Parameter Sweep of ODEs

This is a parameter sweep study of a 2nd order ODE system.

`m*X'' + b*X' + k*X = 0`

We solve the ODE for a time span of 0 to 25 seconds, with initial conditions X(0) = 0 and X'(0) = 1. We sweep the parameters "b" and "k" and record the peak values of X for each condition. At the end, we plot a surface of the results.

We speed up the time to run our simulation by the use of the parfor construct.

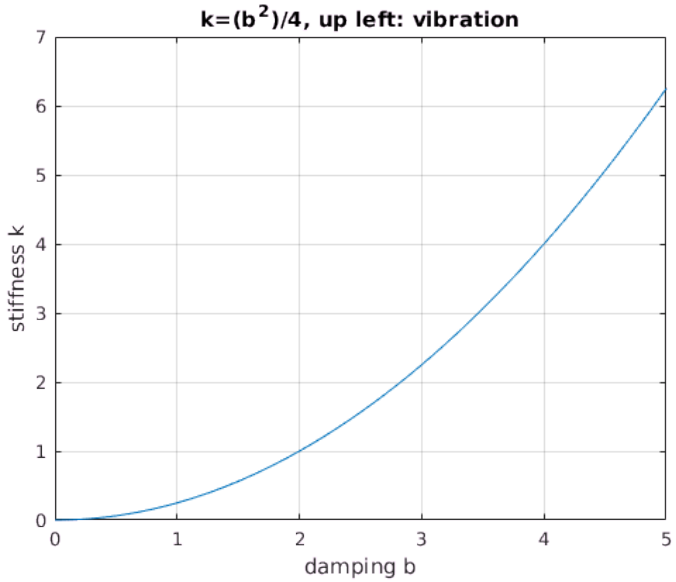
```
% Further developed by HA 28.11.2016
type odesystem.m
```

```
function dy = odesystem(~, y, m, b, k)
% 2nd-order ODE
%
%   m*X'' + b*X' + k*X = 0
%
% --> system of 1st-order ODEs
%
%   y1=X, y2=X' = y1'
%   y2'=X'' = -(1/m)*(k*y1 + b*y2)
% -->
%   y1' = y2
%   y2' = -1/m * (k*y1 + b*y2)
dy = [y(2);
     -1/m * (k * y(1) + b * y(2))];
```

```
clear
close all
```

Underdamped -> vibration $b^2 < 4mk$

```
m=1;
b=0:.1:5;
k=(b.^2)/4;

plot(b,k);grid on;xlabel('damping b');ylabel('stiffness k');
title('k=(b^2)/4, up left: vibration')
```

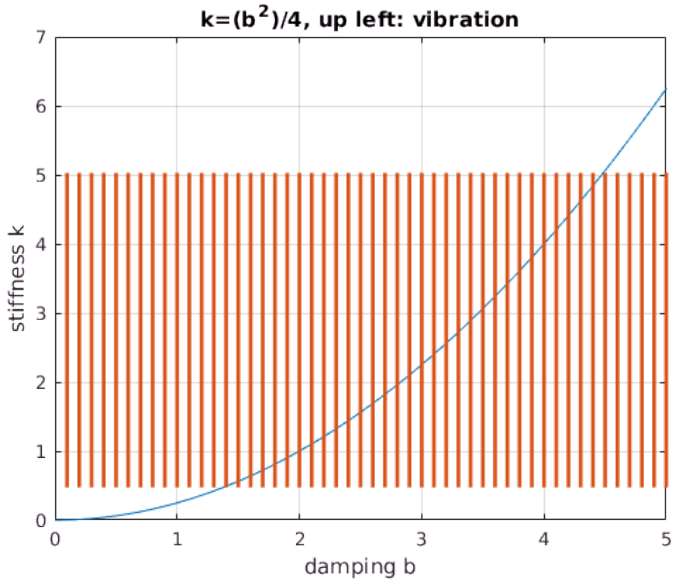



```
shg
```

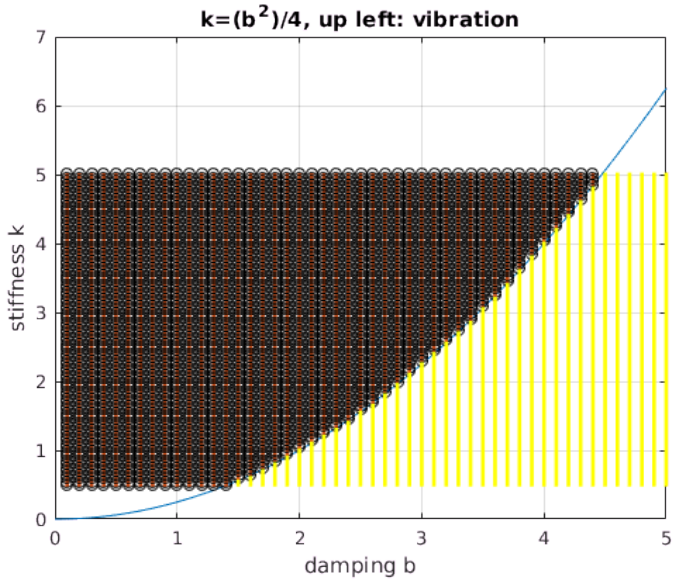
Initialize parameters

```
m     =         1;  % mass
bVals =  .1:.1 :5;  % damping values
kVals = 0.5:.05:5;  % stiffness values
```

```
hold on
[bGrid, kGrid] = meshgrid(bVals, kVals);
BK=[bGrid(:) kGrid(:)];
plot(BK(:,1),BK(:,2),'.')
```



```
bb=BK(:,1);kk=BK(:,2);
vibr=(bb.^2 < 4*kk);
novibr=~vibr;
byes=bb(vibr);
bno=bb(novibr);
kyes=kk(vibr);
kno=kk(novibr);
hold on
plot(byes,kyes,'ok')
plot(bno,kno,'y.')
```




```
peakValsvibr=nan(length(byes),1);
peakValsno=nan(length(bno),1);
```

Let's make one call first for each case

Note the handy handling of extra parameters.

```
[Tyes{1},Yyes{1}] = ode45(@(t,y) odesystem(t, y, m, byes(1), kyes(1)),...
    [0, 25], ...  % simulate for 25 seconds
    [0, 1]) ;      % initial conditions
[Tno{1},Yno{1}] = ode45(@(t,y) odesystem(t, y, m, bno(1), kno(1)),...
    [0, 25], ...  % simulate for 25 seconds
    [0, 1]) ;      % initial conditions

max(Yyes{1}(:,1))   % Max displacement, vibration case
```

```
ans = 1.2716
```

```
min(Yyes{1}(:,2))   % Min velocity, vibration case
```

```
ans = -0.8057
```

```
max(Yno{1}(:,1))    % Max displacement, no vibration case
```

```
ans = 0.4999
```

```
min(Yno{1}(:,2))    % Min velocity, no vibration case
```

```
ans = -0.1250
```

Parameter Sweep in serial

```
disp('Computing Parameter Sweep...');
```

```
Computing Parameter Sweep...
```

```
% Preallocate
Tyes=cell(1,numel(byes));Yyes=cell(1,numel(byes));
tic;
for idx = 1:numel(byes)
  % Solve ODE
  [Tyes{idx},Yyes{idx}] = ode45(@(t,y) odesystem(t, y, m, byes(idx), ...
   kyes(idx)),[0, 25], ...  % simulate for 25 seconds
   [0, 1]) ;      % initial conditions
 peakValsvibr(idx)=max(Yyes{idx}(:,1));
end
toc   % 12.369371 Preallocation of cell-arrays above -> no effect
```

```
Elapsed time is 21.416415 seconds.
```

```
maxindyes=find(peakValsvibr==max(peakValsvibr))
```

```
maxindyes = 1
```

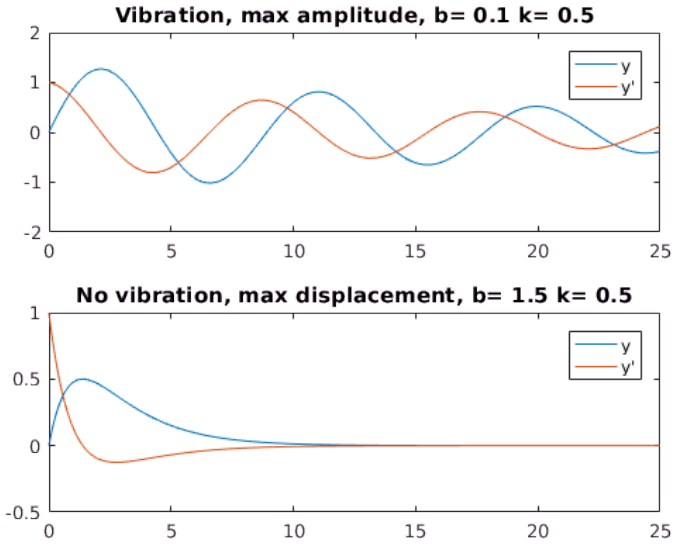
```
tic
for idx = 1:numel(bno)
[Tno{idx},Yno{idx}] = ode45(@(t,y) odesystem(t, y, m, bno(idx), ...
   kno(idx)),[0, 25], ...  % simulate for 25 seconds
   [0, 1]) ;      % initial conditions

peakValsno(idx)=max(Yno{idx}(:,1));
end
toc   % 6.701297
```

```
Elapsed time is 12.752852 seconds.
```

```
maxindno=find(peakValsno==max(peakValsno))
```

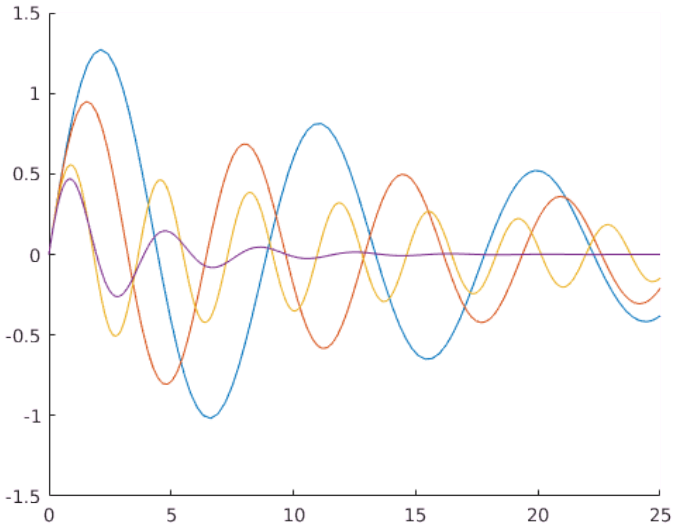
```
maxindno = 1
```

```
subplot(2,1,1)
plot(Tyes{1},Yyes{1})
legend('y','y''')
title(['Vibration, max amplitude, b= ' num2str(byes(1))...
    ' k= ' num2str(kyes(1)) ])
subplot(2,1,2)
plot(Tno{1},Yno{1});
legend('y','y''')
title(['No vibration, max displacement, b= ' num2str(bno(1))...
    ' k= ' num2str(kno(1)) ])
```




```
shg
% Elapsed time is 13.047220 seconds
```

```
figure
hold on
for idx=[1 10 50 500]
    plot(Tyes{idx},Yyes{idx}(:,1))
end
```




```
figure
hold on
for idx=[1 10 50 500]
    plot(Tno{idx},Yno{idx}(:,1))
end
```