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% 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 3---%

% Exporting data to Excel


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


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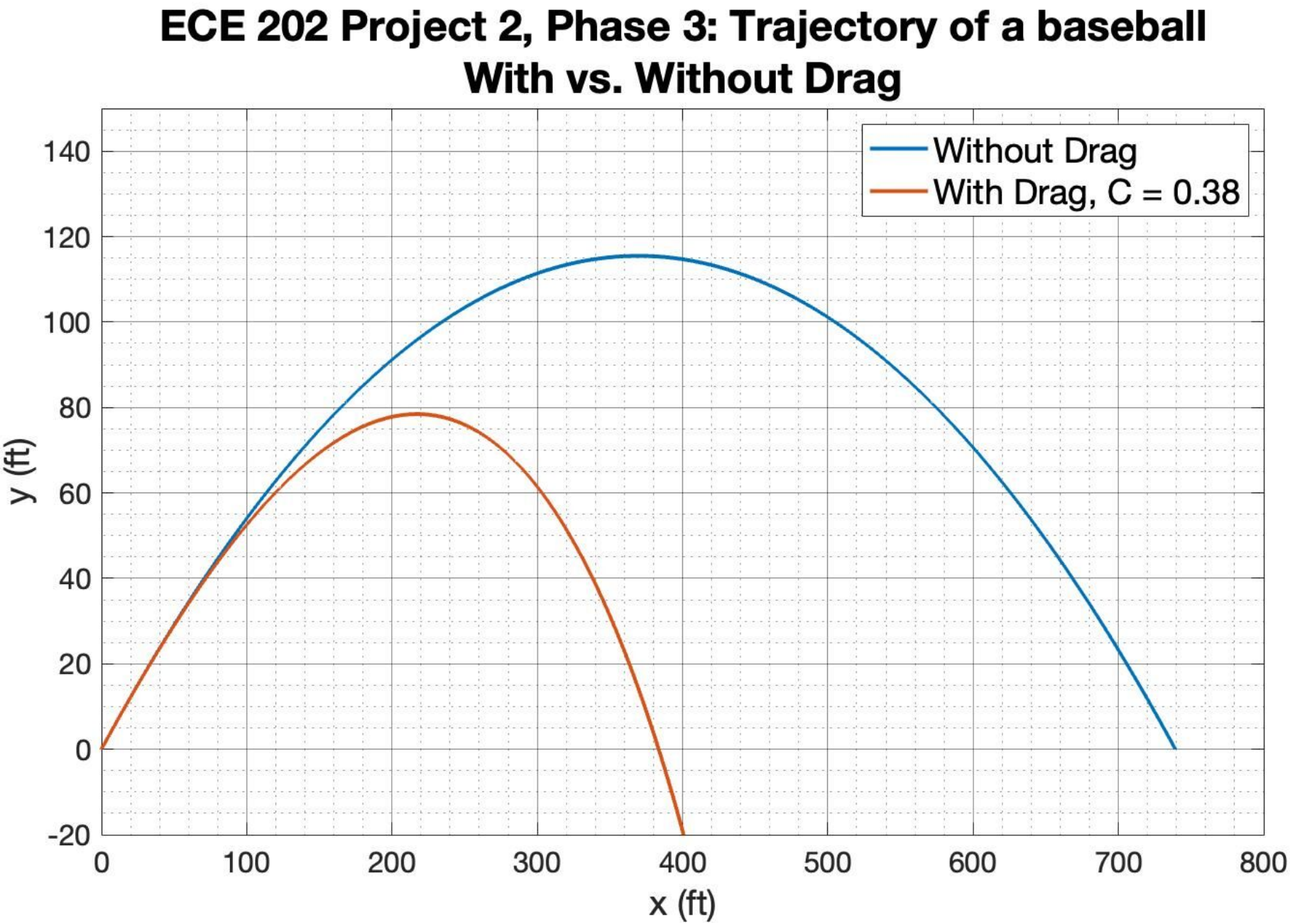
```
49 % ----- compute some useful characteristics of trajectory -----
50
51 tH = v0y/g;    % time to reach max. height
52 tLand = 2*tH;   % time to land (time of flight)
53
54 H = tH * v0y/2;   % max. height
55 R_ft = v0x * tLand;   % range
56
57 R_m = R_ft / m2feet;    % ROUGH conversion from m to 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 for n = 1:N
89
90     v = sqrt(vx^2 + vy^2);
91     fnetx = -D*v*vx;      % net forces acting on the baseball
92     fnety = -g*m - D*v*vy;          % after initial launch
93
94     ay = fnety/m;   % acceleration of y component of baseball
95     ax = fnetx/m;
96
```

```
 97     y(n+1) = y(n) + vy*dt + (1/2)*ay*dt^2;   % vy = y', ay = y"
 98     x(n+1) = x(n) + vx*dt + (1/2)*ax*dt^2;
 99     vy = vy + ay*dt;   % vy(n+1) = vy(n) + ay*dt
100     vx = vx + ax*dt;
101
102 end
103
104 xt = xt * m2feet;       % convert everything to feet
105 yt = yt * m2feet;
106 y = y * m2feet;
107 x = x * m2feet;
108
109 % check to see that y = yt and x = xt, , point by point
110
111 checkSumy = sum(abs(y-yt))
112
113 checkSumx = sum(abs(x-xt))
114
115
116
117 % ----- plot ---- %
118
119 plot(xt, yt, x, y, 'LineWidth', 2)
120
121
122
123 grid on
124 grid minor
125
126 ax = gca; ax.FontSize = 15; ax.GridAlpha = 0.5; ax.MinorGridAlpha = 0.4;
127 ax.MinorGridLineStyle = ':';
128
129 xlabel('x (ft)', 'FontSize', 18)
130
131 ylabel('y (ft)', 'FontSize', 18)
132
133 title({'ECE 202 Project 2, Phase 3: Trajectory of a baseball', ...
134     'With vs. Without Drag'}, 'FontSize', 22)
135
136 legend('Without Drag', sprintf('With Drag, C = %g', C), 'FontSize', 18)
137
138 ylim([-20 150])
139
140 %--- export to a csv file for Excel ---%
141 headers = ["t (s)" "x (ft)" "y (ft)"];    %labels for columns in excel
142
143 data = [t; x; y].';
144
```

```
145 export = [headers; data];
146
147 writematrix(export, 'FurquaanSyedProject2Phase3.csv')
148
149
150
151
```


ECE 202 Project 2, Phase 3: Trajectory of a baseball
With vs. Without Drag
Without Drag
With Drag, C = 0.38
y (ft)
x (ft)
140
120
100
80
60
40
20
0
-20
0
100
200
300
400
500
600
700
800

	A	B	C	D	E
1	t (s)	x (ft)	y (ft)	y(t) / y(t + Δt)	Furquaan Syed
2	0	0	0	=C2/C3	Professor Leonard
3	0.002653225	0.3694634	0.2307509	=C3/C4	ECE 202 Project 2
4	0.00530645	0.7385972	0.4610649	=C4/C5	12.13.21
5	0.007959676	1.107402	0.6909428	=C5/C6	Phase 3: Exporting data to Excel and analyzing
6	0.0106129	1.475879	0.9203852	=C6/C7	
7	0.01326613	1.844028	1.149393	=C7/C8	Flight time (s) :
8	0.01591935	2.211851	1.377966	=C8/C9	=INDIRECT(ADDRESS(E18,1))
9	0.01857258	2.579347	1.606105	=C9/C10	Maximum Height (ft):
10	0.0212258	2.946518	1.833812	=C10/C11	=MAX(C:C)
11	0.02387903	3.313364	2.061086	=C11/C12	Range (ft):
12	0.02653225	3.679885	2.287928	=C12/C13	=INDIRECT(ADDRESS(E18,2))
13	0.02918548	4.046084	2.514339	=C13/C14	
14	0.0318387	4.411959	2.74032	=C14/C15	
15	0.03449193	4.777513	2.965871	=C15/C16	
16	0.03714515	5.142744	3.190992	=C16/C17	
17	0.03979838	5.507655	3.415684	=C17/C18	Row where Y value (ft) becomes 0
18	0.0424516	5.872246	3.639949	=C18/C19	=MATCH(MIN(D:D),D:D,0)
19	0.04510483	6.236517	3.863786	=C19/C20	
20	0.04775805	6.600469	4.087195	=C20/C21	
21	0.05041128	6.964103	4.310179	=C21/C22	
22	0.0530645	7.32742	4.532737	=C22/C23	
23	0.05571773	7.690419	4.75487	=C23/C24	
24	0.05837095	8.053102	4.976578	=C24/C25	
25	0.06102418	8.41547	5.197862	=C25/C26	
26	0.0636774	8.777522	5.418723	=C26/C27	
27	0.06633063	9.13926	5.639161	=C27/C28	
28	0.06898386	9.500684	5.859177	=C28/C29	
29	0.07163708	9.861795	6.078771	=C29/C30	
30	0.07429031	10.22259	6.297945	=C30/C31	

	A	B	C	D	E
1	t (s)	x (ft)	y (ft)	y(t) / y(t + Δt)	Furquaan Syed
2	0	0	0	0	Professor Leonard
3	0.002653225	0.3694634	0.2307509	0.500473794	ECE 202 Project 2
4	0.00530645	0.7385972	0.4610649	0.667298219	12.13.21
5	0.007959676	1.107402	0.6909428	0.750710463	Phase 3: Exporting data to Excel and analyzing
6	0.0106129	1.475879	0.9203852	0.800757617	
7	0.01326613	1.844028	1.149393	0.834122903	Flight time (s) :
8	0.01591935	2.211851	1.377966	0.857955115	4.340676
9	0.01857258	2.579347	1.606105	0.875828602	Maximum Height (ft):
10	0.0212258	2.946518	1.833812	0.889730948	78.45086
11	0.02387903	3.313364	2.061086	0.900852649	Range (ft):
12	0.02653225	3.679885	2.287928	0.909952079	383.5501
13	0.02918548	4.046084	2.514339	0.917534813	
14	0.0318387	4.411959	2.74032	0.923951177	
15	0.03449193	4.777513	2.965871	0.929451092	
16	0.03714515	5.142744	3.190992	0.934217568	
17	0.03979838	5.507655	3.415684	0.938387873	Row where Y value (ft) becomes 0
18	0.0424516	5.872246	3.639949	0.942067961	1638
19	0.04510483	6.236517	3.863786	0.945339285	
20	0.04775805	6.600469	4.087195	0.948265722	
21	0.05041128	6.964103	4.310179	0.950899865	
22	0.0530645	7.32742	4.532737	0.953283055	
23	0.05571773	7.690419	4.75487	0.955449709	
24	0.05837095	8.053102	4.976578	0.957427881	
25	0.06102418	8.41547	5.197862	0.959241135	
26	0.0636774	8.777522	5.418723	0.960909433	
27	0.06633063	9.13926	5.639161	0.962449334	
28	0.06898386	9.500684	5.859177	0.963875264	
29	0.07163708	9.861795	6.078771	0.965199124	
30	0.07429031	10.22259	6.297945	0.966432074	