

```
1 % Furquaan Syed
2 % 12/8/2021
3 % Professor Leonard
4 % ECE 202 Fall 2021 Project 2
5 % Using numerical techniques to calculate range, height and flight time
6 % of a baseball
7
8 % close collaborator with Ryan Palmer
9
10      %---Phase 5---%
11
12 %---Exploring the results ---%
13
14
15 clear
16 clf
17 format shortg
18
19 %--- Parameters ---%
20
21 theta = 32; % launch angle in degrees
22 v0 = 112; % Exit velocity in miles per hour (mph)
23
24 x0 = 0; y0 = 0; % initial position of the ball
25
26 g = 10; % gravitational constant in N/kg (1 N/kg = 1 m/s^2)
27
28 m = 0.145; % mass of baseball in kilograms
29
30 p = 1.225; %density of air in kg/m^3
31 A = pi() * 0.0365^2; %cross sectional area of a baseball in m^2
32
33 C = input('Enter C value for drag coefficient: ');
34
35 mph2mps = 5280 * 12 * 2.54 / 100 / 3600; % mph to m/s conversion
36 deg2rad = pi()/180; % degrees to radians
37 m2feet = 3.281; %meters to feet
38
39 % add a conversion from m to ft, e.g. m2ft, and use it several times
40
41
42 v0mps = v0 * mph2mps; % Exit velocity in meters per second
43 thetaRad = theta * deg2rad; % launch angle in radians
44
45 v0x = v0mps * cos(thetaRad); % x-component of v0
46 v0y = v0mps * sin(thetaRad); % y-component of v0
47
48
```

```
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 intervals
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/second
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 maximum 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
```

```
>> Project2Phase5  
Enter C value for drag coefficient: 0.26
```

```
time_of_flight_s =  
    4.5662
```

```
range_ft =  
    445.82
```

```
maxHeight_ft =  
    86.4
```

```
Final_Velocity_mph =  
    66.664
```

```
energyLoss_J =  
    117.36
```

```
percentError_range =  
   -0.03931
```

```
percentError_maxHeight =  
   -24.211
```

```
percentError_flightTime =  
   -19.891
```

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>>
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