CONCEPT: HEISENBERG UNCERTAINTY PRINCIPLE

- Werner Heisenberg theorized the _____ and _____ of an electron cannot be measured simultaneously.
  - □ Related to an electron behaving both as a wave and a particle.
    - The _____ of the electron is related to its wave nature.
    - The _____ of the electron is related to its particle nature.
  - □ **Complementarity**: Electrons can be seen as particles or waves, but not both simultaneously.

Heisenberg Uncertainty Principle

Momentum can be described as "mass in motion".

Uncertainty in Momentum

$\triangle p = \_\_\_\_ \bullet \_\_\_\_$

□ $\triangle$**p** = uncertainty in momentum in ___.

□ _____ = mass in kg.

□ _____ = uncertainty in velocity in m/s.

Used when given the uncertainties in position and momentum

Uncertainty Principle Formula

$\_\_\_\_ \bullet \_\_\_\_ \geq \frac{h}{4\pi}$

□ $\triangle$**x** = uncertainty in position in _____.

□ h = Planck's Constant as _____ J•s.

EXAMPLE: Calculate the uncertainty in velocity of a neutron if the uncertainty in its position is 712 pm. The mass of a neutron is 1.67510×10^{-27} kg.

PRACTICE: To what uncertainty (in m) can the position of a baseball traveling at 51.0 m/s be measured if the uncertainty of its speed is 0.12%? The mass of the baseball is 150 g.

CONCEPT: HEISENBERG UNCERTAINTY PRINCIPLE

PRACTICE: An electron with a mass of 9.11×10^{-31} kg has an uncertainty in its position of 630 pm. What is the uncertainty in its velocity?

PRACTICE: An proton with a mass of 1.67×10^{-27} kg traveling at 4.7×10^{5} m/s has an uncertainty in its velocity of 1.77×10^{5} m/s. Determine its uncertainty in position.