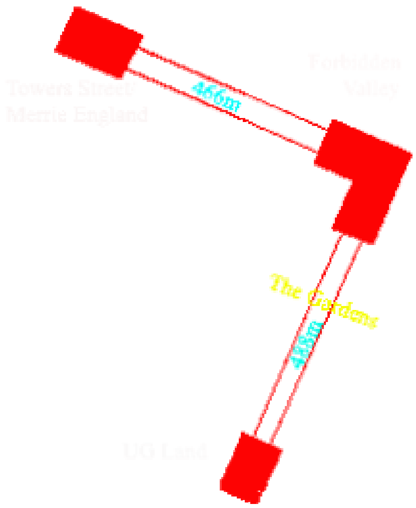
Applying Physics at Alton Towers

Section A

The two aspects of physics that I observed while visiting Alton Towers were:
Tensions in context to the Skyride together with stress and strain
Acceleration due to free fall in context to the Oblivion

In Alton Towers, tensions can be seen everywhere in cables and structures. I have decided to look closely at the Skyride which uses tensions of cables to create not only a ride that shows off parts of the park, but also as a transportation form that takes people from one part of the park to another.



A simple plan of the Skyride including distances between stations.

The Skyride was built to replace the original cable cars, which had a low capacity and only went to the Gardens and back. The new cable cars now allow a maximum of 12 people meaning that now the groups of people can now use the ride whereas before they would have walked or have taken several cars. Even though it is newer than the original, the Skyride still uses the same principals of physics with no new technologies involved.

The Skyride can be described simply as a cable moving cars suspended underneath. The car itself may swing from side to side but it is actually the cable that is moving. Once the car enters a station however, the car engages a clutch and moves from the main transportation cable onto a slower moving chain.

This not only slows the car down while they are in the station but also work with the station platform to reduce swaying while passengers are getting on and off. Once the car reaches the end of the station the clutch disengages and the car moves back on the main transportation cable.

Tension, stress and strain play a big part in working the cable cars and with safety. In section B I will be concentrating more on the physics involved in running the Skyride.

Gravity, the property of mutual attraction possessed by all bodies, and the acceleration due to it, is used in all the rides at Alton Towers simply because it is always there. The Oblivion is no exception as it attempts to use the acceleration due to gravity to its maximum.

The Oblivion is one of the most successful rides at Alton Towers and throughout the world, yet the principal physics behind it are simple.

Two cars leave a loading station where one car then climbs a steep lift hill, travels round a bend, and then sits on the edge of a vertical drop, tipped forward and held by brakes. After a few seconds the brakes release the car and gravity takes over. The car falls down the track and into a hole, where the car still continues to fall underground. It then levels off and goes into a steep banked curve. Before entering the station, a magnetic brake is turned on to reduce the car's velocity. The second car then travels along the same path.

The Oblivion is mainly used by Alton Towers to attract visitors to the park, because there is only an admission fee, the Oblivion doesn't directly make money. The Oblivion's main purpose however, is to be "the ultimate rush." It does this not by making the riders experience difficult helixes, twists and turns but by using the raw power of gravity to scare the rider into believing he is about to hit the ground. This however is only a psychological effect as the ride itself is extremely safe, this is due to the great knowledge of physics the makers used. The Oblivion could be said to be environmentally friendly a most of the power used to accelerate the cars comes from gravity.

Section B

In this section I will be concentrating on the principal physics of tension, stress and strain involved in the Skyride.

Before building the Skyride, designers and engineers thought carefully about the forces which the cable would have to endure in order to put in a safety margin. In particular, tension, stress and strain were looked at.

Tension occurs in cables when a pair of stretching forces is applied. A taut, horizontal wire, being pulled by equal forces will have the same amount of force throughout the wire. In the case of our cable however, which is tilted by about 10 degrees from the horizontal, the forces throughout the cable will not be equal. The tension nearer the top of the cable will be greater than that of the bottom because of the weight of the cable.

Stress, sometimes called tensile stress, is the compression or stretch of the cable. All stresses are defined as a force per unit area and therefore has the same unit as pressure, the Pascal Pa.

$$\sigma = \frac{T}{A} \quad \left(\text{Stress} = \frac{\text{Force}}{\text{Area}}\right) \qquad\qquad P = \frac{F}{A} \quad \left(\text{Pressure} = \frac{\text{Force}}{\text{Area}}\right)$$

Strain is the result and effect of stress and can be defined as the extension per unit length. Strain, therefore, is a ratio of two lengths.

$$E = \frac{x}{L} \quad \left(\text{Strain} = \frac{\text{extension}}{\text{original length}}\right)$$

Strain and stress are related, being for most materials proportional as long as stress is small. When they are proportional they are obeying Hooke's Law.

Hookes' Law = tension $\propto$ extension or stress $\propto$ strain

The ratio of stress to strain is called the Young Modulus.

$$\text{Young Modulus} = \frac{\text{tensile stress}}{\text{tensile strain}}$$

If the ratio of stress to strain is large, like the cable in the Skyride should be, it only distorts a little.

We can work out the tensions of the cable by considering that when the cable car is between two towers, the cable sags by 10º to the horizontal.

We also know that the cable car is 1250 kg and that when full (12 people) an average 780 kg can be added to make 2030 kg.

We can now work out the downward force.

$F = ma$
$= 2030 * 9.81$
$= 1994.3N$

I will consider only half the cable so

$=19914.3 / 2$
$= 9957.15$

or about 10KN

Using trigonometry, I can work out the sidewards force

$\tan \varnothing = opp/adj$
$\tan 80 = opp/10000$
$Opp = 56712$ N

I can now combine these forces to work out the tension throughout the cable.

Pythagoras' Theorem, $a^2 + b^2 = c^2$

$10000^2 + 56712^2 = c^2$
$3316250944 = c^2$
$57587 = c$

We can take this to be about 58 kN.

We can measure the amount of safety to which the cable has. The minimum breaking load is 116 tonnes or 116 kN. If the average weight of one car is 2 kN then the percentage of this compared to the minimum breaking load is

$$\% = \frac{\text{average weight of one car}}{\text{minimum breaking load}} \times 100$$

$$= \frac{2}{116} \times 100$$

$$= 1.73\%$$

This means that the cable has a very high safety margin. An additional 58 full cars could be put on one point without breaking.

Following all this physics, I can compare the cable car cable with the cable used to distribute electricity.

The electricity cable could be said to play a much more important role than that of the Skyride cable. They also have different properties. The electricity cable has to be able to handle high tensions and stresses so as to not break, like the Skyride cable. It doesn't however have to have a low elasticity. So an electricity cable can extend to a high degree as well as do its job, unlike the cable car cable.

There are limitations to the cable car however, the speed at which it transports people can not be increased and the cable car needs to stop when the cars are swayed. On the other hand however the system behind the cable car is also implemented in ski lifts, and also in industry to transport coal from mines.