```matlab
1  % Furquaan Syed
2  % 12/8/2021
3  % Professor Leonard
4  % Close collaborator with Ryan Palmer (and Professor Leonard)
5  % ECE 202 Fall 2021 Project 2
6  % Using numerical techniques to calculate range, height and flight time
7  % of a baseball
8
9
10         %---Phase 1---%
11
12 % Comparing the analytic solutions to the numeric, without drag
13
14
15 clear
16 clf
17 format shortg
18
19 %--- Parameters ---%
20
21 phi0_deg = 32; % launch angle in degrees
22 v0mph = 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 (kg)
29
30
31 mph2mps = 5280 * 12 * 2.54 / 100 / 3600;   % mph to m/s conversion
32 deg2rad = pi()/180;   % degrees to radians
33 m2feet = 3.3;   %Convert from meters to feet
34
35
36
37 v0 = v0mph * mph2mps;       % Exit velocity in meters per second
38 phi0 = phi0_deg * deg2rad;   % launch angle in radians
39
40 v0x = v0 * cos(phi0);   % x-component of v0
41 v0y = v0 * sin(phi0);   % y-component of v0
42
43
44 % ----- compute some useful characteristics of trajectory -----
45
46 tH = v0y/g;    % time to reach max. height
47 tLand = 2*tH;   % time to land (time of flight)
48
```

```matlab
49 H = tH * v0y/2;    % max. height
50 R_ft = v0x * tLand;   % range
51
52 R_m = R_ft / m2feet;     % ROUGH conversion from m to ft
53
54
55 % -----  analytical x(t), y(t)  -----
56
57 tmin = 0; tmax = tLand;
58 N = 2000;   % intervals
59
60 t = linspace(tmin, tmax, N+1);   % time array, connects x(t) with y(t)
61
62 xt = x0 + v0x*t;   % x(t), ax = 0 (no drag)
63 yt = y0 + v0y*t - (1/2)*g*t.^2;   % y(t), ay = -g (no drag)
64
65
66 % ----- add numeric solution -----
67
68
69 dt = (tmax-tmin)/N;     %change in time interals
70
71 y = zeros(1, N+1);   % initialize y(t)
72 x = zeros(1, N+1);
73
74 y(1) = y0;
75 vy = v0y;
76 x(1) = x0;
77 vx = v0x;
78
79 for n = 1:N   % stop at N
80     F_x = 0;                % net forces acting on the baseball
81     F_y = -g*m;             % after initial launch
82
83     ay = F_y/m;   % acceleration of y component of baseball
84     ax = F_x/m;
85
86     y(n+1) = y(n) + vy*dt + (1/2)*ay*dt^2;   % vy = y', ay = y"
87     x(n+1) = x(n) + vx*dt + (1/2)*ax*dt^2;
88     vy = vy + ay*dt;   % vy(n+1) = vy(n) + ay*dt
89     vx = vx + ax*dt;
90
91 end
92
93 xt = xt * m2feet;
94 yt = yt * m2feet;
95 y = y * m2feet;
96 x = x * m2feet;
```

```matlab
 97
 98 % check to see that y = yt and x = xt, , point by point
 99
100 checkSumy = sum(abs(y-yt))
101
102 checkSumx = sum(abs(x-xt))
103
104
105
106 % ----- plot ----
107
108 plot(xt, yt, x, y, 'LineWidth', 2)
109
110
111
112 grid on
113
114 grid minor
115
116 ax = gca; ax.FontSize = 15; ax.GridAlpha = 0.5;
117
118 xlabel('x (m)', 'FontSize', 18)
119 ylabel('y (m)', 'FontSize', 18)
120
121 title({'ECE 202, Project 2 Phase 1: Trajectory of a baseball', ...
122     'no drag, analytic vs. numeric solution'}, 'FontSize', 22)
123
124 legend({'analytic (behind numeric)', 'numeric'}, ...
125     'FontSize', 18)
126
127 ylim([-20 150])
128
129
```