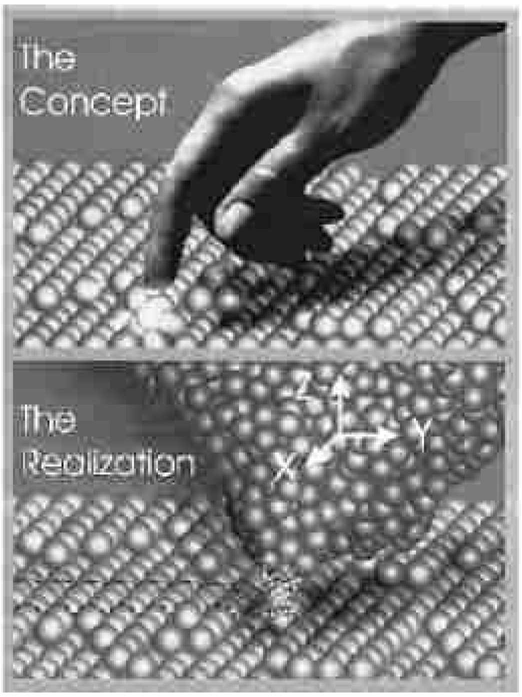
Chapter 1 Physics and Measurement

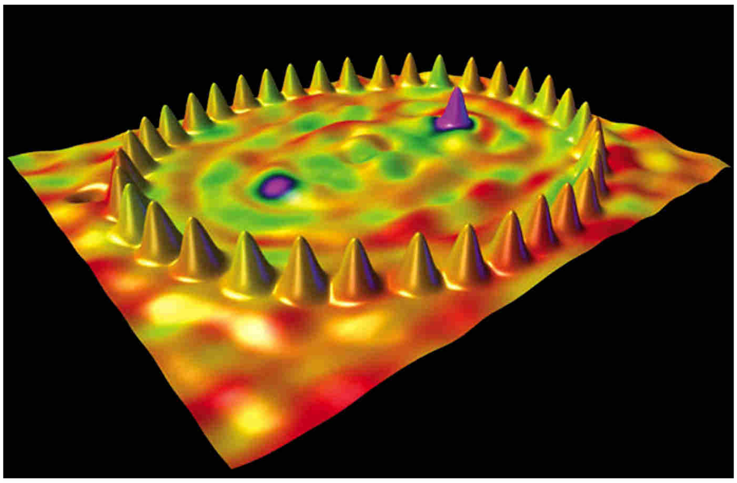
We have always been curious about the world around us.

Classical Physics – It constructs the concepts Galileo (1564-1642) and Newton's space and time. It includes mechanics (rotation), light, heat (James Joule, Sadi Carnot), sound, electricity and magnetism (James Maxwell)

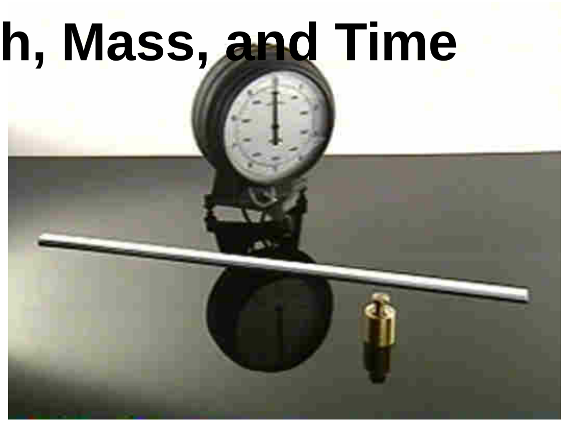
Modern Physics – The application of special relativity, and particularly quantum theory, to such microscopic systems as atoms, molecules, and nuclei, which has led to a detailed understanding of solids, liquids, and gases, is often referred to as modern physics.

Recording / Measurement – Compare with a standard length, mass, or time





1.1 Standard of Length, Mass, and Time



The International System of Units:

SI system: meter, kilogram, second

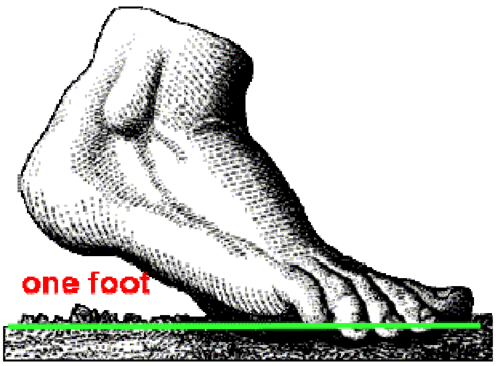
<u>Appendix A (The English System)</u>

1 inch = 2.54 cm, 1 ft = 30.48 cm

1 mi = 1.609 km

1 lb = 0.454 kgw

1 atm = 14.7 lb/in.^{2} (PSI) = 760 mmHg = 101325 Pa (N/m^2) ~ 1 kgw/cm^2

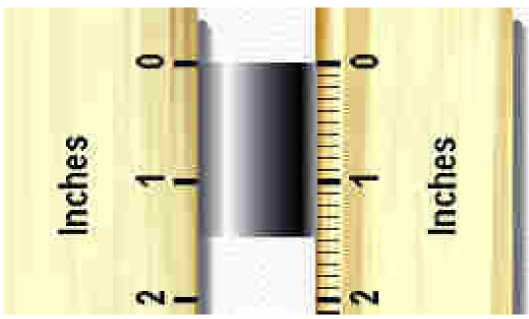


The English system of measurement grew out of the creative way that people measured for themselves. Familiar objects and parts of the body were used as measuring devices. For example, people measured shorter distances on the ground with their feet.

Length:

Distance traveled by light in a vacuum during a time of 1/299 792 458 second.

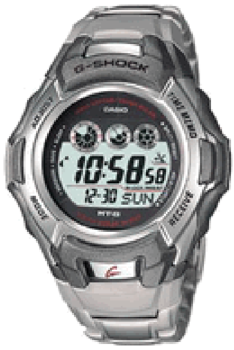
Give the correct length measurement for the left and the right rulers.



Time:

Atomic clock: 9 192 631 770 times the period of oscillation of radiation from the cesium-133 atom.

Radio Controlled Exact Set Atomic Projection, Alarm and Wall Clocks from Oregon Scientific, Casio, La Crosse Technology and more.
Radio controlled clocks or "Atomic Clocks" keep perfect time by automatically synchronizing to the radio signal emitted from the U.S. Atomic Clock in Colorado. Radio controled clocks reset daily to the split second, and adjust automatically to Daylight Savings Time, Leap Year and Time Zone Changes.



Scientists have manufactured the world's smallest atomic clock, with inner machinery about the size of a grain of rice. Requiring very little power to run, the device loses only one second every 300 years and could one day provide precise timekeeping for portable applications such as wireless communication devices and Global Positioning System (GPS) receivers. Like other atomic clocks, the new design relies on the natural vibrations of cesium atoms, which “tick” 9.2 billion times each second. John Kitching of the National Institute of Standards and Technology and his colleagues trapped cesium vapor inside a chamber that is probed by a tiny laser, resulting in two electromagnetic fields. The team then adjusted the fields until the difference between them equaled that of the energy levels within the cesium atoms, causing the atoms to stop absorbing or emitting light. An external oscillator was then stabilized against the natural resonance frequency of cesium. “The real power of our technique is that we're able to run the clock on so little electrical power that it could be battery operated and that it's small enough to be easily incorporated into a cell phone or some other kind of handheld device”, explains Kitching. “And nothing else like it even comes close as far as being mass producible.”

Image: NIST

測日法：

主要是堆八尺高的土堆或豎八尺高的標竿（圭表），在白天的一定時間，也就是太陽照到了一定的角度，對標竿所照日影長度即晷景進行記錄。晷景的長短在一年四季中變化不一，並對節氣有所指示。夏至時日影長為一尺六寸，冬至時為十三尺五寸，這是永世不變的。冬至由長變短，夏至由短變長，故有冬至一陽生，夏至一陰生的概念。中國農諺有〝冬至至長，夏至至短〞之說，指的是，一過了冬至，白晝的時間開始變長，而一過夏至，白晝的時間就逐漸變短；春分、秋分則是晝夜長度相等，其晷景也相同，故稱之為「分」。由於用圭表測日影稱為晷景，故有〝卦者，推究其晷景也〞之論（許慎著《說文解字》）。這也更可證明《易經》測日影的卜卦與後人算命的卜卦是不同的兩回事。

Mass:

Kilogram is defined as the mass of a specified platinum-iridium alloy cylinder kept at the International Bureau of Weights and Measures at Sevres, France.

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You Must Know:

Length:

Mean radius of Earth: 6400 km, 6.4×10^6 m

Diameter of a hydrogen atom: 10^{-10} m, r = 0.529 angs

Diameter of a proton: 10^{-15} m

Mass:

Human: 7×10^1 kg

Hydrogen atom: $1 * 10^{-3} / 6.02 * 10^{23} = 1.67 * 10^{-27}$ kg

Time:

One day: $8.64 * 10^4$

10^{-18}: atto

10^{-15}: femto

10^{-12}: pico

10^{-9}: nano

10^{-6}: micro

10^{-3}: mili

10^{3}: kilo

10^{6}: mega

10^{9}: giga

10^{12}: tera

10^{15}: peta

Density and Atom Mass

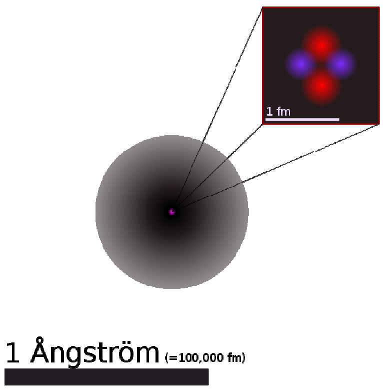
Density: $\rho = m / V$

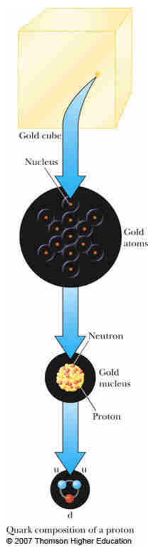
Gold: $19.3 * 10^3$ kg / m^3 = 19.3 g / cm^3

Lead: 11.3 * 10^3 kg / m^3 = 11.3 g / cm^3
Copper: 8.93 * 10^3 kg / m^3 = 8.93 g / cm^3
Aluminum: 2.7 * 10^3 kg / m^3 = 2.7 g / cm^3

Example: A solid cube of aluminum has a volume of 0.200 cm^3. It is known that 27.0 g of aluminum contains 6.02 * 10^{23} atoms. How many atoms are contained in the cube?

1.2 Matter and Model Building





Quarks: up, down, strange, charmed, bottom, and top
You should develop a process of building models as you study physics.

1.3 Dimensional Analysis

$v_f = v_i + at$
v has a dimension of L / T
a has a dimension of L / T^2

Quantity	Symbol	Dimension
Area	A	L^2
Volume	V	L^3
Speed	v	L/T
Acceleration	a	L/T^2
Force	f	ML/T^2
Pressure	p	M/LT^2
Density	d	M/L^3

Energy	E	ML^2/T^2
Power	P	ML^2/T^3

Example:

$$a = kr^n v^m , \quad \frac{L}{T^2} = L^n \left(\frac{L}{T}\right)^m \rightarrow n + m = 1, \quad m = 2$$

1.4 Conversion of Units

$$15.0in. = (15.0in)(\frac{2.54cm}{1in}) = 38.1cm , \quad 240km = (240km)\left(\frac{1mi}{1.61km}\right) = 149mi$$

Example: A car is traveling with a speed of 38.0 m/s. Is the driver exceeding the speed limit of 75.0 mi/h?

$$38\frac{m}{s} = 38\frac{m}{s}\frac{1mi}{1609m}\frac{3600s}{1h} = 85\frac{mi}{h}$$

1.5 Estimates and Order-of-Magnitude Calculation

1. Express the number in scientific notation, with the multiplier of the power of ten between 1 and 10.
2. If the multiplier is less than $\sqrt{10} = 3.162$ (the square root of ten), the order of magnitude of the number is the power of ten in the scientific notation. If the multiplier is greater than 3.162, the order of magnitude is one larger than the power of ten in the scientific notation.

$$10^2 \times 10^3 = 100 \times 1000 = 100000 = 10^5$$

$$N_A = 6.02 \times 10^{23}$$

Example: In 12g of carbon, there are N_A carbon atoms. If you could count 1 atom per second, how long (in years) would it take to count the atoms in 1 g of carbon?

$$6.02 \times 10^{23} / 12 / 1(atom / s) / 86400 / 365 = 1.59 \times 10^{15}$$

$0.0086 \sim 10^{-2}$

1.6 Significant Figures

The significant figures include the first estimated digit.

Rule: multiplication & division – The number of significant figures in the result of multiplication or division is no greater than the least number of significant figures in any of the factors.

2.00 * 6.10 = 12.2

2.00 * 6.112 = 12.2

2.00 * 6.1 = 12

Rule: addition & subtraction – The result of addition or subtraction of two numbers has no significant figures beyond the last decimal place where both of the original numbers had significant figures.

1.001 + 0.003 = 1.004

1.001 + 0.2 = 1.201=1.2

Measurement	**Number of Significant Digits**	**Distance between Markings on Measuring Device**
142.7 g	4	1 g
103 nm	3	10 nm
2.99798 x 10^8 m	6	0.0001 x 10^8 m

Example: A rectangle has a length of 3.21±0.02 m and a width of 2.8±0.1 m. Please calculate the area.

$$(3.21 \pm 0.02)(2.8 \pm 0.1) = (3.21)(2.8) \pm (0.02)(2.8) \pm (0.1)(3.21)$$

$$= 8.988 \pm 0.377$$

$$= 8.988 \pm 0.377$$

$$= 9.0 \pm 0.4$$