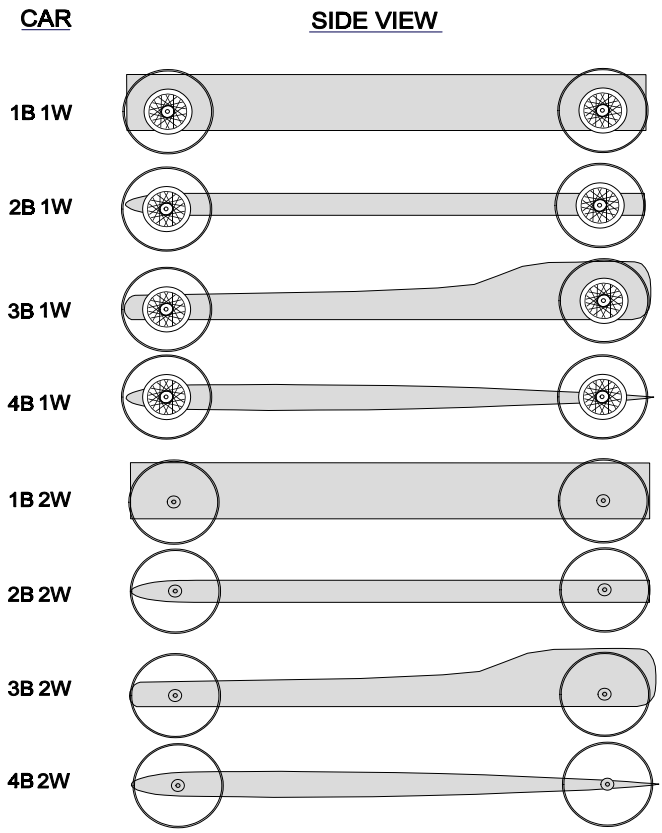
Physics Lecture 9 - The Effects of Air Drag on PWD Race Times



PARAMETERS (cgs units)

C_B	A_B	C_W	A_W	I
0.84	7.43	0.50	2.96	5.123
0.42	2.82	0.50	2.96	5.123
0.42	7.43	0.50	2.96	5.123
0.24	2.82	0.50	2.96	5.123
0.84	7.43	0.68	0.278	0.777
0.42	2.82	0.68	0.278	0.777
0.42	7.43	0.68	0.278	0.777
0.24	2.82	0.68	0.278	0.777

Figure 1 - *Showing 8 cars built according to the aerodynamic summary of bodies and wheels in Lecture 8.*

Summary/Conclusions

The virtual race (VR) program is used to demonstrate the performance of the car bodies and wheels shown in Lecture 8. The 4 bodies are run with the Standard Cub wheels and the RS Racing wheels. The slowest combination is about 2 car lengths behind the winner at the finish line. When the RS wheels have their moment of inertia increased to that of the Standard wide wheels, the air effect alone is shown to cause about a 0.7 car length spread.

Virtual Racing of the 8 Cars from Lecture 8

It takes just a few minutes to build 8 virtual cars that have the parameters of **Figure 1.** See Lecture 10 for a more thorough description of parameters other than the 5 in **Figure 1. Figure 2** shows the VR car edit/create screen with parameters of the top car in **Figure** 1, which is called CAR_1B1W. We keep the car mass (weight), wheel and axle radius, coefficient of friction, CM position, and number of wheels touching constant for all 8 virtual cars.

We start with the StdTrk_HOUSTON_C-BT track. The HOUSTON means is uses the local Houston *g* force and air density. The "C" means this track has a circular are ramp (16' - 7") and a horizontal run (16' - 3'). The net drop height = 47". The BT means the timer is set to trip on the front bumper and not the car CM. Select Race Group of Cars tab and you will see on the left all the cars in your main car file. Put a check next to the 8 cars we just built as the ones selected to race. Now we race by clicking on [Go].

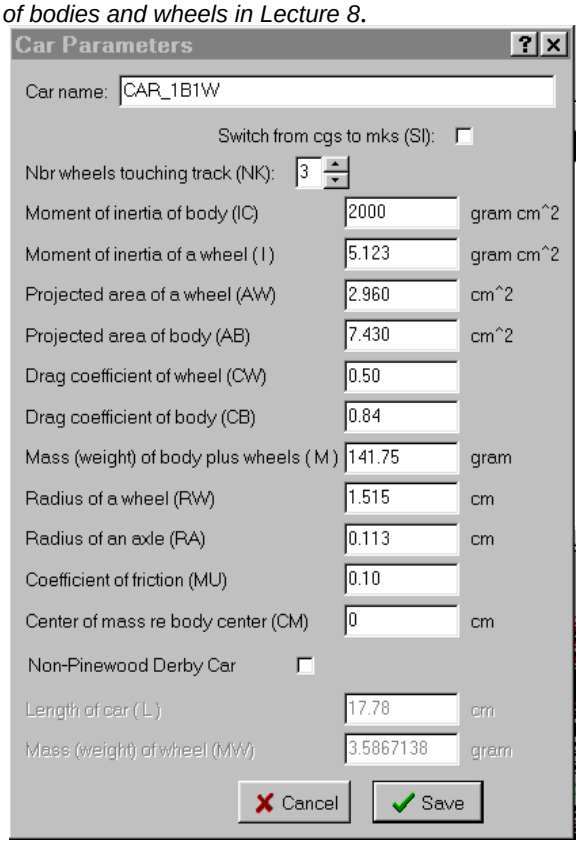


Figure 2 - *Showing the VR car create/edit screen. Note only 3 wheels touch and considered rolling.*

Discussion of Results

The results of the 8 car race on the Standard "32" ft track with a circular arc ramp is shown in **Figure 3**. Consider the top 4 finishers of the 4 cars using the RS wheels (see Hodges wheels). It shows that body projected area size and body drag coefficient can cause a difference of up to 0.374 car lengths difference at the finish line. The last 4 finishers running the wide Cub standard wheels with a much larger moment of inertia show precisely the same finish differences caused by air effects on the body. But there is a big slowdown of about 1.5 car lengths caused by a combination of much larger moment of inertia and much larger wheel projected area. On the inclined plane ramp (same overall projected shadow on the floor as the circular arc) one can see that the air effect is about 15% smaller, i.e., 0.328 vs. 0.374. This is because the circular arc ramp allows the maximum velocity to be approached somewhat faster than on the inclined plane.

To get rid of the wheel moment of inertia effect, play like the RS speed wheels are made from lead so they have a large moment of inertia of 5.123 g-cm^2 like the Cub wide wheels. So build 4 virtual cars to replace the Delrin® RS wheels with ones of the same area, coefficient of friction, etc. and name the cars the same except put a "L" in the name for "lead wheel". **Figure 5** and **Figure 6** show the results. The purely air effect shows a spread of almost 0.7 car lengths on the circular arc track data of **Figure 5**. **Fig. 7** gives a picture of the finish line for this race. Although this is a theoretically perfect race, it shows that air effects are indeed substantial and are a significant factor even in real non-perfect racing after random effects (center strip bumping, etc) are averaged out. Incidentally, by looking at the time differences between, say, 4B2W and 4B2WL we see the wheel inertia effect (with only 3 touching) between 0.777 and 5.123 g-cm^2 gives 0.0452 s or 1.15 car lengths at the finish line on the "C" track and 0.0527 or 1.35 car lengths on the "I" track.

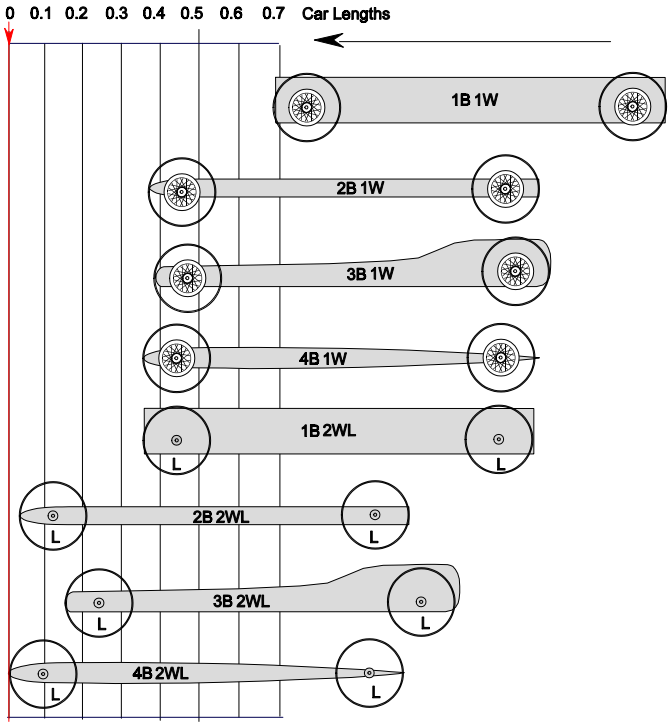


Figure 7 - *How the cars as listed in Figure 1 fared at the finish line when only air drag effects were considered. The VR is Fig. 5.*

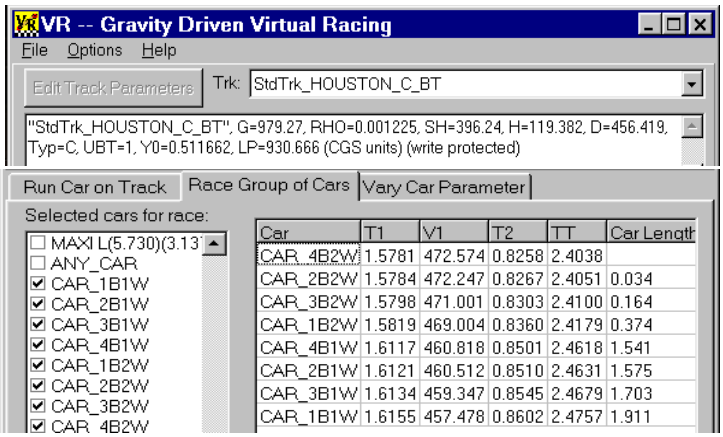


Figure 3 - *Race results for the standard circular arc ramped track.*

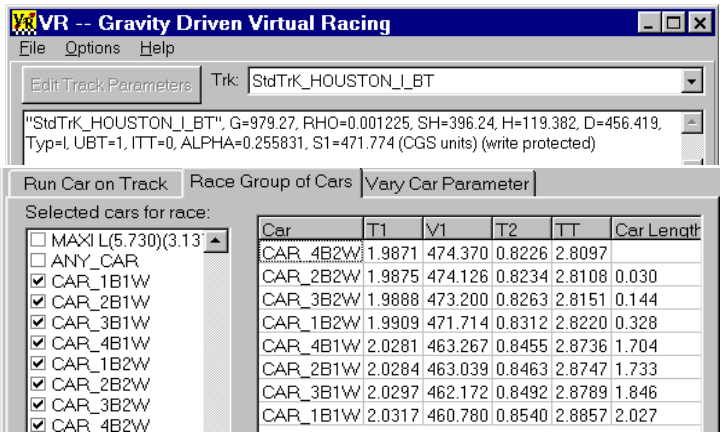


Figure 4 - *Race results for the standard inclined plane ramped track.*

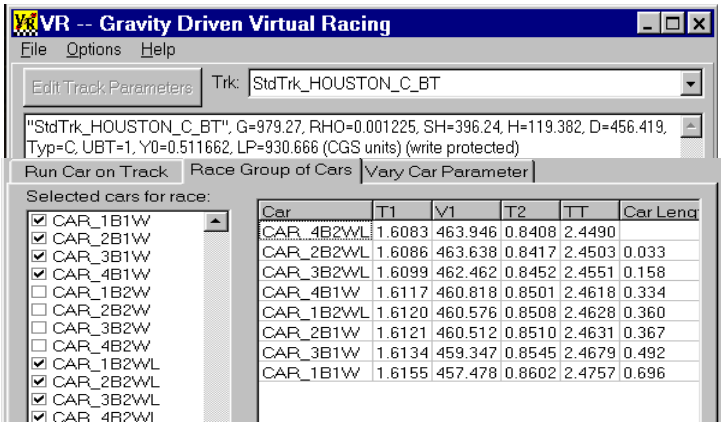


Figure 5 - *Same as Fig 3 with wheel mom of inertia effects removed*

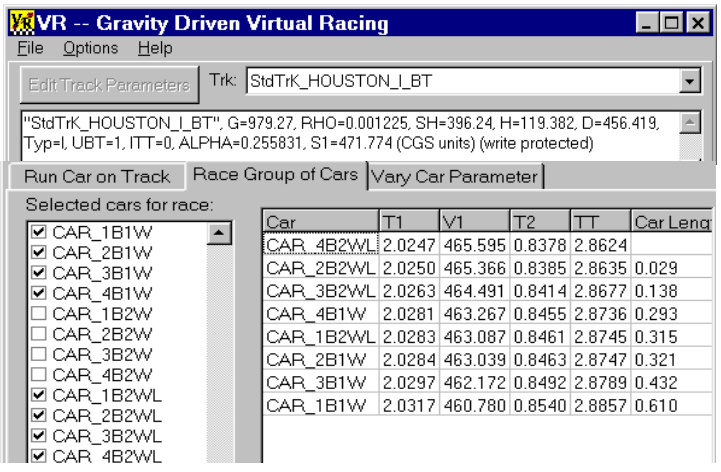


Figure 6 - *Same as Fig 4 with wheel mom of inertia effects removed*