

Name: _____ Date: _____

Cosmic Navigators: Senior Year Precision & Dimensional Analysis Quiz

Synthesize complex SI conversions and evaluate measurement uncertainty to calculate trajectories across astronomical and microscopic scales.

1. A research team is measuring the hyperfine transition frequency of a Caesium-133 atom to redefine a local timescale. Which SI base unit are they fundamentally refining, and what physical constant is now fixed to define it?

- A. The Second; based on the fixed numerical value of the Caesium frequency $\Delta\nu_{Cs}$.
- B. The Kelvin; based on the Boltzmann constant k .
- C. The Candela; based on the luminous efficacy of monochromatic radiation.
- D. The Meter; based on the speed of light in a vacuum c .

2. An astrophysicist calculates the Schwarzschild radius of a black hole to be 4.25×10^4 meters with an instrumental uncertainty of ± 300 meters. The relative uncertainty of this measurement is approximately _____.

- A. 0.007%
- B. 0.71%
- C. 1.42%
- D. 7.05%

3. True or False: In a complex multi-step physics derivation, the Planck constant (h) can be expressed in the derived SI units of $\text{kg}\cdot\text{m}^2/\text{s}$.

- A. True
- B. False

4. A mass spectrometer measures the ratio of m/z (mass-to-charge). If the mass is recorded in unified atomic mass units (u) and charge in elementary charge (e), which conversion factor is necessary to translate the result into the SI derived unit of kg/C ?

- A. Divide by the Avogadro constant and multiply by the Faraday constant.
- B. Multiply by $1.66 \times 10^{-27} \text{ kg}/u$ and divide by $1.60 \times 10^{-19} \text{ C}/e$.
- C. Simply use the 1:1 ratio as the units are equivalent in the SI system.
- D. Multiply by the molar gas constant R .

5. In the analysis of thermal conductivity, the unit $\text{W}/(\text{m}\cdot\text{K})$ is used. When decomposed into SI base units (kg , m , s , K), the power aspect (Watt) results in the numerator being _____.

- A. $\text{kg}\cdot\text{m}/\text{s}$
- B. $\text{kg}\cdot\text{m}^2/\text{s}^2$
- C. $\text{kg}\cdot\text{m}^2/\text{s}^3$
- D. $\text{kg}\cdot\text{m}/\text{s}^3$

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6. True or False: According to the International Bureau of Weights and Measures (BIPM), the kilogram is currently defined by a physical prototype made of platinum-iridium kept in a vault in Sèvres, France.

- A. True
- B. False

7. When performing Taylor series expansions in physical modeling, why must the argument of a transcendental function (like $\ln(x)$ or e^x) be dimensionless?

- A. Because SI units do not exist for logarithmic scales.
- B. To ensure the sum of the power series has consistent dimensions across all terms.
- C. Dimensionless arguments are required only for trigonometric functions, not exponentials.
- D. Because the derivative of a dimensioned quantity is always zero.

8. A volumetric flask is calibrated to 500.00 mL. If a student records a series of measurements as 498.12 mL, 498.11 mL, and 498.13 mL, the data set is _____.

- A. Neither accurate nor precise.
- B. Accurate but not precise.
- C. Both accurate and precise.
- D. Precise but not accurate.

9. True or False: The mole is defined as the amount of substance containing exactly $6.02214076 \times 10^{23}$ elementary entities, a definition that no longer depends on the mass of Carbon-12.

- A. True
- B. False

10. In fluid dynamics, the Reynolds number (Re) is used to predict flow patterns. If $Re = (\rho v d) / \mu$ where ρ is density, v is velocity, d is diameter, and μ is dynamic viscosity, what must be the SI base units of dynamic viscosity for the Reynolds number to remain dimensionless?

- A. $\text{kg}/(\text{m}\cdot\text{s})$
- B. $\text{kg}\cdot\text{m}/\text{s}^2$
- C. m^2/s
- D. $\text{kg}\cdot\text{s}/\text{m}^3$