PRINCIPAL STRESSES OF A 3D OBJECT

Pre-Lecture Assignment for the Class on November 11, 2018

Time estimate to complete this assignment: 30 -- 120 minutes depending upon the level of your skills at doing statics.

Overview

Throughout the semester, we have been learning various components of the work that needs to be done for this class period. While we still have a few weeks of classtime remaining, we are getting to a point where we begin to combine several of the individual calculations we have done before into a sequence which engineers use to solve more complicated engineering questions. All of the drawings that you make during this pre-class assignment should be done by hand, particularly so that you gain experience at how to make these type of graphics on the exam.

Learning Objectives

Basic objectives

1. Draw a complete FBD for an object cut loose from a larger determinant assembly.
2. Determine the cross-section to use to solve for the stresses at a point in an object.
3. Select the correct cross-sectional cut to use for a FBD.
4. Determine the centroid of a cross-section of a simple geometric shape.
5. Calculate the three components of a force or moment vector relative to the coordinates of a cross-section.
6. Determine the force on a cross-section to maintain a FBD in equilibrium.
7. Determine the moment on a cross-section to maintain a FBD in equilibrium.
8. Determine the geometric properties for a cross-section about a neutral axis.
9. Identify the neutral axis due to a bending moment on a cross-section.
10. Calculate the stress at a point on the cross-section due to axial force.
11. Draw a 3D stress cube that will be used to show the stress state at a point, add coordinate system that matched the original object, and indicate which faces of the cube have unique characteristics such as the cutting plane of the FBD or the surface of the object.
12. Draw a coordinate system that can be used for Mohr's Circle with titles, units and sense listed for each axis.

Advanced objectives

13. Calculate the stress at a point on the cross-section due to torque.
14. Calculate the stress at a point on the cross-section due to bending moment.
15. Calculate the stress at a point on the cross-section due to shear due to bending.
16. Draw a 3D stress cube showing the resulting stresses on all six faces.
17. Convert the 3D stress cube to an equivalent 2D stress block.
18. Draw Mohr's Circle for a 2D stress block
19. Determine the stress at an arbitrary plane from Mohr's Circle.
20. Determine the principal stresses and/or max in-plane stress blocks from Mohr's Circle.

The primary outcome of this exercise is for the student to be able to break down a complicated stress mechanics problem into several solvable tasks that we have done before. The list above looks very

extensive, but every learning objective has been part of a previous lecture in CE112 or the pre-requisite Statics course. What we will focus on by doing this relatively long example is how all these pieces fit together.

Preparatory Activities and Resources:

1) **Draw a Free Body Diagram (FBD) that will allow us to determine the forces and moments acting on the cross-section of the assigned problem that contains the Point A.** Make sure that you indicate any unknown forces or moments acting on the cross-section as being applied to the centroid of the cross-section (Point C).

   We discussed drawing FBD the first week of class. This is also a skill that you have used in Statics (CE95). Note that I do not want an Equivalent Force System (EFS) (you would be able to solve the problem using the EFS but we need to know how to use either option). *Linked to Basic Learning Objectives 1 thru 4.*

   Your FBD should be approximately half of a page in size and should be neat and clearly written.

   If you need assistance, you may want to go back and revisit the lecture notes from Week 1 that are available on CANVAS.

2) **Use the Equations of Equilibrium to determine the normal force, the two shear forces, the torque, and the two bending moments acting on the cross-section.** As we have discussed during the first several weeks of class, there is a potential of having six actions being applied to the cross-section (normal axial force, two orthogonal shear forces acting in the plane of the cross-section, a torque acting normal to the cross-section, and two orthogonal bending moments acting in the plane of the cross-section). Usually, some of these six actions turn out to be zero (which simplifies the problem). But as we work through our engineering careers we come across individual situations which have different actions combined. *Linked to Basic Learning Objectives 5 thru 7.*

   Using equilibrium is the primary learning outcome of the Statics (CE99) course you took as the prerequisite to CE112. This problem falls under the category of 3D Solid Body Equilibrium. In Statics, you likely solved these problems using vector mechanics. For CE112, you have two options:

   a. Use 3D vector mechanics to determine the unknown vector of force and moment acting on the cross-section which are needed to hold the object in equilibrium. Once determined, each component of the 3D force vector will be either a normal force or a shear acting on the cross-section. Each component of the moment vector will be either a torque or a bending moment acting on the cross-section.
   b. Use 2D equilibrium six times to determine each force and moment component individually. First use the three force equilibrium equations ($SumF_x = 0$, $SumF_y = 0$, $SumF_z=0$). Then use the three moment equilibrium equations ($SumM_x=0$, $SumM_y=0$, $SumM_z=0$). It is probably easiest to always sum moments about the centroid of the cross-section.

Either method can be used for the example, the homework assignments, and the exams for full credit. The instructor will not specify that students must use either method. In general, when practicing engineers solve these types of problems with paper and pencil, they use the second method. When they use sophisticated software, the software usually uses some form of the first method.

If you struggle with getting the solution for this step, you likely need to review statics. You may choose to revisit your notes and textbook from your statics course. Alternatively, the following videos may help with your review. Note that the list of videos is not in any particular order, any of the videos may be of benefit.

Video1: https://www.youtube.com/watch?v=4uuGpg1al3E Video Title: Statics for All - Part 4 - External Forces Duration = 19:32 – An example of solving for the reactions of a beam. An example of solving for the reactions due to forces on an object. *(Just a note, on her second example she mistakenly writes the force under the wrong symbol, but overall, it's a good video.)*
Video2: https://www.youtube.com/watch?v=sjh90MJkOOA Video Title: How to Solve 3D Statics Problems Duration = 8:36 – The theory of solving for the reactions of a 3D object using vector mechanics.
Video3: https://www.youtube.com/watch?v=yE3hegbEVjc Video Title: Statics Lesson 23 – 3D Moment about a Point and rxF example Duration = 12:45 – An example of determining the moment reactions of a 3D object using vector mechanics. Note that his answer for My would be torque, Mx and Mz are bending moments for his pipe.

3) Draw a 2D view of the cross-section and calculate the relevant geometric properties. On the page with your FBD, draw a small picture of the cross-section. Label the x and z axis that are consistent with the Global X, Z coordinates given in the problem statement. Label the point A and the cross-section centroid (Point C) on your drawing. For each of the non-zero actions determined in Step 2, one geometric property is required (A, J, I_x, I_z). If there is a non-zero bending moment on the cross-section, draw the neutral axis that will correspond with this moment. You do not need to calculate geometric properties for any of the actions that have zero magnitude. *Linked to Basic Learning Objectives 8 and 9.*

Depending upon the geometric property you need, you may want to review the following sections of the textbook or the class lectures.

Property	**Lecture Notes or In-Class Examples**	**Textbook Section**
A (Area)	Lecture-1A-AxialStress Example-1A-AxialStress	Section 1.2A
J (Polar Second Moment of Area)	Lecture-3A-Torsion Example-3A-Torsion	Section 3.1C
I (Second Moment of Area)	Lecture-4A-Bending Example-4A-Bending	Section 4.2

4) **Summarize your work so far into a single page.** On the page with your FBD add the non-zero actions that we determined in Step 2. On the drawing of the cross-section add the geometric properties you determined in Step 3. *Linked to Basic Learning Objectives 1 thru 9.*

   Your drawing should now be a single page summary of your work so far. In engineering practice, we want to be able to summarize our work so that our boss and co-workers can easily understand our findings. Following this summary we will add the pages of calculations that may have been required to come up with the results. While our calculations should be neat and organized, it is uncommon for engineers to 're-write' or type our completed work (hopefully we are being paid a high enough salary that the cost of this time is prohibitive). During your undergraduate education, you want to learn how to complete calculations one time which are neat, orderly and easily understood.

5) **Start the stress mechanics step of our example by determining the normal stress.** Using the equations we have derived the first week of class, determine the normal stress sigma, acting at Point H due to the applied loads. Summarize your results by showing the normal stress on a 3D stress cube drawn for Point C. On your paper, draw a cube aligned with the X, Y and Z coordinate system of the problem. Indicate which face of the cube is in the plane of the cross-section cut for your FBD (it probably is the bottom face). Now show the stress acting on the top and bottom of the cube that represents the normal stress you just calculated. It should be either a tension stress or compression stress and the two stress vectors should be equal and opposite to each other. *Linked to Basic Learning Objectives 10 and 11.*

   As a refresher to calculating normal stress, you may want to revisit the first few lectures of the course or portions of the textbook.

   CANVAS FILE: Lecture-1A-AxialStress
   CANVAS FILE: Example-1A-AxialStress
   Textbook: Section 1.2A

6) **Start the process of drawing Mohr's Circle.** To prepare for what we will be doing in class time, draw the coordinate system that we use for Mohr's Circle. You can expect that the stresses we work in range from positive to negative 500 kPa. Label both the horizontal and vertical axis with a title, the units, and the sense that each direction represents. *Linked to Basic Learning Objective 12.*

   As a refresher to plotting Mohr's Circle, you may want to revisit the last lecture of the course as or the related portion of the textbook.

   CANVAS FILE: Lecture-7D-MohrCircle
   CANVAS FILE: Example-7E-MohrCircle
   Textbook: Section 7.2

7) **Upload your results to CANVAS.** Upload the three pages of drawings you have created to CANVAS by 8 p.m. the night before class. Your three pages should be: 1) a FBD for the object that shows the true value of the unknowns that you determine from statics plus the drawing of the cross-section and the geometric properties, 2) the calculation of the stress at Point A and the 3D stress block of A showing this stress, and 3) the coordinate system that will be used for

plotting Mohr's Circle. Order the pages in the order above and remember that each page needs a title, the initials of the engineer, the date and a page number. You may either scan the drawings into a pdf format or use a phone to carefully take a jpeg image of each page. Verify that the finished image is clear and legible.

Classroom Activity

During class, we will continue the example, please bring your work so far with you as we will not be repeating the above steps during class. The in-class work will require determining all remaining stresses acting on the 3D stress cube, converting that 3D stress cube to a 2D stress block, and then determining the Principal Stresses acting at Point A using either the derived formulas or Mohr's Circle. In preparation for this work, you may want to review our previous lectures related to these topics so that we can discuss your concerns while finishing the problem.

Lesson Plan

Lesson: Determining Principal Stresses for a Point in a 3D Object.

Timeframe: Note how long will it take the learner to complete all of the activities from pre-class to post-class activities.

With expected knowledge of statics, the total time to complete should be about 150 minutes.
(30 minutes for pre-class, 75 minutes for classtime and 45 minutes for post-class)

Materials needed: Describe what items will be needed to complete the in-class activities.

PowerPoint Slides of the activities.
Set up iClickers for CANVAS.
A wooden model of the 3D object would be really nice.
Summary sheet of student performance on pre-class assignment.

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Objectives: List out the basic objectives tied to pre-class activities and the advanced objectives tied to in-class and post-class activities.

Basic:

1. Draw a complete free-body diagram (FBD) for an object cut loose from a larger determinant assembly.
2. Determine the cross-section to use to solve for the stresses at a point in an object.
3. Select the correct cross-sectional cut to use for a FBD.
4. Determine the centroid of a cross-section of a simple geometric shape.
5. Calculate the three components of a force or moment vector relative to the coordinates of a cross-section.
6. Determine the force on a cross-section to maintain a FBD in equilibrium.
7. Determine the moment on a cross-section to maintain a FBD in equilibrium.
8. Determine the geometric properties for a cross-section about a neutral axis.
9. Identify the neutral axis due to a bending moment on a cross-section.
10. Calculate the stress at a point on the cross-section due to axial force.
11. Draw a 3D stress cube that will be used to show the stress state at a point, add coordinate system that matched the original object, and indicate which faces of the cube have unique characteristics such as the cutting plane of the FBD or the surface of the object.
12. Draw a coordinate system that can be used for Mohr's Circle with titles, units and sense listed for each axis.

Advanced:

13. Calculate the stress at a point on the cross-section due to torque.
14. Calculate the stress at a point on the cross-section due to bending moment.
15. Calculate the stress at a point on the cross-section due to shear due to bending.
16. Draw a 3D stress cube showing the resulting stresses on all six faces.
17. Convert the 3D stress cube to an equivalent 2D stress block.
18. Draw Mohr's Circle for a 2D stress block
19. Determine the stress at an arbitrary plane from Mohr's Circle.
20. Determine the principal stresses and/or max in-plane stress blocks from Mohr's Circle.

Background to the Lesson: Note the typical composition of learners in the class, how this lesson fits into the course design/schedule, prerequisite knowledge required, and typical challenges that learners face with this content area.

The topics in this lesson have all been introduced before. That statics are a pre-requisite for the course, but this seems to be where many students are extremely weak. What is new for the students is putting all of these individual calculations into a comprehensive analysis of a 3D object. This involves a lot of 3D visualization. In addition, students have to move from local coordinates to global coordinates and vice versa. Students seem to be overly focused on equations and notation, and then get quickly confused when the local x-axis does not line up with the Global X-axis.

Introduction to Lesson: Describe the purpose of this content area for learners and an overview of the activities and resources for the flipped lesson.

This content area is basically the capstone activity for the course. It is the area requiring students to put together much of what they have been taught into a long, detailed analysis. After this course, students will divide up into their individual majors and will work on assemblies that are unique to their field of study. Once in these specialized areas, they probably get more comfortable with the process because they get much more knowledgeable about the local and Global coordinate systems that their industry uses. But the need to get the basic static equilibrium right to start the process will always be critical.

During the lesson, students will move from individual space to group space and back to individual space. They will start by doing the pre-class activity alone (although they may choose to work with their team partners). During this pre-class, they will be 'setting' up the pages we need for completing the work. Primarily, this is three drawings: 1) a FBD showing the reactive forces and moments, 2) a cube that represents the point in the object, and 3) the coordinate system for Mohr's Circle. During the class period, we will work in group space while we step through the calculations to complete the analysis. Several activities during this will be using the iClickers format to keep students engaged and provide real-time feedback. Finally, in post-class the students will return to individual space and analyze the same object but for a different point.

The in-class example will be more difficult than the post-class assignment. If students actively use the time in class to ask questions about their solution, they should be able to apply their work to a slightly different process with minimal challenge.

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

Pre-Class Individual Space Activities and Resources: Outline the major steps for the preparatory activities and be sure to tie the steps to the basic learning objectives you have noted above. Note resources required for learner preparation.

Steps	Purpose	Estimated Time	Learning Objective
Step 1: Draw a Free Body Diagram (FBD) that will allow us to determine the forces and moments acting on the cross-section of the assigned problem that contains the Point A.	**Review and apply statics**	**5 minutes for someone who has pre-requisite knowledge of statics.**	*1 thru 4*
Step 2: Use the Equations of Equilibrium to determine the normal force, the two shear forces, the torque, and the two bending moments acting on the cross-section.	**Review and apply statics**	**5 minutes for someone who has pre-requisite knowledge of statics.**	*5 thru 7*
Step 3: Draw a 2D view of the cross-section and calculate the relevant geometric properties.	**Apply knowledge from earlier in the course**	**5 minutes**	*8 and 9*
Step 4: Summarize your work so far into a single page.	**Process and summarize**	**3 minutes**	*1 thru 9*
Step 5: Start the stress mechanics step of our example by determining the normal stress.	**Apply knowledge from earlier in the course**	**5 minutes**	*10 and 11*
Step 6: Start the process of drawing Mohr's Circle.	**Apply knowledge from earlier in the course**	**5 minutes**	*12*
Step 7: Upload your results to CANVAS.	**Process and Summarize**	**2 minutes**	

In-Class Group Space Activities and Resources. Outline the major steps for the in-class activities and be sure to tie the steps to the advanced learning objectives you have noted above. Also note any resources needed/developed to provide effective active learning activities within class.

Steps	**Purpose**	**Estimated Time**	**Learning Objective**
Step 1: Activity 8A. Determine stress at Point A due to torsion, bending and/or shear.	**Apply knowledge from earlier in the course**	**20 min**	*13 thru 15*
Step 2: Activity 8B. Draw a 3D stress cube showing the resulting stresses.	**Convert local coordinates into Global Coordinate system**	**10 min**	*16*
Step 3: Activity 8C. Choose an appropriate 2D view of a 3D stress cube and draw a 2D stress block.	**3D visualization and simplifying a problem to a workable model**	**5 min**	*17*
Step 4: Activity 8D. Draw Mohr's Circle for the 2D stress block	**Apply knowledge from earlier in the course**	**15 min**	*18*
Step 5: Activity 8E. Read Mohr's Circle to identify information about the Principal Stresses at the point of interest.	**Apply knowledge from earlier in the course**	**12 min**	*19 and 20*
Step 6: Activity 8F. Determine Principal Stress or Max In-Plane Shear Stress by equation.	**Apply knowledge from earlier in the course**	**10 min**	*19 and 20*

Post-Class Individual Space Activities and Resources. Outline the major steps for the post-class activities and be sure to tie the steps to the advanced learning objectives you have noted above. Also note any resources learners will need to complete any post-class activities assigned after the group space activities.

Steps	**Purpose**	**Estimated Time**	**Learning Objective**
Step 1: Now repeat the process for a different point on the cross-section of the same 3D object. This basically requires them to adjust the work of Activity 8A and repeat the rest of the Activities, except for a different combination of resulting stresses.	**Repeat the in-class work in an environment where they do not have immediate coaching.**	**35 min**	*13 thru 20*
Step 2: Write a short memo to their boss using a provided template. This memo will require them to compare and contrast the results from the two analyses they have completed (the in-class and the post-class).	**To reflect on their work and to analyze their findings. Also to see how engineering calculations get summarized for application.**	**10 min**	*1 thru 20*

Evaluation:

Analysis. In this section, note what you think will work, and what challenges you think you may face in implementation.

I think students will do rather well on the problem as long as we 'step' through it together. But the challenge will be if they really do understand statics or they simply have learned how to go through the motions to get results. Also, the timeline is aggressive to get all of this in for a single period. It may help to have iClickers have been used before so that students can quickly apply that part. Also, getting students to actually complete the pre-class assignment will be a challenge. Surprising how many students show little motivation to prepare for class, even when they receive points for their work.

Connections to Future Lessons. In this section, note how you think this lesson plan connects to your next topics in the course.

Since this is the capstone we really don't build upon it in my course. It would be great to start a dialog with the instructors of the following courses to see if they see improvement in their incoming students.

ACTIVITY DETAILS – LECTURE 17A

Learning Objective: Determine stress at Point A due to torsion, bending and/or shear.

Selected Activity: Team in-class calculation period.

Why is the activity well suited to the concept: This is calculation work using formulas that we have worked with earlier in the semester. However, students seem to struggle isolating individual aspects of a complex problem. The teams have been working together all semester so they should be rather comfortable and productive.

How will you know that students have mastered the Learning Objective?

Formative Assessment: Students will need to call my attention or else I will circle the classroom and follow if students are making progress. Later, when we try to draw the stress cube, teams that have fallen behind will have limited information to make their iClicker response.

Cumulative Assessment: Later, they will need to complete a similar problem on homework assignments and on the Final Exam as a cumulative assessment.

PREP WORK

Instructor Prep Work:	**Student Prep Work:**
Need to solve complete problem and have solution available for class. Make a slide show prompting students to complete each step of the process. One item on the slide needs to be the actual structure we are working with so that students can refer to it.	Students will have used equilibrium to determine the torque, shear and bending on the cross-section. They will have determined geometric properties for the cross-section. All of this work will have been submitted to CANVAS as a pre-class assignment.

IN-CLASS ACTIVITY STEPS

Step 1 – 7 minutes to work on the torsion stress

Instructions to Students:	**Materials Required:**
We now want to continue the work we were doing for the pre-class HW. We have done the first two steps of FBD and Statics. We have started the third step of Stress Mechanics by determining the stress due to the Normal Force. Now let's determine the stress due to Torsion.	One PPoint slide showing the original object. Will need to prompt students that they have already determined the torque and J as part of their pre-class HW. Prompt them on how do we determine the stress at a point due to a known torque.

Step 2 – 3 minutes to work on the bending stress – Example does not have bending stress

Instructions to Students:	**Materials Required:**
Now let's determine the stress due to Bending Moment. The first step of this is to locate the neutral axis that the bending moment develops. What do we know about the stress due to bending for a point that lies on the neutral axis.	One PPoint slide showing the original object. Will need to prompt students that they have already determined the Bending moment and I as part of their pre-class HW. Prompt them on how do we determine the stress at a point due to a known bending moment.

Step 3– 10 minutes to work on the shear stress due to bending

Instructions to Students:	**Materials Required:**
Now let's determine the stress due to shear caused by bending. We have already determined the location of the neutral axis. What do we know about the shear stress due to bending for a point that lies on the neutral axis.	One PPoint slide showing the original object. Will need to prompt students that they have already determined the Shear due to bending as part of their pre-class HW. Prompt them on how do we determine the stress at a point due to a known shear force.

Notes on Developing Activity.

1. In-Class Problem needs to be an object that has axial, torsional and shear stresses but not bending. For the post-class assignment, then choose a point that has the same axial and torsional stresses but now has a bending stress and no shear stress. Post-class assignment is an easier assignment for two reasons, one they have already done a very similar situation and 2) working with axial and bending stresses seems to be much easier for students to comprehend.

ACTIVITY DETAILS – LECTURE 17B

Learning Objective: Draw a 3D stress cube showing the resulting stresses.

Selected Activity: iClickers after students have determined individual stresses.

Why is the activity well suited to the concept: This is a visualization concept, being able to determine the relevant face of a cube upon which a certain stress acts. It also can be easily set-up as a Multiple Choice selection. It will provide the students with quick feedback on how well they are understanding the discussion. Also will provide the instructor with clarity as to which items students need more assistance.

How will you know that students have mastered the Learning Objective?

Formative Assessment: In class the responses will give a good summary of the student understanding.
Cumulative Assessment: Later, they will need to complete a similar problem on homework assignments and on the Final Exam as a cumulative assessment.

PREP WORK

Instructor Prep Work:	**Student Prep Work:**
Need to solve complete problem and have solution available for class. Make a slide show of the possible MC questions which will be used with iClickers.	During pre-class assignment student will have drawn the 3D cube representation and have applied the normal stress to the top and bottom faces.

IN-CLASS ACTIVITY STEPS

Step 1 – 5 minutes to have students' set-up iClicker for first time

Instructions to Students:	**Materials Required:**
Choose the response which correctly shows the stress due to the normal force being applied to the stress cube. Hint, this is what you already did as part of the pre-class assignment.	PPoint Slide with initial stress cube and at least four choices as to the correct answer.

Step 2 – 3 minutes to have students find their results and choose an option

Instructions to Students:	**Materials Required:**
Choose the response which correctly shows the stress due to the torsion being applied to the stress cube.	PPoint Slide with stress cube including the stresses already added and at least four choices as to the correct answer.

Step 3– 2 minutes to have students find their results and choose an option

The in-class problem will involve shear stress, the stress students usually have more trouble calculating. Students will be assigned a post-class assignment that contains the effect of bending stress.

Instructions to Students:	**Materials Required:**
Choose the response which correctly shows the stress due to the bending moment being applied to the stress cube.	PPoint Slide with stress cube including the stresses already added and at least four choices as to the correct answer.

Notes on Developing Activity.

1. Will need to choose best way to identify faces of cube. Can use coordinates, possible use the faces of a die as a humorous option.

ACTIVITY DETAILS – LECTURE 17C

Learning Objective: Choose an appropriate 2D view of a 3D stress cube and draw a 2D stress block.

Selected Activity: iClickers after students have determined individual stresses.

Why is the activity well suited to the concept: This is a visualization concept, being able to view a cube from multiple directions to choose the one direction that will show all the stresses in a 2D image. It's also can be easily set-up as a Multiple Choice selection. Activity will provide the students with quick feedback on how well they are understanding the discussion. Also will provide the instructor with clarity as to how easily students can process.

How will you know that students have mastered the Learning Objective?

Formative Assessment: In class the responses will give a good summary of the student understanding.
Cumulative Assessment: Later, they will need to complete a similar problem on homework assignments and on the Final Exam as a cumulative assessment.

PREP WORK

Instructor Prep Work:	**Student Prep Work:**
Need to solve complete problem and have solution available for class. Make a slide show of the possible MC questions which will be used with iClickers.	Limited as this getting into the more advanced topics. Students should be familiar with 2D block from easier topics we have done in the course before.

IN-CLASS ACTIVITY STEPS

Step 1 – 5 minutes since we are continuing from previous iClicker work.

Instructions to Students:	**Materials Required:**
Which of the directions of viewing the stress cube will show all the active stresses in a 2D stress block.	PPoint Slide with results from the prior activity and at least four choices as to the correct answer.

Notes on Developing Activity.

1. How many possibilities do you want to give them? Should this be a two-part question, first the direction of view and second the actual stresses on the 2D block?

ACTIVITY DETAILS – LECTURE 17D

Learning Objective: Draw Mohr's Circle for the 2D stress block

Selected Activity: Instructor led team work-period.

Why is the activity well suited to the concept: Students will be paced by the instructor on plotting individual points on the graphic and then drawing the actual circle.

How will you know that students have mastered the Learning Objective?

Formative Assessment: Instructor will need to monitor the groups to see if they are making progress.

Cumulative Assessment: Later, they will need to complete a similar problem on homework assignments and on the Final Exam as a cumulative assessment.

PREP WORK

Instructor Prep Work:	**Student Prep Work:**
Need to solve complete problem and have solution available for class. Make a slide show showing the progression of plotting Mohr's Circle.	In-class, the students will have determined the 2D stress block. Prior to class, each student will have drawn the axis for the graph.

IN-CLASS ACTIVITY STEPS

Step 1 – 5 minutes to work on plotting the X-Face of the block.

Instructions to Students:	**Materials Required:**
Using the 2D stress block, now we want to plot one face on the coordinate system you made before class for Mohr's Circle. Show how plotting the negative X-face would have resulted in the same point.	One PPoint slide showing the original axis that we are working with. A second slide showing the X-face plotted. Both slides should have the 2D stress block as a picture.

Step 2 – 4 minutes to work on plotting the Y-Face of the block.

Instructions to Students:	**Materials Required:**
Now let's do the same thing for the Y-face of the block.	Continue the slides from before now starting with a slide showing the X-face plotted. Add a new slide with the Y-face plotted.

Step 3– 6 minutes to draw the actual circle and clean up the drawing.

Instructions to Students:	**Materials Required:**
The two points we just plotted are the two ends of a diameter of the circle, so we can draw the diameter and determine the Center of the circle. We can also determine the radius of the circle. Sketch the shape of the circle by putting 8 points around the shape at the same radius from the center.	Continue the slides from before now starting with a slide showing the two faces plotted. Add a new slide with the diameter drawn. Add a new slide with the Center listed. Add a new slide with the radius determined. Add a new slide showing the 8 points to guide the sketch. Add a new slide with a rough hand sketch of the circle. Add a last slide showing the cleaned up sketch.

Notes on Developing Activity.

1. I think it is best to hand draw the example for the slide show. You can use EXCEL to make the axis but I think students will benefit from seeing rough sketching.

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ACTIVITY DETAILS – LECTURE 17E

Learning Objective: Read Mohr's Circle to identify information about the Principal Stresses at the point of interest.

Selected Activity: iClickers.

Why is the activity well suited to the concept: This is a graphic reading skill without much calculation required.

How will you know that students have mastered the Learning Objective?

Formative Assessment: In class the responses will give a good summary of the student understanding.

Cumulative Assessment: Later, they will need to complete a similar problem on homework assignments and on the Final Exam as a cumulative assessment.

PREP WORK

Instructor Prep Work:	**Student Prep Work:**
Need to solve complete problem and have solution available for class. Make a slide show showing the correct and incorrect choices for the questions posed.	In-class, the students will have determined Mohr's Circle. Students will need to recall the difference between principal stress and max in-plane shear stress and the way to determine the orientation of the resulting stress block.

IN-CLASS ACTIVITY STEPS

Step 1 – 2 minutes to choose the correct point on Mohr's Circle.

Instructions to Students:	**Materials Required:**
Which point on Mohr's Circle represents the max in-plane shear stress orientation?	One PPoint slide showing Mohr's Circle and five or six possible points of interest. A second slide showing that there are actually two points that can be used. Show this slide after the iClicker question.

Step 2 – 1 minute to determine the magnitude of the shear stress and average normal stress

Instructions to Students:	**Materials Required:**
Which combination of max in-plane shear stress and average normal stress most closely matches the actual answer.	One PPoint slide with Mohr's Circle and the options for the iClicker question.

Step 3– 2 minutes to determine the direction and magnitude of rotation to the new orientation.

Instructions to Students:	**Materials Required:**
If we choose the top point of Mohr's Circle to work with, what is the size of the angle and what direction of rotation should we use on the actual item?	One PPoint slide with Mohr's Circle and the options for the iClicker question.

Step 4– 5 minutes to develop the new orientation and debrief.

Instructions to Students:	**Materials Required:**
Which of the suggested orientations would be acceptable as the max in-plane shear stress?	One PPoint slide with Mohr's Circle and the options for the iClicker question. One PPoint slide showing the final result.

Notes on Developing Activity.

1. Need hand drawing of the steps of developing Mohr's Circle.

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ACTIVITY DETAILS – Lecture 17F

Learning Objective: Determine Principal Stress or Max In-Plane Shear Stress by equation.

Selected Activity: Team calculation session.

Why is the activity well suited to the concept: This is a calculation heavy task but one that uses equations the students have used before.

How will you know that students have mastered the Learning Objective?

Formative Assessment: Instructor will need to monitor the team progress.

Cumulative Assessment: Later, they will need to complete a similar problem on homework assignments and on the Final Exam as a cumulative assessment.

PREP WORK

Instructor Prep Work:	**Student Prep Work:**
Need to solve complete problem and have solution available for class. Make a slide showing all the stress transformation equations from the Exam Formula Sheet	The prep work will be the prior activities of the in-class problem.

IN-CLASS ACTIVITY STEPS

Step 1 – 4 minutes to use the max in-plane shear stress formula.

Instructions to Students:	**Materials Required:**
So, if we had been given the 2D stress block from earlier but we didn't have Mohr's Circle, how would we determine the max in-plane shear stress magnitude and orientation?	One PPoint slide showing the original stress block, Mohr's Circle and all of the stress transformation equations from the formula sheet. A second PPoint slide showing the correct formula highlighted. A third PPoint slide showing the inputs for the formula.

Step 2 – 4 minutes to use the stress transformation equation if we were given the angle of interest

Instructions to Students:	**Materials Required:**
What if we knew the angle of the orientation that resulted in the max in-plane shear stress? How would we use our original stress transformation formulas to determine the magnitude of the shear stress? How would we determine the stress normal to the plane that contains this shear stress?	One PPoint slide showing the original stress block, Mohr's Circle and all of the stress transformation equations from the formula sheet. A second PPoint slide showing the correct formula highlighted. A third PPoint slide showing the inputs for the formula.

Step 3– 2 minutes for a final reflection.

Instructions to Students:	**Materials Required:**
So, now hopefully we have used three different methods to determine the max in-plane shear stress that occurs at Point A. Hopefully, they have given answers that are within round-off error of each other. Have we answered the original question we were pursuing?	One PPoint slide the three methods used and the results determined. A second PPoint slide repeating the original engineering question that we were trying to answer.

Notes on Developing Activity.

1. Note that the original question posed was whether this was the best location to minimize the in-plane shear stress. We have only determined the stress at one point, and thus, we don't have any detailed information about whether this is the best point. You may be able to get the class to make educated estimates of where a better or worse point would be. In fact, I think the best training for future engineers is to start with a point which is not the best location. This is more in matching with actual engineering work where the engineer is unlikely to be able to immediately identify the critical condition. It would also alter the perception that one needs to be a professor to start this type of evaluation.

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