Sample Final Exam for Physics 130-3

1) A muon is an unstable particle that has a half-life of 1.52×10^{-6} s. An alien spaceship with an odd muon propulsion system is passing the Earth at 0.5 *c* while firing a muon beam out the back of the spaceship at a speed of 0.9 *c* (relative to the spaceship). What is the half-life of the muons from your point of view on Earth?

2) A satellite, initially at rest in deep space, explodes into two pieces. Piece A has a rest mass of 190 kg and moves away at a speed of 0.28 *c*, while piece B moves in the exact opposite direction at a speed of 0.6 *c*.
a) What is the momentum of piece A?
b) What is the rest mass of piece B?

3) Carbon-14 has a half-life of 5730 years. A wooden totem unearthed by an archaeologist is sent to a laboratory, where it is determined that the activity of the totem is 0.144 μCi / g. The archaeologist knows that the activity of living trees that are growing near his dig site is 0.230 μCi / g. About how old is the totem?

4) Free neutrons do not exist in nature, which is a good thing. If they did, they could easily drift up to protons and fuse with them, since there is no electrostatic repulsion. Suppose I had 6×10^{26} protons in one jar (this is about a kilogram) and 6×10^{26} free neutrons in another jar. How much energy would be released if I mixed the contents of the jars together and created deuterium gas?

5) You are observing distant galaxies with the Hubble Space Telescope when you see the green color of a spectral line of the rare element Hypotheticalium. Your measurements reveal that this spectral line has a wavelength of 520 nm, with an error of ± 1 nm. Since your instruments are perfect, you know this means the error is due *solely* to basic quantum mechanics. Use this information to estimate how long excited electrons remain in that quantum level of Hypotheticalium before decaying.

6) If I accelerate an electron through a potential of 3000 volts, by what percentage does its mass increase?

7) Rachel leaves Earth in a spaceship at a speed of 0.96 *c* relative to an observer on Earth. Rachel's destination is a star system 14.4 light-years away from Earth. According to Rachel, how long does the trip take?

8) If the surface temperature of a star is 6000 K, at what wavelength does the star radiate the bulk of its energy?

9) The de Broglie wavelength of an electron is 380 nm. What is the speed of this electron?

10) A certain crystal has an interatomic spacing of 0.442 nm. A beam of neutrons moving with a speed of 1640 m/s is diffracted from the crystal. What is the de Broglie wavelength of the neutrons?

11) How many values of the magnetic quantum number are possible for an electron if it is in an $l = 8$ state?

12) The wavelength of a beam of light passing through a liquid is 360 nm, but it changes to 469 nm when the beam of light leaves the liquid and enters a vacuum. What is the index of refraction of the liquid?

13) An electron and an anti-electron (positron) run into each other and instantly annihilate, releasing two identical photons. What are the wavelengths of the photons?

14) In a hydrogen atom, the electron makes a transition from the $n = 8$ to the $n = 3$ state. What is the wavelength of the emitted photon?

15) Radium-226 decays into radon-222 by α-decay. What is the kinetic energy of the alpha particle?

Multiple Choice

16) Commander Data is on the planet Techno when he observes a standard 440-Hz tuning fork streaking past at incredible speed. (440 Hz is the frequency stamped on the tuning fork.) However, with his remarkably acute vision, he notices that the tuning fork is actually vibrating at 220 Hz, not 440 Hz. From Commander Data's point of view, the ***mass*** of the tuning fork is:
A) one-half of what it would be if the fork was stationary relative to Data
B) twice what it would be if the fork was stationary relative to Data
C) unchanged
D) square root of two (1.414) times what it would be if the fork was stationary relative to Data
E) one over square root of two (0.707) of what it would be if the fork was stationary relative to Data
F) there is not enough information provided for you to tell

17) When I turn on my computer monitor, and the screen lights up, the mass of the monitor:
A) oscillates at 60 Hz
B) depends on what software I am using
C) decreases
D) stays the same
E) increases
F) is partly converted to electricity

18) I am shining light of a single wavelength on the surface of a metal, but no photoelectrons are being emitted. To rectify this problem, I should:
A) use light of a longer wavelength
B) use light of a shorter wavelength
C) use the same light but increase the intensity
D) use the same light but decrease its intensity
E) use a laser with the same wavelength
F) heat the metal

19) Which of the following is true for the photons in a laser beam?
A) They have the same frequency
B) They have a short half-life
C) They can only be red or green
D) They are moving in the same direction
E) A and D
F) A, B, and C
G) B and C
H) C and D

20) β-decay occurs in an unstable nucleus when:
A) a proton is converted to an electron by the strong force
B) a proton is converted to a neutron by the strong force
C) a neutron is converted to a proton by the weak force
D) a neutron is converted to an alpha particle by the weak force
E) a neutron is converted to a beta particle by the weak force
F) an alpha particle escapes from the nucleus

21) $^{235}U_{92}$ is radioactive and decays to $^{227}Th_{90}$, but not with one reaction. It decays using a series of reactions. In this series, the particles ejected must consist of:
A) one α-particle and three β-particles
B) three α-particles and one β-particle
C) one α-particle and four β-particles
D) four α-particles and one β-particle
E) two α-particles and two β-particles
F) one α-particle and two β-particles

22) In a double-slit interference experiment, you use light of different wavelengths to determine the separation between adjacent maxima. You observe that the separation is greatest when you use light that is:
A) red B) orange C) yellow D) green E) blue F) indigo G) violet
H) The separation is the same for all wavelengths.

23) Which of the following nuclear reactions is impossible? (e = electron, n = neutron)
A) $n + {}^{235}U_{92} \rightarrow {}^{90}Sr_{38} + {}^{136}Xe_{54} + 10n$
B) $^{238}U_{92} + n \rightarrow {}^{239}Pu_{94} + 2e + 2$ anti-neutrinos
C) $^{228}Th_{90} \rightarrow {}^{228}Ac_{89} + e +$ anti-neutrino
D) three $^{4}He_{2} \rightarrow {}^{12}C_{6}$
E) $^{16}O_{8} + {}^{4}He_{2} \rightarrow {}^{20}Ne_{10}$
F) $^{3}H_{1} \rightarrow {}^{3}He_{2} + e +$ anti-neutrino