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

ABSTRACT
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.

Metric Training for the Transportation Industry
Module 5 - Motor Vehicle Licensing and Enforcement

Table of Contents

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

- 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 straight forward 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 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"Unites
(The International System of Units)
Metric system adopted as international standard in 1960
Commonly referred to as SI or SI Metric

Seven Base Units

Length	meter
Mass	kilogram
Time	second
Electric current	ampere
Temperature	kelvin
Amount of matter	mole
Luminous intensity	candela

A closer look at length

Base Unit - meter

Definition of a meter - distance light travels in a vacuum in a time interval of 1/299,792,458 of a second

Symbol for a meter - m

Other length measurements used by Iowa DOT

millimeter
Definition of a millimeter - 1/1000 of a meter
Symbol - mm

kilometer
Definition of a kilometer - 1000 meters
Symbol - km

Area measurements

	Symbol
square meters	m^2
hectare	ha
square kilometers	km^2
square millimeters	mm^2

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 x acceleration
newton = kilograms x 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.

A closer look at temperature

degree Celsius

water freezes = 0^oC	32^oF
water boils = 100^oC	212^oF

replaces Centigrade from older metric systems

room temperature = 20^oC
normal body temperature = 37^oC

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)

	Symbol
cubic meters	m^3
cubic centimeters	cm^3
cubic decimeters	dm^3
cubic millimeters	mm^3

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.

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)

Ht	mm						
4' 6"	1372	5' 1"	1549	5' 9"	1753	6' 5"	1956
4' 7"	1397	5' 2"	1575	5' 10"	1778	6' 6"	1981
4' 8"	1422	5' 3"	1600	5' 11"	1803	6' 7"	2007
4' 9"	1448	5' 4"	1626	6' 0"	1829	6' 8"	2032
4' 10"	1473	5' 5"	1651	6' 1"	1854	6' 9"	2057
4' 11"	1499	5' 6"	1676	6' 2"	1880	6' 10"	2083
5' 0"	1524	5' 7"	1702	6' 3"	1905	6' 11"	2108
		5' 8"	1727	6' 4"	1930	7' 0"	2134

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						
75	34.0	130	59.0	190	86.2	250	113.4
80	36.3	135	61.2	195	88.5	255	115.7
85	38.6	140	63.5	200	90.7	260	117.9
90	40.8	145	65.8	205	93.0	265	120.2
95	43.1	150	68.0	210	95.3	270	122.5
100	45.4	155	70.3	215	97.5	275	124.7
105	47.6	160	72.6	220	99.8	280	127.0
110	49.9	165	74.8	225	102.1	285	129.3
115	52.2	170	77.1	230	104.3	290	131.5
120	54.4	175	79.4	235	106.6	295	133.8
125	56.7	180	81.6	240	108.9	300	136.1
		185	83.9	245	111.1		

Temperature

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

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).

Unit 1 - History and SI Basics

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. 0 K

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/s^2. 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/m^2
B. N
C. Pa
D. N·m

Unit 2 - SI Applications in Federal Work Activities

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

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:

Quantity	From	To	Multiply by
Length	ft	m	0.3048
	in	m	25.4×10^{-3}
	yd	m	0.9144
Mass	lbm	kg	0.4536

EXAMPLES:

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

1000 yards x 0.9144 meters/yard = 914.4 meters

B. Convert 5'7" to SI units

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

So 5 x 12 = 60" plus the 7" == 67"

Now convert the 67" to meters

67 inches x 25.4×10^{-3} m/inch = 1.7018 m => 1.7 m

Unit 2 - SI Applications in Federal Work Activities

Note: Questions in this section are derived from information contained in the Code of Federal Regulations (CFR-49) Parts 100-399.

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?

Unit 3 - SI Applications in State Code Enforcement Activities

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 parenthis 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:

mph over limit	km/h over limit
1 thru 5 over	
6 thru 10 over	
11 thru 15 over	
16 thru 20 over	

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.

lbs over limit	kg over limit
Up to 1,000	
1,001 to 2,000	
2,001 to 3,000	
3,001 to 4,000	
4,001 to 5,000	
5,001 to 6,000	
6,000 +	

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?

Unit 4 - SI Applications in Record Keeping

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

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

unit names	symbols
meter	m
kilogram	kg
newton	N
pascal	Pa
square meter	m^2
cubic meter	m^3
liter	L
degree Celsius	^oC

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:

name	symbol
kilogram	kg
meganewton	MN
kilopascal	kPa

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

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

name	symbol
square meter	m^2
cubic meter	m^3

(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

Old	Correct SI
10K	10 km
K	kg
KPH	km/h
kilos	kilograms
grm or gm	g
Newton	newton
cc, ccm	cm^3

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:

power of 10 representation	equivalent SI prefix
123.4×10^{-3} m	123.4 mm
12.34×10^{6} N	12.34 MN
1.234×10^{3} Pa	1.234 kPa

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

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. mm^3
   C. cmm
   D. mm ^{3}

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^oc
   B. 42.5 ^oC
   C. 42.5 ^oc
   D. 42.5^oC

5. Which of the following is correct?

   A. $19mm^3$
   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 1×10^4 square millimeters?

   A. 10 000 mm^2
   B. 1000 mm^2
   C. 0.0001 mm^2
   D. 0.001 mm^2

Unit 4 - SI Applications in Record Keeping

Worksheet Review

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 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/m^2
    B. 3.9 L's
    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 Metric Tables

SI Base Units

Quantity	Name	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

SI Supplementary Units

Quantity	Name	Symbol
plane angle	radian	rad
solid angle	steradian	sr

SI Derived Units with Special Names

Quantity	Name	Symbol	In terms of Other Units
frequency	hertz	Hz	s^{-1}
force	newton	N	$kg \cdot m \cdot s^{-2}$
pressure, stress	pascal	Pa	N/m^2
energy, work	joule	J	N·m
power	watt	W	J/s
electric charge	coulomb	C	s·A
electric potential	volt	V	W/A
capacitance	farad	F	C/V
electric resistance	ohm	Ω	V/A
electrical conductance	siemens	S	A/V
magnetic flux	weber	Wb	V·s
magnetic flux density	tesla	T	Wb/m^2
inductance	henry	H	Wb/A
luminous flux	lumen	lm	cd·sr
illuminance	lux	lx	lm/m^2
activity (radio)	becquerel	Bq	s^{-1}
absorbed dose	gray	Gy	J/kg
dose equivalent	sievert	Sv	J/kg

SI Metric Tables

Acceptable Units to Use with SI Units

Quantity	Name	Symbol	In terms of Base Units
temperature	degree Celsius	°C	K ($t°C = t$ K - 273.15)
volume	liter	L	10^{-3} m^3
mass	tonne (metric ton)	t	10^3 kg
time	minute	min	60 s
time	hour	h	3600 s
time	day	d	86 400 s
angle	degree	°	($\pi/180$) rad
angle	minute	'	($\pi/10800$) rad
angle	second	"	($\pi/648000$) rad
area	hectare	ha	100m x 100m or 10^4 m^2

Commonly Used Prefixes

Multiple of 10	Prefix	Symbol
1 000 000 000 = 10^9	giga	G
1 000 000 = 10^6	mega	M
1 000 = 10^3	kilo	k
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	µ
0.000 000 001 = 10^{-9}	nano	n

Additional Prefixes

Multiple of 10	Prefix	Symbol
10^{24}	yotto	Y
10^{21}	zetta	Z
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^2	hecto	h
10^1	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a
10^{-21}	zepto	z
10^{-24}	yocto	y

Conversion Factors: English to SI Metric

Quantity	From English Unit:	To SI Metric Unit:	Multiply by:
length	mile	km	1.609347
	yard	m	0.9144
	foot	m	0.3048006 (See note)
	inch	mm	25.4
area	square mile	km^2	2.5989998
	acre	m^2	4047
	acre	hectare	0.4046873
	square yard	m^2	0.8361274
	square foot	m^2	0.09290304
	square inch	mm^2	645.16
volume	acre foot	m^3	1233
	cubic yard	m^3	0.7645549
	cubic foot	m^3	0.02831685
	cubic foot	L	28.32
	100 board feet	m^3	0.2360
	gallon	L	3.785412
	cubic inch	cm^3	16.39
	cubic inch	mm^3	16387.06
	fluid ounce	milliliter	29.57353
mass	lb	kg	0.4535924
	kip (1000 lb)	metric ton	0.4536
	ton (2000 lb)	megagram	0.9071847
	ounce	gram	28.34952
force	lb	N	4.448
	kip	kN	4.448
pressure, stress	pound per sq. ft (psf)	Pa	47.88
	pound per sq. inch (psi)	kPa	6.895
bending moment or torque	ft-lb	N·m	1.356
density	lb per cubic yard	kg/m^3	0.5933
	lb per cubic foot	kg/m^3	16.02
velocity	ft/s	m/s	0.3048
	mph	m/s	0.4470
	mph	km/h	1.609
power	ton (refridg)	kW	3.517
	BTU/h	W	0.2931
	hp (electric)	W	745.7
volume flow rate	cubic ft per sec.	m^3/s	0.02832
	cfm	m^3/s	0.0004719
	cfm	L/s	0.4719
angles	degree	radian	0.01745329
temperature	°F	°C	(t°F-32)/1.8

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

References

1. STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, Fifteenth Edition, AASHTO, 1992.

2. A POLICY ON GEOMETRIC DESIGN OF HIGHWAYS AND STREETS, AASHTO, 1994.

3. T.J.Wipf, F.W.Klaiber, H.El-Arabaty, METRIC SHORT COURSE FOR THE OFFICE OF BRIDGES AND STRUCTURES, IHRB HR-378, February 1995.

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

5. IOWA DEPARTMENT OF TRANSPORTATION POLICIES AND PROCEDURES MANUAL, Metric Style, Policy 030.02, 1994.

Metric Training for the Transportation Industry
Module 5 - Motor Vehicle Licensing and Enforcement Answers

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 - 0.05 km
10. B - Metric system used today
11. C - 3.4 N
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. $$400\ \text{psi} \times \frac{6.895\ \text{kPa}}{\text{psi}} \times \frac{1\ \text{MPa}}{1000\ \text{kPa}} = 2.76\ \text{MPa}$$
No 2.76 > 2.25 MPa

E. $$26001\ \text{lb} \times \frac{0.4536\ \text{kg}}{\text{lb}} \times \frac{1\text{Mg}}{1000\ \text{kg}} = 11.79\ \text{Mg}$$
$$10000\ \text{lb} \times \frac{0.4536\ \text{kg}}{\text{lb}} \times \frac{1\text{Mg}}{1000\ \text{kg}} = 4.54\ \text{Mg}$$

Unit 2

F. $$4.835\ \text{Mg} \times \frac{1000\ \text{kg}}{1\ \text{Mg}} \times \frac{1\ \text{lb}}{0.4536\ \text{kg}} = 10{,}659\ \text{lb}$$
10,659 < 80,000 lb OK

G. 2000 mL /1000 mL x 0.0004 g = 0.0008 g

H. 150 mi x 1.609 km/mi = 241.35 km

Unit 2

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

J. $$2500\ \text{lb} \times \frac{0.4536\ \text{kg}}{\text{lb}} \times \frac{1\text{Mg}}{1000\ \text{kg}} = 1.134\ \text{Mg}$$
1.134/2.00 = 0.567 0.567 > 0.4 yes

K. $$125\ \text{psi} \times \frac{6.895\ \text{kPa}}{\text{psi}} \times \frac{1\text{MPa}}{1000\ \text{kPa}} = 0.86\ \text{MPa}$$

Unit 2

L.

$$20\ \text{mph} \times 1.\frac{609\ \text{km/h}}{\text{mph}} = 32.18\ \text{km/h}$$

21 ft/s^2 x 0.3048 m/ft = 6.4008 m/s^2

20 ft x 0.3048 m/ft = 6.096 m

Metric Training for the Transportation Industry
Module 5 - Motor Vehicle Licensing and Enforcement Answers

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 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

$$\frac{5000\ \text{lb}}{} \left| \frac{0.4536\ \text{kg}}{\text{lb}} \right| \frac{1\text{Mg}}{1000\ \text{kg}} = 2.268\ \text{Mg}$$

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

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

Metric Training for the Transportation Industry
Module 5 - Motor Vehicle Licensing and Enforcement Answers

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 +

Unit 3

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

Unit 3

G. $\frac{80{,}000\text{ lb}}{} \Big| \frac{0.4536\text{ kg}}{\text{lb}} \Big| \frac{1\text{ Mg}}{1000\text{ kg}} = 36.288\text{ Mg}$

H. $\frac{39\text{ Mg}}{} \Big| \frac{1000\text{ kg}}{1\text{ Mg}} \Big| \frac{1\text{ lb}}{0.4535\text{ kg}} = 85{,}979\text{ lb}$

I. $\frac{15\text{ Mg}}{} \Big| \frac{1000\text{ kg}}{1\text{ Mg}} \Big| \frac{1\text{ lb}}{0.4536\text{ kg}} = 33{,}069\text{ lb}$

33,069 lb < 34,000 lb Okay

Unit 3

J. $\frac{3.85\text{ m}}{} \Big| \frac{39.37\text{ in}}{1\text{ m}} \Big| \frac{1\text{ ft}}{12\text{ in}} = 12.63\text{ ft}$

12.63 < 13.5 ft okay

K. $\frac{400\text{ cu in}}{} \Big| \frac{16390\text{ mm}^3}{1\text{ cu in}} = 6{,}556{,}000\text{ mm}^3$

Unit 4

1) B
2) B
3) D
4) D
5) D
6) C
7) A
8) C
9) C

10) D

11 a) 34.88
   b) 87.56
   c) 1230
   d) 877
   e) 0.235

Introduction to SI Metric Module 5

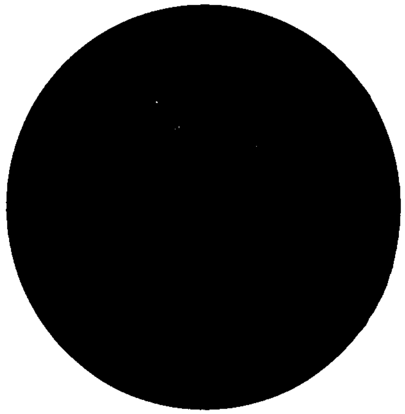
Created by:
Karen Zunkel &
Jim Cable
Iowa State University

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

Quantity	Name	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
temperature	kelvin	K
amount of matter	mole	mol
luminous intensity	candela	cd

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

$lb_f = lb_m \times 32.2$ (where 32.2 ft/s^2 is common acceleration of gravity)

SI Metric

newtons = kilograms x 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"

$$1\ lb_f = 0.4536\ kg$$

(force) to (mass)

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

SI Supplementary Units

Quantity	Name	Symbol
plane angle	radian	rad
solid angle	steradian	sr

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

Other Acceptable Units

Quantity	Name	Symbol
temperature	degree Celsius	°C
volume	liter	L
mass	tonne(metric ton)	t
angle	degree	°
angle	minute	‘
angle	second	““

Other Acceptable Units

Quantity	Name	Symbol
time	minute	min
time	hour	h
time	day	d
area	hectare	ha

Note: hectare is shortened from square hectometer . Hecto is prefix for 100... so a hectare is 100 m by 100 m

Common Prefixes

Prefix	Symbol	Power of 10
giga	G	10^9
mega	M	10^6
kilo	k	10^3
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}

Prefix Example Conversions

1000 mm = 1 m

1000 m = 1 km So for example....

$$1\ \text{km} \times \frac{1000\ \text{m}}{1\ \text{km}} \times \frac{1000\ \text{mm}}{1\ \text{m}} = 1{,}000{,}000\ \text{mm}$$

Ex. 1) $250\ \text{mm} \times \frac{1\ \text{m}}{1000\ \text{mm}} = 0.250\ \text{m}$

Ex. 2) $35\ \text{km} \times \frac{1000\ \text{m}}{1\ \text{km}} = 35{,}000\ \text{m}$

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

Worksheet Answers

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

Worksheet Answers

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^{o}C

B. 100^{o}C

C. 0^{o}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

Worksheet Answers

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

Worksheet Answers

9) Which of the following represents the longest length?

A. 3.0 m	3.0 m
B. 450 mm	0.45 m
C. 0.05 km	50 m
D. 20 cm	0.2 m

Worksheet Answers

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

Number	Place	Rounded
476.55	1 after decimal	476.6
445.25	1 after decimal	445.2

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: 25x1.609 = 40.225

40 km/h

What if you mistyped 1.609 as 16.09 on your calculator??? 25x16.09 = 402.25

402 km/h

Station Conversion

$$492+00.00 \text{ ft} \times \frac{12 \text{ in}}{1 \text{ ft}} \times \frac{1 \text{ m}}{39.37 \text{ in}} = 149+96.190 \text{ m}$$

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

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

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. $\frac{400 \text{ psi}}{} \left| \frac{6.895 \text{ kPa}}{\text{psi}} \right| \frac{1 \text{ MPa}}{1000 \text{ kPa}} = 2.76 \text{ MPa}$

No 2.76 > 2.25 MPa

E. $\frac{26001 \text{ lb}}{} \left| \frac{0.4536 \text{ kg}}{\text{lb}} \right| \frac{1\text{Mg}}{1000 \text{ kg}} = 11.79 \text{ Mg}$

$\frac{10000 \text{ lb}}{} \left| \frac{0.4536 \text{ kg}}{\text{lb}} \right| \frac{1\text{Mg}}{1000 \text{ kg}} = 4.54 \text{ Mg}$

Unit 2

F.

$$\frac{4.835\ \text{Mg}}{} \left| \frac{1000\ \text{kg}}{1\ \text{Mg}} \right| \frac{1\ \text{lb}}{0.4536\ \text{kg}} = 10{,}659\ \text{lb}$$

10,659 < 80,000 lb OK

G. 2000 mL /1000 mL x 0.0004 g = 0.0008 g

H. 150 mi x 1.609 km/mi = 241.35 km

Unit 2

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

J. $\dfrac{2500\ \text{lb}}{} \Big| \dfrac{0.4536\ \text{kg}}{\text{lb}} \Big| \dfrac{1\ \text{Mg}}{1000\ \text{kg}} = 1.134\ \text{Mg}$

1.134/2.00 = 0.567 0.567 > 0.4 yes

K. $\dfrac{125\ \text{psi}}{} \Big| \dfrac{6.895\ \text{kPa}}{\text{psi}} \Big| \dfrac{1\ \text{MPa}}{1000\ \text{kPa}} = 0.86\ \text{MPa}$

Unit 2

L.

$$20 \text{ mph} \times \frac{1.609 \text{ km/h}}{\text{mph}} = 32.18 \text{ km/h}$$

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

$$20 \text{ ft} \times 0.3048 \text{ m/ft} = 6.096 \text{ m}$$

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

$$\frac{5000 \text{ lb}}{} \left| \frac{0.4536 \text{ kg}}{\text{lb}} \right| \frac{1 \text{Mg}}{1000 \text{ kg}} = 2.268 \text{ Mg}$$

5 psi x 6.895 kPa/psi = 34.475 kPa

Worksheet Answers

11) On the moon the acceleration of gravity is about 1.7 m/s^2. 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/m^2

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

	0	.1	.2	.3
0	0	0.03048	0.06096	0.09144
1	0.30480	0.33528	0.36576	0.39624
2	0.60960	0.64008	0.67256	0.70104
3	0.91440	0.94488	0.97536	.....

Example: 2.2 feet equals 0.67256 meters

Short Form

Length

	m	in	ft	yd
m	1	39.370	3.2808	1.0936
in	25.4×10^{-3}	1	83.333×10^{-3}	27.0778×10^{-3}
ft	0.3048	12	1	0.3333
yd	0.9144	36	3	1

Example: 1 foot = 0.3048 meters

2ft x 0.3048 = 0.6096 m

Conversion Factors

Quantity	From	To	Multiply by
Length	ft	m	0.3048
	in	m	25.4×10^{-3}
	yd	m	0.9144
Mass	lbm	kg	0.4536

Example: 2ft x 0.3048 = 0.6096 m

Rounding Rules

Less than 5 - Drop the numbers

Number	Place	Rounded
4.763534	2 after decimal	4.76
234.8732	3 after decimal	234.873
87632	hundreds	87600

Rounding Rules (cont)

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

Number	Place	Rounded
4.763534	1 after decimal	4.8
234.8732	1 after decimal	234.9
87632	thousands	88000

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

X. 1.5 x 18 kg = 27 kg

Unit 3 - State Code

Topic Covered

- ✦ State Code Enforcement Applications

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 +

Unit 3

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

Unit 3

G. $\frac{80{,}000\ \text{lb}}{} \cdot \frac{0.4536\ \text{kg}}{\text{lb}} \cdot \frac{1\ \text{Mg}}{1000\ \text{kg}} = 36.288\ \text{Mg}$

H. $\frac{39\ \text{Mg}}{} \cdot \frac{1000\ \text{kg}}{1\ \text{Mg}} \cdot \frac{1\ \text{lb}}{0.4535\ \text{kg}} = 85{,}979\ \text{lb}$

I. $\frac{15\ \text{Mg}}{} \cdot \frac{1000\ \text{kg}}{1\ \text{Mg}} \cdot \frac{1\ \text{lb}}{0.4536\ \text{kg}} = 33{,}069\ \text{lb}$

$33{,}069\ \text{lb} < 34{,}000\ \text{lb}$ Okay

Unit 3

J. $\dfrac{3.85\text{ m}}{} \Big| \dfrac{39.37\text{ in}}{1\text{ m}} \Big| \dfrac{1\text{ ft}}{12\text{ in}} = 12.63\text{ ft}$

$12.63 < 13.5$ ft okay

K. $\dfrac{400\text{ cu in}}{} \Big| \dfrac{16390\text{ mm}^3}{1\text{ cu in}} = 6{,}556{,}000\text{ mm}^3$

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 = 1.3×10^3 m = 1.3 km

$17{,}500{,}000$ Pa = 17.5×10^6 Pa = 17.5 MPa

0.075 Mg = 75×10^{-3} Mg = 75 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:

<u>number</u>	<u>unit of measure</u>
34 and 1/3	KILOMETERS
75.3	millimeters cubed per sec
237657.5	PASCALS
107000000	GRAM in MEGAGRAMS
0.0076	LITERS in terms of MILLILITERS

Practice Writing Solutions

34.33 km	34.33 kilometers
75.3 mm^3/s	75.3 cubic millimeters per second
237,657.5 Pa	237,657.5 pascals
237.6575 kPa	237.6575 kilopascals
107 Mg	107 megagrams
7.6 mL	7.6 milliliters

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^{o}c

B. 42.5 ^{o}C

C. 42.5 ^{o}c

D. 42.5^{o}C

Worksheet Answers

5) Which of the following is correct?

A. 19mm3

B. 448 cmm

C. 18 Mn

D. 55.7 kPa

Worksheet Answers

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

Worksheet Answers

7) Which of the following is equivalent to 1×10^4 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

Worksheet Answers

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. .78 kg/m^2

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.

ABSTRACT
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.