```
% Furquaan Syed
% 12/8/2021
% Professor Leonard
% ECE 202 Fall 2021 Project 2
% Using numerical techniques to calculate range, height and flight time
% of a baseball

% close collaborator with Ryan Palmer

        %---Phase 5---%

%---Exploring the results ---%


clear
clf
format shortg

%--- Parameters ---%

theta = 32; % launch angle in degrees
v0 = 112;   % Exit velocity in miles per hour (mph)

x0 = 0; y0 = 0;  % initial position of the ball

g = 10;   % gravitational constant in N/kg (1 N/kg = 1 m/s^2)

m = 0.145;     % mass of baseball in kilograms

p = 1.225;   %density of air in kg/m^3
A = pi() * 0.0365^2; %cross sectional area of a baseball in m^2

C = input('Enter C value for drag coefficient: ');

mph2mps = 5280 * 12 * 2.54 / 100 / 3600;   % mph to m/s conversion
deg2rad = pi()/180;   % degrees to radians
m2feet = 3.281;     %meters to feet

    % add a conversion from m to ft, e.g. m2ft, and use it several times


v0mps = v0 * mph2mps;       % Exit velocity in meters per second
thetaRad = theta * deg2rad;   % launch angle in radians

v0x = v0mps * cos(thetaRad);   % x-component of v0
v0y = v0mps * sin(thetaRad);   % y-component of v0


```

```
49 % ----- compute some useful characteristics of trajectory -----
50
51 tH = v0y/g;    % time to reach max. height
52 tLand = 2*tH;   % time to land (time of flight)
53
54 H = tH * v0y/2;   % max. height
55 R_ft = v0x * tLand;   % range
56
57 R_m = R_ft * m2feet;    % ROUGH conversion from m to ft
58
59
60 %--- analytical x(t) and y(t)---%
61
62 tmin = 0; tmax = tLand;
63 N = 2000;   % intervals
64
65 t = linspace(tmin, tmax, N+1);   % time array, connects x(t) with y(t)
66
67         %--- calculations for no drag---%
68
69 xt = x0 + v0x*t;   % x(t), ax = 0 (no drag)
70 yt = y0 + v0y*t - (1/2)*g*t.^2;   % y(t), ay = -g (no drag)
71
72
73 % ----- calculations for drag -----%
74
75
76 dt = (tmax-tmin)/N;     %change in time interals
77
78 y = zeros(1, N+1);   % initialize y(t) and x(t)
79 x = zeros(1, N+1);
80
81 y(1) = y0;
82 vy = v0y;
83 x(1) = x0;
84 vx = v0x;
85
86 D = 0.5*C*p*A;  % Constant for drag
87
88
89 for n = 1:N
90
91
92
93     v = sqrt(vx^2 + vy^2);  %velocity of the baseball
94
95
96     fnetx = -D*v*vx;      % net forces acting on the baseball
```

```
 97      ax = fnetx/m;
 98      x(n+1) = x(n) + vx*dt + (1/2)*ax*dt^2;
 99      vx = vx + ax*dt;
100
101
102      fnety = -g*m - D*v*vy;          % after initial launch
103      ay = fnety/m;   % acceleration of y component of baseball
104      y(n+1) = y(n) + vy*dt + (1/2)*ay*dt^2;   % vy = y', ay = y"
105      vy = vy + ay*dt;   % vy(n+1) = vy(n) + ay*dt
106
107
108
109      if y(n) / y(n+1) < 0
110          time_of_flight_s = t(n)
111          xF = x(n);      %range of travel of baseball in meters
112          vF = v;         % final velocity of baseball in meters/secomd
113      end
114
115  end
116
117  xt = xt * m2feet;       % convert everything to feet
118  yt = yt * m2feet;
119  y = y * m2feet;
120  x = x * m2feet;
121
122  % check to see that y = yt and x = xt, , point by point
123
124  if C == 0
125      checkSumy = sum(abs(y-yt))
126      checkSumx = sum(abs(x-xt))
127  end
128
129
130
131  %---Calculating flight time, maximum height, and range---%
132
133  range_ft = xF * m2feet      % range of travel of baseball in ft
134  maxHeight_ft = max(y)             % maximum height in feet
135  Final_Velocity_mph = vF/mph2mps
136                       % Final velocity of baseball in miles per hour
137
138
139  energyLoss_J = 0.5*m*(v0mps^2 - vF^2) %energy lost In J
140
141
142  %--- Comparing Results to MLB statcast---%
143
144  R0 = 446; % measured range of home run from original diagram
```

```
145                     % in feet
146
147 percentError_range = (range_ft-R0)/R0 * 100
148       % Margin of error from simulated range and range from MLB statcast
149
150 H0 = 114;
151                     % measured maximum height of home run from original
152                     % diagram in feet
153
154 percentError_maxHeight = (maxHeight_ft - H0)/H0 * 100
155         % Margin of error from simulated max height and max height
156         % from MLB statcast
157
158 T0 = 5.7;   % Measured time of flight of home run from original
159                     % diagram in seconds
160
161 percentError_flightTime = (time_of_flight_s-T0)/T0 * 100
162                 % Margin of error from simulated flight time and time
163                 % from MLB statcast
164
165 %  Our calculation for range is almost exactly accurate, with a percent
166 %  error of -0.04%
167 %  The calculation is not as accurate for the maxiumum height and flight
168 %  time
169
170 % ----- plot ---- %
171
172 plot(xt, yt, x, y, 'LineWidth', 2)
173
174
175
176 grid on
177 grid minor
178
179 ax = gca; ax.FontSize = 15; ax.GridAlpha = 0.5;
180
181 xlabel('x (ft)', 'FontSize', 18)
182
183 ylabel('y (ft)', 'FontSize', 18)
184
185 title({'ECE 202 Project 2, Phase 3: Trajectory of a baseball', ...
186     'Drag vs. No Drag'}, 'FontSize', 22)
187
188 legend('Without Drag', sprintf('With Drag, C = %g', C), 'FontSize', 18)
189
190 ylim([-20 150])
191
192 %--- export to a csv file for Excel ---%
```

```
193 headers = ["t (s)" "x (ft)" "y (ft)"];    %labels for columns in excel
194
195 data = [t; x; y].';
196
197 export = [headers; data];
198
199 writematrix(export, 'FurquaanSyedProject2Phase3.csv')
200
201
202
203
```