open up too much, but after moving a certain distance, safe enough to allow the umbrella to open up without hurting the user, this shaft gets engaged with the upper catch. At this instant, there starts a relative motion between this shaft and the links of prismatic pairs.

- *base shaft*

This is the lower shaft carrying the whole weight of the umbrella. Both the catches are on this shaft. The cross-section of the shaft is not circular but has two guideways at 180 degrees to each other provided for the alignment of the hollow shaft so that it finds catches on its path.



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CATCHES



THERE ARE TWO SIMILAR CATCHES :--

- *lower catch*

This catch is provided at the handle and is controlled by a button. this holds the hollow shaft when the umbrella is closed.

- *upper catch*

The upper catch engages the hollow shaft when it's moved a distance safe enough to allow the umbrella to open.

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