Basic SBD Information

Stock, Super Stock and Masters Divisions

The information in this document is opinion based upon years of Soap Box Derby experience, my understanding of the physics involved, currently approved SBD parts, and current SBD rules.

The specific features, conditions and setups that make a SBD car go fast change with track, ramp, part and rule changes. The science does not change, but the application of the science changes based upon different tracks, ramps, parts, and rules.

Primary Influences on a SBD Car *(Listed in random order)*

a. Potential Energy (PE) *[Gravitational Potential Energy for Soap Box Derby cars]*
b. Acceleration
c. Kinetic Energy (KE)
d. Aerodynamics
e. Center of Mass (CM) *[also known as Center of Gravity]*
f. Balance, Weight
g. Moment of Inertia
h. Vibration
i. Friction
j. Driver

The primary influences change order of importance based upon the track, ramp, and lane driving requirements of a specific race.

Goals *(Listed in same order as Primary Influences)*

a. Maximum Potential Energy (See Note 5, page 2)
b. Maximum acceleration
c. Most efficient conversion of Potential Energy into Kinetic Energy
d. Minimum aerodynamic drag
e. Lowest possible Center of Mass
f. Correct weight balance for track and ramp combination
g. Minimum Moment of Inertia
h. Minimum vibration of car and parts in car
i. Minimum friction
j. Minimum driving

The car and driver best at achieving the goals stated above will win.

It is important to understand the different influences that act upon a car when selecting parts, assembling the car, and racing but, only testing on a specific track with a specific car and driver will determine what works best on that track with that car and driver.

Read everything, listen to everyone, observe what others are doing, test, and then use your own judgment to determine what will make your car go fast.

Paul Gale

Notes / Disclaimers

1. The focus of this document is on the primary influences, part conditions and setups that impact the speed of a SBD car.

2. Estimates are not provided for the increase or decrease in speed that may result from the conditions and setups mentioned in this document. Individual contestant's ability to achieve the goals and the specific race conditions would change any estimate provided.

3. There will be exceptions to all statements and recommendations in this document due to specific and unique part, track, and ramp conditions. Possible exceptions and their impact are not addressed in this document.

4. Selecting the best parts and determining the best car setup for racing involves trade-offs. The term "trade-off" is used to describe the process of evaluating the relative value of changes that can be made to the car and then making a judgment on what will work best on a specific track. Changes such as (but not limited to) tighter or looser kingpin torque, longer wheel base or shorter wheel base, light weight or maximum weight, and nose heavy versus balanced versus tail heavy. The difficulty for contestants is working out the trade-offs to make their car as fast as possible for a specific race.

   What works best on one car may not work as well on another car at the same track due to the differences in the individual parts used and how those parts have been assembled in each car. A car setup that works well for a contestant at one track may not work as well for that contestant on another track due to differences in the track and ramp.

5. Maximum Potential Energy (PE) is obtained by correctly positioning the driver and added ballast (weight) within the car. Although on most tracks cars run faster when at the maximum allowed total weight, there are tracks upon which cars will be faster racing at less than maximum allowed weight. Regardless of the cars total weight, it is always important to position the driver and added weight to obtain maximum PE.

   Caution: Racing at less than maximum allowed weight should only be done on calm weather days or on indoor tracks. If a cross wind or uphill wind is possible, it is probably better to race at maximum weight. If rain is possible, it is better to race at maximum weight. If the track surface is very rough, it is probably better to race at maximum weight.

6. It is not suggested or recommended that official SBD parts be altered or modified to achieve the optimum conditions shown in this document.

Basic SBD Information

Stock, Super Stock and Masters Divisions

Contents

1.0 Physics

The following pages provide an explanation of the basic physics involved in Soap Box Derby racing. The intent of these pages is to give the contestant an understanding of the forces that act upon a derby car.

1.1 Primary Influences

The force that propels a SBD car and driver down the track is gravity. The amount of force available, called Potential Energy, is determined by total weight of car and the vertical drop of that weight from start to finish.

When the starting gate releases a car, it accelerates down the hill. While accelerating, the car's Potential Energy (PE) is converted into Kinetic Energy (KE). The more efficiently PE is converted to KE, the faster the car goes.

A car's acceleration is impeded as it rolls down the hill by aerodynamic drag, vibration, friction, Moment of Inertia, and most important: driving. Minimizing the impact of these primary influences will increase the car's acceleration and thus its speed.

The following pages provide a definition for each of the Primary Influences and the impact of weight distribution when racing on various types of ramps and hills.

Contents

1.1 Primary Influences continued

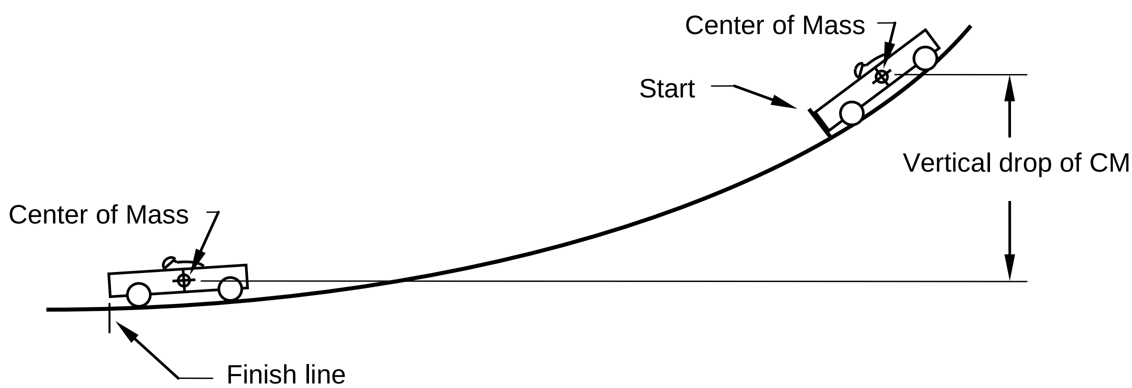
Definition of Primary Influence

1.1.1 Potential Energy: Energy of an object due to its position. *[on ramp, not moving]*

Gravitational Potential Energy

Maximum Potential Energy (PE) occurs on ramp before starting gate is released.

No Kinetic Energy as car sits on ramp.



To calculate Potential Energy (PE): Multiply total weight of car and driver times the car's Center of Mass vertical drop.

(The vertical drop at Akron is approximately 48 feet).

1 pound x 48 feet = 48 foot pounds of Potential Energy

2 lbs. x 48 ft. = 96 ft. lbs. of PE

5 lbs. x 48 ft. = 240 ft. lbs. of PE

200 lbs. x 48 ft. = 9,600 ft. lbs. of PE *(Stock)*

230 lbs. x 48 ft. = 11,040 ft. lbs. of PE *(Super Stock)*

255 lbs. x 48 ft. = 12,240 ft. lbs. of PE *(Masters)*

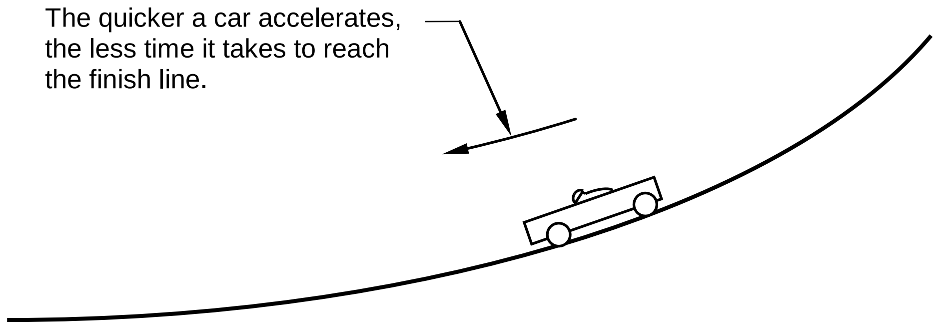
260 lbs. x 48 ft. = 12,480 ft. lbs. of PE

300 lbs. x 48 ft. = 14,400 ft. lbs. of PE *(Ultimate Speed Challenge)*

1.1 Primary Influences continued

Definition of Primary Influence

1.1.2 Acceleration: The rate of change of an object's speed.



Acceleration is impeded by:

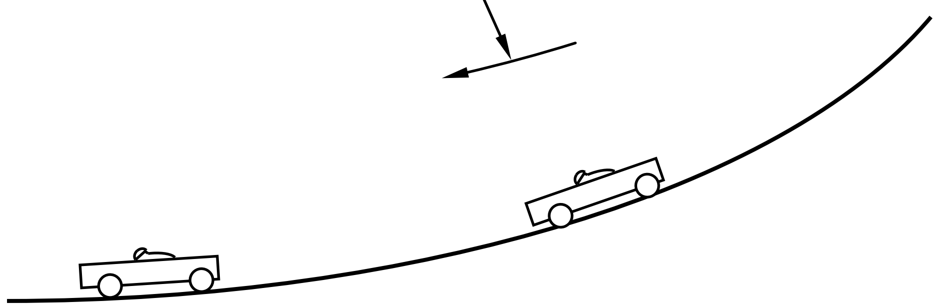
1. Debris on wheel tread (such as small rocks)
2. "Flat" spot on wheel tread due to sitting in starting gate for a long period of time.
3. Imperfections in ramp surface
4. Wheel bearing breakaway torque
5. Wheel tread "squirm" (side to side movement) rolling down hill
6. Rough track surface
7. Aerodynamic drag
8. Friction
9. Vibration
10. Moment of Inertia
11. Steering of car by driver

1.1 Primary Influences continued

Definition of Primary Influence

1.1.3 Kinetic Energy: Energy of an object due to its motion. *[rolling down hill]*

Potential Energy is converted into Kinetic Energy (KE) as the car rolls down hill.



Maximum Kinetic Energy (maximum force) occurs at maximum speed.

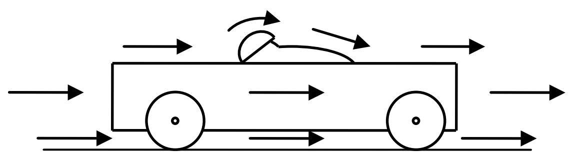
On most tracks, maximum speed is achieved before the finish line. Cars are slowing down when they cross the finish line.

1.1 **Primary Influences** continued

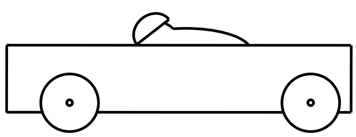
Definition of Primary Influence

1.1.4 Aerodynamics: Effects produced by air upon an object.

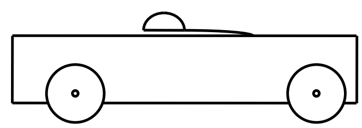
Air flows over, under and around all exposed surfaces of the car and driver. The car/driver "pushes" through the air as it rolls down the hill. Steps, gaps, sharp edges, wavy surfaces, and rough surfaces disrupt the airflow causing increased drag which slows the car's speed.



Example 1-1: Driver Position

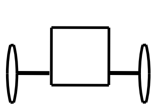


Increased drag

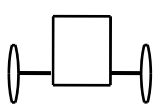


Minimum drag

Example 1-2: Car Body

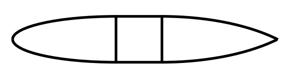


Smaller cross section is less drag.

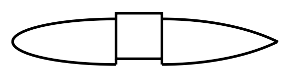


Larger cross section is greater drag.

Example 1-3: Airfoils



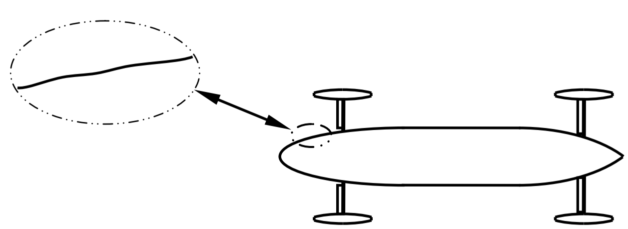
Minimum drag



Increased drag

Example 1- 4: Car's surface Roughness

Waves and other irregularities in body cause drag.



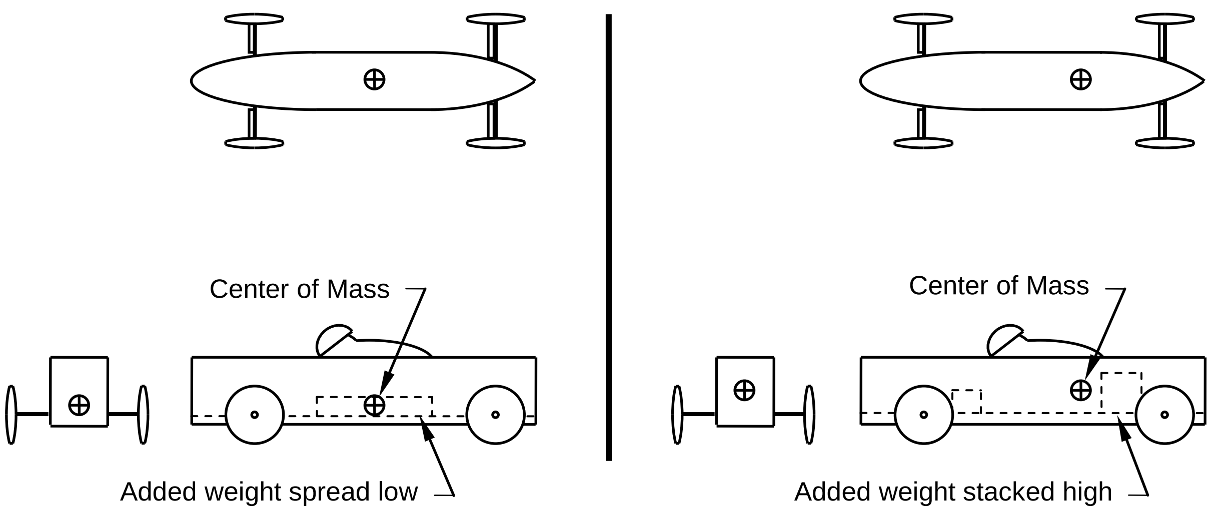
1.1 **Primary Influences** continued

Definition of Primary Influence

1.1.5 Center of Mass: Point at which weight of object is centered. *[all three axis]*

also known as Center of Gravity

The weight of all car parts, added weight and driver, in racing position, are combined to determine the car's Center of Mass (CM).



Low Center of Mass

1. Spreading out weight lowers Center of Mass.

High Center of Mass

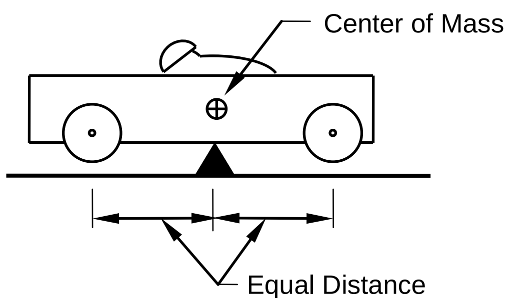
1. Stacking weight raises Center of Mass.

1.1 Primary Influences continued

Definition of Primary Influence

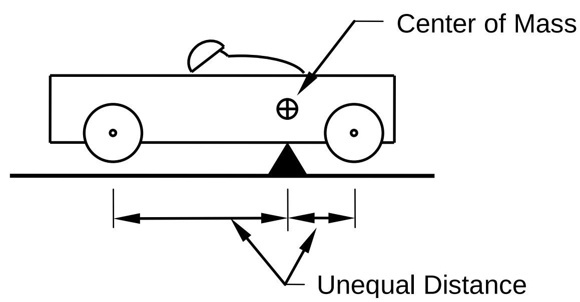
1.1.6 Balance: Weight of car and driver measured at axles.

Balance is determined when car and driver are at racing weight and the driver is in driving position.



Balanced (equal weight)

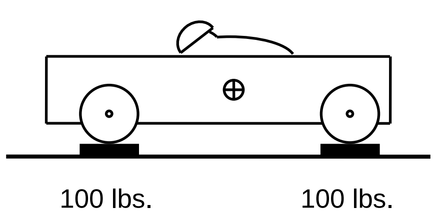
1. Equal weight on front and rear axles.



Tail Heavy (unequal weight)

1. Rear axle weight heavier than front axle.

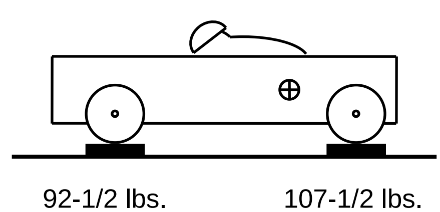
Example 1-5: 200 pounds total weight



100
<u>- 100</u>
0

Balanced

Example 1-6: 200 pounds total weight



107-1/2
<u>- 92-1/2</u>
15 lbs.

Tail Heavy: 15 pounds

1.1 Primary Influences continued

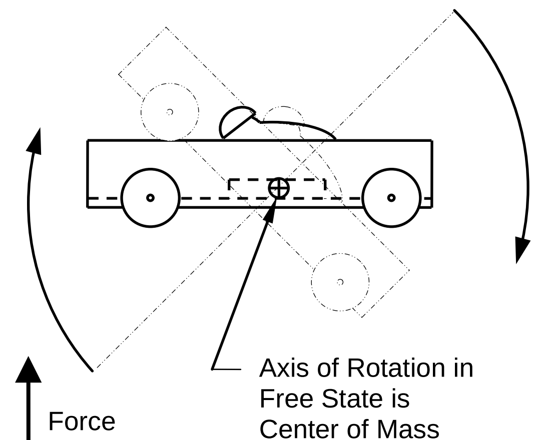
Definition of Primary Influence

1.1.7 Moment of Inertia

1.1.7.1 Car: An object's resistance to rotating about its Center of Mass (CM).

In illustrations below, the car is shown in a theoretical "Free State" (no constraints). It is not rolling down a hill. The car and driver are shown rotating about the car's Center of Mass.

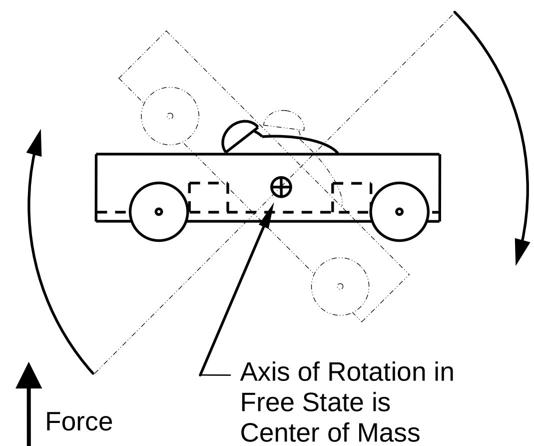
Each wheel, part, and the driver has its own Moment of Inertia. The "car's" Moment of Inertia is determined by the sum of all wheels, parts, and driver in position.



Less force required to rotate object.

Small Moment of Inertia

Most mass (weight) near Axis of Rotation



More force required to rotate object.

Large Moment of Inertia

Most mass (weight) not near Axis of Rotation

1. All weight (car body, wheels, axles, added weight, driver, etc.) not located at the Center of Mass increases the car's Moment of Inertia.
2. The farther a weight is from the CM, the larger the car's Moment of Inertia.
3. Following current rules, only driver position and weight added to the car can be adjusted to minimize a car's Moment of Inertia.

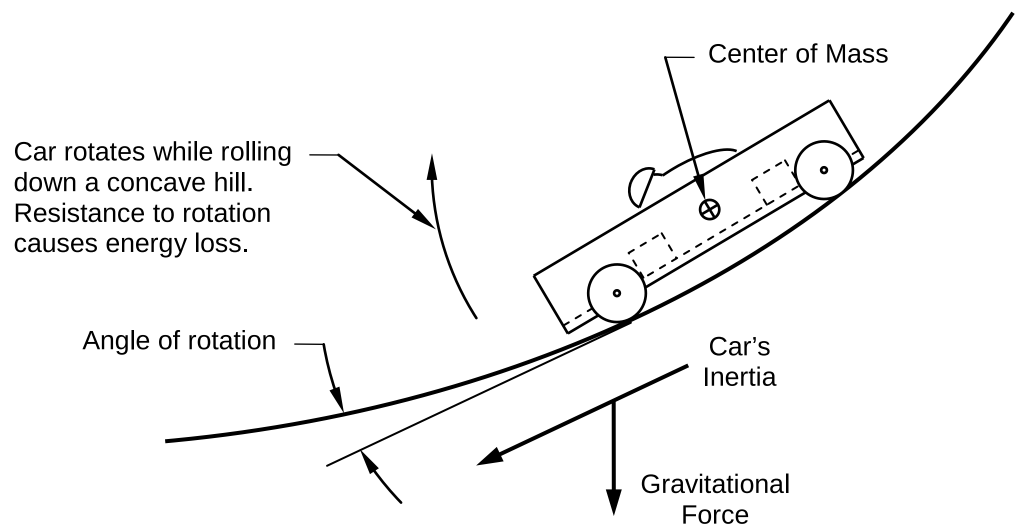
1.1 **Primary Influences** continued

Definition of Primary Influence

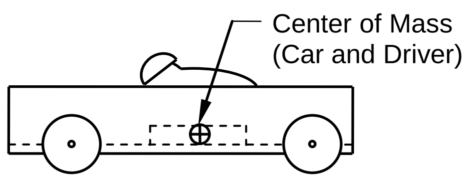
1.1.7 **Moment of Inertia** continued

1.1.7.2 **On Track:** An object's resistance to angular acceleration.

The most common type of track/street used for SBD racing is a varying slope (Concave slope). The slope at the start is greater than the slope at the finish. The car rotates while rolling down the hill due to the varying slope. Reducing the car's Moment of Inertia will reduce the energy loss.

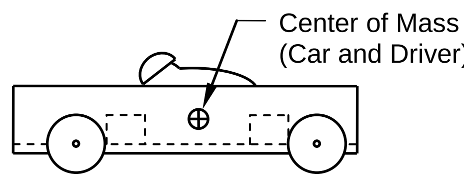


Example 1-7: Small Moment of Inertia



Car with small Moment of Inertia due to location of added weight in center of car

Example 1-8: Large Moment of Inertia



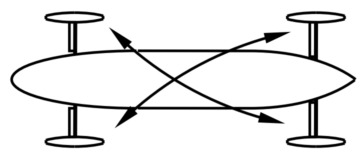
Car with large Moment of Inertia due to location of added weight near axles

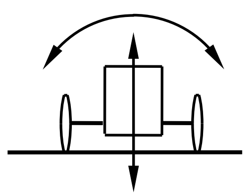
1.1 **Primary Influences** continued

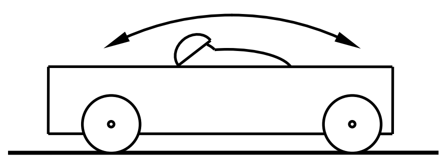
Definition of Primary Influence

1.1.8 Vibration: A cyclic back and forth motion of an object.

Track surfaces are irregular and cause the car to vibrate up/down, front to rear, corner to corner, and side to side.







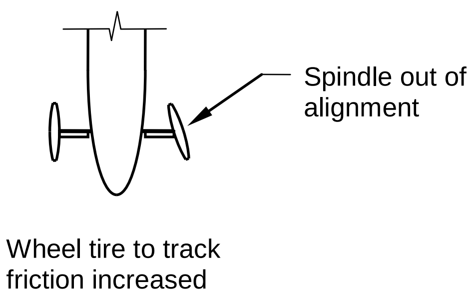
A car that "rattles" rolling down the hill will be slower than a car that does not rattle – all other things being equal.

1.1 Primary Influences continued

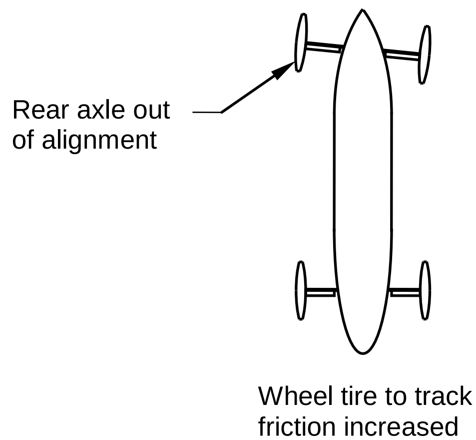
Definition of Primary Influence

1.1.9 Friction: A force that resists the relative motion of two surfaces in contact.

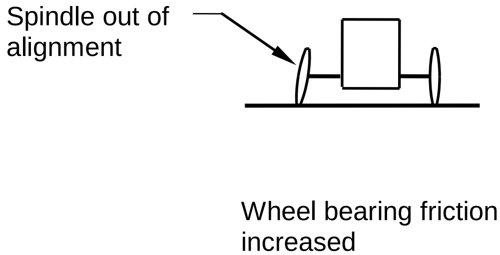
Example 1-9:



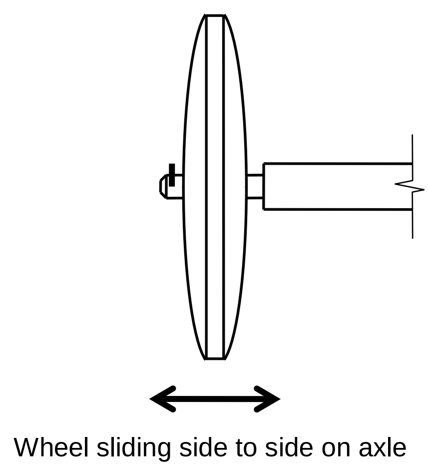
Example 1-10:



Example 1-11:



Example 1-12:



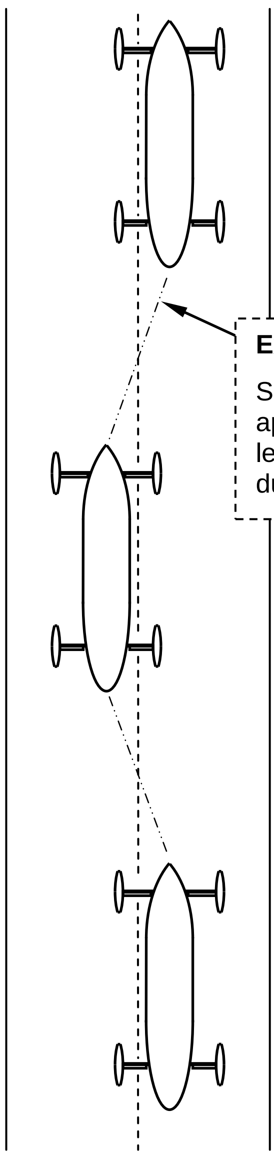
1.1 Primary Influences continued

Definition of Primary Influence

1.1.10 Driver: Individual steering car down hill.

Not driving straight increases length of track and increases wheel friction.

Example 1-13

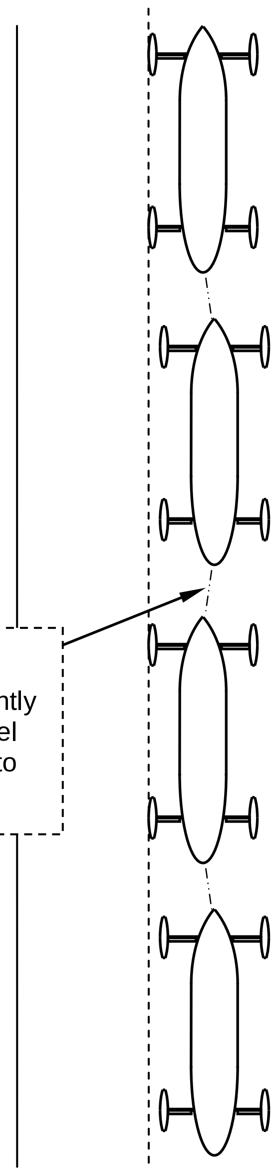


The driver is the most important component of a car.

Example 1-13:

Several large swerves will add approximately six inches to length of track and slows car due to increased wheel friction.

Example 1-14



Example 1-14:

Multiple small swerves significantly slows car due to increased wheel friction and adds about an inch to length of track.

See "Increased Track Length Due to Steering" *in Miscellaneous Info section.*

1.2 Weight Distribution

The following information is a general guide for determining the location of weight (ballast) added to a SBD car. The two most important considerations when determining where to locate weight being added to a car are slope of the hill and shape of the ramp. See Section 1.2.5, page 20, for basic weight distribution recommendations.

Note: *The best way to determine optimum total weight and weight distribution for a specific track and ramp combination is to test on that track/ramp combination.*

1.2.1 Track and Ramp Types

There are three basic hill types used for racing: 1) Constant Slope; 2) Concave Slope; and 3) Convex Slope. See Diagram 1-1. Tracks built for SBD racing normally have a varying slope (referred to in this document as concave). Streets used for racing are often variations or combinations of the basic hill types and present a greater challenge when trying to determine where to place added weight.

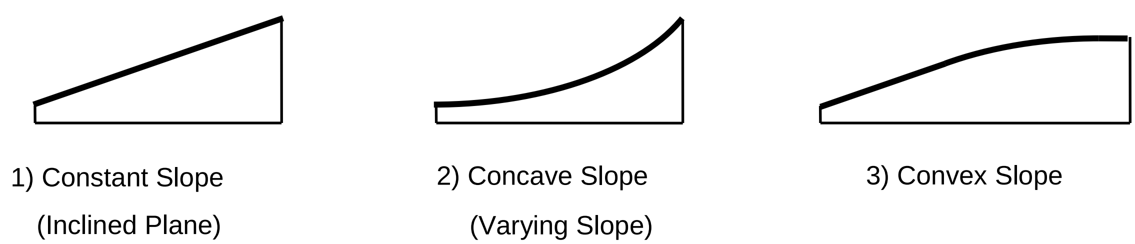


Diagram 1-1: Basic Track Slope Types

There are three basic ramp types used for racing: 1) Flat Ramp (same slope as track); 2) Standard Ramp (the most common style); and 3) Drop-Off Ramp. See Diagram 1-2.

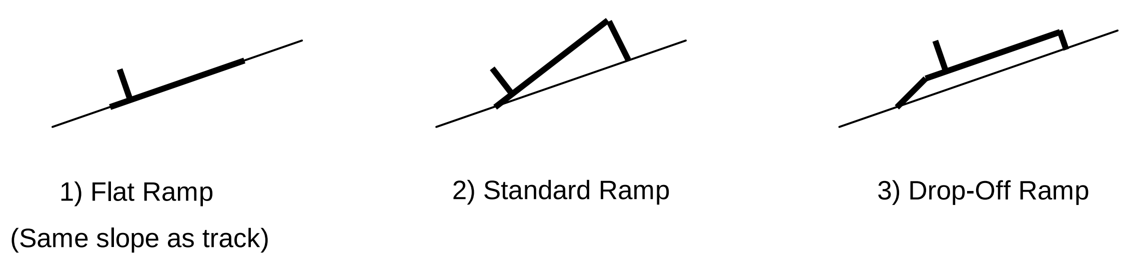


Diagram 1-2: Basic Ramp Types

1.2 Weight Distribution continued

1.2.2 General Information

1.2.2.1 Primary Influences associated with adding weight.

1.2.2.1.1 Potential Energy *[Gravitational Potential Energy in the case of SBD cars]*

1.2.2.1.2 Center of Mass *[also known as Center of Gravity]*

1.2.2.1.3 Balance

1.2.2.1.4 Moment of Inertia

See Section 1.1.1 through Section 1.1.7, pages 5 through 12, for explanation of Primary Influences: Potential Energy, Balance, Center of Mass, and Moment of Inertia.

1.2.2.2 Goals

1.2.2.2.1 Maximum Potential Energy.

1.2.2.2.2 Lowest possible Center of Mass.

1.2.2.2.3 Appropriate balance for track and ramp combination.

1.2.2.2.4 Minimum Moment of Inertia.

1.2.2.3 Basics

1.2.2.3.1 Weight added to a car increases Potential Energy.

1.2.2.3.2 Stacking weight raises the Center of Mass.

1.2.2.3.3 Placement of weight near axles increases car's Moment of Inertia.

1.2.2.3.4 Determining the ideal weight distribution involves trade-offs based upon ramp shape, track slope and track length.

1.2.2.4 Generic Recommendations

1.2.2.4.1 Car and driver should be at the maximum allowed total weight.

1.2.2.4.2 All weight in car (added and driver) should be as low as possible.

1.2.2.4.3 Ramp type is the first consideration when determining car's balance.

1.2.2.4.4 See Section 1.2.5, page 20, for basic weight distribution recommendations.

1.2.2.5 Exceptions

1.2.2.5.1 There will be exceptions to all statements and recommendations in this document due to specific and unique track/ramp conditions. Possible exceptions and their impact are not addressed in this document.

1.2 Weight Distribution continued

1.2.3 Potential Energy on Ramp

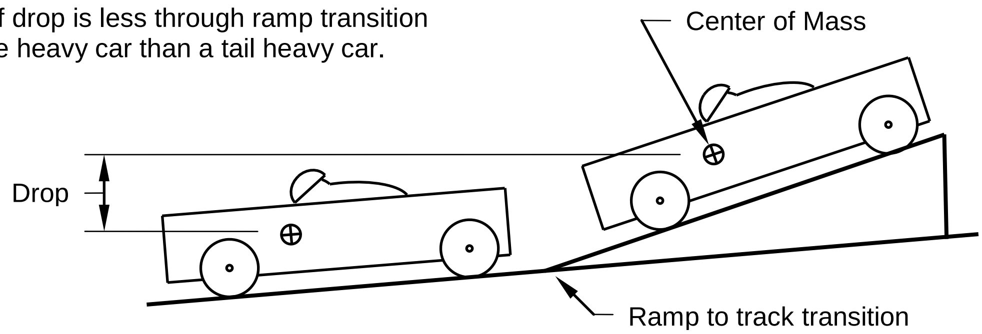
(a) *Flat ramp*: Location of the Center of Mass is based upon track slope.

(b) *Standard ramp*: Locating the Center of Mass toward tail produces a larger vertical drop through ramp to track transition. A larger vertical drop means more Potential Energy. See Example 1-15 and Example 1-16 below.

(c) *Drop-Off ramp*: Nose heavy is generally better but locating the Center of Mass toward tail may increase Potential Energy depending upon ramp slope, ramp transition to track, track slope, and track length. See Example 1-18, page 22.

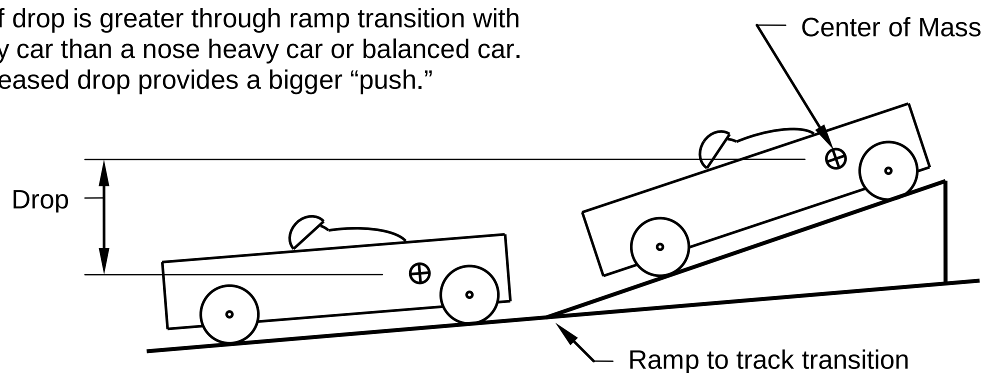
Example 1-15: Nose heavy car on Standard ramp.

Inches of drop is less through ramp transition with nose heavy car than a tail heavy car.



Example 1-16: Tail heavy car on Standard ramp.

Inches of drop is greater through ramp transition with tail heavy car than a nose heavy car or balanced car. This increased drop provides a bigger "push."



1.2 **Weight Distribution** continued

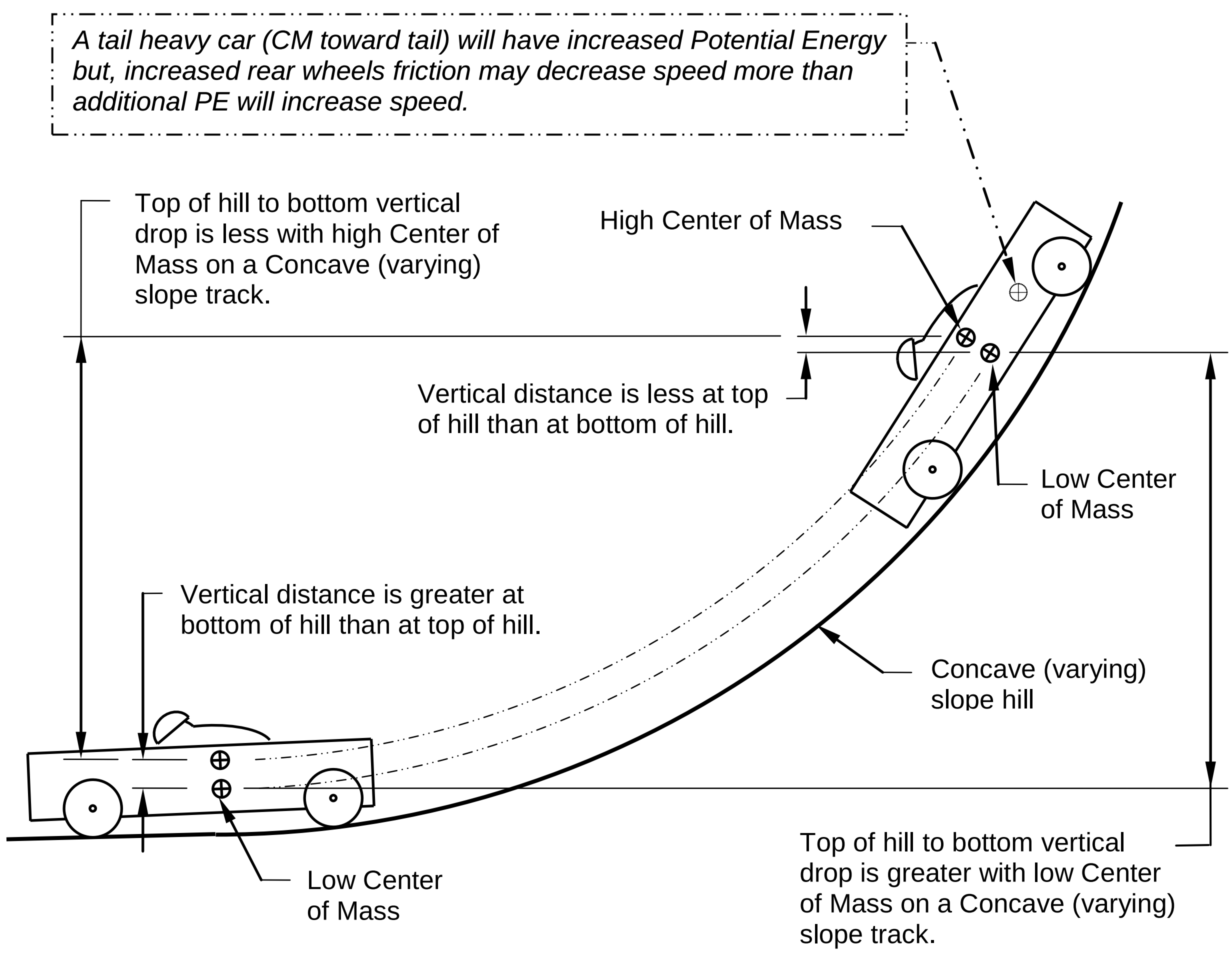
1.2.4 Potential Energy on Track

(a) *Constant (inclined plane) slope*: It does not matter if the Center of Mass is high or low. Locating CM toward tail will increase Potential Energy but also increases rear wheels friction.

(b) *Concave (varying) slope*: A low Center of Mass produces greater vertical drop of weight from top of hill to bottom than a high Center of Mass. A larger vertical drop means more Potential Energy. See Example 1-17 below.

(c) *Convex slope*: A high Center of Mass produces greater vertical drop of weight increasing Potential Energy.

Example 1-17: Center of Mass on concave hill.



1.2 Weight Distribution continued

1.2.5 Basic Weight Distribution Recommendations

1. Constant Slope Track

(a) *Flat ramp:*

Weight centered - balanced

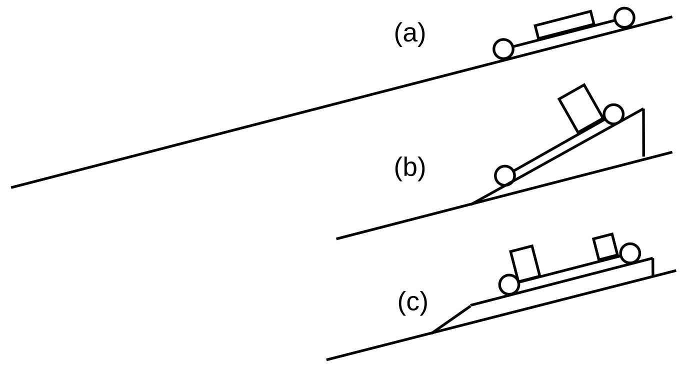
(b) *Standard ramp*:

Maximum weight on rear axle

(c) *Drop-Off ramp*:

Weight at axles - nose heavy

See Note 2 on page 21.



2. Concave Slope Track

(a) *Flat ramp:*

Weight centered - balanced

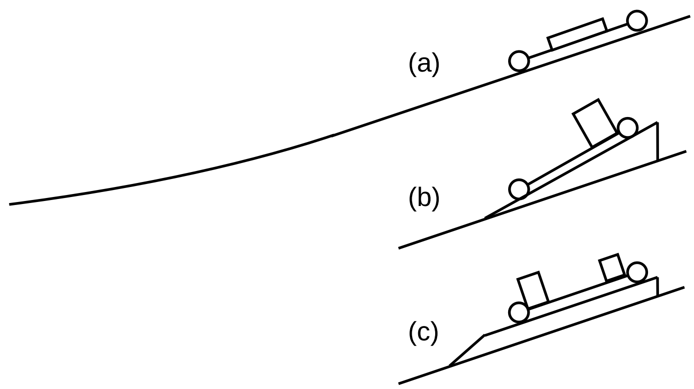
(b) *Standard ramp*:

Maximum weight on rear axle

(c) *Drop-Off ramp*:

Weight at axles - nose heavy

See Note 3 on page 21.



3. Convex Slope Track *[See Example 1-18, page 22]*

(a) *Flat ramp:*

Maximum weight on front axle

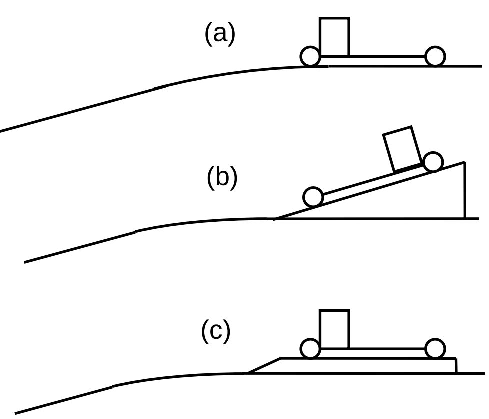
(b) *Standard ramp*:

Maximum weight on rear axle

(c) *Drop-Off ramp*:

Maximum weight on front axle

See Note 4 on page 21.



1.2 Weight Distribution continued

Notes – Section 1.2.5:

1. Only testing on a specific track and ramp combination will determine the best weight distribution for that track and ramp.

2. **Constant Slope Track**

    (a) *Flat Ramp:* Racing tail heavy (see Section 1.1.6, page 10) will increase Potential Energy and may be an advantage but, increasing weight on rear wheels increases wheel friction. Increased rear wheels friction may slow the car's speed more than the speed gained by having more Potential Energy (especially if wheels are slow or "bad"). Wheels used at rallies and Akron range from good to very bad.

    (b) *Standard Ramp:* Racing tail heavy is such a significant advantage, due to the ramp to track transition, that it overrides other considerations.

    (c) *Drop-Off Ramp:* A longer wheel base is the most effective method of increasing speed. Racing nose heavy may increase speed depending upon ramp shape, track slope and track length.

3. **Concave Slope Track**

    (a) *Flat Ramp*: Racing with low weight will produce the maximum advantage.

    (b) *Standard Ramp*: Racing tail heavy is such a significant advantage, due to the ramp to track transition, that it overrides other considerations.

    (c) *Drop-Off Ramp*: A longer wheel base is the most effective method of increasing speed. Racing nose heavy may increase speed depending upon ramp shape, track slope and track length.

4. **Convex Slope Track**

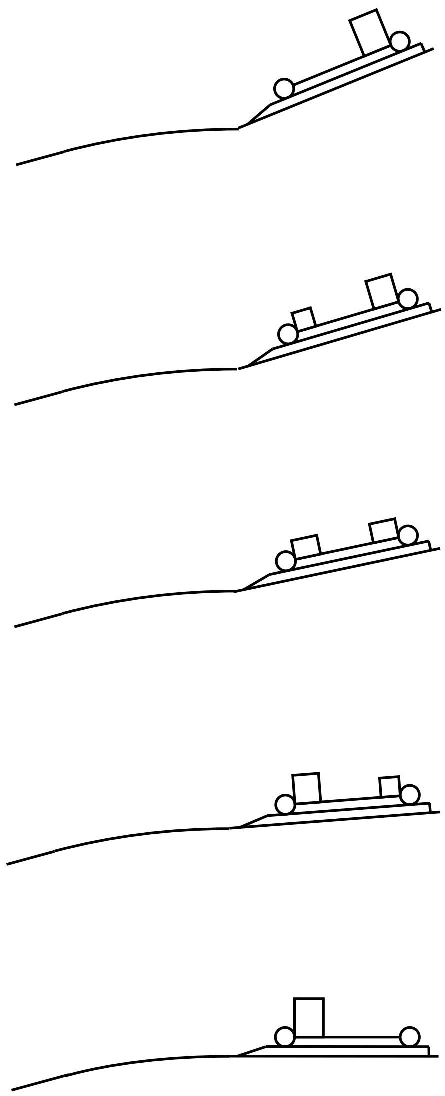
    (a) *Flat Ramp*: A longer wheel base is the most effective method of increasing speed. Racing nose heavy may increase speed depending upon track slope and length.

    (b) *Standard Ramp*: Racing tail heavy is such a significant advantage, due to the ramp to track transition, that it overrides other considerations.

    (c) *Drop-Off Ramp*: A longer wheel base is the most effective method of increasing speed. Racing nose heavy may increase speed depending upon ramp shape, track slope and track length.

1.2 **Weight Distribution** continued

Example 1-18: How weight will shift as conditions change on a Convex hill and Drop-Off ramp



As ramp slope increases the weight distribution should be moved toward the tail of car creating more Potential Energy

Ramp slope almost level

2.0 Parts

The following pages show the basic physical features of Soap Box Derby parts and conditions that may exist. The intent of these pages is to provide guidance when evaluating specific parts. Illustrations are provided to help identify conditions and their impact.

Contents

2.1 Floorboard

The following pages show the basic physical features of a Soap Box Derby floorboard and conditions that may exist. The intent of these pages is to provide guidance when evaluating a floorboard. Illustrations are provided to help identify conditions and their impact.

Because floorboard material, size dimensions and rules change over the years, dimensional values for the floorboard are not provided.

With all manufactured items (even computer numerical control (CNC) parts), the production process produces similar parts with different dimensions. Most of the parts manufactured will be within the allowed tolerance while some will not. Generally, parts outside of the allowed tolerance present the greater possibility for a speed advantage.

If a floorboard is received from Akron with significant defect(s) (e.g.; split along glue line, badly mislocated holes, twisted, etc.), return it to Akron or request permission to repair it.

See Section 2.1.1 through Section 2.1.11 on the following pages for floorboard conditions that may be encountered and the impact of those conditions may cause.

See page 32 and page 33 for the conditions that create an “ideal” floorboard.

It is not suggested or recommended that floorboards be altered or modified to achieve the optimum conditions shown in this document.

Diagram 2-1 below shows how terms are applied to a floorboard.

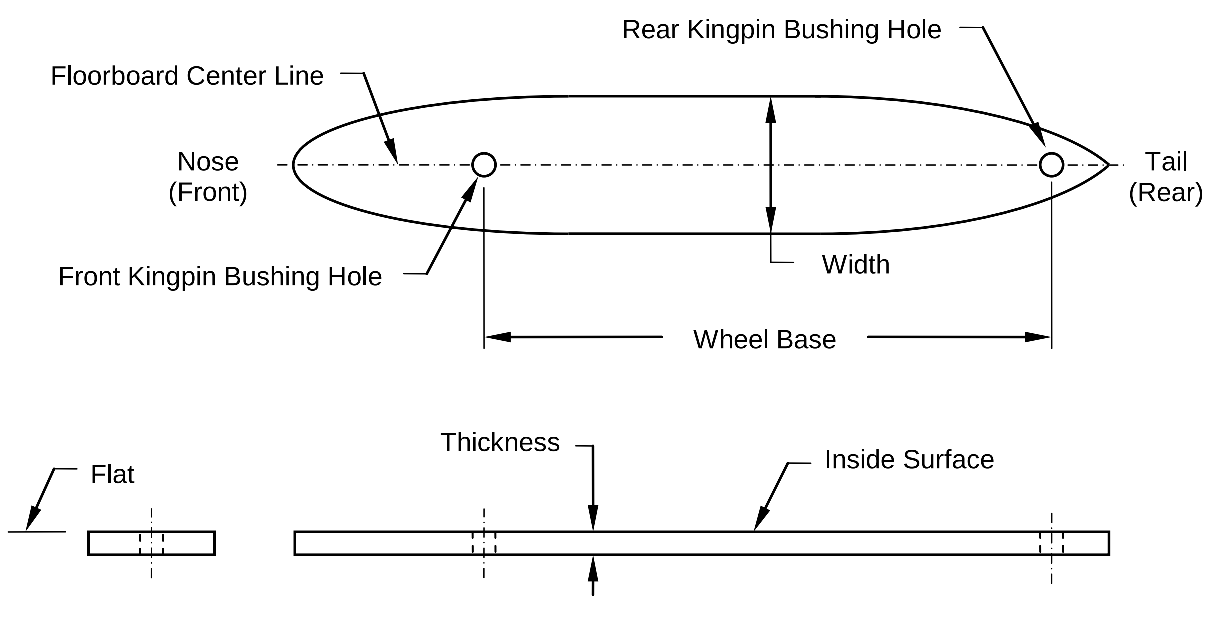


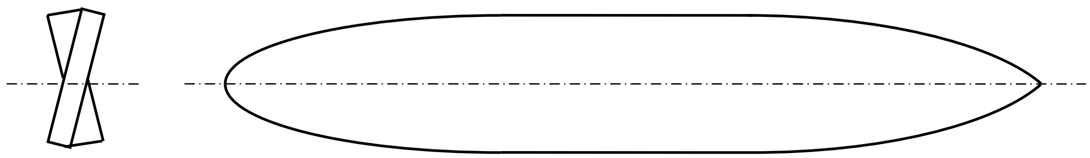
Diagram 2-1: Floorboard Nomenclature

2.1 **Floorboard** continued

Contents

2.1 **Floorboard** continued

2.1.1 Twisted



Impact(s)

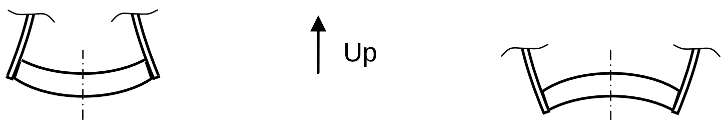
a) Creates cross-bind increasing wheel friction.

b) Difficult to mount car body.

c) Increases aerodynamic drag.

Cross-bind is unequal weight on wheels from side to side (e.g., more weight on left front wheel than right front wheel).

2.1.2 Cupped



Cupped Up

Cupped Down

Impact(s)

<u>Cupped Up</u>:

a) If body shell is raised up, cross section area of car is increased which increases aerodynamic drag.

b) Lowers driver in car decreasing aerodynamic drag.

c) Lowers Center of Mass increasing Potential Energy.

d) Improves air flow along bottom decreasing aerodynamic drag.

<u>Cupped Down</u>:

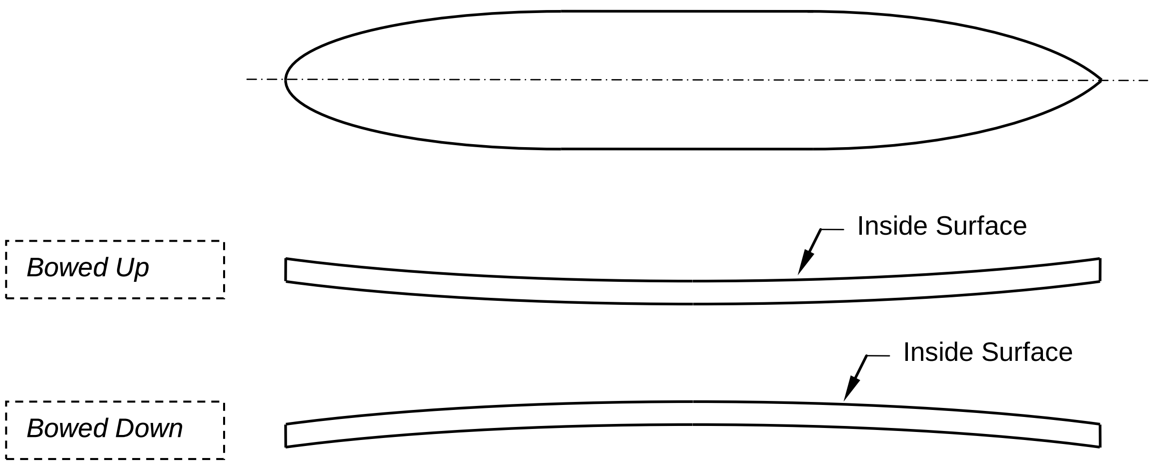
a) Degrades airflow along bottom of car increasing aerodynamic drag.

b) Raises driver in car increasing aerodynamic drag.

c) Raises Center of Mass decreasing Potential Energy.

2.1 **Floorboard** continued

2.1.3 Bowed



Impact(s)

Bowed Up:

a) Difficult to mount car body.

b) If body shell is raised up, cross section area of car is increased which increases aerodynamic drag.

c) Lowers driver in car decreasing aerodynamic drag.

d) Lowers Center of Mass increasing Potential Energy.

e) Tilts kingpins which tilts axles/airfoils increasing aerodynamic drag.

f) Improves air flow along bottom decreasing aerodynamic drag.

Bowed Down:

a) Difficult to mount car body.

b) If body shell is raised up, cross section area of car is increased which increases aerodynamic drag.

c) Raises driver in car increasing aerodynamic drag.

d) Raises Center of Mass decreasing Potential Energy.

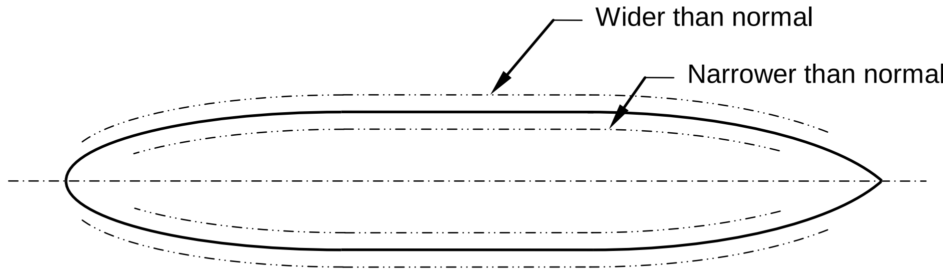
e) Degrades airflow along bottom of car increasing aerodynamic drag.

f) Tilts kingpins which tilts airfoils increasing aerodynamic drag.

g) Forcing floorboard flat to mount body may increase stiffness of car.

2.1 **Floorboard** continued

2.1.4 Width

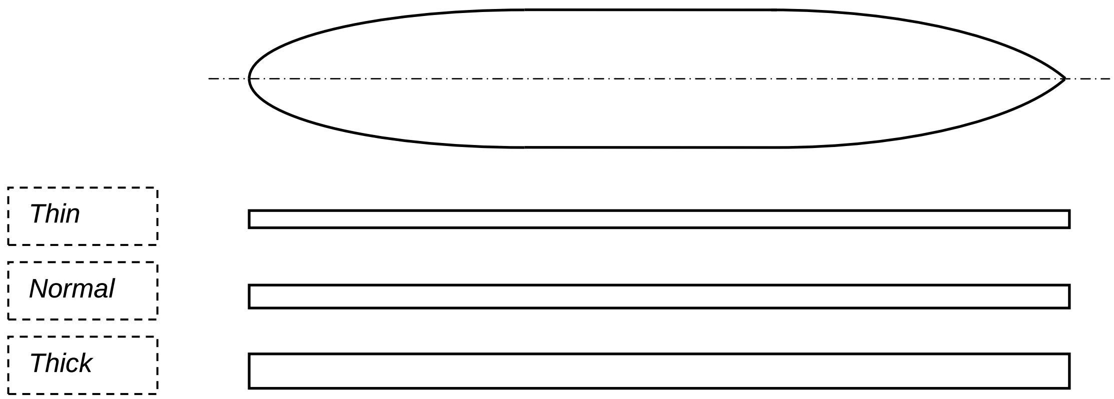


Impact(s)

Wider: a) Increases cross section area increasing aerodynamic drag.

Narrower: a) Decreases cross section area decreasing aerodynamic drag.

2.1.5 Thickness



Impact(s)

Thin:

a) Floorboard flex (up/down bending) may be increased which would increase energy loss (dependent upon driver weight and location of added weight).

Normal:

a) Floorboard cut to basic (standard) thickness.

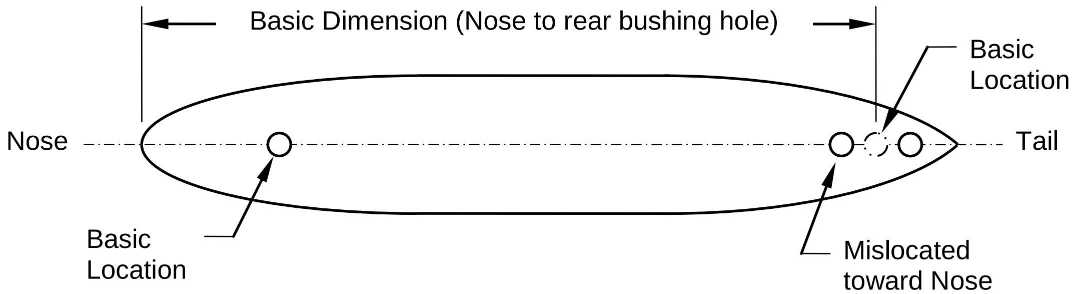
Thick:

a) Floorboard flex (up/down bending) may be decreased which would decrease energy loss (dependent upon driver weight and location of added weight).

b) Heavier floorboard lowers Center of Mass increasing Potential Energy.

2.1 **Floorboard** continued

2.1.6 Rear Kingpin Bushing Hole Mislocated Along Center Line



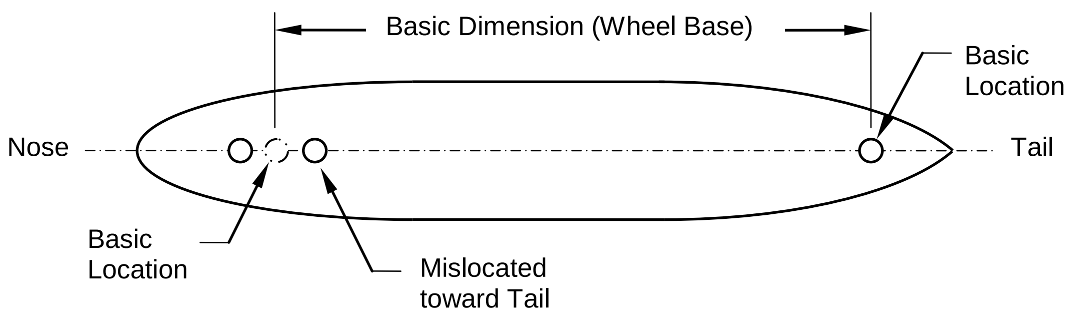
Impact(s)

a) Mislocated toward nose: Center of Mass moved forward (down hill) decreasing Potential Energy.

b) Mislocated toward tail: Center of Mass moved back (uphill) increasing Potential Energy.

Definition of “Basic”: The exact intended location or dimension (distance).

2.1.7 Front Kingpin Bushing Hole Mislocated Along Center Line



Impact(s)

a) Mislocated toward nose: Center of Mass moved forward (down hill) decreasing Potential Energy.

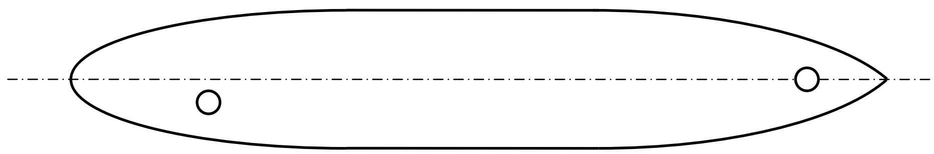
b) Mislocated toward nose: Increases acceleration on Drop-Off ramp.

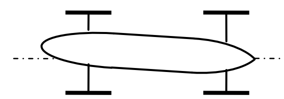
c) Mislocated toward tail: Center of Mass moved back (uphill) increasing Potential Energy.

Definition of “Basic”: The exact intended location or dimension (distance).

2.1 **Floorboard** continued

2.1.8 One Kingpin Bushing Hole Mislocated Off Center Line





Car on track

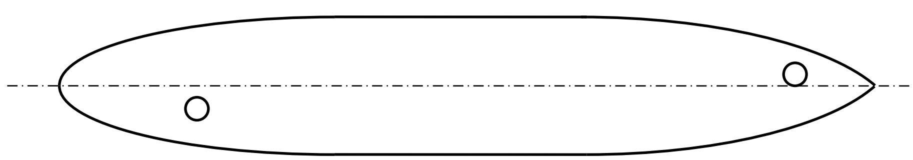
Impact(s)

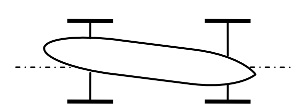
a) Misaligns car body to air flow increasing aerodynamic drag.

b) Difficult to drive straight.

2.1.9 Both Kingpin Bushing Holes Mislocated Off Center Line

Mislocated in opposite direction





Car on track

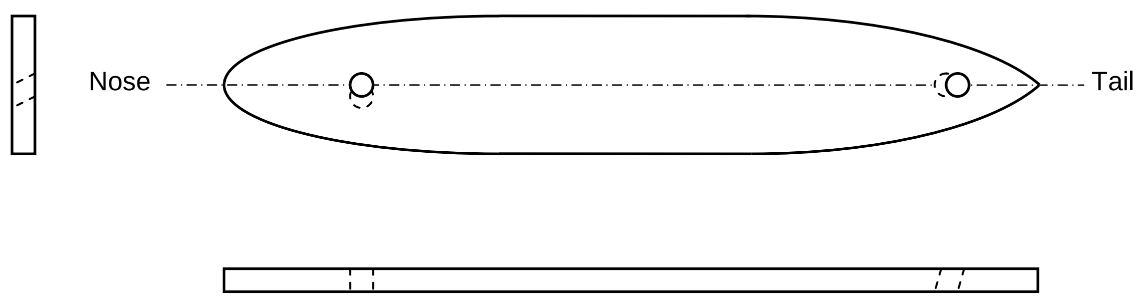
Impact(s)

a) Misaligns car body to air flow increasing aerodynamic drag.

b) Difficult to drive straight.

2.1 **Floorboard** continued

2.1.10 Kingpin Bushing Hole(s) Not Drilled At 90 Degrees

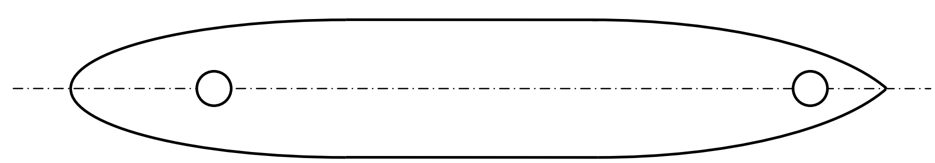


Impact(s)

a) If hole(s) is slanted toward nose or tail, tilts axles/airfoils increasing aerodynamic drag.

b) If hole(s) is slanted toward side, creates cross-bind increasing wheel friction.

2.1.11 Kingpin Bushing Hole(s) Oversize



Impact(s)

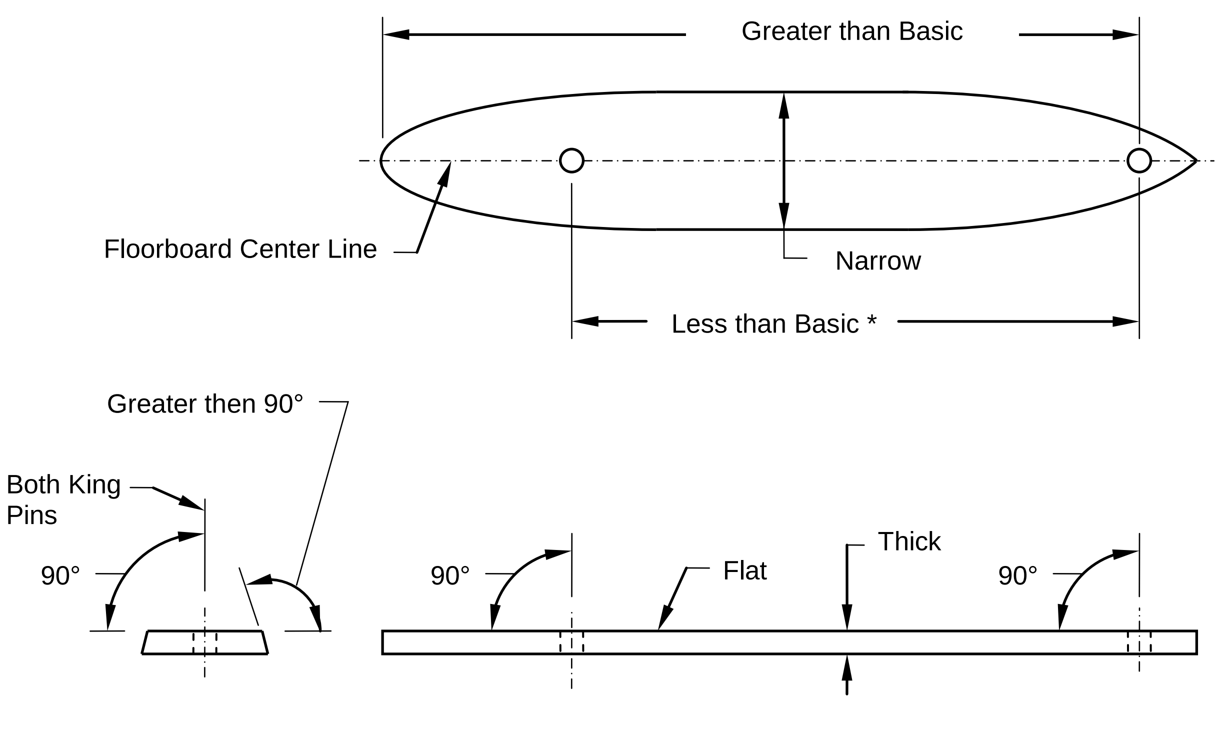
a) Bushing fit not tight allowing bushing and kingpin to move increasing energy loss.

2.1 **Floorboard** continued

2.1.12 **Ideal Floorboard #1:** No Bow or Cup Defects

1) Flat
2) Narrow
3) Thick
4) Rear axle bushing hole mislocated toward tail
5) Wheel base less than basic
6) Kingpin bushing holes located on floorboard center line
7) Kingpin bushing holes drilled 90 degrees to floorboard inside surface
8) Kingpin bushing holes small diameter

Note: Bushings should be a tight fit in floorboard and kingpin bolts should be a tight fit in bushings.



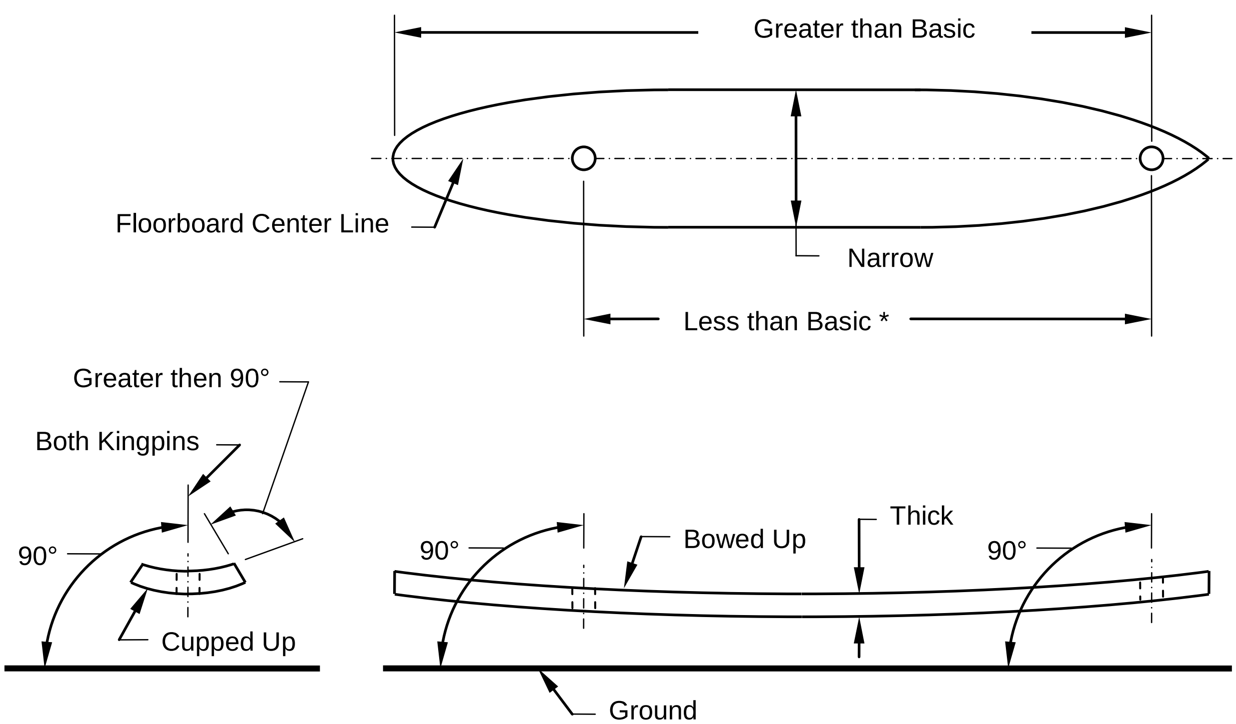
** Basic wheel base: Stock – 61-1/8"; Super Stock – 63-3/8"; and Masters – 65"*

2.1 **Floorboard** continued

2.1.13 Ideal Floorboard #2: Bow and Cup Defects Used to Advantage

1) Bowed up
2) Cupped up
3) Narrow
4) Thick
5) Rear axle bushing hole mislocated toward tail
6) Wheel base less than basic
7) Kingpin bushing holes located on floorboard center line
8) Kingpin bushing holes drilled 90 degrees to ground
9) Kingpin bushing holes small diameter

Note: Bushings should be a tight fit in floorboard and kingpin bolts should be a tight fit in bushings.



** Basic wheel base: Stock – 61-1/8"; Super Stock – 63-3/8"; and Masters – 65"*

Floorboard Condition Data Sheet

Sketch 2-1 and Sketch 2-2 may be used to determine and record the condition of a floorboard. The sketches apply to Stock, Super Stock, and Masters Division. All measurements should be taken before kingpin bushings have been installed, but may be taken after bushings have been installed.

Kingpin Bushings Installed: No _____ Yes _____

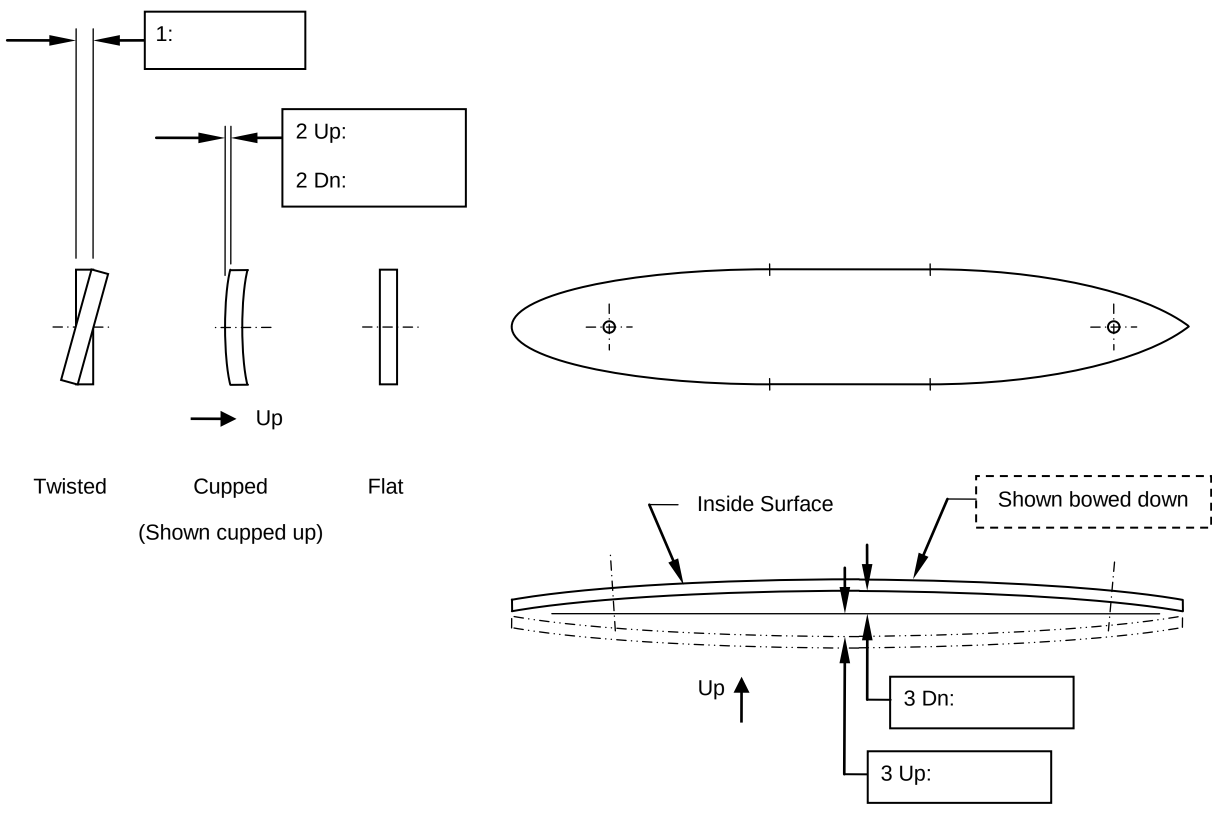
Division: Stock _____ Super Stock _____ Masters _____

Driver: ____________________

Sequence of measurements:

1. Check for Twist, Cup and Bow.
2. Take measurements 1 through 3. Record results on Sketch 2-1.

continued on next page



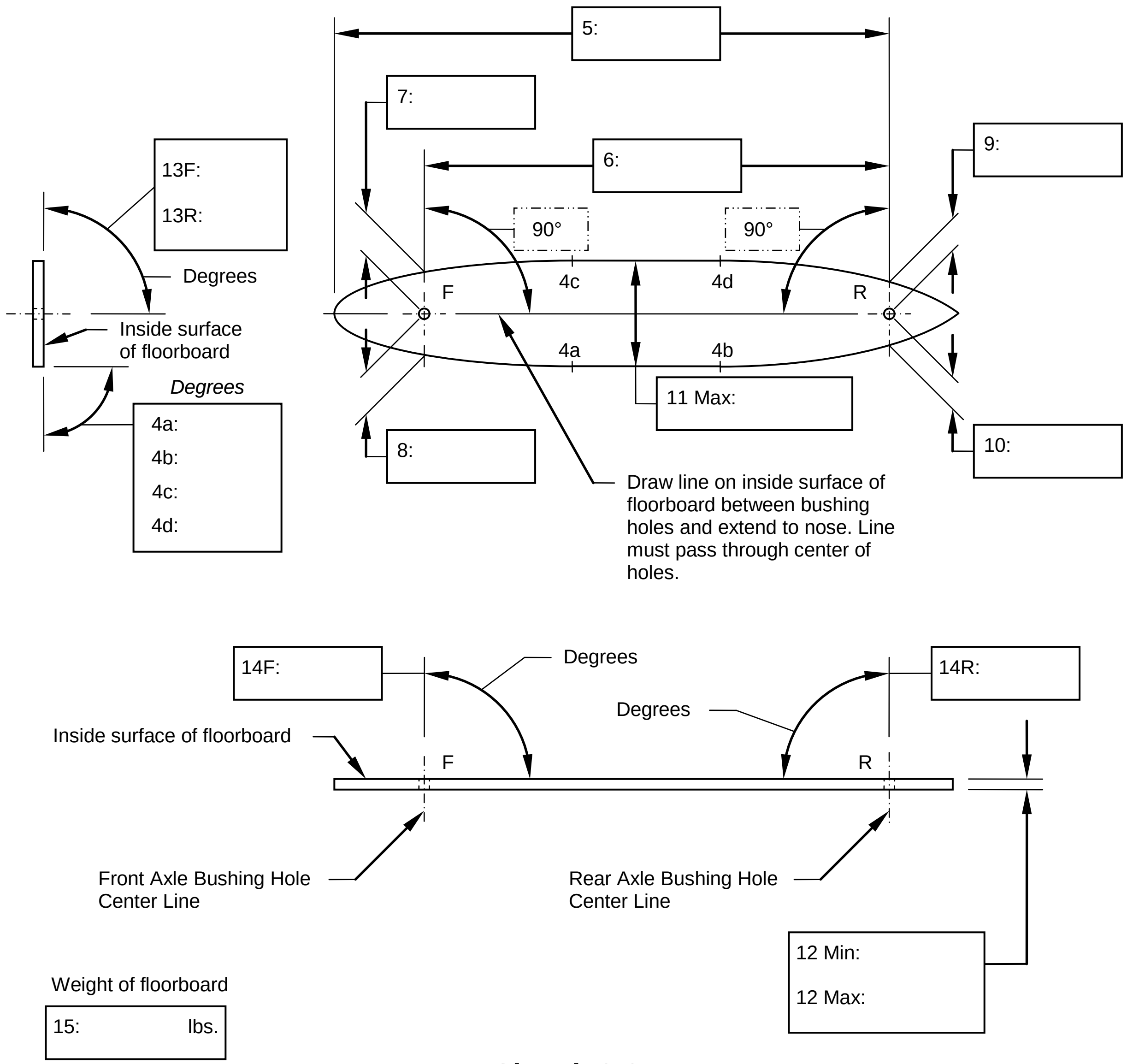
Sketch 2-1

Twist, Cup & Bow Check

Floorboard Condition Data Sheet

Sequence of measurements *continued*

3. Draw a line on inside surface of floorboard between the front axle bushing hole and rear axle bushing hole. Line must pass through exact center of holes.
4. Extend line to nose of floorboard.
5. Draw a line at 90 degrees to “center” line originating at exact center of each bushing hole.
6. Take measurements 4 through 15. Record results on Sketch 2-2.



Sketch 2-2

Basic Dimensions

2.2 Axles

The following pages show the basic physical features of a Soap Box Derby axle (front and rear) and conditions that may exist. The intent of these pages is to provide guidance when evaluating an axle. Illustrations are provided to help identify conditions and their impact.

Because axle material, size dimensions and rules change over the years, dimensional values for the axle features are not provided.

With all manufactured items (even computer numerical control (CNC) parts), the production process produces similar parts with different dimensions. Most of the parts manufactured will be within the allowed tolerance while some will not. Generally, parts outside of the allowed tolerance present the greater possibility for a speed advantage.

See Section 2.2.1 through Figure 2.2.3 on the following pages for axle conditions that may be encountered and the impact those conditions may cause.

See page 47 for the conditions that create an “ideal” axle.

It is not suggested or recommended that axles be altered or modified to achieve the optimum conditions shown in this document.

Diagram 2-2 below shows how terms are applied to an axle.

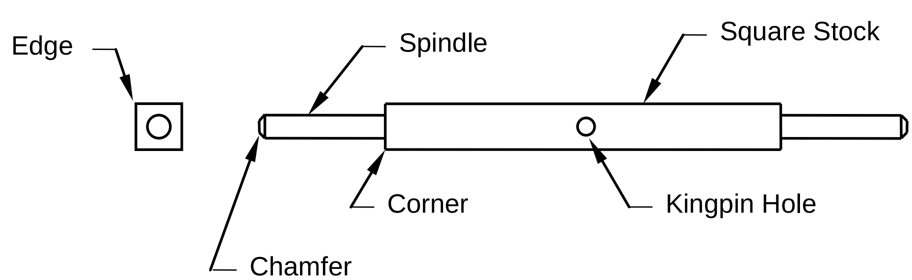


Diagram 2-2: Axle Nomenclature

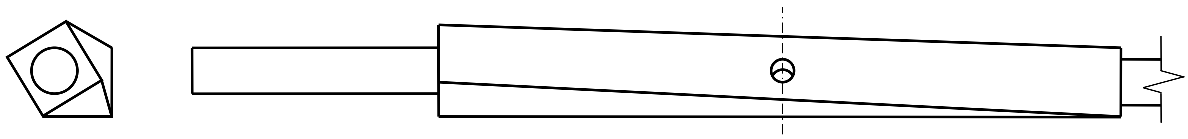
Contents

Section **Page**

2.2 **Axles** continued

2.2.1 Square Stock:

2.2.1.1 Twisted



Impact(s)

a) Tilts airfoils increasing aerodynamic drag.

b) May create cross-bind increasing wheel friction.

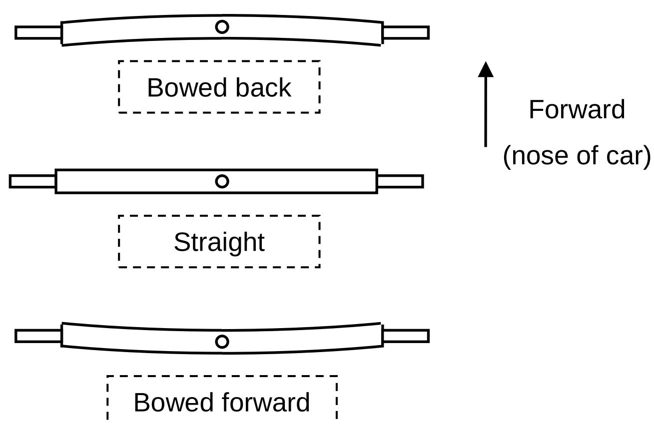
Cross-bind is unequal weight on wheels from side to side (e.g., more weight on left front than right front wheel).

2.2.1.2 Bowed - Forward and Back

Preferred

Acceptable

Advantage on Drop-Off ramp, otherwise unacceptable



Impact(s)

a) Bowed back moves wheel base toward tail increasing Potential Energy.

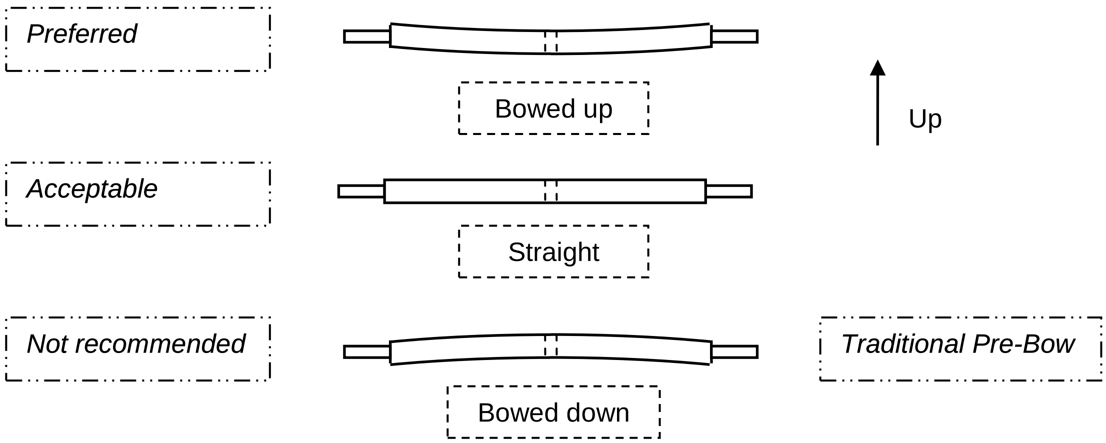
b) Bowed forward moves wheel base toward nose decreasing Potential Energy.

c) Front axle bowed forward moves wheel base toward nose increasing acceleration on Drop-Off ramp.

2.2 **Axles** continued

2.2.1 **Square Stock** continued

2.2.1.3 Bowed - Up and Down *(known as Pre-Bow)*

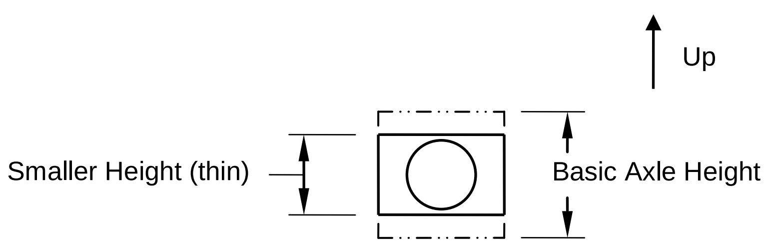


Impact(s)

a) Bowed up lowers Center of Mass increasing Potential Energy.

b) Bowed down raises Center of Mass decreasing Potential Energy.

2.2.1.4 Thin



Impact(s)

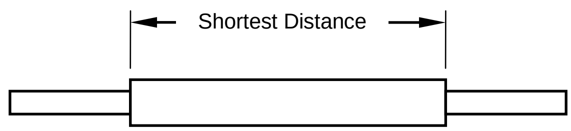
a) Reduces aerodynamic drag.

b) Increases axle flexibility.

2.2 **Axles** continued

2.2.1 **Square Stock** continued

2.2.1.5 Minimum Distance Between Ends

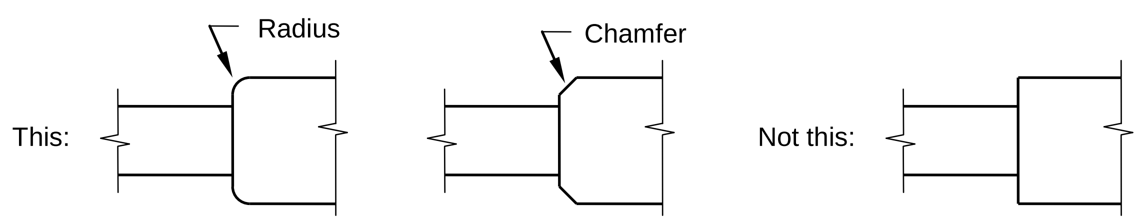


Impact(s)

a) Reduces aerodynamic drag.

b) Decreases axle flexibility.

2.2.1.6 Corners



Impact(s)

a) Radius reduces aerodynamic drag.

b) Chamfer may reduce aerodynamic drag.

2.2.1.7 Edges

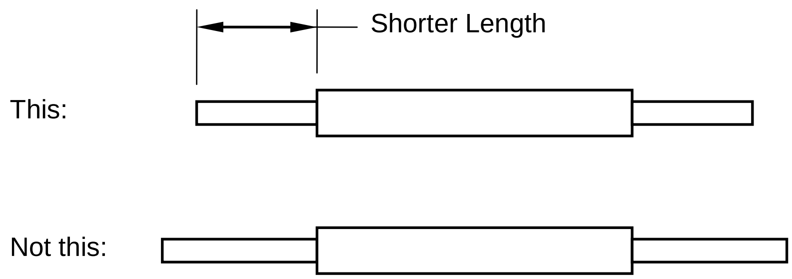
Impact(s)

a) Radius reduces aerodynamic drag.

2.2 **Axles** continued

2.2.2. Spindles:

2.2.2.1 Minimum Length



Impact(s)

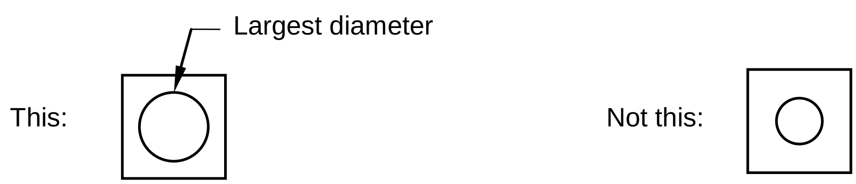
a) Reduces aerodynamic drag.

b) Decreases side to side wheel travel on spindle.

c) With wide wheels and washer, a shorter length may make it difficult to install wheel pin.

It is important that wheels have a little side to side movement.

2.2.2.2 Large Diameter



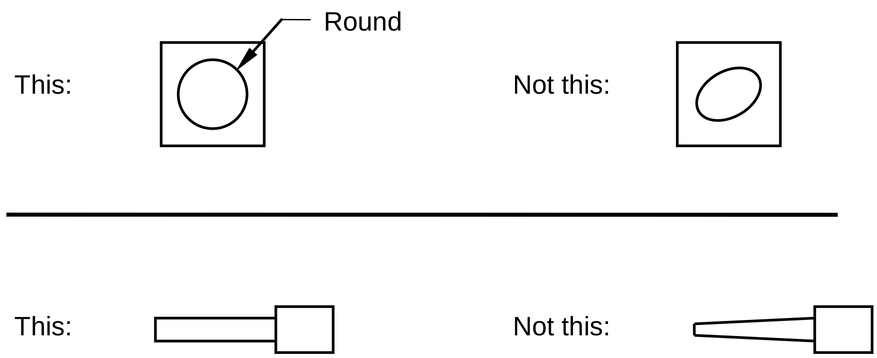
Impact(s)

a) Reduces wheel “wobble” decreasing friction.

2.2 **Axles** continued

2.2.2. **Spindles** continued

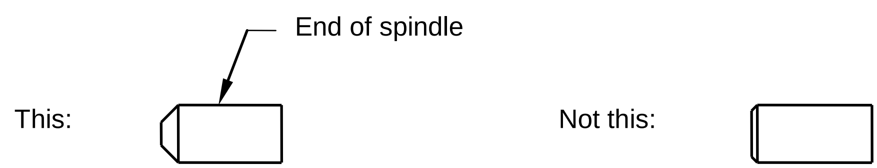
2.2.2.3 Constant Diameter



Impact(s)

a) Reduces wheel “wobble” decreasing friction.

2.2.2.4 Large Chamfer



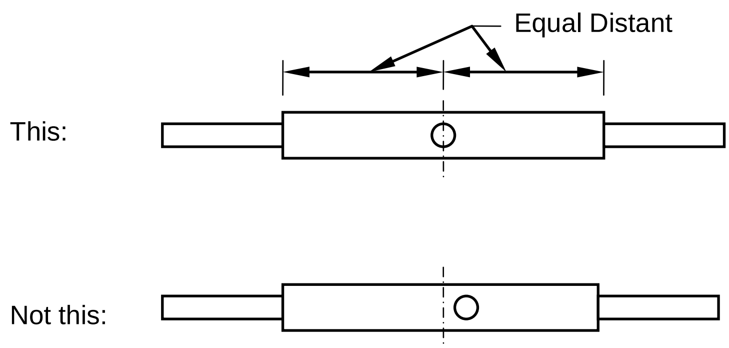
Impact(s)

a) Reduces aerodynamic drag.

2.2 **Axles** continued

2.2.3. Kingpin Hole:

2.2.3.1 Mislocated Side to Side



Front Axle   Rear Axle

Impact(s)

<u>Front Axle</u>:

a) Offsets front axle.

b) May be difficult to drive straight.

<u>Rear Axle</u>:

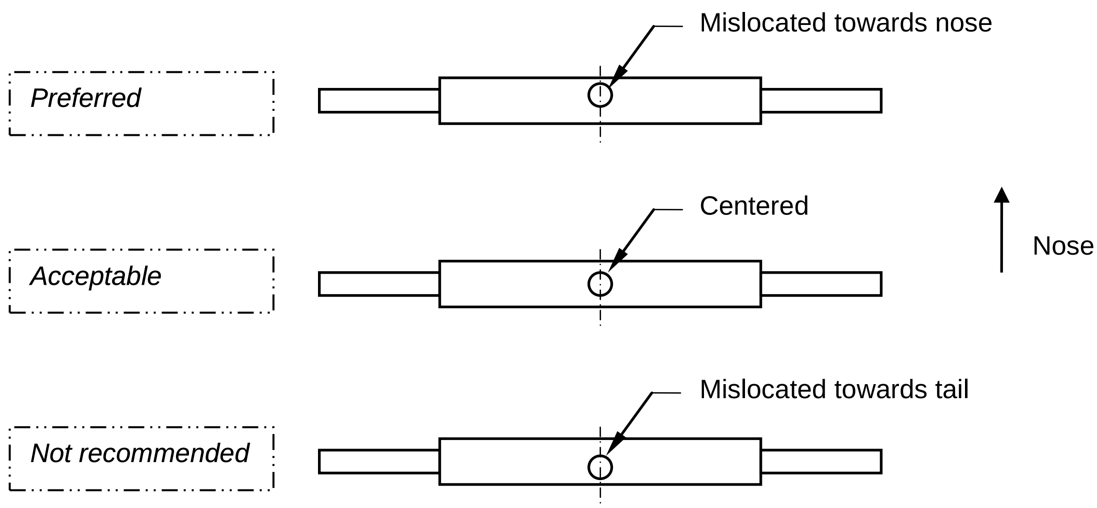
a) Misaligns car body to air flow increasing aerodynamic drag.

b) Difficult to drive straight.

2.2 **Axles** continued

2.2.3 **Kingpin Hole** continued

2.2.3.2 Mislocated Toward Nose or Tail



Impact(s)

Front Axle:

a) Mislocated toward nose improves steering control.

b) Mislocated toward nose moves Center of Mass up hill increasing Potential Energy.

c) Mislocated toward tail reduces steering control.

d) Mislocated toward tail moves Center of Mass down hill decreasing Potential Energy.

e) Mislocated toward tail increases acceleration on Drop-Off ramp.

Rear Axle:

a) Mislocated toward nose moves Center of Mass up hill increasing Potential Energy.

b) Mislocated toward tail moves Center of Mass down hill decreasing Potential Energy.

c) Mislocated toward tail increases acceleration on Drop-Off ramp.

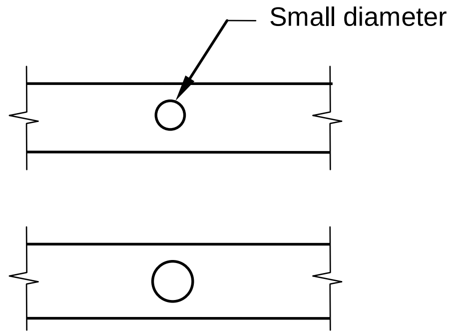
2.2 **Axles** continued

2.2.3 **Kingpin Hole** continued

2.2.3.3 Small Diameter

This:

Not this:

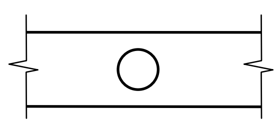


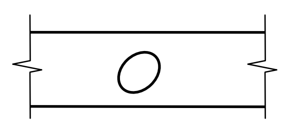
Impact(s)

a) Kingpin fits tight in a small hole minimizing energy loss.

b) Kingpin fits loose in a large hole causing a loss of energy.

2.2.3.4 Round

This: 

Not this: 

Impact(s)

a) Kingpin may move in not-round hole causing a loss of energy.

2.2 **Axles** continued

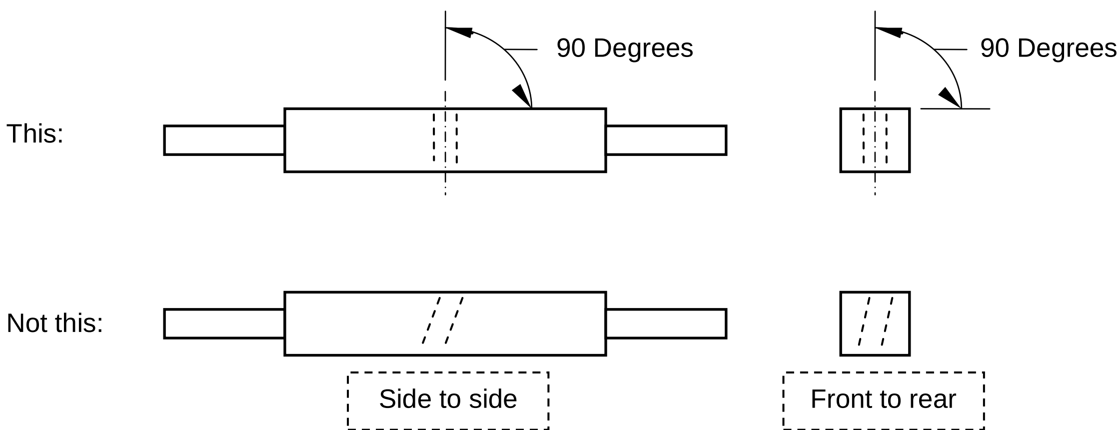
2.2.3 **Kingpin Hole** continued

2.2.3.5 Constant Diameter

Impact(s)

a) Kingpin fits loose in a not-constant diameter hole allowing the axle to “wobble” causing loss of energy.

2.2.3.6 90 Degrees



Impact(s)

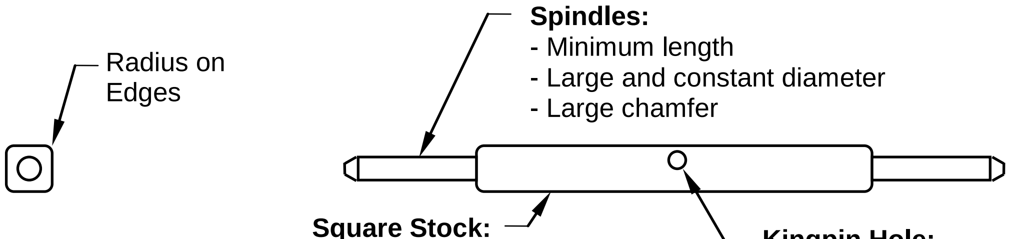
a) Not 90-degrees side to side:
- Hole creates cross-bind increasing wheel friction.
- Prevents proper alignment of rear axle increasing aerodynamic drag.

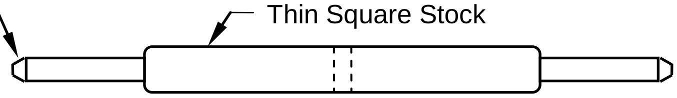
b) Not 90-degrees hole front to rear:
- Tilts airfoils increasing aerodynamic drag.

2.2 **Axles** continued

2.2.4 Ideal Axle – Front and Rear

1) No twist
2) Bowed back
3) Bowed up
4) Thin
5) Shortest length of square stock
6) Radius on corners
7) Radius on edges
8) Shortest length spindles
9) Large diameter spindles
10) Constant diameter spindles
11) Large chamfer on end of spindles
12) Kingpin hole centered between ends of square stock
13) Kingpin hole offset toward nose
14) Small diameter kingpin hole
15) Round kingpin hole
16) Constant diameter kingpin hole through square stock
17) Kingpin hole drilled 90-degrees to square stock surface





2.3 Kingpins

Kingpins provided in the car kits may be Grade BD or Grade 8 Hex Cap Screws and are identified as “kingpin bolt” in the Car Assembly Plans. These are tension “bolts” intended for industrial applications. The kingpin bolts are 1/4 inch diameter and have 28 threads per inch (1/4-28). The yellow coloration is yellow Zinc (Grade BD) or Cadmium plating (Grade 8) applied to prevent corrosion (rust).

Grade BD kingpin bolts, in accordance with ASTM A354, are fabricated from alloy steel that has been quenched and tempered. Grade 8 kingpin bolts, in accordance with SAE J429, are fabricated from medium carbon steel that has been quenched and tempered. Both Grades have the same strength ratings.

Generally, SAE bolts are a more precision fastener and held to tighter tolerances than the ASTM bolts. For the application of SBD racing, SAE bolts are the better bolt.

Tightening the kingpin nut applies a clamping force to the kingpin/axle/floorboard assembly. The amount of clamping force created depends upon the amount of torque applied. Increased torque means increased clamping force.

Continued on page 49

Diagram 2-3 below shows how terms are applied to a kingpin bolt.

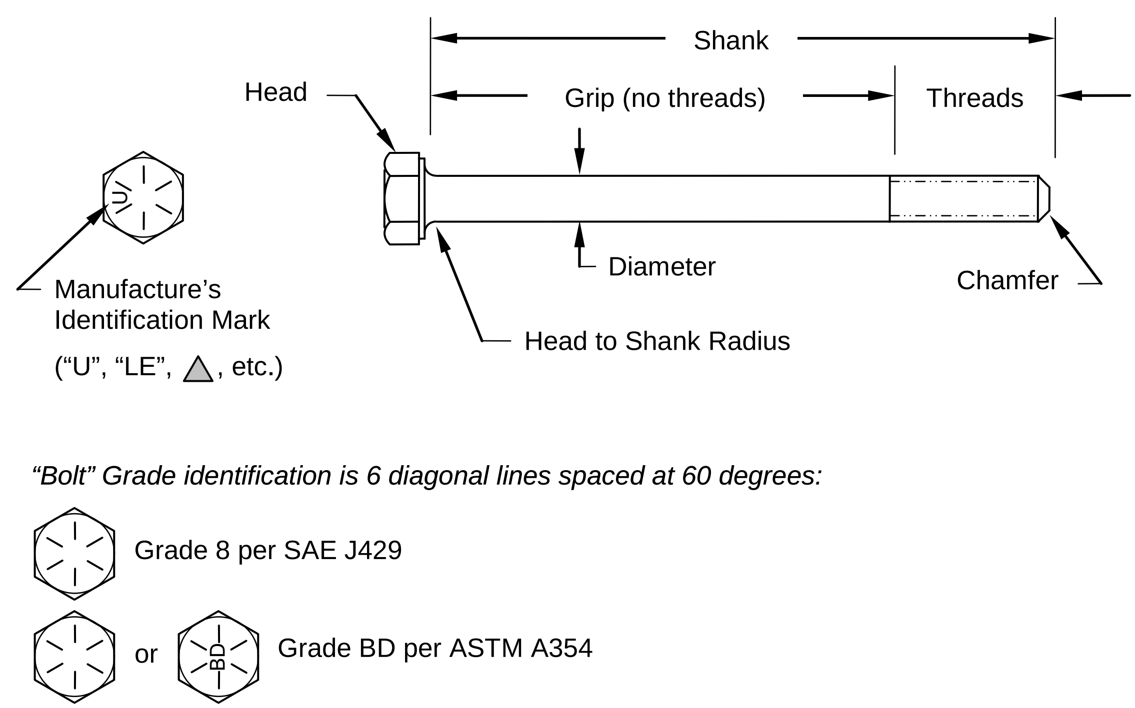


Diagram 2-3: Kingpin Nomenclature

Continued from page 48

A properly tightened kingpin bolt is stretched and acts like a ridged spring pulling the axle and floorboard together. As the car rolls down the hill, uneven track surface pushes a wheel up which causes the kingpin bolt to bend.

The Grade 8 and Grade BD kingpin bolts are rated for a maximum torque of 200 inch pounds (16-1/2 foot pounds) when the kingpin bolt is dry (threads not lubricated). Applying 200 inch pounds of torque too quickly may damage (weaken) and possibly break a kingpin bolt. Exceeding 200 inch pounds of torque will break the kingpin bolt unless it has been strain-hardened. A properly strain-hardened kingpin bolt may have up to 300 inch pounds (25 foot pounds) of torque applied.

Note: Nuts like bolts have Grades. To achieve the maximum torque values quoted above, the proper Grade nut should be used.

Any material applied to the kingpin bolt threads, such as wax, oil, grease, nut lockers such as Loctite, etc. will act as a lubricant and impact the torque value.

Caution: Torque values are reduced significantly if the bolt threads have been lubricated. For example: 200 in. lbs. of torque on dry a nut/bolt would be equivalent to approximately 84 in. lbs. on a nut/bolt with lubricated threads to achieve the same clamp up force.

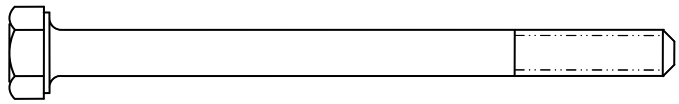
Every kingpin bolt joint is unique and the optimum tightening torque should be determined by experimentation.

Contents

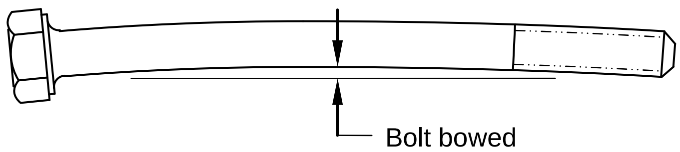
2.3 Kingpins continued

2.3.1 Bowed

This:



Not This:



Impact(s)

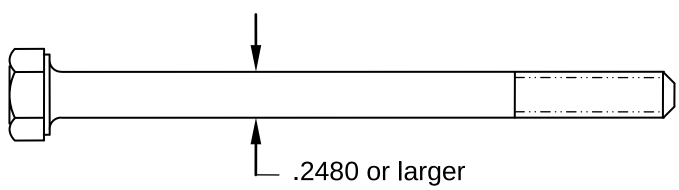
a) Difficult to assemble kingpin into axle and bushing.

b) May make steering more difficult.

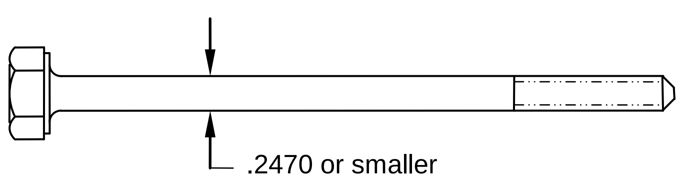
Maximum bow allowed by Standard ASME B18.2.1:
3-1/4" long: .0195"
3-1/2" long: .021"

2.3.2 Larger Diameter

This:



Not This:



Impact(s)

a) Kingpin fits loose in axle and bushing.

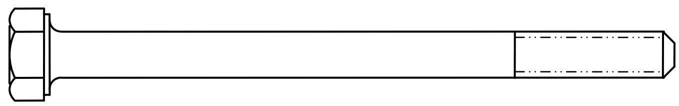
b) Reduces strength of bolt.

Minimum diameter allowed by Standard ASME B18.2.1:
3-1/4" long: .2450"
3-1/2" long: .2450"

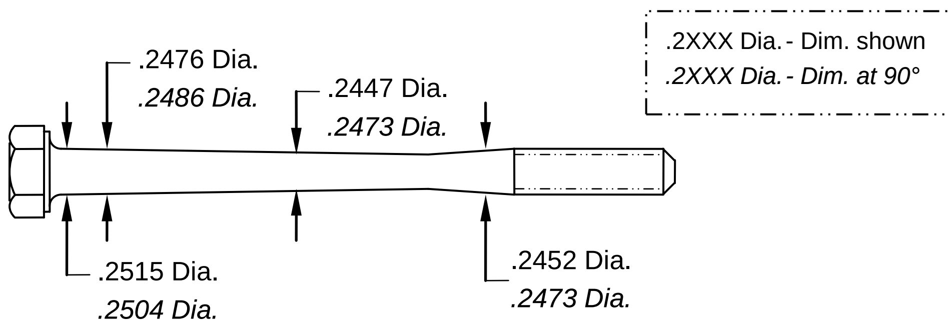
2.3 Kingpins continued

2.3.3 Constant Diameter

This:



Not This:



Impact(s)

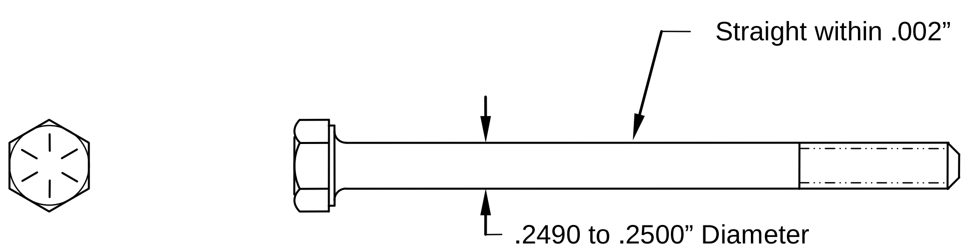
a) Kingpin fits loose in axle and bushing.

b) Reduces strength of bolt.

Diameter measurements from AA supplied kingpin bolt.

2.3.4 Ideal Kingpin

1. Straight within .002” or less.
2. Largest diameter.
3. Constant diameter.
4. Dimensional requirements in accordance with ASME B18.2.1.
5. Manufactured in accordance with SAE J429.



2.4 Washers, Kingpin Assembly

The washers used for the front and rear axle kingpin assemblies are stamped from steel and coated with zinc (silver or yellow in color) or cadmium (yellow in color) for corrosion (rust) protection.

The stamping process routinely creates an uneven “lip” on one side of the washer. This lip creates cross-bind when torque is applied to the kingpin (when kingpin nut is tightened).

There are three different sizes of washers used in the kingpin assemblies:

1) Plain: 1/4" ID by 5/8” OD by 1/16” Thick

2) Fender: 1/4" ID by 1-1/4” OD by 3/32” Thick

3) Large: 1/4" ID by 2” OD by 1/8” Thick

Diagram 2-4 below shows how terms are applied to a washer.

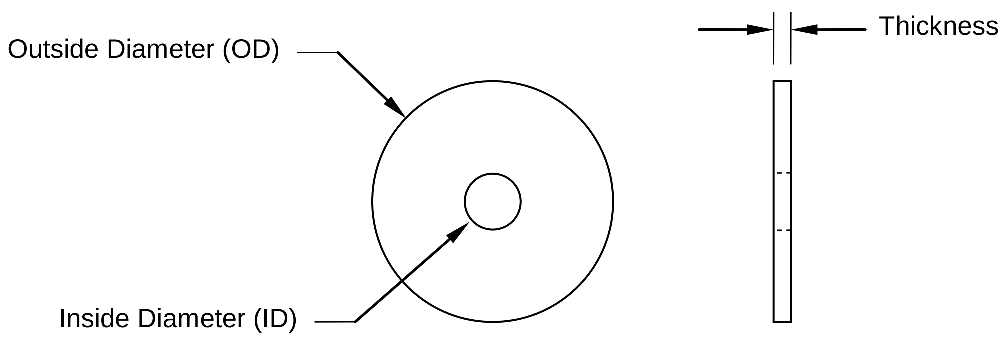
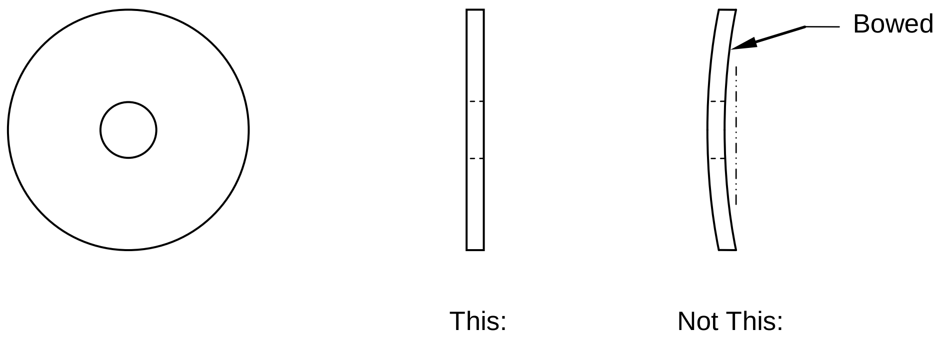


Diagram 2-4: Washer Nomenclature

Contents

2.4 Washers, Kingpin Assembly continued

2.4.1 Bowed

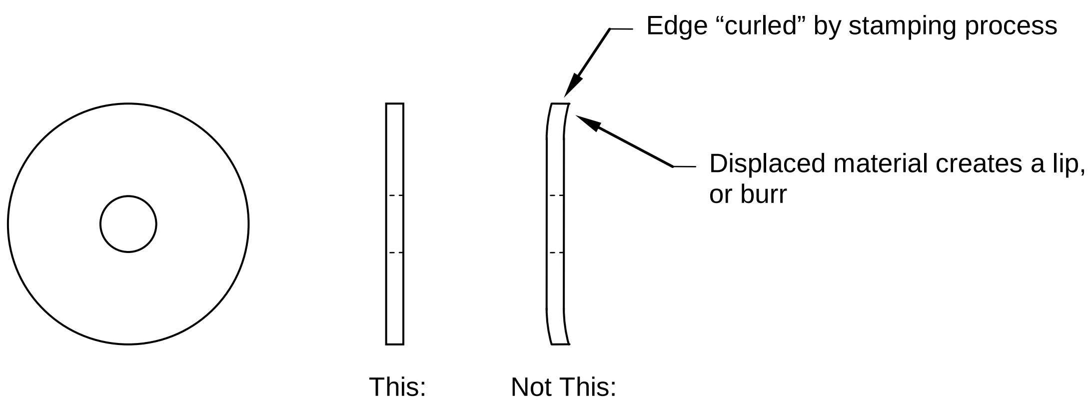


Impact(s)

a) Increased kingpin torque required to flatten washer.

b) May add to cross-bind condition.

2.4.2 Curled Edge



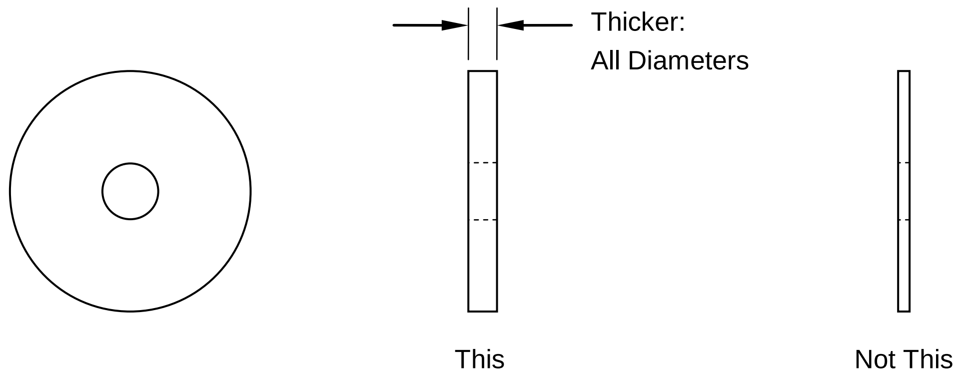
Impact(s)

a) Increased kingpin torque required to flatten washer.

b) Uneven lip creates cross-bind.

2.4 Washers, Kingpin Assembly continued

2.4.3 Thickness



Impact(s)

a) Lowers car’s Center of Mass.

b) Resist bowing when high torque is applied to kingpin.

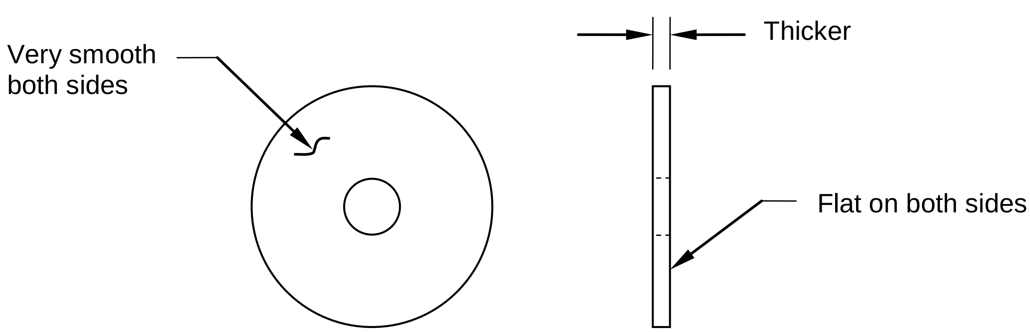
2.4.4 Ideal Washer

Front kingpin assembly washers:

1. Flat on both sides.
2. Thicker
3. Very smooth (polished) on both sides.
4. Lubricated to reduce friction when axle is turned.

Rear kingpin assembly washers:

1. Flat on both sides.
2. Thicker



2.5 Stabilizers, Stock Car

The stabilizers (also called radius rods) are flame cut from 1/8 of an inch thick sheet steel. This method of fabrication leaves the edges irregular (wavy) and the corners sharp. *[**Warning:** Sharp edges and corners may cut hands.]*

The stabilizers have not been finished and will be susceptible to corrosion (rust).

Older stabilizers were manufactured from bar stock which had rounded edges.

Diagram 2-5 below shows how terms are applied to a stabilizer.

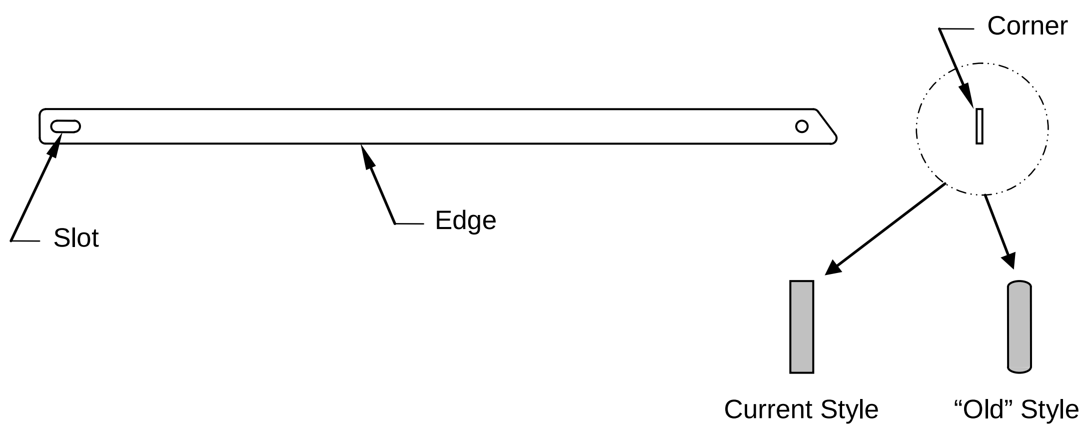
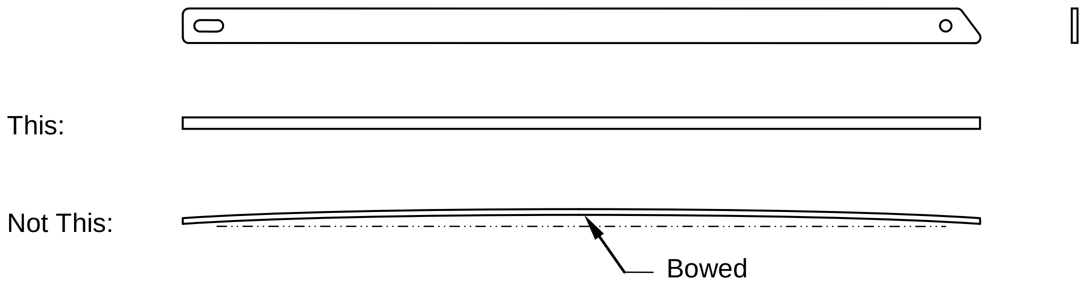


Diagram 2-5: Stabilizer Nomenclature

Contents

2.5 Stabilizers, Stock Car continued

2.5.1 Bowed

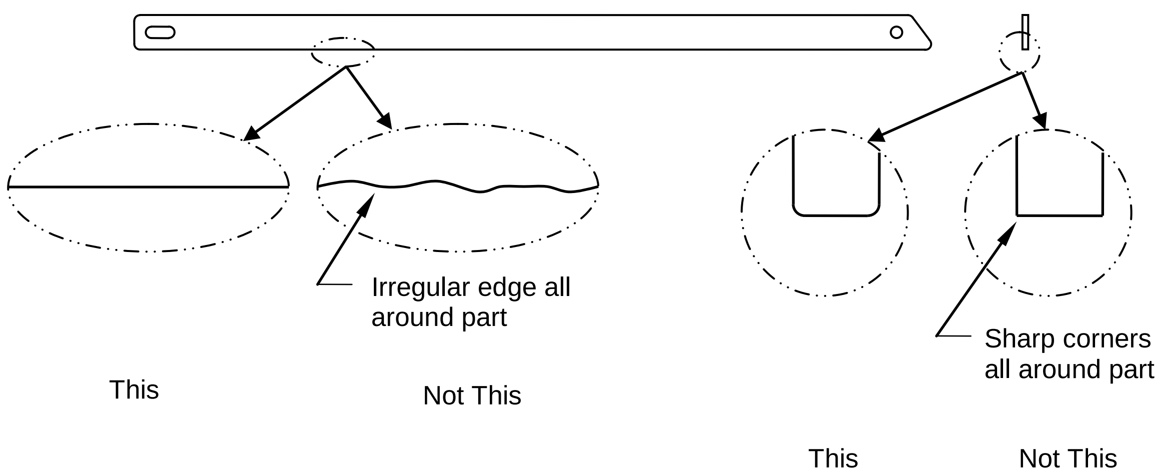


Impact(s)

a) Increased aerodynamic drag.

b) Reduced support to rear axle for maintaining alignment (bowed stabilizer is more likely to bend more under load).

2.5.2 Corners and Edges



Impact(s)

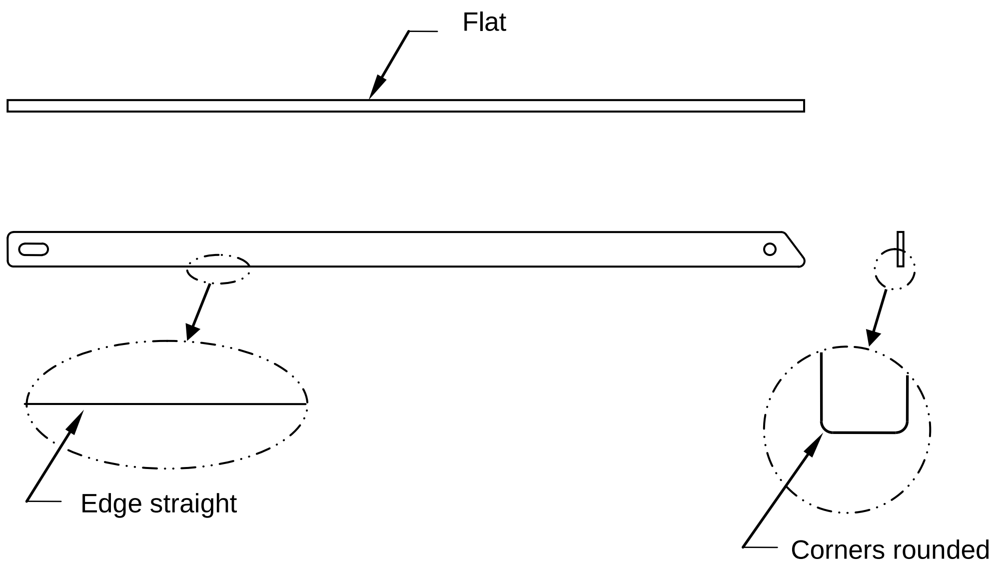
a) Corners and edges may cut hands.

b) Sharp corners and irregular edges increase aerodynamic drag.

2.5 Stabilizers, Stock Car continued

2.5.3 Ideal Stabilizer, Stock Car

1. Flat
2. Edge straight.
3. Corners rounded.
4. Flat surfaces outside of car body smooth and polished.



***Caution:** Always check the rules and verify it is allowed before sanding or filing a part.*

5.0 Miscellaneous Information

The following miscellaneous information is provided to help the contestant better understand car setup and racing.

The information contained in this section is a collection of “raw” data and other information for contestants to evaluate and apply as they deem appropriate.

Contents

5.1 Time into Inches Conversion Data

Basic Data: 1 hour = 60 minutes = 3,600 seconds
1 mile = 5,280 feet = 63,360 inches

1 MPH = 1 mile in 1 hour
1 MPH = 5,280 ft in 60 minutes
1 MPH = 63,360 inches in 3,600 seconds
1 MPH = 17.6 inches in 1.0 seconds

Car Lengths: 75 inches (6 ft 3 in) - Stock
75 inches (6 ft 3 in) - Super Stock
84 inches (7 ft) - Masters

Inches per second Chart:

MPH	Inches per			
	1.00 Second	.10 Sec.	.01 Sec.	.001 Sec.
10	176.0 (14 ft 8 in)	17.60	1.76	.18
15	264.0 (22 ft 0 in)	26.40	2.64	.26
20	352.0 (29 ft 4 in)	35.20	3.52	.35
25	440.0 (36 ft 8 in)	44.00	4.40	.44
26	457.6 (38 ft 2 in)	45.76	4.57	.46
27	475.2 (39 ft 7 in)	47.52	4.75	.48
28	492.8 (41 ft 1 in)	49.28	4.92	.49
29	510.4 (42 ft 6 in)	51.04	5.10	.51
30	528.0 (44 ft 0 in)	52.80	5.28	.53
31	545.6 (45 ft 6 in)	54.46	5.44	.54
32	563.2 (46 ft 11 in)	56.32	5.63	.56
33	580.8 (48 ft 5 in)	58.08	5.80	.58
34	598.4 (49 ft 10 in)	59.84	5.98	.60
35	616.0 (51 ft 4 in)	61.60	6.16	.62

Equivalents

1/64”	.016”	.40 MM
1/32	.031	.79 MM
1/16	.063	1.59 MM
3/32	.094	2.38 MM
1/8	.125	3.18 MM
5/32	.156	3.97 MM
3/16	.188	4.76 MM
7/32	.219	5.56 MM
1/4	.250	6.35 MM
9/32	.281	7.14 MM
5/16	.313	7.94 MM
11/32	.344	8.73 MM
3/8	.375	9.53 MM
13/32	.406	10.32 MM
7/16	.438	11.11 MM
15/32	.469	11.91 MM
1/2”	.500	12.70 MM
17/32	.531	13.49 MM
9/16	.563	14.29 MM
19/32	.594	15.08 MM
5/8	.625	15.88 MM
21/32	.656	16.67 MM
11/16	.688	17.46 MM
23/32	.719	18.26 MM
3/4	.750	19.05 MM
25/32	.781	19.84 MM
13/16	.813	20.64 MM
27/32	.844	21.43 MM
7/8	.875	22.23 MM
29/32	.906	23.02 MM
15/16	.938	23.81 MM
31/32	.969	24.61 MM
1”	1.00”	25.40 MM

Single Phase example. Winning time of .064 seconds at finish line speed of 28 MPH:

Phase time multiplied by inches per second for 28 MPH equals win in inches.

.064 x 492.8 inches = 31.54 inches

Heat (two phase) example. Overall time (both phases) of 1.44 seconds at 28 MPH:

Phase time multiplied by inches per second for MPH at finish line equals win in inches.

1.44 divided by 2 = .72 x 492.8 inches = 354.8 inches (29 feet 6 inches)

Approximation for most tracks:

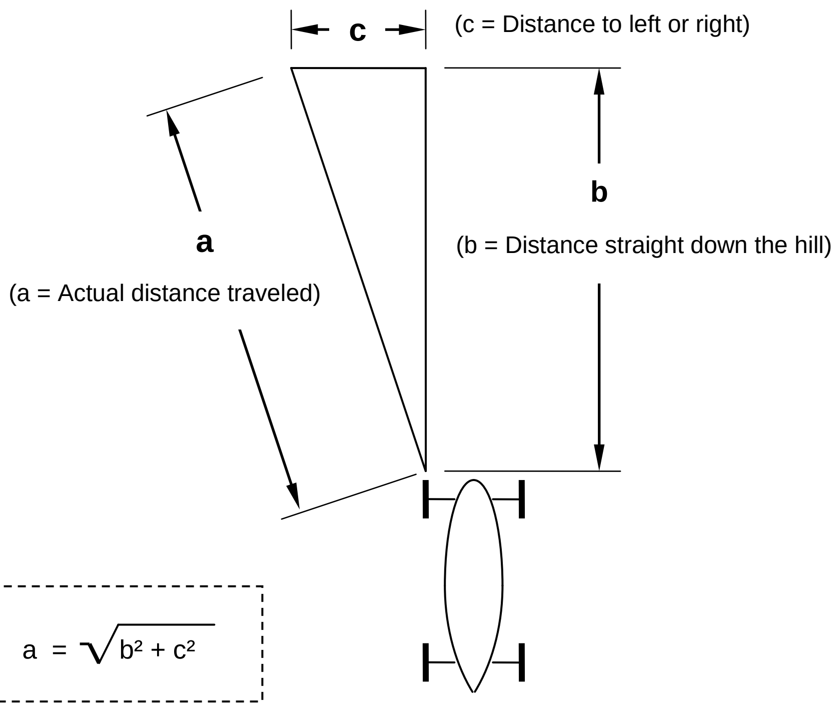
.001 seconds =1/2 inch

.010 seconds = 5 inches

.100 seconds = 49 inches (4 feet 1 inch)

1.00 seconds = 41 feet

5.2 Increased Track Length Due to Steering



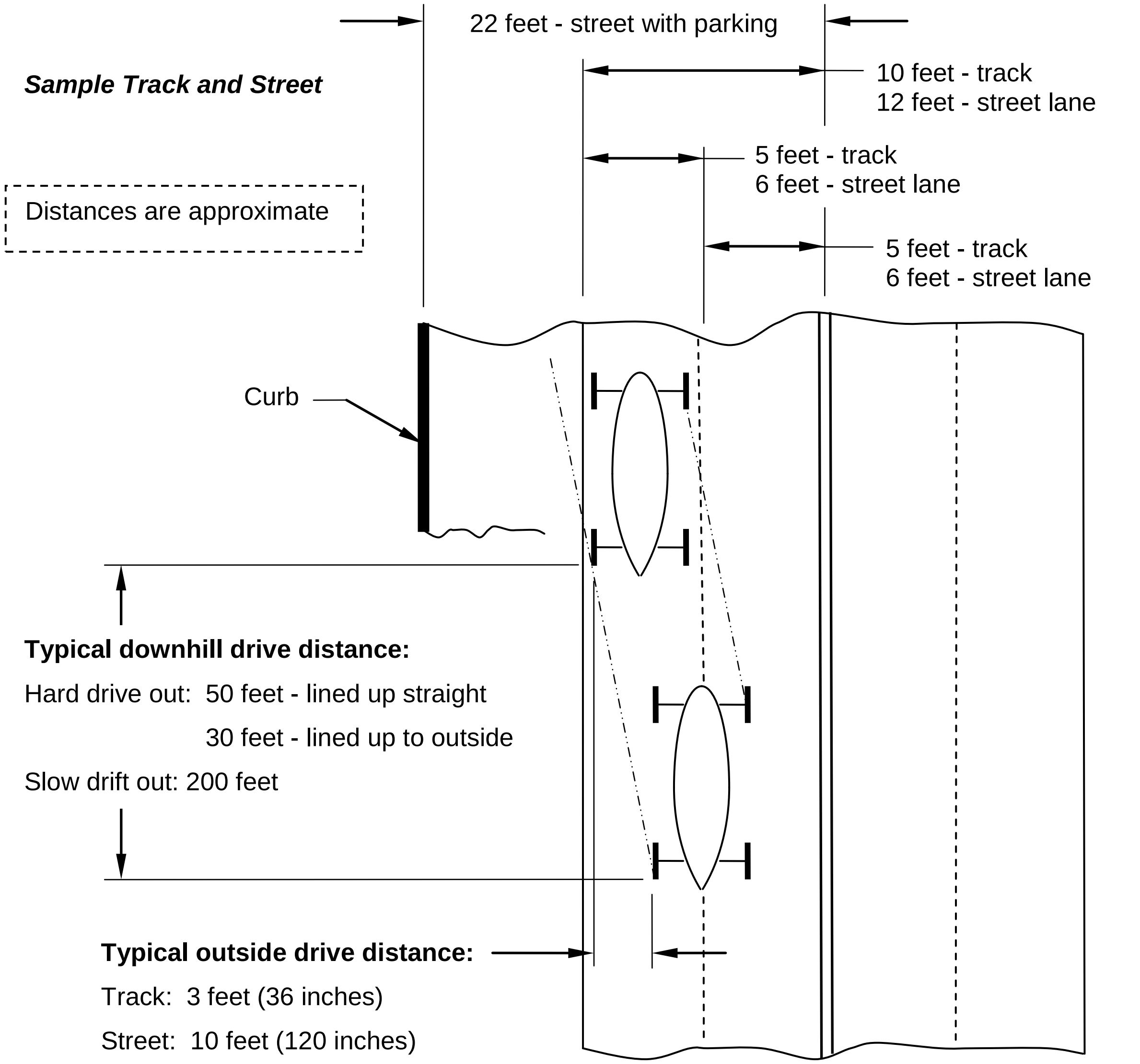
$$a = \sqrt{b^2 + c^2}$$

Sequence of fractions

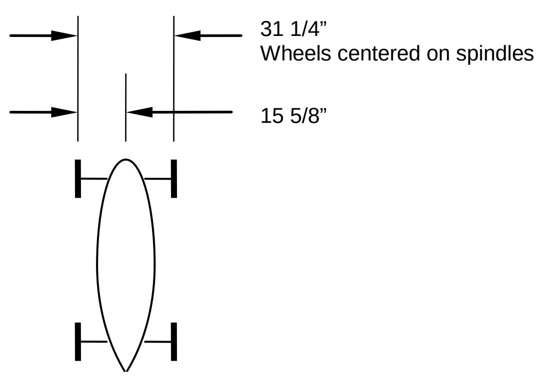
1/64"	1/2"
1/32	17/32
1/16	9/16
3/32	19/32
1/8	5/8
5/32	21/32
3/16	11/16
7/32	23/32
1/4	3/4
9/32	25/32
5/16	13/16
11/32	27/32
3/8	7/8
13/32	29/32
7/16	15/16
15/32	31/32
1/2"	1"

	a Increased distance traveled (fractions rounded up)						
b / **c**	20' (feet) 240" (inches)	30' 360"	40' 480"	50' 600"	100' 1,200"	150' 1,800"	200' 2,400"
6" (inches)	3/32"	1/16"	1/32"	1/32"	1/64"	---	---
9" (inches)	3/16"	1/8"	3/32"	1/16"	1/32"	1/32"	1/64"
12" (1 foot)	5/16"	3/16"	5/32"	1/8"	1/16"	1/32"	1/32"
24" (2 feet)	1 3/16"	13/16"	19/32"	1/2"	1/4"	5/32"	1/8"
36" (3 feet)	2 11/16"	1 13/16"	1 11/32"	1 3/32"	17/32"	3/8"	9/32"
48" (4 feet)	4 3/4"	3 3/16"	2 13/32"	1 29/32"	31/32"	21/32"	1/2"
60" (5 feet)	7 3/8"	4 31/32"	3 3/4"	3"	1 1/2"	1"	3/4"
120" (10 ft)	28 11/32"	19 15/32"	14 25/32"	11 7/8"	6"	4"	3"
180" (15 ft)	60"	42 1/2"	32 21/32"	26 7/16"	13 7/16"	9"	6 3/4"

5.2 Increased Track Length Due to Steering continued



Wheel to wheel dimension

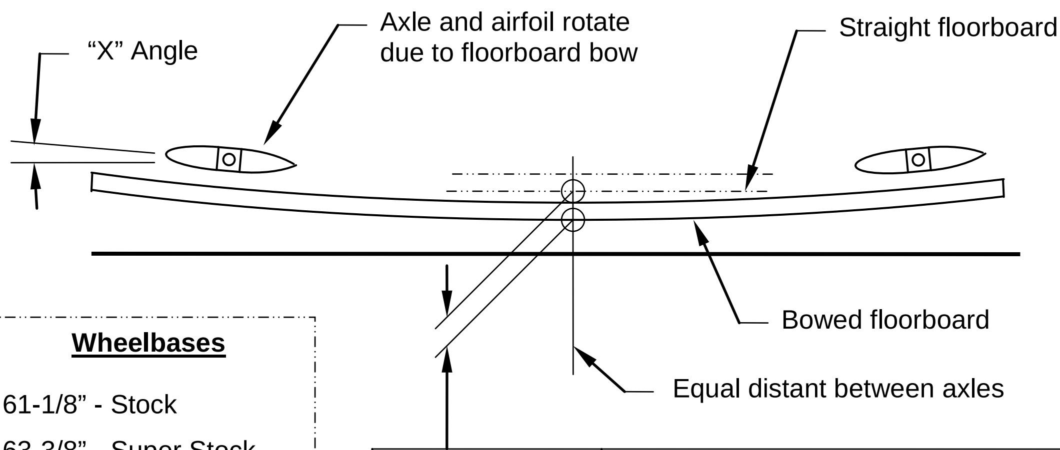


5.3 Airfoil Angle with Bowed Floorboard

A straight (flat) floorboard bows when ballast (weight) is added and the driver gets into the car. A floorboard that is bowed before weight is added or the driver gets into the car is called a pre-bowed floorboard. Pre-bowed floorboards can be created during the manufacturing process, by accident during storage of the car by contestant, or deliberately prior to car assembly.

When the floorboard bows, the axles and attached airfoils are rotated which increases aerodynamic drag.

The following information establishes the degree of rotation for various floorboard bow values.



Wheelbases

61-1/8" - Stock

63-3/8" - Super Stock

65" - Masters

Bow Dimension		"X" value - Airfoil Angle of Rotation		
Decimal	Fraction	Stock	Super Stock	Masters
.06	1/16"	0° 7'	0° 6'	0° 6'
.12	1/8"	0° 14'	0° 13'	0° 13'
.19	3/16"	0° 21'	0° 21'	0° 20'
.25	1/4"	0° 28'	0° 27'	0° 26'
.31	5/1"6	0° 35'	0° 34'	0° 33'
.38	3/8"	0° 43'	0° 41'	0° 40'
.44	7/16"	0° 50'	0° 48'	0° 46'
.50	1/2"	0° 56'	0° 54'	0° 53'
.56	9/16"	1° 3'	1° 1'	0° 59'
.62	5/8"	1° 10'	1° 7'	1° 5'
.68	11/16"	1° 17'	1° 14'	1° 12'
.75	3/4"	1° 24'	1° 21'	1° 19'
.81	13/16"	1° 31'	1° 28'	1° 26'

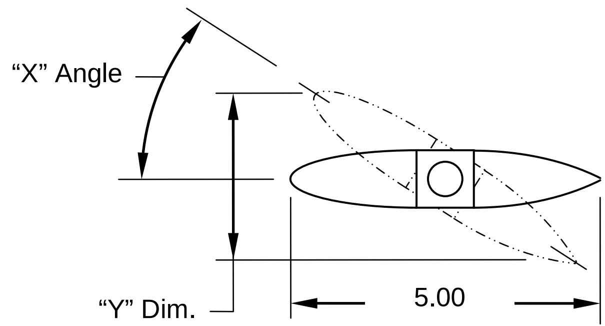
Notes:

1. "X" value angles are rounded off to nearest minute.
2. 30 minutes (30') equals 1/2 degree.

5.3 Airfoil Angle with Bowed Floorboard continued

Axle and airfoils rotate when floorboard is bowed presenting a larger cross section area to the air flow which increases aerodynamic drag.

The following information provides the cross section area height increase dimension for various angles of rotation.



Bow Dimension Approximate	**“X” Angle** Airfoil Angle of Rotation	**“Y” Dimension** Decimal	Fraction Nearest 1/64”
1/16”	0° 5’	.007	0
	0° 10’	.015	1/64”
1/8”	0° 15’	.022	1/64”
	0° 20’	.029	1/32”
	0° 25’	.038	1/32”
1/4"	0° 30’	.044	3/64”
	0° 35’	.051	3/64”
	0° 40’	.058	1/16”
3/8”	0° 45’	.065	1/16”
	0° 50’	.073	5/64”
1/2"	0° 55’	.080	5/64”
9/16"	0° 60’	.087	3/32”
5/8”	1° 5’	.095	3/32”
	1° 10’	.102	7/64”
11/16”	1° 15’	.109	7/64”
3/4"	1° 20’	.116	7/64”
	1° 25’	.124	1/8”
7/8”	1° 30’	.131	1/8”

Notes:
1. Angle of rotation is also known as “angle of attack”
2. 30 minutes (30’) equals 1/2 degree.
3. 60 minutes (60’) equals 1 degree.

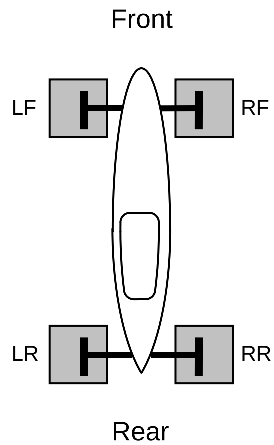
5.4 Pre-Race Car Check List

1. Visually inspect car body, airfoils and floorboard for damage or irregularities ☐
2. Remove shell ☐
3. Rear axle triangulation ☐
4. Rear axle stabilizers secure ☐
5. Kingpin torque
    a. Front axle ☐
    b. Rear axle ☐
6. Front axle parallel to rear axle ☐
7. Steering wheel parallel to front axle ☐
8. Steering wheel direction: left/right ☐
9. Steering cable tension using a cable tension gage (Tensionmeter) ☐
10. Cable clamps secure
    a. Steering ☐
    b. Brake ☐
11. All bolts/nuts secure ☐
12. Place shell on floorboard ☐
13. Install shell attach screws ☐
14. Car at racing weight *(with driver in car wearing racing gear)* ☐
15. Car at desired weight distribution *(with driver in driving position)* ☐
16. Weights secure ☐
17. Cross-bind ☐
18. Axle rocking movement (side to side) using Fischer gage, or equivalent
    a. Front axle ☐
    b. Rear axle ☐
19. Spindle alignment
    a. Front axle ☐
    b. Rear axle ☐
20. Airfoil position
    a. Front axle: left / right ☐
    b. Rear axle: left / right ☐
21. Spindles cleaned ☐
22. Spindle area lubricated
    a. Spindles ☐
    b. Ends of square stock ☐
    c. Wheel washers / wheel pins ☐
23. Body waxed ☐
24. Airfoils waxed ☐
25. Bottom of floorboard waxed ☐
26. Cockpit foam position, and secure ☐
27. Brake function ☐
28. Brake pad ☐

5.5 Weight Record Sheet

Division: □ Stock □ Super Stock □ Masters Date:_______________

Driver: __________________________ **Driver's Weight:** _______



Left Front

Without Driver	With Driver
1 ______	1 ______
2 ______	2 ______
3 ______	3 ______
4 ______	4 ______
5 ______	5 ______
6 ______	6 ______

Right Front

Without Driver	With Driver
1 ______	1 ______
2 ______	2 ______
3 ______	3 ______
4 ______	4 ______
5 ______	5 ______
6 ______	6 ______

Cross-Bind Front

Without Driver	With Driver
1 ______	1 ______
2 ______	2 ______
3 ______	3 ______
4 ______	4 ______
5 ______	5 ______
6 ______	6 ______

Left Rear

Without Driver	With Driver
1 ______	1 ______
2 ______	2 ______
3 ______	3 ______
4 ______	4 ______
5 ______	5 ______
6 ______	6 ______

Right Rear

Without Driver	With Driver
1 ______	1 ______
2 ______	2 ______
3 ______	3 ______
4 ______	4 ______
5 ______	5 ______
6 ______	6 ______

Cross-Bind Rear

Without Driver	With Driver
1 ______	1 ______
2 ______	2 ______
3 ______	3 ______
4 ______	4 ______
5 ______	5 ______
6 ______	6 ______

Rear Axle Weight

Without Driver	With Driver
1 ______	1 ______
2 ______	2 ______
3 ______	3 ______
4 ______	4 ______
5 ______	5 ______
6 ______	6 ______

Total Weight

Without Driver	With Driver
1 ______	1 ______
2 ______	2 ______
3 ______	3 ______
4 ______	4 ______
5 ______	5 ______
6 ______	6 ______

Notes:

5.6 Deleted

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5.7 Spindle Alignment Record Sheet

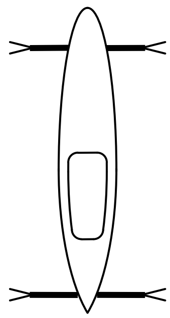
Division: □ Stock □ Super Stock □ Masters **Driver:** ____________ Date: ______

Total Weight: __________ Rear Axle Weight: _________

Left Front		Right Front	
To Front	To Rear	To Front	To Rear
1 ______	1 ______	1 ______	1 ______
2 ______	2 ______	2 ______	2 ______
3 ______	3 ______	3 ______	3 ______
4 ______	4 ______	4 ______	4 ______
5 ______	5 ______	5 ______	5 ______
6 ______	6 ______	6 ______	6 ______

Front

LF RF



LR RR

Rear

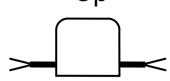
Left Rear		Right Rear	
To Front	To Rear	To Front	To Rear
1 ______	1 ______	1 ______	1 ______
2 ______	2 ______	2 ______	2 ______
3 ______	3 ______	3 ______	3 ______
4 ______	4 ______	4 ______	4 ______
5 ______	5 ______	5 ______	5 ______
6 ______	6 ______	6 ______	6 ______

Car on Saw Horses – No Driver

LF ______F / R	RF ______F / R
LR ______F / R	RR ______F / R

Front Axle

Up



Down

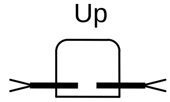
Left Front		Right Front	
Up	Down	Up	Down
1 ______	1 ______	1 ______	1 ______
2 ______	2 ______	2 ______	2 ______
3 ______	3 ______	3 ______	3 ______
4 ______	4 ______	4 ______	4 ______
5 ______	5 ______	5 ______	5 ______
6 ______	6 ______	6 ______	6 ______

Car on Saw Horses – No Driver

LF ______U / D	RF ______U / D

Rear Axle

Up



Down

Left Rear		Right Rear	
Up	Down	Up	Down
1 ______	1 ______	1 ______	1 ______
2 ______	2 ______	2 ______	2 ______
3 ______	3 ______	3 ______	3 ______
4 ______	4 ______	4 ______	4 ______
5 ______	5 ______	5 ______	5 ______
6 ______	6 ______	6 ______	6 ______

Car on Saw Horses – No Driver

LR ______U / D	RR ______U / D

6.0 Glossary of Terms

1. **Acceleration** *(linear acceleration)*
    a. The rate of change of an object's velocity.
    b. The change in velocity divided by the time it takes to make the change
2. **Aerodynamics** Effect produced by air on an object.
3. **Alloy Steel** Alloy steel owes its distinctive properties chiefly to some element or elements other than carbon, or jointly to such other elements and carbon.
4. **ASME** American Society of Mechanical Engineers
5. **ASTM** American Society for Testing and Materials
6. **Balance** Weight of car and driver measured at axles.
7. **Bearing**
    a. A device to allow constrained relative motion between two or more parts, typically rotation or linear movement.
    b. Soap Box Derby wheels use roller element bearings, commonly called "ball bearings."
8. **Carbon Steel** Carbon steel owes its distinctive properties chiefly to the carbon it contains.
9. **Center of Mass** Point at which the weight of an object is centered in all three axis. Also called center of gravity.
10. **Cross-bind** Unequal weight on wheels from side to side (e.g. more weight on left front wheel than right front wheel.
11. **Driver** Individual steering car down the hill.
12. **Friction** A force that resists the relative motion of two surfaces in contact.
13. **Inertia** The property of an object that causes it to resist any change in its motion. Thus, an object at rest remains at rest unless it is acted upon by an external force and an object in motion continues to move at a constant speed in a straight line unless acted upon by an external force.
14. **Inertial Mass** The measure of an object's resistance to acceleration.
15. **Kinetic Energy** Energy of an object due to its motion.
16. **Mass**
    a. Defined as the quantity of matter in an object, expressed as the product of volume times density.
    b. A measure of the amount of material contained in an object. It is the property of an object which causes the force of gravity to give an object weight.
17. **Moment of Inertia** An object's resistance to rotating about it's center of mass (CM)
18. **Potential Energy** Energy of an object due to its position.
19. **psi** Pounds per square inch.
20. **Rolling Resistance** Resistance to rolling down the hill caused by wheel bearing friction, tire hysteresis loss, aerodynamic drag, and track surface roughness.

21. **SAE** Society of Automotive Engineers
22. **Speed** The ratio of distance covered by an object to the time taken (i.e. miles per hour).
    a. Speed is a scalar quantity, i.e. no direction is given. Velocity is a quantity, i.e. both the rate of travel and the direction are specified.
23. **Trade-Off** Describes process of evaluating the relative value of changes that can be made to a car and then making a judgment on what will work best on a specific track.
24. **Velocity**
    a. The rate of displacement of an object. It is the speed of an object in a specified direction.
    b. Velocity is a vector quantity, whereas speed is a scalar quantity.
25. **Vibration** A cyclic back and forth motion of an object.
26. **Weight Distribution** The placement of ballast (weight) within car to obtain desired weight balance, or desired imbalance.
27. **Wheel**
    a. A device with a circular frame, or disk, arranged to revolve on an axis.
    b. A wheel consists of a disk (frame), tire and bearings.