Introduction to Measurements

EIE 240 Electrical and Electronic Measurement
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Exact and Measured Numbers

- Exact numbers e.g.
  I have exactly 10 fingers and 10 toes.
- Any measurements e.g. a pen's length
  Quickly measure → It is about 15 cm.
  More precise → It might be 15.5 cm.
  Even more precise → It would be 15.55 cm.

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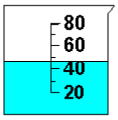
Significant and Estimated Digits

- In any measurements, the number of significant digits is the number of digits believed to be correct.
- It includes one estimated digit. A rule of thumb → read 1/10 of the smallest division for base-10 numeral system.



- e.g. Is the volume in this beaker 47 mL, 48 mL or 49 mL?
  All the answers are correct within the reading error ±1mL. We know the "4" for sure, but the trailing have to be estimated.

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Significant Digits

- Each recorded measurement has a certain number of significant digits or significant figures.
- Calculations done on these measurements must follow the rules for significant digits.
- Placeholders, or digits that have not been measured or estimated, are not considered significant.

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Rules for Significant Digits

- Leading zeros are never significant. The leftmost non-zero digit called the most significant digit, e.g. 00**1**45 0.00**5**2
- Imbedded zeros are always significant, e.g. 1020.045
- Trailing zeros are significant only if the decimal point is specified, e.g. 12.2300 1500 120.0 90.
- A mark may be placed on the last trailing zero if it is significant, e.g. 54<u>0</u>00

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Uncertainty in Calculation

- Measured quantities are often used in calculations. The precision of the calculation is limited by the precision of the measurements on which it is based.
- For adding or subtracting, the answer can only show as many decimal places as the measurement having the fewest number of decimal places, e.g. $4.7832 + 1.234 + 2.02 = 8.04$ (not 8.0372) Sometimes significant figures are lost while performing calculations.
- For multiplying and dividing, the answer may only show as many significant digits as the multiplied or divided measurement showing the least number of significant digits, e.g. $2.8723 \times 1.6 = 4.6$ (not 4.59568)

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Rounding, Truncating and Averaging

- The usual method is to round numbers with digits less than 5 down and numbers with digits greater than 5 up.
- If there is a 5, there is an arbitrary rule,
  if the number before the 5 is odd, round up, else let it be.
  Of course, if we round off 2.459 to 2 significant digits, the answer is definitely 2.4, since 2.459 is closer to 2.5 than 2.4!
- In some instances numbers are truncated, or cut short, rather than rounded.
- Sometimes numbers used in a calculation are exact rather than approximate, e.g. the average height of 30.1 cm, 25.2 cm and 31.3 cm is 86.6 / 3 = 28.9 cm. There are 3 significant digits in the heights even though you are dividing the sum by a single digit.

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Scientific Notation

- Scientific notation is the way that scientists easily handle very large numbers or very small numbers.

Number	Number of Significant Digits	Scientific Notation
0.00682	3	6.82×10^{-3}
1.072	4	1.072×10^{0}
300	1	3×10^{2}
300.	3	3.00×10^{2}
300.0	4	3.000×10^{2}

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Prefixes

e.g.	Abbreviation	Meaning
• Pico	p	$\times 10^{-12}$
• Nano	n	$\times 10^{-9}$
• Micro	μ	$\times 10^{-6}$
• Milli	m	$\times 10^{-3}$
• Centi	c	$\times 10^{-2}$
• Deci	d	$\times 10^{-1}$
• Deca	da	$\times 10^{1}$
• Hecto	h	$\times 10^{2}$
• Kilo	k	$\times 10^{3}$
• Mega	M	$\times 10^{6}$
• Giga	G	$\times 10^{9}$
• Tera	T	$\times 10^{12}$

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SI Unit System

Le Système International d' Unités
(7-Base in 1960)

- Mass (kilogram, kg)
- Length (meter, m)
- Time (second, s)
- Current (Ampere, A)
- Temperature (Kelvin, K)
- Luminous Intensity (Candela, cd)
- Amount of Substance (mole, mol)

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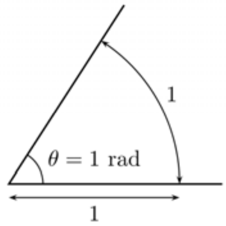
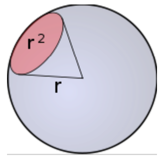
Supplementary Units

- Plane Angle (radian, rad)
  θ = Arc Length / Radius   m/m



- Solid Angle (steradian, sr)
  Ω = Surface Area / Radius^2 m^2/m^2



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Derived Units

e.g.

- Area (m^2)
- Velocity (m/s)
- Frequency (Hertz, Hz = 1/s)
- Force (Newton, N = kg·m/s^2)
- Energy (Joule, J = N·m = kg·m^2/s^2)
- Power (Watt, W = J/s = kg·m^2/s^3)
- Pressure (Pascal, Pa = N/m^2)
- Celsius temperature (°C = K – 273.15)
- Luminous flux (Lumen, lm = cd·sr)
- Illuminance (Lux, lx = lm/m^2)

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Electrical Units

e.g.

- Electric Charge (Coulomb, C = A·s)
- Potential Difference (Volt, V = W/A)
- Capacitance (Farad, F = C/V)
- Resistance (Ohm, Ω = V/A)
- Conductance (Siemens, S = A/V)
- Magnetic flux (Weber, Wb = V·s)
- Inductance (Henry, H = Wb/A)

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Dimensional Analysis

Dimensional analysis, also called unit factor method, is a problem-solving method that uses the fact that any number can be multiplied by one without changing its value, e.g.

- Time in minutes, 1 min = 60 s
- Length in inches, 1″ = 2.54 cm
- Weight in pounds, 1 lb = 0.45359237 kg
- Volume in litres, 1 L = 1000 cc = 1000 cm^3

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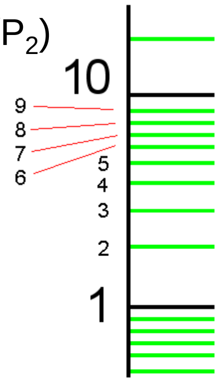
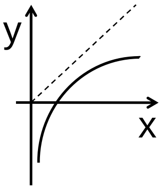
Decibels

The ratio between two values expressed on a logarithmic scale,
e.g. to the base-10 → $y = \log_{10}x$ or $x = 10^y$.

$$N_{bel} = \log(P_1/P_2)$$

$$N_{dB} = 10\log(P_1/P_2)$$





e.g. $10\log(10^{-1}) = -10$ dB

$10\log(10^{0}) = 0$ dB

$10\log(10^{1}) = 10$ dB

$10\log(10^{2}) = 20$ dB

Note: Natural log, $\ln = \log_e$ where $e = 2.718281...$

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References

- Science Help Online Chemistry, http://www.fordhamprep.org/gcurran/sho/sho/index.htm
- Math Skill Reviews: Significant Figures: http://www.chem.tamu.edu/class/fyp/mathrev/mr-sigfg.html

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"If someone separated the art of counting and measuring and weighing from all the other arts, what was left of each (of the others) would be, so to speak, insignificant."

Plato

(Greek philosopher, 427-347 BC)

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