PHYS 1200 Physics of Everyday Experience

Review questions and exercises for Lecture 33 (MP-1)

1. What was the prediction of the classical theory of atoms?
2. What is the range of applicability of Newton's Laws?
3. What is the photoelectric effect?
4. What radical concept did Einstein introduce to explain the photoelectric effect?
5. How does the energy of a photon depend on frequency and wavelength?
6. What is a photon?
7. Who used the photon concept to explain the stability of the hydrogen atom?
8. What conclusions were drawn from the fact that the spectrum of hydrogen contained discreet lines?
9. What is a stationary state of an atom?
10. An electron makes a transition from a state of energy E_2 to a state of lower energy E_1. What are the frequency and wavelength of the photon that is emitted in this process?
11. What is the difference between emission and absorption?
12. What is fluorescence?
13. Two photons have frequencies $f_1 = 1.0 \times 10^{14}$ Hz, and $f_2 = 1.0 \times 10^{15}$ Hz. What is the ratio E_2 / E_1 of the energies of these two photons?
14. Two photons have wavelengths $\lambda_1 = 350$ nm and $\lambda_2 = 700$ nm. What if the ratio E_2 / E_1 of the energies of these two photons?
15. A gamma (γ) ray has 1000 times more energy than an x-ray. What are the ratios of the frequencies (f_γ / f_X) , and wavelengths ($\lambda_\gamma / \lambda_X$) , of these two photons?

Answers and Solutions:

1. In classical electromagnetic theory, an electron in a circular orbit in an atom would continuously radiate energy and would very quickly collapse into the nucleus. Atoms could not exist.

2. Newton's laws are applicable to macroscopic (i.e., non- atomic size) objects. They are also limited to objects that move with speeds much smaller than the speed of light.

3. In the photoelectric effect, when a metal surface is exposed to light, electrons are emitted from the metal. The wavelength of the light must be less than a critical value that varies from metal to metal.

4. Einstein used the photon concept to explain the photoelectric effect. When light interacts with a metal, light behaves like a beam of photons. The photons must have a minimum amount of energy to be able to knock out an electron.

5. $E = h f$, but since $\lambda f = c \rightarrow f = c/\lambda \rightarrow E = h c / \lambda$. The energy of a photon is directly proportional to its frequency and inversely proportional to its wavelength.

6. A photon is a quantized packet of energy.

7. Niels Bohr used the photon concept to explain the characteristics of the hydrogen atom.

8. The observation that light is emitted in discreet spectral lines indicates that the energies of the electrons in atoms are quantized, they can exist only in certain stationary states of specified energy.

9. A stationary state of an atom is a special quantum state of the electrons in which it does not radiate.

10. $hf = E_2 - E_1 \rightarrow f = (E_2 - E_1)/h$, $f = c/\lambda \rightarrow hc/\lambda = E_2 - E_1 \rightarrow \lambda = hc / (E_2 - E_1)$.

11. In the process of emission, an electron in a stationary high energy state of an atom emits a photon and makes a transition to a stationary state of lower energy. In the absorption process, an electron in a low energy state absorbs energy from a photon and makes a transition to a stationary state of higher energy.

12. Fluorescence is a process whereby a substance absorbs a high energy photon and immediately emits a lower energy photon. For example, ultraviolet light (black light) is absorbed by a fluorescent material which then emits green light.

13. $E = h f$, so photon 2 has 10 times more energy than photon 1 $\rightarrow E_2 / E_1 = 10$.

14. $E = h c / \lambda$, so the photon with the shorter wavelength has the higher energy $\rightarrow E_2 / E_1 = 0.5$.

15. $E = h f = h c / \lambda \rightarrow f_\gamma / f_X = E_\gamma / E_X = 1000$, and $\lambda_\gamma / \lambda_X = E_X / E_\gamma = 0.001$.