***Physics: Principle and Applications*, 7e (Giancoli)**
Chapter 27 Early Quantum Theory and Models of the Atom

27.1 Conceptual Questions

1) As the temperature of a blackbody increases, what happens to the peak wavelength of the light it radiates?
A) It gets longer.
B) It gets shorter.
C) The wavelength is not affected by the temperature of the object.
Answer: B
Var: 1

2) Two identical metal bars are heated up until they are both glowing. One of them is "red hot" and the other is "blue hot." Which one is hotter, the one that glows red or the one that glows blue?
A) the red one
B) the blue one
C) We cannot tell without knowing more about the two bars.
Answer: B
Var: 1

3) A photon of blue light and a photon of red light are traveling in vacuum. The photon of blue light
A) has a smaller wavelength than a photon of red light and travels with the same speed.
B) has a smaller wavelength than a photon of red light and travels with a greater speed.
C) has a longer wavelength than a photon of red light and travels with the same speed.
D) has a longer wavelength than a photon of red light and travels with a greater speed.
Answer: A
Var: 1

4) Increasing the *brightness* of a beam of light without changing its color will increase
A) the number of photons per second traveling in the beam.
B) the energy of each photon.
C) the speed of the photons.
D) the frequency of the light.
E) the wavelength of the photons.
Answer: A
Var: 1

5) If the wavelength of a photon is doubled, what happens to its energy?
A) It is reduced to one-half of its original value.
B) It stays the same.
C) It is doubled.
D) It is increased to four times its original value.
E) It is reduced to one-fourth of its original value.
Answer: A
Var: 1

6) If you double the frequency of the light in a laser beam, but keep the number of photons per second in the beam fixed, which of the following statements are correct? (There could be more than one correct choice.)
A) The power in the beam does not change.
B) The intensity of the beam doubles.
C) The energy of individual photons does not change.
D) The energy of individual photons doubles.
E) The wavelength of the individual photons doubles.
Answer: B, D
Var: 1

7) Which of the following actions will increase the energy of a photon? (There could be more than one correct choice.)
A) Increase its wavelength.
B) Increase its frequency.
C) Decrease its wavelength.
D) Decrease its frequency.
E) Increase its speed.
Answer: B, C
Var: 1

8) Two sources emit beams of microwaves. The microwaves from source A have a frequency of 10 GHz, and the ones from source B have a frequency of 20 GHz. This is all we know about the two beams. Which of the following statements about these beams are correct? (There could be more than one correct choice.)
A) Beam B carries twice as many photons per second as beam A.
B) A photon in beam B has twice the energy of a photon in beam A.
C) The intensity of beam B is twice as great as the intensity of beam A.
D) A photon in beam B has the same energy as a photon in beam A.
E) None of the above statements are true.
Answer: B
Var: 1

9) Two sources emit beams of light of wavelength 550 nm. The light from source A has an intensity of 10 μW/m^2, and the light from source B has an intensity of 20 μW/m^2. This is all we know about the two beams. Which of the following statements about these beams are correct? (There could be more than one correct choice.)
A) Beam B carries twice as many photons per second as beam A.
B) A photon in beam B has twice the energy of a photon in beam A.
C) The frequency of the light in beam B is twice as great as the frequency of the light in beam A.
D) A photon in beam B has the same energy as a photon in beam A.
E) None of the above statements are true.
Answer: A
Var: 1

10) A beam of light falling on a metal surface is causing electrons to be ejected from the surface. If we now double the frequency of the light, which of the following statements are correct? (There could be more than one correct choice.)
A) The kinetic energy of the ejected electrons doubles.
B) The speed of the ejected electrons doubles.
C) The number of electrons ejected per second doubles.
D) Twice as many photons hit the metal surface as before.
E) None of the above things occur.
Answer: E
Var: 1

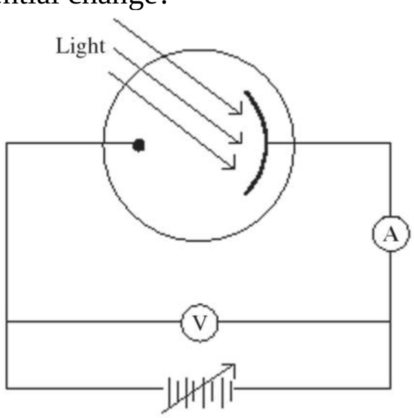
11) Light of a given wavelength is used to illuminate the surface of a metal, however, no photoelectrons are emitted. In order to cause electrons to be ejected from the surface of this metal you should
A) use light of a longer wavelength.
B) use light of a shorter wavelength.
C) use light of the same wavelength but increase its intensity.
D) use light of the same wavelength but decrease its intensity.
Answer: B
Var: 1

12) A blue laser beam is incident on a metallic surface, causing electrons to be ejected from the metal. If the frequency of the laser beam is increased while the intensity of the beam is held fixed,
A) the rate of ejected electrons will decrease and their maximum kinetic energy will increase.
B) the rate of ejected electrons will remain the same but their maximum kinetic energy will increase.
C) the rate of ejected electrons will increase and their maximum kinetic energy will increase.
D) the rate of ejected electrons will remain the same but their maximum kinetic energy will decrease.
Answer: A
Var: 1

13) Monochromatic light falls on a metal surface and electrons are ejected. If the intensity of the light is increased, what will happen to the ejection rate and maximum energy of the electrons?
A) greater rate; same maximum energy.
B) same rate; greater maximum energy.
C) greater rate; greater maximum energy.
D) same rate; same maximum energy.
Answer: A
Var: 1

14) When the surface of a metal is exposed to blue light, electrons are emitted. If the intensity of the blue light is increased, which of the following things will also increase?
A) the number of electrons ejected per second
B) the maximum kinetic energy of the ejected electrons
C) the time lag between the onset of the absorption of light and the ejection of electrons
D) the work function of the metal
E) all of the above
Answer: A
Var: 1

15) Monochromatic light is incident on a metal surface, and the ejected electrons give rise to a current in the circuit shown in the figure. The maximum kinetic energy of the ejected electrons is determined by applying a reverse ('stopping') potential, sufficient to reduce the current in the ammeter to zero. If the intensity of the incident light is increased, how will the required stopping potential change?



A) It will remain unchanged.
B) It will increase.
C) It will decrease.
Answer: A
Var: 1

16) A photon scatters off of a stationary electron. Which of the following statements about the photon are true? (There could be more than one correct choice.)
A) Its wavelength increases due to the scattering.
B) Its frequency increases due to the scattering.
C) Its wavelength decreases due to the scattering.
D) Its frequency decreases due to the scattering.
E) Its energy does not change.
Answer: A, D
Var: 1

17) Photon A has twice the momentum of photon B as both of them are traveling in vacuum. Which statements about these photons are correct? (There could be more than one correct choice.)
A) Photon A is traveling twice as fast as photon B.
B) Both photons have the same speed.
C) Both photons have the same wavelength.
D) The wavelength of photon A is twice as great as the wavelength of photon B.
E) The wavelength of photon B is twice as great as the wavelength of photon A.
Answer: B, E
Var: 1

18) If the frequency of a light beam is doubled, what happens to the momentum of the photons in that beam of light?
A) It stays the same.
B) It is halved.
C) It is doubled.
D) It is reduced to one-fourth of its original value.
E) It is increased to four times its original value.
Answer: C
Var: 1

19) If the wavelength of a light beam is doubled, what happens to the momentum of the photons in that light beam?
A) It is halved.
B) It stays the same.
C) It is doubled.
D) It is reduced by one-fourth of its original value.
E) It is increased to four times its original value.
Answer: A
Var: 1

20) If the wavelength of a photon is the same as the de Broglie wavelength of an electron, which one has the greater momentum?
A) The electron because it has more mass.
B) The photon because it is traveling faster.
C) They both have the same momentum.
Answer: C
Var: 1

21) If the wavelength of a photon in vacuum is the same as the de Broglie wavelength of an electron, which one is traveling faster through space?
A) The electron because it has more mass.
B) The photon because photons always travel through space faster than electrons.
C) They both have the same speed.
Answer: B
Var: 1

22) If a proton and an electron have the same de Broglie wavelengths, which one is moving faster?
A) the electron
B) the proton
C) They both have the same speed.
Answer: A
Var: 1

23) If a proton and an electron have the same speed, which one has the longer de Broglie wavelength?
A) the electron
B) the proton
C) It is the same for both of them.
Answer: A
Var: 1

24) Which of the following actions will increase the de Broglie wavelength of a speck of dust? (There could be more than one correct choice.)
A) Increase its mass.
B) Increase its speed.
C) Decrease its mass.
D) Decrease its speed.
E) Decrease its momentum.
Answer: C, D, E
Var: 1

25) Protons are being accelerated in a particle accelerator. When the energy of the protons is doubled, their de Broglie wavelength will
A) increase by a factor of 4.
B) increase by a factor of 2.
C) decrease by a factor of 2.
D) increase by a factor of $\sqrt{2}$.
E) decrease by a factor of $\sqrt{2}$.
Answer: E
Var: 1

26) Protons are being accelerated in a particle accelerator. When the speed of the protons is doubled, their de Broglie wavelength will
A) increase by a factor of 4.
B) increase by a factor of 2.
C) decrease by a factor of 2.
D) increase by a factor of $\sqrt{2}$.
E) decrease by a factor of $\sqrt{2}$.
Answer: C
Var: 1

27) A proton and an electron are both accelerated to the same final speed. If λ_p is the de Broglie wavelength of the proton and λ_e is the de Broglie wavelength of the electron, then
A) $\lambda_p > \lambda_e$.
B) $\lambda_p = \lambda_e$.
C) $\lambda_p < \lambda_e$.
Answer: C
Var: 1

28) A proton and an electron are both accelerated to the same final kinetic energy. If λ_p is the de Broglie wavelength of the proton and λ_e is the de Broglie wavelength of the electron, then
A) $\lambda_p > \lambda_e$.
B) $\lambda_p = \lambda_e$.
C) $\lambda_p < \lambda_e$.
Answer: C
Var: 1

29) To which of the following values of *n* does the longest wavelength in the Balmer series correspond?
A) 3
B) 5
C) 1
D) 7
E) ∞ (very large)
Answer: A
Var: 1

30) To which of the following values of n does the shortest wavelength in the Balmer series correspond?
A) 3
B) 5
C) 7
D) 1
E) ∞ (very large)
Answer: E
Var: 1

31) The Balmer series is formed by electron transitions in hydrogen that
A) end on the $n = 1$ shell.
B) begin on the $n = 1$ shell.
C) end on the $n = 2$ shell.
D) begin on the $n = 2$ shell.
E) are between the $n = 1$ and $n = 3$ shells.
Answer: C
Var: 1

32) The Lyman series is formed by electron transitions in hydrogen that
A) end on the $n = 1$ shell.
B) begin on the $n = 1$ shell.
C) end on the $n = 2$ shell.
D) begin on the $n = 2$ shell.
E) are between the $n = 1$ and $n = 3$ shells.
Answer: A
Var: 1

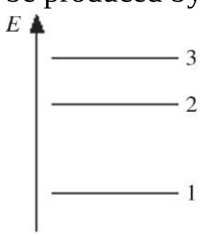
33) The Paschen series is formed by electron transitions that
A) end on the $n = 1$ shell.
B) begin on the $n = 1$ shell.
C) end on the $n = 2$ shell.
D) begin on the $n = 3$ shell.
E) end on the $n = 3$ shell.
Answer: E
Var: 1

34) Hydrogen atoms can emit four spectral lines with visible colors from red to violet. These four visible lines emitted by hydrogen atoms are produced by electrons
A) that start in the $n = 2$ level.
B) that end up in the $n = 2$ level.
C) that end up in the $n = 3$ level.
D) that end up in the ground state.
E) that start in the ground state.
Answer: B
Var: 1

35) When an electron jumps from an orbit where $n = 4$ to one where $n = 2$
A) a photon is emitted.
B) a photon is absorbed.
C) two photons are emitted.
D) two photons are absorbed.
E) None of the given answers are correct.
Answer: A
Var: 1

36) The energy difference between adjacent orbit radii in a hydrogen atom
A) increases with increasing values of n.
B) decreases with increasing values of n.
C) remains constant for all values of n.
D) varies randomly with increasing values of n.
Answer: B
Var: 1

37) The figure shows part of the energy level diagram of a certain atom. The energy spacing between levels 1 and 2 is twice that between 2 and 3. If an electron makes a transition from level 3 to level 2, the radiation of wavelength λ is emitted. What possible radiation wavelengths might be produced by other transitions between the three energy levels?



A) both $\lambda/2$ and $\lambda/3$
B) only $\lambda/2$
C) both 2λ and 3λ
D) only 2λ
Answer: A
Var: 1

38) An ionized atom having Z protons has had all but one of its electrons removed. If E is the total energy of the ground state electron in atomic hydrogen, then what is the total energy of the remaining electron in the ionized atom?
A) Z^2E
B) ZE
C) E
D) E/Z
E) E/Z^2
Answer: A
Var: 1

39) The distance between adjacent orbits in a hydrogen atom
A) increases with increasing values of n.
B) decreases with increasing values of n.
C) remains constant for all values of n.
D) varies randomly with increasing values of n.
Answer: A
Var: 1

40) If a hydrogen atom originally in a state with principal quantum number n is excited to state $n' = 2n$, then
A) its radius and binding energy will double.
B) its radius will quadruple and the binding energy will double.
C) its radius will double and the binding energy will quadruple.
D) its radius will quadruple and the binding energy will be reduced by a factor of four.
E) its radius and binding energy will quadruple.
Answer: D
Var: 1

41) Which of the following statements are true for the Bohr model of the atom? (There could be more than one correct choice.)
A) The spacing between all the electron shells is the same.
B) The energy difference between all the electron shells is the same.
C) As we look at higher and higher electron shells, they get closer and closer together, but the difference in energy between them gets greater and greater.
D) As we look at higher and higher electron shells, they get farther and farther apart, but the difference in energy between them gets smaller and smaller.
E) There is no general pattern in the spacing of the shells or their energy differences.
Answer: D
Var: 1

42) An ionized atom having Z protons has had all but one of its electrons removed. If R is the radius of the ground state electron orbit in atomic hydrogen, then what is the radius of the shell of the remaining electron in the ionized atom?
A) Z^2R
B) ZR
C) R
D) R/Z
E) R/Z^2
Answer: D
Var: 1

27.2   Problems

1) If the surface of our bodies is at 37°C, at what wavelength does the radiation that we emit peak if we behave like a blackbody? The constant in Wien's law is 0.0029 m · K.
Answer: 9.4 μm
Var: 1

2) The cosmic background radiation permeating the universe has the spectrum of a 2.7-K blackbody radiator. What is the peak wavelength of this radiation? The constant in Wien's law is 0.0029 m · K.
Answer: 1.1 mm (microwave region)
Var: 1

3) What are the wavelength and the corresponding photon energy (in electron-volts) of the primary light emitted by an ideal blackbody at each of the following temperatures? ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J, and the constant in Wein's law is 0.00290 m · K)
(a) 400°C?
(b) 800°C?
(c) 1200°C?
Answer: (a) 4.31 μm, 0.288 eV   (b) 2.70 μm, 0.459 eV   (c) 1.97 μm, 0.631 eV
Var: 6

4) What is the surface temperature of a star, if its radiation peak occurs at a frequency of 1.06×10^{15} Hz? ($c = 3.00 \times 10^8$ m/s, and the constant in Wien's law is 0.00290 m · K)
A) 17,000 K
B) 14,500 K
C) 19,000 K
D) 20,400 K
E) 10,200 K
Answer: E
Var: 1

5) If the sunlight from a star peaks at a wavelength of 0.55 μm, what temperature does this imply for the surface of that star? The constant in Wien's law is 0.00290 m · K.
A) 9500 K
B) 5300 K
C) 2500 K
D) 25,000 K
E) 15,000 K
Answer: B
Var: 1

6) The surface temperature of the star is 6000 K. At what wavelength is its light output a maximum? The constant in Wien's law is 0.00290 m · K.
A) 850 nm
B) 907 nm
C) 311 nm
D) 483 nm
E) 502 nm
Answer: D
Var: 1

7) What is the wavelength of the most intense light emitted by a giant star of surface temperature 5000 K? The constant in Wien's law is 0.00290 m · K.
A) 576 nm
B) 578 nm
C) 580 nm
D) 582 nm
Answer: C
Var: 3

8) What is the frequency of the most intense radiation from an object with temperature 100°C? The constant in Wien's law is 0.0029 m · K. ($c = 3.0 \times 10^{8}$ m/s)
A) 2.9×10^{-5} Hz
B) 3.9×10^{13} Hz
C) 1.0×10^{13} Hz
D) 1.0×10^{11} Hz
Answer: B
Var: 1

9) An x-ray tube accelerates electrons through a potential difference of 50.0 kV. If an electron in the beam suddenly give up its energy in a collision, what is the shortest wavelength x-ray it could produce? ($c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s, $e = 1.60 \times 10^{-19}$ C)
Answer: 2.48×10^{-11} m
Var: 1

10) At what rate are photons emitted by a 50.0-W sodium vapor lamp if it is producing monochromatic light of wavelength 589 nm? ($c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
Answer: 1.48×10^{20} photons per second
Var: 1

11) The human eye can just detect green light of wavelength 500 nm if it arrives at the retina at the rate of 2×10^{-18} W. How many photons arrive each second? ($c = 3.0 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
Answer: 5
Var: 1

12) What is the wavelength of a photon having energy 2.00 eV? ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
Answer: 621 nm
Var: 1

13) A small gas laser of the type used in classrooms may radiate light at a power level of 2.0 mW. If the wavelength of the laser light is 642 nm, how many photons does it emit per second? ($c = 3.0 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
Answer: 6.5×10^{15}
Var: 1

14) How much energy is carried by a photon of light having frequency 110 GHz? ($h = 6.626 \times 10^{-34}$ J · s)
A) 1.1×10^{-20} J
B) 1.4×10^{-22} J
C) 7.3×10^{-23} J
D) 1.3×10^{-25} J
Answer: C
Var: 3

15) What frequency of electromagnetic radiation has photons of energy 4.7×10^{-25} J? ($h = 6.626 \times 10^{-34}$ J · s)
A) 710 kHz
B) 4.7 MHz
C) 710 MHz
D) 1.4 GHz
Answer: C
Var: 1

16) What is the energy (in eV) of an optical photon of frequency 6.43×10^{14} Hz. ($h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
A) 2.66 eV
B) 1.62 eV
C) 1.94 eV
D) 3.27 eV
Answer: A
Var: 50+

17) What is the photon energy of red light having a wavelength of 6.40×10^{2} nm? ($c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
A) 1.13×10^{-19} J
B) 1.31×10^{-19} J
C) 3.11×10^{-19} J
D) 1.94×10^{-19} J
Answer: C
Var: 1

18) Each photon in a beam of light has an energy of 4.20 eV. What is the wavelength of this light? ($c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
A) 321 nm
B) 103 nm
C) 296 nm
D) 412 nm
E) 420 nm
Answer: C
Var: 1

19) What is the wavelength of a 6.32-eV photon? ($c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
A) 197 nm
B) 167 nm
C) 216 nm
D) 234 nm
Answer: A
Var: 1

20) *Gamma rays* are photons with very high energy. What is the wavelength of a gamma-ray photon with energy 7.7×10^{-13} J? ($c = 3.0 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
A) 2.6×10^{-13} m
B) 3.9×10^{-13} m
C) 3.1×10^{-13} m
D) 3.5×10^{-13} m
Answer: A
Var: 50+

21) *Gamma rays* are photons with very high energy. How many visible-light photons with a wavelength of 500 nm would you need to equal the energy of a gamma-ray photon with energy 4.1×10^{-13} J?

A) 1.0×10^{6}

B) 1.4×10^{8}

C) 6.2×10^{9}

D) 3.9×10^{3}

Answer: A

Var: 50+

22) An 84-kW AM radio station broadcasts at 1000 kHz. How many photons are emitted each second by the transmitting antenna? ($h = 6.626 \times 10^{-34}$ J · s)

A) 1.3×10^{32}

B) 2.9×10^{24}

C) 6.3×10^{12}

D) 1.4×10^{15}

Answer: A

Var: 50+

23) A laser pulse of duration 25 ms has a total energy of 1.4 J. If the wavelength of this radiation is 567 nm, how many photons are emitted in one pulse? ($c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s)

A) 4.0×10^{18}

B) 9.9×10^{19}

C) 4.8×10^{19}

D) 1.6×10^{17}

E) 3.2×10^{17}

Answer: A

Var: 50+

24) A laser emits a pulse of light that lasts 10 ns. The light has a wavelength of 690 nm, and each pulse has an energy of 480 mJ. How many photons are emitted in each pulse? ($c = 3.0 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s)

A) 1.7×10^{18}

B) 2.1×10^{27}

C) 2.6×10^{37}

D) 3.1×10^{43}

Answer: A

Var: 50+

25) For what wavelength does a 100-mW laser beam deliver 1.6×10^{17} photons in one second? ($c = 3.0 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
A) 320 nm
B) 330 nm
C) 340 nm
D) 350 nm
Answer: A
Var: 25

26) A helium-neon laser emits light at 632.8 nm. If the laser emits 1.82×10^{17} photons/second, what is its power output in mW? ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
A) 57.2 mW
B) 28.6 mW
C) 37.2 mW
D) 45.7 mW
Answer: A
Var: 50+

27) A photoelectric surface has a work function of 2.10 eV. Calculate the maximum kinetic energy, in eV, of electrons ejected from this surface by electromagnetic radiation of wavelength 356 nm. (1 eV = 1.60×10^{-19} J, $c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
Answer: 1.39 eV
Var: 50+

28) If the longest wavelength of light that is able to dislodge electrons from a metal is 373 nm, what is the work function of that metal, in electron-volts? (1 eV = 1.60×10^{-19} J, $c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
Answer: 3.33 eV
Var: 1

29) A metallic surface is illuminated with light of wavelength 400 nm. If the work function for this metal is 2.40 eV, what is the maximum kinetic energy of the ejected electrons, in electron-volts? (1 eV = 1.60×10^{-19} J, $c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
Answer: 0.71 eV
Var: 1

30) A metal surface has a work function of 2.50 eV. What is the longest wavelength of light that will eject electrons from the surface of this metal? (1 eV = 1.60×10^{-19} J, $c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
Answer: 497 nm
Var: 1

31) The work function of a particular metal is 4.20×10^{-19} J. What is the photoelectric cutoff (threshold) wavelength for this metal? ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
A) 473 nm
B) 308 nm
C) 393 nm
D) 554 nm
Answer: A
Var: 50+

32) What is the cutoff (threshold) frequency for a metal surface that has a work function of 5.42 eV? (1 eV = 1.60×10^{-19} J, $h = 6.626 \times 10^{-34}$ J · s)
A) 1.31×10^{15} Hz
B) 2.01×10^{15} Hz
C) 3.01×10^{15} Hz
D) 5.02×10^{15} Hz
E) 6.04×10^{15} Hz
Answer: A
Var: 5

33) The work function of a certain metal is 1.90 eV. What is the longest wavelength of light that can cause photoelectron emission from this metal? (1 eV = 1.60×10^{-19} J, $c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
A) 231 nm
B) 14.0 nm
C) 62.4 nm
D) 344 nm
E) 654 nm
Answer: E
Var: 1

34) A metal has a work function of 4.50 eV. Find the maximum kinetic energy of the photoelectrons if light of wavelength 250 nm shines on the metal. (1 eV = 1.60×10^{-19} J, $c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
A) 0.00 eV
B) 0.37 eV
C) 0.47 eV
D) 0.53 eV
Answer: C
Var: 1

35) What is the longest wavelength of light that can cause photoelectron emission from a metal that has a work function of 2.20 eV? (1 eV = 1.60×10^{-19} J, $c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
A) 417 nm
B) 257 nm
C) 344 nm
D) 565 nm
E) 610 nm
Answer: D
Var: 1

36) Light with a wavelength of 310 nm is incident on a metal that has a work function of 3.80 eV. What is the maximum kinetic energy that a photoelectron ejected in this process can have? (1 eV = 1.60×10^{-19} J, $c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
A) 0.62×10^{-19} J
B) 0.21×10^{-19} J
C) 0.36×10^{-19} J
D) 0.48×10^{-19} J
E) 0.33×10^{-19} J
Answer: E
Var: 1

37) Light with a frequency of 8.70×10^{14} Hz is incident on a metal that has a work function of 2.80 eV. What is the maximum kinetic energy that a photoelectron ejected in this process can have? (1 eV = 1.60×10^{-19} J, $h = 6.626 \times 10^{-34}$ J · s)
A) 8.7×10^{-19} J
B) 3.1×10^{-19} J
C) 1.3×10^{-19} J
D) 2.4×10^{-19} J
E) 4.5×10^{-19} J
Answer: C
Var: 1

38) If the work function of a metal surface is 2.20 eV, what frequency of incident light would give a maximum kinetic energy of 0.25 eV to the photoelectrons ejected from this surface? (1 eV = 1.60×10^{-19} J, $h = 6.626 \times 10^{-34}$ J · s)
A) 2.05×10^{14} Hz
B) 1.02×10^{14} Hz
C) 2.50×10^{14} Hz
D) 3.53×10^{14} Hz
E) 5.92×10^{14} Hz
Answer: E
Var: 1

39) A beam of light with a frequency range from 3.01×10^{14} Hz to 6.10×10^{14} Hz is incident on a metal surface. If the work function of the metal surface is 2.20 eV, what is the maximum kinetic energy of photoelectrons ejected from this surface? ($h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
A) 0.33 eV
B) 0.21 eV
C) 0.42 eV
D) 0.16 eV
E) 0.48 eV
Answer: A
Var: 1

40) When it is struck by 240-nm photons, a metal ejects electrons with a maximum kinetic energy of 2.58 eV. What is the work function of this material? ($c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s, 1 eV = 16.0×10^{-19} J)
A) 2.60 eV
B) 2.18 eV
C) 3.02 eV
D) 3.43 eV
Answer: A
Var: 50+

41) When a metal is illuminated by light, photoelectrons are observed provided that the wavelength of the light is less than 520 nm. What is the metal's work function? ($c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
A) 2.4 eV
B) 2.6 eV
C) 2.8 eV
D) 3.0 eV
Answer: A
Var: 50+

42) What is the longest wavelength of electromagnetic radiation that will eject photoelectrons from sodium metal for which the work function is 2.28 eV? ($c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
A) 580 nm
B) 499 nm
C) 633 nm
D) 668 nm
E) 545 nm
Answer: E
Var: 1

43) A photocathode whose work function is 2.9 eV is illuminated with white light that has a continuous wavelength band from 400 nm to 700 nm. What is the range of the wavelength band in this white light illumination for which photoelectrons are *not produced*?(c = 3.00 × 10^8 m/s, h = 6.626 × 10^{-34} J · s, 1 eV = 1.60 × 10^{-19} J)
A) 430 nm to 700 nm
B) 400 nm to 480 nm
C) 430 nm to 480 nm
D) 400 nm to 430 nm
E) 480 nm to 700 nm
Answer: A
Var: 1

44) A photocathode that has a work function of 2.4 eV is illuminated with monochromatic light having photon energy 3.5 eV. What is the wavelength of this light? (c = 3.00 × 10^8 m/s, h = 6.626 × 10^{-34} J · s, 1 eV = 1.60 × 10^{-19} J)
A) 350 nm
B) 330 nm
C) 300 nm
D) 380 nm
E) 410 nm
Answer: A
Var: 50+

45) A photocathode having a work function of 2.4 eV is illuminated with monochromatic light whose photon energy is 3.4 eV. What is maximum kinetic energy of the photoelectrons produced?(c = 3.00 × 10^8 m/s, h = 6.626 × 10^{-34} J · s, 1 eV = 1.60 × 10^{-19} J)
A) 1.6 × 10^{-19} J
B) 3.8 × 10^{-19} J
C) 4.4 × 10^{-19} J
D) 4.9 × 10^{-19} J
E) 5.4 × 10^{-19} J
Answer: A
Var: 50+

46) A photocathode having a work function of 2.8 eV is illuminated with monochromatic electromagnetic radiation whose photon energy is 4.0 eV. What is the threshold (cutoff) frequency for photoelectron production? (1 eV = 1.60×10^{-19} J, $h = 6.626 \times 10^{-34}$ J · s)
A) 6.8×10^{14} Hz
B) 2.9×10^{14} Hz
C) 7.7×10^{14} Hz
D) 8.6×10^{14} Hz
E) 9.7×10^{14} Hz
Answer: A
Var: 50+

47) When it is struck by 240-nm photons, a material having a work function of 2.60 eV emits electrons. What is the maximum kinetic energy of the emitted electrons? ($c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
A) 2.58 eV
B) 5.18 eV
C) 2.00 eV
D) 4.21 eV
Answer: A
Var: 1

48) When a photoelectric surface is illuminated with light of wavelength 437 nm, the stopping potential is measured to be 1.67 V. (1 eV = 1.60×10^{-19} J, $e = 1.60 \times 10^{-19}$ C, $m_{\text{electron}} = 9.11 \times 10^{-31}$ kg, $h = 6.626 \times 10^{-34}$ J · s)
(a) What is the work function of the metal, in eV?
(b) What is the maximum speed of the ejected electrons?
Answer: (a) 1.17 eV (b) 7.66×10^{5} m/s
Var: 1

49) In her physics laboratory, Mathilda shines electromagnetic radiation on a material and collects photoelectric data to determine Planck's constant. She measures a stopping potential of 5.82 V for radiation of wavelength 100 nm, and 17.99 V for radiation of wavelength 50.0 nm. (1 eV = 1.60×10^{-19} J, $c = 3.00 \times 10^{8}$ m/s)
(a) Using Mathilda's data, what value does she determine for Planck's constant?
(b) What is the work function of the material Mathilda is using, in electron-volts?
Answer: (a) 6.49×10^{-34} J · s (b) 6.35 eV
Var: 1

50) For a certain metal, light of frequency 7.24×10^{-14} Hz is just barely able to dislodge photoelectrons from the metal. ($h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J, $e = 1.60 \times 10^{-19}$ C)
(a) What will be the stopping potential if light of frequency 8.75×10^{-14} Hz is shone on the metal?
(b) What is the work function (in electron-volts) of this metal?
Answer: (a) 0.625 V (b) 3.00 eV
Var: 1

51) When light of wavelength 350 nm is incident on a metal surface, the stopping potential of the photoelectrons is measured to be 0.500 V. What is the work function of this metal? ($c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
A) 0.500 eV
B) 3.05 eV
C) 3.54 eV
D) 4.12 eV
Answer: B
Var: 1

52) When light of wavelength 350 nm is incident on a metal surface, the stopping potential of the photoelectrons is 0.500 V. What is the threshold (cutoff) frequency of this metal? ($c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
A) 3.47×10^{14} Hz
B) 3.74×10^{14} Hz
C) 4.73×10^{14} Hz
D) 7.36×10^{14} Hz
Answer: D
Var: 1

53) When light of wavelength 350 nm is incident on a metal surface, the stopping potential of the photoelectrons is 0.500 V. What is the maximum kinetic energy of these electrons? ($c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
A) 0.500 eV
B) 3.04 eV
C) 3.54 eV
D) 4.12 eV
Answer: A
Var: 1

54) A monochromatic light beam is incident on the surface of a metal having a work function of 2.50 eV. If a 1.0-V stopping potential is required to make the electron current zero, what is the wavelength of light? ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
A) 355 nm
B) 423 nm
C) 497 nm
D) 744 nm
Answer: A
Var: 1

55) X-rays of energy 3.5×10^4 eV scatter through an angle of 105° off of a free electron. What is the energy (in eV) of the scattered x-rays? ($m_{\text{electron}} = 9.11 \times 10^{-31}$ kg, $c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
Answer: 3.2×10^4 eV
Var: 50+

56) In a Compton scattering experiment using x-rays, the wavelength of the x-rays increases by 5.0% as the light is scattered at an angle of 60° with its original direction. What was the original wavelength of the light before scattering? ($m_{\text{electron}} = 9.11 \times 10^{-31}$ kg, $c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
Answer: 2.4×10^{-11} m
Var: 1

57) X-rays with a wavelength of 0.00100 nm are scattered by free electrons at 130° from their original direction. What is the kinetic energy (in keV) of each recoil electron? ($m_{\text{electron}} = 9.11 \times 10^{-31}$ kg, $c = 3.00 \times 10^8$ m/s, 1 eV = 1.60×10^{-19} J, $h = 6.626 \times 10^{-34}$ J · s)
Answer: 993 keV
Var: 1

58) A 140-keV photon strikes an electron and scatters through an angle of 120° from its original direction. ($m_{\text{electron}} = 9.11 \times 10^{-31}$ kg, $c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10-34$ J · s)
(a) What is the wavelength of the photon before scattering?
(b) What is the photon wavelength after scattering?
Answer: (a) 8.87 pm (b) 12.50 pm
Var: 1

59) A certain photon, after being scattered from a free electron that was at rest, moves at an angle of 120° with respect to the incident direction. If the wavelength of the incident photon is 0.6110 nm, what is the kinetic energy of the recoiling electron? ($m_{electron}$ = 9.11 × 10^{-31} kg, c = 3.00 × 10^{8} m/s, h = 6.626 × 10^{-34} J · s)
A) 1.5 × 10^{-18} J
B) 1.9 × 10^{-18} J
C) 3.1 × 10^{-18} J
D) 4.3 × 10^{-18} J
E) 5.2 × 10^{-18} J
Answer: B
Var: 1

60) A certain photon, after being scattered from a free electron that was at rest, moves at an angle of 120° with respect to the incident direction. If the wavelength of the incident photon is 0.591 nm, what is the wavelength of the scattered photon? ($m_{electron}$ = 9.11 × 10^{-31} kg, c = 3.00 × 10^{8} m/s, h = 6.626 × 10^{-34} J • s)
A) 0.380 nm
B) 0 nm
C) 0.550 nm
D) 0.591 nm
E) 0.595 nm
Answer: E
Var: 5

61) A certain photon, after being scattered from a free electron that was at rest, moves at an angle of 120° with respect to the incident direction. If the wavelength of the incident photon is 0.591 nm, what is the energy of the scattered photon? ($m_{electron}$ = 9.11 × 10^{-31} kg, c = 3.00 × 10^{8} m/s, h = 6.626 × 10^{-34} J • s)
A) 1.05 × 10^{-16} J
B) 2.10 × 10^{-16} J
C) 5.71 × 10^{-16} J
D) 3.34 × 10^{-16} J
E) 4.21 × 10^{-16} J
Answer: D
Var: 5

62) A beam of x-rays at a certain wavelength are scattered from a free electron that is at rest, and the scattered beam is observed at 45.0° from the incident beam. What is the change in the wavelength of the x-rays during this process? ($m_{electron}$ = 9.11 × 10^{-31} kg, c = 3.00 × 10^{8} m/s, h = 6.626 × 10^{-34} J · s)
A) 1.75 × 10^{-13} m
B) 2.76 × 10^{-13} m
C) 0 m
D) 3.56 × 10^{-13} m
E) 7.10 × 10^{-13} m
Answer: E
Var: 1

63) A 29.0-pm-wavelength photon is scattered by a stationary electron. What is the maximum energy loss the photon can have? ($m_{electron}$ = 9.11 × 10^{-31} kg, c = 3.00 × 10^{8} m/s, h = 6.626 × 10^{-34} J · s, 1 eV = 1.60 × 10^{-19} J)
A) 4.0 keV
B) 6.1 keV
C) 10 keV
D) 12 keV
E) 15 keV
Answer: B
Var: 1

64) An 18.0 pm wavelength photon is scattered by a stationary electron through an angle of 120°. What is the wavelength of the scattered photon? ($m_{electron}$ = 9.11 × 10^{-31} kg, c = 3.00 × 10^{8} m/s, h = 6.626 × 10^{-34} J · s)
A) 19.2 pm
B) 20.4 pm
C) 21.6 pm
D) 22.9 pm
E) 24.1 pm
Answer: C
Var: 1

65) If the scattering angle of the light in Compton's scattering experiment is 90°, what is the change in the wavelength of the light? ($m_{electron}$ = 9.11 × 10^{-31} kg, c = 3.00 × 10^{8} m/s, h = 6.626 × 10^{-34} J · s)
A) 1.22 × 10^{-12} m
B) 2.42 × 10^{-12} m
C) 3.65 × 10^{-12} m
D) 4.85 × 10^{-12} m
Answer: B
Var: 1

66) X-rays of wavelength 0.20 nm are scattered by a free electron. The change in the wavelength of the x-rays is observed to be 2.0×10^{-12} m at a certain scattering angle measured relative to the incoming x-ray direction. What is the scattering angle of the x-rays? ($m_{electron}$ = 9.11×10^{-31} kg, $c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
A) 20°
B) 40°
C) 60°
D) 80°
Answer: D
Var: 1

67) X-rays with a wavelength of 0.00100 nm are scattered at 130° by free electrons. What is the kinetic energy of each recoil electron? (1 eV = 1.60×10^{-19} J, $m_{electron} = 9.11 \times 10^{-31}$ kg, c = 3.00×10^{8} m/s, $h = 6.626 \times 10^{-34}$ J · s)
A) 0.50 MeV
B) 0.99 MeV
C) 2.0 MeV
D) 0.34 MeV
E) 0.68 MeV
Answer: B
Var: 1

68) What is the wavelength of a photon having the same momentum as an electron that is traveling at 7.5 km/s? ($h = 6.626 \times 10^{-34}$ J · s, $m_{electron} = 9.11 \times 10^{-31}$ kg)
Answer: 97 nm
Var: 1

69) What is the momentum of a photon of light that has a frequency of 2.8×10^{14} Hz?
($c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
A) 1.5×10^{-28} kg·m/s
B) 2.1×10^{-28} kg·m/s
C) 4.4×10^{-28} kg·m/s
D) 6.3×10^{-28} kg·m/s
E) 6.2×10^{-28} kg·m/s
Answer: E
Var: 5

70) What is the momentum of a photon of light that has a wavelength of 480 nm?
($h = 6.626 \times 10^{-34}$ J · s)
A) 1.1×10^{-27} kg·m/s
B) 2.2×10^{-27} kg·m/s
C) 1.8×10^{-27} kg·m/s
D) 1.4×10^{-27} kg·m/s
E) 2.0×10^{-27} kg·m/s
Answer: D
Var: 5

71) Calculate the kinetic energy, in electron-volts, of a neutron that has a de Broglie wavelength of 7.2×10^{-12} m ($m_{neutron} = 1.675 \times 10^{-27}$ kg, 1 eV = 1.6×10^{-19} J, $h = 6.626 \times 10^{-34}$ J · s)
Answer: 16 eV
Var: 50+

72) How "slow" must a 200-g ball move to have a de Broglie wavelength of 1.0 mm? ($h = 6.626 \times 10^{-34}$ J · s)
Answer: 3.3×10^{-30} m/s
Var: 1

73) What would be the de Broglie wavelength for 1-g object moving at the earth's escape speed 25,000 mph (about 11 km/s)? ($h = 6.626 \times 10^{-34}$ J · s)
Answer: 6×10^{-35} m
Var: 1

74) Atoms in crystals are typically separated by distances of 0.10 nm. What kinetic energy must a nonrelativistic electron have, in electron-volts, in order to have a wavelength of 0.10 nm? ($m_{electron} = 9.11 \times 10^{-31}$ kg, 1 eV = 1.60×10^{-19} J, $h = 6.626 \times 10^{-34}$ J · s)
Answer: 150 eV
Var: 1

75) The electrons in a beam are moving at 18 m/s. ($m_{electron} = 9.11 \times 10^{-31}$ kg, $h = 6.626 \times 10^{-34}$ J · s)
(a) What is its de Broglie wavelength these electrons?
(b) If the electron beam falls normally on a diffraction grating, what would have to be the spacing between slits in the grating to give a first-order maximum at an angle of 30° with the normal to the grating?
Answer: (a) 40 μm (b) 81 μm
Var: 5

76) A proton that is moving freely has a wavelength of 0.600 pm. (m_{proton} = 1.67 × 10^{-27} kg, e = 1.60 × 10^{-19} C, h = 6.626 × 10^{-34} J · s)
(a) What is its momentum?
(b) What is its speed?
(c) What potential difference would it have been accelerated through, starting from rest, to reach this speed?
Answer: (a) 1.10 × 10^{-21} kg · m/s (b) 6.61 × 10^{5} m/s (c) 2.28 kV
Var: 1

77) A crystal diffracts a beam of electrons, like a diffraction grating, as they hit it perpendicular to its surface. The crystal spacing is 0.18 nm, and the first maximum scattering occurs at 80° relative to the normal to the surface. (e = 1.60 × 10^{-19} C, $m_{electron}$ = 9.11 × 10^{-13} kg, h = 6.626 × 10^{-34} J · s)
(a) What is the wavelength of the electrons?
(b) What potential difference accelerated the electrons if they started from rest?
Answer: (a) 0.18 nm
(b) 48 V
Var: 5

78) What is the wavelength of the matter wave associated with a 0.50-kg ball moving at 25 m/s? (h = 6.626 × 10^{-34} J · s)
A) 3.5 × 10^{-35} m
B) 5.3 × 10^{-35} m
C) 3.5 × 10^{-33} m
D) 5.3 × 10^{-33} m
Answer: B
Var: 1

79) What is the de Broglie wavelength of a ball of mass 200 g moving at 30 m/s? (h = 6.626 × 10^{-34} J · s)
A) 1.1 × 10^{-34} m
B) 2.2 × 10^{-34} m
C) 4.5 × 10^{-28} m
D) 6.7 × 10^{-27} m
Answer: A
Var: 1

80) A person of mass 50 kg has a de Broglie wavelength of 4.4×10^{-36} m while jogging. How fast is she running? (h = 6.626×10^{-34} J · s)
A) 2.0 m/s
B) 3.0 m/s
C) 4.0 m/s
D) 5.0 m/s
Answer: B
Var: 1

81) Find the de Broglie wavelength of a 1.30-kg missile moving at 28.10 m/s. (h = 6.626×10^{-34} J · s)
A) 1.81×10^{-35} m
B) 2.05×10^{-35} m
C) 2.28×10^{-35} m
D) 2.57×10^{-35} m
Answer: A
Var: 50+

82) If an electron has a wavelength of 0.123 nm, what is its kinetic energy, in electron-volts? This energy is *not* in the relativistic region. ($m_{electron}$ = 9.11×10^{-31} kg, 1 eV = 1.60×10^{-19} J, h = 6.626×10^{-34} J · s)
A) 19.8 eV
B) 60.2 eV
C) 80.4 eV
D) 99.5 eV
E) 124 eV
Answer: D
Var: 1

83) What is the wavelength of the matter wave associated with an electron moving with a speed of 2.5×10^{7} m/s? ($m_{electron}$ = 9.11×10^{-31} kg, h = 6.626×10^{-34} J · s)
A) 29 pm
B) 35 pm
C) 47 pm
D) 53 pm
Answer: A
Var: 1

84) After an electron has been accelerated through a potential difference of 0.15 kV, what is its de Broglie wavelength? (e = 1.60 × 10^{-19} C, $m_{electron}$ = 9.11 × 10^{-31} kg, h = 6.626 × 10^{-34} J · s)
A) 0.10 nm
B) 1.0 nm
C) 1.0 mm
D) 1.0 cm
Answer: A
Var: 1

85) If the momentum of an electron is 1.95 × 10^{-27} kg · m/s, what is its de Broglie wavelength? (h = 6.626 × 10^{-34} J · s)
A) 340 nm
B) 210 nm
C) 170 nm
D) 420 nm
E) 520 nm
Answer: A
Var: 1

86) If the de Broglie wavelength of an electron is 380 nm, what is the speed of this electron? ($m_{electron}$ = 9.11 × 10^{-31} kg, h = 6.626 × 10^{-34} J · s)
A) 2.0 km/s
B) 3.8 km/s
C) 1.9 km/s
D) 4.1 km/s
E) 5.2 km/s
Answer: C
Var: 1

87) An electron is moving with the speed of 1780 m/s. What is its de Broglie wavelength? ($m_{electron}$ = 9.11 × 10^{-31} kg, h = 6.626 × 10^{-34} J · s)
A) 409 nm
B) 302 nm
C) 205 nm
D) 420 nm
E) 502 nm
Answer: A
Var: 1

88) If the de Broglie wavelength of an electron is 2.4 μm, what is the speed of the electron? ($m_{electron} = 9.11 \times 10^{-31}$ kg, $h = 6.626 \times 10^{-34}$ J · s)

A) 3.0×10^{2} m/s
B) 2.5×10^{5} m/s
C) 1.7×10^{3} m/s
D) 8.3×10^{6} m/s
Answer: A
Var: 50+

89) If an electron has the same de Broglie wavelength as the wavelength of a 390-nm photon in vacuum, what is the speed of the electron? ($m_{electron} = 9.11 \times 10^{-31}$ kg, $c = 3.0 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
A) 1900 m/s
B) 2100 m/s
C) 1700m/s
D) 1500 m/s
E) 540 m/s
Answer: A
Var: 50+

90) A proton has a speed of 7.2×10^{4} m/s. What is the energy of a photon that has the same wavelength as the de Broglie wavelength of this proton? ($m_{electron} = 9.11 \times 10^{-31}$ kg, $c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J · s)
A) 230 keV
B) 150 keV
C) 300 keV
D) 370 keV
E) 440 keV
Answer: A
Var: 50+

91) An electron has the same de Broglie wavelength as the wavelength of a 1.8 eV photon. What is the speed of the electron? ($m_{electron} = 9.11 \times 10^{-31}$ kg, $c = 3.00 \times 10^{8}$ m/s, 1 eV = 1.60×10^{-19} J)
A) 1100 m/s
B) 980 m/s
C) 910 m/s
D) 840 m/s
E) 770 m/s
Answer: A
Var: 50+

92) An electron is accelerated from rest through a potential difference. After acceleration the electron has a wavelength of 880 nm. What is the potential difference responsible for the acceleration of the electron? (h = 6.626 × 10^{-34} J · s, $m_{electron}$ = 9.11 × 10-31 kg, e = 1.6 10^{-19} C)

A) 1.9 × 10^{-6} V
B) 1.7 × 10^{-6} V
C) 2.2 × 10^{-6} V
D) 2.5 × 10^{-6} V
Answer: A
Var: 50+

93) Electrons emerge from an electron gun with a speed of 2.0 × 10^{6} m/s and then pass through a double-slit apparatus. Interference fringes with spacing of 2.7 mm are detected on a screen far from the double slit. What would the fringe spacing be if the electrons were replaced by neutrons with the same speed? (h = 6.626 × 10^{-34} J · s, $m_{electron}$ = 9.11 × 10^{-31} kg, $m_{neutron}$ = 1.675 × 10^{-27} kg)

A) 1.5 μm
B) 4.9 m
C) 0.93 nm
D) 1.2 km
Answer: A
Var: 50+

94) Electrons are accelerated to a speed of 4.0 × 10^{4} m/s and are then aimed at a double-slit apparatus, where interference fringes are detected. If the electrons were replaced by neutrons, what speed must neutrons have to produce interference fringes with the same fringe spacing as that observed with the electrons? (h = 6.626 × 10^{-34} J · s, $m_{electron}$ = 9.11 × 10^{-31} kg, $m_{neutron}$ = 1.675 × 10^{-27} kg)

A) 2.2 × 10^{1} m/s
B) 7.3 × 10^{7} m/s
C) 1.7 × 10^{6} m/s
D) 9.3 × 10^{2} m/s
Answer: A
Var: 50+

95) Electrons with a speed of 2.1 × 10^{6} m/s are directed towards a 1.0-μm wide slit. An electron detector is placed 1.0 m behind the slit. How wide is the central maximum of the electron diffraction pattern on the detector? (h = 6.626 × 10^{-34} J · s, $m_{electron}$ = 9.11 × 10^{-31} kg)

A) 690 μm
B) 350 μm
C) 1000 μm
D) 1400 μm
Answer: A
Var: 50+

96) A certain crystal has a spacing of 0.442 nm between atoms. A beam of neutrons moving with a speed of 1640 m/s perpendicular to the surface is diffracted as it passes through the crystal. What is the angle from the central maximum to the next interference maximum? ($m_{neutron}$ = 1.675×10^{-27} kg, $h = 6.626 \times 10^{-34}$ J · s)
A) 17.0°
B) 21.0°
C) 33.1°
D) 60.0°
E) 90.0°
Answer: C
Var: 1

97) The spacing of the atoms of a crystal is 159 pm. A monoenergetic beam of neutrons directed normally at the surface of the crystal undergoes first order diffraction at an angle of 58° from the normal. What is the energy of each of the neutrons? ($m_{neutron}$ = 1.675×10^{-27} kg, 1 eV = 1.6×10^{-19} J, $h = 6.626 \times 10^{-34}$ J · s)
A) 0.045 eV
B) 0.039 eV
C) 0.050 eV
D) 0.056 eV
E) 0.061 eV
Answer: A
Var: 50+

98) One of the emission lines described by the original version of Balmer's formula has wavelength 377 nm. What is the value of n in Balmer's formula that gives this emission line?
A) 11
B) 12
C) 13
D) 14
Answer: A
Var: 17

99) What is the value of n in the Balmer series for which the wavelength is 410.2 nm.
A) 4
B) 5
C) 6
D) 7
E) 9
Answer: C
Var: 1

100) What is the wavelength in the Balmer series for n = 15?
A) 277.1 nm
B) 371.1 nm
C) 188.6 nm
D) 656 nm
E) 754.2 nm
Answer: B
Var: 5

101) The value of a wavelength in the Balmer series is 372.1 nm. What is the corresponding value of n?
A) 6
B) 3
C) 9
D) 10
E) 14
Answer: E
Var: 5

102) What is the longest wavelength in the Balmer series?
A) 240 nm
B) 328 nm
C) 365 nm
D) 656 nm
E) 820 nm
Answer: D
Var: 1

103) What is the shortest wavelength in the Balmer series?
A) 328 nm
B) 365 nm
C) 456 nm
D) 656 nm
E) 820 nm
Answer: B
Var: 1

104) What value of n corresponds to a wavelength of 922.7 nm in the Paschen series?
A) 3
B) 5
C) 7
D) 9
E) 15
Answer: D
Var: 5

105) What value of *n* corresponds to a wavelength of 91.7 nm in the Lyman series?
A) 1
B) 3
C) 5
D) 9
E) 13
Answer: E
Var: 5

106) What is the longest wavelength in the Paschen series?
A) 2.01 nm
B) 2.01 μm
C) 365 nm
D) 1.88 nm
E) 1.88 μm
Answer: E
Var: 1

107) What is the shortest wavelength in the Paschen series?
A) 410.2 nm
B) 410.2 μm
C) 365 nm
D) 820.4 nm
E) 820.4 μm
Answer: D
Var: 1

108) What is the shortest wavelength of the Lyman series?
A) 91.16 nm
B) 45.60 nm
C) 121.5 nm
D) 204.1 nm
E) 365 nm
Answer: A
Var: 1

109) What is the longest wavelength in the Lyman Series?
A) 45.60 nm
B) 91.20 nm
C) 121.5 nm
D) 240.1 nm
E) 365 nm
Answer: C
Var: 1

110) The wavelength of a ruby laser is 694.3 nm. What is the energy difference between the two energy states for the transition that produces this light? ($c = 3.00 \times 10^8$ m/s, 1 eV = 1.60×10^{-19} J, $h = 6.626 \times 10^{-34}$ J · s)
A) 1.54 eV
B) 1.65 eV
C) 1.79 eV
D) 1.81 eV
Answer: C
Var: 1

111) What is the energy (in electron-volts) of the $n = 3$ state of atomic hydrogen?
Answer: -1.51 eV
Var: 1

112) Given that the energy levels of the hydrogen atom are given by $E_n = \frac{Rch}{n^2}$, where $R = 1.097 \times 10^7$ m^{-1}, what wavelength photon is emitted when the atom undergoes a transition from the $n = 4$ to the $n = 6$ level?
Answer: 2.625×10^{-6} m
Var: 1

113) Consider the Bohr model for the hydrogen atom. ($c = 3.00 \times 10^8$ m/s, 1 eV = 1.60×10^{-19} J, $h = 6.626 \times 10^{-34}$ J · s)
(a) How much energy (in eV) is needed to cause a transition of an electron from the second excited state to the third excited state?
(b) What wavelength photon just has enough energy to initiate the transition in (a)?
Answer: (a) 0.661 eV (b) 1.88 μm
Var: 7

114) Given that the binding energy of the hydrogen atom in its ground state is -13.6 eV, what is the energy when it is in the $n = 5$ state?
A) 2.72 eV
B) -2.72 eV
C) 0.544 eV
D) -0.544 eV
Answer: D
Var: 1

115) If a hydrogen atom in the ground state absorbs a photon of energy 12.09 eV, to which state will the electron make a transition?
A) $n = 2$
B) $n = 3$
C) $n = 4$
D) $n = 5$
Answer: B
Var: 1

116) What is the ionization energy of the neutral hydrogen atom?
A) 27.2 eV
B) 13.6 eV
C) 6.8 eV
D) none of the given answers
Answer: B
Var: 1

117) What is the energy of the photon emitted when an electron drops from the $n = 20$ state to the $n = 7$ state in a hydrogen atom?
A) 0.244 eV
B) 0.264 eV
C) 0.283 eV
D) 0.303 eV
Answer: A
Var: 17

118) In a hydrogen atom, the electron makes a transition from the n = 8 to the n = 3 state. The wavelength of the emitted photon is closest to which one of the following values? (c = 3.00 × 10^8 m/s, 1 eV = 1.60 × 10^{-19} J, h = 6.626 × 10^{-34} J · s)
A) 9.57 × 10^{-7} m
B) 1.13 × 10^{-6} m
C) 3.12 × 10^{-7} m
D) 4.52 × 10^{-6} m
E) 6.34 × 10^{-7} m
Answer: A
Var: 1

119) A hydrogen atom is excited to the n = 11 level. Its decay to the n = 7 level is detected in a photographic plate. What is the wavelength of the light photographed? (c = 3.00 × 10^8 m/s, 1 eV = 1.60 × 10^{-19} J, h = 6.626 × 10^{-34} J · s)
A) 7510 nm
B) 4670 nm
C) 12,400 nm
D) 4380 nm
Answer: A
Var: 44

120) A hydrogen atom is excited to the $n = 9$ level. Its decay to the $n = 6$ level detected in a photographic plate. What is the frequency of the light photographed? ($1 \text{ eV} = 1.60 \times 10^{-19}$ J, $h = 6.626 \times 10^{-34}$ J · s)
A) 5.08×10^{13} Hz
B) 5910 Hz
C) 5910 nm
D) 3.28×10^{-9} km
Answer: A
Var: 44

121) A hydrogen atom is in its $n = 2$ excited state when its electron absorbs 9.5 eV in an interaction with a photon. What is the energy of the resulting free electron?
A) 6.1 eV
B) 7.9 eV
C) 8.2 eV
D) 9.2 eV
Answer: A
Var: 50

122) A hydrogen atom makes a downward transition from the $n = 15$ state to the $n = 5$ state. Find the wavelength of the emitted photon. ($c = 3.00 \times 10^8$ m/s, $1 \text{ eV} = 1.60 \times 10^{-19}$ J, $h = 6.626 \times 10^{-34}$ J · s)
A) 2.56 μm
B) 1.54 μm
C) 2.05 μm
D) 3.07 μm
Answer: A
Var: 15

123) The longest wavelength photon that can be emitted by a hydrogen atom, for which the final state is $n = 9$, is closest to which one of the following values? ($c = 3.0 \times 10^8$ m/s,
$1 \text{ eV} = 1.60 \times 10^{-19}$ J, $h = 6.626 \times 10^{-34}$ J · s)
A) 39,000 nm
B) 22,000 nm
C) 7400 nm
D) 16,000 nm
E) 28,000 nm
Answer: A
Var: 9

124) The shortest wavelength of a photon that can be emitted by a hydrogen atom, for which the initial state is $n = 12$, is closest to which one of the following values? ($c = 3.0 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
A) 92 nm
B) 82 nm
C) 72 nm
D) 62 nm
E) 52 nm
Answer: A
Var: 10

125) The longest wavelength of a photon that can be emitted by a hydrogen atom, for which the initial state is $n = 3$, is closest to which one of the following values? ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
A) 550 nm
B) 575 nm
C) 600 nm
D) 625 nm
E) 658 nm
Answer: E
Var: 1

126) What is the shortest wavelength of a photon that can be emitted by a hydrogen atom, for which the initial state is $n = 3$? ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
A) 822 nm
B) 850 nm
C) 103 nm
D) 91.4 nm
E) 950 nm
Answer: C
Var: 1

127) What is the energy required to remove the electron from a hydrogen atom in the $n = 11$ state?
A) 0.112 eV
B) 1.24 eV
C) 13.5 eV
D) 12.4 eV
E) 0.141 eV
Answer: A
Var: 1

128) If light excites atomic hydrogen from its lowest energy level to the $n = 12$ level, what is the energy of the photons of this light?
A) 13.5 eV
B) 32.2 eV
C) 13.6 eV
D) 0.0944 eV
E) 1.13 eV
Answer: A
Var: 1

129) Light shines through atomic hydrogen gas that was initially in its ground state. You observe that after awhile much of the hydrogen gas has been excited to its $n = 5$ state. What wavelength of light entering the gas caused this excitation? ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
A) 110 nm
B) 91.4 nm
C) 95.2 nm
D) 2280 nm
Answer: C
Var: 1

130) Radio astronomers often study the radiation emitted by a hydrogen atom from a transition between the two hyperfine levels associated with the ground state. This radiation has a wavelength of 21 cm. What is the energy difference between the hyperfine levels? (1 eV = 1.60×10^{-19} J)
A) 5.9×10^{-6} eV
B) 5.9×10^{-25} J
C) 1.7×10^{-24} J
D) 4.7×10^{-25} J
Answer: A
Var: 1

131) In a transition from one vibrational state to another, a molecule emits a photon of wavelength 5.56 µm. What is the energy difference between these two states? ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
A) 0.223 eV
B) 2.23 MeV
C) 13.6 eV
D) 13.6 MeV
E) 0.223 MeV
Answer: A
Var: 1

132) What is the wavelength of the photon emitted when an electron in a hydrogen atom which is in the initial state n = 8 jumps to the final state n = 2? (c = 3.00 × 10^8 m/s, h = 6.626 × 10^{-34} J · s, 1 eV = 1.60 × 10^{-19} J)
A) 205 nm
B) 104 nm
C) 389 nm
D) 486 nm
E) 610 nm
Answer: C
Var: 1

133) What is the wavelength of the photon emitted when an electron in a hydrogen atom which is in the initial state n = 4 jumps to the final state n = 2? (c = 3.00 × 10^8 m/s, h = 6.626 × 10^{-34} J · s, 1 eV = 1.60 × 10^{-19} J)
A) 243 nm
B) 486 nm
C) 556 nm
D) 312 nm
E) 609 nm
Answer: B
Var: 1

134) The wavelength of the emitted photon if an electron in the hydrogen atom makes a transition from the n = 2 state to the ground state is closest to which of the following values? (c = 3.0 × 10^8 m/s, h = 6.626 × 10^{-34} J · s, 1 eV = 1.60 × 10^{-19} J)
A) 122 nm
B) 203 nm
C) 243 nm
D) 389 nm
E) 411 nm
Answer: A
Var: 1

135) What is the wavelength of the emitted photon if an electron in the hydrogen atom makes a transition from the n = 7 state to the n = 2 state? (c = 3.00 × 10^8 m/s, h = 6.626 × 10^{-34} J · s, 1 eV = 1.60 × 10^{-19} J)
A) 199 nm
B) 365 nm
C) 4480 nm
D) 398 nm
E) 796 nm
Answer: D
Var: 1

136) What frequency must a photon have to raise an electron in a hydrogen atom from the $n = 2$ to the $n = 4$ state? ($h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
A) 3.06×10^{14} Hz
B) 6.16×10^{14} Hz
C) 4.11×10^{14} Hz
D) 5.20×10^{14} Hz
E) 9.24×10^{14} Hz
Answer: B
Var: 1

137) In making a transition from state $n = 1$ to state $n = 2$, the hydrogen atom must
A) absorb a photon of energy 10.2 eV.
B) emit a photon of energy 10.2 eV.
C) absorb a photon of energy 13.58 eV.
D) emit a photon of energy 13.58 eV.
Answer: A
Var: 1

138) In the $n = 1$ state, the energy of the hydrogen atom is -13.6 eV. What is its energy in the $n = 2$ state?
A) -6.79 eV
B) -4.53 eV
C) -3.40 eV
D) -1.51 eV
Answer: C
Var: 1

139) A neutral boron atom has 5 electrons, but in this case all but one of its electrons have been knocked off. How much energy (in electron-volts) is needed to remove the last electron?
Answer: 340 eV
Var: 1

140) The Bohr model of the hydrogen atom predicts an ionization energy of 13.6 eV. Using this model, what would we expect for the ionization energy of the Li^{++} ion, which has 3 protons?
A) 122 eV
B) 40.8 eV
C) 54.4 eV
D) 27.2 eV
E) 79.6 eV
Answer: A
Var: 1

141) What is the ground state energy of the Li^{++} ion, which has atomic number 3?
A) -40.8 eV
B) -122 eV
C) -61 eV
D) -1.51 eV
E) Li^{++} does not have a ground state.
Answer: B
Var: 1

142) A doubly-ionized lithium atom Li^{++}, which has 3 protons, undergoes a transition from the n = 5 state to the n = 4 state. What is the wavelength of the photon which is emitted during this transition? ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s, 1 eV = 1.60×10^{-19} J)
A) 350 nm
B) 450 nm
C) 550 nm
D) 650 nm
E) 750 nm
Answer: B
Var: 1

143) A highly ionized atom with Z = 5 has only one electron left around it, in its ground state. How much more energy is required to finish the job and have a bare nucleus?
A) 340.0 eV
B) 68.0 eV
C) 10.9 eV
D) 13.1 eV
Answer: A
Var: 5

144) What is the minimum energy an incoming electron must have to knock a K shell electron (n = 1) out of an atom of molybdenum, which contains 42 protons?
A) 10.1 keV
B) 11.3 keV
C) 24.0 keV
D) 34.4 keV
E) 44.0 keV
Answer: C
Var: 1

145) Determine the energy of the most energetic x-ray you can get from an electron transition in a heavy atom having 93 protons.
A) 118 keV
B) 0.865 eV
C) 164 MeV
D) 5.19×10^7 eV
Answer: A
Var: 15

146) What is the ionization energy of singly-ionized helium, which has 2 protons?
A) 54.4 eV
B) 13.6 eV
C) 27.2 eV
D) 6.80 eV
E) 36.4 eV
Answer: A
Var: 1

147) Consider the Bohr model for the hydrogen atom in its second excited state.
(a) Determine the binding energy (eV) of the electron.
(b) What is the radius of the electron orbit, given that r_1 = 0.0529 nm?
(c) How far is it from the next higher excited orbit?
Answer: (a) 1.51 eV (b) 0.476 nm (c) 0.370 nm
Var: 1

148) A hydrogen atom with a barely bound electron may have an average radius as large as a bacterium, which is a radius of 14 μm. What is the nearest principal quantum number of the atom in this state? The radius for ground state hydrogen is 0.0529 nm.
A) 514
B) 51
C) 16
D) 264,650
Answer: A
Var: 10

149) Calculate the orbital Bohr radius of the $n = 2$ excited state in a hydrogen atom. (r_1 = 0.0529 nm)
A) 0.212 nm
B) 0.106 nm
C) 0.170 nm
D) 0.244 nm
Answer: A
Var: 3

150) Using the Bohr model, what is the radius of the lowest-energy electron orbit in a singly-ionized He atom, which has 2 protons? (r_1 = 0.0529 nm for hydrogen)
Answer: 0.0265 nm
Var: 1

151) Calculate the radius of the n = 4 Bohr orbit in O^{7+} (oxygen with 7 of its 8 electrons removed). (for hydrogen, r_1 = 0.0529 nm)
A) 106 pm
B) 74 pm
C) 85 pm
D) 95 pm
Answer: A
Var: 9