Physics 2710 – Exam I Name:
September 29, 2017

Please **circle the letter corresponding to the *best* answer.**

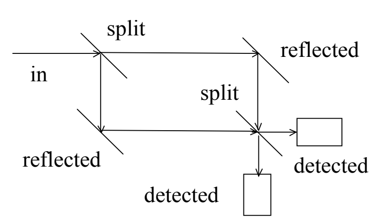
1. In a double slit experiment done with monochromatic (single color) laser light the *wavelength of which is greater than the slit spacing*, there
(a) are no maxima
(b) is exactly one maximum, in the $\theta = 0^\circ$ direction
(c) are two maxima, at $\theta = \pm 10^\circ$
(d) are three maxima, at angles θ that depend on the wavelength

2. A double slit interference pattern produced by monochromatic laser light has 5 bright spots. The largest value of the intensity maxima index n in the expression $d\sin(\theta) = n\lambda$ is
(a) 1
(b) 2
(c) 3
(d) 5

3. The number of photons emitted per second by an FM station with broadcast power of 10^5 W and carrier frequency of 10^8 Hz is closest to
(a) 10^{-5}
(b) 10^5
(c) 10^{10}
(d) 10^{30}

4. The momentum of a photon is
(a) h/λ
(b) hf
(c) $m_{photon}c$
(d) 0

5. When done one photon at a time, the apparatus in the schematic diagram as shown to the right allows one to
(a) determine which path the photon travels over
(b) determine both the photon's particle and wave properties simultaneously
(c) deduce only that a photon has particle properties
(d) deduce only that a photon has wave properties



6. A singly ionized carbon-60 molecule, C_{60}^{+}, and a proton, p^+, both accelerate from rest through an electric potential difference of 100 V. Which *one* of the following is true? They have equal
(a) momenta
(b) masses
(c) kinetic energies
(d) de Broglie wavelengths

Questions 7-8 refer to: The total energy of a free (i.e., no force) massive particle traveling at any speed is $E = \sqrt{(pc)^2 + (mc^2)^2}$.

7. If the particle's speed is $<< c$, E is approximately
(a) $pc + mc^2$
(b) $mc^2 + \frac{(pc)^2}{2}$
(c) $1 + \frac{(pc)^2}{mc^2}$
(d) $mc^2 + \frac{(pc)^2}{2mc^2}$

8. If the particle's speed is close to c , E is approximately
(a) $(pc)^2$
(b) mc^2
(c) $\frac{(pc)^2}{mc^2}$
(d) $pc + \frac{(mc^2)^2}{2pc}$

9. The operator $i\hbar \partial/\partial t$ operating on a quantum wavefunction is used to "measure" which quantity?
(a) energy
(b) energy squared
(c) momentum
(d) momentum squared

10. The expression $\exp(i\theta) = \cos(\theta) + i\sin(\theta)$ is known as
(a) Maxwell's formula
(b) Einstein's formula
(c) Schrödinger's formula
(d) Euler's formula

11. An electron trapped inside a nucleus of diameter equal to 10^{-6} nm would have a kinetic energy on the order of
(a) 10 eV
(b) 1 MeV
(c) 100 MeV
(d) 100 GeV

Questions 12-14 refer to: A photon is trapped in a 1D cavity of length L with perfect reflecting ends. The photon wavelength equals $2L/n$, where n is a positive integer.

12. The average value of the photon energy measured many times starting in the state n is
(a) $(\pi\hbar c/L)\cdot n^2$
(b) $\frac{(\pi\hbar c/L)}{n^2}$
(c) $(\pi\hbar c/L)\cdot n$
(d) 0

13. The standard deviation of the photon energy measured many times starting in the state n is
(a) $(\pi\hbar/L)\cdot n^2$
(b) $\frac{(\pi\hbar/L)}{n^2}$
(c) $(\pi\hbar/L)\cdot n$
(d) 0

14. Suppose the color of a photon in the $n=1$ state is red. How many other different color visible light photon states are allowed in the cavity?
(a) 0
(b) 1
(c) 2
(d) 3

Questions 15-20 refer to: An electron is trapped in a 1D infinite square well between $x=0$ and $x=L=0.2$ nm (where $U=0$). Its wavefunction is $\Psi=\Psi_{max}\sin(n\pi x/L)\exp(-iE_n t/\hbar)$. Assume that Ψ_{max} is a positive real number and the ground state energy is 10 eV.

15. Ψ_{max} is
(a) $5\cdot n$ nm^{-1}
(b) 3.16 nm$^{-1/2}$
(c) $0.2\cdot n$ nm
(d) 1

16. The average value of the electron's position, $\langle x\rangle$, is
(a) 0.1 nm
(b) 0.2 nm$/n$
(c) 0.2 nm
(d) 0

17. If the electron is in the $n=2$ state, the average value of its total energy (kinetic + potential), $\langle E \rangle$, is

(a) 0
(b) 10 eV
(c) 20 eV
(d) 40 eV

18. If the electron is in the $n=2$ state, the average value of its kinetic energy, $\langle p^2c^2 \rangle / 2mc^2$, is

(a) 0
(b) 10 eV
(c) 20 eV
(d) 40 eV

19. If the electron is in the $n=2$ state, the probability of finding it is
(a) zero at $x=0$ and 0.2 nm only
(b) zero at $x=0$, 0.1 nm, and 0.2 nm only
(c) zero at $x=0.1$ nm only
(d) the same at all values of x inside the well

20. The electron, initially in the *second excited state*, somehow undergoes a transition to the ground state by emitting a photon. The photon energy is
(a) 10 eV
(b) 30 eV
(c) 50 eV
(d) 80 eV

21. The wavefunction of a free particle is a plane wave with an exactly known momentum in the x-direction. According to the Heisenberg Uncertainty Principle the uncertainty in the particle's x-position is
(a) about three wavelengths
(b) infinite
(c) hc divided by its kinetic energy
(d) zero

Questions 22-24 refer to: An electron moving along the x-axis experiences a *finite well* potential energy that is zero for $0 < x < 0.5$ nm and $+17$ eV otherwise. There are four bound states within the well with energies (in eV) 1.07, 4.22, 9.26, and 15.47, corresponding to the quantum numbers $n = 1, 2, 3,$ and 4, respectively. The energies (in eV) of the bound states with the same quantum numbers in a 1D *infinite square well* of the same length are 1.50, 6.00, 13.50, and 24.00.

22. Let $P_n = \int_0^{0.5 \text{ nm}} |\Psi_n|^2 dx$ be the probability of finding the electron *inside* the well if it is in the state n. Which *one* of the following is true?
(a) $P_1 > P_2 > P_3 > P_4$
(b) $P_4 > P_3 > P_2 > P_1$
(c) $P_1 = P_2 = P_3 = P_4 = 1$
(d) $P_1 = P_2 = P_3 = P_4 = 0$

23. A transition between 2 bound states ($n_{initial} \rightarrow n_{final}$) is associated with a photon carrying energy equal to 3.15 eV. Which *one* of the following is possible?
(a) $1 \rightarrow 2$
(b) $3 \rightarrow 2$
(c) $2 \rightarrow 4$
(d) $4 \rightarrow 1$

24. An electron in a plane wave state traveling from $x < 0$ to $x > 0$ will pass through the well with *no reflection* if its total energy (kinetic + potential) equals
(a) 1.50 eV
(b) 6.00 eV
(c) 13.50 eV
(d) 24.00 eV

25. An electron in a plane wave state, with initial kinetic energy equal to E_0, traveling from $x < 0$ to $x > 0$ encounters a potential energy that is $U_0 > 0$ for $0 < x < L$ and zero otherwise. If $E_0 < U_0$ the probability of finding the electron at $x > L$ is T. Which *one* of the following is true?
(a) $T = 0$
(b) $T = 1$ and the electron's kinetic energy is less than E_0
(c) $T < 1$ and the electron's kinetic energy is less than E_0
(d) $T < 1$ and the electron's kinetic energy is equal to E_0