Introduction to Measurements

EIE 240 Electrical and Electronic Measurement
Class 1: January 9, 2015
Werapon Chiracharit

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EIE 240 (2/2014)

Electrical and Electronic Measurements

WEEK 1: Introduction
WEEK 2: Measurement & Testing
WEEK 2: Sources of error
WEEK 3: Indicating instruments: DC
WEEK 4: Indicating instruments: AC
WEEK 5: Resistance Measurement & Multimeter
MIDTERM EXAM
WEEK 6: Bridge Method
WEEK 7: Component Measurement: Inductance
WEEK 8: Capacitance Measurement & Other Bridges
WEEK 9: Power & Energy Measurement
WEEK 10: Digital Electronic Meters
WEEK 11: Oscilloscope
WEEK 12: Transducers
FINAL EXAM

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Grading Criteria

• Homework & Quizzes	20%
• Midterm Exam	40%
• Final Exam	40%

Your letter grade is based on your final score relative to your classmates'

A general guideline: to avoid F, you should score $\geq$ 30%

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Class Materials & References

- My homepage
  http://webstaff.kmutt.ac.th/~werapon.chi/
- *Electronic Instrumentation and Measurements*, 2003, D. A. Bell
- *Electrical and Electronic Measurement and Testing*, 1992, W. Bolton
- *Electronic Instrumentation*, 2004, H. S. Kalsi
- *Student Reference Manual for Electronic Instrumentation Laboratories*, 2004, S. Wolf and R. F. M. Smith

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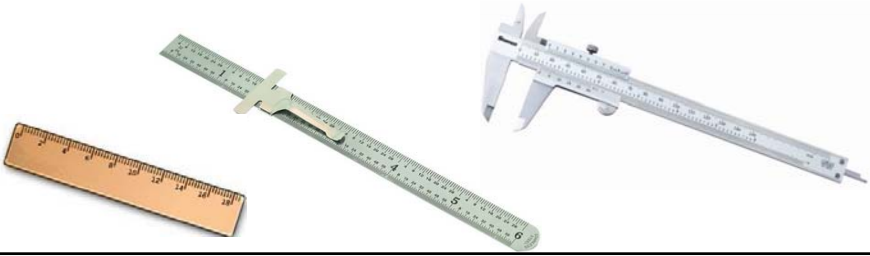
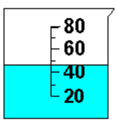
Exact and Measured Numbers

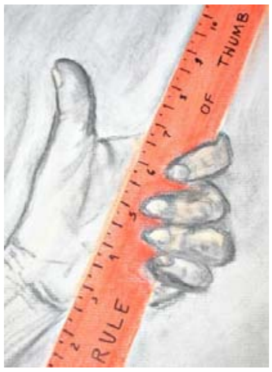
- Exact numbers e.g.
  I have exactly 10 fingers and 10 toes.
- Any measurements e.g. a pen's length
  Quickly measure → It is about 15 cm.
  More precise → It might be 15.5 cm.
  Even more precise → It would be 15.55 cm.



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.

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**145** 0.00**52**
- 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 × 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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Metric Prefixes

e.g.	Abbreviation	Meaning
• Pico	p	$\times10^{-12}$
• Nano	n	$\times10^{-9}$
• Micro	μ	$\times10^{-6}$
• Milli	m	$\times10^{-3}$
• Centi	c	$\times10^{-2}$
• Deci	d	$\times10^{-1}$
• Deca	da	$\times10^{1}$
• Hecto	h	$\times10^{2}$
• Kilo	k	$\times10^{3}$
• Mega	M	$\times10^{6}$
• Giga	G	$\times10^{9}$
• Tera	T	$\times10^{12}$

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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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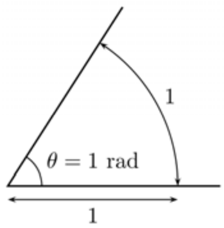
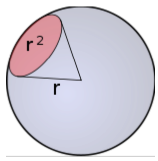
Supplementary Units

- 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 = J/C = 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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Definition of Electric Current

An electric current (Ampere) is a flow of electric charge (Coulomb per second).

In electric circuits this charge is often carried by moving electrons in a wire.

It can also be carried by ions in an electrolyte, or by both ions and electrons such as in a plasma.

The charge of an electron is approximately -1.602×10^{-19} C.

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Amount of Electric Current

How electrical current affects the human body?

An approximate general framework for shock effects is as follows:

Electric Current (1 second contact)	Physiological Effect of Electric Shock
1 mA	Threshold of feeling, tingling sensation.
10-20 mA	"Can't let go!" current - onset of sustained muscular contraction.
100-300 mA	Ventricular fibrillation, fatal if continued.

http://hyperphysics.phy-astr.gsu.edu/hbase/electric/shock.html

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Definition of Potential Difference

Electric potential (Volt) is the amount of work (Joule) needed to move a unit charge (Coulomb) from a reference point to a specific point against an electric field.

Voltage is the difference of electric potentials between those two given points in the space.

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Amount of Voltage

The numerical definition of voltage depends on context. For example, this is in the context of building wiring and the safety of electrical apparatus (IEC 60038 Voltage Standard).

IEC Voltage Range (for Supply System)	AC (V_{rms})	DC (V)	Defining Risk
Extra-low voltage	< 50	< 120	low risk
Low voltage	50-1000	120-1500	electrical shock
High voltage	> 1000	> 1500	electrical arcing

IEC stands for *the International Electrotechnical Commission.* 20

Definition of Electrical Resistance

The electrical resistance (Ohm) of a circuit component or device is defined as the ratio of the voltage (Volt) applied to the electric current (Ampere) which flows through it.

Whether or not a material obeys Ohm's law, its resistance can be described in terms of its bulk resistivity.

The resistivity, and thus the resistance, is temperature dependent.

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Amount of Resistivity

This is resistivity of various materials at measured 20 °C

Material	Example	Resistivity ($\Omega \cdot m$)
Superconductors	Mercury	0
Metals	Copper, Gold, Aluminium	> 10^{-8}
Semiconductors	Up to degree of doping	Variable
Electrolytes	Salt water, Nitric acid	Variable
Insulator	Wood, Air, Teflon	> 10^{16}

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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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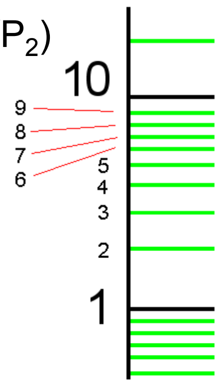
Decibels

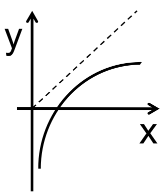
The ratio between two values expressed on a logarithmic scale,
e.g. to the base-10 → $y = \log_{10}x$ or $x = 10^y$.

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

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

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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Decibel to Voltage Gain and Loss

In electrical circuits, dissipated power is typically proportional to the square of voltage or current when the impedance is held constant.

If V_1 is the voltage being measured and V_2 is a specified reference voltage, the power gain expressed in decibels is as follows:

$$G_{dB} = 20 \log(V_1/V_2)$$

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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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