Physics Consolidation Notes

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Contents

Part I

Working as a Physicist

Chapter 1

Uncertainty

This refers to how precise a given measurement is, with an error amount. Usually, this is ± 1 of the smallest digit.

Example 1.0.1 Reading (**??**) Uncertainties

- $1.537g \longrightarrow 1.537 \pm 0.001g$
- $1.2g \longrightarrow 1.2 \pm 0.1g$

Definition 1.0.1: Uncertainty of Multiple Measurements

Example Equation	Uncertainty Equation
$A + B$ or $A - B$	$A_{\text{\|UC\|}} + B_{\text{\|UC\|}}$
$A * B$ or A/B	$A_{\%\text{UC}} + B_{\%\text{UC}}$
A^n	$A_{\%\text{UC}} * n$

1.1 Uncertainty in Graphs

To get the uncertainty in a Graph, we need to firstly draw the lines of best and worst acceptable fit. Then we can calculate the percentage difference between the gradients for the **gradient uncertainty**, as well as the percentage difference in the y intercepts to get the **y intercept uncertainty**.

Example 1.1.1 Gradient Uncertainty

Line of Best Fit:

x	y
1.7	0.41
1.975	0.85

$$m = \frac{0.85 - 0.41}{1.975 - 1.7} = 1.6$$

Line of Worst Acceptable Fit:

x	y
1.7	0.39
1.975	0.86

$$m = \frac{0.86 - 0.39}{1.975 - 1.7} = 1.7\ldots$$

Gradient Uncertainty:

$$\%m = \frac{|m_w - m_b|}{m_b} = \frac{|1.7 - 1.6|}{1.6} = \frac{0.1}{1.6} = 6.3\%$$

Example 1.1.2 Y-Intercept Uncertainty

Line of Best Fit:

x	y
1.7	0.41
1.975	0.85

$$c = 0.41 - (1.6 * 1.7) = -2.3$$

Line of Worst Acceptable Fit:

x	y
1.7	0.39
1.975	0.86

$$c = 0.39 - (1.709 * 1.7) = -2.5$$

Y-Intercept Uncertainty:

$$\%c = \frac{|c_w - c_b|}{|c_b|} = \frac{|-2.5 - -2.3|}{|-2.3|} = \frac{0.2}{2.3} = 8.7\%$$

Chapter 2

SI

2.1 Powers of 10

Most Physicists work in powers of 10, going up and down by 10^3, and here are the SI Prefixes:

Prefix	Power of 10	Symbol
Tera-	12	T
Giga-	9	G
Mega-	6	M
Kilo-	3	k
Deci-	-1	d
Centi-	-2	c
Mili-	-3	m
Micro-	-6	μ
Nano-	-9	n

2.2 SI Base Units

The SI decided that the following are Base Units - they are indivisible, unlike other units like Pa which are combinations of other units ($1Pa \equiv 1Nm^{-2}$, see (3) for more)

Unit	Measures	Repr
Ampere	Electric Current	A
Candela	Luminous Intensity	cd
Kelvin	Thermodynamic Temperature	K
Kilogram	Mass	kg
Metre	Length	m
Mole	Amount of Substance	mol
Second	Time	s

Chapter 3

Dimensional Analysis

3.1 Measurements & Readings

Definition 3.1.1: Reading

The Value of an instrument.

Definition 3.1.2: Measurement

The difference between 2 readings.

3.2 Dimensional Analysis

Dimensional Analysis is combinations of units.

Example 3.2.1 $F = ma$, work out the units of F

$$F = ma \tag{3.1}$$
$$[N] = [kg]\left[ms^{-2}\right] \tag{3.2}$$
$$N = kgms^{-2} \tag{3.3}$$

Example 3.2.2 $E_K = \frac{1}{2}mv^2$, work out the units of E_K

$$E_K = \frac{1}{2}mv^2 \tag{3.4}$$
$$[J] = [kg]\left[ms^{-1}\right]^2 \tag{3.5}$$
$$J = kgm^2s^{-2} \tag{3.6}$$

Example 3.2.3 $F = \frac{Gm_1m_2}{r^2}$, work out the units of G

$$F = \frac{Gm_1m_2}{r^2} \tag{3.7}$$

$$G = \frac{Fr^2}{m_1m_2} \tag{3.8}$$

$$[G] = [N]\,[m]^2\,[kg]^{-2} \tag{3.9}$$

$$G = m^3kg^{-1}s^{-2} \tag{3.10}$$

Part II

Mechanics & Materials

Part III

Electricity

Chapter 4

Electric Current

4.1 Electricity Equations & Utilities

4.1.1 Ohm's Law

$$V = IR$$

$$V = \text{Voltage}\,[V] \tag{4.1}$$
$$I = \text{Current}\,[I] \tag{4.2}$$
$$R = \text{Resistance}\,[\Omega] \tag{4.3}$$

4.1.2 Current

$$I = \frac{\Delta Q}{\Delta t}$$

$$I = \text{Current}\,[A] \tag{4.4}$$
$$Q = \text{Charge}\,[C] \tag{4.5}$$
$$t = \text{Time}\,[s] \tag{4.6}$$

4.1.3 Voltage

$$V = \frac{E}{Q}$$

$$V = \text{Voltage}\,[V] \tag{4.7}$$
$$E = \text{Energy}\,[J] \tag{4.8}$$
$$Q = \text{Charge}\,[C] \tag{4.9}$$

4.1.4 Resistivity

$$\rho = \frac{RA}{L}$$

$$\rho = \text{Resistivity}\,[\Omega m] \tag{4.10}$$
$$R = \text{Resistance}\,[\Omega] \tag{4.11}$$
$$A = \text{Cross-Sectional Area}\,\left[m^2\right] \tag{4.12}$$
$$L = \text{Length}\,[m] \tag{4.13}$$
$$\tag{4.14}$$

This is a useful example of (3), which we could use to find the units for Resistivity.

4.1.5 Thermistors

Definition 4.1.1: Thermistor

An electrical component that changes resistance based on temperature.

There are 2 kinds - Positive and Negative Temperature Coefficient Thermistors. With PTCs, as temperature increases, so does resistance. With NTCs, it falls.

Chapter 5

Direct Current Circuits

5.1 Current & Voltage Laws

Definition 5.1.1: Kirchhoff's 1st Law

The sum of current into a junction is the same as the current out of a junction.

Definition 5.1.2: Kirchhoff's 2nd Law

The sum of potential gain is equal to the sum of potential lost in any closed loop.

5.2 Resistance

As the electrons flow through the metal, the electrons hitting the atoms make the resistance, following (4.1.1).
Resistance depends on a number of variables:

- Temperature
- Material
- Length
- Thickness

5.2.1 Series vs Parallel

Definition 5.2.1: Series Resistance

The electron has to flow through both resistors, so it makes sense to add.

$$R_T = R_1 + R_2 + ldots + R_n$$

Definition 5.2.2: Parallel Resistance

Most current will go through the smaller resistor, but some will go through the larger resistances, and so the electron density for each path is smaller, decreasing the overall resistance compared to if they were in series.

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}$$

5.3 Superconductivity

Resistivity increases with temperature, and vice versa. However, when some materials are cooled to their critical temperature, their Resistivity drops to 0, and they become superconductors.

5.4 Electromotive Force & Internal Resistance

$emf \equiv \mathcal{E} \equiv$ Electromotive Force.

Definition 5.4.1: EMF

The potential difference across the terminals of a cell when no current is flowing.

An ideal voltmeter has infinite resistance, and so no current flows through them. This also means that they keep resistance the same as it was before in a parallel circuit, and voltmeters have to be put in parallel. However, if we put a voltmeter with a cell, current still flows due to the Internal Resistance of the cell. We can then work out the emf of the cell:

$$\mathcal{E} = V_{\text{Lost in circuit}} + V_{\text{Lost in cell}} = IR + Ir = I(R + r)$$

5.4.1 Finding r

1. Make a circuit with a cell, a variable resistor, and a voltmeter in parallel, with an ammeter in the variable resistor bit.
2. As you change the resistance on the variable resistor, more/less pd will be lost over r.
3. Plot I on the x-axis vs V on the y-axis, and then extrapolate. The Y intercept is the EMF. The gradient then represents $-r$.

5.5 Potential Dividers

Assuming a circuit with one battery and two resistors (R_1 and R_2) in series, where V_{in} is the Potential Difference across the battery and V_1 and V_2 are the Potential Differences across R_1 and R_2 respectively. We can then use (4.1.1) for the whole circuit.

$$V_{\text{in}} = I(R_1 + R_2) \rightarrow I = \frac{V_{\text{in}}}{R_1 + R_2} \tag{5.1}$$

$$V_1 = IR_1 \rightarrow V_1 = \frac{V_{\text{in}}}{R_1 + R_2} R_1 \tag{5.2}$$

$$V_2 = IR_2 \rightarrow V_2 = \frac{V_{\text{in}}}{R_1 + R_2} R_2 \tag{5.3}$$

Chapter 6

Alternating Current

We often use AC over DC for advantages in long-distance energy transfers. Transformers can directly trade voltage for current, and current produces heat, so we can increase the voltage and decrease the current to transfer lots of power over a long distance. However, a transformer only works on AC power.

Definition 6.0.1: Alternating Current

AC is current that periodically changes direction and is measured using an Oscilloscope.

6.1 Oscilloscopes

An oscilloscope is a graphical representation of a wave (See example here).

We can adjust the Volts per Division (y-gain) and the Time per Division (x-gain) to try to display 1 or more full waves.

We can then measure the following:

1. Amplitude (Peak Voltage (6.1))
2. Peak-To-Peak Voltage
3. Time Period & Frequency (6.4)

6.2 RMS

Since an alternating current circuit might make it difficult to use calculations, we often use RMS instead.

Definition 6.2.1: RMS

The RMS (Root Mean Squared) value of an AC supply is the value of a DC supply that would produce the same heating effect as the AC supply in the same resistor

.

$$V_{\text{rms}} = \frac{V_{\text{Peak}}}{\sqrt{2}} \tag{6.1}$$

$$I_{\text{rms}} = \frac{I_{\text{Peak}}}{\sqrt{2}} \tag{6.2}$$

$$P_{\text{Average}} = \frac{I_{\text{Peak}}}{\sqrt{2}} \tag{6.3}$$

$$f = \frac{1}{T} \tag{6.4}$$