All the Fun of the Fair
The Millennium

The final ride we are looking at in this video is the Hellraiser. Take a careful look at what is going on and try to describe the motion. This time there are two different rotations happening at the same time. So what are they? Focus first on the rotation of the central column and the arms attached to it. It's rotating uniformly in a horizontal plane. So that's the first rotation. At the ends of each arm is another axis of rotation. Each group of four cars rotates uniformly about this axis. So for each car there are two uniform horizontal rotations at different axes of rotation. Each car rotates uniformly about an axis of rotation which itself rotates uniformly about the central column. So what are the forces exerted on somebody sitting in one of the cars? How can we model what's going on mathematically? Finding forces means we need to find the accelerations involved in the ride. The simplest way to do that is to look at each of the two rotations separately and then combine them. We'll look just at this car. You've seen that one way of finding accelerations is to find the position vector, to differentiate that to get its velocity, and then to differentiate again to get its acceleration. So, let's begin by looking at the position vector of this car. To get the position vector we need the position of the centre of rotation of the carrier wheel relative to the central column, plus the position of the car relative to the centre of the carrier wheel. The overall position vector is the sum of these two parts. So, what is the velocity vector for the car? Well, we can find the velocity vector by differentiating the position vector, so the velocity will have two parts corresponding to the two parts of the position vector. The first part is due to the rotation of the centre of the carrier wheel about the central column, so it will be given by this vector. Its magnitude is the radius of the circle times its angular speed. The second part is due to the rotation of the car relative to the centre of the carrier wheel, and its magnitude is given by the radius of the carrier wheel times its angular speed. So the velocity of this car is the vector sum of the two parts.

So now we can go on to find the acceleration of the car. We can get this by differentiating the velocity so again, like the position of velocity vectors, the acceleration has two parts. We look first at the acceleration of this point, the centre of the carrier wheel. It's directed towards the central column and has magnitude given by the angular speed squared times radius. So what's the acceleration due to the motion relative to the carrier wheel? Well, again it's directed towards the centre of the carrier wheel. So the overall acceleration of the car is the sum of the two accelerations. What does that sum look like? Here's a typical position, and here's the result of the two accelerations as given by the triangle law. The resultant certainly isn't constant. As the car travels round the ride, the acceleration varies.

Mass times acceleration, the force experienced by anyone sitting in the car, varies. So when will the force have the greatest magnitude? And when will it have the least? I'll leave that for you to do. So what does the ride feel like?

Passenger
I felt like I was being flung from one side to the other. It sort of slowed down as you went round and then as you went in you were flung to the inside and as you went out you were flung to the outside.

Well the passenger said that on this particular ride she was thrown from one side to the other. The motion was nearly linear. You may have noticed that, but how can two circular motions combine to give a linear motion? What particular features of this ride lead to that surprising result?

There are many more complicated rides, but they can all be modelled using the same principles we've already used. This ride is called the Top Buzz. How would you describe it? How many rotations can you see? What types are they, and in what planes? In fact the motion experienced on Top Buzz is in three dimensions and involves three rotations: two uniform and one non-uniform, about three different axes. Modelling this ride would be quite complicated,