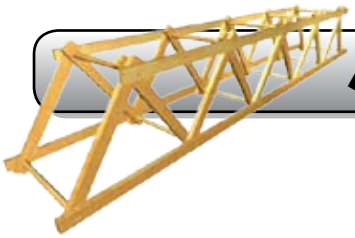
Awesome Bridges

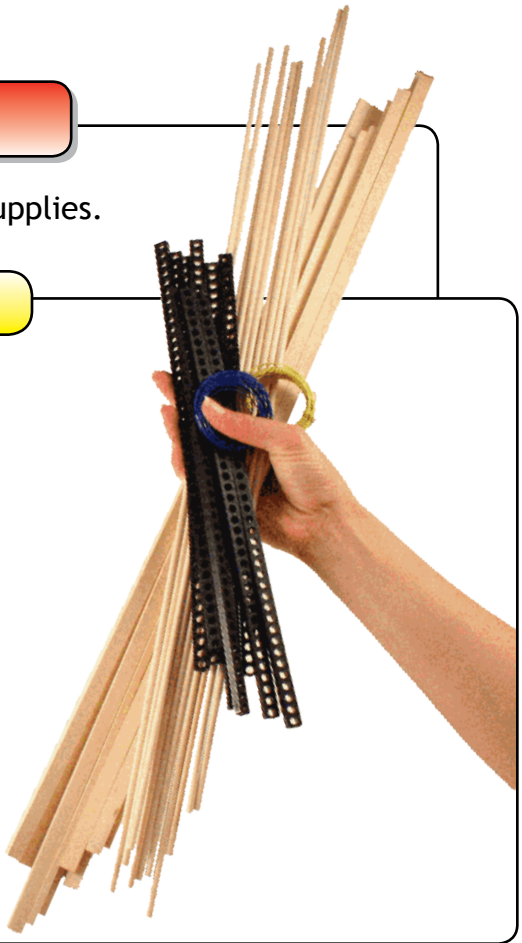
Activity Guide

TeacherGeek.com



What Will You Need?

Bridges can be easily constructed from a few inexpensive supplies.



Supplies for Each Structure Built

Basswood Strips- 5mm x10mm x 600mm:
_____ per bridge (10 standard)

Basswood Dowels- 5mm x 600mm:
_____ per bridge (10 standard)

Plastic Connector Strips- 5mm x 10mm x 300mm:
_____ per bridge (10 standard)

Steel Wire:
_____ per bridge (1 roll standard)

Glue:
_____

Other Teacher-Approved Supplies:
_____

Tools

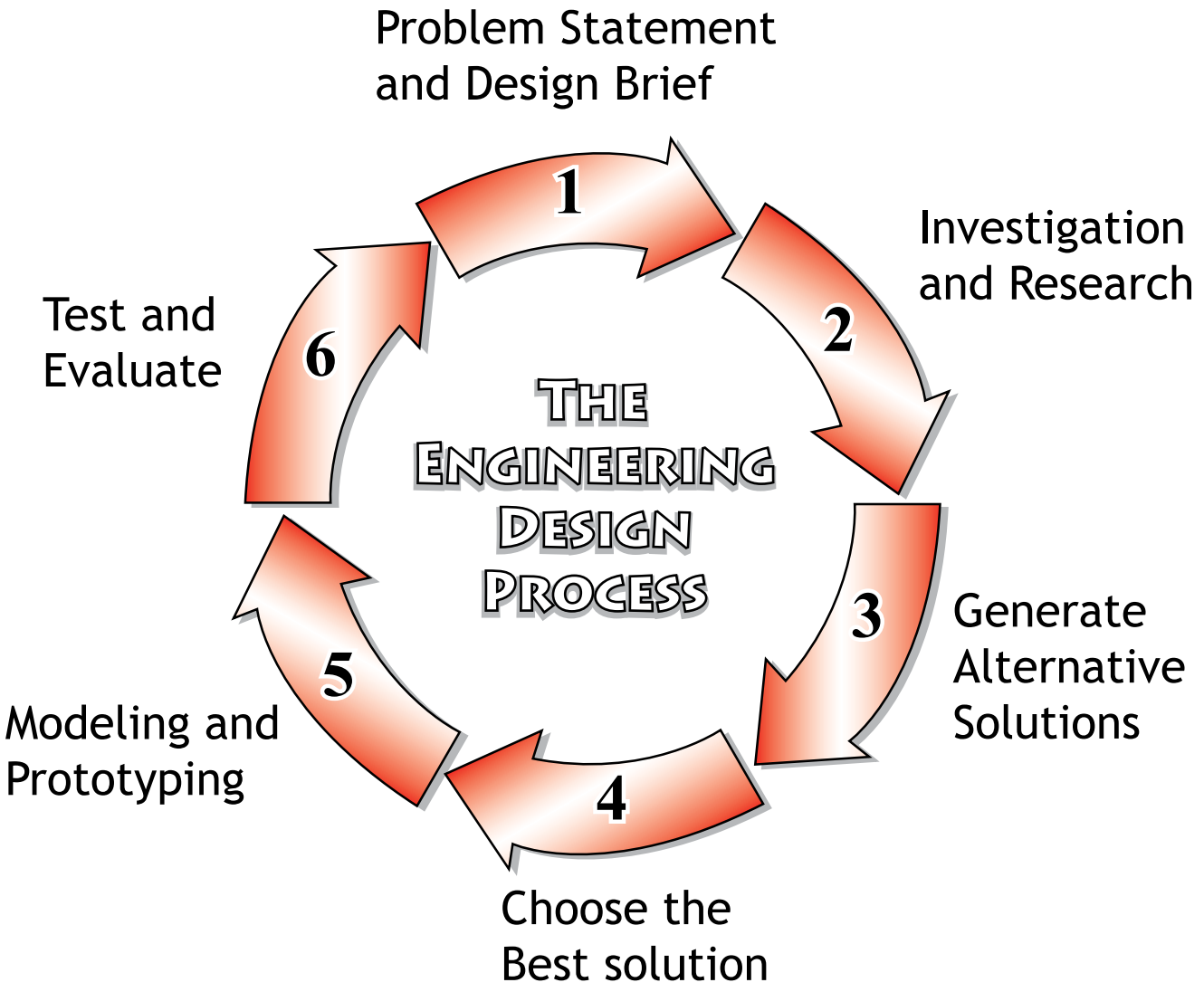
Connector strips, dowels, and wood strips can be cut using Easy Cutters or other wood cutting tools.

A drill with a #3 bit will make holes for dowels.

Look at Easy Engineering Guide

THE ENGINEERING DESIGN PROCESS

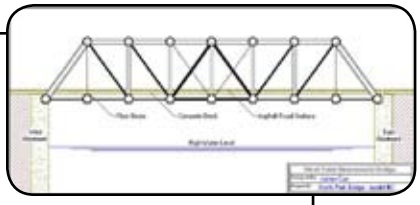
The engineering design process is a series of steps that engineers use to guide them as they solve problems. You will use the engineering design process to help you create your structure.

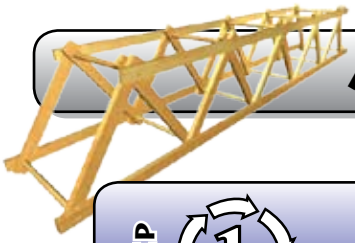


WEST POINT BRIDGE DESIGNER

West Point Bridge Designer is a free program that can be used to design and test bridges prior to constructing them.

Check out: bridgecontest.usma.edu





Step 1

The Engineering Design Process
Problem Statement and Design Brief

The problem statement provides information that justifies the need for a solution to a problem. The design brief helps us focus on the problem and gives guidelines that we will adhere to while designing a solution. These guidelines are referred to as Design Constraints.

Problem Statement

What is your problem?

Design Brief

Your Bridge must meet the following design constraints (provided by your teacher):

Your final bridge will be tested until it fails under load. There are two ways for your bridge to fail:

1. Maximum Deflection is reached- if a bridge deck bends over 13mm (~1/2in)
2. Fracture- If one or more bridge members completely fractures

STEP 2

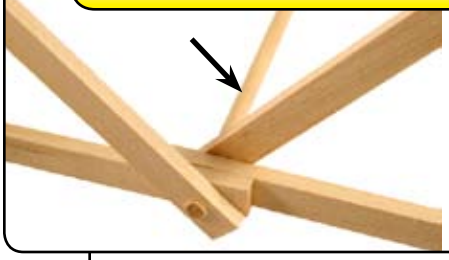
THE ENGINEERING DESIGN PROCESS
Investigation and Research

Engineers and designers rarely start from scratch when solving a problem. They research existing inventions and gather information that could help them find a new solution.

STRUCTURAL MATERIALS

Investigate construction methods and materials. Choose those that will work best on your bridge.

BASSWOOD DOWELS



Dowels attach the two sides of the bridge.

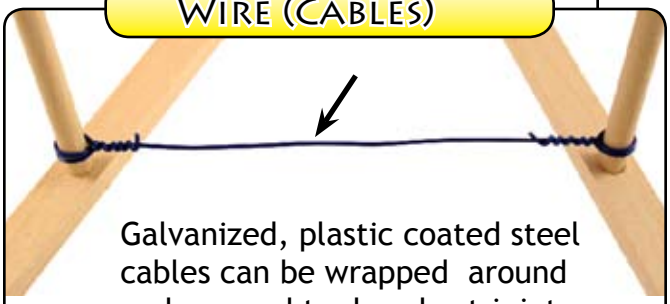
Dowels pin members together to form strong joints.

BASSWOOD STRIPS

5mm x 10mm x 600mm Basswood

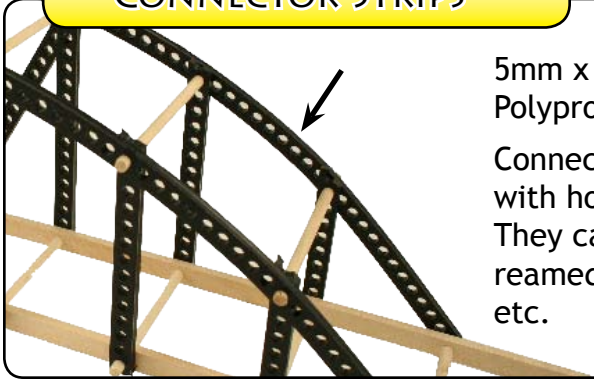
Basswood strips can be cut to length, drilled, shaped, laminated, glued together, painted, etc.

WIRE (CABLES)



Galvanized, plastic coated steel cables can be wrapped around and secured to dowels at joints.

CONNECTOR STRIPS



5mm x 10mm x 300mm Polypropylene Plastic

Connector Strips come with holes every 7.5mm. They can be cut, bent, reamed, drilled, twisted, etc.

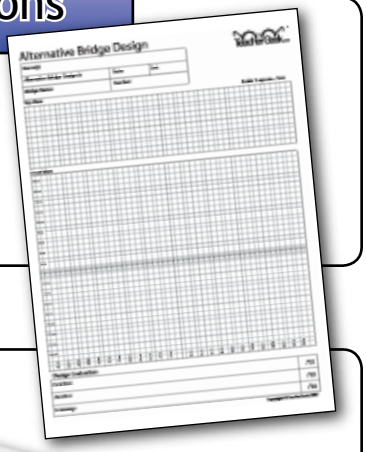
GLUE

Structures can be assembled and evaluated prior to gluing. Glue structures together before the final (destructive) test.

STEP 3

THE ENGINEERING DESIGN PROCESS
Generate Alternative Solutions

There is always more than one way to solve a problem. Your first idea is rarely your best. This process is about using your creativity and the information you gathered from step 2 to generate more then one solution to the problem.



ALTERNATIVE DESIGNS

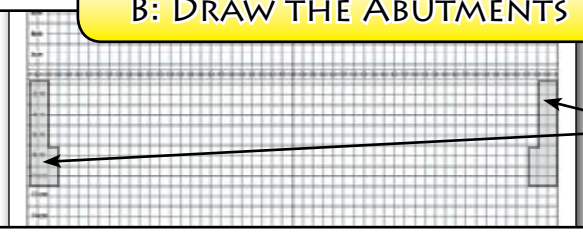
A: BRAINSTORM, SKETCH

Open your head and pour out as many possible bridge designs as you can. Sketch them on scrap paper. Select what you believe to be your 3 best designs. These 3 designs will be put on Alternative Design Sheets.

Explore creative processes: www.creatingminds.org

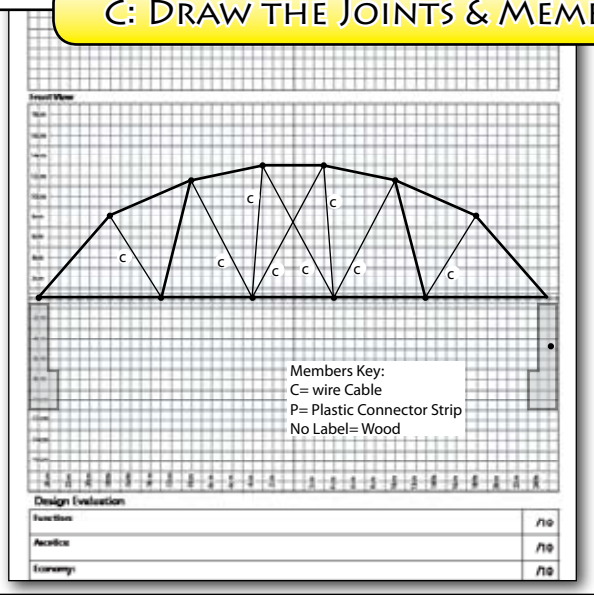
Repeat processes B to E for each of the 3 bridge designs you selected.

B: DRAW THE ABUTMENTS



As specified by your teacher, draw the bridge abutments on the Altnerative Design Sheet(s).

C: DRAW THE JOINTS & MEMBERS



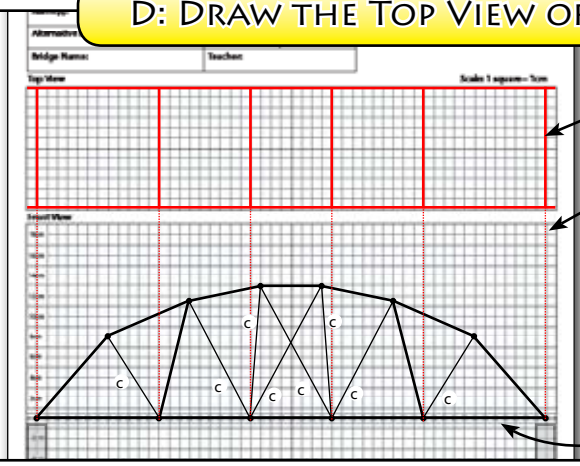
1st Draw dots representing the bridge joints (where the members will connect).

2nd Draw and label the members. Indicate the material and/or shape of each member.

As shown on page 5: The members can be wood, plastic (connector strips), wire, or other allowed materials.

Alternative Design Sheets (continued)

D: Draw the Top View of The Deck



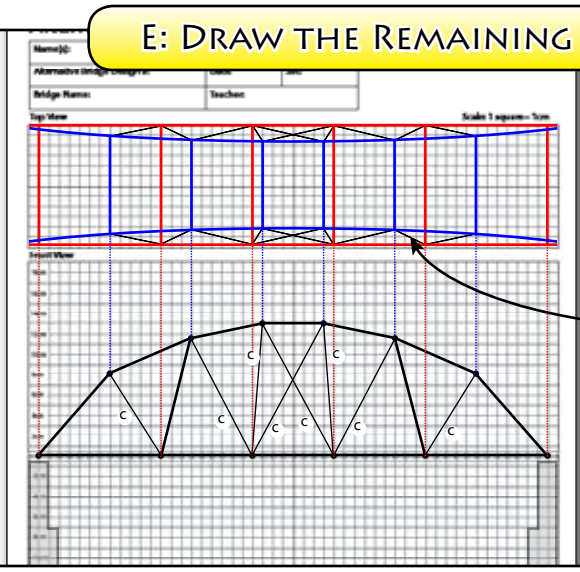
Top View of Bridge Deck

1st Extend lines straight up from the joints on the bridge deck. These lines show where dowels will go on the top view

2nd Draw the top view of the bridge deck.

Bridge Deck

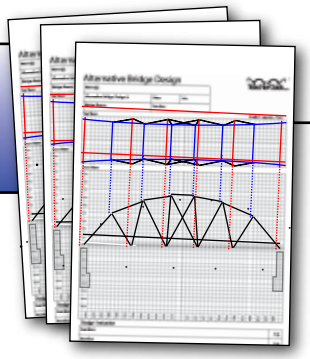
E: Draw the Remaining Members



Finish the top view by drawing the remaining visible members.

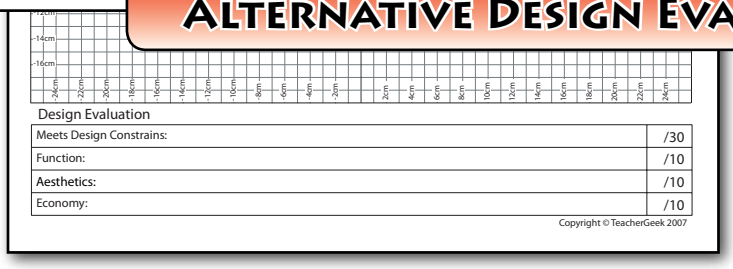
←The arches on this bridge contour inward similar to the bridge drawn to the left.

Step 4 The Engineering Design Process
Choose the Best Solution



Now it's time to analyze and evaluate your alternative designs to see how well they meet the design criteria. A final (best) design will be selected.

Alternative Design Evaluation


Design Evaluation

Meets Design Constrains:	/30
Function:	/10
Aesthetics:	/10
Economy:	/10

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Rate each alternative bridge design by completing the design evaluation at the bottom of each sheet.

Meets Design Constrains: Does it meet the established design constrains?

Function: How heavy of a load can it support without failing?

Aesthetics: Does it stand out as a unique, notable, attractive bridge?

Economy: How much would it cost to build? Members and joints are expensive; the more your bridge has, the heavier it will be, and the more it will cost.

Find the alternative bridge design with the best evaluation. Label it "Final Design." It will become the bridge you prototype and test.

Step 5 The Engineering Design Process
Modeling and Prototyping

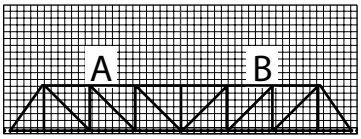
During this step you will create a working model of your final design.

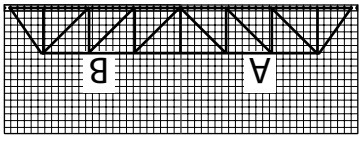
Prototype: An original, full-scale, and usually working model of a new product or new version of an existing product.

Scale Drawing of your Final Design

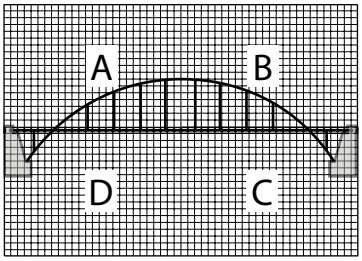
Your final bridge design needs to be drawn to scale (full size). You can use the bridge layout sheets for this. These sheets can be trimmed and taped together as shown:

Tape sheets A and B together for a superstructure bridge →





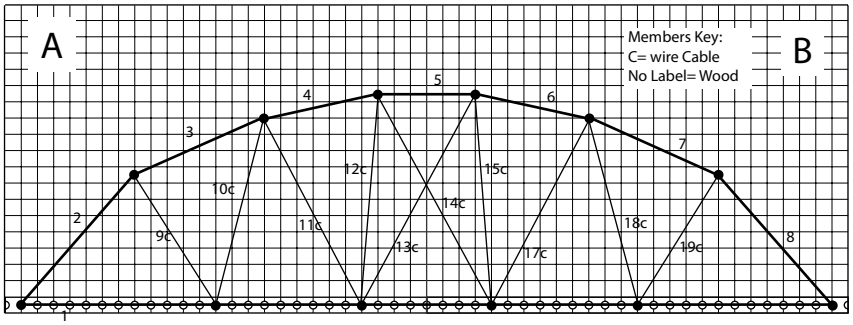
← Tape sheets A and B together, then flip them upside down, for a substructure bridge



Tape sheets A, B, C, and D together for a bridge with substructure and superstructure.

SCALE DRAWING OF YOUR FINAL DESIGN (CONTINUED)

Draw the joints and members from your final alternative design.

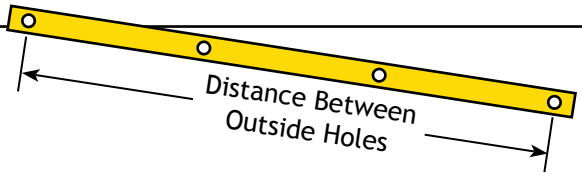


Label each member with a different number.

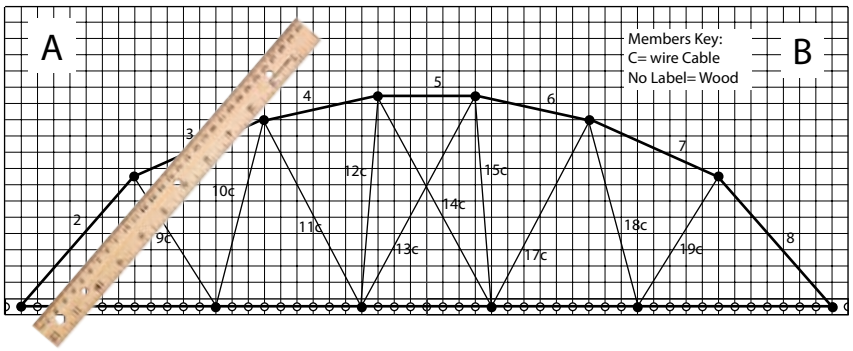
Label members with letters to indicate their material.

Your bridge may use different layout sheets than shown.

MEMBER LENGTH

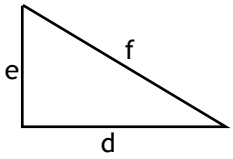


Find the distance between the outside joints on members (joints closest to member ends).



Use one of the following processes:

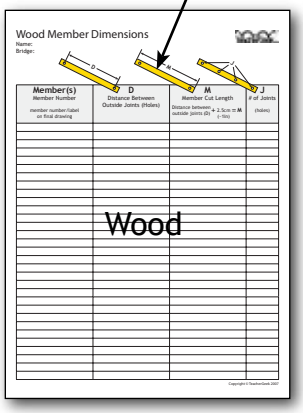
1. Pythagorean Theorem

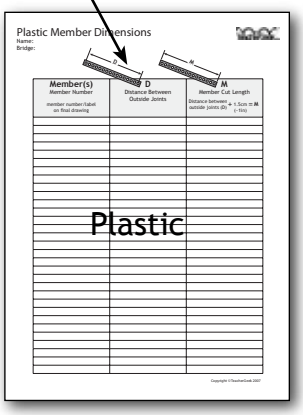


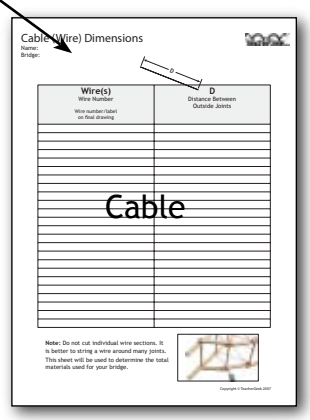
$$d^2 + e^2 = f^2$$

2. Measure with a ruler
3. Both: Use Pythagorean Theorem. Then check your answers with a ruler.

Record the distance between the outside joints for each member using the dimensions sheets.

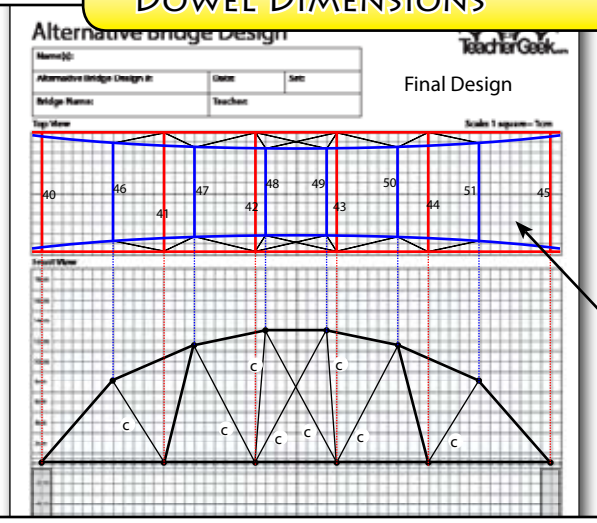






Member Length (continued)

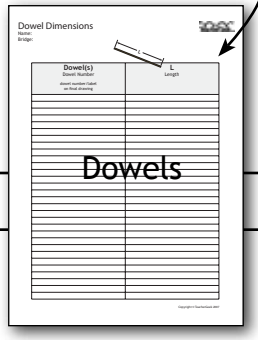
Dowel Dimensions



Use your final alternative bridge design sheet to find the length of the dowels that connect the sides of your bridge.

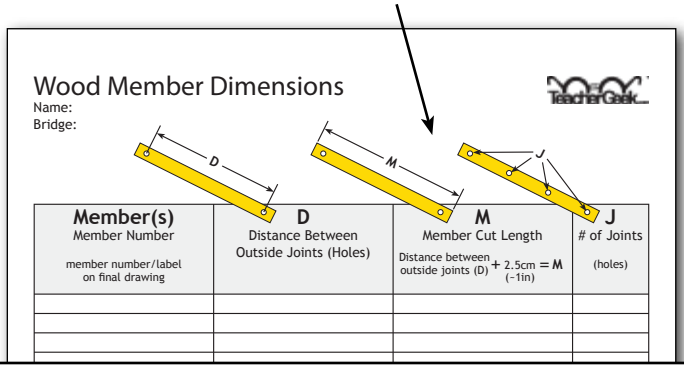
1. Label each dowel with a number
2. Determine the length of each dowel and record it on the Dowel Dimensions sheet

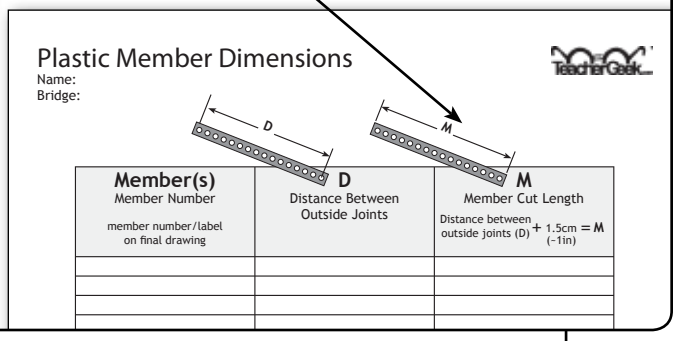
Each cell is 1cm x 1cm



Calculate Member Cut Sizes

Find the size to cut the Wood and Plastic Member to by completing the dimensions sheets.



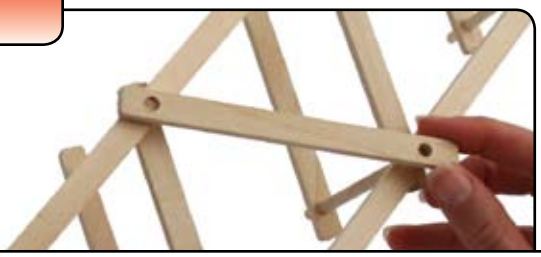


Measure & Cut

Measure and cut the wood members, plastic members and dowels. Label each member with it's number.

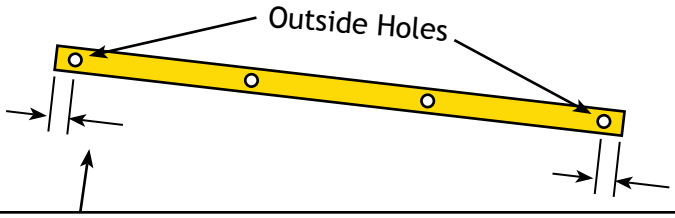
Drill Wood Members

Wood members must be drilled where they will be joined (pinned with a dowel) to other members.



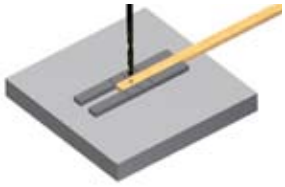
A: Drill Outside Holes

Drill the outside holes in each wood member using a #3 drill bit.



If your bridge members were measured using a **metric** ruler:
The outside holes (joints) should be drilled 1.2cm in from the member ends.

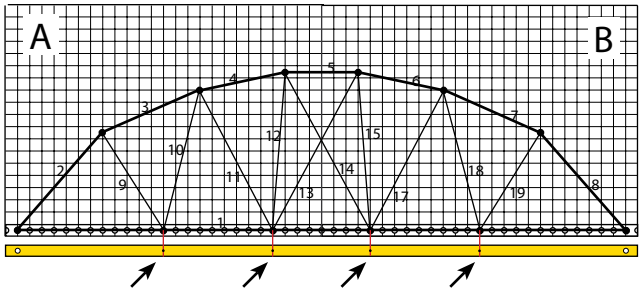
If you bridge members were measured in **inches**:
The outside holes (joints) should be drilled 1/2in from the member ends.

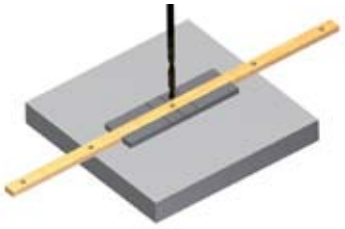


A jig can easily be made to assist in drilling holes. The last page in this packet shows you how to make and use one.

B: Drill Inside Holes

If a member requires more than outside holes, you will need to transfer the hole locations from you full size drawing to the wooden member.





The drilling jig allows you to quickly and accurately drill inside holes.

Assembling The Bridge

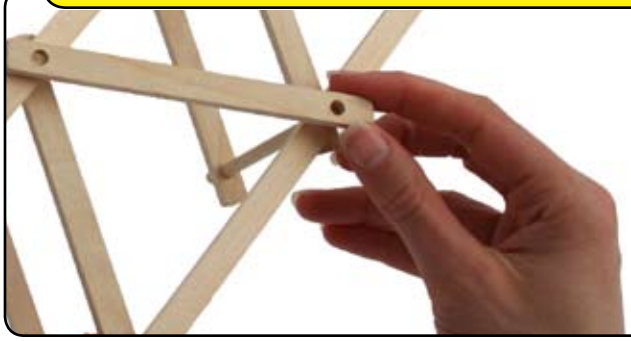
Glue

Most structures can be assembled and evaluated before gluing.
The exception: The members forming an arch must be secured with glue before stringing cables from them.

A: Manufacture Beams

Beams can be made by gluing multiple wooden members together.

B: Assemble the Wooden and plastic Members



Pin the bridge members together using the corresponding dowel sections.

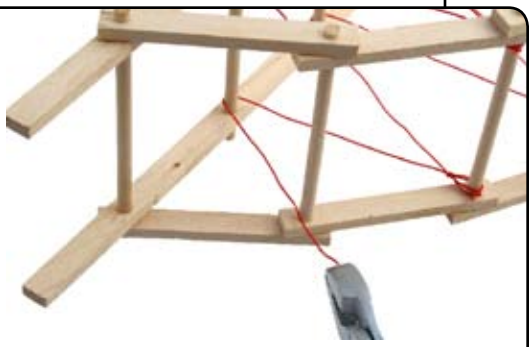
Refer to your final bridge drawing and bridge layout sheet for this process.

Tip: Assemble your bridge on top your bridge layout sheet (full scale drawing).

C: String the Cables (Wire)

Cables can be secured to dowels at joints.

Cables can be wrapped multiple times around joints for added strength.



Pliers can be used to tension cables before fastening them.

D: Move On

Is your bridge the best that it can be? Don't glue it together yet. Move on to step 5

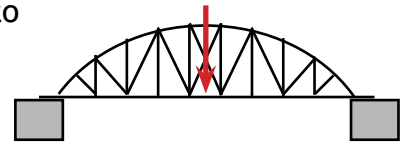
STEP 5

THE ENGINEERING DESIGN PROCESS
Test and Evaluate


Take a picture of your bridge

PRE-TEST EVALUATION

Use the Pre-Test Evaluation & Revision sheet for this process. You will apply a small load to your bridge (without breaking it) to see how it performs.



Around The Design Process

Optimal Solution

GLUE

When your bridge is the best it can be (no more evaluation and revision), glue it together.

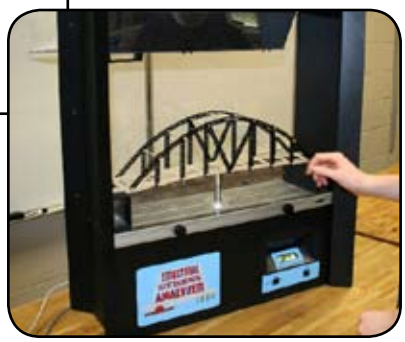
REVISE IT

Use the information gathered in the Pre-Test Evaluation to redesign and improve your bridge.


Take pictures of your bridge

DESTRUCTIVE TEST (FINAL TEST)

Find the maximum load your bridge will support by increasing the load on it until it breaks. Your teacher will be happy to help you break your bridge.



POST EVALUATION

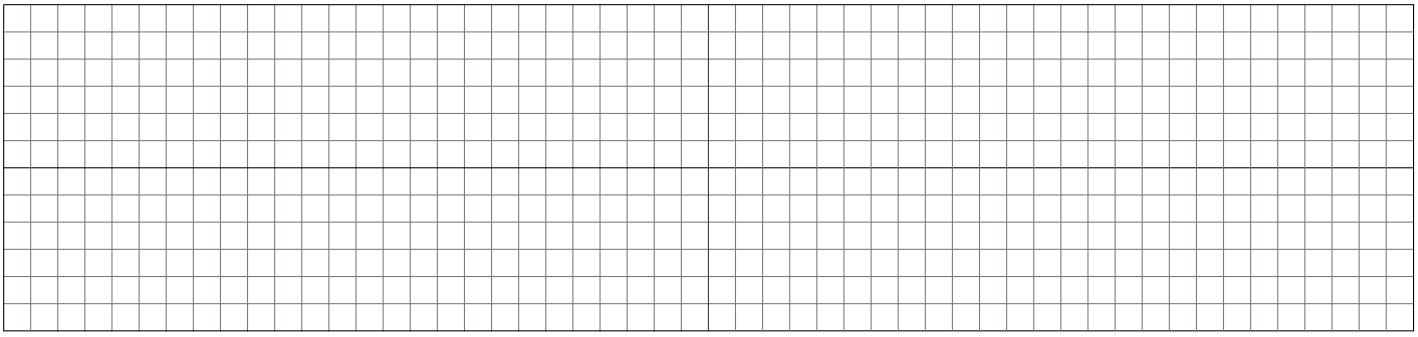
Evaluate and summarize the design and testing of your bridge using the Post-Evaluation Bridge Sheet.

Alternative Bridge Design

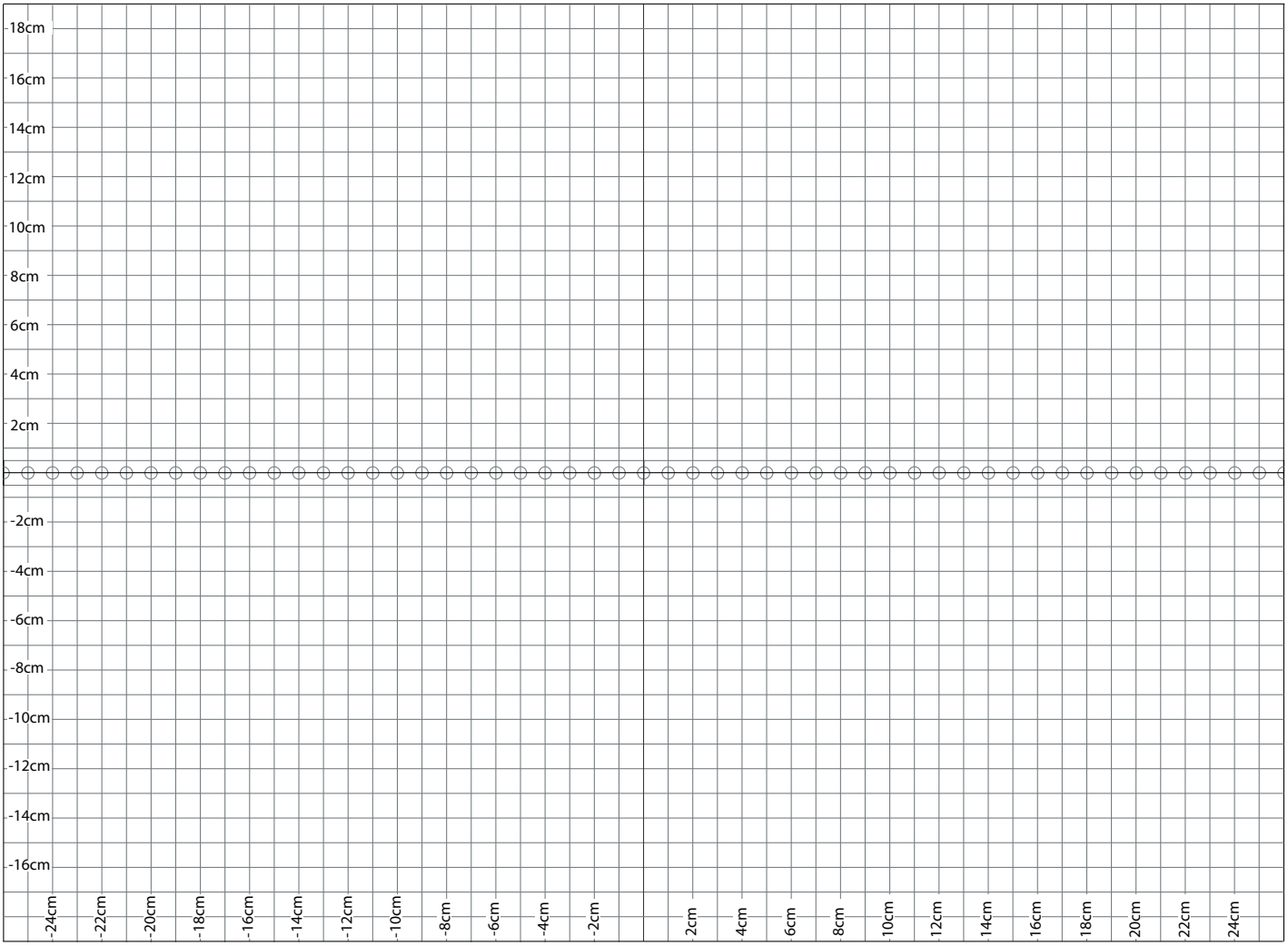
Name(s):		
Alternative Bridge Design #:	Date:	Set:
Bridge Name:	Teacher:	

Top View

Scale: 1 square= 1cm



Front View



Design Evaluation

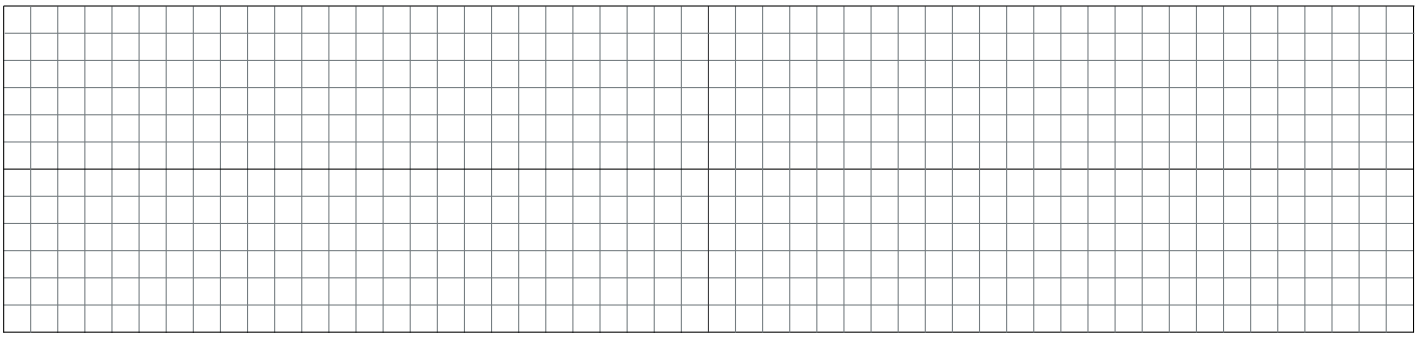
Meets Design Constraints	/30
Function:	/10
Aesthetics:	/10
Economy:	/10

Alternative Bridge Design

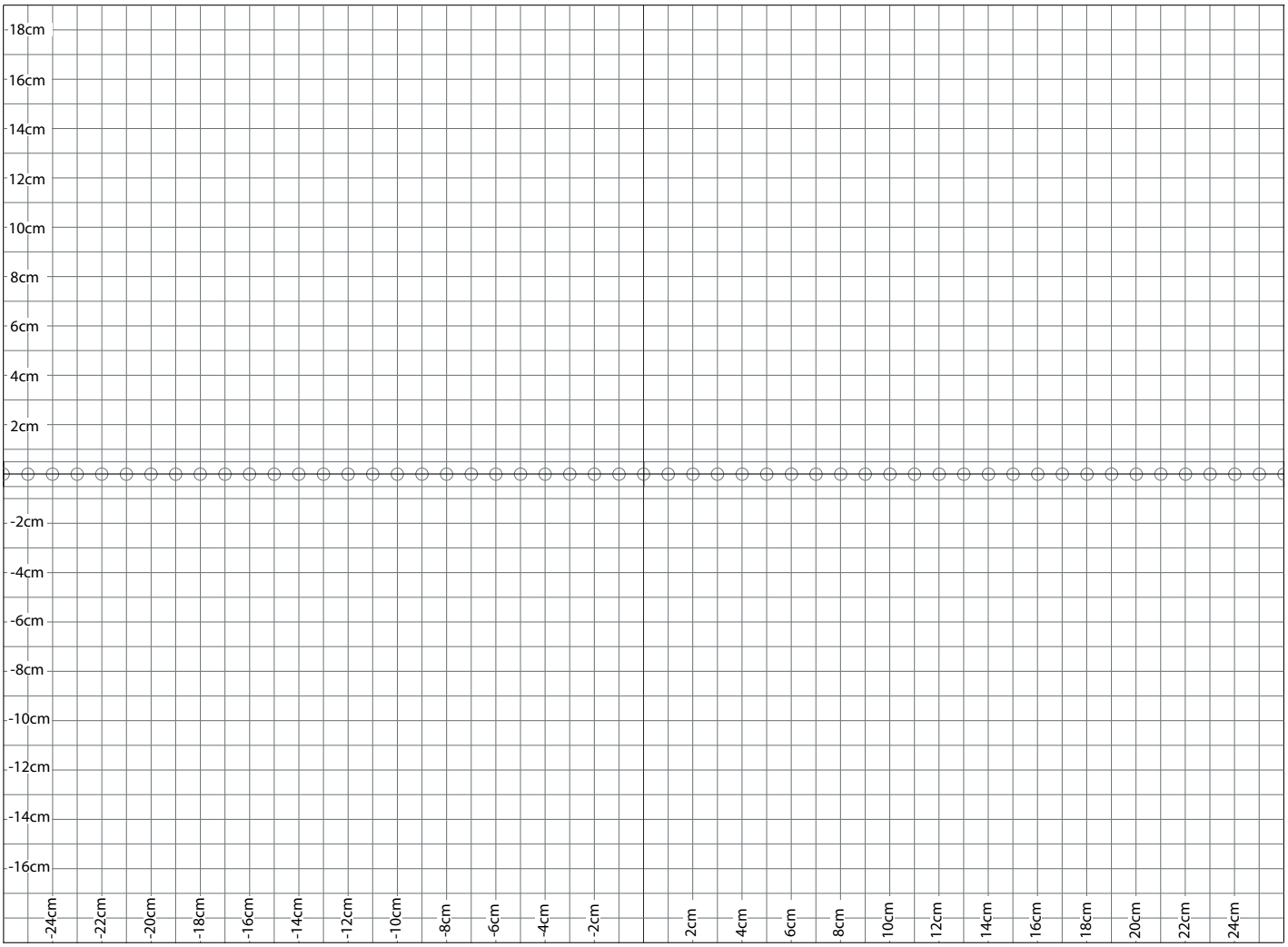
Name(s):		
Alternative Bridge Design #:	Date:	Set:
Bridge Name:	Teacher:	

Top View

Scale: 1 square= 1cm



Front View



Design Evaluation

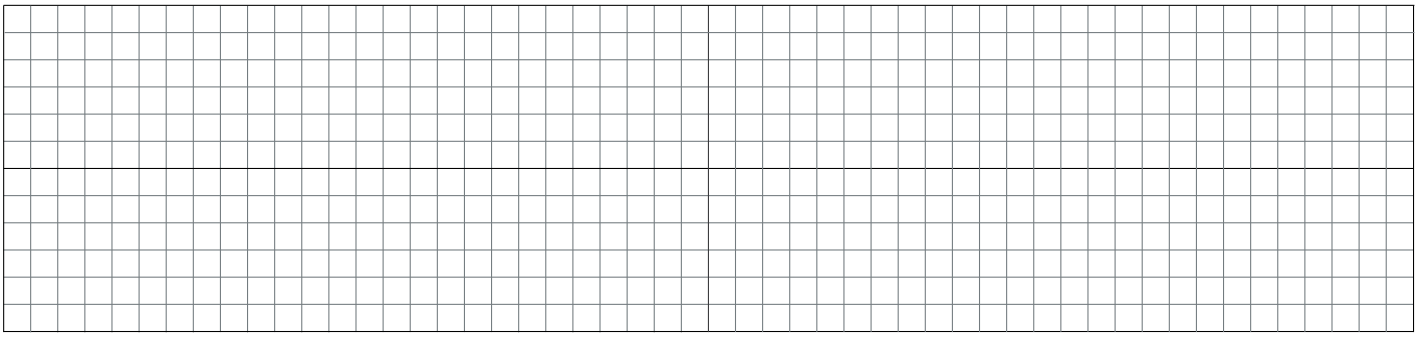
Meets Design Constraints:	/30
Function:	/10
Aesthetics:	/10
Economy:	/10

Alternative Bridge Design

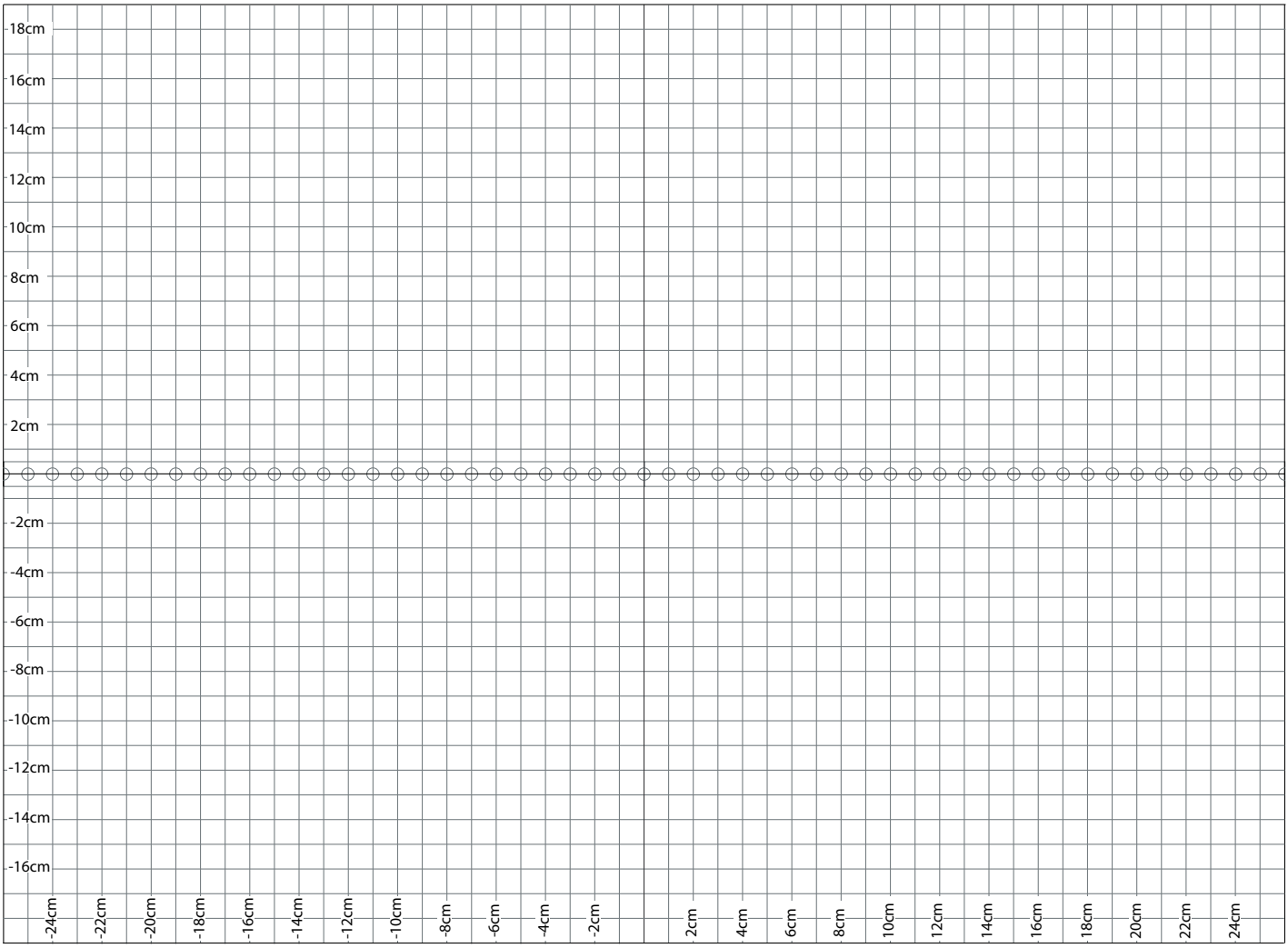
Name(s):		
Alternative Bridge Design #:	Date:	Set:
Bridge Name:	Teacher:	

Top View

Scale: 1 square= 1cm



Front View



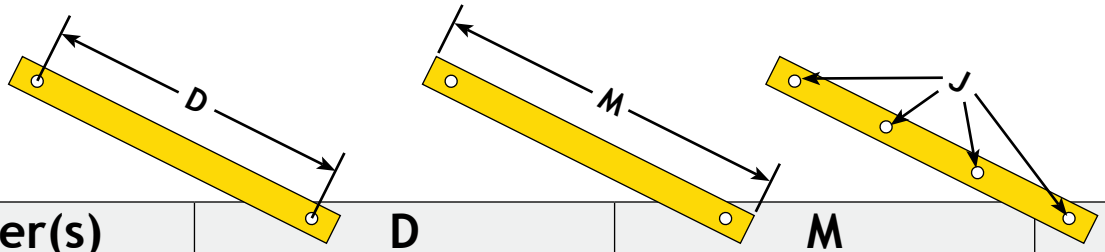
Design Evaluation

Meets Design Constraints:	/30
Function:	/10
Aesthetics:	/10
Economy:	/10

Wood Member Dimensions

Name:

Bridge:

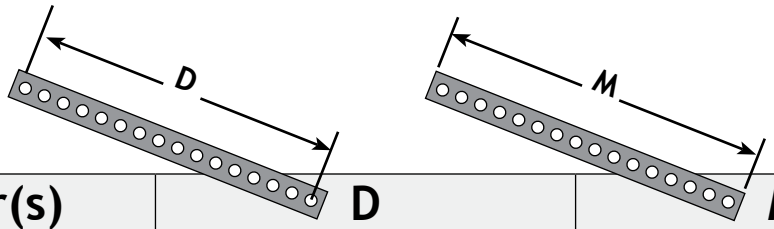


Member(s) Member Number Member number/label on final drawing	**D** Distance Between Outside Joints (Holes)	**M** Member Cut Length Distance between outside joints (D) + 2.4cm or 1in = M	**J** # of Joints (holes)

Plastic Member Dimensions

Name:

Bridge:

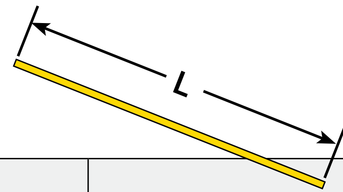


Member(s) Member Number Member number/label on final drawing	**D** Distance Between Outside Joints	**M** Member Cut Length Distance between outside joints (D) + 1.5cm (~1in) = **M**

Dowel Dimensions

Name:

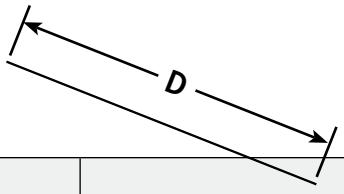
Bridge:



Dowel(s) Member Number Member number/label on Alternative Design Sheet	**L** Length

Cable (Wire) Dimensions

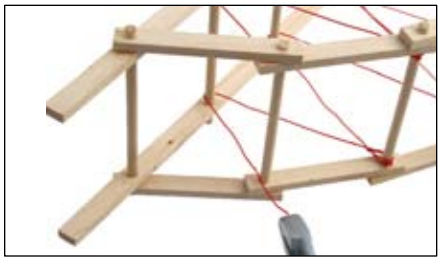
Name:
Bridge:

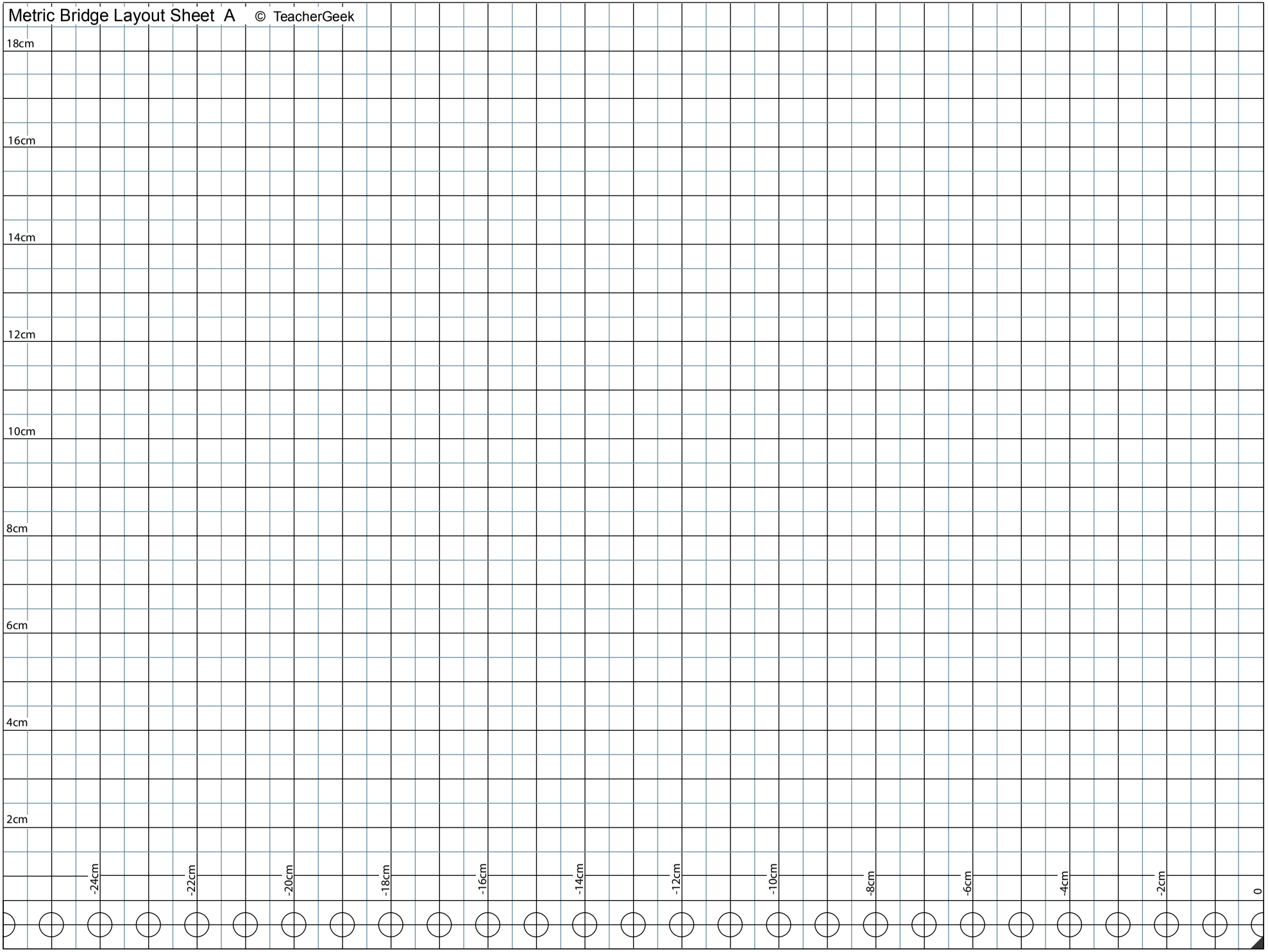


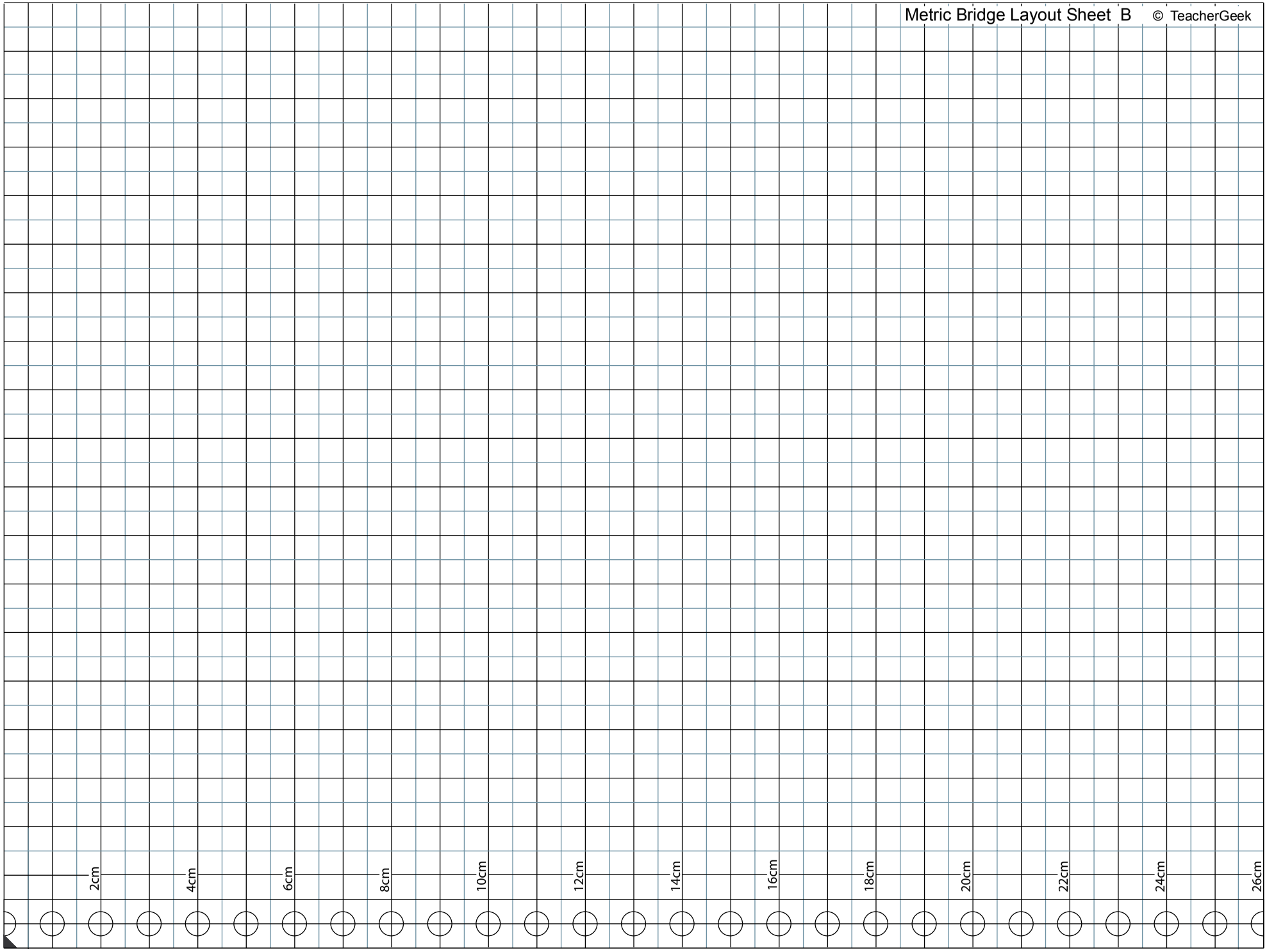
Wire(s) Wire Number Wire number/label on final drawing	**D** Distance Between Outside Joints

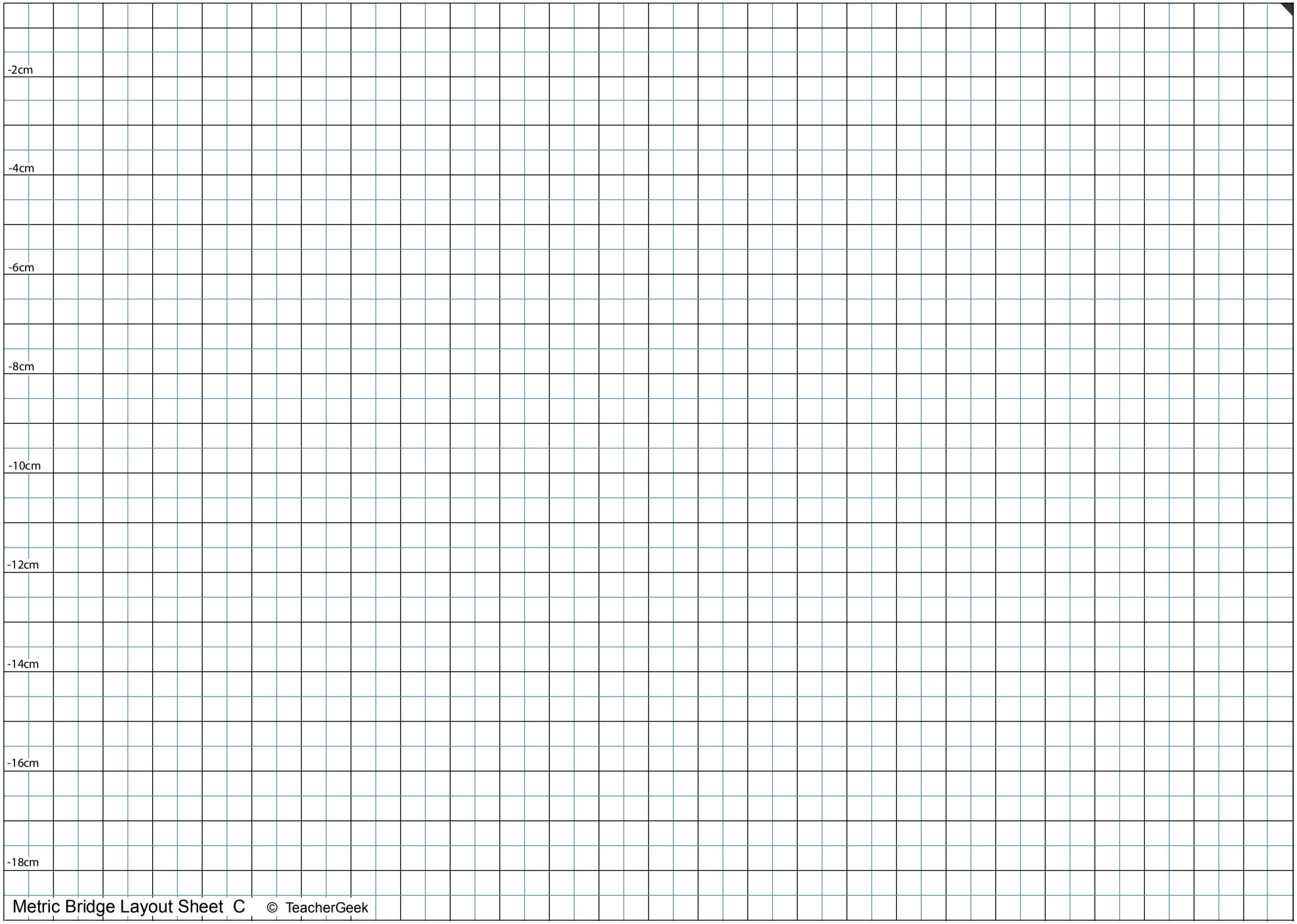
Note: Do not cut individual wire sections. It is better to string a wire around many joints.

This sheet will be used to determine the total materials used for your bridge.




Metric Bridge Layout Sheet A © TeacherGeek
18cm
16cm
14cm
12cm
10cm
8cm
6cm
4cm
2cm
-24cm
-22cm
-20cm
-18cm
-16cm
-14cm
-12cm
-10cm
-8cm
-6cm
-4cm
-2cm
0


Metric Bridge Layout Sheet B
© TeacherGeek
2cm
4cm
6cm
8cm
10cm
12cm
14cm
16cm
18cm
20cm
22cm
24cm
26cm


-2cm
-4cm
-6cm
-8cm
-10cm
-12cm
-14cm
-16cm
-18cm
Metric Bridge Layout Sheet C © TeacherGeek

Metric Bridge Layout Sheet D © TeacherGeek

Pre-Test Bridge Evaluation & Revision

Name:
Bridge:
Set:

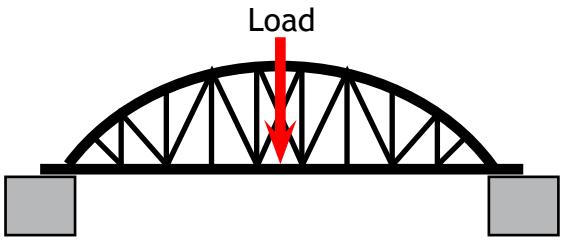
What will you need?

- 1 photocopy of your Final Alternative Bridge Design sheet
- Colored Pencils (3 different colors)
- Bridge Abutments- The ones that will be used to for the final test
- Digital Camera

1. Take a picture of the top and side of your bridge. Save these pictures so they can be used in your concluding report.

2. Write "Pre-Test Evaluation" on the top of one photocopied Final Bridge Design Sheet. Color code the bridge members drawn on the sheet according to the force you think they will be under when tested. Forces: tension, compression, or no load. Use a key to associate each color with the force it represents.

3. **Stress It:**
Place your bridge on the abutments provided by your teacher. Carefully press down with your hands to simulate a load on the center of the bridge deck. Use just enough force to see the bridge deflect (bend) slightly. Don't break it!!! Record your findings below:



Study each member as you apply a slight load to your bridge. Find 2 or more members you think would fail first if the load on your bridge was increased. Label them on the "Pre-Test Evaluation" sheet as F1, F2... Complete the table below.

Member #	Why do you think the member will fail?
F___	
F___	
F___	
F___	

Pre-Test Bridge Evaluation & Revision (continued)

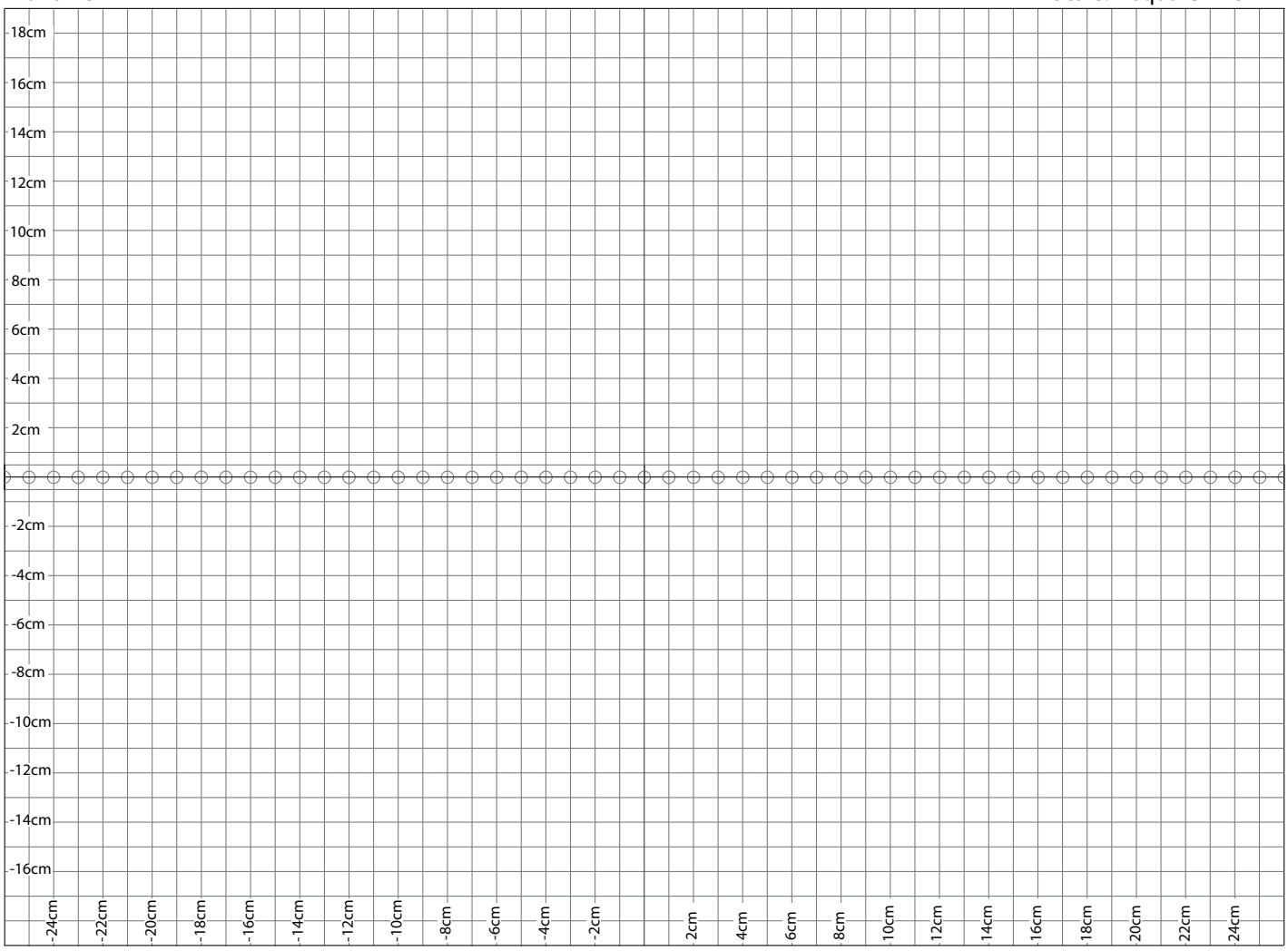
4. **Improve It:**
Use the information gathered in step 3 to redesign and improve your bridge. List the changes and draw the revised bridge.

Changes:

Revised Bridge:

Front View

Scale: 1 square= 1cm



5. **Stress and Evaluate It Again:**
Stress your bridge the same way you did in step 3 while studying the members (without breaking them). Does the redesigned bridge perform as you hoped (better than the original design)?

6. **Decide:**
If your bridge seems to be the best it can be (the optimal solution), glue it together and perform the final destructive test. If the bridge can still be improved, take your bridge through another "Pre-Test Bridge Evaluation & Revision" cycle.

Post-Test Bridge Evaluation

Name:
Bridge:
Set:

1. Calculate the design efficiency of your bridge.
Show the math.

$$\text{Design Efficiency} = \frac{\text{Ultimate Load Capacity}}{\text{Deadweight of Bridge}}$$

Ultimate Load Capacity: Greatest load successfully carried by the bridge (prior to failure)

Deadweight of Bridge: The weight of the bridge and nothing else

2. Total Length of Materials Used:

Wood Members: _____ Plastic Members: _____ Dowels: _____ Cables: _____

3. Concluding Report:

- Construct a _____ page report summarizing the following:
    1. Bridge Design Process & Revisions
    2. Bridge Aesthetics
    3. Bridge Efficiency & Economy
    4. Bridge Performance & Failure
        a. Cause of bridge failure
        b. How the terminal bridge failure could have been avoided (how the bridge design could be improved to support a greater load)

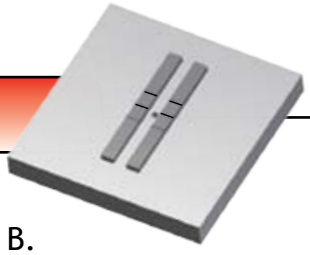
- Reference and include bridge pictures and drawings.

- Properly utilize the following terms in your report.
    1. Abutment
    2. Buckle
    3. Compression
    4. Deflection
    5. Engineer
    6. Force
    7. Joint
    8. Load
    9. Rigid
    10. Span
    11. Stress
    12. Tension

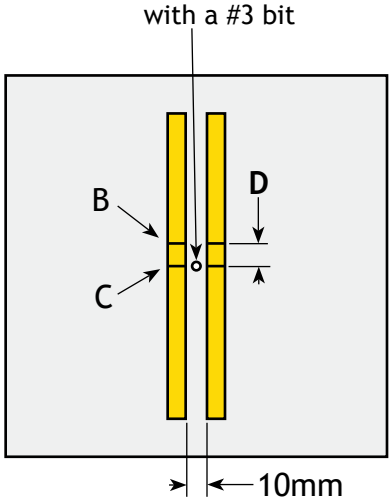
4. Project Evaluation Rubric

	Meets Design Criteria	Performance	Aesthetics	Craftsmanship	Student Participation	Drawings and Sheets	Report	Total Points:
Student:	/15	/15	/15	/15	/10	/10	/20	/100
Teacher:	/15	/15	/15	/15	/10	/10	/20	/100

Making a Drilling Jig



A drilling jig can be made by attaching 2 wood strips to a wood base, as illustrated below, and drawing marks A and B.



Mark C:

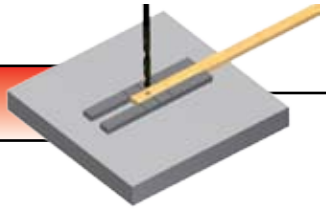
- The center mark. This mark is inline with the hole drilled.

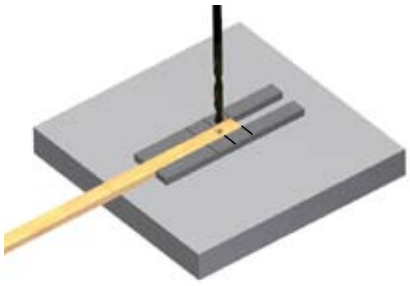
Mark B:

- The end of the wood strip to be drilled will be aligned with this mark.
- Mark B should be placed:
  - 1.2cm from mark A if you are measuring your bridge in metric (distance "D")
  - 1/2in from mark A if you are measuring your bridge in inches (distance "D")

The jig should be secured to a drill press so that bit is precisely aligned with mark C and in the center of the 10mm gap.

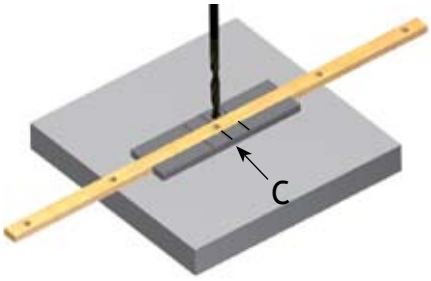
Using a Drilling Jig





To Drill Outside Holes:
Place the wood strip into the drilling jig so it is under the drill bit and its end is aligned with mark B. Secure and drill the member.

To Drill Inside Holes:
Place the member into the jig so the mark for the inside hole aligns with the center mark on the jig (C). Secure and drill the member.



Be safe when drilling members; this includes clamping the work and wearing safety glasses.