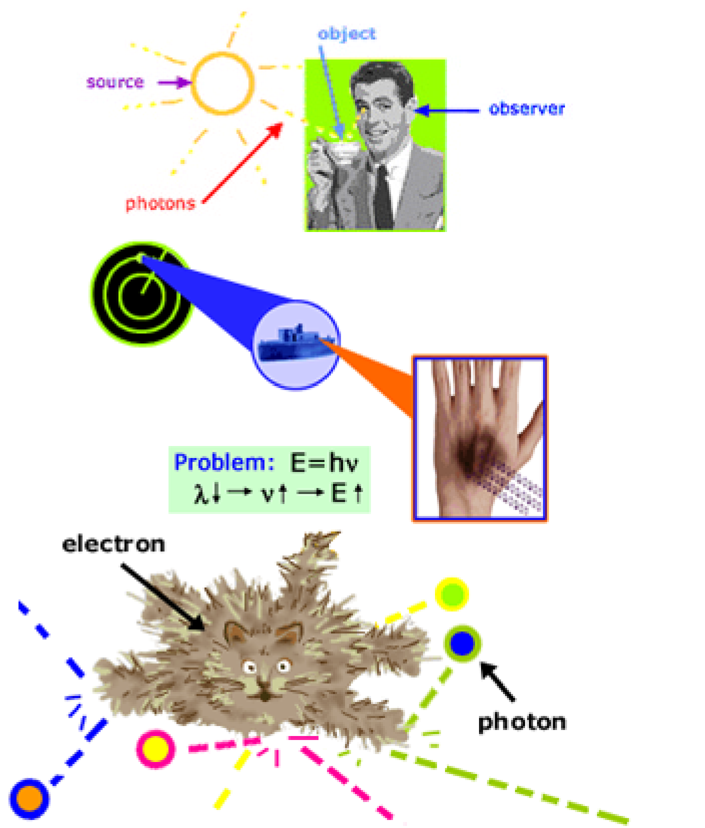
Unit: Modern Atomic Theory **Module:** Electromagnetic Radiation and the Idea of Quantum [page 1 of 1]

The Heisenberg Uncertainty Principle

key concepts:

- One locates things by detecting the **photons** that bounce off the object from a **light** source.
- The **Heisenberg uncertainty principle** states that the smaller the object the greater the relative uncertainty in knowing both the position and the **momentum** of that object.



One locates things by detecting the photons that bounce off the object from a light source.

The **wavelength (λ)** of light used to view an object must be smaller than the object viewed. For example, radar ($\lambda \approx$ 1 m) can be used to view a ship, but visible light ($\lambda \approx 5 \times 10^{-7}$ m) must be used for greater detail. Higher resolution requires still shorter wavelengths. However, the shorter the wavelength, the higher the **frequency**, and therefore the higher the **energy** of each photon. Higher energy photons have a greater effect on the object viewed, and therefore can change the object as it is being viewed. For example, **ultraviolet** light ($\lambda \approx 2 \times 10^{-7}$ m) provides still greater resolution, but can damage skin.

Electrons are very small. To view an electron, one would have to use **electromagnetic radiation** with a very short wavelength, such as **gamma rays** ($\lambda \approx 1 \times 10^{-11}$ m). But gamma rays have a high energy, and would therefore affect the momentum of the electrons being studied. This is analogous to trying to locate a cat with rubber balls—one might locate the cat, but the momentum of the cat would be changed in the act of finding the cat.

The Heisenberg uncertainty principle:

$$(\Delta p)(\Delta x) \geq \frac{h}{4\pi}$$

$$(\text{error in momentum})(\text{error in location}) \geq 5.27 \times 10^{-35}\ \text{J}\cdot\text{s}$$

(*a very small number*)

The Heisenberg uncertainty principle states that the smaller the object the greater the relative uncertainty in knowing both the exact position and the momentum of that object.

Mathematically, the error in momentum ($\Delta\rho$) multiplied by the error in location (Δx) is greater than or equal to **Planck's constant (h)** divided by four pi. This works out to a very small number, and therefore isn't important for macroscopic objects. However, relative to the size of an electron, this number is large. Therefore, it is impossible to know both the location and momentum of an electron precisely.