Collapsible Structures: Pop-Up Books

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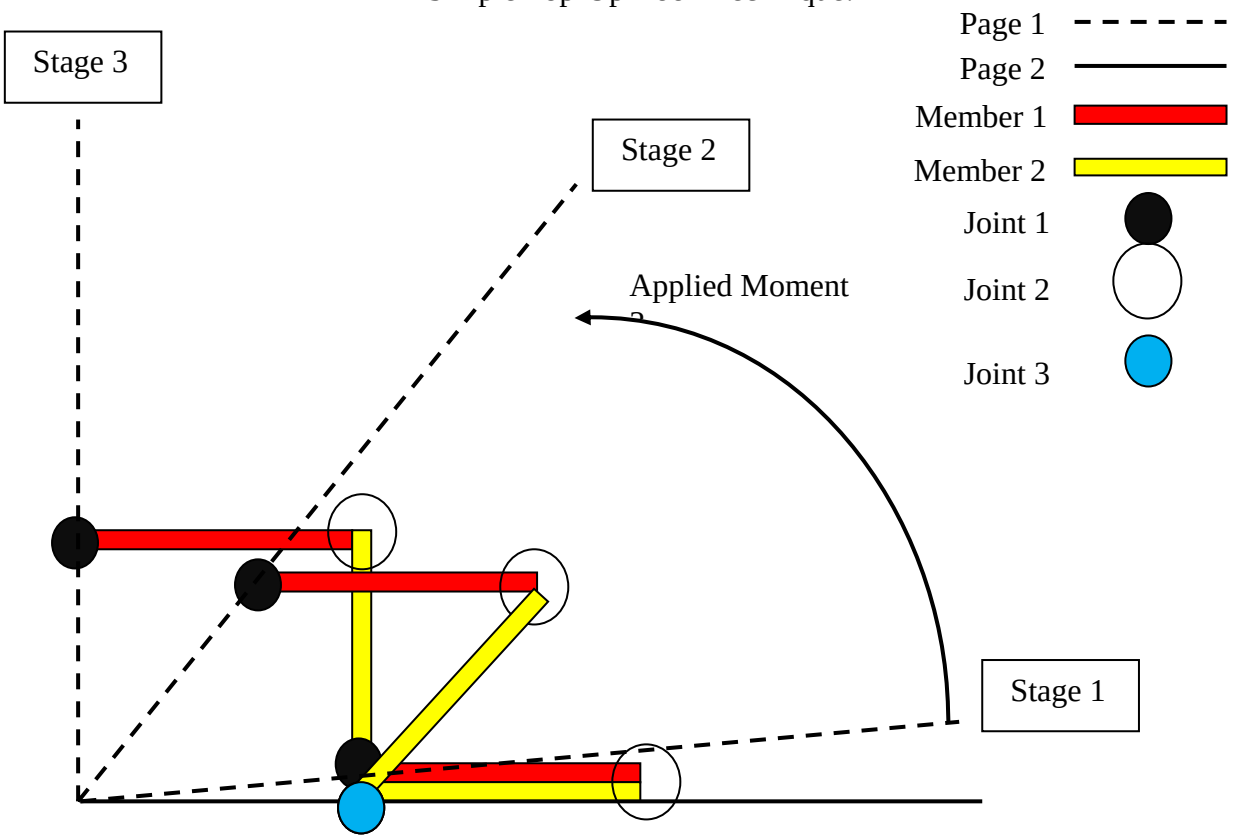
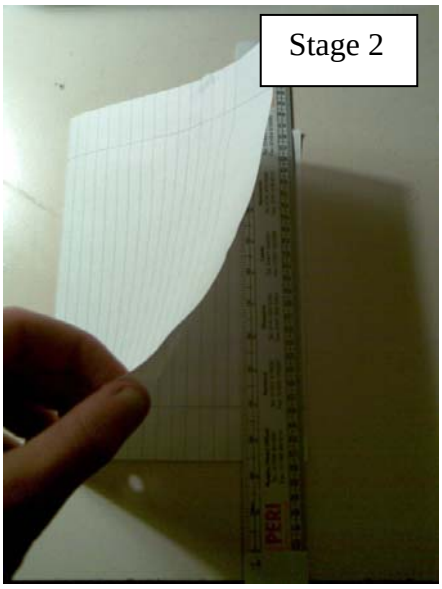
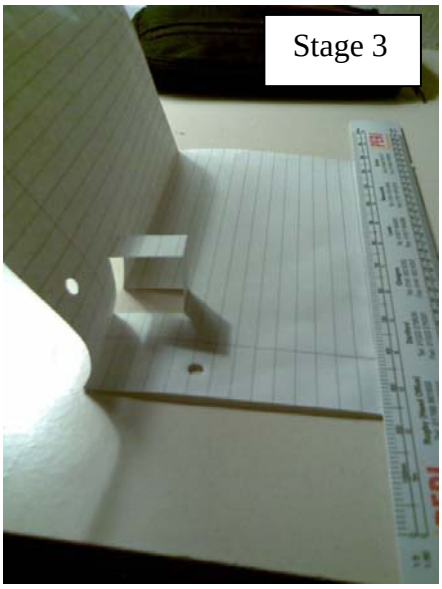
I have looked at the mechanism of collapsible structures, in particular the form of pop-up books. In paper engineering folds and shapes created from cuttings can be directly related to joints and members. The stiffness of a paper structure depends upon the material used such as paper or card. The material is habitually uniform and continuous/connected. A collapsible structure provides advantages such as the ease of storage and also the ease of movement of a structure from place to place as well as the ease of erection. Further examples include soft-top roofs on cars and pop-up tents.

A Simple Pop-Up Book Technique:







Described below is the process by which a plane structure, Member 1 parallel to Member 2, becomes a 3-dimensional structure, Member 1 perpendicular to Member 2, due to the application of a bending moment. The structure formed is self-supporting at any particular angle between the two pages provided that the moment applied to induce that particular angle remains constant.

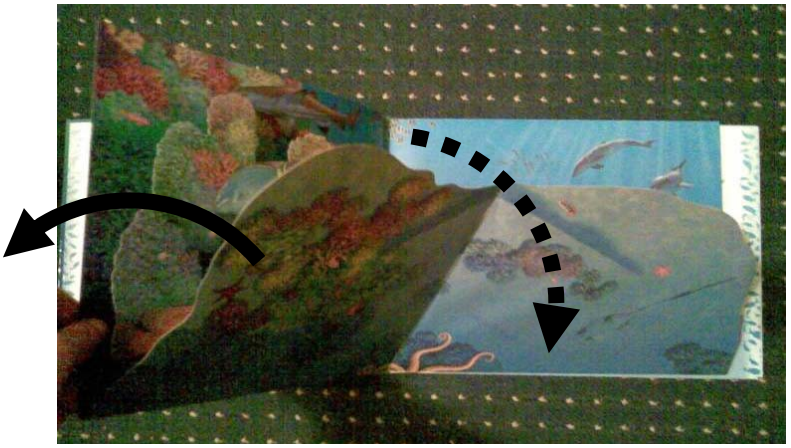
Member 1 and Member 2 are inextensible members. Joint 1 is a fixed joint. Joint 2 and Joint 3 are pinned joints. Page 1 is assumed fixed on a horizontal plane.

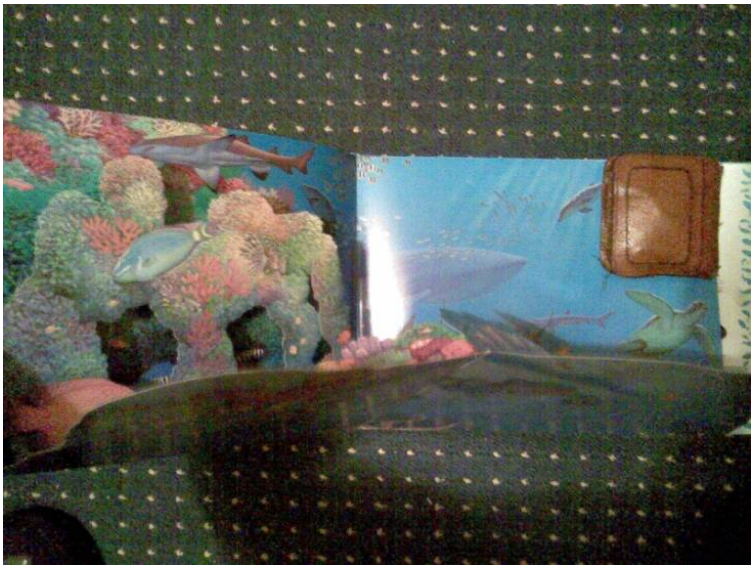
By applying a moment to Page 1, relative to the hinge of the book, Joint 1 moves in a radial fashion because it is fixed to Page 1. Due to the motion of Joint 1, Member 1 is displaced in the same fashion. Member 1 remains horizontal for any angle between Page 1 and Page 2 up to 90 Deg. Joint 2 is a pinned joint which rotates through the same angle as Joint 1 but about a centre of rotation of Joint 3. The rotation of Joint 2 creates a rotation of Member 2. Joint 3 is fixed to Page 2 and allows the rotation of Member 2, i.e. a pinned support. When the moment applied to Page 1 creates an angle of 90 Deg between Page 1 and Page 2 Member 1 is perpendicular to Member 2.

A Complex Pop-Up Book Technique:

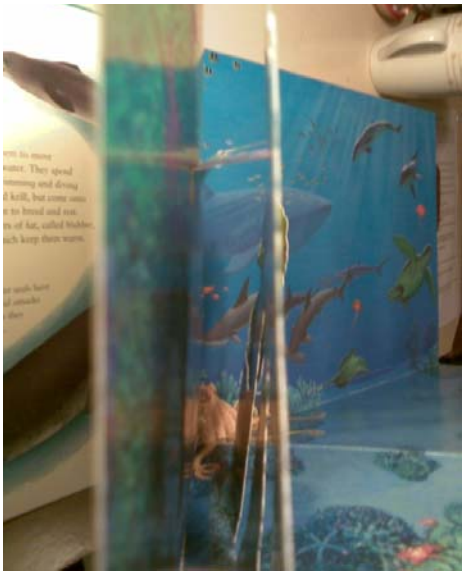
- An applied moment about the hinge of the book.

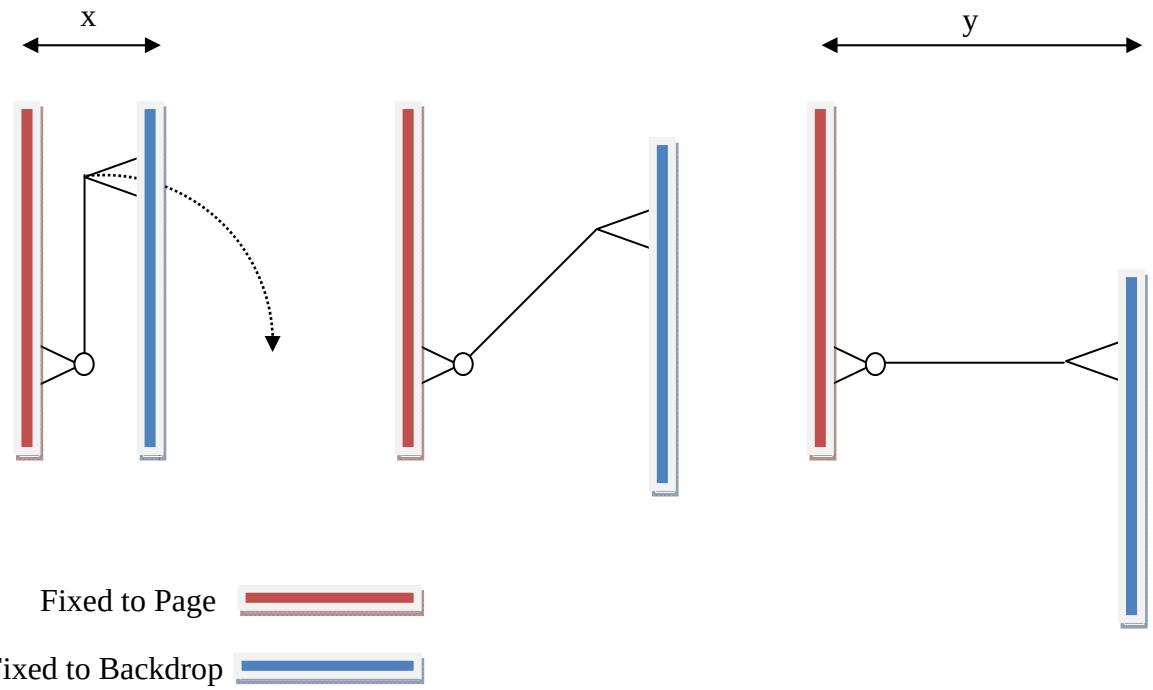
- As the angle between the two pages increases a downward rotation of the bottom flap occurs.





- This downward rotation induces the projection of the backdrop. The rotation of the backdrop is possible using moveable joints as shown below.





Overall rotating the page about the hinge creates a rotation about the support. The support is found along the bottom surface of both the pages. The rotation of the bottom flap about the support causes a rotation of the hinge which supports the backdrop. Thus the backdrop protrudes from the page. x defines the distance between the page and the backdrop which is equal to zero initially in the fully compressed state and extends to its maximum length, y, when the pop-up is opened. The pop-up is self supporting when the moment applied to the page is maintained.

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