METRIC TRAINING
FOR THE TRANSPORTATION INDUSTRY

MODULE V
Motor Vehicle
Licensing and Enforcement

A Series of Programs
Offered via the Iowa Communications Network
to prepare Iowa Transportation Personnel
for Implementation
of the International System of Measurement

Sponsored by the Iowa Highway Research Board,
Iowa Department of Transportation
and
IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY
HR-376
"Metric Training For The Highway Industry", HR-376 was designed to produce training materials for the various divisions of the Iowa DOT, local government and the highway construction industry. The project materials were to be used to introduce the highway industry in Iowa to metric measurements in their daily activities. Five modules were developed and used in training over 1,000 DOT, county, city, consultant and contractor staff in the use of metric measurements.

The training modules developed, deal with the planning through operation areas of highway transportation. The materials and selection of modules were developed with the aid of an advisory personnel from the highway industry. Each module is design as a four hour block of instruction and a stand alone module for specific types of personnel. Each module is subdivided into four chapters with chapter one and four covering general topics common to all subjects. Chapters two and three are aimed at hands on experience for a specific group and subject. The modules include:

Module 1 - Basic Introduction to the Use of International Units of Measurement. This module is designed for use by all levels of personnel, primarily office staff, and provides a basic background in the use of metric measurements in both written and oral communications.

Module 2 - Construction and Maintenance Operations and Reporting. This module provides hands on examples of applications of metric measurements in the construction and maintenance field operations.

Module 3 - Road and Bridge Design. This module provides hands on examples of how to use metric measurements in the design of roads and structures.

Module 4 - Transportation Planning and Traffic Monitoring. Hands on examples of applications of metric measurements in the development of planning reports and traffic data collection are included in this module.

Module 5 - Motor Vehicle Enforcement. Examples from Iowa and Federal Motor Vehicle Codes are used as examples for hands on training for the vehicle enforcement type personnel using this module.

Each of the modules utilizes visual aids in the form of video tapes and others that can be projected by an overhead projector or through the use of computer aided methods. The course can be self administered or is best done through the use of a group session and the use of a class leader.
Metric Training for the Transportation Industry
Module 5 - Motor Vehicle Licensing and Enforcement

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Unit 1 - History and SI Basics

This part of the workshop will introduce you to the basics of SI Metric. Topics covered will include:

- A brief history of the metric system and SI
- The seven SI base units
- Derived units
- Supplemental units
- Prefixes
- Additional units to use with SI

At the end of this unit you will have the opportunity to complete a worksheet which will help you demonstrate your grasp of the metric covered in this part of the workshop.

Brief Metric History

Contrary to many people's beliefs the metric system is not a "new" measurement system. The original metric system was developed in the 1670's by a French Clergyman. In 1795 France officially adopted the Metric System as their system of measurement. Even within the United States the metric system has a lengthy history. Thomas Jefferson and John Quincy Adams were early promoters of the metric system in the U.S. In fact, the metric system has been a legal measurement system in the U.S. since 1866. By 1893 all standard U.S. measures were defined in metric terms. In 1902, Congressional legislation requiring the Federal Government to use metric exclusively was defeated by just one vote. At the General Conference on Weights and Measures held in 1960, a resolution was adopted which officially named the modern version of metric measurement to be the "International System of Units", abbreviated SI.

Motivation to Use SI in the U.S.

In recent decades there have been several efforts to convert the U.S. from the current measurement systems to the metric or SI system. Most of those efforts have met considerable resistance from the general public. However, the metric system has slowly progressed into everyday life in the U.S. Most people are actually already familiar with many metric terms. The following listing provides some examples of "everyday metric" that are already in use in the U.S.

- light bulbs: 100 watt, 75 watt
- electric bill: 800 kWh used
- voltage ratings: 110 volts, 220 volts
Unit 1 - History and SI Basics

- camera film: 35 mm
- beverages: 2-liter bottle of soda
- medicine: 500 mg aspirin
- nutritional label: 10 grams of fat
- athletic events: 100 meter dash, 10K run
- automobile engine sizes: 3.2 liter, 3.8 liter
- radio stations: KGGO - 94.9 MHz, WOI - 90.1 MHz
- skis: 225 centimeter
- time: seconds

The transition to metric usage in the U.S. has been very slow. However, there are several reasons why the U.S. should accelerate the shift to metric usage.

**International communication and competitiveness**

The myth that the U.S. is a self-sufficient, super-power country is quickly disappearing. We live in a "global" economy. In order to survive and prosper in this global economy, the U.S. must be able to easily trade and communicate with other countries. The U.S. is the only industrialized country (and one of only three countries total) in the world which does not use SI. People in other countries are not familiar with the U.S. system of measurements which makes trade and communication difficult. Trade with other countries is hampered due to the need for translation of measurements, or other countries simply refusing to purchase our non-SI designed products. If the U.S. is to maintain its leadership in the global economy it must seriously consider a rapid change to SI.

**Increased Efficiency**

Many companies are reluctant to change to SI because of the inefficiencies that will result due to time lost in learning the new system, and getting up to speed with it. In Canada, which converted to SI in the 1970's, companies have actually shown an improved efficiency due to decreased design costs and simplified dimensioning. A few U.S. firms (Otis Elevator and IBM) have also reported similar benefits.

**Simplicity**

The structure of the metric system, with base units and prefixes designating powers of 10, is a more straightforward system than the English system used in the U.S. Whether a person is discussing length (meters) or mass (kilograms) the prefix names and meanings are consistent. For example in the U.S. there are 12 inches in a foot, 3 feet in a yard, and 5280 feet in a mile. Each factor has different numbers, increasing the likelihood for error between translations. Using metric, when describing larger
Unit 1 - History and SI Basics

distances, everything is just a power of 10: 10 mm in a cm, 1000 mm in a m, and 1000 m in a km. Due to the simplified conversions, there is less chance for mathematical errors. In addition to the simplified conversions, because of the use of prefixes with base units there are fewer "names" to learn or get confused. There are also standardized methods for writing the terms, which leads to less confusion over abbreviations.

Recent History of SI in the Federal Government

On July 25, 1991 President George Bush signed Executive Order 12770 which provides guidelines for departments and agencies in the Federal Government to use metric measures to the extent economically feasible by the end of fiscal year 1992 or by such other date as established in consultation with the Secretary of Commerce.

The Department of Commerce requires federal agencies to use metric and to establish target dates for full implementation of the metric system.

The Department of Transportation and the Federal Highway Administration have established the following target dates for implementation of metric: 1994 - conversion of FHWA manuals, documents and publications, 1995 - data collection and reporting in metric, and September 30, 2000 - all Federal lands Highways and Federal-aid construction contracts must be in metric. This last date is the date which is causing the Iowa State Department of Transportation to also convert to the metric system no later than September 30, 2000. (Note: Recent legislation has shifted the date from September 30, 1996 to September 30, 2000.)

Units of Measure For Construction Video - Goals

Understand the base units and common prefixes
Know SI seven base units
  Describe standard for length - meter
  Describe standard for mass - kilogram
Learn about derived units
  Describe force - newton
  Describe pressure/stress - pascal
Learn about additional units
  Describe temperature - degree Celsius
  Describe fluid volumes - liter
  Describe volume - m$^3$
Unit 1 - History and SI Basics

The following pages contain an outline/guide which should be used as you view the video entitled Units of Measure. Please write any additional notes from the video directly on these sheets.

Units of Measure Video Outline

Le Systeme International d’Unités
(The International System of Units)
Metric system adopted as international standard in 1960
Commonly referred to as SI or SI Metric

Seven Base Units

<table>
<thead>
<tr>
<th>Unit</th>
<th>Base Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>meter</td>
</tr>
<tr>
<td>Mass</td>
<td>kilogram</td>
</tr>
<tr>
<td>Time</td>
<td>second</td>
</tr>
<tr>
<td>Electric current</td>
<td>ampere</td>
</tr>
<tr>
<td>Temperature</td>
<td>kelvin</td>
</tr>
<tr>
<td>Amount of matter</td>
<td>mole</td>
</tr>
<tr>
<td>Luminous intensity</td>
<td>candela</td>
</tr>
</tbody>
</table>

A closer look at length

Base Unit - meter

Definition of a meter - distance light travels in a vacuum in a time interval of $\frac{1}{299,792,458}$ of a second

Symbol for a meter - m

Other length measurements used by Iowa DOT

millimeter
Definition of a millimeter - $\frac{1}{1000}$ of a meter
Symbol - mm

kilometer
Definition of a kilometer - 1000 meters
Symbol - km
Unit 1 - History and SI Basics

Area measurements

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>square meters</td>
<td>m²</td>
</tr>
<tr>
<td>hectare</td>
<td>ha</td>
</tr>
<tr>
<td>square kilometers</td>
<td>km²</td>
</tr>
<tr>
<td>square millimeters</td>
<td>mm²</td>
</tr>
</tbody>
</table>

A closer look at mass

Base unit - kilogram

Definition - set by a specific physical weight (prototype) held at the International Bureau of Weights and measures

Symbol - kg

Other unit of mass

gram
Definition - 1/1000 of a kilogram
Symbol - g

Derived Units

Definition of a derived unit - a unit which is a unique combination of base (or other derived) units which identify a common phenomenon.

Listing of common derived units

- frequency: hertz
- force: newton
- pressure: pascal
- energy: joule
- power: watt
- quantity of electric charge: coulomb
- electric potential: volt
- electric capacitance: farad
- electric resistance: ohm
- electric conductance: siemens
- magnetic flux: weber
- flux density: tesla
- inductance: henry
- luminous flux: lumen
- illumination: lux
- radioactivity: becquerel
- absorbed dose: gray
- dose equivalent: sievert
A closer look at force

unit is the newton

replaces pounds-force in the English system

force = mass \times acceleration

newton = kilograms \times meter/(square seconds)

N = kg \cdot m/s^2

Example using "approximate calculations"
(acceleration is used as 10, which is a rounded number)

1 \ kg \times 10 \ m/s^2 = 10 \ N

Other units of force

kilonewton
Definition - 1000 newtons
Symbol - kN

meganewton
Definition - 1,000,000 newtons
Symbol - MN

A closer look at pressure

unit is the pascal

replaces pounds per square inch (PSI) in the English system

pressure = force/area

pascal = newton/(square meter)

Pa = N/m^2

Other units of pressure

kilopascal
Definition - 1000 pascals
Symbol - kPa

megapascal
Definition - 1,000,000 pascals
Symbol - MPa

Additional Units

Units that have been approved to be used with SI, even though they are not SI units.
Unit 1 - History and SI Basics

A closer look at temperature

degree Celsius

water freezes = 0°C          32°F
water boils = 100°C         212°F

replaces Centigrade from older metric systems

room temperature = 20°C
normal body temperature = 37°C

A closer look at volume

Liter - used for fluid volume

Definition - one cubic decimeter

Symbol - L

one liter is approximately 1 quart + 1/4 cup

Other units of volume

milliliter
Definition - 1/1000 of a liter
Symbol - mL

Other volumes (non-fluid)

<table>
<thead>
<tr>
<th>Volume</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>cubic meters</td>
<td>m³</td>
</tr>
<tr>
<td>cubic centimeters</td>
<td>cm³</td>
</tr>
<tr>
<td>cubic decimeters</td>
<td>dm³</td>
</tr>
<tr>
<td>cubic millimeters</td>
<td>mm³</td>
</tr>
</tbody>
</table>

NOTES FOR IOWA DOT

1) Angular measurements do not change and remain in degrees, minutes and seconds. Even though SI standard is the radian.

2) Measurements made relative to ROW takings, railroad agreements and utility construction will be identified in both English and SI.
Unit 1 - History and SI Basics

Visualizing Metric

Length

1 meter is just a little longer than a yard

1 millimeter, which is 0.001 meters, is about the width of the wire in a paper clip

Length of my hand = ______________ mm or ______________ m

My height = ______________ mm or ______________ m

Dimensions of a 8-1/2” x 11” sheet of paper = ______________ mm x ______________ mm

One pace for me = ______________ m

Height Table (Converted to nearest mm)

<table>
<thead>
<tr>
<th>Ht</th>
<th>mm</th>
<th>5' 1&quot;</th>
<th>5' 9&quot;</th>
<th>6' 5&quot;</th>
<th>5' 2&quot;</th>
<th>5' 10&quot;</th>
<th>6' 6&quot;</th>
<th>5' 3&quot;</th>
<th>5' 11&quot;</th>
<th>6' 7&quot;</th>
<th>5' 4&quot;</th>
<th>6' 8&quot;</th>
<th>6' 9&quot;</th>
<th>5' 5&quot;</th>
<th>6' 10&quot;</th>
<th>6' 11&quot;</th>
<th>5' 6&quot;</th>
<th>6' 12&quot;</th>
<th>6' 13&quot;</th>
<th>5' 7&quot;</th>
<th>6' 14&quot;</th>
<th>6' 15&quot;</th>
<th>5' 8&quot;</th>
<th>6' 16&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>4' 6&quot;</td>
<td>1372</td>
<td>1549</td>
<td>1753</td>
<td>1956</td>
<td>1397</td>
<td>1575</td>
<td>1778</td>
<td>1981</td>
<td>1423</td>
<td>1600</td>
<td>1803</td>
<td>2007</td>
<td>1448</td>
<td>1626</td>
<td>1829</td>
<td>2032</td>
<td>1485</td>
<td>1651</td>
<td>1854</td>
<td>2057</td>
<td>1524</td>
<td>1727</td>
<td>1930</td>
<td>2134</td>
</tr>
<tr>
<td>4' 7&quot;</td>
<td>1397</td>
<td>1575</td>
<td>1778</td>
<td>1981</td>
<td>1422</td>
<td>1600</td>
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<td>2007</td>
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<td>1854</td>
<td>2057</td>
<td>1524</td>
<td>1727</td>
<td>1930</td>
<td>2134</td>
</tr>
<tr>
<td>4' 8&quot;</td>
<td>1422</td>
<td>1600</td>
<td>1803</td>
<td>2007</td>
<td>1448</td>
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<td>2057</td>
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<td>1930</td>
<td>2134</td>
<td>1600</td>
<td>1794</td>
<td>1997</td>
<td>2198</td>
</tr>
<tr>
<td>4' 10&quot;</td>
<td>1473</td>
<td>1676</td>
<td>1880</td>
<td>2083</td>
<td>1499</td>
<td>1682</td>
<td>1886</td>
<td>2089</td>
<td>1549</td>
<td>1735</td>
<td>1939</td>
<td>2142</td>
<td>1524</td>
<td>1727</td>
<td>1930</td>
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<td>1965</td>
<td>2168</td>
<td>1600</td>
<td>1804</td>
<td>2007</td>
<td>2210</td>
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<tr>
<td>4' 11&quot;</td>
<td>1499</td>
<td>1702</td>
<td>1905</td>
<td>2108</td>
<td>1524</td>
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<td>2043</td>
<td>2246</td>
</tr>
<tr>
<td>5' 0&quot;</td>
<td>1524</td>
<td>1727</td>
<td>1930</td>
<td>2134</td>
<td>1559</td>
<td>1762</td>
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<td>1600</td>
<td>1804</td>
<td>2007</td>
<td>2210</td>
<td>1635</td>
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<td>2043</td>
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<td>1676</td>
<td>1880</td>
<td>2083</td>
<td>2287</td>
<td>1702</td>
<td>1905</td>
<td>2108</td>
<td>2311</td>
</tr>
</tbody>
</table>

Mass

1 nickel (5 cents) has a mass of 5 grams

100 pounds is about 45 kilograms

A long ton is about equal to a metric tonne (t) which is equal to a megagram (Mg).

My mass = ______________ kg

Mass table (Converted to nearest 0.1 kg)

| wt(lb) | kg  | 130 | 190 | 250 | 135 | 195 | 255 | 140 | 200 | 260 | 145 | 205 | 265 | 150 | 210 | 270 | 155 | 215 | 275 | 160 | 220 | 280 | 165 | 225 | 285 | 170 | 230 | 290 | 175 | 235 | 295 | 180 | 240 | 300 | 185 | 245 | 305 |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 75 | 34.0 | 59.0 | 86.2 | 113.4 | 34.0 | 61.2 | 88.5 | 115.7 | 34.0 | 63.5 | 90.7 | 117.9 | 34.0 | 65.8 | 93.0 | 120.2 | 34.0 | 68.0 | 95.3 | 122.5 | 34.0 | 70.3 | 97.5 | 124.7 | 34.0 | 72.6 | 99.8 | 127.0 | 34.0 | 74.8 | 102.1 | 129.3 | 34.0 | 77.1 | 104.3 | 131.5 | 34.0 | 79.4 | 106.6 | 133.8 | 34.0 | 81.6 | 108.9 | 136.1 | 34.0 | 83.9 | 111.1 | 8 |
Unit 1 - History and SI Basics

Temperature

<table>
<thead>
<tr>
<th>Degree Celsius</th>
<th>Equals</th>
</tr>
</thead>
<tbody>
<tr>
<td>177</td>
<td>350 degree oven</td>
</tr>
<tr>
<td>100</td>
<td>Water boils (212)</td>
</tr>
<tr>
<td>37</td>
<td>Normal body temperature of 98.6</td>
</tr>
<tr>
<td>22</td>
<td>room temperature (72)</td>
</tr>
<tr>
<td>10</td>
<td>spring or fall day (50)</td>
</tr>
<tr>
<td>0</td>
<td>Water freezes (32)</td>
</tr>
<tr>
<td>-12</td>
<td>Typical Iowa winter temperature (10)</td>
</tr>
<tr>
<td>-18</td>
<td>Zero degrees Fahrenheit (0)</td>
</tr>
<tr>
<td>-30</td>
<td>Frigid winter night in Iowa (-22)</td>
</tr>
</tbody>
</table>

Pressure

Auto tire pressure of 28 (PSI) equals roughly 200 000 Pa  
or 200 kPa  
or 0.2 MPa

Area

A hectare is about 2.5 acres.  
A square mile is about 2.5 square kilometers.

Volume

A quart is a little smaller than a liter.  
1 teaspoon is about 5 mL.  
A concrete mixer truck holds about 7 cubic meters of ready-mix concrete (about 9 cubic yards).  
A typical straight truck holds about 8.5 cubic meters of gravel (about 11.5 cubic yards).
Worksheet Review

1. Which of the following metric units is used to express fluid volume?
   A. liter
   B. cubic centimeter
   C. pascal
   D. hectare

2. Which unit of measuring temperature would be used in construction situations?
   A. degree Fahrenheit
   B. degree Centigrade
   C. Kelvin
   D. degree Celsius

3. Newton replaces which unit in the English system?
   A. pounds per square inch
   B. pound force
   C. pounds per cubic inch
   D. pound mass

4. Iowa DOT drawings should use which of the following units? (Circle all that apply.)
   A. meter
   B. centimeter
   C. millimeter
   D. megameter

5. On the Celsius scale, water freezes at what temperature?
   A. 32°C
   B. 100°C
   C. 0°C
   D. 0K

6. Which SI metric unit listed here would be appropriate to use for expressing the volume of concrete or fill?
   A. cubic decimeter
   B. cubic meter
   C. liter
   D. ton

7. Which of the following is the same as 200 meters?
   A. 0.02 km
   B. 2 km
   C. 0.2 km
   D. 20 km
Unit 1 - History and SI Basics

Worksheet Review

8. Which is the same as 3 meters?
   A. 0.03 km
   B. 3000 mm
   C. 300 mm
   D. 0.3 km

9. Which of the following represents the longest length?
   A. 3.0 m
   B. 450 mm
   C. 0.05 km
   D. 20.0 cm

10. SI refers to:
    A. The system interfaces necessary to implement metric in computers.
    B. The internationally accepted metric system used today.
    C. The governing organization that establishes metric rules and policies.
    D. The international strategies that created the first metric system.

11. On the moon, acceleration of a falling object caused by gravity is about 1.7 m/s². Using the proper metric unit, what is the gravity force of a two kilogram object?
    A. 3.4 pascals
    B. 1.7 pascals
    C. 3.4 newtons
    D. 1.7 newtons

12. Which SI unit replaces PSI in the English measurement system?
    A. kg/m²
    B. N
    C. Pa
    D. N·m
This part of the workshop will provide a brief introduction to the basic of converting measurements from English units to SI Metric. The majority of the time in this unit will be dedicated to working sample conversion and SI metric transportation planning problems. Topics covered will include:

- Hard vs. Soft Conversion
- Use of Conversion Tables
- SI Applications in transportation planning activities

Types of Conversions

Hard Metric Conversion

original design done in metric (use metric standards)

steps required:
- calculate measurement in metric (use conversion factors if "thinking" in English)
- select a preferred metric dimension that meets design performances needed

Example: to design a product that needs a bolt... if this was originally designed in English units you would have selected a 3/4" x 4" hex cap bolt. Determine what standard metric bolt you will want to use in this new metric design.

First determine "equivalent" diameter
1 inch = 25.4 mm
3/4" = (3/4)(25.4) = .75(25.4) = 19.05 mm
closest common (standard) metric diameter screw is 20 mm called an M20

Next determine "equivalent" length
1 inch = 25.4 mm
4" = 4(25.4) = 101.6 mm
closest common (standard) metric length is 100 mm

Metric screw to use would be M20 x 100

Soft Metric Conversion

original design in English (use English Standards)

steps required:
- use conversion factors to translate English unit to metric measurement
- round measurement to intended precision

examples:
- if English design calls for 1 lb use conversion factor and specify 454g (0.454 kg)
- if English design calls for 1 qt use conversion factor and specify 0.9463 L
Unit 2 - SI Applications in Federal Work Activities

Conversion Factors

When converting English units to SI units you will need to use conversion factors. Conversion tables can come in many different formats. For this workshop we will be using conversion tables that look like this:

<table>
<thead>
<tr>
<th>Quantity From</th>
<th>To</th>
<th>Multiply by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>ft</td>
<td>m</td>
</tr>
<tr>
<td></td>
<td>in</td>
<td>m</td>
</tr>
<tr>
<td></td>
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<td>kg</td>
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<table>
<thead>
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<th>Length quantity</th>
<th>conversion factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>ft</td>
<td>0.3048 m/ft</td>
</tr>
<tr>
<td>in</td>
<td>25.4 x 10^{-3} m/in</td>
</tr>
<tr>
<td>yd</td>
<td>0.9144 m/yd</td>
</tr>
<tr>
<td>lbm</td>
<td>0.4536 kg/lbm</td>
</tr>
</tbody>
</table>

EXAMPLES:

A. Convert 1000 yards to meters using the conversion table above:

\[ 1000 \text{ yards} \times 0.9144 \text{ meters/yard} = 914.4 \text{ meters} \]

B. Convert 5'7" to SI units

First convert 5' to inches... must have all one unit only to convert

So 5 \times 12 = 60" plus the 7" = 67"

Now convert the 67" to meters

\[ 67 \text{ inches} \times 25.4 \times 10^{-3} \text{ m/inch} = 1.7018 \text{ m} \Rightarrow 1.7 \text{ m} \]
A. N-Butyl alcohol is listed as a reportable hazardous waste when being transported in quantities of over 5,000 pounds. What is the comparable limit in kilograms?

B. The minimum reportable amount of copper chloride that when transported is considered a hazardous waste is 4.54 kg. Can 9.0 lbs be transported without special reporting?

C. The recommended placard holder size for identification of hazardous waste hauling units is 12-1/2 in. by 12-1/2 in. What should be the same minimum dimensions in system international units?

D. A cylinder of gas is labeled to withstand a pressure of 2.25 MPa. You have measured the pressure to be 400 psi, is this material being legally transported?

E. Chapter III of 49 CFR defines a Group B vehicle as a single vehicle with GVWR of 26,001 or more pounds, or any such vehicle towing a vehicle not in excess of 10,000 lbs. GVWR. What are the equivalent values in megagrams?
F. A towed vehicle of Group Type B is found to have a scale ticket indicating a weight of 4.835 Mg. Is this vehicle legal under federal law?

G. Alcohol/blood concentration limits for drivers when expressed as a percentage means grams of alcohol per 100 milliliters of blood or grams of alcohol per 210 liters of breath. Driving under the influence of alcohol is defined as being 0.04 percent. How many grams of alcohol would this represent in 200 milliliters of blood?

H. Farm to market agricultural vehicles must be used within 150 air miles of a farmer's farm. Express this distance in terms of kilometers.

I. Vehicle markings must be legible during daylight hours, from a distance of 50 feet while the vehicle is stationary. What is the equivalent metric distance in meters?

J. Any full trailer having a GVWR of 3,000 lbs. or less must be equipped with brakes if the weight of the towed vehicle resting on the towing vehicle exceeds 40 percent of the GVWR of towing vehicle. Given a towing vehicle of 2 Mg and the trailer weight resting on the towing vehicle is 2,500 lbs. Are brakes required?

K. The brake air pressure gage in a vehicle is calibrated in terms of MPa. If an air pressure of 125 psi in English measurements is required, what is the equivalent measure in MPa?
L. The braking rate for vehicles from 20 mph to a stop is required to be less than or equal to 21 ft/sec/sec to stop in 20 ft for a passenger car. Convert the speed, deceleration rate and distance into appropriate metric measurements.

M. Windows may have cracks of 1/4 inch in width or 3/4 inch in diameter. What are the equivalent measurements in millimeters?

N. Liquid fuel tanks with a capacity of 25 gallons or more must have a venting system to aid in fire safety. The tanks on a truck are identified as having a capacity of 10 L. Does this tank require a vent system?

O. The tank noted in question N is to be tested for fire safety. The test requires heating the fuel to between 50 and 80 degrees Fahrenheit. What is the equivalent range (nearest degree) that you will use in testing with a Celsius thermometer?

P. Tow bars of the type which depend upon the bumpers as a means of transmitting forces between the vehicles shall not be used to tow a motor vehicle weighing more than 5,000 pounds. What is the limiting mass of the towed vehicle in kilograms?
Q. U-bolts used as part of the towing attachment on a towed vehicle of greater than 5,000 lbs. must have a diameter of 0.6875 inches and a cross sectional area of 1.4 square inches. What is the equivalent mass in kilograms, diameter in millimeters, and area in square millimeters?

R. Truck tire pressures have been measured on a vehicle traveling between 41 and 55 mph with tires having a measured load rating of 5,000 lbs. If the pressure due to heat build up is 5 psi, what are the equivalent speed range limits km/h, load rating in Mg and pressure correction factor in kPa?

S. A sleeper berth is required to have dimensions of at least 72 inches in length, 18 inches of width, and 18 inches of height. The manufacturers data sheet for a given truck berth indicates a length of 3 m and a width and height of 0.5 m. Does the berth meet minimum requirements?

T. Timbers measuring 2x4 inches or 4x4 inches have been required for securing most loads on flatbed trailers. Assuming the timbers were the noted dimensions, what are the equivalent metric measurements in mm?

U. A single article being secured on a flatbed must have at least one tiedown assembly for each 8 feet of length. How many tiedown assemblies are required for a 13 m article?

V. A 100 mile radius driver has driven some 150 km from her work reporting location. Is this person subject to the limitations on hours of driving without rest?
W. A truck odometer indicates that the vehicle has traveled some 500,000 km. How many miles has this truck traveled?

X. The aggregate static breaking strength of the tie down devices used to secure an article against movement in any direction must be at least 1.5 times the weight of the article. What must be the static breaking strength of the tie down device if the article mass is 18 kg?
Special Notes:

1. Court records are not being converted to metrics in many areas at this time. Dual units with English followed by the metric value in parenthesis will be the rule in most local jurisdictions. It is important that the same level of accuracy be retained in each measurement for legal purposes.

2. Accident location and analysis records at this point in time will also carry dual unit measurements. Mileposts and milepoints will be retained physically along the highways until at least the year 2000. They will be referred to as linear reference points in the Iowa DOT base record system.

3. Information contained on detour and embargo map language should be reviewed for legends and units of measure before assuming either English or metric units.

The following questions are contained in the "Iowa Compendium of Scheduled Violations and Scheduled Fines", and "Trucking Through Iowa" publications.

A. Speeding violations based on the 55 mph speed limit are levied in terms of the speed over the limit. Develop a range of metric speed values to replace the English values in the following list:

<table>
<thead>
<tr>
<th>mph over limit</th>
<th>km/h over limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 thru 5 over</td>
<td></td>
</tr>
<tr>
<td>6 thru 10 over</td>
<td></td>
</tr>
<tr>
<td>11 thru 15 over</td>
<td></td>
</tr>
<tr>
<td>16 thru 20 over</td>
<td></td>
</tr>
</tbody>
</table>

B. A speed of 37 mph over the posted limit equates to how many km/h over the limit? (note - retain the same level of accuracy in the conversion)
C. Overload fines for weights in excess of the maximum 20,000 lb axle limit are shown in the table below. These values must be converted to metric units of mass.

<table>
<thead>
<tr>
<th>Lbs over limit</th>
<th>Kg over limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 1,000</td>
<td></td>
</tr>
<tr>
<td>1,001 to 2,000</td>
<td></td>
</tr>
<tr>
<td>2,001 to 3,000</td>
<td></td>
</tr>
<tr>
<td>3,001 to 4,000</td>
<td></td>
</tr>
<tr>
<td>4,001 to 5,000</td>
<td></td>
</tr>
<tr>
<td>5,001 to 6,000</td>
<td></td>
</tr>
<tr>
<td>6,000 +</td>
<td></td>
</tr>
</tbody>
</table>

D. Vehicle lengths for combination vehicles of 2 or 3 vehicles on nondesignated highways are limited to 60 ft. What is the equivalent metric length in meters?

E. A 15 meter semitrailer has been stopped on the designated highway system. Is this trailer legal in Iowa?

F. Convert the 8 ft. 6 inch allowable width into meters and retain the same level of accuracy.

G. What is the maximum weight in Mg allowed for any vehicle without a special permit?

H. Is a truck with a mass of 39 Mg legal in Iowa?
I. A tandem axle has been measured with 15 Mg of mass. Is this within legal limits?

J. A vehicle with a height of 3.85 m is being considered for a permit on a highway with a bridge clearance of 13 ft. 6 in. Should the permit be issued?

K. A 400 cubic inch engine is needed to power a given hauling unit. What is the equivalent volume displacement engine in metric in cubic millimeters?
This part of the workshop will introduce you to the basic reading and writing rules of SI Metric and some of the standard conventions used in the Iowa DOT. Following these few simple rules will make it easier for us to understand each other, and lessen the chance for errors or misinterpretation. Topics covered will include:

- Proper notation
- Prefixes
- Separating digits
- Spacing
- Intended Precision
- Capitalization
- Rounding
- Spelling
- Estimating
- Singular/Plurals
- Decimal markers
- Powers of ten
- Powers of ten

At the end of this unit you will have the opportunity to complete a worksheet which will help you demonstrate your grasp of the metric concepts covered in this part of the workshop.

The following pages contain an outline/guide which was extracted from a video entitled SI Metric: Reading, Writing, Rules. Although you will not be viewing this video as part of this workshop, the information in the outline may be helpful to you in the future.

**Reading, Writing, Rules Video Outline**

**Reasons for correct usage**

- avoid mistakes
- eliminate need for translation

**SI Symbols**

- most are lower case
- exceptions - when the symbol is derived from a proper name
- no periods - these are not abbreviations!
- no plurals or "s" on symbols
Unit 4 - SI Applications in Record Keeping

<table>
<thead>
<tr>
<th>unit names</th>
<th>symbols</th>
</tr>
</thead>
<tbody>
<tr>
<td>meter</td>
<td>m</td>
</tr>
<tr>
<td>kilogram</td>
<td>kg</td>
</tr>
<tr>
<td>newton</td>
<td>N</td>
</tr>
<tr>
<td>pascal</td>
<td>Pa</td>
</tr>
<tr>
<td>square meter</td>
<td>m²</td>
</tr>
<tr>
<td>cubic meter</td>
<td>m³</td>
</tr>
<tr>
<td>liter</td>
<td>L</td>
</tr>
<tr>
<td>degree Celsius</td>
<td>°C</td>
</tr>
</tbody>
</table>

Prefixes

- no space between prefix and unit
- no hyphen between prefix and unit
- all prefixes below 1,000,000 (mega) have lower case symbols
- all prefixes from mega and above the prefixes are uppercase symbols
- never mix with abbreviations

Examples:

<table>
<thead>
<tr>
<th>name</th>
<th>symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>kilogram</td>
<td>kg</td>
</tr>
<tr>
<td>meganewton</td>
<td>MN</td>
</tr>
<tr>
<td>kilopascal</td>
<td>kPa</td>
</tr>
</tbody>
</table>

only one prefix allowed

No -- kMN or Mmm

Spelling, Capitalizing, and Plurals

Unit names when written out are all lower case... even those derived from proper names such as pascal and newton. The only exception is degree Celsius

In the U.S. use meter and liter (not metre and litre)

Plural may use an optional "s" don't need it

kilogram or kilograms

between the prefix and the unit:
- no separation (not milli meter)
- no hyphens (not milli-meter)

millimeter is correct

degree Celsius
degrees Celsius
Unit 4 - SI Applications in Record Keeping

For area or volumes... square and cubic are written first in name, but shown as an exponent in symbol

<table>
<thead>
<tr>
<th>name</th>
<th>symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>square meter</td>
<td>m²</td>
</tr>
<tr>
<td>cubic meter</td>
<td>m³</td>
</tr>
</tbody>
</table>

(Not meters square)

Spacing

leave a space between the numerical value and the SI unit symbol

Examples:

35 mm
7.63 kPa

NOTE: The video is wrong when it discusses degrees Celsius. There is NOT a space between the numeric value and the degree symbol.

Example:

Wrong ---- 37 °C
Correct --- 37°C

Obsolete Metric

<table>
<thead>
<tr>
<th>Old</th>
<th>Correct SI</th>
</tr>
</thead>
<tbody>
<tr>
<td>10K</td>
<td>10 km</td>
</tr>
<tr>
<td>K</td>
<td>kg</td>
</tr>
<tr>
<td>KPH</td>
<td>km/h</td>
</tr>
<tr>
<td>kilos</td>
<td>kilograms</td>
</tr>
<tr>
<td>grm or gm</td>
<td>g</td>
</tr>
<tr>
<td>Newton</td>
<td>newton</td>
</tr>
<tr>
<td>cc, ccm</td>
<td>cm³</td>
</tr>
</tbody>
</table>
Unit 4 - SI Applications in Record Keeping

Decimal Points, Commas, and Groups of Three

if number is a decimal less than 1, use a leading "0"  (Example: 0.1234)

outside of the U.S. many people use a comma instead of a period to indicate the decimal point. this can be confusing

1.33  US    =    1,33  Outside US

rather than grouping every three numbers with a comma, as we do in the US, SI uses a small space

old US English system  1,365,020.034589
SI system (using decimal point)  1 365 020.034 589

group all numbers in three except when it is only a four digit number

Correct:  4567.987
Incorrect:  4 567.987

NOTE: The Iowa DOT will continue to use the standard English system method of grouping. The period will still be used for the decimal point, and commas will be used to separate every three digits.

Powers of Ten

sometimes people prefer to represent values as powers of ten of the base unit rather than using the prefixes

Examples:

<table>
<thead>
<tr>
<th>power of 10 representation equivalent SI prefix</th>
</tr>
</thead>
<tbody>
<tr>
<td>(123.4 \times 10^{-3} \text{ m} )</td>
</tr>
<tr>
<td>(12.34 \times 10^{6} \text{ N} )</td>
</tr>
<tr>
<td>(1.234 \times 10^{3} \text{ Pa} )</td>
</tr>
</tbody>
</table>
Unit 4 - SI Applications in Record Keeping

Intended Precision

"what does the number really reflect, and how will it be used"

Example of a quart of oil

1 qt = 0.9463529 L

however, when you add oil to your car... would substitute 1L for 1 qt
(you are not going to measure to 0.0000001 L to get 0.9463529L)

All conversions must reflect an intended precision of the original quantity which can be implied by significant digits (and/or tolerance)

Examples:

1.54 quarts has 3 significant digits
intended precision is +/- one-half of the last significant digit
1.54 ..... +/- 0.005
1.535 ... 1.54 ... 1.545 (true measurement somewhere between 1.535 and 1.545)

given number   probable intended precision   range number between

5.14          +/- 0.005    5.135 ... 5.145
645.117       +/- 0.0005   645.1165 ... 645.1175
10.            +/- 0.5      9.5 ... 10.5
10             +/- 1       9 ... 11

Be cautious with decimals... could represent fractions and mislead you on the number of significant digits. For example: 3.1875 could mean 3.1875 or 3-3/16. Would have different "intended precision" with these two.

Be cautious of numbers with no decimal places... "5" could mean approximately 5 or could mean 5.0000

Knowledge of the circumstances related to the measurement are important
understand accuracy of measuring equipment
origination of the measurement
purpose of the original measurement
purpose of the conversion
(all of the above give you information about the intended precision)

Rounding Rules

If number after last significant digit to be saved is less than 5, drop the numbers

4.763534 round to 2 after decimal place = 4.76
234.8732 round to 3 after the decimal place = 234.873
87632 round to nearest hundred = 87600

If the number after last significant digit to be saved is greater than 5, add one to last number

4.763534 round to 1 after the decimal place = 4.8
234.8732 round to 1 after the decimal place = 234.9
87632 round to nearest thousand = 88000

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Unit 4 - SI Applications in Record Keeping

If the number after the last significant digit to be saved is exactly equal to 5 (with nothing after it) then

... Make the number an even number.....

If the last significant digit is odd... round up
If the last significant digit is even... do nothing (drop 5)

476.55 round to 1 after decimal = 476.6
445.25 round to 1 after decimal = 445.2

Importance of Estimating

When doing conversion calculations, it is easy to hit the wrong key on the calculator therefore it is important to do two things:

1) double check the answer (punch the numbers again) to see if you get the same answer
2) verify your answer using estimations and common sense

For example if you are converting 25 miles per hour to kilometers per hour....

Your answer should be 25 x 1.609 = 40.225 km/h => 40 km/h

However if you typed 16.09 instead of 1.609 your answer would say 402.25 or 402 km/h

When you get your answer stop and think... use your visualizing metric rules of thumb, does the answer seem logical???

We know that a kilometer is a little more than half a mile (about .6). Therefore in the same amount of time (one hour) we would expect to go almost twice as many kilometers as miles (or 50). An answer of 402 is obviously not the correct. The correct answer of 40 is reasonable.

The more familiar you become with SI metric units, the easier it will be for you to recognize when you have made a mathematical error. Until then... double check your work!
Unit 4 - SI Applications in Record Keeping

Worksheet Review

1. What is the correct symbol for megapascals?
   A. Mpa
   B. MPa
   C. mPa
   D. mPA

2. What is the correct symbol for cubic millimeter?
   A. cu.mm.
   B. mm³
   C. cmm
   D. mm³

3. Which of the following is not a correct SI plural?
   A. 44.65 m
   B. 5.4 kilopascal
   C. Eighteen cubic millimeters
   D. 149 MNs

4. Which of the following is the correct representation of temperature in degree Celsius?
   A. 42.5°c
   B. 42.5°C
   C. 42.5 c°
   D. 42.5°C

5. Which of the following is correct?
   A. 19mm³
   B. 448 cmm
   C. 18 Mn
   D. 55.7 kPa

6. Which of these expressions is a proper expression for kilometers per hour?
   A. 75 KPH
   B. 75 Km/H
   C. 75 km/h
   D. 75 km/hr

7. Which of the following expressions is equivalent to $1 \times 10^4$ square millimeters?
   A. 10 000 mm²
   B. 1000 mm²
   C. 0.0001 mm²
   D. 0.001 mm²
8. Which of the following pairs of symbols and unit names is correct?
   A. 17 MPa 17 Megapascals.
   B. 3434.6 N 3434.6 Newtons
   C. 1.67 kg 1.67 kilograms
   D. 2.3 mm 2.3 millimeters

9. Which of the following is a correct sentence for temperature?
   A. The temperature outside was ten Degrees Celsius.
   B. The temperature outside was ten degrees celsius.
   C. The temperature outside was ten degrees Celsius.
   D. The temperature outside was ten Degrees celsius.

10. Which of the following is correct?
    A. .78 kg/m²
    B. 3.9 L
    C. 4.539 KPa
    D. 3.87 ha

11. Round the following numbers as specified
    Round to
    a) 34.876 2 after decimal place
    b) 87.565 2 after decimal place
    c) 1234 10's place
    d) 876.52 whole number
    e) 0.2347 3 after decimal place
SI Metric Tables
### SI Metric Tables

#### SI Base Units

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>length</td>
<td>meter</td>
<td>m</td>
</tr>
<tr>
<td>mass</td>
<td>kilogram</td>
<td>kg</td>
</tr>
<tr>
<td>time</td>
<td>second</td>
<td>s</td>
</tr>
<tr>
<td>electric current</td>
<td>ampere</td>
<td>A</td>
</tr>
<tr>
<td>temperature</td>
<td>kelvin</td>
<td>K</td>
</tr>
<tr>
<td>amount of substance</td>
<td>mole</td>
<td>mol</td>
</tr>
<tr>
<td>luminous intensity</td>
<td>candela</td>
<td>cd</td>
</tr>
</tbody>
</table>

#### SI Supplementary Units

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>plane angle</td>
<td>radian</td>
<td>rad</td>
</tr>
<tr>
<td>solid angle</td>
<td>steradian</td>
<td>sr</td>
</tr>
</tbody>
</table>

#### SI Derived Units with Special Names

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Name</th>
<th>Symbol</th>
<th>In terms of Other Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>frequency</td>
<td>hertz</td>
<td>Hz</td>
<td>s⁻¹</td>
</tr>
<tr>
<td>force</td>
<td>newton</td>
<td>N</td>
<td>kg m s⁻²</td>
</tr>
<tr>
<td>pressure, stress</td>
<td>pascal</td>
<td>Pa</td>
<td>N/m²</td>
</tr>
<tr>
<td>energy, work</td>
<td>joule</td>
<td>J</td>
<td>N·m</td>
</tr>
<tr>
<td>power</td>
<td>watt</td>
<td>W</td>
<td>J/s</td>
</tr>
<tr>
<td>electric charge</td>
<td>coulomb</td>
<td>C</td>
<td>s·A</td>
</tr>
<tr>
<td>electric potential</td>
<td>volt</td>
<td>V</td>
<td>W/A</td>
</tr>
<tr>
<td>capacitance</td>
<td>farad</td>
<td>F</td>
<td>C/V</td>
</tr>
<tr>
<td>electric resistance</td>
<td>ohm</td>
<td>Ω</td>
<td>V/A</td>
</tr>
<tr>
<td>electrical conductance</td>
<td>siemens</td>
<td>S</td>
<td>A/V</td>
</tr>
<tr>
<td>magnetic flux</td>
<td>weber</td>
<td>Wb</td>
<td>V·s</td>
</tr>
<tr>
<td>magnetic flux density</td>
<td>tesla</td>
<td>T</td>
<td>Wb/m²</td>
</tr>
<tr>
<td>inductance</td>
<td>henry</td>
<td>H</td>
<td>Wb/A</td>
</tr>
<tr>
<td>luminous flux</td>
<td>lumen</td>
<td>lm</td>
<td>cd·sr</td>
</tr>
<tr>
<td>illuminance</td>
<td>lux</td>
<td>lx</td>
<td>lm/m²</td>
</tr>
<tr>
<td>activity (radio)</td>
<td>becquerel</td>
<td>Bq</td>
<td>s⁻¹</td>
</tr>
<tr>
<td>absorbed dose</td>
<td>gray</td>
<td>Gy</td>
<td>J/kg</td>
</tr>
<tr>
<td>dose equivalent</td>
<td>sievert</td>
<td>Sv</td>
<td>J/kg</td>
</tr>
</tbody>
</table>
## SI Metric Tables

### Acceptable Units to Use with SI Units

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Name</th>
<th>Symbol</th>
<th>In terms of Base Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>temperature</td>
<td>degree Celsius</td>
<td>°C</td>
<td>K (°C = t K - 273.15)</td>
</tr>
<tr>
<td>volume</td>
<td>liter</td>
<td>L</td>
<td>10^{-3} m^3</td>
</tr>
<tr>
<td>mass</td>
<td>tonne (metric ton)</td>
<td>t</td>
<td>10^3 kg</td>
</tr>
<tr>
<td>time</td>
<td>minute</td>
<td>min</td>
<td>60 s</td>
</tr>
<tr>
<td>time</td>
<td>hour</td>
<td>h</td>
<td>3600 s</td>
</tr>
<tr>
<td>time</td>
<td>day</td>
<td>d</td>
<td>86400 s</td>
</tr>
<tr>
<td>angle</td>
<td>degree</td>
<td>°</td>
<td>(π/180) rad</td>
</tr>
<tr>
<td>angle</td>
<td>minute</td>
<td>′</td>
<td>(π/10800) rad</td>
</tr>
<tr>
<td>angle</td>
<td>second</td>
<td>″</td>
<td>(π/648000) rad</td>
</tr>
<tr>
<td>area</td>
<td>hectare</td>
<td>ha</td>
<td>100m x 100m or 10^4 m^2</td>
</tr>
</tbody>
</table>

### Commonly Used Prefixes

<table>
<thead>
<tr>
<th>Multiple of 10</th>
<th>Prefix</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 000 000 000 = 10^9</td>
<td>giga</td>
<td>G</td>
</tr>
<tr>
<td>1 000 000 = 10^6</td>
<td>mega</td>
<td>M</td>
</tr>
<tr>
<td>1 000 = 10^3</td>
<td>kilo</td>
<td>k</td>
</tr>
<tr>
<td>0.001 = 10^{-3}</td>
<td>milli</td>
<td>m</td>
</tr>
<tr>
<td>0.000 001 = 10^{-6}</td>
<td>micro</td>
<td>μ</td>
</tr>
<tr>
<td>0.000 000 001 = 10^{-9}</td>
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</table>

### Additional Prefixes

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</tr>
</thead>
<tbody>
<tr>
<td>10^{24}</td>
<td>yotto</td>
<td>Y</td>
</tr>
<tr>
<td>10^{21}</td>
<td>zetta</td>
<td>Z</td>
</tr>
<tr>
<td>10^{18}</td>
<td>exa</td>
<td>E</td>
</tr>
<tr>
<td>10^{15}</td>
<td>peta</td>
<td>P</td>
</tr>
<tr>
<td>10^{12}</td>
<td>tera</td>
<td>T</td>
</tr>
<tr>
<td>10^{9}</td>
<td>hecto</td>
<td>h</td>
</tr>
<tr>
<td>10^{6}</td>
<td>deka</td>
<td>da</td>
</tr>
<tr>
<td>10^{3}</td>
<td>deci</td>
<td>d</td>
</tr>
<tr>
<td>10^{-2}</td>
<td>centi</td>
<td>c</td>
</tr>
<tr>
<td>10^{-12}</td>
<td>pico</td>
<td>p</td>
</tr>
<tr>
<td>10^{-15}</td>
<td>femto</td>
<td>f</td>
</tr>
<tr>
<td>10^{-18}</td>
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<td>a</td>
</tr>
<tr>
<td>10^{-21}</td>
<td>zepto</td>
<td>z</td>
</tr>
<tr>
<td>10^{-24}</td>
<td>yocto</td>
<td>y</td>
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</tbody>
</table>
## SI Metric Tables

### Conversion Factors: English to SI Metric

<table>
<thead>
<tr>
<th>Quantity</th>
<th>From English Unit:</th>
<th>To SI Metric Unit:</th>
<th>Multiply by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>length</td>
<td>mile</td>
<td>km</td>
<td>1.609347</td>
</tr>
<tr>
<td></td>
<td>yard</td>
<td>m</td>
<td>0.9144</td>
</tr>
<tr>
<td></td>
<td>foot</td>
<td>m</td>
<td>0.3048006 (See note)</td>
</tr>
<tr>
<td></td>
<td>inch</td>
<td>mm</td>
<td>25.4</td>
</tr>
<tr>
<td>area</td>
<td>square mile</td>
<td>km²</td>
<td>2.5989998</td>
</tr>
<tr>
<td></td>
<td>acre</td>
<td>m²</td>
<td>4047</td>
</tr>
<tr>
<td></td>
<td>acre</td>
<td>hectare</td>
<td>0.4046873</td>
</tr>
<tr>
<td></td>
<td>square yard</td>
<td>m²</td>
<td>0.8361274</td>
</tr>
<tr>
<td></td>
<td>square foot</td>
<td>m²</td>
<td>0.09290304</td>
</tr>
<tr>
<td></td>
<td>square inch</td>
<td>mm²</td>
<td>645.16</td>
</tr>
<tr>
<td>volume</td>
<td>acre foot</td>
<td>m³</td>
<td>1233</td>
</tr>
<tr>
<td></td>
<td>cubic yard</td>
<td>m³</td>
<td>0.7645549</td>
</tr>
<tr>
<td></td>
<td>cubic foot</td>
<td>m³</td>
<td>0.02831685</td>
</tr>
<tr>
<td></td>
<td>cubic foot</td>
<td>L</td>
<td>28.32</td>
</tr>
<tr>
<td></td>
<td>100 board feet</td>
<td>m³</td>
<td>0.2360</td>
</tr>
<tr>
<td></td>
<td>gallon</td>
<td>L</td>
<td>3.785412</td>
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<tr>
<td></td>
<td>cubic inch</td>
<td>cm³</td>
<td>16.39</td>
</tr>
<tr>
<td></td>
<td>cubic inch</td>
<td>mm³</td>
<td>16387.06</td>
</tr>
<tr>
<td></td>
<td>fluid ounce</td>
<td>milliliter</td>
<td>29.57353</td>
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<tr>
<td>mass</td>
<td>lb</td>
<td>kg</td>
<td>0.4535924</td>
</tr>
<tr>
<td></td>
<td>kip (1000 lb)</td>
<td>metric ton</td>
<td>0.4536</td>
</tr>
<tr>
<td></td>
<td>ton (2000 lb)</td>
<td>megagram</td>
<td>0.9071847</td>
</tr>
<tr>
<td></td>
<td>ounce</td>
<td>gram</td>
<td>28.34952</td>
</tr>
<tr>
<td>force</td>
<td>lb</td>
<td>N</td>
<td>4.448</td>
</tr>
<tr>
<td></td>
<td>kip</td>
<td>kN</td>
<td>4.448</td>
</tr>
<tr>
<td>pressure, stress</td>
<td>pound per sq. ft (psf)</td>
<td>Pa</td>
<td>47.88</td>
</tr>
<tr>
<td></td>
<td>pound per sq. inch (psi)</td>
<td>kPa</td>
<td>6.895</td>
</tr>
<tr>
<td>bending moment or torque</td>
<td>ft-lb</td>
<td>N·m</td>
<td>1.356</td>
</tr>
<tr>
<td>density</td>
<td>lb per cubic yard</td>
<td>kg/m³</td>
<td>0.5933</td>
</tr>
<tr>
<td></td>
<td>lb per cubic foot</td>
<td>kg/m³</td>
<td>16.02</td>
</tr>
<tr>
<td>velocity</td>
<td>ft/s</td>
<td>m/s</td>
<td>0.3048</td>
</tr>
<tr>
<td></td>
<td>mph</td>
<td>m/s</td>
<td>0.4470</td>
</tr>
<tr>
<td></td>
<td>mph</td>
<td>km/h</td>
<td>1.609</td>
</tr>
<tr>
<td>power</td>
<td>ton (refridg)</td>
<td>kW</td>
<td>3.517</td>
</tr>
<tr>
<td></td>
<td>BTU/h</td>
<td>W</td>
<td>0.2931</td>
</tr>
<tr>
<td></td>
<td>hp (electric)</td>
<td>W</td>
<td>745.7</td>
</tr>
<tr>
<td>volume flow rate</td>
<td>cubic ft per sec.</td>
<td>m³/s</td>
<td>0.02832</td>
</tr>
<tr>
<td></td>
<td>cfm</td>
<td>m³/s</td>
<td>0.0004719</td>
</tr>
<tr>
<td></td>
<td>cfm</td>
<td>L/s</td>
<td>0.4719</td>
</tr>
<tr>
<td>angles</td>
<td>degree</td>
<td>radian</td>
<td>0.01745329</td>
</tr>
<tr>
<td>temperature</td>
<td>°F</td>
<td>°C</td>
<td>(°F-32)/1.8</td>
</tr>
</tbody>
</table>

**Note:** 39.37 inch = 1 m  
(For US Survey foot, 12 inches per foot)
References


4. METRIC STANDARD SPECIFICATIONS FOR HIGHWAY AND BRIDGE CONSTRUCTION, Series 1995, Iowa Department of Transportation.

### Unit 1

1. A - liter
2. D - Degree Celsius
3. B - Pound force
4. A - meter and C millimeter
5. C - 0°C
6. B - cubic meter
7. C - 0.2 km
8. B - 3000 mm
9. C - 0.06 km
10. B - Metric system used today
11. C - UN
12. C - Pa

### Unit 2

- **A.** 5000 lbs x 0.4536 kg/lb = 2268 kg
- **B.** 9.0 lb x 0.4536 kg/lb = 4.08 kg
  - 4.08 kg < 4.54 kg
  - yes
- **C.** 12.5 in x 25.4 mm/in = 317.5 mm
  - Assume hard conversion to 318 x 318 mm

#### Unit 2

- **D.** 400 psi | 6.895 kPa | 1 MPa = 2.76 MPa
  - psi | 1000 kPa
  - No 2.76 > 2.25 MPa
- **E.** 26001 lb | 0.4536 kg | 1 Mg = 11.79 Mg
  - lb | 1000 kg
  - 10000 lb | 0.4536 kg | 1 Mg = 4.54 Mg
  - lb | 1000 kg
- **F.** 4.835 Mg | 1000 kg | 1 lb = 10,659 lb
  - Mg | 0.4536 kg
  - 10,659 < 80,000 lb
  - OK
- **G.** 2000 mL | 1000 mL x 0.0004 g = 0.0008 g
- **H.** 150 mi | 1.609 km/mi = 241.35 km

#### Unit 2

- **I.** 50 ft x 0.3048 m/ft = 15.24 m
- **J.** 2500 lb | 0.4536 kg | 1 Mg = 1.134 Mg
  - lb | 1000 kg
  - 1.134/2.00 = 0.567
  - 0.567 > 0.4
  - yes
- **K.** 125 psi | 6.895 kPa | 1 MPa = 0.86 MPa
  - psi | 1000 kPa

#### Unit 2

- **L.**
  - 20 mph x 1.609 km/h = 32.18 km/h
  - 21 ft/s^2 x 0.3048 m/ft = 6.4008 m/s^2
  - 20 ft x 0.3048 m/ft = 6.096 m
Unit 2

M. 0.25 in x 25.4 mm/in = 6.35 mm
0.75 in x 25.4 mm/in = 19.05 mm

N. 10 L / 3.785 L/gal = 2.642 gallon
2.64 < 25  No

O. (50-32)/1.8 = 10°C
(80-32)/1.8 = 27°C

Unit 2

P. 5000 lbs x 0.4536 kg/lb = 2268 kg
Q. 5000 lb x 0.4536 kg/lb = 2268 kg

0.6875 in x 25.4 mm/in = 17.46 mm

1.4 sq in x 645.2 mm²/sq in = 903.28 mm²

Unit 2

R.
41 mph x 1.609 km/h/mph = 65.97 or 66 km/h
55 mph x 1.609 km/h/mph = 88.50 or 89 km/h
5000 lb x 0.4536 kg/lb = 2268 kg

1 Mg = 1000 kg

5 psi x 6.895 kPa/psi = 34.475 kPa

Unit 2

S. 3 m x 39.37 in/m = 118.11 in
0.5 m x 39.37 in/m = 19.685 in
both dimensions okay

T. 2 in x 25.4 mm/in = 50.8 mm
4 in x 25.4 mm/in = 101.6 mm
Assume hard conversion

2x4 == 50 mm x 100 mm
4x4 == 100 mm x 100 mm

Unit 2

U. 13 m / (0.3048 m/ft) = 42.65 ft
42.65/8 = 6 tiedowns

V. 150 km / (1.609 km/mi) = 93.23 mi
93.23 < 100 mi  No

W. 500,000 km / (1.609 km/mi) = 310,752.02 mi

Unit 2

X. 1.5 x 18 kg = 27 kg

Unit 3

A. Sample xxx mph x 1.609 km/h/mph
    assume hard conversion to nearest 5 km/h
    1 to 10
    11 to 15
    16 to 25
    26 to 30

B. 37 mph x 1.609 km/h/mph = 59.333 km/h
Unit 3

C. Sample xxx lbs x 0.4536 kg/lb
   assume hard conversion to nearest 5 kg
   up to 455
   456 to 910
   911 to 1360
   1361 to 1815
   1816 to 2270
   2271 to 2720
   2721 +

D. 60 ft x 0.3048 m/ft = 18.29 m

E. 15 m/(0.3048 m/ft) = 49.21 ft
   49.21 < 65 ft Yes

F. 8 ft x 12 in/ft = 96 in
   96 + 6 = 102 in
   102 in/(39.37 in/m) = 2.5909 m

G. 80,000 lb x 0.4536 kg/lb = 36,288 Mg

H. 39 Mg / 1000 kg = 1 lb
   1 Mg / 0.4535 kg = 85,979 lb

I. 15 Mg / 1000 kg = 1 lb
   1 Mg / 0.4536 kg = 33,069 lb

J. 3.85 m / 39.37 in = 1 ft / 12 in
   12.63 < 13.5 ft okay

K. 400 cu in / 16390 mm³ = 6,556,000 mm³

Unit 4

1) B
2) B
3) D
4) D
5) D
6) C
7) A
8) C
9) B
10) D
11 a) 34.88
   b) 87.56
   c) 1230
   d) 877
   e) 0.235
Introduction to SI Metric Module 5
Created by: Karen Zunkel & Jim Cable
Iowa State University
Workshop Overview

- Unit 1 - History and SI Basics
- Unit 2 - SI Applications in Federal Work Activities
- Unit 3 - SI Applications in State Code Enforcement
- Unit 4 - Record Keeping
Why Use SI Metric?

- To join the global marketplace (only 3 countries don’t use SI metric)
- We already use many SI units
- International communication
- International competitiveness
- Simplicity / Efficiency
- Sept. 30, 2000 - all highway/lands receiving federal aid must be bid, designed, & constructed using SI
SI Basics

Topics Covered
▪ Seven base units of SI
▪ Derived units
▪ Supplemental units
▪ Prefixes
▪ Additional units to use with SI
### SI Base Units

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>length</td>
<td>meter</td>
<td>m</td>
</tr>
<tr>
<td>mass</td>
<td>kilogram</td>
<td>kg</td>
</tr>
<tr>
<td>time</td>
<td>second</td>
<td>s</td>
</tr>
<tr>
<td>electric current</td>
<td>ampere</td>
<td>A</td>
</tr>
<tr>
<td>temperature</td>
<td>kelvin</td>
<td>K</td>
</tr>
<tr>
<td>amount of matter</td>
<td>mole</td>
<td>mol</td>
</tr>
<tr>
<td>luminous intensity</td>
<td>candela</td>
<td>cd</td>
</tr>
</tbody>
</table>
Mass versus Weight

We are familiar with “weight”
We say... “I weigh 130 pounds”
Pounds are actually units of force (lb_f)
Force = mass x acceleration of gravity
Acceleration due to gravity varies
Easiest diet ... move to the moon! Even though I have the same body, I weigh less (about 1/5 as much).
Mass versus Weight (cont.)

**English**

\[ \text{lb}_f = \text{lb}_m \times 32.2 \] (where 32.2 ft/s\(^2\) is common acceleration of gravity)

**SI Metric**

newtons = kilograms \times 9.806

(where 9.806 m/s\(^2\) is common acceleration of gravity)
Mass versus Weight (cont.)

To ease the "transition"... conversion tables will list "from pounds force" to "kilograms"

\[ 1 \text{ lb}_f = 0.4536 \text{ kg} \]

(force) to (mass)

This conversion uses the standard acceleration of gravity on earth to translate a force back to a mass.
## SI Supplementary Units

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>plane angle</td>
<td>radian</td>
<td>rad</td>
</tr>
<tr>
<td>solid angle</td>
<td>steradian</td>
<td>sr</td>
</tr>
</tbody>
</table>

Note: Iowa DOT will continue to use degrees for surveying. However, other angular measurements will likely be in radians.
SI Derived Units

- A combination of base units and prefixes
- Example: meters per second = m/s
- Some derived units have special names (Ex: newtons => force)
- See table in handout for a listing
<table>
<thead>
<tr>
<th>Quantity</th>
<th>Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>temperature</td>
<td>degree Celsius</td>
<td>°C</td>
</tr>
<tr>
<td>volume</td>
<td>liter</td>
<td>L</td>
</tr>
<tr>
<td>mass</td>
<td>tonne (metric ton)</td>
<td>t</td>
</tr>
<tr>
<td>angle</td>
<td>degree</td>
<td>°</td>
</tr>
<tr>
<td>angle</td>
<td>minute</td>
<td>'</td>
</tr>
<tr>
<td>angle</td>
<td>second</td>
<td>&quot;</td>
</tr>
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</table>
## Other Acceptable Units

<table>
<thead>
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<th>Quantity</th>
<th>Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>minute</td>
<td>min</td>
</tr>
<tr>
<td>time</td>
<td>hour</td>
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</tr>
<tr>
<td>time</td>
<td>day</td>
<td>d</td>
</tr>
<tr>
<td>area</td>
<td>hectare</td>
<td>ha</td>
</tr>
</tbody>
</table>

Note: hectare is shortened from square hectometer. Hecto is prefix for 100... so a hectare is 100 m by 100 m
<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Power of 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>giga</td>
<td>G</td>
<td>$10^9$</td>
</tr>
<tr>
<td>mega</td>
<td>M</td>
<td>$10^6$</td>
</tr>
<tr>
<td>kilo</td>
<td>k</td>
<td>$10^3$</td>
</tr>
<tr>
<td>milli</td>
<td>m</td>
<td>$10^{-3}$</td>
</tr>
<tr>
<td>micro</td>
<td>μ</td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td>nano</td>
<td>n</td>
<td>$10^{-9}$</td>
</tr>
</tbody>
</table>
Prefix Example Conversions

1000 mm = 1 m
1000 m = 1 km

So for example....

1 km x 1000 m x 1000 mm = 1,000,000 mm

Ex. 1) 250 mm x 1 m = 0.250 m

1000 mm

Ex. 2) 35 km x 1000 m = 35,000 m

1 km
Visualizing Metric

Sample answers

- Height: 5'6" = 1676 mm = 1.676 m

- Pace: 53 cm = 530 mm = 0.53 m
Worksheet Answers

1) Which of the following expresses fluid volume?

A. liter
B. cubic kilogram
C. pascal
D. hectare
2) Which unit of temperature is used at construction sites?
A. degree Fahrenheit
B. degree Centigrade
C. kelvin
D. degree Celsius
Worksheet Answers

3) Newton replaces which unit?
A. pounds per square inch
B. pound force
C. pounds per cubic inch
D. pounds mass
4) Iowa DOT drawings will use which measurements? (circle all that apply)

A. meter  
B. centimeter  
C. millimeter  
D. megameter
Worksheet Answers

5) On the Celsius scale, water freezes at what temperature?
   A. 32°C
   B. 100°C
   C. 0°C
   D. 0 K
Worksheet Answers

6) Which SI Unit listed here would be used to express volume of concrete or fill?
A. cubic decimeter
B. cubic meter
C. liter
D. ton
Worksheet Answers

7) Which of the following is the same as 200 meters?
A. 0.02 km
B. 2.0 km
C. 0.2 km
D. 20.0 km
8) Which of the following is the same as 3 meters?
A. 0.03 km
B. 3000 mm
C. 300 mm
D. 0.3 km
9) Which of the following represents the longest length?

A. 3.0 m
B. 450 mm
C. 0.05 km
D. 20 cm
10) SI refers to:
A. The system of interfaces necessary to implement metric in computers.
B. The metric system used today.
C. The governing organization that establishes metric rules.
D. The international strategies that created first metric system.
## Rounding Rules (cont)

Exactly equal to 5 (With nothing after it!)
- Make the number even
  - If last significant digit is odd... round up
  - If last significant digit is even.. drop number

<table>
<thead>
<tr>
<th>Number</th>
<th>Place</th>
<th>Rounded</th>
</tr>
</thead>
<tbody>
<tr>
<td>476.55</td>
<td>1 after decimal</td>
<td>476.6</td>
</tr>
<tr>
<td>445.25</td>
<td>1 after decimal</td>
<td>445.2</td>
</tr>
</tbody>
</table>
Rounding Rules - standards

DOT establishing standards for “rounding”/precision for many items

Examples:

- Reinforced concrete boxes - to tenth of a meter (1.8 x 1.2 x 9.8)
- Horizontal alignments, tie-ins, etc. - to closest 0.001m (tolerances ± 3mm)
Rounding Rules - standards

More examples:

- Entrance locations - closest 0.01 m
- Culvert locations - closest 0.1 m

(Note: many other standards, such as scales on plans, etc... see DOT metric conversion guidelines and AASHTO green book. etc...)
Verifying Answers

- Humans aren’t perfect
- Double check your answers
- Use common sense and estimates
Verifying Answers (cont.)

Example: Convert 25 mph to km/h
Correct Answer: 25 \times 1.609 = 40.225
40 km/h

What if you mistyped 1.609 as 16.09 on your calculator???
25 \times 16.09 = 402.25
402 km/h
Station Conversion

492+00.00 ft x 12 in x 1 m = 149+96.190 m

1 ft 39.37 in
Station Equation

Sta 149+96.190 (m) This survey/sta 492+00.0 (E) as built

OR

Sta 149+96.19 (m) = Sta 492+00.0 (E)
US Foot Conversion

\[
\frac{39.37\text{ in} \times 1\text{ ft}}{1\text{ m} \times 12\text{ in}} = 39.37\text{ ft} = 3.28083\text{ ft/m}
\]

1 m 12 in 12 m
Unit 2

A. 5000 lbs x 0.4536 kg/lb = 2268 kg

B. 9.0 lb x 0.4536 kg/lb = 4.08 kg
   4.08 kg < 4.54 kg
   yes

C. 12.5 in x 25.4 mm/in = 317.5 mm
   Assume hard conversion to 318 x 318 mm
Unit 2

D. 400 psi 6.895 kPa 1 MPa = 2.76 MPa

\[
\begin{array}{c|c|c|c}
\text{psi} & \text{1000 kPa} \\
\hline
400 & 6.895 \\
\end{array}
\]

No 2.76 > 2.25 MPa

E. 26001 lb 0.4536 kg 1Mg = 11.79 Mg

\[
\begin{array}{c|c|c|c}
\text{lb} & \text{1000 kg} \\
\hline
26001 & 0.4536 \\
\end{array}
\]

10000 lb 0.4536 kg 1Mg = 4.54 Mg

\[
\begin{array}{c|c|c|c}
\text{lb} & \text{1000 kg} \\
\hline
10000 & 0.4536 \\
\end{array}
\]
Unit 2

F. \[
\frac{4.835 \text{ Mg}}{1 \text{ Mg}} \times \frac{1000 \text{ kg}}{1 \text{ Mg}} \times \frac{1 \text{ lb}}{0.4536 \text{ kg}} = 10,659 \text{ lb}
\]

\[
10,659 < 80,000 \text{ lb} \quad \text{OK}
\]

G. \[
2000 \text{ mL} / 1000 \text{ mL} \times 0.0004 \text{ g} = 0.0008 \text{ g}
\]

H. \[
150 \text{ mi} \times 1.609 \text{ km/mi} = 241.35 \text{ km}
\]
Unit 2

I. 50 ft x 0.3048 m/ft = 15.24 m

J. 2500 lb | 0.4536 kg | 1Mg = 1.134 Mg

\[
\frac{2500 \text{ lb}}{1000 \text{ kg}} = \frac{0.4536 \text{ kg}}{1 \text{ Mg}}
\]

1.134/2.00 = 0.567

0.567 > 0.4 yes

K. 125 psi | 6.895 kPa | 1MPa = 0.86 MPa

\[
\frac{125 \text{ psi}}{1000 \text{ kPa}} = \frac{6.895 \text{ kPa}}{1 \text{ MPa}}
\]

48
Unit 2

L.

\[
20 \text{ mph} \times 1.609 \text{ km/h} = 32.18 \text{ km/h}
\]

\[
21 \text{ ft/s}^2 \times 0.3048 \text{ m/ft} = 6.4008 \text{ m/s}^2
\]

\[
20 \text{ ft} \times 0.3048 \text{ m/ft} = 6.096 \text{ m}
\]
Unit 2

M. 0.25 in x 25.4 mm/in = 6.35 mm
0.75 in x 25.4 mm/in = 19.05 mm

N. 10 L / 3.785 L/gal = 2.642 gallon
2.64 < 25 No

O. (50-32)/1.8 = 10°C
(80-32)/1.8 = 27°C
Unit 2

P. 5000 lbs x 0.4536 kg/lb = 2268 kg

Q. 5000 lb x 0.4356 kg/lb = 2268 kg

0.6875 in x 25.4 mm/in = 17.46 mm

1.4 sq in x 645.2 mm$^2$/sq in = 903.28 mm$^2$
Unit 2

R.

41 mph x 1.609 km/h/mph = 65.97 or 66 km/h
55 mph x 1.609 km/h/mph = 88.50 or 89 km/h

\[
\begin{array}{c|c|c}
5000 \text{ lb} & 0.4536 \text{ kg} & 1 \text{ Mg} \\
\hline
\text{lb} & 1000 \text{ kg} & = 2.268 \text{ Mg}
\end{array}
\]

5 psi x 6.895 kPa/psi = 34.475 kPa
11) On the moon the acceleration of gravity is about 1.7 m/s². What is the gravity force of a 2 kg object on the moon?

A. 3.4 pascals
B. 1.7 pascals
C. 3.4 newtons
D. 1.7 newtons
Worksheet Answers

12) Which SI unit replaces PSI?
A. kg/m²
B. N
C. Pa
D. newton-meters
Unit 2 - Federal Work

Topics Covered

- Conversion Types and Factors
- Federal Work Applications
Soft Conversion

✦ Use factors on English units to get metric equivalent - 1 step
✦ Often will lead to long, “strange” numbers
✦ Going “soft” on us... use new measurement system, but don’t change physical value
✦ Example: 16.0 ft == 4.88 m
Hard Conversion

- Use factors on English units to get metric equivalent ... then round to “reasonable” metric number - 2 steps
- Going “hard” or tough on us... use new measurement system, and probably even change physical value
- Example: 16.0 ft == 5.0 m
Hard Conversion

Pipe diameter 30” == 762 mm
   hard conversion == 750 mm
Lane width 12’ == 3.6576 m
   hard conversion == 3.6 m
Pavement thickness 10” == 254 mm
   hard conversion == 260 mm
# Long Form

## Feet to Meters

<table>
<thead>
<tr>
<th>0</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0.03048</td>
<td>0.06096</td>
</tr>
<tr>
<td>1</td>
<td>0.30480</td>
<td>0.33528</td>
<td>0.36576</td>
</tr>
<tr>
<td>2</td>
<td>0.60960</td>
<td>0.64008</td>
<td>0.67256</td>
</tr>
<tr>
<td>3</td>
<td>0.91440</td>
<td>0.94488</td>
<td>0.97536</td>
</tr>
</tbody>
</table>

Example: 2.2 feet equals 0.67256 meters
**Short Form**

**Length**

<table>
<thead>
<tr>
<th></th>
<th>m</th>
<th>in</th>
<th>ft</th>
<th>yd</th>
</tr>
</thead>
<tbody>
<tr>
<td>m</td>
<td>1</td>
<td>39.370</td>
<td>3.2808</td>
<td>1.0936</td>
</tr>
<tr>
<td>in</td>
<td>25.4x10^{-3}</td>
<td>1</td>
<td>83.333x10^{-3}</td>
<td>27.0778x10^{-3}</td>
</tr>
<tr>
<td>ft</td>
<td>0.3048</td>
<td>12</td>
<td>1</td>
<td>0.3333</td>
</tr>
<tr>
<td>yd</td>
<td>0.9144</td>
<td>36</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

Example: 1 foot = 0.3048 meters

\[2\text{ft} \times 0.3048 = 0.6096 \text{ m}\]
## Conversion Factors

<table>
<thead>
<tr>
<th>Quantity</th>
<th>From</th>
<th>To</th>
<th>Multiply by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>ft</td>
<td>m</td>
<td>0.3048</td>
</tr>
<tr>
<td></td>
<td>in</td>
<td>m</td>
<td>25.4x10^{-3}</td>
</tr>
<tr>
<td></td>
<td>yd</td>
<td>m</td>
<td>0.9144</td>
</tr>
<tr>
<td>Mass</td>
<td>lbm</td>
<td>kg</td>
<td>0.4536</td>
</tr>
</tbody>
</table>

**Example:** 2ft x 0.3048 = 0.6096 m
# Rounding Rules

Less than 5 - Drop the numbers

<table>
<thead>
<tr>
<th>Number</th>
<th>Place</th>
<th>Rounded</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.763534</td>
<td>2 after decimal</td>
<td>4.76</td>
</tr>
<tr>
<td>234.8732</td>
<td>3 after decimal</td>
<td>234.873</td>
</tr>
<tr>
<td>87632</td>
<td>hundreds</td>
<td>87600</td>
</tr>
</tbody>
</table>
Rounding Rules (cont)

Greater than 5 - Raise (Add 1 to) the number

<table>
<thead>
<tr>
<th>Number</th>
<th>Place</th>
<th>Rounded</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.763534</td>
<td>1 after decimal</td>
<td>4.8</td>
</tr>
<tr>
<td>234.8732</td>
<td>1 after decimal</td>
<td>234.9</td>
</tr>
<tr>
<td>87632</td>
<td>thousands</td>
<td>88000</td>
</tr>
</tbody>
</table>
Unit 2

S. 3 m x 39.37 in/m = 118.11 in
0.5 m x 39.37 in/m = 19.685 in
both dimensions okay

T. 2 in x 25.4 mm/in = 50.8 mm
4 in x 25.4 mm/in = 101.6 mm
Assume hard conversion

2x4 == 50 mm x 100 mm

4x4 == 100 mm x 100 mm
Unit 2

U. 13 m / (0.3048 m/ft) = 42.65 ft

42.65/8 = 6 tiedowns

V. 150 km / (1.609 km/mi) = 93.23 mi

93.23 < 100 mi  No

W. 500,000 km / (1.609 km/mi) = 310,752.02 mi

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X. 1.5 x 18 kg = 27 kg
Unit 3 - State Code

Topic Covered

- State Code Enforcement Applications
B. 37 mph x 1.609 km/h/mph = 59.333 km/h
Unit 3

C. Sample xxx lbs x 0.4536 kg/lb
assume hard conversion to nearest 5 kg

up to 455
456 to 910
911 to 1360
1361 to 1815
1816 to 2270
2271 to 2720

57  2721 +
Unit 3

D. \(60 \text{ ft} \times 0.3048 \text{ m/ft} = 18.29 \text{ m}\)

E. \(15 \text{ m} / (0.3048 \text{ m/ft}) = 49.21 \text{ ft}\)
   \(49.21 < 65 \text{ ft} \quad \text{Yes}\)

F. \(8 \text{ ft} \times 12 \text{ in/ft} = 96 \text{ in}\)
   \(96 + 6 = 102 \text{ in}\)
   \(102 \text{ in} / (39.37 \text{ in/m}) = 2.5909 \text{ m}\)
Unit 3

G. 80,000 lb | 0.4536 kg | 1 Mg = 36.288 Mg
     lb          1000 kg

H. 39 Mg | 1000 kg | 1 lb = 85,979 lb
     1 Mg    0.4535 kg

I. 15 Mg | 1000 kg | 1 lb = 33,069 lb
     1 Mg    0.4536 kg

33,069 lb < 34,000 lb    Okay
## Unit 3

<table>
<thead>
<tr>
<th>J. 3.85 m</th>
<th>39.37 in</th>
<th>1 ft</th>
<th>= 12.63 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 m</td>
<td>12 in</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12.63 < 13.5 ft okay

<table>
<thead>
<tr>
<th>K. 400 cu in</th>
<th>16390 mm³</th>
<th>= 6,556,000 mm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 cu in</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Unit 4 - Record Keeping

Topics Covered
- Notation
- Prefixes
- Spacing and Capitalization
- Spelling and Pluralization
- Decimal markers and Spacing
- Powers of Ten
Rules review

- name vs. symbol  meter  m
- prefix mega or bigger
  - symbol is capital, name is small letter
- combine prefix with name or symbol
  - no hyphen or spaces
- plurals at end of names not symbols
- spacing: 37.5 km
Rules review continued

✦ volume and area
  ✓ square meter(s) not meters squared
  ✓ symbol use superscript number $m^2$

✦ decimal and commas
  ✓ Iowa DOT will use period for decimal and commas to group by threes
  ✓ Example: 123,456.789
  (Note: SI would be 123 456,789)
Rules review continued

✦ powers of ten examples

1300 m = 1.3 \times 10^3 \text{ m} = 1.3 \text{ km}

17,500,000 \text{ Pa} = 17.5 \times 10^6 \text{ Pa} = 17.5 \text{ MPa}

0.075 \text{ Mg} = 75 \times 10^{-3} \text{ Mg} = 75 \text{ kg}
# Multiplication and Division

## Multiplication
- ✔️ use dot in middle of symbol
- ✔️ use hyphen in written text

✧ Example:

| N ⋅ m | newton-meter |

## Division
- ✔️ use slash in middle of symbol
- ✔️ use slash in written text (or per)

✧ Example:

| m/s | meters/second |
| meters per second |
Practice Writing In Pairs

Write in both number symbol and number written name format:

<table>
<thead>
<tr>
<th>number</th>
<th>unit of measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>34 and 1/3</td>
<td>KILOMETERS</td>
</tr>
<tr>
<td>75.3</td>
<td>millimeters cubed per sec</td>
</tr>
<tr>
<td>237657.5</td>
<td>PASCALS</td>
</tr>
<tr>
<td>1070000000</td>
<td>GRAM in MEGAGRAMS</td>
</tr>
<tr>
<td>0.0076</td>
<td>LITERS in terms of MILLILITERS</td>
</tr>
</tbody>
</table>
## Practice Writing Solutions

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>34.33 km</td>
<td>34.33 kilometers</td>
</tr>
<tr>
<td>75.3 mm³/s</td>
<td>75.3 cubic millimeters per second</td>
</tr>
<tr>
<td>237,657.5 Pa</td>
<td>237,657.5 pascals</td>
</tr>
<tr>
<td>237.6575 kPa</td>
<td>237.6575 kilopascals</td>
</tr>
<tr>
<td>107 Mg</td>
<td>107 megagrams</td>
</tr>
<tr>
<td>7.6 mL</td>
<td>7.6 milliliters</td>
</tr>
</tbody>
</table>
Worksheet Answers

1) Which is the correct symbol for megapascals?
   A. Mpa
   B. MPa
   C. mPa
   D. mPA
Worksheet Answers

2) What is the correct symbol for cubic millimeters?

A. cu. mm.
B. mm$^3$
C. cmm
D. mm$^3$
Worksheet Answers

3) Which is not a correct SI plural?
A. 44.65 m
B. 5.4 kilopascal
C. Eighteen cubic millimeters
D. 149 MNs
Worksheet Answers

4) Which of the following is the correct representation of degrees Celsius?

A. 42.5°C
B. 42.5 °C
C. 42.5 °C
D. 42.5°C
Worksheet Answers

5) Which of the following is correct?

A. 19mm$^3$
B. 448 cmm
C. 18 Mn
D. 55.7 kPa
6) Which is the proper expression for kilometers per hour?

A. 75 KPH
B. 75 Km/H
C. 75 km/h
D. 75 km/hr
7) Which of the following is equivalent to $1 \times 10^4$ square millimeters?

A. 10,000 mm$^2$
B. 1000 mm$^2$
C. 0.0001 mm$^2$
D. 0.001 mm$^2$
Worksheet Answers

8) Which of the following pairs of symbols and unit names is correct?

A. 17 MPa 17 Megapascals
B. 3434.6 N 3434.6 Newtons
C. 1.67 kg 1.67 kilograms
D. 2.3 mm 2.3 milli-meters
9) Which of the following is a correct sentence for temperature?
A. The temp ... ten Degrees Celsius.
B. The temp ... ten degrees celsius.
C. The temp ... ten degrees Celsius.
D. The temp ... ten Degrees celsius.
Worksheet Answers

10) Which of the following is correct?
A. 0.78 kg/m²
B. 3.9 L’s
C. 4.539 KPa
D. 3.87 ha
Worksheet Answers

11) Rounding

a) 34.876 34.88
b) 87.565 87.56
c) 1234 1230
d) 876.52 877
e) 0.2347 0.235
Resources

✦ George Sisson, DOT Metric Coordinator, 239-1461
✦ AASHTO Green Book
✦ DOT Interim Metric Guide
✦ Conversion Calculators
✦ Numerous books, industry magazine articles, etc.
IHRB PROJECT HR-376

"Metric Training For The Highway Industry", HR-376 was designed to produce training materials for the various divisions of the Iowa DOT, local government and the highway construction industry. The project materials were to be used to introduce the highway industry in Iowa to metric measurements in their daily activities. Five modules were developed and used in training over 1,000 DOT, county, city, consultant and contractor staff in the use of metric measurements.

The training modules developed, deal with the planning through operation areas of highway transportation. The materials and selection of modules were developed with the aid of an advisory personnel from the highway industry. Each module is design as a four hour block of instruction and a stand along module for specific types of personnel. Each module is subdivided into four chapters with chapter one and four covering general topics common to all subjects. Chapters two and three are aimed at hands on experience for a specific group and subject. The modules include:

Module 1 - Basic Introduction to the Use of International Units of Measurement. This module is designed for use by all levels of personnel, primarily office staff, and provides a basic background in the use of metric measurements in both written and oral communications.

Module 2 - Construction and Maintenance Operations and Reporting. This module provides hands on examples of applications of metric measurements in the construction and maintenance field operations.

Module 3 - Road and Bridge Design. This module provides hands on examples of how to use metric measurements in the design of roads and structures.

Module 4 - Transportation Planning and Traffic Monitoring. Hands on examples of applications of metric measurements in the development of planning reports and traffic data collection are included in this module.

Module 5 - Motor Vehicle Enforcement. Examples from Iowa and Federal Motor Vehicle Codes are used as examples for hands on training for the vehicle enforcement type personnel using this module.

Each of the modules utilizes visual aids in the form of video tapes and others that can be projected by an overhead projector or through the use of computer aided methods. The course can be self administered or is best done through the use of a group session and the use of a class leader.