CALIFORNIA STATE SCIENCE FAIR
2011 PROJECT SUMMARY

Name(s)

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31414

Project Title

The Physics of the Party Balloon: On Laplace's Law, Nonlinear Elasticity, and Their Uses in Physiology and Medicine

Abstract

Objectives/Goals

Balloons are similar to many mammalian organs such as the heart, bladder, lungs and arteries. Balloons are also used in angioplasty to unclog blocked arteries. In all of these cases, the function of the balloon-like vessel depends strongly on the relationship between the pressure within it, and its size. In this experiment, I have used party balloons as model systems to investigate this relationship

My main question was about how the pressure within an inflating balloon depends on its radius. I investigated this question using 12" spherical party balloons. I then asked further questions: How does the pressure-radius curve change as (a) the manufactured size of the balloon, (b) the shape of the balloon, and (c) the wall thickness of the balloon are changed? I used party balloons of different sizes, and shapes.

Methods/Materials

I built a U-tube manometer using commonly available materials. I attached the balloon under test, and a bike pump to this setup. I inflated the balloon in small increments and recorded its pressure, and radius. I did this until the balloon was fully inflated. I repeated this for each balloon three times. I collected over 500 data points for all the variations in my experiment.

Results

The experimental pressure-radius curves I obtained were surprisingly complex. I used Laplace#s Law ($P=2T/R$) - where P is the pressure, T is the wall tension, and R is the balloon radius - to analyze my results. The wall tension T is a function of R. So I needed to use a law of elasticity along with Laplace to model my experimental data. First I tried the famous Hooke#s Law, which is a linear law of elasticity. This failed to fit my data. I then tried different nonlinear theories of elasticity and Mooney and Rivlin, and obtained progressively better fits.

Conclusions/Discussion

I found that the manufactured size of a balloon does not affect the pressure-radius curve much. I showed that Laplace#s Law itself has to be modified to account for geometrical differences between spheres, and cylinders. I found that the pressure required to inflate a balloon depends linearly on wall thickness. Medical balloons are smaller, and are made of more exotic materials. However, the theoretical methods I have used to study party balloons are conceptually similar to those used by professional medical balloon designers.

Summary Statement

I showed that Laplace#s Law, and a suitable nonlinear theory of elasticity can be used to model the complicated pressure-size behavior of an elastic container.

Help Received

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