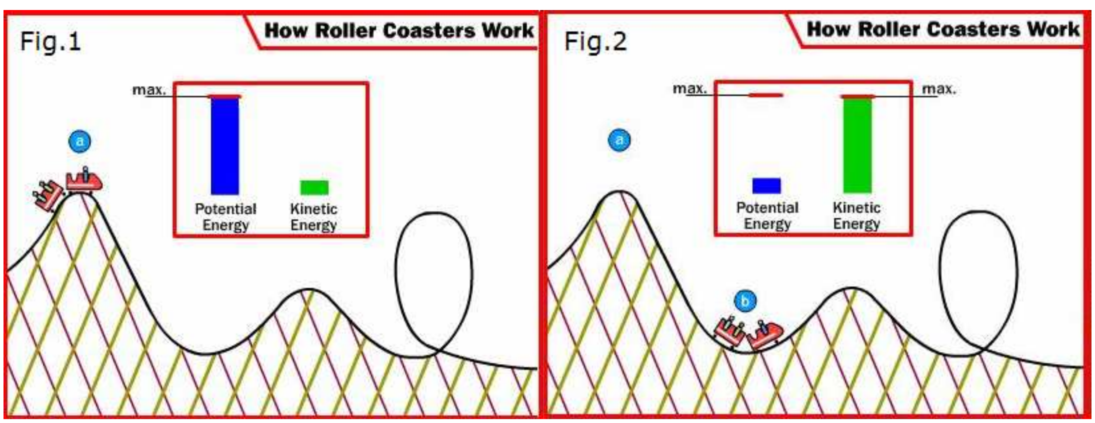
Theme Park Visit Report

On the 11th October 2007, we visited Drayton Manor theme park. We set out to learn more about the physics involved in theme parks. Although there are many aspects of physics present in a theme park I have concentrated my effort on just two aspects in this report. The two aspects I have chosen are power and efficiency.

Before I start calculating power and efficiency I have decided to explain the basic principles of a roller coaster as it helps when explaining the usefulness of knowing power and efficiency how they can be calculated and the equations to calculate them.

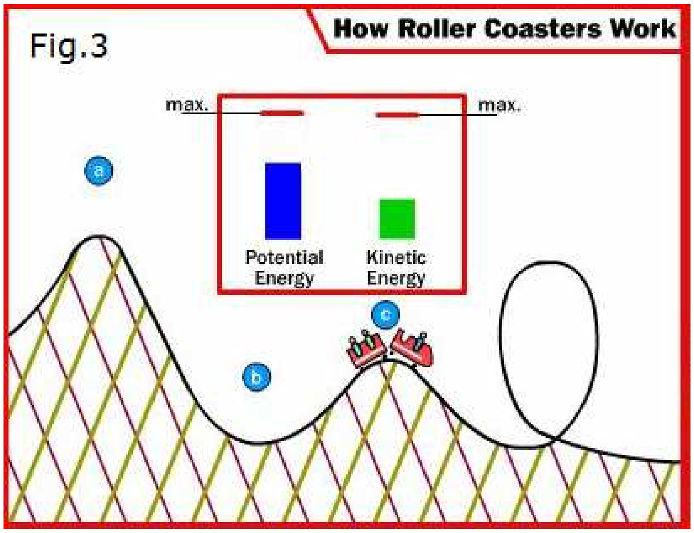
Physics of the roller coaster.

The purpose of a roller coasters initial ascent is to build up gravitational potential energy(*fig.1*). Once you pass over the crest of the initial ascent the built up gravitational potential energy of the cart is transferred to kinetic energy as you descend for the first time(*fig.2*).

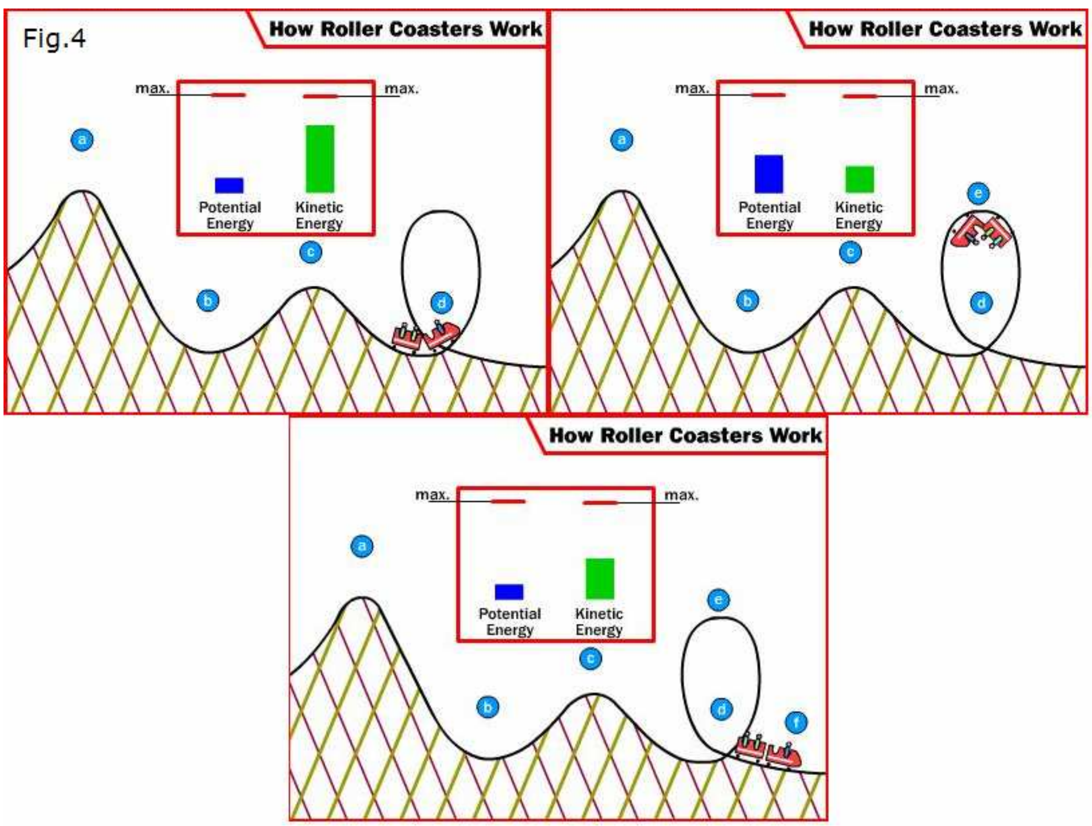


A force of 9.81 NKg^{-1} is applied to the cart as this is the Earth's gravitational field strength which gives the cart an acceleration of about 9.81 ms^{-2} as it falls towards the Earth.

As Newton's third law states the conservation of momentum means that an object in motion retains momentum and in turn motion. So as the cart ascends up the second ascent it will retain motion(*fig.3*), but decelerates at 9.81 ms^{-2} as it travels against the force of gravity converting it's kinetic energy into gravitational potential energy.



This process of gravitational potential energy being converted into kinetic energy and then converted into gravitational potential energy again is repeated over and over again as the cart follows the twisting and turning track(*fig.4*).



*Gravitational potential energy: gravitational potential energy is energy an object possesses because of its position in a gravitational field gained by height.

*Kinetic energy: kinetic energy is the energy of a body or a system with respect to the motion of the body or of the particles in the system.

Another force associated with roller coasters is friction. Fiction is the force which opposes the motion of the car, but also holds the car to the track. Although this friction is needed it is not wanted as it slows the car down. Efficiency calculates the percentage of useful energy output of the total energy input. So can tell us the amount of energy transferred to efficient forms and inefficient forms by friction.

Importance of efficiency and limitations

Efficiency is very important to ride manufacturers as it enables them to create tracks that reduce useful energy loss by friction. This reduces the energy needed at the start which helps them to reduce costs. Another important attribute that comes from finding efficiency is limitations. Efficiency enables ride manufactures to put limitations on their rides. This is important as insufficient energy input initially may make the car loose motion part the way through the ride. Excessive initial energy input may cause the ride to exceed other limitations such as track strength and G-force limits.

Importance of power and limitations

Power is very important to ride manufacturers as it is proportional to the energy consumption and therefore cost of the roller coaster. Because of this limitations are very important. A powerful motor increases the energy consumption and the costs but a weak motor takes a long time to transfer energy making rides potentially uninteresting, which also decreases profits. So a balance between these two limitations must be found.

Developments using efficiency

Using efficiency, developments into new track design and rollers can be made. These developments can be into even more frictionless tracks and rollers as these developments will be made to increase the useful energy transferred and therefore to decrease the running costs of the roller coaster. Another development using the efficiency of tracks is the track complexity. As the efficiency of the tracks increase the length of tracks could increase using the same input of power and therefore be more complex.

How to calculate power

Power is a measure of how quickly work can be done. It can be expressed Power = Energy / Time. To find out the power of anything we need two things, energy and time.

To work out energy of a roller coaster for the initial climb we can find the potential energy its gained.
Gravitational potential energy = Mass*Gravitational field strength *Vertical height

GPE = M*G*H

So Power = $\frac{M*G*H}{Time}$

How to calculate efficiency

'Energy conversion efficiency' is the ratio between the useful output of an energy conversion machine and the input.'

We are able to find the efficiency of any part of the track although is complex, so to simplify the problem we shall calculated the efficiency of the entire track.

Efficiency = (Useful energy/Total energy)*100

Useful energy
E = (Ke/GPE)*100

Energy out is kinetic and energy in is GPE but GPE equals Ke so if we make energy in and out Ke then we can write the equation as:

E = (V/U)*100 U = Velocity in
V = Velocity out

To work out V:

$$V = \Delta s/\Delta t$$

Calculating power and efficiency

Ride name: G-Force

Data known:	m	=	1350Kg
	t	=	6.49s
	g	=	9.81
	U	=	$20.25ms^{-1}$
	U Δs	=	8m
	V Δt	=	1.74s
Data needed:	h	=	?
	GPE	=	?
	P	=	?
	V	=	?
	Ef	=	?

Finding h

$mgh=0.5mv^2 \Rightarrow h=0.5g^{-1}v^2 \Rightarrow$
$h = 0.5*9.81^{-1}*20.25^2 \Rightarrow$ **h= 20.90m**

Finding GPE

$GPE=mgh \Rightarrow GPE = 1350*9.81*20.9 \Rightarrow$
GPE= 276789.15j

Finding P

$P=E/t \Rightarrow P=GPE/t \Rightarrow P= 276789.15/6.49 \Rightarrow$
P= 42648.56w

Finding V

$V=\Delta s/\Delta t \Rightarrow V=V\Delta s/V\Delta t \Rightarrow V= 8/1.74 \Rightarrow$
V= 4.60ms-1

Finding Ef

$Ef=(V/U)*100 \Rightarrow Ef= (4.60/20.25)*100 \Rightarrow$
Ef= 22.72%

Ride name: Apocalypse

Data known:	m	=	500Kg
	g	=	9.81
	h	=	54m
	t	=	15.12s
	V Δs	=	51m
	V Δt	=	2.72s
Data needed:	GPE	=	?
	P	=	?
	U	=	?
	V	=	?
	Ef	=	?

Finding GPE

GPE=mgh $\Rightarrow$ GPE = 500*9.81*54 $\Rightarrow$

GPE= 264870j

Finding P

P=E/t $\Rightarrow$ P=GPE/t $\Rightarrow$ P= 264870/15.12 $\Rightarrow$

P= 17517.86w

Finding U

mgh=0.5mv² $\Rightarrow$ v=√(2gh) $\Rightarrow$

v=√(2*9.81*54) $\Rightarrow$ **v= 32.55ms-²**

Finding V

V=Δs/Δt $\Rightarrow$ V=VΔs/VΔt $\Rightarrow$ V= 51/2.72 $\Rightarrow$

V= 18.75ms-¹

Finding Ef

Ef=(V/U)*100 $\Rightarrow$ Ef= (18.75/32.55)*100 $\Rightarrow$

Ef= 57.60%

Bibliography

Physics of the roller coaster:
Fig.1
Fig.2
Fig.3 - sourced form:
http://science.howstuffworks.com/

Gravitational potential energy:
Quote on gravitational potential energy- sourced from:
http://hyperphysics.phy-astr.gsu.edu/

Efficiency:
Quote on energy conversion efficiency - sourced from:
http://en.wikipedia.org/wiki/

Kinetic energy:
Quote on kinetic energy - sourced from:
http://dictionary.reference.com