Modern Physics Practice Items

1. Often observed in radio astronomy at a characteristic frequency of 1420.41 MHz, the precession frequency of neutral hydrogen atoms, the microwaves of the hydrogen line come from the atomic transition of an electron between the two hyperfine levels of the hydrogen 1 s ground state that have an energy difference of ≈ 5.87μeV. What is the wavelength in a vacuum of this electromagnetic radiation?

A. 4.1×10^{-15} m
B. 21 μm
C. 21 cm
D. 4.7 m

2. What is the energy carried by a single photon of yellow light, $\lambda = 505$ nm ($h = 6.63 \times 10^{-34}$ J·s)?

A. 3.5×10^{-40} J
B. 3.9×10^{-19} J
C. 7.6×10^{-12} J
D. 1.2×10^{-10} J

3. The same X-rays that can eject photoelectrons from zinc metal may also be diffracted by the surface of ZnS crystal. Which of the following principles does this demonstrate?

A. Electrons may be diffracted.
B. Zinc metal exhibits Rayleigh scattering of incident X-rays while ZnS does not.
C. The work function for a pure metal is higher than it is for an ore of the metal.
D. Light exhibits both particle and wave properties.

4. Consider two monochromatic sources of light A and B. The frequency of the electromagnetic waves emitted by source A and the power of source A are both half that of source B. In the time it takes source A to emit *n* number of photons, how many photons does source B emit?

A. ¼ *n*
B. *n*
C. 2*n*
D. 4*n*

5. A 100 W HeNe laser emits coherent yellow light ($\lambda = 598$ nm). Assuming light production were 100% efficient, how many photons does it produce per second?

A. 6.0×10^{4}
B. 3.0×10^{20}
C. 6.0×10^{23}
D. 2.5×10^{41}

6. What will be the result of measuring the distance from a hydrogen electron in its ground state to the nucleus?

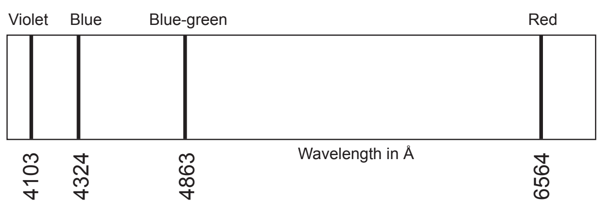
A. the Bohr radius
B. a set of distances corresponding to the Balmer series of spectral emissions
C. a distance equal to the radius of the nucleus
D. the Bohr radius, most likely, but a range of distances is possible

7. A spacecraft exposed to sunlight will develop a positive charge. This is most likely due to

A. the photoelectric effect
B. pair production
C. quantum tunneling
D. the solar wind

8. Below is a portion of the line spectrum in the visible region for hydrogen. The red line results from photons released in the electronic transition from n = 3 to n = 2. What is the value of the energy involved in this electronic transition? (h = 6.63 × 10^{-34} J·s)

A. 3.01 × 10^{-20} J
B. 1.00 × 10^{-19} J
C. 3.01 × 10^{-19} J
D. 4.84 × 10^{-19} J



9. In a 1923-27 experiment by Clinton Davisson and Lester Germer, electrons, scattered by the surface of a crystal of nickel metal, displayed a diffraction pattern. This confirmed the hypothesis, advanced by Louis de Broglie in 1924, of

A. quantized atomic energy levels
B. the uncertainty principle
C. wave-particle duality
D. photon theory

10. Which of the following particles would have the shortest de Broglie wavelength traveling at 1.5 × 10^4 m/s?

A. neutrino
B. positron
C. proton
D. α particle

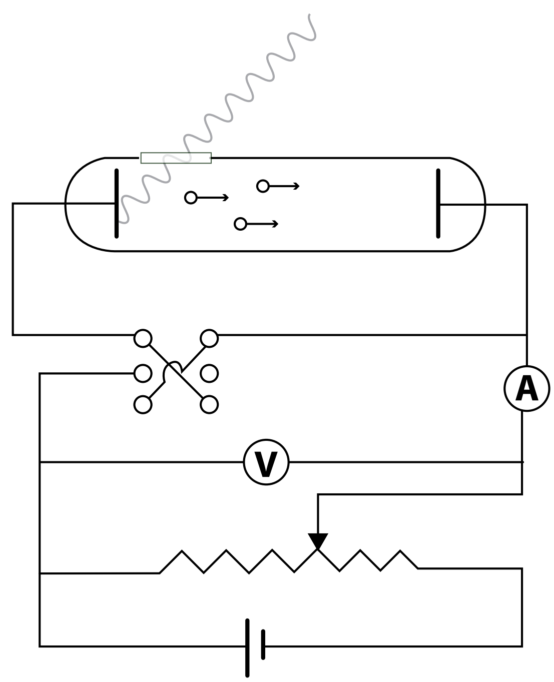
The following passage pertains to questions 11 - 15.

The photoelectric effect is the emission of electrons when electromagnetic radiation strikes a material. Electrons emitted in this manner can be called photoelectrons. In 1905, Einstein proposed an explanation of the photoelectric effect using a concept first put forward by Max Planck that light waves consist of tiny bundles or packets of energy known as photons or quanta.

The maximum kinetic energy of an ejected electron is given by

$$K_{mzx} = hf - \phi$$

The term ϕ is the work function which gives the minimum energy required to remove an electron from the surface of the metal.



The relation between current and applied voltage in the apparatus above illustrates the nature of the photoelectric effect. A light source illuminates a metal plate within a vacuum tube, and another plate electrode collects any emitted electrons. The potential between the two plates is varied and the current flowing in the external circuit between the two plates is measured.

If the frequency and the intensity of the incident radiation are fixed, the photoelectric current increases gradually with an increase in the positive potential on the collector electrode until all the photoelectrons emitted are collected. The photoelectric current attains a saturation value and does not increase further for any increase in the positive potential. The saturation current increases with the increase of the light intensity. It also increases with greater frequencies of incident light.

If we apply a negative potential to the collector plate Q with respect to the plate P and gradually increase it, the photoelectric current decreases, becoming zero at a certain negative potential. The negative potential on the collector at which the photoelectric current becomes zero is called the stopping potential.

11. If the device illuminating the metal is changed from a lamp producing mid UV light to a far UV lamp, the speed of emitted photoelectrons will

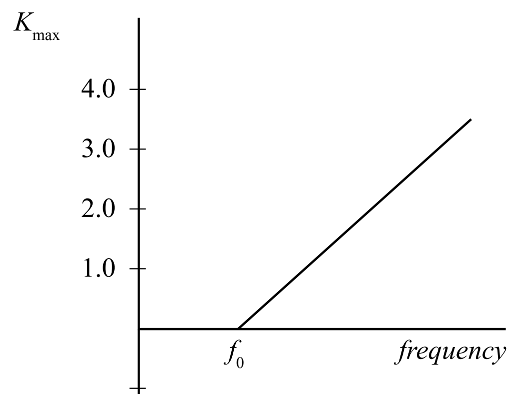
- **A.** remain the same.
- B. increase.
- C. decrease.
- D. become zero.

12. For a given frequency of incident radiation leading to production of photoelectrons in the apparatus depicted in the passage, the stopping potential

- **A.** is determined by the minimum kinetic energy of the photoelecrons that are emitted.
- B. decreases when a metal with lower threshold frequency is bombarded with the light.
- C. increases with decreasing wavelength of incident light.
- D. is independent of the intensity of the radiation.

13. The graph below shows current measurements for a photoelectric effect trial with a constant intensity of varying frequencies of incident UV radiation on a 1.5 cm^2 copper plate. A positive potential was applied to the collector plate. Which is the correct way to compute the value of the work function for copper?

- **A.** $(6.63 \times 10^{-34}\ \text{J·s})(1.1 \times 10^{15}\ \text{s}^{-1})$
- B. $\dfrac{(6.63 \times 10^{-34}\ \text{J·s})(3 \times 10^{8}\ \text{m/s})}{(1.1 \times 10^{15}\ \text{s}^{-1})}$
- C. $9.0 \times 10^{-19}\ \text{J} - (6.63 \times 10^{-34}\ \text{J·s})(1.1 \times 10^{15}\ \text{s}^{-1})$
- D. $\dfrac{(6.63 \times 10^{-34}\ \text{J·s})(1.1 \times 10^{15}\ \text{s}^{-1})}{2\pi}$



14. A trial was conducted using the apparatus depicted in the passage. A 145-nm light (*photon energy* = 8.55 eV) was shined on an unknown metal. The measured photocurrent dropped to zero at potential – 3.50 V. Determine the maximum kinetic energy possessed by the photoelectrons emitted from the metal surface.

- **A.** 3.50 eV
- B. 5.05 eV.
- C. 8.55 eV.
- D. 12.05 eV

15. The graph below represents a series of photoelectric effect trials employing a particular metal. Which of the following represents the work function of the metal?

A. 1.50 eV
B. 2.50 eV.
C. 3.00 eV.
D. 3.50 eV