

Engineering Renewable Energy 3D Print Lab Curriculum



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The Engineering Renewable Energy 3D Print Lab engages students in the engineering process as they develop CAD skills and become 3D printer machine operators while fabricating working wind turbines and solar energy arrays. Students learn, explore, and design solutions to engineering challenges, using their newly developed design skills to customize and improve electrical output.

Author



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Curriculum Structure

The *Engineering Renewable Energy 3D Print Lab Curriculum* is composed of the following lessons. Approximate lesson times are included.

Lesson	Title	Approximate Time
One	Introduction to the Solar Design Challenge	50-80 minutes
Two	3D CAD Solar Components	50+ minutes
Three	Learn the EasyPrint Slicer Program OR Learn the OrcaSlicer Program	50-80 minutes
Four	Preparing Solar Files for Printing in the Slicer	50-80 minutes
Five	Operating the Printer and Printing Solar Components	50-80 minutes
Six	Build, Test, and Improve the Solar Power Systems	50-80 minutes
Seven	Introduction to the Wind Turbine Design Challenge	50-80 minutes
Eight	3D CAD Wind Turbine Components	50+ minutes
Nine	Preparing Wind Turbine Files for Printing in the Slicer	50-80 minutes
Ten	Operating the Printer and Printing Wind Turbine Components	50-80 minutes
Eleven	Build, Test, and Improve the Wind Turbine	50-80 minutes
Twelve	Resources for Troubleshooting 3D Printing Challenges	
	Total	9-30 hours

Lesson Structure

Each lesson begins with a Lesson Overview, Lesson Objectives, and a Lesson at a Glance table, which lists lesson activities, materials required, suggested preparation steps, and approximate class time.

Lesson Components

Content and Learning Guide Slide Presentation: We developed this curriculum to give the teacher freedom to implement it as they see fit. The slide presentation can be used to support teacher-guided whole-class learning, or teams of students can use the slides to work independently. Many teachers upload the slides into their LMS for easy student access and freedom of pacing.

Student Engineering Workbook: As students follow the guided lessons in the slides, they should complete the corresponding section of their student workbook.

Lesson One – Introduction to the Solar Design Challenge

Lesson Overview

In this lesson, participants explore solar energy fundamentals and are introduced to the Solar Design Challenge, where they apply engineering principles to design, 3D print, and assemble solar array components. By the end of Lesson Six, they will test and optimize their designs to maximize voltage output, reinforcing concepts of efficiency, wiring, and renewable energy production.

Lesson Objectives

After completing this lesson, participants will be able to:

- Explain how photovoltaic cells convert sunlight into electricity
- Identify factors that influence solar energy production and panel efficiency
- Understand what the Solar Design Challenge will include in the following lessons

Lesson at a Glance

Activity	Materials	Preparation	Approximate Class Time
Content and Learning Guide	• Lesson 1 slide presentation	1. Share the slides with students.	50-80 minutes
Student Workbook	• <i>Lesson 1: Introduction to the Solar Design Challenge</i> in the Student Engineering Workbook • Student Engineering Workbook – Answer Key	1. Print the Student Engineering Workbook for each student or provide digitally.	

Lesson One – Introduction to the Solar Design Challenge

50-80 minutes

Purpose:

Participants explore solar energy fundamentals and are introduced to the Solar Design Challenge, where they apply engineering principles to design, 3D print and assemble solar array components.

Materials:

- Lesson 1 slide presentation
- *Lesson 1: Introduction to the Solar Design Challenge* in the Student Engineering Workbook
- Student Engineering Workbook – Answer Key

Facilitation Steps:

1. Divide the class into teams of 2-4 students. This lab can be structured in many ways to match your classroom setting. Some ideas are:
 - a. **All together (recommended):**
Have teams work through the lessons in numerical order. The curriculum starts with Solar, then progresses to Wind. This is the optimal way to deliver the curriculum, purposefully starting students with the easier-to-design solar components.
 - b. **Divide teams into 3 categories:**
Have teams rotate between the 3 design challenges:
 - i. 1/3 of teams fabricate the Solar Residential Array. There are 4 sets of Residential buildings to support this.
 - ii. 1/3 of teams fabricate the Solar Commercial Array. There are 4 sets of Commercial buildings to support this.
 - iii. 1/3 of teams fabricate the Wind Turbine. There are 4 Wind Turbine Nacelle Units to support this.
 - c. **Divide teams into 2 categories:**
Have them rotate between the 2:
 - i. Solar Residential and Commercial Arrays
 - ii. Wind Turbine
2. Students should have access to the slides for *Lesson 1: Introduction to the Solar Design Challenge* in their Student Engineering Workbooks. These can be uploaded to your LMS for individual or group work, or you can work through the slides collectively as a whole class.
3. As students work through the slides, they should complete the corresponding Lesson 1 questions in their workbook.
4. Once students view the Lesson 1 slides and complete the corresponding workbook questions, students should have the opportunity to check their work against the key. Different ways to do this:
 - a. Post a printed key in the room for them to compare answers with
 - b. Go over the answers as a class
 - c. Exchange workbooks and have a peer check

Lesson Overview

In this lesson, students learn to use CAD software to design eight solar array components. They will select appropriate tools, follow expert-led video tutorials, and create accurate 3D models that will be printed and assembled in later steps.

Lesson Two – 3D CAD Solar Components

Lesson Objectives

After completing this lesson, participants will be able to:

- Navigate tutorials for Tinkercad, Fusion 360, or SolidWorks
- Design eight essential solar array components using CAD tools
- Collaborate to assign design tasks and ensure all components are completed

Lesson at a Glance

Activity	Materials	Preparation	Approximate Class Time
Content and Learning Guide	• Lesson 2 slide presentation • CAD tutorials	1. Share the slides and tutorial videos with students.	Each CAD tutorial video is approximately 10-45 minutes long depending on the component's complexity. Designing the 8 components can span 3-6 class periods.
Student Workbook	• <i>Lesson 2: 3D CAD Solar Components</i> in the Student Engineering Workbook • Student Engineering Workbook – Answer Key	2. Print the Student Engineering Workbook for each student or provide digitally.	

Lesson Two – 3D CAD Solar Components

3-6 class periods

Purpose:

Students learn to use CAD software to design eight solar array components. They will select appropriate tools, follow expert-led video tutorials, and create accurate 3D models that will be printed and assembled in later steps.

Materials:

- Lesson 2 slides
- *Lesson 2: 3D CAD Solar Components* Student Engineering Workbook
- Student Engineering Workbook – Answer Key

Facilitation Steps:

1. Select CAD Software. 3 Options Supported:

Tinkercad:

- Great introductory experience
- Free
- Works on any device
- Chromebook friendly
- Web-based = can be used at school or home

Autodesk Fusion 360:

- Industry software
- Made by same company as Tinkercad
- Offer free student accounts
- Browser-based and downloadable program options

SolidWorks

- Industry software
- License required
- Downloadable program

2. Decide expectations for designing components in CAD software. 2 Options:
 - a. **Individually Design All:** Have each student design every component. This will require them to work through each tutorial video and develop the most complete set of skills and design experience.

- b. **Team Design:** Allow teams to divide and conquer; each student only designs a few of the total needed. This is faster but will not give individual students as much design experience.

3. As students work through the slides, they should complete the corresponding Lesson 2 questions in their Engineering Student Workbook.
4. In the slides, students will be able to access tutorial videos for each component. These videos are linked in the slides. Clicking the link will take students to an unlisted YouTube playlist that can only be accessed by having the direct link.

Direct Link to Tutorial Video Playlists:

[Solar CAD Tutorials: Engineering Renewable Energy 3D Print Lab - YouTube](#)

Once students view the Lesson 2 slides and complete the corresponding workbook questions, students/teams should have designed the 8 components needed for the Solar Arrays in CAD.

Note: CAD tutorials were created by Aaron Rhodes, a mechanical engineer and the owner of an engineering design company. He has nearly twenty years of experience in product design and manufacturing. Rhodes has worked in labs and factories across the U.S., Asia, and Europe. He's developed everything from simple prototypes to patented industrial equipment.

5. For reference/teacher use, the 3D printable .STL files for each component have been provided with the curriculum in the "Printable STL Files for Teachers" Folder. This contains completed designs for each of the components that students design in the tutorial videos. This resource may be helpful for groups who have not been able to successfully design the more complex components.

Lesson Three – Learn the Slicer Program

Lesson Overview

In this lesson, students learn to use a slicer program (EasyPrint or OrcaSlicer) to prepare their CAD-designed solar components for 3D printing. They will practice loading files, adjusting settings, adding supports, and previewing prints to ensure successful fabrication.

Lesson Objectives

After completing this lesson, participants will be able to:

- Load .STL files into a slicer program and navigate its interface
- Adjust component orientation, scale, and position for optimal printing
- Apply strength settings, including infill, shell thickness, and print profiles
- Add supports to address overhangs, bridges, and stability challenges
- Preview sliced models and evaluate filament use, print time, and layer structure
- Practice modifying slicer settings to influence print quality and efficiency

Lesson at a Glance

Activity	Materials	Preparation	Approximate Class Time
Content and Learning Guide	Lesson 3 slide presentation (choose either EasyPrint or OrcaSlicer)	1. Share the slides with students.	50-80 minutes
Student Workbook	<i>Lesson 3: Learn the Slicer</i> in the Student Engineering Workbook - Student Engineering Workbook – Answer Key	1. Print the Student Engineering Workbook for each student or provide digitally.	

Lesson Three – Learn the Slicer

50-80 minutes

Purpose:

Students learn to use a slicer program (EasyPrint or OrcaSlicer) to prepare their CAD-designed solar components for 3D printing. They will practice loading files, adjusting settings, adding supports, and previewing prints to ensure successful fabrication.

Materials:

- Lesson 3 slides (choose either EasyPrint or OrcaSlicer)
- *Lesson 3: Learn the Slicer* in the Student Engineering Workbook
- Student Engineering Workbook – Answer Key

Facilitation Steps:

1. Select slicer software. 2 Options Supported:

EasyPrint:

- Free slicer program that can be accessed in an internet browser

- Offers streamlined file preparation for printing
- Access at www.printables.com

OrcaSlicer:

- Free, downloadable slicer program that works on Windows and Apple computers
- Offers a more comprehensive set of file preparation options for advanced applications
- Access at <http://orcaslicer.com/download>

2. As students work through the slides, they should complete the corresponding Lesson 3 questions in their Student Engineering Workbook.
3. Once students view the Lesson 3 slides and complete the corresponding questions in the student workbooks, students/teams should check their answers.

Lesson Four: Preparing Solar Files for Printing in the Slicer

Lesson Overview

In this lesson, students export their CAD-designed solar components as .STL files, prepare them in a slicer program using recommended settings, and save the sliced files to a USB drive for 3D printing.

Lesson Objectives

After completing this lesson, participants will be able to:

- Export solar component designs from CAD software as .STL files
- Load .STL files into a slicer program and confirm the correct dimensions and orientation
- Apply recommended slicer settings, including infill, pattern, and supports
- Save sliced files in the correct format and transfer them to a USB drive
- Safely eject the USB drive and prepare for 3D printing in the next lesson

Lesson at a Glance

Activity	Materials	Preparation	Approximate Class Time
Content and Learning Guide	• Lesson 4: Preparing Solar Files for Printing in the Slicer slide presentation	1. Share the slides with students.	50-80 minutes
Student Workbook	• <i>Lesson 4: Preparing Solar Files for Printing in the Slicer</i> in the Student Engineering Workbook	1. Print the Student Engineering Workbook for each student or provide digitally.	

Lesson Four – Preparing Solar Files for Printing in the Slicer

50-80 minutes

Purpose:

Students export their CAD-designed solar components as .STL files, prepare them in a slicer program using recommended settings, and save the sliced files to a USB drive for 3D printing.

Materials:

- Lesson 4 slides
- *Lesson 4: Preparing Solar Files for Printing in the Slicer* in the Student Engineering Workbook

Facilitation Steps:

1. Optional: Provide each team with a USB flash drive. This is most effective for managing team file storage, organization, and transfer.
2. Teams will collaborate to prepare their solar designs for printing. As students work through the slides, they should complete the corresponding Lesson 4 questions in their Student Engineering Workbook.

The student workbook guides teams to assign responsibility for slicing and tracking completion for each component.

Once finished, teams should have 8 sliced files ready to transfer to the 3D printer in Lesson 5.

Note: The “Slicer Settings Quick Reference Table” has been provided on the following page of this teacher’s guide. These settings are recommended but purposefully not ideal. When teams begin to iterate and improve their designs, these settings can be altered to improve the system.

Slicer Settings Quick Reference Table:

Solar First Prints

Component # and Name	Dimensions (XYZ)	Infill %	Infill Pattern	Supports	Notes
1. Solar Rack Base	133 mm x 15 mm x 18 mm	15%	Grid	No	—
2. Solar Rack Upright	12 mm x 80 mm x 10.5 mm	15%	Grid	No	—
3. Solar Rack C Channel	18 mm x 260 mm x 9.8 mm	15%	Grid	No	Rotate diagonally to fit on print bed
4. Solar Angle Rail	27 mm x 149 mm x 15 mm	15%	Grid	Yes	Large overhangs and bridges require support
5. Solar Spacer	16.75 mm x 16.75 mm x 5 mm	15%	Grid	No	—
6. Solar T Nut	13.4 mm x 12 mm x 5 mm	15%	Grid	Optional	Supports may help with small overhangs
7. Solar L Clip	16.4 mm x 5.25 mm x 9.4 mm	15%	Grid	No	—
8. Solar T Clip	23.4 mm x 5.25 mm x 9.4 mm	15%	Grid	No	—

Lesson Five – Operating the Printer and Printing Solar Components

Lesson Overview

In this lesson, students learn how to operate a 3D printer to manufacture solar array components. They will prepare the printer, transfer files, monitor the printing process, validate component quality, and fabricate additional parts for complete residential and commercial solar arrays.

Lesson Objectives

After completing this lesson, participants will be able to:

- Prepare the 3D printer for operation, including filament and bed checks
- Transfer sliced files from a USB drive to the printer and confirm settings
- Monitor the printing process and troubleshoot issues such as failed prints
- Safely remove printed components and clean support material
- Validate component dimensions and fit using CAD drawings
- Manufacture additional copies of components for complete solar array builds

Lesson at a Glance

Activity	Materials	Preparation	Approximate Class Time
Content and Learning Guide	• (1) 3D printer per team: minimum print volume of 220 mm x 220 mm x 220 mm • Lesson 5: Operating the Printer and Printing Solar Components slide presentation	1. Share the slides with students.	3-6 class periods
Student Workbook	• <i>Lesson 5: Operating the Printer and Printing Solar Components</i> in the Student Engineering Workbook • USB flash drive (1 per team) • 3D printer (1 per team) • Measuring tool such as a metric ruler or digital caliper	1. Print the Student Engineering Workbook for each student or provide digitally.	

Lesson Five – Operating the Printer and Printing Solar Components

3 – 6 Class Periods

Purpose:

Students learn how to operate a 3D printer to manufacture solar array components. They will prepare the printer, transfer files, monitor the printing process, validate component quality, and fabricate additional parts for complete residential and commercial solar arrays.

Materials:

- Access to 3D printer with print volume of 220 mm x 220 mm x 220 mm or greater (1 printer per team)
- Lesson 5 slides
- *Lesson 5: Operating the Printer and Printing Solar Components* in the Student Engineering Workbook
- Measuring tool such as metric ruler or digital caliper for component validation measurements
- USB flash drive (1 per team)

Facilitation Steps:

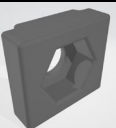
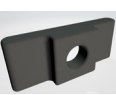
1. Teams will collaborate to print their solar array components. As students work through the slides, they should complete the corresponding Lesson 5 questions work in their Student Engineering Workbook.

The student workbook guides teams to assign responsibility for printing and tracking completion for each component.

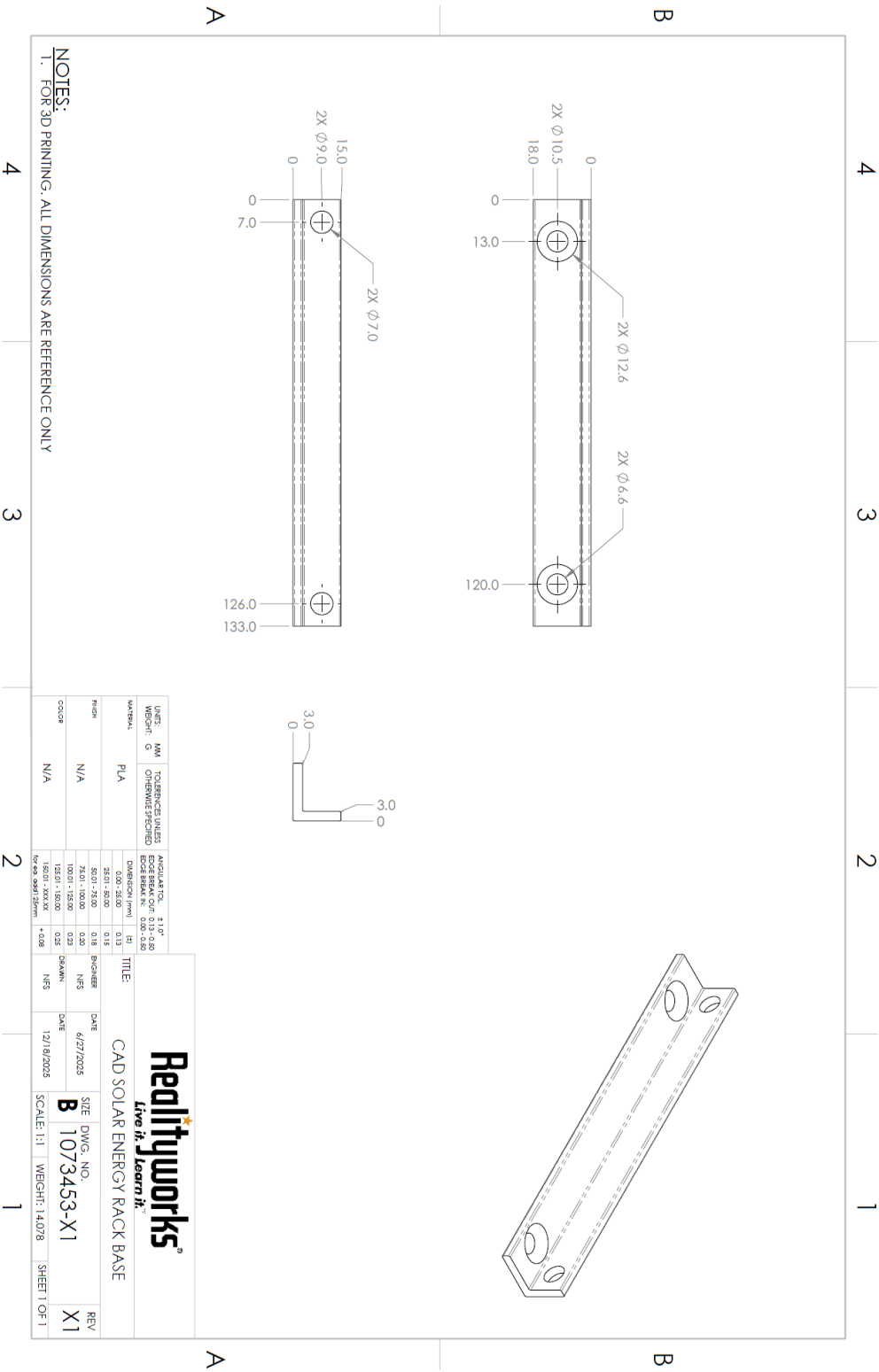
Teams are directed to print 1 of each component, then validate the size, properties, and quality of each component to confirm correct design using CAD Component Drawings included in their Engineering Workbook.

Note: CAD Component Drawings are included in this document for your reference in the following pages.

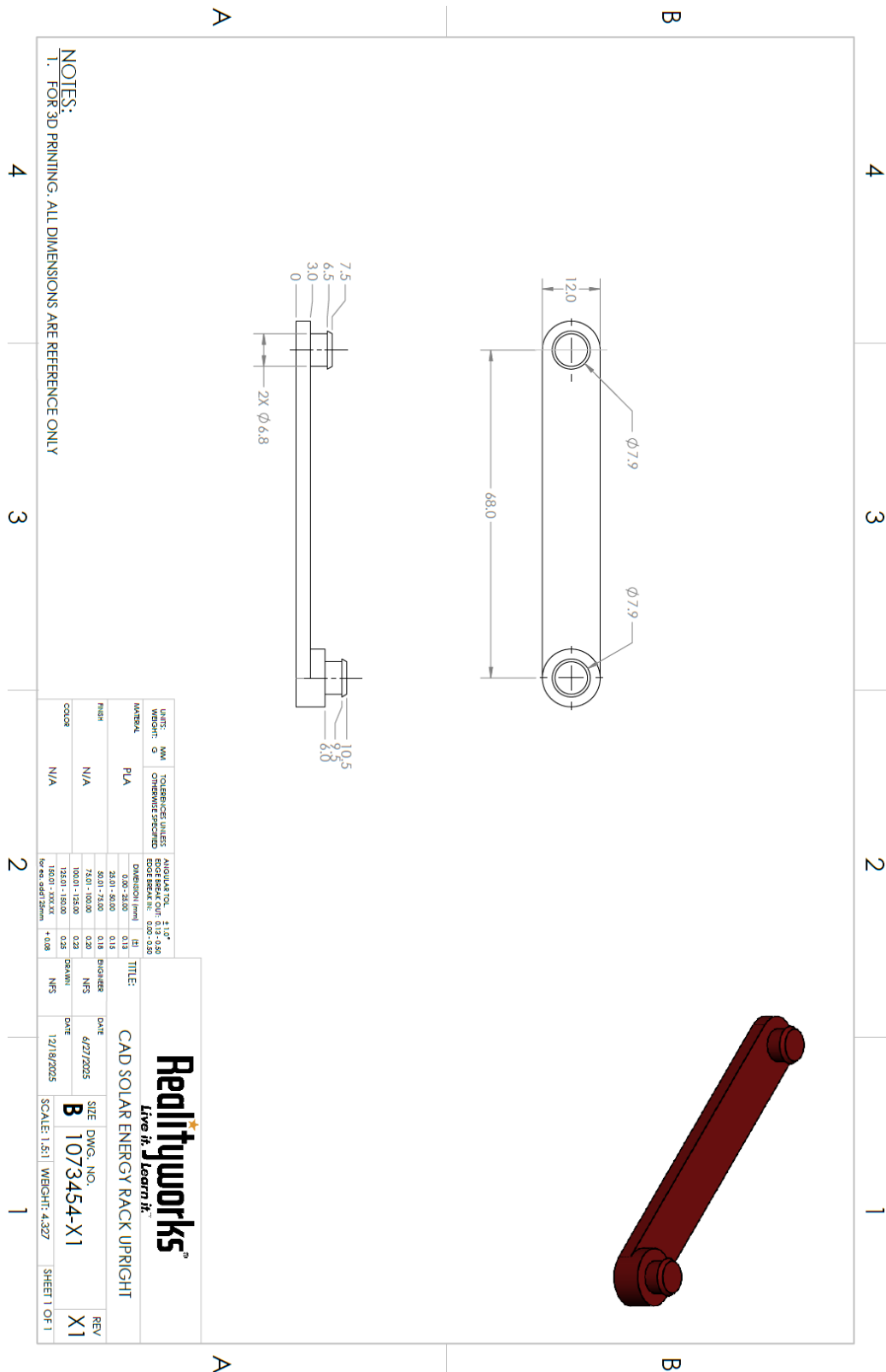
2. Once a component is validated and passes inspection, each team should print additional copies. Specific quantities are listed in their workbook and provided in the table on the next page.

Solar Component Print Quantities Per Team		
Component	Reference Image	Total Copies to Print Per Team
1. Solar Rack Base		2
2. Solar Rack Upright		2
3. Solar Rack C Channel		6
4. Solar Angle Rail		2
5. Solar Spacer		4
6. Solar T Nut		20
7. Solar L Clip		12
8. Solar T Clip		8

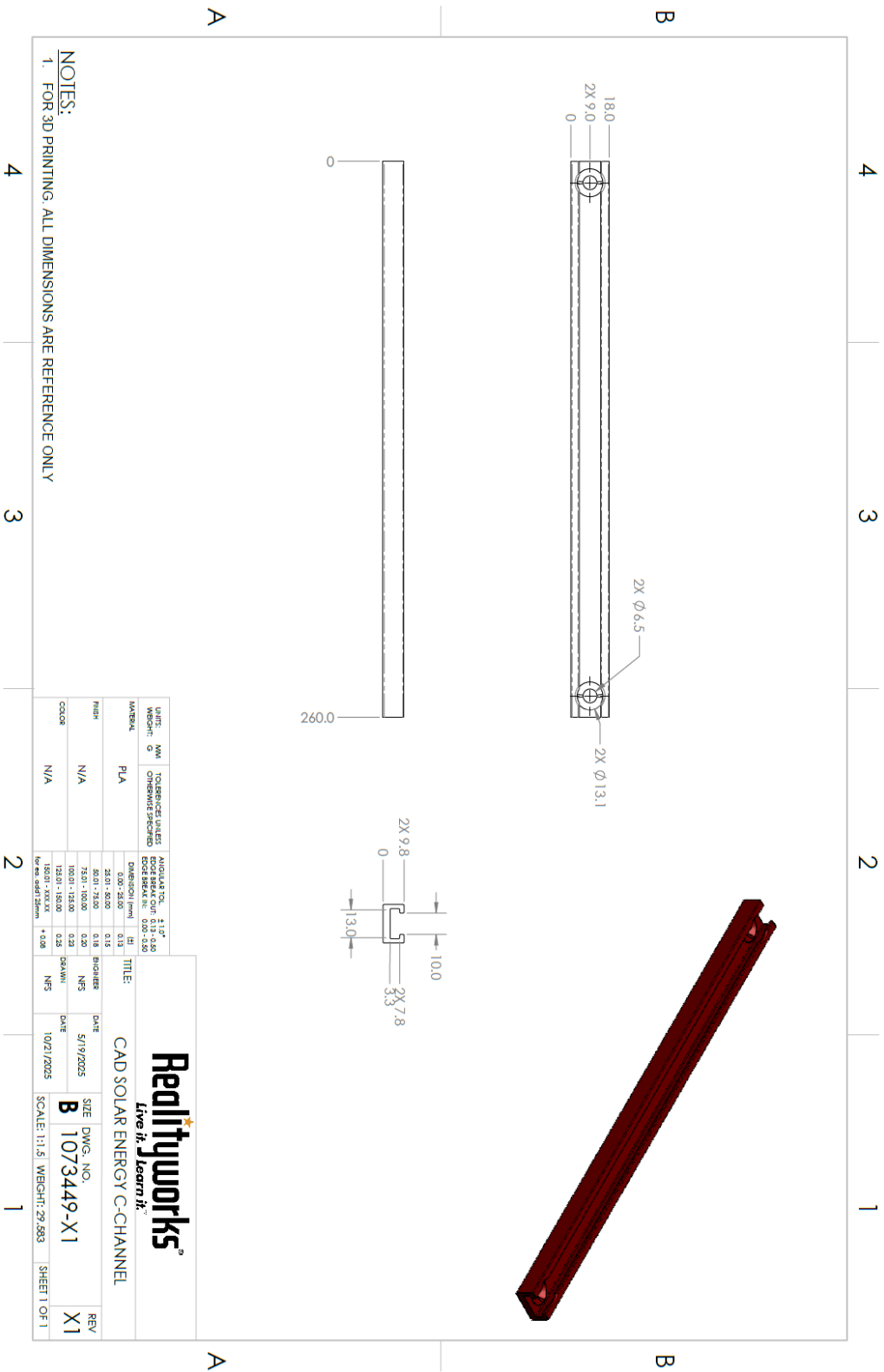
Engineering CAD Component Drawing: 1. Solar Rack Base



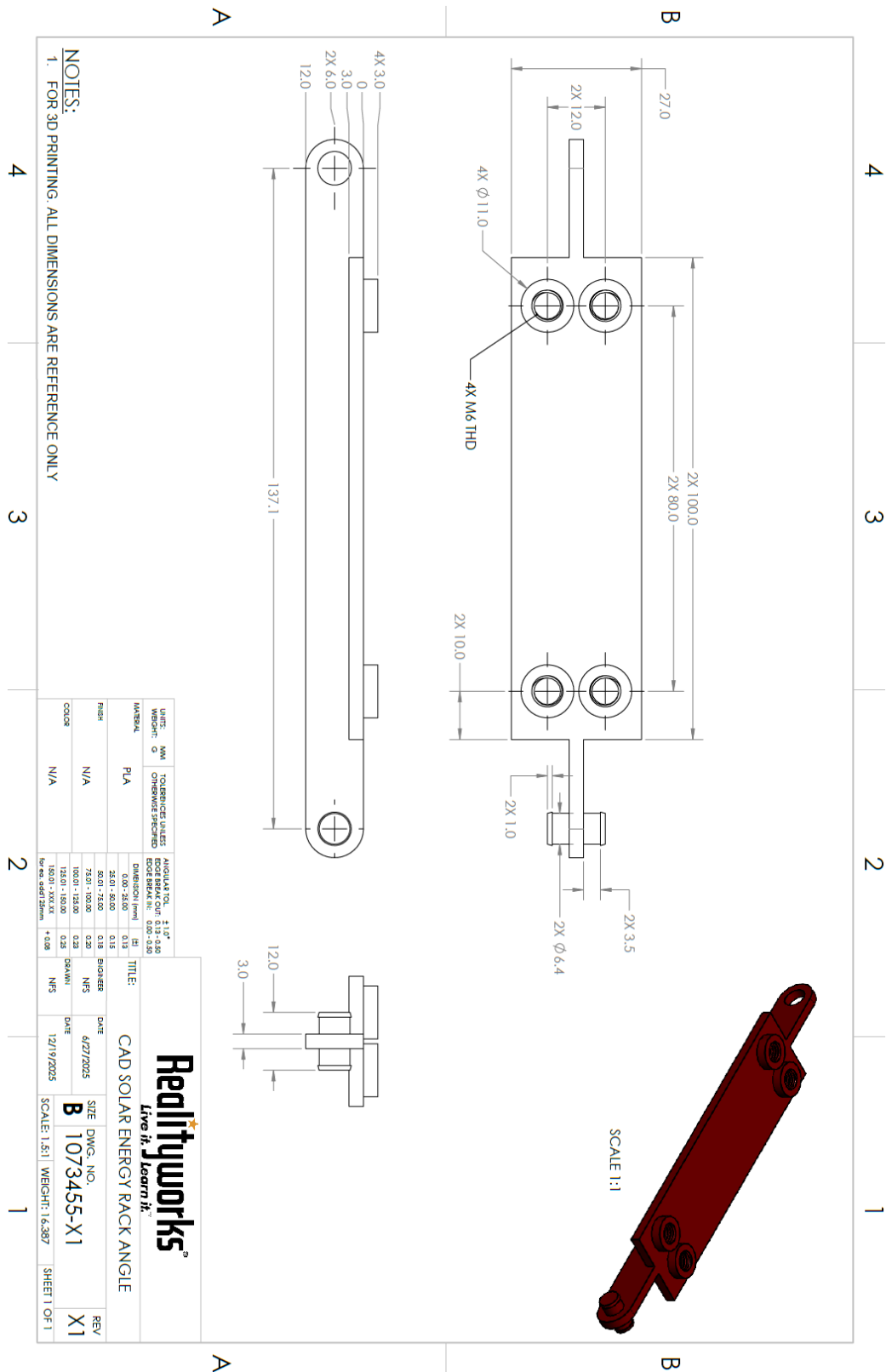
Engineering CAD Component Drawing: 2. Solar Rack Upright



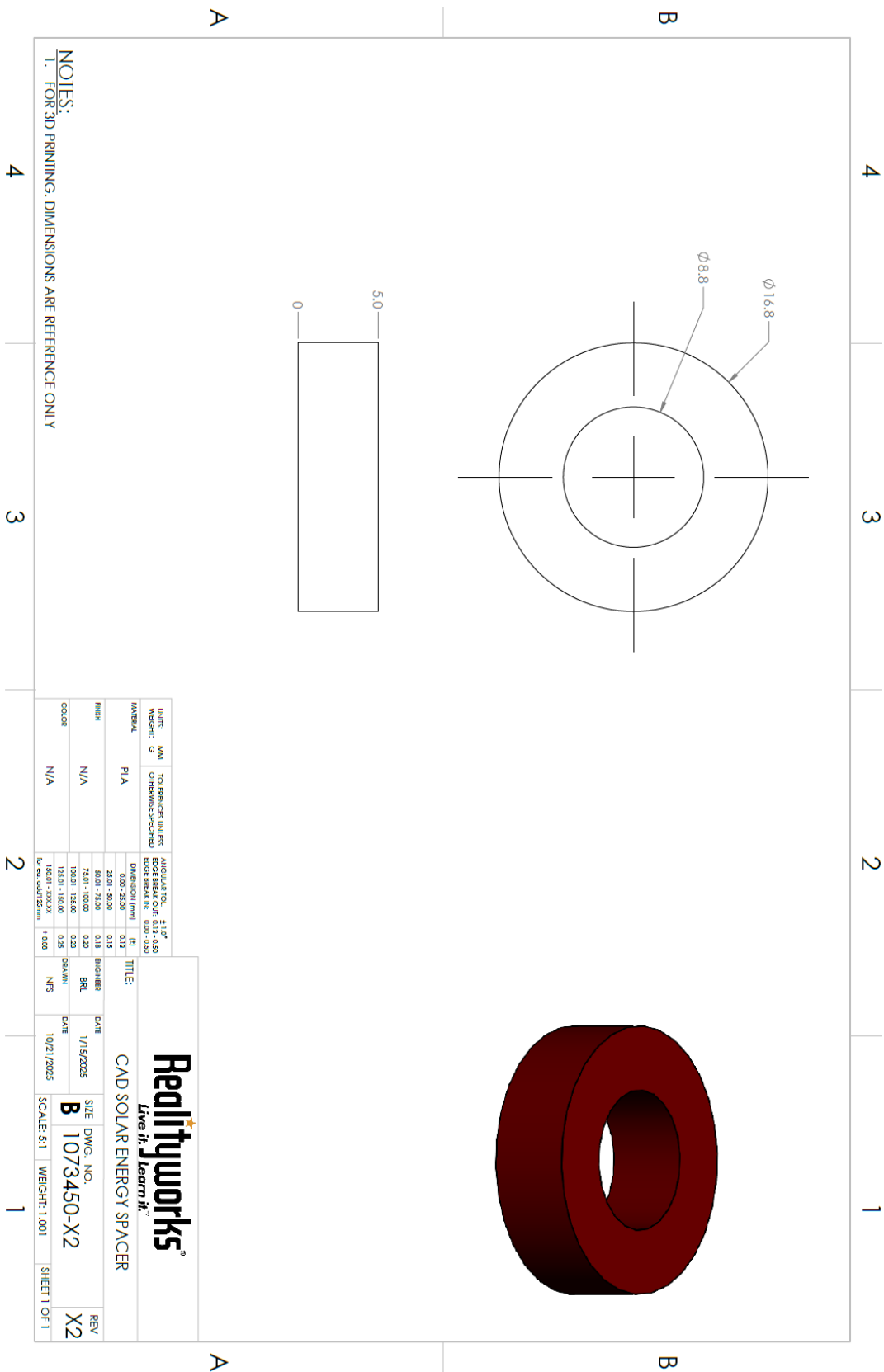
Engineering CAD Component Drawing: 3. Solar Rack C Channel



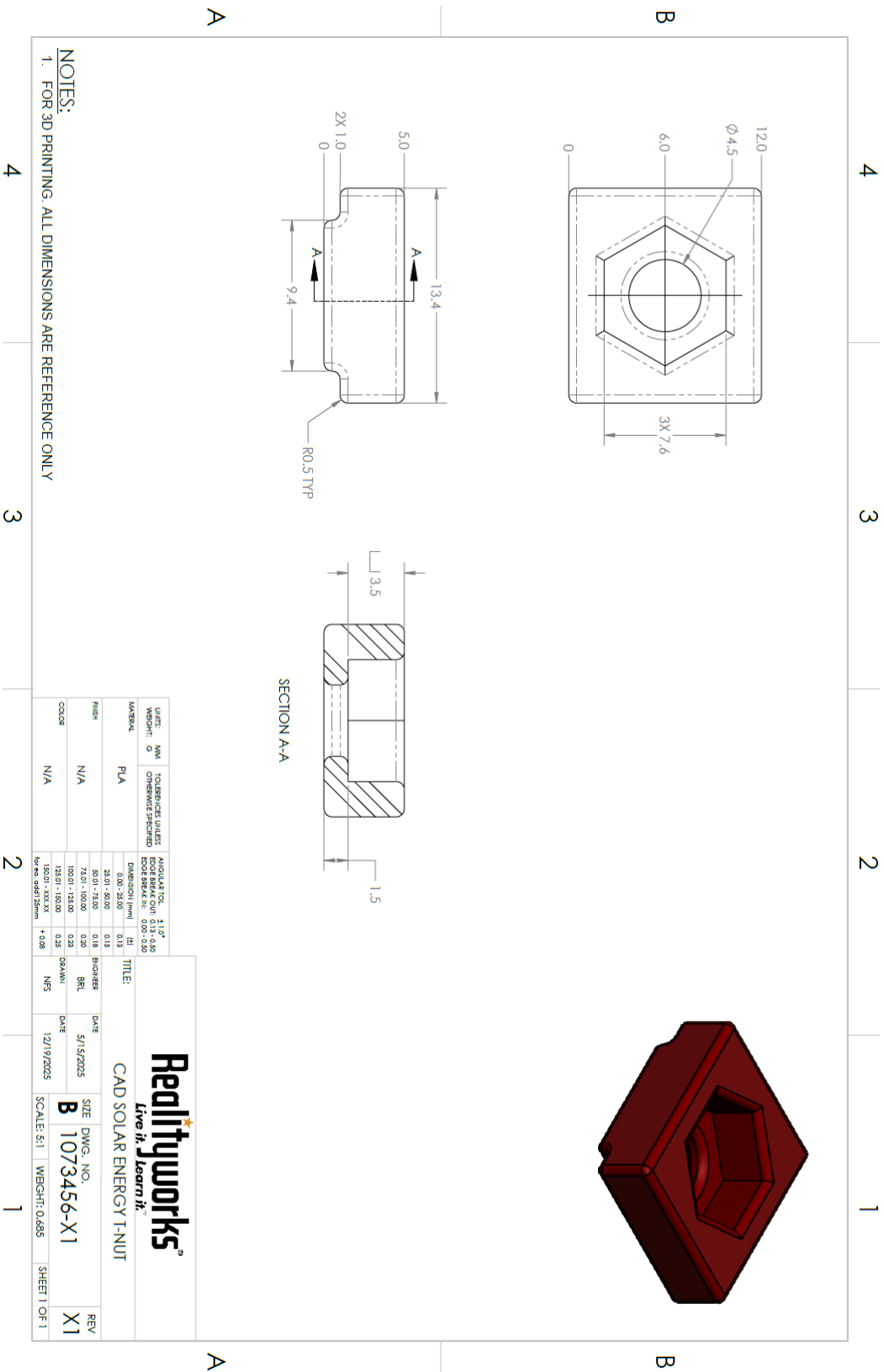
Engineering CAD Component Drawing: 4. Solar Angle Rail



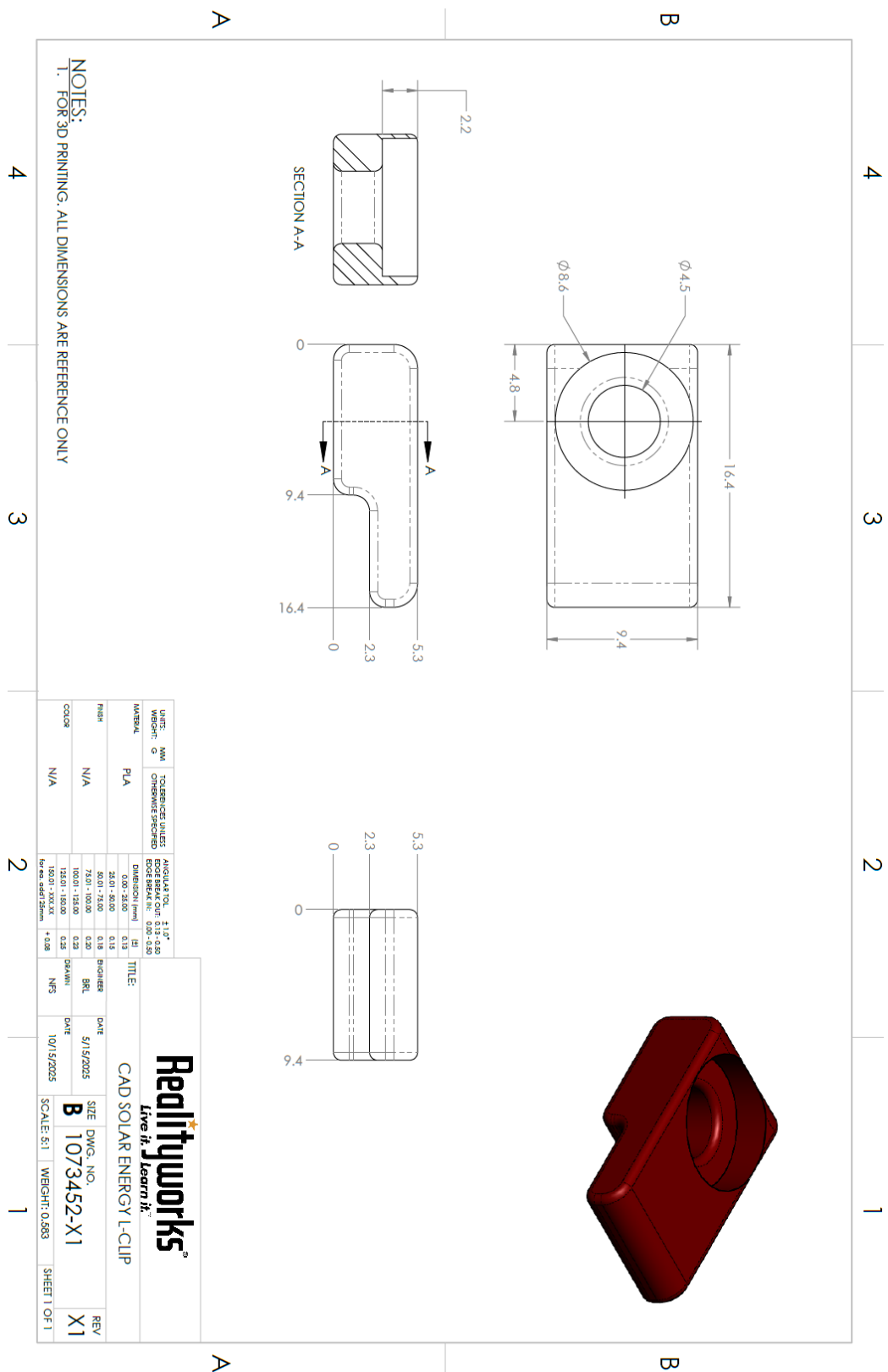
Engineering CAD Component Drawing: 5. Solar Spacer



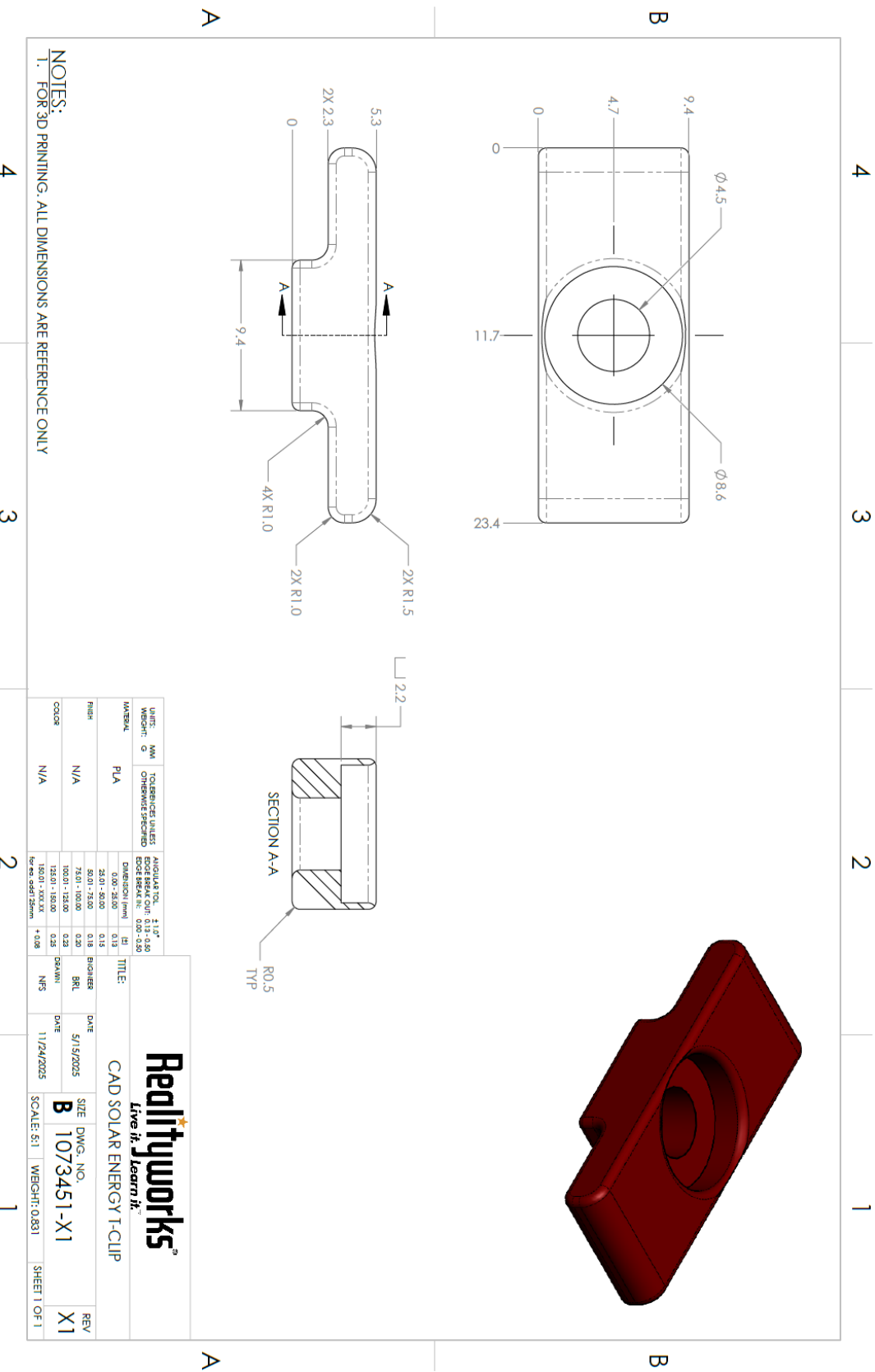
Engineering CAD Component Drawing: 6. Solar T Nut



Engineering CAD Component Drawing: 7. Solar L Clip



Engineering CAD Component Drawing: 8. Solar T Clip



Lesson Six – Build, Test, and Improve the Solar Power Systems

Lesson Overview

In this lesson, participants assemble residential and commercial solar PV arrays, connect panels using series and parallel wiring, test voltage and current outputs, and iterate designs to improve system performance.

Lesson Objectives

After completing this lesson, participants will be able to:

- Assemble residential and commercial solar PV arrays using printed components
- Connect solar panels and understand series versus parallel wiring configurations
- Measure voltage and current using a multimeter under controlled light conditions
- Record and analyze test data to evaluate system performance
- Brainstorm and implement design improvements to optimize voltage output

Lesson at a Glance

Activity	Materials	Preparation	Approximate Class Time
Content and Learning Guide	• Lesson 6: Build, Test, and Improve the Solar Power Systems slide presentation	1. Share the slides with students.	50-80 minutes
Student Workbook	• <i>Lesson 6: Build, Test, and Improve the Solar Power Systems</i> in the Student Engineering Workbook • USB flash drive (1 per team) • 3D printer with a print volume of 220 mm x 220 mm x 220 mm or greater	1. Print the Student Engineering Workbook for each student or provide digitally.	

Lesson Six – Build, Test, and Improve the Solar Power Systems

50-80 minutes

Purpose:

Participants assemble residential and commercial solar PV arrays, connect panels using series and parallel wiring, test voltage and current outputs, and iterate designs to improve system performance.

Materials:

- Access to 3D printer with a print volume of 220 x 220 x 220 mm or greater
- Lesson 6 slides
- *Lesson 6: Build, Test, and Improve the Solar Power Systems* Student Engineering Workbook
- Residential and commercial building models, hardware, solar panels, and multimeters
- USB flash drive (1 per team)

Facilitation Steps:

1. Teams will collaborate to build their solar arrays, using the detailed instructions in the slides. As students work through the slides, they should complete the corresponding Lesson 6 questions in their Student Engineering Workbook.
2. Once assembled and wired, teams are directed to collect voltage and current measurements for both series and parallel wiring arrangements under 2 different light sources.
 - a. Light Source 1: Classroom lights – Identify a “test zone” so every team uses the same light conditions to test their arrays.
 - b. Light Source 2: Find another area with different light conditions than source 1. A location with natural sunlight is interesting and likely to produce higher values, however seasonal and daily variations can make this a challenge if students are expected to compare data across different time periods.

3. With measurements collected, teams have now established a performance baseline for their solar array. The slides and workbook guide teams to brainstorm ways to increase the voltage output of their designs.

Suggestions to drive their engineering work:

- a. Remind them to refer back to Lesson 1, where they learned about solar power production. Variables were identified that they can optimize their system to.
- b. **Aesthetic Design:** Challenge teams to create a racking system that mounts on the commercial or residential models but looks better and incorporates artistic preferences into the design.
- c. **Material and Cost Optimization:** Turning this into a financial competition between teams can be highly engaging. Challenge teams to redesign their system to use the smallest amount of filament possible. Set a cost per gram of filament (\$2 per gram as a proxy for aluminum), measured after the system is assembled and tested. The team with the lowest cost and highest voltage produced wins.

Lesson Seven – Introduction to the Wind Turbine Design Challenge

Lesson Overview

In this lesson, participants explore wind energy fundamentals and develop an understanding of the Wind Turbine Design Challenge, where each team will apply engineering principles to design, 3D print, and assemble a power-generating wind turbine. They will then test voltage output and iterate designs to improve turbine performance.

Lesson Objectives

After completing this lesson, participants will be able to:

- Explain how wind turbines convert kinetic energy into electricity
- Identify key components and variables that influence wind turbine efficiency
- Understand the steps of the Wind Turbine Design Challenge that follow in the next lessons

Lesson at a Glance

Activity	Materials	Preparation	Approximate Class Time
Content and Learning Guide	• Lesson 7: Introduction to the Wind Turbine Design Challenge slide presentation	1. Share the slides with students.	50-80 minutes
Student Workbook	• <i>Lesson 7: Introduction to the Wind Turbine Design Challenge</i> in the Student Engineering Workbook • Student Engineering Workbook – Answer Key	2. Print the Student Engineering Workbook for each student or provide digitally.	

Lesson Seven – Introduction to the Wind Turbine Design Challenge

50-80 minutes

Purpose:

Participants explore wind energy fundamentals and develop an understanding of the Wind Turbine Design Challenge, where each team will apply engineering principles to design, 3D print and assemble a power-generating wind turbine.

Materials:

- Lesson 7 slides
- *Lesson 7: Introduction to the Wind Turbine Design Challenge* in the Student Engineering Workbook
- Student Engineering Workbook – Answer Key

Facilitation Steps:

1. Students should have access to the slides for Lesson 7. These can be uploaded to your LMS for individual or group work, or you can work through the slides collectively as a whole class.
2. As students work through the slides, they should complete the corresponding Lesson 7 questions in their Student Engineering Workbook.
3. Once students view the Lesson 7 slides and complete the corresponding workbook questions, they should have the opportunity to check their work against the Answer Key. To do this, you can use one of the following options:
 - a. Post a printed Key in the room for students to compare answers with
 - b. Go over the answers as a class
 - c. Exchange workbooks and have a peer check

Lesson Eight – 3D CAD Wind Turbine Components

Lesson Overview

In this lesson, students learn to use CAD software to design seven wind turbine components. They will select appropriate tools, follow expert-led video tutorials, and create accurate 3D models that will be printed and assembled in later steps.

Lesson Objectives

After completing this lesson, participants will be able to:

- Navigate tutorials for Tinkercad, Fusion360, or SolidWorks
- Design seven essential wind turbine components using CAD tools
- Collaborate to assign design tasks and ensure all components are complete

Lesson at a Glance

Activity	Materials	Preparation	Approximate Class Time
Content and Learning Guide	• Lesson 8: 3D CAD Design Wind Turbine Components slide presentation	1. Share the slides with students.	Each CAD Tutorial video is approximately 10-45 minutes long depending on the component's complexity. Designing the 7 components can span 3-6 class periods.
Student Workbook	• <i>Lesson 8: 3D CAD Wind Turbine Components</i> in the Student Engineering Workbook	1. Print the Student Engineering Workbook for each student or provide digitally.	

Lesson Eight – 3D CAD Design Wind Turbine Components

3-6 Class Periods

Purpose:

Students learn to use CAD software to design seven wind turbine components. They will select appropriate tools, follow expert-led video tutorials, and create accurate 3D models that will be printed and assembled in later steps.

Materials:

- Lesson 8 slides
- *Lesson 8: 3D CAD Wind Turbine Components* in the Student Engineering Workbook

Facilitation Steps:

1. Select CAD Software: 3 Options Supported:

Tinkercad:

- Great introductory experience
- Free
- Works on any device
- Chromebook friendly
- Web-based – can be used at school or home

Autodesk Fusion 360:

- Industry software
- Made by same company as Tinkercad
- Offer free student accounts
- Browser-based and downloadable program options.

SolidWorks:

- Industry Software
- License required
- Downloadable program

2. Decide expectations for designing components in CAD software. 2 Options:
 - a. **Individually Design All:** Have each student design every component. This will require them to work through each of the tutorial

videos and develop the most complete set of skills and design experience.

- b. **Team Design:** Allow teams to divide and conquer, each student only designs a few of the total needed. This is faster but will not give individual students as much design experience.

3. As students work through the slides, they should complete the corresponding Lesson 8 questions in their Student Engineering Workbook.

4. In the slides, students will be able to access tutorial videos for each component. These videos are linked in the slides. Clicking the link will take students to an unlisted YouTube playlist that can only be accessed by having the direct link.

Direct Link to Tutorial Video Playlists:

[Wind CAD Tutorials: Engineering Renewable Energy 3D Print Lab - YouTube](#)

5. Once students view the Lesson 8 slides and complete the Lesson 8 workbook questions, they should have designed in CAD the 7 components needed to build the wind turbine.

Note: The 3D printable STL files for each component have been provided with the curriculum in the “Printable STL Files for Teachers” Folder. This contains completed designs for each of the components that students design in the tutorial videos. This resource may be helpful for groups who have not been able to successfully design the more complex components.

Lesson Nine – Preparing Wind Turbine Files for Printing in the Slicer

Lesson Overview

In this lesson, students export their CAD-designed wind turbine components as .STL files, prepare them in a slicer program using recommended settings, and save the sliced files to a USB drive for 3D printing.

Lesson Objectives

After completing this lesson, participants will be able to:

- Export turbine component designs from CAD software as .STL files
- Load .STL files into a slicer program and confirm correct dimensions and orientation
- Apply recommended slicer settings, including infill, pattern, and supports
- Save sliced files in the correct format and transfer them to a USB drive
- Safely eject the USB drive and prepare for 3D printing in the next lesson

Lesson at a Glance

Activity	Materials	Preparation	Approximate Class Time
Content and Learning Guide	• Lesson 9: Preparing Wind Turbine Files for Printing in the Slicer slide presentation	1. Share the slides with students.	50-80 minutes
Student Workbook	• <i>Lesson 9: Preparing Wind Turbine Files for Printing in the Slicer</i> in the Student Engineering Workbook • USB flash drive (1 per team is ideal)	1. Print the Student Engineering Workbook for each student or provide digitally.	

Note: Make sure students have completed Lesson 3 before beginning this lesson.

Lesson Nine – Preparing Wind Turbine Files for Printing in the Slicer

50-80 minutes

Purpose:

Students export their CAD-designed wind turbine components as .STL files, prepare them in a slicer program using recommended settings, and save the sliced files to a USB drive for 3D printing.

Materials:

- Lesson 9 slides
- *Lesson 9: Preparing Wind Turbine Files for Printing in the Slicer* in the Student Engineering Workbook
- USB flash drive (1 per team is ideal)

Facilitation Steps:

1. Optional: Provide each team with a USB flash drive. This is most effective for managing team file storage, organization, and transfer.
2. Teams will collaborate to prepare their wind turbine designs for printing. As students work through the slides, they should complete the corresponding Lesson 9 questions in their Student Engineering Workbook.

The Student Workbook guides teams to assign responsibility for slicing and tracking completion for each component.

Once finished, teams should have 7 sliced files ready to transfer to the 3D printer in Lesson 10.

Note: The “Slicer Settings Quick Reference Table” has been provided on the following page of this teacher’s guide. These settings are recommended, but purposefully not ideal. When teams begin to iterate and improve their designs, these settings can be altered to improve the system.

Slicer Settings Quick Reference Table:

Wind Turbine First Prints

Component # and Name	Dimensions (XYZ)	Infill %	Infill Pattern	Supports	Notes
1. Wind Base	184.4 mm x 184.4 mm x 31.75 mm	15%	Grid	Paint <u>brims</u> at ends of legs to increase bed adhesion	Rotate component to fit on print bed
2. Wind Pole	19.05 mm x 19.05 mm x 152.4 mm	15%	Grid	Paint <u>brims</u> around base to increase bed adhesion	-
3. Wind Hub	40 mm x 40 mm x 47 mm	15%	Grid	No	-
4. Wind Blade	29.75 mm x 202.75 mm x 33.7 mm	15%	Grid	Yes	-
5. Wind Hub Cap	40 mm x 40 mm x 33 mm	15%	Grid	No	-
6. Wind Nacelle Rim	150 mm x 70 mm x 15 mm	15%	Grid	No	-
7. Wind Nacelle Cover	150 mm x 70 mm x 15.5 mm	15%	Grid	No	-

Lesson Ten – Operating the Printer and Printing Wind Turbine Components

Lesson Overview

In this lesson, students learn how to operate a 3D printer to manufacture wind turbine components. They will prepare the printer, transfer files, monitor the printing process, validate component quality, and fabricate additional parts for the complete turbine assembly.

Lesson Objectives

After completing this lesson, participants will be able to:

- Prepare the 3D printer for operation, including filament and bed checks
- Transfer sliced files from a USB drive to the printer and confirm settings
- Monitor the printing process and troubleshoot issues such as failed prints
- Safely remove printed components and clean off support material
- Validate component dimensions and fit using CAD drawings
- Manufacture additional copies of components for complete turbine assembly

Lesson at a Glance

Activity	Materials	Preparation	Approximate Class Time
Content and Learning Guide	• Lesson 10: Operating the Printer and Printing Wind Turbine slide presentation • (1) 3D printer per team with a minimum print volume of 220 mm x 220 mm x 220 mm	1. Share the slides with students.	3-6 class periods
Student Workbook	• <i>Lesson 10: Operating the Printer and Printing Wind Turbine Components</i> in the Student Engineering Workbook • USB flash drive (1 per team is ideal) • Measuring tool such as a metric ruler or digital caliper	1. Print the Student Engineering Workbook for each student or provide digitally.	

Lesson Ten – Operating the Printer and Printing Wind Turbine Components

3-6 class periods

Purpose:

Students learn how to operate a 3D printer to manufacture wind turbine components. They will prepare the printer, transfer files, monitor the printing process, validate component quality, and fabricate additional parts for the complete turbine assembly.

Materials:

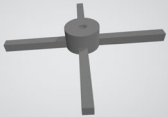
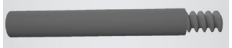
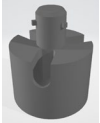
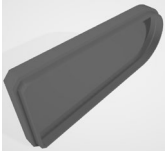
- Access to 3D printer with print volume of 220 mm x 220 mm x 220 mm or greater
- Lesson 10 slides
- *Lesson 10: Operating the Printer and Printing Wind Turbine Components* in the Student Engineering Workbook
- Measuring tool such as metric ruler or digital caliper

Facilitation Steps:

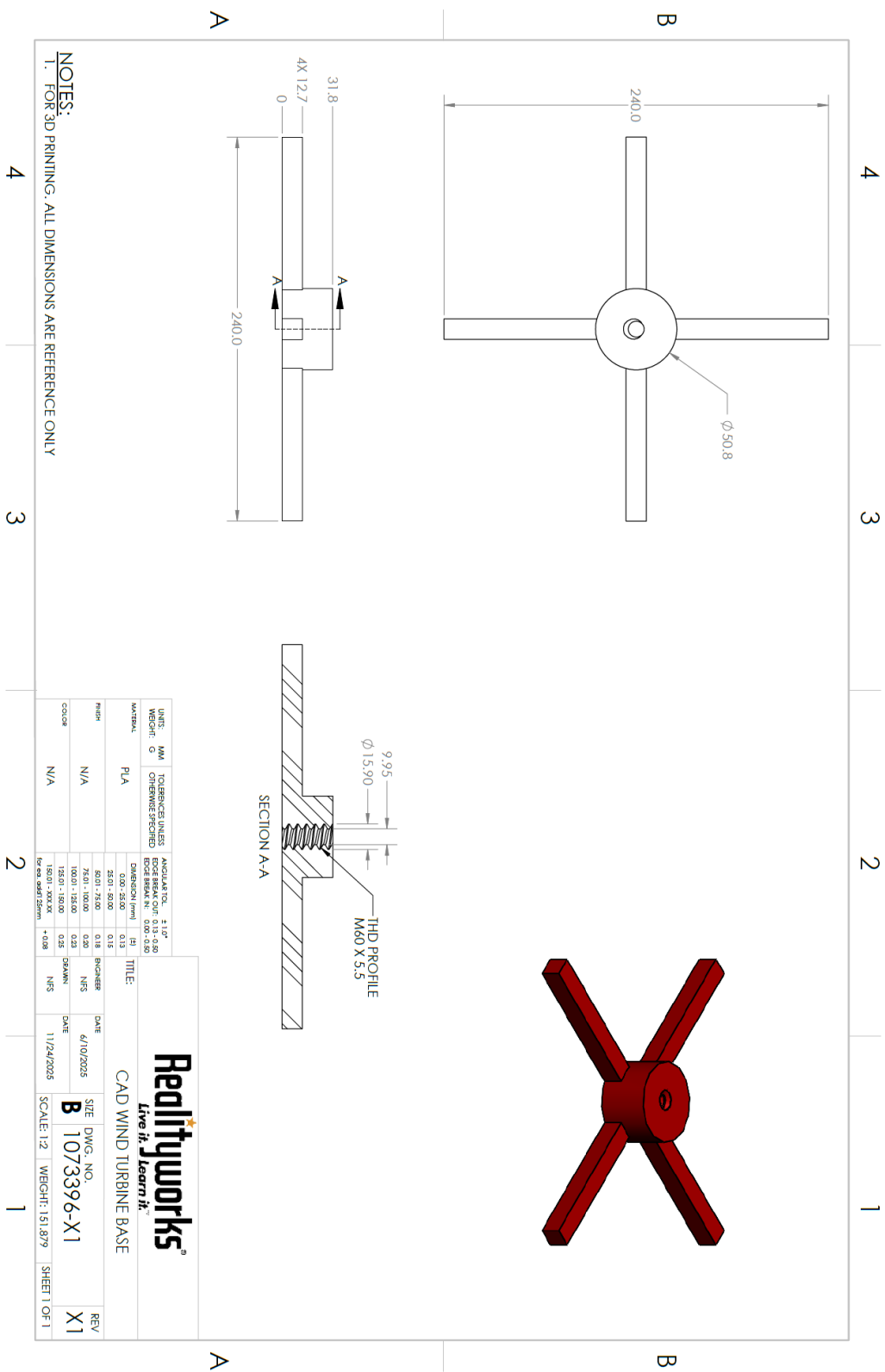
1. Teams will collaborate to print their wind turbine components. As students work through the slides, they should complete the corresponding Lesson 10 questions in their Student Engineering Workbook.

The Student Workbook guides teams to assign responsibility for printing and tracking completion for each component.

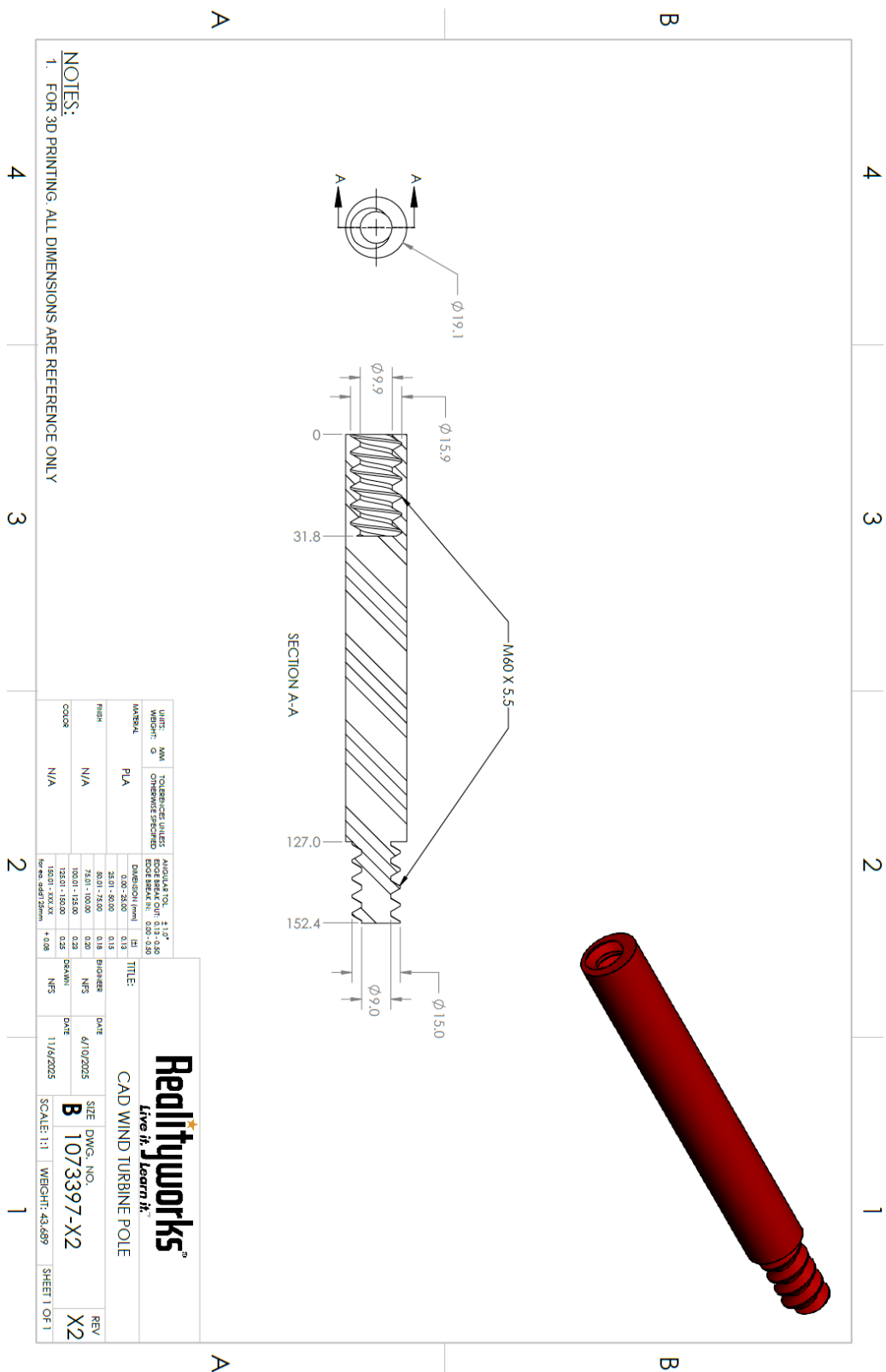
2. Teams are directed to print 1 of each component, then validate the size, properties, and quality of each component to confirm correct design using CAD Component Drawings included in their student workbook.
3. Once a component is validated and passes inspection, each team should print additional copies. Specific quantities are listed in their workbook and provided in the table on the following page.

Wind Turbine Component Print Quantities Per Team		
Component	Reference Image	Total Copies to Print Per Team
1. Wind Base		1
2. Wind Pole		2
3. Wind Hub		1
4. Wind Blade		3
5. Wind Hub Cap		1
6. Wind Nacelle Rim		1
7. Wind Nacelle Cover		1

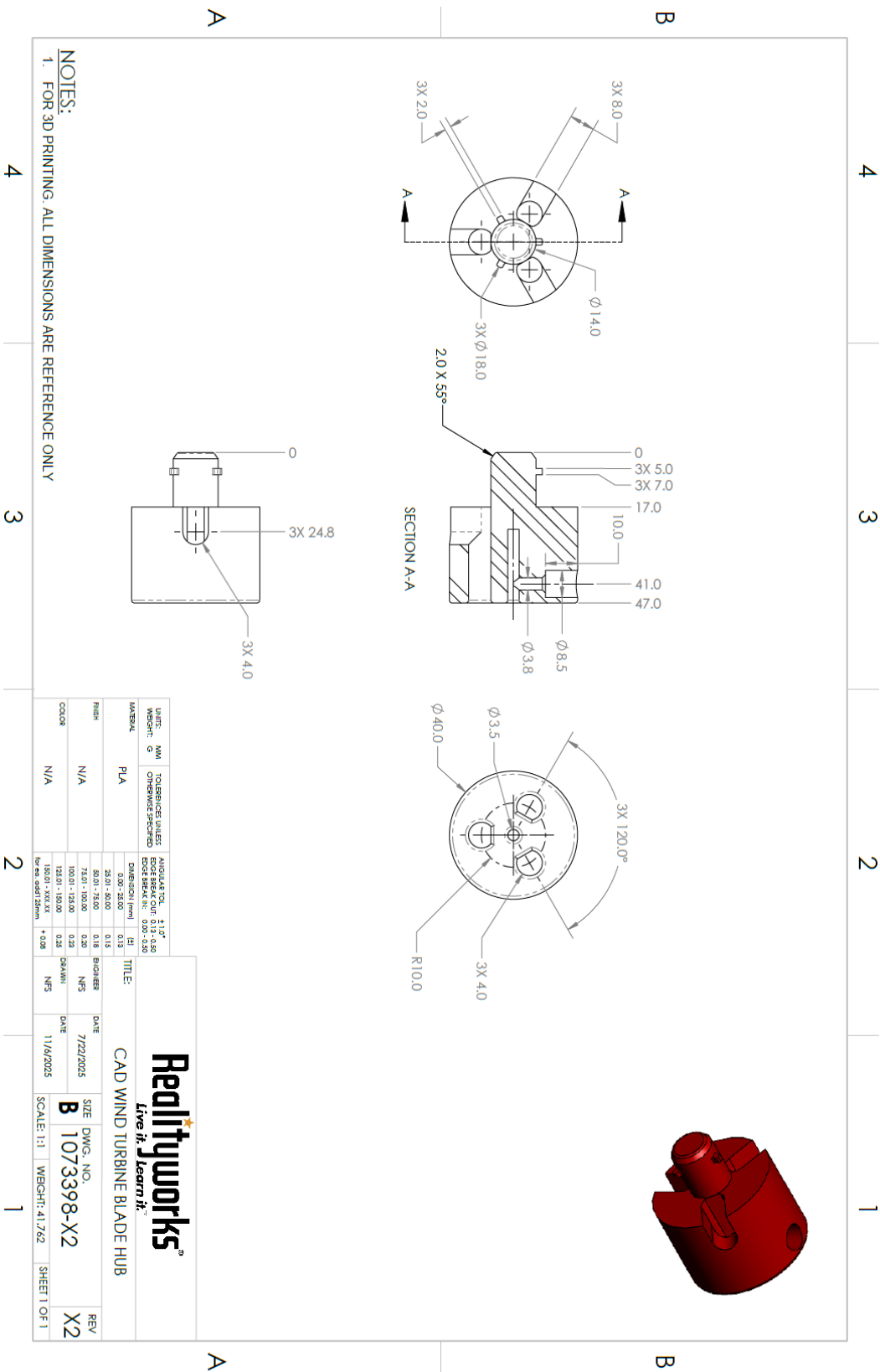
Engineering CAD Component Drawing: 1. Wind Base



Engineering CAD Component Drawing: 2. Wind Pole



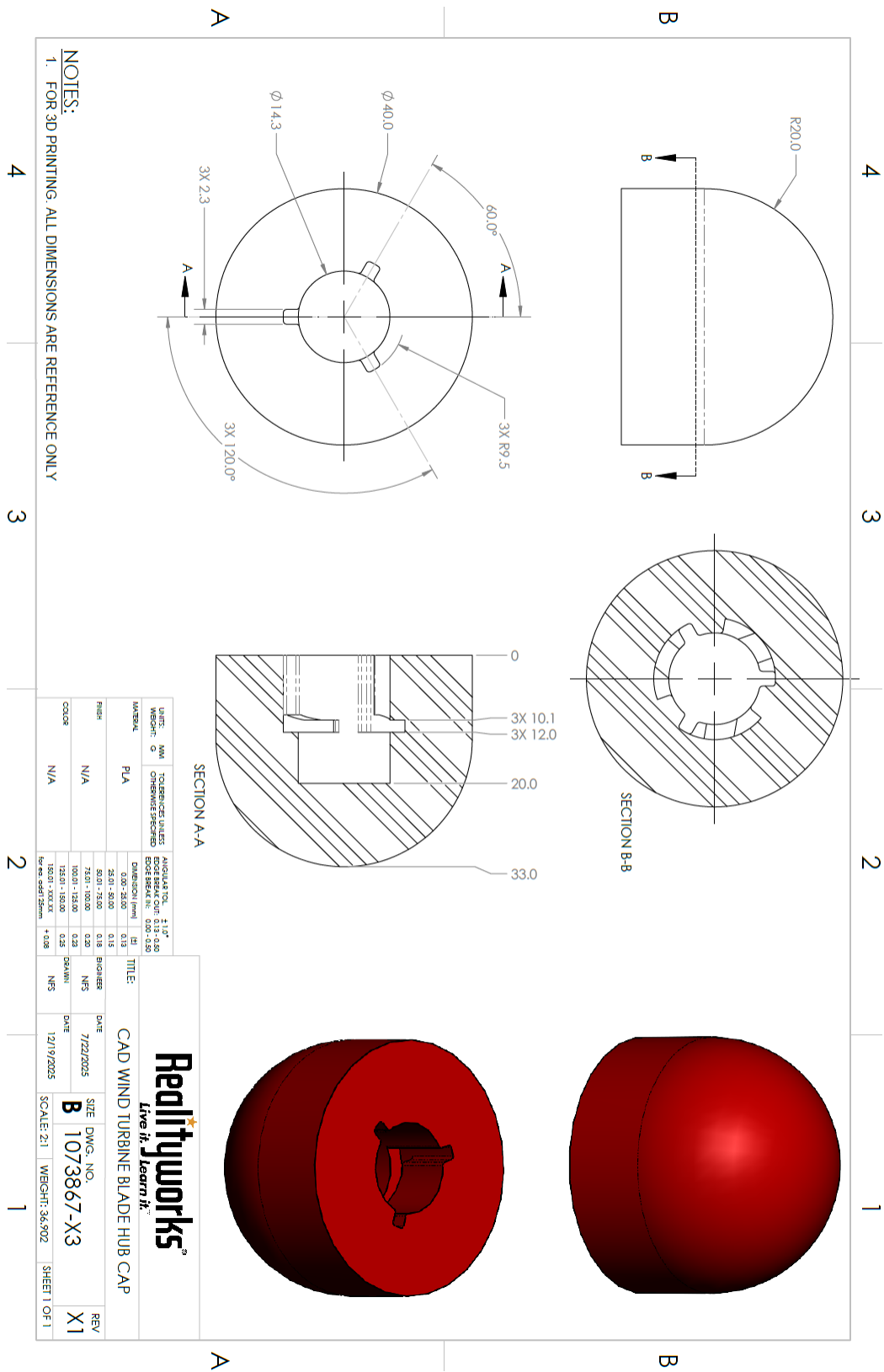
Engineering CAD Component Drawing: 3. Wind Hub



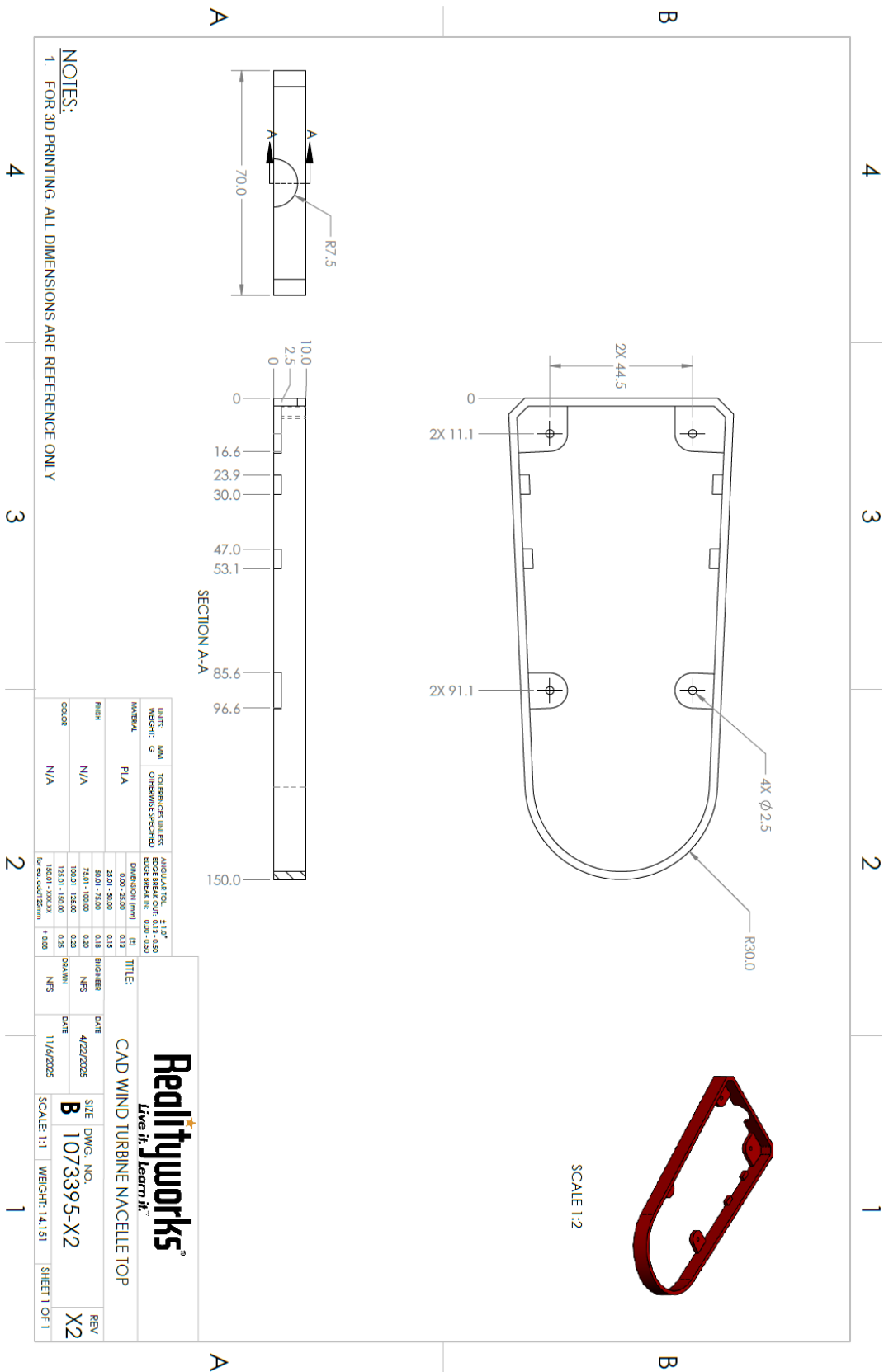
41



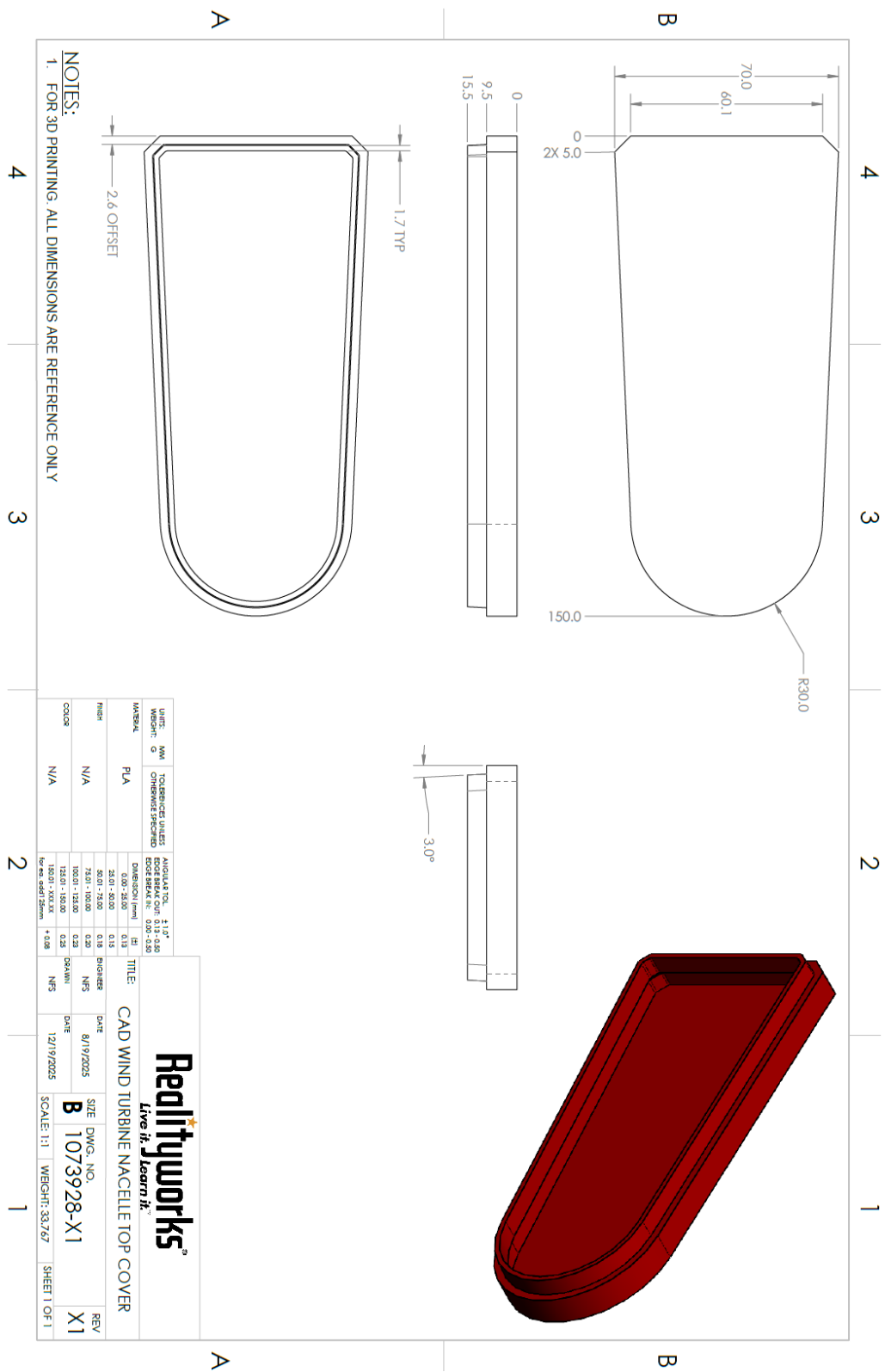
Engineering CAD Component Drawing: 5. Wind Hub Cap



Engineering CAD Component Drawing: 6. Wind Nacelle Rim



Engineering CAD Component Drawing: 7. Wind Nacelle Cover



Lesson Eleven – Build, Test, and Improve the Wind Turbine

Lesson Overview

In this lesson, participants assemble the wind turbine, connect the generator to the multimeter, test voltage and current outputs using the fan to provide wind, and iterate designs to improve system performance.

Lesson Objectives

After completing this lesson, participants will be able to:

- Assemble wind turbines using printed components
- Measure voltage and current using a multimeter in controlled wind speed conditions
- Record and analyze test data to evaluate system performance
- Brainstorm and implement design improvements to optimize voltage output

Lesson at a Glance

Activity	Materials	Preparation	Approximate Class Time
Content and Learning Guide	• Lesson 11: Build, Test, and Improve the Wind Turbine slide presentation • Turbine nacelle, hardware, tools, and multimeter for each team	1. Share the slides with students.	50-80 minutes
Student Workbook	• <i>Lesson 11: Build, Test, and Improve the Wind Turbine</i> in the Student Engineering Workbook • USB flash drive (1 per team is ideal)	2. Print the Student Engineering Workbook for each student or provide digitally.	

Lesson Eleven – Build, Test, and Improve the Wind Turbine

50-80 minutes

Purpose:

Participants assemble the wind turbine, connect the generator to the multimeter, test voltage and current outputs using the fan to provide wind, and iterate designs to improve system performance.

Materials:

- Access to 3D printer with print volume of 220 mm x 220 mm x 220 mm or greater
- Lesson 11 slides
- *Lesson 11: Build, Test, and Improve the Wind Turbine* in the Student Engineering Workbook
- Turbine nacelle, hardware, tools, and multimeters for each team
- USB flash drives (1 per team is ideal)

Facilitation Steps:

1. Teams will collaborate to build their wind turbines, using the detailed instructions in the slides. As students work through the slides, they should complete the corresponding Lesson 11 questions in their Student Engineering Workbook.
2. Once assembled and wired, teams are directed to collect voltage and current measurements for 3 different wind speeds using a fan.

As directed in the slides, a test zone should be established to create a standard distance between the fan and turbine to guarantee accurate testing results between teams.

3. With measurements collected, teams have now established a performance baseline for their wind turbine. The slides and workbook guide teams to brainstorm ways to increase the voltage output of their designs. **Suggestions to drive their engineering work:**
 - a. Remind them to refer back to Lesson 7, where they learned about wind power production. Variables were identified that they can optimize their system to.

- b. **Aesthetic Design:** Challenge teams to create a turbine that looks better and incorporates artistic preferences into the design.
- c. **Material and Cost Optimization:** Turning this into a financial competition between teams can be highly engaging. Challenge teams to redesign their system to use the smallest amount of filament possible. Set a cost per gram of filament (\$3 per gram as a proxy for carbon fiber or fiberglass) that is measured after the system is assembled and tested. The team with the lowest cost and highest voltage produced wins.
- d. **Component Specific Challenge:** There are many parts to the turbine. Suggestions to scale the challenge to a specific part:
 - i. **Blade Design:** The blade shape, mass, and size is the most important factor in producing electricity. How teams design their blade in CAD is just as important to the slicer settings established (infill %, walls, etc.).
 - ii. **Off-Shore Tower/Base Design:** Challenge teams to build an offshore floating base that can be anchored with string to weights on the bottom of the water test tub.

Resources for Troubleshooting 3D Printing

Resource Overview

In this slide presentation, participants presented with resources to expand their machine operation abilities and troubleshoot the 3D printer and process.

Resource Objectives

Students can use this resource to:

- Locate and use official troubleshooting resources for the Flashforge Adventurer 5M Pro
- Resolve common issues such as filament loading, print quality problems, and error codes
- Perform routine maintenance to keep the printer in optimal condition
- Identify when to contact technical support for advanced assistance

Note:

This is not a lesson; it is a resource that students should be guided to when questions arise or troubleshooting is necessary.