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eqs to test

polynomial from book: (-.1*x^4) - (.15*x^3) - (.5*x^2) - (.25*x) + 1.2; cos(x) linear (3x) tan(x) step function heaviside

```
% graphs of the error:
% multiple graphs (10)
% 1 - first estimations, 1st deriv of each of 3 methods
%   forward vs backward vs center vs actual
% 2 - second estimations, 1st deriv of each of 3 methods
%   forward vs backward vs center vs actual
% 3 - first estimations, 2nd deriv of each of 3 methods
%   forward vs backward vs center vs actual
% 4 - second estimations, 2nd deriv of each of 3 methods
%   forward vs backward vs center vs actual

% compare 1st derivative methods
%   5 - first vs second vs actual (forward)
%   6 - first vs second vs actual (backward)
%   7 - first vs second vs actual (center)

% compare 2nd derivative methods
%   8 - first vs second vs actual (forward)
%   9 - first vs second vs actual (backward)
%  10 - first vs second vs actual (center)


clear;clc;close all;
syms x;
```

Define Testing functions

The following 5 functions will be used to test the derivative approximation techniques.

```
poly = (-.1*x^4) - (.15*x^3) - (.5*x^2) - (.25*x) + 1.2;
cosine = cos(x);
linear = 3*x;
tangent = tan(x);%% eqs to test
% polynomial from book: (-.1*x^4) - (.15*x^3) - (.5*x^2) - (.25*x) +
 1.2;
% cos(x)
% linear (3x)
```

```
% tan(x)
% step function heaviside

% graphs of the error:
% multiple graphs (10)
% 1 - first estimations, 1st deriv of each of 3 methods
%   forward vs backward vs center vs actual
% 2 - second estimations, 1st deriv of each of 3 methods
%   forward vs backward vs center vs actual
% 3 - first estimations, 2nd deriv of each of 3 methods
%   forward vs backward vs center vs actual
% 4 - second estimations, 2nd deriv of each of 3 methods
%   forward vs backward vs center vs actual

% compare 1st derivative methods
%   5 - first vs second vs actual (forward)
%   6 - first vs second vs actual (backward)
%   7 - first vs second vs actual (center)

% compare 2nd derivative methods
%   8 - first vs second vs actual (forward)
%   9 - first vs second vs actual (backward)
%  10 - first vs second vs actual (center)


clear;clc;close all;
syms x;
```

Define Testing functions

The following 5 functions will be used to test the derivative approximation techniques.

```
poly = (-.1*x^4) - (.15*x^3) - (.5*x^2) - (.25*x) + 1.2;
cosine = cos(x);
linear = 3*x;
tangent = tan(x);
step = heaviside(x-3)*sin(2*x);
```

Setup

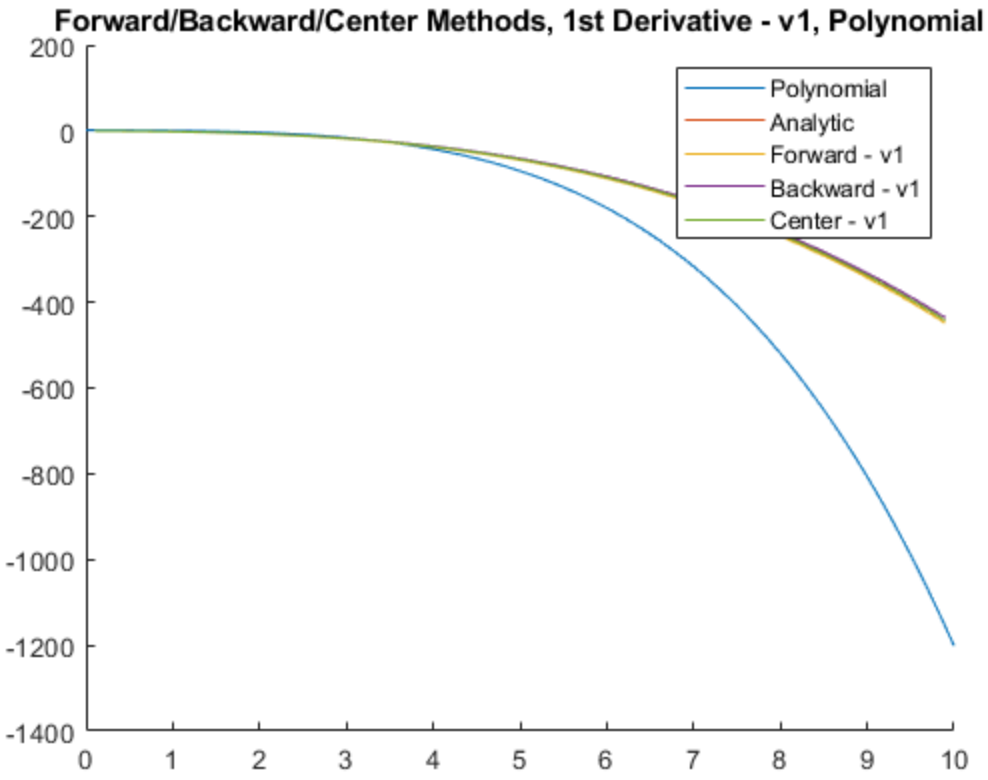
```
xmin = 0;
xdelta = .1;
xmax = 10;

x_vector = [xmin : xdelta : xmax];

poly_h = matlabFunction(poly);
lin_h = matlabFunction(linear);
step_h = matlabFunction(step);

poly_res = Compare_Difference_Formulas(poly, xmin, xmax, xdelta);
cos_res = Compare_Difference_Formulas(cosine, xmin, xmax, xdelta);
linear_res = Compare_Difference_Formulas(linear, xmin, xmax, xdelta);
```

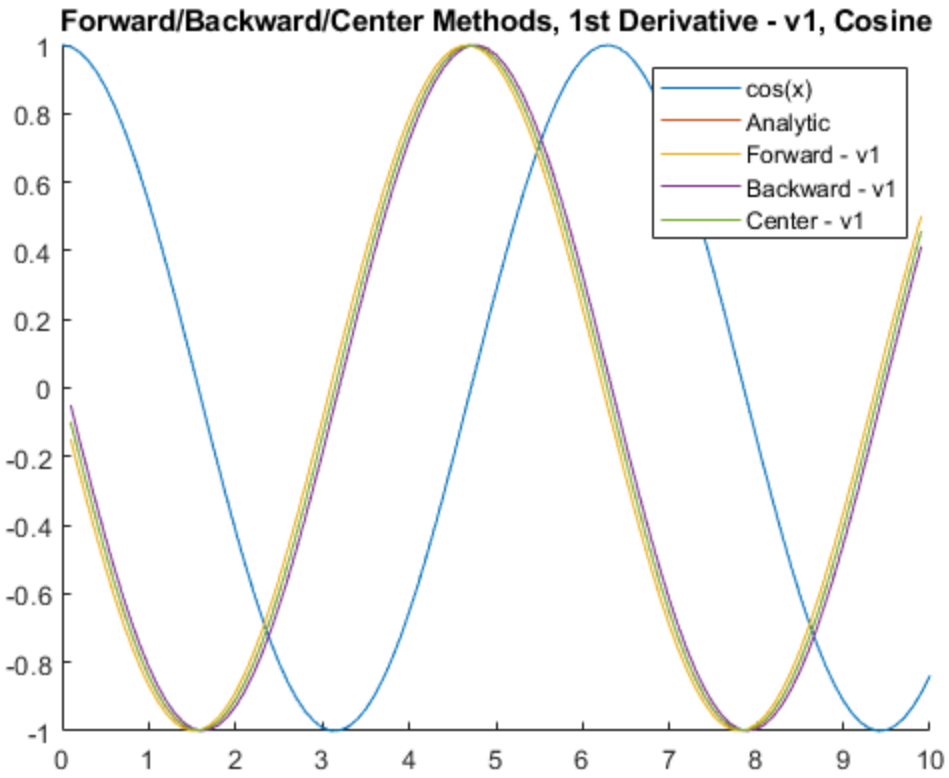
```
tangent_res = Compare_Difference_Formulas(tangent, xmin, xmax,
 xdelta);
step_res = Compare_Difference_Formulas(step, xmin, xmax, xdelta);
```

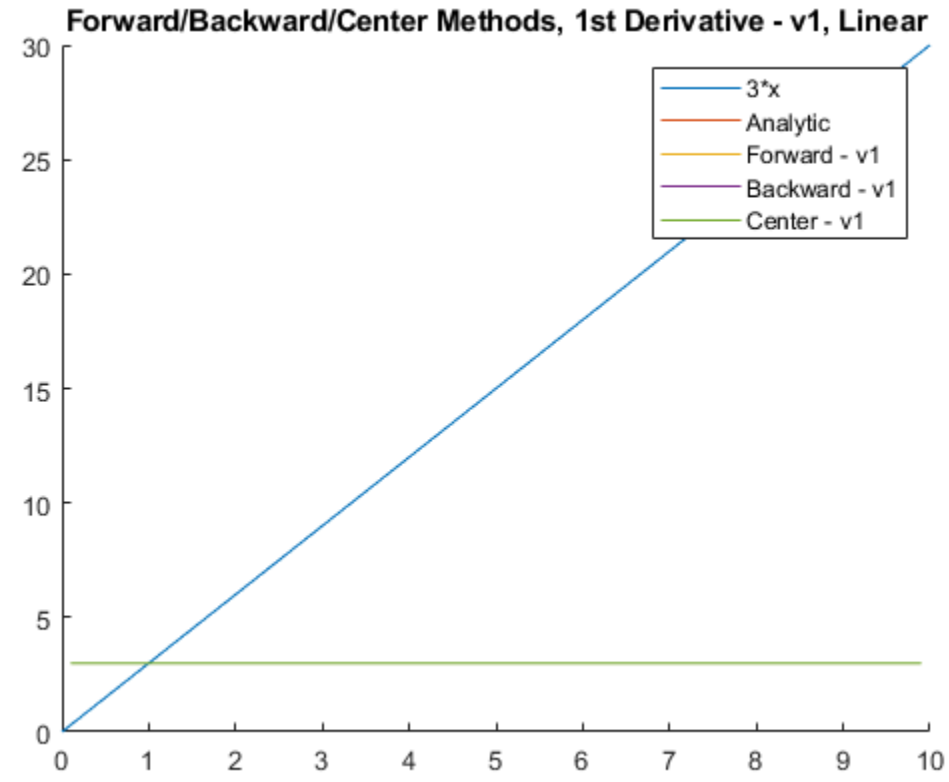
Forward/Backward/Center, 1st Derivative, v1

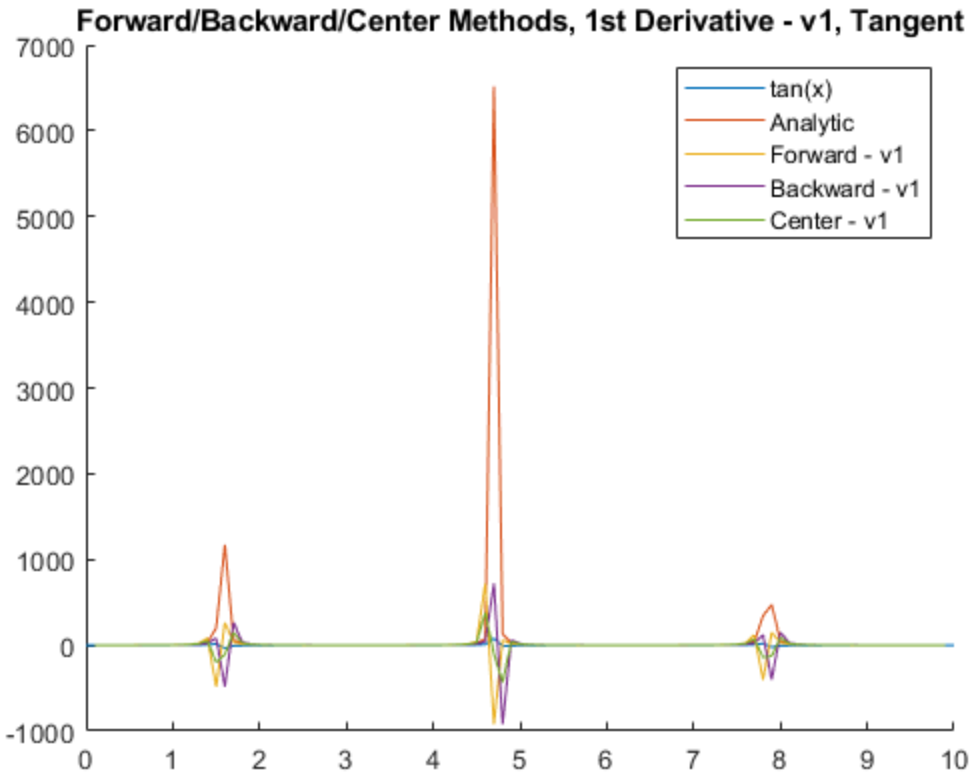
```
figure; % plot function itself, 1st deriv actual, 1st deriv method 1,
 1st deriv
hold on;
plot(x_vector, poly_h(x_vector)); % plot the polynomial
plot(x_vector(2:end-1), poly_res{1,1}); % 1st deriv, actual
plot(x_vector(2:end-1), poly_res{1,2}); % 1st derivative, forward v1
plot(x_vector(2:end-1), poly_res{1,6}); % 1st deriv, backward v1
plot(x_vector(2:end-1), poly_res{1,10}); % 1st deriv, center v1
title('Forward/Backward/Center Methods, 1st Derivative - v1,
 Polynomial');
legend('Polynomial', 'Analytic', 'Forward - v1', ...
       'Backward - v1', 'Center - v1');

figure;
hold on;
plot(x_vector, cos(x_vector)); % plot the cosine
plot(x_vector(2:end-1), cos_res{1,1}); % 1st deriv, actual
plot(x_vector(2:end-1), cos_res{1,2}); % 1st derivative, forward v1
plot(x_vector(2:end-1), cos_res{1,6}); % 1st deriv, backward v1
plot(x_vector(2:end-1), cos_res{1,10}); % 1st deriv, center v1
title('Forward/Backward/Center Methods, 1st Derivative - v1, Cosine');
legend('cos(x)', 'Analytic', 'Forward - v1', ...
       'Backward - v1', 'Center - v1');

figure;
hold on;
plot(x_vector, lin_h(x_vector)); %
plot(x_vector(2:end-1), linear_res{1,1}); % 1st deriv, actual
plot(x_vector(2:end-1), linear_res{1,2}); % 1st derivative, forward v1
plot(x_vector(2:end-1), linear_res{1,6}); % 1st deriv, backward v1
plot(x_vector(2:end-1), linear_res{1,10}); % 1st deriv, center v1
title('Forward/Backward/Center Methods, 1st Derivative - v1, Linear');
legend('3*x', 'Analytic', 'Forward - v1', ...
       'Backward - v1', 'Center - v1');

figure;
hold on;
plot(x_vector, tan(x_vector)); %
plot(x_vector(2:end-1), tangent_res{1,1}); % 1st deriv, actual
plot(x_vector(2:end-1), tangent_res{1,2}); % 1st derivative, forward
 v1
plot(x_vector(2:end-1), tangent_res{1,6}); % 1st deriv, backward v1
plot(x_vector(2:end-1), tangent_res{1,10}); % 1st deriv, center v1
title('Forward/Backward/Center Methods, 1st Derivative - v1,
 Tangent');
legend('tan(x)', 'Analytic', 'Forward - v1', ...
       'Backward - v1', 'Center - v1');
```

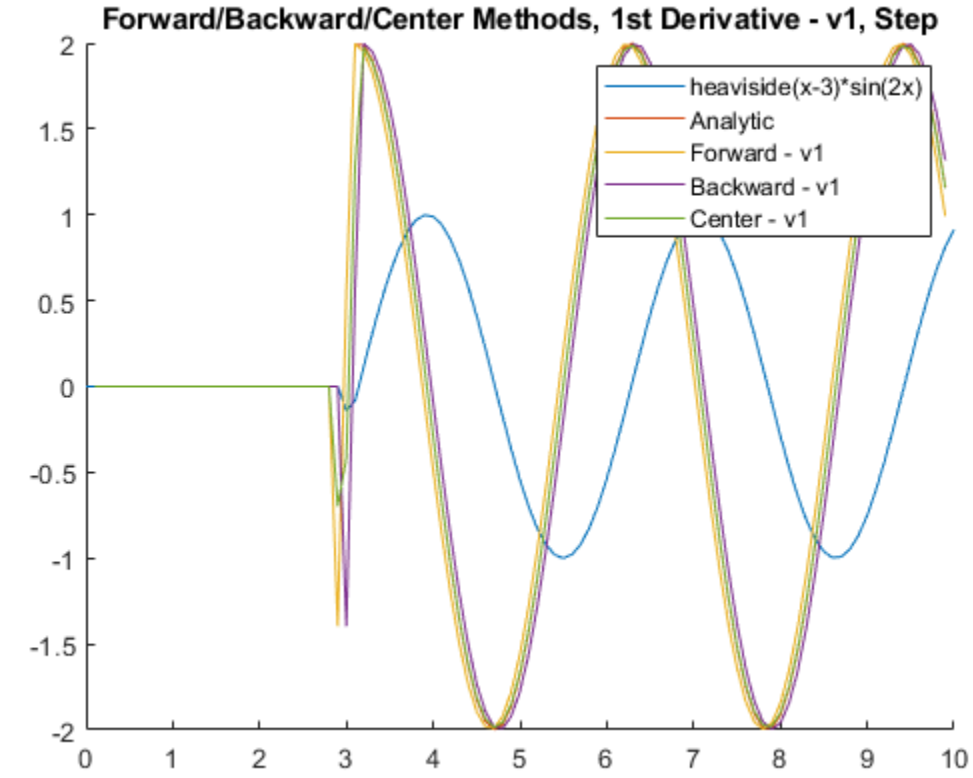
```
figure;
hold on;
plot(x_vector, step_h(x_vector)); %
plot(x_vector(2:end-1), step_res{1,1}); % 1st deriv, actual
plot(x_vector(2:end-1), step_res{1,2}); % 1st derivative, forward v1
plot(x_vector(2:end-1), step_res{1,6}); % 1st deriv, backward v1
plot(x_vector(2:end-1), step_res{1,10}); % 1st deriv, center v1
title('Forward/Backward/Center Methods, 1st Derivative - v1, Step');
legend('heaviside(x-3)*sin(2x)', 'Analytic', 'Forward - v1', ...
       'Backward - v1', 'Center - v1');
```




Forward/Backward/Center Methods, 1st Derivative - v1, Cosine
cos(x)
Analytic
Forward - v1
Backward - v1
Center - v1
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
1
2
3
4
5
6
7
8
9
10


Forward/Backward/Center Methods, 1st Derivative - v1, Linear
3*x
Analytic
Forward - v1
Backward - v1
Center - v1
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
9
10

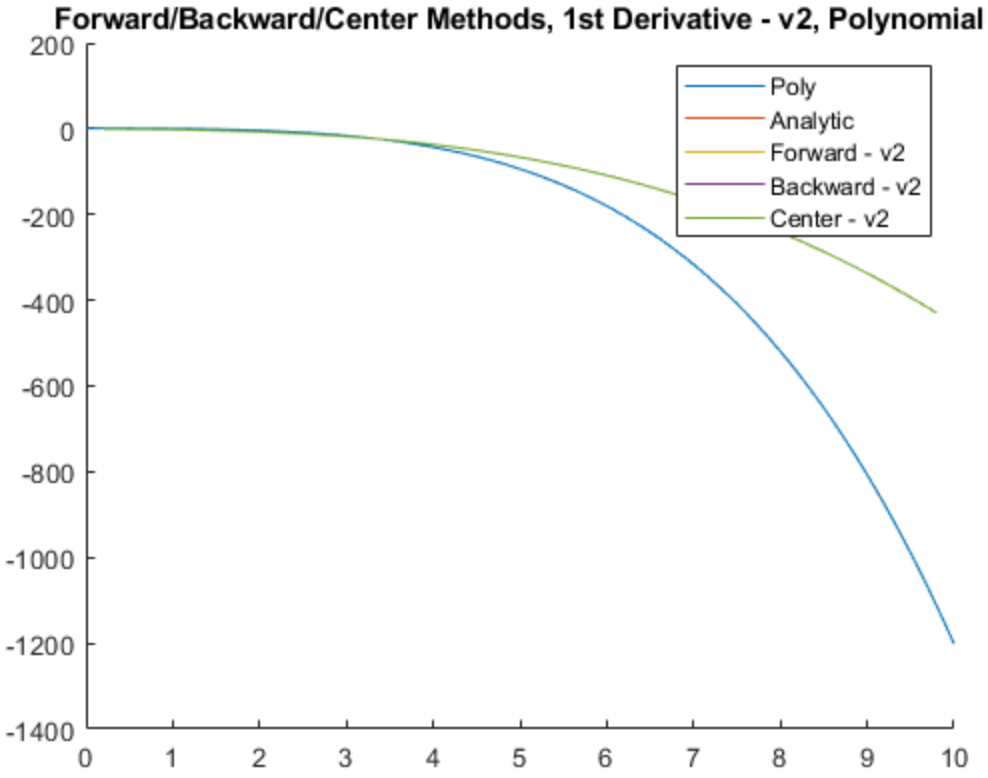

Forward/Backward/Center Methods, 1st Derivative - v1, Tangent
tan(x)
Analytic
Forward - v1
Backward - v1
Center - v1
7000
6000
5000
4000
3000
2000
1000
0
-1000
0
1
2
3
4
5
6
7
8
9
10

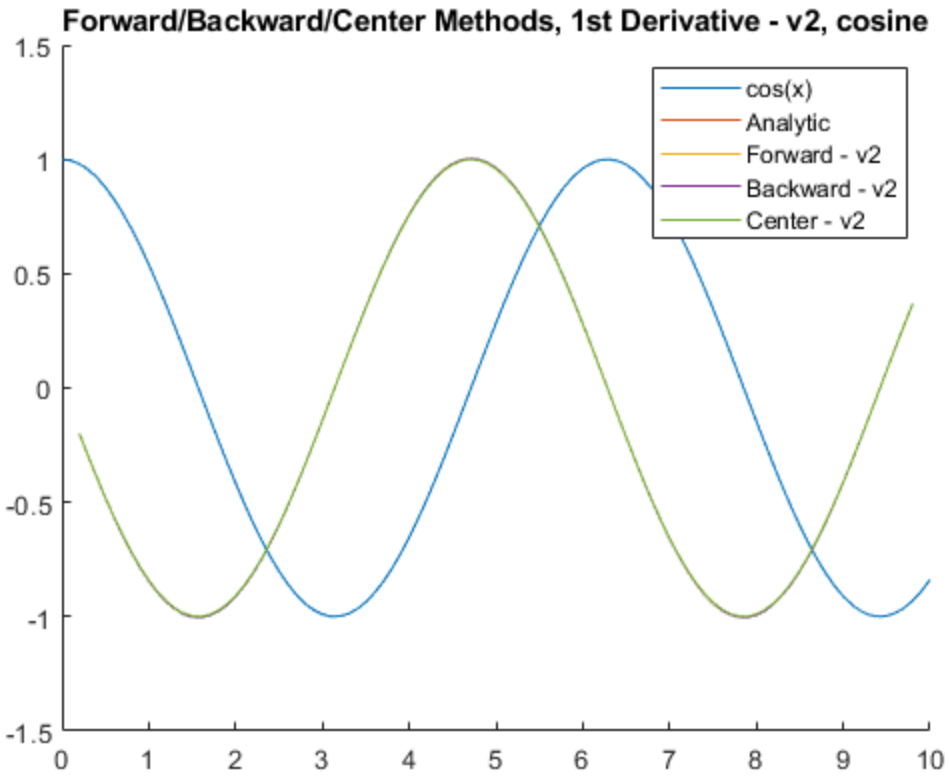

Forward/Backward/Center Methods, 1st Derivative - v1, Step
heaviside(x-3)*sin(2x)
Analytic
Forward - v1
Backward - v1
Center - v1
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
1
2
3
4
5
6
7
8
9
10

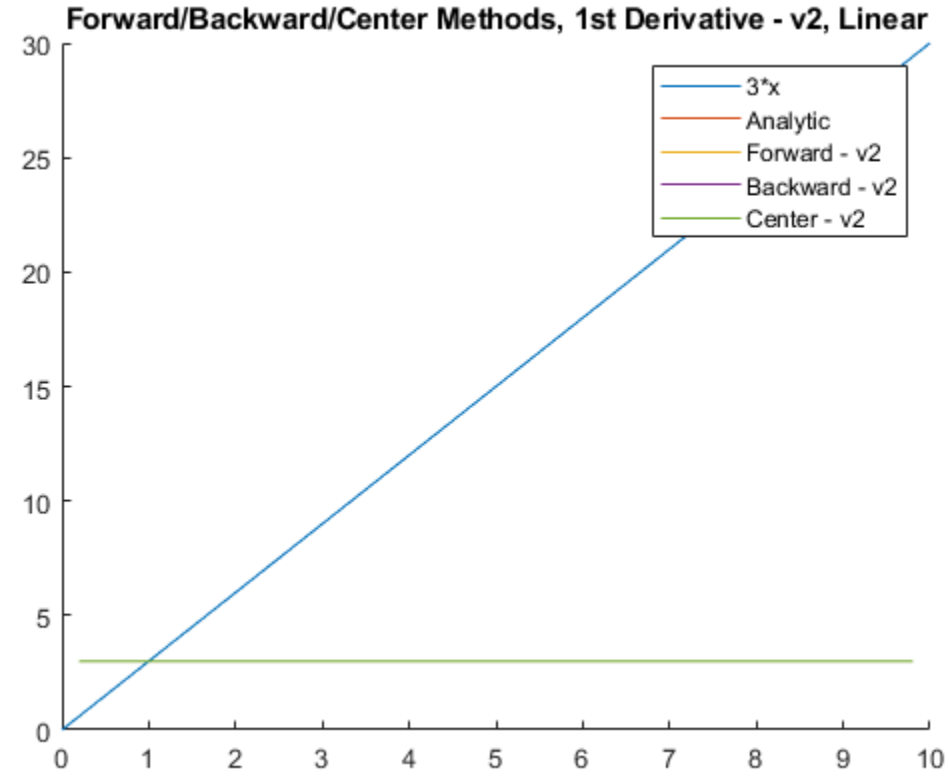
Forward/Backward/Center, 1st Derivative, v2

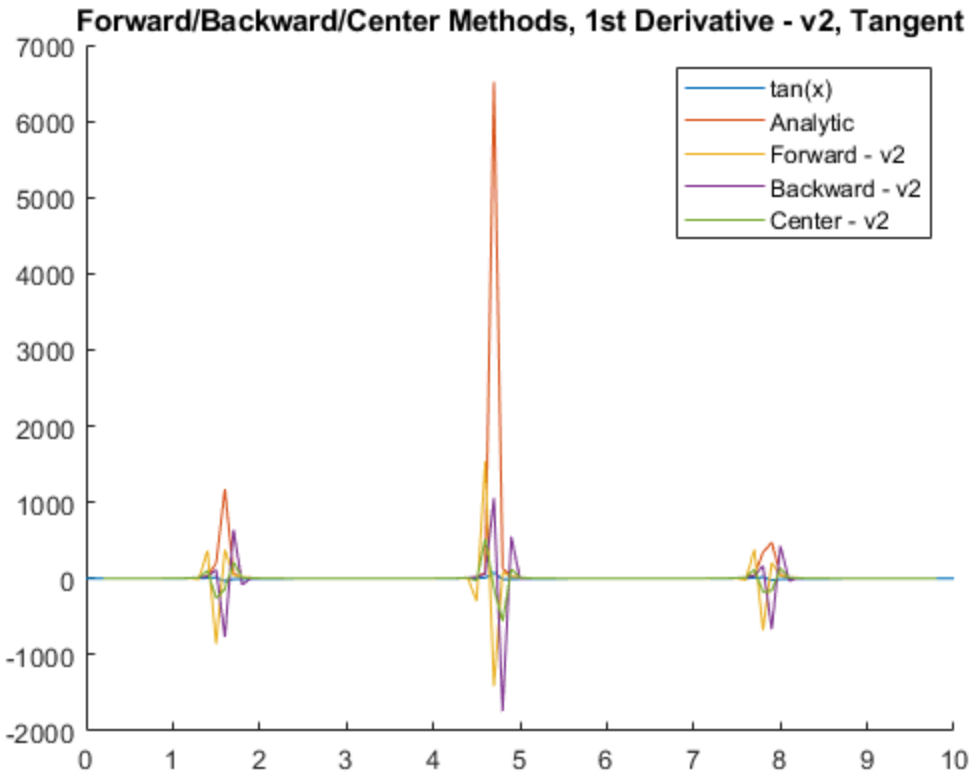
```
figure;
hold on;
plot(x_vector, poly_h(x_vector)); %
plot(x_vector(3:end-2), poly_res{1,3}); % 1st deriv, actual
plot(x_vector(3:end-2), poly_res{1,4}); % 1st derivative, forward v2
plot(x_vector(3:end-2), poly_res{1,8}); % 1st deriv, backward v2
plot(x_vector(3:end-2), poly_res{1,12}); % 1st deriv, center v2
title('Forward/Backward/Center Methods, 1st Derivative - v2,
 Polynomial');
legend('Poly', 'Analytic', 'Forward - v2', ...
       'Backward - v2', 'Center - v2');

figure;
hold on;
plot(x_vector, cos(x_vector)); %
plot(x_vector(3:end-2), cos_res{1,3}); % 1st deriv, actual
plot(x_vector(3:end-2), cos_res{1,4}); % 1st derivative, forward v2
plot(x_vector(3:end-2), cos_res{1,8}); % 1st deriv, backward v2
plot(x_vector(3:end-2), cos_res{1,12}); % 1st deriv, center v2
title('Forward/Backward/Center Methods, 1st Derivative - v2, cosine');
legend('cos(x)', 'Analytic', 'Forward - v2', ...
       'Backward - v2', 'Center - v2');

figure;
hold on;
plot(x_vector, lin_h(x_vector)); %
plot(x_vector(3:end-2), linear_res{1,3}); % 1st deriv, actual
plot(x_vector(3:end-2), linear_res{1,4}); % 1st derivative, forward v2
plot(x_vector(3:end-2), linear_res{1,8}); % 1st deriv, backward v2
plot(x_vector(3:end-2), linear_res{1,12}); % 1st deriv, center v2
title('Forward/Backward/Center Methods, 1st Derivative - v2, Linear');
legend('3*x', 'Analytic', 'Forward - v2', ...
       'Backward - v2', 'Center - v2');

figure;
hold on;
plot(x_vector, tan(x_vector)); %
plot(x_vector(3:end-2), tangent_res{1,3}); % 1st deriv, actual
plot(x_vector(3:end-2), tangent_res{1,4}); % 1st derivative, forward
 v2
plot(x_vector(3:end-2), tangent_res{1,8}); % 1st deriv, backward v2
plot(x_vector(3:end-2), tangent_res{1,12}); % 1st deriv, center v2
title('Forward/Backward/Center Methods, 1st Derivative - v2,
 Tangent');
legend('tan(x)', 'Analytic', 'Forward - v2', ...
       'Backward - v2', 'Center - v2');

figure;
hold on;
plot(x_vector, step_h(x_vector)); %
plot(x_vector(3:end-2), step_res{1,3}); % 1st deriv, actual
```

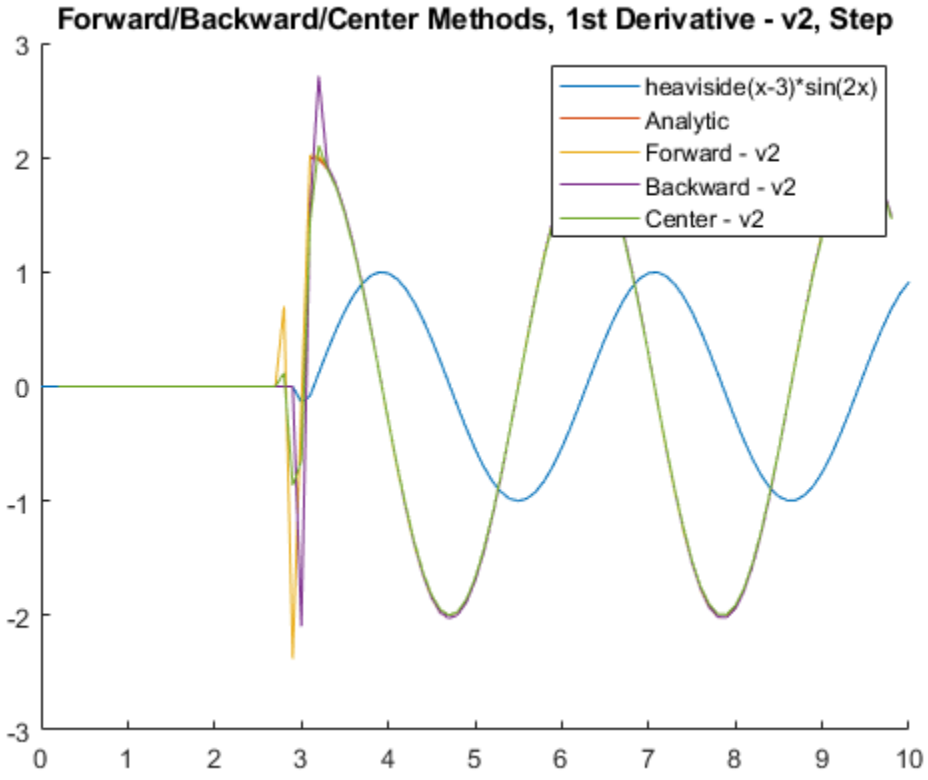
```
plot(x_vector(3:end-2), step_res{1,4}); % 1st derivative, forward v2
plot(x_vector(3:end-2), step_res{1,8}); % 1st deriv, backward v2
plot(x_vector(3:end-2), step_res{1,12}); % 1st deriv, center v2
title('Forward/Backward/Center Methods, 1st Derivative - v2, Step');
legend('heaviside(x-3)*sin(2x)', 'Analytic', 'Forward - v2', ...
       'Backward - v2', 'Center - v2');
```




Forward/Backward/Center Methods, 1st Derivative - v2, cosine
cos(x)
Analytic
Forward - v2
Backward - v2
Center - v2
1.5
1
0.5
0
-0.5
-1
-1.5
0
1
2
3
4
5
6
7
8
9
10


Forward/Backward/Center Methods, 1st Derivative - v2, Linear
3*x
Analytic
Forward - v2
Backward - v2
Center - v2
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
9
10


Forward/Backward/Center Methods, 1st Derivative - v2, Tangent
tan(x)
Analytic
Forward - v2
Backward - v2
Center - v2
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
0
1
2
3
4
5
6
7
8
9
10


Forward/Backward/Center Methods, 1st Derivative - v2, Step
heaviside(x-3)*sin(2x)
Analytic
Forward - v2
Backward - v2
Center - v2
3
2
1
0
-1
-2
-3
0
1
2
3
4
5
6
7
8
9
10

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