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## A4 4 Lightning McQueen Vs NASCAR: A Physics Comparison

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### Abstract

Pixar's 'Cars' portrays Lightning McQueen as a prominent competitor in the fictional 'Piston Cup', an obvious parody of NASCAR racing. This analysis compares McQueen's car to a real NASCAR stock car, focusing on aerodynamics, banked cornering dynamics, and slipstreaming. McQueen's cartoon streamlined form likely reduces drag, enhancing his drafting and "slingshot" manoeuvre, but limited downforce would limit his cornering speeds.

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### Introduction

The Pixar movie, Cars (2006), anthropomorphises Lightning McQueen as a top-performance car racing in an inspired NASCAR Cup Series-inspired competition. We investigate whether McQueen's streamlined body design would provide him an advantage or disadvantage over an actual NASCAR stock car on the Daytona International Speedway.

NASCAR performance depends on three factors [1, 2]: aerodynamics, where drag and downforce determine straight-line speed and cornering performance; banked corners, where maximum speed on oval tracks depends on centripetal force and banking angle at bends; and drafting (slipstreaming), where a trailing car experiences reduced drag when following closely, allowing for more overtaking opportunities.

This approach models forces on both cars using standard drag and cornering dynamics equations [3, 4]. Note that while some depictions of Lightning McQueen feature a rear spoiler, this analysis models his streamlined form without one to represent a lower downforce body compared to a stock car.

### Theory

#### *Banked Corner Dynamics*

For a car on a banked curve of radius  $r$  and banking angle  $\theta$ , the maximum speed ( $v_{\max}$ ) without downforce ( $F_L$ ) is given by the approximation,

$$v_{\max} = \sqrt{\frac{rg(\tan \theta + \mu)}{1 - \mu \tan \theta}}, \quad (1)$$

where  $r \approx 1000$  m,  $\theta = 31^\circ$  [5], and  $\mu = 1.0$  (assumed tyre-road friction coefficient [1]).

#### *Aerodynamic Forces*

The aerodynamic forces in the car are the drag force ( $F_D$ ) and the downforce ( $F_L$ ), both of which are proportional to the square of the velocity ( $v$ ):

$$F_D = \frac{1}{2}\rho C_D A v^2, \quad (2)$$

$$F_L = \frac{1}{2}\rho C_L A v^2, \quad (3)$$

This equation establishes the speed limit based on track banking and friction alone, before considering aerodynamic effect. Where  $\rho = 1.229$  kg m<sup>-3</sup> (standard air density at sea level [6]),  $C_D$  is the drag coefficient,  $C_L$  is the lift coefficient (negative for downforce) and  $A$  is the frontal area.

The required centripetal force for circular motion is

$$F_c = \frac{mv^2}{r}, \quad (4)$$

and the maximum frictional force is proportional to the normal force:

$$F_{\text{Friction}} \leq \mu N. \quad (5)$$

The normal force includes the weight of the car and the aerodynamic downforce:  $N = mg + F_L$ .

### **Condition for Cornering Stability**

The condition to stay on track without slipping at a specific velocity  $v$  on a flat track (when combining forces on a banked track) is

$$\frac{mv^2}{r} = \mu \left( mg + \frac{1}{2} \rho C_L A v^2 \right). \quad (6)$$

Equation (6) represents a simplified model that accounts for downforce but does not accurately incorporate the effect of the banking angle on the normal and friction forces simultaneously, as the full mechanics require vector summation. This simplification is maintained to focus on the comparative effect of downforce.

## **Results and Discussion**

For this comparative analysis, the following aerodynamic coefficients and frontal areas were used: NASCAR:  $C_L = 0.30$ ,  $A = 2.20 \text{ m}^2$ ; McQueen (assumed race car with a sleeker trim):  $C_L = 0.25$ ,  $A = 2.00 \text{ m}^2$  [2].

Given that downforce is directly proportional to the lift coefficient and frontal area and is proportional to the square of the velocity, the NASCAR setup generates a significantly higher downforce. This theoretical difference, quantified by the product ( $C_L \cdot A$ ), forms the basis for the subsequent comparison of cornering speeds.

Neglecting downforce in Equation (6) shows that both cars would attain the same maximum speed on the banking. However, NASCARs generate significant downforce, effectively increasing the normal and frictional forces.

Using the simplified stability condition (Equation (6)) for  $v_{\text{max}}$ :

$$v_{\text{max}} = \sqrt{\frac{\mu mg}{\frac{m}{r} - \frac{1}{2} \mu \rho C_L A}}. \quad (7)$$

Using  $m \approx 1500 \text{ kg}$  [7],  $g = 9.81 \text{ m s}^{-2}$ , and the parameters mentioned, the calculated maximum speeds are the following:

$$\text{NASCAR: } v_{\text{max}} = 417.42 \text{ km h}^{-1},$$

$$\text{McQueen: } v_{\text{max}} = 399.85 \text{ km h}^{-1}.$$

This calculation explicitly shows that McQueen's lower downforce profile results in a lower calculated maximum cornering speed in this simplified model.

Aerodynamic drafting lowers the drag coefficient by approximately 30% [4], depending on the distance travelled. This reduction is treated in this model as a simple decrease in  $C_D$ . McQueen's sleeker design, characterised by a lower  $C_L$  profile, would theoretically provide him with an advantage during a *slingshot pass*.

This analysis makes a few simplifying assumptions. First, the aerodynamic coefficients ( $C_D$ ,  $A$ ) for both cars were approximated using typical ranges rather than measured values. Second, the model for drafting assumes a pure reduction in drag force and neglects turbulence and pressure field effects that accompany real-world drafting. Finally, the banked cornering model (Equation 1) simplifies the complex force summation on a banked track. All these factors would influence the actual performance of the car in competition.

## **Conclusion**

This analysis demonstrates that Lightning McQueen would experience a different balance of racing performance compared to real NASCAR vehicles. McQueen's lower downforce profile makes him relatively more efficient in slipstream techniques, enabling the slingshot manoeuvre. Crucially, the performance gap between the cars is governed by the relation  $F_L \propto v^2$ , meaning the cornering speed difference of  $17.57 \text{ km h}^{-1}$  increases quadratically with velocity, emphasising the aerodynamic design's growing dominance at greater speeds. The physics of drafting and slingshot passes in *Cars* are consistent with actual NASCAR strategies.

## References

- [1] Fu, Y. (2023). *Aerodynamics and Drag of a Car*. Highlights in Science Engineering and Technology, **46**, 63–70. doi:<https://doi.org/10.54097/hset.v46i.7665>.
- [2] Katz, J. (2006). *Aerodynamics of Race Cars*. Annual Review of Fluid Mechanics, **38**(1), 27–63. doi:<https://doi.org/10.1146/annurev.fluid.38.050304.092016>.
- [3] Tipler, P.A. and Mosca, G. (2008). *Physics for Scientists and Engineers*. New York, NY: W.H. Freeman and Company.
- [4] Glenn Research Center — NASA. (2023). *Guide to Aerodynamics*. Available at: <https://www1.grc.nasa.gov/beginners-guide-to-aeronautics/learn-about-aerodynamics/#drag> [Accessed: 30 Sept 2025].
- [5] Daytona International Speedway. (2022). *About Us - Daytona International Speedway*. Available at: <https://www.daytonainternationalspeedway.com/about-us/> [Accessed: 30 Sept 2025].
- [6] NASA. (2023). *Properties of Air - Text Version*. Glenn Research Center — NASA. Available at: <https://www1.grc.nasa.gov/beginners-guide-to-aeronautics/properties-of-air-text-version/> [Accessed: 30 Sept 2025].
- [7] Opong, R. (2022). *How Much Do NASCAR Cars Weigh? (Why Weight Matters) - FLOW RACERS*. Flow Racers. Available at: <https://flowracers.com/blog/nascar-car-weight/?srsltid=AfmB0op8A7aSMbrLpF3J04etA1NrRS3utXGo-vWaBFXA4seWg6v3xwrw> [Accessed: 25 Oct 2025].