Phairy Tale Physics

According to the fairy tale, Rapunzel was imprisoned in a high tower with a single window as the only way in or out. In the story, a prince was able to climb up her extraordinarily long hair and rescue her.

An experiment was done to find the Young modulus of hair. A sample of hair had a length of 8mm and a diameter of 65μm. A force of 0.2 N was applied to it, and produced an extension of 0.08mm.

1) Calculate the cross-sectional area of the hair (assume it is circular).

2) Calculate the stress exerted on the hair.

3) Calculate the strain of the stretched hair.

4) Hence calculate the Young modulus of the hair.

In the same experiment, the hair started to become permanently deformed at a stress of about 90 MPa.

5) Calculate the maximum Force that this hair could hold without being permanently deformed.

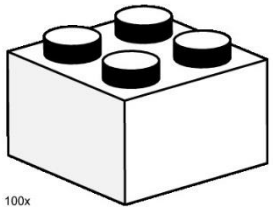
6) If the prince has a mass of 85kg, calculate the minimum number of hairs needed in Rapunzel's pony tail for him to climb up without the hair permanently deforming.

7) Calculate the diameter of this bundle of hair.

8) Using ideas about Forces, explain why more hair than this would be needed.

Physics Fun with Lego

You have almost certainly played a lot with Lego as a child (or possibly more recently). You may have wondered how tall a tower of Lego bricks could be. Recently, some tests were done on a standard 2x2 Lego brick[1] which yielded some interesting results:



Data: Dimensions of block: 16 mm x 16 mm x 9.6 mm (WxDxH)
Mass of brick: 1.152 g
'Knob diameter' [*sic*]: 4.8 mm
Average compressive force required to plastically deform brick: 4240 N

1) The 'knob diameter' has to be accurate to 10μm, otherwise the bricks won't stick together reliably nor come apart easily. Calculate the uncertainty of this as a percentage.

2) Calculate the area of the base of the brick, in m^2.

3) Calculate the weight of one brick (use $g = 9.81\ Nkg^{-1}$)

4) Calculate the pressure exerted by one brick on its base, in Pascals.

5) Calculate the compressive stress at which the brick fails, and compare it to concrete (≈ 50 MPa).

6) Calculate the maximum number of bricks which could be built vertically upwards before the bottom brick failed.

7) What would the height of this tower therefore be?

8) Comment on the additional problems you would be likely to face in practice when trying to build a tower this high.

[1] www.bbc.co.uk/news/magazine-20578627

Cable Cars

The Peak-to-Peak Gondola was built in 2007-8 and connects Whistler Mountain and Blackcomb Mountain in Canada, making the largest skiing resort in the world. It holds the record for the longest unsupported cable-car run in the world:

At the gondola stations, they have samples of the cables used, with technical data:

Upper caption reads: **Haulage Rope** (*the cable which pulls the cars along*)

Diameter	46 mm
Length	9490 m
Weight[2]	8.28 kg/m
Minimum breaking strength	1523 kN

Lower caption reads: **Track Rope** (*the cable the cars actually move on*)

Diameter	56 mm
Length	4 x 4760 m
Weight	17.94 kg/m
Minimum breaking strength	3415 kN

[2] An unfortunate choice of word. The quantity stated is actually the rope's linear density – its mass per metre of its length.

Questions:

1) Why is the haulage rope about twice as long as the track rope?

2) Calculate the average speed the cars move at.

3) How can you tell that the track rope has a higher 'weight' than the haulage rope just by looking at the second picture?

4) Calculate the total mass of a) the Haulage rope and b) the Track ropes

5) Calculate the density of the material used to make a) the Haulage rope and b) the Track ropes

6) Calculate the effective UTS of a) the Haulage rope and b) the Track rope