Physics Consolidation Notes

Jack Maguire

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 $A - B$	$A_{\lvert UC \rvert} + B_{\lvert UC \rvert}$
$A * B$ or A/B	$A_{\%UC} + B_{\%UC}$
A^n	$A_{\%UC} * n$

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

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.

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

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

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

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

.

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

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

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

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

Part III

Mechanics & Materials

Chapter 7

Forces In Equilibrium

7.1 Vectors

7.1.1 Examples

Scalar Quantities	Vector Quantities
Energy	Force
Charge	Momentum
Speed	Velocity
Distance	Displacement
Mass	Weight
Temperature	Acceleration
Time	Jerk
Density	Snap
Pressure	Crackle
	Pop

7.1.2 Combining Vectors

We can either use lots of Trigonometry, or draw out the diagram to scale, top-to-tail and record the line from end to start, and that is the resultant vector.

If we can't use a diagram, and we are given a complicated example, turn each vector to x and y components using trig and add them together.

7.2 Motion

7.2.1 Motion Graphs

Y-Axis	Gradient Shows	Area under Shows
Displacement	Velocity	-
Velocity	Acceleration	Displacement

7.2.2 SUVAT Equations

Definition 7.2.1: SUVAT

$$S = \text{Displacement}\,[m] \tag{7.1}$$
$$U = \text{Initial Velocity}\,\left[ms^{-1}\right] \tag{7.2}$$
$$V = \text{Final Velocity}\,\left[ms^{-1}\right] \tag{7.3}$$
$$A = \text{Acceleration}\,\left[ms^{-2}\right] \tag{7.4}$$
$$T = \text{Time}\,[s] \tag{7.5}$$

Definition 7.2.2: SUVAT Equations

Technically, there are 3 SUVAT equations but these have been rearranged so that each is missing one 4, except for u which if missing $\equiv 0$

$$v = u + at \tag{7.6}$$
$$s = \frac{u+v}{2}t \tag{7.7}$$
$$s = ut + \frac{at^2}{2} \tag{7.8}$$
$$v^2 = u^2 + 2as \tag{7.9}$$

- (7.6) is missing s
- (7.7) is missing a
- (7.8) is missing v
- (7.9) is missing t

7.2.3 Projectile Motion

Here, we have both x and y to consider, but the only force acting on the object is weight. This means that $a_x = 0$ and $a_y = -9.81$.

An object undergoing projectile motion will follow a parametric path, for example:

- A kicked ball
- A fired bullet
- A dropped phone

7.2.4 SUVAT Tips

- Choose a consistent start and end point
- Set clear positive directions
- If drag doesn't apply, $a_x = 0$
- Trajectories are symmetrical around the maximum point - this can help for finding the peak of a kicked ball, for example

Chapter 8

Forces

There are 4 fundamental forces:

1. Gravitational
2. EM
3. Weak Nuclear
4. Strong Nuclear

All forces we think are their own forces come from these 4. For example Weight comes from Gravity ($W = mg$). All of the following come from EM:

- Normal
- Friction
- Drag
- Upthrust
- Thrust
- Tension
- Lift

To represent the forces acting on a body, we can use Free-Body Diagrams, where we draw where the forces on an object act from.

Definition 8.0.1: Newton's 3rd Law

If Object A exerts a force on object B, then object B will exert an equal and opposite force on object A.

8.1 Quick-Fire Notes

8.1.1 Equations

Subject	**Equation**
Work Done	$W = fd$
Kinetic Energy	$E_K = \frac{1}{2}mv^2$
Gravitational Potential Energy	$E_P = mgh$
Power	$P = \frac{W}{t} = Fv$
Efficiency	$E = \frac{\text{Useful Out}}{\text{Total In}}$
Two-Support	$F_a = \frac{WD_b}{D} \quad F_b = \frac{WD_a}{D}$
Tilting	$Fd > \frac{Wb}{2}$

8.1.2 Work & Energy

- Energy is measured in Joules. $1J$ is the energy required to raise a $1N$ weight $1m$ vertically.
- Energy can neither be created nor destroyed.
- Work is done on an object when a force acting on it makes it move.
- A force-distance graph shows the forces acting on an object.
- The area under a force-distance graph shows the work done.

8.1.3 Kinetic & Potential

Definition 8.1.1: Kinetic Energy

The Energy of an object due to its motion.

Definition 8.1.2: Potential Energy

The energy of an object due to its position.

8.1.4 Power & Energy

Definition 8.1.3: Power

The rate of transfer of energy.

8.1.5 Centre of Mass

Definition 8.1.4: Centre of Mass

The point through which a single force on the body has no turning effect.

8.2 Stability

If a body in stable equilibrium is displaced and then released, it returns to its equilibrium position. This is because the CoM is directly below the point of support when at rest., so the support force and weight are in equilibrium. Therefore, when displaced the weight force tries to go back. If a body is in unstable equilibrium, then all is reversed: the support is above the weight, and when displaced the object leaves the equilibrium. An object will topple if the line of action from its weight passes over the pivot.

Chapter 9

Momentum

$$P = mv$$

$$P = \text{Momentum}\left[kgms^{-1}\right] \text{ or } [Ns] \tag{9.1}$$
$$m = \text{Mass}\,[kg] \tag{9.2}$$
$$v = \text{Velocity}\left[ms^{-1}\right] \tag{9.3}$$

Momentum is a vector.

9.1 Conservation of Momentum

Definition 9.1.1: Conservation of Momentum

The total momentum before a collision is equal to the total momentum after a collision, provided that no external forces are acting.

$$\sum P_1 \equiv \sum P_2 \therefore P_1 = P_2$$

9.2 Forces from Momentum

$$F = \frac{\Delta P}{t}$$

$$F = \text{Force}\,[N] \tag{9.4}$$
$$P = \text{Momentum}\left[kgms^{-1}\right] \text{ or } [Ns] \tag{9.5}$$
$$t = \text{Time}\,[s] \tag{9.6}$$

A large force will result if the ΔP is large or if the time is short (ie if the change occurs very quickly).

9.3 (In)Elastic Equations

Definition 9.3.1: Elastic Collision

An Elastic Collision is one where Kinetic Energy is conserved.

Definition 9.3.2: Inelastic Collision

An Inelastic Collision is one where Kinetic Energy is **not** conserved.
A sign of this is objects sticking together and moving together post-collision or any deformations.