Contextualized Basic Skills Development and Integration Guide

VOLUME II Mathematics
Safety and Quality

A Project IMPACT Publication

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Class Listings

Introduction to Industrial Safety

Kathryn Woitaszewski and Dave Hamilton

Introduction to Quality and Continuous Improvement

Doug Holt, Shanelle Grudzinski, and Dave Hamilton

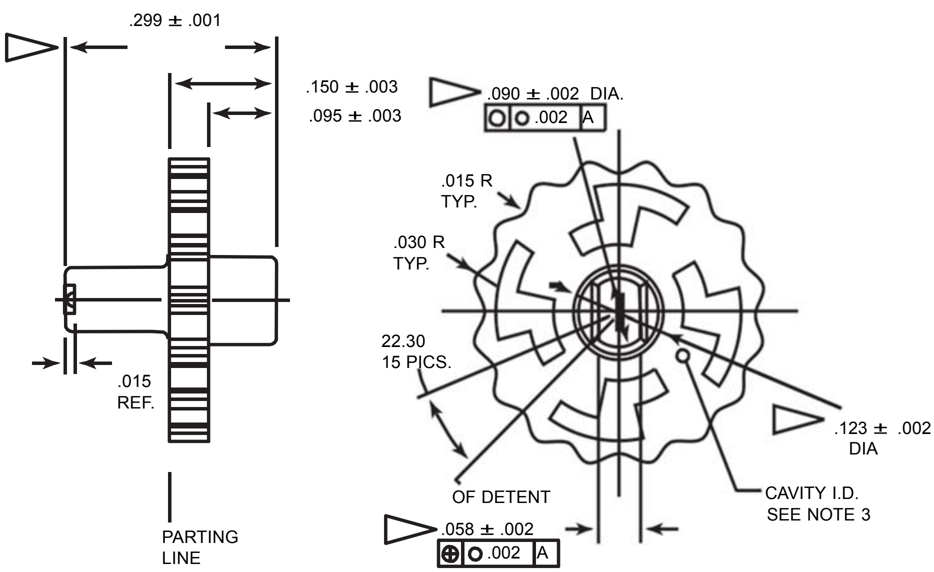
Introduction to Industrial Safety

Kathryn Woitaszewski and Dave Hamilton

Quality Overview 100

Quality manufactured parts must meet design specifications. Blueprints of the parts show what the dimensions of the parts need to be. However, tolerances are usually allowed in the manufacturing process. Tolerances are an acceptable variation from the specified dimensions of a part.

The partial blueprint below shows that some tolerances are ± .001 inch while others are ± .002 and ± .003 inch. These tolerances are in thousandths of an inch.



Print supplied by Grayhill, Inc.

The one dimension is shown as .095 ± .003. This means that the part is designed to have a dimension of .095 inch, but the part can be manufactured .003 inch less or .003 inch more and still be an acceptable quality part.

Maximum acceptable dimension = .095 + .003 = .098 inch

Minimum acceptable dimension = .095 - .003 = .092 inch

If the part is not manufactured with a dimension from .098 to .092 inch, the part will become scrap.

EXERCISES:

1. The radius of a manufactured part is indicated on a blueprint as .411 ± .002 inch. Determine the acceptable maximum and minimum radius if dimensions are in inches.

2. The specified dimension of a part is .150 inch. The blueprint indicates that all decimal tolerances are ± .005 inch. Determine the acceptable dimensions for this to be a quality part.

Intro to OSHA 100

Prevention is the priority of any safety program in the workplace. The purpose of the safety program is to inform workers about common safety practices, and to protect workers from on-the-job injuries, illnesses, and even death.

Since the establishment of OSHA in 1970, work-related injuries, illnesses, and fatalities have decreased.

To work a percent of decrease problem, the three parts of a percent problem should be identified so that the known values can be substituted into the general percent formula.

$$\text{Amount} = \text{Rate} \times \text{Base}$$

$$A = R \times B$$

The base (B) is the whole or original amount the problem is based on. If one compares work-related statistics in 1970 before OSHA to current statistics, the 1970 value is the base because it is the original value.

The rate (R) is part of the base in percent form. For a problem involving a decrease, the percent of decrease, changed to a decimal, is the rate.

The amount (A) is the numerical part of the base that the rate also represents. If the rate is a percent of decrease, the amount represents how much decrease there was in the original, base value.

ADDITIONAL NOTE:

If a percent problem involved a percent of increase instead of a percent of decrease, the process for solving the problem would be the same. The rate of increase would replace the rate of decrease and the amount would now be how much the original, base value had increased.

EXAMPLE:

Prior to 1970, there were 300,000 new cases of occupational illnesses and diseases reported each year. Since the establishment of OSHA, the overall illness rate has decreased by 42%. With a decrease of 42% in reported cases, what is the current number of new cases of illnesses and diseases each year?

SOLUTION:

Base (B) = 1970 value = 300,000 new cases

Rate of decrease (R) = 42%

First change the 42% to a decimal value. Since percent (%) means "parts per hundred," the rate of 42% must be divided by 100 which moves the decimal point two places to the left.

$$42\% = \frac{42}{100} = .42$$

Now substitute the known values into the percent formula.

Amount = Rate x Base

A = R x B

A = .42 x 300,000 = 126,000

Because the 42% represented the decrease in the new cases of occupational illnesses, 126,000 represents the decrease in the number of new cases.

To find the current number of new cases of occupational illnesses each year, subtract the decrease from the original value in 1970.

300,000 - 126,000 = 174,000

The current number of new cases of occupational illness each year is 174,000 compared to the 300,000 cases in 1970.

EXERCISES:

1. Prior to 1970, there were 14,000 job-related deaths every year. Since OSHA was established, work-related deaths have decreased 62%. What is the current number of job-related deaths each year?

2. Current OSHA statistics show that almost 6 million non-fatal workplace injuries occur each year. However, this number of injuries indicates that there was a 42% decrease from 1970 statistics. What would have been the number of non-fatal workplace injuries each year in 1970?

Fire Safety and Prevention 110

Some workplaces train employees to fight fires that may occur. Standpipe and small hose systems provide the water used to fight the fires. There are several classifications of these water-supply systems; each classified by the diameters of the hose connections.

A Class I system has a 2 1/2 inch diameter hose connection.

A Class II system has a 1 1/2 inch diameter hose connection.

Small hose systems have 5/8 inch to 1 1/2 inch diameter hose connections.

Since the cross-sectional areas of the hoses are circles, the amount of water each hose provides can be compared not only by calculating the cylindrical volume of the hose, but also by calculating the cross-sectional area of the hoses if the length of hose is the same.

Area of circle $= \pi r^2$

where $\pi \approx 3.14$

r = radius of circle = 1/2 (diameter)

EXAMPLE:

The minimum diameter of a small hose system is 5/8 inch. A Class II system has a 1 1/2 inch diameter hose connection. How many times more water can be provided by the Class II system compared to the small hose system?

SOLUTION:

<u>Small hose system</u>

diameter = 5/8 in = .625 in

radius = .625 in/2 = .3125 in

$A = \pi r^2$

$A = (3.14)(.3125\ in)^2 \approx .307\ in^2$

<u>Class II system</u>

diameter = 1 1/2 in = 1.5 in

radius = 1.5 in/2 = .75 in

$A = \pi r^2$

$A = (3.14)(.75\ in)^2 \approx 1.77\ in^2$

Comparing the two areas: $\frac{1.77\ in^2}{.307\ in^2} \approx 5.77$

The cross-sectional area of the Class II hose is approximately 5.77 times larger than the cross-sectional area of the 5/8 inch small hose system. That means that for the same length hose, the Class II hose will provide approximately 5.77 times the amount of water.

How does that compare to a ratio of the diameters or radii?

$$\frac{\text{Class II radius}}{\text{small hose radius}} = \frac{1\frac{1}{2}\text{ in}}{\frac{5}{8}} = \frac{.75\text{ in}}{.3125\text{ in}} = 2.4$$

The comparison of the diameters or radii does not match the comparison of the cross-sectional areas. That is because the formula for the area depends on r^2. The squaring effect of the radii (or diameters) is also carried over to the comparisons of the cross-sectional areas.

Ratio of diameters (or radii) = 2.4

Square this ratio = $(2.4)^2$ = 5.76

The <u>squared</u> ratio of the diameters (or radii) equals the ratio of the cross-sectional areas.

EXERCISES:

1. A Class I standpipe system has a 2 1/2 inch diameter hose. A small hose system can have a 1 inch diameter hose.

   a. Determine the cross-sectional area of the Class I hose.

   b. Determine the cross-sectional area of the small hose system.

   c. Compare the cross-sectional area of the Class I hose to the cross-sectional area of the small hose system. How many times larger is the area of the Class I hose?

   d. Explain what the answer in part c means.

   e. Compare the Class I hose diameter to the small hose diameter. How many times larger is the Class I diameter?

   f. Explain why the answers to parts c and e are not the same.

Personal Protective Equipment 120: Hard Hats

When working around electrical hazards, it is important to have the proper hard hat for the job. According to ToolingU, hard hats are classified by electrical insulation rating.

- Class C hard hats provide no protection from electrical hazards.
- Class G hard hats provide voltage protection up to 2200 volts.
- Class E hard hats provide the highest level of protection against voltage, up to 20,000 volts.

EXERCISES:

1. a. What is the ratio of voltage protection for the Class E hard hat compared to the Class G hard hat?

   b. How many times more protection does the Class E hard hat provide compared to the Class G hard hat?

2. a. If an employee is required to work around 10,000 volts of electricity, what classification of hard hat meets safety standards?

   b. How many times more protection than the 10,000 volts does the Class E hard hat provide?

Personal Protective Equipment 120: Hearing Protection

Noise can reach hazardous levels in the workplace. If over an 8-hour shift, the noise levels reach or exceed 85 decibels, the employer is required to put a hearing conservation program in place, which includes the use of hearing protection and regularly scheduled hearing tests for the employees.

At first glance, the 85 decibel noise level may appear to be an 85 decibel average over an 8-hour shift. However, 85 decibels cannot be an average because an average allows for some values to be less than 85 decibels. This is not the case since the noise level must be at 85 decibels or more for the entire 8-hour shift.

What if an employee is exposed to more than 85 decibels of noise during an 8-hour shift? Can an average noise level be calculated if the noise level changes throughout the 8-hour shift? This type of average is called a weighted average or weighted mean because the noise levels are weighted by the length of time the noise level lasted. This weighting (unequal relevance) of the noise levels must be taken into account when the weighted mean or average is calculated.

Rule for Figuring a Weighted Average

1. Multiply each of the values that are to be averaged by their assigned weight and add these products.

2. Add the weights to determine the total weight.

3. Divide the sum in Step 1 by the total weight in Step 2.

EXAMPLE:

The noise levels in the workplace reached the following values over an employee's 10-hour shift. Calculate the average noise level taking into account the amount of time the employee was exposed to each noise level.

85 decibels for 3 hours
90 decibels for 2 hours
100 decibels for 1 hour
92 decibels for 4 hours

SOLUTION:

1. The values to be averaged are the noise levels. The weights are the numbers of hours during which the noise level lasted.

Value x Weight	
85 decibels x 3 =	255
90 decibels x 2 =	180
100 decibels x 1 =	100
92 decibels x 4 =	368
	903 decibels

2. The total weight is the total number of hours.

$3 + 2 + 1 + 4 = 10$ hours

3. $\frac{903 \text{ decibels}}{10 \text{ hours}} = 90.3 \frac{\text{decibels}}{\text{hour}}$

Over the 10-hour shift, the average noise level was 90.3 decibels/hour.

Even though the weighted average (mean) was used here to calculate the average noise level, it can be used to calculate the average number of welds per hour during a shift or the average number of parts shipped per day over a week's time.

EXERCISES:

1. During an 8-hour shift, an employee completed the following number of welds in the given time.

   15 welds per hour over 2 hours
   12 welds per hour over 3 hours
   10 welds per hour over 2 hours
   0 welds in 1 hour

   Determine the average number of welds per hour for this employee.

2. One department within the company manufactured the following number of parts during the indicated days. What was the department's average production per day?

   500 parts per day Monday and Tuesday
   480 parts per day Wednesday and Thursday
   530 parts Friday

Noise Reduction and Hearing Conservation 170

MEASURES OF CENTRAL TENDENCY

In this lesson, OSHA standards require an eight-hour time weighted average. The background information you should know is how do you find an average (the mean)? Related to this is mode (the most frequent) and median (the middle value).

To find an average (the mean) you add the values and divide by the number of values present. In example

Suppose we measure 7 items as 10, 40, 24, 31, 17, 22, 38; the sum of the values is 182 which when divided by 7 is 26. The **mean** of our sequence of measurement is 26.

Try these sequences, find the mean

1. 18,24,55,11,23,25,18,22,41
2. 18,25,11,55,43,42,11,25,11,52,11

In our second sequence we notice that the number 11 appears more often than the others. This is the **mode**, or the most frequent number.

Lastly we have another measure, the **median** (middle) value. To find the median you have to arrange the numbers in order. If there is an odd number of values as in my first example, it's simple

10,17,22,24,31,38,40 … 24 is the middle one

But what if we have an even number of values like 10,17,22,22,24,31,38,40? Well we average the middle 2 like we did above. We add the 22 + 24 = 46 and divide by 2. The median is 23.

Try these sequences, find the mode and median

1. 18,24,55,11,23,25,18,22,41
2. 18,25,11,55,43,42,11,25,11,52,11

Why do we need both mean and median? The closer the two values are, the closer the number sequence is. The further apart the mean and the median, the more spread out the numbers. Here is a great example. Your boss claims he pays an average salary of $40,000 to his workers, but you know you and the others make a lot less, so you check. He pays Jill, 24,000; Sam $28,000; you, $28,000; Bob, $26,000 and himself, $94,000. So is he right? What is the median salary at your workplace? Notice how far apart the median and mean are in this example. What does it tell you about the salaries? Yup, they are spread out.

What is a **decibel**? The decibel is a **logarithmic** unit used to express the ratio between two values power and intensity. A logarithmic scale is often used to display a physical quantity such as the level of sound.

Table 5 Maximum Noise Levels

Sound Level (decibels)	Maximum Hours of Continuous Exposure per Day	Examples
90	8	Power lawn mower
92	6	Belt sander
95	4	Tractor
97	3	Hand drill
100	2	Chain saw
102	1.5	Impact wrench
105	1	Spray painter
110	0.5	Power shovel
115	0.25 or less	Hammer drill

You are familiar with a linear scale like 1,2,3,4,5, etc., which is a line of numbers. What if we need to express much larger ranges of values? This is where a logarithmic scale comes into use as it grows by powers of 10,100,1000,10000, etc.

Decibel	Power
0	1
10	10
20	100
30	1000
40	10,000
50	100,000

Note. Table 5 OSHA Certification student training manual

Lastly, what is a **weighted average**? When I calculate a mean, I give every number in the sequence an even weight.

Are these the same?

$$\frac{10, 40, 24, 31, 17, 22, 38}{7} \quad \text{and} \quad 1/7\ (10) + 1/7\ (40) + 1/7\ (24) + 1/7\ (31) + 1/7\ (17) + 1/7\ (22) + 1/7\ (38)$$

They are the same. Each number was given the same weight ($1/7^{th}$). In a weighted average, I give more weight to one number than other.

But what if using Table 5 you spend most of your day with a chain saw and only a brief period with a power mower. Does that get you out of wearing hearing protection? The difference between 90 decibels and 100 decibels is not just 10 but a power of 10. The chain saw is 10 times louder in decibels!

Average decibels over my 7 hour day where I spent 4 hours with a chain saw, 2 hours mowing and 1 hour at the computer may look like this, adding my chain saw time + my mowing time + my computer time as:

4/7 (100) + 2/7 (90) + 1/7 (30) = 87 average decibels. See how the time spent with the chain saw was weighted 4/7 while time at the computer 1/7. The chain saw had 4 times the impact on my hearing.

My time with the chain saw was much less but the impact on my future hearing was much greater. Wear the protection!

Respiratory Safety 195

When the workplace atmosphere is contaminated and contains less than 19.5% oxygen, an atmosphere-supplying respirator must be used to provide breathable air through a protective mask. One type, a self-contained breathing apparatus (SCBA), is used when workers have short- term exposure or need to escape from an environment that is immediately dangerous to life and health (IDLH). Depending on its design, the SCBA can provide from 30 minutes to 4 hours of air.

EXAMPLE 1:

If a self-contained breathing apparatus (SCBA) is used for two hours and twenty-eight minutes, and it is designed to provide 4 hours of air, how much time will be left before the tank is empty?

SOLUTION:

The time remaining on the SCBA is the difference between 4 hours and 2 hours 28 minutes.

$$\begin{array}{r} 4 \text{ hr} \\ \underline{-\ 2 \text{ hr } 28 \text{ min}} \end{array}$$

Borrow 1 hour from the 4 hours and rewrite as 3 hr 60 min.

$$\begin{array}{r} 3 \text{ hr } 60 \text{ min} \\ \underline{-\ 2 \text{ hr } 28 \text{ min}} \\ 1 \text{ hr } 32 \text{ min} \end{array}$$

The SCBA should have 1 hr 32 min remaining before the tank runs out of air.

EXAMPLE 2:

A SCBA with a small air tank provides 30 minutes of air. Sixteen minutes of the air is used. What percent of the air remains in the tank?

SOLUTION:

When working a percent problem, it is helpful to identify each part of the problem so that the values can be substituted correctly into the general percent formula.

Amount = Rate x Base

$A = R \times B$

The base (B) is the whole or original amount the problem is based on. For this problem, the base is the 30 minutes of air that the tank provides.

The rate (R) is part of the base in percent form. In this problem, the percent is the unknown.

Rate (R) = ??

The amount (A) is the numerical part of the base that the rate also represents. Since this problem is asking for the percent of air that remains in the tank, that amount must be calculated from the given information.

Amount (A) = 30 - 16 = 14 minutes remaining

$A = R \times B$

$14 \text{ min} = R \times 30 \text{ min}$

Solve the formula by dividing out the 30.

$$R = \frac{14 \text{ min}}{30 \text{ min}} = .4\overline{6}$$

Change the decimal form to a percent by multiplying by 100 which moves the decimal point two places to the right.

$R = .4\overline{6} \times 100 = 46.\overline{6}$ or 47% (to the nearest percent)

Approximately 47% of the air remains in the tank.

EXERCISES:

1. A self-contained breathing apparatus (SCBA) is used in a contaminated workplace atmosphere during three short intervals of time: 22 minutes, 25 minutes and 38 minutes.

   a. How much total time has the SCBA been used? Write the answer in hours and minutes.

   b. If the SCBA provides three hours of air, how much time could the SCBA be used before it runs out of air?

2. A worker enters a contaminated workplace atmosphere at 6:30 a.m. with a SCBA and leaves the area at 8:10 a.m.

   a. How long did the worker use the SCBA?

   b. Was the worker getting close to running out of air if the tank provides 2 hours of air?

3. A SCBA that provides four hours of air is used for three hours and 24 minutes.

   a. What percent of its air was used?

   b. What percent of its air still remains?

Safety for Electrical Work 115

Safety is key when working with electricity. A basic understanding of electricity is important in preventing electric shock and preventing fire hazards due to overheated electrical equipment and wiring.

Three quantities used to measure electricity are voltage (V), current (I), and resistance (R).

Current, sometimes called amperage, is the rate of charge (electron) flow through the electrical wiring. It is measured in amperes (A), or simply amps. Amps of current is what causes electric shock, and becomes a fire hazard when the current is more than what the electrical wiring can handle.

Voltage is the force that causes the current flow. It is measured in volts (V). **Resistance** is the opposition to the current flow. It is measured in ohms (Ω).

The mathematical relationship between voltage, current, and resistance is called **Ohm's Law**. It states that the voltage is the product of the current and resistance.

Voltage = Current x Resistance

$$V = IR$$

Where V = voltage in volts (V)

I = current or amperage in amps (A)

R = resistance in ohms (Ω)

For a given resistance, an increase in voltage results in an increase in current, and a decrease in voltage results in a decrease in current. This means that current and voltage are directly proportional.

For a set voltage, if the resistance increases, the current will decrease and if the resistance decreases, the current will increase. This means that current and resistance are indirectly or inversely proportional.

To apply Ohm's Law correctly, each of the quantities must be measured in the base units of volts, amps, and ohms. If a metric prefix like "milli-"is part of the unit, the unit must first be changed back into the base unit. For example, if a current is measured in milliamps (mA), it must be converted to amps (A) before being substituted into Ohm's Law.

EXAMPLE:

A light bulb is plugged into a 120V circuit and draws 910 mA of current. What is the resistance of the light bulb?

SOLUTION:

Voltage (V) = 120 V

Current (I) = 910 mA = .91 A

(Since milli- means 0.001, 910 mA can be converted to amps (A) by multiplying by 0.001.)

Substitute the values into Ohm's Law and solve for the unknown resistance.

$$V = IR$$

$$120\text{ V} = (.91\text{ A})\,R$$

$$R = \frac{120\text{ V}}{.91\text{ A}} \approx 132\text{ ohms }(\Omega)$$

EXERCISES:

1. A fan motor in a ventilation system runs on 115 V and draws 1.7 A of current. What is the resistance of the fan motor?

2. Two coils are connected to a 120 V source. One coil has a resistance of 95 ohms (Ω) while the second coil has a resistance of 185 Ω.

   a. Calculate the current flow through each coil.

   b. Did the coil with the larger resistance have a larger or smaller current flow through it?

   c. Based on the answer to part b, are current and resistance directly proportional or inversely proportional?

3. An antenna coil runs on 5 V of electricity and has a resistance of 85 Ω.

   a. Determine the current flow through the coil in milliamps (mA).

   b. Based on the current found in part a, what reaction would the human body have to an electric shock from the coil? See the table, "Effects of Electrical Current on the Body," on the next page.

Effects of Electrical Current on the Body	
Current	Reaction
1 mA	Faint tingle.
5 mA	Slight shock felt but not painful.
6 - 30 mA	Painful shock. Muscles freeze. May not be able to let go.
50 - 150 mA	Extremely painful shock. Breathing stops. Severe muscle contractions. Death is possible.
1 - 4.3 A	Ventricular fibrillation. Muscles contract. Nerve damage occurs. Death is likely.
10 A	Cardiac arrest. Severe burns. Death is probable.

4. A water heater element with a resistance of 15 Ω is connected to a 230 V source.

   a. Determine the current through the element.

   b. Will wiring that has a maximum amperage of 25 A help prevent overheating?

   c. Is a 15 A breaker for the water heater large enough?

Ladder safety is addressed several times within the ToolingU lessons. The attached image comes from Safety – Walking and Working Surfaces 180. It illustrates that a metal rung ladder must be placed ¼ of the ladder length away from the base of the wall. In addition, this lesson states that if the ladder is used to reach a walkway or roof, it must extend 3 feet past the walkway or roof.

A ladder that leans against a vertical structure (wall), will form a right triangle with the wall and the ground distance from the wall to the base of the ladder. Because of this right triangle relationship, if two of the distances are known, the third distance can be calculated using the Pythagorean Theorem.

Simply stated, the Pythagorean Theorem says: $a^2 + b^2 = c^2$

The lengths a and b are the lengths of the sides that form the 90° right angle. In a ladder situation, these lengths are the height of the wall (or the vertical height the ladder reaches) and the distance on the ground between the wall and the base of the ladder.

The length c is called the hypotenuse and would represent the length of the ladder, or that part of the ladder that reaches to the roof or walkway if it extends past.

EXAMPLE:

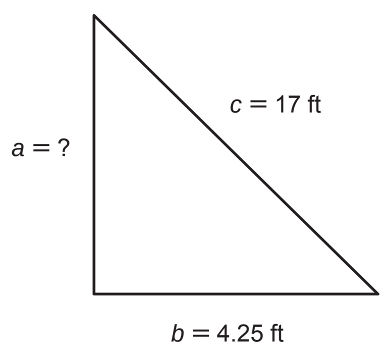
A 20 ft. metal rung extension ladder is being used to reach the roof of a building. To be safe, what is the maximum height the 20 ft. ladder can reach?

SOLUTION:

Because the worker must step off the ladder onto the roof, the worker must use 3 ft of the ladder for overhang.

20 ft. - 3 ft. overhang = 17 ft. of ladder available

1/4 of the 17 ft. = 1/4(17) = 17/4 = 4.25 ft. distance from the wall to base of ladder



$$a^2 + b^2 = c^2$$

$$a^2 + (4.25\text{ ft})^2 = (17\text{ ft})^2$$
$$a^2 + 18.0625\text{ ft}^2 = 289\text{ ft}^2$$
$$a^2 + 289\text{ ft}^2 - 18.0625\text{ ft}^2 = 270.9375\text{ ft}^2$$

Because the height is a and not a^2, the value of a^2 must be square rooted.

$$a = \sqrt{270.9375\text{ ft}^2} \approx 16.5\text{ ft}$$

The maximum height reached by the 20 ft ladder is just under 16.5 ft.

EXERCISES:

1. A 15 ft. ladder is used to reach an overhead walkway. How high is the walkway?

2. a. The top of a ladder reaches a 10 ft. height when leaned against a wall. If the base of the ladder is 2 ft. from the wall, how long is the ladder?

   b. Is this ladder being used safely? Why or why not?

Bloodborne Pathogens 115

Lesson 13 in Bloodborne Pathogens 115 states, “When an employee is injured or exposed to blood or bodily fluids in the workplace, employers are required to maintain the employee’s medical record for the duration of their employment and for 30 years thereafter.” Based on this statement, answer the following exercises.

EXERCISES:

1. a. An employee who was hired in 1990 was injured on the job in 1993. If he plans to retire in 2022, what is the last year that the company is required to maintain the employee’s medical record?

   b. How many years total will be maintained on this employee’s medical record?

2. A local company disposes of former employees’ medical records each year. In 2015, the medical records of employees that ended their employment with the company previous to what year can be disposed of?

Walking and Working Surfaces 180

LADDER SAFETY

Image provided by ToolingU-SME shows the proper length for an extension ladder. To be safe, an extension ladder should be set up so that the distance between the base of the structure it is leaning against must be one-fourth of the length of the ladder to the point the ladder touches the structure. If you are going to step off, extend 3 feet past the height of the structure.

1. How far should a 16´ ladder be from the wall?

2. How far should a 30´ ladder be from the wall?

3. What angle is the ladder relative the ground base?

4. Does the angle change with a higher wall and longer ladder?

Safety for Assembly 105

Screws are sized by length, diameter and threads per inch. For example, 3-1/4-20 would be a 3"-long screw, 1/4-inch shaft diameter, and 20 threads per inch. The number of threads per inch gives the screw its pitch. With each complete rotation, the screw goes in or out of a distance equal to its pitch.

Image supplied by [dreamstime.com](http://www.dreamstime.com/) or http://www.dreamstime.com/ and edited by author

a. The pitch of the screw is 1/16 inch. How far will it go into a piece of oak if it is turned 10 complete rotations clockwise?

____

b. The pitch of a screw is 3/32 inch. How far will it stick out of a piece of oak if it is initially flush and then turned 10 complete rotations counterclockwise?

____

c. After an initially flush screw has been turned eight complete rotations counterclockwise, it extends 1/2-inch above the surface of the drywall. What is its pitch?

____

d. The pitch of a screw is 3/32 inch. How many complete rotations are necessary to drive the screw 3/4-inch into a piece of wood?

Intro to Fastener Ergonomics 130

The lifting of impact wrenches and the posture while using them may be an ergonomic concern partly because of the power-to-weight ratio of the impact wrench. This power-to-weight ratio is defined as the power the tool generates compared to the weight of the tool.

Ratios show a comparison between two quantities and are usually written in one of three forms. The two quantities are 1) written as a fraction, 2) separated by a colon (:), or 3) separated by the word "to."

For example, if a larger impact wrench generates 720 ft-lb of torque and weighs 12 lb, the power-to-weight ratio can be written in three different ways.

$\frac{720 \text{ ft−lb}}{12 \text{ lb}}$ 720 ft-lb: 12 lb   720 ft-lb to 12 lb

Because the ratio can be written as a fraction, the ratio can be reduced or simplified like a fraction. To reduce a ratio, find a common factor in both the numerator and denominator and divide out the common factor in both the numerator and denominator.

In the previous example, 720 and 12 are both divisible by a factor of 12. Simplify the ratio by dividing both by 12.

$$\frac{720 \text{ ft-lb}}{12 \text{ lb}} \begin{matrix} \div 12 \\ \div 12 \end{matrix} = \frac{60 \text{ ft-lb}}{1 \text{ lb}}$$

If it is difficult to find a common factor as large as 12, start with dividing out a smaller common factor, and repeat the process until the ratio can no longer be reduced.

$$\frac{720 \text{ ft−lb}}{12 \text{ lb}} \begin{matrix} \div 2 \\ \div 2 \end{matrix} = \frac{360 \text{ ft−lb}}{6 \text{ lb}} \begin{matrix} \div 2 \\ \div 2 \end{matrix} = \frac{180 \text{ ft−lb}}{3 \text{ lb}} \begin{matrix} \div 3 \\ \div 3 \end{matrix} = \frac{60 \text{ ft−lb}}{1 \text{ lb}}$$

The reduced or simplified result is the same.

EXERCISES:

1. An impact wrench that generates 100 ft-lb of torque weighs 3 pounds. What is the power-to-weight ratio of the wrench? Write the ratio in three different forms.

2. An impact wrench generates 360 ft-lb of torque and weighs 8 pounds. What is the power-to-weight ratio written as a fraction? Simplify the ratio if possible.

Flammable and Combustible Liquids 155: Safety Cans

OSHA-approved safety cans for holding flammable and combustible liquids cannot hold more than five gallons.

Many of the safety cans are cylindrical in shape. By measuring the dimensions of the can, the volume can be calculated and converted to gallons so as to determine whether OSHA safety standards have been met.

A right circular cylinder is shown in the diagram. The volume of a cylinder is determined by the formula $V = \pi r^2 h$.

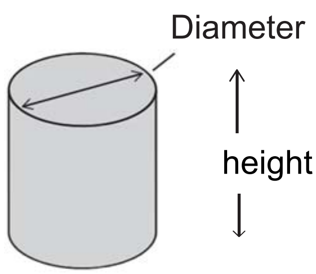


Image illustrated by the author

Where r = radius of the circular end

h = height of the cylinder

$\pi \approx 3.14$

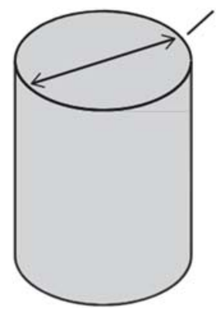
The diagram above shows the diameter of the circular end which is the distance across the circular end. The formula for volume uses the radius which is the distance from the center of the circular end to the outside edge. Once the diameter is measured, the radius, being half the diameter, is found by dividing the diameter by two.

$$\text{radius} = \frac{\text{diameter}}{2}$$

EXAMPLE:

A cylindrical safety can is found to have a diameter of 12 inches and a height of 15 inches. If the can is filled to a height of 15 inches with a flammable liquid, will it meet OSHA standards?

SOLUTION:



Diameter = 12 in

Radius $= \dfrac{\text{diameter}}{2} = \dfrac{12 \text{ in}}{2} = 6 \text{ in}$

$\mathbf{V} = \pi r^2 h = (3.14)(6 \text{ in})^2(15 \text{ in}) = 1695.6 \text{ in}^3$

(Be sure to follow the order of operations by squaring the radius before performing the multiplications. Also, be sure to label the volume with the appropriate units since cubic units indicate a volume or three-dimensional space.)

V = **1695.6 in^3** Is this less than the 5 gallon OSHA standard?

To determine whether the volume of 1695.6 in^3 is less than the 5 gallon standard, the volume in cubic inches must be converted to gallons. The conversion between gallons and cubic inches is

1 gallon = 231 in^3

Therefore, 5 gallons is five times as much

5 gallons = 5 x 231 in^3 = 1155 in^3

If filled to a height of 15 inches, the safety can in this example contains more than the allowed amount by OSHA standards.

$$1695.6 \text{ in}^3 > 1155 \text{ in}^3 \text{ standard}$$

EXERCISES:

1. A cylindrical safety can is found to have a diameter of 14 inches and a height of 8 inches.

   If the can is filled to the height of 8 inches with a combustible fluid, will it meet OSHA standards?

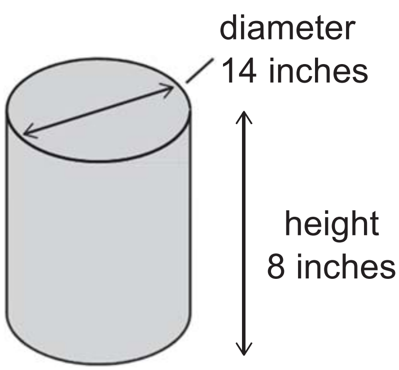


Image illustrated by the author

2. A 12-inch diameter safety can contains 5 gallons of a flammable liquid, meeting OSHA standards. What is the allowable height of liquid to meet the 5 gallon standard?

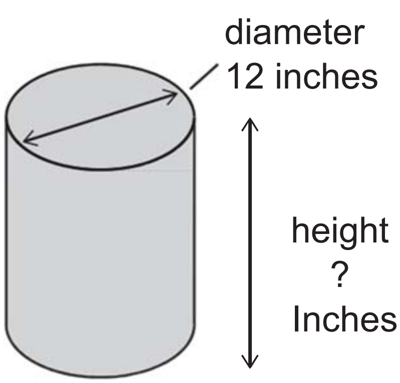
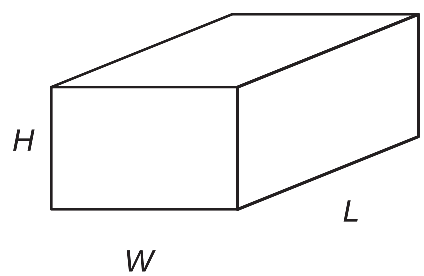


Image illustrated by the author

Flammable and Combustible Liquids 155: Storage Rooms

An OSHA-approved storage room is required if the company stores more than twenty-five gallons of flammable and combustible liquids. The approved storage room must have a ventilation system that can completely exchange the air within the room at least six times per hour. To be sure that the ventilation system is the proper size, the volume of air in the room that must be exchanged must be known. With most storage rooms being rectangular, the volume that needs to be calculated is the volume of a rectangular box or prism.



This image of a rectangular prism shows the three dimensions of the prism as length (*L*), width (*W*), and height (*H*). The formula for finding the volume is $V = LWH$.

Image illustrated by author

Remember that the volume is the amount of space inside the rectangular prism. Therefore, the proper units for volume are cubic units, indicating it is three-dimensional.

Once the volume is known, the exchange rate can be determined by dividing the volume of air that must be exchanged by the time frame for the exchange.

$$\text{Exchange rate} = \frac{\text{Volume of air to be exchanged}}{\text{Time for exchange}}$$

This exchange rate is also called the air flow capacity of a ventilation system and is usually given in cubic feet per minute (cfm).

EXAMPLE:

A storage room is 14 feet wide and 20 feet long, and has 8 foot ceilings.

a. What volume of air is in an empty storage room of this size?

b. What is the air exchange rate for this room if the air is exchanged six times per hour?

SOLUTION:

a. length (L) = 20 ft

width (W) = 14 ft

height (H) = 8 ft

$V = LWH = (20 \text{ ft})(14 \text{ ft})(8 \text{ ft}) = 2240 \text{ cubic feet} = 2240 \text{ ft}^3$

b. Since the air in the room must be exchanged at least six times per hour, first determine the volume of air exchanged after six times.

$2240 \text{ ft}^3 \times 6 = 13{,}440 \text{ ft}^3$

Now find the exchange rate.

$$\text{Exchange rate} = \frac{\underline{\text{Volume of air to be exchanged}}}{\text{Time for exchange}}$$

$$\text{Exchange rate} = \frac{13{,}440 \text{ ft}^3}{1 \text{ hour}} = 13{,}440 \text{ ft}^3/\text{hr}$$

or $$\text{Exchange rate} = \frac{13{,}440 \text{ ft}^3}{60 \text{ min}} = 224 \text{ ft}^3/\text{min} = 224 \text{ cfm}$$

EXERCISES:

1. A storage room with 10 ft ceilings is 15 feet wide and 18 feet long. What volume of air is in a room of this size?

2. To be OSHA approved, the storage room in exercise 1 must have a complete air exchange at least 6 times per hour. Determine the exchange rate in ft^3/hr, if the air is exchanged 6 times per hour.

3. Change the exchange rate in exercise 2 to ft^3/min (cfm) so as to know the required airflow capacity of the ventilation system.

Flammable and Combustible Liquids 155: Flashpoint

Every flammable and combustible liquid has a flashpoint, a temperature at which the liquid will ignite when it comes into contact with flames or sparks. Manufacturers are required to include the flashpoint on labels of flammable and combustible liquids. The flashpoints could be in degrees Fahrenheit or degrees Celsius.

To convert between the Fahrenheit and Celsius temperature scales, the following formulas can be used.

$$F = 1.8C + 32 \qquad\qquad C = \frac{F - 32}{1.8}$$

When using the formulas, be sure to follow the correct order of operations. In the Fahrenheit (F) formula, multiply the Celsius (C) temperature by 1.8 before adding 32. In the Celsius (C) formula, find the answer in the numerator before dividing by 1.8.

EXERCISES:

1. Some classes of flammable liquids are extremely dangerous because they can ignite at room temperatures below 73°F. If the room temperature is 65°F, what is the equivalent Celsius temperature?

2. Combustible liquids have flashpoints that are 100°F or more. A very warm industrial environment has a temperature of 44°C. Is there a potential hazard for a combustible liquid to ignite in this environment?

Metal Working Fluid Safety 165

The concentrate for semi-synthetic metal working fluids (MWFs) contains from 5 – 30 % severely refined lubricant-based oil, and from 30 – 50% water, with the remainder being other materials such as additives, emulsifiers, etc.

To work with percents such as these, the three parts of a percent problem should be identified so the known values can be substituted into the general percent formula.

$$\text{Amount} = \text{Rate} \times \text{Base}$$

$$A = R \times B$$

The base (B) is the whole or original amount the problem is based on. For this type of problem, the base would be the size of the container holding the concentrate.

The rate (R) is part of the base in percent form. The rate would be the 5 – 30% lubricant-based oil or the 30 – 50% water, depending upon what part is wanted. These percents would need to be changed to decimal values before any calculations are made.

The amount (A) is the numerical part of the base that the rate also represents. If using the percent of water in the concentrate in the percent formula, the amount found would be the amount of water in the concentrate.

EXERCISES:

1. If a 30 gallon drum of semi-synthetic MWF concentrate has 25% lubricant-based oil and 40% water, determine each of the following amounts.

    a. Number of gallons of lubricant-based oil in the drum of concentrate.

    b. Number of gallons of water in the drum of concentrate.

    c. Percent of other materials in the concentrate.

    d. Number of gallons of other materials in the drum of concentrate.

2. A 50 gallon barrel of semi-synthetic MWF concentrate contains 30% severely refined lubricant-based oil and 25% other materials like additives, etc.

    a. Determine what percent of the concentrate is water.

    b. How many gallons of water are contained in the 50 gallon barrel of concentrate?

Hand and Power Tool Safety 145

Many manufacturers are either using measurements in the metric system in their manufacturing processes or are in the process of converting their processes over to the metric system, since the metric system is used prominently world-wide. For this reason, it is becoming more important for employees to understand the conversion process between the U. S. Customary (English) measurements, and the metric system of measurements. One particular conversion to be proficient in is the conversion between inches and millimeters. Manufacturers use the following conversion factor:

1 inch (in) = 25.4 millimeters (mm)

To express one measurement as an equal measurement in another unit of measure that is necessary is a multiplication by a well-chosen fractional equivalent of one. The well-chosen fraction equal to one is derived from the conversion factor between the unit needing to be changed and the desired unit. When the original measurement is multiplied by the fraction equal to one, the unwanted unit of measure will cancel and the desired unit will remain.

Example 1: Change 3/8 inch to millimeters.

1. The conversion factor between the inches and millimeters is 1 inch = 25.4 millimeters.

2. After changing 3/8 inch to 0.375 in, set up a multiplication by a fraction derived from the conversion factor in step 1 so that the inch cancels.

$$0.375 \text{ in} \times \frac{25.4 \text{ mm}}{1 \text{ in}}$$

3. Multiply across the top and bottom and then divide if necessary.

$$\frac{0.375 \text{ x } 25.4 \text{ mm}}{1} = 9.525 \text{ mm}$$

4. The desired result is 9.525 mm.

Example 2: The dimension on a blueprint reads 80 millimeters. Change this dimension to the nearest thousandth of an inch.

1. The conversion factor between the millimeters and inches is 1 inch = 25.4 millimeters.

2. Set up the multiplication of the original unit by the conversion fraction so that the millimeters will cancel.

$$80 \text{ mm X } \frac{1 \text{ in}}{25.4 \text{ mm}}$$

3. Multiply across the top and bottom and then divide if necessary.

$$\frac{80 \times 1 \text{ in}}{25.4} = 3.1496 \text{ in}$$

4. The desired result rounded to the nearest thousandth is 3.150 in.

EXERCISES:

1. When fasteners are applied with a hand or power tool, such as a powder tool, OSHA regulations state that the fastener must be a certain distance from the edge of the material. If the material is brick or concrete, the fastener must not be more than 3 inches from an unsupported edge or corner. If the material is steel, the fastener must be at least ½ inch from an unsupported corner edge.

   Convert both of these OSHA standards into millimeters.

2. a. When working with steel, a fastener is driven 11 mm from an unsupported corner. Would this meet OSHA regulations?

   b. Would OSHA regulations be met if a fastener is driven 15 mm from an unsupported edge on a piece of steel?

Lifting and Moving Equipment 130

Block and Tackles

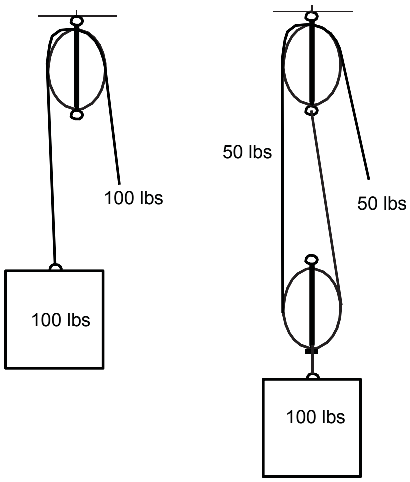


Image illustrated by author

A block and tackle is an arrangement of ropes and pulleys that works by substituting distance for force. The more distance, the less force. In the first drawing, we lift a 100 lb. weight with a single pulley, requiring 100 lbs. of pull on the rope. By doubling the rope length and adding a second pulley, in the second illustration, I have cut in 1/2 the pull needed to lift the weight. The ceiling supports the upper pulley and ½ of the weight. It's a force-distance trade-off. You must pull the rope twice as far!

We can continue to add pulleys and more rope to gain additional lifting advantage. Look up at crane. How does it lift that much weight? Notice the block and tackle at the end of the crane and then trace back and notice the rigging.

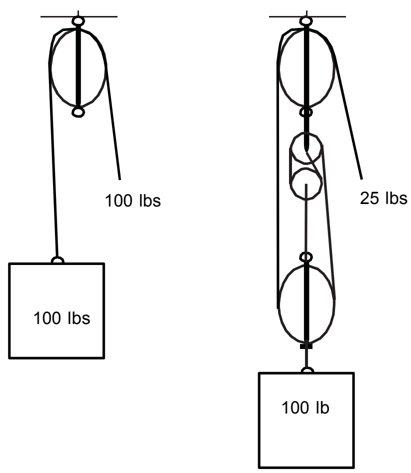


Image illustrated by author

This can be expressed mathematically as $\mathbf{n} = \mathbf{F_b} / \mathbf{F_a}$

where F_a is the haul (pull) and F_b is the load and n is the number of rope sections.

Block and tackle arrangements you will commonly see with their values for n are:

- Gun Tackle: 2
- Luff Tackle: 3
- Double Tackle: 4
- Gyn Tackle: 5
- Threefold purchase: 6

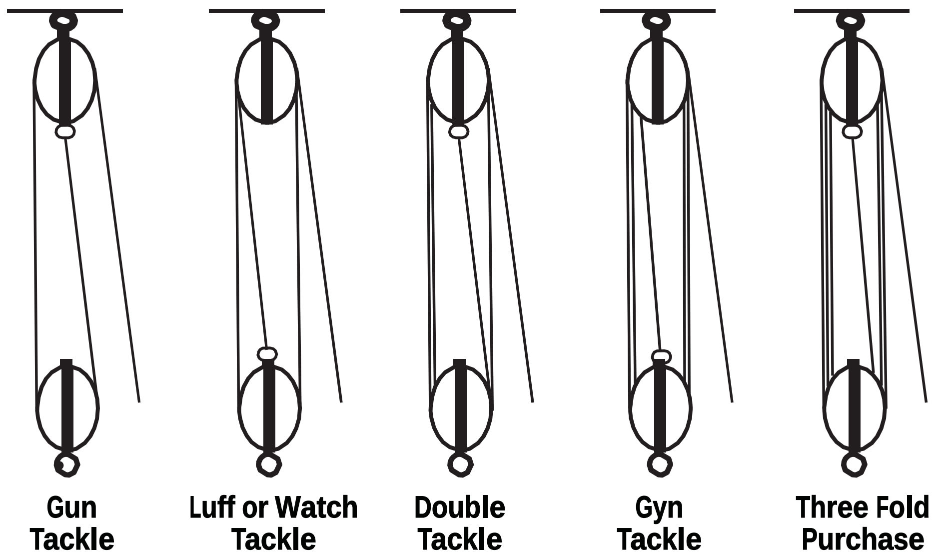


Image illustrated by author

Assume I can comfortably haul (pull) 50 lbs. I have a 250 bale of hay to lift. Which block and tackle is the simplest solution?

We need to move a piece of equipment weighing 2500 lbs. I have a double block and tackle and plenty of rope. How many workers need to pull if I want each to exert no more than 50 lbs.?

Suppose I was designing an overhead crane to do various jobs in the facility. What factors would I need to consider in this design?

Safety for Lifting Devices 135

To ensure compliance with OSHA standards, lifting devices must have a rated load test to check lifting capacity. The test loads must exceed 125% of the rated load.

To work a percent problem, it is best to identify the three parts associated with every percent problem so the known values can be substituted into the general percent formula.

Amount = Rate x Base

A = R x B

The base (B) is the whole or original amount the problem is based on. For test load problems, the base is the rated load of the lifting device.

The rate (R) is part of the base in percent form. The percent form must be changed to a decimal before being substituted into the formula.

The amount (A) is the numerical part of the base that the rate also represents. For test load problems, the amount is the test load.

EXAMPLE 1:

A portable hoist has a rated lifting capacity of 500 pounds. When a load test is performed, the test load must exceed 125% of the rated lifting capacity. What must be achieved for the hoist to meet OSHA standards?

SOLUTION:

Base (B) = 500 lbs

Rate (R) = 125%

First, change the 125% to a decimal value. Since percent (%) means "parts per hundred," the rate of 125% must be divided by 100 which moves the decimal point two places to the left.

$$125\% = \frac{125}{100} = 1.25$$

Now substitute the known values into the percent formula

Amount = Rate x Base

$A = R \times B$

$A = 1.25 \times 500$ lbs

$A = 625$ lbs

A test load must exceed 625 pounds.

EXAMPLE 2:

A hoist with a rated load capacity of one ton (2000 pounds) is tested. The test load is 2400 pounds. Did the hoist exceed the 125% OSHA standard?

SOLUTION:

Base (B) = 2000 lbs

Amount (A) = 2400 lbs

Amount = Rate x Base

A = R x B

2400 lbs = R x 2000 lbs

To solve for the unknown rate (R), each side of the equation must be divided by 2000 lbs.

$$R = \frac{2400 \text{ lbs}}{2000 \text{ lbs}} = 1.2$$

To change the decimal form of the rate back to a percent, multiply by 100.

R = 1.2 x 100 = 120%

120% does not exceed the 125% OSHA standard.

EXERCISES:

1. A hoist has a 2 ton rated lifting capacity. If a load test is performed, what load must be exceeded for the hoist to meet the 125% OSHA standard?

2. A portable hoist has a rated load capacity of 300 pounds and achieves a test load of 385 pounds. Did it meet the OSHA standard?

3. A load test was performed on a hoist. A test load of 1875 pounds is 125% of the rated load capacity. How much is the rated load of the hoist?

Intro to Machine Rigging 110: Hydraulic Jack

A hydraulic jack is a tool for lifting large or heavy objects. A piston at the source forces an incompressible fluid through a cylinder to the load piston in order to lift a load (see diagram). Because a much heavier load can be lifted than the force applied at the source, the hydraulic jack has a mechanical advantage.

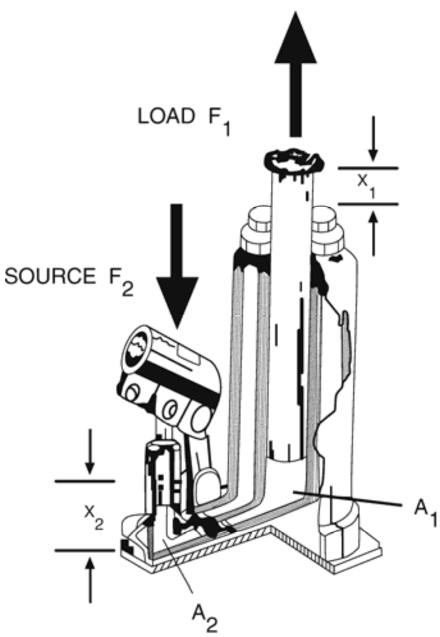


Image Supplied by CORD Communications, Inc.

The mechanical advantage of a hydraulic jack can be calculated with the following formula.

$$M = \frac{A_1}{A_2}$$

where M = mechanical advantage

A_1 = cross-sectional area of piston on the load side

A_2 = cross-sectional area of piston on the source side

Because the pistons have a circular cross-sectional area, the area of the pistons can be calculated with the following formula.

Area of circle (A) = πr^2

where $\pi \approx 3.14$

r = radius of the circle

The cross-sectional areas of the pistons are also proportional to the forces at the source and load.

$$\frac{A_1}{A_2} = \frac{F_1}{F_2}$$

where F_1 = force or weight of load or lifting capacity of jack
F_2 = force applied at the source

Knowing the weight of the load or the lifting capacity, and the cross-sectional areas, the force needed at the source can be calculated.

EXAMPLE:

A 12 ton hydraulic bottle jack has a source piston 3/8 inch in diameter and a load piston with a diameter of 1-1/2 inches.

a. Determine the mechanical advantage of this jack.

b. Determine the force needed on the source piston if the jack is required to lift a load of 3 ton.

SOLUTION:

a. Area of source piston $(A_2) = \pi r_2^2$

$$r_2 = \frac{\text{diameter of source piston}}{2} = \frac{3/8}{2} = \frac{.375 \text{ in}}{2} = .1875 \text{ in}$$

$$A_2 = (3.14)(.1875 \text{ in})^2 \approx .11 \text{ in}^2$$

Area of load piston $(A_1) = \pi r_1^2$

$$r_1 = \frac{\text{diameter of load piston}}{2} = \frac{1\frac{1}{2}}{2} = \frac{1.5 \text{ in}}{2} = .75 \text{ in}$$

$$A_1 = (3.14)(.75 \text{ in})^2 \approx 1.77 \text{ in}^2$$

$$\text{Mechanical advantage (M)} = \frac{A_1}{A_2} = \frac{1.77 \text{ in}^2}{.11 \text{ in}^2} \approx 16$$

The mechanical advantage of 16 means that the force applied on the source piston is multiplied by a factor of 16 on the load piston. Whatever force is applied at the source is 16 times larger on the load side.

b. Area of load piston = A_1 = 1.77 in^2

Area of source piston = A_2 = .11 in^2

Force of load = F_1 = 3 ton = 3 x 2000.0 lbs = 6000.0 lbs

$$\frac{A_1}{A_2} = \frac{F_1}{F_2} \qquad \frac{1.77\ \text{in}^2}{.11\ \text{in}^2} = \frac{6000\ \text{lbs}}{F_2}$$

The easiest way to solve a proportion is to diagonally cross-multiply across the equal sign.

(1.77 in^2)(F_2) = (.11 in^2)(6000 lbs)

(1.77 in^2)(F_2) = 660 in^2-lbs

To solve for F_2 , divide out the 1.77 in^2.

$$F_2 = \frac{600\ \text{in}^2\ \text{lbs}}{1.77\ \text{in}^2} = 372.9\ \text{lbs}$$

Approximately 372.9 lbs of force is needed on the input piston to be able to lift a load of 3 ton or 6000 lbs.

EXERCISES:

1. A hydraulic lift has a load piston 9 inches in diameter and a source piston 1 inch in diameter.

   a. Determine the mechanical advantage for the lift and explain what it means.

   b. Determine the force required on the source piston if a 5000.0 lb load is lifted.

c. Referring to part b, if the cross-sectional areas of the pistons and the forces on the pistons are proportional, that means that as the area increases, the force ____________________________, and as the area decreases, the force_______________________.

2. A 20 ton hydraulic bottle jack has a source piston with a 1/2 inch diameter and a load piston with a 2 inch diameter.

   a. Determine the mechanical advantage of the jack.

   b. If a person is able to apply 200 lbs of force on the source piston, how many pounds of load can be lifted?

Intro to Machine Rigging 110: Load Calculation

The most important part of rigging is calculating the weight of the load that has to be moved. To calculate the weight, two things must be known, 1) the type of material to be moved and its weight per cubic foot, and 2) the volume of the load in cubic feet.

Based on the type of material to be moved, the weight per cubic foot of the material can be calculated using the table of values shown from ToolingU-SME Intro to Machine Rigging 110 or any available handbook of standard weights.

Weights (1sq. ft. x 1in.)	
Steel:	40.6lbs
Iron:	37.5lbs
Aluminum:	13.3lbs
Pine lumber:	2.5 – 3.6lbs

According to the table, square foot of iron that is 1 inch thick weighs 37.5 lbs. To determine the weight for 1 cubic foot of iron, a square foot of iron must be 12 inches thick. Therefore, the weight of 1 square foot of iron that is 1 inch thick must be multiplied by 12 to represent a thickness of 12 inches.

$$\text{Weight of 1 cubic foot of iron} = 37.5 \text{ lbs.} \times 12 = 450 \text{ lbs.}$$

To find the volume of the load moved, substitute the length, width, and height of the load into the formula for the volume of a rectangular solid.

$$\text{Volume} = \text{length} \times \text{width} \times \text{height}$$

$$V = lwh$$

For example, a 4 ft. x 8 ft. sheet of iron 1/2″ thick would have the following volume in cubic feet.

width = 4 ft.

length =8 ft.

height (thickness) $= \frac{1}{2}\text{ in} = \frac{1}{2}\text{ in x } \frac{1\text{ ft}}{12\text{ in}} = \frac{1}{24}\text{ ft}$

$$V = \text{lwh} = (8\text{ ft})(4\text{ ft})\left(\frac{1}{24}\text{ ft}\right) = 1\frac{1}{3}\text{ ft}^3 \approx 1.33\text{ ft}^3$$

Knowing the weight per cubic foot of the material moved, and the volume of material moved, the weight of the load can be determined.

Weight of load = weight per ft^3 x volume in ft^3

For the iron example:

Weight of load $= 450\ \frac{\text{lb}}{\text{ft}^3}$ x $1\frac{1}{3}\text{ ft}^3 = 600\text{ lbs}$

The weight of the 4 ft. x 8 ft. sheet of ½” thick iron is 600 lbs.

EXERCISES:

1. Using the table of weights provided, determine the weight of 1 cubic foot of aluminum.

2. Determine the weight of six sheets of steel measuring 4 ft. x 10 ft. x 1 in.

3. Determine how much heavier a load of 48 pine 2″ x 4″ studs are if they are 10 ft. long instead of 8 ft. in length. Use a weight of 3 lbs. for a 1 sq. ft. x 1 in. piece of pine lumber.

Introduction to Quality and Continuous Improvement

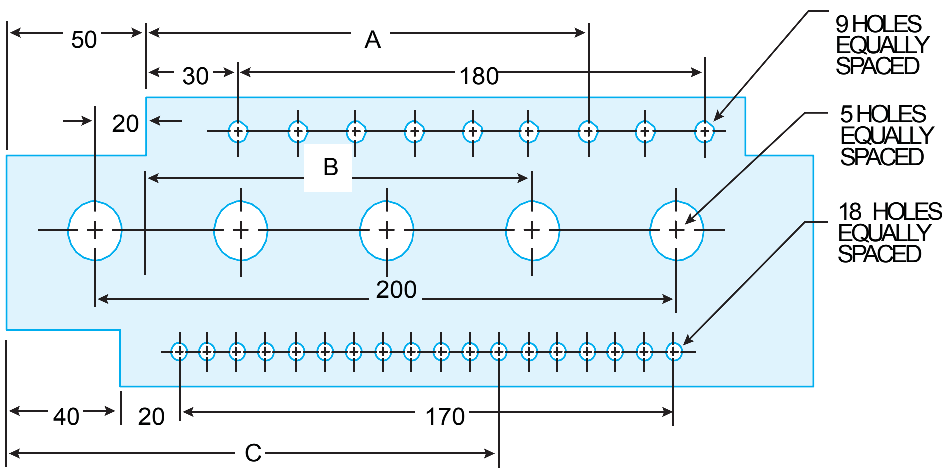
Doug Holt, Shanelle Grudzinski, and Dave Hamilton

Blue Print Reading 130

It’s a matter of presentation. Which is more interesting?

(160/8) * 6 + 30 (200/4) * 2 + 30 (170/17) * 11 + 20 + 40

or

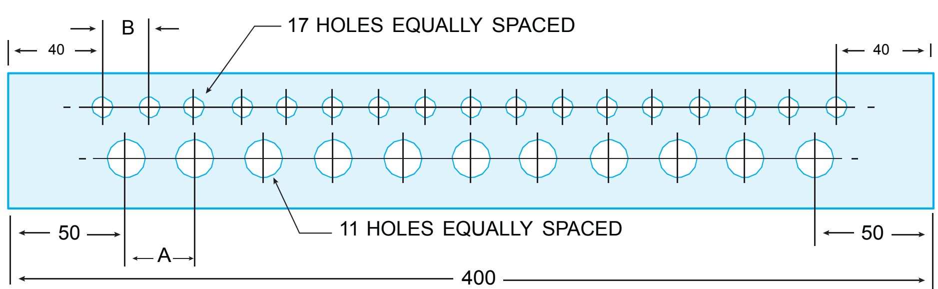


Note: Images from Smith, R. & Peterson, J. C. (2007). *Introductory Technical Mathematics (5e) p. 27*

Find, in millimeters, dimension A

Find, in millimeters, dimension B

Find, in millimeters, dimension C



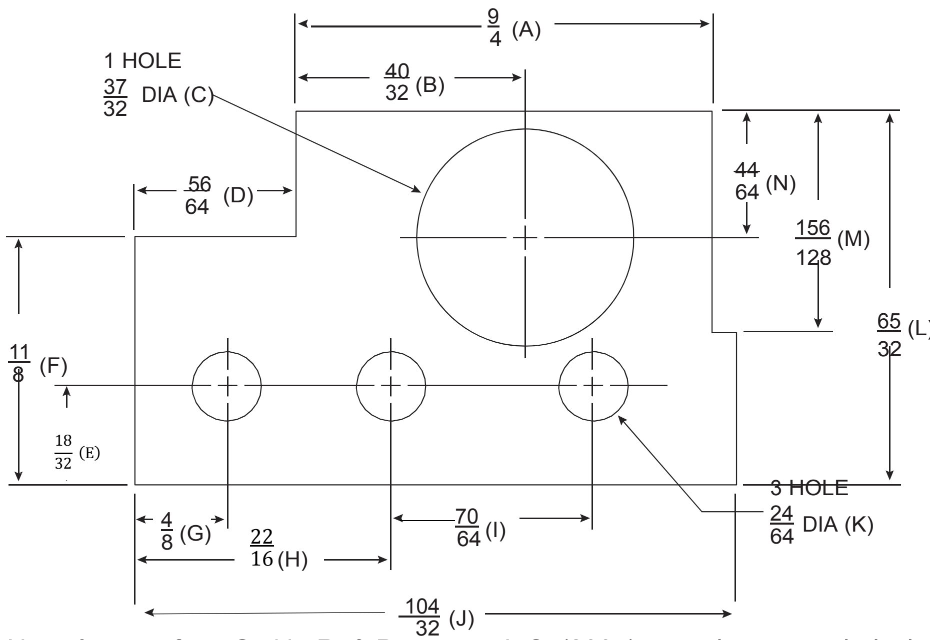
Note: Images from Smith, R. & Peterson, J. C. (2007). *Introductory Technical Mathematics (5e) p. 18*

Can you go the other way? Find A and B as an expression, make sure you use the parenthesis correctly.

A =

B =

In this next exercise the fractions are all recorded as improper numbers. Reduce to mixed numbers with proper fractions.



Note: Images from Smith, R. & Peterson, J. C. (2007). *Introductory Technical Mathematics (5e) p. 39*

A =

B =

C =

D =

E =

F =

G =

H =

I =

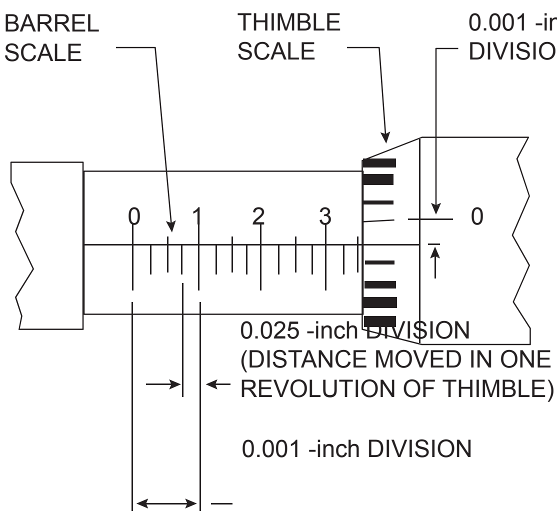
J =

K =

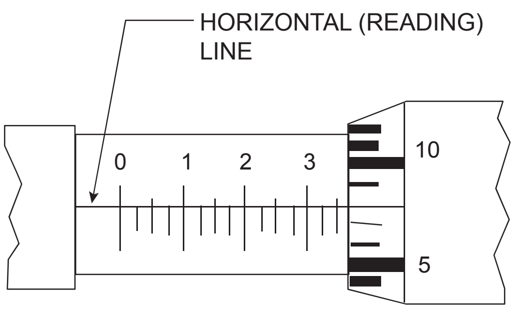
L =

M =

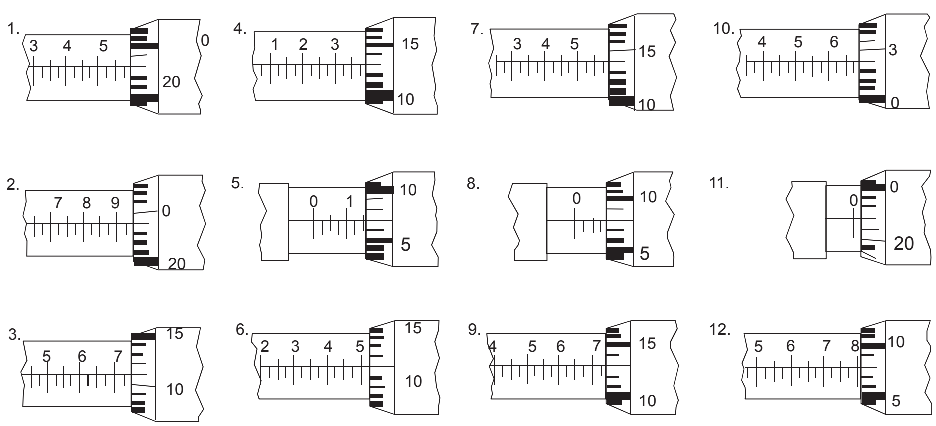
N =



Reading a micrometer



I read this as: 0.300″ + 0.050′ + 0.008″ = 0.358″. Can you see where I found each of these from the diagram?



Note: Micrometer images from Smith, R. & Peterson, J. C. (2007). *Introductory Technical Mathematics (5e) pp, 282-283*

Math Fundamentals 100

You've taken a series of hourly measurements on a manufacturing process. The rule at work is to recalibrate if during your shift the process measured results in a measurement more than 1 SD from the mean. Did it do this during your shift? You will need a calculator for this one!

1. Determine the range of 12, 15, 42, 37, 14, 9, 25, 27, 32 and 30
2. Determine the mean = total / n = 243 / 10 = 24.3
3. Variance $= \dfrac{\text{Sum of (measurement - mean)}^2}{\text{Number of measurements - 1}}$ or $\dfrac{n(\text{Sum of } x^2) - \text{Sum}(x)^2}{n(n-1)}$

Standard deviation is a measure of how spread out the numbers are from the mean

Step 1

x	x^2
12	144
15	225
42	1764
37	1369
14	196
9	81
25	625
27	729
32	1024
30	900
243	7057

Step 2 Variance $= \dfrac{10(7057) - 243^2}{10(10-1)}$

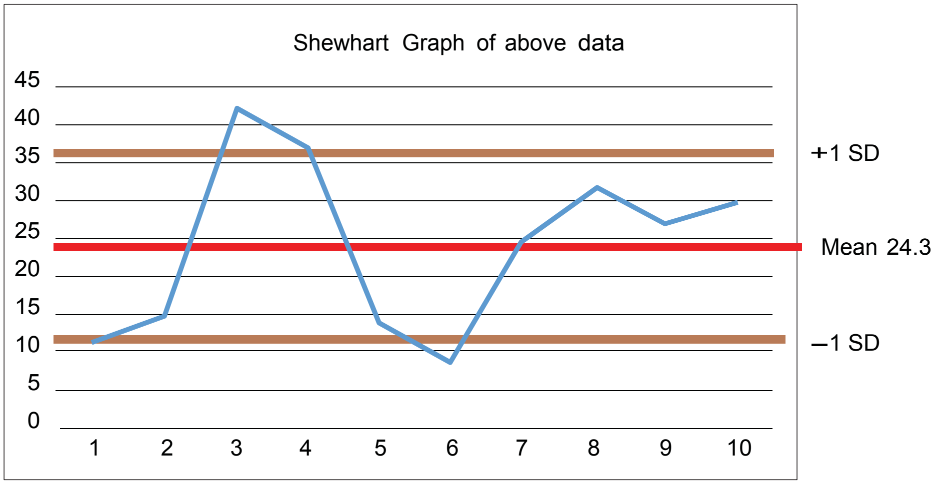
$= \dfrac{70{,}570 - 59049}{90}$

$= 128.011$

Step 3 Standard Deviation $= \sqrt{\text{Variance}}$

$= +/- \ 11.3$

Step 4: Return back to the Quality discussion. Maybe bring in a process control chart (Shewhart charts), have them plot the data around the mean and +/- 1 SD and determine at what data points the machine was out.



Graph illustrated by author

Notice, we used addition, subtraction, multiplication and division as well as throwing in a twist at the end. We did it in a way that students view the math as part of a skill needed in manufacturing work, not as just a math problem.

Your turn

1. Determine the range of 17, 21, 42, 37, 19, 29, 15, 29, 38 and 30

2. Determine the mean

3. Determine the Variance

4. Determine the Standard Deviation.

5. Plot your data on a Shewhart chart.

Math Fundamentals 100: Time Cards

Complete the following Payroll

Bob Jones worked 40 hours at $13.50

Jill Smith worked 40 hours at $18.25

John Smith worked 42 hours at $18.25

Joe Powel worked 44 hours at $13.50

Sam Boss worked 50 hours at $25.00

Hours over 40 are paid at “time and a half”. The federal withholding rate for all is assumed to be 28% and the state withholding rate 5.7%. John, Sam and Joe have family health insurance so an additional $130 is taken from each per pay period. Social Security is withheld at 6.2%, Medicare at 1.45%

Complete this chart

Payroll For Second Period of March, 2014									
	hours	rate	gross pay	Fed With	State With	SS With	Medi With	Health Ins	Take Home
Bob Jones									
Jill Smith									
John Smith									
Joe Powel									
Sam Boss									

Math: Fractions and Decimals 105

Many students face fractions with trepidation; “they’re too hard, I don’t understand”. If this is you, there is no better tool to bring yourself back up to speed than a tape measure. A tape measure is a number line: addition is moving forward, subtraction is moving back. Get a tape measure and we’ll look at it together.

Look at how an inch is divided up. The one pictured has the inch divided in 16 pieces.

Understand what 1/16 is. 1/16 (one-sixteenth) of an inch is usually the smallest measurement on a tape measure. The distance between every line on the tape measure is 1/16 of an inch.

Understand what 1/8 is. 1/8 (one-eighth) of an inch is twice as big as 1/16 of an inch. It is every other mark. Notice we have dotted every other one. 1/8 is twice as big as 1/16.

Understand what 1/4 is. 1/4 (one-quarter) of an inch is twice as big a 1/8 of an inch. It is every fourth mark. Also note 1/4 is 4 times as big as 1/16.

Understand what 1/2 is.

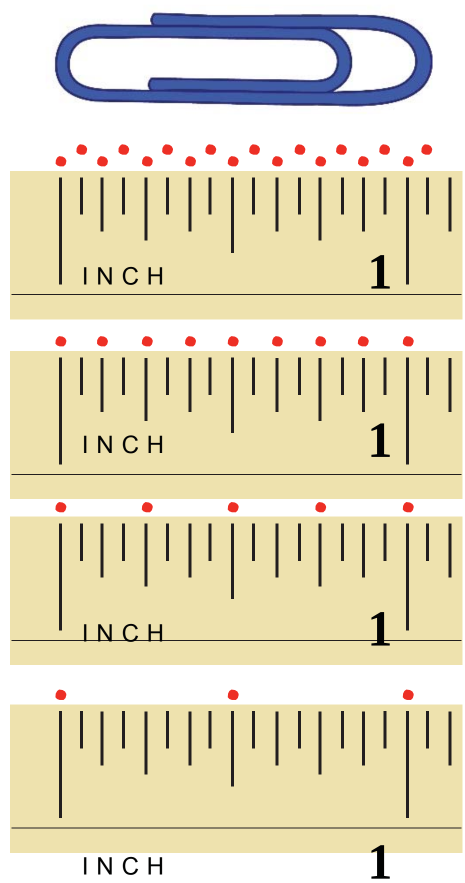


Image supplied by dreamstime.com or http://www.dreamstime.com/ and edited by author

1/2 (one-half) of an inch is twice as big as 1/4. It is four times as big as 1/8 and eight times as big as 1/16.

Understand what an inch is. The large markings on the tape measure are inches. They are numbered to proceed (from the left) the mark. An inch is twice as big as 1/2, 4 times as big as 1/4, 8 times as big as an 1/8, and 16 times as big as 1/16. Do you see the pattern?

Equivalent fractions

8/16 = 4/8 = 2/4 = 1/2

Try it

Image supplied by author

1″ = ___/2 = ___/4 = ___/8 = ___/16

3/4″ = 6/___ = 12/___

Adding and Subtracting

The picture describes simple addition. Where the numbers cross over, the end of the tape provides the answer.

For example: 43 + 5 = end of tape 48.

44 + 4 = end of tape 48. 45 + 3 = end of tape 48 and so on.

This is actually a very common practice. You nail boards together, weld pieces and are asked "how long is the result of your work?"

But everything you measure won't be exact to the inch in length. Pick up anything. Most likely if you read the tape as closely as you can, you will end up with a fraction.

Warning: Do not permanently bend the tape measure by bending too sharply.

Try something a little more challenging: 39-5/8 + 6-9/16 = 46-3/16. Play with this technique in subtraction. You can become quite proficient in a short while.

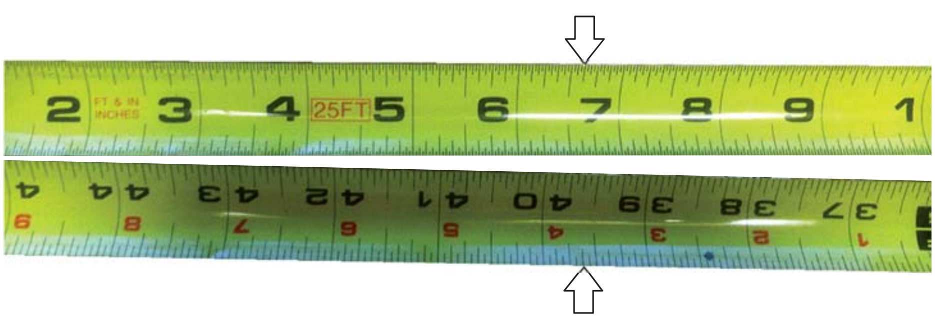


Image supplied by author

Within the inch: 3/8 + 3/8 = 6/8 or 3/4, right? Use 60″ as the starting point. Go to 60-3/8. Put the lower tape on any start point. We’re using 13 in this photo. Go over 3/8 towards the 12, now ‘cross’ to the top for the answer: 3/4. No long hand needed when you are familiar with a tape.

Going back to the idea of 60″ as the starting point, having a number line handy makes introduction of negative numbers easy. What if we just call 60” as Zero? Move right from 60 to add and move left to subtract.

Going back to the idea of 60″ as the starting point, having a number line handy makes introduction of negative numbers easy. What if we just call 60″ as Zero? Move right from 60 to add, move left to subtract.

The tape measure will also allow you to introduce mixed numbers quickly into the classroom and also to frame the discussion of adding unlike fractions and equivalent fractions.

How to begin? **Get a pile of scraps** of anything lying about, such as 2 x 4 pieces of iron. Label them A, B, C, D etc. and measure several times until you get a consistent answer every time. Try to guess lengths before you measure. You should be able to guess down to 1″ and measure with precision and agreement down to 1/16″.

Image supplied by author

Now take your pieces and answer.

What is A + C?

What is D – A?

Addition with a Tape:

To add with a tape, we mark the first number, move our tape to that mark and measure off the second number in the same direction. Addition, when we have only feet, inches, or fractions, is just addition. It becomes much more interesting when we are measuring and end with a mixed number which could be in feet, inches and a fraction. Handle the parts separately beginning with the largest unit. You may need to clean up the answer. Example:

```
   5´ 6˝
+  9´ 3˝
 -------
  14´ 9˝
```

Simple enough, but what happens when you have more inches than there are in a foot?

```
    5´ 6˝
+   9´ 11˝
 ---------
   14´ 17˝
```

In this case, we need to carry across the units to convert the answer from 14´ 17˝ to 15’ 5˝. The same thing can happen with a fraction.

```
    3´ 7-1/2˝
+   2´ 5-3/4˝
 ------------
    5´ 12-5/4˝
```

This answer would convert to: 6´ 1-1/4˝

Carry and Borrow

When we first learned to add, we learned about units: ones, tens, hundreds, thousands, and so forth.

In arithmetic, whenever we have a sum greater than 9 in any column, we will need to carry over into the next column. Example:

$$\begin{array}{r} 17 \\ +\ 14 \\ \hline =\ 31 \end{array}$$

In order to get the answer (31), we had to carry the one after we added 7 + 4. The sum from the "ones" column added up to 11. We leave the 1 from the "ones" column and carry the 1 from the "tens" column over. We then have three 1s in the "tens" column which adds up to 3.

When using a tape measure, this comes up often. 12˝ = 1´, so 13˝ is the same as 1´ 1˝.

A fraction of an inch works the same way.

8/16 + 9/16 = 17/16, which is the same as 1-1/16˝

When the fractions do not share the same denominators (the bottom number in the fraction), we make the problem easier if we convert them to have a common denominator.

EXAMPLE:

Add 1/2 and 1/4. First convert 1/2 to share a common denominator with 1/4. 1/2 = 2/4, so simply add 2/4 and ¼ to get 3/4.

Subtraction with a Tape

Now we are ready to look at subtraction with the tape measure. Subtraction is the opposite of addition, moving left on the number line (tape measure). Mark off the first value and move the tape to this mark.

When you subtract you measure back to where you started.

EXAMPLE:

40-3/16 - 8-1/16 = 32-2/16 or 32-1/8

32-1/8 - 8-1/8 = 24″

Try it

$$\begin{array}{r} 12 \\ \underline{-\ 3\ 1/8} \end{array}$$

This is the same as if we had written:

$$\begin{array}{r} 11\text{-}8/8 \\ \underline{-\ 3\ 1/8} \end{array}$$

Solve the fraction first: 8/8 – 1/8 = 7/8

Then, complete the problem by subtracting the whole numbers: 11 - 3 = 8

The answer is 8-7/8.

Just as in addition, sometimes the problem is mixed. To make it easier, we need to rewrite it using easier terms like this:

$$\begin{array}{r} 35\text{-}1/4 \\ \underline{-\ \ 27\text{-}1/8} \end{array}$$

Remember to use a common denominator for addition and subtraction. The problem can be rewritten like this:

$$\begin{array}{r} 35\text{-}2/8 \\ \underline{-\ 27\text{-}1/8} \\ 8\text{-}1/8 \end{array}$$

Multiply with the Tape

You are asked for three boards measuring 3´ 2˝ each. How many board feet are needed? Use the tape to repeatedly add by marking off the first, moving the tape to the mark and marking off the second, and then move the tape to the second mark and measure the third 3´ 2˝. You may see this as time consuming. Is there a better way? Handle the feet first, then the inches, then the overflow.

3´ 2˝ x 3

3´ 2˝ + 3´ 2˝ + 3´ 2˝ = 9´ 6˝

3´ 8˝ x 3 = 9´ 24˝ = 11´

What about multiplying with a fraction?

What is 1/2 of 12˝? 1/2 of 10˝? 1/2 of 13˝?

What is 1/2 of 1/2˝? 1/2 of 1/4˝? 1/2 of 1/8˝? Do you see the pattern?

What is 1/2 of 4˝?

Is this division or multiplication? How are they similar? Dividing by 2 is the same as multiplying by ½. Dividing by 5 is the same as ________________?

What is 1/2 of 4´ 10˝? 1/2 of 6´ 6˝?

Measure a 2 x 4. How much would be 1/4 of it?

What about a mixed problem?

4-1/8 x 12-1/4 = (4-1/8 x 12) + (4-1/8 x 1/4)

Hint: Remember to borrow what you need.

Division with a Tape

What is 1/2 of 1/8?

How many boards, each 3´ 3˝, can I cut from an 8´ board? From a 10´ board?

How many quarters are in an inch?

How many eighths are in an inch?

How many eighths are in two inches?

Looking at your measuring tape, this is easy.

Division is the opposite of multiplication.

Always invert the second number.

Works with whole numbers as well $8 \div 5 = 8 \div \frac{5}{1} = 8 \text{ x } \frac{1}{5}$

What is 1/2 of 8/8? 8/16.

What is 1/2 of 16/16? 16/32.

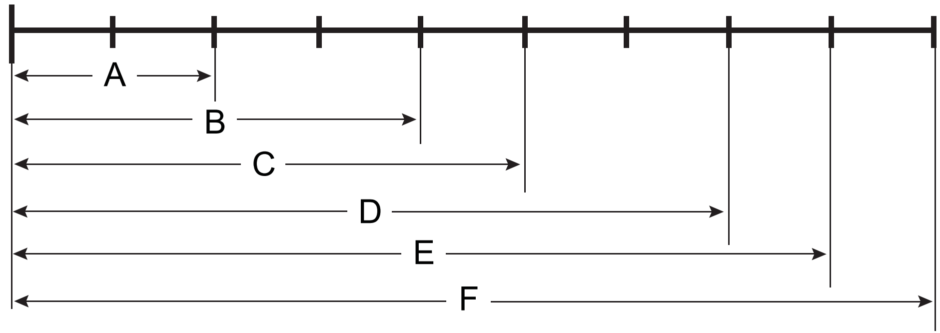
Remember: 1/2 is the same as 2/4 is the same as 4/8 is the same as 8/16 is the same as 16/32.

Idea for thought: Some may ask what about all the other fractions, like 12/61 and 7/53, etc? What if your students knew just whole inches, halves, quarters, eighths, sixteenths and 32nds and 64ths real well?

Try these (with or without your tape):

3-5/16˝ + 2-3/16˝ = ________convert________
3-5/16˝ - 2-3/16˝ = ________convert________
5-1/8˝ + 3-7/8˝ + 4-3/8˝ = ________convert________

Now do this with a number line. It's not a ruler, so no dimensions.



What fractional piece of the total line is each?

A =

B =

C =

D =

E =

F =

Math Units of Measure 115

The United States is the only major country that has not converted to the metric system (the only other two nations which have not switched are Liberia and Burma).

There are two measuring systems used in the United States and internationally. For the most part, we use the English system in the United States. However, much of the rest of the world uses the metric system. Here are a few of the standard measurements used in the English system:

Base Length	Volume	Mass	Temperature
12″ = 1 foot	2 cups = 1 pint	16 oz = 1 lb	Water freezes at 32° F
3′ = 1 yard	2 pints = 1 quart	2000 lb = 1 ton	
5280′ = 1 mile	4 quarts = 1 gallon		F = Fahrenheit

Working with tools, you may have found that most things are made somewhere else. The metric system of wrenches is used on all bicycles and many cars. The wrench system at the left comes in sizes 10 through 18 millimeters. An SAE or English wrench set would come in the sizes we have studied: 3/16, 1/8, 1/4, 5/16, 3/8, 1/4, 9/16, 5/8, 11/16 and 3/4 of an inch. Only four metric sizes can be interchanged with English sizes.

Note. Bing Images New Holland Wrench Set

Metric	SAE	To convert multiply the SAE size by 25.4
8	5/16 in	
11	7/16 in	(1/2 x 25.4 = 12.7 which will slip)
12	15/32 in	(1/4 x 25.4 = 6.35 which will slip)
15	19/32 in	(3/4 x 19.05 will work, pretty well)

Can you see how the metric system is easier? Using the wrong set will strip the head of the bolt.

Convert:

SAE		Metric
3/16	=	______
3/4	=	______
_____	=	18
_____	=	9
1 1/2	=	______
3	=	______
_____	=	50
_____	=	130

The metric system is easier to understand than English units. It is based on the number 10, and it uses prefixes to annotate size in 10s (similar to how we count pennies and dollars. The metric system actually better matches our system of numbers (Arabic).

Prefixes:			
One thousandth = milli		1000x = kilo	
One hundredth = centi		100x= hecta	
One tenth = deci		Ten times = deca	
Base Length	**Volume**	**Mass**	**Temperature**
Meter	liter	gram	Water freezes at 0° C
			C = Centigrade

Thus, 1000 meters is a kilometer (0.6 miles) .001 meters is millimeter

10 liters is a deciliter .01 liter is centiliter

100 grams = hectogram .1 gram is decigram

From working with computers, you may be familiar with larger scales of the metric system: Kilobyte (10^3), megabyte (10^6), gigabyte (10^9) and terabyte (10^{12}).

In the metric system, the base units stay the same. This is improved over the English system in which we have inches, feet, cubits, yards, fathoms, rods, chains, furlongs, miles, nautical miles, and leagues.

The Metric System Length

1 in. = 2.54 cm.

39 inches = 1 meter

1 mile = 1.67 km

Volume

1 quart = .95 liters

1 gallon = 3.79 liters

Mass

1 pound = .45 kg

Temperature

F°= (C° * 1.8) + 32°

C° = (F° - 32°) ÷ 1.8

1. Which prefix is the smallest?
   a. centi
   b. hecto
   c. kilo
   d milli
2. A woman has a body mass of 53 kg. What is her mass in grams?
   a. 0.053
   b. 5.3
   c. 53
   d. 53,000
3. In the English system, the base unit of length is the
   a. foot.
   b. liter.
   c. meter.
   d. mile.
4. In the metric system, the base unit of mass is the
   a. gram.
   b. liter.
   c. ounce.
   d. pound.
5. The liter is a unit of
   a. length.
   b. mass.
   c. temperature.
   d. volume.

6. What happens to a decimal place in the number when you are converting from a smaller metric unit to a larger unit?

   a. converting does not require a placement of decimal point

   b. decimal place does not move at all

   c. decimal place moves to the left

   d. decimal place moves to the right

7. A marathon race is 26.2 miles long. How long is that in km?

8. What number does 6.3×10^{11} represent?

   a. 0.000000000063

   b. 42

   c. 630,000,000,000

   d. 631011

9. What is the purpose of scientific notation?

   a. to complicate things

   b. to measure things

   c. to represent large numbers

   d. to approximate numbers

10. Why is the metric system used most commonly in science?

   a. It can measure larger and smaller things than the English system.

   b. It has been around the longest.

   c. It is decimal based and therefore easier to convert units.

   d. It is more accurate than the English system.

11. The metric was developed

 a. because the English system was not very accurate.

 b. in order to standardize units of measurement.

 c. to help scientists calculate very large and small numbers.

 d. to help scientists convert numbers more easily.

12. Gas today in Switzerland is selling for $4.74 per liter. How much is that per gallon?

13. The shot put is a track event which determines how far an athlete can throw a 12lb steel ball, but when they compete in the Olympics, US athletes are given a 7.26-kg ball (the international standard). How much, in pounds, does this shot put weigh?

Basics of Tolerance 120

PRACTICE:

1. We want to install a fastener on an object that has been manufactured, and we want the latch to fit snuggly in the hole without have to force the fastener into place. In order to ensure the latch is positioned properly on the object, companies will use positional tolerance. A positional tolerance defines:

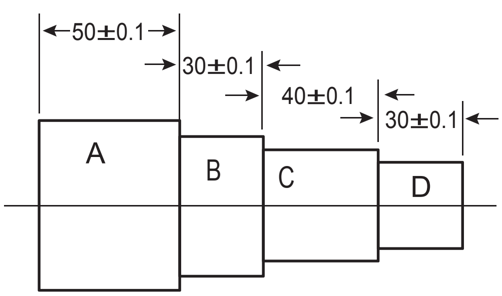
   a. A zone within which the center, axis, or center plane of a feature of size is permitted to vary from a true position.

   b. Desired position that may not be violated.

   c. A and B

   d. None of the above

2. Each section of the following telescoping pole must readily slide into the larger section. Using the following diagram, complete the table regarding the size and tolerance of each section of the pole.



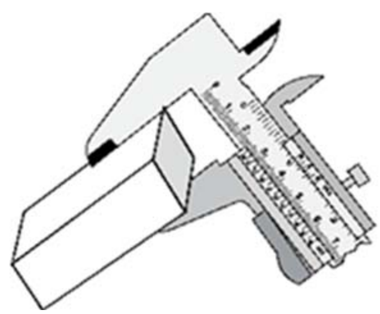
Box	Desired Values	Tolerance	Minimum Tolerance	Maximum Tolerance
A				
B				
C				
D				

3. Parts specification requirements are often identified on a specification sheet. Use the following table to answer questions *a–d* regarding the required measurements of the steel block.

Inspection Specification Sheet		
Characteristic	**Specification**	**Measurement Tool**
Weight	280-320 grams	Scale
Thickness	5.5 mm ± 0.5 mm	Calipers
Splits	No splits allowed	Visual Inspection
Length	14.5 mm ± 0.5 mm	Calipers
Width	10 mm ± 1.5 mm	Calipers
Date Code	Present and correct	Visual

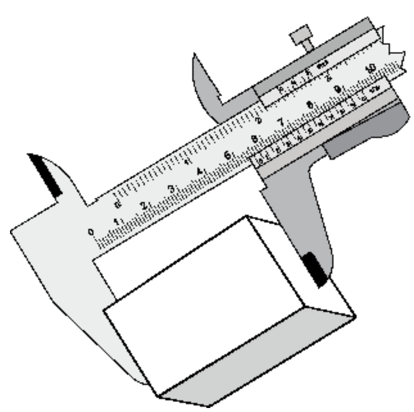
Decide whether each part pictured below meets the customer specifications in the chart by reading the caliper or scale measurements. Circle YES or NO.

a. Yes or No. Discuss your answer:



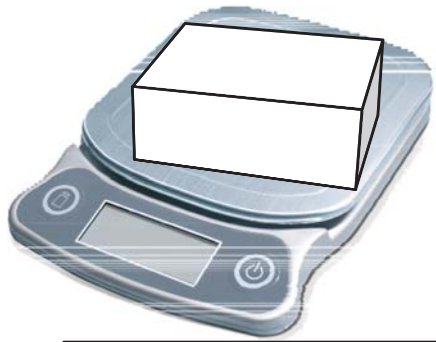
6.5 mm

b. Yes or No. Discuss your answer:



14 mm

c. Yes or No.   Discuss your answer:



Weight = 0.5 kg

Note: kilogram is 1000 times as heavy as a gram

d. Yes or No.   Discuss your answer:

Weight = 30 grams

Note: kilogram is 1000 times as heavy as a gram

Image Sources:

Telescoping Pole—Modified by S. Grudzinski using concepts presented by the following source: Braithwaite, A. (2011). Geometrical Tolerance. Retrieved from http://www.webpages.uidaho.edu/mindworks/machine_shop/general_shop_info/geometrical_tolerancing.ppt

Vernier Calipers—Modified by S. Grudzinski using image overlays from Mitutoyo. (n.d.). Vernier Calipers Series 520 – Standard Model. Retrieved from http://ecatalog.mitutoyo.com/Vernier-Calipers-Series-530-Standard-Model-C1401.aspx

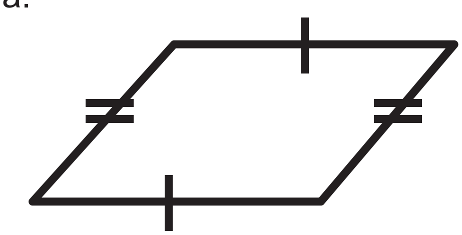
Scale—Modified by S. Grudzinski based upon scale image from Gourmande (n.d.). Gourmande in the Kitchen. Retrieved from http://gourmandeinthekitchen.com/2012/gift-ideas-under-fifty-dollars/

Shop Geometry Overview 170

Name:____
Date:____

1. You are asked to build a chair. To ensure the chair can be properly assembled, you need the front and back lengths to be equal and the left and right sides to be equal. By understanding the properties of the various shapes an individual can determine the necessary measurements needed to produce the proper parts. Identify each type of quadrilateral or polygon and describe the key characteristics.

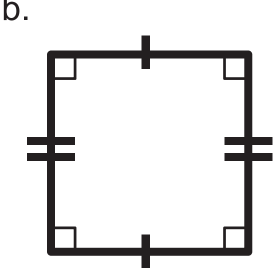
   a.

   Shape:___________________________________

   Key Characteristics:__________________________
   ____
   ____

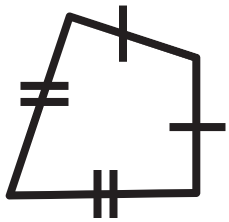
   b.

   Shape:___________________________________

   Key Characteristics:__________________________
   ____
   ____

c.



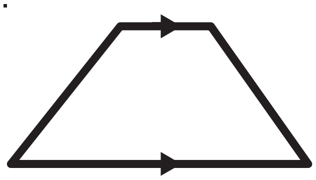
Shape:____

Key Characteristics:______________________________

____

____

d.



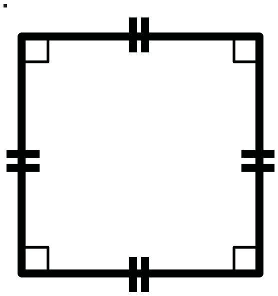
Shape:____

Key Characteristics:______________________________

____

____

e.



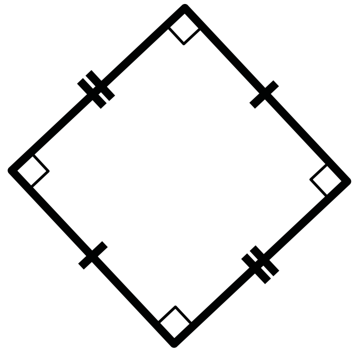
Shape:____

Key Characteristics:______________________________

____

____

f.



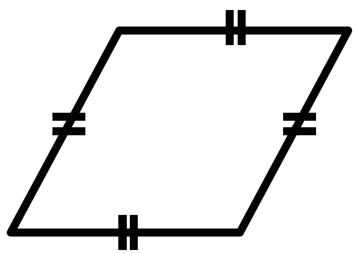
Shape:____________________________________

Key Characteristics:___________________________

____

____

g.



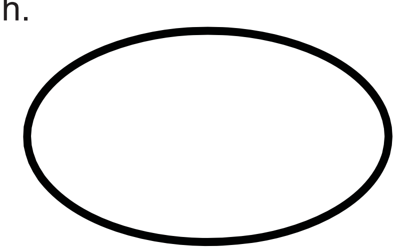
Shape:______________________________________

Key Characteristics:___________________________

____

____

h.



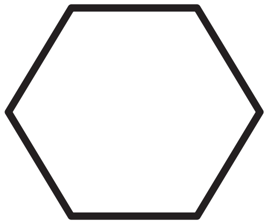
Shape:____________________________________

Key Characteristics:___________________________

____

____

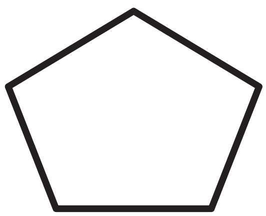
i.



Shape:

Key Characteristics:

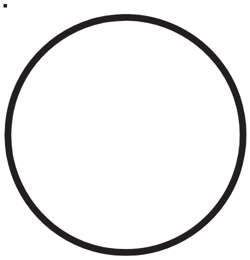
j.



Shape:

Key Characteristics:

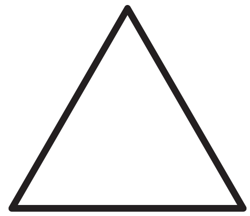
k.



Shape:

Key Characteristics:

I.



Shape:______________________________________

Key Characteristics:___________________________

____

____

Image Resource:

Images created by S. Grudzinski

Geometry: Lines and Angles 155

Name:_______________________________________

Date: _______________________________________

Everywhere you look in manufacturing you see lines and angles.



1. To better understand the terminology use in manufacturing, write the letter of the correct term beside each definition.

_______The point at which two lines intersect

_______A set of points in a straight path that extends infinitely in both directions.

_______Two lines that form a right angle at their point off intersection

_______Position in space, often represented by a dot

_______A finite portion of a line that has two endpoints

_______Three or more points that lie in the same line

_______A point that bisects a line segment

_______Lines in the same plane that never intersect

_______A portion of a line that extends from one endpoint infinitely in one direction

_______A flat surface that extend infinitely in all directions

_______Two rays that share an endpoint and extend in opposite directions of a line

A opposite rays

B point

C ray

D point of intersection

E linear

F midpoint

G parallel lines

H collinear points

I perpendicular lines

J line segment

K line

_______ Something that relates to or resembles a line

_______ Three or more points that lie in the same plane

_______ If three points are coplanar, then the line containing two of the points are in the same plane

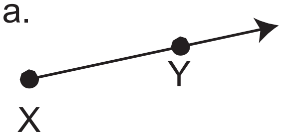
L plane

M coplanar points

N flat-plane rule

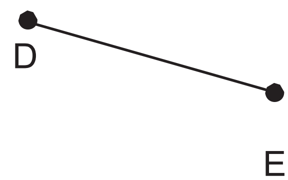
2. It is impossible to manufacture a part from a print diagram without understanding what that diagram is describing. Identify each point as a point, a line, a segment, or a ray.

a.



____

b.

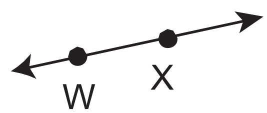


____

c.

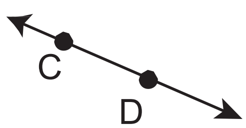
____

d.



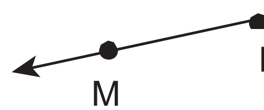
____

e.



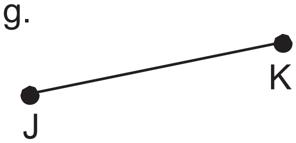
____

f.



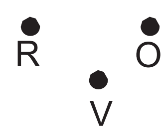
____

g.



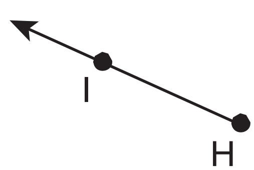
____

h.



____

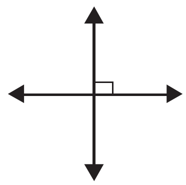
i.



____

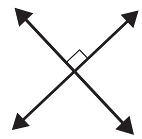
3. Identify each figure as parallel or perpendicular.

a.



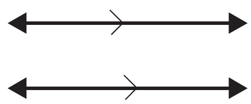
____

b.



____

c.



____

4. Draw and label of each of the following:

a. $\overleftrightarrow{AB}$

b. points C and D

c. $\overline{RS}$

d. points X, Y, Z

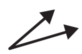
e. $\overrightarrow{DE}$

f. $\overleftrightarrow{JK}$

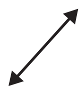
5. Much manufacturing requires the use of angles. Some of the materials such as angle iron, channels, and beams must be installed at specific angles to ensure stability and strength. Classify each angle as acute, obtuse, right, or straight. (You can verify your answer with a protractor)

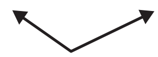
a.  ________

b.  ________

c.  ________

d.  ________

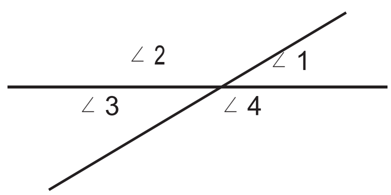
e.  ________

f.  ________

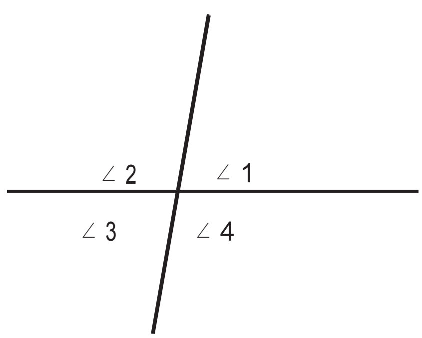
g.  ________

h.  ________

6. Find the missing vertical angle.



∠ 1 = 23.87°
∠ 2 = 156.13°
∠ 3 = ________
∠ 4 = ________



∠ 1 = 79.84°
∠ 2 = ________
∠ 3 = ________
∠ 4 = 100.16°

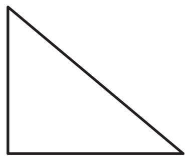
Image sources:

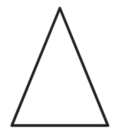
Picture 1—LeDuc & Dexter Inc. (2002). Dehlinger Windery-The Return of a Favorite Son. Retrieved from http://www.leducanddexterplumbing.com/news-sept2002.html
Picture 2—AASHTO. (n.d.). John Greenleaf Whittier Bridge. Retrieved from bridges.transportation.org or http://bridges.transportation.org/Pages/Massachusetts.aspx
Picture 3—Aston Service Dorset (n.d.). Cup Fitting Manifolds. Retrieved from astonservicedorset.com or http://www.astonservicedorset.com/

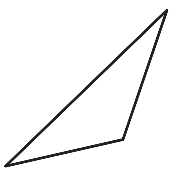
Line and angles were developed by S. Grudzinski

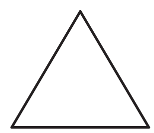
Geometry: Triangles 165

1. Identify the different types of triangles as: equilateral, isosceles, scalene, right triangles.

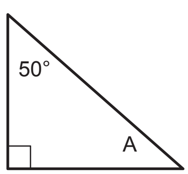
a. 

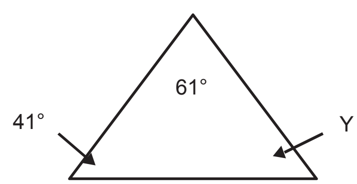
b. 

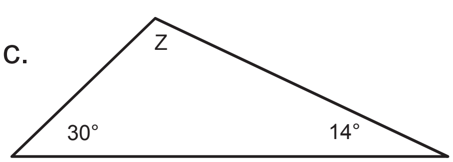
c. 

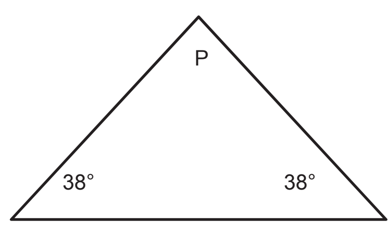
d. 

2. When machining parts if you know two angles you can determine the correct angle for the third. Solve for the given variable.

a. 

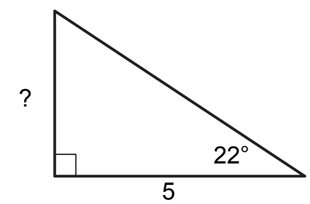
b. 

c. 

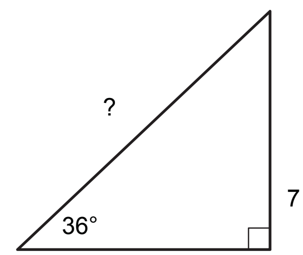
d. 

3. When machining parts involving right triangles, if an individual knows an angle and one side, the length of the remaining sides can be determined using basic calculations. Likewise, if an individual knows two sides of a triangle, they can determine the correct angle that needs to be formed using basic calculations. Find the unknown quantity of the following right triangles

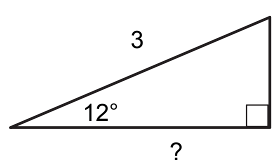
a.



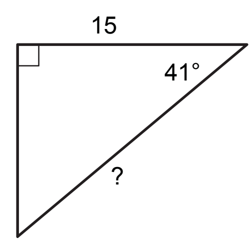
b.



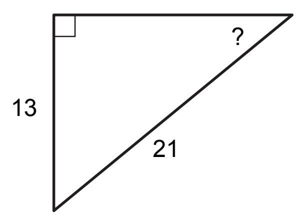
c.



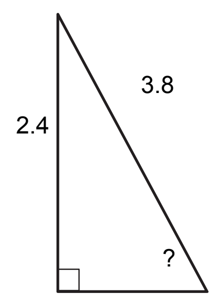
d.



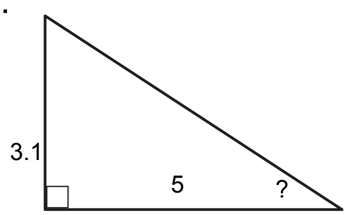
e.



f.

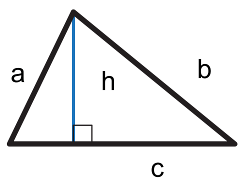


g.



4. Calculate the area and perimeter of the following triangles. Also identify the type of triangle.

a.



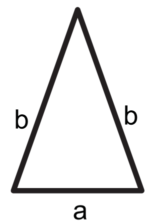
a = 5.78 cm
b = 8.33 cm
c = 9.0 cm
h = 5.3 cm

Area =__________________

Perimeter =______________

Type of triangle =_________

b.



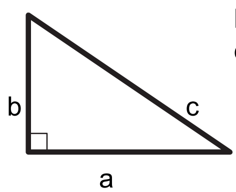
a = 4.1 in
b = 6.6 in

Area =__________________

Perimeter =______________

Type of triangle =_________

c.



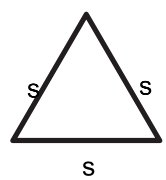
a = 8.5 cm
b = 5.9 cm
c = 10.35 cm

Area =__________________

Perimeter =______________

Type of triangle =_________

d.



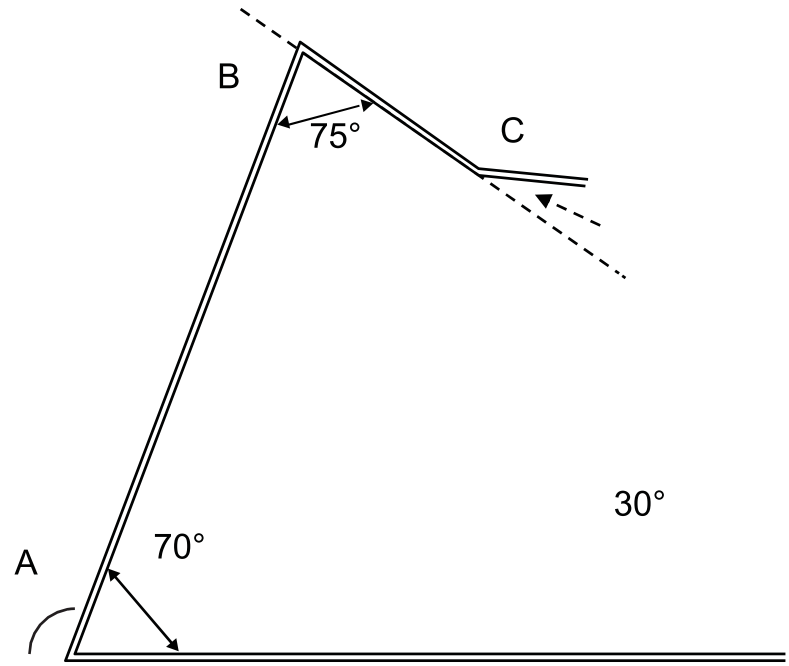
s = 5.3 inches

Area =__________________

Perimeter =______________

Type of triangle =_________

5. You must bend a bar of metal for a customer. The engineering department gives a set of prints, but the information on them is not complete.



a. What is the angle of A? ______________________

b. What is the angle of B? ______________________

c. What is the angle of C? ______________________

Image Resource: Images developed by S. Grudzinski.

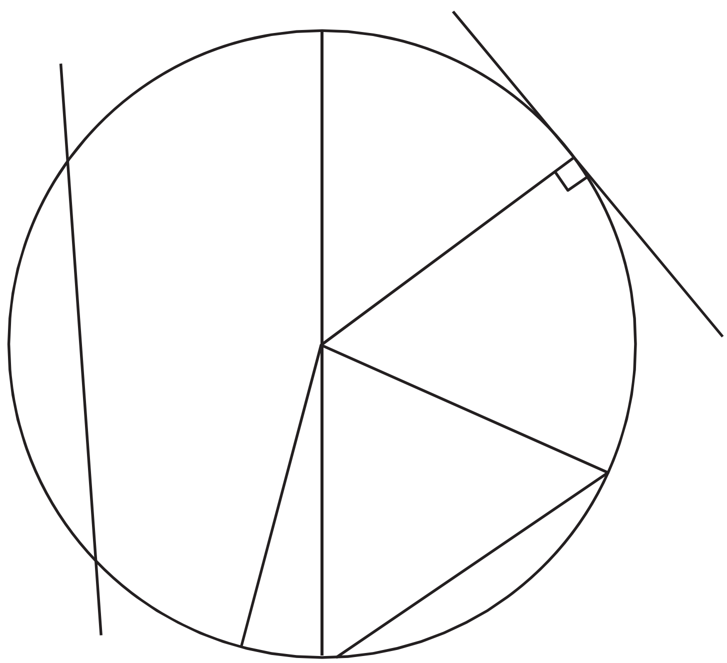
Geometry: Circles and Polygons 185

Name:____

Date:____

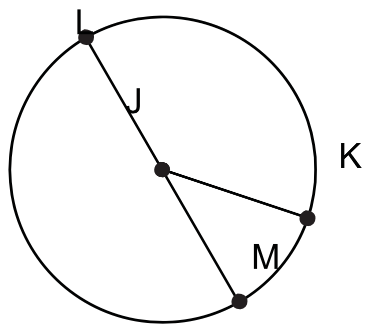
1. Using the following list of terms, label all of the parts of a circle.

   Chord, Tangent, Diameter, Radius, Circumference, Secant



2. Solve for the missing element. Please use 3.14 for pi (π)

a.



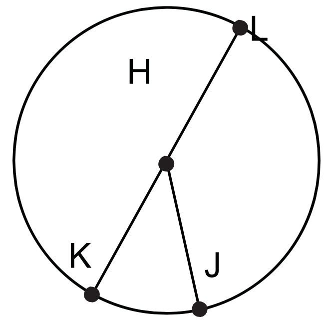
Radius: ____________________

Diameter: 8 inches

Circumference: ____________

Area: ______________________

b.



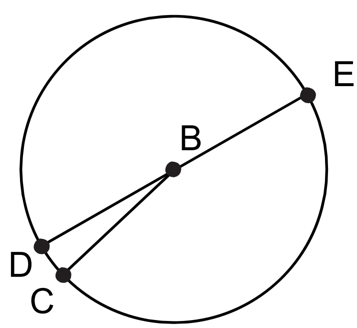
Radius: 14 cm

Diameter: ____________________

Circumference: ________________

Area: _________________________

c.



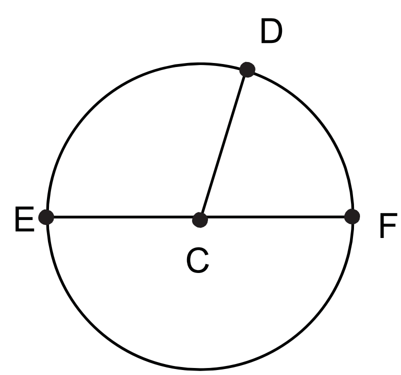
Radius: ____________________

Diameter: __________________

Circumference: ____________

Area: 28.26 inches^2

d.



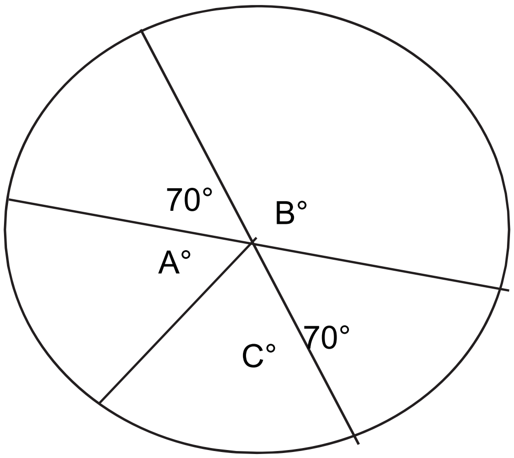
Radius: ________________________

Diameter: ______________________

Circumference: 81.64 cm

Area: _________________________

3. Find the missing angles.



Note: Angles A and C are equal

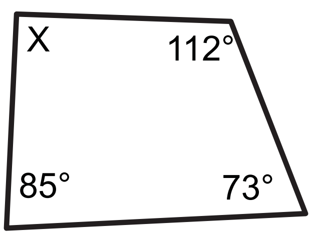
Angle A:______________________________

Angle B:______________________________

Angle C:______________________________

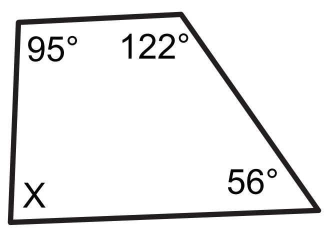
4. Solve for X.

a.



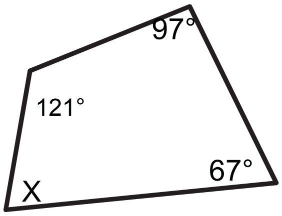
X =___________________

b.



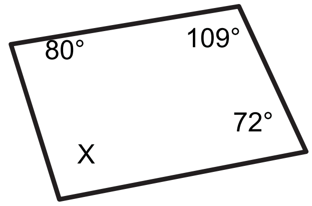
X =________________________

c.



X =____________________

d.



X =________________________

Image Source: Images developed by S. Grudzinski

Surface Measurement 140

Name:____

Date:____

Manufactured parts often twist, turn, and rotate such as rotors. Other parts remain stationary. Furthermore, parts such as gears intentionally come into contact with one another. Both customer specification and use determine whether the surface of the part must be smooth, rough, flat, or wavy. Considering the various uses and designs of materials that you have seen, answer the following questions.

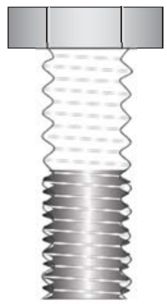
1. Differentiate between static and dynamic surfaces.

2. Define the terminology lay, roughness, and waviness.

3. Discuss in your own words how the finish of a surface affects cost. Include examples of common items with varying surface finishes.

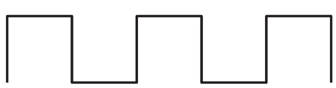
Overview of Threads 150

1. Bolts are used to join materials together either permanently or temporarily. Many steel structures, including buildings, bridges, frames and others, are simply bolted together. Bolts used in manufacturing are often classified by their characteristics. Using the image of the bolt below, identify and label: the *crest*, the *flank*, the *pitch*, and the *root*.



2. Identify the shapes of the thread and explain a use for it. Provide a brief explanation of why this thread type would be preferred over other thread types of the identified use.

3. Identify the shapes of the thread and explain a use for it. Provide a brief explanation of why this thread type would be preferred over other thread types of the identified use.



4. Identify the shapes of the thread and explain a use for it. Provide a brief explanation of why this thread type would be preferred over other thread types of the identified use.

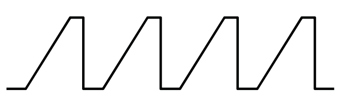


Image source:

Okuma. (n.d.). About Thread or what is meant by thread. Retrieved from http://okumacnc.blogspot.com/2011/06/about-thread-or-what-is-mean-by-thread.html.

Basic Measurement 110

Name:____

Date:____

When manufacturing parts, it is important that the parts fit together in a specific manner. Replacement parts must also fit together the same way as the original parts. Take for instance the size of your jeans. You buy a pair of name brand jeans size 34 x 34. If you purchase two pairs of jeans, you expect that both pairs of jeans will fit the same. In order to ensure the fit, companies must accurately measure and precisely sew the jeans every time. To gain a better understanding for accuracy and precision, complete the following questions.

Accuracy and Precision

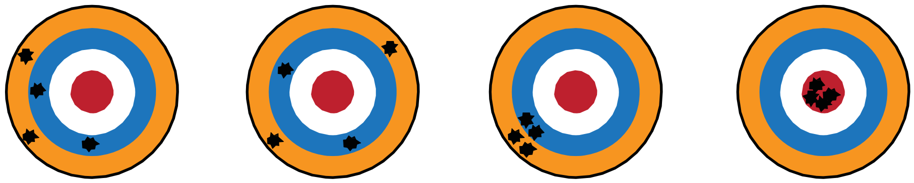
	Trial 1	**Trial 2**	**Trial 3**
Student A	5.43 g	5.44 g	5.42 g
Student B	5.43 g	5.40 g	6.43 g
Student C	5.54 g	5.56 g	6.41 g
Student D	6.86 g	6.86 g	6.87 g

1. Use the above table for the following question. Four students measured the mass of one 5.43 g sample three times. The results in the above table indicate that the data collected by the students.

   a. Which student results represents the greatest precision, but worst accuracy? Explain your answer.

   b. Which student results represents the second greatest precision and the greatest accuracy? Explain your answer.

2.



Using the targets in questions two, describe each experiment as having good or bad accuracy and precision.

Experiment	Precision Good or bad	Accuracy Good or bad
Exp I		
Exp II		
Exp III		
Exp IV		

3. A measurement was taken three times. The correct measurement was documented to be 68.1 mL. Knowing the true value, circle whether the following data represents measurements that are accurate, precise, both, or neither.

a. 78.1 mL, 43.9 mL, 2 mL accurate, precise, both, neither

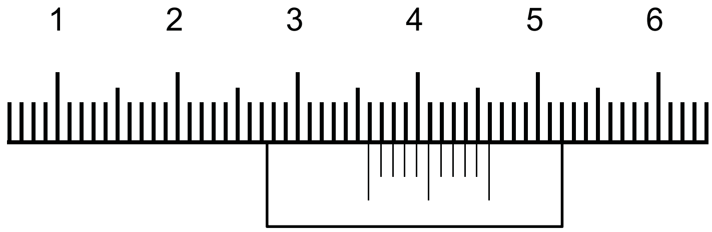
b. 68.1 mL, 68.2 mL, 68.0 mL accurate, precise, both, neither

c. 98.0 mL, 98.2 mL, 97.9 mL accurate, precise, both, neither

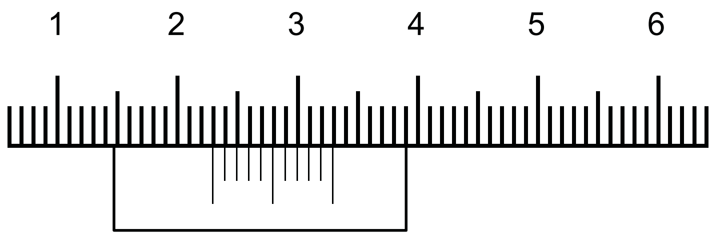
d. 72.0 mL, 60.3 mL, 68.1 mL accurate, precise, both, neither

4. Many measuring devices like manual calipers and micrometers use a Vernier Scale to measure materials with greater precision. Read the following Vernier caliper measurements.

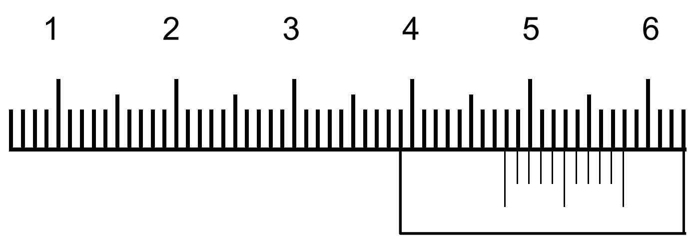
a.



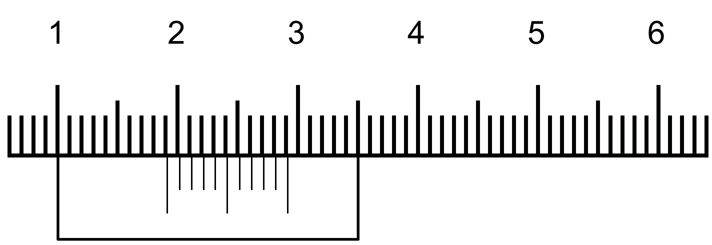
b.



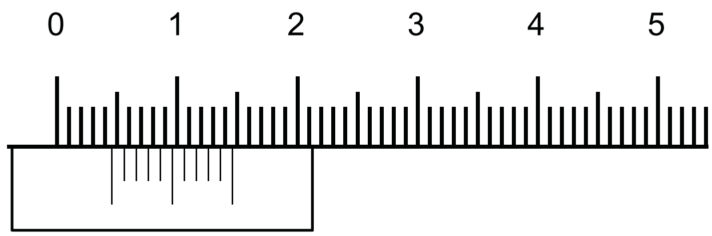
c.



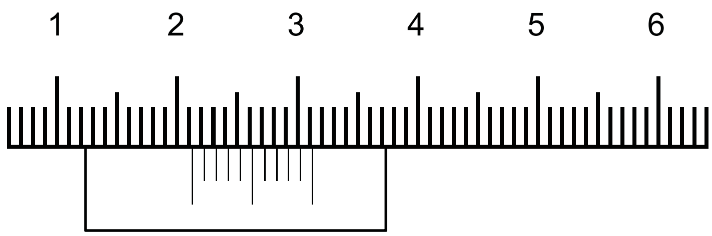
d.



e.

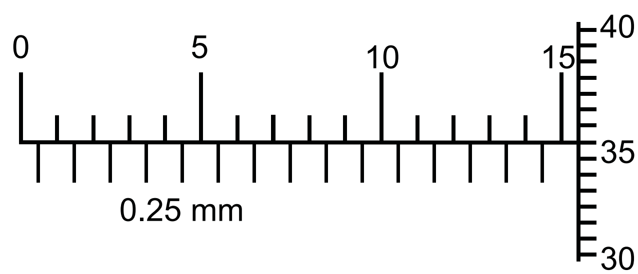


f.

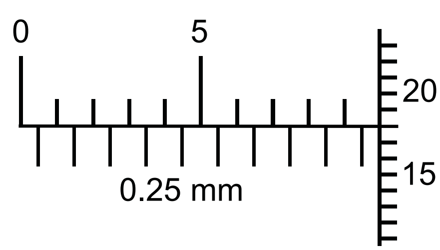


5. Record the measurements of the following micrometer measurements.

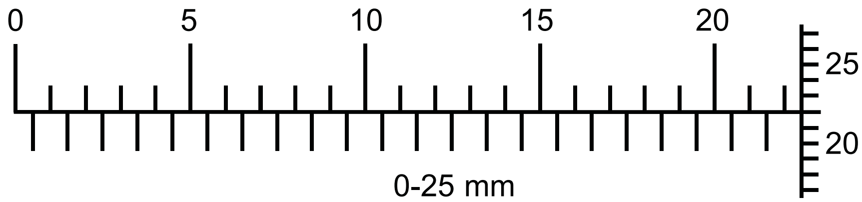
a.



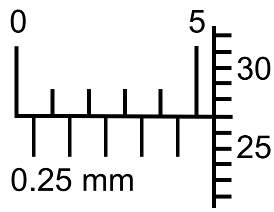
b.



c.



d.



e.

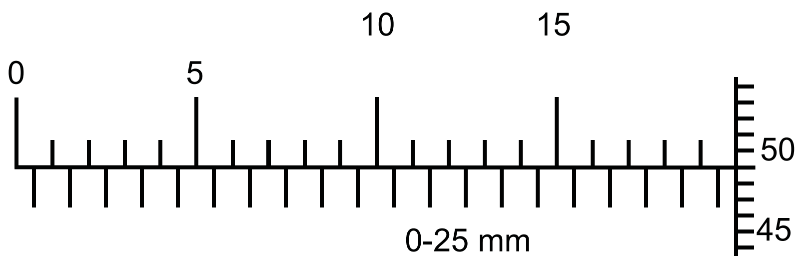


Image Source:

Images were modified from examples provided by Quast, J. (2002). Applied Math 10. Retrieved from http://jquast.weebly.com/uploads/3/6/9/7/3697444/micrometers-calipers-worksheet.pdf

Basics of CMM 120

1. Describe in your own words what a CMM is and the advantages of using such a machine in precision measurement.

2. Define what the Cartesian Coordinating System is.

3. How would you explain to a fellow student what the x-axis, y-axis, and z-axis are?

Basics of Optical Comparator 130

1. Some manufactured parts are very small such as parts for watches. Although tiny, these parts must continue to meet customer specifications. In order to measure the quality of these small parts, companies use a magnification device called an optical comparator.
   In a short essay, discuss how an optical comparator works using your own words. Be sure to include both advantages and disadvantages of using an optical comparator for measurement purposes.

Linear Instrument Characteristic 115

1. You are manufacturing a new type of string for a bow. When you pull the string back to fire the arrow, you expect the string to return rapidly to its original position. The rate, or lag time, required for the string to return to its original position is known as hysteresis. Describe the term hysteresis and how it affects the accuracy of a measurement.

2. You manufacture a part that weighs two pounds. For two parts, the total weight should equal four pounds. For three parts, the weight should equal six pounds. If this was graphed, you should see a straight line, or system linearity. Describe the term linearity as it applies to measurement.

3. You are required to drill a hole every 6 inches. As you are drilling the holes, you realize that the holes are drilled somewhere between 5 13/16 inches and 6 1/8 inches. Thus, you have introduced a small amount of error when drilling the holes. Differentiate between systematic and random errors.

4. You are scheduled to go to lunch as 12:10 pm. The clock in your area only displays the time to the nearest half hour. Your watch, however, measures to the exact second. Your watch has greater resolution than the clock in your area. Discuss what is meant by instrument resolution.

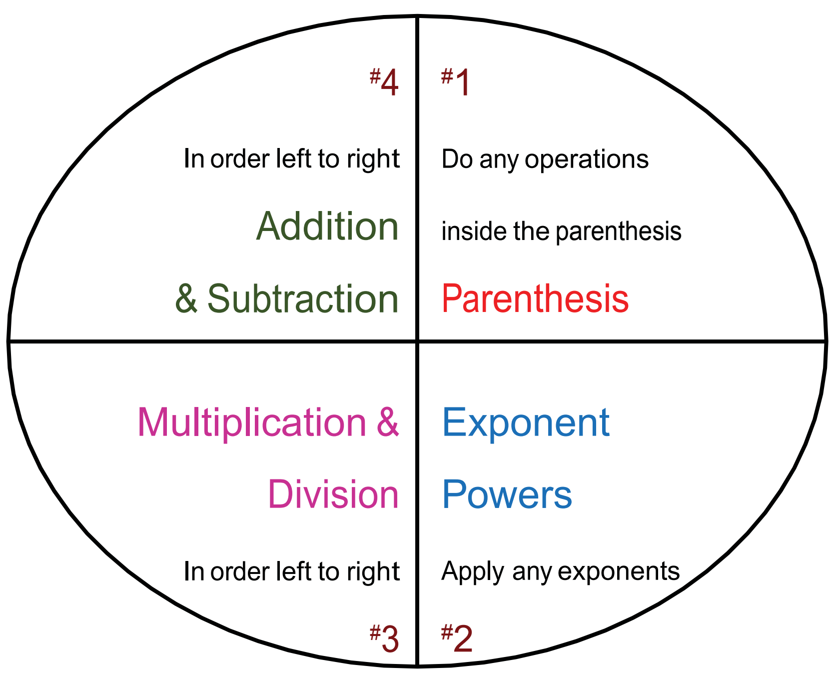
Quality Overview 100: Order of Operations

A very important aspect in looking at Quality is the process, if the process is faulty—the outcome may not be the quality required by the customer. The math used in these processes must be held to the same quality in its use as well.

A great example of a process that requires consistence is what we call the "Order of Operations." That is, what operation is completed first to simplify in a math expression. The operations used are addition, subtraction, multiplication, division, exponents and parenthesis. The question is, what is the order of this process and does it change the outcome if the process is changed?

The answer is yes! The process must be done correctly if a consistent outcome is required—and it is! Look at **10 - 2 x 4**, we could **SUBTRACT 10 - 2 = 8**, then **MULTIPLY 8 x 4** which is **32**. The problem is that it is not the correct answer. The correct order of this process is to **MULTIPLY 2 x 4 = 8**, then **SUBTRACT 10 - 8 = 2**.

Here is the "Order of Operations"



ORDER OF OPERATIONS WORD PROBLEMS

1. A certain small factory employs 98 workers. Of these, 10 receive a wage of $150 per day and the rest receive $85.50 per day. To the management, a week is equal to 6 working days. How much does the factory pay out for each week?

2. If the same factory has supply expenses of $1135.78 per day, in addition to the wages above and makes $60,128.72 in a week, what is the factory's total profit or loss in one week?

3. A certain Math Club makes 35 bars of laundry soap a week and sells these at $20 each. Before the soap can all be sold, the pupils found out that 6 bars were destroyed by mice. How much will be the total sale at the end of a four-week month? Write an expression and show your work and answer.

4. Emily had 30 cookies to bring to school for her birthday. Three students wanted two cookies each. Then, a new student came to the school that day and he wanted three cookies. Then, one of the three kids gave their two cookies back. Emily was still passing out cookies. How many cookies did Emily have left to pass out after the students gave theirs back?

5. Lilia scores 15 points fewer than Bob, who scores 35 points. Carol scores half as many points as Lilia. How many points does Carol score? Write an expression and evaluate it.

6. The middle school team scored three field goals worth three points each and two touchdowns worth six points each, with a single extra point for each touchdown. Write a numerical expression to find the team's score. Evaluate the expression.

7. Use the order of operations and the digits 2, 4, 6, and 8 to create an expression with a value of 2. Tip: You may add exponents and/or negatives at your will.

ISO 9000 Overview 110: Rules—Properties of Real Numbers

ISO 9000 supplies the industry with a set of common rules to follow. This brings consistent quality control to the customer regardless of who the supplier is.

The same type of rules or Properties exists in Mathematics, called the Properties of real numbers. Below is a list of the Properties of Multiplication and Addition. There are no properties of Division or Subtraction, but that is a different lesson.

	Property	Example
1.	Commutative Property of Addition $a + b = b + a$	$2 + 3 = 3 + 2$
2.	Commutative Property of Multi-plication $a \bullet b = b \bullet a$	$2 \bullet (3) = 3 \bullet (2)$
3.	Associative Property of Addition $a + (b + c) = (a + b) + c$	$2 + (3 + 4) = (2 + 3) + 4$
4.	Associative Property of Multiplication $a \bullet (b \bullet c) = (a \bullet b) \bullet c$	$2 \bullet (3 \bullet 4) = (2 \bullet 3) \bullet 4$
5.	Distributive Property $a \bullet (b + c) = a \bullet b + a \bullet c$	$2 \bullet (3 + 4) = 2 \bullet 3 + 2 \bullet 4$
6.	Additive Identity Property $a + 0 = a$	$3 + 0 = 3$
7.	Multiplicative Identity Property $a \bullet 1 = a$	$3 \bullet 1 = 3$
8.	Additive Inverse Property a + (-a) = 0	3 + (-3) = 0
9.	Multiplicative Inverse Property $a \bullet \left(\frac{1}{a}\right) = 1$ Note: *a* cannot = 0	$3 \bullet \left(\frac{1}{3}\right) = 1$
10.	Zero Property $a \bullet 0 = 0$	$5 \bullet 0 = 0$

The following are questions for exhibiting the rules of arithmetic. See if you can identify the properties of each problem.

1. Choose a number between 1 and 10. Add 4 and double the result. Subtract 3, then, multiply by 3. Subtract 5 times one more than the original number. Tell me the answer and I will tell you your original number. (It is ten less than the answer.) How does this work?

   Equation—

   Work—

   Properties used—

2. Choose a number. Add 2, double the result. Subtract 2, double again. Divide by 4. Subtract your original number. I will tell you the answer. (It is 1.)

   This can be justified by manipulations similar to those of the previous problem.

   Equation—

   Work—

   Properties used—

3. The crib sells safety glasses for $7.95 and gloves for $3.95. It offers 10% discount if you buy them together. One Saturday they sold 17 safety glasses / gloves combinations, and on Sunday they sold 19. What was their total value of sales of the safety glasses / gloves combinations for the weekend?

Equation—

Work—

Properties used—

4. Janelle runs a press. She has 3 aluminum molds, each of which holds 8 parts, and 2 cast iron molds which also hold 8 parts each. She also has two stainless steel molds which hold 12 parts each. If Janelle fills all her molds at once, how many parts would that be?

Equation—

Work—

Properties used—

5. Prunella is inspecting parts. Plastic Parts are $2.50 per part to inspect. Steel parts are $3.00 per part, large metal parts are also $3.00, and brass parts are $3.50 each. Prunella gets two plastic bearings, two plastic shafts, one plastic housing, three steel cups, one large steel plate, and two brass screws. Everything is subject to 6% tax. How much will the inspections cost the company?

Equation—

Work—

Properties used—

Quality Intro to Six Sigma 170

DISCRETE VS. CONTINUOUS

A **discrete variable** is one with a well-defined finite set of possible values. Examples are: the number of dimes in a purse, a statement which is either “true” or “false”, which party will win the election, the country of origin, voltage output of a digital device, and the place a roulette wheel stops.

A **continuous variable** is one which can take on a value between any other two values, such as: indoor temperature, time spent waiting, water consumed, color wavelength, and direction of travel.

A discrete variable corresponds to a digital quantity, while a continuous variable corresponds to an analog quantity.

From this definition and the one in the text, place each one of the variables into the proper category of Continuous or Discrete.

number of inspectors present	height of inspector
weight of inspector	number of heads when flipping three coins
distance traveled between Jobs	Inspectors’ grade level
number of red marbles in a jar	time it takes to get Inspection completed

A **discrete variable** is a variable whose value is obtained by counting.

A **continuous variable** is a variable whose value is obtained by measuring.

Lean Manufacturing Overview 130

As with the "Five S Approach" there are rules that help to stream line or shorten the steps needed to complete some mathematical problems. One such area is when working with Exponents. Below are some of the rules of Exponents that will help in solving the following problems.

Exponents rules and properties

Rule Name	Rule	Example
Product rules	$a^n \cdot a^m = a^{n+m}$	$2^3 \cdot 2^4 = 2^{3+4}$
Power rules	$(b^n)^m = b^{n \cdot m}$	$(2^3)^2 = 2^{3 \cdot 2}$
Quotient rules	$a^n / a^m = a^{n-m}$	$2^5 / 2^3 = 2^{5-3}$
Zero rules	$b^0 = 1$	$5^0 = 1$
Negative exponents	$b^{-n} = 1 / b^n$	$2^{-3} = 1/2^3$

1. SPACE SHUTTLE: The cost of each flight of the Space Shuttle is about $10,000,000. Write this amount in exponential form.

2. Grinders: One of the largest grinders in the plant weighs about 8 tons. Write this amount in exponential form.

3. VOLUME: To find the volume of a rectangular box, you multiply the length times the width times the height. In a cube, all sides are the same length. If the cube has length, width, and height of 6 inches, write the volume as a product. Then write it in exponential form.

4. SCIENCE: A certain type of cell doubles every hour. If you start with one cell, at the end of one hour you would have 2 cells, at the end of two hours you have 4 cells, and so on. The expression $2 \times 2 \times 2 \times 2 \times 2$ tells you how many cells you would have after five hours. Write this expression in exponential form; then evaluate it.

5. MATH: Write 625 using exponents in as many ways as you can.

6. PREFIXES: Many prefixes are used in mathematics and science. The prefix giga in gigameter represents 1,000,000,000 meters. Write this prefix as a power of ten.

7. Shop: The Shop contains 9^4 part trays. How many part trays are in the shop?

8. Parts: The Worker Assembled 6^3 parts on the first day. How many parts did he assemble?

Quality Introduction to 5S 155

In mathematics, you'll see many references about numbers. Numbers are classified by groups and initially it may seem confusing but as you work with numbers, they will soon become second nature to you. Below is a breakdown of how we classify numbers. This should help put some order to our number systems.

Natural Numbers
Natural numbers are what you use when you are counting objects. You may be counting parts, inspections completed, or cookies. When you use 1,2,3,4 and so on, you are using the **counting numbers** or to give them a proper title, you are using the **natural numbers**.

Whole Numbers
Whole numbers are easy to remember. They're not fractions. They're not decimals. They're simply whole numbers. The only thing that makes them different than natural numbers is that we include the zero **(the number with a hole in it)** when we are referring to whole numbers. **Whole numbers** are 0, 1, 2, 3, 4, and so on.

Integers
Integers can be whole numbers or they can be whole numbers with a negative sign in front of them. Individuals often refer to integers as the positive and negative numbers. **Integers** are -4, -3, -2, -1, 0, 1, 2, 3, 4 and so on.

Rational Numbers

Rational numbers have integers AND fractions AND decimals. Rational numbers can also have repeating decimals which you will see be written like 0.54444444... This means it repeats forever.

Irrational Numbers
Irrational numbers don't include integers OR fractions. However, irrational numbers can have a decimal value that continues forever WITHOUT a pattern, unlike the example above. Pi is an example of an irrational number which is 3.14. If we look deeper at it, it is actually 3.14159265358979323846264338327950288419…

Real Numbers

Here is another category where some other number classifications will fit. Real numbers include natural numbers, whole numbers, integers, rational numbers and irrational numbers. Real numbers also include fraction and decimal numbers.

$$\left\{-9, -\frac{3}{5}, 0, 0.1, \sqrt{25}, \pi, 6.5, \sqrt{5}, 6\right\}$$

From the list above write all that fit in each number group

Natural Numbers

Whole Numbers

Integers

Rational Numbers

Irrational Numbers

Real Numbers

Statistics 220

The **mean** of a set of observations is the average. It is obtained by dividing the sum of data by the number of observations.

The formula is:

$$\text{Mean} = \frac{\text{Sum of data}}{\text{Number of observations}}$$

EXAMPLE:

Find the mean of the following times it took for an inspection to be completed.

8, 11, -6, 22, -3

SOLUTION:

$$\text{Mean} = \frac{8 + 11 + (-6) + 22 + (-3)}{5} = 6.4$$

EXAMPLE:

The set of scores on a shop safety test taken by new employees 12, 5, 7, -8, *x*, 10 these scores have a mean of 5. Find the value of *x*.

SOLUTION:

$$\text{Mean} = \frac{12 + 5 + 7 + (-8) + x + 10}{6} = 5$$

$\Rightarrow 26 + X = 30$

$\Rightarrow X = 4$

When there are changes in the number or the values of the observations in a set, the mean will be changed.

EXAMPLE:

The mean run time of a group of 20 parts is 65. Two other parts whose run time are 89 and 85 were added to the group. What is the new mean of the group of parts?

SOLUTION:

The mean of a quantity of 6 orders is 20. If we remove one of the numbers, the mean of the remaining numbers is 15. What is the number that was removed?

SOLUTION:

Using the formula: Sum = Mean x Number of numbers

EXAMPLE:

[The mean score is the time required to inspect an order in minutes] 10 Inspectors had a mean score of 70. The remaining 15 Inspectors had mean score of 80. What is the mean score of the entire class?

SOLUTION:

Shop Algebra Overview 200

Basically there are six steps that need to be used to successfully complete an application problem. This assignment requires that each step be shown. An example is given to show the steps.

1. **Read the problem** just to understand what the problem is, then read it again to start to see the information you will need to solve the problem.

2. With only one unknown quantity, **assign a variable** to represent it. Explain what the variable represents.

3. Use the information from # 1 & # 2 to **write an equation** that will solve for the unknown.

4. Using the operations taught in this chapter, **solve the equation.**

5. **State the answer** to the equation with a proper label. This is not always the needed answer to the question, so look and see if more work is required.

6. **Check** and see if this answer looks reasonable and fits with the information given in the application.

Use the 6 steps listed above to solve the following:

1. Bob ordered four crates of bar stock. The first weekend he used one full crate. The next weekend he used 140 bars. If two boxes plus 60 bars remain. How many bar stocks are in each box?

2. When eight times a number is subtracted from eleven times the number the result is -9. What is the number?

3. Jill can complete five less than three times as many inspections as Mary. If Jill has completed 13 inspections, how many inspections has Mary completed?

4. John is using the shop floor jack to lift 180 lbs. This is 2 lbs less than six times the safe maximum weight limit of the floor jack. How much weight can this floor jack safely be used to lift?

Shop Trig Overview 210

Use the trig taught in this lesson to complete the following problems.

1. A boy flying a kite lets out 300 feet of string which makes an angle of 38° with the ground. Assuming that the string is straight, how high above the ground is the kite?

2. A ladder leaning against the wall makes an angle of 74° with the ground. If the foot of the ladder is 6.5 feet from the wall, how high on the wall is the ladder?

3. A straight road to the top of a hill is 2500 feet long and makes an angle of 12° with the horizontal. Find the height of the hill.

4. A 25 foot ladder leans against a building. The ladder's base is 13.5 feet from the building. Find the angle which the ladder makes with the ground.

5. In order to reach the top of a hill, which is 250 feet high, one must travel 2000 feet straight up a road. Find the number of degrees contained in the angle which the road makes with the horizontal.

Troubleshooting: Identifying Problems 180

The Problem

Revenue and Cost (Refer to Example 12.) The cost to produce one part is $1.50 plus one-time fixed cost of $2000. The revenue received from selling one part is $12.

a. Write a formula that gives the cost C of producing x parts. Be sure to include the fixed cost.

b. Write a formula that gives the revenue R from selling x parts.

c. Profit equals revenue minus cost. Write a formula that calculates the profit P from selling x parts.

d. What numbers of parts need to be sold to yield a positive profit?

Troubleshooting: Understanding Cause and Effect 182

1. The following data show the numbers of defective parts in each order.

   6, 5, 4, 4, 5, 3, 9, 8, 6, 4, 3, 4, 7, 5, 4, 3, 8, 4, 9, 3

   Make a frequency table of the data.

Defective Parts	Frequency
3	4

Check sheet supplied by ToolingU-SME

The “range” is just the difference between the largest and smallest values.

2. Find the mean, median, mode, and range for the following list of values:

   13, 18, 13, 14, 13, 16, 14, 21, 13

   mean:

   median:

   mode:

   range:

Troubleshooting: Taking Corrective Actions 184

CAUSE-AND-EFFECT DIAGRAM OR FISHBONE

After collecting data from a process and then preparing a pareto or histogram diagram, it's time to consider the reasons for the variation and those defects created. This data collected will reveal that items produced do not always turn out the same on a consistent basis. That is, parts produced can vary from production line to production line, from day shift to night shift, from day to day, and so forth. In other words, you seldom get consistent parts produced every time. What causes these differences or variations within the process? Basically, the variation created can originate from one or more of the following sources:

1. Raw Materials
2. Machinery, equipment or tooling
3. Work method or process
4. Work force—new people, trained differently, etc.
5. Measurement method or inconsistency in ways of measurement
6. Environment—high humidity, cold temperatures, dust, etc.

The real problem becomes which one of the above factors is either totally, mostly, or somewhat responsible for the cause of our problem? Or is it a combination of several causes?

A Cause-and-Effect diagram is useful in sorting out the causes of dispersion and organizing mutual relationships. This is an excellent team problem solving tool, where a team can gather together to "brain storm" the potential causes and resolutions to solve the variation problem.

The Cause-and-Effect Diagram was created by Dr. Kaoru Ishikawa, an engineer and professor in Japan. The Cause-and-Effect Diagram is also referred to as a “Fishbone” diagram, getting the name from its resemblance to a fish skeleton when created. The main purpose of this diagram is to define a problem, identify a possible cause, isolate the cause, and then develop a solution. Below is an example of a generic Cause-and-Effect Diagram. Please fill in the Fishbone for this situation.