STEERING

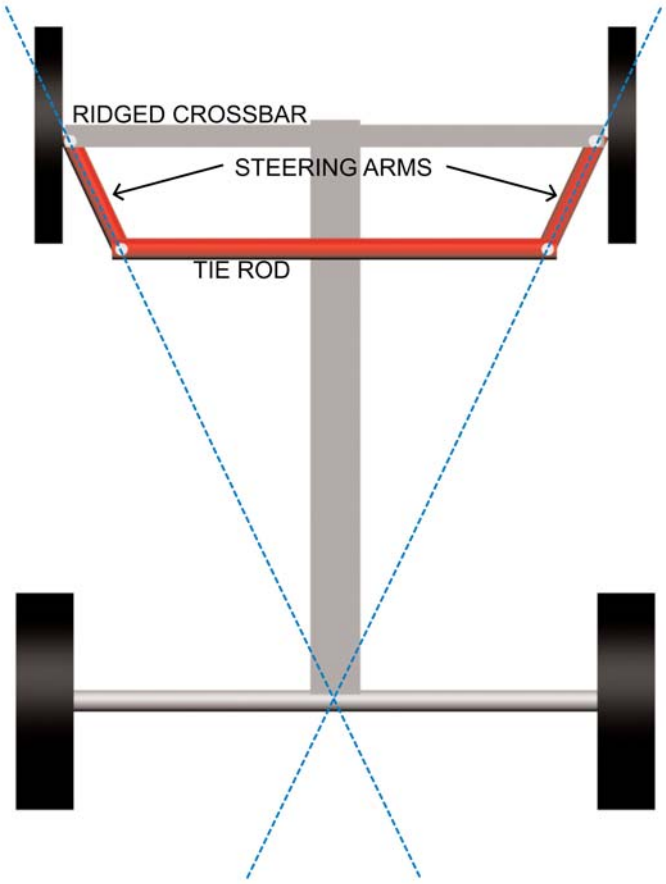
TRAPAZOID- a four-sided figure with one pair of sides

ACKERMAN PRINCIPLE- steering geometry where the front tires are toed-out slightly during cornering making the inside tire turn tighter than the outside front tire. Named for Rudolf Ackerman.

STEERING WITH ONE OR TWO WHEELS

Perhaps the most simple steering design is found on a standard tricycle. One wheel directly attached to a handle bar and peddles attached directly to the wheel.

Another relatively simple approach to steering design is found in this model of a coaster car I made as a kid. It was made of old 2by4s and a set of wheels I found. Each of the wheels was bolted to the wood. One plank in the front had both front wheels attached to it. The plank was attached to the car with 1 bolt thru the center. To turn I pulled a rope attached to each end of the plank. Occasionally, however, after gaining great speed coasting down a hill, the plank would turn too far and the car would roll over after becoming unstable. Ouch!!! Clearance for the plank to turn also took up a lot of space.



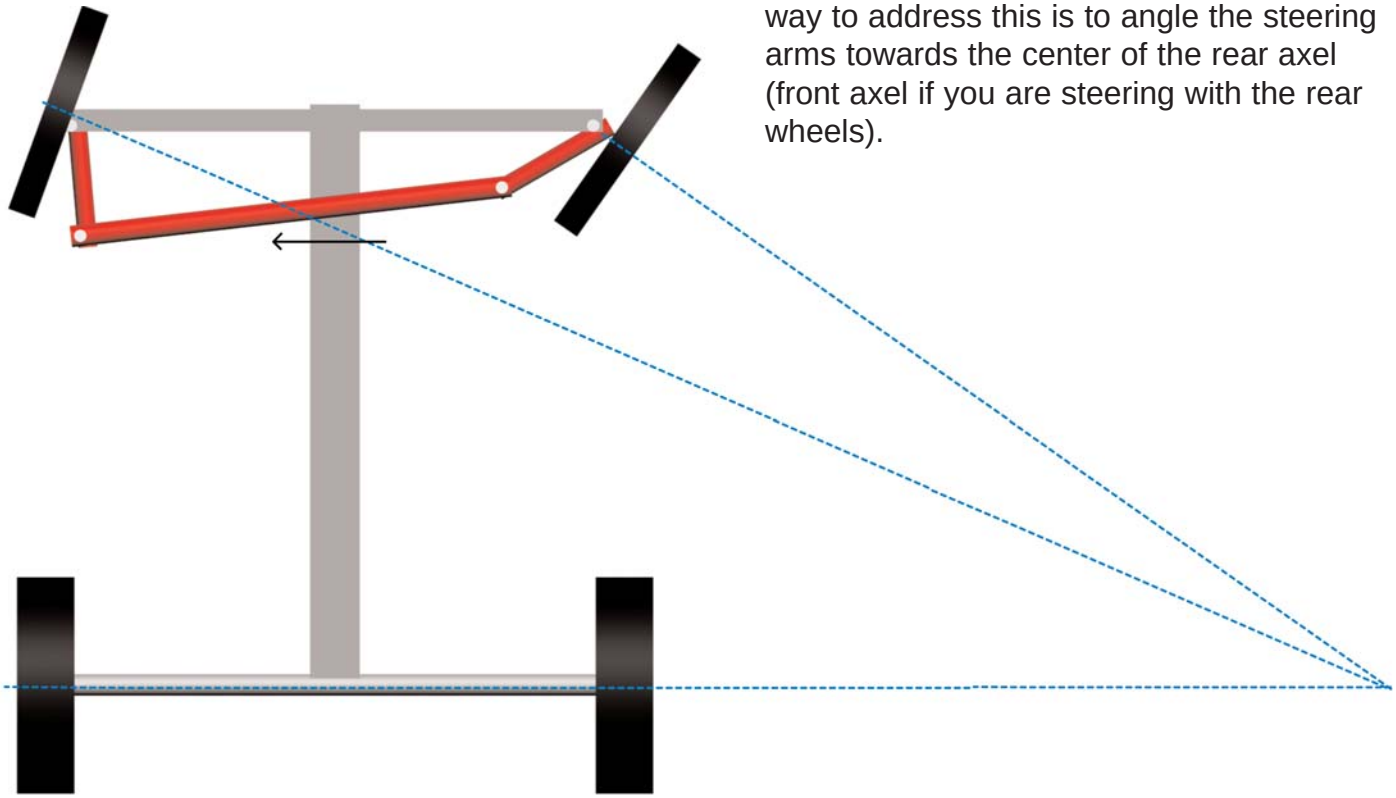
GEOMETRY TO THE RESCUE

One system that solves the issues of clearance and stability my coaster car had is shown here.

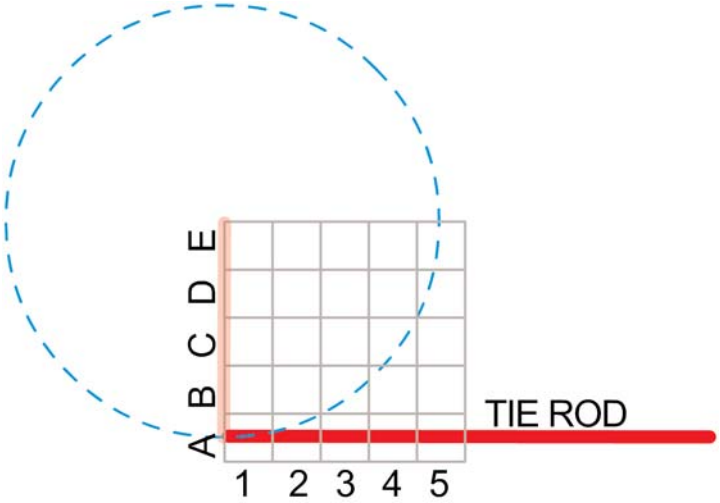
A pair of wheels are each attached with a pivot point to a ridged crossbar. Short steering arms are also attached to each wheel. These steering arms are attached to each other with a tie rod. When the tie rod is moved side to side the wheels turn.

ACKERMAN PRINCIPLE

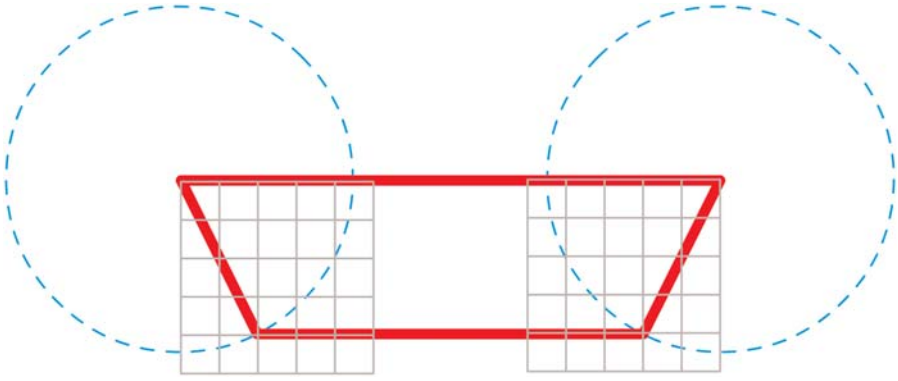
Notice that the steering arms are angled to the center of the rear axel. This angle is key to making the vehicle turn properly. As the vehicle turns, the inside and outside wheel follow 2 different tracks. The radius of the inside wheel's track is smaller then the radius of the outside wheel's so it has to turn more sharp. If the wheels do not turn at differing angles to meet these differing tracks they will scrub. Scrubbing is when a wheel slides sideways instead or rolling forward. Scrubbing slows the vehicle down, wears out the tires, and puts undue stress on the vehicle. A very simple and common way to address this is to angle the steering arms towards the center of the rear axel (front axel if you are steering with the rear wheels).



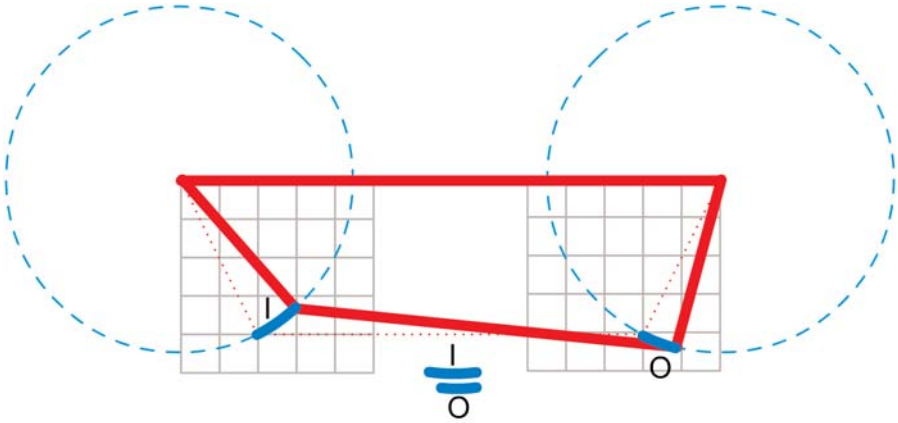
THE BEHAVIOR OF A TRAPEZOID



The secret of why this simple angling works has to do with the trapezoid shape created by this steering design and how a trapezoid behaves when it collapses. Lets start by looking at how 1 end of the tie rod (short parallel side of the trapezoid) behaves as it moves from left to right. It follows the run and rise of the circumference scribed by the steering arm (non-parallel side of the trapezoid). As it runs across 1 & 2 on the grid it only rises ½. As it runs thru 3 & 4 it rises 2, 4X as much as in 1 & 2. As it runs across the first ½ of 5 it rises 2, 16X the rise in 1&2. In this steering design the greater the rise the more the wheel turns so when the end of the tie rod moves from 4 to 5 the wheel on that side will turn more then it does when the tie rod moves from 1 to 2.



When the wheels are facing forward the trapezoid is symmetrical and not deformed. Both ends of the tie rod are at symmetrical points on the circumferences of their corresponding steering arms. As the tie rod is moved to the right the trapezoid begins to collapse. The left end of the tie rod moves thru a section of the circumference that produces a greater change in rise then the right end. The greater change in rise translates to a greater angle of turn so the left wheel turns sharper.

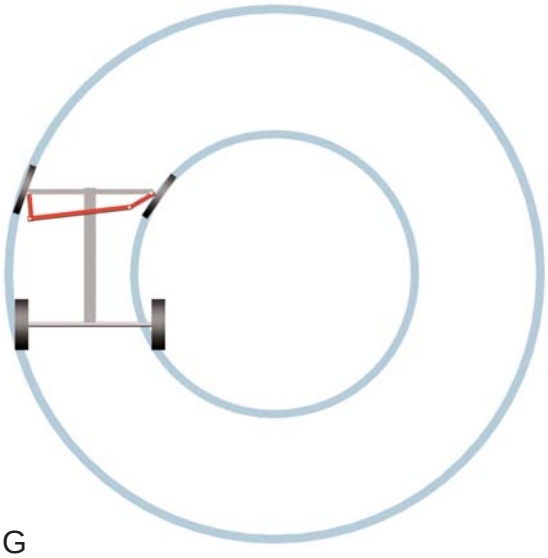


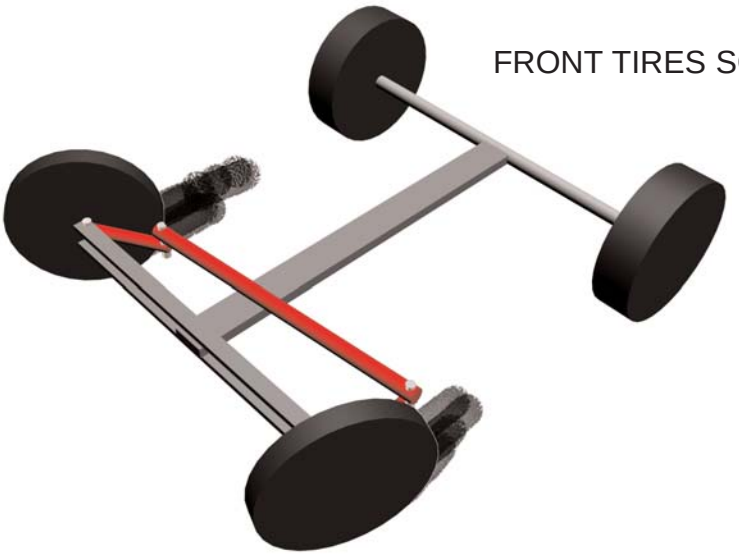
Which wheel is on the inside of the turn in this description, the left or right one? Why?

Why would a rectangle behave differently then the trapezoid?

DIFFERENTIALS AND RATCHETS

Once 2 or more wheels are side by side it is necessary to make each wheel capable of rolling at a different speed then the others. This is because as the vehicle goes around a turn the outside wheel rolls faster then the inside wheel. The outside wheel is traveling a longer distance then the inner wheel in the same time so to make up for the difference in distance it rolls faster.



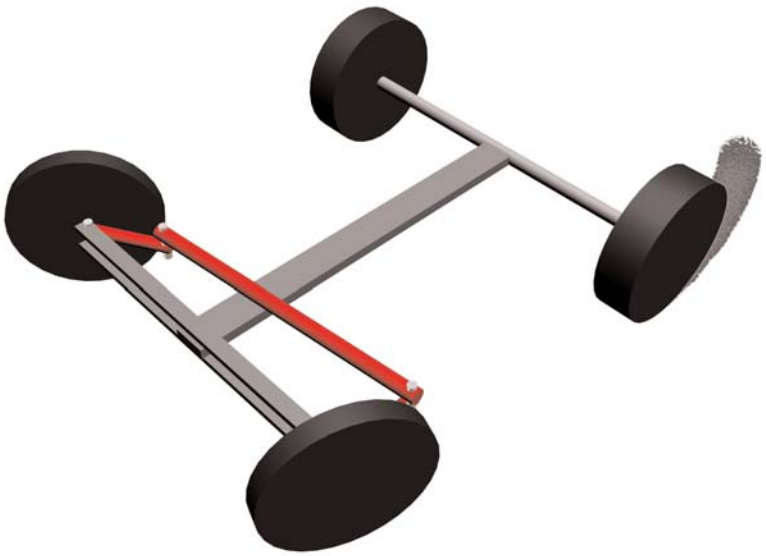


FRONT TIRES SCRUBBING

If two wheels are on the same axel and not capable of rotating at different speeds one of two things will happen. In the first scenario the traction of the drive wheels is greater then the traction of the turning wheels and the vehicle will not turn. Even if the two front wheels in this example are turned the vehicle will continue to go forward.

REAR TIRE SKIDDING

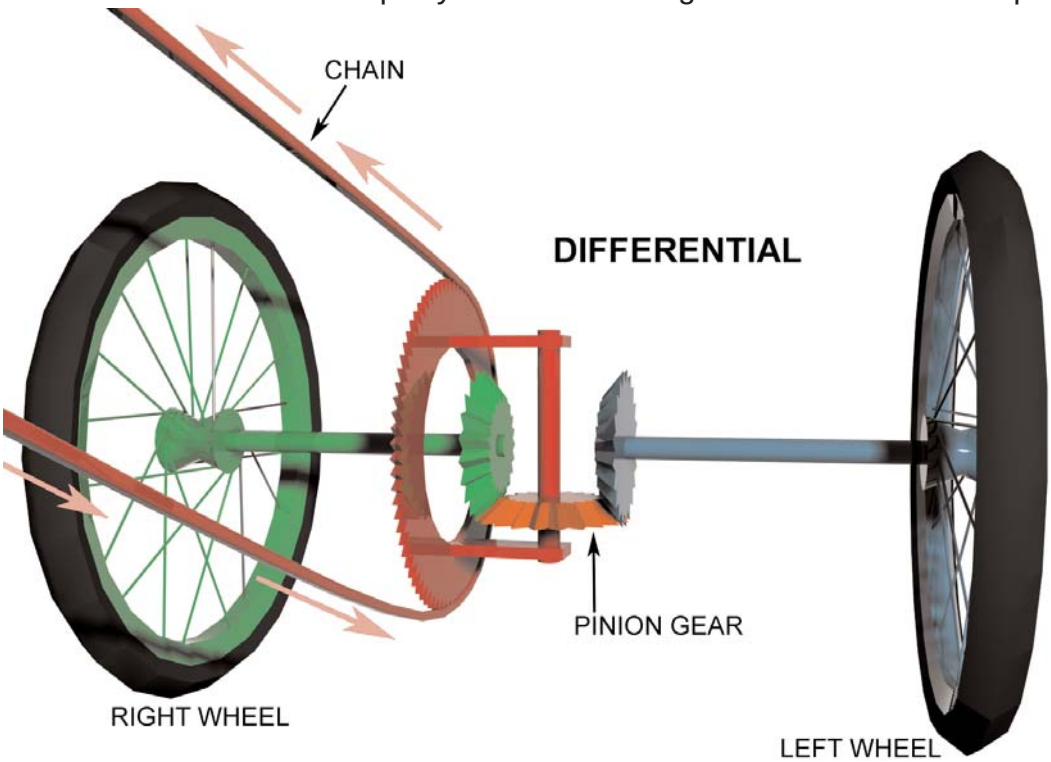
In the second scenario the traction of the turning wheels is greater then the traction of the drive wheels. Here the vehicle will turn but the back wheels will skid to go the different distances required to make the turn.



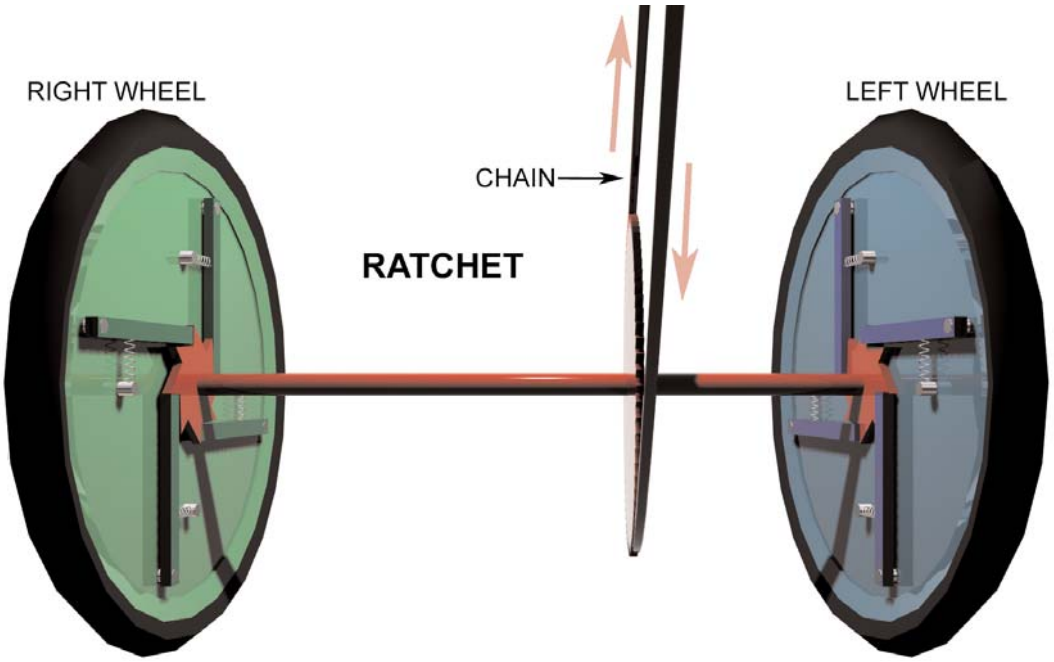
One solution is to have only 1 drive wheel and the others each on independent bearings.

Another is to have each drive wheel independently driven. Each pilot powers their own wheel with their own drive train.

To have a 2 or more wheel drive vehicle with one drive train it is necessary to make each drive wheel capable of receiving power from the drive train but also capable of coasting. The most common way this is achieved is by using a differential. A differential uses a combination of parallel and perpendicular gears in the middle of an axel. The drive train comes in to a pinion gear. The pinion gear is on a rod that rotates with the drive train. As the pinion gear is spun around the axel it engages the bevel gears attached to the left and right wheel. Because the axel is in two parts connected by the pinion gear each half can rotate together or in opposite directions relative to each other. Driving straight down a smooth road the pinion gear will not rotate on its rod and both sides of the axel will roll forward equally. As the vehicle goes around a turn the pinion gear will rotate on its rod allowing the two ends of the axel to rotate at different speeds. The downside of this differential is that power is transferred to the wheel with the least resistance. This means if one of wheels is off the ground or on less firm footing it can be difficult to get traction. One way to solve this is to put separated brakes on each wheel. If one wheel begins to spin the pilot can engage its brake sending the power to the other wheel.



Another way to solve this problem is to use ratchets where the drive wheels attach to the axel. The ratchets allow each wheel to be pushed forward by the drive train or coast ahead of it. It is more difficult to make a vehicle with ratchets be powered to go backwards but you won't have the issue of traction that a differential brings.



SHOW ME DON'T TELL ME

Pinzgauer 8by8 Vehicle.

1. Notice how in addition to the inside turning wheel being at a tighter angle, each wheel is angled less as you look from front to back. Explain why it is necessary that each wheel is angled less and how this could be achieved using the Ackerman Principle. Use illustrations as part of your answer.

2.This vehicle is 8 wheel drive. How many differentials would it need?

2. This recumbent trike steers with its front wheels. Is the Ackerman Principle relevant to its steering design? Why or why not?