6. Optimizing the design

The next step is to study the system's behavior at other forcing frequencies, as we want to minimize the largest amplitude of the building's oscillations that can occur in the range $\Omega \in [0.7, 1.3]$.

LTI Consumer (External resource) (1.0 / 1.0 points)

Sweeping through input frequencies

The script below is designed to compute and plot the swaying amplitude of the building over a range of driving frequencies. The swaying amplitude of the building without a TMD will also be plotted for comparison. To complete the script, you must:

1. Define the variable **`omSweep`** to be a row vector containing 50 equally spaced points over the interval $[0.7, 1.3]$. (Hint: use MATLAB function linspace.)
2. Copy the relevant lines of code from the previous problem to solve the system using ODE45.

To test the script, use the parameters:

$$\begin{aligned} m_1 &= 1, & m_2 &= 0.05, \\ k_1 &= 1, & k_2 &= 0.02, \\ b_1 &= 0.001, & b_2 &= 0.02. \end{aligned}$$

Use the initial conditions $\mathbf{x}_0 = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$,

and solve the system for times t on the interval $[0, 500]$. If your script runs correctly, you will see how the TMD changes the swaying amplitude of the building for each forcing frequency Ω in the range $[0.7, 1.3]$.

Your Script

Save Reset MATLAB Documentation (https://www.mathworks.com/help/)

```
load('Reference.mat')

%Define parameters
m1 = 1;
m2 = 0.05;
k1 = 1;
k2 = 0.02;
b1 = 0.001;
b2 = 0.02;
omSweep = linspace(0.7,1.3,50);

%Numerically solve DE at each forcing frequency
for i=1:length(omSweep)

    om = omSweep(i);

    %Copy code to solve DE here
    x0 = [0;0;0;0];
    tspan = [0,7000];
```

```
    A = [0,0,1,0;0,0,0,1;-(k1+k2)/m1,k2/m1,-(b1+b2)/m1,b2/m1;k2/m2,-k2/m2,b2/m2,-b2/
    [t,x] = ode45(@(t,x) A*x + [0;0;sin(om*t)/m1;0],tspan,x0);

    %Compute steady state solution and extract building oscillation amplitude
    lt = length(t);
    per = 2*pi/om;
    [~,idx] = min(abs(t-(t(end)-5*per)));
    ampBuilding(i) = max(x(idx:lt,1));

end

%Plot
plot(OmRef,ampRef,'r'); hold on;
plot(omSweep,ampBuilding,'k');
xlim([0.7,1.3]); ylabel('Max. Amp. of Building'); xlabel('$\Omega$');
legend('Without TMD','With TMD')

```

Run Script ()

Previous Assessment: Correct

Submit ()

Correct definition of OmSweep

Opitmization problem

The optimal values of k_2 and b_2 will minimize the maximum value of the black response curve. This is a two-dimensional minimization problem. However, in our example where the building has a small damping constant, b_1, it can be shown that the parameters k_2 and b_2 can be optimized independently of each other. Therefore, let's first determine the optimal value, k_2^*, of the spring constant.

MATLAB exploration 1

1/1 point (graded)

Copy the script you used in problem 2 to MATLAB online or on your computer. You will also need to save and copy the file 'Reference.mat'. You can do this by typing

```
url = 'https://courses.edx.org/asset-
v1:MITx+18.033x+1T2018+type@asset+block@Reference.mat';
websave('Reference.mat', url);
```

into MATLAB command window.

While keeping all of the other parameters constant, change k_2 and see what effect it has on the response curve of the building. Based on your observations, enter the optimal value, k_2^*, that is accurate to three decimal places.

$k_2^* =$ 0.0449 ✔ **Answer:** 0.045

Solution:

$$k_2^* = 0.045$$

Submit

You have used 2 of 10 attempts

Answers are displayed within the problem

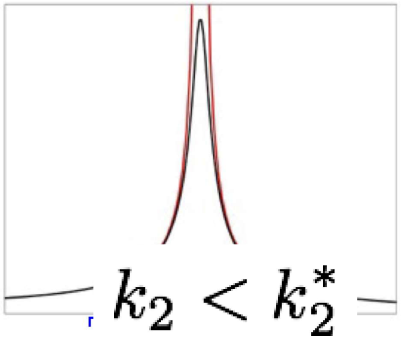
Matching graphs 1

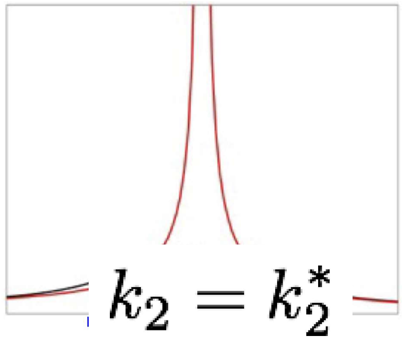
3/3 points (graded)

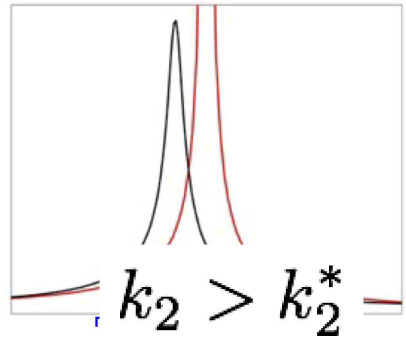
Keyboard Help

PROBLEM

Match the three graphs to the corresponding inequalities based on your MATLAB exploration.







Submit You have used 1 of 2 attempts.

Reset Show Answer

FEEDBACK

✔ Correctly placed 3 items.

✔ Good work! You have completed this drag and drop problem.

✔ Your highest score is 3.0

MATLAB exploration 2

1/1 point (graded)

Now that you have found the optimal spring constant, k_2^*, the last step is to determine the optimal damping constant, b_2^*. Using your value of k_2^* and keeping all of the other parameters constant, vary b_2 and see what effect it has on the response curve of the building. Like in the previous problem, based on your observations, enter the optimal value, b_2^*, that is accurate to three decimal places.

$b_2^* =$ 0.0127 ✔ **Answer:** 0.013

Solution:

$$b_2^* = 0.013$$

Submit You have used 1 of 10 attempts

Answers are displayed within the problem

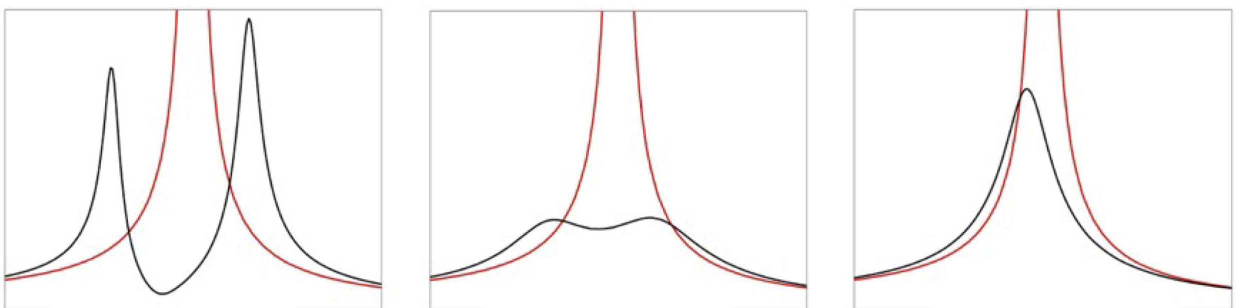
Matching graphs 2

3/3 points (graded)

Keyboard Help

PROBLEM

Match the three graphs to the corresponding inequalities based on your MATLAB exploration.



$b_2 < b_2^*$ $b_2 = b_2^*$ $b_2 > b_2^*$

Submit You have used 1 of 2 attempts.

Reset Show Answer

FEEDBACK

✔ Correctly placed 3 items.

✔ Good work! You have completed this drag and drop problem.

✔ Your highest score is 3.0

We have achieved our goal and have determined the optimal spring and damping constants that minimize the swaying amplitude of the building over a range of forcing frequencies! You should double check that using the value of b_2 found in the previous step and then optimizing k_2 will give you the same result. (A general numerical approach to optimizing two parameters is to iteratively optimize each parameter independently, and using the new value to re-optimize the other parameter until no changes are detected.)

Note that this problem is a toy model. In reality, there are often many other factors that engineers must consider when designing a TMD for a building. For example:

- The building might sway in multiple dimensions and might also twist around its vertical axis.
- The building might need to withstand forcing from the ground due to seismic activity, which can produce a very different response compared to wind forcing.

---

6. Optimizing the design

Hide Discussion

Topic: Unit 3: Solving systems of first order ODEs using matrix methods / 6. Optimizing the design

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Copy and running of problem 2 on PC
Dear staff, I have two issues: (1) the grader does not grade my code of problem and all a "marked" corre... 2

Figures for "Matching graphs 1" and "Matching graphs 2"
Are the figures for "Matching graphs 1" and "Matching graphs 2" swapped? I did the simulations and stro... 9

? Problem 2
I do not see how the code in problem 2 is connected to this problem (do not see a reason to copy it). 2

Where can I get Reference.mat?
I don't see anywhere in this page where I can get the file. 3

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