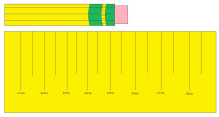
IB Mark Schemes Analysis
(formerly Data Collection and Processing)

Honors Physical Science 2015

Errors and Uncertainty

- Random Errors (precision)
  - Errors in apparatus
  - Can't be avoided; they are part of the measuring process
  - Uncertainties are measures of random errors
  - Can be predicted; estimated to be half of the smallest division on a scale



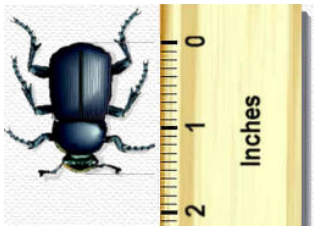
Errors and Uncertainty

- Systematic Errors (accuracy)
  - Due to incorrect use of equipment or poor experimental design
  - Accuracy (how well an experiment measures what it is trying to measure) is a measure of systematic error
  - Can be eliminated
    - Personal errors: BE PREPARED and CAREFUL
    - Instrumental errors: CALIBRATION
    - Method errors: CONTROL YOUR VARIABLES

Reporting Measurement

- Three parts to a measurement
  - The measurement
  - The uncertainty
  - The unit
- EX: 5.2 ± 0.5 cm
  - You are reasonably sure the length is between 4.7 and 5.7 cm
- You should ESTIMATE the last digit.
  "Degree of Freedom"
  - If your measurement tool is 0.1, then your last digit should be in the hundredths place (i.e. 0.10)

How big is the beetle?



Measure between the head and the tail!

Between 1.5 and 1.6 in

Measured length: 1.54 ± 0.05 in

The 1 and 5 are known **with certainty**

The last digit (4) is **estimated** between the two nearest fine division marks.

Your uncertainty is half of the smallest division on a scale.

How big is the penny?

Measure the diameter.

Between 1.9 and 2.0 cm
Estimate the last digit and the uncertainty.

What diameter do ***you*** measure?

How does that compare to your classmates?

Is any measurement EXACT?

Counting Significant Figures

The Digits	Digits That Count	Example	# of Sig Figs
Non-zero digits	ALL	4.337	4
Leading zeros (zeros at the BEGINNING)	NONE	0.00065	2
Captive zeros (zeros BETWEEN non-zero digits)	ALL	1.000023	7
Trailing zeros (zeros at the END)	ONLY IF they follow a significant figure AND there is a decimal point in the number	89.00 but 8900	4 2
Leading, Captive AND Trailing Zeros	Combine the rules above	0.003020 but 3020	4 3
Scientific Notation	ALL	7.78×10^3	3

Calculating With Sig Figs

Type of Problem	Example
MULTIPLICATION OR DIVISION: Find the number that has the ***fewest*** sig figs. That's how many sig figs should be in your answer.	**3.35 x 4.669 mL = 15.571115 mL rounded to 15.6 mL** 3.35 has only **3** significant figures, so that's how many should be in the answer. Round it off to **15.6 mL**
ADDITION OR SUBTRACTION: Should be rounded to the digit of least precision. If there is no decimal, it is still employed.	**64.25 cm + 5.333 cm = 69.583 cm rounded to 69.58 cm** 64.25 has only **two** digits to the right of the decimal, so that's how many should be to the right of the decimal in the answer. Drop the last digit so the answer is **69.58 cm.**

Calculating With Sig Figs cont

Type of Problem	Example
ADDITION OR SUBTRACTION: Should be rounded to the digit of least precision. If there is no decimal, it is still employed.	Example1: 1237 + 120 = 1357 which is rounded to 1360 because 120 only has a significant figure in the tens place but not the ones place. Example 2: 214,000 + 1,899 = 215,899 which is rounded to 216,000 because 214,000 only has a significant figure in the thousands place and not the hundreds place.

Exploration: Been there, done that…

Exploration	
Mark	Descriptor
0	• The student's report does not reach a standard described by the descriptors below.
1–2	• The topic of the investigation is identified and a research question of some relevance is stated but it is not focused. • The background information provided for the investigation is superficial or of limited relevance and does not aid the understanding of the context of the investigation. • The methodology of the investigation is only appropriate to address the research question to a very limited extent since it takes into consideration few of the significant factors that may influence the relevance, reliability and sufficiency of the collected data. • The report shows evidence of limited awareness of the significant safety, ethical or environmental issues that are relevant to the methodology of the investigation*.
3–4	• The topic of the investigation is identified and a relevant but not fully focused research question is described. • The background information provided for the investigation is mainly appropriate and relevant and aids the understanding of the context of the investigation. • The methodology of the investigation is mainly appropriate to address the research question but has limitations since it takes into consideration only some of the significant factors that may influence the relevance, reliability and sufficiency of the collected data. • The report shows evidence of some awareness of the significant safety, ethical or environmental issues that are relevant to the methodology of the investigation.*
5–6	• The topic of the investigation is identified and a relevant and fully focused research question is clearly described. • The background information provided for the investigation is entirely appropriate and relevant and enhances the understanding of the context of the investigation. • The methodology of the investigation is highly appropriate to address the research question because it takes into consideration all, or nearly all, of the significant factors that may influence the relevance, reliability and sufficiency of the collected data. • The report shows evidence of full awareness of the significant safety, ethical or environmental issues that are relevant to the methodology of the investigation.*

Data Collection and Processing

Analysis	
Mark	Descriptor
0	• The student's report does not reach a standard described by the descriptors below.
1–2	• The report includes insufficient relevant raw data to support a valid conclusion to the research question. • Some basic data processing is carried out but is either too inaccurate or too insufficient to lead to a valid conclusion. • The report shows evidence of little consideration of the impact of measurement uncertainty on the analysis. • The processed data is incorrectly or insufficiently interpreted so that the conclusion is invalid or very incomplete.
3–4	• The report includes relevant but incomplete quantitative and qualitative raw data that could support a simple or partially valid conclusion to the research question. • Appropriate and sufficient data processing is carried out that could lead to a broadly valid conclusion but there are significant inaccuracies and inconsistencies in the processing. • The report shows evidence of some consideration of the impact of measurement uncertainty on the analysis. • The processed data is interpreted so that a broadly valid but incomplete or limited conclusion to the research question can be deduced.
5–6	• The report includes sufficient relevant quantitative and qualitative raw data that could support a detailed and valid conclusion to the research question. • Appropriate and sufficient data processing is carried out with the accuracy required to enable a conclusion to the research question to be drawn that is fully consistent with the experimental data. • The report shows evidence of full and appropriate consideration of the impact of measurement uncertainty on the analysis. • The processed data is correctly interpreted so that a completely valid and detailed conclusion to the research question can be deduced.

Aspect 1: Recording raw data

- Raw data – actual data measured
- Includes quantitative and qualitative data
- Uncertainties are identified
- Data is collected into tables with:
  - Variables and trials identified
  - Cells contain only one value
  - Values are aligned by decimal point
  - Clear headings and titles
  - All measurements contain units and uncertainties with appropriate and consistent significant digits

Aspect 1: Example

DCP 1

Data		Sound S / arbitrary units ±0.5 units	
Mass M / kg ±0.001 kg	1st trial S_1	2nd trail S_2	3rd trial S_3
0.000	0.5	1.0	0.5
0.010	1.0	1.0	0.5
0.020	2.0	1.5	2.0
0.030	2.0	2.5	1.5
0.040	2.5	3.0	2.5
0.050	3.0	3.5	3.0
0.060	3.5	3.5	3.5
0.070	3.5	4.0	3.5
0.080	4.5	5.0	4.5
0.090	4.5	5.5	5.0

Aspect 1: Students should NOT be…

- Told how to record the raw data
- Given a pre-formatted table with any columns, headings, units, or uncertainties.

Aspect 2: Processing Raw Data

- All raw data has been completely processed
  - Adding, subtracting, squaring, dividing, etc.
- Sample calculations are present & clearly explained
- Calculations show propagation of uncertainty
- Involves taking the average of several measurements and transforming data into a form suitable for graphical representation

Aspect 2: Example

DCP 2

Average Sound S_{ave} / units ±0.5 units
0.7
0.8
1.8
2.0
2.7
3.2
3.5
3.4
4.7
5.0

DCP 2

The average of three sound measures is, e.g., $S_{ave} = \frac{S_1 + S_2 + S_3}{3} = \frac{1.0 + 1.0 + 0.5}{3} = 0.8$

Aspect 2: Example cont

DCP 2

Data For Graphing	
Mass M / kg ±0.001 kg	Average Sound Due to Added Mass $S_{ave\ (added\ mass)}$ / units ±0.5 units
0.000	0
0.010	0.2
0.020	1.2
0.030	1.3
0.040	2.0
0.050	2.5
0.060	2.8
0.070	2.7
0.080	4.0
0.090	4.3

DCP 2

The maximum gradient is 58.89 and the minimum gradient is 36.67. Again, the best-straight line gradient is 47.44.

The uncertainty **above** the best straight line is 58.89 – 47.44 = + 11.45.

The uncertainty **below** the best straight line is 36.67 – 47.44 = – 10.77.

The **gradient and its uncertainty** are thus 44.77 (+11.45)/(–10.77) or about 45 ± 11 to 2 SD.

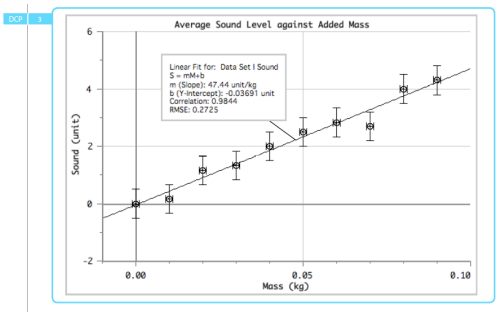
Aspect 2: Students should NOT be…

- Told how to process data
- Told what quantities to graph/plot

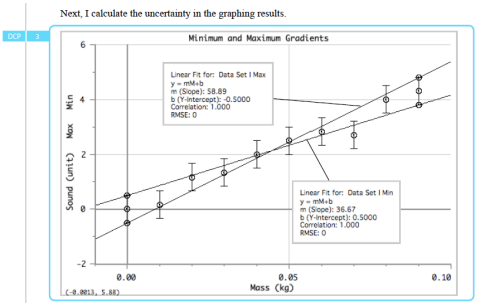
Aspect 3: Presenting Processed Data

- Suitable format (graphs/tables) shows the relationship between IV & DV
- Graphs/tables have proper titles
- Graphs have appropriate scales, labeled axes with units & uncertainties & accurately plotted data with best fit line/curve describing graphical relationships
- Graphs/tables have annotations describing graphical relationships

Aspect 3: Example



Aspect 3: Example cont

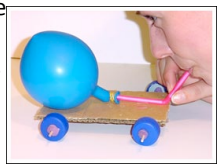


Aspect 3: Students should NOT be…

- Told how to present their data
- Told what uncertainties are and are not significant

1. Collect, record, and analyze

How does the number of fingers used to flick a matchbox car affect the distance it travels?



While I'm not going to write out your procedure, you need to 1, 2, and 3 fingers and run 3 trials of each. Record in your data table, process your data, and graph ALL ON PAPER. When we go to the computer lab, you will use Excel and LoggerPro.

2. Analyze YOUR Analysis by using the checklist

- Take 5 minutes or so and read over your Analysis.
- Make sure you have included all the listed requirements.
- Assess your aspects using the checklist and the rubric.
- "What grade would I earn?"

3. Analyze Partner's Analysis

- Trade with the partner (See Board)
- Analyze using the checklist and rubric.
- Assign a grade at the top of the paper
  - Write the number, 1-6
  - Justify using the checklist

4. Reflection Time!

- Trade with partner to get YOUR Analysis back
- Look at feedback – agree or disagree? No hard feelings, we're all new at this :)
- Reflection free write:
  - 1. Which part was my strength? Why?
  - 2. Which part was my weakness? Why?
  - 3. How can I improve my current Analysis?
  - 4. What will I do differently when I create my next Analysis?
- Hand in your Analysis and Reflection