Multiple Choice Questions

(You only need to mark the correct answer. Calculate on the back of the equation sheets. Careful because you must mark the correct answer.)

(10) 1. In the Compton Effect a photon is incident on an atom and an electron is ejected. The scattered photon is given off at an angle of 45 degrees. This scattered photon

a. has the same wavelength as the incident photon [b. has a longer wavelength than the incident photon] c. has a shorter wavelength than the incident photon, d. has a wavelength 24 pm shorter than the incident photon.

(10) 2. A surface has a work function 1.70 eV and has light of wavelength 400 nm shone on it. What is the maximum speed of the photoelectrons emitted?

a. 7.7 x 10^4 m/s. b. 1.0 x 10^6 m/s. c. 1.3 x 10^6 m/s. d. 7.0 x 10^5 m/s

\[ h\nu = \frac{hc}{\lambda} = \frac{4.136 \times 10^{-15} \text{ eV} \cdot \text{s}}{4.0 \times 10^{-8} \text{ m}} \]

\[ h\nu - \phi = KE_{\text{max}} = 3.1 \text{ eV} \]

\[ 3.1 - 1.7 \text{ eV} = 1.4 \text{ eV} \]

\[ 1.4 \text{ eV} \cdot 1.6 \times 10^{-19} \text{ J} = 2.24 \times 10^{-19} \text{ J} \]

\[ \frac{1}{2} MV^2 = 2.24 \times 10^{-19} \text{ J} \]

\[ V^2 = \frac{2(2.24 \times 10^{-19})}{9.1 \times 10^{-31} \text{ kg}} \]

\[ V = \sqrt{2.4 \times 10^5 \frac{\text{m}}{\text{s}}} \]
(10) 3. A light-emitting diode emits one microwatt ($10^{-6}$ J/s) of 640 nm ($10^{-9}$) photons. How many photons are emitted each second?

- a. $3.2 \times 10^{12}$
- b. $2.5 \times 10^{20}$
- c. $9.7 \times 10^{20}$
- d. $2.0 \times 10^{31}$

\[ E_{\text{each photon}} = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \text{ J s} \cdot \text{s} \cdot \text{m}}{640 \times 10^{-9} \text{ m}} \]

\[ \text{#photons/s} = \frac{10^{-6} \text{ J/s}}{3.11 \times 10^{-19} \text{ J/photons}} = 3.22 \times 10^{12} \text{ photons/second} \]

(10) 4. Which of the following is NOT a valid set of quantum numbers for an electron in a hydrogen atom?

a. $n=1$, $l=0$, $m=0$; b. $n=2$, $l=2$, $m=1$; c. $n=2$, $l=1$, $m=-1$; d. $n=3$, $l=2$, $m=0$

- $n=1$, $l=0$, $m=0$
- $n=2$, $l=2$, $m=1$ (X)
- $n=2$, $l=1$, $m=-1$
- $n=3$, $l=2$, $m=0$

(10) 5. A laser pulse shines for 10s delivering a total energy of $4 \times 10^{-3}$ J at a wavelength of 633 nm ($633 \times 10^{-9}$ m) of light. Another laser delivers the same amount of energy with a wavelength of 408 nm ($408 \times 10^{-9}$ m) of light.

Which laser is delivering more photons of light to the sample?

a. red laser (633 nm).
- b. blue laser (408 nm).
- c. both deliver the same number.
- d. not enough information to determine

\[ m_{633} = \text{# of photons with } \lambda = 633 \text{ nm} \]
\[ m_{408} = \text{# of photons with } \lambda = 408 \text{ nm} \]

\[ \text{Total Energy for photons with } \lambda = \frac{E_{\text{total}}}{c} \]
\[ = m_{633} (h\nu)_{633} \]
\[ = m_{408} (h\nu)_{408} \]

Therefore:
\[ m_{633} \frac{(h\nu)_{633}}{m_{408} (h\nu)_{408}} \Rightarrow (h\nu)_{408} > (h\nu)_{633} \]

Hence: $m_{633} > m_{408}$
(10) 6. The energy of the ground state for hydrogen in the Bohr model is $-13.6 \text{ eV}$. In a transition from the $n = 2$ to the $n = 4$ state, a photon of energy

\[ E_n = \frac{-13.6 \text{ eV}}{n^2} \]

\[ E_1 = -13.6 \text{ eV} \quad E_2 = -3.4 \text{ eV} \]
\[ E_3 = -1.51 \text{ eV} \quad E_4 = -0.85 \text{ eV} \]

\[ E_2 \rightarrow E_4 \quad \text{difference} = 2.55 \text{ eV} \]

- From lower state $\rightarrow$ upper
- Must absorb $2.55 \text{ eV}$

a. 304 eV is absorbed. b. 0.85 eV is emitted. c. 2.55 eV is absorbed. d. 2.55 eV is emitted;
(20) 7. A spherical blackbody $0.10 \text{ m}$ in diameter is held at a constant temperature. What is this temperature if the power radiated by the body is $10^3 \text{ J/s}$?

\[
A = 4\pi R^2 = 4\pi (0.05 \text{ m})^2 = 3.14 \times 10^{-2} \text{ m}^2
\]

\[
W = \frac{E/\Delta t}{A} \quad E/\Delta t = 10^3 \text{ J/s}
\]

\[
W = \sigma T^4
\]

\[
3.18 \times 10^{-2} \frac{4}{m^2} = \sigma T^4
\]

\[
T^{-4} = \frac{3.18 \times 10^4 \text{ J/s}^2}{5.67 \times 10^{-8} \text{ J/kg} \text{ K}^4}
\]

\[
T = 5666 \text{ K}
\]
(20) 8. A large distance separates two particles, an electron and a proton. The electron is fired at the proton with a speed of $10^5$ m/s and is captured by the proton forming a hydrogen atom in the ground state. What wavelength photon will be given off? (Non-relativistic problem.)

\[
\text{Energy before} - \text{Energy after} = \text{Energy of photon}
\]

\[
\text{Energy before} = \frac{1}{2} m v^2 = \frac{1}{2} \left( 9.1 \times 10^{-31} \right) \left( 10^5 \text{ m/s} \right)^2
\]

\[
= 4.55 \times 10^{-19} \text{ J}
\]

\[
= \frac{4.55 \times 10^{-19} \text{ J}}{1.6 \times 10^{-19} \text{ eV}} = 2.84 \text{ eV}
\]

\[
\text{Energy after} = \text{Energy of H in ground state}
\]

\[
= -13.6 \text{ eV}
\]

\[
\text{Difference} = 2.84 \text{ eV} - (-13.6 \text{ eV}) = 16.4 \text{ eV}
\]

\[
E = \frac{hc}{\lambda}
\]

\[
\lambda = \frac{hc}{16.4 \text{ eV}} = \left( 4.136 \times 10^{-15} \text{ eV} \cdot \text{m} \cdot \text{s} \right) \left( 3 \times 10^8 \text{ m/s} \right)
\]

\[
= 16.4 \text{ eV}
\]

\[
\lambda = 17.57 \times 10^{-8} \text{ m}
\]