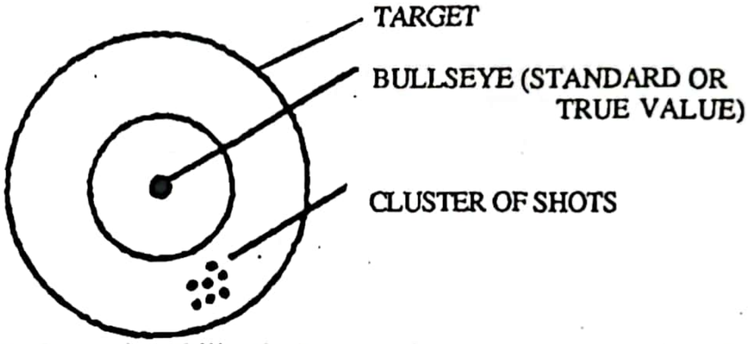
SIGNIFICANT FIGURES AND UNIT CONVERSIONS (F 99)

Purpose

To gain a better understanding of SIGNIFICANT FIGURES
To become acquainted with metric units
To practice unit conversions
To understand the differences in precision, accuracy, and uncertainty.

Introduction

Accuracy - the closeness to the standard or true value. This is usually unknown.
Precision - the statistical repeatability of several measurements.
Uncertainty - the variation expected in a single measurement using a device whose precision is known.
Significant Figures - a measure of the precision or uncertainty in a measured number
The following illustrates good precision but poor accuracy :



Accuracy and precision depend on the skill of the experimenter, but are also limited by the measuring device used. Each has a different PRECISION or UNCERTAINTY of measure. For example, the laboratory thermometer has a precision of ± 0.1 °C and a temperature of 25.0 °C should be reported as 25.0 ± 0.1 °C. This means that the actual temperature could be either 24.9, 25.0, or 25.1 °C when considering the uncertainty implied in the number. A trained person will look at the quantity 25.0 °C and know that it has an implied uncertainty of ± 0.1 °C.

PRECISION FOR SOME MEASURING DEVICES (UNCERTAINTY, IF A SINGLE MEASUREMENT)

Balance, AC-400 electronic	± 0.001	g (milligram balance)
Balance, XD-800 electronic	± 0.01	g (centigram balance)
Balance, Metler electronic	± 0.0001	g (analytical balance)
Balance, Triple Beam	± 0.01	g (the quadruple beam is also ± 0.001 g)
Thermometer, 110 °C	± 0.1	°C
Pipet, Volumetric, 15 mL	± 0.02	mL
Pipet, Volumetric, 10 mL	± 0.02	mL
Pipet, Volumetric, 20 mL	± 0.04	mL
Cylinder, Graduated, 100 mL	± 0.5	mL
Cylinder, Graduated, 10 mL	± 0.1	mL
Cylinder, Graduated, 500 mL	± 1	mL
Flask, Volumetric, 100 mL	± 0.1	mL
Flask, Volumetric, 50 mL	± 0.1	mL
Flask, Volumetric, 250 mL	± 0.05	mL
Buret, 50 mL	± 0.02	mL
Ruler, 15 cm	± 0.01	cm
Barometer	± 0.1	mm Hg
Hydrometer	± 0.002	unitless

SIGNIFICANT FIGURES

Precision refers to how close repeated measurements are to each other. Accuracy refers to how close the repeated measurements are to the true or standard value. Thus, a dart player can be precise but inaccurate, or can be imprecise but get lucky enough so that the average represents good accuracy. In this case the bulls eye was the true value. However, if we do not know the true value we cannot consider accuracy at all, but must rely upon precision. Significant figures are the number of digits necessary to express the results of a measurement to the precision with which it is made. Significant figures do not refer to accuracy but must be used to get an idea of how well we make a measurement.

For example, I walk into a room and estimate, without really counting, that there are 50 students. There is only one significant figure in the number 50, the 5, and this tells me that there is uncertainty in the decimal place representing 10. Therefore, the number means 50 $\pm$ 10, that the number of students is between 40 and 60. Next, I count the students and arrive at the number 49. There are two significant figures in 49 and the uncertainty occurs in the decimal place representing 1. Therefore, the number means 49 $\pm$ 1, that the number is between 48 and 50. If I would have counted exactly fifty students, it would be written as 50. so that the uncertainty would be $\pm$ 1.

COUNTING SIGNIFICANT FIGURES

1) all integers (nonzeros) are significant
2) zeros between integers are significant, 909 has 3 sig figs
3) zeros after the first nonzero digit for a decimal number are significant, 909.0 and 0.09090 both have 4 sig figs
4) zeros on right of last integer when there is no decimal place are ambiguous
   90900 must be considered as 3 sig figs
   90900. has 5 sig figs
   You must use scientific notation to be unambiguous. For example, to show the above number with 4 sig figs: 9.099×10^4
5) any zero included in a number written in scientific notation is significant

Exercises How many significant figures are there in each or the following numbers?

a) 325	f) 56,004	k) 0.00304	p) 0.00560	u) 0.001
b) 18.263	g) 1.010×10^5	l) 0.003040	q) 10.0240	v) 0.0010
c) 8.0	h) 2.50×10^{-12}	m) 500	r) 0.1060	
d) 10.1	i) 1.01×10^{-2}	n) 500.	s) 1020.00	
e) 10.10	j) 0.0034	o) 1.0087	t) 0.0260	

Answers

a) 3	f) 5	k) 3	p) 3	u) 1
b) 5	g) 4	l) 4	q) 6	v) 2
c) 2	h) 3	m) 1	r) 4	
d) 3	i) 3	n) 3	s) 6	
e) 4	j) 2	o) 5	t) 3	

ROUNDING OFF

1) If the number to be dropped is 5 or greater, increase the preceding number
2) If the number to be dropped is less than 5, drop the number
3) complete mathematical operations before rounding off - rounding is done after all calculations
4) exact conversion factors do not limit significant figures (12 things = 1 dozen, 2.54 cm = 1 inch)

Exercises - Round off the following numbers as indicated.

Number	Round To	Your Answer	Answer
$58.921	nearest cent		($58.92)
0.1281 mm	two digits		(0.13 mm)
$11.50	nearest dollar		($12)
4.3645 Mm	one decimal place		(4.4 Mm)
31,579 Mg	nearest thousand		(32,000 Mg)

MULTIPLICATION AND DIVISION - look at the least number of sig. figs.

In multiplying and dividing, the number of significant figures in the answer is the same as in *the number that has the fewest significant figures.*

Examples

1) (2.11 cm)(2 cm) = 4.22 cm^2 but the correct answer is 4 cm^2 since the answer should have only one significant figure.
2) 8.2 cm / 3.194 s = 2.56713 cm/s but the correct answer is 2.6 cm/s since the answer should have only two significant figures.

ADDITION AND SUBTRACTION - look at the decimal place

When numbers are added or subtracted the final answer cannot have more digits to the right of the decimal point than that number which has the fewest digits to the right of the decimal point.

Examples

$$\begin{array}{r} 6.82 \\ 234.0 \\ +\ 10. \\ \hline 250.82 \end{array}$$

The correct answer is 251 since the number 10. has no digits past the decimal point the answer cannot have any digits to the right of the decimal point and the number had to be rounded off to the 'ones' place.

$$\begin{array}{r} 3\ .0999 \\ -\ 0.1 \\ \hline 2.9999 \end{array}$$

The correct answer is 3.0

Exercises

Express your answers to the correct number or significant figures.
a) 0.1893 m + 1.045 m - 0.0042 m
b) (9.50 x 10^{14} m) / (3.0 x 10^3 m)
c) (3.26 x 10^{-4} m)·(8.0 x 10^{-2} m) / (1.04 x 10^{-2} m)
d) (63.2 mm + 1.18 mm) / 15.61 s
e) (3.06 x 10^{10} cm^2 - 1.0 x 10^{10} cm^2) / 4.51 x 10^6 cm

Answers

a) 1.230 m b) 3.2 x 10^{11} c) 2.5 x 10^{-3} m d) 4.12 mm/s e) 4.6 x 10^3 cm

USING RULES FOR BOTH TYPES OF OPERATIONS - apply each rule

When doing sequencial problems all rules for significant figures must be applied.

Example

$$\% \text{ error} = \left| \frac{25.000\text{ g} - 24.990\text{ g}}{25.000\text{ g}} \right| \times 100\% = \left| \frac{0.010\text{ g}}{25.000\text{ g}} \right| 100\% = 0.040\ \%$$

The numerator is subtraction and results in a number with 2 significant figures. The final answer is the result of dividing a number with 2 significant figures by a number with 5 significant figures.

PRELABORATORY ASSIGNMENT

Graph of Water Density vs Temperature

Graph the data provided on its own separate piece of graph paper and then draw the best line through the data points. Plot density on the y-axis and choose a scale which will provide for a useful graph so that the density of water at a given temperature can be read from the graph. This graph will be useful in the next few experiments:

density, g/mL	Centigrade
0.9982	20
0.9980	21
0.9978	22
0.9975	23
0.9973	24
0.9970	25

Procedure Part A - Area of a 3 x 5 Index Card

The purpose of Part A is to obtain the area of a 3 x 5 index card to the proper number of Significant Figures.

1) Obtain a 3 x 5 index card.
2) Measure its length and width in centimeters using a plastic ruler.
3) Enter the data on the Data Sheet and do the indicated calculations.
4) Convert square cm into square inches using 1 in = 2.54 cm exactly. Square both sides of the equation to get the relationship between in^2 and cm^2.

Procedure Part B - Total Mass

The purpose is to obtain the total mass of three objects to the correct number of significant figures.

1) Obtain any object.
2) Weigh the object on three different balances (triple beam, XD-800, and AC-400).
3) Calculate the total mass on the Data Sheet using significant figures.
4) Convert grams into ounces using the given conversion factor.

Procedure Part C - Comparing Accuracies

1) Obtain a 50 mL beaker with graduations, a 10 mL graduated cylinder, and a 100 mL graduated cylinder.
2) Weigh each piece of glassware to the nearest mg (± 0.001 g) on the data sheet.
3) Fill each piece of glassware with 10 mL of distilled water as carefully as you can using the graduations on the piece of glassware. Reweigh each and record the masses in the Data Sheet.
4) Measure the temperature of the water in one piece of glassware to ± 0.1 °C. Use the graph you plotted for your prelab assignment to determine the density of this water at this temperature.
5) Use your calculated water density to convert g of water into mL of water. This is your experimental volume.
6) Calculate your % error using the given equation. This is an absolute value, do not bother with a negative % error because we are assuming that this error could be in either direction, or ±. The actual volume is the 10 mL your were trying to measure which is considered to be a perfect number. Be sure to use significant figures to round off % error. Do the math to get the unrounded answer. Then round off according to the rules for subtraction and division. For example if the experimental volume in the beaker was 9.090 g/mL,

$$\%\ \text{error} = \left| \frac{9.090 - 10.000}{10.000} \right| 100\% = \left| \frac{0.910}{10.000} \right| 100\% = 9.10\%$$

SIGNIFICANT FIGURES DATA SHEET(F2018)

Name Tong Li day/time Aug 31, 2023

PART A - AREA OF A 3 X 5 INDEX CARD

Length 12.70 cm # sig figs 2

Width 7.70 cm # sig figs 3

Area = (12.70 cm)(7.70 cm) = 97.8 cm^2 DO NOT ROUND-OFF !

Given $(1)^2 (in)^2 = (2.54)^2 cm^2$ (exactly), convert the area to square inches using sig. figs.

$(97.8 \; cm^2)\left(\frac{1 \; in^2}{6.4516 \; cm^2}\right) = 15.2 \; in^2$ # sig figs 3

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PART B - TOTAL MASS

Mass of object (triple beam balance)	17.8 g	# sig figs	3
Mass of object (mg scale)	17.873 g	# sig figs	5
Mass of object (cg scale)	17.87 g	# sig figs	4
Total Mass	53.5 g	# sig figs	3

Given that 1.00000 g = 0.0352739 ounce, convert the mass to ounces using sig. figs.

Total Weight = $(53.5 \; g)\left(\frac{0.352739 \; oz}{1 \; g}\right) = 18.9$ oz # sig figs 3

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PART C - COMPARING ACCURACIES AT 10 mL

Mass of beaker + water	38.306 g	#sig figs	4
Mass of beaker	28.593 g	#sig figs	5
Mass of water	9.716 g	#sig figs	4
Mass 10 mL cylinder + water	46.487 g	#sig figs	
Mass 10 mL cylinder	36.902 g	#sig figs	5
Mass water	9.587 g	#sig figs	4
Mass 100 mL cylinder + water	135.833 g	#sig figs	6
Mass 100 mL cylinder	126.575 g	#sig figs	6
Mass water	9.259 g	#sig figs	4
Temperature of water used	24.0 ^0C	#sig figs	2
Density of water from graph	0.9973 g/mL	#sig figs	4

formula : 0.997 g = 1ml.

Convert mass of water (g) to volume of water (mL) by using the density from your graph. (Refer to Part C (5))

Volume in beaker _______ mL #sig figs _____

mass of beaker 9.716 g

Volume in 10 mL cylinder _______ mL #sig figs _____

mass of 10ml cylinder: 36.902 g

Volume in 100 mL cylinder _______ mL #sig figs _____

mass of 100ml cylinder : 126.175 g

Calculate the accuracy of each piece of glassware using the following equation.
Show your calculations. (Refer to Part C (6))

$$\% \text{ error} = \left| \frac{\text{experimental volume} - \text{actual volume}}{\text{actual volume}} \right| \times 100\% =$$

% error using beaker _______ % #sig figs _____

% error using 10 mL cylinder _______ % #sig figs _____

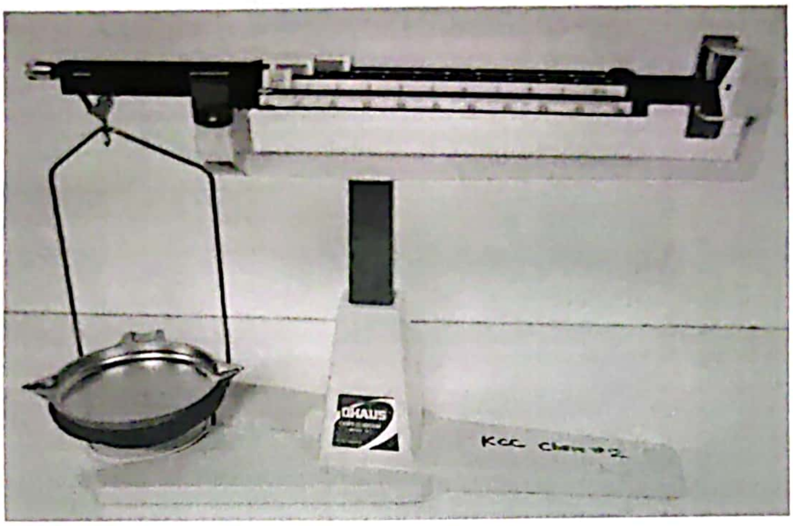
% error using 100 mL cylinder _______ % #sig figs _____

Which would you expect to be the most accurate and why?

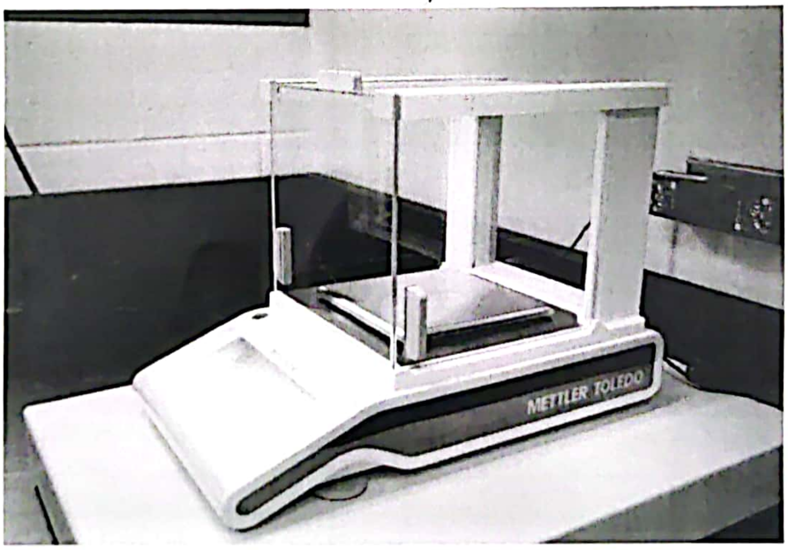
Which is the most accurate and why?

TRIPLE BEAM BALANCE OPERATING INSTRUCTIONS

Triple Beam Balance



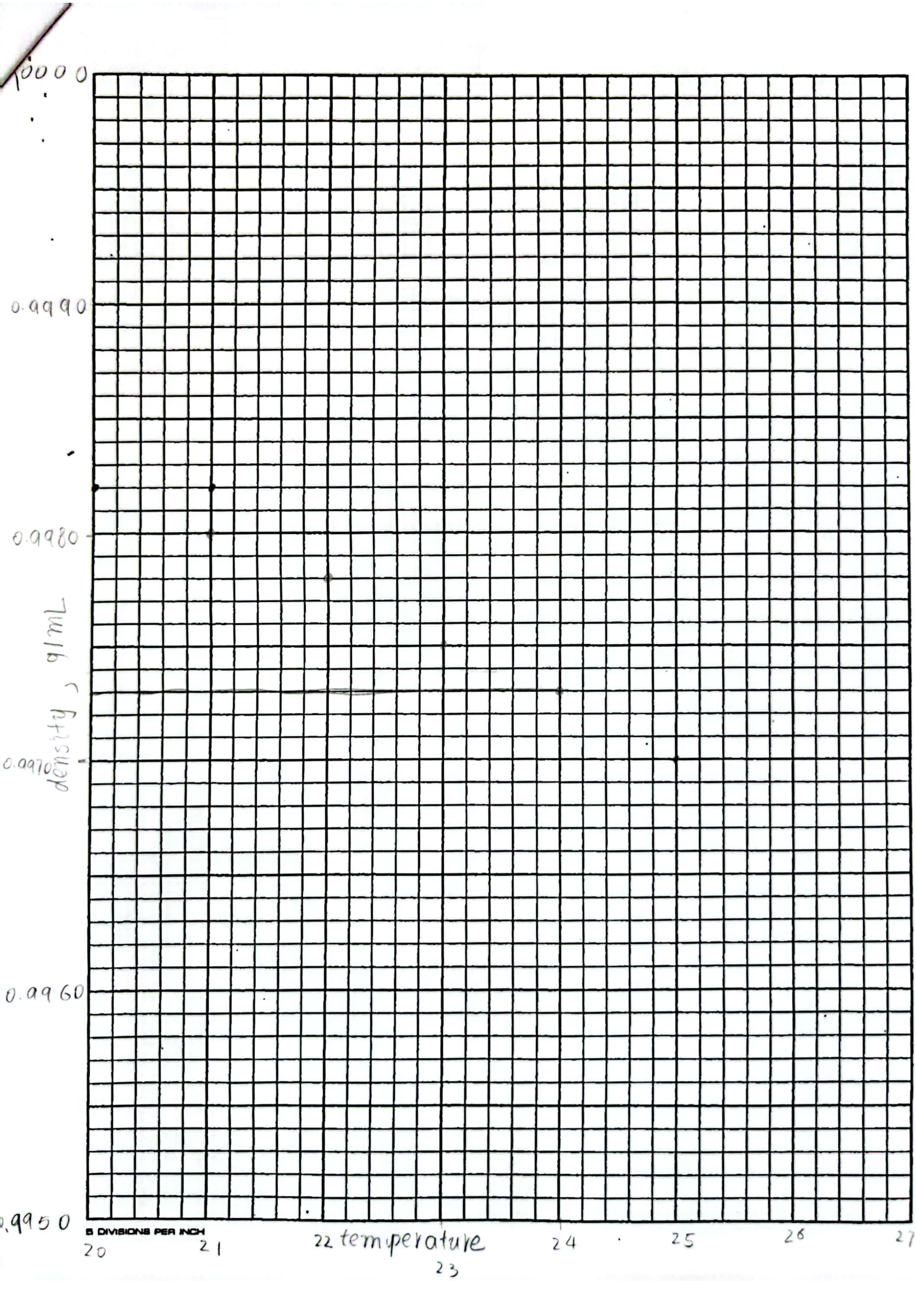
Mettler Balance



The triple beam balance is used routinely in many laboratories to obtain rough measurements. For analytical work, however, the electronic balances should be used.

1) Zero the balance by turning the ADJUSTMENT KNOB until the pointer rests on the zero mark (see Figure 1).
2) Make sure that all SLIDING RIDERS are positioned at the extreme left on the GRADUATED SCALE.
3) Place the object to be weighed on the WEIGHING PAN.
4) Beginning with the largest GRADUATED SCALE division, the hundred gram, slide the RIDER from left to right until you are in the mass range as indicated by the POINTER.

5) Repeat this process with the ten gram and one gram RIDERS until the POINTER rest on the zero mark.
6) Read the mass to $\pm$ 0.02 gram by estimating between the graduated scale lines.


0000
0.9990
0.9980
0.9970
0.9960
.9950
density, g/mL
5 DIVISIONS PER INCH
20
21
22
temperature
23
24
25
26
27