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A1_3 Breaking the Broom

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Abstract

In this paper we have examined the forces that act on the broomstick in the children's book 'Room on the Broom'. By considering a magical correcting force and the weights of the animals We have calculated the maximum mass on a maple wood broomstick to be 166 kg. The broomstick would be able to support the witch and her friends.

A1_3 Breaking the Broom

Introduction

In the popular children's book 'Room on the Broom' by Julia Donaldson, a witch goes on a journey meeting various animals and brings them on her broomstick [1]. Eventually the broomstick breaks as there are too many creatures riding on it. In this paper we investigate how much weight a broomstick could carry.

Theory

The various animals that join the witch on her broomstick are a ginger cat, Jack Russel, green woodpecker and a frog. In Table 1 we have included the average masses of each of these animals in addition to the cauldron that the witch carries on her broomstick. The animals have been sorted into the order that they join the witch on her journey. To simplify this problem we have assumed that the masses of all the animals act from the same point as a combined centre of mass of their weights.

The forces that are acting on the broomstick are shown in Fig. 1, where CoM stands for Centre of Mass. The correcting magnetic force acts on the opposite side of the pivot point to correct for the load of the witch. This force acts opposite to the witch and is capable of supporting her weight to allow the broomstick to fly.

Table 1: Weights of animals and objects

Animal	Weight/kg
Broomstick	1.55 [2]
Witch	70.2 [3]
Cat	3.5 [4]
Dog	7.5 [5]
Bird	0.2 [65]
Frog	0.02 [7]
Cauldron	4.2 [8]

The modulus of rupture is the stress in a material just before it breaks as a result of the stress. It can be expressed as

$$\sigma = \frac{3FL}{2bd^2}, \tag{1}$$

where F is the force of the fracture point, L is the total length of the broomstick, b is the width, d is the thickness [9].

We have assumed that the broomstick is made out of maple wood. Throughout this paper we

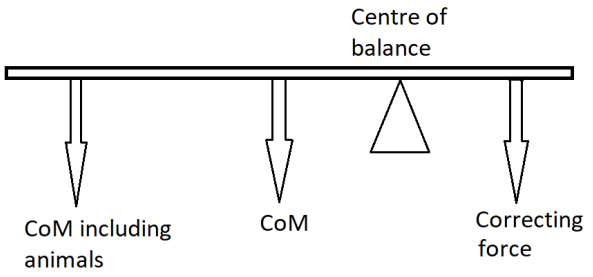

Figure 1: Forces acting on the broomstick

have assumed that the broomstick will be perfectly balanced and that the Centre of Mass of the broomstick will be at the midpoint of the wood. Details about the properties of this wood are in Table 2. We have estimated the length, width and thickness of the wood.

Table 2: Properties of broomstick

Property	Value
Length	1.2 m
Width	3 cm
Thickness	3 cm
Modulus of rupture	109 MPa [2]

Results

From Table 2 the maximum shear stress which the maple can withstand is 109 MPa. Rearranging Eqt. 1 to find the force required to break the broomstick was calculated to be 1635 N. The maximum mass the broomstick can support is 166 kg.

In the story it is the frog that leads to the broomstick breaking [1], however the combined mass of the witch, broomstick and animals is 87.17 kg which is considerably lower than the mass required to break the broomstick.

Conclusions

From the calculations above it is evident that a broomstick made of maple wood would be able to support the witch and all the animals. There is plenty of room on the broomstick for everyone - or at least for another 78.83 kg of animals.

References

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