# THE METIC SYSTEM

## Learning the Concept

The metric system is the official system of measurement in nearly every country of the world today, including Canada. The U.S. is one of only three countries (Myanmar and Liberia are the others) that have not converted to the modern International System of Units, "Systeme International", that was established by international agreement in 1960. Because of its widespread use in international trade, many American companies now use the metric system.

In order to use the metric system, you need to keep two basic ideas in mind.

1. The names of all units have a logical meaning. You can always know the size of the unit just by reading its name.

2. The mathematical relationship among units is consistent throughout the system. The metric system is a decimal system, that is, a system based on the number 10. Every unit is 10 times, or $10^2$ (100) times, or $10^3$ (1,000) times, or one tenth (0.1), or one hundredth (0.01), or some other multiple of 10 larger or smaller than other units in the system.

You should begin your study of the metric system by memorizing the names of the four basic units and of the prefixes used in the system. The basic units of measure are as follows:

| | |
|---|---|
| length: | meter (m) |
| volume: | liter (L) |
| weight: | gram (g) |
| temperature: | degrees Celsium (°C) |

The prefixes used in the system, with their meanings, are as follows:

| | | |
|---|---|---|
| mega- | (M) | 1,000,000 times |
| *kilo- | (k) | 1,000 times |
| hecto- | (h) | 100 times |
| deka- | (da) | 10 times |
| *deci- | (d) | 0.1 times |
| *centi- | (c) | 0.01 times |
| *milli- | (m) | 0.001 times |
| micro- | (u) | 0.000 001 times |
| nano- | (n) | 0.000 000 001 times |
| pico | (p) | 0.000 000 000 001 times |

The great majority of metric measurements you will encounter make use of only four of these prefixes, the ones marked with an asterisk above. You should learn these by heart, and then know where to look up the value of the other prefixes.

Knowing the four basic units and the prefixes listed above, you can now create units of any size for any kind of measurement. Here are some examples:

A decimeter (dm) = one tenth of a meter, or 0.1 m

A centigram (cg) = a hundredth of a gram, or 0.01 g

A kiloliter (kL) = a thousand liters, or 1,000 L

That's really all there is to the system. The examples that follow demonstrate how much easier the metric system is to use (once you have become familiar with it) than the British system.

One problem you may have at first in working with the metric system is visualizing the size of the more common units. We grow up knowing what an inch, a pound, and a quart are. But we may not have any idea what a meter, a gram, or a liter looks like. The best way to develop this familiarity is to look at a meter stick, a 1-L flask, or a set of gram weights in your own classroom. Also, you can keep the following approximate relationships in mind.

| | |
|---|---|
| A meter is about a yard. | A liter is about a quart. |
| A gram is about 1/28 oz. | A kilogram (1,000 g) is about 2.2 lb. |
| An inch is about 2.5 cm. | A mile is about 1.6 km. |

One final point about the metric system. You may encounter a unit of volume called the **cubic centimeter,** abbreviated either as **cc** or as **cm$^3$**. One cubic centimeter is almost exactly the same as (1) one milliliter: 1 cc = 1 mL.

**Example A:** Change 2.3 mm to its equivalent in centimeters (cm).

**Solution:** The problem is to find x in the expression below.

2.3 mm = x cm
Answer = .23 cm

# PRINCIPLES OF METRICS

**LENGTH**

One of the most common units is length. In SI, the base length unit is the meter. To get an idea of size in metrics, see the next figure.

The kilometer (1000 meters) is used for much longer lengths. It is comparable to the English Standard use of the mile. See the next figure for a descriptive example.

A speed of 62 mph is equal to a speed of 100 km/h.
Kilometer should be pronounced KILL'-o-meter, like kilogram.

MASS/WEIGHT

Mass is often used to mean the same as "weight" but it does have another meaning. Mass is a base quantity while weight is a derived quantity related to mass and the acceleration due to gravity. A person's mass does not change when walking on the moon instead of the earth, but the person's weight does. Weight is gravitational pull acting on mass.

A description of mass is shown in the first figure on the next page, and a comparison of weight and mass in the second.

Relax, if someone asked a 220 lb. Man his weight he would not say, "981 N" (newtons) but would answer, "100 kg".

A "metric ton" (t) is different from a U.S. Ton.

A metric ton = 1000 kg = 1 Mg (megagrams)

**VOLUME**

The liter is commonly used to measure volume. Anyone who drinks soda is familiar with the liter and two-liter sized bottles. When you buy a liter of soda you're actually buying a little more than a quart. The base unit is the meter: one liter = one cubic decimeter ($dm^3$).

## TIME

Time uses the same basic unit, seconds, as in the English system. It adds "kiloseconds" (ks). Minutes and hours are not metric measurements but may be used with metrics.

## TEMPERATURE

Kelvin is the base temperature unit in SI. NYSDOT will use Celsius (also acceptable in metrics) for most applications but kelvin is necessary for some science and engineering uses.

Celsius is based on a range from 0 to 100. At 0°C water freezes and at 100°C water boils. A comparison of Celsius-Fahrenheit and Celsius-kelvin is shown in the next figure.

To really have a "feel" for metrics you have to use it. Try to estimate the size of some of the items on your desk and in the room you are in. Then measure them using a metric ruler. The instructor will show you some common items, try to guess their mass.

## INTERNATIONAL SYSTEM (SI) RULES FOR WRITING METRIC

Rules for writing symbols and numbers were created to avoid confusion. Be careful to write them correctly.

These are examples of correct usage. The rules listed below provide more complete explanations. If you have a question about how something should be written, find the example immediately following and then look for the same highlighted symbol under "Writing Symbols."

| | | |
|---|---|---|
| kg | $kg \cdot m \cdot s^{-2}$ | five liters |
| 90 kg | 0.75mm | 5 L |
| 25° | 0.3675 kg | 2456 kg |
| 21°C, 273 K | 0.367 56 kg | 24 567 kg |

## <u>WRITING SYMBOLS</u>

Capitalization

- Unit symbols are lower-case letters in Roman (upright) type, except for L (liter) and those from proper names such as N (newton) and J (joule). For example: **5 L, 3 N, 4 J, 3 m**

- Decimal prefixes are in lower case when magnitudes are less than or equal to $10^3$ **(e.g., k, m, and m).** Magnitudes greater than or equal to $10^6$ **(e.g., M and G)** are in upper case.

Spacing

· Leave no space between the decimal prefix and symbol **(e.g., kg, not k g).**

· Leave a space between the numeral and the symbol **(e.g., 24.7 kg, not 24.7 kg).** Exception: No space is left between the numerical value and the symbols for degree, minutes, and second of plane angle and degree Celsius. For example, use **25°, 21°C.**

· Leave a space but do not use a degree mark with kelvin temperature (i.e., **273 K,** not 273°K. Do use a degree mark for degrees Celsius).

Numerals

· In technical writing, write symbols when numerals are used, but use whole unit names when no numerals are used – for example, write **8 m$^2$,** but **"one square meter."**

Composite Units

• Use a dot between two symbols to indicate the product of two units **(e.g.,kg$\cdot$m$\cdot$s$^{-2}$).**

· Use either a slash or negative power to indicate division, **(e.g., m/s$^{-1}$).**

· Use either symbols or names for composite units, but do not mix them – write **N.m** or **newton meter,** not N.meter or newton.m.

Plurals

· Do not use the plural of unit symbols **(e.g., 90 kg,** not 90 kgs), but do use the plural of terms written out **(e.g., several kilograms).**

Hyphenating

· Hyphenating is not necessary when a numeral and metric unit are used as a modifier before a noun. For example, a "35 mm camera", a "2 L bottle." However, if a unit name is used, then a hyphen is also used. For example, write "two-liter bottle" and "thirty-millimeter camera."

Periods

· Do not use a period after a symbol **–e.g., 12 kg** not 12 kg. – except at the end of a sentence.

## WRITING NUMBERS

· Always use decimals, not fractions – write **0.75 mm,** not 3/4 mm.

· Always use a zero before the decimal point for values less than one – write **0.45 g,** not .45 g.

· Use spaces instead of commas to separate units of three digits both before and after the decimal points, if the quantities are over four digits – write **4371 kg** or **0.3675 kg,** but **24 567 kg** or **6.374 68 kg.**

- Use only millimeter **(mm)** and meter **(m)** for units of length.

## CONVERSION AND ROUNDING

- Maintain the same number of significant digits when converting – 15 ft. at 0.3048 m/ft equals 4.572 m, which rounds to 4.6 m.

- Convert a mixed US customary unit to a smaller unit before converting to the metric unit and rounding – 6 ft 4 in. equals 76 in., 76 in. x 25.4 mm/in. = 1930.4 mm, and round to 1930 mm.

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**USEFUL CHARACTERS IN METRIC CONVERSION**

| **USAGE** | **CHARACTER** | **WORD PERFECT** | **ASCII** |
|---|---|---|---|
| micro | µ | Ctrl-V 6,37 | Alt 230 |
| products of 2 units | . | Ctrl-V 6,32 | Alt 250 |
| degrees | ° | Ctrl-V 6,36 | Alt 248 |

superscript – Ctrl F8, 1 size, 1 superscript, put in numbers, move the cursor to exit superscript.

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## CONVERSION RULES

There are two philosophies for converting our current measurements and standards to SI; one is "hard conversion" and one is "soft conversion." The differences are as follows:

Soft conversion:

> This is a direct mathematical conversion. The physical dimension of a standard of product is unchanged, only the numeral value changes. If Campbell's Soup changes to metrics, it keeps the can but adds "___ grams" after the number of ounces.
>
> Examples: A 55 mph speed limit becomes 88.51 km/h.
> A 12-foot lane becomes a 3.658 m lane.

Hard conversion:

> This is conversion to a whole number. Usually the size of the product changes in addition to the label. An example is the conversion of some soda bottles from quarts to liters; the actual size of the bottle changed.
>
> Examples: A 55 mph speed limit becomes 90 km/h.
> A 12-foot lane becomes a 3.6 m lane.

One way to remember which is which is to think of "soft conversion" as easy- just change the numbers exactly. A "hard conversion" is harder- you have to think and make a decision as to how you want to change the numbers.

NYSDOT will soft-convert all existing contracts and hard-convert future designs.

Use the conversion chart at the end of the manual to change from the English system to SI.

## B. SPECIAL AREAS OF THE HIGHWAY FIELD

### 1. Planning and Road Design

Planning and road design generally are the first activities involved in developing new or rehabilitating old roadways. As such, much activity in SI conversion is focused on this topic area. In particular, AASHTO has produced a guide to metric conversion which discusses many standards and specifications for planning and road design and has also prepared a supplement to the "Green Book."

The following list shows several areas to pay attention to when converting to SI:

- Location.
- Right-of-way.
- Map and plan ratios.
- Contour intervals.
- Design speeds/AADT.
- Speed limits/signing.
- Cut/fill estimates.
- Horizontal and vertical alignment.
- Roadside safety and vertical clearance.
- Stationing.
- Cross section intervals.

**Development of standards**

Many of the above areas are covered in the AASHTO Green Book. The metric task force within AASHTO has finished establishing metric criteria. Approved January 6, 1993, by AASHTO and adopted by FHWA through regulatory actions, the new metric criteria may be used by states as an interim design criteria on Federal-aid projects.

Most of the selected design values are hard conversions. Figure 2.1 describes sample design values for lane widths, shoulders, and limited clear zone information. The 9, 10, 11, and 12 ft. lanes are replaced with 2.7, 3.0, 3.3, and 3.6 m lanes, respectively. These are hard conversions because the size of the lane changes slightly. Canadian values for lane widths are slightly different. They are based on 0.25 m increments rather than 0.3 m increments.

Figure 2.2 shows additional design values for stationing and horizontal curvature. The present practice of expressing curvature by degree of curve will be discontinued and the radius definition will be adopted instead. Kilometer stationing has been adopted by the AASHTO geometric design subcommittee after its adoption by the AASHTO construction subcommittee. One hundred meter stationing has also been considered. Cross section spacing will be at intervals of 10 m, 20m, and/or 50 m depending on the application.

Table 2.1, found in the "AASHTO Guide to Metric Conversion," gives minimum rounded radii in meters for values of super-elevations and design speeds. These serve only as examples.

Figure 2.2 AASHTO design values for stationing and horizontal curvature.

Table 2.1. Horizontal Curvature.

| Design Speed km/h | Minimum rounded radius in meters | |
|---|---|---|
| | 6% max. superelevation | 8% max. superelevation |
| 40 | 55 | 50 |
| 50 | 90 | 80 |
| 60 | 135 | 125 |
| 70 | 195 | 175 |
| 80 | 250 | 230 |
| 90 | 335 | 305 |
| 100 | 435 | 395 |
| 110 | 560 | 500 |
| 120 | 755 | 665 |

Source: "AASHTO Guide to Metric Conversion," 1993.

Map scales (or map ratios) will also be affected by conversion to SI. SI scales follow the number series 1-2-5 and 1-2.5-5. Examples are shown in table 2.2 along with English equivalents. Example SI ratios may include 1:200 for urban plan sheets; 1:500 for other plan sheets; and 1:100 for vertical alignment and cross sections. A special note is that land areas are given in three different metric units, depending on what is being measured.

- meters² - plats, plans, deeds, etc.
- hectare (ha) - farm land, public land, small watersheds, etc.
- km² - watersheds, states, etc.

Contour intervals will also be affected and represented as 0.5, 1, 2, 5, or 10 m unless more accuracy is required. Other government agencies who generate mapping products used by highway engineers are in the process of conversion to SI as well.

**Table 2.2 Map ratios (scales).**

| | SI RATIO | CLOSEST ENGLISH SCALES | EQUIV. ENGLISH RATIO | |
|---|---|---|---|---|
| | 1:100 | 1" = 10' | 1:120 | |
| | 1:200 | 1" = 25' | 1:300 | |
| • | | | 1:250 | 1" = 20' |
| • | | | 1:500 | 1" = 50' |
| • | | | 1:1000 | 1" = 80' |
| | | 1" = 100' | 1:1200 | |
| • | | | 1:2500 | 1" = 200' |
| • | | | 1:5000 | 1" = 400' |
| | 1:10 000 | 1" = 800' | 1:9600 | |
| | | 1" = 1000' | 1:12 000 | |
| | 1:25 000 | 1" = 2000' | 1:24 000 | |
| | 1:50 000 | 1" = 1 mile | 1:63 360 | |
| | 1:250 000 | 1" = 4 mile | 1:253 440 | |
| | 1:500 000 | 1" = 8 mile | 1:506 880 | |
| | 1:1 000 000 | 1" = 16 mile | 1:1 013 760 | |

- Metric Right of Way (ROW) mapping scales.

Figure 2.3 schematically represents vertical clearance and bridge length. The recommended values represent hard conversions to reasonable quantiti

**Figure 2.3. AASHTO design values for vertical clearance and bridge length.**

The standard vertical clearance of 4.9 m is related to clearance on interstate highways. Other sample specifications are as follows:

- Curbs 150 mm (6 in)
  225 mm (9 in)

- Stopping sight distance eye height - 1070 mm (3.51 ft)
  Object height - 150 mm (0.49 ft.)

- Cuts and fills - volume measurements in $m^3$

- Signing - letter sizes will be in millimeters

- Pavement markings (use approximate conversion)
  * inches x 25 = millimeters, ex. 4 in = 100 mm
  * feet x 0.3 = meters

**Example: Calculation of stopping distance**

Calculations are equivalent or simpler in SI. For example, we are asked to find the stopping distance of a car moving 90 km/h up a hill of 4 percent grade. We use an equation similar to the English equation for stopping distance. After converting the basic equation to metric units, the only difference is the presence of the coefficient “255" instead of the coefficient “30". Notice that the friction coefficient, F = 0.35 is applicable in both English and SI because it is dimensionless.

**Example problem:**

Find: Stopping distance, S

Given: V = velocity = 90 km/h.
G = 4% upward grade = 0.04.
F = coef of friction = 0.35.
T = reaction time = 2.5 s.
D = reaction distance = V x T x 1000 m/km
x 1 hr/3600 s.

Solution: $S\text{ (feet)} = V^2 / [30 (F + G)] + D$, in feet. (English)

$S \text{ (meters)} = V^2 / [255 (F + G)] + D$, in meters. (SI)

$S = 90^2 / [255 (0.35 + 0.04)] + (90 \times 2.5 \times 1000/3600)$.

$S = 81.4$ m + 62.5 m.

$S = 143.9$ m = approx 140 m.

2. Drainage

The areas of highway drainage include culverts, storm drains, open channels, pavement drainage, roadside channels, and many other topics. These areas are discussed in the AASHTO drainage manual. However, this manual is not yet converted to SI.

**General**

The HYDRAIN computer software package referred to in the AASHTO manual is made up of several hydraulic and hydrologic computer software programs such as the following:

- WSPRO - open channel flow/bridge hydraulics.
- HYDRA - storm drains.
- HYDRO - hydrology.
- HYCHL - roadside channels.
- HYCLV - culverts.
- HY8 - culverts.

Like most existing software, English units are employed. However, HYCHL can be used in metric units, HY8 is partially metric, and WSPRO is currently being rewritten for metric units. The remaining programs will be enhanced in the near future.

An important aspect of learning SI is refamiliarizing oneself with a relevant physical constants and expressions. The following list provides a sample of these for drainage applications.

* Manning's equation (SI): $V = 1/n\, R^{2/3} S^{1/2}$

* velocity, $V \rightarrow$ m/s

* hydraulic radius, $R \rightarrow$ m

- longitudinal friction slope, $S_f \rightarrow$m/m
- Mannings roughness coefficient, $n \rightarrow$ dimensionless

- Rational formula (SI): $Q = K\, CiA$

  - flow, $Q \rightarrow m^3/s$
  - rainfall intensity, i = mm/h
  - drainage area, A = hectares
  - coefficient, K = 1/360
  - runoff coefficient C, dimensionless

- Acceleration due to gravity:
  English → 32.2 ft/$s^2$
  SI → 9.81 m/$s^2$

- Mass density of water (4°C):
  English → 1.94 slugs/$ft^3$
  SI → 1000 kg/$m^3$ or 1.0 g/$cm^3$

- Specific weight of water (15° C):
  English → 62.4 lb/$ft^3$
  SI → 9810 N/$m^3$

- Specific gravity of water
  English →1.0
  SI →1.0

Manning's equation is simplified slightly in the metric system. Notice that there is no constant of 1.486 before the equation. The Rational formula has different units and therefore a different coefficient. The "K" coefficient has a new value of 1/360 rather than 1. Physical constants have different values: acceleration of gravity on Earth, density of water, and specific weight of water. It is no coincidence that water has a density that is a power of 10. (*Note: A cubic meter of water has a mass of 1000 kg.)*

**Example: Channel design for lining stability**

The example given in figure 2.4 is one that can be performed using the HYCHL engineering program. Let's walk through the example where we are going to design a channel size. The design parameters are given in English units. We want to find the minimum base width so that the channel is stable.

- the design flow is 30 $ft^3$/s.
- The longitudinal slope is 0.02 ft/ft.
- the lining is vegetative Class C (medium height and thickness).

By converting the parameters to SI, the longitudinal slope stays the same, and side slopes stay the same, as is shown in figure 2.5 The design flow is 0.85 $m^3$/s. The units on shear stress convert to N/$m^2$ or Ppa. The solution may be found by using the computer program, HYCHL, to find base width. After trial and error, the base width of 5 m yields a stability factor of 1.04, and a base width of 6m yields a stability factor of 1.1. Therefore, a base width of 6 m is recommended.

**Figure 2.4. Example of channel lining design.**

## 3. Bridge Design

The area of bridge design is very broad and covers a number of subjects, as illustrated in figure 2.6. The analysis of beams and trusses for appropriate loads, pressures, and forces requires an understanding of SI. Beam and truss lengths are dimensioned in meters. Loads are given in either kN or MN instead of pounds or tons. Pressures on a bridge are given in the metric unit of kPa. Forces are given in kN, and distributed loads are given in kN/m. Plan detailing and specifications will also be performed in SI.

**Figure 2.6 Bridge design topic areas.**

The use of the metric system can greatly simplify the specifications process as shown in figures 2.7 and 2.8. Figure 2.7 shows a guiderail dimensioned in English units. This example is found in the AASHTO "Standard Specifications for Highway Bridges." The drawing uses combined units of feet and inches. It is not easy to directly add or subtract such units because they must be combined before doing so. The SI drawing, figure 2.8, uses only one unit, the millimeter. The values in this example are "hard" conversions into metric. That is, the metric values are rounded for convenience.

**Figure 2.7 Sample guiderail design values in English units.**

**Figure 2.8. Sample guiderail design values in SI units.**

In addition to length, area, and loading units and measurements, there are a variety of commonly used constants with which engineers must familiarize themselves. For example, the modulus of elasticity and compressive strength are material properties of great importance. As shown below, the numerical values differ depending on the unit system, but their meaning is identical.
Physical constants and expressions in English and SI:

- Modulus of elasticity (E) in a beam

  - Steel $E = 29 \times 10^6$ lb/in$^2$ → English
    E = 200 Gpa → SI

  - Concrete $E = 57{,}000\sqrt{f}$ → English
    (E, $f_c$ →lb/in$^2$) → English

    $E = 4730\sqrt{f_c}$ → SI
    (E, $f_c$ →MPa) → SI

  - Some typical values of concrete strength

    English $f_c$ = 3500 psi
    SI: $f_c$ = 25 Mpa

## 4. Materials

In the materials area, much activity is already conducted in metric units. This is primarily because of the connection with science and the role of laboratories. Common activities with conversion implications including the following:

- Concrete mixtures - cement content, aggregate size, slump, density.
- Asphalt mixtures - penetration, ductility, viscosity, flash point, density.
- Bearing capacity.
- Strength of materials Modulus of Elasticity.
- Soil strength as a function of $D_{50}$.

Table 2.3 shows an example of the properties of fresh concrete in metric. Some material charts are already in metric and others are in dual units.

**Table 2.3. Example concrete characteristics**

| Type of Construction | Consistency | Cement Content kg/m$^3$ | Max. Size Aggregate (mm) |
|---|---|---|---|
| massive | stiff | 140-280 | 75-150 |
| semimassive | medium still | 225-340 | 50-100 |

| | | | |
|---|---|---|---|
| pavement | medium | 250-340 | 40-65 |
| heavy building | medium wet | 280-340 | 25-50 |
| light | wet | 310-390 | 10-25 |

The following list shows representative physical constants and expressions:

- Concrete density.
  - English: 150 lb/ft.$^3$
  - SI: 2400 kg/m$^3$, 24kN/m$^3$

- Specific gravity.
  - Dimensionless, therefore it does not change

- Sieve sizes.
  - English: U.S. Standard No. 60 yields a grain diameter of 0.42 mm
  - SI: Metric Standard 500 yields a grain diameter of 0.50 mm

- Soil stresses.
  - English: kilopounds per square inch
  - SI: kilopascals

Concrete density is converted to both mass density (kg/m$^3$) and force of gravity density (kN/m$^3$). Specific gravity of a material does not change. This is an example of several constants that do not change when you convert to metric. Another example is voids ratio. Soil stresses as well as stresses for other materials are all affected quantities.

## 5. Quantity/Cost Estimation

The construction area of highway engineering presents a unique issue with respect to metrication. That is, construction personnel must interact with contractors and suppliers who may or may not have made the transition to metric. In some cases, the availability of some products in hard converted sizes may lag behind a highway department's ability to use them. The topics of relevance for this module are summarized below:

- Specifications.
- Quantity takeoffs (methods of measurement).
- Basis of payment.
- Equipment.

- Construction requirements.

**CONVERSION TABLES**

| Quantity | From US Units | To SI Units | Multiply by: |
|---|---|---|---|
| Length | ft | m (meter) | 0.304 8 |
| | yd | m | 0.914 4 |
| | in. | mm (millimeter) | 25.4 |
| | mi | km (kilometer) | 1.609 344 |
| | fathom | m | 1.828 8 |
| Area | $ft^2$ | $m^2$ (square meter) | 0.092 903 04 |
| | $yd^2$ | $m^2$ | 0.836 127 36 |
| | $in^2$ | $mm^2$ (square millimeter) | 645.16 |
| | acre | $m^2$ | 4 046.856 |
| | acre | ha (hectare) | 0.404 685 6 |
| | $mi^2$ | $km^2$ (square kilometer) | 2.589 988 |
| Volume | $ft^3$ | $m^3$ (cubic meter) | 0.028 316 8 |
| | $yd^3$ | M3 | 0.764 555 |
| | in.$^3$ | $mm^3$ (cubic millimeter) | 16 387.064 |
| | in.$^3$ | mL (milliliter) | 16.387 |
| | gal | L (liter) | 3.785 41 |
| | qt | L | 0.946 353 |
| Mass/Weight | lb | kg (kilogram) | 0.453 592 |
| | kip | ton | 0.453 592 |
| | ton (US short ton) | ton (metric ton) | 0.907 184 |
| | oz | g (gram) | 28.349 5 |
| Force | lb | N (newton) | 4.448 22 |
| | kip | kN (kilonewton) | 4.448 22 |
| Pressure | psi | kPa (kilopascal) | 6.894 76 |
| Stress | ksi | Mpa (megapascal) | 6.894 76 |
| Modulus of | psf | Pa | 47.880 3 |
| Elasticity | ksf | Kpa | 47.880 3 |
| Energy | ft-lb | J (joule) | 1.355 8 |
| | Btu | kJ (kilojoule) | 1.054 4 |
| Power | HP | kW (kilowatt) | 0.745 7 |
| Moment | lb·ft | N·m (newton meter) | 1.355 8 |
| Temperature | °F | °C (celsius) | °C=(°F-32)x0.555 |
| Velocity | ft/s | m/s (meter/second) | 0.304 8 |
| | m/h | km/h (kilometer/hr) | 1.609 3 |
| Flow Rate | $ft^3$/s | M3/s (cubic meter/second) | 0.028 317 |
| | $ft^3$/m | M3/s | 0.000 472 |
| | $ft^3$/m | L/s (liter/second) | 0.471 947 |

| | | | |
|---|---|---|---|
| Acceleration | $ft^2$ | $m/s^2$ | 0.304 8 |
| Fuel Efficiency | m/g | km/L (kilometer/liter) | 0.425 144 |

**PRACTICE QUIZ**

Answer the following questions:

1. The base SI unit of length is the <u>meter.</u>
2. The commonly used SI unit of volume is the <u>$m^3$.</u>
3. The base SI unit of time is the <u>second.</u>
4. The unit of mass/weight to which prefixes are added is the <u>gram.</u> The base unit is the <u>kilogram.</u>
5. A kilometer is <u>1000</u> times as large as a meter.
6. A millimeter is <u>1000</u> times smaller than a meter.
7. Which is the NYSDOT preferred unit for temperature.
   _____ kelvin
   __X__ Celsius
   _____ Fahrenheit
   _____ Egans
8. Converting a speed from 60 miles per hour to 100 kilometers per hour is known as what?
   __X__ hard conversion
   _____ soft conversion
   _____ either hard or soft is acceptable
9. One gram is the approximate weight of:
   _____ a full glass
   __X__ a large paperclip
   _____ a can
   _____ two pencils
10. What is the boiling point of water in Celsius?
   _____ 212°
   _____ 98.6°
   __X__ 100°
   _____ 273°

Correct the following:

| | | |
|---|---|---|
| 1) | 13 1/5 g | <u>13.2g</u> |
| 2) | 12 newton/meters | <u>12N•m</u> |
| 3) | 56.4m | <u>56.4 m</u> |
| 4) | 99 gm. | <u>99 g</u> |
| 5) | ten g's | <u>10 g or 10 grams</u> |
| 6) | 6 K race | <u>6 Km race</u> |
| 7) | 35°K | <u>35 K</u> |

8) 45°c		45°C

1. How many meters is a 402-ft home run to center field?
   1) 122
   2) 122.5
   3) 123 — c) 123

2. What force of gravity (newtons) is generated by a 14-pound bowling ball?
   1) 62 N
   2) 6.4 N
   3) 60 N — a) 62 N

3. If it is 3100 miles from Boston to San Francisco, how many kilometers is it?
   1) 4990 km
   2) 1930 km
   3) 5000 km — c) 5000 km

4. Converting a speed from 65 mph to 104.6 kilometers per hour is known as what?
   1) hard conversion
   2) soft conversion
   3) either — b) soft

5. Convert 9.00 yards to SI.
   1) 10 m
   2) 8 m
   3) 8.23 m — c) 8.23 m

6 Convert the acceleration of gravity constant of 32.2 ft/$s^2$ tp SI.
   1) 9.81 m/$s^2$
   2) 10 m/$s^2$
   3) 9.806 m/$s^2$ — a) 9.81 m/$s^2$

Fill in the following blanks:

7. A 0.004 ft/ft slope becomes a 0.004 m/m slope.

8. A hard conversion is converting from one measurement system to another using the numerical conversion factor to calculate quantities in a new system.

9. The general rule to maintain precision while converting to metric is to round off to the same number of significant figures.

10. The fuel economy of an automobile (km/L or L/100 that uses 2.0 g of gasoline per second and is traveling at 100 km/hr is what? Assume that the density of gasoline is 0.8 g/$cm^3$. 11.1 km/L or 9.0 L/100 km.

## Glossary

**AASHTO** - American Association of State Highway Transportation Officials

**acceleration** - The rate of change of velocity with respect to time.

**ampere** - Base unit to measure electricity. The unit of current in two straight parallel wires of a long length separated by one meter in free space, which products a magnetic force between the two wires of 2 x $10^{-7}$ newtons per meter length.

**ASTM** - American Society of Testing Materials

**base units** - Seven SI units: meter, kilogram, second, ampere, kelvin, mole and candela.

**candela** - Unit of luminous intensity in a given direction.

**Celsius** - A temperature scale that registers the freezing point as 0 and the boiling point as 100 degrees.

**conversion hard** - Conversion from one measurement system to another using the numerical conversion factor to calculate quantities in a new system and then rounding to a convenient dimension.

**conversion soft** - Conversion from on measurement system to another using the numerical conversion factor to calculate quantities in a new system.

**derived units** - Units that can be formed by combining base units.

**force** - A vector quantity that tends to produce an acceleration of a body in the direction of application.

**hectare** - The derived unit of area equal to 10 000 $m^2$.

| | | |
|---|---|---|
| **joule** | - | The derived unit of energy equal to one newton meter. |
| **kelvin** | - | Unit of temperature that is the fraction 1/273.16 of the thermodynamic triple point of water. |
| **kilogram** | - | The mass of a cylinder of platinum-iridium alloy kept by the International Bureau of Weights and Measures near Paris. |
| **liter** | - | The unit of volume occupied by a mass of one kilogram of pure water at its maximum density and at standard atmospheric pressure. Also 1 $dm^3$. |
| **mass** | - | The measure of inertia that an object has, or the measure of the ability of an object to resist acceleration. |
| **meter** | - | The length of path traveled by light in a vacuum during a time interval of 1/299 292 458 of a second. |
| **Metric Conversion Act of 1975** | - | Established for voluntary conversion to metrics by U.S. industries. |
| **mole** | - | Base unit to measure the amount of any substance involved in a chemical or other reaction. |
| **newton** | - | The derived unit of force that is equal to one kilogram meter per squared second. |
| **pascal** | - | The derived unit of pressure equal to one newton per square meter. |
| **plane angle** | - | An angle formed by two straight lines. |
| **radian** | - | The supplementary unit of plane angle with its vertex at the center of a circle that is subtended by arc equal in length to the radius. |
| **second** | - | Duration of 9 192 631 770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of the cesiium-133 atom. |
| **SI** | - | International System (Systeme Internationale - French) of Units. |
| **solid angle** | - | An angle subtended at a point by a surface measured in steradians. |

**specification** - A criterion or measurement found on a design drawing.

**standard** - A criterion or level of performance required to be met.

**steradian** - The solid angle with its vertex at the center of a sphere such that the surface area is equal to radius of the sphere squared.

**supplementary units** - 2 SI units that are dimensionless. They are the radian and steradian.

**weight** - The force of an object due to gravity derived as mass multiplied by gravitational acceleration.