Name: _____ **Date:** _____

Answer Key: Shatter the Scale: Advanced Metrology Challenge for 11th Grade

Probe beyond simple conversions by modeling multidimensional dimensional analysis and quantifying the propagation of uncertainty in complex laboratory environments.

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1. A researcher measures the resistivity of a new alloy using the formula ρ = RA/L. If the uncertainty in resistance (R) is 2% and the uncertainty in the dimensions (A and L) is 1% each, what is the total propagated percentage uncertainty in resistivity?

Answer: C) 4%

When multiplying or dividing independent values, the relative uncertainties (percentages) are summed to find the total uncertainty: 2% (R) + 1% (A) + 1% (L) = 4%.

2. In the derivation of fundamental constants, the _____ is the only SI base unit defined by fixing the numerical value of the Planck constant (h) to exactly $6.62607015 \times 10^{-34}$ $kg \cdot m^2 \cdot s^{-1}$.

Answer: B) Kilogram

As of the 2019 redefinition, the kilogram is no longer defined by a physical artifact (Le Grand K) but by the Kibble balance and the Planck constant.

3. Systematic errors can be significantly reduced by calculating the mean of a very large set of repeated trials.

Answer: B) False

Averaging reduces random error, but systematic error relates to the accuracy of the instrument or setup; if a scale is calibrated incorrectly, the error persists in every measurement regardless of the number of trials.

4. Evaluate the following calculation to the correct number of significant figures: (12.55 × 3.00) / 0.01201.

Answer: B) 3135

12.55 has 4 sig figs, 3.00 has 3 sig figs, and 0.01201 has 4 sig figs. The final answer must be limited by the factor with the fewest significant figures, which is 3. Result: 3130 or 3.13 x 10^3.

5. Which derived unit is used to express the frequency of a periodic signal in terms of base SI units (s^{-1})?

Answer: B) Hertz

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The Hertz (Hz) is the derived SI unit for frequency, defined as cycles per second (1/s).

6. The luminous intensity (candela) is the only SI base unit that accounts for the human eye's perception of light brightness.

Answer: A) True

The candela is unique because it is weighted according to the CIE photopic luminosity function, which describes human eye sensitivity to different wavelengths.

7. If a theoretical equation for velocity is given as v = sqrt(2GM/r), what must be the SI base units of the gravitational constant (G)?

Answer: A) $m^3 kg^{-1} s^{-2}$

Squaring both sides gives $v^2 = 2GM/r$. Rearranging for $G = v^2 r/M$. Units: $(m/s)^2 * m / kg = (m^2/s^2) * m / kg = m^3 kg^{-1} s^{-2}$.

8. The SI base unit for thermodynamic temperature, the Kelvin, is defined by fixing the numerical value of the _____ to 1.380649×10^{-23} $J K^{-1}$.

Answer: B) Boltzmann constant

The Boltzmann constant (k) relates the average relative kinetic energy of particles in a gas with the thermodynamic temperature.

9. A student measures the thickness of a wire using a micrometer screw gauge with a zero error of -0.02 mm. The observed reading is 1.45 mm. What is the corrected measurement?

Answer: C) 1.47 mm

Corrected reading = Observed reading - Zero Error. Thus, 1.45 mm - (-0.02 mm) = 1.47 mm.

10. Dimensions and units are synonymous; if two quantities share the same dimensions (e.g., L^2), they must be expressed in the same SI units.

Answer: B) False

Dimensions represent the nature of a physical quantity (e.g., Energy/Work is ML^2T^{-2}). Different units can exist for the same dimension (e.g., Joules and Watt-seconds), or specific concepts like Torque and Energy share dimensions but are fundamentally different vector/scalar types.