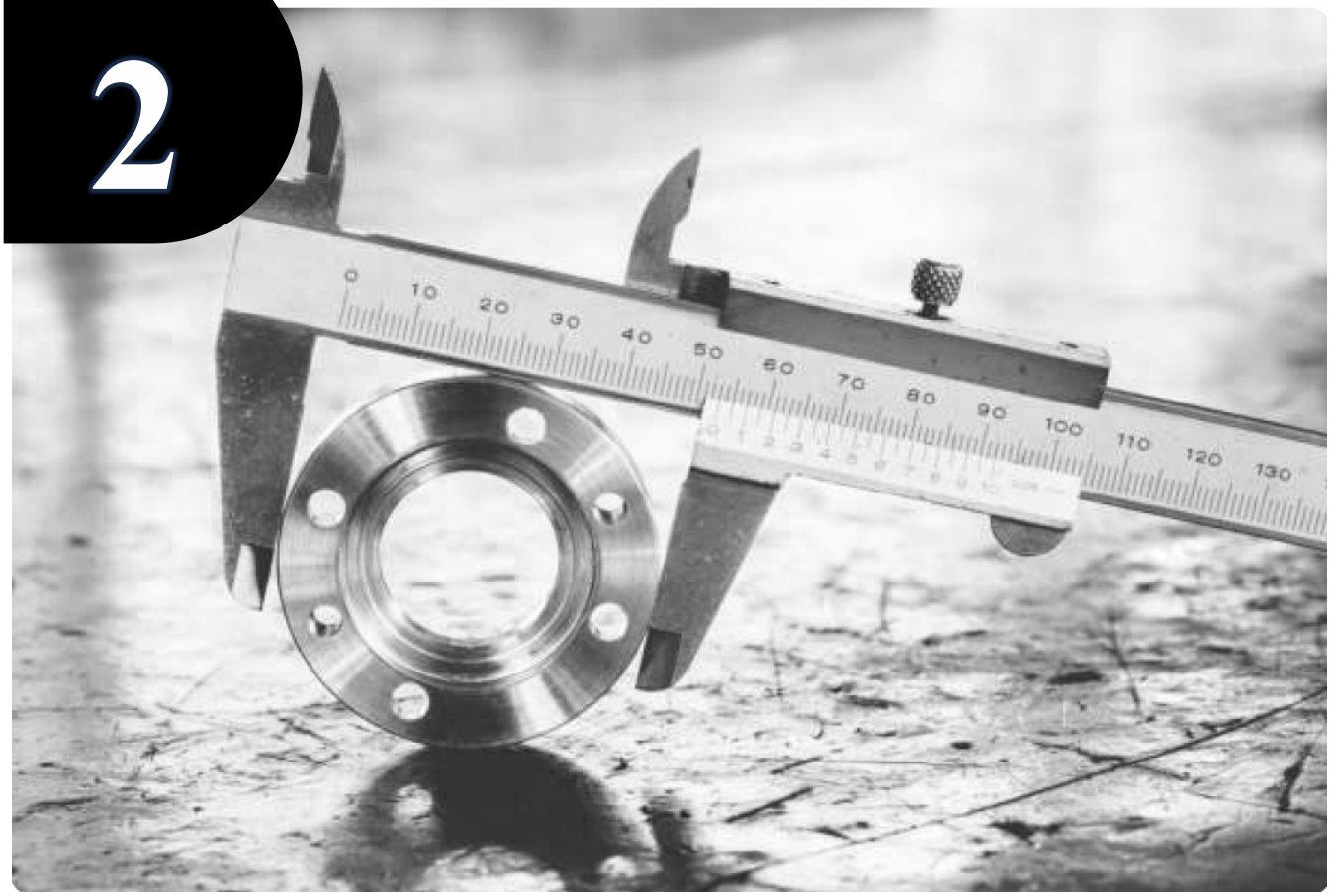
CHAPTER 2

Measurements



2.1 Knowledge Foundation of Physics

SLO: P-09-A-02	*Explain with examples that physics is based on physical quantities [Including that these consist of a magnitude and a unit].*	**18**	
SLO: P-09-A-01	*Differentiate Between physical and non-physical quantities.*	**20**	
SLO: P-09-A-03	*Differentiate between base and derived physical quantities and units.*	**21**	

2.2 Knowledge Mastering SI Units and Scientific Notation

SLO: P-09-A-04	*Apply the seven units of System International (SI) [along with their symbols and physical quantities (standard definitions of SI units are not required].*	**22**	
SLO: P-09-A-05	*Analyze and express numerical data using scientific notation [In measurements and calculations].*	**23**	

2.3 Knowledge SI Prefixes and Estimation

SLO: P-09-A-06	*Analyze and express numerical data, using prefixes. [including use of their symbol to indicate decimal submultiples or multiples of both base and derived units. Specially: Pico (p), nano (n) micro (μ), milli (m), centi (c) deci (d), kilo (k), mega (M), giga (G), tera (T). This also includes: interconverting the prefixes and their symbol to indicate multiples and sub-multiples for both base and drive units.].*	**25**	
SLO: P-09-A-011	*Make reasonable estimates of physical quantities [of those that are discussed in the topics of this grade level].*	**27**	

2.4 Knowledge Analyzing and Correcting Measurement Errors

SLO: P-09-A-17	*Critique and analyze experiments for sources of error [including identifying sources of systematic and random error in measurements and suggesting steps to correct them].*	**28**	

2.5 Knowledge Understanding Measurement Concepts

SLO: P-09-A-18	*Differentiate between precision and accuracy.*	**31**	

SLO: P-09-A-01	*Differentiate Between physical and non-physical quantities.*

Cognitive Level: (K + U) **Type of assessment: Summative**

Multiple Choice Questions

1. Which of the following is a physical quantity?
A) Happiness B) Mass
C) Sadness D) Anger
Answer: B) Mass

2. Which of the following is a non-physical quantity?
A) Mass B) Force
C) Happiness D) Length
Answer: C) Happiness

3. Which quantity can be measured using a thermometer?
A) Time B) Happiness
C) Temperature D) Sadness
Answer: C) Temperature

4. Why is 'time' considering a physical quantity?
A) Because it can be seen but not felt
B) Because it has both magnitude and a unit
C) Because it cannot be measured
D) Because it is a feeling
Answer: B) Because it has both magnitude and a unit

Short Response Question

Question 1: Define measurable and non-measurable quantities and provide one example of each.

Criteria: Marks

Definition of physical quantities	(1)
Definition of non-physical quantities	(1)
Example	(1)
Total marks	(3)

Answer:

Physical quantities

Physical quantities are measurable properties that have both a numerical value (magnitude) and a unit. They are used to describe physical phenomena and can be measured using instruments. Examples include mass, length, time, and temperature.

Non-physical quantities

Non-physical quantities are properties or concepts that cannot be measured or quantified with a numerical value or unit. They are often subjective and based on personal perception or experience. Examples include happiness, emotions, feelings, and opinions.

Question 2: Why 'temperature' is considered a measurable quantity while 'happiness' is not?

Criteria:	Marks
States the reason why 'temperature' is measurable	(1.5)
States why 'happiness' is not measurable	(1.5)
Total marks	(3)

Answer:

Why Temperature is Measurable (1.5 marks):

Temperature is measurable because it can be quantified using tools like thermometers. These tools give exact readings in standard units such as degrees Celsius (°C). The measurements are consistent, repeatable, and objective.

Why Happiness is Not Measurable (1.5 marks):

Happiness is not measurable because it is a personal and subjective feeling. It has no standard tools or units to measure it. People's happiness depends on their emotions and experiences, which vary greatly and cannot be quantified.

Question 3: Compare and contrast the properties of 'mass' and 'sadness' in terms of their measurability.

Identifies "mass" as a measurable quantity	(1)	Identifies "sadness" as a non-measurable quantity	(1)
Compares and contrasts "mass" and 'sadness'	(1)	Total marks	ss (3)

Answer:

Aspect	**Mass**	**Sadness**
Type of Quantity	Measurable	Non-measurable
Definition	Represents the amount of matter in an object.	Represents an emotional state or feeling.
Measurement	Can be quantified using tools such as a scale or balance.	Cannot be quantified using any tools or instruments
Units	Has standard units like grams (g) or kilograms (kg).	No standard units exist for measurement.
Nature	Objective, consistent, and quantifiable across different situations.	Subjective, varies from person to person, and cannot be quantified.
Use in Calculations	Can be used in scientific calculations and experiments.	Cannot be used in scientific calculations or experiments.
Comparison	Mass is measurable and objective, making it suitable for scientific use.	Sadness is subjective and non-measurable, making it unsuitable for scientific quantification.

SLO: P-09-A-02	*Explain with examples that physics is based on physical quantities [Including that these consist of a magnitude and a unit].*

Cognitive Level: (U) **Type of assessment: Summative**

Multiple Choice Questions

1. Which of the following statements best describes physical quantities?

A) They are abstract concepts that cannot be measured.

B) They are properties of matter and energy that have both magnitude and unit.

C) They are emotions that vary between individuals.

D) They do not require any standard units for measurement.

Answer: B) They are properties of matter and energy that have both magnitude and unit.

2. What are the two essential components of a physical quantity?

A) Unit and Emotion

B) Magnitude and Opinion

C) Magnitude and Unit

D) Thought and Feeling

Answer: C) Magnitude and Unit

Short Response Questions

Question 1: Why are physical quantities fundamental to physics, and provide one example that illustrates a physical quantity consisting of both magnitude and unit?

States the reason why physical quantities are fundamental to physics	(2)
Given an example that includes both magnitude and unit for a physical	(1)
Total marks	(3)

Answer:

Physical quantities are essential to physics because they allow scientists to measure and describe natural phenomena like force, energy, and motion. By using measurable quantities with standard units, physicists can create models, test predictions, and apply physical laws consistently in real-world situations.

Example of a physical quantity:

A physical quantity has both magnitude and unit. For example, the speed of a car can be expressed as 60 kilometers per hour (km/h), where '60' is the magnitude and 'kilometers per hour' is the unit. This combination ensures precise communication of measurements.

Question 2: How do physical quantities help us understand the world around us, and provide two examples?

Identifies how physical quantities help us understand the world	(1)
Gives a first example of a physical quantity	(1)
Gives a second example of a physical quantity	(1)
Total marks	(3)

Answer:

Physical quantities, like mass, time, and temperature, help us measure and describe the world scientifically. They provide standardized data to analyze phenomena, apply physical laws, and solve real-world problems.

Examples:

1. Mass (measured in kilograms) tells us how much matter an object has. For instance, knowing the mass of an object helps calculate its weight or the force needed to lift it, useful in engineering or construction.
2. Time (measured in seconds) quantifies how long events last. For example, measuring the time a car takes to travel a distance allows us to calculate its speed, helping us understand motion and plan efficiently.

SLO: P-09-A-03 *Differentiate between base and derived physical quantities and units.*

Cognitive Level: (K + U) **Type of assessment: Summative**

Multiple Choice Question

1. Which of the following is an example of a base quantity?

A) Length B) Acceleration

C) Density D) Pressure

Answer: A) Length

2. Which statement best describes a derived quantity?

A) A quantity that is directly measured without using other quantities.

B) A quantity formed by combining two or more base quantities.

C) A quantity that does not need a unit for measurement.

D) A quantity that has no relationship to base quantities.

Answer: B) A quantity formed by combining two or more base quantities

3. Which of the following quantities is an example of a derived quantity?

A) Mass B) Time

C) Volume D) Electric current

Answer: C) Volume

Short Response Question

Question 1: What is the difference between base and derived quantities, and give one example of each?

States the difference between base and derived quantities	(2)
Give one example of a base quantity and one example of a derived quantity	(1)
Total marks	(3)

Answer:

Difference Between Base and Derived Quantities:

Base quantities are fundamental quantities like length, mass, and time, which can be measured directly. Derived quantities are calculated by combining two or more base quantities using formulas, such as speed, force, or area.

Examples:

Base Quantity: Length, measured in meters (m).
Derived Quantity: Force, measured in newtons (N), is calculated using mass and acceleration ($F = ma$).

Question 2: If you want to calculate how fast a car is moving, which derived quantity would you be determining, what base quantities would you need to measure, and how would you use them to calculate the car's speed?

Derive Quantity: Identifies speed as the derived quantity.	(1)
Base Quantities: Identifies distance and time as the required base quantities.	(1)
Formula Explanation: Explains the relationship speed = distance/time.	(1)
Total marks	(3)

Answer:

Derived Quantity (1 mark):
To calculate how fast a car is moving, you are determining the derived quantity called speed.
Speed is the rate at which an object covers distance over time.
Base Quantities (1 mark):
To find speed, you need to measure two base quantities:

1 Distance: The total length the car has travelled, measured in meters (m) or kilometers (km).

2 Time: The duration it takes the car to travel that distance, measured in seconds (s) or hours (h).

Formula Explanation (1 mark):
Speed is calculated using the formula:

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

For example, if a car travels 100 kilometers in 2 hours, the speed is:

$$\text{Speed} = \frac{100\ \text{km}}{2\ \text{h}} = 50\ \text{km/h}$$

Question 3: When measuring the amount of electrical charge flowing through a circuit, which base quantity are you dealing with, which instrument would you use to measure it, and how does this instrument relate to charge measurement?

Identifies electric change as the base quantity.	(1)
Identifies the ammeter as the measuring instrument.	(1)
Clarifies that the ammeter measures current. Which relates to the flow of charge through the circuit.	(1)
Total marks	(3)

Answer
Base Quantity (1 mark):
The base quantity being measured is electric charge, which is measured in coulombs (C).
Measuring Instrument (1 mark):
The instrument used to measure it is an ammeter, which measures the electric current.
Relationship Explanation (1 mark):
The ammeter measures current, which is the rate at which charge flows through a circuit. The relationship between current and charge is:

$$\text{Current (I)} = \frac{\text{Charge (Q)}}{\text{Time (t)}}$$

This means the ammeter indirectly helps determine the flow of charge by measuring the current.

SLO: P-09-A-04	*Apply the seven units of System International (SI) [along with their symbols and physical quantities (standard definitions of SI units are not required].*

Cognitive Level: (A) **Type of assessment: Summative**

Multiple Choice Question

1. A laboratory experiment requires you to measure the temperature of a chemical reaction. Which SI unit should you use?
A) Mole (mol) B) Kelvin (K)
C) Candela (cd) D) Ampere (A)
Answer: B) Kelvin (K)

2. A lab experiment requires the measurement of electric current passing through a circuit. Which SI unit would be appropriate for this measurement?
A) Ampere B) Kelvin
C) Mole D) Candela
Answer: A) Ampere

3. A chemist measures the amount of substance in a reaction and records it as 0.02 moles. Which SI unit is being applied here?
A) Mole B) Kilogram
C) Ampere D) Candela
Answer: A) Mole

Short Response Question

Question 1: Name three base units from the International System of Units (SI) and provide the corresponding physical quantities they measure.

Criteria:	Names the first base unit and its corresponding physical quantity	(1)
	Names the second base unit and its corresponding physical quantity	(1)
	Names the third base unit and its corresponding physical quantity	(1)

Answer:

Base Unit	Symbol	Physical Quantity Measured
Meter	m	Length
Kilogram	kg	Mass
Second	s	Time

Question 2; If you want to calculate the pressure exerted on a surface, which derived unit would you use, and how is it expressed in terms of base units?

Identifies the derived unit used to measure pressure	(1)
Expresses the derived unit in terms of base units	(1)
Show the derivation of the derived unit from base units	(1)
Total marks	(3)

Answer

Derived Unit (1 mark):
The derived unit for pressure is the Pascal (Pa), defined as one Newton per square meter ($\mathrm{N/m^2}$).

Expression in Base Units (1 mark):
The Pascal is expressed in base units as:

$$\mathrm{Pa = kg\ m^{-1}\ s^{-2}}$$

Derivation of Unit (1 mark):
Pressure is force per unit area:

$$P = \frac{\text{Force (F)}}{\text{Area (A)}}$$

Force is mass times acceleration ($F = \mathrm{m \cdot a}$), with units:

$$F = \mathrm{kg \cdot\ m/s^2}$$

Area is measured in square meters ($\mathrm{m^2}$). Substituting:

$$P = \frac{\mathrm{kg \cdot\ m/s^2}}{\mathrm{m^2}} = \mathrm{kg \cdot\ m^{-1} \cdot\ s^{-2}}$$

SLO: P-09-A-05	*Analyze and express numerical data using scientific notation [In measurements and calculations].*

Cognitive Level: (U + A) **Type of assessment: Summative**

Multiple Choice Question

1. What is scientific notation used for?

A) Writing equations

B) Expressing very large or very small numbers using powers of 10

C) Calculating temperatures

D) Describing shapes

Answer: B) Expressing very large or very small numbers using powers of 10

2. In scientific notation, what does a negative exponent indicate?

A) A very small number
B) A very large number
C) A whole number
D) A number equal to zero

Answer: A) A very small number

3. Which of the following represents the number 0.0001 in scientific notation?

A) 1.0×10^{4} B) 1.0×10^{-4}
C) 1.0×10^{3} D) 1.0×10^{-3}

Answer: B) 1.0×10^{-4}

4. How would you express the product of (4×10^{2}) and (2×10^{3}) using scientific notation?

A) 6×10^{5} B) 8×10^{2}
C) 8×10^{5} D) 8×10^{7}

Answer: C) 8×10^{5}

Short Response Question

Question 1: Convert the number 350,000 into scientific notation and explain the steps involved.

Correctly converts 350,000 into scientific notation	(2)	Outlines the steps involved in converting the number	(1)

Answer:

To convert the number **350,000** into scientific notation:

Step 1: Move the Decimal Point

Shift the decimal point in 350,000 to the left until only one digit is left before the decimal. This gives 3.5.

Step 2: Count the Places

The decimal point moved 5 places to the left.

Step 3: Write in Scientific Notation

Write the number as 3.5×10^{5}.

So, 350,000 in scientific notation is 3.5×10^{5}. The exponent is positive because the decimal point moved to the left.

Question 2: Convert 0.000032 into scientific notation and why the exponent is negative.

Correctly converts 0.000032 into scientific notation	(2)
Explains why the exponent is negative	(1)
Total marks	(3)

Answer:

To convert 0.000032 into scientific notation:

1. **Step 1:** Move the decimal point so that there is one non-zero digit to the left of the decimal. In this case, we move the decimal 5 places to the right, making the number 3.2.
2. **Step 2:** Multiply by a power of 10 to account for the movement of the decimal. Since we moved the decimal 5 places to the right, the exponent on the 10 will be -5.

So, 0.000032 in scientific notation is written as 3.2×10^{-5}.

The exponent is negative because the original number is less than 1. In scientific notation, a negative exponent indicates that the decimal point was moved to the right, signifying a very small number.

Question 3: Multiply (5×10^{6}) and (3×10^{4}) using scientific notation and provide the result.

Multiplies the coefficients correctly	(2)
Adds the exponents correctly	(1)
Total marks	(3)

Answer:

To multiply (5×10^{6}) and (3×10^{4}) using scientific notation:

Step 1: Multiply the numbers 5 and 3:

$$5 \times 3 = 15$$

Step 2: Add the exponents 6 and 4:

$$6 + 4 = 10$$

Step 3: Combine the coefficient and the power of 10: 15×10^{10}

Step 4: In scientific notation, the coefficient must be between 1 and 10. Therefore, adjust by moving the decimal one place to the left: $15 = 1.5 \times 10^1$

Combine with the power of 10: $1.5 \times 10^1 \times 10^{10} = 1.5 \times 10^{11}$

Result

The product of (5×10^6) and (3×10^4) in scientific notation is 1.5×10^{11}.

Question 4: If you have two numbers, (7×10^5) and (2×10^2), and you need to divide them using scientific notation, what would the result be?

Divides the coefficients correctly	(2)
Subtracts the exponents correctly	(1)
Total marks	(3)

Answer

To divide (7×10^5) by (2×10^2) using scientific notation:

Step 1: Divide the coefficients 7 by 2: $7 \div 2 = 3.5$

Step 2: Subtract the exponents: $5 - 2 = 3$

Step 3: Write in Scientific Notation

Combine the coefficient and the power of 10: 3.5×10^3.

Result

The result of dividing (7×10^5) by (2×10^2) is 3.5×10^3.

SLO: P-09-A-06	*Analyze and express numerical data, using prefixes. [including use of their symbol to indicate decimal submultiples or multiples of both base and derived units. Specially: Pico (p), nano (n) micro (μ), milli (m), centi (c) deci (d), kilo (k), mega (M), giga (G), tera (T). This also includes: interconverting the prefixes and their symbol to indicate multiples and sub-multiples for both base and drive units.]*

Cognitive Level: (U + A) **Type of assessment: Summative**

Multiple Choice Question

1. Which prefix represents a factor of 10^{-6}?

A) Nano (n) B) Micro (μ)

C) Milli (m) D) Pico (p)

Answer: B) Micro (μ)

2. What does the prefix "kilo" (k) signify in the metric system?

A) 10^2 B) 10^{-3}

C) 10^3 D) 10^6

Answer: C) 10^3

3. Convert the diameter of the Earth (10^7 m) to kilometers using the appropriate prefix.

A) 10 km B) 100 km

C) 10,000 km D) 10,000,000 km

Answer: C) 10,000 km

4. If the radius of an atomic nucleus is 10^{-15} meters, which prefix can be used to express this measurement?

A) Pico (p) B) Nano (n)

C) Femto (f) D) Tera (T)

Answer: C) Femto (f)

Short Response Question

Question 1: State why prefixes are used in scientific measurements, provide an example of how the prefix 'mega' (M) is applied to a unit of measurement, and describe the relationship between the base unit and the prefix.

Why Prefixes are Used.	(1)	Example Using "Mega"	(1)
Base Unit Relationship:	(1)	Total marks	(3)

Answer:

Prefixes:

Prefixes simplify the representation of very large or small numbers, making measurements easier to read and communicate.

Example Using "Mega":

The prefix 'mega' (M) means 1 million. For example, 1 megawatt (MW) equals 1 million watts, often used to describe the power output of large power plants.

Base Unit Relationship:

The base unit "watt" measures power, and the prefix "mega" scales it up by 1 million times. Thus, 1 MW = 1,000,000 watts.

Question2: What is the meaning of the prefix "giga" and how does it relate to the base unit?

Defines "giga" as 10^9.	(1)
Describes its relationship to the base unit (1giga = 1 billion times the base unit).	(1)
Provides an example (e.g. 1 gigabyte = 1 billion bytes).	(1)
Total marks	(3)

Answer:

Definition of Giga:

The prefix "giga" means 10^9, or 1 billion. It is used to express very large values by scaling the base unit up by a billion.

Relationship to Base Unit:

'Giga' multiplies the base unit by 1 billion. For example, 1 gigawatt (GW) equals 1 billion watts, or 1,000,000,000 watts.

Example:

In data storage, 1 gigabyte (GB) equals 1 billion bytes, making it easier to describe large amounts of data, such as hard drive capacity or file sizes.

Question 3: Express 0.0025 meters in micrometers and kilometers.

Conversion to micrometer	(1.5)	Conversion to kilometer	(1.5)

Answer:

Conversion to Micrometers:

1 meter $= 10^6$ micrometers.

So, 0.0025 meters $\times 10^6 = 2500$ micrometers.

Conversion to Kilometers:

1 kilometer $= 1000$ meters.

So, 0.0025 meters $\div 1000 = 0.0000025$ kilometers.

Final Answer:

- 0.0025 meters $= 2500$ micrometers.
- 0.0025 meters $= 0.0000025$ kilometers.

Question 4: Convert 3.5 megabytes (MB) into gigabytes (GB) and describe the process.

Criteria:	**Correct Conversion:** Coverts **3.5 MB** to **0.0035GB**	(1)
	Prefix Clarification: States 1GB = 1000MB.	(1)
	Process Explanation: Explains dividing 3.5 by 1000.	(1)
	Total marks	(3)

Answer

To convert 3.5 megabytes (MB) into gigabytes (GB):

1 **Conversion:** Since 1 gigabyte (GB) equals 1000 megabytes (MB), divide 3.5 by 1000:

$$3.5\text{MB} = \frac{3.5}{1000} = 0.0035\ \text{GB}$$

2 **Clarification of prefix:** The prefix 'mega' (M) represents 10^6, or 1 million, and the prefix 'giga' (G) represents 10^9, or 1 billion. Therefore, 1 gigabyte is 1000 megabytes.

3 **Process:** To convert megabytes to gigabytes, divide the number of megabytes by 1000.

Thus, 3.5 megabytes $= 0.0035$ gigabytes.

SLO: P-09-A-11	*Make reasonable estimates of physical quantities [of those that are discussed in the topics of this grade level].*

Cognitive Level: (A) **Type of assessment: Summative**

Multiple Choice Question

1. Which of the following is the most reasonable estimate for the height of an average adult human?

A) 0.2 meters B) 1.7 meters

C) 5.0 meters D) 10.0 meters

Answer: B) 1.7 meters

2. What is a reasonable estimate for the mass of an apple?

A) 100 grams B) 5 grams

C) 5 kilograms D) 20 kilograms

Answer: A) 100 grams

Short Response Question

Question 1: Estimate the length of your classroom without any measuring tools. What method would you use, and what steps would you take to make a reasonable estimate?

Detailed, relevant method with adequate explanation	(2)
Clear steps or logical reasoning	(1)
Total marks	(3)

Answer:

To estimate the length of the classroom without any measuring tools, I would use the 'pacing' method. I would walk from one end of the classroom to the other while counting the number of steps I take. Knowing that each of my steps is approximately 0.75 meters long, based on my average step length, I would then multiply the total number of steps by this length. For example, if it takes me 20 steps to walk across the room, I would calculate the estimated length as 20 multiplied by 0.75, which equals 15 meters. This method is reasonable because it provides a practical and straightforward way to estimate the length using an average step length and the number of steps taken.

Question 2: Estimate the time it would take for a car traveling at an average speed of 60 km h^{-1} to cover a distance of 120 km. Show your calculation process.

Correctly calculates the estimated time	(2)
Provides the calculation steps used to reach the answer	(1)
Total marks	(3)

Answer:

Step 1: Identify the speed and relation for 60 km (1 mark)

At a speed of 60 km/h :

Time to cover 60 km = 1 hour.

Step 2: Extend the calculation for 120 km (1 mark)

For 120 km:

Time = 2 × 1 hour = 2 hours.

Step 3: Final statement (1 mark)

Therefore, the car will take 2 hours to cover 120 km.

Question 3: Find the amount of water in a swimming pool that is 10 meters long, 5 meters wide, and filled to an average depth of 2 meters. How would you calculate the volume of water in cubic meters, and why is this calculation reasonable?

Correctly identifies the formula to calculate volume	(1)
Substitutes the given dimensions into the formula	(1)
Provides a logical explanation for why the calculation is reasonable	(1)
Total marks	(3)

Answer:

To find the amount of water in the swimming pool, I would calculate the volume of the pool using the formula for the volume of a rectangular prism:

$$\text{Volume} = \text{Length} \times \text{Width} \times \text{Depth}$$

Given:

- Length = 10 meters
- Width = 5 meters
- Depth = 2 meters

Substitute these values into the formula:

$$\text{Volume} = 10\ \text{m} \times 5\ \text{m} \times 2\ \text{m} = 100 \text{ cubic meters}$$

The volume of water in the swimming pool is 100 cubic meters. This calculation is reasonable because it uses the appropriate formula for finding the volume of a rectangular space, and it takes into account the correct dimensions provided for the pool.

SLO:P-09-A-17	*Critique and analyze experiments for sources of error [including identifying sources of systematic and random error in measurements and suggesting steps to correct them].*

Cognitive Level: (U + A) **Type of assessment: Summative**

Multiple Choice Question

1. What is a zero error in the context of using a Vernier calliper?

A) A reading error due to environmental conditions

B) An error caused by not setting the instrument to zero before use

C) A random error caused by fluctuation in readings

D) An error that occurs due to human reaction time

Answer: B) An error caused by not setting the instrument to zero before use

2. Which of the following is an example of a systematic error?

A) Measuring the mass of an object multiple times and getting different results

B) A parallax error due to improper alignment of the observer's eye

C) Changes in readings due to varying room temperatures

D) Fluctuations in pressure readings when doors open and close

Answer: B) A parallax error due to improper alignment of the observer's eye

3. What step would you take to minimize random errors when measuring the time period of a pendulum's swing?

A) Use a stopwatch with a smaller least count

B) Ensure the pendulum is free of air resistance

C) Repeat the measurements multiple times and calculate an average

D) Use a metal bob instead of a wooden bob

Answer: C) Repeat the measurements multiple times and calculate an average

4. Which step would you take to minimize systematic errors when measuring the length

of an object with a ruler that has uneven markings?

A) Use a different ruler with standard markings

B) Take multiple measurements and calculate an average

C) Measure in different environmental conditions

D) Increase the sample size of objects being measured

Answer: A) Use a different ruler with standard markings

Short Response Question

Question 1: How could systematic errors be introduced in an experiment involving the measurement of temperature using a thermometer? Provide one example of such an error and a method to minimize it.

Identifies how systematic errors could occur in temperature measurement	(2)
Gives an example and a method to minimize the error	(1)
Total marks	(3)

Answer:

Systematic errors happen when a thermometer consistently provides incorrect readings due to calibration issues, manufacturing defects, or external factors like improper placement. These errors cause all measurements to deviate consistently from the true value.

Example and Method to Minimize:

For example, if a thermometer always reads 1°C higher due to a defect, all recorded measurements will be inaccurate.

To minimize this, the thermometer should be calibrated regularly using a reliable reference and checked for damage before use.

Question 2: When measuring the volume of a liquid using a graduated cylinder, what are two potential sources of error that could affect the accuracy of your measurements, and how could you reduce these errors?

Identifies two potential sources of error	(2)
Provides methods to reduce these errors	(1)
Total marks	(3)

Answer:

Two potential sources of error in measuring the volume of a liquid using a graduated cylinder are parallax error and calibration error:

Potential Sources of Error:

- **Parallax Error:** This happens if the liquid level is read from an angle instead of at eye level, causing incorrect readings.
- **Calibration Error:** This occurs if the graduated cylinder markings are inaccurate or unevenly spaced.

Methods to Reduce Errors:

- To avoid parallax error, always read the liquid level at eye level and align with the bottom of the meniscus.
- To prevent calibration error, use a properly calibrated graduated cylinder verified against a trusted reference.

Question 3: A student conducts an experiment to measure the force required to pull a block across different surfaces. What steps should the student take to improve the reliability of the measurements in this experiment?

Lists steps to improve the reliability of measurements	(2)
Provides reasoning for these steps	(1)
Total marks	(3)

Answer

Steps to Improve Reliability (2 marks):

1. Take multiple measurements for each surface and calculate the average to reduce random errors.
2. Use the same block and ensure consistent surface conditions to minimize variables.

Reasoning (1 mark):
Repeating measurements reduces fluctuations and provides a more reliable average. Controlling variables ensures that differences in force are due to the surface type, not other factors.

Question 4: In an experiment to measure the length of a table, a student uses a ruler that starts at 1 cm instead of 0 cm. Analyze this source of error and suggest two steps the student could take to correct it.

Analyzes the source of error (using a ruler that starts at 1cm)	(2)
Suggests two valid steps to correct the error	(1)
Total marks	(3)

Answer:
Source of Error (2 marks):
The error occurs because the ruler does not start at 0 cm, introducing a **systematic error**. This means all measurements will be consistently 1 cm longer than the actual length of the table.
Steps to Correct the Error (1 mark):
1. Subtract 1 cm from all measurements to account for the offset.
2. Use a properly calibrated ruler that starts at 0 cm to avoid the error entirely.

Queston 5: During an experiment to measure the time it takes for a ball to fall from a certain height, a student records different times in each trial using a stopwatch. What type of error is occurring in this experiment, and how could this error be reduced?

Identifies the type of error occurring	(2)
Suggests methods to reduce the error	(1)
Total marks	(3)

Answer:
Type of Error:
The error in this experiment is a **random error**, caused by unpredictable variations such as the student's reaction time when starting and stopping the stopwatch. Each trial may record slightly different times due to inconsistent human reaction or environmental factors like air currents.
Ways to Reduce the Error:
- Take multiple measurements and calculate the average to minimize the effect of random variations.
- Use automated timing devices, such as light gates, to eliminate human reaction time errors.

Extended Response Question

Question: An experiment is conducted to measure the mass of a liquid using a balance, but several errors are observed. Based on the provided scenarios:
1. Identify and explain two possible sources of random errors in the experiment.
2. Identify and explain two possible sources of systematic errors in the experiment.
3. Suggest practical steps to minimize both random and systematic errors and improve the reliability of the experiment's results.

Explanation of Errors	(3)
Suggestions for Minimizing Errors	(2)
Total marks	(5)

Answer:

1 Random Errors (1.5 marks):

- *Environmental Changes:* Air currents or temperature changes can cause fluctuations in balance readings, leading to inconsistent results. For example, an open window or door can create air movement that affects the balance.
- *Observational Errors:* Slight differences in how the beaker is placed on the balance or how the scale is read can cause variations. Parallax errors may occur if the measurement is not viewed at the correct angle.

2 Systematic Errors (1.5 marks):

- *Calibration Error:* If the balance is not calibrated properly, such as starting at 0.02 g instead of 0 g, all measurements will have the same bias.
- *Container Residue:* If the container is not fully clean or dry, leftover residue adds extra mass, making all measurements consistently higher than the actual value.

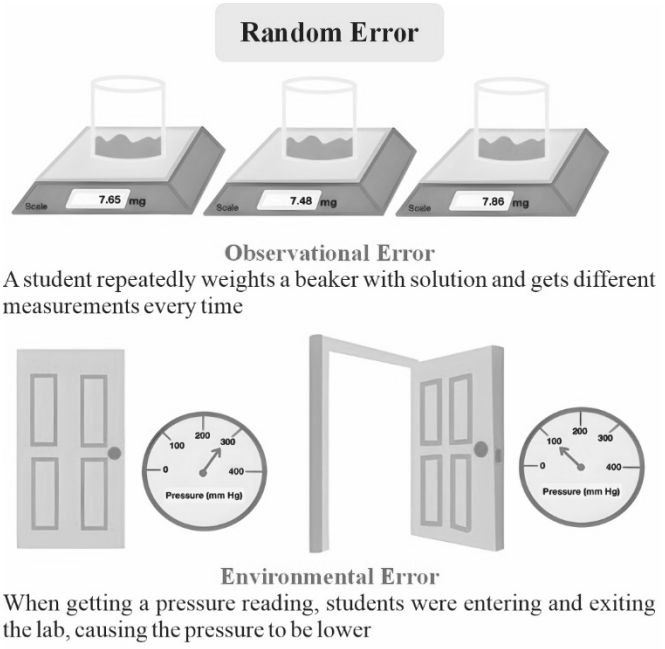


Figure: Random error in measurements of time and mass.

3 Steps to Minimize Errors (2 marks):

- *Minimizing Random Errors:*

1 Perform the experiment in a closed, stable environment to reduce air currents and vibrations.

2 Take multiple readings and calculate the average to reduce the effect of fluctuations.

- *Minimizing Systematic Errors:*

3 Calibrate the balance before use to ensure accurate readings.

4 Use clean and dry containers to avoid extra mass from residue or contamination.

These steps improve the reliability and accuracy of the experiment's results.

SLO: P-09-A-18 *Differentiate between precision and accuracy.*

Cognitive Level: (U) **Type of assessment: Summative**

Multiple Choice Question

1. What does "accuracy" refer to in scientific measurements?

A) The consistency of repeated measurements

B) The closeness of a measurement to the true or accepted value

C) The smallest unit that a measuring instrument can detect

D) The total number of measurements taken in an experiment

Answer: B) The closeness of a measurement to the true or accepted value

2. Which statement best defines "precision" in the context of measurements?

A) The ability to measure with the highest possible sensitivity

B) The difference between the highest and lowest measurements

C) The ability to obtain the same measurement repeatedly

D) The ability to measure against a known standard

Answer: C) The ability to obtain the same measurement repeatedly

Short Response Question

Question 1: Provide an example of an experiment where measurements are precise but not accurate. Why is it important to distinguish between precision and accuracy in scientific research?

Gives an example where measurements are precise but not accurate	(2)
States the importance of distinguishing between precision and accuracy	(1)
Total marks	(3)

Answer:

Example of precision without accuracy:

In an experiment to measure the boiling point of water, a thermometer consistently reads 95°C every time the measurement is taken. These readings are precise because they are consistent and repeatable. However, the actual boiling point of water at sea level is 100°C, meaning the measurements are not accurate. The thermometer is giving a systematic error that makes all the readings lower than the true value.

Importance of distinguishing between precision and accuracy:

Distinguishing between precision and accuracy is important because precision ensures consistency, while accuracy reflects correctness. Understanding both helps identify errors and improves the reliability of experimental results.

Question 2: Why might a scientific measurement be accurate but not precise? Provide an example to illustrate this situation.

Explains how a measurement can be accurate but not precise	(2)
Provides an example illustrating this situation	(1)
Total marks	(3)

Answer:

Reason for accuracy without precision:

A scientific measurement can be accurate but not precise when the average of the measurements is close to the true or accepted value, but the individual measurements themselves vary widely. This often occurs when there are inconsistencies in the measurement technique, environmental fluctuations, or when the equipment being used is not sufficiently sensitive to detect small differences. The lack of precision means the measurements are not consistently close to each other, even though they may still provide a good estimate of the true value.

Example:

If the true length of a table is 1 meter and a student measures 0.98 m, 1.05 m, and 1.02 m, the average is 1 m (accurate), but the measurements vary significantly, showing a lack of precision.

Extended Response Question

Question 3: Compare and contrast the concepts of accuracy and precision in scientific measurements. Discuss how both influence the reliability and validity of experimental data.

Compares and contrasts accuracy and precision in detail	(3)
Discusses how accuracy and precision affect reliability and validity	(2)
Total marks	(5)

Answer:

Differentiating Between Precision and Accuracy

Precision is the consistency of repeated measurements. It shows how close the results are to each other under the same conditions. For example, if a scale gives readings of 10.01 g, 10.02 g, and 10.01 g for a 10 g object, it is precise. Instruments like micrometers provide higher precision than rulers. Precision focuses on consistency and does not consider how close measurements are to the true value.

Accuracy measures how close a result is to the true value. For example, if the true weight is 10 g and readings are 9.99 g, 10.01 g, and 10.00 g, the results are accurate. Accuracy depends on reducing errors like miscalibration. It reflects how correct a measurement is, even if it is not consistent.

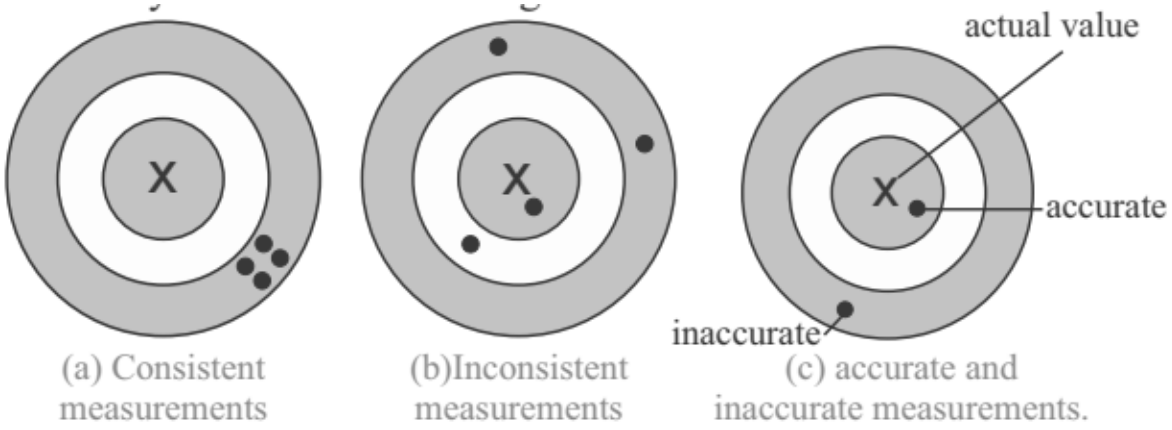


Figure: Precision and Accuracy

Impact on Reliability and Validity of Experimental Results

Precision ensures consistent results, reducing random errors like environmental changes. Reliable data needs repeated measurements with minimal variation. Without precision, measurements are unpredictable and less reliable.

Accuracy ensures results match the true value. It reduces systematic errors and improves validity. Without accuracy, results may be consistent but still incorrect, leading to wrong conclusions.

Examples:

- **Precision without accuracy:** Measurements are grouped but far from the true value, often due to a systematic error.
- **Accuracy without precision:** Results may match the true value but vary widely, making them unreliable.

Both accuracy and precision are needed to ensure measurements are correct and consistent. This makes experimental results reliable and valid.