DEVELOPING TRADES MATH WORKSHEETS

A Handbook for Construction Trades Instructors

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DEVELOPING A Handbook for Construction Trades Instructors
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Introduction

If you are reading this guide, it probably means you are looking for ways to make technical training math worksheets that work. The information in this guide is based on an Essential Skills foundation and extensive experience developing math worksheets for apprentices in technical training settings.

Who is this guide for?
Are you a technical training instructor? Is math a part of your instruction? Then this guide is for you. During training and on a work site, apprentices need more than just math skills. They need strong Essential Skills to succeed in training and on the job. You will learn how to apply Essential Skills understanding to make worksheets that meet your instructional goals and help your apprentices to better learn trades math.

What are Essential Skills?
Essential Skills is the name for the nine skills that people need for learning, work and life. The nine skills are: reading, document use, numeracy, writing, oral communication, working with others, thinking, computer use and continuous learning.

How do apprentices use Essential Skills during technical training?
Apprentices use Essential Skills during technical training in a variety of ways. The following are just a few examples of how apprentices use Essential Skills. They use:

- reading skills when they read textbooks, codebooks and manuals
- document use skills to locate and understand information in drawings, tables and schematics
- writing skills to take notes and fill-in forms
- numeracy skills to calculate volumes, weight loads and ratios

What do apprentices bring to technical training?
Each of the apprentices in your classroom has a unique history and skill set. Some may have done well in school, some may not have finished school and some may have struggled with math. In our experience with apprentices, those who have difficulty with numeracy:

- Have forgotten math basics
- Did not learn some concepts in the first place
- Do not see the connection between what they did in school and technical training

As an instructor, you may need to address these issues when you teach numeracy and math skills. Those who have forgotten need review and practice. Those who did not learn in the first place need to be taught. Those who do not see the connection need help to make the connection between what they did in school and their application to technical training.
What do apprentices find difficult?
Knowing the difficulties some apprentices have will help you target your teaching and worksheets to address those problems and close the gaps. The following are some of the common numeracy problems apprentices have:

- translating a problem into a set of mathematical operations
- deciding where to start
- transferring what they learned solving one problem to another similar problem
- seeing relationships between formulas

Who are the worksheets for?
The worksheets you make using this guide are aimed at apprentices who are performing at a borderline percentile of between 65 - 75% which is around the IP Red Seal examination pass/fail percentile of 70%. The ones who are doing well will do well without these worksheets. The ones who lag far behind need more support than these worksheets can offer. This guide aids the instructor in making worksheets that may help apprentices who are performing at the borderline to address the problems mentioned in the previous paragraph and help close the gaps.

How do you use this guide?
This guide will lead you through the process of developing an effective technical training math worksheet. It is a good idea to skim through the table of contents to get an overall picture of how to develop worksheets. The guide is arranged in several sections. The sections guide you through the planning process, so it is a good idea to work through the guide in order. A Developing Numeracy Worksheets Checklist is included in Section 5. This checklist brings all the information together on one page for easy reference.

Included in this guide are worksheets developed by actual technical training instructors who used the process presented in this guide. Use these worksheets as a reference, as a source for ideas or to photocopy for use in your own instructional setting.
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Provides examples of worksheets and answer keys that can be used as reference or copied for use in technical training classrooms. Includes a complete Developing Numeracy Worksheets Checklist for easy reference.
Section 1: Identifying an Instructional Goal

In this section
• What do you want apprentices to be able to do?
• Is your instructional goal general or specific?
• What skills and subtopics do the apprentices need to know?
• Do you need to review these skills and subtopics?
• What are you going to test?
• Identifying an Instructional Goal Checklist

What do you want apprentices to be able to do?
Know what your instructional goal or focus is. If you are clear about what you want apprentices to do, then you can build your worksheet toward your instructional goal. To set your instructional goal, finish this statement:

*This statement is your instructional goal*

**Examples**

- I want apprentices to be able to calculate the amount of paint needed for a room.
- I want apprentices to be able to calculate distances and angles to lay out materials for cutting and fabrication.
- I want apprentices to be able to calculate the weight of a load lifted by a crane.
- I want apprentices to be able to calculate a 45° offset.
- I want apprentices to be able to calculate the amount of paint needed for a room.
- I want apprentices to be able to calculate distances and angles to lay out materials for cutting and fabrication.
- I want apprentices to be able to calculate the daylight opening of a window.
- I want apprentices to be able to calculate the weight of a load lifted by a crane.
Is your instructional goal general or specific?
Look at the following examples of instructional goals. One is general and the other is more specific. Both types are useful; it depends on what your instructional goal is.

General
The more general your instructional goal is, the broader your worksheet can be. This may be helpful when introducing a skill or reviewing a skill. In this example, calculating weight loads is the skill that is being taught or reviewed.

Specific
The more specific your instructional goal is, the more targeted your worksheet will be. This may be helpful when targeting a particular skill or to reinforce a particular concept. In this example, calculating weight loads is the skill being practiced while working in cubic feet is being reinforced.

What skills or subtopics do the apprentices need to know?
For each instructional goal, there are skills and subtopics that are needed in order to achieve that instructional goal. Look at the following example.

Now list the skills or subtopics the apprentices need in order to: calculate weight loads in cubic feet.

Skills and Subtopics:
- formulas for volume for:
  - rectangular solids: \( V = L \times W \times H \)
  - cylinders: \( V = \frac{d \times d \times \pi \times H}{4} \)
- commonly used approximate weights for:
  - steel: 490 lbs/ft\(^3\)
  - reinforced concrete: 150 lbs/ft\(^3\)
- converting inches and fractions of an inch to decimals of a foot
- formula for weight: \( W = V \times \text{weight in lbs/ft}^3 \)
Do you need to review these skills and subtopics?

Look at the list of skills and subtopics you listed for your instructional goal.

- Decide which of these subtopics will need to be reviewed
- Decide how you will review
  - as a class
  - as a note on the worksheet
  - through tutoring
  - by assigning self-study work

What are you going to test?

Know which skills and topics you are going to test. Develop your worksheets with the tests in mind. That means you will need to think about testing early on.

- What are you going to test?
- How are you going to test?

When you develop worksheets that reflect what and how you are going to test the apprentices, you are preparing them for success.

Developing Numeracy Worksheets Checklist

Identifying an instructional goal:
- Identify your instructional goal.
  \[ \text{I want apprentices to be able to} \text{_______________________________} \]
- Make a list of skills apprentices need to reach the goal:
  - 
  - 
  - 
  - 
- Gather or make materials that relate to the instructional goal.
  - Diagrams
  - Photos
  - Examples

Setting up an example:
- Include the question
- Include a note, if needed, of information that is required or helpful
- Include clearly labelled photos or drawings
- Break down the process into steps
- Explain each step briefly
Section 2: Trades-Related Questions and Materials

What are trades-related questions?
Trades-related questions have a clear connection to technical training. The questions that you develop for your worksheet should be relevant to an apprentice’s technical training. The skills and knowledge content in technical training can be sorted into these main purposes:

- for foundational understanding of trades principles
- for practical application on the job
- for background knowledge needed for the IP Red Seal examination

Questions that are directly linked to any one of these purposes are trades-related questions. Using authentic materials in an authentic trades-related way is the best way to make your questions relevant.

What are authentic materials?
Authentic materials include drawings, tables, photos, diagrams, textbooks and codebooks that apprentices encounter during their training. Any material that has a real-world, technical training connection is authentic.
**Why should you use authentic materials?**
When the material is real, relevant and useful, apprentices are more motivated to learn. When motivation is high, success in learning and retaining what they learned is improved.

**What materials should you collect?**
You may teach from a textbook and set curriculum, but you can develop worksheets using a wide variety of authentic materials. The following are some ideas for the materials you can collect:

- textbooks
- codebooks
- reference guides
- manuals
- trade magazines
- specifications
- products labels
- product instructions
- data books
- operator manuals
- drawings
- diagrams
- photos
- old tests
- multi-media presentations (e.g. PowerPoint)
- electronic white boards

You can find authentic materials in several places. You can find materials from training school libraries, colleagues, school workshops, work sites, colleges, written material or packaging that comes with equipment, health and safety organizations and the internet (photos, diagrams, manufacturers’ websites, and trades’ associations websites).

**NOTE:**
Some issues to consider about collecting materials:

- Meets your instructional goals. Choose material based on how well it fits with your instructional goals.
- Accurate content. Sometimes there are errors in the materials you collect. Look over the material carefully to see that all the information is accurate.
- Current with trade standards. Check the National Occupational Analysis (NOA) for your trade for codes and practices that are the current standard.
- Copying permission. If you are using material from another source and want to make copies for classroom use and distribution, be sure to comply with copying rights to make copies.
- Reprint permission. If you plan to publish your worksheets and distribute them outside of your classroom, be aware that you need to get permission to reprint material that you get from other sources.
How do you develop trades-related questions?

1. Identify your instructional goal.

2. Collect authentic material that is relevant to this goal.

3. Provide the necessary background knowledge and trades-specific formulas or procedures that apprentices need to answer the question.

For example, a standard formula for the area of a circle is $A = \pi r^2$, but in some trades they use $A = \frac{(d \times d \times \pi)}{4}$.

### Load Weights - Calculating

<table>
<thead>
<tr>
<th>Materials and Liquids - Pounds / Cubic Feet</th>
<th>Pounds / Square Feet</th>
<th>Pounds / Gal.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>165</td>
<td>Steel plate</td>
</tr>
<tr>
<td>Asbestos</td>
<td>153</td>
<td>$\frac{1}{8}$</td>
</tr>
<tr>
<td>Asphalt</td>
<td>81</td>
<td>$\frac{1}{4}$</td>
</tr>
<tr>
<td>Brass</td>
<td>524</td>
<td>$\frac{3}{4}$</td>
</tr>
<tr>
<td>Brick</td>
<td>120</td>
<td>1</td>
</tr>
<tr>
<td>Bronze</td>
<td>534</td>
<td>Aluminum plate</td>
</tr>
<tr>
<td>Coal</td>
<td>56</td>
<td>$\frac{3}{8}$</td>
</tr>
<tr>
<td>Concrete, Reinf.</td>
<td>150</td>
<td>$\frac{1}{8}$</td>
</tr>
<tr>
<td>Crushed Rock</td>
<td>95</td>
<td>Lumber</td>
</tr>
<tr>
<td>Diesel</td>
<td>52</td>
<td>$\frac{3}{4}$</td>
</tr>
<tr>
<td>Dry Earth, Loose</td>
<td>75</td>
<td>$\frac{3}{8}$</td>
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<tr>
<td>Gasoline</td>
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</tr>
<tr>
<td>Glass</td>
<td>162</td>
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<tr>
<td>Iron Casting</td>
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<td>Lead</td>
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<tr>
<td>Lumber- Fir</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Lumber- Oak</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>Lumber- RR Ties</td>
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<tr>
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<td>58</td>
<td></td>
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<tr>
<td>Paper</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>Portland Cement</td>
<td>94</td>
<td></td>
</tr>
<tr>
<td>River Sand</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Steel</td>
<td>480</td>
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</tr>
<tr>
<td>Water</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>437</td>
<td></td>
</tr>
</tbody>
</table>

### Formulas and Information

- $H =$ Height
- $W =$ Width
- $L =$ Length
- $d =$ diameter
- $r =$ $\frac{1}{2}$ diameter
- $\pi =$ 3.2 (approx.)
- Area of square or rectangle = $LW$
- Volume of cube = $HWL$
- Area of circle = $\pi r^2$
- Circumference = $\pi d$
- The area of a circle is approx. 80% of its diameter squared (diameter $\times$ diameter)
- Load Weight (to estimate) = Volume in cu. ft. $\times$ 500 lbs. $\times$ density factor 0.02, 0.05, 0.10, 0.20, 0.30, etc.

### Trades-Related Questions Checklist

Gather or make materials that relate to the instructional goal.

- Diagrams
- Photos
- Examples

Provide background knowledge and trades-specific formulas and procedures.
Section 3: Developing Worksheets

In this section
- What does a worksheet include?
- How do you plan a worksheet?
- How do you set up an example?
- How do you write steps?
- How do you organize questions?
- Developing Numeracy Worksheets Checklist

What does a worksheet include?
A worksheet includes at least one example and a series of questions to practice the instructional goal. The example is important because it models one way to solve the problem systematically and logically.

How do you plan a worksheet?
As always, start with your instructional goal.

I want apprentices to be able to calculate the weight load for a crane lift.

Then brainstorm the skills and knowledge needed to complete the instructional goal. Look at the example that follows:

In order for apprentices to calculate the weight load for a crane lift, they need to:
- know the formulas for the volumes of different geometric solids
- know the common approximate weights of different materials
- know the formula for calculating weights
- convert inches and fractions of an inch to decimals of a foot

Once you have brainstormed the skills and background knowledge needed, you can see what you might need to review or teach the apprentices in order for them to successfully do the worksheet. Decide how you will review or teach these skills in order to prepare apprentices for success with the worksheet.
How do you set up an example?

You have decided on your instructional goal. You have brainstormed the skills and knowledge needed to complete the instructional goal and have decided how to review or teach those necessary skills or knowledge. In Section 2, you learned how to write trades-related questions using authentic materials. Now you are ready to set up an example to start your worksheet.

To set up an example:

- Include the question.
- Include a note, if needed, for information that is needed or helpful.
- Include clearly labelled photos and drawings.
- Break down the process into steps.
- Explain each step briefly.

Calculate the volume of concrete needed for the battered wall.

**Note:** Convert all measurements to feet and decimals of a foot before calculating the volume.

\[
\begin{align*}
6'' &= 0.5' \\
1' - 6'' &= 1.5' \\
6' - 5'' &= 6.42'
\end{align*}
\]

**Step 1:** Calculate the average wall thickness.

\[
\text{Average wall thickness} = \frac{1.5' + 0.5'}{2} = \frac{2'}{2} = 1'
\]

**Step 2:** Calculate the volume of concrete.

\[
\text{Volume} = L \times W \times H = 6.42' \times 1' \times 2' = 12.84 \text{ ft}^3
\]

**Step 3:** Convert ft\(^3\) to yd\(^3\).

\[
12.84 \text{ ft}^3 \div 27 \text{ ft}^3 = 0.48 \text{ yd}^3
\]
How do you write steps?

- Decide on the breakdown of steps
  - Each step includes one or more calculations. For example, for calculating weight loads, **Step 1** would be **Calculate the volume of the object**. The shape of the object (regular or irregular shape) determines how many calculations are needed for that first step.
  - Breakdown steps to address the apprentices’ level of understanding
  - Breakdown steps to match standard practices used in your trade
  - Choose the formulas and constants that are typically used in your trade

- Start each step with an action word.
- Decide on the order of steps
- Explain each step in a brief sentence

Some notes about the example steps:

Calculate the volume of concrete needed for the battered wall.

Note: Convert all measurements to feet and decimals of a foot before calculating the volume.

\[
6'' = 0.5' \\
1' - 6'' = 1.5' \\
6' - 5'' = 6.42'
\]

**Step 1**: Calculate the average wall thickness.

\[
\text{Average wall thickness} = \frac{1.5' + 0.5'}{2} = \frac{2'}{2} = 1'
\]

**Step 2**: Calculate the volume of concrete.

\[
\text{Volume} = L \times W \times H = 6.42' \times 1' \times 2' = 12.84 \text{ ft}^3
\]

**Step 3**: Convert ft\(^3\) to yd\(^3\).

\[
12.84 \text{ ft}^3 + 27 \text{ ft}^3 = 0.48 \text{ yd}^3
\]
Consistent Wording

Always use the same words to describe a particular action when writing steps for your worksheets. For example, don’t switch between “calculate” and “find” or “convert” and “change”. Consistent wording:

- Increases the apprentice’s efficiency in learning
- Makes patterns in problem solving easier to see
- Makes problem-solving strategies easier to remember

Develop Strategies

By breaking a problem down into its steps, you are modeling a strategy that apprentices can apply to similar problems. Step-by-step thinking helps apprentices to pay attention to the process that led them to getting the answer. By repeating the same basic steps, a habit is formed and apprentices develop a strategy.

How do you organize questions?

The first few questions of the worksheet should be the same as the example. This means the wording of the questions is the same but the numbers are different. Keeping the first few questions the same reinforces the skill, provides practice and builds confidence. You can increase the difficulty of the questions by:

- wording the questions differently
- increasing the complexity of the numbers (for example, introducing fractions)
- presenting a more complex situation/diagram/problem
Developing Numeracy Worksheets Checklist

Identifying an instructional goal:
Identify your instructional goal.
I want apprentices to be able to ________________________________.
Make a list of skills apprentices need to reach the goal:
•
•
•
•

Gather or make materials that relate to the instructional goal.
• Diagrams
• Photos
• Examples

Setting up an example:
Include the question
Include a note, if needed, of information that is required or helpful
Include clearly labelled photos or diagrams
Break down the process into steps
Explain each step briefly

Writing questions:
Provide background knowledge and trades-specific formulas and procedures
Make the first few questions the same as the example
Order questions from simple to complex
Section 4: Making Answer Keys

In this section
- When do you give answer keys?
- What types of answer keys are there?
- How do you write answer keys?
- Answer key examples
- Making Answer Keys Checklist

When do you give answer keys?
For all the worksheets you make, you will also make an answer key. When and how you intend to use the answer keys determines the type of answer keys you will make. Decide when to hand out answer keys:
- after apprentices complete worksheets
- while apprentices are working on worksheets

What types of answer keys are there?
Look at the table below for the types of answer keys you can make and how they can be used. You will see that answer keys can be valuable teaching and diagnostic tools that are just as useful as the worksheets you make.

<table>
<thead>
<tr>
<th>Answer Key Type</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Answers only</td>
<td>• To mark answers right or wrong</td>
</tr>
</tbody>
</table>
| Answers with formula | • To mark answers right or wrong  
|                  | • For questions that use one formula to get the answer  
|                  | • To show the formula with values in correct places |
| Answers with steps | • To mark answers right or wrong  
|                  | • For questions that use more than one formula to get the answer  
|                  | • To allow apprentices to see where they went wrong and what they should have done instead by comparing their steps to answer steps  
|                  | • To show the steps in solving problems that are different or more complex than the worksheet example  
|                  | • To reinforce the steps and provide extra modeling of the steps (strategy) |
| Combination of answers with steps and answers only | • To mark answers right or wrong  
|                  | • Answers with steps allow apprentices to see where they went wrong and what they should have done instead  
|                  | • Answers with steps provide extra modeling of the steps (strategy)  
|                  | • Answers only allows apprentices to work through wrong answers on their own |
How do you write answer keys?
If you choose to make an answer key with full answer steps provided, the answer steps need to be set up the same way as the worksheet example:

- use the same number of steps when possible
- use consistent wording
- include diagrams when helpful

Answer key examples
The following are some examples of the different types of answer keys.

Answers with formula
This type of answer key is good for questions that require just one formula to get the answer.

| Title that matches worksheet title | Correct formula in words | Correct values inserted into formula | Answer
|------------------------------------|--------------------------|-------------------------------------|--------
| **Total Fall = Length × Grade** = 75 feet × 1/4 inch = 18 3/8 inches | **Total Fall = Length × Grade** = 75 feet × 1/4 inch = 18 3/8 inches | **Total Fall = Length × Grade** = 75 feet × 1/4 inch = 18 3/8 inches | **Total Fall = Length × Grade** = 75 feet × 1/4 inch = 18 3/8 inches |
| **Total Fall = Length × Grade** = 125 feet × 0.01 = 1.25 feet | **Total Fall = Length × Grade** = 125 feet × 0.01 = 1.25 feet | **Total Fall = Length × Grade** = 125 feet × 0.01 = 1.25 feet | **Total Fall = Length × Grade** = 125 feet × 0.01 = 1.25 feet |
| **Length = Total Fall** \[\text{Grade}\] = \[\frac{0.75 \text{ feet}}{0.0104}\] = 72.12 feet | **Length = Total Fall** \[\text{Grade}\] = \[\frac{11 \text{ inches}}{1/8 \text{ inch per foot}}\] = 88 feet | **Length = Total Fall** \[\text{Grade}\] = \[\frac{15 \text{ inches}}{72 \text{ feet}}\] = 0.208 inches per foot = 3/16 inches per foot | **Length = Total Fall** \[\text{Grade}\] = \[\frac{4.5 \text{ feet}}{375 \text{ feet}}\] = 0.012 = 1.2% |
Answers with steps
Answer keys with steps allow apprentices to see where in the calculation process they made an error if they got the answer wrong. This type of answer key teaches and corrects at the same time.

8. Calculate the length of the rafter.

Calculate the mathematical line length.
\[ a^2 + b^2 = c^2 \]
\[ 3.8^2 + 11.5^2 = c^2 \]
\[ 14.44 + 132.25 = c^2 \]
\[ 146.69 = c^2 \]
\[ \sqrt{146.69} = c \]
\[ 12.11' = c \]

Calculate the overhang length.
\[ a^2 + b^2 = c^2 \]
\[ 0.45^2 + 1.3^2 = c^2 \]
\[ 0.2025 + 1.69 = c^2 \]
\[ 1.8925 = c^2 \]
\[ \sqrt{1.8925} = c \]
\[ 1.38' = c \]

Rafter length = 12.11' + 1.38' = 13.49'

Highlight answer with bold font
Answer keys with steps that show more than one way to get an answer show apprentices different ways of thinking. They could find a method or way of thinking that makes more sense to them than the way they were taught.

### Paving Asphalt

10a. Calculate the volume of bedding material. Convert inches to feet. 

\[ 2\text{"} \div 12\text{"} = 0.17' \]

There are three ways to calculate the volume.

#### Method 1

Area of lot = L × W
\[ = 316.7' \times 90' \]
\[ = 28,503 \text{ ft}^2 \]

Area of warehouse = L × W
\[ = 200' \times 64' \]
\[ = 12,800 \text{ ft}^2 \]

Area of driveway and parking lot
\[ = 28,503 \text{ ft}^2 - 12,800 \text{ ft}^2 \]
\[ = 15,703 \text{ ft}^2 \]

#### Method 2

Area 1 = L × W
\[ = 316.7' \times 26' \]
\[ = 8,234.2 \text{ ft}^2 \]

Area 2 = L × W
\[ = 62.59' \times 64' \]
\[ = 4,005.76 \text{ ft}^2 \]

Area 3 = L × W
\[ = 54.11' \times 64' \]
\[ = 3,463.04 \text{ ft}^2 \]

Total Area
\[ = 8,234.2 \text{ ft}^2 + 4,005.76 \text{ ft}^2 + 3,463.04 \text{ ft}^2 \]
\[ = 15,703 \text{ ft}^2 \]

#### Method 3

Area 1 = L × W
\[ = 62.59' \times 90' \]
\[ = 5,633.1 \text{ ft}^2 \]

Area 2 = L × W
\[ = 200' \times 26' \]
\[ = 5,200 \text{ ft}^2 \]

Area 3 = L × W
\[ = 54.11' \times 90' \]
\[ = 4,869.9 \text{ ft}^2 \]

Total Area
\[ = 5,633.1 \text{ ft}^2 + 5,200 \text{ ft}^2 + 4,869.9 \text{ ft}^2 \]
\[ = 15,703 \text{ ft}^2 \]
Making Answer Keys Checklist

Making answer keys:

☐ Decide how the answer key will be organized
  • Answers only
  • Answers with steps
  • Combination of answers with steps and answers only

☐ Decide when to give the answer key
  • After apprentices complete worksheet
  • While apprentices are doing the worksheet
Section 5: Worksheet Examples

In this section
- Instructor-made worksheets
- Developing Numeracy Worksheets Checklist
- Before and after examples of a worksheet
- Instructor-made worksheet examples

Instructor-made worksheets
The worksheet development guidelines in this guidebook were used with a group of technical training instructors. They used technical training problems from their own classrooms and applied the guidelines in this book to make their own worksheets. The worksheets that they developed are included in this section. You can use their examples as a reference to help you develop your own numeracy worksheets or photocopy them for use in your training program.

Before and after examples of a worksheet

Before
Below is a worksheet for Heavy Equipment Operators to practice calculating weight loads for crane lifts. There are different shapes of objects to lift. A separate table of weights of materials that apprentices refer to when completing this worksheet is not shown. The After example that starts on page 18 applies the guidelines from this book to re-make the worksheet. The complete Developing Numeracy Worksheets Checklist is on page 22.

Determine the weight of the following:

Reinforced Concrete Block

Pipe 20 ft. long Diameter 5 ft. Wall thickness 1 inch

Steel Cylinder

Steel Beam
Calculating Weight Loads in Pounds (lbs) Worksheet

Example 1:

Calculate the weight of the reinforced concrete block.

Notes:
Convert inches to decimals of a foot.
6" ÷ 12" = .5'

Split the irregular shape into separate regular shapes.

Step 1: Calculate the volume.

Volume of A
Volume = L × W × H
= 4 ft × 3 ft × 5 ft = 60 ft³

Volume of B
Volume B = L × W × H
= (9.5 ft – 4 ft) × 3 ft × 2 ft
= 5.5 ft × 3 ft × 2 ft = 33 ft³

Total Volume
Total Volume = Volume A + Volume B = 60 ft³ + 33 ft³ = 93 ft³

Step 2: Calculate the weight.

1 ft³ reinforced concrete = 150 lbs

Weight = Total Volume × lbs/ft³ = 93 ft³ × 150 lbs/ft³ = 13,950 lbs
Example 2:

Calculate the weight of the steel cylinder.

Step 1: Calculate the volume.

\[
\text{Volume} = \frac{(d \times d \times \pi \times d)}{4} = \frac{4 \pi \times 4 \pi \times 8 \pi}{4} = \frac{402.12385974}{4} = 100.53 \text{ ft}^3
\]

Note: The \( \pi \) button was used to calculate this answer. If you used 3.1416 or 3.14 you may get a slightly different answer.

Step 2: Calculate the weight.

\[
1 \text{ ft}^3 \text{ steel} = 490 \text{ lbs}
\]

\[
\text{Weight} = \text{Volume} \times 490 \text{ lbs/ft}^3 = 100.53 \text{ ft}^3 \times 490 \text{ lbs/ft}^3 = 49,259.7 \text{ lbs}
\]

Practice

Calculate the load weights of the following shapes. Remember to convert inches and fractions of an inch to decimals of a foot.

1. Calculate the load weight of the reinforced concrete block.
2. Calculate the load weight of the steel beam.

3. Calculate the load weight of the steel cylinder.
4. Calculate the load weight of the pipe.  
   *Hint: Think outside volume minus inside volume.*

   **Pipe**  
   20 ft. long  
   Diameter 5 ft.  
   Wall thickness 1 inch

4.1 Alter the way the diagram is labelled to add difficulty

5. What is the load weight of the tank?

5.1 Change the question wording for variety

These pages were an illustrated example of the changes made to the original worksheet. The following pages are worksheets you can use for reference or to photocopy for use in your classroom.
## Developing Numeracy Worksheets Checklist

### Identifying an instructional goal:
- [ ] Identify your instructional goal.
  I want apprentices to be able to ________________________________.
- [ ] Make a list of skills apprentices need to reach the goal:
  - 
  - 
  - 
  - 
- [ ] Gather or make materials that relate to the instructional goal.
  - Diagrams
  - Photos
  - Examples

### Setting up an example:
- [ ] Include the question
- [ ] Include a note, if needed, of information that is required or helpful
- [ ] Include clearly labelled photos or diagrams
- [ ] Break down the process into steps
- [ ] Explain each step briefly

### Writing questions:
- [ ] Provide background knowledge and trades-specific formulas and procedures
- [ ] Make the first few questions the same as the example
- [ ] Order questions from simple to complex

### Making answer keys:
- [ ] Decide how the answer key will be organized
  - Answers only
  - Answers with steps
  - Combination of answers with steps and answers only
- [ ] Decide when to give the answer key
  - After apprentices complete worksheet
  - While apprentices are doing the worksheet
Worksheet Examples
### Example 1:
Calculate the weight of the reinforced concrete block.

**Notes:** Convert inches to decimals of a foot.
6" ÷ 12" = .5'

Split the irregular shape into separate regular shapes.

**Step 1:** Calculate the volume.

- **Volume of A**
  \[\text{Volume} = L \times W \times H\]
  \[= 4 \text{ ft} \times 3 \text{ ft} \times 5 \text{ ft} = 60 \text{ ft}^3\]

- **Volume of B**
  \[\text{Volume B} = (9.5 \text{ ft} - 4 \text{ ft}) \times 3 \text{ ft} \times 2 \text{ ft}\]
  \[= 5.5 \text{ ft} \times 3 \text{ ft} \times 2 \text{ ft} = 33 \text{ ft}^3\]

**Total Volume**
\[\text{Total Volume} = \text{Volume A} + \text{Volume B} = 60 \text{ ft}^3 + 33 \text{ ft}^3 = 93 \text{ ft}^3\]

**Step 2:** Calculate the weight.

- 1 ft³ reinforced concrete = 150 lbs

\[\text{Weight} = \text{Total Volume} \times \frac{\text{lbs}}{\text{ft}^3} = 93 \text{ ft}^3 \times 150 \text{ lbs/ft}^3 = 13,950 \text{ lbs}\]

### Example 2:
Calculate the weight of the steel cylinder.

**Step 1:** Calculate the volume.

\[\text{Volume} = \frac{(d \times d \times \pi \times H)}{4}\]

\[= \frac{(4 \text{ ft} \times 4 \text{ ft} \times \pi \times 8 \text{ ft})}{4} = \frac{402.1238597}{4} = 100.53 \text{ ft}^3\]

**Note:** The \( \pi \) button was used to calculate this answer.
*If you used 3.1416 or 3.14 you may get a slightly different answer.*

**Step 2:** Calculate the weight.

- 1 ft³ steel = 490 lbs

\[\text{Weight} = \text{Volume} \times 490 \text{ lbs/ft}^3 = 100.53 \text{ ft}^3 \times 490 \text{ lbs/ft}^3 = 49,259.7 \text{ lbs}\]
Practice
Calculate the load weights of the following shapes. Remember to convert inches and fractions of an inch to decimals of a foot.

1. Calculate the load weight of the reinforced concrete block.

   ![Reinforced Concrete Block Diagram]

   - Length: 5.5 ft.
   - Height: 7 ft.
   - Depth: 4 ft.
   - Width: 3 ft.

2. Calculate the load weight of the steel beam.

   ![Steel Beam Diagram]

   - Length: 30 ft.
   - Width: 1 in.
   - Height: 2 ft.
   - Depth: 18 in.

3. Calculate the load weight of the steel cylinder.

   ![Steel Cylinder Diagram]

   - Length: 5 ft.
   - Diameter: 12’ - 6”
4. Calculate the load weight of the steel pipe.  
   *Hint: Think outside volume minus inside volume.*

   Pipe 20 ft. long  
   Diameter 5 ft.  
   Wall thickness 1 inch

5. What is the load weight of the steel tank?
Answer Key

1. **Volume of A**
   \[ V = L \times W \times H = 5.5 \text{ ft} \times 4 \text{ ft} \times 7 \text{ ft} = 154 \text{ ft}^3 \]
   Volume of B
   \[ V = L \times W \times H = 5.25 \text{ ft} \times 4 \text{ ft} \times 3 \text{ ft} = 63 \text{ ft}^3 \]
   Total Volume = 154 ft³ + 63 ft³ = 217 ft³
   Weight = Total Volume × lbs/ft³ = 217 ft³ × 150 lb/ft³ = 32,550 lbs

2. **Calculate the weight of the flanges.**
   Volume = \[ L \times W \times H = 30 \text{ ft} \times 1.5 \text{ ft} \times 0.083 \text{ ft} = 3.735 \text{ ft}^3 \]
   Two flanges = 3.735 ft³ × 2 = 7.47 ft³
   Calculate the weight of the web.
   Volume = \[ L \times W \times H = 30 \text{ ft} \times 2 \text{ ft} \times 0.083 \text{ ft} = 4.98 \text{ ft}^3 \]
   Total Volume = 7.47 ft³ + 4.98 ft³ = 12.45 ft³
   Weight = Total Volume × lbs/ft³ = 12.45 ft³ × 490 lb/ft³ = 6,100.5 lbs

3. **Calculate the volume.**
   \[ \text{Volume} = \frac{(d \times d \times \pi \times h)}{4} = \frac{(5 \text{ ft} \times 5 \text{ ft} \times \pi \times 12.5 \text{ ft})}{4} = \frac{981.7477042}{4} = 245.437 \text{ ft}^3 \]
   Calculate the weight.
   Weight = volume × 490 lbs/ft³ = 245.437 ft³ × 490 lbs/ft³ = 120,264.13 lbs

4. **Calculate outside volume.**
   \[ \text{Volume} = \frac{(d \times d \times \pi \times h)}{4} = \frac{(5 \text{ ft} \times 5 \text{ ft} \times \pi \times 20 \text{ ft})}{4} = \frac{1,570.796327}{4} = 392.7 \text{ ft}^3 \]
   Calculate the inside volume.
   Inside diameter = 5 ft – 2 in = 5 ft – 0.167 ft = 4.833 ft
   \[ \text{Volume} = \frac{(d \times d \times \pi \times h)}{4} = \frac{(4.833 \text{ ft} \times 4.833 \text{ ft} \times \pi \times 20 \text{ ft})}{4} = \frac{1,467.61945}{4} = 366.905 \text{ ft}^3 \]
   Total Volume = outside volume – inside volume = 392.7 ft³ – 366.905 ft³ = 25.795 ft³
   Weight = volume × 490 lbs/ft³ = 25.795 ft³ × 490 lbs/ft³ = 12,639.55 lbs
5. Calculate the weight of the two ends.

\[
\text{Volume} = \frac{(d \times d \times \pi \times h)}{4} = \frac{(5 \text{ ft} \times 5 \text{ ft} \times \pi \times 0.083 \text{ ft})}{4} = \frac{6.518804756}{4} = 1.63 \text{ ft}^3
\]

Two ends = 1.63 \text{ ft}^3 \times 2 = 3.26 \text{ ft}^3

Weight = 3.26 \text{ ft}^3 \times 490 \text{ lb/ft}^3 = 1,597.4 \text{ lbs}

Calculate the weight of the tank shell.

<table>
<thead>
<tr>
<th>Method 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume = \pi \times d \times H \times TH = \pi \times 5' \times 8' \times 0.083' = 10.43 \text{ ft}^3</td>
</tr>
<tr>
<td>Weight = 10.43 \text{ ft}^3 \times 490 \text{ lb/ft}^3 = 5,110.7 \text{ lbs}</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside volume = \frac{(d \times d \times \pi \times H)}{4} = \frac{(5 \text{ ft} \times 5 \text{ ft} \times \pi \times 8 \text{ ft})}{4} = 157.08 \text{ ft}^3</td>
</tr>
<tr>
<td>Inside Diameter = 5 \text{ ft} - 2 \text{ in} = 5 \text{ ft} - 0.167 \text{ ft} = 4.833 \text{ ft}</td>
</tr>
<tr>
<td>Inside Volume = \frac{(4.833 \text{ ft} \times 4.833 \text{ ft} \times \pi \times 8 \text{ ft})}{4} = 146.76 \text{ ft}^3</td>
</tr>
<tr>
<td>Total Volume = 157.08 \text{ ft}^3 - 146.76 \text{ ft}^3 = 10.32 \text{ ft}^3</td>
</tr>
<tr>
<td>Weight = 10.32 \text{ ft}^3 \times 490 \text{ lb/ft}^3 = 5,056.8 \text{ lbs}</td>
</tr>
</tbody>
</table>

Note: There is a difference of 53.9 pounds between the two methods. Method 2 is more accurate than Method 1.

Calculate the total weight of the tank.

<table>
<thead>
<tr>
<th>Method 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Weight = Weight of two ends + Weight of tank shell</td>
</tr>
<tr>
<td>= 1,597.4 \text{ lbs} + 5,110.7 \text{ lbs} = 6,708.1 \text{ lbs}</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Weight = Weight of two ends + Weight of tank shell</td>
</tr>
<tr>
<td>= 1,597.4 \text{ lbs} + 5,056.8 \text{ lbs} = 6,654.2 \text{ lbs}</td>
</tr>
</tbody>
</table>
Calculating Total Fall, Length and Grade

The basic formula used to calculate slope and grade problems is as follows:

\[
\text{TF} = L \times G
\]

\[
L = \frac{\text{TF}}{G}
\]

\[
G = \frac{\text{TF}}{L}
\]

Calculating total fall

Total fall can be calculated using percent grade or inches per foot. Look at examples 1 and 2.

Example 1: Using Percent Grade

A sewer line slopes at a 2.08 % grade. Calculate the total fall in 45 feet.

Note: Convert percent to a decimal

\[
2.08\% = 2.08 \div 100 = 0.0208
\]

Step 1: Calculate the total fall.

Total fall = length \times grade = 45' \times 0.0208 = 0.936'

Note: The answer is in feet because it was calculated in feet.

Step 2: Convert decimals of a foot to inches and fractions of an inch.

\[
0.936' \times 12 = 11.232''
\]

\[
0.232 \times 16 = \frac{3.712}{16} = \frac{4}{16} = \frac{1}{4}
\]

The total fall is \(11 \frac{1}{4}''\).
Example 2: Using Inches Per Foot

A sewer line slopes at ¼" per foot grade. Calculate the total fall in 45 feet.

\[
\text{length} = 45 \text{ feet}
\]

\[
\text{total fall} = _____
\]

\[
\text{grade} = \frac{1}{4}" \text{ per foot}
\]

Step 1: Calculate the total fall.

\[
\text{Total fall} = \text{length} \times \text{grade} = 45 \text{ ft} \times \frac{1}{4 \text{ in}} = 11 \frac{1}{4}"
\]

Note: The answer is in inches because the feet cancel each other out.

Calculating a grade

Example:

Calculate the grade on a sewer line that is 115 feet in length and has a total fall of 14 3/8" inches. The total fall is given in inches so your answer will be inches per foot.

\[
\text{length} = 115'
\]

\[
\text{total fall} = 14 \frac{3}{8}"
\]

\[
\text{grade} = _________
\]

Step 1: Calculate the grade.

\[
\text{Grade} = \frac{\text{total fall}}{\text{length}} = \frac{14 \frac{3}{8}''}{115 \text{ ft}}
\]

Grade = ½" per foot

Calculating a Length

Example:

Calculate the length of the sewer line. The grade is 1.04% and the total fall is 2.49 feet.

\[
\text{total fall} = 2.49'
\]

\[
\text{length} = _________
\]

\[
\text{grade} = 1.04\%
\]

\[
\text{Length (feet)} = \frac{\text{total fall}}{\text{grade}} = \frac{2.49 \text{ ft}}{0.0104} = 239.42 \text{ feet}
\]
Practice

Calculate the total fall, length or grade in the following problems. Round off final answers to two decimal places.

1. Calculate the total fall of the sewer line.
   
   *Hint: Your answer will be inches because you are calculating total fall using inches per foot.*

   \[ \text{length} = 125' \]
   \[ \text{total fall} = \_\_\_\_\_\_\_ \] \[ \text{grade} = \frac{1}{4}'' \text{ per foot} \]

2. Calculate the total fall of the sewer line.
   
   *Hint: Your answer will be in feet because you are calculating total fall using percent grade.*

   \[ \text{length} = 98.5' \]
   \[ \text{total fall} = \_\_\_\_\_\_\_ \] \[ \text{grade} = 1\% \]

3. Calculate the length of the sewer line.

   \[ \text{total fall} = 0.87' \]
   \[ \text{length} = \_\_\_\_\_\_\_ \] \[ \text{grade} = 1.04\% \]
4. Calculate the length of the sewer line.

\[ \text{length} = \underline{\text{__________}} \]

Total fall = 27"

Grade = \( \frac{1}{8} \) " per foot

5. Calculate the grade of the sewer line.

\[ \text{length} = 67.5' \]

Total fall = 12"

Grade = \underline{\text{______________}}

6. Calculate the grade of the sewer line.

\[ \text{length} = 258' \]

Total fall = 3.75'

Grade = \underline{\text{______________}}
Answer Key

1. \( TF = L \times G = 125' \times \frac{1}{4} \text{ in} \times \frac{1}{4} \text{ ft} = 31 \frac{1}{4} '' \)

2. \( TF = L \times G = 98.5' \times 0.01 = 0.99' \)

3. \( L = \frac{TF}{G} = \frac{0.87 \text{ ft}}{0.0104} = 83.65' \)

4. \( L = \frac{TF}{G} = \frac{27''}{18'} = 216' \)

5. \( G = \frac{TF}{L} = \frac{12''}{76.5'} = 0.178'' \text{ per foot} = \frac{3}{16} '' \text{ per foot grade} \)

6. \( G = \frac{TF}{L} = \frac{3.75'}{258'} = 0.0145 = 1.45\% \text{ grade} \)
Section 5: Worksheet Examples
Calculating Btus

The Things to Remember:
Heat loss = heat gained
Sensible Heat: Can be measured with a thermometer, no change in state
\[ \text{Btu} = W \times \text{S.H.} \times \Delta T \]

Latent Heat: Change in state, no change in temperature
\[ \text{Btu} = W \times \text{Btu/lb} \]

<table>
<thead>
<tr>
<th>Fahrenheit (°F)</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Btu (British Thermal Units) to raise 1 pound of water 1 degree Fahrenheit</td>
</tr>
</tbody>
</table>

| Sensible Heat  | Ice = 0.53 |
|                | Water = 1  |
|                | Steam = 0.48 |

| Latent Heat     | Ice to water = 144 Btu/lb |
|                | Water to steam = 970 Btu/lb |

Example:
Calculate the number of Btu needed to convert 12 pounds of ice at 15° F to steam at 235° F.

Step 1: Set up the problem to calculate the total Btu.

- ice – ice
  - 15° - 32°
- ice – water
  - 32° - 32°
- water – water
  - 32° - 212°
- water – steam
  - 212° - 212°
- steam – steam
  - 212° - 235°
### Step 2: Write the formulas.

<table>
<thead>
<tr>
<th>State Change</th>
<th>Formula</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice – ice</td>
<td>( W \times \text{SH} \times \Delta T )</td>
<td>( 12 \text{ lbs} \times 0.53 \times (32° - 15°) = 108.12 \text{ Btu} )</td>
</tr>
<tr>
<td>Ice – water</td>
<td>( W \times \text{Btu/lb} )</td>
<td>( 12 \text{ lbs} \times 144 \text{ Btu/lb} = 1,728 \text{ Btu} )</td>
</tr>
<tr>
<td>Water – water</td>
<td>( W \times \text{SH} \times \Delta T )</td>
<td>( 12 \text{ lbs} \times 1 \times (212° - 32°) = 2,160 \text{ Btu} )</td>
</tr>
<tr>
<td>Water – steam</td>
<td>( W \times \text{Btu/lb} )</td>
<td>( 12 \text{ lbs} \times 970 \text{ Btu/lb} = 11,640 \text{ Btu} )</td>
</tr>
<tr>
<td>Steam – steam</td>
<td>( W \times \text{SH} \times \Delta T )</td>
<td>( 12 \text{ lbs} \times 0.48 \times (235° - 212°) = 132.48 \text{ Btu} )</td>
</tr>
</tbody>
</table>

### Step 3: Calculate the btus.

<table>
<thead>
<tr>
<th>State Change</th>
<th>Formula</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice – ice</td>
<td>( W \times \text{SH} \times \Delta T )</td>
<td>( 12 \text{ lbs} \times 0.53 \times (32° - 15°) = 108.12 \text{ Btu} )</td>
</tr>
<tr>
<td>Ice – water</td>
<td>( W \times \text{Btu/lb} )</td>
<td>( 12 \text{ lbs} \times 144 \text{ Btu/lb} = 1,728 \text{ Btu} )</td>
</tr>
<tr>
<td>Water – water</td>
<td>( W \times \text{SH} \times \Delta T )</td>
<td>( 12 \text{ lbs} \times 1 \times (212° - 32°) = 2,160 \text{ Btu} )</td>
</tr>
<tr>
<td>Water – steam</td>
<td>( W \times \text{Btu/lb} )</td>
<td>( 12 \text{ lbs} \times 970 \text{ Btu/lb} = 11,640 \text{ Btu} )</td>
</tr>
<tr>
<td>Steam – steam</td>
<td>( W \times \text{SH} \times \Delta T )</td>
<td>( 12 \text{ lbs} \times 0.48 \times (235° - 212°) = 132.48 \text{ Btu} )</td>
</tr>
</tbody>
</table>

### Step 4: Calculate the total Btu.

Total Btu = 108.12 + 1,728 + 2,160 + 11,640 + 132.48 = \textbf{15,768.6 Btu}

### Practice

1. Calculate the number of Btu needed to convert 15 lbs of ice at 13° F to steam at 218° F
2. Calculate the number of Btu needed to convert 5 pounds of ice at -10° F to steam at 242° F.

3. Calculate the number of Btu needed to convert 45 imperial gallons of water at 36° F to steam at 219°.

4. Calculate the number of Btu needed to convert 125 imperial gallons of water at 49° F to 212°.

5. A tank of has a diameter of 3' 9" and height of 8' 6" and is completely full of water. Calculate the number of Btu needed to raise the water temperature from 43° F to 185° F.

6. A tank has a diameter of 36" and a height of 15' 7" and is ¾ full of water. Calculate the number of Btu needed to raise the water temperature from 39° F to 145° F.
Answer Key

1.

<table>
<thead>
<tr>
<th>State</th>
<th>Formula</th>
<th>Calculation</th>
<th>Btu</th>
</tr>
</thead>
<tbody>
<tr>
<td>ice – ice</td>
<td>( W \times SH \times \Delta T )</td>
<td>( 15 \text{ lbs} \times 0.53 \times (32° - 13°) = 151.05 \text{ Btu} )</td>
<td></td>
</tr>
<tr>
<td>15° - 32°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ice – water</td>
<td>( W \times \text{Btu/lb} )</td>
<td>( 15 \text{ lbs} \times 144 \text{ Btu/lb} = 2,160 \text{ Btu} )</td>
<td></td>
</tr>
<tr>
<td>32° - 32°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>water – water</td>
<td>( W \times SH \times \Delta T )</td>
<td>( 15 \text{ lbs} \times 1 \times (212° - 32°) = 2,700 \text{ Btu} )</td>
<td></td>
</tr>
<tr>
<td>32° - 212°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>water – steam</td>
<td>( W \times \text{Btu/lb} )</td>
<td>( 15 \text{ lbs} \times 970 \text{ Btu/lb} = 14,550 \text{ Btu} )</td>
<td></td>
</tr>
<tr>
<td>212° - 212°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>steam – steam</td>
<td>( W \times SH \times \Delta T )</td>
<td>( 15 \text{ lbs} \times 0.48 \times (218° - 212°) = 43.2 \text{ Btu} )</td>
<td></td>
</tr>
<tr>
<td>212° - 235°</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Btu = 151.05 + 2,160 + 2,700 + 14,550 + 43.2 = **19,604.25 Btu**

2.

<table>
<thead>
<tr>
<th>State</th>
<th>Formula</th>
<th>Calculation</th>
<th>Btu</th>
</tr>
</thead>
<tbody>
<tr>
<td>ice – ice</td>
<td>( W \times SH \times \Delta T )</td>
<td>( 5 \text{ lbs} \times 0.53 \times (32° - 13°) = 111.3 \text{ Btu} )</td>
<td></td>
</tr>
<tr>
<td>15° - 32°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ice – water</td>
<td>( W \times \text{Btu/lb} )</td>
<td>( 5 \text{ lbs} \times 144 \text{ Btu/lb} = 720 \text{ Btu} )</td>
<td></td>
</tr>
<tr>
<td>32° - 32°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>water – water</td>
<td>( W \times SH \times \Delta T )</td>
<td>( 5 \text{ lbs} \times 1 \times (212° - 32°) = 900 \text{ Btu} )</td>
<td></td>
</tr>
<tr>
<td>32° - 212°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>water – steam</td>
<td>( W \times \text{Btu/lb} )</td>
<td>( 5 \text{ lbs} \times 970 \text{ Btu/lb} = 4,850 \text{ Btu} )</td>
<td></td>
</tr>
<tr>
<td>212° - 212°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>steam – steam</td>
<td>( W \times SH \times \Delta T )</td>
<td>( 5 \text{ lbs} \times 0.48 \times (242° - 212°) = 72 \text{ Btu} )</td>
<td></td>
</tr>
<tr>
<td>212° - 235°</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Btu = 111.3 + 720 + 900 + 4,850 + 72 = **6,653.3 Btu**

3. Convert imperial gallons to pounds.

\( 45 \times 10 \text{ lbs} = 450 \text{ lbs} \)

<table>
<thead>
<tr>
<th>State</th>
<th>Formula</th>
<th>Calculation</th>
<th>Btu</th>
</tr>
</thead>
<tbody>
<tr>
<td>water – water</td>
<td>( W \times SH \times \Delta T )</td>
<td>( 450 \text{ lbs} \times 1 \times (212° - 36°) = 79,200 \text{ Btu} )</td>
<td></td>
</tr>
<tr>
<td>36° - 212°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>water – steam</td>
<td>( W \times \text{Btu/lb} )</td>
<td>( 450 \text{ lbs} \times 970 \text{ Btu/lb} = 436,500 \text{ Btu} )</td>
<td></td>
</tr>
<tr>
<td>212° - 212°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>steam – steam</td>
<td>( W \times SH \times \Delta T )</td>
<td>( 450 \text{ lbs} \times 0.48 \times (219° - 212°) = 1,512 \text{ Btu} )</td>
<td></td>
</tr>
<tr>
<td>212° - 219°</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Btu = 79,200 + 436,500 + 1,512 = **517,212 Btu**
4. Convert imperial gallons to pounds.
   \[125 \times 10 \text{ lbs} = 1,250 \text{ lbs}\]
   
   Water - water
   \[W \times SH \times \Delta T\]
   \[49° - 212°\]
   \[1,250 \text{ lbs} \times 1 \times (212° - 49°) = 203,750 \text{ Btu}\]

5. Calculate the volume of the tank in cubic feet.
   Volume =
   \[d^2 \times 0.7854 \times h =\]
   \[3.75^2 \times 0.7854 \times 8.5 =\]
   93.88 ft\(^3\) rounded off to two decimal places
   Convert cubic feet to pounds.
   93.88 ft\(^3\) \times 62.4 lb/ft\(^3\) = 5,858.112 lbs
   
   Water - water
   \[W \times SH \times \Delta T\]
   \[43° - 185°\]
   \[5,858.112 \text{ lbs} \times 1 \times (185° - 43°) = 831,851.904 \text{ Btu}\]

6. Calculate the volume of the tank in cubic feet.
   Volume =
   \[d^2 \times 0.7854 \times h =\]
   \[3^2 \times 0.7854 \times 15.58 =\]
   110.13 ft\(^3\) rounded off to two decimal places
   Calculate the volume of water in the tank.
   Volume of water = Volume of tank \times \frac{3}{4}
   = 110.13 ft\(^3\) \times 0.75
   = 82.598 ft\(^3\)
   Convert cubic feet to pounds.
   82.598 ft\(^3\) \times 62.4 lb/ft\(^3\) = 5,154.12 lbs
   
   Water - water
   \[W \times SH \times \Delta T\]
   \[39° - 145°\]
   \[5,154.12 \text{ lbs} \times 1 \times (145° - 39°) = 546,336.72 \text{ Btu}\]
Calculating HMA (Asphalt) Quantities

Note: 2 400 kg is an approximation. The exact weight per cubic metre could be a little more or a little less. It depends on:
- the type of aggregate
- quantity of oil
- gradation

You may be asked to calculate any of three things.
- the number of tonnes of HMA needed to cover an area at a given depth
  \[
  \text{tonnes} = L \times W \times 0.0024 \times D
  \]
- the distance that can be covered with a given amount of HMA at a set width and depth
  \[
  \text{Distance (length)} = \frac{\text{tonnes}}{\text{width}} \div 0.0024 \div \text{depth}
  \]
- the depth or application rate the HMA has been laid
  \[
  \text{Depth} = \frac{\text{tonnes}}{\text{area}} \div 0.0024
  \]

**Example 1:**
How many tonnes of HMA are required to cover an area that measures 1 500 m long by 7.5 m wide at a depth of 50 mm.

**Step 1:** Write the formula.
\[
\text{tonnes} = L \times W \times 0.0024 \times D
\]
Note: length and width must be in metres. Depth must be in millimetres.

**Step 2:** Calculate.
\[
\text{tonnes} = 1 500 \text{ m} \times 7.5 \text{ m} \times 0.0024 \times 50 \text{ mm} = 1 350 \text{ tonnes}
\]
Example 2:
What is the distance in metres that will be paved at 65 mm in depth with a width of 3.65 m if 125 tonnes is used?

Step 1: Write the formula.
Distance (length) = tonnes ÷ width ÷ 0.0024 ÷ depth

Step 2: Calculate.
Distance (length) =
125 tonnes ÷ 3.65 m ÷ 0.0024 ÷ 65 mm =
219.5 m rounded off to one decimal place

Example 3:
Calculate the depth.
A 95 m long mat that is 4 m wide has been laid using 75 tonnes of HMA. Calculate the asphalt rate of placement (depth).

Step 1: Write the formula.
Depth = tonnes ÷ area ÷ 0.0024

Step 2: Calculate.
Depth =
75 tonnes ÷ (95 m × 4 m) ÷ 0.0024 =
75 tonnes ÷ 380 m² ÷ 0.0024 = 82.2 mm =
82 mm rounded off to the nearest mm

Practice
1. How many tonnes of HMA are required to cover an area 2 200 m in length by 8.5 m wide at a depth of 50 mm? Round off answers to the nearest tonne.

2. How many tonnes of HMA are required to cover an area 900 m in length by 7.75 m wide at a depth of 65 mm? Round off answers to the nearest tonne.
3. How many tonnes of HMA are required to cover an area 1800 m in length by 7.5 m wide at a depth of 50 mm? Round off answers to the nearest tonne.

4. What is the distance in metres that will be paved at 65 mm in depth with a width of 4.5 m if 175 tonnes of HMA is used?

5. What is the distance in metres that will be paved at 50 mm in depth at a width of 5.25 m if 250 tonnes of HMA is used?

6. What is the distance in metres that will be paved at 65 mm in depth at a width of 7.5 m if 450 tonnes of HMA is used?
7. A 110 m long mat that is 4 m wide has been laid using 85 tonnes of HMA. Calculate the asphalt rate of placement (depth).

8. A 115 m long mat that is 5.25 m wide has been laid using 125 tonnes of HMA. Calculate the asphalt rate of placement (depth).

9. A 1350 m long mat that is 6.5 m wide has been laid using 1225 tonnes of HMA. Calculate the asphalt rate of placement (depth).
10. a) A job site measures 185 m × 163 m. There are also three driveways: one driveway measures 45 m × 8 m and two driveways measure 18 m × 7.5 m. Calculate each area that needs to be paved.

b) Calculate amount of HMA required for each area to be paved. The application rate will be 65 mm. Round off answers to the nearest tonne.

c) Calculate the tonnes per hour (TPH) to be placed. Assume the job is to be spread over 3 shifts that are 10 hours each.

d) If the paver operates at 80 % efficiency, how many tonnes per hour must be laid in order to maintain the production rate?
Answer Key

1. tonnes = 
   \[ L \times W \times 0.0024 \times D = \]
   \[ 2200 \text{ m} \times 8.5 \text{ m} \times 0.0024 \times 50 \text{ mm} = \]
   2 244 tonnes

2. tonnes = 
   \[ L \times W \times 0.0024 \times D = \]
   \[ 900 \text{ m} \times 7.75 \text{ m} \times 0.0024 \times 65 \text{ mm} = \]
   1 088 tonnes

3. tonnes = 
   \[ L \times W \times 0.0024 \times D = \]
   \[ 1800 \text{ m} \times 7.5 \text{ m} \times 0.0024 \times 50 \text{ mm} = \]
   1 620 tonnes

4. Distance (length) = 
   \[ \text{tonnes} \div \text{width} \div 0.0024 \div \text{depth} = \]
   \[ 175 \text{ tonnes} \div 4.5 \text{ m} \div 0.0024 \div 65 \text{ mm} = \]
   249.3 m

5. Distance (length) = 
   \[ \text{tonnes} \div \text{width} \div 0.0024 \div \text{depth} = \]
   \[ 250 \text{ tonnes} \div 5.25 \text{ m} \div 0.0024 \div 50 \text{ mm} = \]
   396.8 m

6. Distance (length) = 
   \[ \text{tonnes} \div \text{width} \div 0.0024 \div \text{depth} = \]
   \[ 450 \text{ tonnes} \div 7.5 \text{ m} \div 0.0024 \div 65 \text{ mm} = \]
   384.6 m

7. Depth = 
   \[ \text{tonnes} \div \text{area} \div 0.0024 = \]
   \[ 85 \text{ tonnes} \div (110 \text{ m} \times 4 \text{ m}) \div 0.0024 = \]
   \[ 85 \text{ tonnes} \div 440 \text{ m}^2 \div 0.0024 = \]
   80.4 mm = 80 mm rounded off to the nearest mm

8. Depth = 
   \[ \text{tonnes} \div \text{area} \div 0.0024 \text{ kg/m}^2 = \]
   \[ 125 \text{ tonnes} \div (115 \text{ m} \times 5.25 \text{ m}) \div 0.0024 \text{ kg/m}^2 = \]
   \[ 125 \text{ tonnes} \div 603.75 \text{ m}^2 \div 0.0024 \text{ kg/m}^2 = \]
   86.2 mm = 86 mm rounded off to the nearest mm
9. Depth = 
  \[ \text{tonnes} \div \text{area} \div 0.0024 = \]
  \[ 1 \, 225 \, \text{tonnes} \div (1 \, 350 \, \text{m} \times 6.5 \, \text{m}) \div 0.0024 = \]
  \[ 1 \, 225 \, \text{tonnes} \div 8 \, 775 \, \text{m}^2 \div 0.0024 = \]
  \[ 58.1 \, \text{mm} = \boxed{58 \, \text{mm}} \text{ rounded off to the nearest mm} \]

10. a) Area of job site = \( L \times W = 185 \, \text{m} \times 163 \, \text{m} = 30 \, 155 \, \text{m}^2 \)
    
    Area of driveway 1 = \( L \times W = 45 \, \text{m} \times 8 \, \text{m} = 360 \, \text{m}^2 \)
    
    Area of driveway 2 and 3 = \( L \times W \times 2 = 18 \, \text{m} \times 7.5 \, \text{m} \times 2 = 270 \, \text{m}^2 \)

    b) tonnes for job site = \( L \times W \times 0.0024 \times D = \)
    \[ 30 \, 155 \, \text{m}^2 \times 0.0024 \times 65 \, \text{mm} = \]
    \[ \boxed{4 \, 704} \, \text{tonnes rounded off to the nearest tonne} \]

    tonnes for driveway 1 = \( L \times W \times 0.0024 \times D = \)
    \[ 360 \, \text{m}^2 \times 0.0024 \times 65 \, \text{mm} = \]
    \[ \boxed{56} \, \text{tonnes} \text{ rounded off to the nearest tonne} \]

    tonnes for driveway 2 and 3 = \( L \times W \times 0.0024 \times D = \)
    \[ 270 \, \text{m}^2 \times 0.0024 \times 65 \, \text{mm} = \]
    \[ \boxed{42} \, \text{tonnes} \text{ rounded off to the nearest tonne} \]

    c) total tonnes = 4704 + 56 + 42 = 4802 tonnes
    
    tonnes/hour = \[ 4 \, 802 \, \text{tonnes} \div 30 \, \text{hours} = \boxed{160 \, \text{tonnes/hr}} \]

    d) 80% = 0.8
    
    80% of ? = 160 tonnes/hour
    
    \[ ? = \frac{160}{0.8} = \boxed{200 \, \text{tonnes/hr}} \]
Section 5: Worksheet Examples
Calculating Glass Sizes

Example 1:
Calculate the glass size width.

Step 1: Calculate the DLO width.
DLO width = FS – mullions = \(79 \frac{1}{2} \text{"} - (2 \times 2\text{"}) = 75 \frac{1}{2} \text{"} \)
Width glass size = DLO + glass coverage = \(75 \frac{1}{2} \text{"} + \frac{3}{4} \text{"} = 76 \frac{1}{4} \text{"} \)

Step 2: Calculate the glass size height.
DLO height = FS – mullions = \(34 \frac{1}{4} \text{"} - (2 \times 2\text{"}) = 30 \frac{1}{4} \text{"} \)
Height glass size = DLO + glass coverage = \(30 \frac{1}{4} \text{"} + \frac{3}{4} \text{"} = 31\text{"} \)

Step 3: Record the glass size.
Unit required: 1 @ \(76 \frac{1}{4} \text{"} \times 31\text{"} \)
Note: Glass size is always recorded width \(\times\) height
Example 2:
Calculating glass sizes with equal DLO’s.

Step 1: Calculate the glass size width.

Overall DLO width = FS – mullions = 65 $\frac{1}{2}$" – (3 × 2") = 59 $\frac{1}{2}$"

DLO = $\frac{59}{2} = 29 \frac{3}{4}$"

Width glass size = DLO + glass coverage = 29 $\frac{3}{4}$" + $\frac{3}{4}$" = 30 $\frac{1}{2}$"

Step 2: Calculate the glass size height.

Overall DLO Height = FS – mullions = 37 $\frac{5}{8}$" – (2 × 2") = 33 $\frac{5}{8}$"

Height glass size = 33 $\frac{5}{8}$" + $\frac{3}{4}$" = 34 $\frac{3}{8}$"

Step 3: Record the glass sizes.

Units required: 2 sealed units @ 30 $\frac{1}{2}$" × 34 $\frac{3}{8}$"
Example 3:
Calculating Glass Sizes with an Unknown DLO

Step 1: Calculate the glass size width.
Overall DLO width = FS – mullions = $37 \frac{1}{2}" - (2 \times 2") = 33 \frac{1}{2}"
Width glass size = DLO + glass coverage = $33 \frac{1}{2}" + \frac{3}{4}" = 34 \frac{1}{4}"$

Step 2: Calculate the bottom glass size height.
Bottom glass size = DLO + glass coverage = $21 \frac{1}{16}" + \frac{3}{4}" = 21 \frac{13}{16}"

Step 3: Calculate the top glass size height.
Top FS = $73 \frac{1}{4}" - 21 \frac{1}{16}" = 52 \frac{3}{16}"
DLO Height = FS – mullions = $52 \frac{3}{16}" - (3 \times 2") = 46 \frac{3}{16}"
Height glass size = $46 \frac{3}{16}" + \frac{3}{4}" = 46 \frac{15}{16}"

Step 4: Record the glass sizes.
Units required: $1 @ 34 \frac{1}{4}" \times 21 \frac{13}{16}"
$1 @ 34 \frac{1}{4}" \times 46 \frac{15}{16}"

Practice

1.

2.

37 1/4” FS.

84 1/2” FS.

31 1/4” FS.

67 5/8” FS.
3.

\[ 92 \frac{1}{2} \text{ FS.} \]

\[ 2'' \quad \text{EQ} \quad 2'' \]

\[ 36 \frac{3}{8} \text{ FS.} \]

\[ 2'' \quad \text{EQ} \quad 2'' \]

4.

\[ 104 \frac{3}{4} \text{ FS.} \]

\[ 2'' \quad \text{EQ} \quad 2'' \]

\[ 42 \frac{5}{8} \text{ FS.} \]

\[ 2'' \quad \text{EQ} \quad 2'' \]
Section 6: Practice

5.

50 3/8” FS.

140 3/4” FS.

2” 2” 2” 2”

EQ

EQ

EQ

6.

40 1/4” FS.

120 1/8” FS.

2” 2” 2” 2”

EQ

EQ

EQ
7. SP-Window-Q7

39 1/2" FS.

2"

71 1/4" FS.

2"

8. SP-Window-Q8

41 5/8" FS.

2"

82 7/8" FS.

2"
Answer Key

1. Calculate the glass size width.
   DLO width = $84 \frac{1}{2}" - (2 \times 2") = 8 \frac{1}{2}" \text{ DLO}
   
   Width glass size = $80 \frac{1}{2}" + \frac{3}{4}" = 81 \frac{1}{4}"$
   
   Calculate the glass size height.
   
   DLO height = FS – mullions = $37 \frac{1}{4}" \text{ DLO} - (2 \times 2") = 33 \frac{1}{4}"$
   
   Height glass size = $33 \frac{1}{4}" + \frac{3}{4}" = 34"$
   
   Record the glass size.
   Units required: $1 @ 81 \frac{1}{4}" \times 34"$

2. Calculate the glass size width.
   DLO width = $67 \frac{5}{8}" - (2 \times 2") = 63 \frac{5}{8}" \text{ DLO}$
   
   Width glass size = $63 \frac{5}{8}" + \frac{3}{4}" = 64 \frac{3}{8}"$
   
   Calculate the glass size height.
   
   DLO height = $31 \frac{1}{4}" \text{ DLO} - (2 \times 2") = 27 \frac{1}{4}"$
   
   Height glass size = $27 \frac{1}{4}" + \frac{3}{4}" = 28"$
   
   Record the glass size.
   Units required: $1 sealed unit @ 64 \frac{3}{8}" \times 28"$

3. Calculate the glass size width.
   Overall DLO width = $92 \frac{1}{2}" - (3 \times 2") = 86 \frac{1}{2}"$
   
   DLO = $\frac{86 \frac{1}{2}}{2} = 43 \frac{1}{4}"$
   
   Width glass size = $43 \frac{1}{4}" + \frac{3}{4}" = 44"$
   
   Calculate the glass size height.
   
   Overall DLO Height = $36 \frac{3}{8}" - (2 \times 2") = 32 \frac{3}{8}"$
   
   Height glass size = $32 \frac{3}{8}" + \frac{3}{4}" = 33 \frac{1}{8}"$
   
   Record the glass sizes.
   Units required: $2 sealed units @ 44" \times 33 \frac{1}{8}"$
4. Calculate the glass size width.

Overall DLO width = $104 \frac{3}{4} \text{"} - (3 \times 2\text{")} = 98 \frac{3}{4} \text{"}$

$$DLO = \frac{98 \frac{3}{4}}{2} = 49 \frac{3}{8} \text{"}$$

Width glass size = $49 \frac{3}{8} \text{"} + \frac{3}{4} \text{"} = 50 \frac{1}{8} \text{"}$

Calculate the glass size height.

Overall DLO Height = $42 \frac{5}{8} \text{"} - (2 \times 2\text{")} = 38 \frac{5}{8} \text{"}$

Height glass size = $38 \frac{5}{8} \text{"} + \frac{3}{4} \text{"} = 39 \frac{3}{8} \text{"}$

Record the glass sizes.

**Units required:** 2 sealed units @ $50 \frac{1}{8} \text{"} \times 39 \frac{3}{8} \text{"}$

5. Calculate the glass size width.

Overall DLO width = $140 \frac{3}{4} \text{"} - (4 \times 2\text{")} = 132 \frac{3}{4} \text{"}$

$$DLO = \frac{132 \frac{3}{4}}{3} = 44 \frac{1}{4} \text{"}$$

Width glass size = $44 \frac{1}{4} \text{"} + \frac{3}{4} \text{"} = 45 \text{"}$

Calculate the glass size height.

Overall DLO Height = $50 \frac{3}{8} \text{"} - (2 \times 2\text{")} = 46 \frac{3}{8} \text{"}$

Height glass size = $46 \frac{3}{8} \text{"} + \frac{3}{4} \text{"} = 47 \frac{1}{8} \text{"}$

Record the glass sizes.

**Units required:** 3 sealed units @ $45 \text{"} \times 47 \frac{1}{8} \text{"}$
6. Calculate the glass size width.

Overall DLO width = 120 \frac{1}{8}" - (4 \times 2") = 112 \frac{1}{8}"

DLO = \frac{112 \frac{1}{8}}{3} = 37 \frac{3}{8}"

Width glass size = 37 \frac{3}{8}" + \frac{3}{4}" = 38 \frac{1}{8}" \\

Calculate the glass size height.

Overall DLO Height = 40 \frac{1}{4}" - (2 \times 2") = 36 \frac{1}{4}"

Height glass size = 36 \frac{1}{4}" + \frac{3}{4}" = 37"

Record the glass sizes.

Units required: 3 sealed units @ 38 \frac{1}{8}" \times 37"

7. Calculate the glass size width.

Overall DLO width = 39 \frac{1}{2}" - (2 \times 2") = 35 \frac{1}{2}"

Width glass size = 35 \frac{1}{2}" + \frac{3}{4}" = 36 \frac{1}{4}"

Calculate the bottom glass size height.

Bottom glass size = 27 \frac{3}{4}" + \frac{3}{4}" = 28 \frac{1}{2}"

Calculate the top glass size height.

Top FS = 71 \frac{1}{4}" - 27 \frac{3}{4}" = 43 \frac{1}{2}"

DLO Height = 43 \frac{1}{2}" - (3 \times 2") = 37 \frac{1}{2}"

Height glass size = 37 \frac{1}{2}" + \frac{3}{4}" = 38 \frac{1}{4}"

Record the glass sizes.

Units required: 1 @ 36 \frac{1}{4}" \times 28 \frac{1}{2}"

1 @ 36 \frac{1}{4}" \times 38 \frac{1}{4}"
8. Calculate the glass size width.

Overall DLO width = \(41 \frac{5}{8}" - (2 \times 2") = 37 \frac{5}{8}"\)

Width glass size = \(37 \frac{5}{8}" + \frac{3}{4}" = 38 \frac{3}{8}"\)

Calculate the bottom glass size height.

Bottom glass size = \(31 \frac{3}{16}" + \frac{3}{4}" = 31 \frac{15}{16}"\)

Calculate the top glass size height.

Top FS = \(82 \frac{7}{8}" - 31 \frac{3}{16}" = 51 \frac{11}{16}"\)

DLO Height = \(51 \frac{11}{16}" - (3 \times 2") = 45 \frac{11}{16}"\)

Height glass size = \(45 \frac{11}{16}" + \frac{3}{4}" = 46 \frac{7}{16}"\)

Record the glass sizes.

Units required: 1 @ \(38 \frac{3}{8}" \times 31 \frac{15}{16}"\)

1 @ \(38 \frac{3}{8}" \times 46 \frac{7}{16}"\)

9. Calculate the glass size width.

DLO width = \(66 \frac{3}{4}" - (2 \times 2") = 62 \frac{3}{4}"\)

Width glass size = \(62 \frac{3}{4}" + \frac{3}{4}" = 63 \frac{1}{2}"\)

Calculate the glass size height.

Overall DLO Height = \(88 \frac{1}{2}" - (5 \times 2") = 78 \frac{1}{2}"\)

DLO = \(78 \frac{1}{2}" = 19 \frac{5}{8}"\)

Height glass size = \(19 \frac{5}{8}" + \frac{3}{4}" = 20 \frac{3}{8}"\)

Record the glass sizes.

Units required: 4 sealed units @ \(63 \frac{1}{2}" \times 20 \frac{3}{8}"\)
Notes
The Construction Sector Council (CSC) – a partnership between industry and government – is a national not-for-profit organization committed to the development of a highly skilled workforce that will support the future needs of Canada’s construction industry.

This publication is available in both official languages and can be obtained electronically at www.csc-ca.org

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