Assignment 9: Matlab Functions and Polynomials

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Problem 1

Figure 1 shows fuel economy car data compiled by the Oak Ridge National Laboratory. The data is included in a companion Excel file.

Year	FuelEconomy_mpg	Weight_lbs	HP	AccelTime_s
1980	19.2	3227.9	103.8	15.6
1981	20.5	3201.8	102.1	15.6
1982	21.1	3201.8	103.0	16.6
1983	21.0	3257.3	106.9	14.9
1984	21.0	3261.6	108.6	14.7
1985	21.3	3271.1	114.1	14.1
1986	21.8	3238.0	114.4	13.4
1987	22.0	3220.5	117.6	13.4
1988	21.9	3283.5	123.5	13.3

Figure 1. Light Vehicle Data for Problem 1.

A) Create Matlab script to read the data. Save every column as a vector.

noiseFunction.m | callnoiseFunction.m | P1_A9_carData.m

```
% Script for A9
% Data was imported and saved in a Matlab file
load ('carDataA9.m')

% C1 - Year
% C2 - FuelEconomy_mpg
% C3 - Weight_lbs
% C4 - HP
% C5 - AccelTime_s
% 1980    19.16  3228    103.83    15.57
% 1981    20.52  3202    102.12    15.58
% 1982    21.07  3202    102.95    16.63

year = carDataA9(:,1);
fuelEcon_mpg = carDataA9(:,2);
weight_lbs = carDataA9(:,3);
hp = carDataA9(:,4);
accelTime_s = carDataA9(:,5);
```

Code to read car data.

B) Add code to the script in (a) to find the best 4th order polynomial to fit horsepower (independent variable) and acceleration from 0-60 mpg (dependent variable). Display the 4th order polynomial in the Command Window and make a screen capture. The polynomial is of the form:

$$Accel = A(HP^4) + B(HP^3) + C(HP^2) + D(HP) + E$$

Where:

A, B, C, D, E are the regression coefficients found using the Least-Square Method.

HP is the vehicle horsepower (horsepower)

$Accel$ is the vehicle acceleration time from 0-60 mph (seconds)

C) Make a plot of HP versus acceleration and also plot the polynomial found.

D) Plot the residuals of the regression using the Matlab basic fitting functionality

E) State the value of R-square and tell if the polynomial is a good fit.

```
figure
plot(hp,accelTime_s,'or')
xlabel('Horsepower')
ylabel('Acceleration 0-60 mph (s)')
grid

hold on

% Create a 4th order polynomial to fit the data

coefficients = polyfit(hp,accelTime_s,4);

% Evaluate the polynomial fitted to the data

hp_vector = 100:1:260;      % Creates a vector values of hp
accelerationTimeModel = polyval(coefficients,hp_vector);

plot(hp_vector,accelerationTimeModel ,'+-b')
```

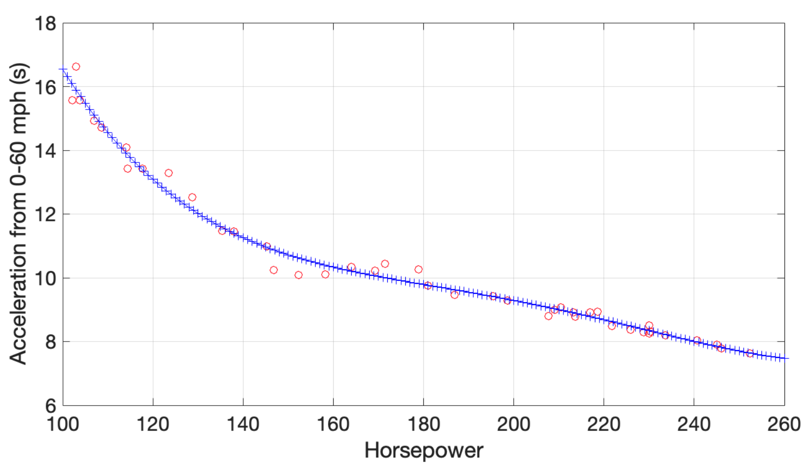


Figure . Matlab code to find fourth order polynomial. Plot of the fitted polynomial and the data.

$$Accel = A(HP^4) + B(HP^3) + C(HP^2) + D(HP) + E$$

The coefficients found using the Matlab least-square method are:

$$A = 4.8756e - 08$$
$$B = - 4.019197e - 05$$
$$C = 0.012260$$
$$D = - 1.6685$$
$$E = 96.0999$$

The data is fitted with a fourth-order polynomial. The R-square value is 0.988 which is very high. The polynomial fit is very good.

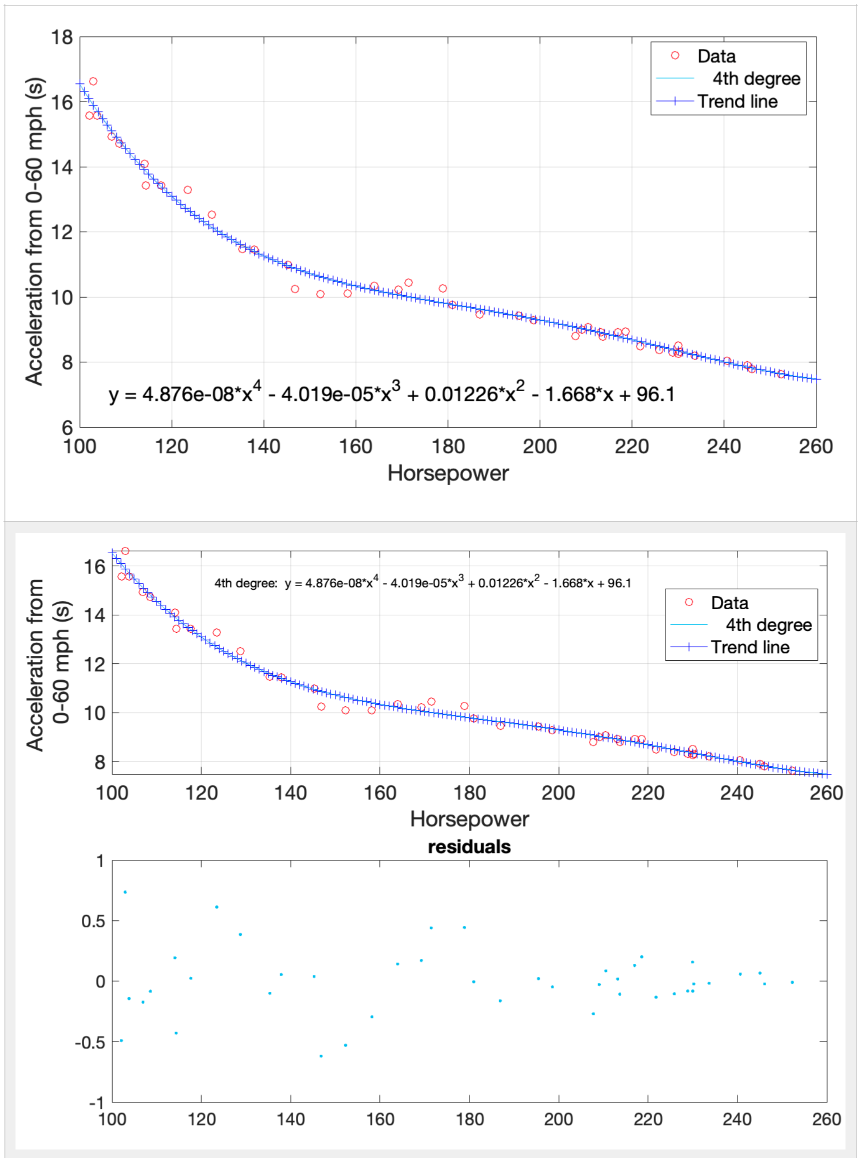


Figure . Fourth order polynomial. Plot of the fitted polynomial and the data. Residuals.

Problem 2

Figure 2 presents consumption data and emissions is for a small SUV vehicle. The fuel consumption and emissions are presented in columns 3 and 4.

Speed (km/hr)	Speed (m/s)	Fuel Consumption (l/s)	CO2 Emissions (mg/s)
0	0.00	0.00025	2.04
10	2.78	0.00034	2.44
15	4.17	0.00040	3.04
20	5.56	0.00045	4.15
30	8.33	0.00055	6.33
40	11.11	0.00065	8.91
50	13.89	0.00075	12.01
60	16.67	0.00090	16.10
70	19.44	0.00105	22.24
80	22.22	0.00120	32.85
90	25.00	0.00140	53.81
100	27.78	0.00180	101.39

Figure 2. Small SUV Fuel Consumption Data.

A) Create Matlab script to read the data.Save every column as a vector.

B) Add code to the script in (A) to find the best second order polynomial to predict fuel consumption (dependent variable) as a function of speed (independent variable). Display the polynomial in the Command Window and make a screen capture. The polynomial is of the form:

$$FC = A(V^2) + B(V) + C$$

Where:

A, B, C are the regression coefficients found using the Least-Square Method.

V is the vehicle speed (m/s)

FC is the vehicle instantaneous fuel consumption (liters/second)

C) Make a plot (in code) of the fuel consumption data and also show your polynomial fit in the same plot.

The figure shows below the code and the plots produced.

The second order polynomial coefficients are:

A = 1.2859e-06

B = 1.4799e-05

C = 0.0002977

```
% Imported variables using Matlab import Wizard
% speed_kmh = speed in km/hr;
% speed_ms = speed in meters/second;
% fc_ls = fuel consumption (liters/second);
% em_mgs = CO2 emissions (miligrams/second);

coeff_fuel_consumption = polyfit(speed_ms,fc_ls,2);                % 2nd order polynomial coefficients
speedVector = 0:1:30;                                               % speed in m/s
fuel_economy_ls = polyval(coeff_fuel_consumption,speedVector);  % fuel consumption from polynomial regression

% Make a plot
figure
plot(speed_ms,fc_ls,'or',speedVector,fuel_economy_ls,'+-b')
xlabel('Speed (m/s)')
ylabel('Fuel Economy (l/s)')
grid
```

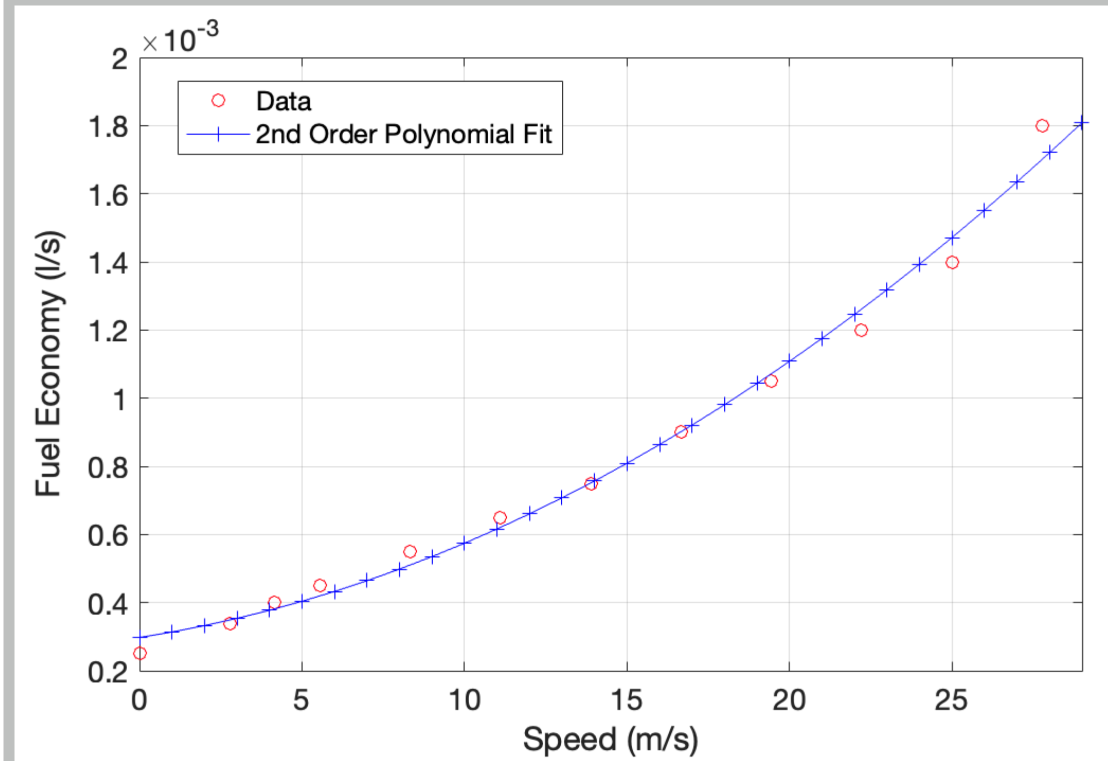


Figure . Matlab code to find the second order polynomial to predict fuel consumption. Plot of the fitted polynomial and the data.

D) Add code to part (C) to find the best 5th order polynomial to predict vehicle emissions (mg/s) as a function of speed (m/s). The polynomial takes the form:

$$Em = A(V^5) + B(V^4) + C(V^3) + D(V^2) + E(HP) + F$$

Where:

A, B, C, D, E, F are the regression coefficients found by Matlab using the Least-Square Method.

V is the vehicle speed (m/s)

Em is the vehicle instantaneous emission rate (mg/s)

E) Make a plot (in code) of the emissions data and also show your polynomial fit in the same plot.

F) Comment on the quality of both polynomial fits.

The coefficients of the CO2 emissions polynomial are:

A = 0.000974

B = -0.03974

C = 0.54273

D = -1.7877

E = 2.88235

```
44 % Imported variables using Matlab import Wizard
45 % speed_kmh = speed in km/hr;
46 % speed_ms = speed in meters/second;
47 % fc_ls = fuel consumption (liters/second);
48 % em_mgs = CO2 emissions (miligrams/second);
49
50 coeff_CO2_emissions = polyfit(speed_ms,em_mgs,4);                  % 4th order polynomial coefficients
51 emissions_C02_mgs = polyval(coeff_CO2_emissions,speedVector);  % emissions calculation from polynomial regression
52
53 figure
54 plot(speed_ms,em_mgs,'or',speedVector,emissions_C02_mgs,'+-b')
55 xlabel('Speed (m/s)')
56 ylabel('Emissions (mg/s)')
57 legend('Data','4th-order polynomial regression')
58 grid
```

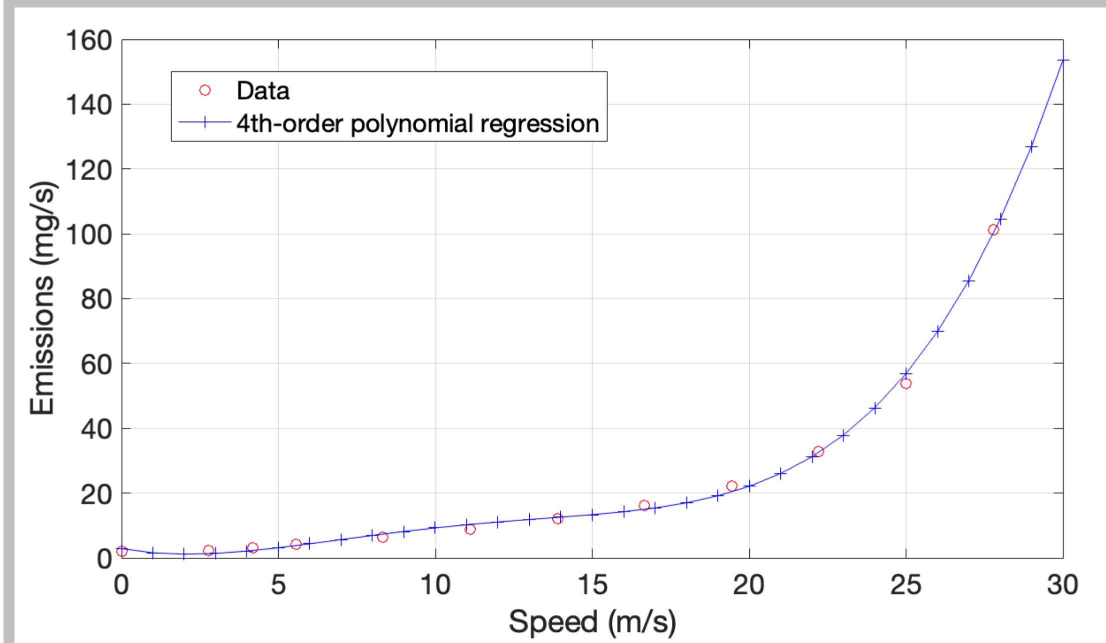


Figure . Matlab code to find the fourth-order polynomial to predict SUV vehicle CO2 emissions. Plot of the fitted polynomial and the data. Note the use of polyfit function in line 50 to perform the least-square estimation of the fourth order polynomial. Line 51 uses the polyval function to evaluate the polynomial obtained in line 50.

Problem 3

The United States Federal Code publishes a city driving cycle to compare fuel economy standards for all vehicles sold in the US.

Time (s)	Speed (mph)	Speed (m/s)
0	0.0	0.00
1	0.0	0.00
2	0.0	0.00
3	0.0	0.00
4	0.0	0.00
5	0.0	0.00
6	0.0	0.00
7	0.0	0.00

Figure 3. United States Driving City Cycle.

A) Create a Matlab script to read the data.

```
% Specify sheet and range
opts.Sheet = "TEDB Edition 40";
opts.DataRange = "A2:C1374";

% Specify column names and types
opts.VariableNames = ["Time_seconds", "Speed_mph", "Speed_ms"];
opts.VariableTypes = ["double", "double", "double"];

% Import the data
tbl = readtable("/Users/vuela-adm/Courses/CEE 3804/CEE 3804 Spring 2024

%% Convert to output type
Time_seconds = tbl.Time_seconds;
Speed_mph = tbl.Speed_mph;
Speed_ms = tbl.Speed_ms;
```

Figure . Matlab script to read the United States driving city cycle data.

B) Add to the script in part (A) to integrate numerically the vehicle speed to obtain the distance traveled in meters. Report the result of the total distance traveled and the travel time in the Command Window. You are allowed to use the trapezoidal function or the Quad function in Matlab to do the numerical integration Your choice.

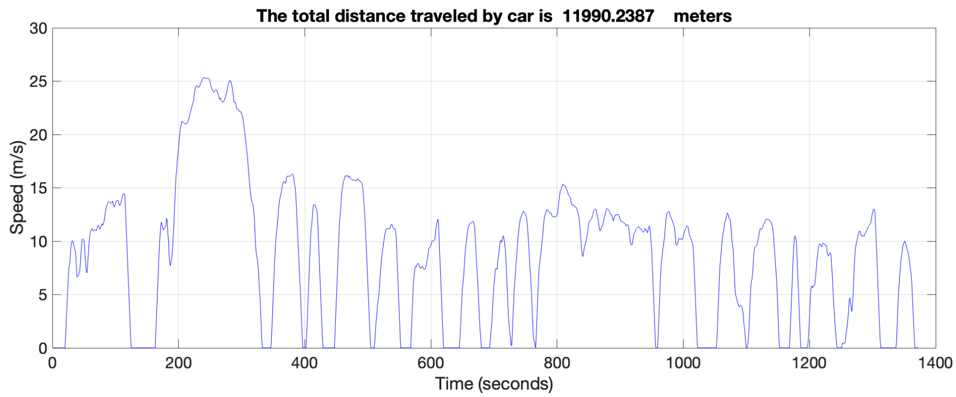
```
% Part (b) integrate numerically the speed profile.
% Integral is the distance traveled
% I used the trapezoidal rule function

distanceTraveled = trapz(Time_seconds,Speed_ms);
disp(['The total distance traveled by car is  ', num2str(distanceTraveled), '    meters'])
```

```
The total distance traveled by car is  11990.2387    m
```

Figure . Matlab script to find integrate the speed profile in the US driving city cycle.

C) Add code to part (B) to make a plot of time (in x-axis) and the speed profile (m/s). Write the total distance traveled in the title of the plot. The title should be coded in your script.



The total distance traveled by car is 11990.2387 m

Figure . Matlab script to find integrate the speed profile in the US driving city cycle.

```
% Part (c) plot the speed profile and add the title with distance traveled
% Create a title
titleName = horzcat(['The total distance traveled by car is  ', num2str(distanceTraveled), '    meters']);
plot(Time_seconds,Speed_ms,'-b')
xlabel('Time (seconds)')
ylabel('Speed (m/s)')
title(titleName)
grid
```

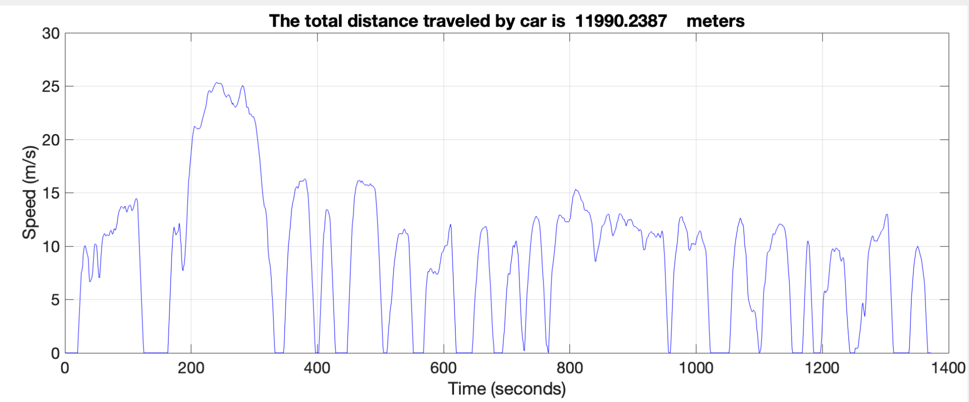


Figure . Matlab script to find integrate the speed profile in the US driving city cycle.

D) Create a single function with the regression equations found in Problem 2 (parts B and D) to predict the fuel consumption and emissions as a function of speed. Your function produces two outputs (*Fc* and *Em*) and requires one input (*V*). You are allowed to hard code the coefficients of the regression equations in the function.

```matlab
function [CO2_emissions_mgs,fuelConsumption_ls] = fuel_and_emissions_calculator(speed_ms)
% Function to estimate fuel and CO2 emissions

% Outputs:
% CO2_emissions_mgs = CO2 emissions in mg/second
% fuelConsumption_ls   = fuel consumption liters/second

% Input:
% speed_ms = vehicle speed in meters/second

% Define the coefficients of the emissions regression model
% Added the label "e" to distinguish these coefficients from the fuel
% consumption values

Ae = 0.000974;
Be = -0.03974;
Ce = 0.54273;
De = -1.7877;
Ee = 2.88235;

% Calculate the CO2 emissions using the fourth-order polynomial model
CO2_emissions_mgs = Ae * speed_ms.^4 + Be * speed_ms.^3 + Ce * speed_ms .^2 + De * speed_ms + Ee;

% Define the coefficients of the fuel consumption model
% Added the label "f" to distinguish these coefficients from the emission
% values

Af = 1.2859e-06;
Bf = 1.4799e-05;
Cf = 0.0002977;

% Calculate the fuel consumption using the second-order polynomial model
fuelConsumption_ls = Af * speed_ms.^2 + Bf * speed_ms + Cf;

```

Figure . Matlab function to estimate CO2 emissions and fuel consumption in the US driving city cycle as a function of speed (m/s).

E) Add code to part (C) to predict the instantaneous fuel consumption and emissions generated by the light SUV vehicle at every point in the US city driving cycle.

```matlab
47  % Part (e) make calculations for fuel and emissions in the US driving cycle
48  % using the function created. The folliwing predicts the instantaneous
49  % emissions and fuel consumption.
50
51  [CO2_emissions_mgs,fuelConsumption_ls] = fuel_and_emissions_calculator(Speed_ms);
52
53  % Calculate the total emissions and fuel used.
54
55  totalEmissions_mg = trapz(Time_seconds,CO2_emissions_mgs);
56  totalFuelUsed_l = trapz(Time_seconds,fuelConsumption_ls);
57
58  clc
59  disp(['Total emissions in the US driving cycle  = ', num2str(totalEmissions_mg), '   miligrams'])
60  disp(['Total fuel used in the US driving cycle  = ', num2str(totalFuelUsed_l ), '   liters'])
```

Figure . Matlab function to estimate CO2 emissions and fuel consumption in the US driving city cycle as a function of speed (m/s). Line 51 estimates the instantaneous emissions and fuel consumption of the SUV. Lines 55 and 56 estimate the total emissions in the cycle using the trapezoidal rule (numerical integration).

F) Make a subplot with *FC* versus time and another subplot for *Em* versus time.

```
subplot(2,1,1)
plot(Time_seconds,fuelConsumption_ls,'-b')
xlabel('Time (seconds)')
ylabel('Fuel Consumption (liters/s)')
grid

subplot(2,1,2)
plot(Time_seconds,CO2_emissions_mgs,'-r')
xlabel('Time (seconds)')
ylabel('CO2 Emissions (mg/s)')
grid
```

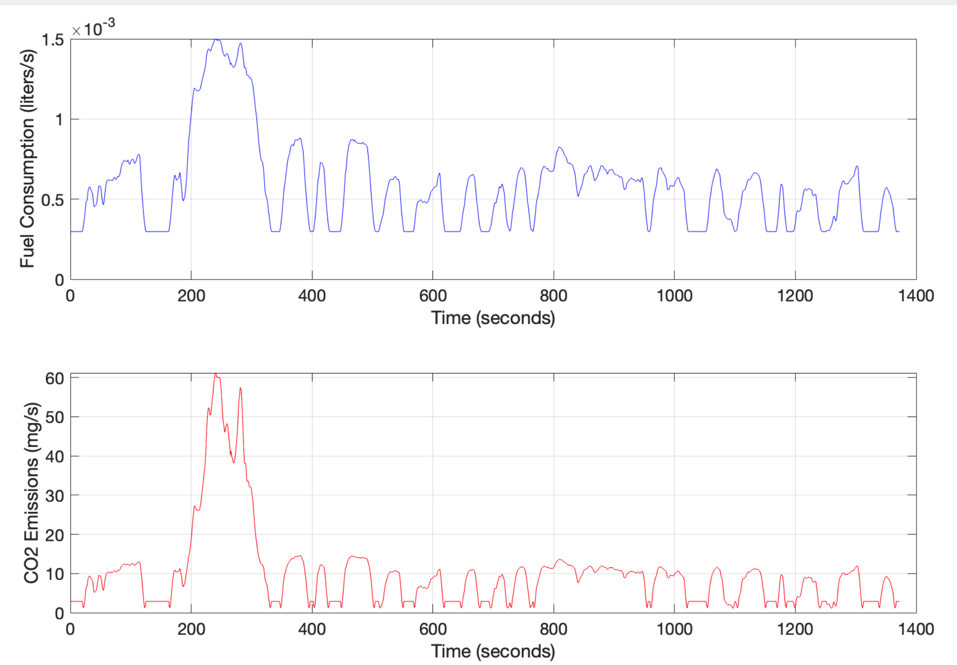


Figure . Matlab code to plot CO2 emissions and fuel consumption in the US driving city cycle as a function of speed (m/s).

G) Predict the total emissions produced by the SUV by numerically integrating the values of *Em* over time.

```
[CO2_emissions_mgs,fuelConsumption_ls] = fuel_and_emissions_calculator(Speed_ms);

% Calculate the total emissions and fuel used.

totalEmissions_mg = trapz(Time_seconds,CO2_emissions_mgs);
totalFuelUsed_l = trapz(Time_seconds,fuelConsumption_ls);

clc
disp(['Total emissions in the US driving cycle  = ', num2str(totalEmissions_mg), '   miligrams'])
disp(['Total fuel used in the US driving cycle  = ', num2str(totalFuelUsed_l ), '   liters'])
```

Command Window

```
Total emissions in the US driving cycle  = 13742.714   miligrams
Total fuel used in the US driving cycle  = 0.79681   liters
```

Figure . Matlab code to predict total CO2 emissions and total fuel consumption in the US driving city cycle.