Name:_______________ IB Physics 1

Topic 1 – Measurement and Uncertainty

Concepts I Should Know:

- Fundamental and derived SI units
- Scientific notation and metric multipliers
- Significant figures
- Orders of magnitude
- Estimation
- Random and systematic errors
- Absolute, fractional and percentage uncertainties
- Error bars
- Uncertainty of gradient and intercepts
- Vector and scalar quantities
- Combination and resolution of vectors

Things I Should Be Able to Do:

- Use SI units in the correct format for all required measurements, final answers to calculations and presentation of raw and processed data (p. 2-3)
- Use scientific notation and metric multipliers (p.5-7)
- Quote and compare ratios, values and approximations to the nearest order of magnitude (p. 7)
- Estimate quantities to an appropriate number of significant figures (p. 4-5)
- Explain how random and systematic errors can be identified and reduced (p. 9-11)
- Collect data that include absolute and/or fractional uncertainties and stating these as an uncertainty range (expressed as: best estimate ± uncertainty range) (p. 11)
- Propagate uncertainties through calculations involving addition, subtraction, multiplication, division and raising to a power (p. 12-14)
- Determine the uncertainty in gradients and intercepts (p. 14-16)
- Solve vector problems graphically and algebraically (p. 18-23)

I. Orders of Magnitude

A. The order of magnitude represents the relative size of the number.

B. Order of magnitude is not concerned with the actual number but instead what power of ten best estimates that number

C. To find the order of magnitude, use a log function

Example: For the number 5600, the order of magnitude is 10^4
log 5600 = 3.74 which rounds to 4
hence 10^4

Sample Problem # 1

Determine the order of magnitude of the following numbers using a calculator:

a) 4300 b) 2.4×10^{-19}

D. If you are not using a calculator, you can compare your number (written in scientific notation) to the number 3.16. If the number itself (not the exponent in scientific notation) is greater than or equal to 3.16, you add one to the exponent to give the order of magnitude

Example: 5.60×10^3
$5.60 > 3.16$
therefore one is added to the exponent and the order of magnitude is 10^4

1.12×10^2
$1.12 < 3.16$
nothing is added to the exponent making the order of magnitude 10^2

Sample Problem # 2

Determine the order of magnitude of the number of inches in a mile. (1 mi = 5280 ft)

II. Units

A. Fundamental units are those quantities defined as the most basic value.

B. The fundamental units are m, kg, s, A, K, mol, candela

C. A derived unit involves two or more fundamental units combined mathematically

III. Significant Figures

A. When adding or subtracting, the answer should have the same number of decimal places as the least precise value.

B. When multiplying or dividing, the answer should have the same number of significant figures as the least precise value.

Sample Problem # 3

Determine the correct answer using sig figs.

a) 4.732 – 3.62 = b) 4.56 X 1.4 =

IV. Types of Error

A. **Random error** is due to the natural fluctuations in data. For example, not all pennies will have the same mass.

1. The error due to random effects can be minimized by having a large sample size (conducting many trials)
2. The value is said to be precise when the random error is small.

B. **Systematic error** is due to poor experimental design or poor equipment.

1. Repeated trials do not lessen systematic error because you are just repeating the same mistakes over and over again.
2. To reduce systematic error, a modified lab procedure or replacement of equipment is needed.
3. The value is said to be accurate when the systematic error is small.

C. **Zero error** or **zero offset error** is a type of systematic error that occurs when equipment was not truly zeroed or properly calibrated.

1. Zero offset error is often realized when the actual intercept on a graph of data values does not match the expected intercept.
2. Suppose a student plots the force exerted versus stretch of a spring. The student would expect if no force is applied, there should be no stretch of the spring. However, the student's actual data plot yielded an intercept that was not zero. This could be attributed to zero error.

V. Precision and Accuracy

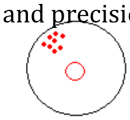
A. Accuracy represents how close a value is to an accepted result and indicates the amount of systematic error.

B. Precision represents the size of the spread of your reported values and indicates the amount of random error.

C. Investigators strive for accuracy and precision.

Conceptual Question #1

Beams of laser light are projected onto target on a screen. Several beams emanating from the same area strike the screen as shown. Describe the results in terms of both accuracy and precision.



VI. Uncertainties

A. Error should be written to one significant digit in most cases. Two significant digits may be allowed if there is too much loss in precision when the error is

B. The significance of the error should agree with the significance of the reported value.

Example: 2.44± 0.5 is not written correctly
2.4± 0.5 is correct

Example: 256 ± 40 is not written correctly
260 ± 40 is correct

C. The smallest permissible uncertainty is ±1/2 of the smallest unit that can be read. Example: If a meter stick only has markings every 1 cm, then the smallest permissible uncertainty is ±0.5cm. The experimenter could choose to make the uncertainty larger than this depending on the lab.

D. To report the value of a set of repeated measurements

1. Report the average of the repeated measurements
2. Uncertainty = $\frac{\text{Largest of individual measurements} - \text{smallest of individual measurements}}{2}$

Sample Problem # 4

Multiple choice: A student makes the following measurements of the volume of water needed to saturate identical soil samples: 14.8 mL, 16.2 mL, 15.3 mL, 15.7 mL, 16.0 mL, 16.1 mL. The graduated cylinder used is marked in increments of 1 mL. What is the correct way to report the amount of water needed to saturate the soil sample?

a) 15.68 mL ± 0.5 mL
b) 15.7 mL ± 1 mL
c) 15.7 mL ± 0.7 mL
d) 16 mL ± 1 mL

VII. Propagating Errors

A. Errors are propagated throughout the calculations.

B. When adding/subtracting add the absolute uncertainties

C. When multiply/dividing add the relative/percentage uncertainties. If the relative uncertainties are given, one must convert to relative/percentage uncertainties before multiplying/dividing.

Sample Problem # 5

Calculate the total distance you ran this week if your runs were: 1.5km ± 0.1km, 3.7km ± 0.2km, 4.0km ± 0.1km .

Sample Problem # 6

The power dissipated in a resistor of resistance R carrying a current I is equal to I^2R. The value of I has an uncertainty of ± 4% and the value of R has an uncertainty of ±8%. Calculate the value of the uncertainty in the calculated power dissipated.

Sample Problem # 7

Determine the density of an object whose mass is 14.2g ± 0.5g and volume is 6.36cm^3 ± 0.09 cm^3.

VIII. Transforming Data To Produce Linear Graphs

- **A.** A linear function should be plotted for all graphs
- **B.** If your data is not linear, you need to transform it to the equation y = mx + b

Conceptual Question #2

Given the equation $y = \dfrac{A\sqrt{B}}{C^3 D}$, determine what plots would need to be made to create *linear* graphs for *y* vs A, B, C and D.

Sample Problem # 8

Given $y = ax^b$, determine the slope and *y*-intercept of the linear equation when $\log y$ is plotted against $\log x$.