1.2: Measurement

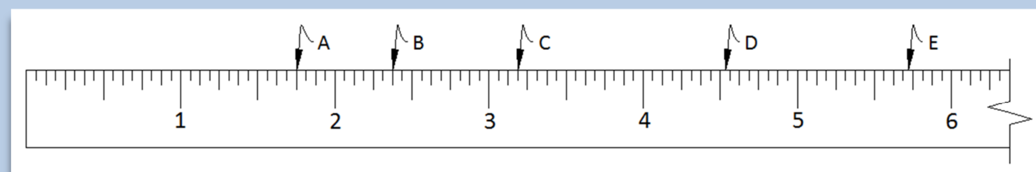
Simply put, measurement is the language of industry. A familiarity with the metric and standard systems of measurement is essential in creating and reading blueprints.

The standard system is cumbersome, based on the size of thumbs, arms and feet and divided and named without any thought as to the trouble it would cause us here in the 21st century. There are 3 feet in a yard, 12 inches in a foot, and 5280 feet in a mile; and this without even mentioning rods, chains, furlongs or fathoms. The key for most applications is an understanding of feet, inches and parts of an inch. For most applications, measuring accurately to the nearest 32nd of an inch is more than sufficient. Most rulers and tape measures divide the inch into 16 equal parts so it takes practice to measure to the nearest 32nd. The number of divisions also evolved slowly as the need for accuracy increased with technology. First the inch was divided in half (1/2), then the halves in half for quarters (1/4), then the quarters in half for eighths (1/8), next the eighths in half for sixteenths (1/16), and finally the sixteenths in half for thirty-seconds (1/32).

In the ruler below, notice the inches are divided into 16 parts, so each division represents $\frac{1''}{16}$:

Example 1.2.1: Naming measures on a standard ruler

Name the measurements:



Final Answers: $A = 1 + \frac{12}{16}$ or $1\frac{3''}{4}$

$B = 2 + \frac{6}{16}$ or $2\frac{3''}{8}$

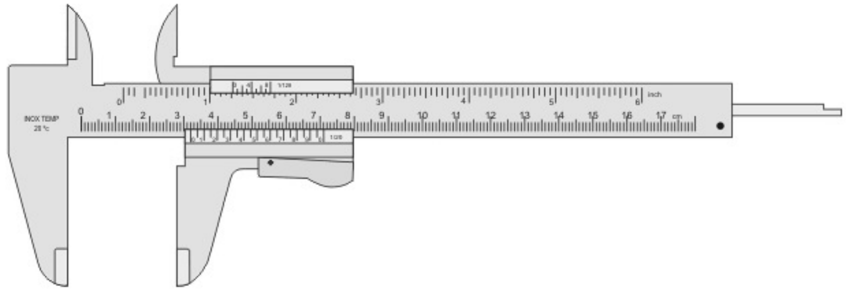
$C = 3 + \frac{3}{16}$ or $3\frac{3''}{16}$

$D = 4 + \frac{1}{2} + \frac{1}{32}$ or $4 + \frac{16}{32} + \frac{1}{32}$ or $4\frac{17''}{32}$

$E = 5 + \frac{3}{4} - \frac{1}{32}$ or $5 + \frac{24}{32} - \frac{1}{32}$ or $5\frac{23''}{32}$

Note: the marks indicating half inches are shorter than those indicating inches. The marks for quarters are shorter than those for halves; marks for eighths are even shorter, and so on. With practice you should be able to identify a measurement like $3\frac{5''}{8}$ without counting individual lines.

A notable exception to this degree of accuracy in the standard system exists in manufacturing where the inch is divided into 1000 equal parts. A measurement off by $\frac{1"}{32}$ is beyond tolerance for pistons in an automobile engine, for example. One nice advantage, beyond the increased level of accuracy, is that a measurement of $5\frac{243"}{1000}$ can easily be written in decimal form as 5.243”. Admittedly this may disappoint manufacturing students not to be able to work with fractions, but some sacrifices must be made in the name of progress!



It is interesting to note that 1000 marks between each inch would be impossible to distinguish on a typical ruler, so a brilliant device called a vernier caliper is used. Half an hour with someone familiar with this device will enable you to confidently measure with it.

As you are probably aware, the entire world, save the Englishman, recognized the ease of dividing measurements by powers of ten (tenths, hundredths, thousandths, etc.). The basic unit of length in the metric system is the meter, and all other units are found by multiplying or dividing the meter by a power of 10. Measurements in the metric system can always be written in decimal form, making calculations much easier. The same prefixes are used in the metric system, regardless of whether one is measuring a length, weight, or liquid measure.

Common Metric Prefixes

Prefix	Meaning
Kilo-	1 thousand = 1000
Centi-	1 hundredth = $\frac{1}{100}$
Milli-	1 thousandth = $\frac{1}{1000}$
Micro-	1 millionth = $\frac{1}{1000000}$

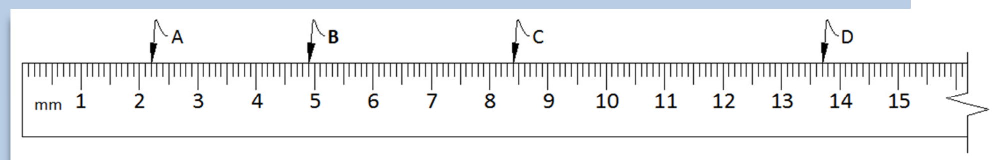
7.8 kilometers is 7800 meters and

346 centimeters is 3.46 meters, for example.

In the typical metric ruler below, the numbers represent centimeters (cm) which are divided into 10 parts. Each division represents a millimeter (mm):

Example 1.2.2: Naming measures on a metric ruler

Name the measurements:



Final Answers: A = 2.2 cm or 22 mm
B = 4.9 cm or 49 mm
C = 8.4 cm or 84 mm
D = 13.7 cm or 137 mm

The ability to convert back and forth from decimals to fractions is essential since many of the calculations that we will explore in this text involve formulas that will result in decimal answers. Our standard system of measurement requires that numbers be in fraction form so that they can be measured. Consider the following practical example:

Example 1.2.3: Applying skills with fractions and decimals

A cabinet is to be built with 3 equal spaces for sinks and drawers. Find the size of each space if the overall size is $112\frac{3}{4}$”, rounded to the nearest 32^{nd} of an inch.

Solution:

It is simple to use a calculator to convert a fraction into a decimal. A fraction bar is a symbol for division so $\frac{3}{4}$ = 3 ÷ 4 = .75. This should come as little surprise since with money three quarters is 75 cents. With a calculator then 112.75 ÷ 3 ≈ 37.5833, rounded to four decimal places. It is a little more than 37”, but how many 32^{nds} of an inch is .5833? Restated as a simple equation it becomes apparent, $\frac{?}{32}$ = .5833. Multiplying .5833 x 32 and rounding gives the answer 18.7 which is close to 19 so it is nearest to $\frac{19}{32}$.

Final Answers: $37\frac{19}{32}$”

One more example just to be sure you have it:

Example 1.2.4: Skills with fractions and decimals

A $91\frac{3}{8}$”piece of steel is to be divided into 5 equal pieces. Find the size of each piece rounded to the nearest 16^{th} of an inch.

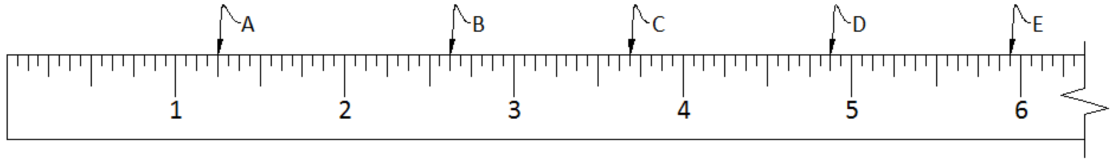
Solution:

Again, $\frac{3}{8}$ = 3 ÷ 8 = .375. With a calculator then 91.375 ÷ 5 = 18.275. Notice that in the previous example the decimal required rounding, since the decimal never stops, whereas this time it does not. Mathematicians get pretty excited about this difference since you cannot technically get the previous example correct in decimal form. Again the simple equation, $\frac{?}{16}$ = .275. Multiplying .275 by 16 and rounding gives the answer. .275 x 16 = 4.4 which is closer to 4 so it is nearest to $\frac{4}{16}$ or $\frac{1}{4}$.

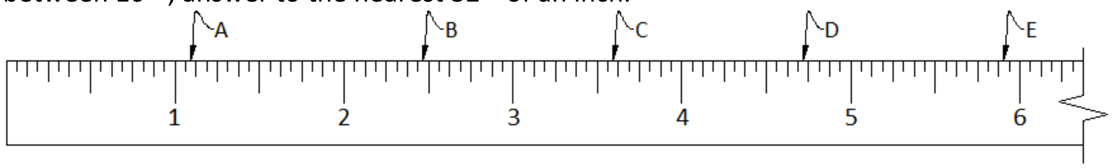
Final Answers: $18\frac{1}{4}$”

Section 1.2: Measurement

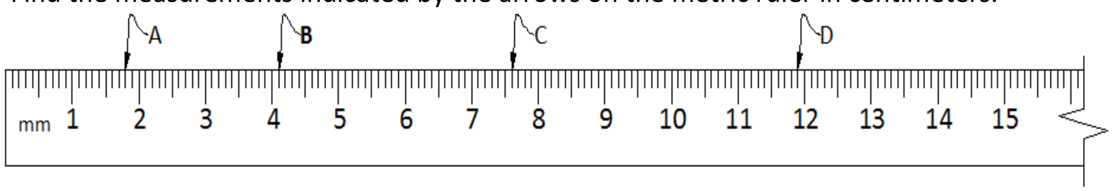
1. Find the measurements indicated by the arrows on the standard ruler.



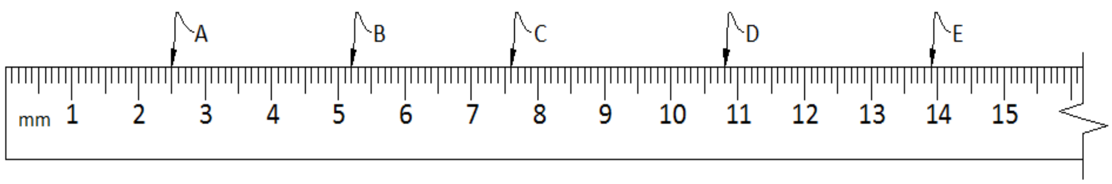
2. Find the measurements indicated by the arrows on the standard ruler. All measurements fall between 16ths, answer to the nearest 32nd of an inch.



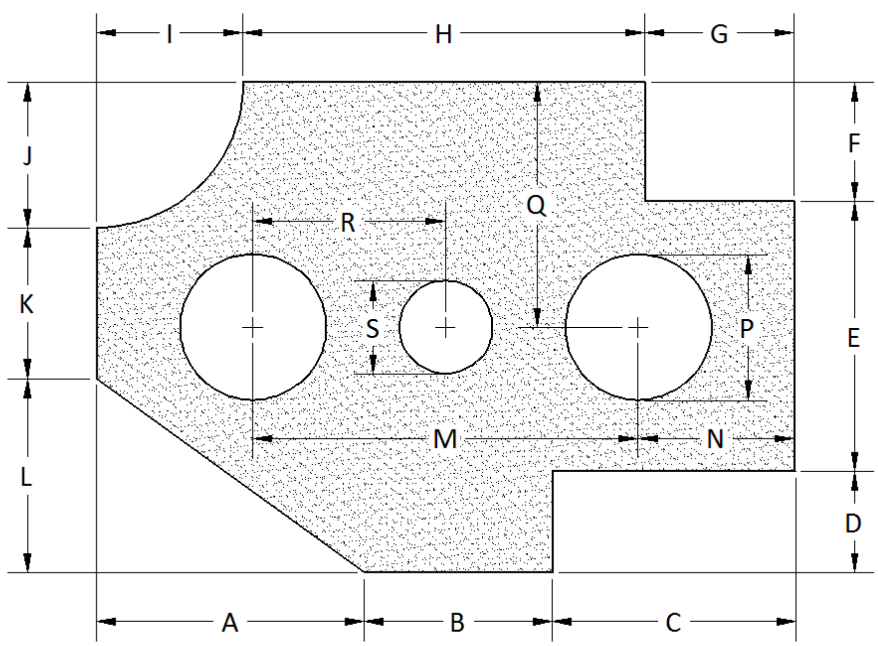
3. Find the measurements indicated by the arrows on the metric ruler in centimeters.



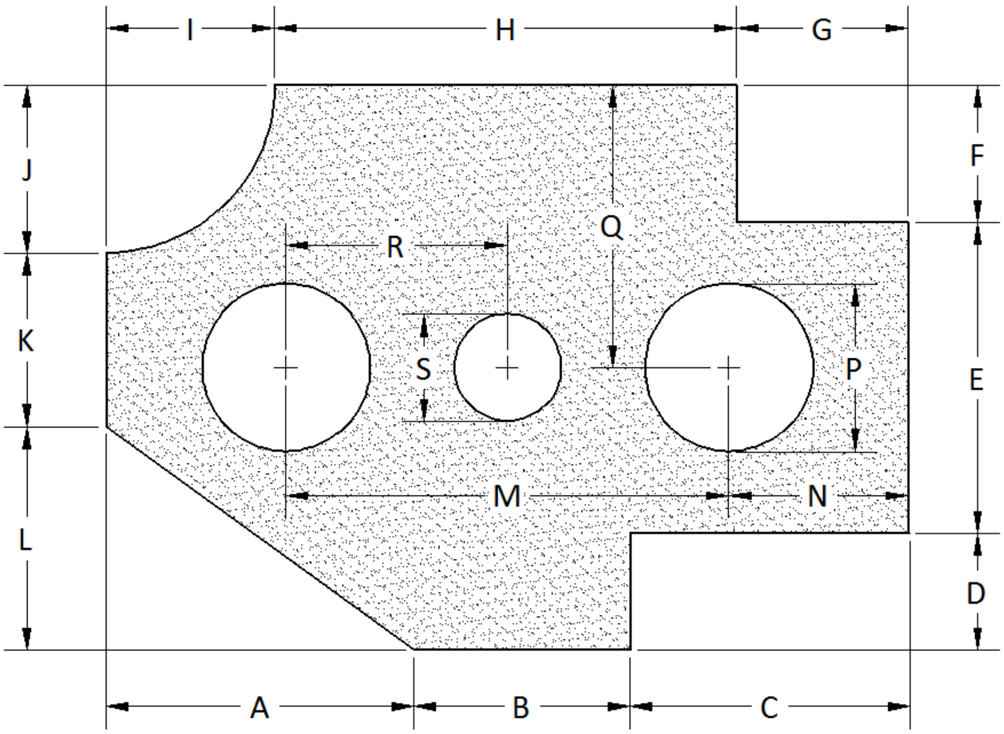
4. Find the measurements indicated by the arrows on the metric ruler in millimeters.



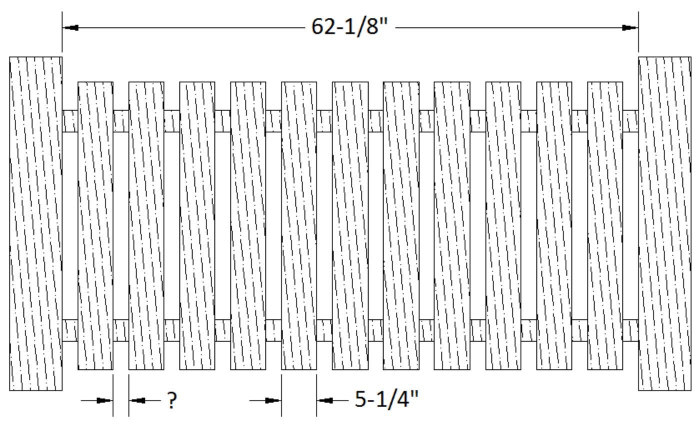
5. Measure the dimensions A through S on the part to the nearest millimeter.



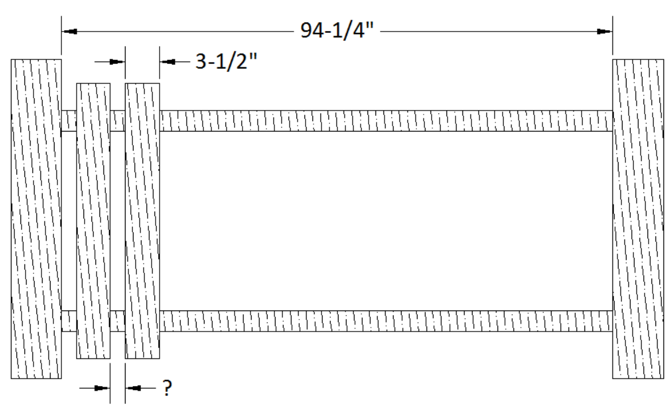
6. Measure the dimensions A through S on the part to the nearest 32^{nd} of an inch. Answer as a reduced fraction.



7. A fence is to have 11 boards between two posts so that the space between each board is the same. Calculate the distance between each board rounded to the nearest 16^{th} of an inch.



8. A fence is to have $3\frac{1"}{2}$ wide boards between two posts that are $94\frac{1"}{4}$ apart so that the space between each board is the same. Calculate the number of boards and the spacing so that the spacing between the boards is as small as possible. Round your answer for the spacing to the nearest 16^{th} of an inch.

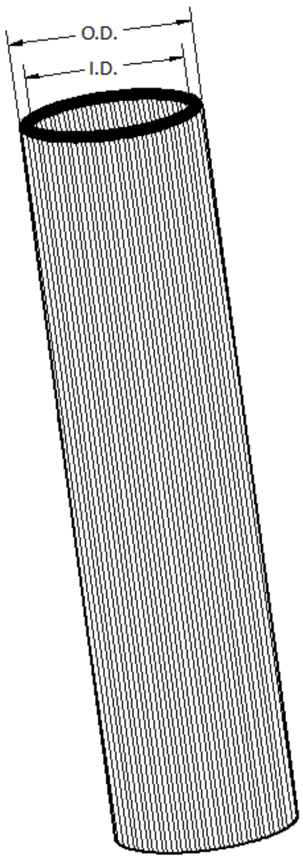


9. Copper pipe is manufactured in three types according to wall thickness. Use the outside and inside diameter measurements from the chart to calculate the wall thickness as a decimal rounded to three places <u>and</u> as a fraction rounded to the nearest 32nd of an inch. All measurements are in inches.

   a) Size 3/8 Type M

   b) Size 5/8 Type L

   c) Size $1\frac{1}{4}$ Type K

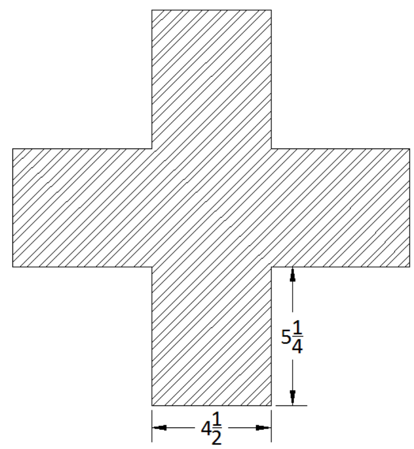


Size	outside diameter (O.D.)	Type		
		K	L	M
		inside diameter (I.D.)		
3/8	1/2	0.402	0.430	0.450
1/2	5/8	0.528	0.545	0.569
5/8	3/4	0.652	0.668	0.690
3/4	7/8	0.745	0.785	0.811
1	1-1/8	0.995	1.025	1.055
1¼	1-3/8	1.245	1.265	1.291
1½	1-5/8	1.481	1.505	1.527
2	2-1/8	1.959	1.985	2.009

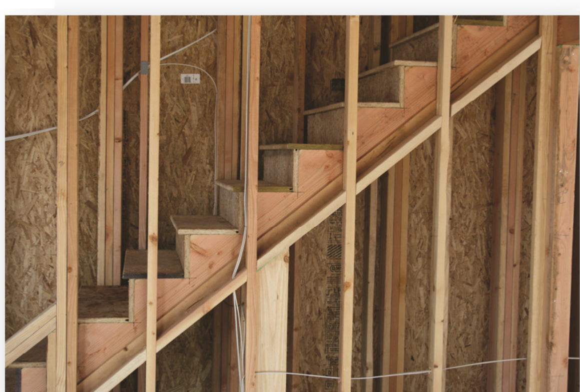
10. Fill in the missing columns in the pilot-hole size chart below. Loose pilot holes should be fractions rounded up to the nearest 32^{nd} of an inch so that the screw can slide through. Tight pilot holes should be rounded down to the nearest 32^{nd} of an inch so the screw threads have wood to grip. Answer as a reduced fraction.

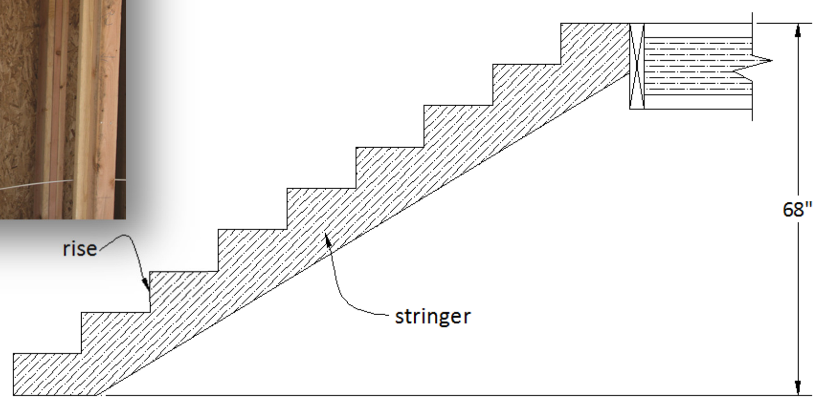
Wood Screw Pilot Hole Sizes			
Screw Size	Thread Diameter	Loose Pilot Hole	Tight Pilot Hole
4	.112		
6	.138		
11	.203		
14	.242		

11. If the first aid sign below is scaled down by a factor of nine, find the new dimensions for the <u>overall</u> width and height rounded to the nearest 16^{th} of an inch. Assume the shape to be symmetrical and all dimensions to be in inches.

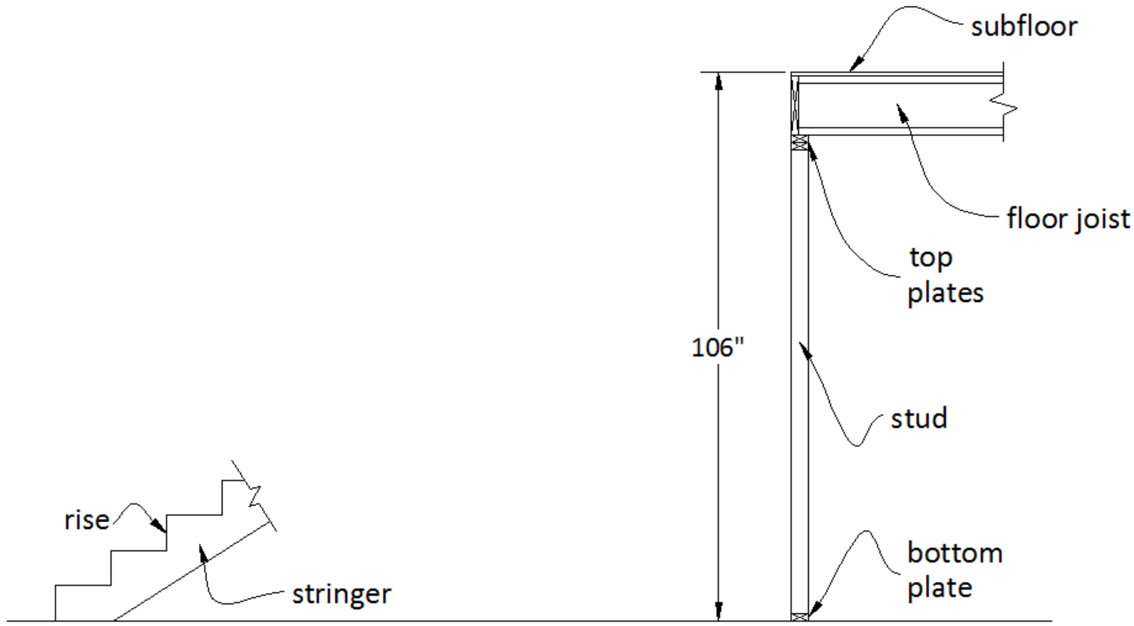


12. A stair stringer is to be cut with nine rises to reach a deck that is 68 inches above the ground. Construction code stipulates that each rise must be equal so that the stair case will not be a trip hazard. Calculate the height of each rise rounded to the nearest 16^{th} of an inch.

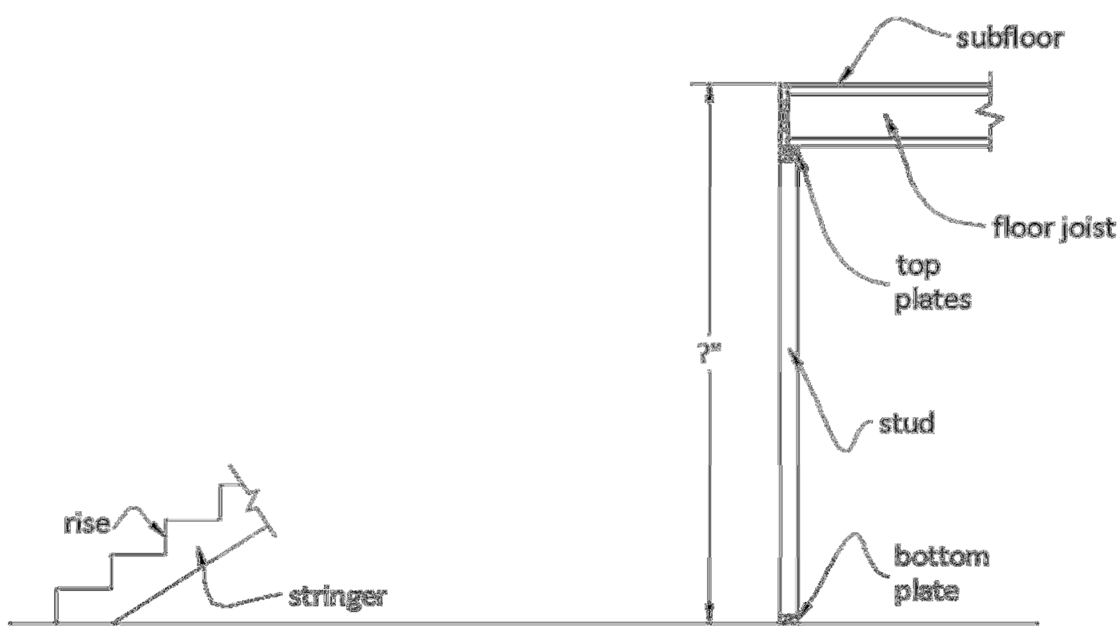




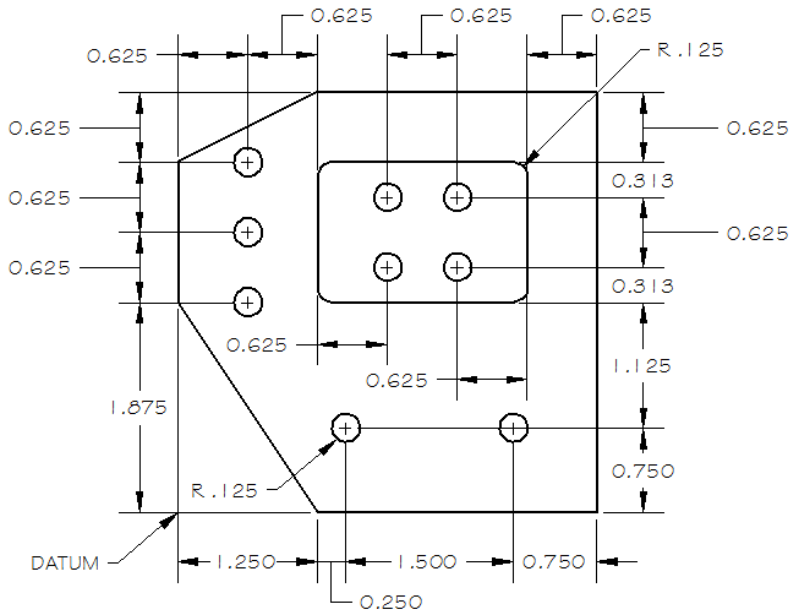
13. A stair stringer is to be cut to reach a 2nd story floor that is 106 inches above the ground floor. Construction code stipulates that each rise must be equal so that the stair case will not be a trip hazard. Calculate the whole number of rises so the height of each rise is as near the ideal of seven inches as possible. Next, use the whole number of rises to calculate the height of each rise rounded to the nearest 16th of an inch.

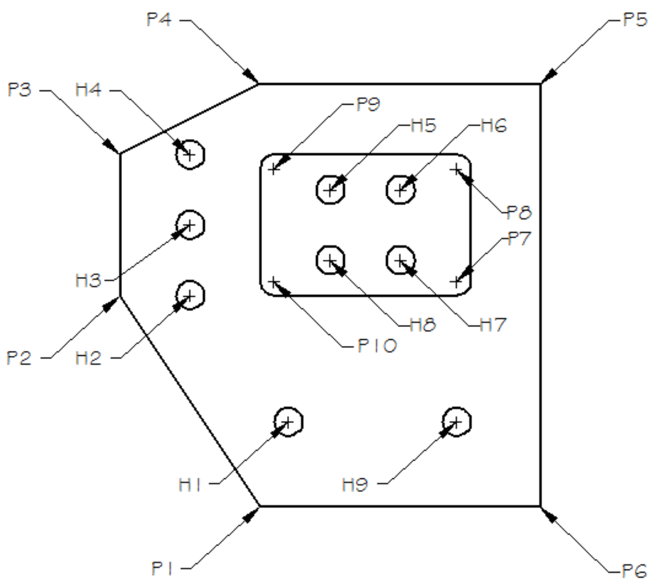


14. A stair stringer is to be cut to reach a 2nd story floor in a house with nine foot ceilings. The distance from the 1st to the 2nd floor can be calculated by adding up the height of each material. Bottom plate $1\frac{1"}{2}$, stud $104\frac{1"}{4}$, two top plates $1\frac{1"}{2}$ each, floor joist $11\frac{7"}{8}$, and subfloor $\frac{3"}{4}$. Construction code stipulates that each rise cannot exceed eight inches and must be equal so that the stair case will not be a trip hazard. Calculate the number of rises and the height of each rise (rounded to the nearest 16th of an inch) for all possible designs where the rise is between six and eight inches.



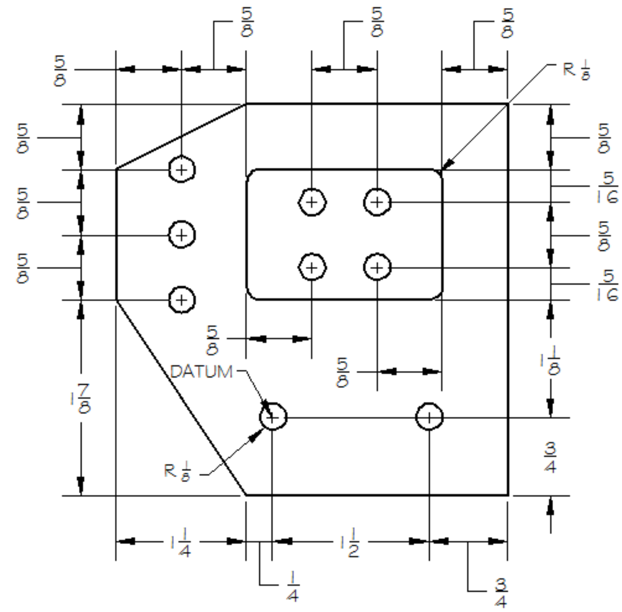
15. A manufacturer must describe a dimensioned part according to its x & y coordinates for a CNC (computer numerically controlled) machine to produce it. These coordinates are measured relative to a datum. The x-coordinate is the horizontal distance from the datum and the y-coordinate is the vertical distance from the datum. Fill in the chart that locates the holes and points that define the part.

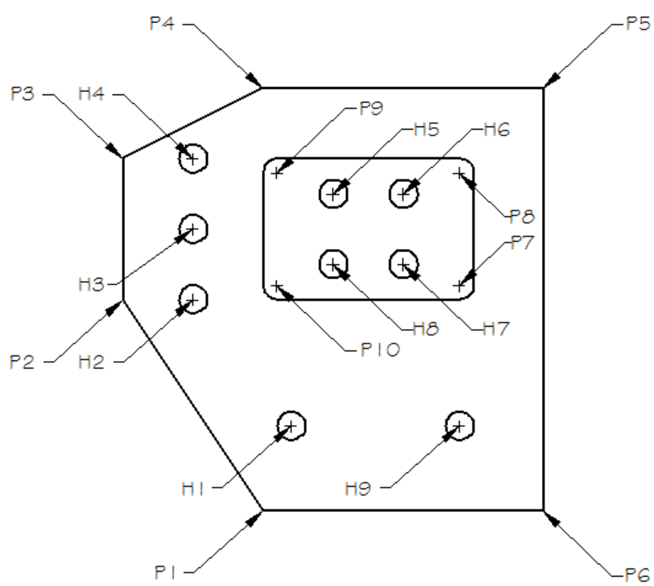




	X - Coordinate	Y - Coordinate
P2		
P4		
P6		
P9		
H3		
H6		
H8		
H9		

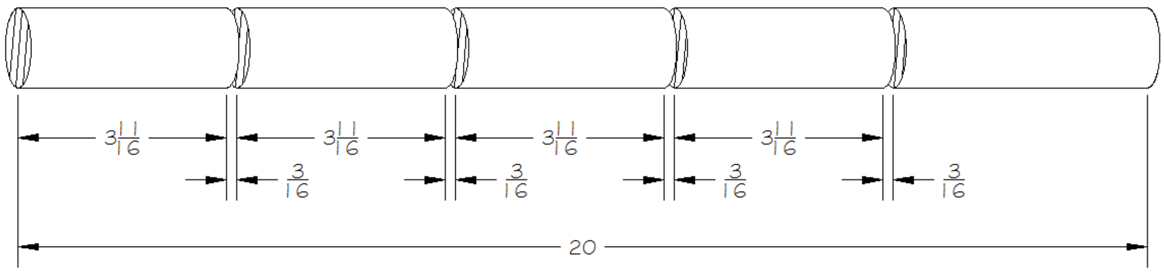
16. A manufacturer must describe a dimensioned part according to its x & y coordinates for a CNC (computer numerically controlled) machine to produce it. These coordinates are measured relative to a datum. The x-coordinate is the horizontal distance from the datum, right is positive and left is negative. The y-coordinate is the vertical distance from the datum, up is positive and down is negative. Fill in the chart that locates the holes and points that define the part.



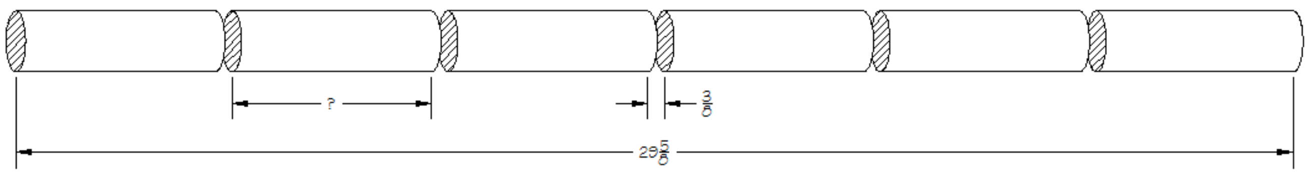


	X - Coordinate	Y - Coordinate
P1		
P3		
P5		
P7		
P8		
P10		
H1		
H2		
H4		
H5		
H7		

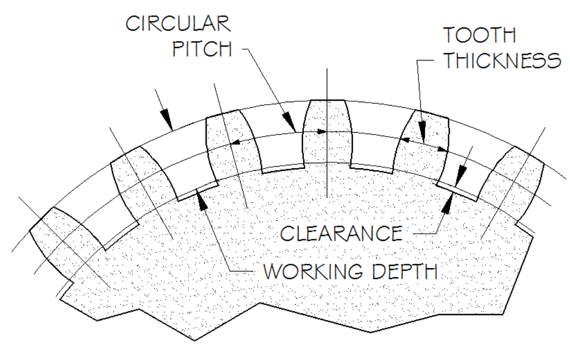
17. Four pieces of equal length are cut from the 20 inch length of round stock. If the saw takes 3/16", calculate the length of the left over piece as a fraction. All dimensions are in inches.



18. A length of round stock is to be cut into six equal lengths using a saw that removes 3/8" with each cut. Calculate the length of the equal piece. All dimensions are in inches.



19. A section of a gear is shown. Given the formulas below and the circular pitch in the chart, determine the working depth, clearance, and tooth thickness. Answer as decimals rounded to 3 decimal places.



Working Depth = .6366 x Circular Pitch
Clearance = .05 x Circular Pitch
Tooth Thickness = .5 x Circular Pitch

Circular Pitch	**Working Depth**	**Clearance**	**Tooth Thickness**
.398 inches			
2.65 cm			
$\frac{9}{16}$ inches			
$\frac{472}{1000}$ of an inch			