

Homework 2 - Computational Problems

Problem 1

```
type ball_intrp.m
```

```
function [time_imp, range_imp] = ball_intrp(airFlag, tau)
% find range and time for a ball.
% inputs:
%   airFlag: 0 or 1 to determine air resistance in problem
%   tau: time step

%* Set initial position and velocity of the baseball
y1 = 0;
r1 = [0, y1]; % Initial vector position
speed = 50; % m/s
theta = 45; % deg
v1 = [speed*cos(theta*pi/180), ...
      speed*sin(theta*pi/180)]; % Initial velocity
r = r1; v = v1; % Set initial position and velocity

%* Set physical parameters (mass, Cd, etc.)
Cd = 0.35; % Drag coefficient (dimensionless)
area = 4.3e-3; % Cross-sectional area of projectile (m^2)
grav = 9.81; % Gravitational acceleration (m/s^2)
mass = 0.145; % Mass of projectile (kg)
if( airFlag == 0 )
    rho = 0; % No air resistance
else
    rho = 1.2; % Density of air (kg/m^3)
end
air_const = -0.5*Cd*rho*area/mass; % Air resistance constant

%* Loop until ball hits ground or max steps completed
maxstep = 1000; % Maximum number of steps
for istep=1:maxstep

    %* Record position (computed and theoretical) for plotting
    xplot(istep) = r(1); % Record trajectory for plot
    yplot(istep) = r(2);
    t = (istep-1)*tau; % Current time
    xNoAir(istep) = r1(1) + v1(1)*t;
    yNoAir(istep) = r1(2) + v1(2)*t - 0.5*grav*t^2;

    %* Calculate the acceleration of the ball
    accel = air_const*norm(v)*v; % Air resistance
    accel(2) = accel(2)-grav; % Gravity

    %* Calculate the new position and velocity using Euler method
    r = r + tau*v; % Euler step
    v = v + tau*accel;

    %* If ball reaches ground (y<0), break out of the loop
    if( r(2) < 0 )
        xplot(istep+1) = r(1); % Record last values computed
        yplot(istep+1) = r(2);
        break; % Break out of the for loop
    end
end

% find the range and time of flight by interpolation
% interpolate x as a function of y at yi = 0
x = xplot((length(xplot) - 2):end);
```

```

y = yplot((length(yplot) - 2):end);
dx = intrpf(0, y, x);
range_imp = (r(1) - dx) / r(1) * 100;
% use a similar method to find t as a function of y
tp = [(t- 2*tau), (t - tau), t];
dt = intrpf(0, y, tp);
time_imp = (t - dt) / t * 100;
end

```

```

tau = [0.5, 0.1, 0.01]; % time step in sec
% calculate results
range = zeros(length(tau));
time = range;
disp("tau time range")

```

```
tau time range
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for i = 1:length(tau)
    [time(i), range(i)] = ball_intrp(0, tau(i));
    fprintf("%f %f %f\n", tau(i), time(i), range(i))
end

```

```

0.500000 3.871087 3.629144
0.100000 1.259956 1.242930
0.010000 0.027459 0.027421

```

Problem 3

get different data points

```
type ball_coef.m
```

```

function [xplot, yplot, dx, dt] = ball_coef(table, airFlag, tau)
% find trajectory for a ball.
% inputs:
%   airFlag: 0 or 1 to determine air resistance in problem
%   tau: time step

%* Set initial position and velocity of the baseball
y1 = 0;
r1 = [0, y1]; % Initial vector position
speed = 50; % m/s
theta = 45; % deg
v1 = [speed*cos(theta*pi/180), ...
      speed*sin(theta*pi/180)]; % Initial velocity
r = r1; v = v1; % Set initial position and velocity

%* Set physical parameters (mass, Cd, etc.)
Cd = 0.35; % Drag coefficient (dimensionless)
area = 4.3e-3; % Cross-sectional area of projectile (m^2)
grav = 9.81; % Gravitational acceleration (m/s^2)
mass = 0.145; % Mass of projectile (kg)
if( airFlag == 0 )
    rho = 0; % No air resistance
else
    rho = 1.2; % Density of air (kg/m^3)
end

air_const = -0.5*Cd*rho*area/mass; % Air resistance constant

```

```

%* Loop until ball hits ground or max steps completed
maxstep = 1000; % Maximum number of steps
for istep=1:maxstep

    %* Record position (computed and theoretical) for plotting
    xplot(istep) = r(1); % Record trajectory for plot
    yplot(istep) = r(2);
    t = (istep-1)*tau; % Current time
    xNoAir(istep) = r1(1) + v1(1)*t;
    yNoAir(istep) = r1(2) + v1(2)*t - 0.5*grav*t^2;

    if table == 1
        % use data from table to find new Cd
        % first convert velocity from m/s to mph
        v_mph = norm(v)* 2.23649; % mph
        % table values
        v_table = [0, 25, 50, 75, 100, 125];
        C_table = [0.5, 0.5, 0.5, 0.4, 0.28, 0.23];
        Cd = interp1(v_table, C_table, v_mph);
        % detect errors in interpolation
        if Cd < 0.23
            disp("out of range")
            disp(Cd)
        end
    else
        Cd = 0.35;
    end

    air_const = -0.5*Cd*rho*area/mass; % Air resistance constant

    %* Calculate the acceleration of the ball
    accel = air_const*norm(v)*v; % Air resistance
    accel(2) = accel(2)-grav; % Gravity

    %* Calculate the new position and velocity using Euler method
    r = r + tau*v; % Euler step
    v = v + tau*accel;

    %* If ball reaches ground (y<0), break out of the loop
    if( r(2) < 0 )
        xplot(istep+1) = r(1); % Record last values computed
        yplot(istep+1) = r(2);
        break; % Break out of the for loop
    end
end

% find the range and time of flight by interpolation
% interpolate x as a function of y at yi = 0
x = xplot((length(xplot) - 2):end);
y = yplot((length(yplot) - 2):end);
dx = intrpf(0, y, x);
% use a similar method to find t as a function of y
tp = [(t- 2*tau), (t - tau), t];
dt = intrpf(0, y, tp);
end

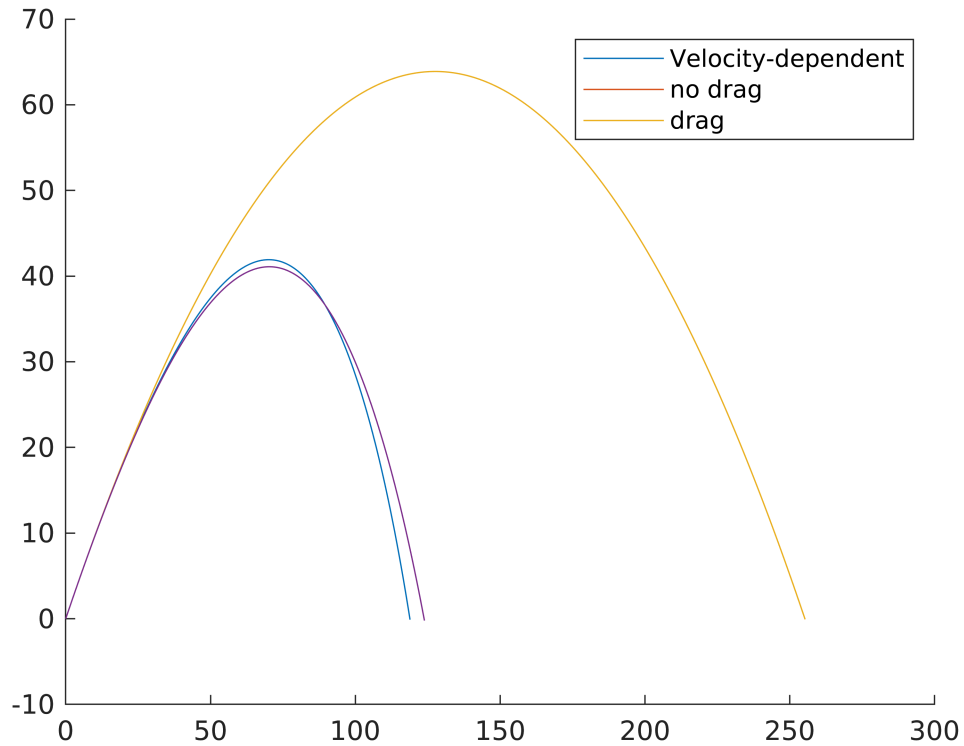
[x, y, dx, dt] = ball_coef(1, 1, 0.01);
[xb, yb] = ball(1, 0.01);
[x_noair, y_noair] = ball(0, 0.01);
[x2, y2, dx_fix, dt_fix] = ball_coef(0, 1, 0.01);
% plot results
hold on

```

```

plot(x, y)
plot(xb, yb)
plot(x_noair, y_noair)
plot(x2, y2)
hold off
legend('Velocity-dependent', 'no drag', 'drag')

```



```

% range and time of flight for fixed vs dependent
disp("range and time of flight for velocity dependent drag force")

```

```

range and time of flight for velocity dependent drag force

```

```

fprintf("%f %f \n", dx, dt)

```

```

118.818538 5.835442

```

```

disp("range and time of flight for velocity independent drag force")

```

```

range and time of flight for velocity independent drag force

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```

fprintf("%f %f \n", dx_fix, dt_fix)

```

```

123.728316 5.741265

```

Problem 4

range of initial angle

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type pendul.m

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```

function [AvePeriod] = pendul(small_angle, theta0)
% AvePeriod = pendul(small_angle, tau)
% small_angle: 1 or 0, whether to use small angle approx
% tau: time step in sec
% AvePeriod: average period in sec

%* Select the numerical method to use: Euler or Verlet
NumericalMethod = 2; % use verlet

% set time step
tau = 0.05;

%* Set initial position and velocity of pendulum
theta = theta0*pi/180; % Convert angle to radians
omega = 0; % Set the initial velocity

%* Set the physical constants and other variables
g_over_L = 1; % The constant g/L
time = 0; % Initial time
irev = 0; % Used to count number of reversals
period = []; % accumulator for period

%* Take one backward step to start Verlet
if small_angle == 1
    accel = -g_over_L*sin(theta); % Gravitational acceleration
else
    accel = -g_over_L;
end
theta_old = theta - omega*tau + 0.5*tau^2*accel;

%* Loop over desired number of steps with given time step
% and numerical method
nstep = 5000;
for istep=1:nstep

    %* Record angle and time for plotting
    t_plot(istep) = time;
    th_plot(istep) = theta*180/pi; % Convert angle to degrees
    time = time + tau;

    %* Compute new position and velocity using
    % Euler or Verlet method
    if small_angle == 0
        accel = -g_over_L*sin(theta); % Gravitational acceleration
    else
        accel = -g_over_L * theta;
    end
    if( NumericalMethod == 1 )
        theta_old = theta; % Save previous angle
        theta = theta + tau*omega; % Euler method
        omega = omega + tau*accel;
    else
        theta_new = 2*theta - theta_old + tau^2*accel;
        theta_old = theta; % Verlet method
        theta = theta_new;
    end

    %* Test if the pendulum has passed through theta = 0;
    % if yes, use time to estimate period
    if( theta*theta_old < 0 ) % Test position for sign change
        fprintf('Turning point at time t= %f \n',time);
        if( irev == 0 ) % If this is the first change,
            time_old = time; % just record the time
        end
    end
end

```

```

    else
        period(irev) = 2*(time - time_old);
        time_old = time;
    end
    irev = irev + 1;      % Increment the number of reversals
end
end

%* Estimate period of oscillation
AvePeriod = mean(period);
end

```

```
type elli_period.m
```

```

function [T] = elli_period(L_over_g, theta_m)
% elliptic apprxiomation of the period for small angles
T = 2*pi*sqrt(L_over_g)*(1 + (theta_m.^2 / 16));
end

```

```

thm = deg2rad([5:5:175]);
% approximations of period
disp("Run with no approximation")

```

Run with no approximation

```
T_sin = arrayfun(@(th) pendul(0, th), thm);
```

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disp("Run with approximation")
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Run with approximation
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T_small = arrayfun(@(th) pendul(1, th), thm);
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T_small = 1x35
    6.2823    6.2823    6.2823    6.2823    6.2823    6.2823    6.2823 ...

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```

L = 9.8; % m
T_ellip = elli_period(L, thm);
% plot functions
figure(2)
hold on
    plot(thm, T_sin)
    plot(thm, T_small)
    plot(thm, T_ellip)
hold off
legend('No approximation', 'Small angle', 'Elliptic')
title("Approximations of Period")
xlabel("\theta_m (deg)")
ylabel("T (sec)")

```

