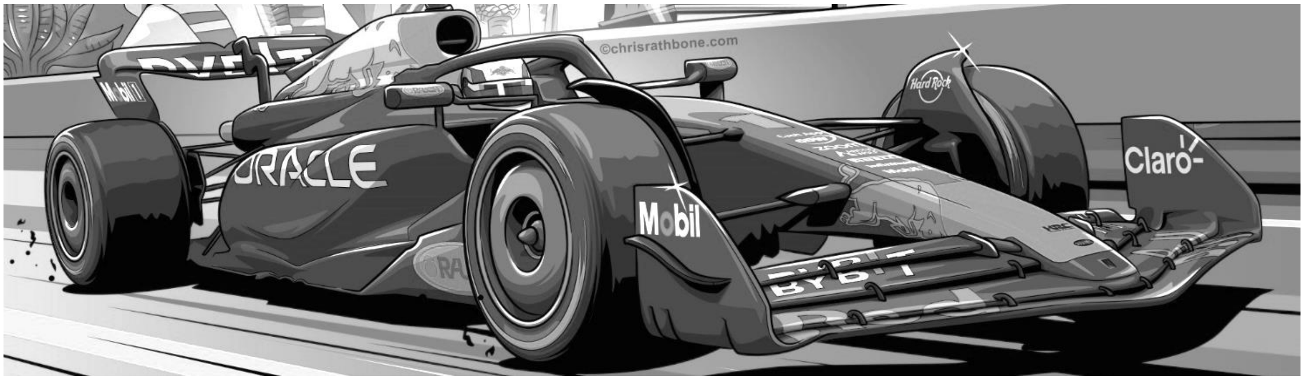
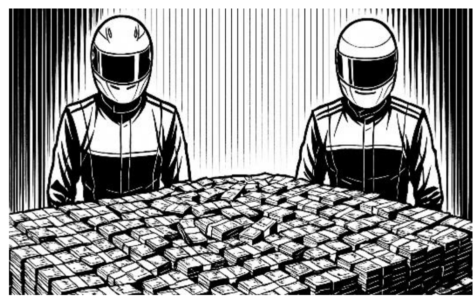
PROJECT - EGME 205-10 20304– FALL 2025



1. INTRODUCTION

Congratulations!

You are now acting as **Team CEO**, **Race Engineer** and **Performance Analyst** of your very own ***Formula 1*** Racing Team!



Your investors have pledged **$100,000,000** for next season if you can show a convincing **data-driven** plan to improve lap time. Your job is to build a **MATLAB** based racing simulation, then write a proposal that shows exactly how you will spend that **$100M** to upgrade your car and why your plan will make you competitive.

BASELINE PACKAGE

Your baseline F1 car starts with:

- **Mass**, *M* = 850kg
- **Power**, *P* = 380 kW
- **Braking Efficiency**, *n_B* = 80%
- **Tire Grip**, *mu* = 1.6
- **Coefficient of Drag**, *C_dg* = 0.7
- **Coefficient of Downforce**, *C_df* = 4.6
- **Frontal Area of car**, *A* = 1.3 m^2
- **Pit Lane Time**, *t_PL* = 35 *seconds*
- **Drivetrain Efficiency**, *n_Dt* = 91%

BASELINE TRACK (In addition, the track you are racing on is allowing you to race for free, but on a rainy day.)

- **Weather Factor**, n_W= *rainy, gloomy* (90% effective Tire Grip)

TRACK CONSTANTS (These are determined by properties of your track)

- **Air Density,** rho kg/m^3

Find the altitude of your track and then find your corresponding Air Density here:

https://www.ngdc.noaa.gov/stp/space-weather/online-publications/miscellaneous/us-standard-atmosphere-1976/us-standard-atmosphere_st76-1562_noaa.pdf

- **Track Age Coefficient**, n_A

Search the year that your track was last resurfaced. The grip from the pavement will have worn down considerably over the years. Use the table below to determine a coefficient of lowering the grip based on how old the track is:

Track Age (years)	Grip Coefficient	Notes
<2	**1**	freshly laid, maximum grip
2	**0.993**	oils still present; very high adhesion
3	**0.986**	beginning to polish slightly
4	**0.979**	light aggregate exposure
5	**0.972**	grip starting to noticeably decline
6	**0.965**	moderate wear, surface smoothing
7	**0.958**	reduced microtexture
8	**0.951**	polished racing line, less bite
9	**0.944**	aging asphalt, minor microcracking
10	**0.937**	grip plateau at ~6–7% total loss

- **Koppen Factor Coefficient,** n_K

The Köppen climate classification divides Earth's climates into five main climate groups, with each group being divided based on patterns of seasonal precipitation and temperature. The five main groups are A (tropical), B (arid), C (temperate), D (continental), and E (polar). Each group and subgroup is represented by a letter. Find what climate your track falls into, and pick a coefficient based on the table below.

https://www.mindat.org/climate.php#:~:text=The%20K%C3%B6ppen%20Climate%20Classification%20divides,Cold

Köppen Code	Climate Type	Grip Coefficient	Explanation
Af	Tropical Rainforest	**0.88**	Hot, humid, frequent rain → low grip
Am	Tropical Monsoon	**0.86**	High humidity, damp surface → poor grip
Aw/As	Tropical Savanna	**0.92**	Warm but more dry → decent grip
BWh	Desert Hot	**0.96**	Dry, warm, clean asphalt → high grip
BWk	Desert Cold	**0.91**	Dry but colder → less rubber activation
BSh	Semi-Arid (hot steppe)	**0.94**	Hot & dusty → moderate grip
BSk	Semi-Arid (cold steppe)	**0.90**	Dust + cooler → reduced grip
Csa	Mediterranean (hot summer)	**0.98**	Best grip conditions (Barcelona, Portimão)
Csb	Mediterranean (warm summer)	**0.99**	Slightly cooler → excellent grip
Cfa	Humid Subtropical	**0.95**	Warm, humid, occasional rain
Cfb	Marine West Coast	**0.93**	Mild temp but damp (Silverstone-style)
Cfc	Subpolar Oceanic	**0.88**	Cold & wet → much lower grip
Dfa/Dfb	Humid Continental	**0.92**	Hot summers, cold winters → variable grip
Dfc	Subarctic	**0.85**	Cold most of the year → weak grip
ET	Tundra	**0.75**	Very cold → extremely low grip
EF	Ice Cap	**0.65**	Ice/snow, nearly no grip (fictional tracks)

2. UPGRADES

You can upgrade any of these baseline parameters using the **$100M**.

Mass: Lower mass reduces the inertia of the car, allowing it to accelerate faster, brake harder, and change direction more quickly. Every kilogram removed improves responsiveness and reduces lap time, especially in technical sections.

Stage I	850 kg	$0
Stage II	830 kg	$10M
Stage III	820 kg	$20M
Stage IV	815 kg	$30M

Power (Engine Power): More power increases the car's ability to generate acceleration at medium and high speeds. Higher power means stronger exit speed out of corners and a higher maximum velocity on long straights.

Stage I	380 kW	$0
Stage II	400 kW	$15M
Stage III	410 kW	$20M
Stage IV	415 kW	$30M

Braking Efficiency (Max Efficiency = 100% of Max Tire Grip): Braking efficiency determines how effectively the brakes can use the tire grip available. Higher efficiency lets the driver brake later and slow down more precisely, reducing time lost entering corners.

Stage I	80%	$0
Stage II	90%	$5M
Stage III	95%	$10M
Stage IV	97%	$15M

Tire Grip (Unitless, Coefficient of Friction): Tire grip sets the maximum friction force the tires can produce. Higher grip improves cornering speed, traction, and braking performance, especially critical in rainy weather where baseline grip is reduced.

Stage I	1.6	$0
Stage II	1.8	$10M
Stage III	1.9	$20M
Stage IV	1.92	$30M

Coefficient of Drag: Drag opposes forward motion. Lower drag increases straight-line speed and reduces energy loss at high velocities. This is one of the most impactful upgrades for tracks with long straights.

Stage I	0.7	$0
Stage II	0.6	$5M
Stage III	0.55	$10M
Stage IV	0.52	$15M

Coefficient of Downforce: Downforce pushes the car downward, increasing grip at high speeds. More downforce improves stability and allows faster cornering.

Stage I	4.6	$0
Stage II	5	$5M
Stage III	5.2	$10M
Stage IV	5.3	$15M

Pit Lane Time (We will assume there are 2 Pit Stops per Race): Pit Lane time includes slowing down, stopping, and re-accelerating twice per race. Reducing pit time directly cuts race duration, especially over multiple pit stops. Faster pit times improve strategic flexibility.

Stage I	35 seconds	$0
Stage II	25 seconds	$5M

Weather (You can pay for better weather by paying more to race on a day with less rain): Weather affects tire grip dramatically. Paying for better weather reduces the rain penalty and increases available grip. This improves braking, cornering, and acceleration across the entire lap.

Stage I	90% Effective Tire Grip	$0
Stage II	95% Effective Tire Grip	$5M
Stage III	97% Effective Tire Grip	$10M
Stage IV	100% Effective Tire Grip	$15M

Drivetrain Efficiency: The drivetrain is everything between the engine and the tires—gears, shafts, differentials, bearings, etc. As power flows through these components, some of it is lost as heat due to friction. Drivetrain efficiency tells you what percentage of the engine's power survives the trip to the wheels.

Stage I	91% Efficiency	$0
Stage II	94% Efficiency	$10M
Stage III	96% Efficiency	$20M
Stage IV	97% Efficiency	$30M

3. MATLAB Simulation Requirements

Your MATLAB simulation must model a **full 50-lap race** on the track you selected. The simulation should compute the **total race time** based on the performance characteristics of your upgraded car.

3.1 MATLAB Inputs

Luckily, your race engineers have done **most** of the legwork. They have provided you with a MATLAB script that takes the following inputs, using these variable names:

Parameter	**Variable Name**	**Unit**
Mass	m	kg
Engine Power	P_ENG	kW
Braking Efficiency	n_B	N/A
Tire Grip	mu_t	N/A
Coefficient of Drag	C_dg	N/A
Coefficient of Downforce	C_df	N/A
Pit Lane Time	t_PL	Seconds
Drivetrain Efficiency	n_Dt	N/A
Weather Factor Coefficient	n_W	N/A
Koppen Factor Coefficient	n_K	N/A
Track Age Coefficient	n_A	N/A
Air Density	rho	kg/m^3

In addition, you will need to provide X and Y coordinates of a race track in your choosing in an Excel sheet, where the first column is X coordinates, and the second column is Y coordinates.

Using the xlsread command, you will import your racetrack into a matrix named ‘circuit’.

Using **switches**, make your input section of your code such that you can change the parameters of your car using switches like so:

```
% USER DEFINED PARAMETERS

%Set stage of each option
stage_mass       = 3;
stage_power      = 1;
stage_brakeEff   = 1;
stage_tireGrip   = 1;
stage_cd         = 1;
stage_cdf        = 1;
stage_pitTime    = 1;
stage_weather    = 1;
stage_drivetrain = 1;
```

Your Koppen Factor Coefficient, Track Age Coefficient and Air Density don’t need to be input as switches.

3.2 MATLAB Outputs

The boilerplate code will **output** the following parameters:

Parameter	**Variable Name**	**Unit**
Time	**t**	seconds
Lap Time	**lap_time**	seconds
Acceleration, Lateral	**a_lat**	m/s^2
Acceleration, Longitudinal	**a_lon**	m/s^2
Acceleration, Braking	**a_braking**	m/s^2
Downforce	**F_lift**	N
Accelerative Engine Force	**F_engine**	N
Force from Drag	**F_drag**	N
Total Force used to Accelerate	**Fx**	N
Centrifugal Force	**Fy**	N
Braking Force	**Fx_b**	N
Velocity	**Vel**	m/s
Velocity	**Vel_kmh**	km/h
Steering Angle	**delta_1_plot**	degrees
Yaw Rate	**r_plot**	1/sec
Distance	**s**	meters
X-Coordinate of track	**x**	meters
Y-Coordinate of track	**y**	meters
Curvature	**curvature**	1/meters
Turn Percentage Point	**turnp**	%
Turn Markers	**turnmarkers**	N/A
Section Points	**sectionpoints**	N/A
Section Markers	**sectionmarkers**	N/A

3.2.1 Using fprintf, output:

1. Lap Time
   a. Use the following code to change the format:

```
LTS = seconds(lap_time);
LTS.Format = 'mm:ss.SSS';
```

2. Total Race Time (50 Laps + 2 Pit Stops)
   a. Use the following code to change the format:

```
RTS=seconds(race_time);
RTS.Format='hh:mm:ss.SSS';
```

3. Average Velocity (kmph)
4. Max Velocity (kmph)
5. Min Velocity (kmph)
6. Total Heat Generated from Braking (J)
   a. Using **trapz**, calculate the heat generated by the brake force.
   The equation for heat is

$$Q_{heat} = \int_{0}^{END} -F_{brake} ds$$

   Where s is distance, you need to integrate braking over distance using trapz.
7. Cost ($M)

3.2.2 Plot:

Include xlabels, ylabels, grid on, and titles for all plots

Title	**X**	**Y**
g-g Diagram	Acceleration, Lateral [g]	Acceleration, Longitudinal [g]
Velocity Profile	Distance [m]	Velocity
Lateral Acceleration Profile	Distance [m]	Acceleration, Lateral [g]
Longitudinal Acceleration Profile	Distance [m]	Acceleration, Longitudinal [g]

3.2.3 Turn & Section Barplots:

To find the turns and sections of your track, start by looking at the official turn #'s of your track.

For example, the official turns of Austin are laid out here:
https://en.wikipedia.org/wiki/Circuit_of_the_Americas#/media/File:Austin_circuit.svg

After inputting your car parameters, run the code once at least to see Figure 50, which will show you the percentage labels of your track. Using that plot and the online map of your track, decide where each turn is located (% of track).

Open **defining_sectors.m** and edit the **turnp** vector so each row corresponds to the percentage location of a turn on your track.

Rerun the function: Figure 51 will now show your numbered turns, and the function will output **turnmarkers, sectionmarkers,** and **sectionpoints**, which you will use to analyze each section.

The **sectionpoints** will tell you what points to use for each vector to find the values of each section. For example, if you're looking at section 3, your section markers might be 100 to 150. Then to find the braking forces for that section, you would just call the values of those points:

```
Fx_b(sectionpoints(3,1):sectionpoints(3,2))
```

If you want to find the max for that section:

```
max(Fx_b(sectionpoints(3,1):sectionpoints(3,2)))
```

However, because the track sections interfere with the starting point and ending point of the track, additional code is needed to make it work. An example for loop for you below is provided to find the properties of average, mean and max of a specific property for each section. The example shows finding the acceleration. The **distance** is calculated for you. Find time spent in each section the same way distance is calculated here. **defining_sectors.m** has been updated as well, download the newest version from the project page. **Copy your turnp values into the new defining_sectors.m code.**

```
total_datapoints = length(t);
for i = 1:length(turnp)
    secstart = sectionpoints(i,1);
    secfinish = sectionpoints(i,2);

    if secfinish >= secstart
        range = secstart:secfinish;
        distance(i)=s(sectionpoints(i,2))-s(sectionpoints(i,1));
    else
        range = [secstart:total_datapoints, 1:secfinish];
        distance(i)=s(sectionpoints(i,2))+max(s)-s(sectionpoints(i,1));
    end

    averageAccelPerSection(i) = mean(a_accel(range));

end
```

Using values from each section, make the following barplots below:

Include ylabels, grid on, and titles for all barplots

Bar Plots
Distance of Each Section
Average Velocities of Each Section
Average Longitudinal Acceleration of Each Section
Min Velocities of Each Section
Max Velocities of Each Section
Max Braking Force of Each Section
Time Spent in Each Section
Max Centrifugal Force in Each Section

3.2.4 Subplot:

Plot the following in a 3x1 Subplot, include a legend for the first plot.

Include xlabels, ylabels, grid on, and titles for all plots

Title	**X**	**Y**
Accelerations vs Time	Time [sec]	Acceleration, Lateral [g], Acceleration, Longitudinal [g]
Velocity vs Time	Time [sec]	Velocity [kmph]
Distance vs Time	Time [sec]	Distance [m]

3.2.5 Circuit Plots:

Plot the following as a circuit plot, the values will be colored:

1. Velocity vs Circuit Position
2. Lateral Acceleration vs Circuit Position
3. Longitudinal Acceleration vs Circuit Position

To plot a circuit, use the code below, fill in the figure number appropriately.

For the value you want to plot, make it equal to c, you may need to transpose it, you can use the apostrophe' to turn the vector.

For colormap, you can use either **turbo** or **jet**. Turbo has a smoother transition, jet is what we are used to seeing.

```
figure(XXXX)
z = zeros(size(x));
c = XXXX;
surface([x;x],[y;y],[z;z],[c;c],'facecolor','none','edgecolor','interp','linewidth',3);
colormap XXXX
axis equal
colorbar
h = colorbar;
ylabel(h, 'XXXX [XXXX]')
```

3.2.6 Pie Chart

Create a pie chart showing how your $100 million budget was allocated across all upgrades. Be sure to include a title and a labeled legend.

4. Report

1. Intro (Proposal)
    a. Write an introduction for the report (200 words +/- 50)
2. Team Identity
    a. Team Name
    b. Driver name, photo & Car Number of each driver
    c. Driver bio
        i. Make up a short bio for each driver
    d. Logo
        i. Show the logo on some swag (T shirts, hats, etc)
    e. Team Tagline, think like: ‘Mercedes: The Best or Nothing’
3. Track Selected
    a. Geographic Location of Racetrack
        i. Coordinates
        ii. Country, City, State,
    b. Climate of Racetrack
        1. Koppen Climate Classification
        2. Track Altitude and Corresponding Air Density
        3. How many days of the year does it rain in this city?
        4. How many days of sunshine are there?
        5. Average Temperature? Pick a month that you would prefer to race in.
    ii. History of track
        1. When was it built?
        2. When was it last resurfaced?
    iii. Key Track Features
        1. Walk us through the track, turns and turn radii
            a. How many straights, corners, hairpins are there?
            b. What is the longest straight?
            c. What is the length of this track (m)?
            d. What is the fastest lap time recorded on this track?
                i. What car is it?
        2. Extra Credit (10 points) Link to an over the shoulder video of you driving the racetrack on a simulation or video game

c. Analysis
    i. Fast Car Parameters (Text)
    ii. Lap Time & Total Race Time (Text)
    iii. Average Velocity, Max Velocity, Min Velocity (Text)
    iv. Highest G Forces (Show g-g Diagram) (Plot)
    v. Deltas versus Base Car (Lap Time, Total Time, Peak G Forces) (Text)
    vi. Velocity Profile (Plot)
    vii. Lateral Acceleration Profile (Plot)

viii. Longitudinal Acceleration Profile (Plot)
ix. Subplot (Acceleration/Velocity/Distance)
x. Circuit-Velocity (Circuit Plot)
xi. Circuit-Lateral Acceleration (Circuit Plot)
xii. Circuit-Longitudinal Acceleration (Circuit Plot)
xiii. Heat Generated by Brakes (per Lap & Per Total Race) (Text)
xiv. Distance of Each Section (Bar Plot)
xv. Average Velocities of Each Section (Bar Plot)
xvi. Average Longitudinal Acceleration of Each Section (Bar Plot)
xvii. Min Velocities of Each Section (Bar Plot)
xviii. Max Velocities of Each Section (Bar Plot)
xix. Time Spent in Each Section (Bar Plot)
xx. Max Centrifugal Force in Each Section (Bar Plot)
xxi. Upgrade Cost Pie Chart
xxii. Which upgrade had the biggest effect on laptime?
xxiii. Which section of the track decides most of the race time?
xxiv. Find the official length of your track online, compare it to your total distance. What is the % error?

4. Conclusion (250 words +/- 50 words)
    a. Write a conclusion/summary for the report.
5. Appendix
    a. MATLAB Code
6. EXTRA Credit:
    a. Link to an over-the-shoulder video of one of your teammates driving 1 lap on the track on any simulator or video game, make it obvious that it's you in the video beginning or ending.

5. Presentation (Pitch Deck)

1. Title Slide
    a. Team Name
    b. Team Member Names
    c. Logo
2. Executive Summary
    a. Purpose of the project: How much money are you asking for and why?
    b. Base Car Lap Time
    c. Upgraded Car Lap Time
3. Team Identity
    a. Team Name, Tagline, Logo
    b. Driver Photos + Car Number
    c. 1-2 sentence bio per driver
4. Team Branding / Swag
    a. Show logo on T-shirt/hoodie/hat
    b. Car livery Mockups
5. Track Selection Overview
    a. Track Name
    b. Coordinates
    c. Country/City
    d. Why this track was chosen
    e. Picture/Map of the circuit
6. Track Climate & Conditions
    a. Koppen Climate Class
    b. Rainy days per year
    c. Sunny days per year
    d. Track altitude/air density
    e. Track age/last resurfaced
7. Track Map w/ Turns Labeled
    a. Show the track w/turn Numbers
    b. Indicate total turns and sections
    c. Mention longest straight, # of hairpins
8. Base Car Summary
    a. Show starting (Stage 1 Parameters)
    b. Brief text "This is our baseline before investing any money"
9. Upgrade Strategy ($100M Budget Plan)
    a. Upgrades you purchased
    b. How much each upgrade cost
    c. Relative Seconds saved with each upgrade
10. Upgraded Car Stats (Post-Investment)
    a. Also list Lap Time and Total Race Time

11. Subplot (Accel/Vel/Distance)
12. Circuit-Velocity Map, include text of max and min velocities
13. G-G Diagram
14. Bar Charts (at least show 3 from report)
15. Brake Heat Analysis
    a. Total Heat per Lap
    b. Total Heat per Race
16. Upgrade Cost Pie Chart
17. Conclusion
    a. Summary of key findings
    b. Final confidence statement
18. EXTRA CREDIT: Over-the-shoulder video of one of your teammates driving 1 lap on the track on any simulator or video game, make it obvious that it's you in the video beginning or ending.

6. GRADING RUBRIC (100 pts) (continued on next page)

Category	Subcategory	Description	Points
MATLAB Code (10 pts)	Code Runs	Simulation runs start-to-finish with no errors	5
	Switches	Switches implemented correctly for all upgrade categories	3
	Outputs	fprintf outputs present (Lap Time, Race Time, Velocities, Heat, Cost)	2
Written Report (55 pts)	Introduction	200-word intro explaining $100M proposal	5
	Team Identity	Team name, logo, tagline	2
		Driver photos, numbers, bios	2
		Team swag shown	1
	Track Info	Geographic location + coordinates	2
		Köppen climate classification	2
		Rainy/sunny days, temperature	2
		Track altitude & air density	2
		Track history & resurfacing year	2
	Track Features	Turn-by-turn description	2
		Track length & longest straight	2
		Fastest lap and car	1
	Analysis	Fast car parameters summary	1
		Lap time & race time	1
		Avg/Max/Min velocity	1
		g-g diagram (Plot)	3
		Velocity Profile (Plot)	3
		Lateral Acceleration Profile (Plot)	3
		Longitudinal Accel Profile (Plot)	3
		Subplot (Accel/Vel/Distance)	3
		Circuit Plots (Velocity/Lateral/Longitudinal)	6
		Heat generated per lap & per race	2
		All required section bar plots (Distance, Avg Vel, etc.)	6
		Upgrade cost pie chart	2
	Insight	Delta vs Base Car explained	2
		Upgrade with biggest effect explained	2
		Key section affecting lap time explained	1
	Conclusion	250-word conclusion	2

Presentation (35 pts)	Delivery	Clear speaking, pacing, and confidence		5
		Clean slide design & readability		5
	Slides	Executive summary w/ $100M funding request		2
		Team identity & branding		2
		Track location & climate		2
		Track map w/ turns labeled		2
		Base car + upgrade strategy		2
	Technical	Subplot included		2
		Circuit heatmap included		2
		g-g diagram shown		2
		At least 3 bar charts shown		2
		Brake heat analysis		2
	Investment	Persuasive $100M funding ask		2
		Upgrade cost breakdown		2
		Justification based on MATLAB results		1
Extra Credit (5 pts)	Driving Simulation	Over-the-shoulder lap video showing student driving the track		5