Lesson Plan

Lesson: Introduction to Buckling, a Lecture from ARO 327

Timeframe: 1 hr and 30 minutes
Materials needed:

1- A few videos
2- Solution to the activities, so I can post them online
3- A few experimental columns to show the buckling on them (we can purchase these or use our structural lab for it)
4- A few sets of quizzes

Objectives:

Basic: Pre-class objectives

1-I can calculate the eigenvalues and eigenvectors of a 2*2, 3*3, and 4*4 matrix by hand. (must-know)
2-I can use Matlab to calculate eigenvalues and eigenvector of any n*n matrix. (must-know)
3- I explain the meaning of eigenvalue operation in terms of vector rotation. (should know)
4-I can define buckling. (must-know)
5- I can find examples of buckling in life. (could-know)
6- I can distinguish buckling from other forms of instability for example flutter. (could-know)

Advanced: In-class objectives

1- I can derive the governing equations of buckling for rigid bar plus springs system.
2- I can use eigenvalue analysis to calculate buckling force (must-know).
3- I can identify the parameters that buckling depends on (bending stiffness and the geometry). (should-know)
4- I can design a column for better buckling performance. (could-know)

Background:

So far in the course and in ARO 326, we studies strength of structures. We studied how structures behave under axial and transverse force, and bending and torsional moment. We studied different cross-sections in this regard. Now we are switching gears and we are going to study a different phenomenon, instability. The simplest structural stability is buckling. Instabilities refer to sudden change in structural behavior, such as sudden deformation. We are going to use eigenvalue analysis extensively. You should remember eigenvalue analysis from your Math classes.

Introduction to Lesson:

Buckling is a static instability that depends on the geometry and stiffness of the structure. We generally like to avoid buckling unless in some novel applications like energy harvesting. In this class, we learn how to derive the buckling governing equations for a rigid bar plus springs. In this lesson, we show that the governing equations will be an eigenvalue problem and we can use Matlab to find the buckling load.

A rigid bar plus spring(s) is an academic example. In real life applications, the bar is flexible. Next session, we will study the buckling of flexible bars.

Procedure [Time needed, include additional steps if needed]:

Students have to do all the activities that are marked as ``must-do" and do at least 2 of ``should -do" activities. "Could-do" activities are optional. They are allowed to work in groups.

Activity 1: Listen to two videos by Khan Academy on calculating eigenvalues (must-do)
Purpose: Reviewing calculating eigenvalues.
Estimated Time: 40 minutes
Learning Objective: I can calculate eigenvalues of a 2*2, 3*3, and 4*4 matrix by hand.

https://www.youtube.com/watch?v=pZ6mMVEE89g&t=52s
https://www.youtube.com/watch?v=11dNghWC4HI

Activity 2: Listen to a video by Khan Academy on calculating eigenvectors (must-do)
Purpose: Reviewing calculating eigenvalues
Estimated Time: 20 minutes
Learning Objective: 1) I can calculate eigenvectors of a 2*2, 3*3, and 4*4 matrix by hand. (must-know) **2**)I explain the meaning of eigenvalue operation in terms of vector rotation.
https://www.youtube.com/watch?v=3-xfmbdzkqc&t=162s

Activity 3: Listen to a video on definition of buckling (must-do)
Purpose: Introduction to buckling.
Estimated Time: 10 minutes
Learning Objective: I can define buckling

I have to either find a video here or make short one.

Activity 4: Write a Matlab program to calculate eigenvalue and eigenvectors. (must-do)
Purpose: Review calculating eigenvalue and eigenvectors with Matlab.
Estimated Time: 10 minutes
Learning Objective: I can use Matlab to calculate eigenvalues and eigenvector of any n*n matrix

Pick a 2*2 or 3*3 matrix, calculate the eigenvalues and eigenvectors by hand and by Matlab. Compare your results. Now, pick a 50*50 matrix and calculated eigenvalues and eigenvectors using Matlab. Do you appreciate using Matlab instead hand calculating?

Activity 5: Make a list of 3 structures in you every day life that can go under buckling. (should-do)
Purpose: Understanding of buckling.
Estimated Time: 10 minutes
Learning Objective: I can find examples of buckling in life

I can design this on blackboard in a way that after students submit their answer, they see a set of examples as a sample solution.

Activity 6: Find a structure/object that you can bring in class that buckles easily and you can show it to your classmates. (should-do)
Purpose: Understanding of buckling.
Estimated Time: 10 minutes
Learning Objective: I can find examples of buckling in life

Examples are a flexible ruler or a can of soda, etc.

Activity 7: Use Mathematica to calculate eigenvalue and eigenvectors. (could-do)
Purpose: See the difference between how Mathematica and Matlab presents eigenvectors.
Estimated Time: 30 minutes
Learning Objective: I can use Mathematica to calculate eigenvalues and eigenvector of any n*n matrix

Use the provided script in Mathematica and check the eigenvalues and eigenvectors for the 2*2 and 3*3 matrixes in activity 4. Do you see any difference? Explain any differences?

Activity 8: Other use of eigenvalue and eigenvectors. (could-do)
Purpose: Observe the relationship between buckling and other aerospace examples that can be described as an eigenvalue problem.
Estimated Time: 30 minutes
Learning Objective: I can use eigenvalue analysis as a mathematical tool to different engineering problems.

Make a list of every time you have used eigenvalue problem in your previous engineering class? Discuss them with your group and figure out what do they have in common.

Activity 8: Experiment (could-do)
Purpose: Understanding the effect of geometry and material on buckling
Estimated Time: 30 minutes
Learning Objective: I can identify the parameters that buckling depends on (bending stiffness and the geometry).

Set up an experiment at home using kitchen tissue tubes and toile paper tubes, which one is easier to buckle? Why? Make a similar length column by paper, and repeat the experiment, compare your results. Explain the different in the results.

In-Class Group Space Activities and Resources:

Activity 1: Lecture format/Students chatting in groups
Purpose: Review the pre-class activity and objectives, answer student questions
Estimated Time: 15 minutes
Learning Objective: Reviewing the pre-class objectives and making sure students are ready for the in-class activities.
Ask students what they learned. Ask them to give a 5-minute explanation of it to their class-partner (s).

Activity 2: Lecture format with student participation.
Purpose: Show how step by step one can derive the buckling governing equations.
Estimated Time: 20 minutes
Learning Objective: In-class objective 1

Here is an example how this will work: 1) Put a figure on the board, 2) ask students to draw a FBD for this example. 3) Ask to see who used deformed and undeformed configurations to draw the FBD. 4) Explain why undeformed configuration FBD doesn't work. 4) Ask students to draw the FBD for the undeformed configuration. 5) Show them the correct FBD. 5) Ask them to write the equilibrium equations. 6) Derive the correct equilibrium equation on the board. 6) Put the equations in the eigenvalue format.

Activity 3: Group problem solving.
Purpose: Show how step by step one can derive the buckling governing equations.
Estimated Time: 10 minutes
Learning Objective: In-class objective 2

In a group students will solve that eigenvalue example related to the problem we just solved. The first group will get an extra credit or something

Activity 4: Lecture format
Purpose: Understanding of the buckling force
Estimated Time: 5 minutes
Learning Objective: In-class objective 3

Show the final solution and discuss the effect of bending stiffness and the geometry in an interactive way.

Activity 5: In-class problem solving
Purpose: Understanding of the buckling force
Estimated Time: 25 minutes
Learning Objective: In-class objective 1,2,3

I will give two problems and ask students to solve them in-group. I'll walk in between and help them to get the final answer. If they cannot finish both problems, the remaining problem will become their homework.

Activity 6: Wrap-up
Purpose: Answering questions and wrapping up the class
Estimated Time: 15 minutes
Learning Objective: In-class objective 1,2,3
Wrap up, answer question, and review what did they learn today by "pair and share"? go over what they are supposed to do for next session. (15 minutes)

Closure/Evaluation:
This is post-class activity: 1) If you did not finish both examples in class, solve them as home-work. 2) Check your solution against posted solutions on the Blackboard. 3) Take an online quiz.

I can design the quiz, such has it has several levels. For example, if you pass level 1, you get C for this lecture, if you pass level 2, you will get B, and if you pass level 3, you will get A. Students can also take each quiz a few times. In this case, the questions should be randomly assigned and change in each iteration.

Analysis:

The students are supposed to know eigenvalue analysis when they take this class, however, my experience shows that have not used it and they possibly have forgotten the details. So, most of the pre-class activities are focused on reviewing this topic. The post-class activates are light, because the students have to start studying for the next session.

Post-Class Individual Space Activities:

There is only the iterative quiz and finishing the in-class problems as I explained in the evaluation section. Students need to have time to start working on the next lecture.

Connections to Future Lesson Plan(s):
Next lecture will focus on buckling for beam structures. The pre-class activities focus on the derivations, since they are tedious and time-consuming for in-class activities. The in-class activities will be focused on problem solving and practical examples.

Note:
After designing this lecture, I think it would be better to design based on a week (two lectures), not a single lectures. Our classes are either Monday/Wednesday or Tuesday/Thursday. In this schedule, there is not much time between Lecture 1 and 2 in each week, so practically I cannot expect students to do a lot of pre-class activities. This is a work in progress and for a real application of this plan, I need to think about this difference between the two sessions of each week more.