Physics Lecture 11 - Debunking Another Friction Myth

Summary/Conclusions

A special car is built to demonstrate that your car's wheel/axle frictional drag and its effect on race time has very little to do with how many wheels support your car's weight. Those web sites that advertise otherwise should re-examine their claims. The only solid surface friction parameter that affects your car's finish times when center strip rubbing is absent is the coefficient of wheel/axle friction. With a heavy wheel, especially the outer rim part, raising one front wheel does increase speed considerably, but the increase has nothing to do with friction reduction. The car is faster because not allowing one wheel to spin (roll) means that 25% of the rotational energy formerly used by all 4 wheels is available to make the system increase its linear velocity. As a matter of fact, lifting one wheel above the track actually increases the net frictional drag because now the body mass pressing on the other 3 wheel axles/bores goes up by the raised wheel amount since it is no longer self supporting.

Bill Builds a Car

"Hi Bill", said Dad, "How's that pinewood derby car building project coming?"
"Oh, Hi yourself Dad", Bill answered, " I just doubled the weight of my car to 10 ounces."
"How will you get it through inspection, Son?"
"Well, I'll figure out something, Dad"
"Wow!, twice the weight—that means you'll be unbeatable! Some people stand around the judge's scale for 30 minutes just trying to add a tiny fraction of an ounce"
"Yeah Dad, I know—They think if double the gravity force then double the speed. Actually, though, my car has 6 wheels touching the track. Most cars I'll be racing have only 3 wheels touching. So perhaps 6 wheels would slow me down because the total wheel moment of inertia would be twice that of 3 wheels. However, I'm using the RS racing speed wheels which have only a small fraction of the rotational inertia effect of regular stock wheels."
"Hey Bill, I know what we can do—I just saw on a web site that on a 4-wheel car if you raise one wheel so it doesn't rotate on its axle then you get rid of 25% of the wheel/axle friction. They even sell bodies with one front wheel hole drilled higher based on that claim."
"So you believe that, huh, Dad"
"Sure do Bill—It makes sense just like more force on a more massive object is going to speed it up—Say, lets have a look at this 10-oz 6-wheeled car of yours."
"OK, Dad. Have a squint at **Figure 1**".
"Hey! What's going on—It looks like 2 regular cars have been hooked rigidly together!"
"That's right, Dad. They'll pass inspection separately and then just before racing we'll slip the connecting rods between them."
"Now wait just a minute, Son. If those cars are identical then it looks like they would tie at the finish line whether or not they are hooked together. So you have just proved that total car weight has no preferential effect compared to drag forces because you just doubled them too! Brilliant demonstration, Son. How in the world did you get so smart?"
"I'm not sure, Dad. You think maybe Mom's side of the family?"
"Huh? Well I'll show you a thing or two. Just you go ahead and race that car and I'll show you how to get rid of half of that doubled frictional drag force."

Bill Races the Car on the Friction Test Rig (FTR - Lecture 6)

"OK, Dad. I'm sure you'll show me something. I'm not going to lube the wheel axles so we'll have the maximum wheel/axle friction effect for you to get rid of. Here I go, I'll run 10 times. I call this 6-wheels-touching car A6."
"Wow again, Billy Boy. Those times on the 2 lanes in **Table 1** are like only a tenth of a millisecond different. You must have adjustable finish sensors"
"Yep Dad, that's right. And I also fixed up an optical start trigger so I now get good repeatability. Notice the Standard Deviations are only 0.0031 seconds"
" So, Bill, you have 6 wheels rolling and 2 just occasionally touching the guide strip."

Table 1 - *Car A6 run times*

RUN	LANE 1	LANE 2
1	1.7582	1.7582
2	1.7624	1.7625
3	1.7607	1.7608
4	1.7579	1.7580
5	1.7615	1.7617
6	1.7533	1.7533
7	1.7586	1.7587
8	1.7609	1.7610
9	1.7562	1.7566
10	1.7540	1.7542
AVG	1.7584	1.7585
STD	0.0031	0.0031

Figure 1 - *Side view of the dual car that weighs 10 oz. The 2 inside front wheels do not touch. The front brass rod is 3/32" ID covering 3/32" wood dowels protruding from each car body. The rear aluminum rod is 1/8" ID to allow enough play for each of the 4 rear wheels to be firmly planted.*

Dad Will Now Reduce Frictional Drag (He Thinks)

“OK, Billy, you’ve had your fun. Now I’ll show you. Yank that right rear wheel off the lane two body and call the resulting car B5 for 5 wheels touching, like in **Figure 2.** Now run, run, run...10 times. Look at ‘er go. What’s the average of these times Bill, (heh heh).”
“Well, sorry Dad, it didn’t help hardly any. The average was 1.7542 seconds. That 0.004 s apparent improvement, about the same as the combined noise level of 0.0031+ 0.0015 = 0.0046, could be partly due to not having the small rotational inertia of the removed wheel present. Remember the other day with these lubricated RS wheels we got 1.6500 s. So you are only 1/25 of the way there. You said you would get rid of 1/6 of the friction, but 0.004 s is only 0.020 car lengths.”
“Rats! Go ahead and take off the right front wheel on the lane 1 body. Make car C4 like in **Figure 2**. We should get rid of 2/6 or 1/3 of the friction. Then run, run, run, 10 times (I got him this time for sure, heh heh).”
“Good math Dad, but see **Table 2**, you only improved times by 0.003 s, so you’re only 1/14 of the way there not 1/3.”

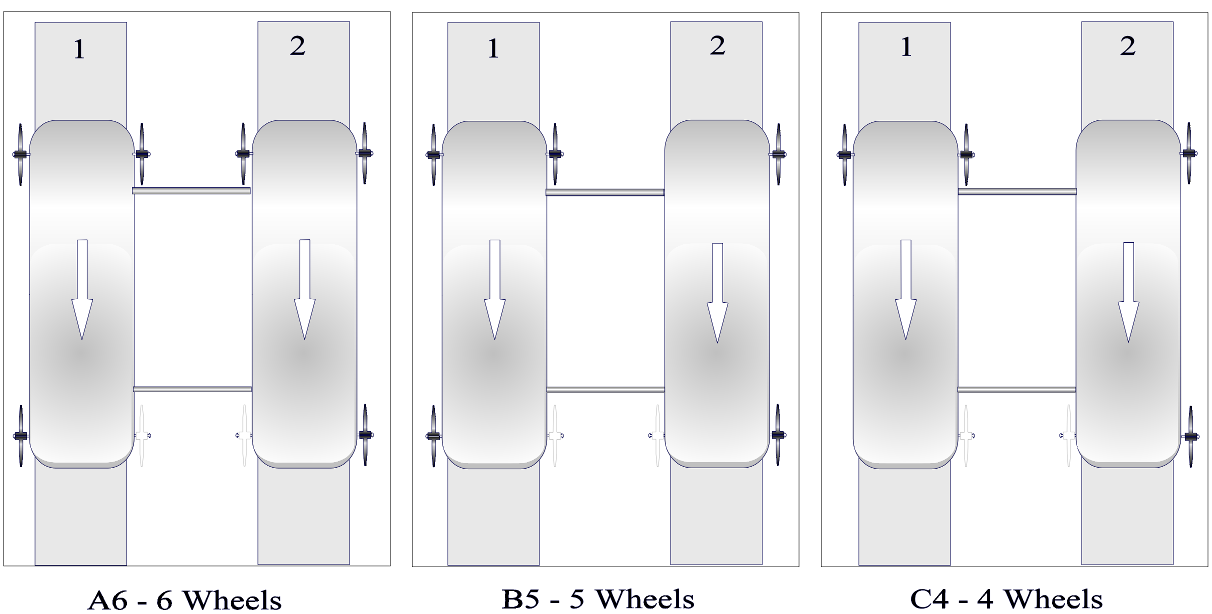

Figure 2 - *Top view of the dual car with A6 - 6 wheels supporting car, B5 - 5 wheels supporting car, and C4 - 4 wheels supporting car. The Shaded light wheels do not touch track surface.*

“Dadgum it Billy, take off that right rear wheel on the lane 1 body and call it D3 for just 3 wheels rolling. That should cut friction way back. Its like running a single car with only 1½ wheels rolling and supporting the body. Hot dog! I bet this speeds that baby up. The friction should be only 50% of a 3 wheeled car—says so on the Internet!”

“Sorry Dad—Car D3 came out like car B5, at about 1.7543 s. So you are still, at the biggest stretch of the data, only about 1/20 rather than ½ to the 1.6500 s lubricated time. Plus recall Lecture 6, Fig. 2, which showed the zero friction time for these low inertia RS wheels on the FTR should be 1.5950 s. So halfway to that time would be 1.6750 s but we have essentially no effect.”

“Bill, I know what’s going on—perhaps there’s enough flexure or sag between the heavy rear bodies to cause the wheels to tilt or bind on the axles some, thus increasing wheel/axle friction.”

“OK, Dad, I’ll use double-stick tape to fasten a light but stiff 1/8" thick aluminum brace across the tops of the car bodies so the rear wheels for sure have no camber. So, as you say, ‘run, run, run’ and we get the E3 average time of about 1.7612 s, about where we started with 6 wheels.”

“I give up, Bill. Where did I go wrong?”

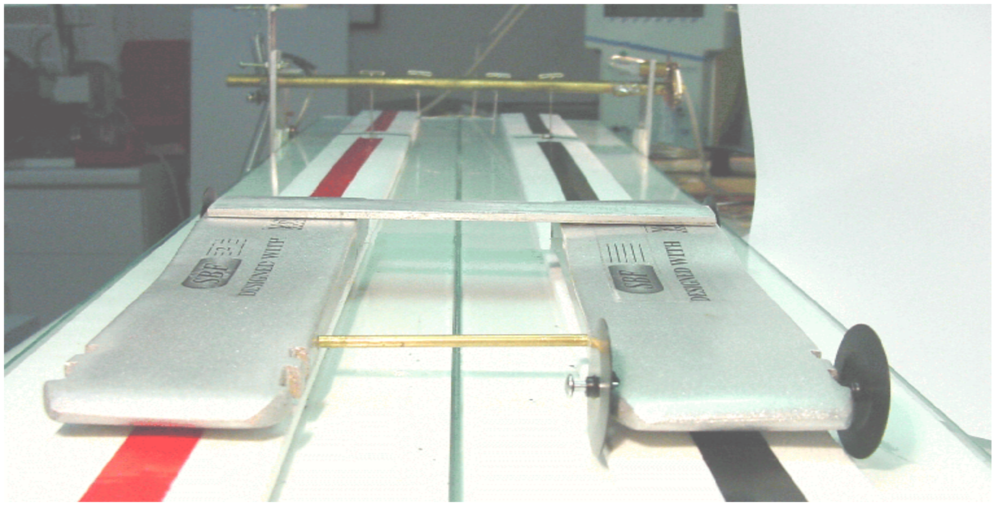

Figure 3 - *Front view of car configuration E3. Only the 2 outside rear wheels and the rightmost front wheel are touching. The inside front wheel is only for center strip guiding if needed. The rod in the rear is replaced by an aluminum bar that keeps the body insides from drooping at an angle.*

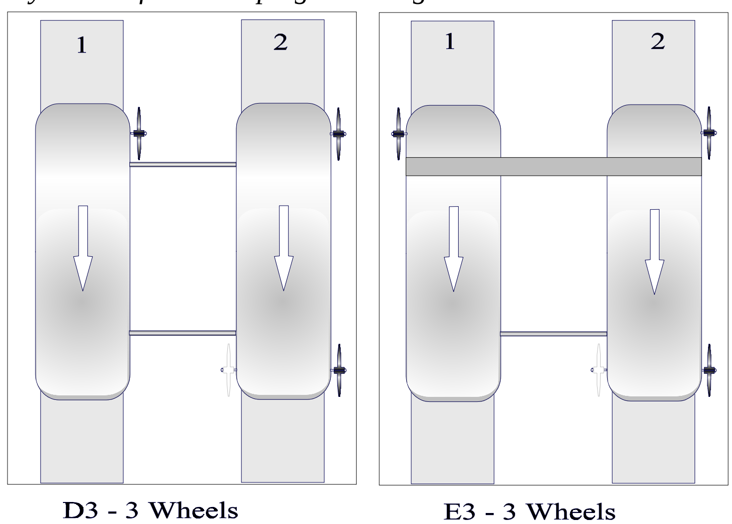

Figure 4 - *3 wheels touching. Top view of Fig. 3 to the right.*

Bill’s Answer

“Dad—as shown in Lecture 2, frictional drag is just the coefficient of friction times the weight, period! Apparent contact area has nothing to do with it. You just can’t see the real contact area. With A6, we had 10 oz divided up and supported by the 6 axles pressing down on the bottoms of 6 wheel bores. If you had a microscope, you could see perhaps 1/1000 of the apparent contact area was actually the area where real atoms in the axle bottom were touching real atoms in the bore surface. When you go to body D3 or E3, you double the weight pressing down on each bore surface so that now about 1/500 of the apparent area is really atomic forces dragging against atomic forces. Thus you have doubled the drag per wheel so overall nothing changes. The same effect means there is no overall difference in drag in how the 10 oz is distributed among *n* wheels. You could have 90% on one wheel and 10% on several other wheels. All of this may seem odd but remember you can’t see where the real drag action is. Now, if you push things to an extreme, like put 1 pound force on one wheel vs. on 100 wheels, you may start to see deviations in overall drag based on distortions in the materials themselves. But, to a very good approximation, with modest sliding or rubbing conditions, frictional drag only depends on weight being applied times the coefficient of friction.”

Table 2. *Final results*

Car	Result	LANE1	LANE 2
A6	AVG	1.7584	1.7585
	STD	0.0031	0.0031
B5	AVG	1.7542	1.7543
	STD	0.0015	0.0015
C4	AVG	1.7531	1.7534
	STD	0.0034	0.0034
D3	AVG	1.7542	1.7548
	STD	0.0045	0.0046
E3	AVG	1.7605	1.7620
	STD	0.0047	0.0044

“ Gee, thanks Bill. I’m going to go tell Mom thanks for all the good genes she brought to our family.”

“A noble thought, Dad, but really its not genes. It’s just fact versus fiction. Your dad probably passed on those friction myths to you because he just didn’t know better, but he was an adult and you were a child so you took it as truth. There’s nothing wrong with your genes. Just go have a look at that physics 101 book on my desk.”