Table of Contents


```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
% CODE CHALLENGE 6 - Template Script
%
% The purpose of this challenge is to predict whether or not the
 Boulder
% Reservior will have to close due to a major leak.
%
% In Coding Challenge 5, you did the following:
% - Part 1:
%     1) Read in the provided data file
%     2) Estimated reservoir volume w/ Trapezoidal and Simpson's 1/3
 Rules
%     3) Compared the accuracy of the two results
%
% - Part 2:
%    1) Propagated t and h using Euler's Method
%    2) Used plots to observe the effect of different timesteps on the
%       estimation accuracy
%
% In Coding Challenge 6, you will build upon the code that you wrote
 up
% for Coding Challenge 5. Fill in what you can in the below code
 template
% by using the code you completed last week. Once you get to the
% Runge-Kutta approximation, calculate K-values and use the Runge-
Kutta
% equations to approximate the reservoir height over time.
%
% In the last section of this code, create plots that effectively
% illustrate differences between approximation methods and parameters,
% comparing Runge-Kutta using different time steps and also Runge-
Kutta vs.
% Euler's Method.
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
%
% NOTE: DO NOT change any variable names already present in the code.
%
% Upload your team's script to Gradescope when complete.
%
```

```
% NAME YOUR FILE AS Challenge6_Sec{section number}_Group{group
 breakout #}.m
% ***Section numbers are 1 or 2***
% EX File Name: Challenge6_Sec2_Group30.m
%
% STUDENT TEAMMATES
% 1) Maitreyi K
% 2) Nathan Sharp
% 3) Sruthi Bandla
% 4) Tristan Workman
% 5) Max Gerber
%
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%
```

Housekeeping

Don't clear variables (i.e. with "clear"); this makes grading difficult.

```
close all;    % Close all open figure windows
clc;          % Clear the command window
```

Prerequisites from Coding Challenge 5 %%

```
% Reading in Provided Depth Data %
data = dlmread('depth_data.csv',',',1,0); % Read in depth data
 from .csv
x = data(:,1);                            % Position along reservoir
 [ft]
h = data(:,2);                            % Depth of reservoir
 [ft]
L = 4836;                                 % Length of reservior
 [ft]
```

Set-up for Runge Kutta Method %%

Problem Parameters %

```
h0 = 20;                     % Initial reservoir depth
  [ft]
alpha = 1.5e6;               % Relating volume change to depth
 [ft^2/day]
dV_in = 2e7;                 % Volume inflow rate
 [ft^3/day]

% Approximation Parameters %
timestep = [16 8 4 2 1];     % Timesteps to use for approximation
 [days]
for j = 1:length(timestep)
    t_end = 100;             % Choose an end time for your program
 [days]
```

```
    t = 0:timestep(j):t_end; % Allocate a time vector
 [days]
    h = zeros(1,length(t));  % Allocate a depth vector
  [ft]
    h(1) = h0;               % Set a depth vector initial value
  [ft]
    h_RK = h;                % Set a depth vector for Runge-Kutta
  [ft]

    for i = 1:(length(t)-1)  % Euler's Method - use your code from Lab
 6
        dhdt = get_dhdt(h(i),L,alpha,dV_in);          % Get dh/dt at
 this depth              [ft/day]
        h(i+1) = h(i) + dhdt*timestep(j);        % Compute next depth
 value
    end

    for i = 1:(length(t)-1)  % Runge-Kutta Method
        K1 = get_dhdt(h_RK(i),L,alpha,dV_in);            % Calculate
 your K1 value
        K2 = get_dhdt(h_RK(i)+(K1 * (timestep(j)/2)),L,alpha,dV_in);
          % Calculate your K2 value
        K3 = get_dhdt(h_RK(i)+(K2 * (timestep(j)/2)),L,alpha,dV_in);
          % Calculate your K3 value
        K4 = get_dhdt(h_RK(i)+(K3 * (timestep(j))),L,alpha,dV_in);
        % Calculate your K4 value
        h_RK(i+1) = h_RK(i) + timestep(j) * (K1 + 2*K2 + 2*K3 + K4)/6;
     % Compute your next reservoir height      [ft]
    end

    % Don't touch these three lines of code... %
    eval(['t_' num2str(timestep(j)) ' = t;'])
    eval(['h_E_' num2str(timestep(j)) ' = h;'])
    eval(['h_RK_' num2str(timestep(j)) ' = h_RK;'])
end
```

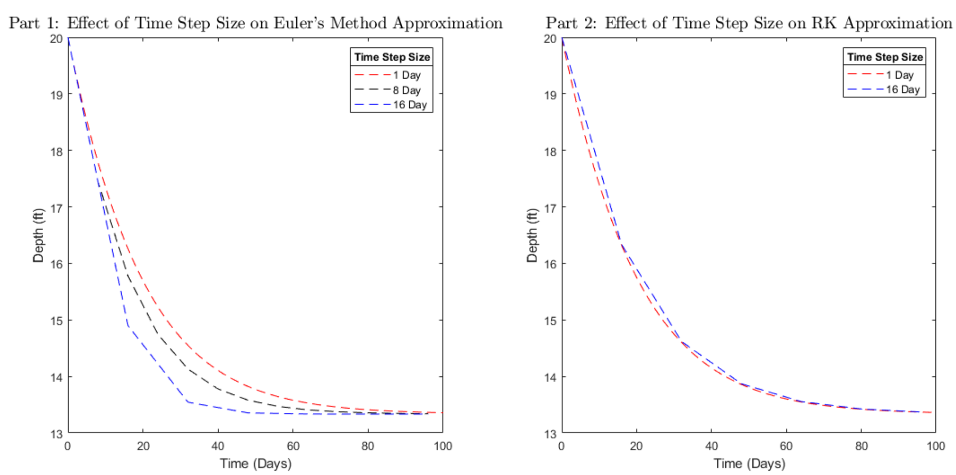
Plotting Results %%

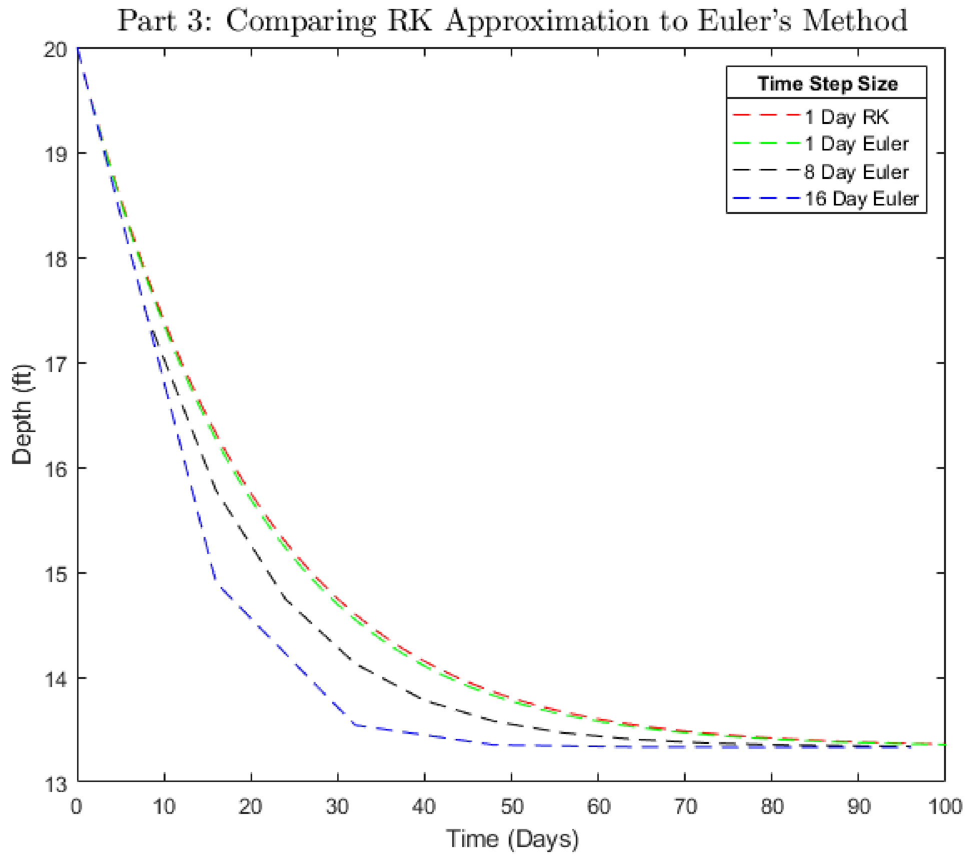
READ THIS: After the above code runs, the "eval" statements at the end of the loop create three sets of variables. One set holds the time vectors used in the various approximations, named "t_16" for the 16-day time step, "t_8" for the 8-day time step, etc. Another set holds the Euler approximation results for the various timesteps, named "h_E_16" for the 16-day time step, "h_E_8" for the 8-day time step, etc. The last set holds the Tunge-Kutta approximation results for the various timesteps, named "h_RK_16", "h_RK_8", etc. For simplicity, you may use these vectors in your plotting.

```
fig1 = figure('Units','Normalized','Position',[0 0.25 0.65 0.50]);


% Part 1: Effect of timestep on Euler's Method approximation %
subplot(1,2,1)
plot(t_1,h_E_1,"r--")
hold on
plot(t_8,h_E_8,"k--")
```

```
plot(t_16,h_E_16,"b--")
xlabel("Time (Days)")
ylabel("Depth (ft)")
lgd1 = legend("1 Day","8 Day","16 Day");
lgd1.Title.String = 'Time Step Size';
title('Part 1: Effect of Time Step Size on Euler''s Method
 Approximation', ...
    'Interpreter','latex','Fontsize',14)
hold off
% Here, plot the results of your Euler's approximation using different
% time steps. Is there a significant difference between time steps?

% There is a pronounced difference in the accuracy of depth values
 relative
% to the time step size, evidenced by the wide gap between a delta_t
 of 16
% days and a delta_t of 1 day.


% Part 2: Effect of timestep on Runge-Kutta approximation %
subplot(1,2,2)
plot(t_1,h_RK_1,"r--")
hold on
% plot(t_8,h_RK_8,"k--")
plot(t_16,h_RK_16,"b--")
xlabel("Time (Days)")
ylabel("Depth (ft)")
lgd1 = legend("1 Day","16 Day");
lgd1.Title.String = 'Time Step Size';
title('Part 2: Effect of Time Step Size on RK Approximation', ...
    'Interpreter','latex','Fontsize',14)
hold off
% Here, plot the results of your Runge-Kutta Method approximation
 using different
% time steps. Is there a significant difference between time steps?

% There is still a difference, for larger delta_t values the
 intermediary
% depth approximations differ the most, but still return to the better
% delta_t approximation (1 day) every "cycle" of 16 days.


fig2 = figure('Units','Normalized','Position',[0.65 0.25 0.35 0.50]);


% Part 3: Comparing Runge-Kutta to Euler's Method %
plot(t_1,h_RK_1,"r--")
hold on
plot(t_1,h_E_1,"g--")
plot(t_8,h_E_8,"k--")
plot(t_16,h_E_16,"b--")
xlabel("Time (Days)")
ylabel("Depth (ft)")
lgd1 = legend("1 Day RK","1 Day Euler","8 Day Euler","16 Day Euler");
```

```
lgd1.Title.String = 'Time Step Size';
title('Part 3: Comparing RK Approximation to Euler''s Method', ...
    'Interpreter','latex','Fontsize',14)
hold off
% Here plot the results of your Runge-Kutta and Euler's Method
% approximations together. You are encouraged to use a few different
 step
% sizes for Euler's Method, but you can decide for yourself how best
 to
% illustrate the difference in accuracy between Euler and Runge-Kutta.
 Is
% there a significant difference in approximation accuracy?

% We know from lecture that RK is significantly more accurate than
 Euler,
% on the order of 10^5. This means that we can surmise that the RK
 method
% is the most accurate, but Euler's method with a delta_t of 1 day
 comes
% quite close in accuracy, differing by an almost imperceptible amount
 at
% times. It is clear, however, that Euler's method with larger delta_t
% values differ unacceptably from the actual value.
```





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