Physics 107: Ideas of Modern Physics

Exam 3
Apr. 19, 2006

Name______________________________________________________

ID #_________________________               Section #______________

On the Scantron sheet,
1) Fill in your name
2) Fill in your student ID # (not your social security #)
3) Fill in your section # (under ABC of special codes)

Fundamental constants:

\[ c = \text{speed of light} = 3 \times 10^8 \text{ m/s} \]
\[ g = \text{accel. of gravity on Earth} = 10 \text{ m/s}^2 \]
\[ G = \text{gravitational constant} = 6.7 \times 10^{-11} \text{ Nm}^2/\text{kg}^2 \]

Photon energy \( E = \frac{hc}{\lambda} = 1240 \text{ eV-nm}/\lambda \)
1. A

2. Experiments have shown that a dark-adapted eye can detect a 0.001 sec duration flash of green light at a power level of only \(4 \times 10^{-14}\) Watts. A green photon has 2.5 eV of energy (1 eV = \(1.6 \times 10^{-19}\) Joules). How many photons is this?
   
a. 40,000  
b. 4,000  
c. 10,000  
d. 100  
e. 10

3. A scientist is trying to eject electrons from a metal by shining a light on it. The electrons are bound inside the metal by an energy of 4.2 eV. Which wavelength will eject electrons?
   
a. 640 nm  
b. 420 nm  
c. 350 nm  
d. any of these  
e. none of these

4. A beta particle, gamma ray, and alpha particle all have the same momentum. Which has the longest wavelength?
   
a. beta particle.  
b. gamma ray.  
c. alpha particle.  
d. all the same.  
e. depends on gamma ray energy.

5. Particular red (600 nm) and blue (300 nm) lasers both shoot out the same number of photons per second. How does the power output of the two lasers compare?
   
a. Both the same.  
b. Blue has 1/4 the power as red.  
c. Blue has 1/2 the power as red.  
d. Blue has 2 times the power as red.  
e. Blue has 4 times the power as red
6. A quantum particle in a box is in the lowest energy (ground) state. If the size of the box is increased, the wavelength and energy of the particle change as

a. wavelength shorter, energy larger
b. wavelength longer, energy smaller
c. wavelength shorter, energy smaller
d. wavelength longer, energy larger
e. wavelength and energy unchanged

7. A typical x-ray photon used in a dentist’s office to produce an x-ray of your teeth has an energy of 10,000 eV. Its wavelength is about

a. 0.1 nm  
b. 1 nm  
c. 10 nm  
d. 100 nm  
e. 1000 nm

8. A hydrogen atom has quantum states with energies $-13.6eV/n$. Which of the following transitions emits the shortest wavelength photon?

a. $n=2$ to $n=1$  
b. $n=3$ to $n=2$  
c. $n=3$ to $n=1$  
d. $n=4$ to $n=3$  
e. all emit the same wavelength photon

9. A particular quantum system has quantum states with energies $E_{(n=1)}=1$ eV, $E_{(n=2)}=4$ eV, $E_{(n=3)}=9$, $E_{(n=4)}=16$ eV, ... This is NOT a hydrogen atom. Calculate the wavelength of a photon emitted as a result of the $n=3$ to $n=2$ transition.

a. 140 nm  
b. 410 nm  
c. 250 nm  
d. 1240 nm  
e. 620 nm
10. The energy levels of a hydrogen atom are given by $E = -\frac{13.6}{n^2}$ eV. Calculate the wavelength of a photon emitted as a result of the $n=4$ to $n=3$ transition.

a. 2700 nm  
b. 1875 nm  
c. 360 nm  
d. 820 nm  
e. 650 nm

11. An electron is confined to a box of length $L$. It is in an excited state. The momentum of the particle is uncertain because

a. the particle is not in the quantum ground state.  
b. the concept of momentum is not well-defined.  
c. the particle is moving in two different directions.  
d. the particle has an electrostatic charge.  
e. the particle could quantum-mechanically tunnel out of the box.

12. Here is the first excited state wavefunction for a particle in a box. Compare the probabilities ($P$) of finding the particle at the indicated locations.

a. $P(0.25 \text{ nm})=P(0.75 \text{ nm})$  
b. $P(0.25 \text{ nm})<P(0.75 \text{ nm})$  
c. $P(0.25 \text{ nm})>P(0.75 \text{ nm})$  
d. the probabilities are uncertain  
e. need to know mass of particle

13. The force binding together neutrons and protons in the nucleus is

a. the Coulomb force  
b. the gravitational force  
c. the strong force  
d. the weak force  
e. none of the above
14. Neutral hydrogen has one electron orbiting around it’s nucleus. Which of the following is NOT the nucleus of an isotope of hydrogen?

a. One proton.
b. One proton, one neutron
c. One proton, two neutrons
d. Two protons, two neutrons
e. All of them are isotopes of hydrogen

15. $^8$C is an extremely unstable isotope of carbon. It has 6 protons and 2 neutrons in its nucleus. It decays by emitting a positron (anti-particle of electron). After the decay, it becomes

a. $^7$C
b. $^9$C
c. $^8$B
d. $^8$N
e. $^7$B

16. A fossil bone has a $^{14}$C : $^{12}$C ratio that is 1/4 of the $^{14}$C : $^{12}$C ratio in the bone of a living animal. What is the approximate age of the fossil? ($^{14}$C half-life is 5,730 years).

a. 11,460 years
b. 17,190 years
c. 22,920 years
d. 45,840 years
e. 91,680 years

17. $^{241}$Am is used in smoke detectors to ionize gas atoms with alpha particles it emits from its nucleus. In the $^{241}$Am nucleus, there are 95 protons and 241 total nucleons. After the alpha emission, $^{241}$Am becomes

a. $^{239}$Np
b. $^{237}$Np
c. $^{239}$Pa
d. $^{237}$Pa
e. $^{237}$U
18. A particular radioactive nucleus has 60 neutrons and 50 protons in the nucleus. The particle it emits when it decays is likely to be
   a. a neutron  
   b. a proton  
   c. an electron  
   d. an alpha particle  
   e. a gamma particle

19. The Pauli exclusion principle says that
   a. no two particles are exactly identical  
   b. fermions are excluded from the quantum ground state  
   c. electrons are fermions  
   d. no two fermions can be in the same quantum state  
   e. all bosons have spin

20. In a hypothetical nuclear fission event, the original nucleus (binding energy 6 MeV/nucleon) has 200 nucleons, and splits into two nuclei, each with 100 nucleons (binding energy 6.2 MeV/nucleon). The TOTAL energy released in the fission of ONE nucleus is
   a. 40 MeV  
   b. 20 MeV  
   c. 0.4 MeV  
   d. 620 MeV  
   e. 0.2 MeV

21. A pure semiconductor is an insulator, but becomes useful electrically when
   a. it is cooled to low temperature  
   b. not too large a magnetic field is applied  
   c. some of its atoms are replaced with different atoms  
   d. quantum states are created in it  
   e. it is patterned to very small (nanometer) sizes