Name: _____ Period: _____

Modern-Wave Particle Duality

1. Compared to a photon of red light, a photon of blue light has a
   1. greater energy
   2. longer wavelength
   3. smaller momentum
   4. lower frequency

2. Exposure to ultraviolet radiation can damage skin. Exposure to visible light does not damage skin. State *one* possible reason for this difference.

Base your answers to questions 3 and 4 on the information below.

Louis de Broglie extended the idea of wave-particle duality to all of nature with his matter-wave equation:

$$\lambda = \frac{h}{mv}$$

where λ is the particle's wavelength, m is its mass, v is its velocity, and h is Planck's constant.

3. Using this equation, calculate the de Broglie wavelength of a helium nucleus (mass=6.7×10^{-27} kg) moving with a speed of 2.0×10^{6} meters per second.

4. The wavelength of this particle is of the same order of magnitude as which type of electromagnetic radiation?

5. A photon of light carries
   1. energy, but not momentum
   2. momentum, but not energy
   3. both energy and momentum
   4. neither energy nor momentum

6. Wave-particle duality is most apparent in analyzing the motion of
   1. a baseball
   2. a space shuttle
   3. a galaxy
   4. an electron

7. A photon of which electromagnetic radiation has the most energy?
   1. ultraviolet
   2. x ray
   3. infrared
   4. microwave

8. Light of wavelength 5.0×10^{-7} meter consists of photons having an energy of
   1. 1.1×10^{-48} J
   2. 1.3×10^{-27} J
   3. 4.0×10^{-19} J
   4. 1.7×10^{-5} J

9. Electrons oscillating with a frequency of 2.0×10^{10} hertz produce electromagnetic waves. These waves would be classified as
   1. infrared
   2. visible
   3. microwave
   4. x ray

10. The energy of a photon is inversely proportional to its
    1. wavelength
    2. speed
    3. frequency
    4. phase

11. A photon has a wavelength of 9.00×10^{-10} meter. Calculate the energy of this photon in joules. [Show all work, including the equation and substitution with units.]

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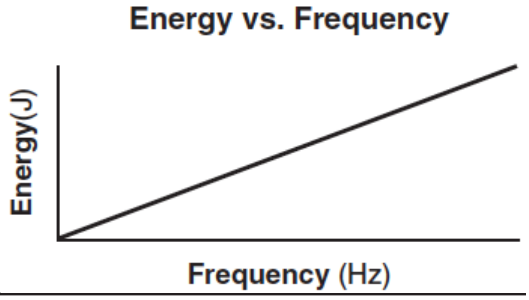
Modern-Wave Particle Duality

Base your answers to questions 12 and 13 on the data table at right.
The data table lists the energy and corresponding frequency of five photons.

Photon	Energy (J)	Frequency (Hz)
A	6.63×10^{-15}	1.00×10^{19}
B	1.99×10^{-17}	3.00×10^{16}
C	3.49×10^{-19}	5.26×10^{14}
D	1.33×10^{-20}	2.00×10^{13}
E	6.63×10^{-26}	1.00×10^{8}

12. In which part of the electromagnetic spectrum would photon D be found?
    1. infrared
    2. visible
    3. ultraviolet
    4. x ray

13. The graph at right represents the relationship between the energy and the frequency of photons. The slope of the graph would be
    1. 6.63×10^{-34} J·s
    2. 6.67×10^{-11} N·m^2/kg^2
    3. 1.60×10^{-19} J
    4. 1.60×10^{-19} C



Base your answers to questions 14 through 16 on the information below.

The alpha line in the Balmer series of the hydrogen spectrum consists of light having a wavelength of 6.56×10^{-7} meter.

14. Calculate the frequency of this light. [Show all work, including the equation and substitution with units.]

15. Determine the energy in joules of a photon of this light.

16. Determine the energy in electronvolts of a photon of this light.

17. Which phenomenon provides evidence that light has a wave nature?
    1. emission of light from an energy-level transition in a hydrogen atom
    2. diffraction of light passing through a narrow opening
    3. absorption of light by a black sheet of paper
    4. reflection of light from a mirror

18. The momentum of a photon, p, is given by the equation $p = \frac{h}{\lambda}$ where h is Planck's constant and λ is the photon's wavelength. Which equation correctly represents the energy of a photon in terms of its momentum?
    1. $E_{photon} = phc$
    2. $E_{photon} = \frac{hp}{c}$
    3. $E_{photon} = \frac{p}{c}$
    4. $E_{photon} = pc$

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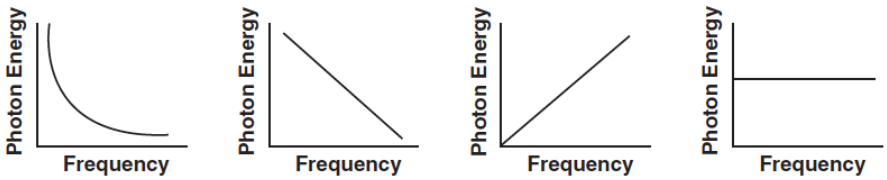
Modern-Wave Particle Duality

19. Which graph best represents the relationship between photon energy and photon frequency?



20. Light demonstrates the characteristics of
    1. particles, only
    2. waves, only
    3. both particles and waves
    4. neither particles nor waves

21. The slope of a graph of photon energy versus photon frequency represents
    1. Planck's constant
    2. the mass of a photon
    3. the speed of light
    4. the speed of light squared

22. A photon of light traveling through space with a wavelength of 6.0×10^{-7} meter has an energy of
    1. 4.0×10^{-40} J
    2. 3.3×10^{-19} J
    3. 5.4×10^{10} J
    4. 5.0×10^{14} J

23. On the atomic level, energy and matter exhibit the characteristics of
    1. particles, only
    2. waves, only
    3. neither particles nor waves
    4. both particles and waves

24. A variable-frequency light source emits a series of photons. As the frequency of the photon increases, what happens to the energy and wavelength of the photon?
    1. The energy decreases and the wavelength decreases.
    2. The energy decreases and the wavelength increases.
    3. The energy increases and the wavelength decreases.
    4. The enery increases and the wavelength increases.

25. Calculate the wavelength of a photon having 3.26×10^{-19} joule of energy. [Show all work, including the equation and substitution with units.]

26. All photons in a vacuum have the same
    1. speed
    2. wavelength
    3. energy
    4. frequency

27. Which phenomenon best supports the theory that matter has a wave nature?
    1. electron momentum
    2. electron diffraction
    3. photon momentum
    4. photon diffraction

28. Moving electrons are found to exhibit properties of
    1. particles, only
    2. waves, only
    3. both particles and waves
    4. neither particles nor waves

29. Determine the frequency of a photon whose energy is 3.00×10^{-19} joule.

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Modern-Wave Particle Duality

Base your answers to questions 30 through 33 on the information below and your knowledge of physics.

An electron traveling with a speed of 2.50×10^{6} meters per second collides with a photon having a frequency of 1.00×10^{16} hertz. After the collision, the photon has 3.18×10^{-18} joule of energy.

30. Calculate the original kinetic energy of the electron. [Show all work, including the equation and substitution with units.]

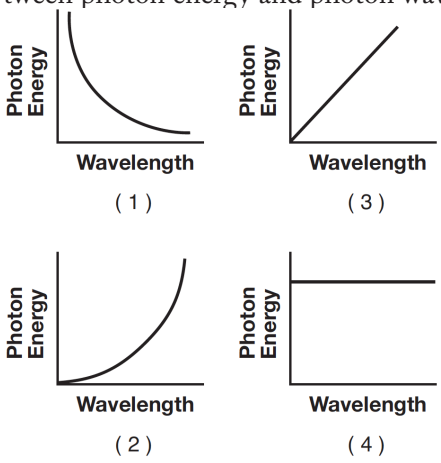
31. Determine the energy in joules of the photon before the collision.

32. Determine the energy lost by the photon during the collision.

33. Name *two* physical quantities conserved in the collision..

34. A monochromatic beam of light has a frequency of 7.69×10^{14} hertz. What is the energy of a photon of this light?
    1. 2.59×10^{-40} J
    2. 6.92×10^{-31} J
    3. 5.10×10^{-19} J
    4. 3.90×10^{-7} J

35. Which graph best represents the relationship between photon energy and photon wavelength?



36. A blue-light photon has a wavelength of 4.80×10^{-7} meter. What is the energy of the photon?
    1. 1.86×10^{22} J
    2. 1.44×10^{2} J
    3. 4.14×10^{-19} J
    4. 3.18×10^{-26} J