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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. 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');

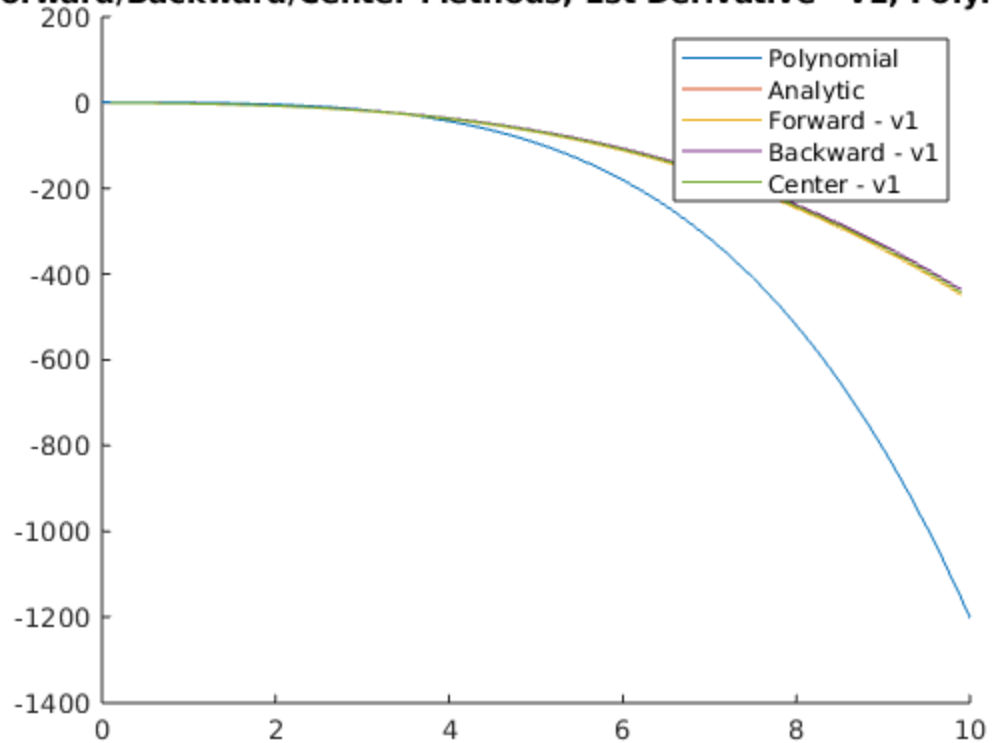
figure;
hold on;
plot(x_vector, step_h(x_vector)); %
```

```

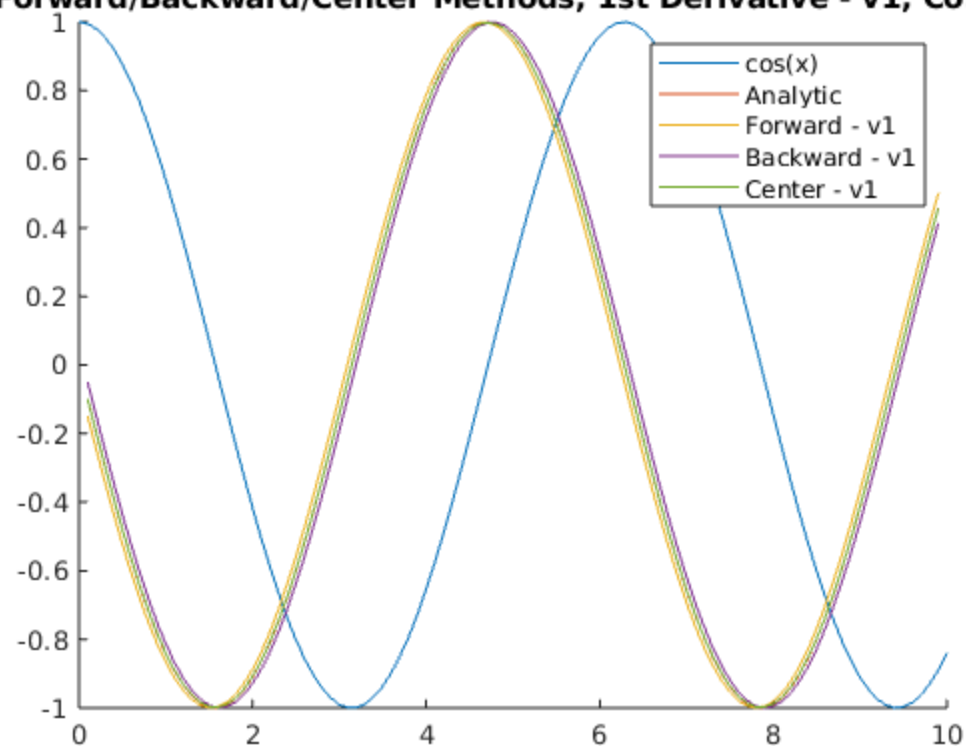
plot(x_vector(2:end-1), step_res{1,1}); % 1st deriv, actual
plot(x_vector(2:end-1), step_res{1,2}); % 1st derivative, forward v1
plot(x_vector(2:end-1), step_res{1,6}); % 1st deriv, backward v1
plot(x_vector(2:end-1), step_res{1,10}); % 1st deriv, center v1
title('Forward/Backward/Center Methods, 1st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

```

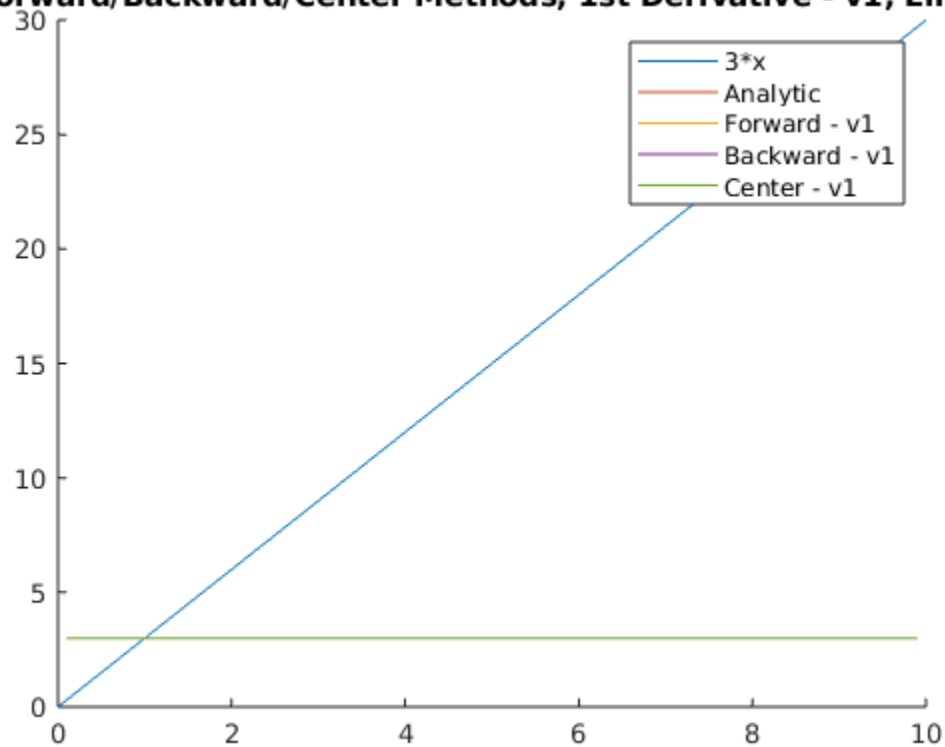
Forward/Backward/Center Methods, 1st Derivative - v1, Polynomial



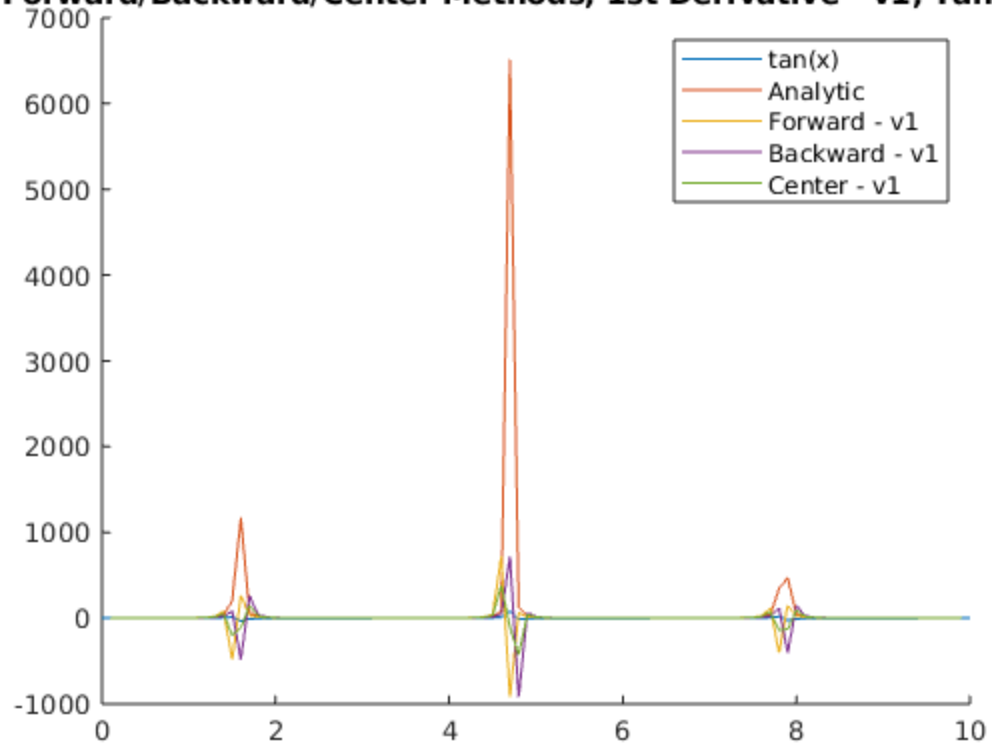
Forward/Backward/Center Methods, 1st Derivative - v1, Cosine



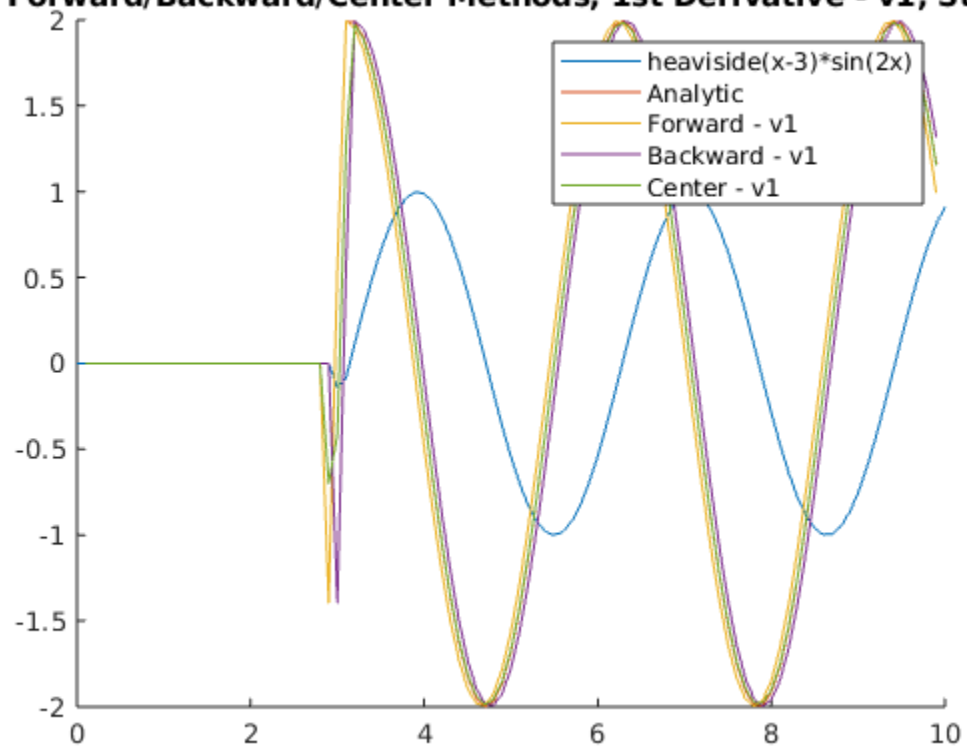
Forward/Backward/Center Methods, 1st Derivative - v1, Linear



Forward/Backward/Center Methods, 1st Derivative - v1, Tangent



Forward/Backward/Center Methods, 1st Derivative - v1, Step



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');
```



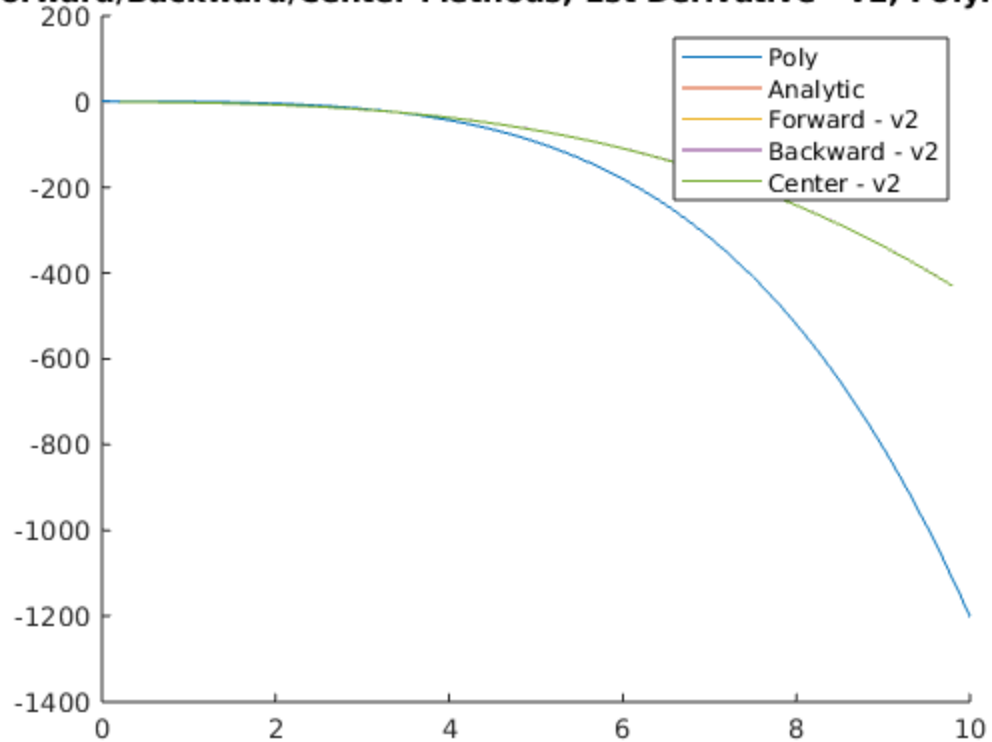
```
figure;
hold on;
plot(x_vector, step_h(x_vector)); %
plot(x_vector(3:end-2), step_res{1,3}); % 1st deriv, actual
```

```

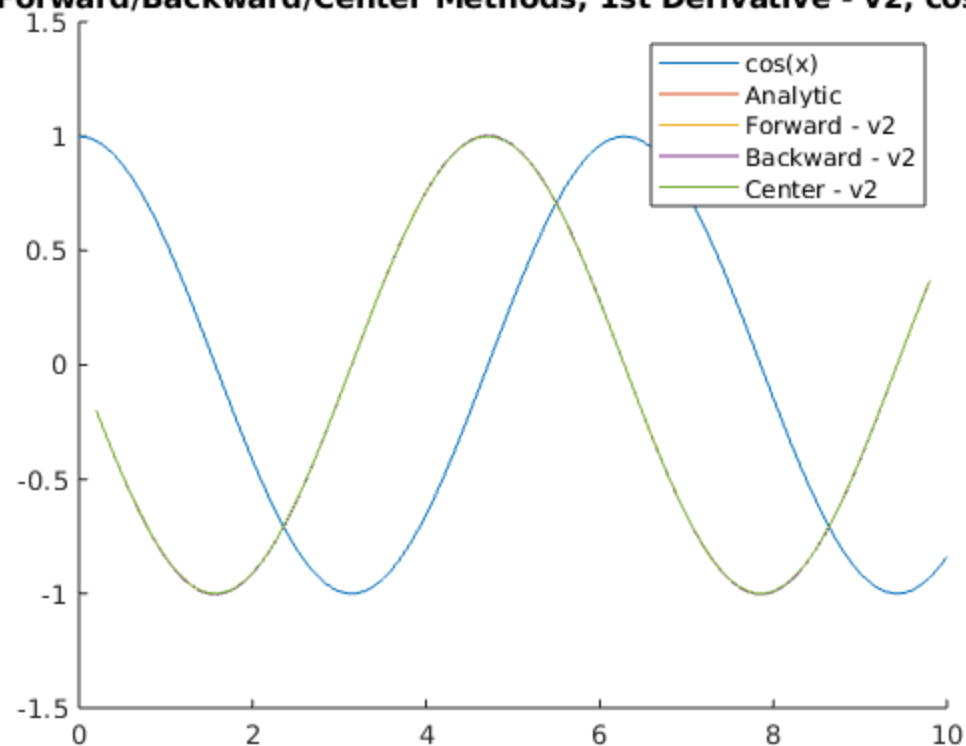
plot(x_vector(3:end-2), step_res{1,4}); % 1st derivative, forward v2
plot(x_vector(3:end-2), step_res{1,8}); % 1st deriv, backward v2
plot(x_vector(3:end-2), step_res{1,12}); % 1st deriv, center v2
title('Forward/Backward/Center Methods, 1st Derivative - v2, Step');
legend('heaviside(x-3)*sin(2x)', 'Analytic',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

```

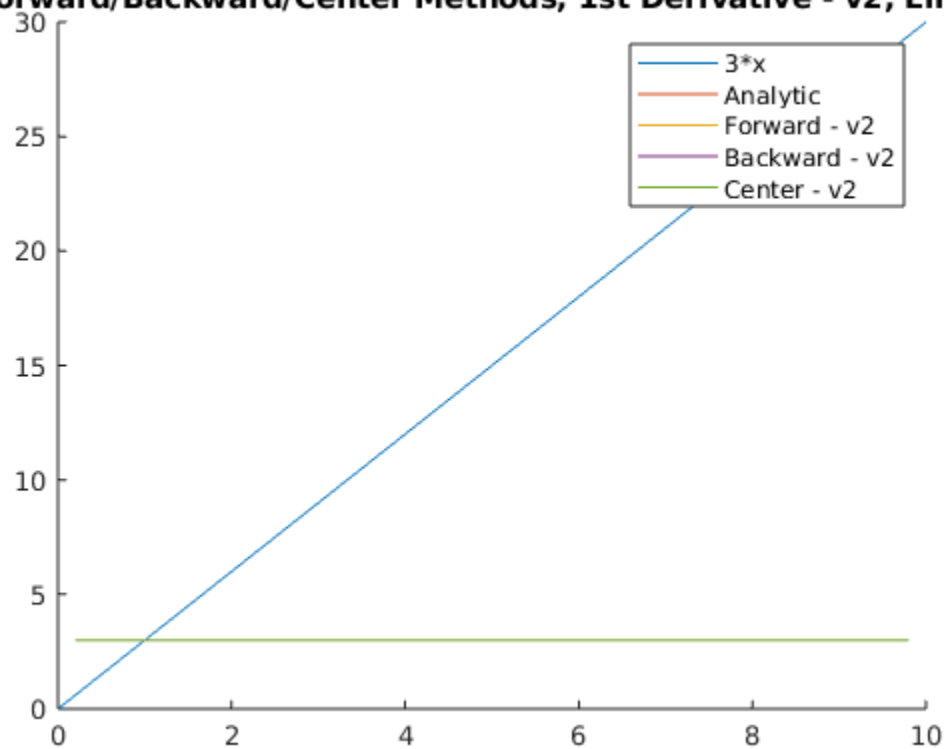
Forward/Backward/Center Methods, 1st Derivative - v2, Polynomial



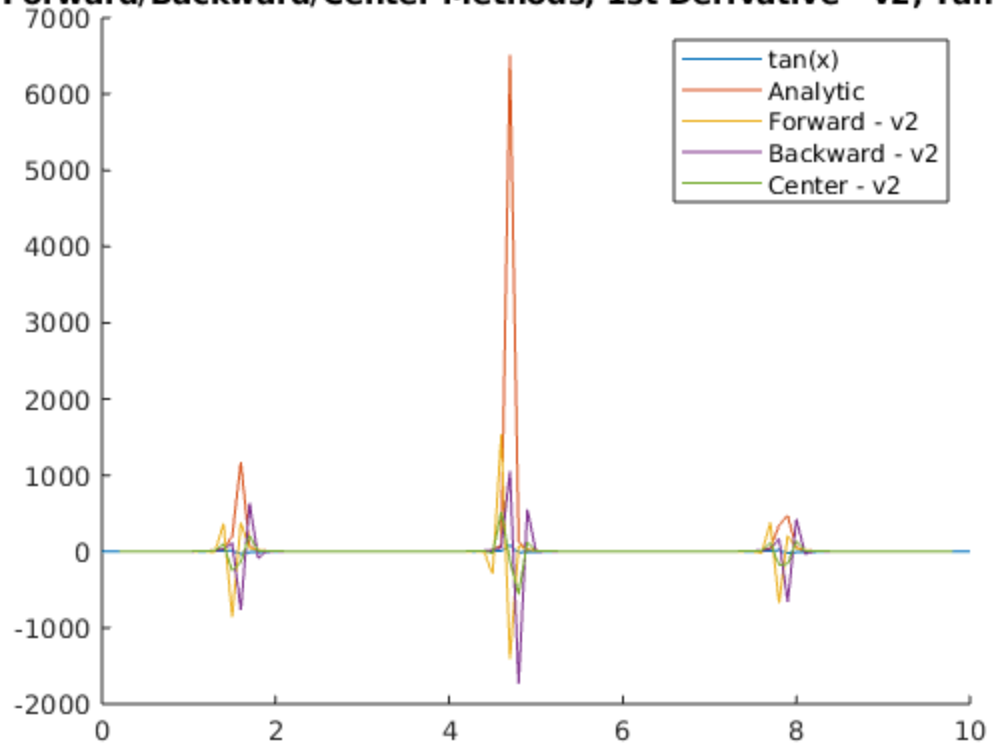
Forward/Backward/Center Methods, 1st Derivative - v2, cosine



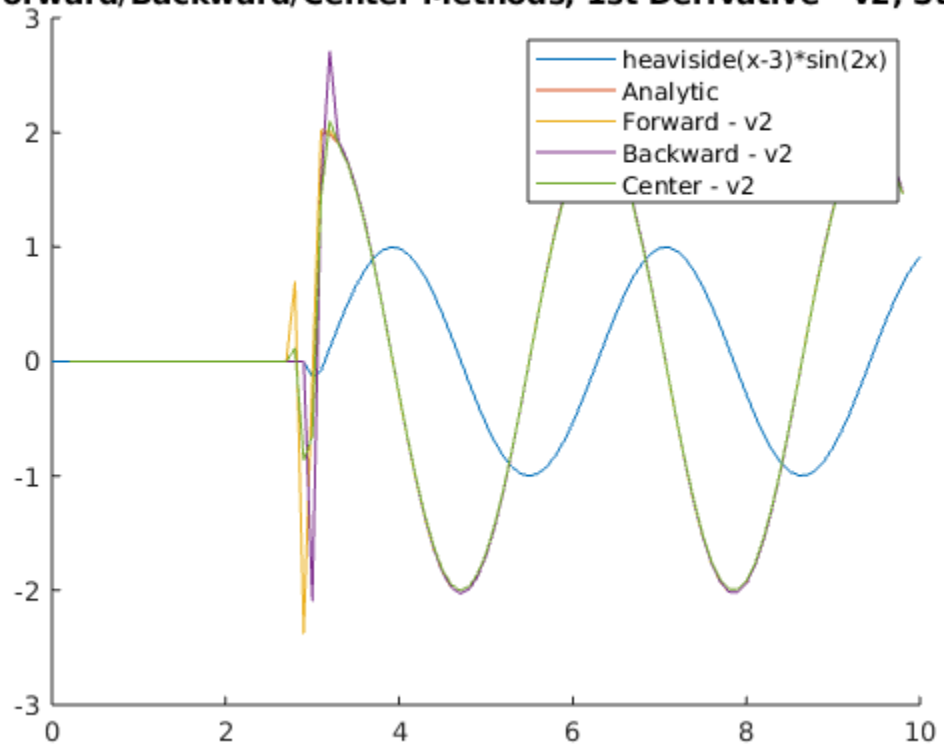
Forward/Backward/Center Methods, 1st Derivative - v2, Linear



Forward/Backward/Center Methods, 1st Derivative - v2, Tangent



Forward/Backward/Center Methods, 1st Derivative - v2, Step



Forward/Backward/Center, 2nd Derivative, v1

```
figure;
hold on;
plot(x_vector, poly_h(x_vector)); % plot the polynomial
plot(x_vector(3:end-2), poly_res{2,1}); % 2nd deriv, actual
plot(x_vector(3:end-2), poly_res{2,2}); % 2nd derivative, forward v1
plot(x_vector(3:end-2), poly_res{2,6}); % 2nd deriv, backward v1
plot(x_vector(3:end-2), poly_res{2,10}); % 2nd deriv, center v1
title('Forward/Backward/Center Methods, 2nd 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(3:end-2), cos_res{2,1}); % 2nd deriv, actual
plot(x_vector(3:end-2), cos_res{2,2}); % 2nd derivative, forward v1
plot(x_vector(3:end-2), cos_res{2,6}); % 2nd deriv, backward v1
plot(x_vector(3:end-2), cos_res{2,10}); % 2nd deriv, center v1
title('Forward/Backward/Center Methods, 2nd 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(3:end-2), linear_res{2,1}); % 2nd deriv, actual
plot(x_vector(3:end-2), linear_res{2,2}); % 2nd derivative, forward v1
plot(x_vector(3:end-2), linear_res{2,6}); % 2nd deriv, backward v1
plot(x_vector(3:end-2), linear_res{2,10}); % 2nd deriv, center v1
title('Forward/Backward/Center Methods, 2nd 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(3:end-2), tangent_res{2,1}); % 2nd deriv, actual
plot(x_vector(3:end-2), tangent_res{2,2}); % 2nd derivative, forward
v1
plot(x_vector(3:end-2), tangent_res{2,6}); % 2nd deriv, backward v1
plot(x_vector(3:end-2), tangent_res{2,10}); % 2nd deriv, center v1
title('Forward/Backward/Center Methods, 2nd Derivative - v1,
Tangent');
legend('tan(x)', 'Analytic', 'Forward - v1', ...
      'Backward - v1', 'Center - v1');
```



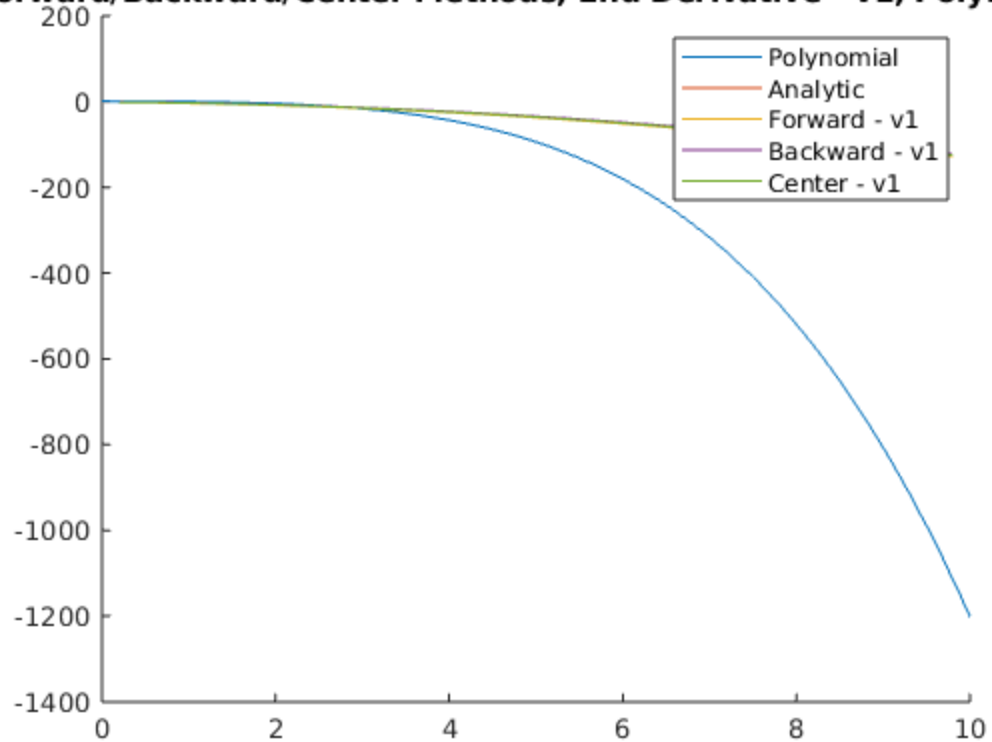
```
figure;
hold on;
plot(x_vector, step_h(x_vector)); %
plot(x_vector(3:end-2), step_res{2,1}); % 2nd deriv, actual
```

```

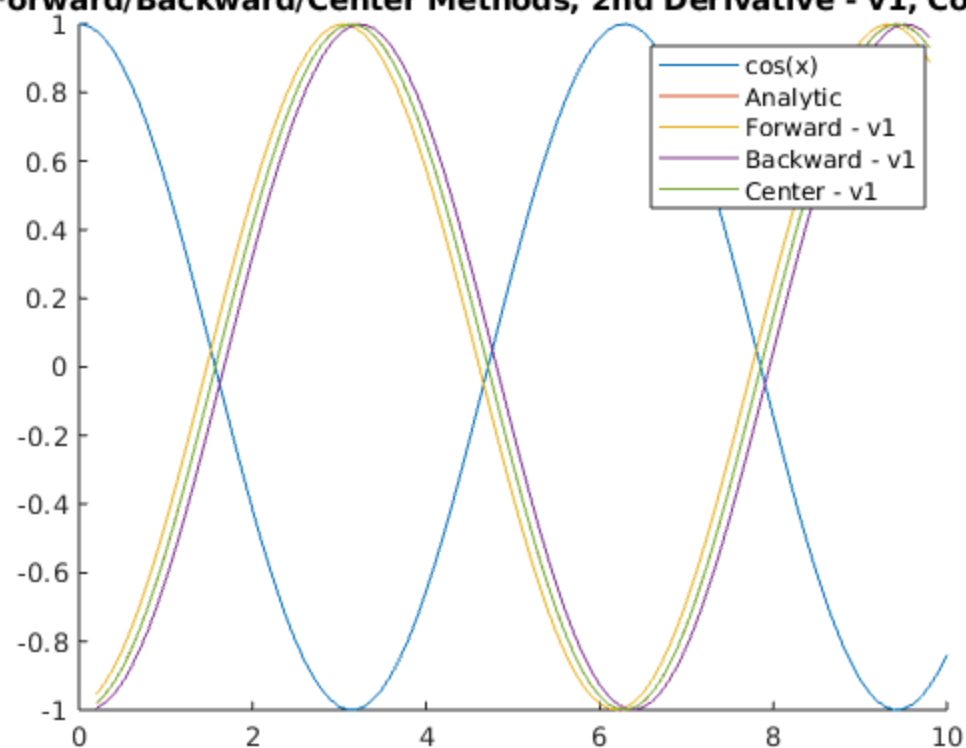
plot(x_vector(3:end-2), step_res{2,2}); % 2nd derivative, forward v1
plot(x_vector(3:end-2), step_res{2,6}); % 2nd deriv, backward v1
plot(x_vector(3:end-2), step_res{2,10}); % 2nd deriv, center v1
title('Forward/Backward/Center Methods, 2nd Derivative - v1, Step');
legend('heaviside(x-3)*sin(2x)', 'Analytic',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

```

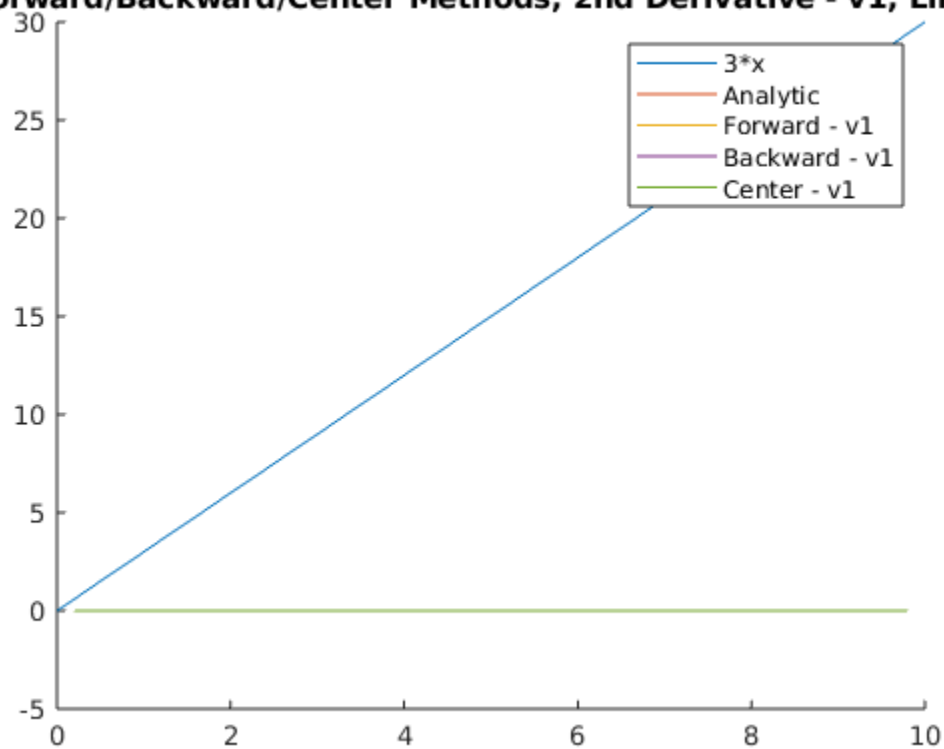
Forward/Backward/Center Methods, 2nd Derivative - v1, Polynomial



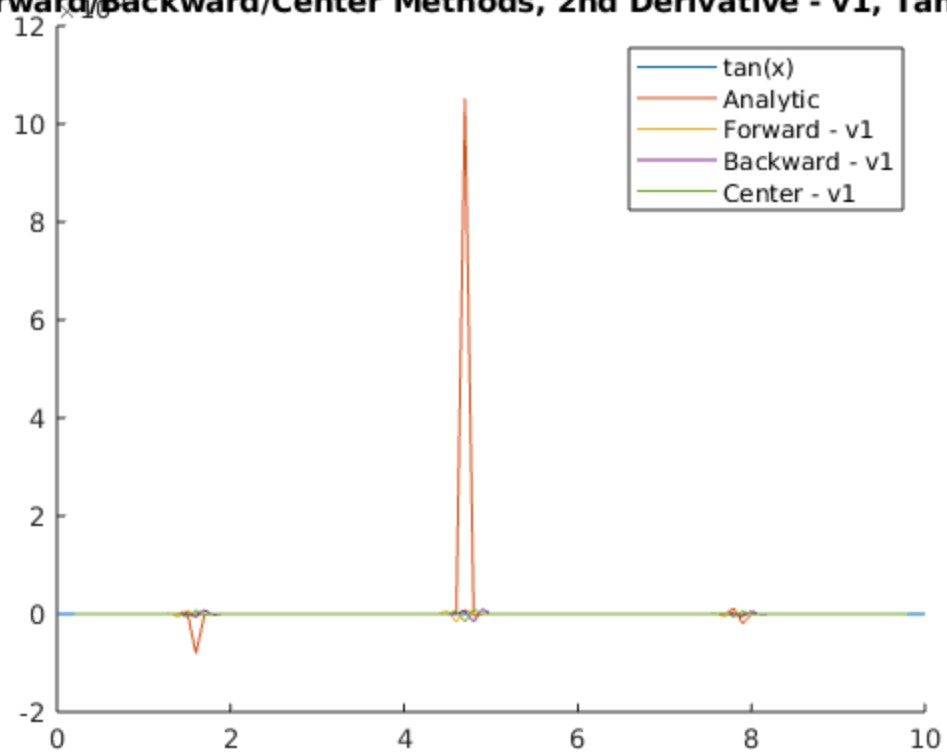
Forward/Backward/Center Methods, 2nd Derivative - v1, Cosine



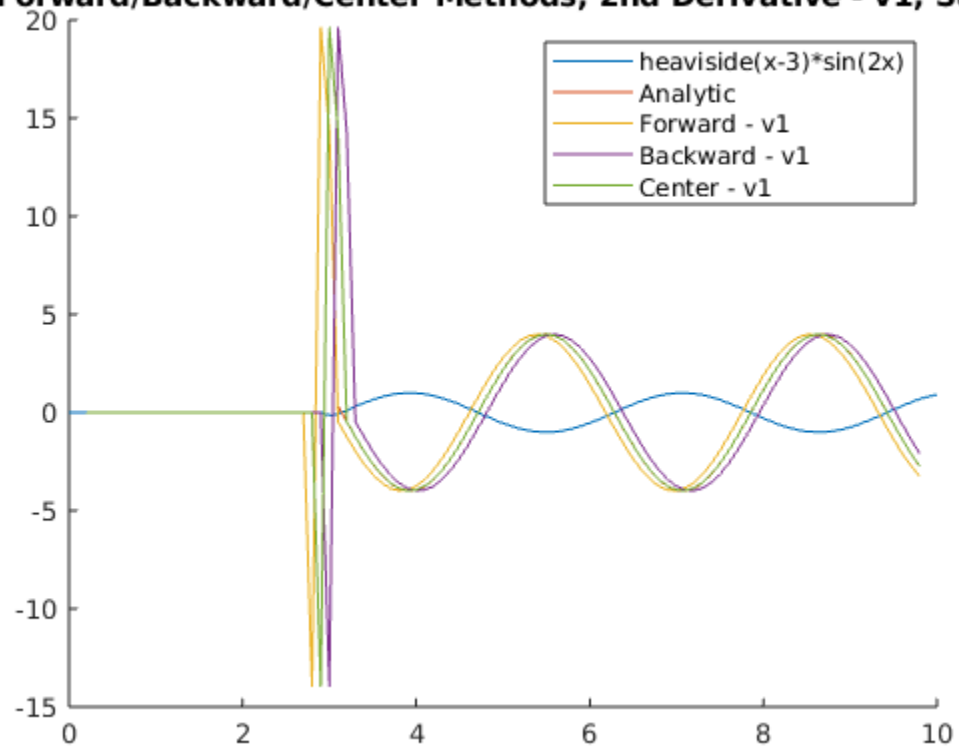
Forward/Backward/Center Methods, 2nd Derivative - v1, Linear



Forward/Backward/Center Methods, 2nd Derivative - v1, Tangent



Forward/Backward/Center Methods, 2nd Derivative - v1, Step



Forward/Backward/Center, 2nd Derivative, v2

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



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



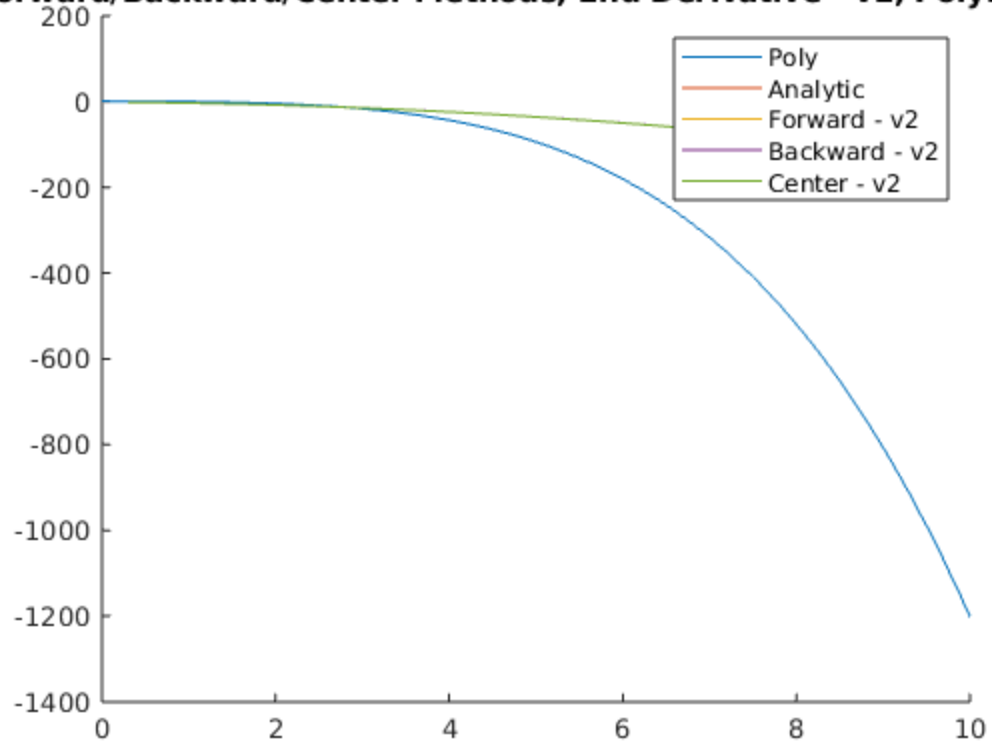
```
figure;
hold on;
plot(x_vector, step_h(x_vector)); %
plot(x_vector(4:end-3), step_res{2,3}); % 1st deriv, actual
```

```

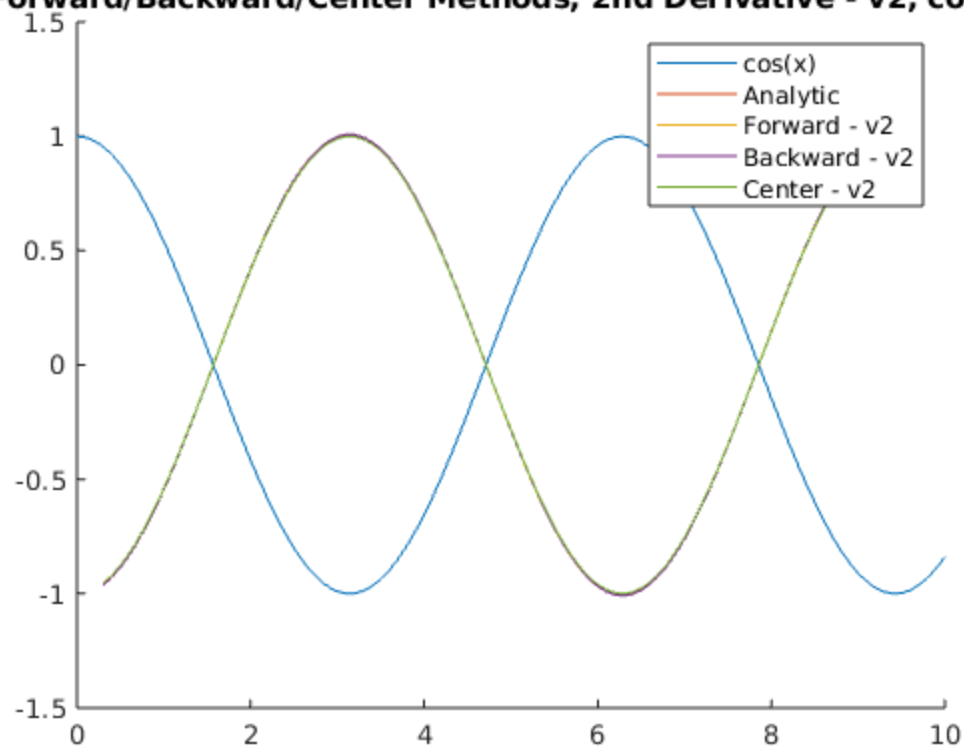
plot(x_vector(4:end-3), step_res{2,4}); % 1st derivative, forward v2
plot(x_vector(4:end-3), step_res{2,8}); % 1st deriv, backward v2
plot(x_vector(4:end-3), step_res{2,12}); % 1st deriv, center v2
title('Forward/Backward/Center Methods, 2nd Derivative - v2, Step');
legend('heaviside(x-3)*sin(2x)', 'Analytic',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

```

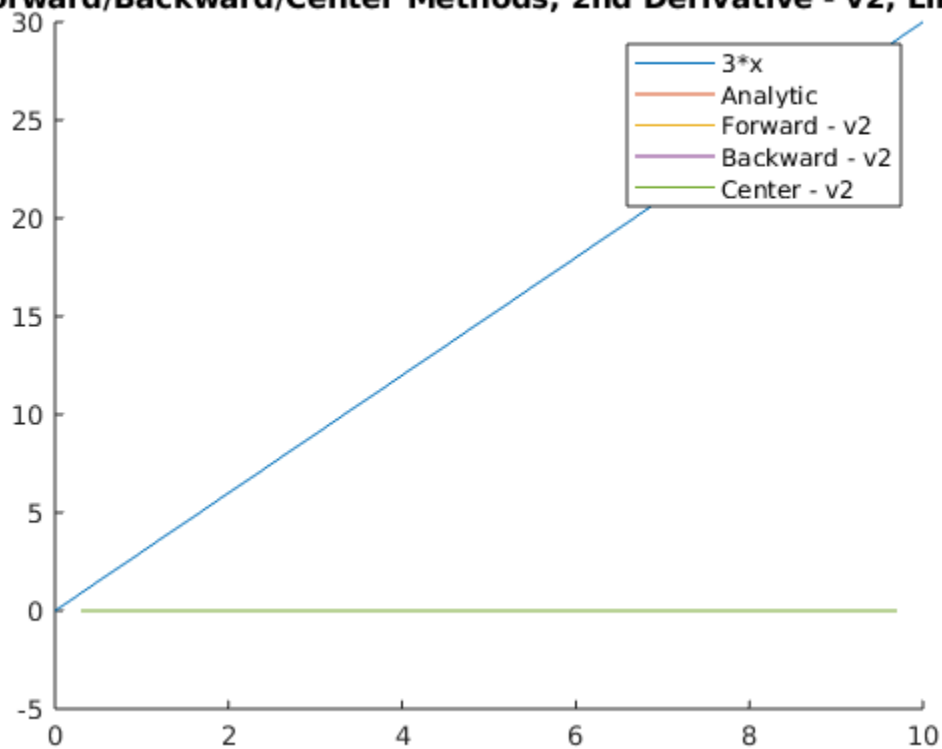
Forward/Backward/Center Methods, 2nd Derivative - v2, Polynomial



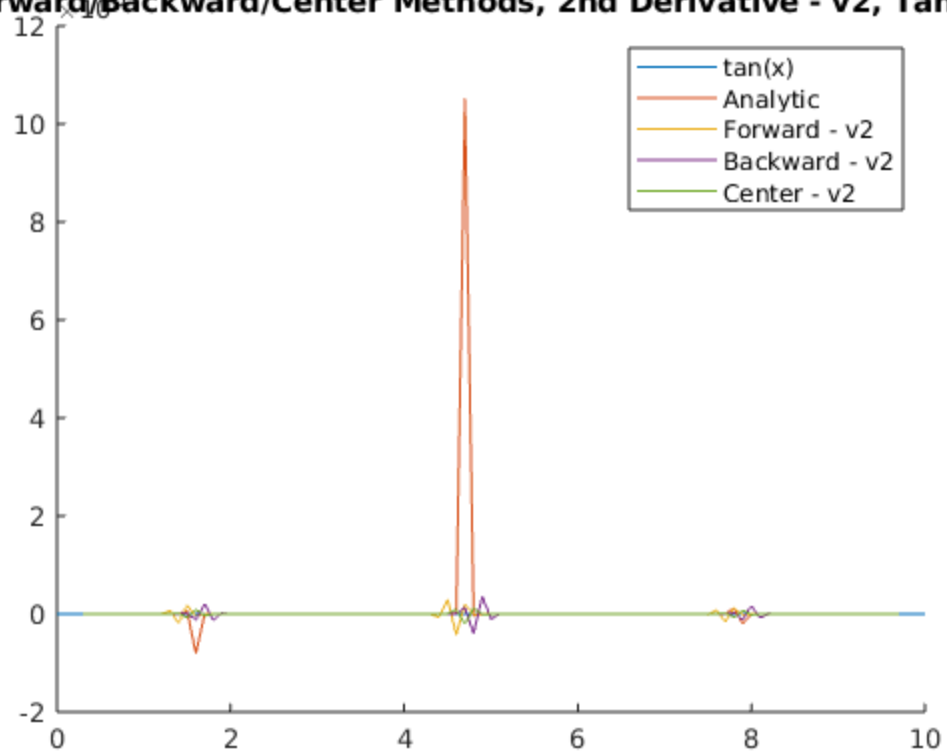
Forward/Backward/Center Methods, 2nd Derivative - v2, cosine



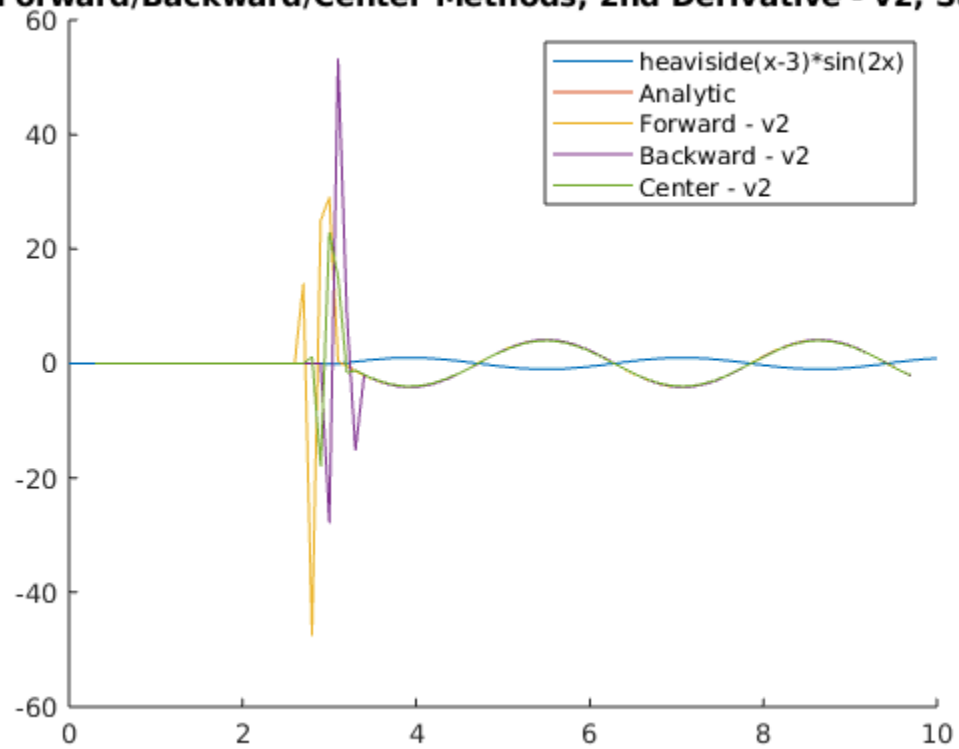
Forward/Backward/Center Methods, 2nd Derivative - v2, Linear



Forward/Backward/Center Methods, 2nd Derivative - v2, Tangent



Forward/Backward/Center Methods, 2nd Derivative - v2, Step



Forward - 1st Derivative, v1 vs v2

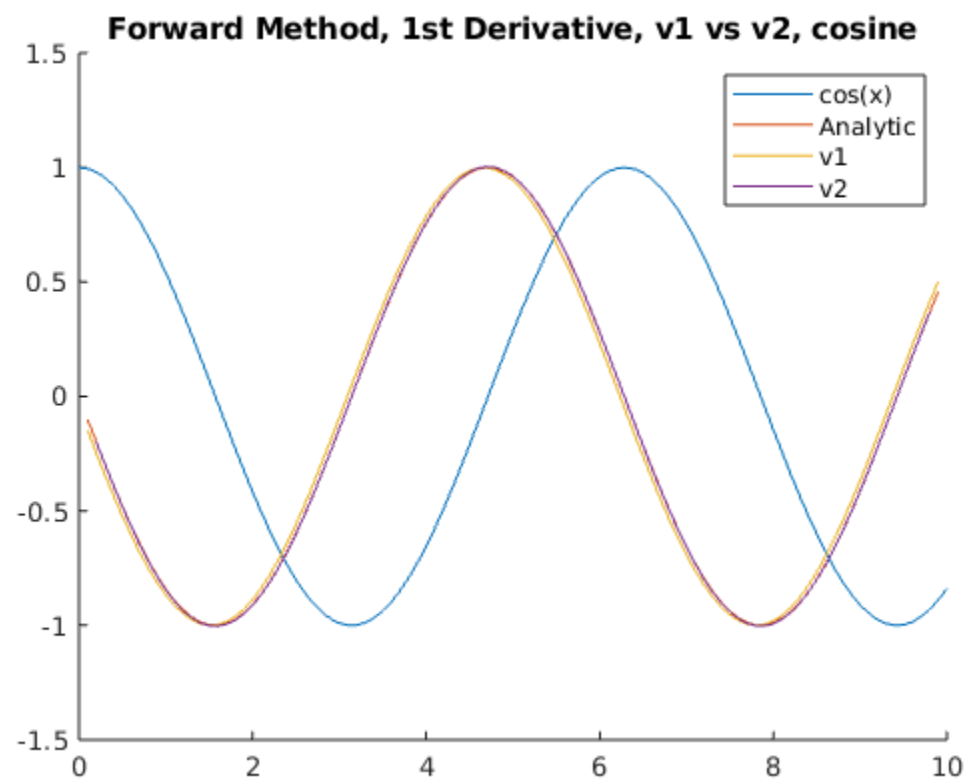
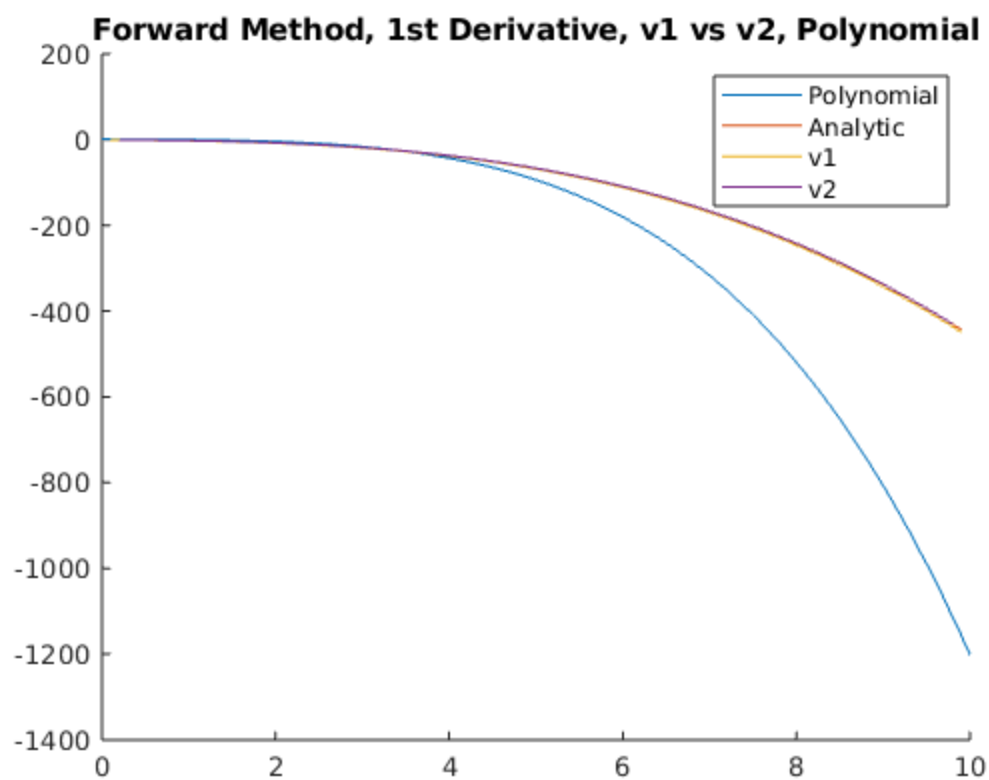
```
figure;
hold on;
plot(x_vector, poly_h(x_vector));
plot(x_vector(2:end-1), poly_res{1,1}); % 1st deriv, actual
plot(x_vector(2:end-1), poly_res{1,2}); % 1st derivative, forward v1
plot(x_vector(3:end-2), poly_res{1,4}); % 1st deriv, forward v2
title('Forward Method, 1st Derivative, v1 vs v2, Polynomial');
legend('Polynomial', 'Analytic', 'v1', 'v2');

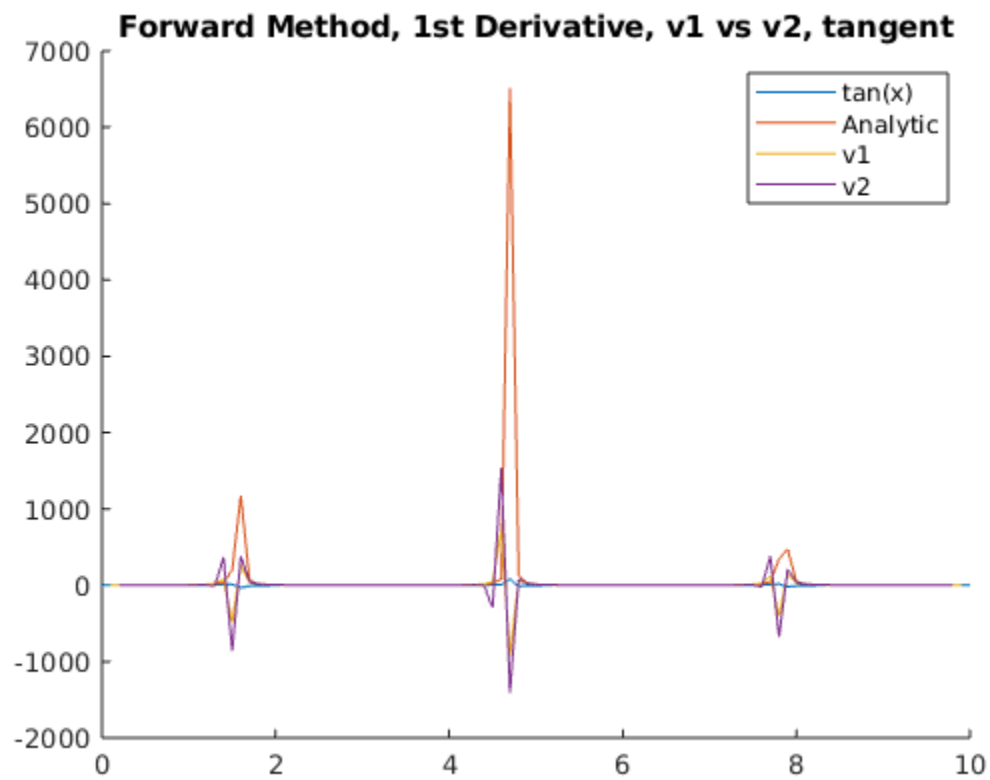
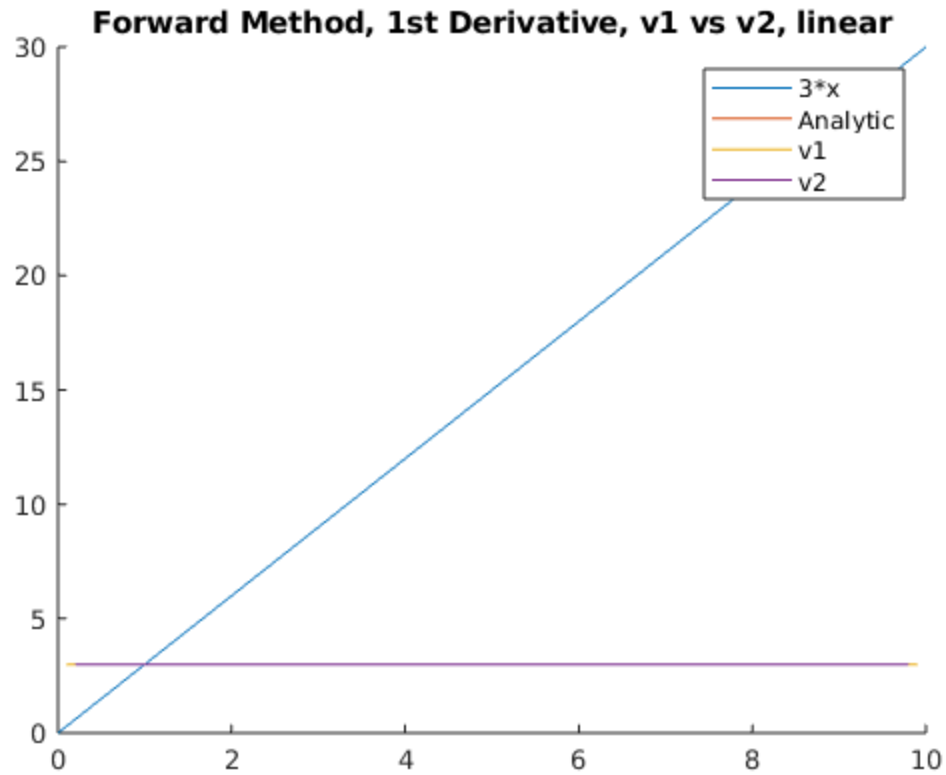
figure;
hold on;
plot(x_vector, cos(x_vector));
plot(x_vector(2:end-1), cos_res{1,1}); % 1st deriv, actual
plot(x_vector(2:end-1), cos_res{1,2}); % 1st derivative, forward v1
plot(x_vector(3:end-2), cos_res{1,4}); % 1st deriv, forward v2
title('Forward Method, 1st Derivative, v1 vs v2, cosine');
legend('cos(x)', 'Analytic', 'v1', 'v2');

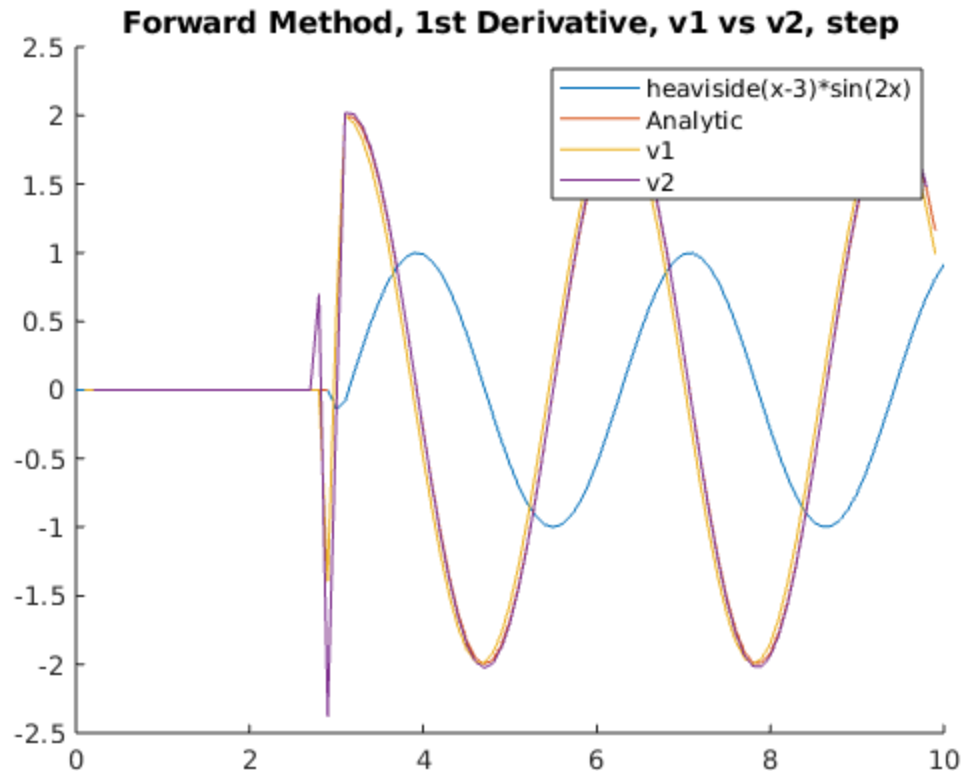
figure;
hold on;
plot(x_vector, lin_h(x_vector));
plot(x_vector(2:end-1), linear_res{1,1}); % 1st deriv, actual
plot(x_vector(2:end-1), linear_res{1,2}); % 1st derivative, forward v1
plot(x_vector(3:end-2), linear_res{1,4}); % 1st deriv, forward v2
title('Forward Method, 1st Derivative, v1 vs v2, linear');
legend('3*x', 'Analytic', 'v1', 'v2');

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(3:end-2), tangent_res{1,4}); % 1st deriv, forward v2
title('Forward Method, 1st Derivative, v1 vs v2, tangent');
legend('tan(x)', 'Analytic', 'v1', 'v2');

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(3:end-2), step_res{1,4}); % 1st deriv, forward v2
title('Forward Method, 1st Derivative, v1 vs v2, step');
legend('heaviside(x-3)*sin(2x)', 'Analytic', 'v1', 'v2');
```







Backward - 1st Derivative, v1 vs v2

```
figure;
hold on;
plot(x_vector, poly_h(x_vector));
plot(x_vector(2:end-1), poly_res{1,1}); % 1st deriv, actual
plot(x_vector(2:end-1), poly_res{1,6}); % 1st derivative, backward v1
plot(x_vector(3:end-2), poly_res{1,8}); % 1st deriv, backward v2
title('Backward Method, 1st Derivative, v1 vs v2, Polynomial');
legend('Polynomial', 'Analytic', 'v1', 'v2');
```

```
figure;
hold on;
plot(x_vector, cos(x_vector));
plot(x_vector(2:end-1), cos_res{1,1}); % 1st deriv, actual
plot(x_vector(2:end-1), cos_res{1,6}); % 1st derivative, backward v1
plot(x_vector(3:end-2), cos_res{1,8}); % 1st deriv, backward v1
title('Backward Method, 1st Derivative, v1 vs v2, cosine');
legend('cos(x)', 'Analytic', 'v1', 'v2');
```

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

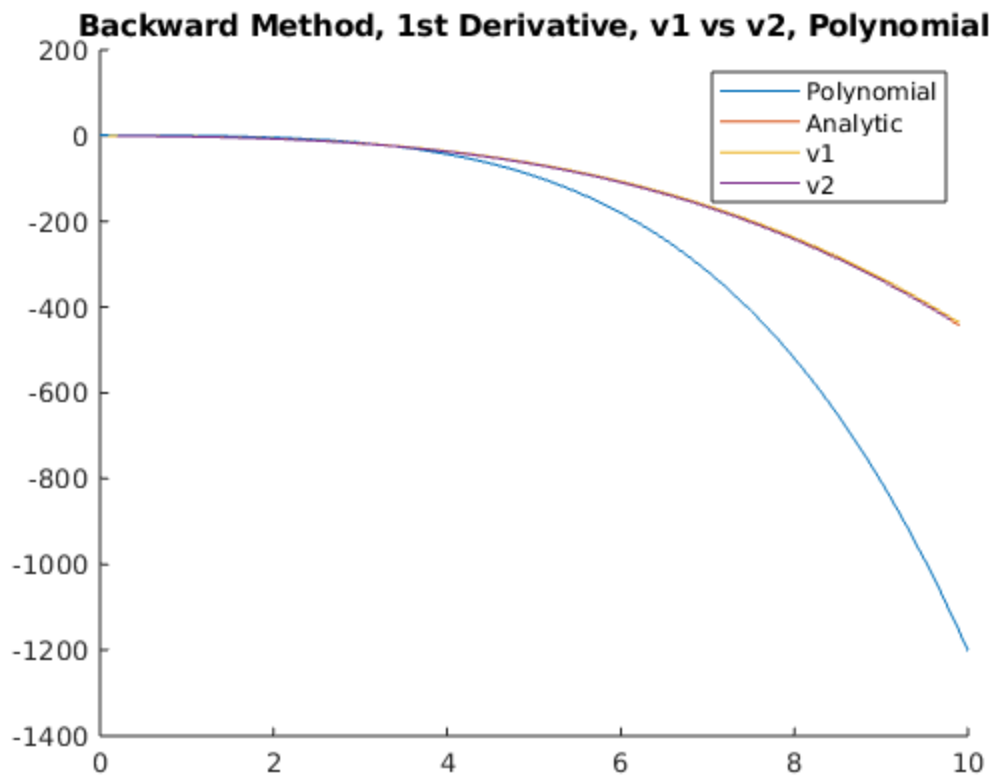
```

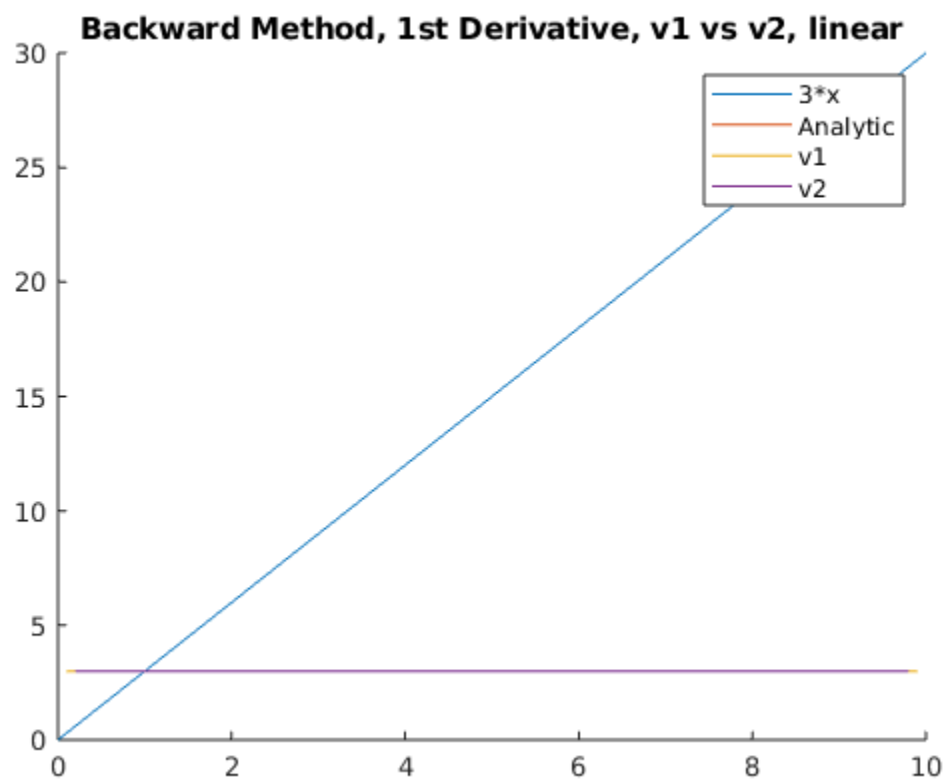
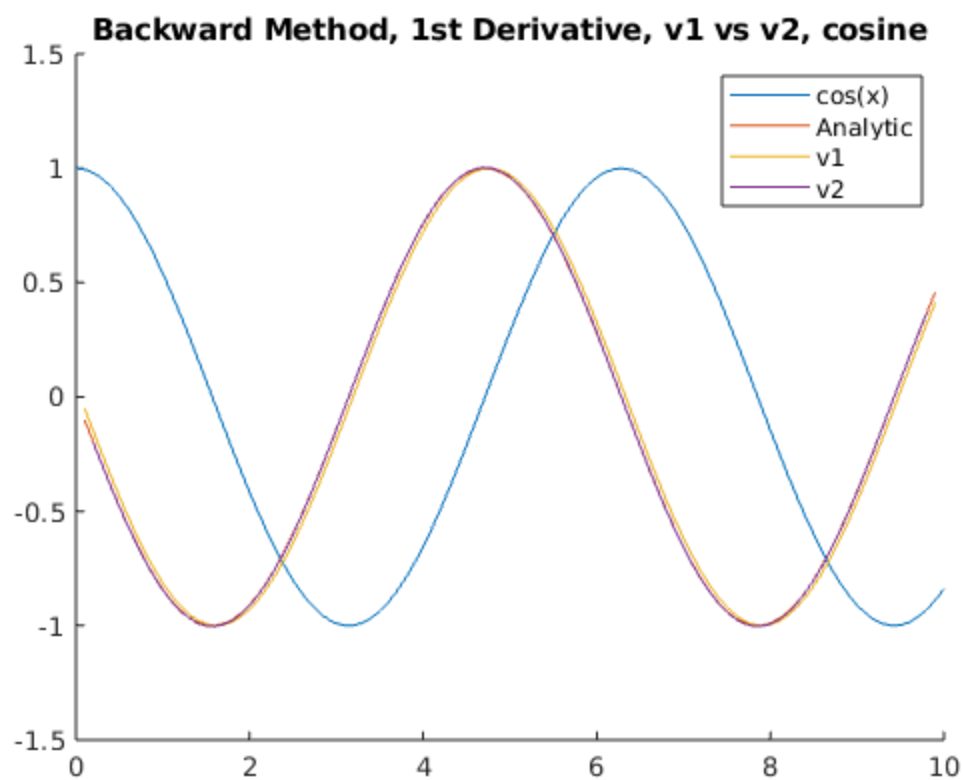
plot(x_vector(2:end-1), linear_res{1,6}); % 1st derivative, backward
v1
plot(x_vector(3:end-2), linear_res{1,8}); % 1st deriv, backward v2
title('Backward Method, 1st Derivative, v1 vs v2, linear');
legend('3*x', 'Analytic', 'v1', 'v2');

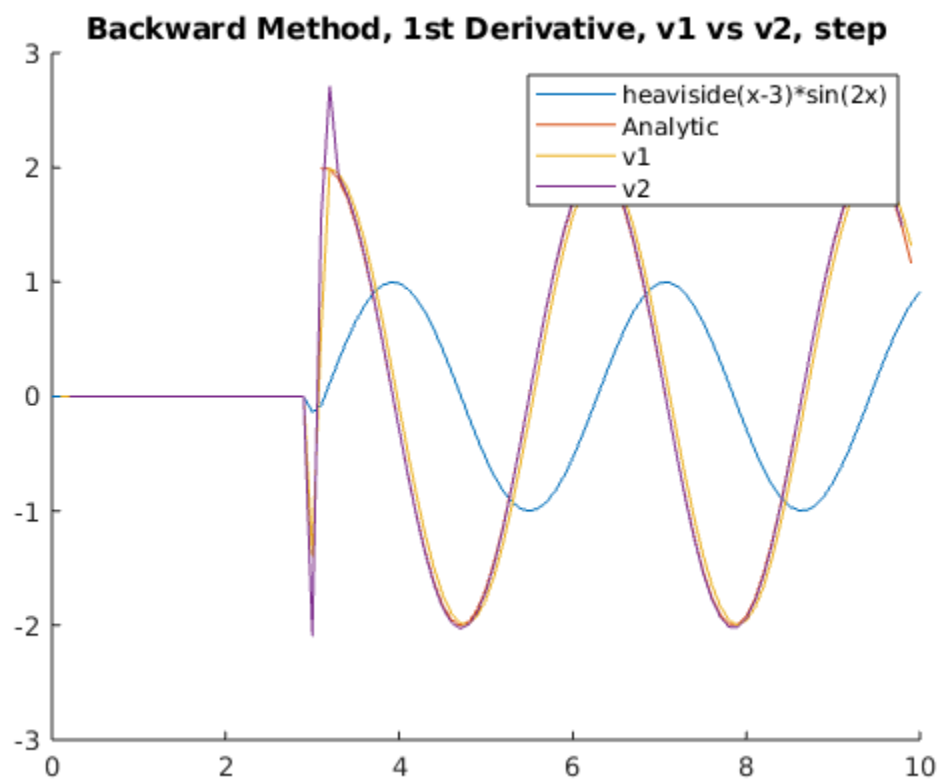
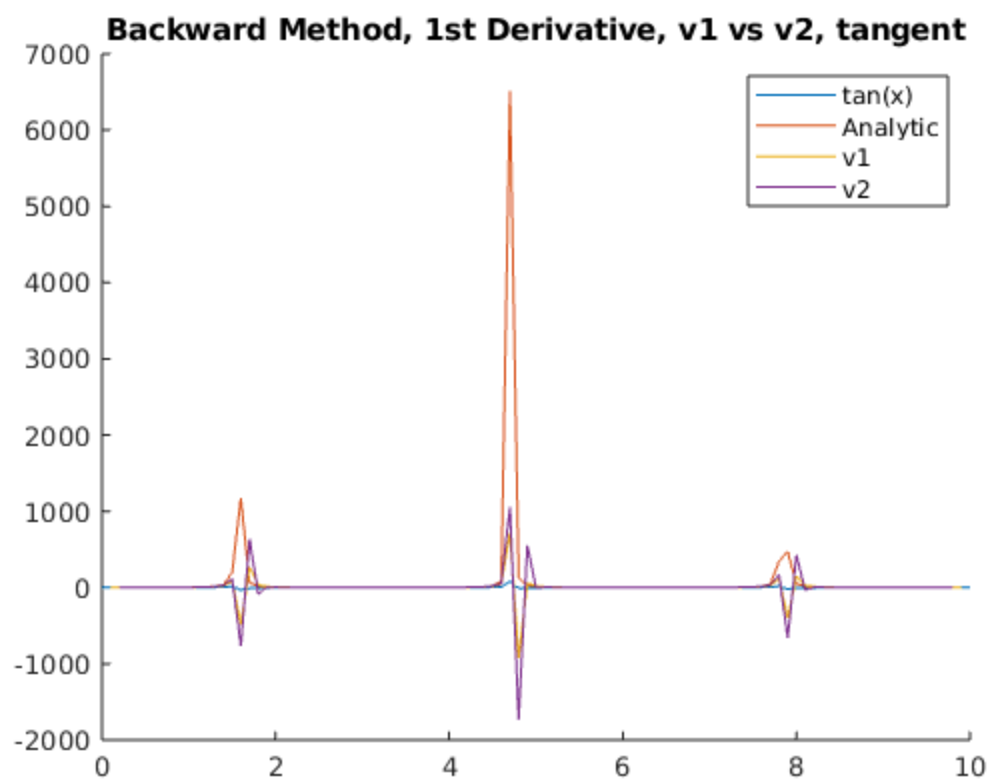
figure;
hold on;
plot(x_vector, tan(x_vector));
plot(x_vector(2:end-1), tangent_res{1,1}); % 1st deriv, actual
plot(x_vector(2:end-1), tangent_res{1,6}); % 1st derivative, backward
v1
plot(x_vector(3:end-2), tangent_res{1,8}); % 1st deriv, backward v2
title('Backward Method, 1st Derivative, v1 vs v2, tangent');
legend('tan(x)', 'Analytic', 'v1', 'v2');

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{1,6}); % 1st derivative, backward v1
plot(x_vector(3:end-2), step_res{1,8}); % 1st deriv, backward v2
title('Backward Method, 1st Derivative, v1 vs v2, step');
legend('heaviside(x-3)*sin(2x)', 'Analytic', 'v1', 'v2');

```







Center - 1st Derivative, v1 vs v2

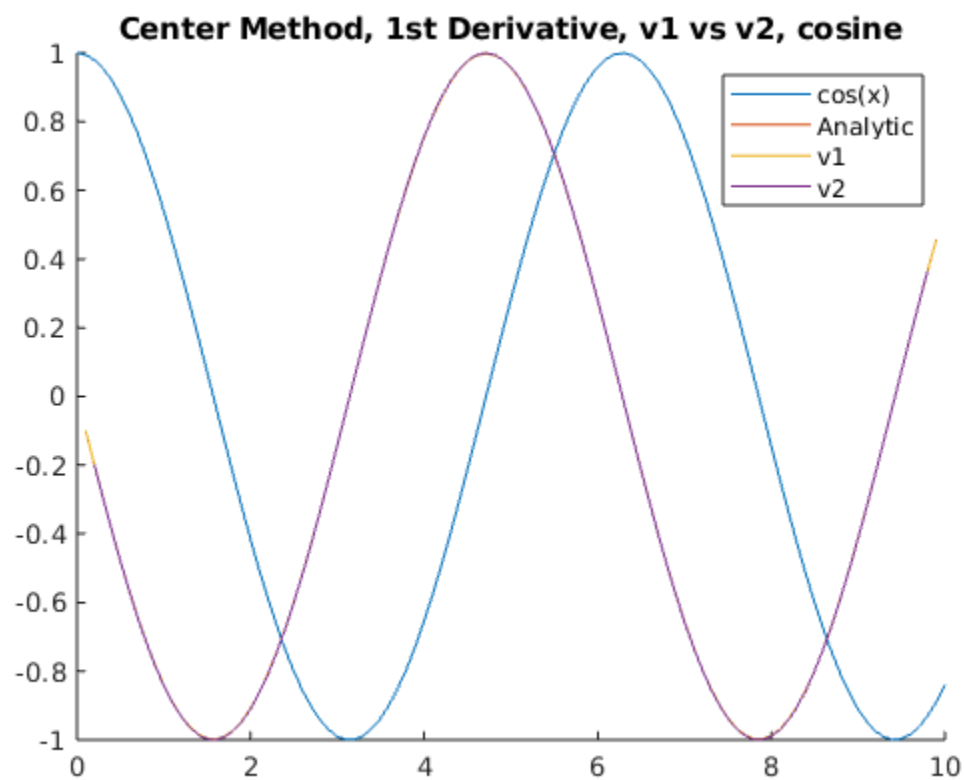
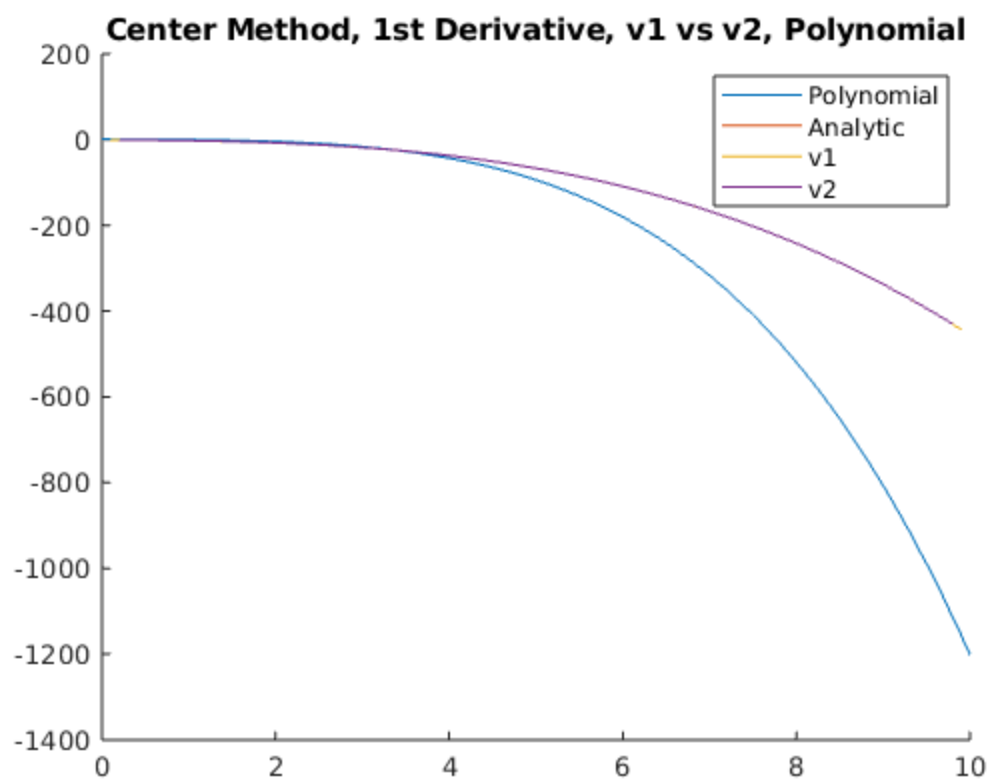
```
figure;
hold on;
plot(x_vector, poly_h(x_vector));
plot(x_vector(2:end-1), poly_res{1,1}); % 1st deriv, actual
plot(x_vector(2:end-1), poly_res{1,10}); % 1st derivative, center v1
plot(x_vector(3:end-2), poly_res{1,12}); % 1st deriv, center v2
title('Center Method, 1st Derivative, v1 vs v2, Polynomial');
legend('Polynomial', 'Analytic', 'v1', 'v2');

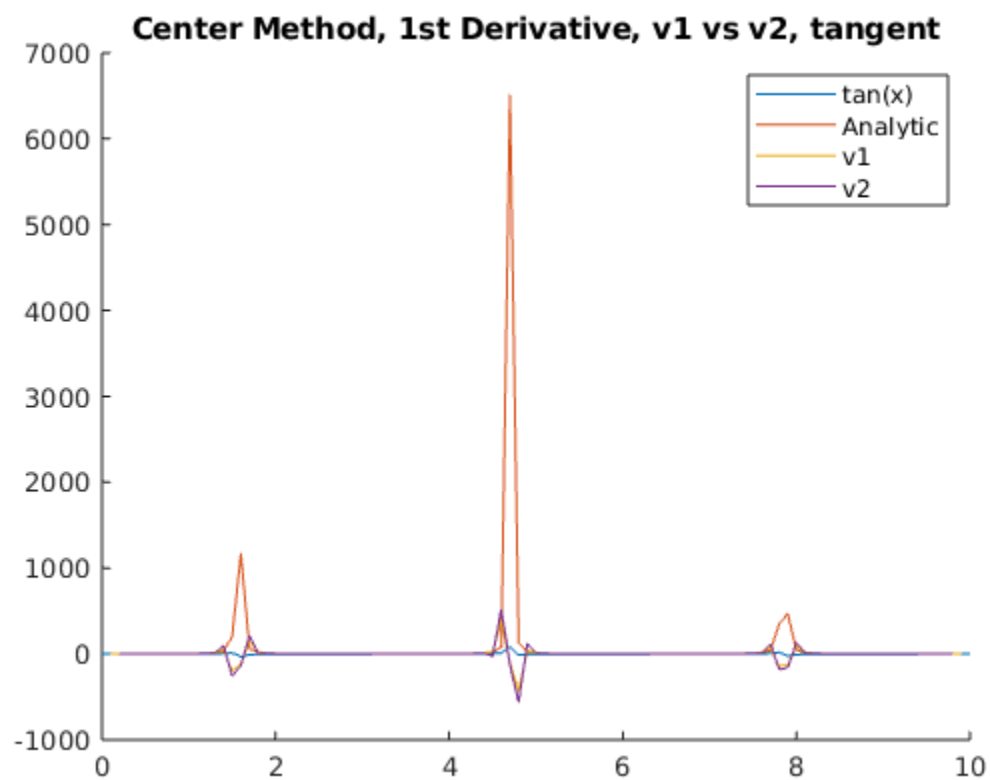
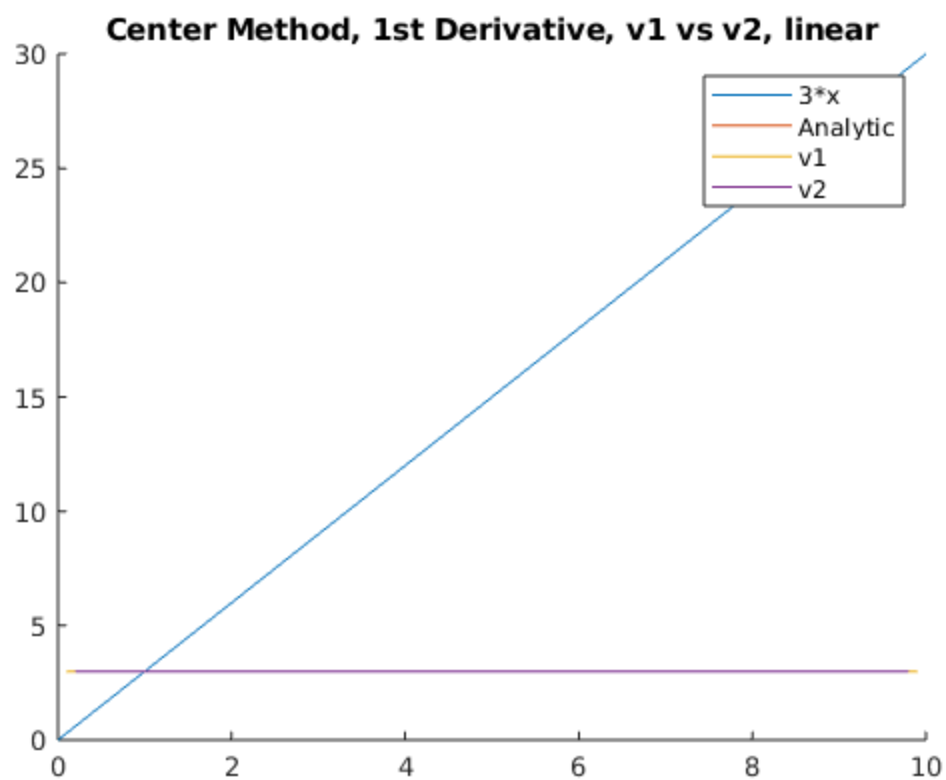
figure;
hold on;
plot(x_vector, cos(x_vector));
plot(x_vector(2:end-1), cos_res{1,1}); % 1st deriv, actual
plot(x_vector(2:end-1), cos_res{1,10}); % 1st derivative, center v1
plot(x_vector(3:end-2), cos_res{1,12}); % 1st deriv, center v2
title('Center Method, 1st Derivative, v1 vs v2, cosine');
legend('cos(x)', 'Analytic', 'v1', 'v2');

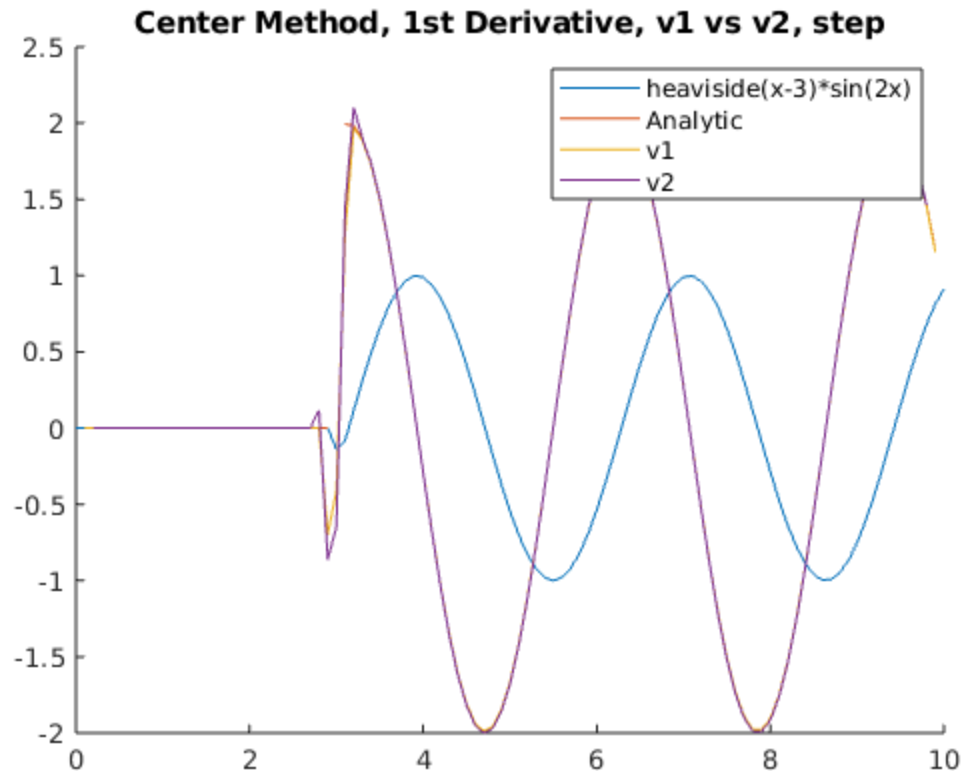
figure;
hold on;
plot(x_vector, lin_h(x_vector));
plot(x_vector(2:end-1), linear_res{1,1}); % 1st deriv, actual
plot(x_vector(2:end-1), linear_res{1,10}); % 1st derivative, center v1
plot(x_vector(3:end-2), linear_res{1,12}); % 1st deriv, center v2
title('Center Method, 1st Derivative, v1 vs v2, linear');
legend('3*x', 'Analytic', 'v1', 'v2');

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{1,10}); % 1st derivative, center
v1
plot(x_vector(3:end-2), tangent_res{1,12}); % 1st deriv, center v2
title('Center Method, 1st Derivative, v1 vs v2, tangent');
legend('tan(x)', 'Analytic', 'v1', 'v2');

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{1,10}); % 1st derivative, center v1
plot(x_vector(3:end-2), step_res{1,12}); % 1st deriv, center v2
title('Center Method, 1st Derivative, v1 vs v2, step');
legend('heaviside(x-3)*sin(2x)', 'Analytic', 'v1', 'v2');
```







Forward - 2nd Derivative, v1 vs v2

```
figure;
hold on;
plot(x_vector, poly_h(x_vector));
plot(x_vector(3:end-2), poly_res{2,1}); % 2nd deriv, actual
plot(x_vector(3:end-2), poly_res{2,2}); % 2nd derivative, forward v1
plot(x_vector(4:end-3), poly_res{2,4}); % 2nd deriv, forward v2
title('Forward Method, 2nd Derivative, v1 vs v2, Polynomial');
legend('Polynomial', 'Analytic', 'v1', 'v2');
```

```
figure;
hold on;
plot(x_vector, cos(x_vector));
plot(x_vector(3:end-2), cos_res{2,1}); % 2nd deriv, actual
plot(x_vector(3:end-2), cos_res{2,2}); % 2nd derivative, forward v1
plot(x_vector(4:end-3), cos_res{2,4}); % 2nd deriv, forward v2
title('Forward Method, 2nd Derivative, v1 vs v2, cosine');
legend('cos(x)', 'Analytic', 'v1', 'v2');
```

```
figure;
hold on;
plot(x_vector, lin_h(x_vector));
plot(x_vector(3:end-2), linear_res{2,1}); % 2nd deriv, actual
plot(x_vector(3:end-2), linear_res{2,2}); % 2nd derivative, forward v1
```

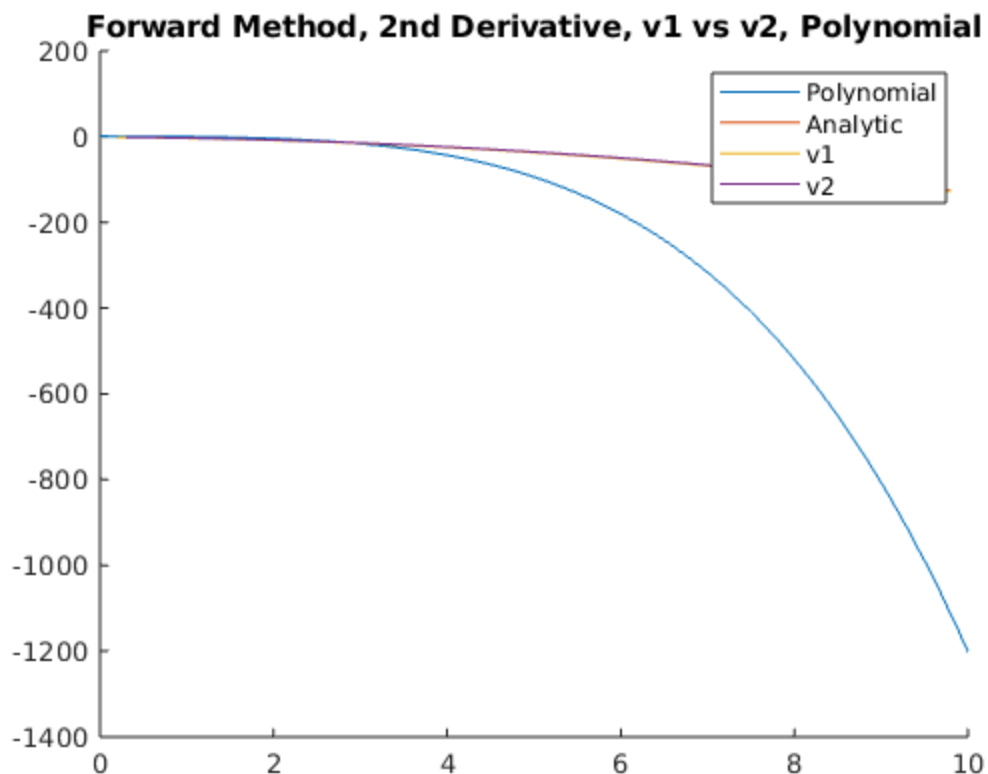
```

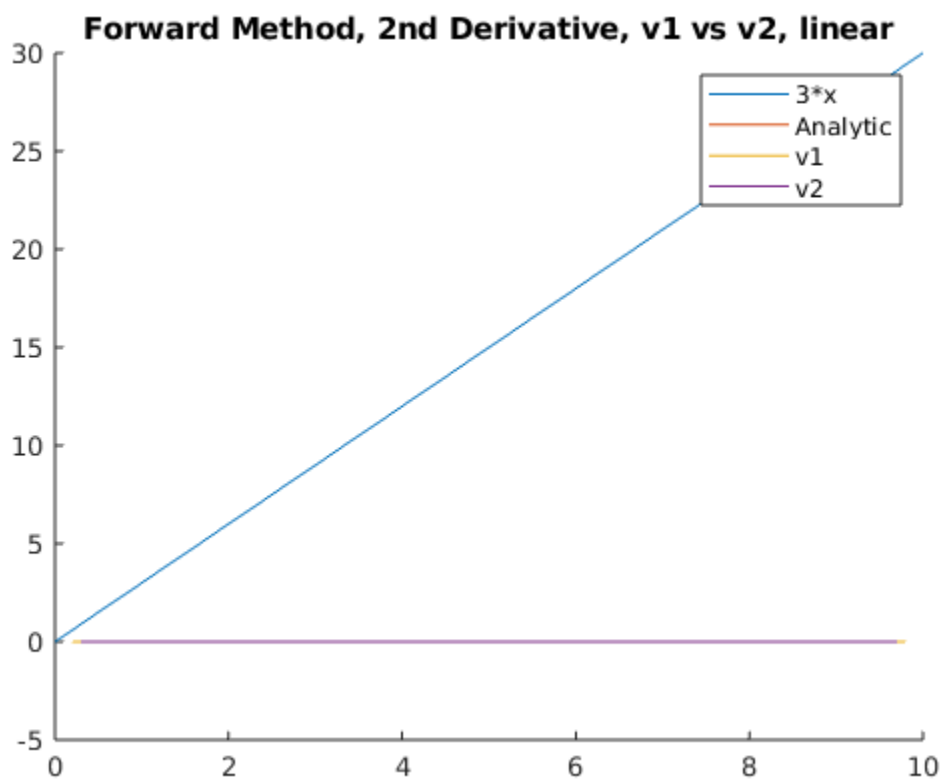
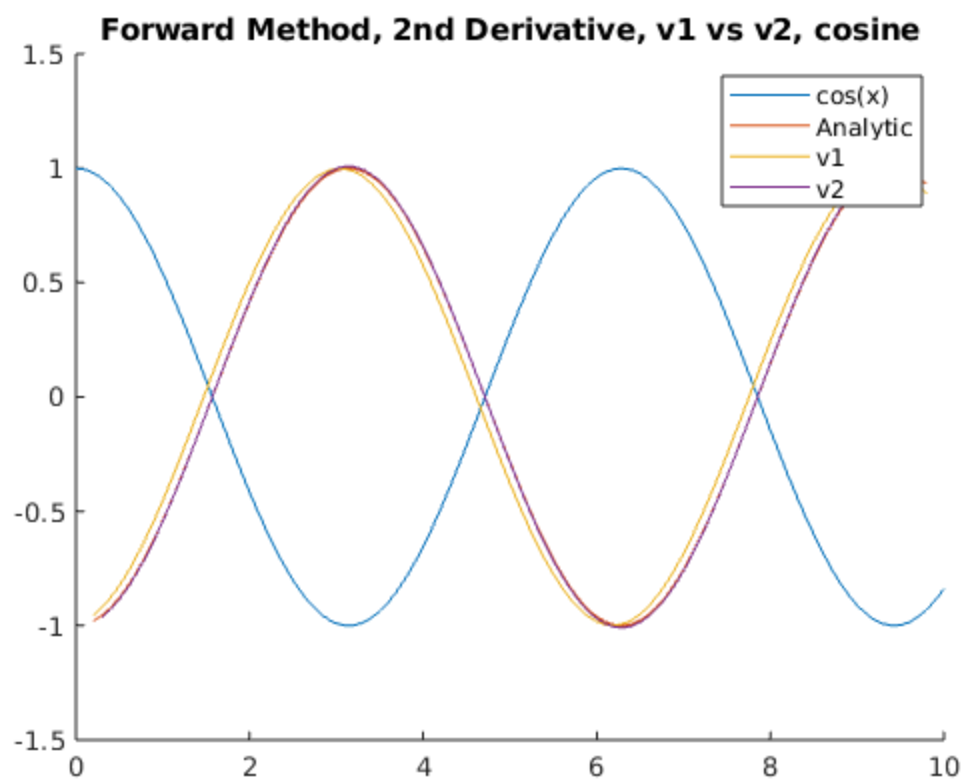
plot(x_vector(4:end-3), linear_res{2,4}); % 2nd deriv, forward v2
title('Forward Method, 2nd Derivative, v1 vs v2, linear');
legend('3*x', 'Analytic', 'v1', 'v2');

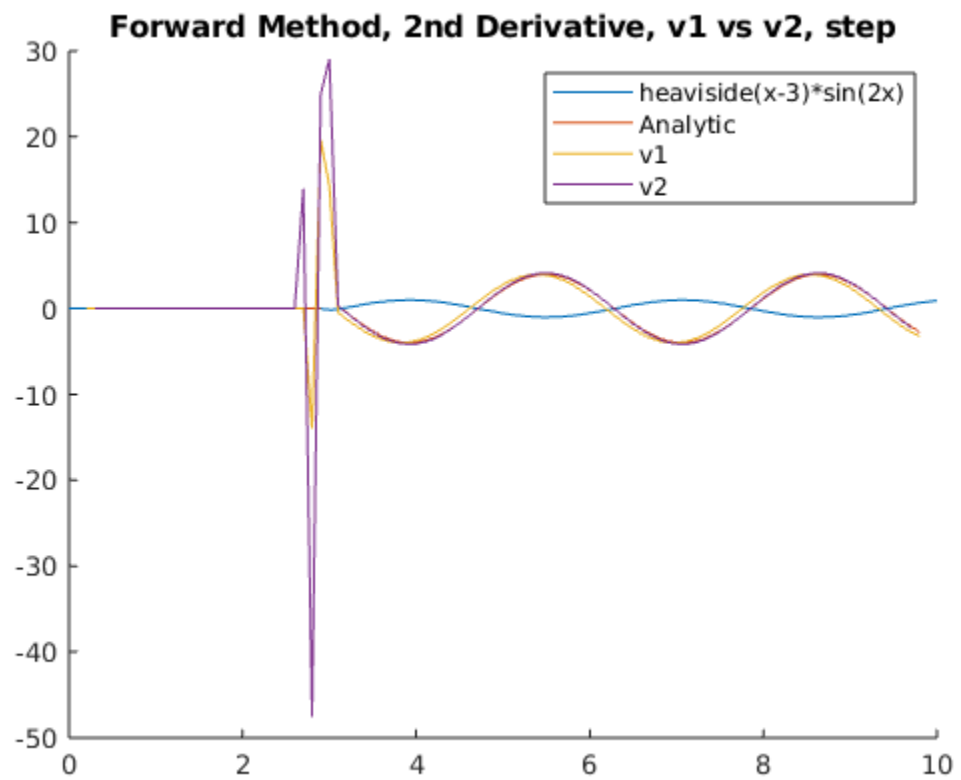
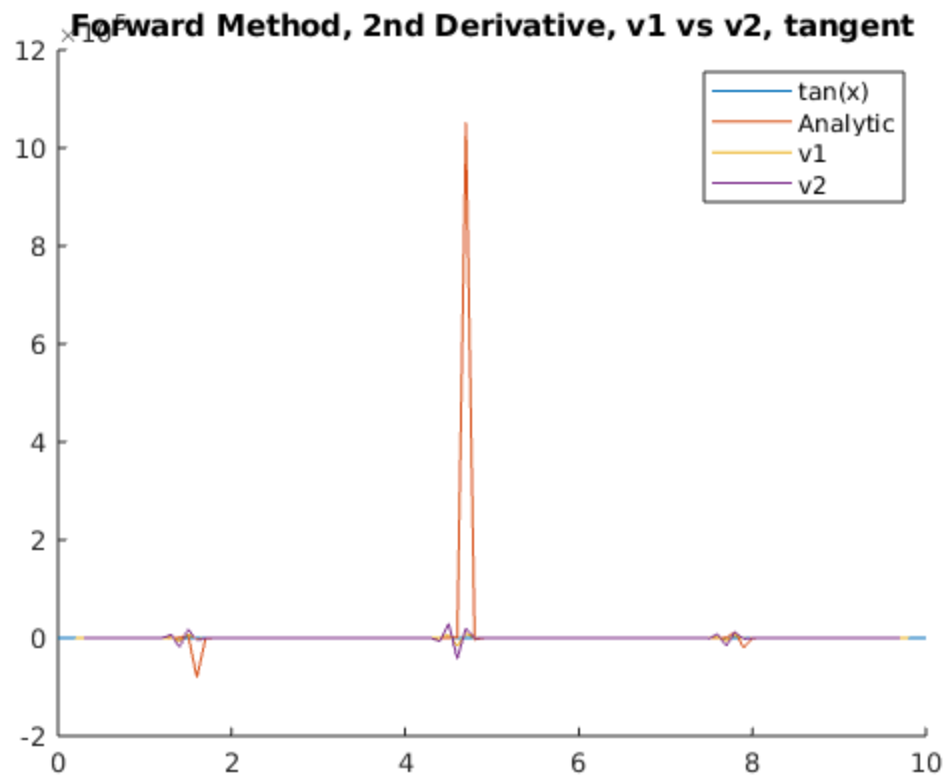
figure;
hold on;
plot(x_vector, tan(x_vector));
plot(x_vector(3:end-2), tangent_res{2,1}); % 2nd deriv, actual
plot(x_vector(3:end-2), tangent_res{2,2}); % 2nd derivative, forward
v1
plot(x_vector(4:end-3), tangent_res{2,4}); % 2nd deriv, forward v2
title('Forward Method, 2nd Derivative, v1 vs v2, tangent');
legend('tan(x)', 'Analytic', 'v1', 'v2');

figure;
hold on;
plot(x_vector, step_h(x_vector));
plot(x_vector(3:end-2), step_res{2,1}); % 2nd deriv, actual
plot(x_vector(3:end-2), step_res{2,2}); % 2nd derivative, forward v1
plot(x_vector(4:end-3), step_res{2,4}); % 2nd deriv, forward v2
title('Forward Method, 2nd Derivative, v1 vs v2, step');
legend('heaviside(x-3)*sin(2x)', 'Analytic', 'v1', 'v2');

```







Backward - 2nd Derivative, v1 vs v2

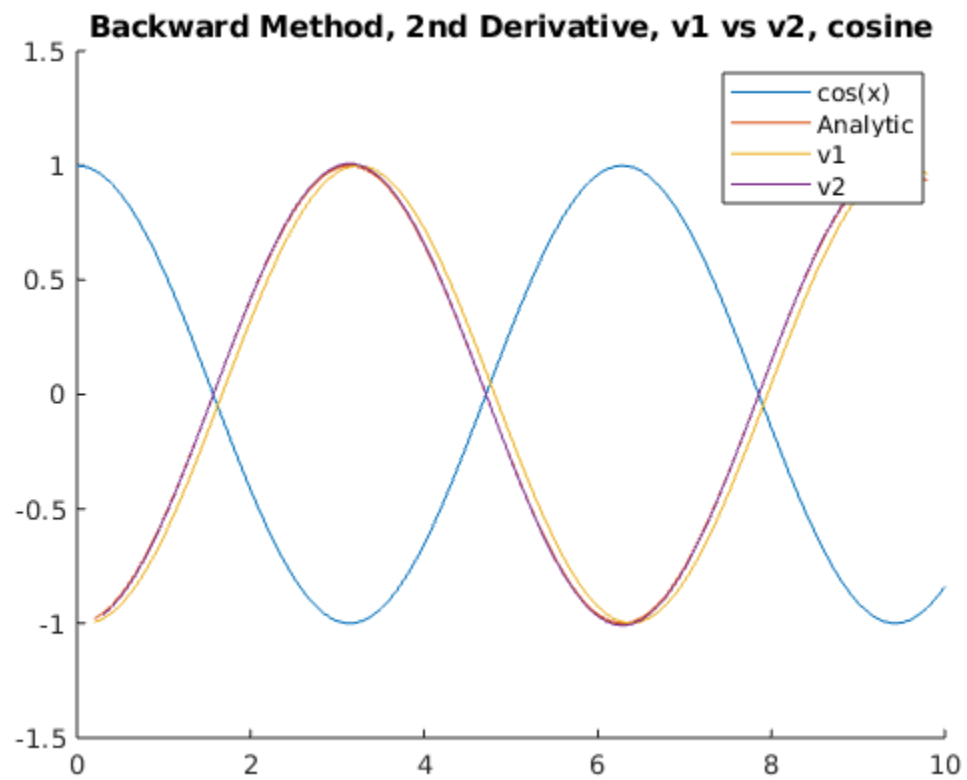
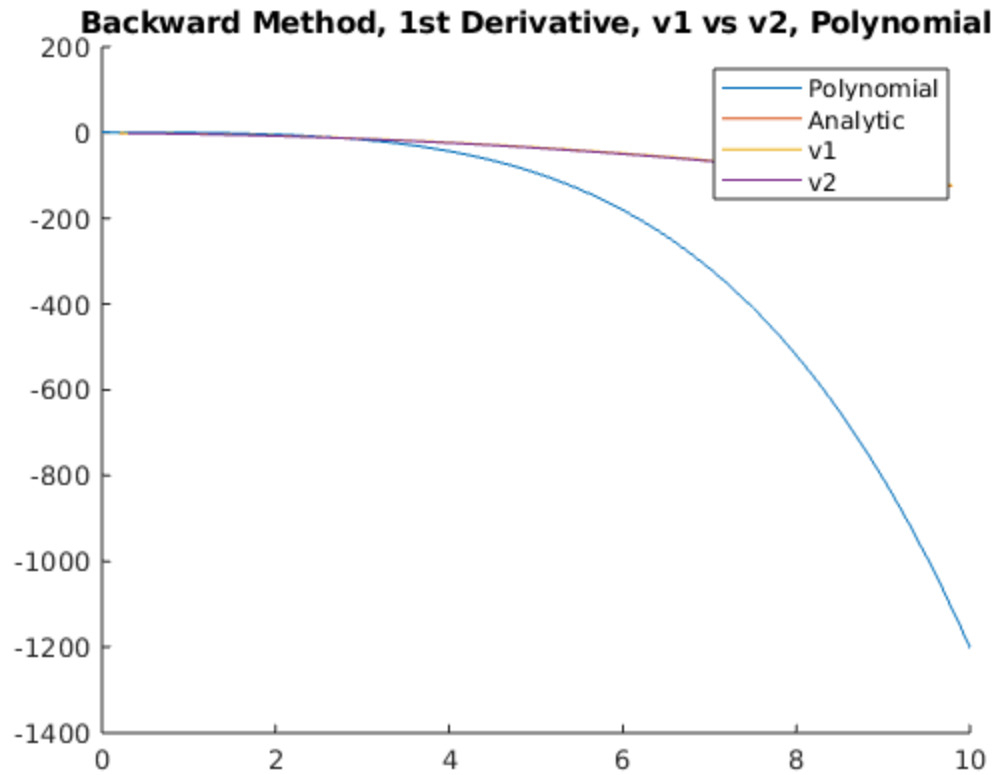
```
figure;
hold on;
plot(x_vector, poly_h(x_vector));
plot(x_vector(3:end-2), poly_res{2,1}); % 2nd deriv, actual
plot(x_vector(3:end-2), poly_res{2,6}); % 2nd derivative, backward v1
plot(x_vector(4:end-3), poly_res{2,8}); % 2nd deriv, backward v2
title('Backward Method, 1st Derivative, v1 vs v2, Polynomial');
legend('Polynomial', 'Analytic', 'v1', 'v2');

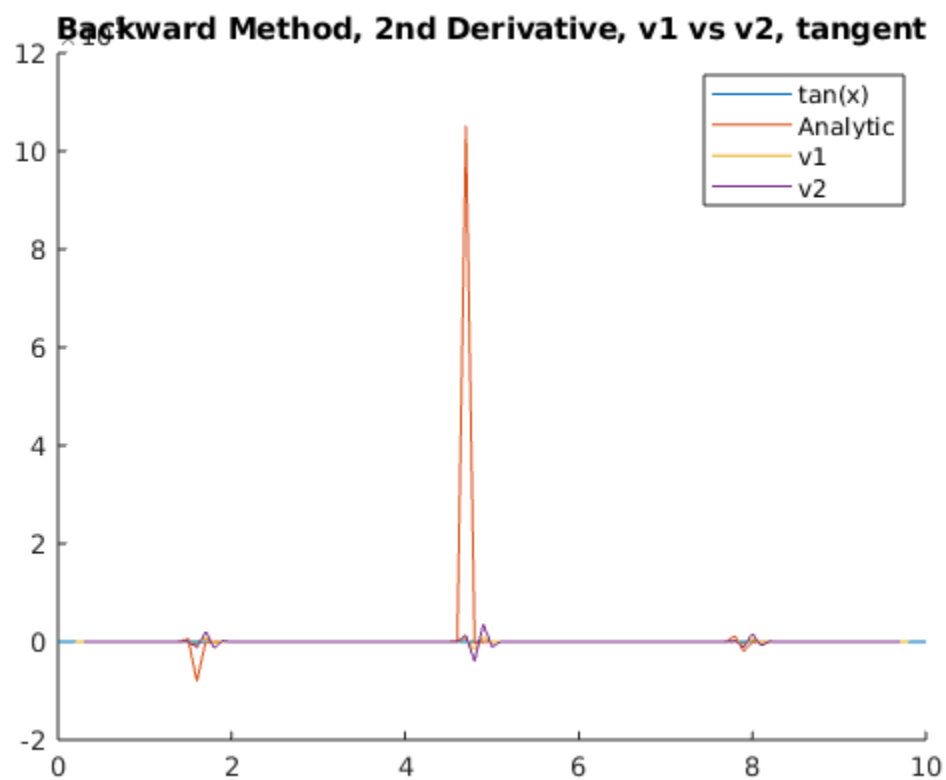
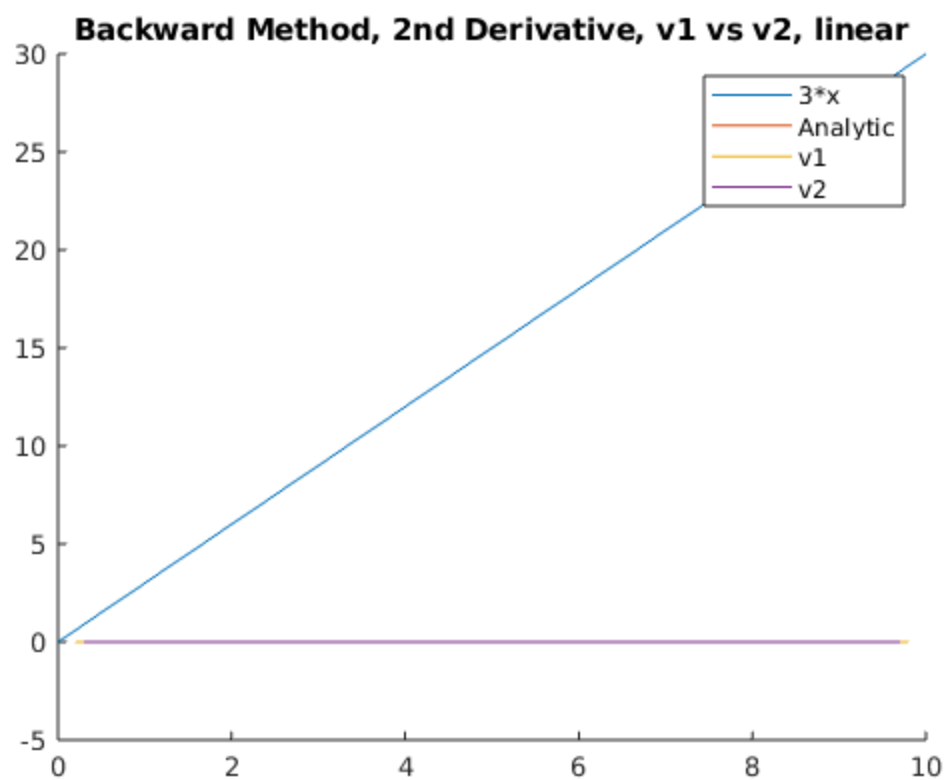
figure;
hold on;
plot(x_vector, cos(x_vector));
plot(x_vector(3:end-2), cos_res{2,1}); % 2nd deriv, actual
plot(x_vector(3:end-2), cos_res{2,6}); % 2nd derivative, backward v1
plot(x_vector(4:end-3), cos_res{2,8}); % 2nd deriv, backward v2
title('Backward Method, 2nd Derivative, v1 vs v2, cosine');
legend('cos(x)', 'Analytic', 'v1', 'v2');

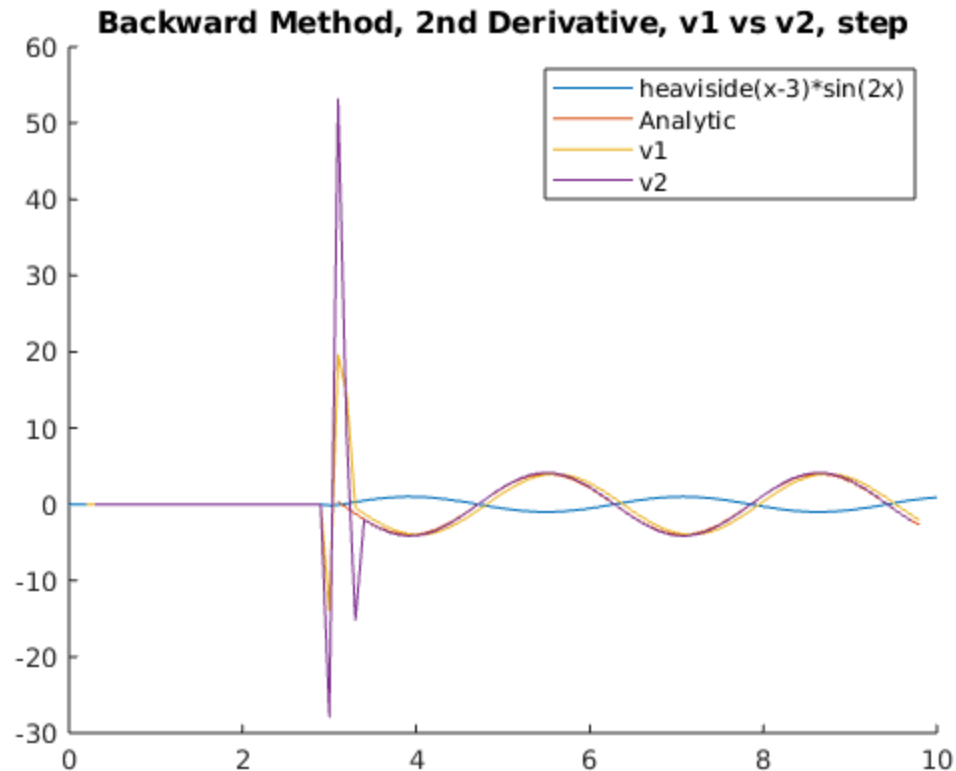
figure;
hold on;
plot(x_vector, lin_h(x_vector));
plot(x_vector(3:end-2), linear_res{2,1}); % 2nd deriv, actual
plot(x_vector(3:end-2), linear_res{2,6}); % 2nd derivative, backward
v1
plot(x_vector(4:end-3), linear_res{2,8}); % 2nd deriv, backward v2
title('Backward Method, 2nd Derivative, v1 vs v2, linear');
legend('3*x', 'Analytic', 'v1', 'v2');

figure;
hold on;
plot(x_vector, tan(x_vector));
plot(x_vector(3:end-2), tangent_res{2,1}); % 2nd deriv, actual
plot(x_vector(3:end-2), tangent_res{2,6}); % 2nd derivative, backward
v1
plot(x_vector(4:end-3), tangent_res{2,8}); % 2nd deriv, backward v2
title('Backward Method, 2nd Derivative, v1 vs v2, tangent');
legend('tan(x)', 'Analytic', 'v1', 'v2');

figure;
hold on;
plot(x_vector, step_h(x_vector));
plot(x_vector(3:end-2), step_res{2,1}); % 2nd deriv, actual
plot(x_vector(3:end-2), step_res{2,6}); % 2nd derivative, backward v1
plot(x_vector(4:end-3), step_res{2,8}); % 2nd deriv, backward v2
title('Backward Method, 2nd Derivative, v1 vs v2, step');
legend('heaviside(x-3)*sin(2x)', 'Analytic', 'v1', 'v2');
```







Center - 2nd Derivative, v1 vs v2

```
figure;
hold on;
plot(x_vector, poly_h(x_vector));
plot(x_vector(3:end-2), poly_res{2,9}); % 2nd deriv, actual
plot(x_vector(3:end-2), poly_res{2,10}); % 2nd derivative, center v1
plot(x_vector(4:end-3), poly_res{2,12}); % 2nd deriv, center v2
title('Center Method, 1st Derivative, v1 vs v2, Polynomial');
legend('Polynomial', 'Analytic', 'v1', 'v2');

figure;
hold on;
plot(x_vector, cos(x_vector));
plot(x_vector(3:end-2), cos_res{2,9}); % 2nd deriv, actual
plot(x_vector(3:end-2), cos_res{2,10}); % 2nd derivative, center v1
plot(x_vector(4:end-3), cos_res{2,12}); % 2nd deriv, center v2
title('Center Method, 2nd Derivative, v1 vs v2, cosine');
legend('cos(x)', 'Analytic', 'v1', 'v2');

figure;
hold on;
plot(x_vector, lin_h(x_vector));
plot(x_vector(3:end-2), linear_res{2,9}); % 2nd deriv, actual
plot(x_vector(3:end-2), linear_res{2,10}); % 2nd derivative, center v1
```

```
plot(x_vector(4:end-3), linear_res{2,12}); % 2nd deriv, center v2
title('Center Method, 2nd Derivative, v1 vs v2, linear');
legend('3*x', 'Analytic', 'v1', 'v2');

figure;
hold on;
plot(x_vector, tan(x_vector));
plot(x_vector(3:end-2), tangent_res{2,9}); % 2nd deriv, actual
plot(x_vector(3:end-2), tangent_res{2,10}); % 2nd derivative, center
v1
plot(x_vector(4:end-3), tangent_res{2,12}); % 2nd deriv, center v2
title('Center Method, 2nd Derivative, v1 vs v2, tangent');
legend('tan(x)', 'Analytic', 'v1', 'v2');

figure;
hold on;
plot(x_vector, step_h(x_vector));
plot(x_vector(3:end-2), step_res{2,9}); % 2nd deriv, actual
plot(x_vector(3:end-2), step_res{2,10}); % 2nd derivative, center v1
plot(x_vector(4:end-3), step_res{2,12}); % 2nd deriv, center v2
title('Center Method, 2nd Derivative, v1 vs v2, step');
legend('heaviside(x-3)*sin(2x)', 'Analytic', 'v1', 'v2');
close all;
```

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