

Weights & Measures Course



Applied Scholastics, Ferndale WA

Measurement

A measure is an exact and agreed upon amount of something.

Measurement means finding the size of a thing by counting how many measures there are to it.

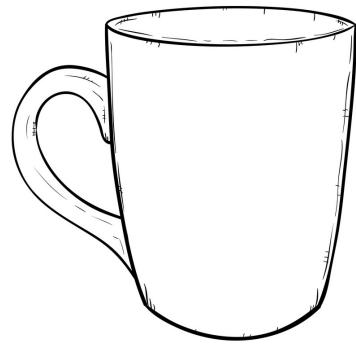
The idea of measuring things accurately has always been important. Whether it's for fair trade, building things right, or other everyday needs, knowing exactly how much of something there is important in making things work well in our world.

1. What is a measure?
2. What is measurement?

Units of Measurement

In general, a unit is one single thing.

A cooling unit, for example, means one single cooling machine that doesn't need anything else to run. It's just one thing, and usually one that is just like a lot of other similar things.

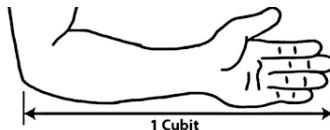


In measurement, a unit is the thing being used as a measure.

There are lots of different units used for measuring different things. A foot used in measuring length is a unit of measurement, for example. A wall could be measured as 8 feet high. A cup, used to measure ingredients in cooking, is another unit of measurement. Your cake recipe may call for 2 cups of flour.

All sorts of things have been used in the past as units for measurement, and all sorts of scales made up, with different things being used in different parts of the world.

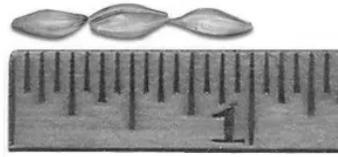
- The cubit for example, that is mentioned in the bible in giving the size of Noah's ark, is the length of a forearm. This length was also once called an ell, which was the word for a forearm. The word elbow means "arm bend."



- The earliest known yard (a length equal to three feet) was an iron rod kept by the English king Edgar over a thousand years ago.



- An inch was once defined as the width of the king's thumb, or as the length of three grain of barley laid end to end.



- A Smoot is a unit of length named after Oliver Smoot who was a student at MIT. In 1958 Smoot lay down repeatedly along Harvard Bridge while other students marked off the distance using his height (five feet and seven inches.) Harvard Bridge is exactly 364.4 smoots in length.



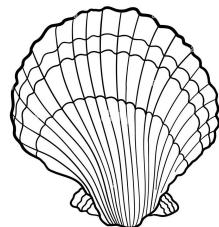
3. What is a unit?
4. What are some other units of measure?

Scales

Scale, originally, meant to climb, and it still has that meaning. Later it came to mean a ladder, and we still "scale" a ladder, meaning to climb it.



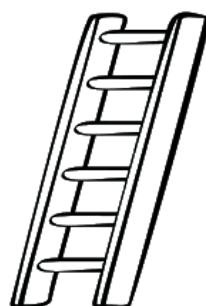
Also, scale once meant a shell or a shell used as a cup. Scallops still use this old word in their name.



A scale is also a device used for measuring weight, which takes its name from the cups used to hold the thing being weighed.

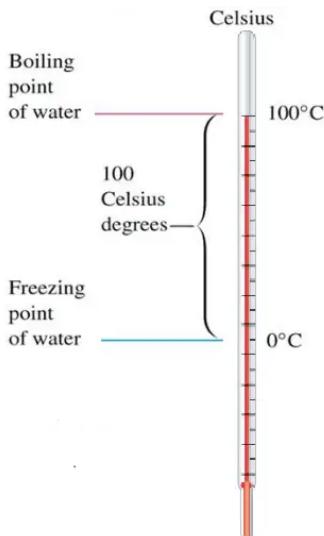


In measurement, a scale is also a line marked into evenly spaced sections, called divisions, that are each one unit in size. It is called a scale because it is like a ladder with evenly spaced rungs.



There are two ways to make a scale:

1. Two fixed points are decided on and some number of divisions made between them, which sets the size of a unit. For example, the scale for temperature is made from the freezing and boiling points of water, marked as 0 and 100, with 100 divisions marked between them. Each division is a unit of temperature, called a degree.



2. The divisions of the scale are some physical thing of a known size that is used to mark the divisions. For example, using a foot as a unit of measure, a mile is a distance of 5,280 feet. Any distance less than a mile can be measured on this scale.



3. If you scaled a hill, what did you do?
4. What are weighing scales?
5. What are measuring scales?
6. What are the two ways that a measuring scale can be made?

Standardized Measuring Units

In the past, people around the world have used all sorts of different units to measure things. It was often unclear and confusing with different countries and different trades using different units for measuring the same things. As science got better and countries started working

together more, they began to agree on standard measurements that everyone could understand. They tried to use measurements based on universal things rather than just what a ruler said or specific objects.

Over time, standard systems for measuring things were made, and now we have two main ones: metric and imperial. Each has its own units for measuring.

7. Why is it important to have exactly defined and agreed upon units for measuring?

8. What are the two main systems of measurement units called?

The Metric System

Metric units are widely used around the world. They are based on powers of 10 which makes them easier to use than older systems. The metric system is used for science and for most countries except for the USA.

9. What does metric mean?

Metric Prefixes

The metric system uses Greek prefixes in naming its divisions and multiples of units.

- deci- (d) means 10^{-1} or $\frac{1}{10}$ of a unit.
- centi- (c) means 10^{-2} or $\frac{1}{100}$ of a unit.
- milli- (m) means 10^{-3} or $\frac{1}{1000}$ of a unit.
- micro- (μ) means 10^{-6} or $\frac{1}{1,000,000}$ of a unit.
(Represented by the Greek letter "mu," μ .)
- nano- (n) means 10^{-9} or $\frac{1}{1000,000,000}$ of a unit.
- deca- (da) means 10^1 or 10 units.
- hecto- (h) means 10^2 or 100 units.
- kilo- (k) means 10^3 or 1,000 units.

- mega- (M) means 10^6 or 1,000,000 units.
- giga- (G) means 10^9 or 1,000,000,000 units.
- tera- (T) means 10^{12} or 1,000,000,000,000 units.

There are prefixes for metric units greater and smaller than these but they are rarely needed.

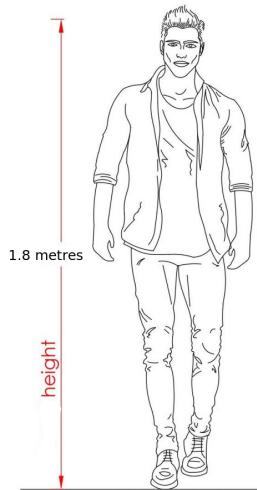
10. What are metric prefixes, and what are they for?

Length

Metre (m): The standard unit of length in the metric system.

← 1 metre →

Average-sized adults are about 1.7 to 1.8 metres tall. Doors are usually 2.04 metres high by 0.82 metres wide. Ceilings are generally 2.4 metres high.

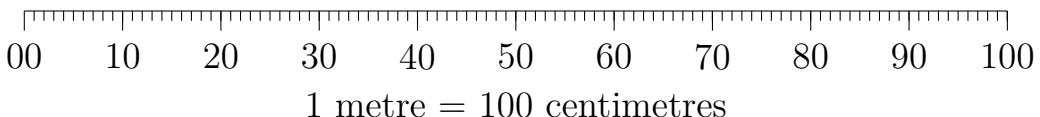


The metre is spelled "meter" in the US.

The metre was first established in France in the eighteenth century, defined as $\frac{1}{10,000,000}$ of the distance from the North pole to the equator, passing through Paris. A platinum bar of that exact length was made and was the standard metre until modern times when it became possible for other even more precise methods to be used to define an exact metre.

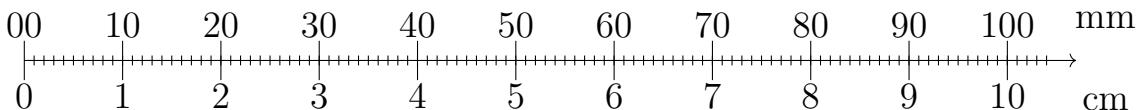
Lengths smaller than a metres are measured in centimetres (cm), millimetres (mm), or even smaller units.

- 1 centimetre (cm) = $\frac{1}{100}$ of a metre.



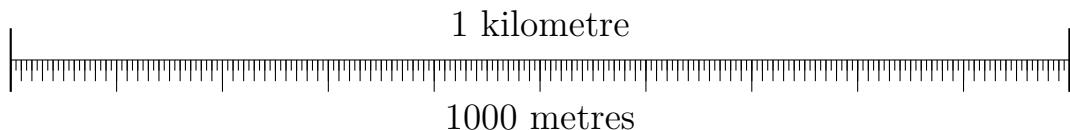
- Find a long ruler or a tape measure and look at the length of a metre. Get a good idea of just how long that is.
- If you hold the end of your ruler or tape measure in one hand, how far does the other end of the metre reach when you hold both arms out to the sides?
- On your long ruler or tape measure, look at the length of a centimetre. Get a good idea of just what size that is.
- Compare the width of your pointer finger to a centimetre. Is that finger bigger or smaller than a centimetre?
- With your long ruler or tape measure, measure the length of the wall nearest to you in metres and centimetres.
- Stand against a wall and mark your height. With your long ruler or tape measure, measure your height in metres and centimetres.

- 1 millimetre (mm) = $\frac{1}{10}$ of a centimetre = $\frac{1}{1000}$ of a metre.



Lengths in construction plans and materials are often just given in millimetres rather than in centimetres or metres.

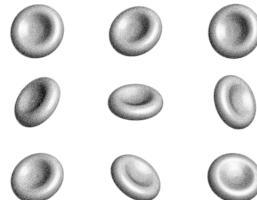
- Find a ruler or tape measure that has centimetres and millimetres. Look at the centimetres and look at the millimetres. Get a good idea of just how big is a millimetre, and how it compares to the size of a centimetre.
 - Measure the length and width of this page in millimetres.
 - How many millimetres is the width of your pointer finger?
- Lengths greater than a few hundred metres or so are measured in kilometres (km). There are 1,000 metres in a kilometre.



20. Find a map of your local area. How many kilometres is it from you to the middle of the nearest town?
21. Find a map of your state. How many kilometres is it from east to west? How many kilometres is it from north to south?

Physics

- 1 micron (μ) is 10^{-6}m or $\frac{1}{1,000,000}$ of a metre or one micrometre.



The diameter of a red blood cell is about $7\ \mu\text{m}$

- 1 nanometre (nm) = 10^{-9}m or $\frac{1}{1,000,000,000}$ of a metre.

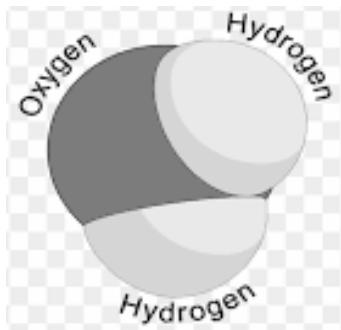


A DNA molecule is about 2 nm across and about 340 nm long

- 1 Ångstrom (\AA) is $\frac{1}{10}$ of a nanometre.

(The symbol \AA is a letter from the Swedish alphabet because this unit is named after the Swedish physicist Anders Jonas Ångström. It is a letter A with a little letter O on top. The sound of the letter \AA is a mix of O and A sounds, a bit like an Australian would say the word "oar.")

The Ångstrom was first used to measure wavelengths of light from the sun. The wavelength of visible light ranges from 4000 Ångstroms (violet) to 7000 Ångstroms (red).



A water molecule is about 3 Ångstroms across.

22. How big is a micron?
23. What sorts of things could you measure in microns?
24. How big is an nanometre?
25. What sorts of things could you measure in nanometres?
26. How big is an Ångstrom?
27. What sorts of things could you measure in Ångstroms?

Astronomy

- An Astronomical Unit (AU) is the average distance from the Sun to the Earth, which is 149,597,870.7 km. It is a useful unit when measuring distances to the other planets in the solar system.
- A Light Year is the distance that light travels in one year, which is 9,460,730,472,580.8 km, or 63241.1 AU. It is 4.246 light years from the Sun to the next nearest star. The galaxy that we are in is about 105,700 light years across. Distances in astronomy are usually given in light years.
- A Parsec (pc) comes from the words "parallax" and "second."
 - Parallax is the apparent change of position of an object when it is viewed from different angles. The apparent motion of a nearby star is a small ellipse in the sky relative to background stars over the period of a year. This is caused by the Earth's change of position during its orbit around the Sun. The angle between a star's two apparent positions, 6 months apart, is called its parallax angle.

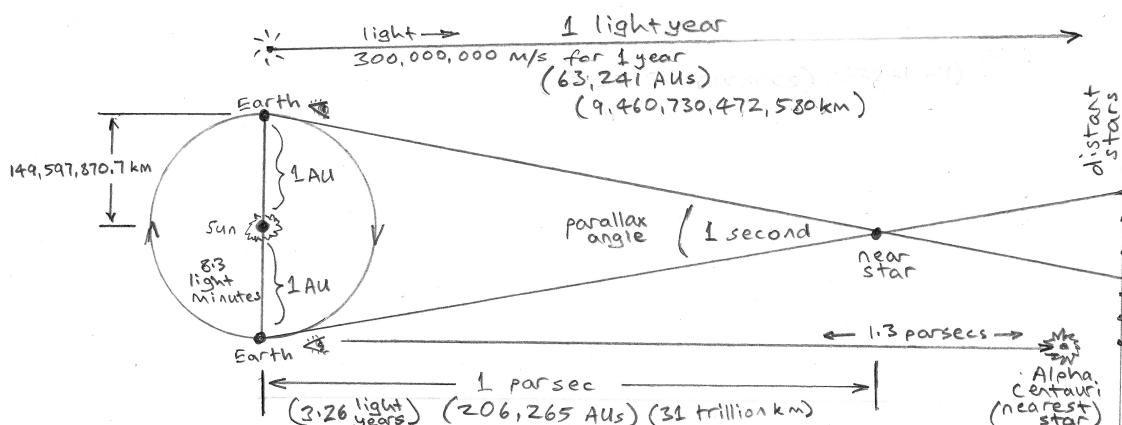
– Seconds, as well as being units of time, are units used in measuring angles. In measuring time, there are 24 hours in a day, 60 minutes in an hour, and 60 seconds in a minute. In measuring angles, there are 360 degrees in a full circle, 60 minutes in a degree, and 60 seconds in a minute. Actually, "minute" means a small part, and "second" is short for "second minute", meaning the second small part. A second is a time of $\frac{1}{24 \times 60 \times 60} = \frac{1}{86,400}$ of a day, and a second is an angle of $\frac{1}{360 \times 60 \times 60} = \frac{1}{1,296,000}$ of a degree.

A parsec (a **parallax-second**) is the distance at which one AU (astronomical unit) appears to have a parallax angle of one second.

Parallax angles are measured in seconds of degrees. Parallax is only observable on fairly nearby stars, but orbiting telescopes have accurately measured the parallax of over a billion stars so far, and their distances have been worked out. That is how the parsec has come to be a unit of distance between stars.

A parsec is a distance of $\frac{648,000}{\pi} = 206,265$ AU, which is 3.26156 light years or 30,856,775,814,913.673 kilometres.

The nearest star to the sun has a parallax angle of 0.772 seconds, meaning that it is 1.302 parsecs away. The most distant star measured so far in this way is 9,500 parsecs away. The galaxy that we are in is about 32,408 parsecs across.



28. How long is an AU?

29. What sort of distances would be measured in AUs?

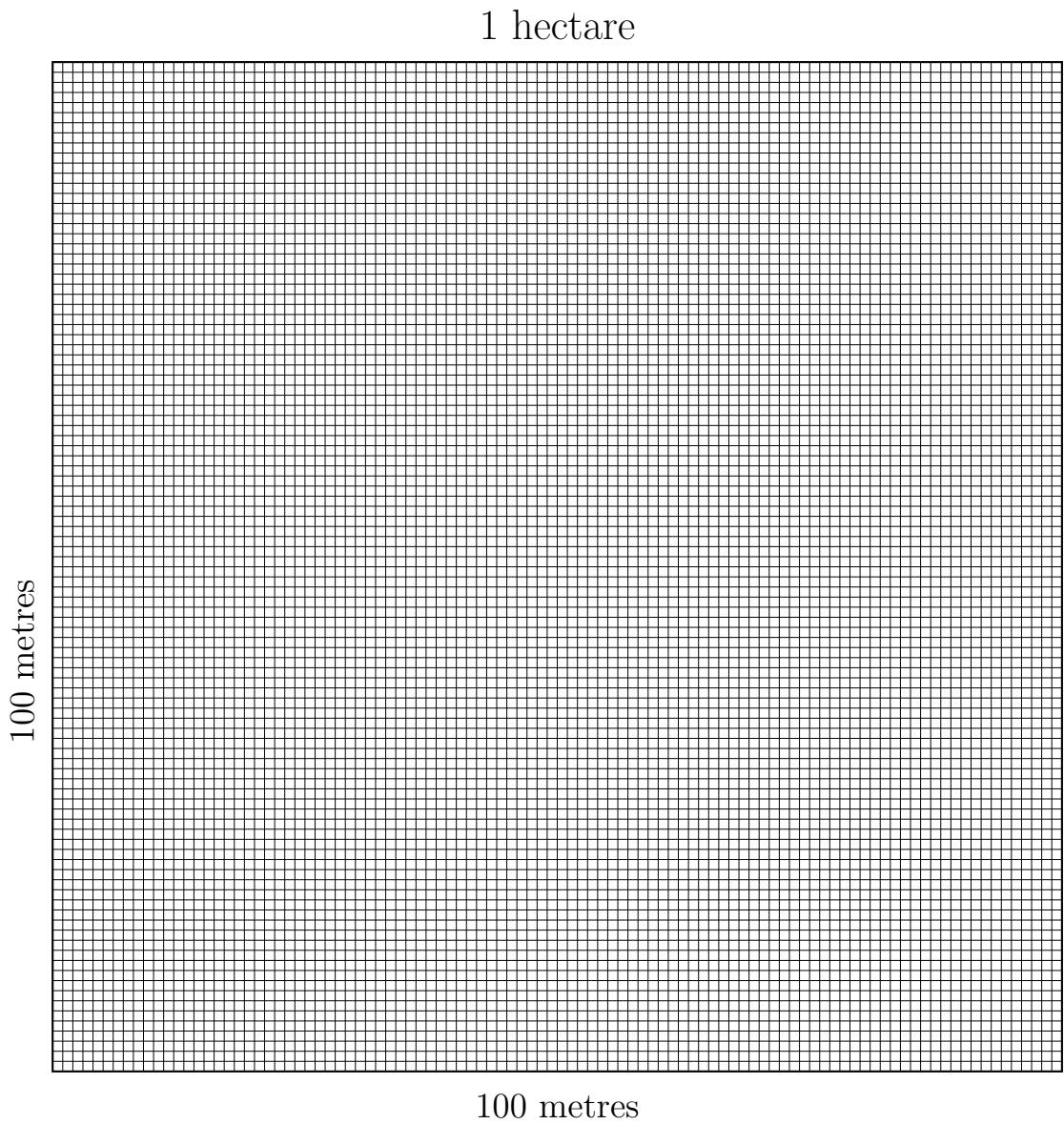
30. What is a light year?

31. How many AUs are in a light year?

32. What sorts of distances would be measured in light years?
33. What is parallax?
34. What is a second of a degree?
35. What is a parsec?
36. How does an AU compare to a parsec?
37. How many light years are in a parsec?
38. What sorts of distances would be measured in parsecs?

Area

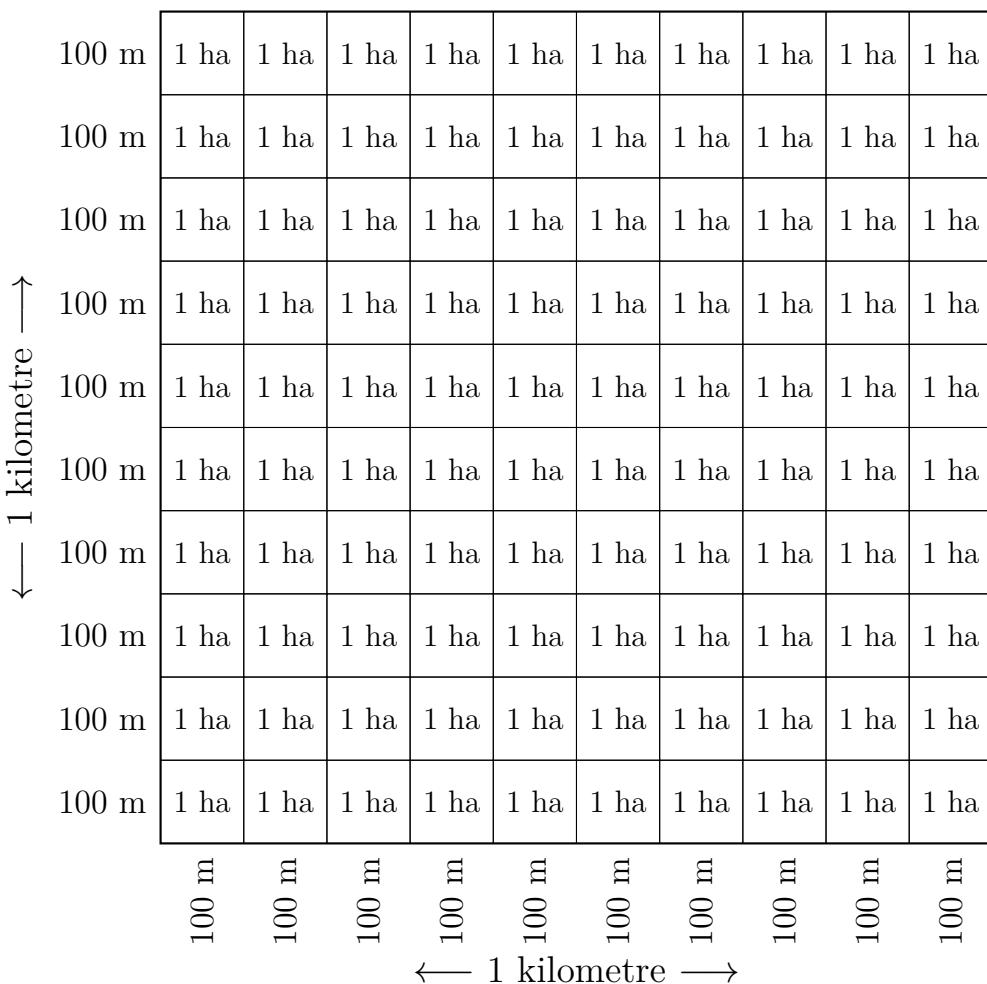
- Small areas are measured in square centimetres or square metres.
- Larger areas, such as areas of land, are measured in hectares, which are 100 metres by 100 metres.



Ares The word "hectare" is from "hecto-" meaning 100, and "are" which is the area of a square of 10 metres to a side. The are was originally part of the metric system but is no longer included except for its use in the hectare, which is an area of 100 ares. The are, and some other units based on the are, are still used in some parts of the world.

- A square kilometre is 100 hectares.

1 square kilometre



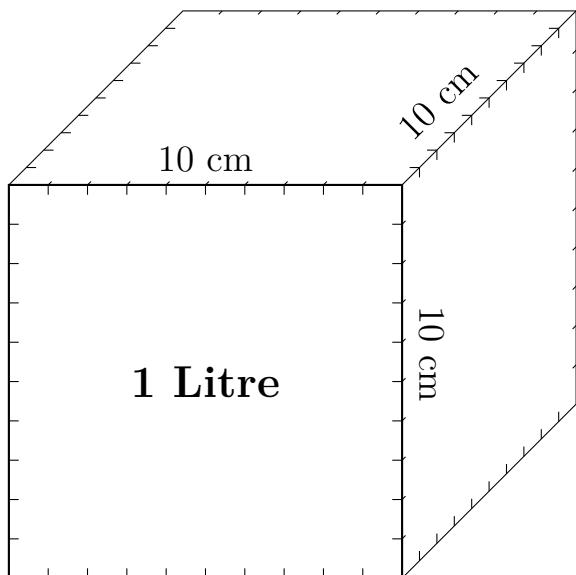
39. Measure, in millimetres, the length and the width of your left thumbnail. Multiply the two measurements. What is the area, in square millimetres (mm^2), of your left thumbnail?
40. Measure the length and the width of this page to the nearest centimetre. Multiply the two measurements. About what is the area of this page in square centimetres (cm^2)?
41. With a long ruler or tape measure, measure the length and the width of the room that you are in, to the nearest metre. Multiply the two measurements. Roughly what is the area of the room in square metres (m^2)?

Volume

Litre (L): The metric unit of volume in the metric system.

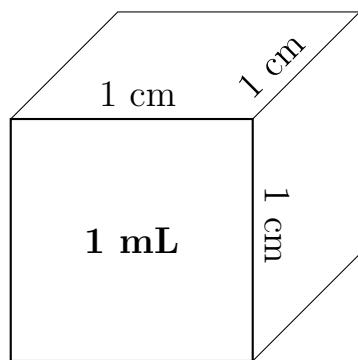
Milk is often sold in 1 litre or 2 litre bottles.

- A litre is the volume of a cube with sides of 10 centimetres.



- Volumes smaller than a litre can be measured in millilitres (mL).

A millilitre (mL) has a volume of exactly 1 cubic centimetre.



Cooking

- A metric cup is 250 mL.

In the US and in the UK, a metric cup is 240 mL.

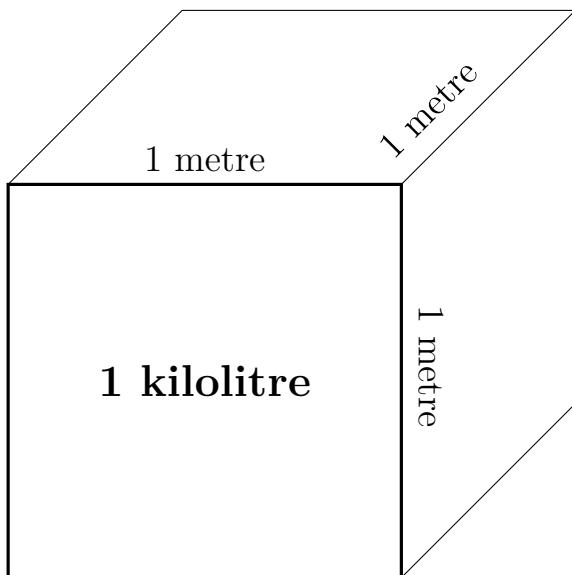
- A metric tablespoon (tbspn) is 20 mL.

In the US and in the UK a metric tablespoon is 15 mL.

- A metric teaspoon (tsp) is 5 mL.

- Large volumes are given in kilolitres (kL).

A kilolitre is equal to 1000 litres, one cubic metre.



This unit was originally called a stere (ST). Stere means solid or three-dimensional.

Domestic water bills are usually measured in kilolitres.

- Even larger volumes are measured in megalitres (ML).

A megalitre is 1,000,000 litres or the volume of a cube with sides of 10 metres.

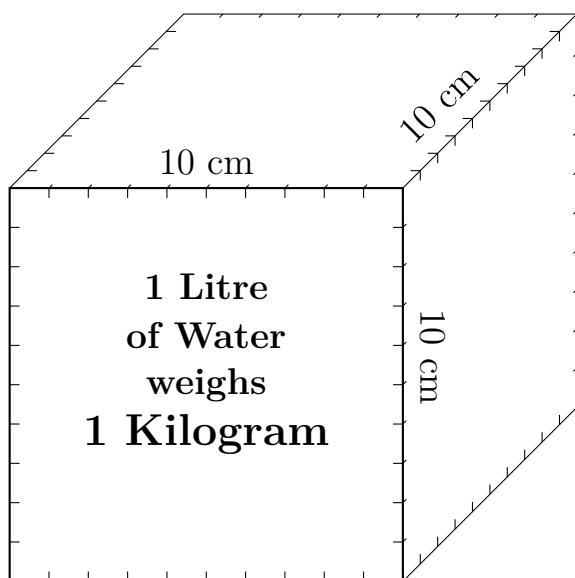
Water storage in dams is measured in megalitres.

42. Find a measuring jug that measures litres and millilitres. Get a cup of water and tip it into the jug. How many millilitres of water was in the cup?
43. Find a bucket and fill it with water. Find a funnel and an empty 1-litre bottle. Keep filling and emptying the bottle to count how many bottles of water the bucket held. What is the volume of the bucket in litres?
44. Find a measuring cup and measure out a metric cupful of water. How many millilitres of water is that?
45. Find a set of measuring spoons and measure out a teaspoonful of water. How many millilitres of water is that?
46. Find a set of measuring spoons and measure out a tablespoonful of water. How many millilitres of water is that?

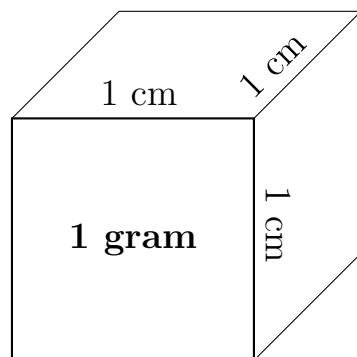
47. Find out how many teaspoonsful of water it takes to fill a tablespoon.
48. Fill up a 1-litre bottle using the measuring cup. How many metric cups are in a litre?
49. If a square pool is one metre deep and five metres to a side, then its volume is 25 cubic metres. What is the volume of the pool in kilolitres?

Mass

Kilogram (kg): The metric unit for mass.



- One litre of water weighs exactly one kilogram.
- One cubic centimetre of water (one millilitre) weighs exactly one gram (g).

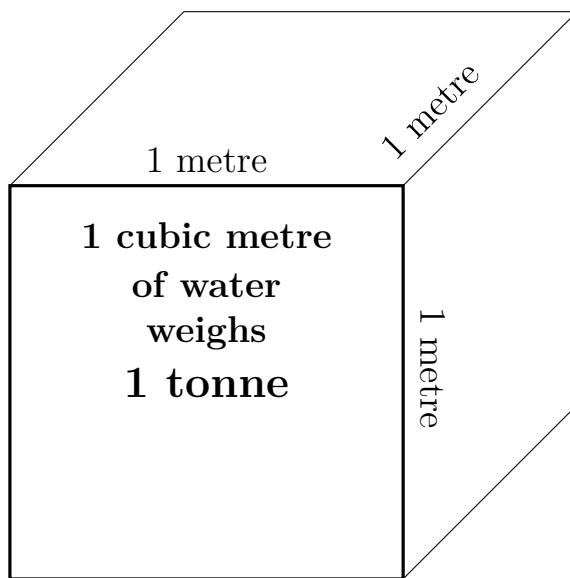


50. Measure out exactly one litre of water and get a good idea of how much one kilogram weighs.

51. Find a weighing scale and measure your own weight in kilograms.

- One cubic metre of water weighs exactly one tonne (T).

The metric system uses the spelling "tonne" rather than "ton," although sometimes "ton" is used regardless.



Tare

Tare weight, sometimes called unladen weight, means the weight of the container that has to be deducted to get the net weight, which means the weight of the contents only.

You will see the word "Tare" on the side of trucks and trailers sometimes, alongside a weight in kilograms. It is the weight of the truck or trailer when it isn't carrying anything.

The weight of the loaded truck or trailer is called its gross vehicle mass (GVM), which might also be written there. It is the tare weight plus the maximum weight that it can safely carry.

This way the load of a truck or trailer can be weighed by driving onto a weigh bridge and deducting the tare weight from the gross weight.

50. What does tare weight mean?

51. What does gross weight mean?

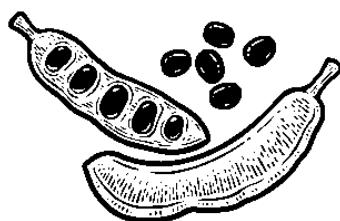
52. What does net weight mean?

53. If the gross weight of a cup of flour was 250 grams, and the tare weight of the cup was 50 grams, what is the net weight of the flour?
54. If your ute's GVM is 2,826 kg, and its Tare is 1,483 kg, what is it the heaviest load that it could safely carry?
55. How could you weigh a small animal that you could carry in your arms, but you couldn't get to stand on scales to be weighed?

Carat (ct)

Carats are units of mass used to measure gemstones and pearls.

- The term "carat" comes from the carob seeds historically used as counterweights on balance scales to measure gemstones. Carob seeds were used because they were thought to be of uniform size and weight.



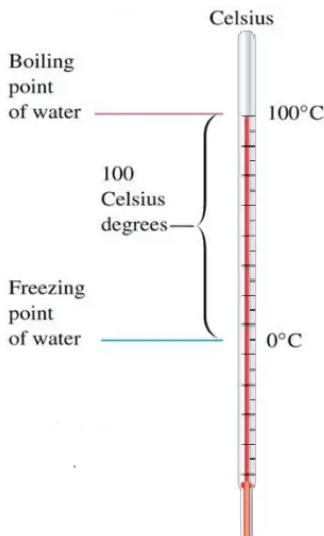
carob seeds

- One metric carat is 200 milligrams, divisible into 100 "points" of 2 mg.
56. If you had a pile of rubies that weighed 7 grams, how many carats do you have?

Temperature

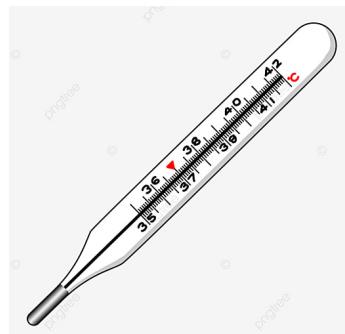
degrees Celsius (°C) The metric unit for temperature, named for its Swedish inventor Anders Celsius.

- On the Celsius scale, 0 °C is the freezing point of water and 100 °C is the boiling point of water.



A thermometer showing degrees Celsius

- This was once also called the centigrade scale with temperatures measured as degrees centigrade with the same symbol °C.
- Room temperature on the Celsius scale is 20 °C.



Normal human body temperature is 37 °C

57. What is a degree Celsius, and how does the Celsius temperature scale work?
58. Is 35 °C a hot day?
59. What should your healthy body temperature be?

Kelvin (K): The metric unit for temperature used by scientists.

- Heat is caused by the motion of atoms and molecules. Zero degrees Kelvin, known as absolute zero, is where atoms and molecules cease to move at all so that there is no heat.

- The Kelvin scale was developed from the Celsius scale so that 0°C is equal to 273.15 K, and a change in temperature of 1 K is the same as a change of 1°C . The Kelvin scale is the same as the Celsius scale, but starts from absolute zero, 0 K, which is -273.15°C .

60. What does a temperature of absolute zero mean?
61. What are degrees Kelvin?
62. Where are degrees Kelvin used?
63. What is the relationship between $^{\circ}\text{C}$ and degrees Kelvin?

Time

Second (s) The metric unit of time.

The metric system of units for time is not decimal. Various metric systems of time have been proposed over the years, but none have become widespread. The most notable attempt was from 1794 to 1800 during the French revolution where the day was divided into 10 hours and each hour into 100 minutes and each minute into 100 seconds.

- There are 24 hours in a day.
- There are 60 minutes in an hour.
- There are 60 seconds in a minute.

One second is defined as $\frac{1}{24 \times 60 \times 60} = \frac{1}{86,400}$ of a day.



A clock divides 12 hours into 60 minutes and 60 seconds.

- The short hand turns once every 12 hours, and points to the current hour. Sometimes these are not numbered, or only some of the hours are numbered. You are expected to know the hour by the position only.

- The long hand turns once an hour and points to the current minute.
 - * There are five minutes between every marked hour position. They do not have their own numbering and they are read by the minute hand's position.
 - * 15 minutes past the hour is at the 3 position. This is sometimes read as "a quarter past" the hour.
 - * 30 minutes past the hour is at the 6 position. This is sometimes read as "half past" the hour.
 - * Rather than reading the number of minutes past the hour for the full hour, times are often read by how many minutes to the next hour.
 - * 45 minutes past the hour is at the 9 position. This is sometimes read as "a quarter to" the current hour.
- The longest hand turns once a minute and points to the current second. Clocks and watches sometimes don't have a second hand.
- A millisecond (ms) is $\frac{1}{1000}$ s.
- A microsecond (μs) is $\frac{1}{1,000,000}$ s.
- A year is $365\frac{1}{4}$ days.

There are 365 days in a year, and 366 days in a leap year every 4 years. The extra day is inserted as February 29th.

The calendar that we use is called the Gregorian calendar because it was established by Pope Gregory XIII in 1582. It was an adjustment of the earlier Julian calendar, established by Julius Caesar in 45 BC. The Julian calendar was based on a year of exactly $365\frac{1}{4}$ days, but the actual length of a year is 11 minutes and 14 seconds shorter than that. This slight difference had accumulated over the centuries so that seasons were no longer in step with the calendar. He changed leap centuries so that century years (2000, 2100, 2200...) are only leap years if they are divisible by 400. It will take 3000 years for the Gregorian calendar to gain an extra day in error.

- There are 7 days in a week.
- There are 2 weeks in a fortnight.
(A fortnight is short for "fourteen nights.")

2016

JANUARY					FEBRUARY					MARCH					APRIL				
1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
24	25	26	27	28	29	30	28	29	30	31	27	28	29	30	31	24	25	26	27
MAY					JUNE					JULY					AUGUST				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	28	29	30	31
SEPTEMBER					OCTOBER					NOVEMBER					DECEMBER				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

- There are 52 weeks in a year.
- There are 12 months in a year.

A month is the time between new moons. A new moon is where the moon is completely in shadow and can't be seen. It takes a week for a new moon to grow to a half moon, another week to grow to a full moon, another week for a half moon again, and one more week for a new moon.



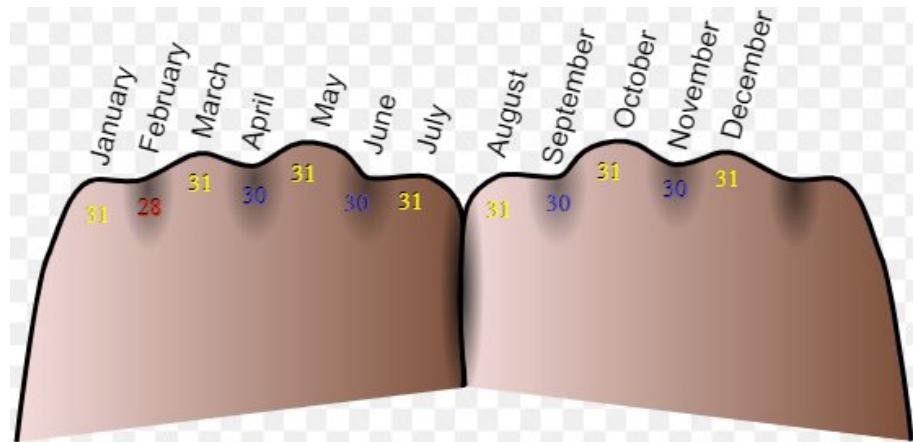
Months have different numbers of days. They mostly alternate between 30 and 31 days in length and it can be hard to remember. There are two different ways of remembering the length of each month:

- This poem that is at least 500 years old:

“Thirty days hath September, April, June, and November. All the rest have 31, but February’s 28. The leap year, which comes once in four, gives February one day more.”

- You can also use your knuckles:

Look at the backs of your hands placed side by side. A knuckle represents a month of 31 days and the dip between knuckles represents a month of 30 days (or 28/29 days for February.)



- There are 10 years in a decade.
- There are 100 years in a century.
- There are 1000 years in a millenia.
- There 1,000,000,000 years in an eon.
- An epoch is a starting point for counting of years in calendars.

The birth of Jesus Christ is used as the epoch for the counting of years in most parts of the world.

Years are either AD, which stands for Anno Domini meaning "the year of our lord," or BC, meaning "before Christ."

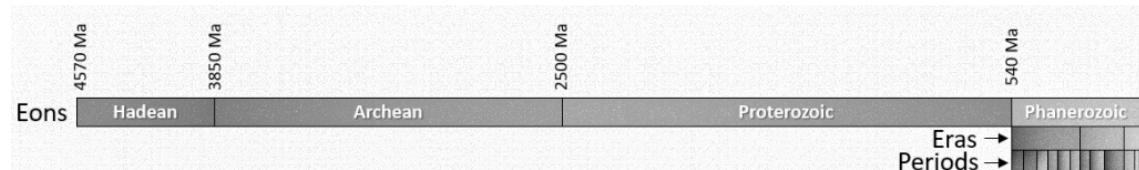
In recent years it has become more common to use the non-religious terms CE meaning "common era" and BCE meaning "before the common era."

Astronomers use the exact time of noon, 1 Jan. 2000 as their epoch in synchronising clocks.

- An era, aside from its other meaning of 1,000,000,000 years, is a long period of time starting at an epoch or at some other important date.

The Edwardian era started with the coronation of King Edward and ended with his death, for example.

- Geological time, measuring the entire age of this planet, is divided up into:
 - 4 eons, each from several hundred million years to two billion years long
 - 10 eras, each from tens to hundreds of millions of years long
 - 22 periods, each from millions to tens of millions of years long
 - 37 epochs, each from hundreds of thousands of years to tens of millions of years long
 - 96 ages, each from thousands to millions of years long



A Mega annum (Ma) means a period of a million years

64. Describe how the hands on a clock work to indicate hours, minutes, and seconds.
65. Explain the concept of "a quarter past," "half past," and "a quarter to" the hour.
66. How would you convert 500 seconds to minutes?
67. How many weeks are in a year?
68. Why is the metric system for time not decimal?
69. What historical attempt was made to introduce a decimal metric system for time? Why don't you think it became widespread?
70. What are leap years? Why are they needed?
71. What does a month have to do with the phases of the moon?
72. How could you remember how many days are in each month?
73. What is an era and an epoch?
74. What is geological time, and how is it measured?

The Imperial System

The imperial system of measurement was used and spread by the British Empire, though these countries and most of the world now use the metric system. Imperial units are much older than metric and require an ability to work with various fractions and multiples. The USA still uses imperial units, slightly modified, which they call United States customary units.

Length

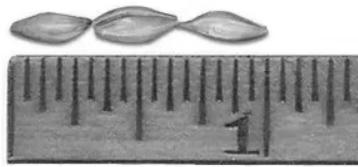
Inch (in), Foot (ft), Yard (yd), Mile (mi): The basic units of length in the imperial system.

- A foot (ft) is, of course, based on the length of a foot.



- An inch (in) is $\frac{1}{12}$ of a foot.

The inch was also once said to be the width of the King's thumb, or the length of three barley seeds laid end to end.



Lengths smaller than an inch are usually given in fractions of an inch such as half inches, quarter inches, eighths of inches, and so on.

An apostrophe is used as an abbreviation for feet, and a double apostrophe for inches. 6'3" means 6 feet and 3 inches.

- A yard (yd) is 3 feet.

Various metal rods of exact length have been used as yardsticks and kept as standards by the monarch or his officials over the centuries.

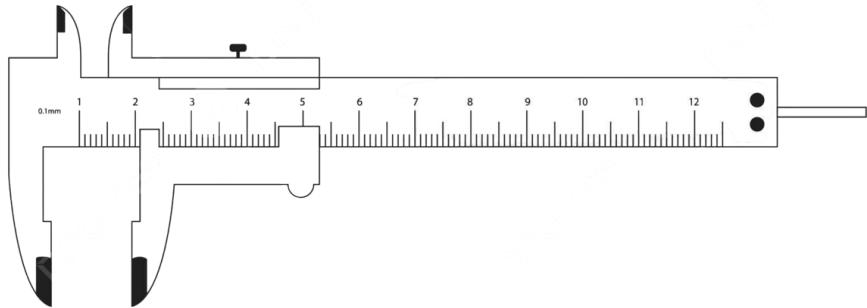


- A mile (mi) is 5,280 feet or 1,760 yards.



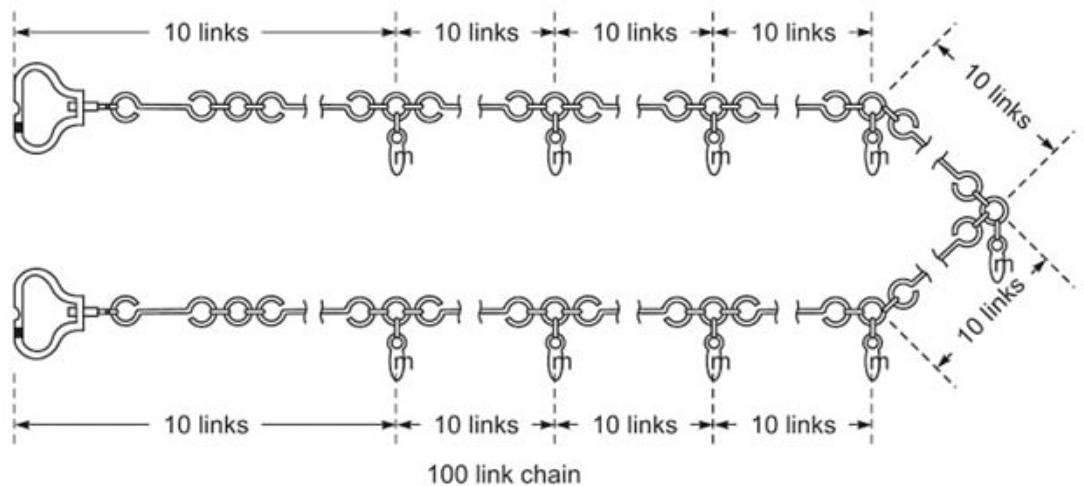
This was originally 1000 paces of a Roman soldier.

75. Find a ruler or tape measure that is marked in feet and inches.
Get a good idea of how long is an inch and a foot.
 76. Measure the length of your foot in inches and fractions of an inch.
 77. Measure you height in feet and inches.
 78. Make a yardstick by marking a length of 3 feet on a stick.
 79. Use your yardstick to measure the length, in yards, of the walls of the room you are in.
 80. Look on a map and find how many miles it is from your house to the nearest beach.
- There are other less commonly used imperial units of length:
 - A mil or a thou is $\frac{1}{1000}$ of an inch.



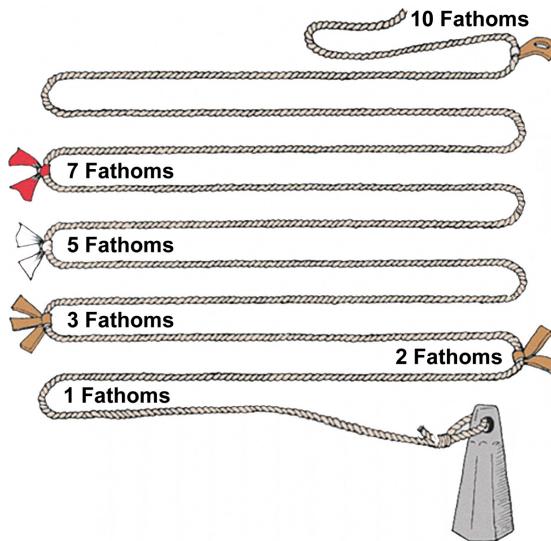
Machinery is often built to this very precise measurement, measured by tools such as these calipers.

- A chain is 4 rods or 22 yards (once used in surveying land.)

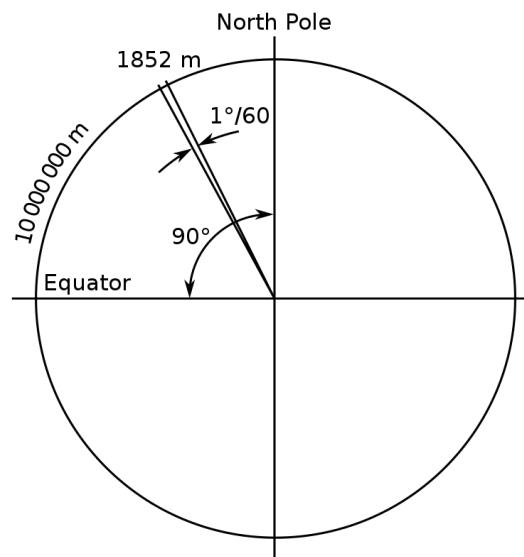


There are 80 chains to a mile.

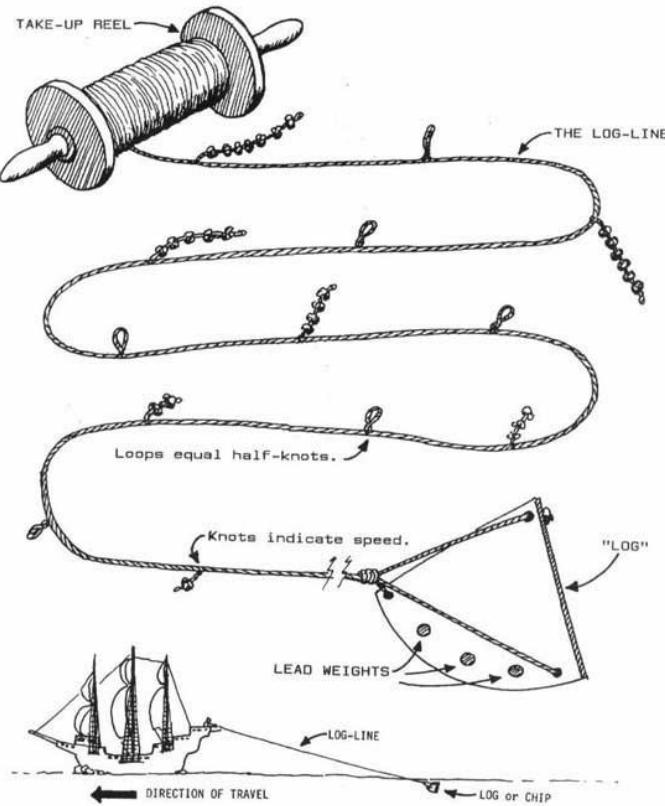
- A link is $\frac{1}{100}$ of a chain (7.92".)
- A rod (also called a pole or perch) is 25 links or $5\frac{1}{2}$ yards.
- A fathom is 6 feet. Also the distance between finger tips with arms spread. Originally the fathom was used to measure land and was equal to one pace (two steps.) It came to be only used to measure water depth at sea, which was done by dropping a lead weight on a marked rope.



- A cable is 100 fathoms or $\frac{1}{10}$ of a nautical mile.
- A nautical mile (nm), used for measuring distances at sea and in aviation, is 1,852 metres or 6076 feet. There are 1.852 km to 1 nm. Originally, a nautical mile was defined as $\frac{1}{60}$ of a degree of latitude at the equator so that the Earth's circumference is $60 \text{ minutes} \times 60 \text{ degrees} = 21,600 \text{ nautical miles}$.



- A knot, the unit of speed used by water and air craft, is a speed of 1 nautical mile per hour.



The knot gets its name from sailors measuring their speed by dropping a log on the end of a knotted rope and counting how many knots along the rope were pulled into the water in a set length of time. The result was entered daily into the "log" book to track how far the ship had travelled.

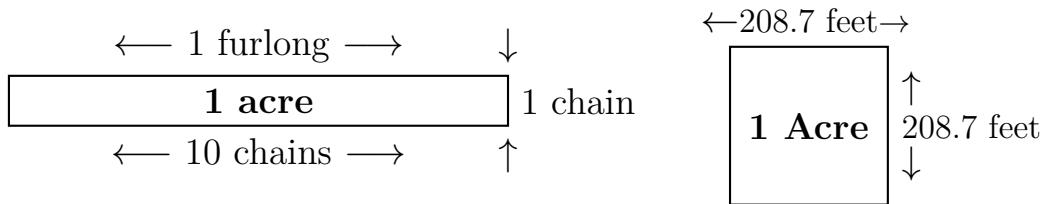
- A league is 3 miles. It is roughly how far a person can walk in an hour.

Land Area

Acre The imperial unit used to measure the size of land.

- An acre was originally the amount of land that could be ploughed by a team of oxen in a single day. It is still the basic unit of land area in the imperial system.

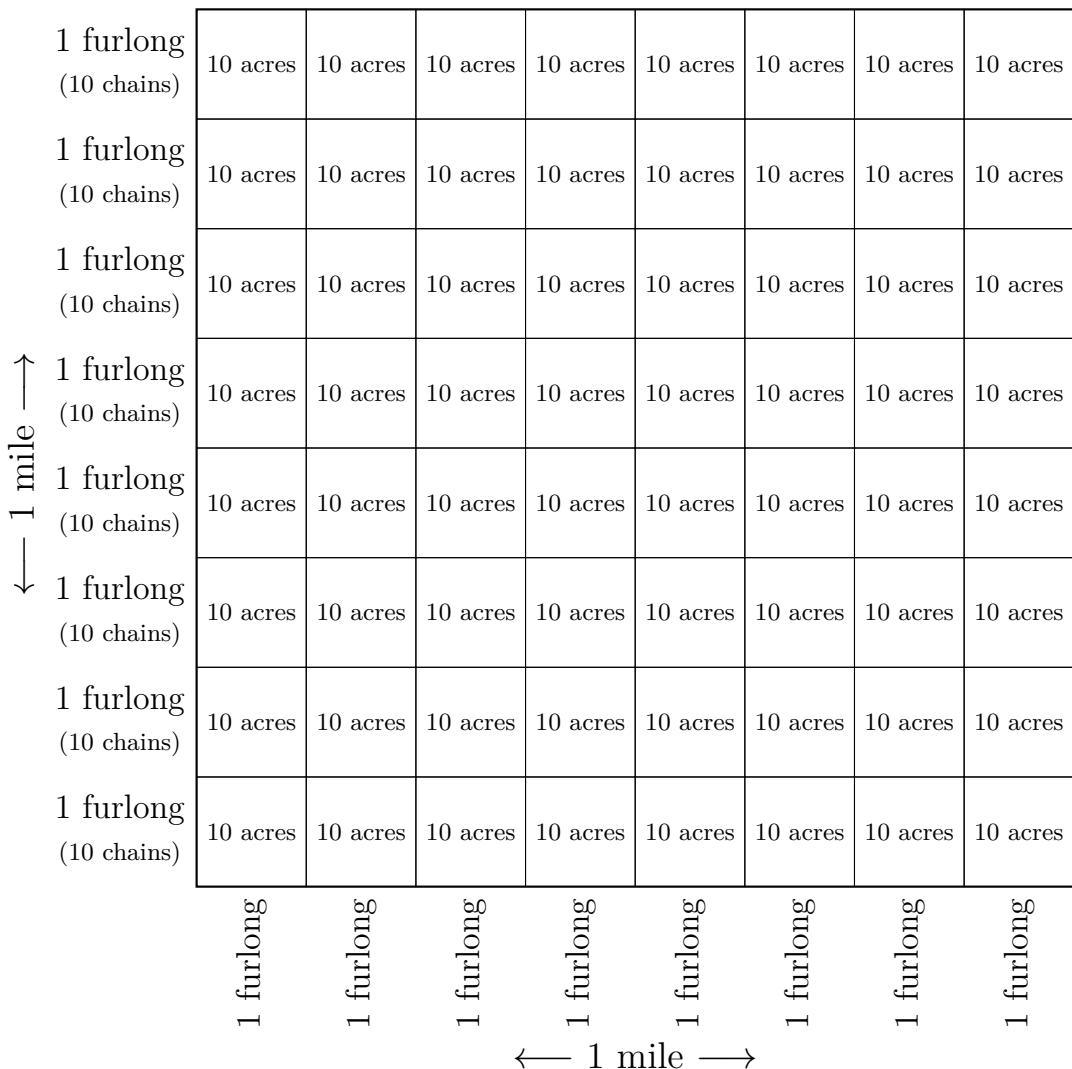




Other historic measures of land area were:

- A rood was a quarter of an acre.
- An oxgang was the amount of land that an ox could plough during a season, which was around 15 acres.
- A virgate was the amount of land that two oxen could plough during a season, which was around 30 acres.
- A carucate was the amount of land that a team of eight oxen could plough during a season, which was around 120 acres.
- Furlong means "furrow long" which was the length that a team of oxen could plough without resting. A furlong is 10 chains (220 yards) long. There are 8 furlongs to a mile.
- Horse races are sometimes still measured in furlongs.
- An acre is an area of one furlong by one chain, 10 square chains, 4840 square yards, or a square of 208.7 feet to a side.
- An acre is a furlong (10 chains) by a chain, so there are 10 acres in a square furlong. There are 8 furlongs to a mile so a square mile, also called a section, is 8 by 8 square furlongs which is 640 acres. Land is often divided up into various fractions of a section.

1 Section = 1 Square Mile = 640 Acres



75. How big is an acre in square yards?
 76. What is a furlong?
 77. How many yards are in a furlong?
 78. How big is a section of land?
 79. How many acres are in a section of land?

Volume

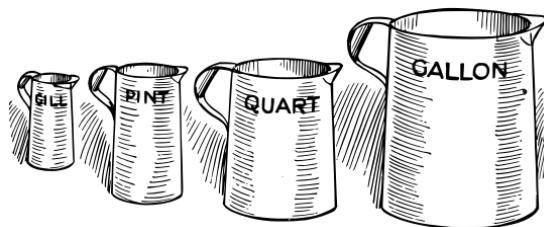
Gallon (gal), Quart (qt), Pint (pt), Fluid Ounce (fl oz):

- A gallon \approx 154 fluid ounces or \approx 277 cubic inches.

A US gallon is 128 fluid ounces or 231 cubic inches.

It was originally the volume of 10 pounds of water.

- A quart is $\frac{1}{4}$ of a gallon.
- A pint is $\frac{1}{2}$ of a quart.
- A gill is $\frac{1}{4}$ of a pint.
- A fluid ounce is $\frac{1}{20}$ of a pint.
 - In the US a fluid ounce is $\frac{1}{16}$ of a pint.



80. Find a bucket and fill it with a gallon of water. Get a good idea of just how much water is in a gallon.
 81. Tip out half of the water from the bucket. Then tip out half again. What volume of water is left in the bucket?
 82. How many quarts are in a gallon?
 83. Tip your quart of water into a bottle. Then tip out half. What volume of water is left in the bottle?
 84. How many pints are in a quart? item How many pints are in a gallon?
 85. Tip your pint of water into a cup. Then tip out half of that pint. Then tip out half again. What volume of water is left in the cup?
 86. How many gills are in a pint?
 87. Tip out half of your gill of water. Then tip out half again. What volume is left in the cup?
 88. How many US fluid ounces are in a pint?
- The US has fluid and dry volumes.
 - A dry gallon \approx 269 cubic inches.
It was originally the volume of 8 pounds of wheat.

- A peck is 2 dry gallons.

Remember "Peter Piper picked a peck of pickled peppers"?

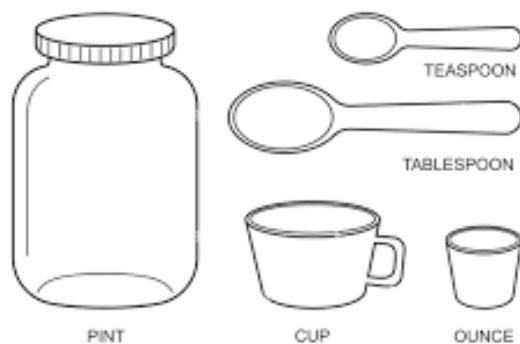
- A bushel is 8 dry gallons.



89. What is the difference between dry volume and fluid volume?
90. How big is a dry gallon?
91. How big is a peck?
92. How big is a bushel?

Cooking

- A cup is $\frac{1}{2}$ of a pint or 8 fluid ounces.
- A stick is half a cup. (Sticks are usually referring to amounts of butter.)
- A tablespoon is $\frac{2}{3}$ of a fluid ounce.
In the US a tablespoon is $\frac{1}{2}$ of a fluid ounce.
- A dessert spoon is $\frac{1}{2}$ of a tablespoon.
- A teaspoon is $\frac{1}{3}$ of a tablespoon.
A teaspoon is $\frac{1}{4}$ of a tablespoon in Australia.



80. Measure out half a pint of water into a cup and get a good idea of the volume of a standard cup measure.

81. Tip out half of the water from the cup and get a good idea of the volume of a stick.
82. How many sticks are in a cup?
83. Measure out a tablespoonful of water.
84. In the US, how many tablespoons are in a fluid ounce?
85. Measure out a dessert spoon full of water.
86. How many dessert spoons are in a tablespoon?
87. Measure out a teaspoon full of water.
88. In Australia, how many teaspoons are in a tablespoon?

Casks

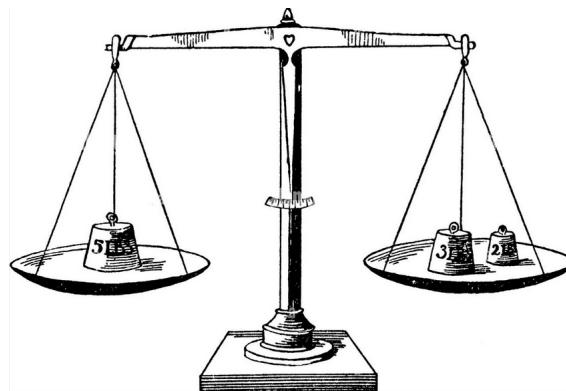
- A Tun is a cask of 252 wine gallons. That is about 210 imperial gallons. A wine gallon, used for measuring wine, honey, or cooking oils, was 128 fluid ounces.
- A Pipe or Butt is $\frac{1}{2}$ a Tun.
- A Puncheon or Tertian is $\frac{1}{3}$ of a Tun.
- A Hogshead is $\frac{1}{4}$ of a Tun.
- A Tierce is $\frac{1}{6}$ a Puncheon, $\frac{1}{3}$ of a Butt, or $\frac{1}{6}$ of a Tun. (The Tierce is related to the size of modern oil barrels.)
- A Barrel is $\frac{1}{2}$ a Hogshead or $\frac{1}{8}$ a Tun.
- A Rundlett is $\frac{1}{7}$ of a Butt or $\frac{1}{14}$ of a Tun.
- A beer barrel is 36 imperial gallons or 43 US gallons.
- In the oil industry, an oil barrel (bbl) is 35 imperial gallons or 42 US gallons. This unit can be given metric prefixes such as kbbl for a kilobarrel of oil (1000 barrels.)



Mass

Ounce (oz), Pound (lb):

Known as the "avoirdupois" weight system, French for "goods of weight," originally referring to goods sold in bulk by weight and not by item.



- **Pound (lb)** The pound has a long and complicated history with various sorts of pounds being used for different purposes.
 - The abbreviation "lb" is used because the pound comes from an even earlier Roman unit of weight called the libra.
 - The word pound comes from the Latin phrase libra pondo, meaning "the weight measured in libra."
- **Ounces (oz)** An ounce is $\frac{1}{16}$ of a pound.
 - An ounce of water has a volume of one fluid ounce.
 - The abbreviation "oz" is from the Italian word for ounce, "onza."

There are some other less commonly used imperial units of weight:

- **Stone (st)** One stone weighs 14 pounds.
 - Body weight is often given in stones and pounds, although in the US usually only pounds are used.
 - The plural of stone is stone, not stones.
- **hundredweight (cwt)** There are 8 stone to a hundredweight, or 112 pounds. This is the long hundredweight.



- The US and Canada use the short hundredweight of 100 pounds.
- **Ton (t)** There are 20 hundredweight or 2240 pounds to a ton. This is known as the imperial ton or the long ton.
 - In the US and Canada there are 2000 pounds to a ton, called the short ton.



This same word, ton, is used for large weights in both the metric and imperial systems so the ton is often specified either as a metric ton or an imperial ton. Also, the metric ton is spelled "tonne," although this is often not done.

89. Put a jug on some weighing scales and measure out a pound of water. Pick it up and get a good idea of how heavy a pound is.

90. Tip out half of that pound of water, four times. You should now have an ounce of water left. Can you feel the weight of a single ounce?
91. How many ounces are in a pound?
- **Troy Weight** Troy weight is used for precious metals.



- There are 24 grains to a pennyweight, 20 pennyweights to a troy ounce, and 12 troy ounces (oz t) to a troy pound.
- A troy ounce is about 1.1 times heavier than an avoirdupois ounce.



- The name probably comes from the French town of Troyes where English merchants traded.
92. What is Troy weight?
93. How does a Troy ounce compare to a normal ounce?
94. What sorts of things would be measured in Troy weight?

- **Carats** are units of mass used to measure gemstones and pearls.



- Before the metric system came into use, a carat was defined as $\frac{1}{12 \times 12 \times 12} = \frac{1}{1,728}$ of a pound.
- Carat (c or Ct) is also used as a measure of the purity of gold, with 24 being pure gold. A system evolved where one carat referred to $\frac{1}{24}$ of a total weight. 18 carat gold, for example, is 18 parts gold and 6 parts other metals. US spelling is karat (k or Kt).



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95. What is a Carat?

96. What sorts of things would be weighed in carats?

97. How pure is 24 carat gold?

- **Apothecaries' Weights** Apothecaries were what are now called pharmacists or chemists, whose job was to prepare and dispense medicines. Their system of weights and volumes for this purpose goes back to the Roman Empire and was still in use until fairly recent times. Many variations of this have existed.



It consisted of pounds, ounces, drams, scruples, and grains, with special symbols used to represent each unit.

- A pound (**lb**) consisted of 12 ounces.
- An ounce (**ʒ**) was made up of 8 drams or drachms.
- A dram (**ʒ**) was made of 3 scruples.
- A scruple (**ʒ**) was made of 20 grains (gr.).

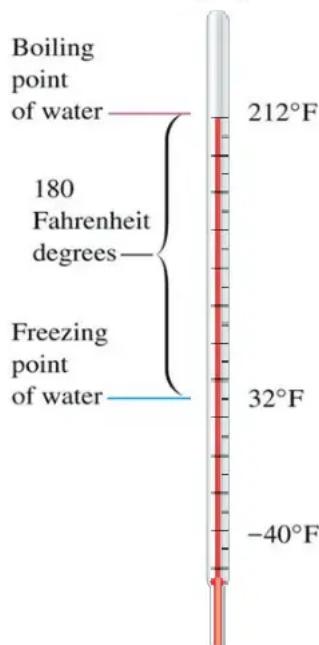
The volume of an apothecaries' ounce of water was called a fluid ounce (**fʒ**), divided into fluid drams (**fʒ**) and fluid scruples (**fʒ**). Fluid grains were minims (**m**). A minim was one drop of liquid.

There were also unofficial apothecaries' measures such as:

- Tumbler 8 **fʒ**
- Breakfast cup 8 **fʒ**
- Tea cup 5 **fʒ**
- Wine glass 2 **fʒ**
- Table spoon $\frac{1}{2}$ **fʒ**
- Dessert spoon 2 **fʒ**
- Tea-spoon 1 **fʒ**

Temperature

- **degrees Fahrenheit ($^{\circ}\text{F}$)** Imperial unit for measuring temperature, named for its inventor Daniel Farenheit.



- 0 $^{\circ}\text{F}$ is said to have been originally defined as the lowest winter temperature in Danzig, Poland, where Daniel Farenheit was born. 30 $^{\circ}\text{F}$ was the melting point of ice, and 90 $^{\circ}\text{F}$ was normal human body temperature.
 - The scale was later adjusted so ice melts at 32 $^{\circ}\text{F}$ and body temperature is 96 $^{\circ}\text{F}$ allowing 64 intervals to be marked between them. Water boils at 212 $^{\circ}\text{F}$ on this scale, exactly 180 degrees higher than the freezing point, which then put normal body temperature at 98.6 $^{\circ}\text{F}$.
 - Room temperature on the Farenheit scale is 68 $^{\circ}\text{F}$.
 - Temperature in the US is given in degrees Farenheit.
98. What is the Farenheit temperature scale?
99. At what temperature does water freeze on the Farenheit scale?
100. At what temperature does water boil on the Farenheit scale?
101. What is normal body temperature on the Farenheit scale?

Time

Imperial units for measuring time are the same as used by the metric system.

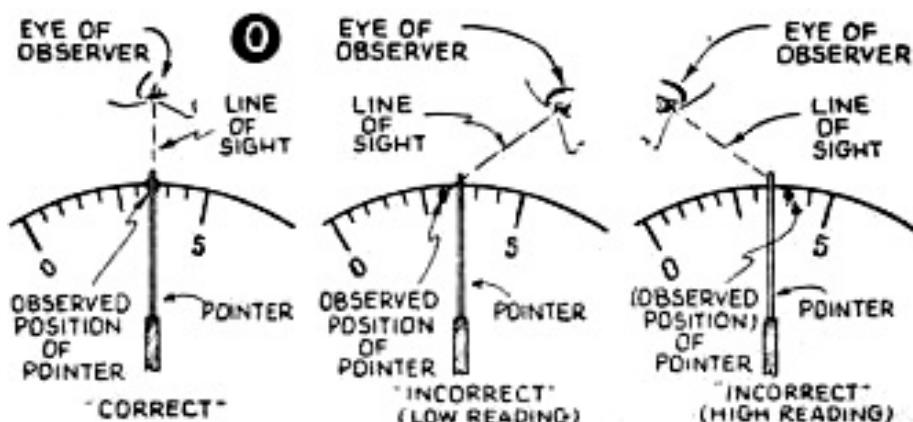
Reading Scales

Measuring tools such as:

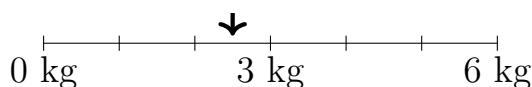
- rulers for measuring length
- jugs with lines for measuring volume
- scales for weighing
- thermometers for measuring temperature
- clocks for measuring time

all use scales that have to be read.

When reading a scale that uses a pointer above a scale, because there is usually some distance between the scale and the pointer, always be sure to keep your eye directly above the pointer or you will read the wrong value.



1. Read this weighing scale.



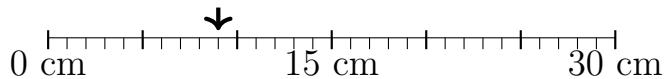
The weight indicated by the pointer is _____ kg.

2. Read this outdoor thermometer.



The temperature indicated by the pointer is _____ °C.

3. What length is shown by the pointer on this ruler?



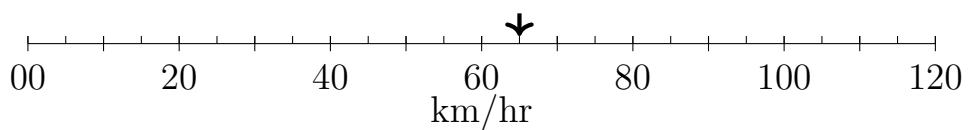
The length indicated by the pointer is _____ cm.

4. Read this tape measure.



The length indicated by the pointer is _____ m.

5. Read the speedometer. How fast are we going?.



The speed indicated by the pointer is _____ km/h.

Converting between Metric and Imperial Units

Length

Imperial to Metric

$$1 \text{ mile} \approx 1.61 \text{ kilometres}$$

$$1 \text{ yard} \approx 0.91 \text{ metres}$$

$$1 \text{ foot} \approx 30.48 \text{ centimetres}$$

$$1 \text{ inch} \approx 2.54 \text{ centimetres}$$

1. Convert 3 miles to kilometers.
2. How many meters are there in 10 yards?
3. If a room is 15 feet long, what is its length in meters?

Metric to Imperial

1 kilometres \approx 0.62 miles

1 metre \approx 1.09 yards

1 centimetre \approx 2.54 inches

1. Convert 2 kilometers to miles.
2. How many feet are there in 5 meters?
3. If a board is 3 meters long, what is its length in feet?

Area

Imperial to Metric

1 acre \approx 0.4 hectares

1. Convert 5 acres to hectares.
2. If a field is 2 hectares, what is its area in acres?

Metric to Imperial

1 hectare \approx 2.47 acres

1. Convert 3 hectares to acres.
2. If a garden is 4 acres, what is its area in hectares?

Volume

Imperial to Metric

1 gallon \approx 4.55 litres

1 quart \approx 1.14 litres

1 pint \approx 0.57 litres

1. Convert 2 gallons to litres.
2. How many millilitres are there in 3 pints?
3. If a bottle is 500 millilitres, how many fluid ounces is that?

Metric to Imperial

1 litre \approx 0.22 gallons
1 litre \approx 0.26 US gallons
1 litre \approx 1.06 quarts
1 litre \approx 2.11 pints

1. Convert 1.5 litres to US gallons.
2. How many fluid ounces are there in 750 millilitres?
3. If a jug is 2 quarts, what is its volume in millilitres?

Mass

Imperial to Metric

1 ton \approx 1016 kilograms
1 US ton \approx 907 kilograms
1 pound \approx 0.45 kilograms
1 ounce \approx 28.35 grams

1. Convert 1.5 tons to kilograms.
2. How many grams are there in 8 pounds?
3. If a bag weighs 2.5 pounds, what is its mass in kilograms?

Metric to Imperial

1000 kilograms \approx 0.98 tons
1000 kilograms \approx 1.1 US tons
1 kilogram \approx 2.2 pounds
1 gram \approx 0.035 ounces

1. Convert 600 kilograms to tons.
2. How many ounces are there in 3.5 kilograms?
3. If a box is 2 kilograms, what is its weight in pounds?

Temperature

Celsius to Fahrenheit

To convert Celsius to Fahrenheit, use the formula:

$$F = \frac{9}{5}C + 32$$

1. Convert 25 degrees Celsius to Fahrenheit.
2. If it's 68 degrees Fahrenheit, what is the temperature in Celsius?

Fahrenheit to Celsius

To convert Fahrenheit to Celsius, use the formula:

$$C = \frac{5}{9}(F - 32)$$

1. Convert 98.6 degrees Fahrenheit (body temperature) to Celsius.
2. If the temperature is 20 degrees Celsius, what is it in Fahrenheit?

Choosing Appropriate Units

1. When would you use kilometers instead of miles for measuring distance?
2. Where is it more appropriate to use hectares instead of acres for area?
3. Why might someone use litres instead of gallons when measuring volume?
4. If you were measuring the height of a person, would you use centimeters or kilometers?
5. When expressing the length of a swimming pool, which unit is more suitable: meters or millimeters?
6. You are measuring the area of a small kitchen floor. Would you prefer square feet or square inches?
7. In measuring the capacity of a water bottle, which unit is more practical: milliliters or liters?

8. When weighing a truck at a weighbridge, should you use kilograms or grams?
9. In a long-distance bicycle race, would you measure the distance in miles or feet?
10. If you were measuring a notebook cover, which unit would you use: centimeters or kilometers?
11. When talking about the volume of a swimming pool, which is more convenient: gallons or quarts?
12. If you were weighing a bag of apples, would you express the weight in tons or grams?

Conclusion

Measurements are an integral part of our lives, helping us make sense of the world in quantitative terms. Understanding metric and imperial units, common measuring devices, and how to read scales will empower you to navigate the dimensions of the world with confidence.