VD ASSIGNMENT - 1

ANSWER KEY

1) **Problem 1:-**

$V_{xT} = 290 \text{ Kph} = 80.5556 \text{ m/s}$

$P_{wheels} = P_{Aero}$ [$P_{acc} = 0$ since $a = 0$ at top speed]

$\frac{1}{2} \times \rho \times C_d \times A \times V^3 = 230 \times 746$

$\rho = 1.225$, $A_f = 1750 \text{ mm} \times 1210 \text{ mm}$
$= 2.1175 \text{ m}^2$

$F_{drag} \times \cancel{V_{xT}} = \frac{230 \times 746}{80.556}$

$= 2129.94 \text{ N}$

(or)

$= 2.129 \text{ KN}$

2) We have drivetrain loss of about 12.5 %.

$(1-n_d) \times 100\% = 12.5$ (given)

$\Rightarrow n_d = 0.875$

$P_w = n_d \times P_e$

$= 0.875 \times 310 \times 746$

$= 0.875 \times 231260$

$= 202352.5\, W$

(or)

$P_w = 202.35\, kW$

$F_d = \frac{P_w}{V_x}$

$F_d = \frac{202352.5}{80.556}$

$= 2511.94\, N$

$$\frac{1}{2} \times \rho \times C_d \times A \times V^2 = 2511.94\ N$$

$$C_dA = \frac{5023.88}{(80.556^2 \times 1.225)}$$

$$C_dA = 0.63$$

$$A_f = 1.750 \times 1.210 = 2.1175$$

(from dimensions)

$$C_d = \frac{0.63}{2.1175 \times 0.79} = 0.37\ (79\%)$$

$$C_d = \frac{0.63}{2.1175 \times 0.84} = 0.354\ (84\%)$$

Thus C_d ranges from 0.354 to 0.37

Now with approximations

$$A_f = 1.6 + 0.00056\,(m - 765)$$

$$= 1.6 + 0.00056\,(1117 - 765)$$

$$= 1.7912$$

$$C_d = \frac{0.63}{1.7912} = 0.3517$$

3) $P_{wheels} = 1160\ Hp$

$= 1160 \times 746$

$= 865360\ W$

(or)

$= 865.36\ kW$

$P_{wheels} = P_{Aero}$

$$865360 = \frac{1}{2} \times 1.225 \times C_d \times 1.872 \times 124.277^2$$

$C_d = 0.393$

4) For Calculating HP at wheels for Mercedes, consider top Speed of Agera

$\therefore \; V = 124.277$ m/s

$F = \frac{1}{2} \times \rho \times C_d \times A \times v^2$

Since C_d is unaffected, we consider $C_dA = 0.63$

$F = \frac{1}{2} \times 1.225 \times 0.63 \times 124.277^2$

$F = 5959.75$ N

(or)

5.95 KN

$P = F \times V$

$= 5959.751 \times 124.277$

$= 740660.05$ W

(or)

740.66 KW

(or)

993.241 HP

Problem 2:

corner = 0.35 miles × 1609.344 = 563.27 m

$\pi R = 563.27 \Rightarrow R = 179.295 \approx 179.3$ m

straight, $L = \frac{1.5 - 2(0.35)}{2} = 0.4$ miles $= 643.74$ m

lateral acceleration $a_y = \frac{V_x^2}{R}$

$$V_x = \sqrt{a_y R}$$

$$= \sqrt{1.2 \times 9.81 \times 179.3}$$

Cornering speed, $V_x = 45.94$ m/s

Straights :

For Acceleration :

$$V_{i_+} = 45.94 \text{ m/s}$$

$$a_{x_+} = 0.5 \times 9.81 = 4.905 \text{ m/s}^2$$

For deceleration,

$$V_{i_-} = 45.94 \text{ m/s}$$

$$a_{x_-} = 11.772 \text{ m/s}^2$$

a_{x-} is positive because although we are decelerating, we are calculating the velocity profile in reverse.

let, transition point $\rightarrow S_T$, length of straight $\rightarrow L$

since $V_{F+} = V_{F-}$ (at S_T)

$$V_{i+}^2 + 2a_{x+} S_T = V_{i-}^2 + 2a_{x-}(L - S_T)$$

$$V_{i+} = V_{i-} \quad \text{[cornering velocity)}$$

$$a_{x+} S_T = a_{x-}(L - S_T)$$

$$a_{x+} S_T = a_{x-} L - a_{x-} S_T$$

$$S_T = \frac{a_{x-} L}{(a_{x+} + a_{x-})} = \frac{11.772 \times 643.74}{(4.905 + 11.772)}$$

$$= \frac{7578.107}{16.677} = 454.40 \text{ m}$$

$\therefore$ velocity at S_T:

$$V_{F+}^2 = V_{i+}^2 + 2a_{x+} S_T = (45.94)^2 + 2(4.905)(454.4)$$

$$V_{F+} = 81.04 \text{ m/s}$$

Time taken to accelerate

$$V_F = V_i + a_{x+} t_A$$

$$81.04 = 45.94 + 4.905 t_A$$

$$t_A = 7.156 \text{ s}$$

Time taken to decelerate

$$V_F = V_i + a_{x-} t_B$$

$$81.04 = 45.94 + 11.772 t_B$$

$$t_B = 2.982 \text{ s}$$

Time taken to corner:

$$t_c = \frac{D_c}{V_c} = \frac{0.35 \times 1609.344}{45.94} \Rightarrow t_c = 12.261 \text{ s}$$

$$\text{Total time} = 2(7.156) + 2(2.982) + 2(12.261)$$

$$= 44.798 \text{ s}$$

$$\text{Average speed} = \frac{\text{total ditance}}{\text{total time}} = \frac{2414.016}{44.798}$$

$$= 53.887 \text{ m/s}$$

A) Minimum time required = 44.798 s

B) Average speed = 53.887 m/s

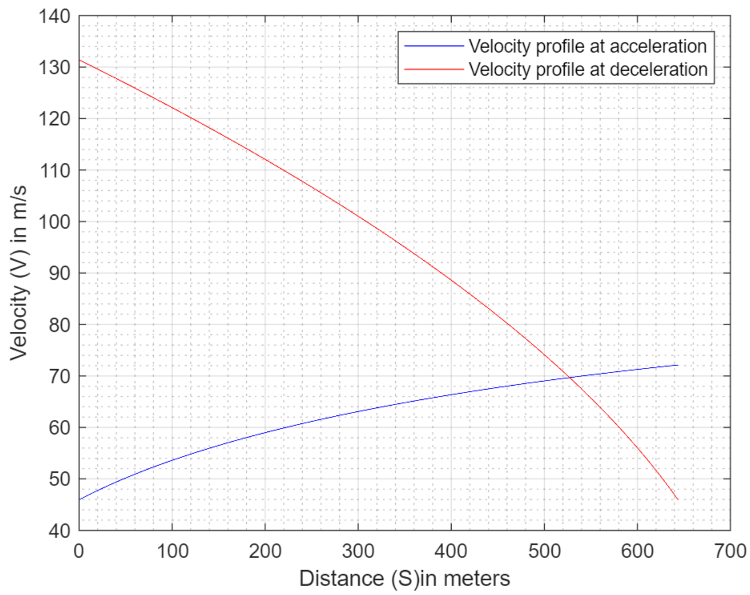
C) Cornering speed = 45.94 m/s

D) Maximum speed = 81.04 m/s

E) Braking transition point = 454.40 m

Problem 3:

Forward and backward velocity profile:



Results:

The maximum speed on straights = 69.6831 m/s

Braking point, ST = 527.1884 m

Time taken during acceleration; ta = 8.8260 s

Time taken during deceleration; td = 2.0169 s

Time taken to corner; tc = 12.2610 s

Minimum lap time; lap_time = 2*(ta+td+tc) = 46.2078 s

Average speed; avg_speed = 52.2426 m/s

(MATLAB scripts can be found in Appendix)

Problem 4:

Coast-down procedure without considering headwind

Part A

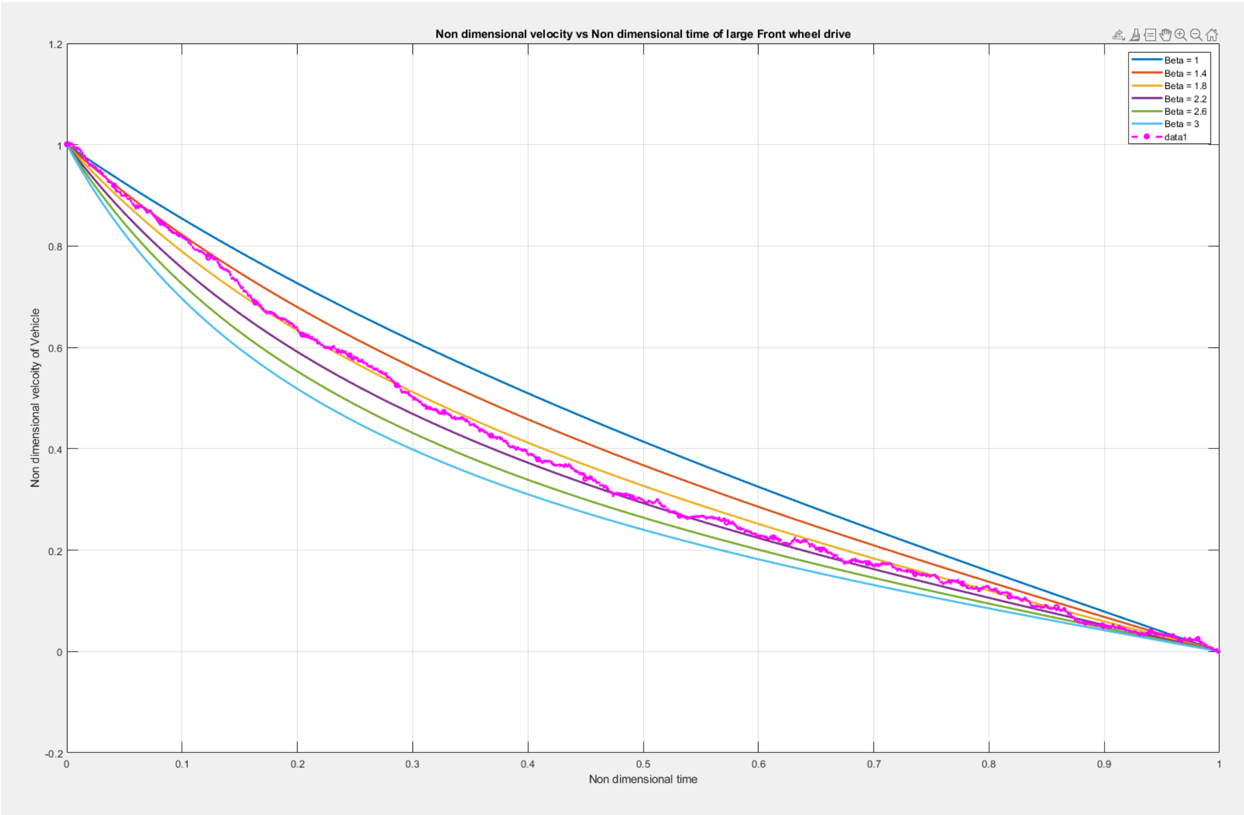


Figure 1 Non dimensional velocity vs Non dimensional time

Part B

You can use different methods as mentioned in class to identify which value of β fits the given experimental data. Nonlinear least squares, manually identifying the value and root mean square error are some of the useful methods. We can notice the value of $\beta \approx 1.8$ from manual identification.
The value of β can be between 1.8 to 2

Part C

From the value of chosen β, we can calculate the coefficient of drag and Rolling resistance

$$C_d = \frac{2 * m * \beta * \tan^{-1} \beta}{\rho * A_f * V_0 * T}$$

$$R_x = \frac{V_0 * m * \tan^{-1} \beta}{\beta * T}$$

Based on value of chosen β, range of C_d is [0.514, 0.594] and range of R_x is [154.3, 144.4]

Coast-down procedure with wind

Part a

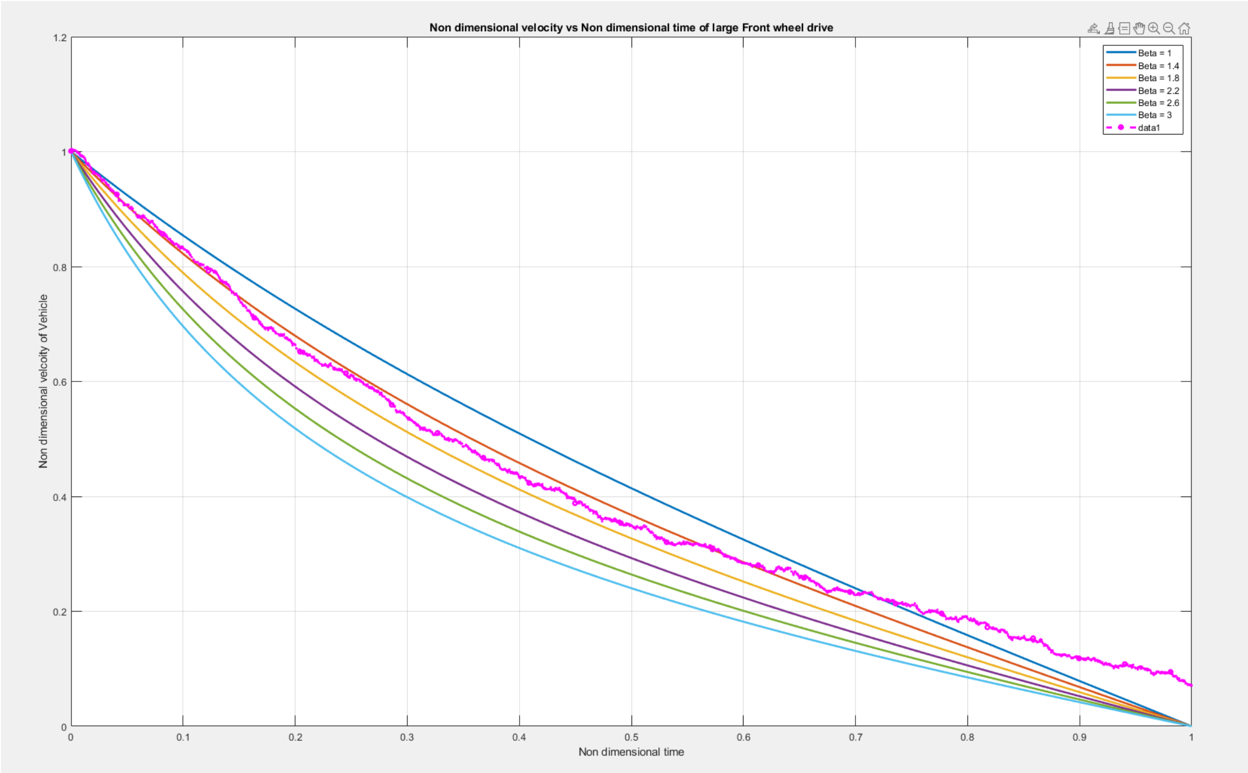


Figure 2 Non dimensional velocity vs Non dimensional time

Part B

You can use different methods as mentioned in class to identify which value of β fits the given experimental data. Nonlinear least squares, manually identifying the value and root mean square error are some of the useful methods. We can notice the value of $\beta \approx 1.8$ from manual identification.
The value of β can be between 1.4 to 1.8

Part C

From the value of chosen β, we can calculate the coefficient of drag and Rolling resistance

$$C_d = \frac{2 * m * \beta * \tan^{-1}\beta}{\rho * A_f * V_0 * T}$$

$$R_x = \frac{V_0 * m * \tan^{-1}\beta}{\beta * T}$$

Based on value of chosen β, range of C_d is [0.31, 0.45] and range of R_x is [204, 178]

Appendix:

```
%Problem3

clc;
clear all;
close all;

mass=80*14.593903; %Kg
Pwheel=370*746;
L=643.738;
CdA=7.5*0.09290304; %m^2
rho=1.225;
dragpower_constants=0.5*rho*CdA;

%% Euler Forward during acceleration:
dt=0.001;
v_init=45.94; %CORRECTION
vx_acc=[]; vx_acc(1)=v_init;
s_acc=[]; s_acc(1)=0;
j=1;
for i=0:dt:20
   ax_acc=(Pwheel - dragpower_constants*(vx_acc(j)^3))/(mass*vx_acc(j));
   vxPlus=vx_acc(j)+dt*ax_acc;
   sPlus=s_acc(j)+dt*vx_acc(j);

   if sPlus>L
       break;
   end

   vx_acc=[vx_acc,vxPlus];
   s_acc=[s_acc,sPlus];
   j=j+1;
end

%% Euler Forward during deceleration:
vx_dec=[]; vx_dec(1)=v_init;
ax_dec=11.772;                     % deceleration limit
s_dec=[];s_dec(1)=L;
k=1;
for i=0:dt:20
   vxMinus=vx_dec(k)+ax_dec*dt;
   sMinus=s_dec(k)-dt*vx_dec(k);

   if sMinus<0
       break;
   end

   vx_dec=[vx_dec,vxMinus];
   s_dec=[s_dec,sMinus];
   k=k+1;
end
```

```
%% Determining intersection of velocity profiles:
st_vx_t=[];
check=[];
for i=1:length(s_acc)
    for j=1:length(s_dec)
        deltaS=abs(s_acc(i)-s_dec(j));
        if deltaS<0.1   % tolerance for difference in distance
           deltaV=abs(vx_acc(i)-vx_dec(j));
           if deltaV<0.01   %tolerance for difference in velocity

st_vx_t=[st_vx_t;[i,s_acc(i),vx_acc(i),deltaS,j,s_dec(j),vx_dec(j),deltaV]];     %array
saving the acceptable sequences of S and corresponding Vx for inspection later
           end
        end
    end
end
[M,I]=min(st_vx_t(:,8));    %Here, the point with least velocity difference is accepted
as ST. Condition can also be placed on the difference in distance or both distance and
velocity as well. Could be checked manually too

%% Other parts
k=st_vx_t(I,1);
ta=dt*k;    % time to accelerate
td=(vx_acc(k)-v_init)/ax_dec; % time to decelerate; Vf=v0-at

Lc = 0.35*1609.344; % Cornering length
tc = Lc/v_init; %Cornering Speed

lap_time = 2*(tc+ta+td);  %lap time
avg_speed = (2*(L+Lc))/lap_time; % average speed

%% Output & Plots
figure(1)
plot(s_acc,vx_acc,'b');
hold on;
plot(s_dec,vx_dec,'r');
grid on;
grid minor;
xlabel('Distance (S)in meters')
ylabel('Velocity (V) in m/s')
legend('Velocity profile at acceleration','Velocity profile at deceleration')


display('The maximum speed on straights=')
display(vx_acc(k))
display('Braking point, ST=')
display(s_acc(k))
display('Time taken during acceleration;')
display(ta)
display('Time taken during deceleration;')
display(td)
display('Time taken to corner;')
display(tc)
display('Minimum lap time;')
display(lap_time)
```

```
display('Average speed;')
display(avg_speed)
```

```
%%Problem4

%% Vehicle Parameters
m=78.8*14.5939; % mass of vehicle in kg by multiplying slugs with conversion factor
l=2660; % length of wheelbase in mm
a=1064; % distance from front axle to CG
b=l-a; % distance between rear axle to CG
rho=1.225; % Standard atmospheric density
A_f=22.17*0.092903; % Frontal area in m^2 by multiplying sq.ft with conversion factor
g=9.81; % acceleration due to gravity in m/s^2
Vel_win=4.8*1.61*5/18; % Wind Velocity in m/s by converting mph to m/s
%% Loading the data and simulating without considering Velocity of wind
load LargeFWD1.mat % loading data onto workspace
T=t(end); % time at which Velocity of car is zero
V0=27.778; % Initial velocity of car in m/s

figure(1)
plot(t/T,Vx/V0,'LineWidth',2)
xlabel('Non dimensional time')
ylabel('Non dimensional velocity of Vehicle')
title('Non dimensional velocity vs Non dimensional time of large Front wheel drive')
grid on

% Non dimensional velocity and time for various values of beta
t1=0:0.1:T; % time data for velocity plot
beta=1:0.4:3; % range of beta values
y=zeros(length(t1),length(beta));
for i=1:length(beta)
    y(:,i)=(V0/beta(i))*tan((1-t1/T)*atan(beta(i)));
    txt=['Beta = ', num2str(beta(i))];
    figure(2)
    plot(t1/T,y(:,i)/V0,'Linewidth',2,'DisplayName',txt)
    xlabel('Time in Seconds')
    ylabel('Velocity of Vehicle in m/s')
    title('Velocity vs time of large Front wheel drive for various values of beta')
    grid on
    hold on
end

plot(t/T,Vx/V0,'m--o','LineWidth',2, 'MarkerSize',4,'MarkerIndices',1:500:length(t))
xlabel('Non dimensional time')
ylabel('Non dimensional velocity of Vehicle')
title('Non dimensional velocity vs Non dimensional time of large Front wheel drive')
grid on
legend show
%% Calculating coefficient of drag and Rolling resistance
beta_f=1.8:0.1:2;
Cdrag= 2*m*beta_f.*atan(beta_f)/(V0*T*rho*A_f); % Values of coefficient of drag
Rx=V0*m*atan(beta_f)./(beta_f*T); % Rolling Resistance in N
%% Loading the data and simulation considering Velocity of wind
figure(3)
V0=27.778+Vel_win; % Initial velocity of car in m/s
plot(t/T,(Vx+Vel_win)/V0,'LineWidth',2)
xlabel('Non dimensional time')
ylabel('Non dimensional velocity of Vehicle')
title('Non dimensional velocity vs Non dimensional time of large Front wheel drive')
```

```
grid on

% Non dimensional velocity and time for various values of beta
t1=0:0.1:T; % time data for velocity plot
beta=1:0.4:3; % range of beta values
y=zeros(length(t1),length(beta));
for i=1:length(beta)
    y(:,i)=(V0/beta(i))*tan((1-t1/T)*atan(beta(i)));
    txt=['Beta = ', num2str(beta(i))];
    figure(4)
    plot(t1/T,y(:,i)/V0,'Linewidth',2,'DisplayName',txt)
    xlabel('Time in Seconds')
    ylabel('Velcoity of Vehicle in m/s')
    title('Velocity vs time of large Front wheel drive for various values of beta')
    grid on
    hold on
end

plot(t/T,(Vx+Vel_win)/V0,'m--o','LineWidth',2, 'MarkerSize',4,'MarkerIndices',1:500:length(t))
xlabel('Non dimensional time')
ylabel('Non dimensional velcoity of Vehicle')
title('Non dimensional velocity vs Non dimensional time of large Front wheel drive')
grid on
legend show
%% Calculating coefficient of drag and Rolling resistance
beta_f=1.4:0.1:1.8;
Cdragw= 2*m*beta_f.*atan(beta_f)/((V0+Vel_win)*T*rho*A_f); % Values of coefficient of drag
Rxw=(V0+Vel_win)*m*atan(beta_f)./(beta_f*T); % Rolling Resistance in N
```