Why is quantum theory not needed to describe the behavior of everyday objects, such as a moving baseball and an oscillator attached to a spring?

A) baseball has large wavelength; oscillator has large quantum number
B) baseball has small wavelength; oscillator has small quantum number
C) baseball has large wavelength; oscillator has small quantum number
D) baseball has small wavelength; oscillator has large quantum number

Answer: D

Explanation:

B)

C)

D) See sections 30–1 and 30–5 in the textbook.

PARTIAL CREDIT: 0.3 point for A or B
2) Three particles (labeled as 1, 2, 3) all have the same magnitude of charge. They are initially moving horizontally with the same speed in a region with zero magnetic field. When they enter the region shown below with a uniform magnetic field (pointing out of the page), they follow the paths shown.

Which particle has the smallest mass? (Neglect gravity.)

A) particle 1  
B) particle 2  
C) particle 3  
D) cannot be determined from the information given

Answer: C

Explanation: For circular motion in a magnetic field, the radius is \( r = \frac{mv}{|q|B} \). Since the particles have the same speed and magnitude of charge, the particle with the smallest mass follows the path with the smallest radius. This is similar to Chapter 32 Conceptual Question 6 (see the sample problems for Chapter 32 on the course webpage).
3) A coil of wire has inductance 2 H. Initially there is no current flowing through the coil. When a steady current of 2 A flows through the coil, what is the change in the mass of the coil?

A) The mass decreases by $1.1 \times 10^{-17}$ kg
B) The mass increases by $2.2 \times 10^{-17}$ kg
C) The mass decreases by $3.3 \times 10^{-9}$ kg
D) The mass increases by $4.4 \times 10^{-17}$ kg

Answer: D
Explanation: A)
B)
C)
D) You solved a similar problem on your homework. The magnetic energy stored in the inductor is $U = \frac{1}{2} LI^2$, so the increase in mass is

$$\Delta m = \frac{E}{c^2} = \frac{\frac{1}{2} LI^2}{c^2} = \frac{\frac{1}{2} (2 \text{ H})(2 \text{ A})^2}{(3 \times 10^8 \text{ m/s})^2} = 4.4 \times 10^{-17} \text{ kg}$$

PARTIAL CREDIT: 0.3 point for B (using correct approach but making errors)

4) A light ray travels from air into plastic. The angle of incidence is 50 degrees and the angle of refraction is 30 degrees. What is the index of refraction of the plastic?

A) 0.65
B) 1.19
C) 1.31
D) 1.53

Answer: D
Explanation: A) $n_2 = n_1 (\sin \theta_1) / \sin \theta_2 = (1.0) \sin(50^\circ) / \sin(30^\circ) = 1.53$
B)
C)
D)
5) Consider two particles. Particle 1 has uncertainty in position of $\Delta x$, and minimum uncertainty in momentum of $\Delta p$. If the uncertainty in the position of particle 2 is $2\Delta x$, the minimum uncertainty in its momentum is

A) $\frac{1}{4} \Delta p$
B) $\frac{1}{2} \Delta p$
C) $\Delta p$
D) $2 \Delta p$
E) $4 \Delta p$

Answer: B
Explanation: A)

B) By the uncertainty principle the minimum uncertainty in momentum is

$$\Delta p = \frac{h}{2\pi} \frac{1}{\Delta x},$$

so doubling $\Delta x$ will halve $\Delta p$.

**PARTIAL CREDIT:** 0.3 point for A

C)
D)
E)

6) Which of the following are examples of when the path of a light ray can bend?

A) light traveling from air into glass at non-normal incidence
B) light from a distant star that passes near the sun
C) mirages
D) only two of A, B, C
E) all of A, B, C

Answer: E
Explanation: A)

B)
C)
D)
E) See these Figures in the textbook:
   Figure 26–21 (refraction), Figure 26–23 (mirages), Figure 29–22 (gravitational bending)

**PARTIAL CREDIT:** 0.3 point for D
7) What is the binding energy of a deuterium nucleus? (In other words, how much energy is needed to completely break up a deuterium nucleus into its constituent nucleons?)
   A) 1.1 MeV
   B) 1.3 MeV
   C) 2.2 MeV
   D) 2.9 MeV
   Answer: C
   Explanation: A)
   B)
   C) Use $E = (\Delta m) c^2$. As throughout Chapter 32 (and in the example in class), we can use the masses of atoms (which contain electrons) instead of the masses of nuclei because the extra electrons' mass cancels out when we compute the mass difference:

   $\Delta m = (m_{\text{H atom}} + m_{\text{neutron}}) - m_{\text{deuterium atom}}$
   $\Delta m = (1.007825 \text{ u} + 1.008665 \text{ u}) - 2.014102 \text{ u}$
   $\Delta m = 0.00239 \text{ u}$
   $\Delta m = (0.00239) (931.5 \text{ MeV} / c^2)$
   $\Delta m = 2.2 \text{ MeV} / c^2$

   So $E = (\Delta m) c^2 = 2.2 \text{ MeV}$
   D)

8) Nucleus X has 100 times as many nucleons as nucleus Y. Compared to nucleus Y, nucleus X has
   A) a larger radius and a higher density
   B) a larger radius and a smaller density
   C) a larger radius and an equal density
   D) a smaller radius and a smaller density
   E) a smaller radius and a higher density
   Answer: C
   Explanation: A)
   B)
   C) The radius is proportional to $A^{1/3}$ (where $A$ is the number of nucleons) but the nuclear density is the same for all nuclei (as we derived in class). See section 32-1 in the textbook.
   D)
   E)
9) Helium has atomic number $Z = 2$. What is the minimum energy a photon must have to remove the electron from a singly-ionized Helium atom in the $n = 5$ state?

A) 0.54 eV  
B) 1.1 eV  
C) 2.2 eV  
D) 13.6 eV  

Answer: C  
Explanation: A)  
B)  
C) The energies are: $E_n = -(13.6 \text{ eV})(Z^2 / n^2)$.  
The initial energy is $E_5 = -(13.6 \text{ eV})(2^2 / 5^2) = -2.2 \text{ eV}$.  
The final energy is zero so the energy needed is: $\Delta E = |0 - E_5| = 2.2 \text{ eV}$  
D)
10) A thin film of oil (with $n > 1.33$) floats on water as shown below.

If light is incident from the air and strikes the film, does it experience any phase changes due to reflection?

A) yes, at the air-oil interface only
B) yes, at the oil-water interface only
C) yes, at both the air-oil interface and the oil-water interface
D) no phase changes occur due to reflection
E) cannot be determined from the information given

Answer: A
Explanation: A) See section 28-3 for the phase change rule.
11) Two long parallel wires carry currents of different magnitudes. If the current in each wire is halved, what happens to the magnitude of the force between the wires?
   A) it is four times smaller
   B) it is half as large
   C) it stays the same
   D) it is twice as large
   E) it is four times larger

Answer: A
Explanation: A) For the reasoning, see the solutions to the similar problem on the midterm.

B)
C)
D)
E)

12) The concave side of a spoon has a focal length of 5 cm. A tiny candle is placed 2 cm from the spoon. The image of the candle is
   A) virtual, and located 3.33 cm from the spoon
   B) virtual, and located 1.43 cm from the spoon
   C) real, and located 3.33 cm from the spoon
   D) real, and located 1.43 cm from the spoon

Answer: A
Explanation: A) This is Exercise 26-1 (c). See page 861 in the textbook.

B)
C)
D)

13) When light reflects from a horizontal surface, like a tabletop or the surface of lake, it is partially polarized in the
   A) horizontal direction
   B) vertical direction

Answer: A
Explanation: A) We reviewed this in class before the final exam. See Figure 25–22 in the textbook.

B)
14) When violet light shines on a piece of sodium metal, electrons are ejected from the surface of the metal. If you increase the intensity of the light and keep the wavelength of light the same, what happens to the number of electrons ejected per second and their maximum kinetic energy?

A) same number of electrons ejected per second; maximum kinetic energy increases
B) same number of electrons ejected per second; maximum kinetic energy does not change
C) more electrons ejected per second; maximum kinetic energy decreases
D) more electrons ejected per second; maximum kinetic energy does not change
E) more electrons ejected per second; kinetic energy increases

Answer: D
Explanation: A) B) C) D) This is the photoelectric effect. See section 30-2 in the textbook. E)

15) A spear and a pipe are each 10 m long when they are at rest. The spear is thrown at a very high speed through the pipe. If you are holding the pipe, what do you see as the spear passes through the pipe?

A) the spear is shorter than the pipe
B) the pipe is shorter than the spear
C) the pipe and the spear have the same length
D) cannot be determined from the information given

Answer: A
Explanation: A) This is length contraction. In your frame of reference the spear is moving so its length is contracted (shorter) compared to its length when it is at rest. B) C) D)
16) The three rings of wire in the figure below are in a uniform magnetic field (pointing out of the page). Ring 1 swings back and forth like a pendulum. Ring 2 rotates about a vertical axis. Ring 3 oscillates vertically on the end of a spring.

Which ring or rings has a changing magnetic flux through it?

A) ring 1 only
B) ring 2 only
C) ring 3 only
D) more than one of the rings
E) all three of the rings

Answer: B

Explanation: A)

B) This is Conceptual Checkpoint 23-1. See page 752 in the textbook.

C)

D)

E)
17) How fast must you drive your car in order for a yellow traffic light to appear green? (Assume yellow light has a wavelength of 590 nm and green light has a wavelength of 550 nm where 1 nm = 10^{-9} m.)

A) 0.073 c  
B) 0.13 c  
C) 0.36 c  
D) 0.68 c  

Answer: A  
Explanation: A) As mentioned in class, you CANNOT use length contraction to solve this. This is a Doppler problem (Chapter 25 Problem 18). In order to observe \( \lambda' < \lambda \) you must approach the source of light. This means we use the + sign in the Doppler formula, and also use \( f = \frac{c}{\lambda} \):

\[
1 + \frac{v}{c} = \frac{\lambda'}{f} = \frac{\lambda}{\lambda'}
\]

\[
\frac{v}{c} = \frac{\lambda}{\lambda'} - 1 = \frac{590 \text{ nm}}{550 \text{ nm}} - 1 = 0.073
\]

PARTIAL CREDIT: 0.3 point for D (using correct approach but making errors)

B)  
C)  
D)  

18) In an experiment, electrons pass through two thin slits and form an interference pattern on a distant screen. If the momentum of the electrons is doubled (and nothing else in the experiment is changed), what happens to the bright fringes in the interference pattern? (You may assume the angles involved are small.)

A) the bright fringes move closer together  
B) the bright fringes move farther apart  
C) the bright fringes do not change their positions  
D) cannot be determined from the information given  

Answer: A  
Explanation: A) As mentioned in class, the angular separation of the bright fringes is \( \Delta \theta = \frac{\lambda}{d} \). (This is because bright fringes occur where \( d \sin \theta = m \lambda \), and \( \sin \theta \approx \theta \) for small angles). Also, quantum theory says \( \lambda = \frac{h}{p} \) so if the only change is that \( p \) increases, then \( \Delta \theta = \frac{\lambda}{d} = \frac{h}{pd} \) decreases.

B)  
C)  
D)
19) This exam lasts 85 minutes. As measured by an astronaut moving past the Earth at a very high speed, your exam lasts
   A) less than 85 minutes
   B) more than 85 minutes
   C) either A or B, depending on the value of the astronaut’s speed
   D) either A or B, depending on the direction of the astronaut’s motion

Answer: B
Explanation: A)
   B) This is time dilation. In your frame of reference the two events (the start and end of the exam) occur at the same location, so the time interval that you measure is the proper time. Thus, the astronaut measures the dilated (longer) time.
   C)
   D)

20) Carbon has atomic number $Z = 6$. Which of the following is the correct electronic configuration for carbon?
   A) $1s^2\ 2s^1\ 2p^3$
   B) $1s^1\ 2s^1\ 2p^6$
   C) $1s^2\ 2s^2\ 2p^2$
   D) $1s^1\ 2s^1\ 2p^4$
   E) $1s^1\ 2s^2\ 2p^3$

Answer: C
Explanation: A)
   B)
   C) The lowest energy levels and subshells are filled first, and there can be no more than 2 electrons per state. See section 31–6 in the textbook.
   D)
   E)
21) In the Schrodinger model for the ground state of the hydrogen, what is the most probable location of the electron?
   A) the first Bohr radius $r_1$
   B) the second Bohr radius $r_2$
   C) the nucleus
   D) infinitely far from the nucleus

Answer: A
Explanation: A) See section 31-5 and Figure 31-13 in the textbook. This was also emphasized in class.

22) An amateur astronomer’s reflecting telescope has a mirror with diameter 0.200 m. Assume visible light with wavelength of $5.00 \times 10^{-7}$ m. What is the minimum distance between two points on the Moon’s surface that can be resolved with this telescope? (The Moon is $4.00 \times 10^8$ m from the Earth, and the angle involved is small.)
   A) 430 m
   B) 840 m
   C) 1220 m
   D) 5760 m

Answer: C
Explanation: A) You solved a similar problem on your homework.

\[ \theta_{\text{min}} = 1.22 \frac{\lambda}{D} = 1.22 \frac{5.00 \times 10^{-7} \text{ m}}{0.200 \text{ m}} = 3.05 \times 10^{-6} \text{ radians} \]

\[ y = L \tan \theta_{\text{min}} \text{ or, for small angles,} \]

\[ y = L \theta_{\text{min}} = (4.00 \times 10^8 \text{ m})(3.05 \times 10^{-6} \text{ radians}) = 1220 \text{ m} \]
23) The number of radioactive nuclei in a particular sample decreases to one-eighth of its original number in 21 days. What is the half-life of these nuclei?
   A) 2 days
   B) \(\frac{21}{8}\) days
   C) 7 days
   D) 8 days
   E) 21 days
   Answer: C
   Explanation: A) B) C) After one half-life, the number of nuclei is \((1/2)\) of its original value, so after three half-lives, the number of nuclei is \((1/2)^3 = 1/8\) of its original value. This means 21 days is three half-lives, so the half-life is 7 days.
   D) E)

24) As shown below, Circuit 1 has an AC generator and a light bulb (resistor). Circuit 2 has an identical AC generator and an identical light bulb, and also an inductor L.

In which circuit does the light bulb glow less brightly?
   A) Circuit 1
   B) Circuit 2
   C) equally bright in both circuits
   Answer: B
   Explanation: A) B) This is Conceptual Checkpoint 24–3. See page 800 in the textbook.
   C)
25) Suppose that an electron and a neutron have the same speed (assume they are both free particles, not inside an atom). Compared to the neutron, the electron has
   A) less momentum and a longer wavelength
   B) less momentum and a shorter wavelength
   C) more momentum and a longer wavelength
   D) more momentum and a shorter wavelength
   E) none of the above

Answer: A

Explanation: A) The electron has a much smaller mass than the neutron. Since they have the same speed $v$, the electron's momentum $p = mv$ is much smaller and hence its wavelength $\lambda = \frac{h}{p}$ is longer.

PARTIAL CREDIT: 0.3 point for B or C

26) In the two situations (a) and (b) shown below, the incident light is unpolarized. The angle $\theta$ is nonzero, less than 90 degrees, and is the same for (a) and (b).

How does the intensity of the transmitted light in (a) compare to the intensity of the transmitted light in (b)?
   A) greater than in (b)
   B) smaller than in (b)
   C) the same as in (b)
   D) cannot be determined from the information given
Answer: C
Explanation: A)
B)
C) This is Chapter 25 Conceptual Question 10. In both (a) and (b), the relative angle $\theta$ between the two polarizers is what matters, and this is the same for (a) and (b). In both (a) and (b), the first polarizer halves the intensity, and the next polarizer reduces it further, by a factor of $(\cos \theta)^2$.
D)

27) In a double slit interference experiment, consider the $m=5$ bright fringe. At this location on the screen, the waves from the two slits have a path difference of:
A) 1.2 wavelengths
B) 1.5 wavelengths
C) 2.5 wavelengths
D) 5 wavelengths
E) 10 wavelengths

Answer: D
Explanation: A)
B)
C)
D) The path difference is $d \sin \theta = m\lambda = 5\lambda$
E)
28) An oxygen-15 nucleus, $^{15}_8$O, decays by emitting a positron (e$^+$ particle), a neutrino ($\nu_e$ particle), and one other particle. What is this other particle?

A) $^{15}_6$C

B) $^{15}_7$N

C) $^{17}_7$N

D) $^{16}_8$F

Answer: B

Explanation: A)

B) For $\beta^+$ decay, the atomic number decreases by 1, and the mass number is unchanged.

C)

D)

29) A hypothetical neutral atom has only three energy levels, as shown below.

0  ________________
-2 eV  ________________
-8 eV  ________________

If the atom is originally in the state with energy of -8 eV, what will happen if a photon with energy 5 eV strikes the atom?

A) an electron will be ejected

B) the atom will end up in the state with energy -2 eV

C) the atom will end up in the state with energy 0

D) more than one of the above is possible

E) none of the above is possible (the atom cannot absorb a 5 eV photon)

Answer: E

Explanation: A)

B)

C)

D)

E) A jump from the lowest energy level to the next higher energy requires a photon with 6 eV (the difference between -2 eV and -8 eV) so the atom cannot absorb a 5 eV photon.
30) In an RLC circuit that is driven at its resonance frequency, what characterizes the impedance and the current in the circuit?
   A) impedance is a minimum, current is a maximum
   B) impedance is a minimum, current is a minimum
   C) impedance is a maximum, current is a maximum
   D) impedance is a maximum, current is a minimum

Answer: A
Explanation: A) See section 24-6 and Figure 24-4 in the textbook.
   B) 
   C) 
   D)