MY SO LESSON PLAN

OVERVIEW, LESSON PLAN & STUDENT WORKSHEET

How to use this Lesson Plan

Welcome to the February **MY SO** lesson plan on **Structures**! **MY SO** is a new program from Science Olympiad that provides a 9-month, calendar-based set of supports to keep individuals engaged in Science Olympiad at home, at school, or afterschool. **MY SO** is open to any individual whether or not he or she is a Science Olympiad team member. Each themed month is built off of popular Science Olympiad events and offers free resources like these Lesson Plans that can be used at home or at school; Science Olympiad STEM Sessions, webinars and interviews with leading experts in the field about careers and workforce; and the option to participate in STEM Showdowns, national-level, online Science Olympiad tests you'll take in real time to gauge your knowledge against your peers, complete with prizes and a national monthly leaderboard. **MY SO** can be used as a standalone activity or to support any regular Science Olympiad season.

One of the hallmarks of our in-person program are events that require teams to build things. This month seemed like a good time to have the **MY SO** program focus on the science of Structures! Structures is a topic which we had to cover not only because building structures has been a part of Science Olympiad's traditional, team-based, in-person competitive tournaments since the beginning but also because man-made structures are something that everyone single one of us interacts with on a daily basis. Through events like Towers, Boomilever, Elevated Bridge, Mystery Architecture, and now Digital Structures Science Olympiad, our nation-wide network of Event Supervisors, and content experts have challenged thousands of students annually to learn about the forces and processes required to build different types of structures that surround us. Many student participants have been inspired by their experiences in these events to become structural engineers, civil engineers, architects, designers, and other construction professionals who apply their knowledge to provide shelter, facilities, roads, and communication access to people around the world. Some of them used their knowledge and experiences to help prepare the various **MY SO** materials that make up this month. A special thank you goes out those alums who are members of Science Olympiad at Cornell who helped to develop this month's STEM Showdowns.

This Lesson Plan was written to provide students interested in the **MY SO** theme for the month a structured way to explore their own knowledge of the subject as well as increase and extend it. Additionally, the lesson plan provides some guidance for **MY SO** participants who will be taking part in the STEM Showdown later in the month as it serves as an introduction to many of the topics that will be featured in the STEM Showdown. While this lesson plan may be used with a wide range of individuals and in a variety of settings it was targeted at a typical middle school student who was learning at home. That does not mean it can't be used by high school students or students learning in the classroom. In fact, in both cases it can. Where appropriate, in the lesson plan modifications for high school students, the classroom setting, and diverse learning needs are included.

What's Inside this Lesson Plan

Note for Parents & Teachers

In the home setting, both parents/guardians and students will want to read through the material contained in this lesson plan. It is recommended that parents/guardians or teachers will want to read through the lesson plan first as this lesson plan is written specifically for them. Additionally, answers and explanations for the activities are provided. In many cases, if students had this information in advance it would ruin the learning opportunity for them. To the greatest extent possible, we tried to select and write the activities so that they could be completed with minimal adult supervision. However, if adult supervision is required for an activity it has been called out in multiple places.

The format of the Lesson Plan follows the research-tested 5E instructional model (Bybee et al., 2006; Duran & Duran, 2004). Science Olympiad has chosen the 5E model proven science education approach which features many of the hallmarks essential to the Science Olympiad program: uncovering and exploring ideas; in-depth research on a topic; hands-on activities; and working through struggles and challenges. In this lesson, learners will start in the **ENGAGE** phase where they will be asked some questions to help them identify what they already think or know about the topic of the month. In the **EXPLORE** phase, learners will complete an activity that will provide them new information about the ideas that they expressed in the **ENGAGE** phase. In **EXPLAIN**, learners will have the opportunity to increase their content knowledge of the monthly topic by reviewing slides, watching videos, or listening to lectures. This is the phase where learners should be working to prepare notes from which they can study for the **MY SO** STEM Showdown at the end of the month, the quizzes at the end of this lesson, or whatever other learning challenges may be put in front of them. Learners will then tackle the **ELABORATE** phase in which they will have the opportunity to deepen and extend their knowledge of the monthly theme through additional videos, readings, and most importantly, extended hands-on activities and data collection. The lesson ends with the **EVALUATION** phase where the learners will have a developmentally appropriate short quiz they can take to see how much they have increased their knowledge and where they might still need some more work.

Each part of the lesson will start with a brief description of the activity along with any tips that would be helpful for the adult working with the student to know in advance. This activity description will also include a brief rationale as to why this activity was chosen or is important. The materials needed for that activity specifically will be listed and suggested modifications for high school students or diverse learners will be provided. Any student specific instructions or handouts will be provided at the end of the section.

Next Generation Science Standards Addressed

The Next Generation Science Standards (NGSS) associated with this lesson are included to represent the specific learning outcomes that students are working towards during the course of this lesson. Teachers use these standards to guide their instructional planning and selection of learning activities. In particular, these standards help teachers determine the specific science content is developmentally appropriate for a student as well as how it should be sequenced over the course of a student's time in school.

For parents and guardians, this information is provided so you can see some of the "big ideas" that your student is working toward in this lesson. Additionally, these standards show you how the different topics in science combine to help inform your collective understanding of issues. We have selected the NGSS as our reference for all **MY SO** Lesson Plans because they represent the best national thinking around science learning for K-12 students. Also, many states have either adopted the NGSS as their state science standards or revised their state science standards to reflect information contained in the NGSS. If you would like to learn more about the NGSS you can find additional information, including which states have officially adopted the NGSS, at nextgenscience.org.

In this lesson, activities and topics will have students use their investigative skills in the scientific study of structures which addresses aspects of the following learning standards:

Middle School Physical Science

- *MS. Forces and Interactions*
- *MS-PS 2-2.* – Plan an investigation to provide evidence that a change in an object's motion depends on the sum of the forces on the object and the mass of the object.

Middle School Engineering Design

- *MS. Engineering Design*
- *MS-ETS 1-1.* - Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- *MS-ETS 1-2.* - Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- *MS-ETS 1-3.* - Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- *MS-ETS 1-4.* - Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

High School Physical Science

- *HS. Forces and Interactions*
- *HS-PS 2-1.* – Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
- *HS-PS 2-2.* – Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.

High School Engineering Design

- *HS. Engineering Design*
- *HS-ETS 1-2.* – Design a solution to a complex real-world problem by breaking it down into smaller more manageable problems that can be solved through engineering.
- *HS-ETS 1-3.* – Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
- *HS-ETS 1-4.* – Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Lesson Plan Information - Engage Phase

Activity Description
In this part of the lesson, the student will analyze a few scenarios to introduce them to ideas and processes that structural engineers engage in regularly. How the student responds reveals their understanding of the engineering design process, how engineers evaluate their work, and the importance of testing to solve problems in a design or plan. Determining where a student's thinking is at relative to problem solving, particularly with regard to engineering problems, provides important information that can inform future study as well as address any learning issues that might arise. As presented here, this activity was developed by Page Keeley, Cary Sneider, and Mihir Ravel (Keely, Sneider, & Ravel, 2020).
This activity should take approximately 5 – 10 minutes from start to finish.

Materials
- A copy of the "Testing for Success?" student worksheet

Modifications for a Classroom Setting
This activity makes an excellent "Bell Ringer" or "Do Now" in a classroom setting. The teacher would just need to make sure there are enough student worksheets for the whole class. If the teacher desires this activity could be done as a "Think-Write-Share" to increase student collaboration. It is recommended that the teacher collects student answers via volunteers and then has the rest of the class raise their hands to indicate if they had the same answer. This will allow the teacher to see the degree to which misconceptions are shared across the class. Also collecting the information in this format allows the teacher to review graphing and data analysis techniques with his or her students. With high school students, the teacher may want to review the germ theory with their class before proceeding with the lesson.

Modifications for High School Students
There are no particular modifications needed to make this activity relevant to high school students as high school students often have limited exposure to the engineering design process and the evaluation of models. This lack of understanding can often lead them to try and solve problems through "Trial & Error" or "Brute Force" approaches both of which can cost more, in time and resources, as well as overlook potential problems and opportunities. This can be especially problematic when there are numerous combinations or variables to consider.

Modifications for Diverse Learners
If the student has visual impairment or fine motor difficulties this activity runs perfectly well with either large-print or read-aloud formats as well as a scribe to record responses. If the student is a second language learner all of the text and prompts can be translated into the student's native language. For Spanish speakers, a translated version of the worksheet was provided by the authors (Keely, Sneider, & Ravel, 2020).

Answers and Background Information for Parents/Guardians and Teachers
When talking with the student or looking over his or her answers on the worksheet, you will hopefully see that he or she indicated that Jayanti had the best idea about the test results. She wasn't just concerned with whether out not the test was a success. Her answer included an analysis of the results which could be used to improve the design. Ishan's answer also included an improvement to the design but his solution ignored the constraints that the "cost of the materials" placed on the design. Jayanti's design changes accounted for this constraint. If the student didn't select Jayanti's answer as best is likely that he or she hasn't had much experience with design projects and the engineering design process. The remaining activities in this lesson will provide opportunities to develop that experience and thinking. One activity that may be helpful if the student is struggling with these concepts would be to first have him or her breakdown the assignment that was given to identify the task that was assigned as well as how it would to be judged. After that is completed, the student should then analyze the responses from each student highlighting different parts of the response that either address the task at hand or the ways that the design is going to be evaluated.

Engage Phase

Testing for Success Student Worksheet

Reproduced from *Uncovering Student Ideas About Engineering and Technology* by Keeley, Sneider & Ravel; NSTA Press 2020

Three students are building a model house using craft sticks that each cost $100 in play money. Their challenge is to construct a framework that will support the weight of at least three books at the lowest possible cost. This is what they talked about as they tested their model:

Adam: **Our model house is supposed to hold at least three books and it only starts to break when we load it with four books. Our test was successful. Time to celebrate!**

Jayanti: **Hey, it's great we got it to work, but take a close look. You can see it's only breaking in one place where we forgot to put in triangle braces for support. If we put braces in the place where it broke, it will only cost a little bit more but we might be able to make it a lot stronger and safer.**

Ishan: **Let's repair it by replacing the broken columns and improve it by putting in more triangle braces in all of the corners. Then we can test it to check the strength – maybe we can get to six books and be twice as safe as the requirement!**

Who do you think has the best idea about the result of testing their model? Explain your thinking.

Lesson Plan Information - Explore Phase

Activity Description
For this activity, the student is going to experience his or her very own design project. Using uncooked spaghetti and mini-marshmallows they are going to build the tallest tower they possibly can that will be able to hold an unaltered golf ball at its highest point for at least 90 seconds. **This activity should take most students between 20 and 30 minutes.**

Materials
- 25 pieces of uncooked, unbroken spaghetti noodles
- 3 cups, at least, of mini-marshmallows
- 1 unaltered golf ball
- 1 6 foot, or longer, tape measure
- 1 stopwatch, clock or timer, that can time 90 seconds
- Blank sheets of paper
- One (1) pencil or pen

Modifications for a Classroom Setting
To fit this activity into the classroom setting, the teacher would acquire enough materials so that every student in class would have his or her own set as this is best done as an individual activity. If resources are scarce then the activity could be done in pairs. While tape measures can be shared across groups the activity will work better if each group has access to their own golf ball. The teacher could collect the student data and photos of the towers as artifacts of student learning as well as an assignment to grade.

Modifications for High School Students
For this activity, there are no particular modifications for working with high school students. Most high school students will have limited prior experiences designing and building structures. IF they do, it is unlikely that they will have worked with these particular building materials which will introduce a new challenge for them. Parents/Guardians and teachers might expect that high school students will complete the activity slightly faster than a middle school student so the activity time estimate may be closer to the lower limit. To increase the academic rigor of the activity for some students, you might consider having them on a piece of paper create a design of their tower from a few different perspectives before giving them the actual building materials.

Modifications for Diverse Learners
This activity could present a challenge for students with significant visual impairments depending upon the severity of the impairment. While they may be able to manipulate the building materials it might be difficult to determine the height of the tower or the time if they do not have access to specialized equipment. An adult, or partner, could work with the student, read instructions, and describe the arrangement of all of the items including the results. For students with fine motor difficulties this activity may present challenges in aligning and arranging all the items properly. Again, a partner, or assistant, might facilitate the student's interaction with the materials. As always if needed a scribe is perfectly acceptable to record responses and all text and prompts can be translated into the student's native language if needed.

Answers and Background Information for Parents/Guardians and Teachers
At the conclusion of the **EXPLORE** phase the student will have had the opportunity to participate in a design challenge and get first-hand experience with both the engineering design process as well as the physical principles and forces at work when building a structure. There are a few things that a Parent/Guardian or teacher will want to pay attention as a student works in the **EXPLORE** phase.

If you interact with your student while he or she is working, you will want to resist touching the materials once these items have been given to the student. This point is important as taking the items from the student negatively impact his or her sense of agency in this activity. If the student struggles it is best to suggest different arrangements, such as “Have you tried …”, or have your own set of materials with which you can model different arrangements. The exception to this point is at the end of the activity where the student is trying to determine the height of his or her tower. At this point helping to manipulate the tape measure is perfectly fine as long as the student is the one determining the measurement. It is perfectly acceptable for you to double-check the measurement but the student should declare a value first.

It is important to monitor how well the student is following the instructions for this activity. It is very easy for the student to “adjust” the parameters and use more pieces of spaghetti than they are allowed or connect his or her tower to a stable base. Doing either of these things will reduce the complexity of the task and allow designs that otherwise would fail to hold together long enough to claim success.

Last but not least, Parents/Guardians and Teachers should use their judgement to monitor the student’s engagement as well as the student’s level of frustration with this part of the activity. The objective of the **EXPLORE** phase is to test and build on his or her knowledge that was revealed in the **ENGAGE** phase. If the student is getting frustrated and discouraged you can prompt them with different examples of buildings and designs using pictures or plans found on the Internet. It is also acceptable to demonstrate options using your own set of materials. That said, please use your judgement to decide if further attempts are not worth it to ensure that the task isn’t becoming counterproductive. In the **ELABORATE** phase the student will have the option of repeating this activity having gained new knowledge and understanding.

Explore Phase

Student Activity Instructions

1. With your parent's/guardian's or teacher's permission gather the following materials to use in this task:
- 25 pieces of uncooked, unbroken spaghetti noodles
- 3 cups, at least, of mini-marshmallows
- 1 unaltered golf ball
- 1 6 foot, or longer, tape measure
- 1 stopwatch, clock or timer, that can time 90 seconds
- Blank sheets of paper
- One (1) pencil or pen

2. Find a clear, flat surface (i.e., desktop, kitchen table, kitchen island, the floor) on which to work.

3. Use the spaghetti noodles and mini-marshmallows to build the tallest tower possible.

4. Your tower must hold an unaltered, standard sized golf ball for 15 seconds.

5. The spaghetti noodles may be broken or cut but they can only be joined by a mini-marshmallows.

6. Your tower MAY NOT be taped down or physically attached to anything.

7. You have 20 minutes to complete your build.

8. At the end of the 20 minutes, use the tape measure to measure from the flat surface that your tower rests on to the bottom of where you intend for the golf ball to rest. Record this measurement.

9. Place the golf ball where you intended in your tower, remove your hands, and begin to time.

10. If the golf ball remains in place for 15 seconds and the tower remains standing, without any external support, you have succeeded.

11. If the tower should fail and time remains, go ahead an attempt to repeat the steps while improving the tower's design.

12. Good Luck!

Lesson Plan Information - Explain Phase

Activity Description
In the **EXPLAIN** phase, the student should review the material to learn more about key vocabulary, history, and concepts related to structures, structural engineering, and the physics behind this field. It is recommended that the student takes notes on what he or she reads as these notes not only help with information retention but also can be used during the STEM Showdown, if your student chooses to participate. There are many different note-taking systems in use throughout the United States and it is recommended that your student uses one supported by his or her teachers that he or she feels comfortable with. If you are looking for a note-taking system, Science Olympiad recommends Cornell Notes as it is widely used, offers great flexibility, and is supported by a wealth of training materials.

This activity should take an hour or two to fully complete. It should not be done in one sitting. It is recommended that students take appropriate breaks when needed.

Materials
- MY SO Structures Slide Show (available at soinc.org/MYSO)
- Laptop or computer
- Paper
- Pencil or Pen

Modifications for a Classroom Setting
This activity gives the multiple options as to how he or she might use it with his or her class. At the simplest level, the teacher can familiarize himself or herself with the material contained in the PowerPoint and deliver them as a lecture to his or her class. Alternatively, a teacher could have the students in class explore the contents of the PowerPoint through a Jigsaw technique or other independent learning approach.

Modifications for High School Students
For this activity, there is no real modification to make for high school students. The PowerPoints and videos are designed for both grade bands and contain high school-level content.

Modifications for Diverse Learners
As with the previous activity, students with visual impairments may not be able to complete this activity entirely independently depending upon the degree of their impairment. In those cases, it would be advantageous for the student to listen to the videos as opposed to trying to just work off the PowerPoints. An adult, or partner, could help the student by explaining or describing the more visual elements. As always if needed a scribe is perfectly acceptable to record responses and all text and prompts can be translated into the student's native language if needed.

Answers and Background Information for Parents/Guardians and Teachers
The biggest things that a parent/guardian or teacher can do after this activity is talk with the student. The objective here is to see how learning the new information is going. This is most easily accomplished through a discussion using open-ended questions. Some questions that you might think about using are:
- What was the most interesting thing you've learned so far?
- What have you learned that surprised you the most?
- Are you still confused by anything that you have learned?
- Out of all the material you've looked at, what has been the hardest to understand?
- What's the biggest question that you still have?

By providing the student the opportunity to talk about and explain what they have learned you are actually helping them to commit the material to memory; reinforcing what they have already learned. If there are points are unclear encourage them to use the notes he or she took as well as show you the section in the video or PowerPoints where the materials were presented. For teachers in a classroom, you could accomplish the goals described here by converting the one-on-one, at-home questioning to an Exit or Entrance ticket where your students write down their responses to the questions that you select. Last but not least, if your student mentions topics that he or she is still struggling to understand encourage them to start with those topics when they move into the **ELABORATE** phase.

Student Activity Instructions

1. With your parent's or guardian's permission download the **MY SO** Structures Slide Show from soinc.org/MYSO.

2. You may want to download and print out the PowerPoint to take notes on and write down import ideas. If you do choose to print them out consider printing in Black & White to preserve your toner cartridge.

3. Find a quiet place to sit and review the slide show taking notes on the material that you feel is important. These notes can be used later in the month if you chose to participate in the STEM Showdown.

4. It is recommended that you follow whatever note-taking strategy you normally would whether it comes from a teacher or it is one you developed yourself.

5. If you are looking for a note-taking strategy you can Google the topic and find dozens of them. One particular strategy that we often recommend at Science Olympiad is Cornell Notes.

6. Take as long as you need to go through the Slide Show. If you have questions or don't quite understand something write it down and you can try and answer that question or focus on learning more about the topic in the **ELABORATE** phase.

Lesson Plan Information - Elaborate Phase

Activity Description

In the **ELABORATE** phase, the student has the opportunity to deepen his or her knowledge, address remaining misunderstandings, and expand his or her learning to new but related topics. All these things are accomplished through a mix of learning methods, such as readings, videos, hands-on activities, and online simulations, chosen by the student to best meet his or her specific learning needs.

As the activity in the **ELABORATE** phase is student-directed there is no specific timeframe for how long any activities in this phase should take or how long the student may spend on this phase at all. It is generally recommended that a student should select and complete at least one activity either from the list recommended here or of his or her own choosing. Once the student is ready to move on from the **ELABORATE** phase he or she should move to **EVALUATE** and complete one of the brief quizzes provided.

Materials

Since the **ELABORATE** phase can go in so many directions we cannot provide a comprehensive and inclusive list of materials that will be used in this learning step as we have previously. Instead what we have done here is to provide some recommendations of possible activities. These activities are divided into two broad categories; Videos and Readings and Hands-on Activities. For Videos and Readings, we have identified open source online courses, lessons, textbooks, and videos that apply to the topic of **Structures, Structural Engineering, and Physics.** For Hands-on Activities, we have identified simple activities that can be conducted at home using materials either found around the house, acquired from "Big Box" stores, or pharmacies. Additionally, we have listed free online learning activities. By no means are either of these lists comprehensive. They reflect some of the materials that our top national teams have been using to prepare for Structures events such as Boomilever, Elevated Bridge, Mystery Architecture, and Towers that are part of our National Competition based on the recommendations of our Event Supervisors.

Videos & Recordings

Physics: an OpenStax high school textbook written by Paul Peter Urone and Roger Hinrichs - https://openstax.org/details/books/physics

- This is a free online physics textbook was written as an introductory textbook for high school students studying physics. It uses real-world examples to introduce and help students understand physics concepts but does not require students to have a well-developed mathematics background. Each chapter shows how physics is applicable everywhere in the natural world and provides multiple practice problems, tasks, and multiple-choice questions to monitor student understanding. Students will benefit the most from Chapters 1, 4, and 5.

College Physics: an OpenStax textbook written by Paul Peter Urone and Roger Hinrichs - https://openstax.org/details/books/college-physics

- Beginners and advanced learners might wish to deepen or expand their knowledge through this series of videos and other resources from Khan Academy. One of the key elements of this unit is that it will delve into both forces and how free body diagrams are used to represent them. Like all Khan Academy units there are brief assessments embedded to test student knowledge.

Khan Academy: Types of Forces and Free Body Diagrams - https://www.khanacademy.org/science/high-school-physics/forces-and-newtons-laws-of-motion/introduction-to-forces-and-free-body-diagrams/v/types-of-forces-and-free-body-diagrams

- Beginners and advanced learners might wish to deepen or expand their knowledge through this series of videos and other resources from Khan Academy. One of the key elements of this unit is that it will delve into both forces and how free body diagrams are used to represent them. Like all Khan Academy units there are brief assessments embedded to test student knowledge.

Hands-On & Simulation Activities

- Repeat the **EXPLORE** activity but this time but this time try a different design, use fewer pieces of spaghetti, or try a different material instead.

- If you have a smartphone considered downloading the Simple Physics App, a free game in which you are presented with a different design challenges to complete. Not only does each challenge present you with different structures to build but also each challenge presents different constraints that factor into your design.

- Students who are very interested in structural engineering and want to get a first-hand experience designing and testing structures while working with professional engineering software may want to consider getting a Science Olympiad license for SkyCiv. SkyCiv is a cloud-based structural engineering software used by professional engineers worldwide that has partnered with Science Olympiad to provide this professional resource to our teams. With this program students can design a variety of structures from a catalog of materials and conduct the exact same modeling tests that structural engineers use to evaluate their designs. Interested students can learn more about the program as well as purchase a license at https://skyciv.com/olympiad/.

Modifications for a Classroom Setting

Since there is no specific activity that the makes up the **ELABORATE** phase a classroom teacher has a wide range of ways to incorporate the above information into his or her instruction. One recommendation would be that the teacher identifies a hands-on activity or online simulation for the class to complete. One option supported by educational research (Loehr, et al., 2012; Tai, Sadler, & Loehr, 2005, Sadler & Tai, 2001, Sadler & Tai, 1997) would be to have the class repeat a prior activity and either rework the activity based on what they think went wrong from the previous attempt or instead look at how the extent of a contact affects the transmission rate of an infection as is suggested above. Another option that a teacher is encouraged to consider is to group students and use a Jigsaw technique to have them expand their learning by having different groups complete different activities and then report back on what they learned from the activity.

Modifications for High School Students

As with the EXPLAIN phase, there are no specific modifications for high school students. The only consideration that should be made is the student is engaging in material that supports his or her learning needs and is consistent with his or her ability in mathematics.

Modifications for Diverse Learners

As with the previous activity, students with visual impairments may not be able to complete this activity entirely independently depending upon the degree of their impairment. In those cases, an adult, or partner, should help the student with the activity with the readings, selecting videos, or preparing materials for hands-on activities. For students with fine motor difficulties parents and guardians may direct them away from some hands-on activities or find that they may have to help on occasion. For students with auditory issues, they may want to use assistive listening devices or close captioning features on videos if available. As always if needed a scribe is perfectly acceptable to record responses and all text and prompts can be translated into the student's native language if needed.

Answers and Background Information for Parents/Guardians and Teachers

Much like the **EXPLAIN** phase of the lesson, the biggest thing that a parent/guardian or teacher can do during the **ELABORATE** phase is monitor student progress, making sure that any struggles that he or she may be having are reasonable and are being addressed properly (e.g., trying new resources, asking questions, repeating tasks to correct mistakes). If the parent/guardian or teacher finds that the student is "inappropriately struggling" (e.g., taking the struggles personally, losing interest in the topic, feeling discouraged) it is recommended that the parent/guardian or teacher has a conversation with the student that should not only remind the student that struggling is part of the learning process, especially when working with advanced content like is presented here, but also the conversation should help to redirect the student to materials that may be more helpful (e.g., general as opposed to specialized videos, grade-level readings or academic resources, experiments with fewer variables or requiring less precision).

During the **ELABORATE** phase, the other role that a parent/guardian or teacher must play is that of time keeper. While the activities of the **ELABORATE** phase are meant to be open-ended allowing the student to explore his or her interests and deepen his or her knowledge of the subject. **Weather** is an area of ever-expanding knowledge with many related disciplines and specializations. Individuals can, and have, committed their lives to its study and still do not know everything. At some point, the student should complete his or her **ELABORATE** activities that are part of this lesson and move onto the **EVALUATE** phase. The parent/guardian or teacher may need to remind the student that he or she can always return to learning more after the EVALUATE phase is completed. In fact, the **EVALUATE** phase may help provide the student with some guidance as to where his or her future study of should lead.

Lesson Plan Information - Evaluate Phase

Activity Description
In the **EVALUATE** phase, the student has the opportunity to assess how much he or she has learned about the topic of the lesson. Additionally, he or she will gain insight into areas where further study may be warranted is he or she so chooses. These goals will be accomplished by taking either of the two brief tests, one for middle school students and one for high school students, provided in this lesson. The student may refer to notes they have previously taken during the lesson though it is recommended that he or she try to answer as many of the questions as is possible without the use of notes.

After completing the test, the student, parent/guardian, or teacher can use the included answer key to grade the test. Once the test is graded the student may want to go through and review any questions that he or she got wrong. This is an important step in the learning process as it allows the student to examine his or her mistakes to determine what lead to the mistake. Sometimes the mistake happens because of a simple error (e.g., working to quickly, making an assumption about the question, not learning that material) but on other occasions the mistake is the result of a fundamental misunderstanding the student holds about the topic that needs to be addressed through additional study. In both cases, the student's future learning benefits from this examination.

The **EVALUATE** phase should take about an hour to 90 minutes to take and grade the test

Materials
- The Middle School (Division B) **Structures** test and answer key can be accessed online at soinc.org/MYSO
- The High School (Division C) **Structures** test and answer key can be accessed online at soinc.org/MYSO

Modifications for a Classroom Setting
There are no specific modifications that need to be made to adapt the **EVALUATE** phase to a classroom setting. A classroom teacher may want to make changes with regard to how the test is administered (e.g., use of notes, talking, asking questions) to match his or her normal classroom procedures for administering tests. In addition, a classroom teacher should feel free to add additional questions or use a different age appropriate assessment that better aligns with his or her instructional needs and objectives.

Modifications for High School Students
Like previous phases, there are no specific modifications for high school students outside of using the provided high school test.

Modifications for Diverse Learners
As with the previous activities, students with visual impairments may not be able to complete this activity entirely independently depending upon the degree of their impairment. In those cases, an adult, or partner, should help the student with the test by reading questions and explaining tables and graphs. As always if needed a scribe is perfectly acceptable to record responses and all text and prompts can be translated into the student's native language if needed.

Answers and Background Information for Parents/Guardians and Teachers
After the student has completed the brief **EVALUATE** test for his or her age, his or her responses can be checked using the included answer key. As was discussed above, students should be encouraged to examine why they may have gotten particular questions wrong. After completing this examination, the students may want to trying additional questions. If parents, guardians, or teachers feel it is appropriate the student may attempt the practice test provided in this lesson for the opposite grade brand. Additionally, differentiated practice problems can be found on the Boomilever Event Pages on the Science Olympiad website (soinc.org). Students looking for even more information about Structures are encouraged

to visit the Science Olympiad Store (store.soinc.org). There they will find a mix of learning resources on the topic of Structures; in particular the Problem Solving/Technology CD as well as the Boomilever and Towers Digital DVDs.

Conclusion, Resources, & References

We hope that your learner has enjoyed this lesson. Thank you for the opportunity to be a small part of his or her education. If you haven't done so already we would encourage you to sign up for this month's **STEM Showdown**. You can check out the other resources produced for this month as well as future months on our **MY SO** page (https://www.soinc.org/myso).

A special thanks goes out to the members of Science Olympiad at Cornell for their help in preparing the Slide Show Presentation, Practice Tests and the STEM Showdown.

If you would like to learn more about Science Olympiad, please investigate our website (soinc.org) which includes information about all of our programs for Elementary, Middle, and High School as well as how to start a competitive team or volunteer to support the program.

Additional Resources

1. Science Olympiad Boomilever Division B (Middle School) Event Page - https://www.soinc.org/boomilever-b
2. Science Olympiad Boomilever Division C (High School) Event Page - https://www.soinc.org/boomilever-c
3. Science Olympiad At Home – Volume 2 Video and Lesson - https://www.soinc.org/programs/elementary
4. Science Olympiad Website. https://www.soinc.org
5. Science Olympiad Store. https://store.soinc.org

References & Citations

1. Bybee, R.W., Taylor, J.A., Gardner, A., Van Scotter, P., Carlson Powell, J., Westbrook, A., & Landes, N. (2006) *The BSCS 5e Instructional Model: Origins, Effectiveness, and Applications.* Colorado Springs, CO, BSCS.
2. Duran, L.B. & Duran, E. (2004) The 5E Instructional Model: A Learning Cycle Approach for Inquiry-Based Science Teaching. *The Science Education Review*. (3)2, 49-58.
3. Keely P., Sneider, C., & Ravel, M. (2020) Testing for Success, *Uncovering Student Ideas About Engineering and Technology* (pp. 191-195). Arlington, VA, National Science Teaching Association Press.
4. Loehr, J. F., Almarode, J.T., Tai, R. H., & Sadler, P. M. (2012) High school and college biology: A multi-level model of the effects of high school courses on introductory course performance. *Journal of Biological Education*. 46(3), 165-172.
5. Sadler, P. M. & Tai, R. H. (2001). Success in college physics: The role of high school preparation. *Science Education.* 85(2), 111 – 136.
6. Sadler, P. M. & Tai, R. H. (1997). The role of high school physics in preparing students for college physics. *The Physics Teacher*. 35(5), 282 – 285.
7. Tai, R. H., Sadler. P. M., & Loehr, J. F. (2005). Factors influencing success in introductory college chemistry. *Journal of Research in Science Teaching*. 42(9), 987-1012.

MY SO PRACTICE TEST

DIVISION B - MIDDLE SCHOOL, GRADES 6-9

PRACTICE TEST

Instructions

- You have 20 minutes to complete this test.
- You may write your answers directly in the test.
- You may use any notes or resources you have created or collected.
- You may use a calculator and scratch paper if necessary.
- Good Luck!

Test Questions

1. Carbon fiber is an example of an...
    a. Isotropic material, where the strength is the same in every direction
    b. Isotropic material, where the strength depends on the direction
    c. Anisotropic material, where the strength depends on the direction
    d. Anisotropic material, where the strength depends on the direction

2. Which of the following is NOT true about historical structural innovations?
    a. The ancient Greeks created pillars by stacking shorter sections on top of each other to form a taller pillar
    b. Ancient Greek pillars have high tensile strength
    c. A keystone is set last in an arch and plays an important role in the structural integrity of the arch
    d. Ancient Roman arches are strong under compression

3. Why is rebar generally made with an uneven surface?
    a. To help adhere better to the concrete
    b. To withstand corrosion in areas with high humidity
    c. To keep the manufacturing process simpler and cheaper
    d. To prevent bending in areas prone to earthquakes

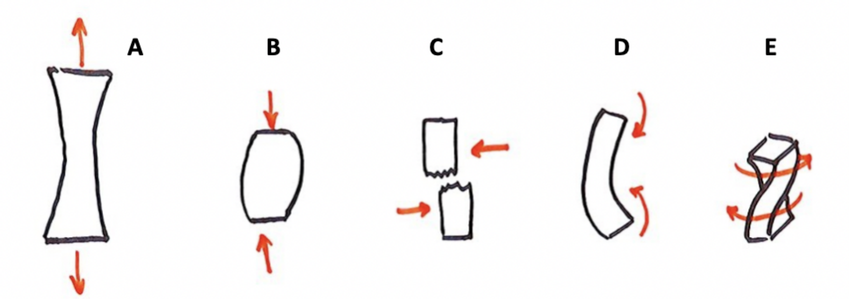
4. Crushing a long cardboard piece from two ends is an example of...
    a. Tension
    b. Torsion
    c. Bending
    d. Buckling

5. Calculate the cross sectional area of a rope with radius 2 cm.
   a. $A = \pi\ cm^2$
   b. $A = 2\pi\ cm^2$
   c. $A = 4\pi\ cm^2$
   d. $A = 8\pi\ cm^2$

6. How much weight does 6 kilograms of mass exert, where g = 9.81 m/s2?
   a. ⅙ * g Newtons
   b. 6 Newtons
   c. 6 * g Newtons
   d. 36 Newtons

7. How many Pascals does a force of 8 Newtons exert on an area of 4 square meters?
   a. ½ Pascal
   b. 2 Pascals
   c. 8 Pascals
   d. 32 Pascals

For questions 8-9, consider the loading scenarios pictured below.



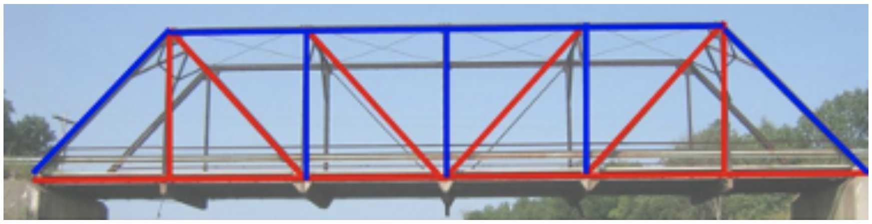
(source: StructurePlanet - Internal Forces)

8. Which image depicts tension?
   a. A
   b. B
   c. C
   d. D
   e. E

9. Which image depicts torsion?
   a. A
   b. B
   c. C
   d. D
   e. E

.

10. In the following image of a truss bridge, which color depicts members that primarily experience tension?



a. Blue
b. Red
c. There is no correlation between the colors at all

Questions 11 and 12 will reference the below diagram of a compression bridge:

© 2012 Encyclopædia Britannica, Inc.

11. What force do the cables of a compression bridge primarily experience?
a. Compression
b. Tension
c. Torsion
d. Shear

12. What about the towers of the bridge?
a. Compression
b. Tension
c. Torsion
d. Shear

Consider the arm of the construction tower shown below for questions 13-16.

13. Let's say the arm supports a load P at a distance L away from the central tower. Which part of the arm is under the most stress?
    a. The part of the arm closest to the tower.
    b. The halfway point between the weight and the tower
    c. The part of the arm closest to the load P
    d. All parts of the arm of the crane are under equal stress

14. If we said that the tower could support a maximal load of P = 120,000 lbs (at a distance L) before it collapses, but in real life, the most it would ever be loaded with would be P = 80000 lbs at a (distance L), what is the safety factor of the arm?
    a. 0.66
    b. 1.2
    c. 1.33
    d. 1.6
    e. 2.2

15. At the right hand side of this image, there are many concrete slabs on the backside of the arm. These are known as counterweights. What is the purpose of these counter weights?
    a. To increase the moment of inertia of the crane so it does not spin too fast
    b. To keep the tower equally loaded on both sides, to prevent it from toppling over when the load P is large.
    c. To serve as catapult projectiles if the tower falls over to one side
    d. To keep the arm equally loaded in torsion whenever it needs to withstand torsion

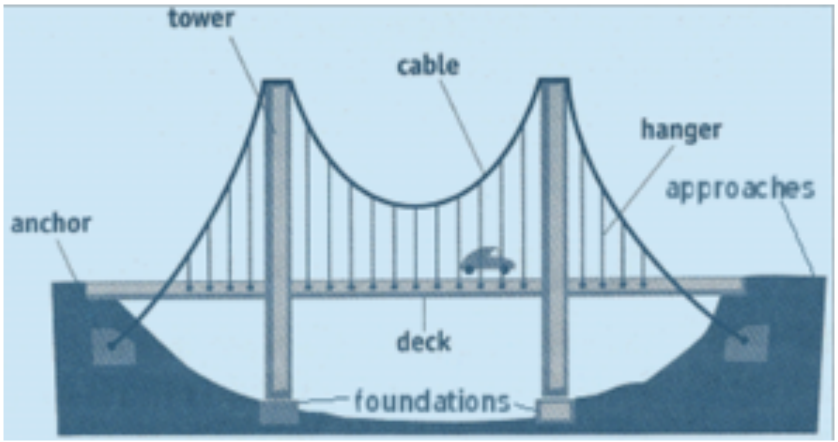
16. Let's say that a certain engineer wants to double the maximal theoretically supportable load of this crane. What could the engineer do to the dimension L to support a load of P = 180,000 lbs or more?
    a. Let L be twice as long as its original length
    b. Let L be 0.5 of its original length (half)
    c. Let L be 0.75 of its original length (three fourths)
    d. Keep L the same dimension. The built in safety factor is sufficient.

17. What is a drawback to having too much water in a concrete mix?
    a. Increased workability of the concrete
    b. The risk of having gaps in the concrete, leading to weaknesses in the structure.
    c. Different amounts of water leads to concrete with different uses, and thus there is no drawback.
    d. Longer drying time for the concrete, which may lead to delays in the construction.

18. Which of the following are loads that need to be accounted for when designing a structure?
    - Wind load
    - Structure self weight
    - Precipitation
    - Seismic load
    - Human
    a. Only I and II
    b. Only I, II and IV
    c. Only I, II, IV, and V
    d. All of them

19. Why is steel used to help reinforce concrete over other metals?
   - Steel has a thermal expansion coefficient similar to that of concrete.
   - Steel is strongest when acting as reinforcement for concrete.
   - Steel is relatively cheaper compared to other metals of similar strength.
      a. Only I and II
      b. Only I and III
      c. I, III, and III
      d. Only I

20. Which of the following part(s) of the suspension bridge is in tension?



      a. The deck and the foundation
      b. The tower and the deck
      c. The hanger and the deck
      d. The hanger and the cable

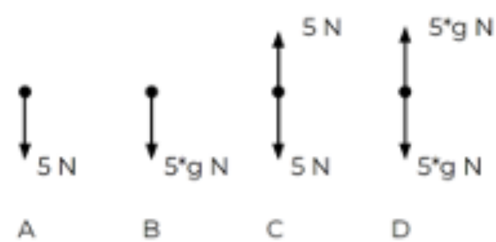
21. Steel has a thermal expansion coefficient α = 12 * 10-6. If a bridge made of steel is 1000m long when it is 10°C outside, how long will it be when it is 20°C outside? Remember that

$$\alpha = \frac{1}{length} * \frac{change\ in\ length}{change\ in\ temperature})$$

      a. 1000.012m
      b. 1000.12m
      c. 1001.2m
      d. 1012m

22. Which type of annealing would be useful to make hardened steel with 1% carbon workable again?
      a. Spheroidize
      b. Normalize
      c. Process Anneal
      d. Full Anneal

23. A box sitting on the ground weighs 5kg. Which free body diagram correctly shows the forces acting on the box?
      a. A
      b. B
      c. C
      d. D



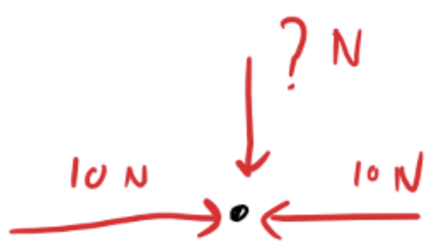
24. When cutting a piece of paper with a pair of scissors, what force is being applied to the paper?
    a. Compression
    b. Tension
    c. Shear
    d. Bending

25. A rope suspends a box from the ceiling that weighs 300 N and is experiencing a force directed 400 N to the right. What is the magnitude of the tension in the rope? (the rope will not hang straight down)
    a. 300 N
    b. 400 N
    c. 500 N
    d. 600 N

26. A 10 ft long steel beam has a safety factor of 3. If the designed load is 5,000 N then what is the maximum load this steel beam can withstand?
    a. 15,000 N
    b. 20,000N
    c. 1666.67 N
    d. 5,000 N

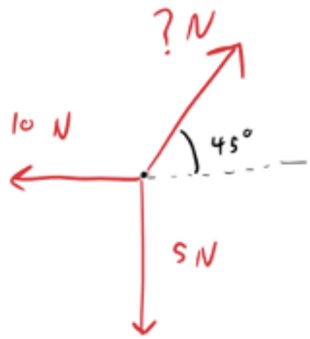
27. What is steel?
    a. An alloy of aluminum
    b. An alloy of iron
    c. An mixture of silver and aluminum
    d. Pure iron that has been heat treated

28. Solve for the force needed to place the particle in equilibrium.



    a. 0 N
    b. 10 N
    c. 20 N
    d. 40 N
    e. No equilibrium possible

29. Solve for the force needed to place the particle in equilibrium.



a. 7.07 N
b. 14.1 N
c. 15 N
d. 20 N
e. No equilibrium possible

30. A bicycle chain delivers power to the rear wheel by withstanding what kind of stress?
a. Torsion
b. Tension
c. Compression
d. Bending

ANSWER KEY

1.	**D**	15.	**B**	29.	**E**
2.	**B**	16.	**B**	30.	**B**
3.	**A**	17.	**B**		
4.	**D**	18.	**D**		
5.	**C**	19.	**B**		
6.	**C**	20.	**D**		
7.	**B**	21.	**B**		
8.	**A**	22.	**A**		
9.	**E**	23.	**D**		
10.	**B**	24.	**C**		
11.	**B**	25.	**C**		
12.	**A**	26.	**A**		
13.	**A**	27.	**B**		
14.	**C**	28.	**A**		

MY SO PRACTICE TEST

DIVISION C - HIGH SCHOOL, GRADES 9-12

PRACTICE TEST

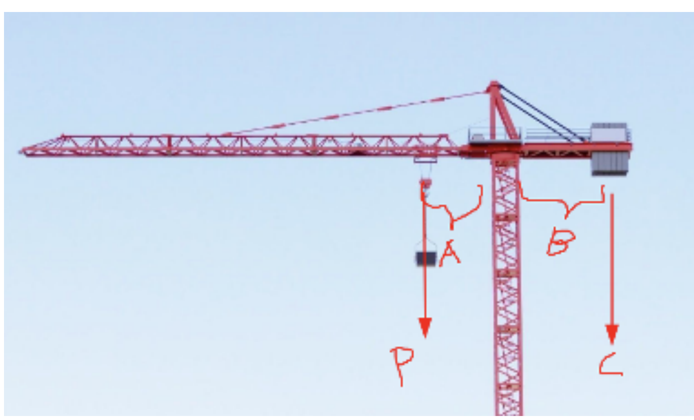
Instructions

- You have 20 minutes to complete this test.
- You may write your answers directly in the test.
- You may use any notes or resources you have created or collected.
- You may use a calculator and scratch paper if necessary.
- Good Luck!

Test Questions

Questions 1-2 use the following diagram and scenario.

A construction crane supports a load P a distance A from the tower, and it has a counterweight a distance B from the tower, exerting a load C.



1. If P = 80,000 lbs, and A = 12 ft, how much should the counterweight weigh if the distance B was known to be 15 ft, so that the tower is only loaded in axial compression?
   a. 60000 lbs
   b. 64000 lbs
   c. 72000 lbs
   d. 80000 lbs
   e. 92000 lbs

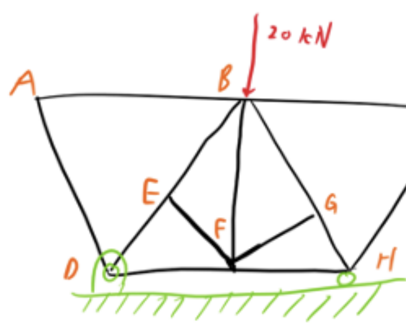
2. Given the above answer, is the calculated weight of the counterweight actually ideal if it were to be used in real life for a crane?
    a. No, since it was calculated for a very specific loading condition, where P and A are already chosen.
    b. No, since the tower can also withstand some off-centered loading causing it to undergo some bending
    c. Yes, cranes have counterweights designed for loads that are only a specific weight and distance away from the tower
    d. Yes, the calculated counter weight is the worst case loading this tower will see given the loading P
    e. Both a) and b) are correct
    f. Both c) and d) are correct

3. What is the use of rebar in concrete?
    a. Rebar increases the tensile strength of concrete
    b. Rebar increases the compressive strength of concrete
    c. Rebar increases both the compressive and tensile strength of concrete by a significant amount
    d. Rebar helps prevent cracks from forming in the concrete

4. Where is the first recorded use of the truss in construction?
    a. In ancient Greek roofs
    b. Primitive lake dwellings around 2500 B.C.
    c. Ancient Roman bridges
    d. Mesopotamia around 3500 B.C.

5. If a rope has a radius of 10 cm and is under a force of 10 N, what is the tensional stress in the rope?
    a. 31.8 kPa
    b. 318 Pa
    c. 0.0318 Pa
    d. Need more information to calculate

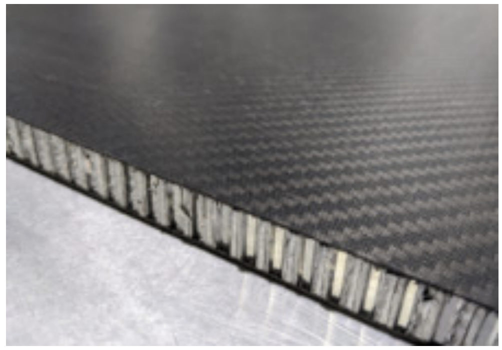
Questions 6 and 7 use the following diagram.



6. Identify the members of the truss that are NOT zero force members.
    a. AD, DB, BH, DH
    b. DB, BH, DH, EF, FG, FB
    c. DB, BH, DH
    d. None of the above

7. In a real scenario, the zero force members in the structure help most to reduce...
    a. Buckling
    b. Tension and compression
    c. Instability
    d. Nothing, they are useless because they carry zero force

8. The picture below shows a sandwich panel which is made up of 2 carbon fiber sheets with an aluminum honeycomb in between and usually held together with adhesive. What is a major advantage to adding an aluminum honeycomb in this fashion instead of just using carbon fiber?



a. Reducing the weight of the panel
b. To make up for carbon fiber's poor shear stress properties
c. Increase the rigidity and resistance of the plate to bending
d. Prevents the carbon fiber from delaminating
e. Allow bees to inhabit the space, resulting in a more eco
f. friendly structure

9. A 10 ft long steel beam has a safety factor of 3. If the current load is 5,000 N then what is the maximum load this steel beam can withstand?
a. 15,000 N
b. 20,000N
c. 1666.67 N
d. 5,000 N

10. Let's say there exists a beam supported by two pillars on both ends. Let's say it is 63 ft long, and the beam has a mass of 47500 kg. Approximately what is the expected axial load P on each beam?
a. 172 kN
b. 168 kN
c. 237 kN
d. 233 kN

11. Referencing the previous question, let's say that each pillar is made from a special new 3D printed concrete material that has a maximum compressive strength of 18 MPa. Assuming the concrete pillars have a rectangular cross section, which of the below cross sectional dimensions allow for a safety factor of 1.2?
a. 11.37 cm by 11.37 cm
b. 12.46 cm by 12.46 cm
c. 12.01 cm by 12.01 cm
d. 2.44 cm by 2.44 cm
e. 1.44 cm by 1.44 cm

12. A bridge designer is building a very particular bridge that must conserve precious material during construction. The engineer is not worried about the strength of the deck of the bridge, but wants to know how strong the pillars should be in the worst possible loading case. Which of the following describes the worst possible loading case given that the maximum length of a train is 100 ft, the distance between towers of the bridge is 1000 ft, and the bridge will only ever see one train at a time?
    a. A tower is under greatest load when the train is between two towers
    b. A tower is under greatest load when the train is anywhere between two towers
    c. A tower is under greatest load when the middle of a train is directly over top a tower
    d. A tower is under greatest load when the train is moving the fastest across the bridge

13. The are two pistons that can both be pressured to the same maximum internal pressure. One cylinder cavity has a cross section of 50 cm2 and a maximum cylinder length of 10 cm, and another with a cross section of 75 cm2 and a maximum cylinder length of 2 cm. Which piston could deliver a greater maximum actuation force?
    a. The 75 cm2 piston since it has a greater cross sectional area
    b. The 50 cm2 piston since it has a greater internal volume
    c. You can't tell since you need more information to determine the maximum possible actuation force

14. Which of the following may be a cause for failure in a building supported by rebar?
    a. The steel used for the rebar expands faster than the concrete, causing cracks
    b. The rebar is poorly placed, leading to the rebar slipping out of place
    c. The rebar was created with rough edges, causing the concrete to crack
    d. The use of carbon steel rebars in an location with low humidity

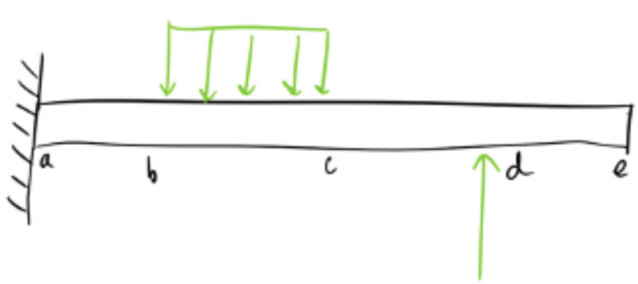
Questions 15 and 16 use the following scenario.

The second floor of a single family two story house functions as bedrooms and is 55ft by 40ft.

15. The live load for furnitures and human occupation that needs to be accounted for is 40 pounds per square foot (psf). What is the total live load of this floor?
    a. 8,800 lb
    b. 88,000 lb
    c. 2,200 lb
    d. 22,000 lb

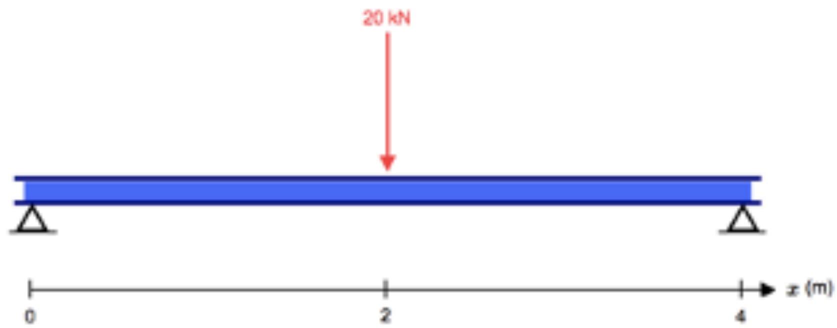
16. Suppose this floor is a ⅞ inch hardwood floor that has a dead load of 4 psf. What is the total load including live and dead load for this floor?
    a. 8,800 lb
    b. 88,000 lb
    c. 96,800 lb
    d. 30,800 lb

17. Describe the shape of the shear stress diagram of the following cantilever beam



a. Linear downwards until B, Linear upwards until C, Horizontal until D, Jumps up and horizontal again until E
b. Horizontal until B, Linear downwards until C, Horizontal until D, Jumps up and horizontal again until E
c. Horizontal until B, Linear upwards until C, Horizontal until D, Jumps down and horizontal again until E
d. Linear upwards until B, Linear downwards until C, linear downwards until D, linear upwards until E

A diagram of a point load acting on a beam is shown below. Questions 18 and 19 will refer to this diagram.



18. Which of the following effects would the point load have on the stress diagram?
    a. A diagonal line
    b. A "jump" (vertical line)
    c. A horizontal line
    d. The point load would have no effect on the stress diagram

19. Would this effect be in the positive or negative direction on the stress diagram?
    a. Positive
    b. Negative
    c. No effect

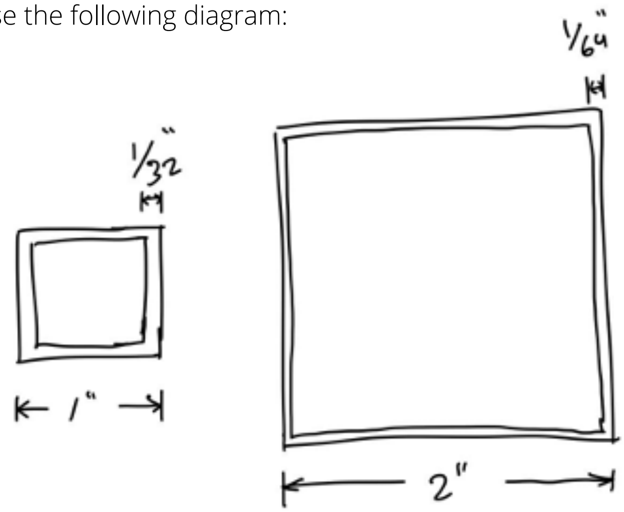
20. You are placing books on a very weak bookshelf similar to the one shown below. In order to reduce bending stress on the horizontal "shelves," you should place the books...

    a. Near the center of the shelves
    b. Half against the left edge of the shelf, half against the right edge of the shelf
    c. Spread evenly across the shelf
    d. Does not matter, the book shelves carry the same weight

21. In the shelf from the previous question, how can you place the books in order to reduce the compression load that the legs experience?
    a. Near the center of the shelves
    b. Half against the left edge of the shelf, half against the right edge of the shelf
    c. Spread evenly across the shelf
    d. Does not matter, the book shelves carry the same weight

22. You pick up a strand of carbon fiber and notice that no matter how hard you pull on the ends, the strand does not break. You decide to tie a knot in the strand and you pull again and the strand snaps much more easily. You decide knot to do that again, but are curious why it broke so easily. What is a possible explanation?
    a. By tying the knot, you are loading the strand in shear instead of only tension
    b. By tying the knot, you are causing the strand to rub against itself, wearing down the CF
    c. By tying the knot, you are loading the strand in compression instead of only tension
    d. None, you just got lucky

Questions 23 through 25 will use the following diagram:



23. The two above square box girders have the cross-sections pictured above. Notice that they are different in both their outer dimension and wall thickness. Which of the below statements is true about the strength of the girders when loaded in compression axially down the length of the beam?
    a. The 1" box girder is significantly stronger than the 2" box girder
    b. The 2" box girder is significantly stronger than the 1" box girder
    c. Both girders can support approximately the same load in axial compression (within 5%)

24. Which of the below statements is true about the strength of the girders when they are loaded in bending (resisting being bent)?
    a. The 1" box girder is significantly stronger than the 2" box girder
    b. The 2" box girder is significantly stronger than the 1" box girder
    c. Both girders can support approximately the same load in bending

25. Which of the below statements is true about the strength of the girders when the girders are loaded in torsion about an axis down the length of the beam?
    a. The 1" box girder is significantly stronger than the 2" box girder
    b. The 2" box girder is significantly stronger than the 1" box girder
    c. Both girders can support approximately the same load in torsion

Use the following scenario for questions 26-30.

Say there existed some tall radio tower, with 4 guy wires arranged in a cross configuration, all exerting some tension T at the top of the tower. This tower can support a maximal load P at the top.

26. Some engineer decides to double the amount of guy wires on this tower, so now there are 4 more of the same guy wires (all under tension T), for a total of an eight way cross of guy wires on this tower. What could you say about the load that this tower can now support at the top compared to the original load P?
    a. < P
    b. > P
    c. P
    d. Exactly 2P

27. Some other engineer decides that they want to move the ground anchor points of the guy wires further outward, moving further away from the base of the tower. They do this without changing the tension T exerted at the top of the tower (perhaps some parameters of the guy wires need to be altered to do so). What could you say about the load that this tower can now support at the top compared to the original load P?
    a. < P
    b. > P
    c. P
    d. Exactly 2P

28. Finally another engineer decides that they want to make the guy wires 2 times thicker (the diameter is increased by a factor of two). What could you say about the load that this tower can now support at the top compared to the original load P? (Hint the T that each cable exerts on the tower changes)
    a. < P
    b. > P
    c. P
    d. Exactly 2P

29. Another engineer decides that they want to make the guy wires out of a heavier metal (supposed they switched to a heavier steel alloy, keeping all other dimensions of the cable constant). What could you say about the load that this tower can now support at the top compared to the original load P? (Hint: the T that each cable exerts on the tower changes)
    a. < P
    b. > P
    c. P
    d. Exactly 2P

30. Another engineer decides that they want to make the guy wires out of a lighter metal (supposed they switched from aluminum to steel, but maintained the same T that each cable exerts on the tower). What could you say about the load that this tower can now support at the top compared to the original load P?
    a. < P
    b. > P
    c. P
    d. Exactly 2P

ANSWER KEY

1.	**B**	15.	**B**	29.	**A**
2.	**E**	16.	**C**	30.	**C**
3.	**A**	17.	**B**		
4.	**B**	18.	**B**		
5.	**D**	19.	**B**		
6.	**C**	20.	**B**		
7.	**A**	21.	**D**		
8.	**C**	22.	**A**		
9.	**A**	23.	**C**		
10.	**D**	24.	**B**		
11.	**B**	25.	**B**		
12.	**C**	26.	**A**		
13.	**A**	27.	**B**		
14.	**B**	28.	**A**		

MY SO: Structures

Division B+C Presentation

Topics Covered

- **Div B and C**
    - Historical structures
    - Material properties
    - Thermal expansion
    - Loading scenarios
    - Cross sections and stress
    - Forces and equilibrium
    - Trusses
    - Dynamic loads
    - Safety factor
- **Div C only**
    - Zero force members
    - Two force members
    - Shear stress diagrams
    - Pistons
    - Cascading failures
    - Guy wires
    - Tuned mass dampers

Heavy Focus:

- Both tests will focus on the ability to analyze a structure, and think about what forces/stresses members are withstanding
    - Tension
    - Compression
    - Bending
    - Shear
    - Torsion
    - Buckling
- Please note that all of the above are not mutually exclusive!
- Be comfortable with the definitions of the above, and intuitive scenarios of their occurrences

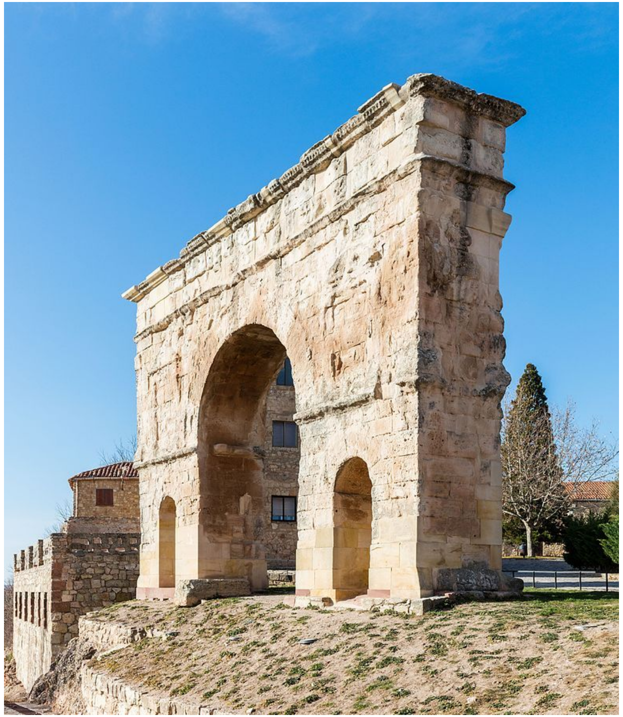
Historic Structures: Greek

- One important historical innovation of **ancient Greek** structures is the use of **pillars**
- These pillars were created by **stacking smaller pillars** on top of each other
- This structure has **little tensile strength**, but is **strong under compression**

Source:
https://etc.ancient.eu/photos/ancient-greek-temples-mediterranean/

Historic Structures: Roman

- The **Roman arch** was the foundation of many buildings in ancient Rome
- The **keystone** is the most important component of an arch
  - It is a **wedge shaped stone** at the **top** of the arch that is set last and **holds the rest of the arch in place**
- An arch is **strongest under compression** as it distributes the load on it downwards
- Roman arches are usually made up of **concrete**

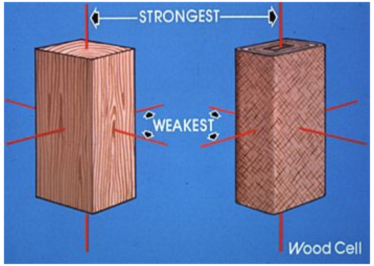


Material Properties

- **Mechanical** material properties: strength, toughness, hardness, brittleness, malleability, and ductility
- **Physical** material properties: density and thermal expansion
- **Chemical** material properties: ability to corrode and chemical stability
- **Isotropic vs Anisotropic**
    - **Isotropic -** Material properties are independent of direction
        - Example - Aluminum, same strength in every direction
    - **Anisotropic -** Material properties are direction dependent
        - Example - Carbon Fiber, strength depends on the direction you consider and its orientation with the grain of the fibers

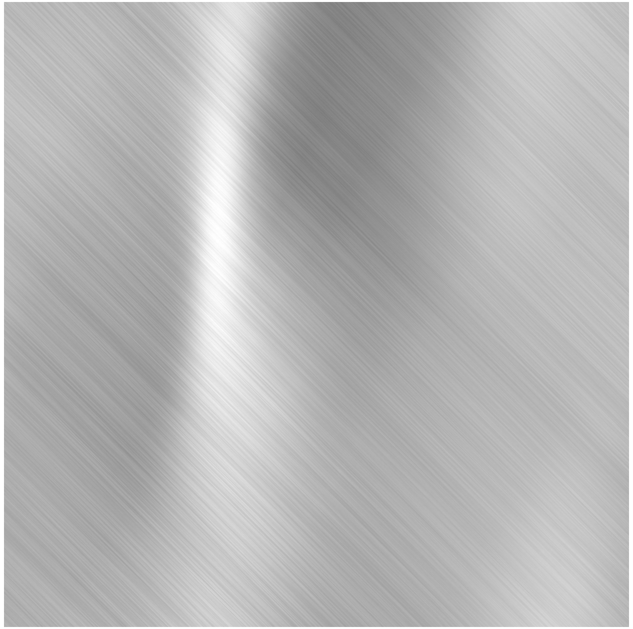
Anisotropic Materials

- Do not have the same strength when loaded in different directions
- Wood
  - Composed of many grains, **strongest when grains are in tension/compression**
- Carbon Fiber
  - Also composed of fibers glued together with epoxy, **fibers are strongest in tension only** (like fabric)
- 3D - Printed Material
  - Composed of **stacked layers of plastic**
  - Each individual layer is reasonably strong, but they **tend to be easily pulled apart/separated**



Material Properties: Steel

- Steel is an **alloy of iron** that is part **carbon** to improve the **strength** and **fracture resistance**
- Steel is **highly recyclable**, with steel that is made in the US being up to 98% recyclable, more than other construction products
- The Bessemer process allowed for the cheap mass production of steel, enabling large scale projects using steel.

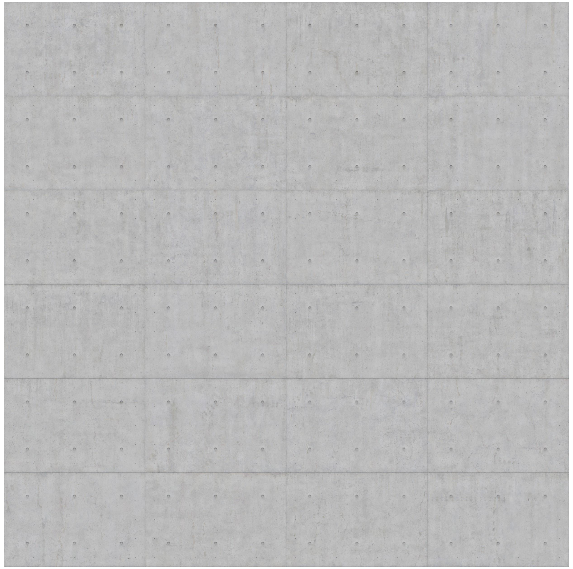


Steel Annealing

- **Annealing** steel changes the **physical properties** of steel by heat treating it. Listed below are a few types:
- **Stress Relief**: Helps reduce stress on the steel caused by processes such as forming, straightening, or rolling.
- **Spheroidize**: Only works on steel that have more than 0.8% carbon. The process improves the ductility and toughness of the steel but reduces hardness and strength. Generally used on steel that has already hardened to allow it to be workable again.
- **Normalize**: Only used on ferrous alloys and helps achieve an uniform grain in the alloy
- **Process Anneal:** Softens steel by slowing heating and slowly cooling it.
- **Full Anneal:** Heats up steel to beyond its upper critical temperature before being cooled down.

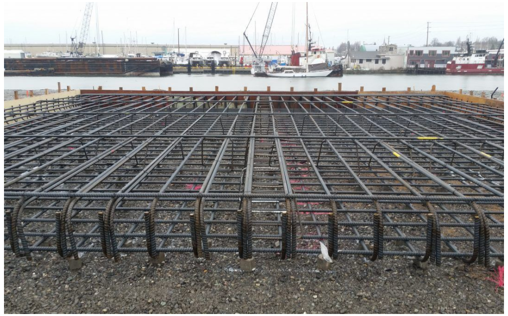
Material Properties: Concrete

- **Concrete** is generally made up of a mix of **cement**, **water**, and either **stone, gravel, or sand**. There is also a **binder** that is mixed in.
- **Water** is required to increase the **workability** of concrete, although the exact ratio can vary depending on the compressive strength needed from the concrete
- The **water to cement ratio** generally falls between **0.4 to 0.7**
- Too much water in concrete can lead to the liquid evaporating after the concrete has already set, forming gaps in the concrete which compromises strength



Material Properties: Rebar

- **Reinforcement bar,** also known as **rebar,** is a **steel bar or wire** that runs through the concrete and is used to **increase the tensile strength** of concrete
- Rebar is generally made with an **uneven surface** to better bond with the concrete



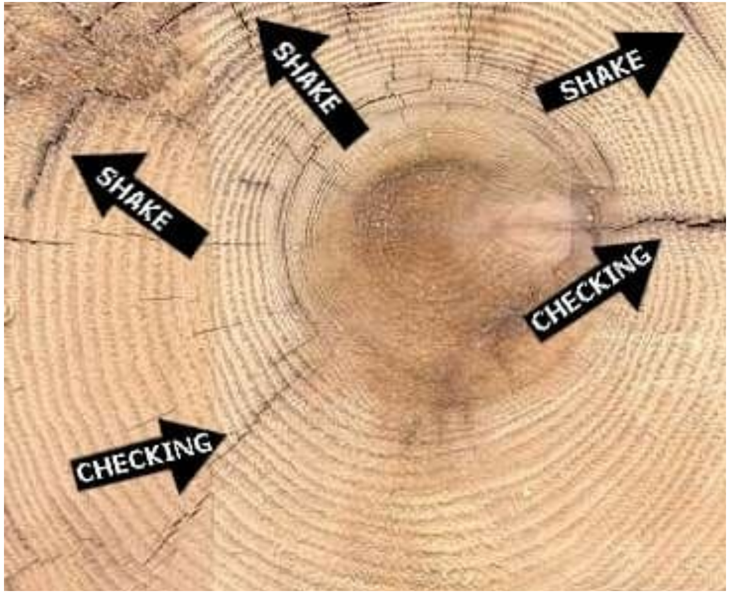
- Steel has a **thermal expansion coefficient** similar to that of concrete, thus lowering the possibility of additional stresses on the concrete
- Poorly designed rebars and improper placement can become displaced and lead to **structural failure** such as in the collapse of the **Cypress Street Viaduct** located Oakland, California
- Depending on the **location** of the cement, different types of rebars can be used such as sheet metal, welded wire fabric, stainless steel, and epoxy-coated rebars

Material Properties: Wood

- **Wood** is classified into **hardwood** and **softwood**
  - Hardwoods generally have **broad leaves**
  - Softwoods have **needle-like leaves**
- Wood is **hygroscopic**, meaning that the **moisture level of wood** depends on the **humidity** of the surrounding air
  - The fiber saturation point refers to the point in which a piece of wood has no free or excess water.
  - Below the **fiber saturation point**, wood shrinks as it loses water and swells as it gains water

Wood Warping

- The uneven drying of wood can cause **warps and distortions** in the wood
- If this uneven drying happens frequently, it can create separations in the wood called **checks**
- Checks are **perpendicular** to the **growth rings** of the wood



Source: Vermont Timber Works

Thermal Expansion

- Materials **expand and contract** depending on the **temperature** of their surroundings
- The **thermal expansion coefficient** α_L describes a ratio change in length per unit temperature change
  - The units are 1/°F or °F^{-1} (1/other units of temperature like C or K)
- If a material had an α_L = 0.01 °F^{-1}, it would grow by 1% in length for every degree increase in temperature Fahrenheit if heated uniformly

$$\alpha_L = \frac{1}{L}\frac{dL}{dT}$$

α_L = thermal expansion

L = particular length measurement

dL = change in length

dT = change in temperature

Thermal Expansion Continued

- Assuming the material has a positive α_L, a material is also going to **shrink** by the same percentage for a corresponding temperature drop
- If a material is **not uniformly heated**, different parts of the material will **expand differently** and **cause stresses** within the material as a result
- If a material is **uniformly heated** (meaning all parts change by the same temperature at the same rate), it undergoes **no stresses** at all
- Materials can still cause stresses from uniform heating if they expand against something, for example against something else that doesn't want to move

Loading Scenarios

- Compression
- Tension
- Shear
- Bending
- Torsion

Compression

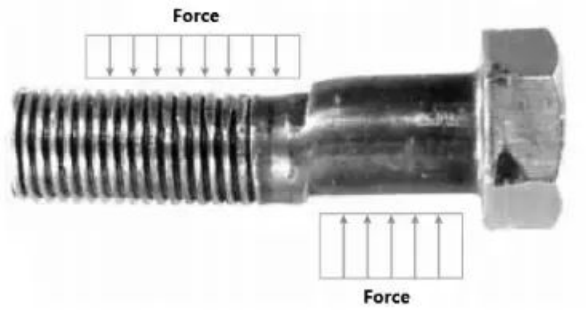
- Pushed together
- **Arches** and **columns** are under compression
- In some scenarios, if a certain beam or column is sufficiently long compared to its cross sectional area/width, it may **buckle** before it actually fails in compression
  - Pasta will buckle, and then bend until it fractures. As soon as buckling occurs, the structure has failed
  - Cardboard often buckles when you try to crush it from the ends

Tension

- Pulling apart
- **Cables** and **ropes** are under tension
- The chain supporting a chandelier is under tension
- All the cables in the bridge below are loaded in tension

Shear

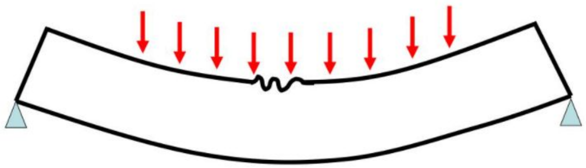
- Shear is a loading scenario where part of a material is being **forced one way**, but another part of it is being **forced another way**
- This can cause a material to **break apart along a plane** prematurely
- Some materials are **not as strong in certain directions**
  - For example, wood is resistant to shear loads that avoid the grain plane, but not loads that are parallel to the grain

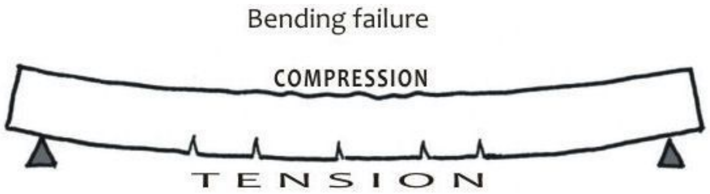


This bolt was holding two plates of materials together, and deformed under a shear loading

Bending

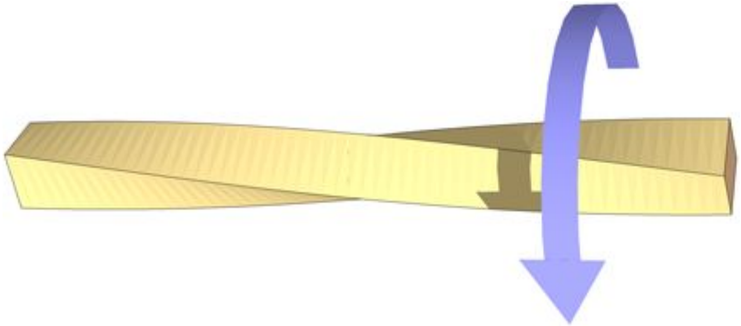
- A given beam under bending typically is actually partly loaded in compression and partly loaded under tension
- A beam typically fails under a bending load because it exceeds the **maximal tensile load** or exceeds the **maximal compressive load** in a given part of the beam
- Certain bending scenarios like **four-point-bending** can lead to the beam being loaded in pure internal shear





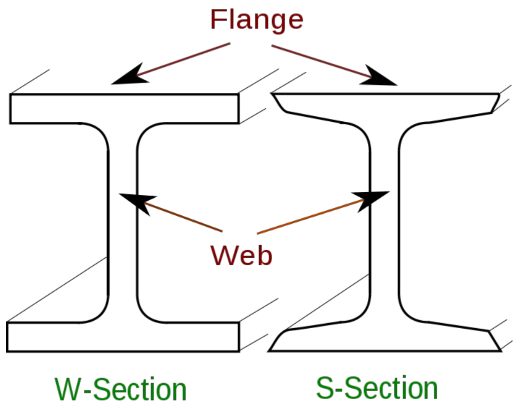
Torsion

- Torsion is type of loading that tends to cause the material to **twist**
- The **highest stress region** of a cylinder or beam is the region on the **outside**, furthest from the rotation axis
- Shafts that spin like a **drive shaft** or an **axle** are typically loaded under torsion
- Torsion from an applied torque causes **shear stress** on the material



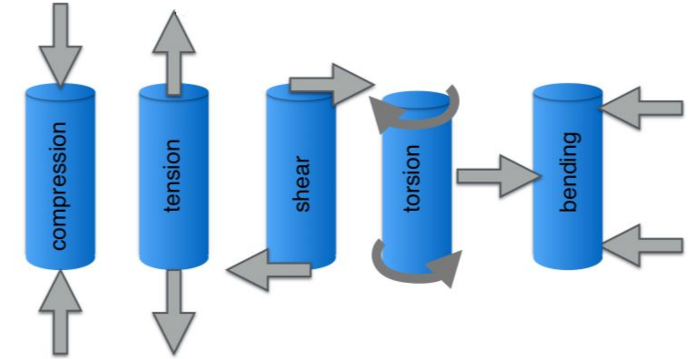
Cross Sections

- A **cross section** is like a **sliced view** of an object
    - For example, the included image is an image of two cross sections of two steel **I-beams**
    - The area contained inside a cross section is called the **cross-sectional area**
- The strength of a given structure or beam is often dependent on its cross section

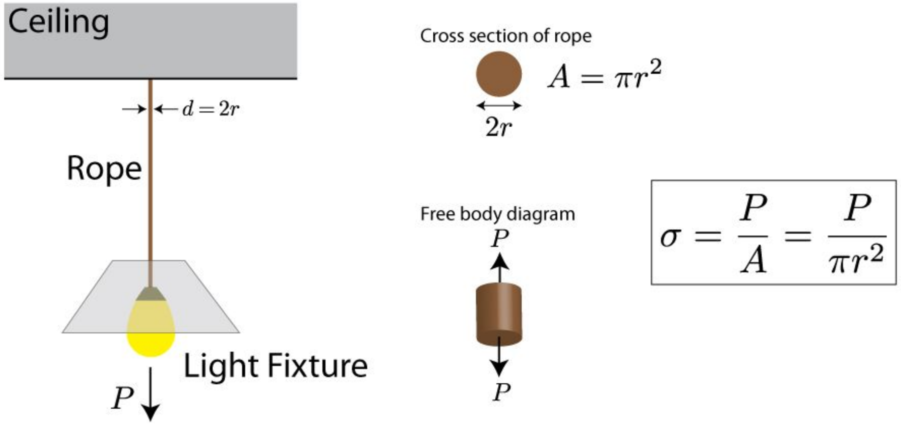


Stress

- Stress = force acting on the cross section / cross sectional area
- Examples of Stress:
  - **Tensional Stress** (Force Tension / Cross Sectional Area)
  - **Shear Stress** (Shear Force / Cross Sectional Area)



Source: https://www.linearmotiontips.com/mechanical-properties-of-materials-stress-and-strain/



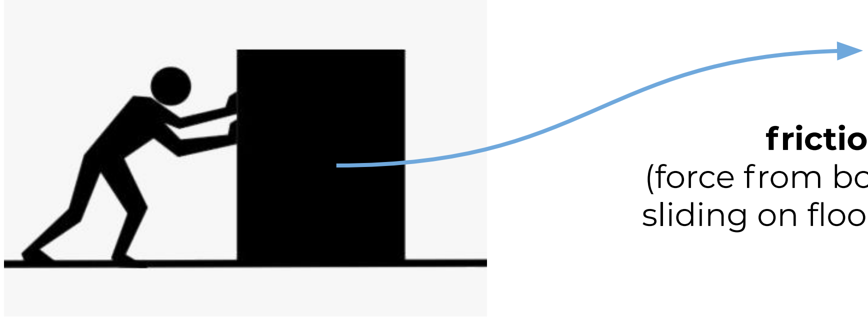
Source: https://www.bu.edu/moss/mechanics-of-materials-stress/

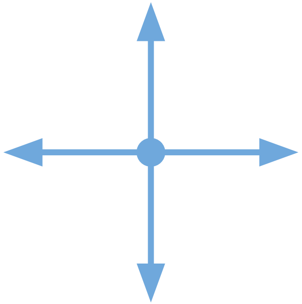
Units

- A unit of area has dimensions of **length squared**
  - 1 square meter or 1 m^2 is an example of a unit of area
- **Newtons** are a unit of force
  - 1 Newton is 1 kg * m/s^2
- **Pascals** are a unit of stress or pressure, it is a force per unit area
  - 1 Pascal is 1 Newton per square meter
  - 1 psi is 1 pound per square inch
- **Kilograms** are a unit of **mass**, not of weight
  - On earth, one kilogram does **not** exert one Newton of force
  - On earth, one kilogram of mass exerts a weight of 9.81 Newtons since g = 9.81m/s^2

Forces + Free Body Diagrams

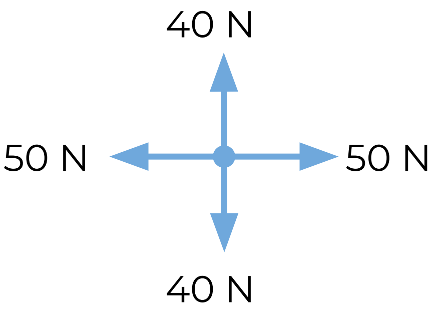
- A **free body diagram** shows the forces (pictured as arrows) acting on an object (pictured as a dot)



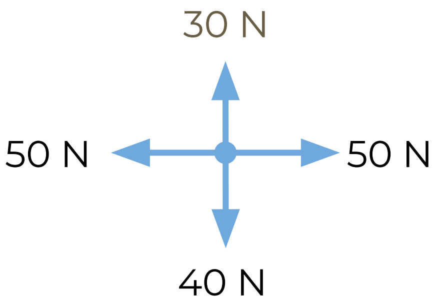


Equilibrium

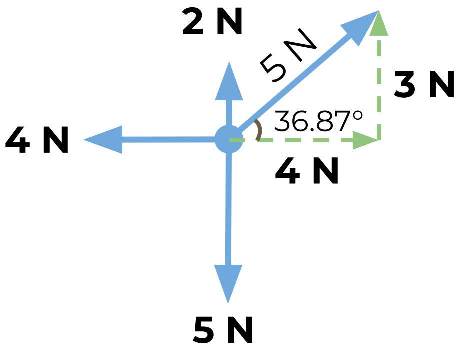
- An object is in **equilibrium** if there the forces are **balanced** so that there is **no net force**
  - This means its horizontal forces balance out and its vertical forces balance out (sum of forces to the left = sum of forces to the right, similar for up and down)
  - Diagonal forces can be split into their components (methods on next slide)



✓ In equilibrium:
40=40 (vertical),
50=50 (horizontal)



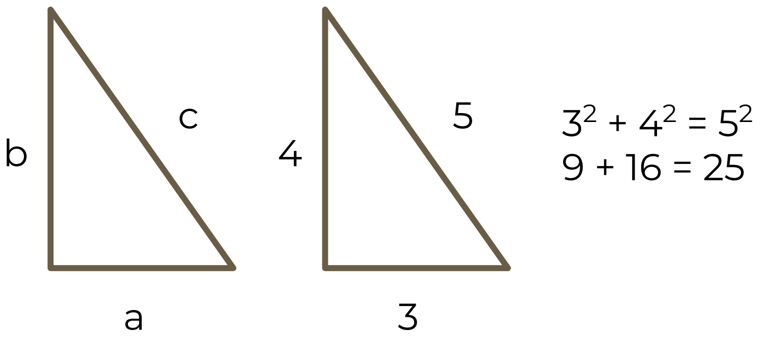
❌ Not in equilibrium:
40≠30, object would be moving downwards



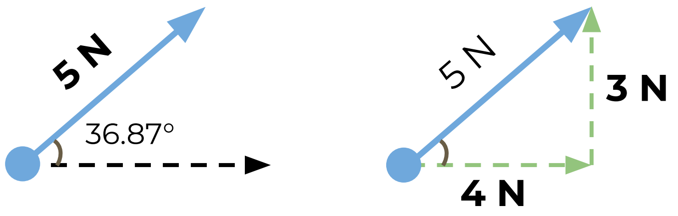
✓ In equilibrium:
2+3 = 5, (vertical),
4=4 (horizontal)

Triangles

- Pythagorean Theorem
  - Applies for **right triangles**
  - **$a^2 + b^2 = c^2$**
  - a = length of one leg
  - b = length of other leg
  - c = length of hypotenuse



- Trigonometry
  - 5 is the **magnitude** of the diagonal force
  - 36.87° is the **angle**
  - The horizontal component has a magnitude of 5 * cos(36.87°) = 4
  - The vertical component has a magnitude of 5 * sin(36.87°) = 3



Trusses

- Trusses are assemblies of beams connected at **joints** to form a rigid structure
- The earliest known truss dates back to early lake dwellings from the early **Bronze Age**
- For truss problems, make the following assumptions
  - Pin joints at the ends of each member (or “link”)
  - Each member can only experience tension/compression
- Solve using method of joints
  - Each joint must be in equilibrium (forces sum to zero), pick a joint and solve for unknown forces

Dynamic Loads

- Not all structures are static
- Some structures are meant to move, like a wind turbine or a drawbridge
- Even structures that are traditionally static have to undergo **dynamic loads** such as wind

Safety Factor

- If a certain part of a structure would only say see loads between 600 pounds and 800 pounds, you might not want to design the part to fail at exactly 800 pounds as it would be very likely to fail in real life
- Instead, engineers design parts with a **safety factor**, so that they can withstand the maximal value of the real world load, plus some more **margin**
- For example, in the above case, if the part was designed to fail at 1000 lbs, it would be said to have a safety factor of 1.25 since 1000/800 = 1.25
- The formula for the safety factor is: maximum load / current load

Pressure Vessels

- Containers that hold in pressure, known as pressure vessels, generally have their walls loaded in tension. The gas or liquid inside is high pressure and wants to expand outwards. This pulls the walls apart, loading them in tension.
- Balloons, and shaken soda bottles are examples of pressure vessels.
- A pressurized piston is also an example of a pressure vessel

Div C Only Slides

Zero Force Members

- Zero force members can usually be identified when there is a joint with **no external load/support** AND...
  - Only two non-collinear members and no external load or support (Type 1)
  - OR 2 collinear members and 1 non collinear member (Type 2)
- Carry no load assuming truss members are 100% rigid
- Can reduce buckling in other members in a real scenario

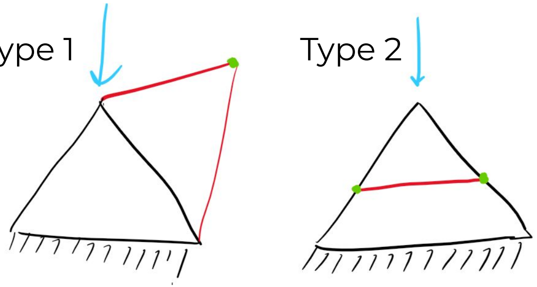
Type 2 Type 1

ZFM Free Body

No equilibrium possible if red forces are non zero

Examples in structures

Type 1 Type 2

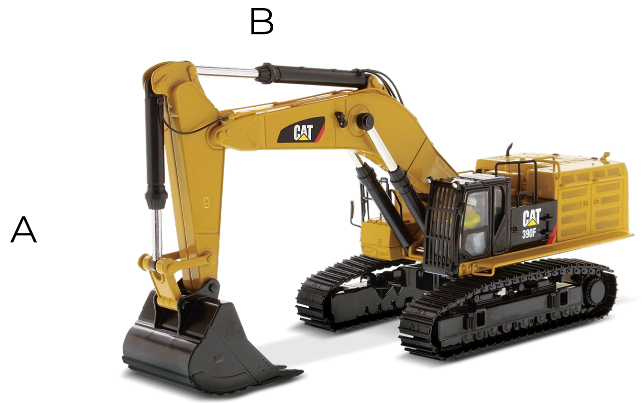


ZFM Indicated in Red

Two Force Members

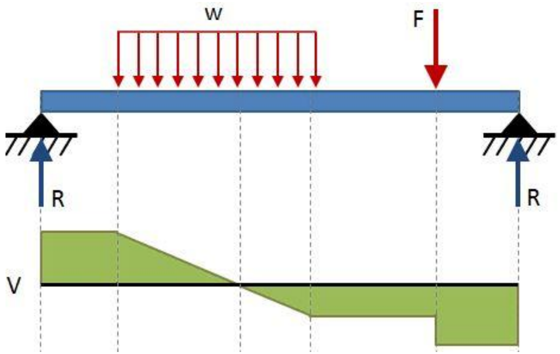
- Two force members only carry **tension** and **compression**
- A member is a two force member if
  - It only has 2 joints
  - It has only 2 forces acting on those two joints
- Can simplify statics problems

The hydraulic pistons (A and B) are 2 force members



Shear Stress Diagrams

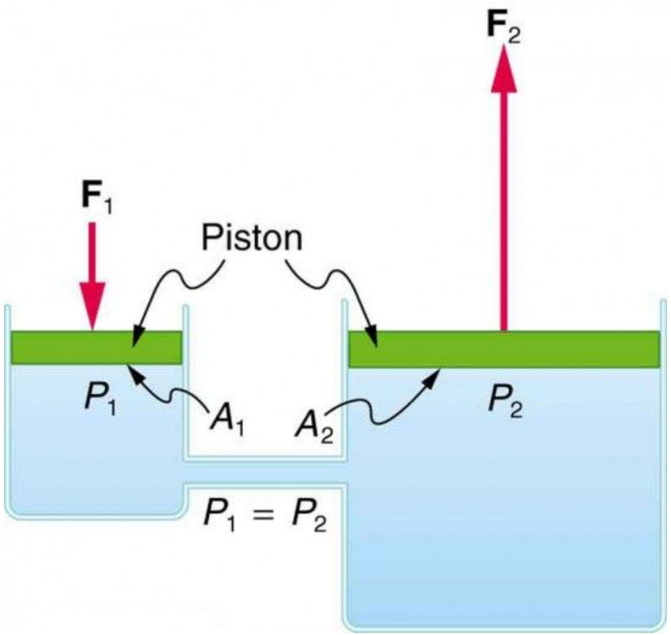
- A shear diagram shows the shear along a beam
- Common forces shown on a shear diagram:
  - **Point loads** = vertical jump in diagram, direction same as sign of point load
  - **Uniform distributed loads** = straight sloped line, slope is equal to value of load
  - **No Load** = horizontal line on diagram



Source:
https://mechanicalc.com/reference/beam-analysis

Pistons

- Pistons deliver force by **pressurizing an internal cavity** with a fluid or a gas
- If the internal pressure of a cylinder has some pressure *P*, and an cylinder cross-sectional area of *A*, then it delivers a force **F = P*A**
- Liquid pressure on both sides is the same
    - Therefore, **F1/F2=A1/A2**



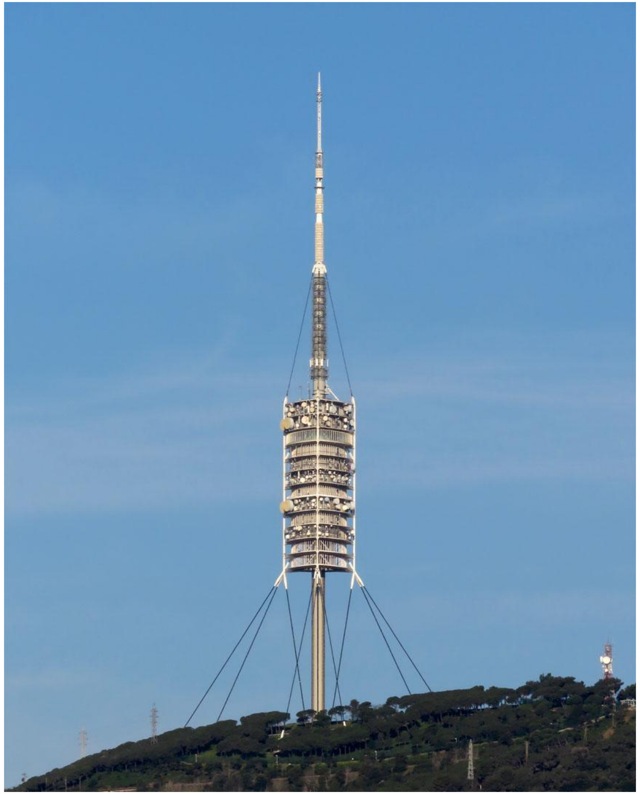
Source: Lumen Learning - Pascal's Principle

Cascading Failures

- The failure of a given component in a structure often causes loads to be **redistributed** among the remaining members
- The redistributed stress is often **higher** for remaining members, pushing them closer to failure as well
- Eventually this causes more failures to occur, causing a **chain reaction** that speeds up over time, and can quickly lead to the failure of the structure as a whole

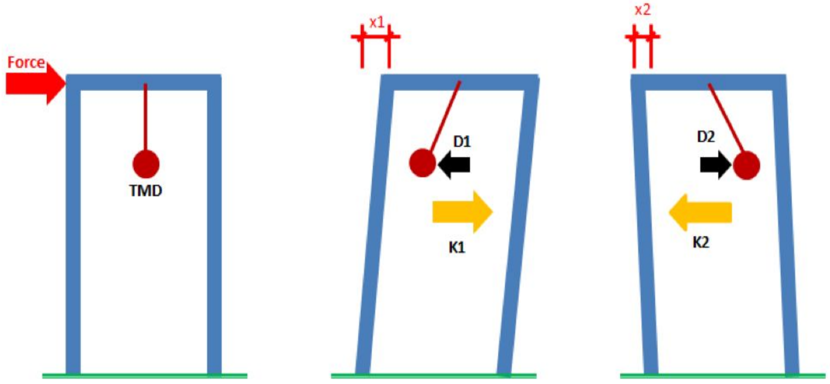
Guy Wires

- Guy wires are cables loaded in **tension** to prevent tall towers from toppling, leaning, or buckling
- Cables in tension apply load to the tower **parallel** to the cable



Tuned Mass Damper

- Used to reduce the amplitude of mechanical vibrations affecting a structure
    - For example, absorbs seismic waves from an earthquake
    - It is specifically tuned such that it has a similar resonance frequency as the structure so as to absorb the energy of unwanted vibrations.
- Consists of a mass mounted on one or more damped springs



Source: Physics Stack Exchange

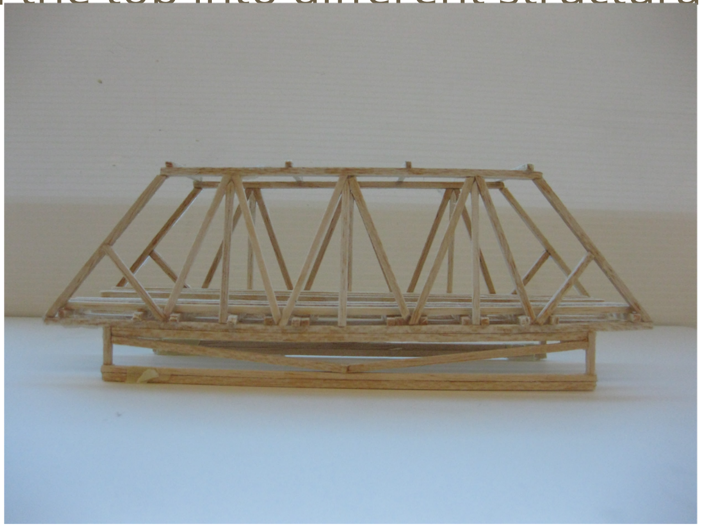
SCIENCE
OLYMPIAD
at
CORNELL

Special thanks to Science Olympiad at Cornell for the development of this resource.

Joints

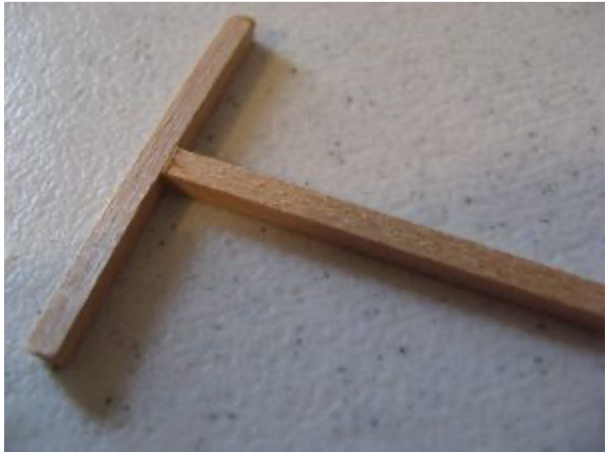
Joints

- Connects two pieces of wood together in a structure
  - More than one joint can be at a single location
- Adds additional structural integrity
- Allows one to disperse the forces from the top into different structural beams in the structure
- Main three joints:
  - End Joint
  - Lap Joint
  - Gusset Joint



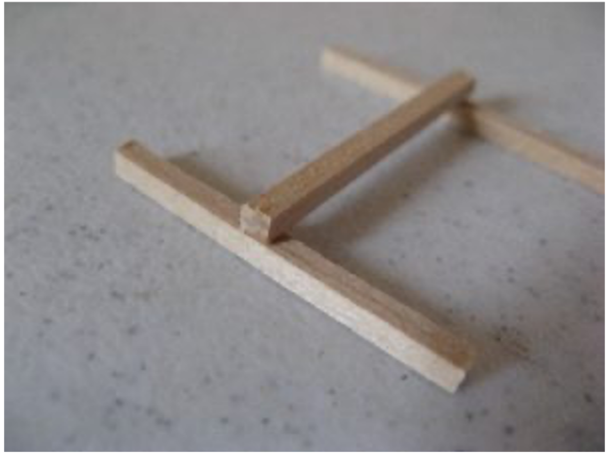
End Joint

- Weakest joint
  - Small surface area
  - Grain structure of tip is non ideal for structures
- Connecting end of wood piece to the side of a wood piece to create a flat T shape
- Requires sanding to create flush contact
- Best used under compression
  - Easy to pull off
    - Contact can be weak/not flush
    - Grain does create optimum contact
  - Compression increase forces
    - Increase friction between wood parts
  - Pushes opposite members away from each other



Lap Joint

- Stronger Joint
  - Better grain structure with grains running perpendicular to one another
  - Larger contact area when using side of wood piece.
- Connects side of an end piece of wood to attach to the side of a piece of wood creating a elevated piece
- Great for pieces under tension
  - Perpendicular grains allow for better contacts
  - Prevents members on side from stretching outwards
    - Pulls members towards each other

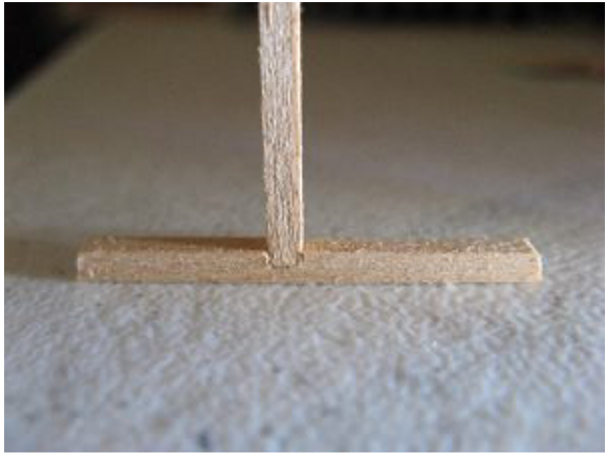


Gusset Joint

- Improvements upon end joints and lap joints
- Adds additional support with lap joints on side of end joint
- Increases the contact area greatly
  - Allows for tension and compression
    - lap joints increases ability to handle tension
    - End joint allows for ability to be compressed.
- Extra wood increase the material and weight
  - Lap joint section is used to secure the connection of end joint
  - Covers the gap of end joint so it can be under tension

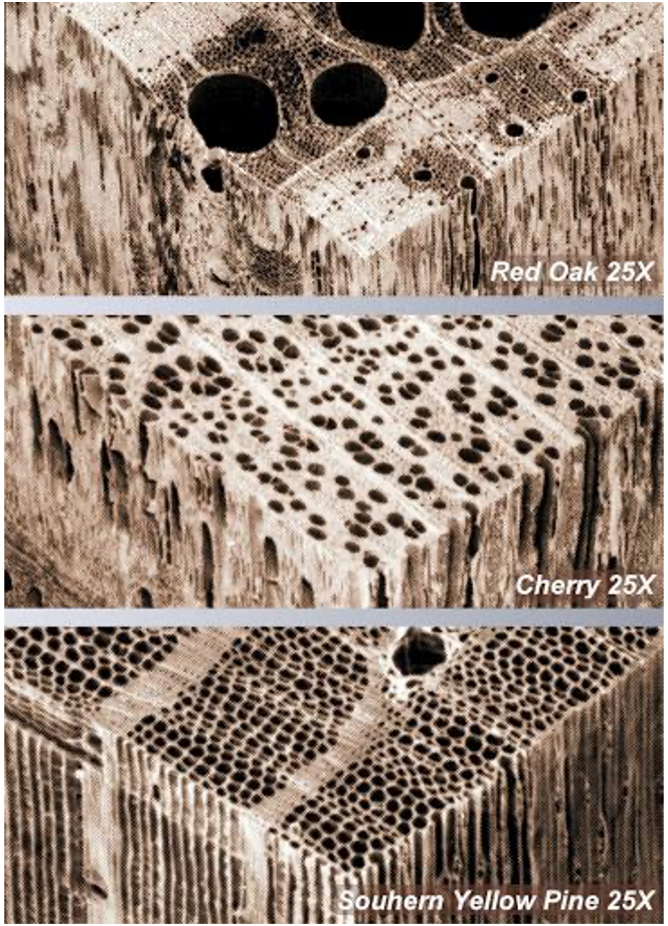
Notching

- Notching is the cutting of wood to increase the contact area
  - Reduces the weight of overall piece
  - Increases friction to allow stronger tension and compression members
- Hypothetically this is best case scenario
  - Structure building is at small scale so these adjustments drastically affect stability and strength
  - Cutting wood Modifies the grains and thus strength
- More appropriate for larger scale projects
  - Grain direction of wood and structure is not as impact at larger scales



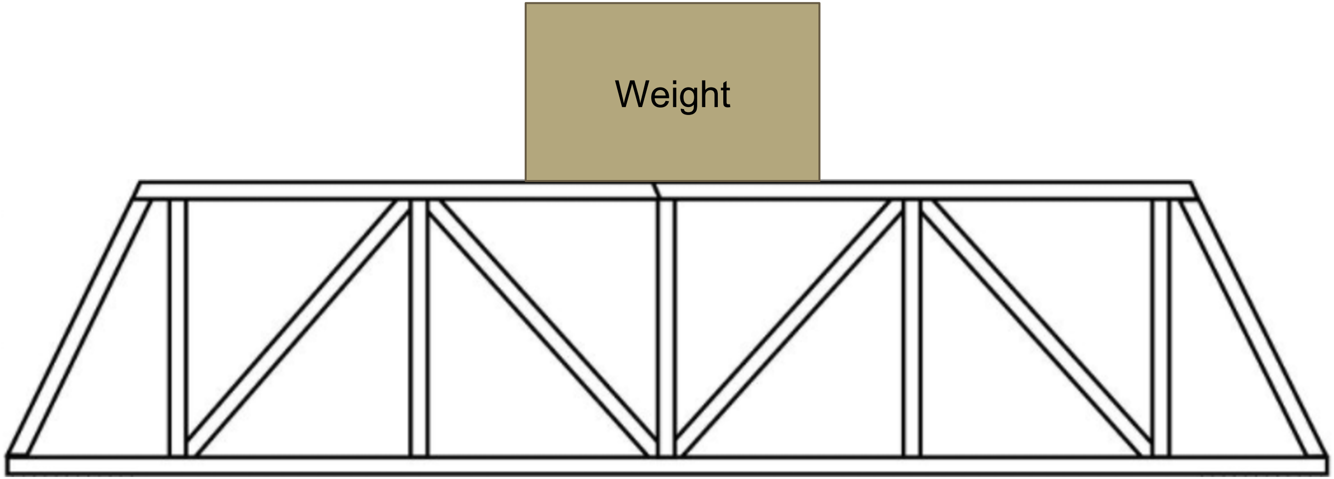
Joint Creation/Lamination

- Joints are usually attached with glue
  - Glue is a hardening agent that laminates the joints
- Glue fills the pores in the wood
  - The glue hardens in the pores to increase density
  - Hardened wood also increases strength and density
- Glue fills gap between two pieces of wood
  - Connects the two pieces
  - Fills all holes to increase structural integrity
- Lamination using glue creates a composite
  - Layers of materials increases strength and durability



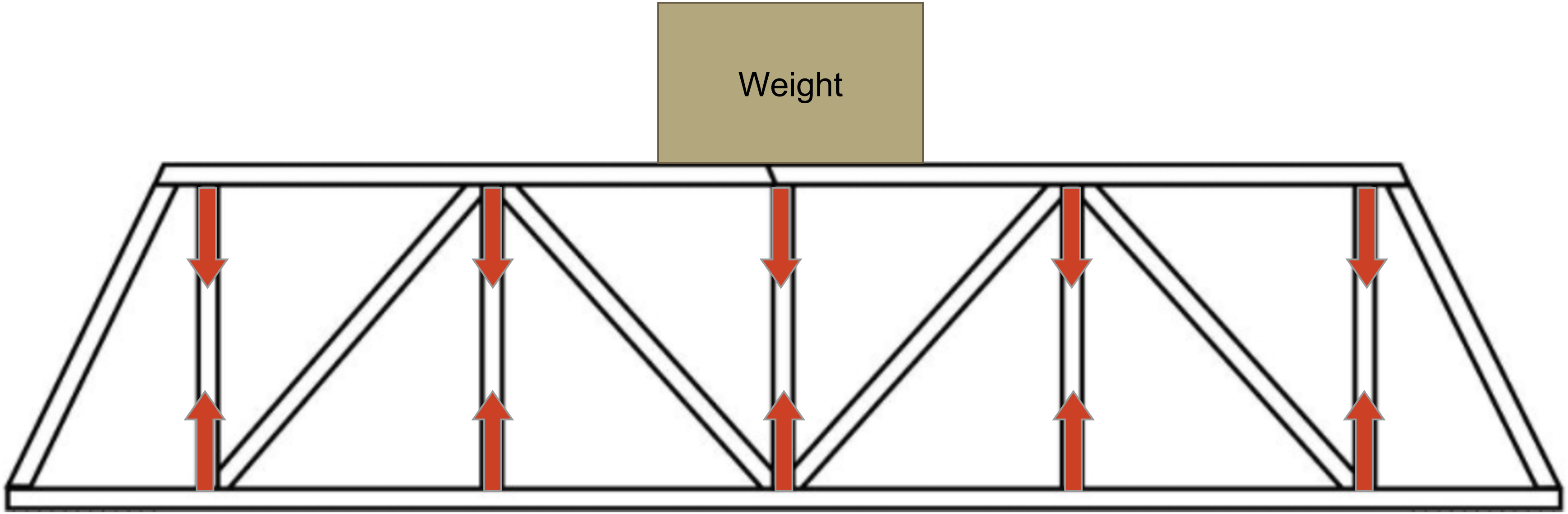
Joint Force Distribution (1)

- Joints not only support but distribute forces from different parts of the structure
- We will use the following joint as an example and analyze the forces of some parts of the joints



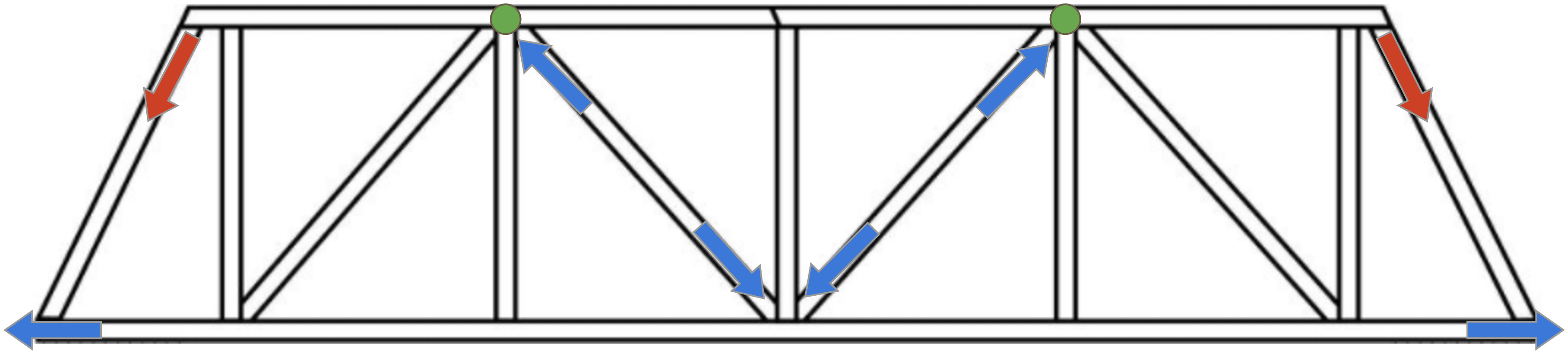
Joint Force Distribution (2)

- Arrows shows direction of how wood is compressed or stretched
- Weight applies a downward force on all horizontal members
- Bottom membrane pushes back on compression force of weight



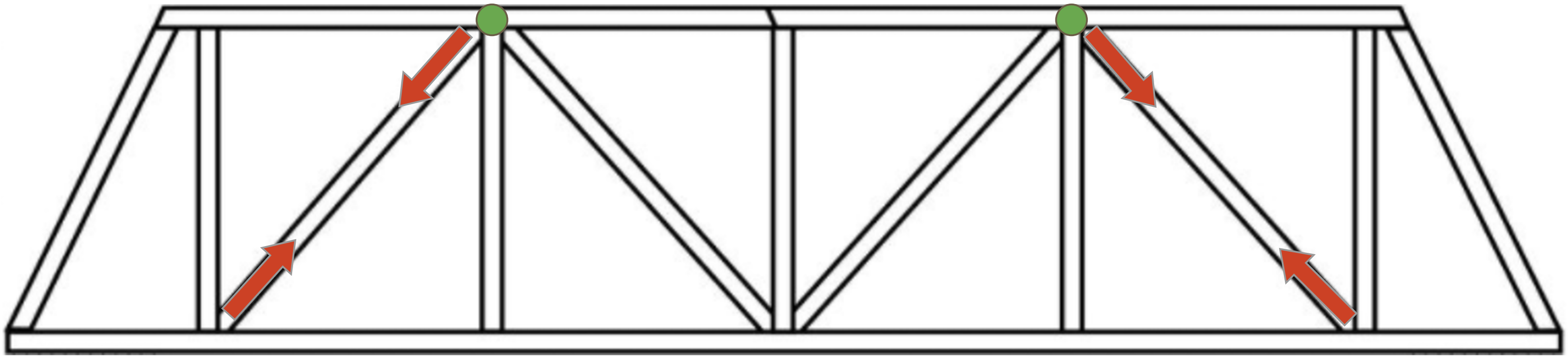
Joint Force Distribution (3)

- Outer members converts weight into a more diagonalized force (red)
- This force causes the bottom membrane to be stretched (blue)
- Middle joints (green) bend downwards causing the middle to compress and thus these members pushes back
- Middle joints also stretch the outer middle members



Joint Force Distribution (4)

- Top member bends downwards causing out members at the joints (green) to be stretched inwards on the top and outwards on the bottom
- This is the tension member that holds the two pieces together



Special thanks to Science Olympiad at Caltech & Southern California Science Olympiad for the development of this resource.

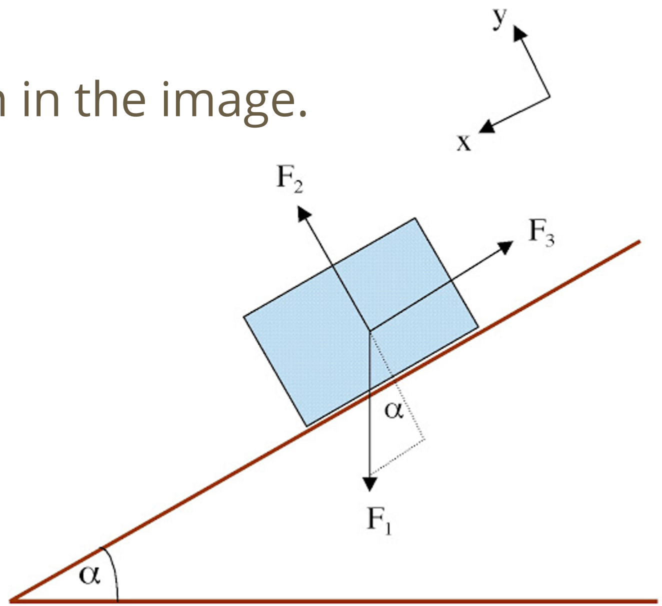
Free Body Diagrams

Guiding Standards

- HS-PS 2-1. – Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
- HS-PS 2-2. – Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.

Basics

- Free body diagrams represent the forces acting on an object.
- Forces can be represented as vectors, which have both magnitude (length) and direction.
- Always set up a coordinate axes first, as shown in the image.



http://ffden-2.phys.uaf.edu/211_fall2004.web.dir/Jeff_Levison/Freebody%20diagram.htm

Newton’s Second Law

- Free body diagrams tell us how to sum up forces.
- The sum of forces, through Newton’s Second Law, can tell us about the acceleration of our object.
  - This assumes that we know the mass of our object.
  - This can only be applied in a particular direction, which will also be the acceleration’s direction.

For a particular direction:

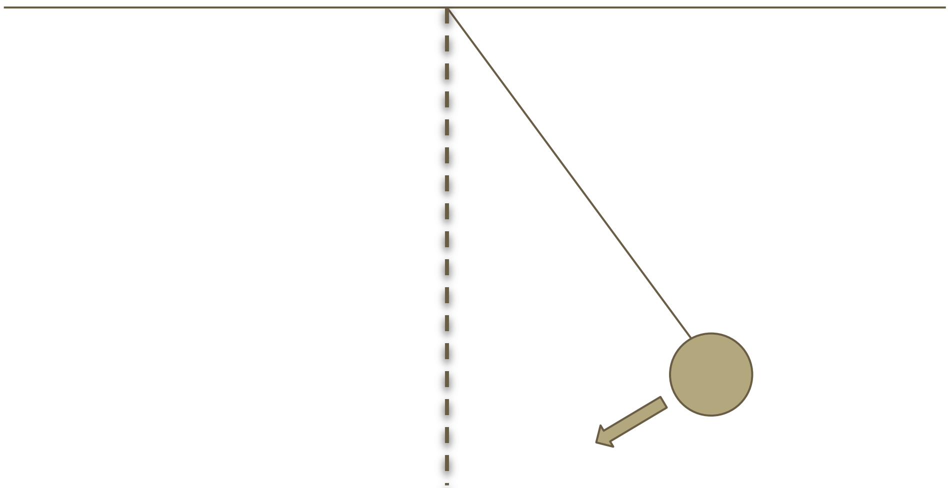
$\sum F$ = sum of forces = (object mass)*(object acceleration)

Khan Academy Resource

- If this is your first time learning about free body diagrams, complete the Khan Academy activity below first:
    - https://www.khanacademy.org/science/high-school-physics/forces-and-newtons-laws-of-motion/introduction-to-forces-and-free-body-diagrams/v/types-of-forces-and-free-body-diagrams

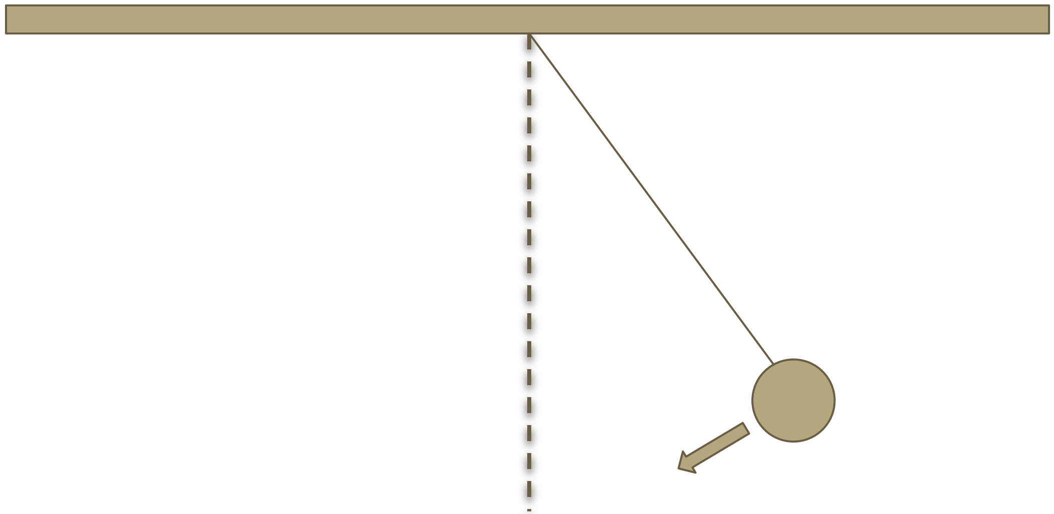
Analysis of Forces on a Pendulum (1)

- A pendulum is a ball on a string that swings back and forth.
- Consider this pendulum at a moment where the ball is displaced a certain amount from the resting position and is swinging back to the centerline.
- We wish to find the acceleration of the object along its axis of motion.



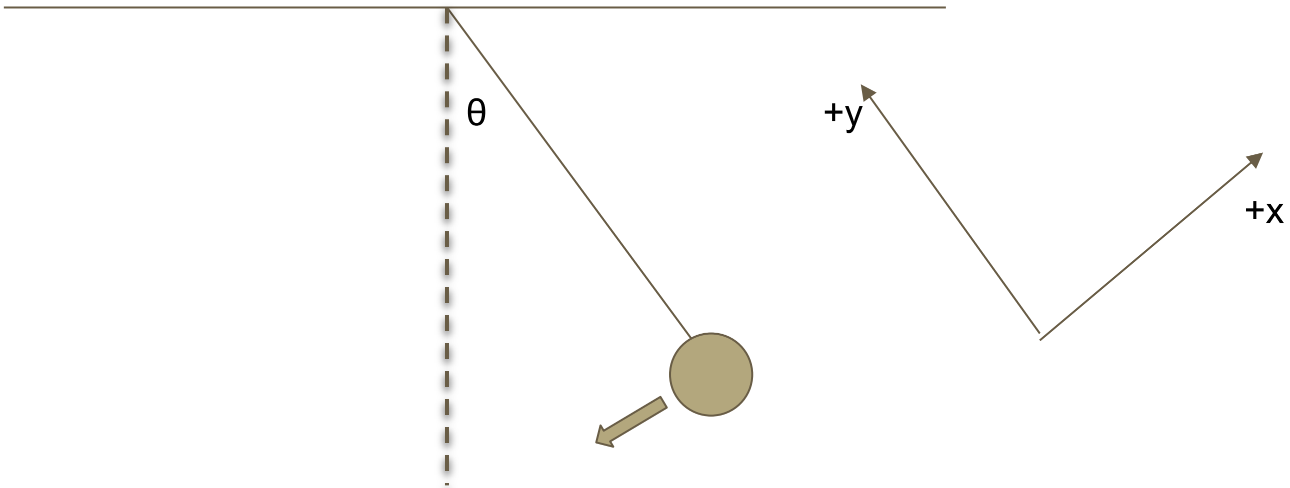
Analysis of Forces on a Pendulum (2)

- We wish to analyze this system with (x, y) Cartesian axes. How should our axes be oriented and where should the origin be?
- What forces are acting on our ball?



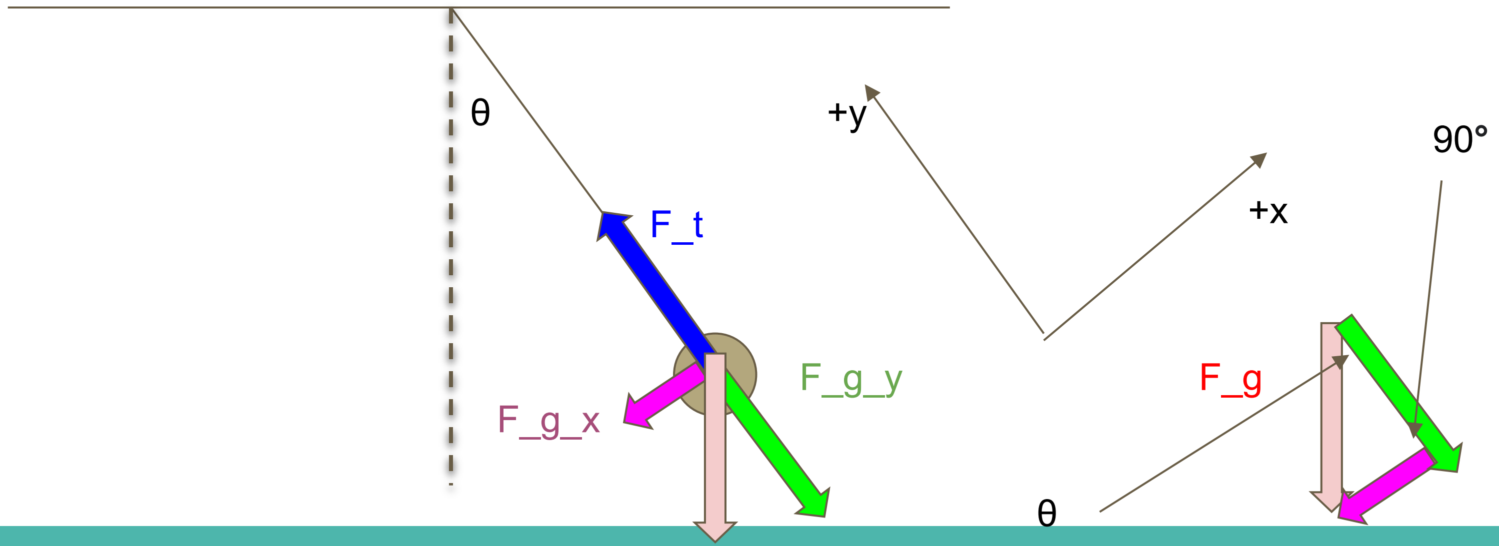
Analysis of Forces on a Pendulum (3)

- Origin: ball. Our y-axis should point along the string. The x-axis must be perpendicular to our y-axis and points along the direction of motion.
- Gravity and tension must be acting on our object.
- On paper, draw out the components of the tension and gravity force.



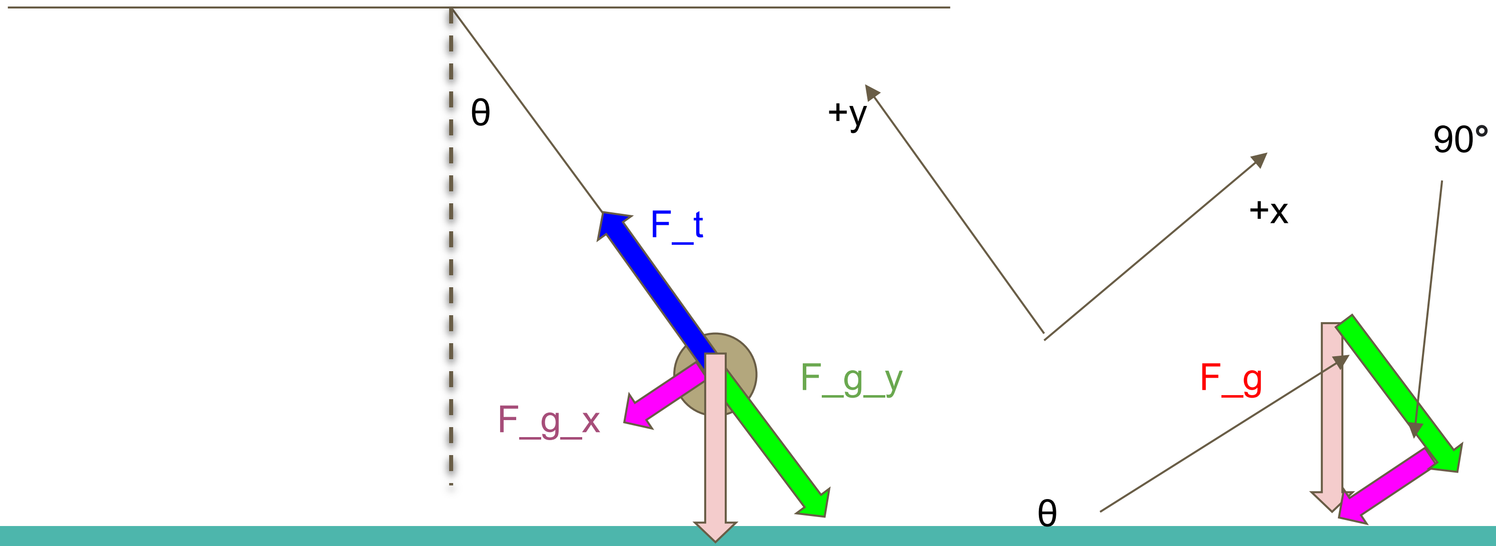
Analysis of Forces on a Pendulum (4)

- Tension force (F_t) and the y-component of gravity act along the y-axis.
- Only the x-component of gravity acts along the x-axis.
- What must F_g_y and F_g_x be, in terms of F_g and θ? Use the right triangle and trigonometry.



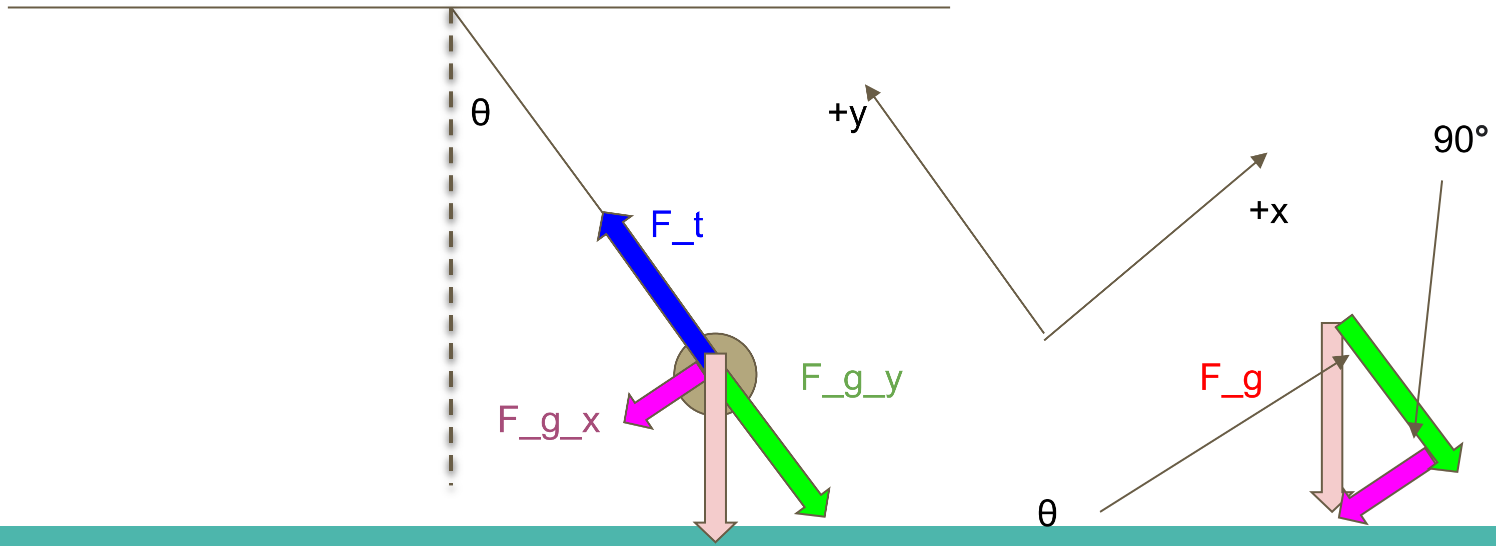
Analysis of Forces on a Pendulum (5)

- cos(θ) = adjacent/hypotenuse = F_g_y/F_g
- Thus, F_g_y = F_g*cos(θ).
- Similarly, using the sine function, we get: F_g_x = F_g*sin(θ).



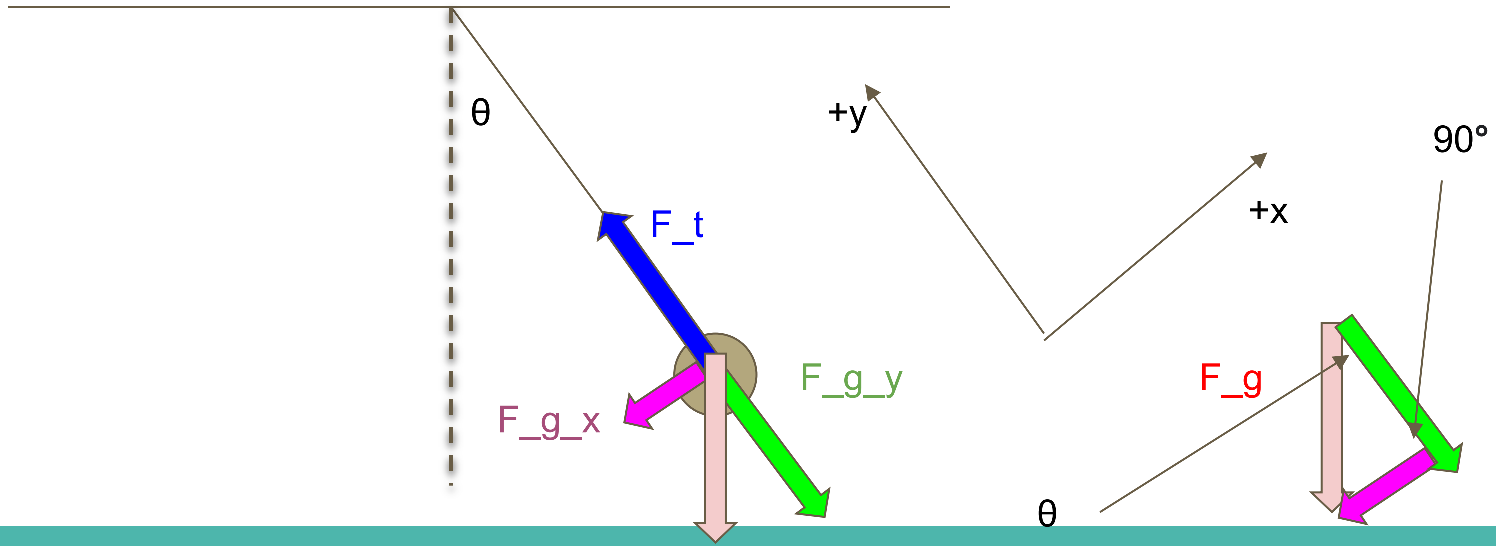
Analysis of Forces on a Pendulum (6)

- Now it's time to apply Newton's Second Law in the x- and y-direction.
- Is there any acceleration in the y-direction?
- What about in the x-direction? If so, what is the sign of the acceleration?



Analysis of Forces on a Pendulum (7)

- There is no acceleration in the y-direction.
- However, there **is** acceleration in the x-direction.
- Write out Newton's Second Law for both directions.



Sum of Forces in the y-direction

- $\sum F$ = sum of forces in the y-direction = (object mass)*(0)
- $F_t - F_{g\_y} = 0$
- $F_t = F_{g\_y}$
- **$F_t = F_g \cdot \cos(\theta)$ ... Equation 1**

Sum of Forces in the x-direction

- $\sum F$ = sum of forces in the x-direction = $(m)*(a_x)$
- m = object mass
- a_x = acceleration in the x-direction

- **$-F_{g\_x} = m*a_x$ ... Equation 2**

Calculation Exercise

Using Equations 1 and 2, calculate:

- F_t, the force of tension exerted on the ball
- a_x, the acceleration of the ball in the x-direction
- Keep in mind that F_g, force of gravity, is represented as:

$$F_g = m*g$$

Constants:

- g, the acceleration of gravity, is 9.8 m/s^2
- θ, the angle of displacement, is 45 degrees
- In the activity, you used five quarters as the pendulum weight. Approximate the ball mass as: 30 grams

All finished!

Thank you for completing this exercise and we hope you learned something valuable about using free body diagrams to analyze physical systems!

Special thanks to Science Olympiad at Caltech & Southern California Science Olympiad for the development of this resource.

Caltech

SOUTHERN CALIFORNIA SCIENCE OLYMPIAD

STEM SESSION TRANSCRIPT

FEBRUARY, STRUCTURES

CeAnn Chalker

Hello! I'm CeAnn Chalker, and I have worn many many hats over the years in Science Olympiad. I started out as a Science Olympiad parent back in 1990. That's when I became aware of Science Olympiad when our oldest son Alan Chalker was a freshmen in high school and joined the Science Olympiad team. All four of our children were involved in their school years, and continue to be involved in various ways to the present day in Science Olympiad. They all recognize what Science Olympiad did for them during their school years and continue to give back to the program so other students can benefit from their experiences. As a Science Olympiad coach then, I started the middle school team in 1996, when our third child, Matthew Chalker, entered middle school. Our coaches had two main goals: to provide the opportunity for students to expand their knowledge in various areas of science and to have students learn to work as a team. The model then, and that we still continue to use, is "We strive for excellence. Excellence is not judged by winning. Excellence is judged by trying and doing the best job possible as a team member."

I moved on to become part of the technology committee. I co-chaired the committee with Erv Zimmerman back in the early 2000s, and became the chair of the technology committee when Erv retired. As technology committee chair, I oversee seven tech events, as you may know, the build events. Structures, Vehicles, Aeronautical (the flight events) and Tech Design, which includes Mission, Robotics, Roller Coaster, Electronics, and Detector Building. On the committee there are over 20 experts in the events including engineers and alumni. From there, I became part of the Rules Committee, and my involvement at the National Science Olympiad level morphed into head of the Rules Committee as their Chair, as I helped proofread and edit the rules in their final draft before they went to print. Because I was so familiar with the rules, I became the point of contact for the FAQs and clarifications. I send all FAQs to committee chairs and national event supervisors for answers to questions that are not clear in the rules.

Then on to the National Tournament. In 2003, I helped co-chair The Ohio State University tournament that was sponsored then. In 2013, I chaired the Wright State University National Science Olympiad tournament, and then in 2017 I was the chair of that tournament at Wright State University. Because I was chair of the National Tournaments, I became a member of the National Advisory Committee, and have been a member of that committee for years. As far as Science Olympiad educational opportunities, I've sponsored many for teams and for coaches. Annually, I've sponsored Invitational Tournaments since 1998. I've sponsored the Midwest Coaching Academy, to train over 300 coaches annually since 2004 in Centerville Ohio. I've also taught coaches from across the US at the Science Olympiad Summer Institute annually since 2002.

My actual education background is in accounting. I have a full time job at a large brokerage firm. Many people ask me why do I spend so much time with Science Olympiad? Even my license plate has SO in it. I spend so much time on SO because I have seen the benefits for the students over the last 30 years - not only for our children, but for the thousands of children who have been involved in the program. I've seen students blossom into engineers and scientists because of their experience in participating on a Science Olympiad team. I've seen students realize that it's important to work with others, to share ideas, to research together and to work as a team. I've seen students find that there is always more to learn. I've seen students learn to not be afraid to try something new. And I've seen students find friendships that last a lifetime beyond their school years.

I'd like to introduce Sam Carigliano. He is the CEO of SkyCiv, a national corporate partner. He will be sharing how he has adapted his software especially for SO students and how it helps to prepare them for engineering careers in the digital age.

Sam Carigliano

Hi everyone, my name's Sam and I'm the CEO of SkyCiv Engineering. We're a proud sponsor of the Science Olympiad competition and have been for the last three years. SkyCiv is a structural engineering software program that allows you to model and design your structures like boomilevers and towers before you go out and construct them.

I started the company five years ago with a business partner of mine, and we're glad to be sponsors of the Science Olympiad competition. As part of our sponsorship this year, we took it a little bit further and built an app for students to use during the competition. So up until now, all students would normally use our software for was to design the structures before they went out and built them. But this year, given the current situation that we're all in, we took it a step further and built and app that would actually test the structure and give you a score rating based on perimeters such as the weight of the structure and how much the structure would hold. We're really excited to be a part of this because this is something that had never been done before as far as we had seen on such a scale as being able to roll this out to a national program to so many students in such a short period of time. So we're really excited to work with the organizers of Science Olympiad to develop this app and the feedback we've been getting from the students has been fantastic. They're engaged, they're enjoying learning the software, and for us it's such a thrill to see that side of the competition unfold.

So we actually started SkyCiv as students and we really wanted to learn software before we entered the workforce. We saw that the existing software was difficult and really hard to learn. We were actually students when we started the company, so we have this very deep root in education, and that's why partnering with the Science Olympiad program is so exciting for us because we believe in education and STEM courses so much, and we're really passionate about giving back to the student community. I personally wish we had a competition like this when I was growing up or in Australia at least because it's just such an engaging and inspiring competition. Students learn so much. They can learn software that really prepares them for the industry and I think that's something that Science Olympiad excels far ahead of its other competitions. So once again we're so glad to be part of the program and we hope you all get a lot out of the partnership.

CeAnn Chalker

Now I'd like to introduce Savvas Papadopoulos. Savvas is an SO alumni. He will share with you where his SO experience has led him in the workforce, and how he has continued to give back to the Science Olympiad community.

Savvas Papadopoulos

Hi everyone, my name is Savvas Papadopoulos. I'm a Senior Project Engineer at the Gilbane Building Company, and I'm here to tell you a little bit about how Science Olympiad has influenced my choice in major and my choice in career. I've been involved in Science Olympiad for about 13 years now, since middle school. I started out in middle school as a competitor, went on to high school as a competitor as well, and then moved on to helping run tournaments over the last few years. In middle school, I was just getting involved in Science Olympiad. I'd heard about it in 6th grade, and one of the 7th grade Science Olympiad students came into our class and spoke about doing this thing called Science Olympiad and it sounded interesting. I was interested in the sciences, not particularly one specific area of it, but I was excited.

So my friends and I signed up, and our middle school had a class. We got involved in the class, and the first few days were talking about which events we wanted to be involved in. As a kid, I had always enjoyed flying and flights and airplanes and that kind of thing. When Wright Stuff came up as an event, me and a friend jumped on the idea and said alright, let's do Wright Stuff, not realizing that would lead to a six or seven year obsession with the flying events and years of tireless work, but it was very enjoyable. So in middle school I was involved in Wright Stuff and Helicopters as they switched out over the years. I became interested in structures and the construction of things and how things get built and refined to work as well as possible.

Over the 6 or 7 years I was involved as a competitor, my team from Long Island went to the regional tournaments as well as the state tournament, and a few invitationals as well towards my senior year of high school, when invitational tournaments led by colleges were just becoming popular. That transitioned a lot into my interest in running tournaments. I got to see the last year or two of high school, these students from college start to run invitational tournaments, and in New York where I'm from, that became something of legend. It became the place to be, to go to these invitational tournaments. When I was starting to apply to schools, and ultimately chose to go to Cornell University, I said to my coach I wanted to be involved in starting a tournament there, and be able to give back and run tournaments that I would've wanted to compete in.

That became possible very quickly because the first year I came to Cornell, I was involved in the first year of the Cornell Invitational tournament. They were already starting up when I got there, and I jumped in and got involved. I was a member of Cornell's invitational board for the four years I was in college, starting off as Build Events Director for the first couple of years, which of course related a lot to my experience with build events before, and then served as President my junior year, and as Advisor my senior year. What I found is that managing an invitational is a lot like managing any project, similar to a construction project. You have a lot of moving parts, you're working with a lot of different people, and a lot of people who may not be involved in Science Olympiad, particularly from the university getting rooms reserved and other logistical aspects ready. I learned a lot about what it is to be able to manage a project, to be able to manage a team, and put together an event or project tangentially that is successful.

As I got on in my college years, I became incredibly interested in construction management as a speciality and ultimately joined Gilbane Building Company as a Project Engineer, and now Senior Project Engineer. What we do day-to-day at Gilbane is we're construction management. We work with architects and engineers and developers and clients to produce projects and see them to completion successfully. A lot of what I've used from my Science Olympiad career and from my major at Cornell is not only knowing what goes into a building so that I can review a drawing and make sure that it's correct, but the mindset of problem solving, the mindset of team building, working with others, communicating effectively to be able to see a project to completion. I'm specifically in the healthcare sector in our New York City office, so we focus on constructing hospital facilities and lab facilities, which I've done both of over the last three years. Even within construction, I get to see the more technical projects, so we have advanced heating and air conditioning facilities for hospitals to more effectively control climate, with lab facilities you see more technical aspects, and it's useful with a background in science and engineering to be able to see and understand what it is the drawings are calling for, what it will take to build whatever it is that we're building.

My advice to current and prospective Science Olympiad competitors is to really embrace not only the knowledge you learn preparing for your events but also the soft skills - the team building aspects, the communication aspects, working together leading a team. These are skills that are going to stay with you, no matter what your major ends up being. Science Olympiad can lead you down a wide variety of opportunities and a wide variety of career paths. What is common amongst all of them is communication, leadership, team building and being able to work with others. I really encourage you to focus on that in addition to everything it is that you do. It's incredible all the things that you all do in preparing for your events and compete in such a challenging environment. I wish you all the best of luck, remember that you are among the best that the world has to offer, the best students, the best scientists, the best engineers, so continue on what you're doing and best of luck.

CeAnn Chalker

Science Olympiad offers so much to everyone. I love when parents say they have never seen their students so interested in a subject. Whether it's studying birds, stars, ecology, electronics or building events, students seem to find their niche. Science Olympiad is not a short-term project in school, it's a long-term project that can cary through a student's lifetime.

MY SO STEM SHOWDOWN

CONTENT, RECOMMENDED MATERIALS & SCORING

STEM SHOWDOWN CONTENT

The STEM Showdown will consist of a series of online multiple-choice questions. Participants at both levels will be expected to demonstrate their understanding of the physics and principles of structural engineering. In particular, Showdown participants will need to demonstrate the ability to analyze a structure, and think about what forces/stresses members are withstanding. A Showdown participant will have 55-minutes to login and answer as many questions as possible.

The Structures content and skills covered by the Showdown this month are as follows:

1. Historic Structures:
    a. Understand and apply the design principles employed by the Ancient Greeks
    b. Understand and apply the design principles employed by the Ancient Romans
2. Material Properties:
    a. Understand the various mechanical properties of materials that are typically used in construction of buildings
        i. strength;
        ii. toughness;
        iii. hardness;
        iv. brittleness;
        v. malleability; and,
        vi. ductility
    b. Understand the various physical properties of materials that are typically used in construction of buildings
    c. Understand the various chemical properties of materials that are typically used in construction of buildings
    d. Recognize and apply the differences between Isotropic and Anisotropic material properties
    e. Typically used construction materials include:
        i. Steel
        ii. Concrete
        iii. Rebar
        iv. Wood
    f. Types of material deformities (i.e., warping, thermal expansion, spalling)
3. Load Scenarios:
    a. Understand the following loading scenarios and stresses as well as their impact on structures and their structural members
        i. Compression
        ii. Tension
        iii. Shear
        iv. Bending
        v. Torsion
    b. Types of loads (i.e., static, dynamic)
    c. Understand how load scenarios occur and explain the design and behavior of pressure vessels

4. Representations and Computations:
    a. Understand and use following representations of structures and structural members
        i. Compression
        ii. Tension
        iii. Shear
        iv. Bending
        v. Torsion
    b. Types of loads (i.e., static, dynamic)
    c. Understand and use the appropriate units in calculations and equations
    d. Understand and apply the appropriate forces and equilibrium in calculations and diagrams
5. Shapes and Members:
    a. Understand the mathematics and underlying principles behind the use of triangles in structures
    b. Understand the underlying principles behind trusses and how they are used in a variety of structures
    c. Understand and apply different types of joints to construction problems of structures
    d. Understand and apply the concept of safety factor to computations, calculations and given problems
6. Unique High School (Division C) Content:
    a. Understand the mathematics, underlying principles, and use of Zero Force Members
    b. Understand the mathematics, underlying principles, and use of Two Force Members
    c. Understand, interpret, and use Shear Stress Diagrams
    d. Understand the mathematics, underlying principles, and use of pistons
    e. Understand the mathematics, underlying principles, and occurrence of cascading failures
    f. Understand the mathematics, underlying principles, and use of guy wires
    g. Understand the mathematics, underlying principles, and use of tuned mass dampers

Recommended Materials

- Each Showdown participant will need a computer with internet access, scratch paper, something to write with, and a stand-alone calculator
- Showdown participants may use resources available to help them answer the questions asked during the Showdown. These resources could be a collection of notes on the topics listed below, copies of magazine or journal articles, a textbook, or any combination of these items.

Scoring

- High score wins.
- Ties will be broken using:
    a. The time it takes to complete the test; and
    b. The number of test questions attempted.

Additional Resources

- The Science Olympiad Store (store.soinc.org) carries the Problem Solving & Technology CD as well as various videos and resources
- Other resources can be found on the Boomilever Event Pages at http://soinc.org/.