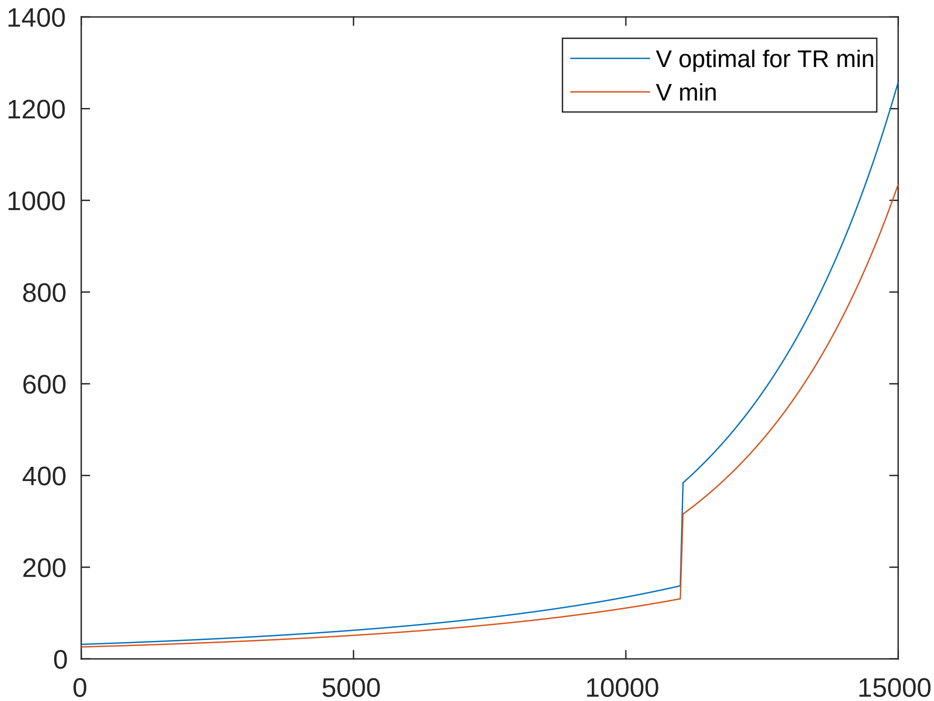
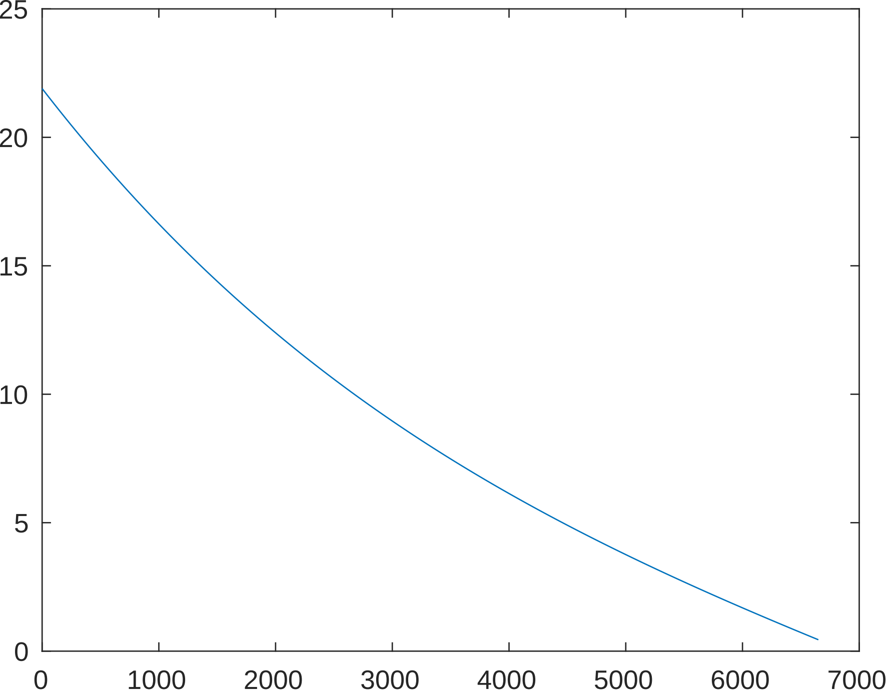
```
%AER1216_Assignment3_q1
clear

%% Background Information

rho_s = 1.2250;
temp_s = 288.16;

cl_max = 1.2;
S = 20; % in m2
W = 10000; %in N
AR = 10;
cd_0 = 0.03;
epsilon = 0.7;
K = 1/(pi*epsilon*AR);
cl_TR_min = sqrt(cd_0/K);
Ts = 5000; % in N

%% Part A

heights = 0:50:15000;

V_min = zeros(length(heights),1);
V_TR_min = zeros(length(heights),1);

for i = 1:length(heights)
    h_a = heights(i);
    rho_curr = atm(h_a); % Rho at current Height
    V_min(i) = sqrt(2*W/(S*cl_max*rho_curr));
    V_TR_min(i) = sqrt(2*(W/S)/(rho_curr*cl_TR_min));
end

plot(heights,V_TR_min);
hold on
plot(heights,V_min);
legend({'V optimal for TR min','V min'});
hold off

%% Part B

alt_b = zeros(5,1);
cr_max = zeros(5,1);
v_cr_max = zeros(5,1);

j = 1;
cr_max(length(cr_max)) = 1; % to initiate the loop
while cr_max(length(cr_max)) >= 0.5
    alt_b(j) = 50*(j-1);
    rho_curr = atm(alt_b(j)); % Rho at current Height
    T = (rho_curr/rho_s)*Ts;
    v_cr_max(j) = sqrt((T/S)*(1 +
sqrt(1+(12*cd_0*K/((T/W)^2))))/(3*rho_curr*cd_0));
```

```
    cr_max(j) = v_cr_max(j)*((T/W) -
((0.5*rho_curr*cd_0*v_cr_max(j)^2)/(W/S)) -
((2*K*W)/(S*rho_curr*v_cr_max(j)^2)));
    j = j+1;
end

plot(alt_b,cr_max);

%alt_b(length(alt_b))



%% Generating the Standard Atmosphere conditions till 15 Km
function rho = atm(h)    % h taken in Km

rho_s = 1.2250;
temp_s = 288.16;

temp = temp_s + -0.0065*h;

    if h <= 11000
        rho = rho_s*(temp/temp_s)^-(9.8/(-0.0065*287 + 1));
    else
        rho_1 = rho_s*(temp/temp_s)^-(9.8/(-0.0065*287 + 1));
        rho = rho_1*(2.718)^-(9.8*(h-11)/(287*temp));
    end
end
```


V optimal for TR min
V min
0
200
400
600
800
1000
1200
1400
0
5000
10000
15000



25
20
15
10
5
0
0
1000
2000
3000
4000
5000
6000
7000

(c)

$$R = -\int_{W_0}^{W_1} \frac{V}{C_t T}\, dW$$ (Taken from Notes)

$$\Rightarrow -\int_{W_0}^{W_1} \underbrace{\frac{V}{C_t}}_{\text{TSFC}} \times \frac{C_L}{C_D} \times \frac{dW}{W}.$$

V → Constant

$\underline{\alpha \rightarrow \text{Const}}$; $C_L, C_D \longrightarrow$ Const

$$\Rightarrow W_0 = W$$

$$\Rightarrow W_1 = W - W_f$$

$$R = -\frac{V C_L}{C_t C_D} \int_{W_0}^{W_1} \frac{dW}{W}$$

$$\Rightarrow -\frac{V C_L}{C_t C_D} \times \ln\left(\frac{W_1}{W_0}\right)$$

$$\boxed{R \Rightarrow \frac{V C_L}{C_t C_D} \times \ln\left(\frac{W_0}{W_1}\right)}$$

(d) for $R = 100$ km

$$\left(\frac{C_L}{C_D}\right)_{max} \Rightarrow \frac{1}{2\sqrt{K C_{D_0}}}$$

$$10^5 \Rightarrow \frac{\cancel{(0.7)}(V_{sound})}{\cancel{(0.7)}} \times \left(\frac{1}{2\sqrt{K C_{D_0}}}\right) \times \ln\left(\frac{10000}{W_1}\right)$$

$$10^5 = 343 \times \frac{1}{2\sqrt{\frac{C_{D_0}}{\pi e AR}}} \times \ln\left(\frac{10000}{W_1}\right)$$

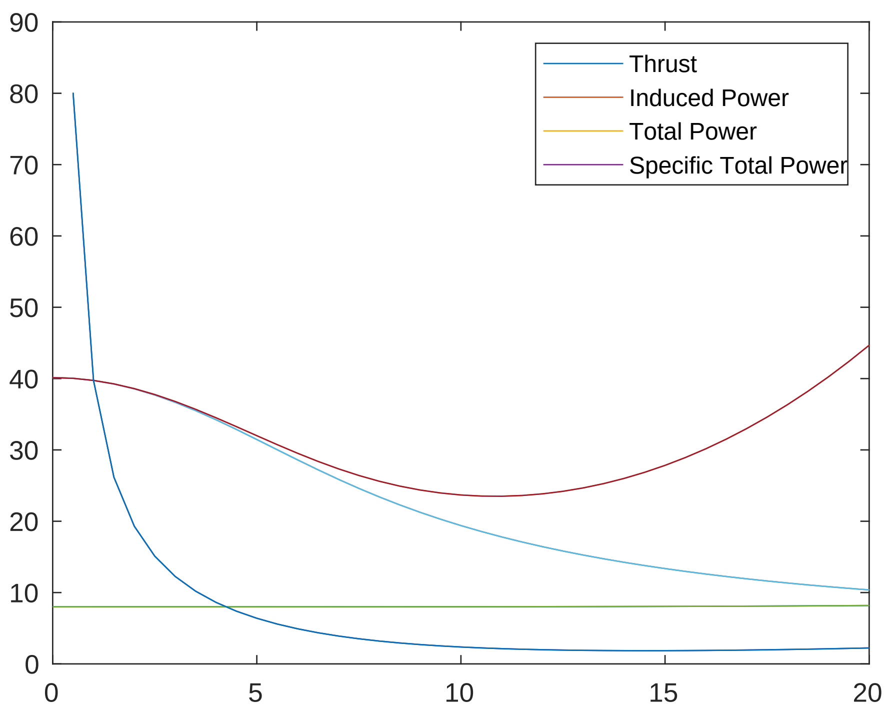
$$W_1 \Rightarrow 2 \times 10^5 \Rightarrow \left(343 \times \sqrt{\frac{\pi e AR}{C_{D_0}}}\right) \times \ln\left(\frac{10000}{W_1}\right)$$

$$\ln\left(\frac{W_1}{10000}\right) \Rightarrow -\frac{2 \times 10^5}{343} \times \sqrt{\frac{C_{D_0}}{\pi e AR}}$$

Code :

```
clear
% AER1216 Assignment3 Q2

W = 8; % in N
cd = 0.7;
S = 0.01; % in m2
k_v = 1050*(2*pi/60); % in rpm/V
i_0 = 0.4; % in A
r_m = 0.12; % in Ohms
k_t = 1/k_v;
r_e = 0.05; % in Ohms

rad = 4*0.0254; % in m
A = 4*pi*(rad)^2; % in m2
rho = 1.225; % in Kg/m3

%% Q2 - Part A
p_ind_momentum = sqrt((W^3)/(2*rho*A))

%% Q2 - Part B
cells = 3;
power = (1300/1000)*3600; % in A-s
e_b = cells*3.7*power;
t_e_momentum = e_b/(p_ind_momentum)

%% Q2 - Part C
% Hover -> V = 0
% We need Thrust  = 2N, Which we recieve for 5000 RPM
% Thus, Power Required = 15.6596973 W * 4

p_actual = 15.6596973 * 4

%% Q2 - Part D
t_e_actual_ideal = e_b/p_actual

%% Q2 - Part E
t_e_actual_actual = t_e_actual_ideal*0.85*0.95

%% Q2 - Part F
c =  12.3063;

d =  -0.000328;

b =  -0.008112;

e =  -4.7809e-7;

a =  -7.7835e-7;

f = 1.4086e-10;

T = W/4; % in N
ct = 0.1415;
n = sqrt(T/(ct*rho*(2*rad)^4));
Q = 0.030166949343; % in N-m
i_m = Q/k_t + i_0; % in A
omg = 5000;
v_mi = omg/k_v + i_m*r_m;
v_et = v_mi + i_m*r_e;

dt = 1; % in s
D = 1; % in mA-hr
t = 0;
k_e = 1;

while D <= power && k_e >= 1

g = (a*D^2 + b*D + c)/(1 + d*D + e*D^2 + f*D^3);
k_e = (v_et*(i_m^0.05)/g)^(1.052);
i_b = i_m*k_e;

D = D + i_b*dt;
k_e;
t = t + dt;

end

t_e_f = t


%% Q2 - Part G
values = 0:0.5:20;

thrust_all = zeros(2,1);
p_induced_all = zeros(2,1);
p_tot_all = zeros(2,1);
syms v

for j = 1:length(values)
```

```
    V = values(j);
    D = 0.5*rho*V*V*S*cd;
    alpha_d = atan(D/W);
    eqn = v^4 +  (2*V*sin(alpha_d))*v^3 + V^2*v^2 - (W^2 + D^2)/(2*rho*A)^2 == 0;
    thrust = sqrt(W^2 + D^2);
    v_val = double(max(solve(eqn,v, 'Real',true)));
    P_ind = thrust*(v_val);
    P_tot = thrust*(v_val+ V*sin(alpha_d));

    thrust_all(j) = thrust;
    p_induced_all(j) = P_ind;
    p_tot_all(j) = P_tot;
end

specific_power = p_tot_all./values';

plot(values,thrust_all);
hold on;
plot(values,p_induced_all);
plot(values,p_tot_all);
plot(values,specific_power);

legend({'Thrust','Induced Power','Total Power','Specific Total Power'})


Answers:

All powers in Watts
All time in seconds

part a =

   40.1378 W

part b =

   1.2942e+03 s

part c =

   62.6388 W

part d =

  829.3264 s

part e =

  669.6810 s

part f =

   262 s

part g = Plot added

part h =

  t_max =

   1.7846e+03 s


  V =

   11.5000 m/s
```



Thrust
Induced Power
Total Power
Specific Total Power
0
10
20
30
40
50
60
70
80
90
0
5
10
15
20

1. In the cruising situation, the drag and thrust are balaced perfectly. Now in case, the thrust is suddenly cut-off, the drag will start reducing the forward speed of the aeroplane ultimately leading to the stall condition. For extending the Flight time, pilot can try to decrease the altitude and at the same time, increase the angle of attack on the wings. This will reduce the Thrust required. The pilot must try to maintain the plane at the minimum drag location in the Thrust required curve.

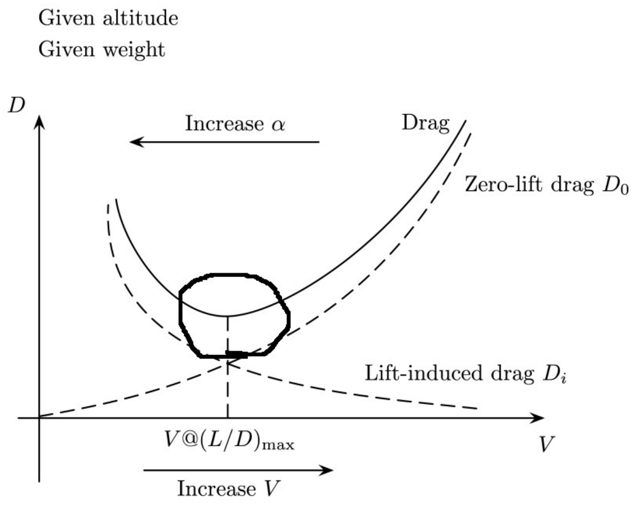


Figure 6: Thrust-required Curve

2. Thrust is a function of both the lift and the Drag. Thus, with increase in the velocity, both the lift and the drag increase, but the term L/D depends on the relative increase. Furthermore, the Lift coefficient and the Drag Coefficient depend on the nagle of attack, which is also function of velocity. As Velocity increases, angle of attack decreases, and thus, Cl decreases. The dynamics of velocity and angle of attack determine the Thrust required.

3. Considering a regular civil flight, with the mission of having the best fuel economy, we choce of propeller becomes a simple question of the power requirements. Now, We need to decide on the pitch and the Diameter of a propeller, keeping in mind that we need to be able to have the required Lift at the cruise speed so as to balance weight. For the given situation, we will further consider the velcoity at which we want the cruising speed. So we start wuth the velocity, decide the L/D for minimum thrust requirements form the plot. Once we have the thrust, we know the requirement of thrust from the propeller. Next, we pickup the APC database and search for propellers of suitable size according to the plane size and manueverability requiremnts. Once we select a few propellers, we calculate the power requirements for each propeller, as performed in the class, and then keep the one with the minimum power requirements.