# LECTURE T1 –What Doc Jobe Found by a Close Friend of Doc Jobe

We just ran across a patent, US 8,469,831 B2 "CYCLOID RAMP FOR GRAVITY DRIVEN RACE CARS". When we contacted the inventor, John "Doc" Jobe of PinewoodDerbyPhysics.com, Doc Jobe explained to us that he has run across something very interesting regarding various aluminum tracks which he has been testing in his lab. It has to do with a geometric shape called a cycloid, a curve first discovered by Johann Bernoulli in 1696 .e.g. **See**: **https://en.wikipedia.org/wiki/Brachistochrone_curve**

**See also:https://en.wikipedia.org/wiki/Tautochrone_curve**

It turns out that the cycloid curve is the curve of fastest descent for rolling from point A to a lower point B in a gravitational field. Also, any point on a section of the cycloid has this same fastest descent property. **Figure 1A** shows how a point *P* fixed on the circumference of a circle will draw a cycloid curve *s* as the circle is rolled underneath the $x$ axis. If $\theta$ is angle of rotation of the rolling circle, and the subscript $\theta o$ denotes its starting angle, then the 2 equations that describe the starting point on the cycloid curve ramp are,

$$x_0 = \frac{h}{2}(\theta_0 - \sin\theta_0) \qquad (1)$$

$$y_0 = \frac{h}{2}(1 - cos\theta_0) \qquad (2)$$

The radius *r* of the rolling circle is taken equal to *h*, the height of the car center of mass above the plane of the horizontal run, 27and 28, when ready to start. The distance *d* is the horizontal distance to where the ramp becomes tangent to the horizontal. Using the value of *h* and *d* for a particular ramp allows the intermediate points on *s* to be calculated by methods given in the patent. Doc Jobe was able to solve the equations that would give these points. Another curious property of the cycloid is that if you race two identical cars down a section of the cycloid, they will hit the end of the ramp in a tie. It doesn't matter where they start, as long as they are released simultaneously. One could be started at 4 feet high, and another at 2 feet high, and they tie in elapsed time at the ramp bottom where the higher velocity car passes the slower car. Now get this — this elapsed time is the same for any cars simultaneously released anywhere on the cycloid.

But most importantly, the cycloid curve also puts the least possible downward force on a car to pull out of its descent. This is only 20% of a "G" for the cycloid ramp so the net force on the car wheels is only 1.2 G total at pull out. Since most of us test our cars on a level surface at 1G, the slight additional 20% load doesn't make much difference in their tracking. So, they don't deviate much from straight tracking down the cycloid ramp and along the horizontal run to the finish line.

One aluminum extrusion Doc Jobe tested had a curing procedure that caused a specific stiffness or bending moment. When testing this bending moment something very interesting happened when this inventor found a "sweet spot" on the ramp where a force pulling down on the ramp and directed towards where the front legs touch the floor can cause the whole downward ramp section to bend into a cycloid section shape. The whole idea here is to have the bend or curvature of the ramp be highest where the velocity is the lowest. This sweet spot is close to item 43 in **Figure 1B**. The fold out braces 31 pull this area down when the front legs are pulled down and locked. The patent examiners at the USPTO thought the cycloid use was unique enough and unobvious enough to qualify for a patent in gravity racing. In the G-Track we pull down with a force of approximately 30 lbs per lane at point 43.

FIG. 1A

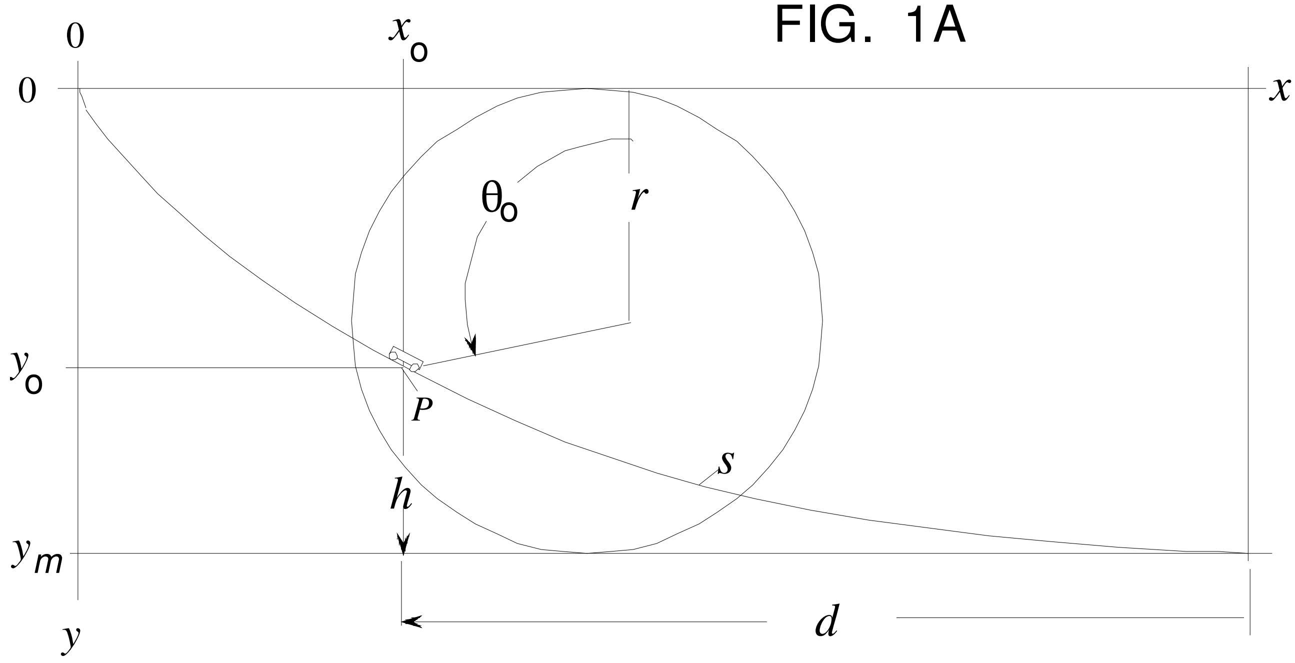


FIG. 1B

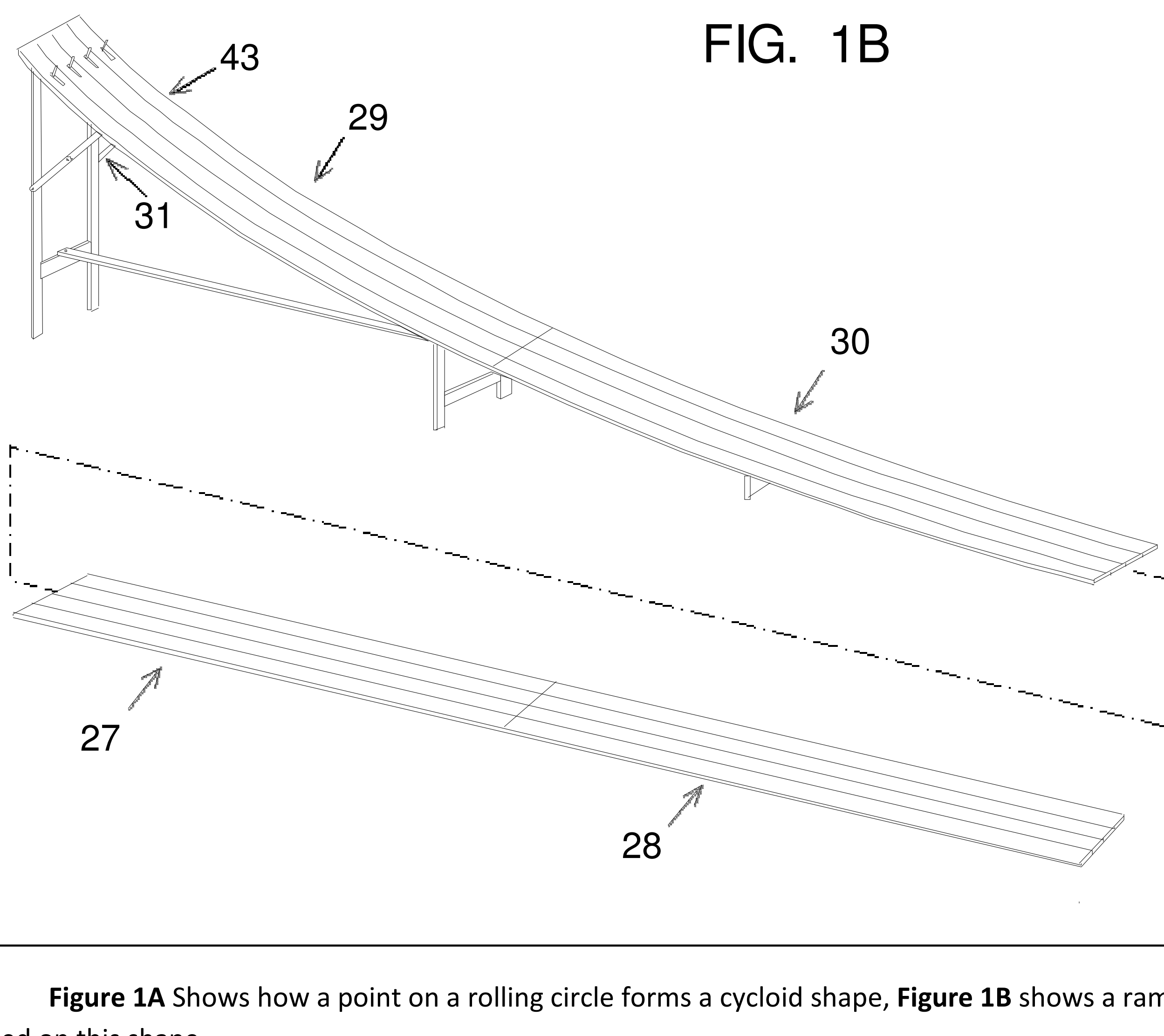


**Figure 1A** Shows how a point on a rolling circle forms a cycloid shape, **Figure 1B** shows a ramp based on this shape.-

In **Figure 2**, consider what the other major aluminum track builder has to offer, namely a track where at the critical maximum speed spot close to the floor they have unfortunately placed their single sharp pullout curve of $r = 4$ ft radius. The velocity here is $v = \sqrt{2Gh}$ where $G = 32$ ft/s$^2$ is the acceleration due to gravity and $h = 4$ ft. So $v = \sqrt{(2)(32)(4)}$ ft/s = $\sqrt{256}$ ft/s = 16 ft/s.The extra G force introduced is easy to calculate, being simply $v^2/r$. Thus the extra G force = (16ft/s)$^2$/4ft = 64 ft/s$^2$ = 2G. If we now add the car weight of 1 G, we have the net downward force at the pullout point = 3 G. So all the rolling tests we do at 1 G to get straight tracking are no longer valid because this friction increase at triple weight usually does not always go up equally for each rear wheel. This sudden unbalance rear force can cause the car to start bouncing side-to-side like when you pull the handle on a commercial lawnmower to increase one rear wheel rolling resistance to make the lightly loaded

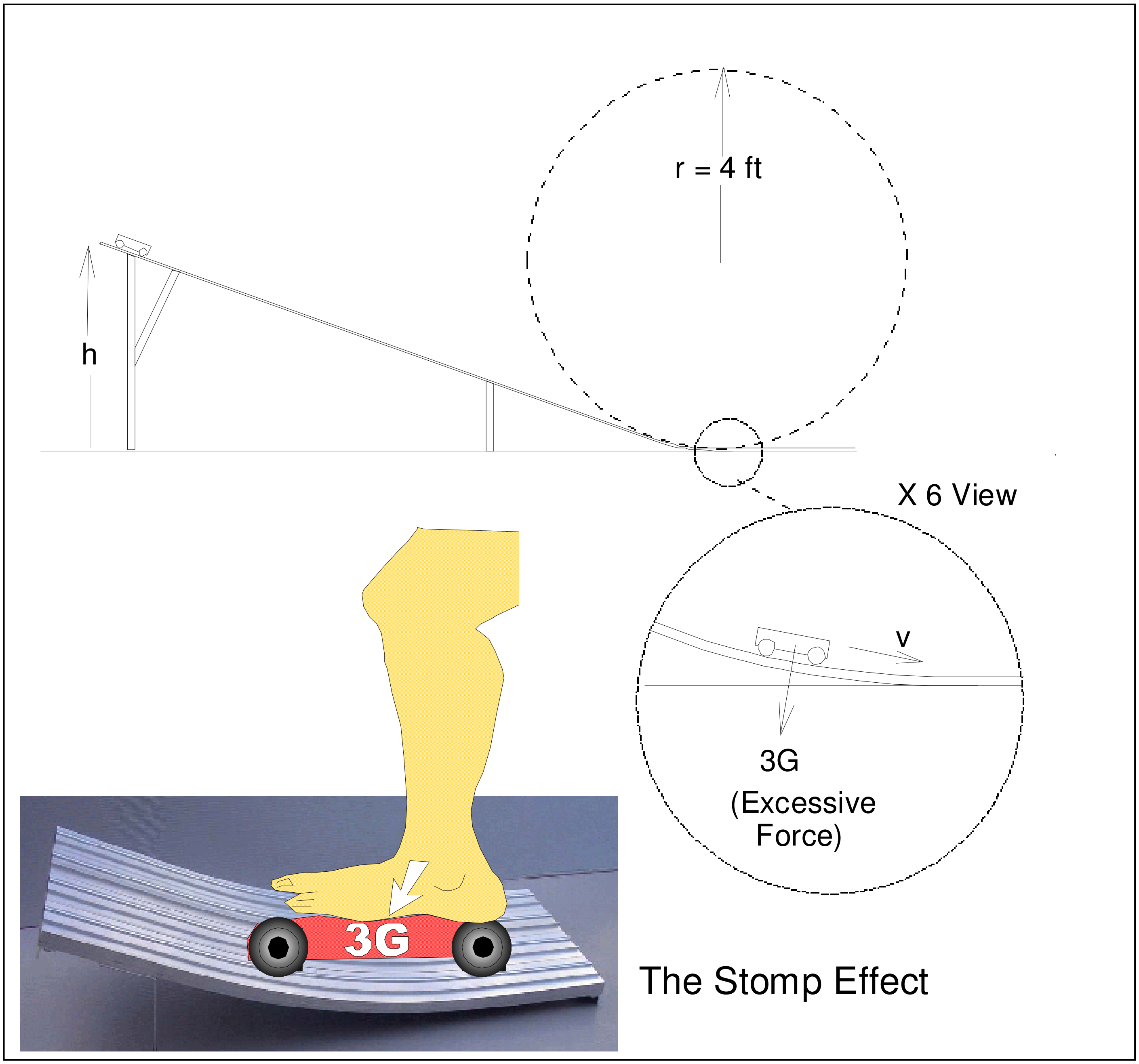


**Figure 2 –** Showing the excessive weight force introduced from the sharp pullout curve at the ramp bottom

front swing in that direction. (**See Lawnmower**) See This front end swing is what starts the bouncing (**See Slo Mo Vid-Allow 60 sec download time**), taken by a mini camera car 1 lane over). Hardly a "best" track compared to the perfect cycloid shaped ramp that is described here. This video shows a car entering the horizontal run sections 27 and 28, shown in **Figure 1B**, where side to side motion occurs. In Some cases, motion such as that shown can be less severe and not easily seen with the unaided eye at the high car speeds entering the horizontal coasting run. Nevertheless, the finish times can be slower as will be demonstrated in the following lectures.

**Figure 3** shows a side view of a track that uses a tension bar in position to curve the ramp at the "sweet spot".


**Figure 3 –** Showing the tension bar used to curve track at the "sweet spot" described in the text