Exam 2 (November 23, 2009)

Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary.

Problem 1 (4 pts, no need to show work):

Higher energy photons have (relative to lower energy photons)

a) longer wavelengths.
b) greater speed.
c) higher frequency.
d) all of the above.
e) none of the above.

Problem 2 (4 pts, no need to show work):

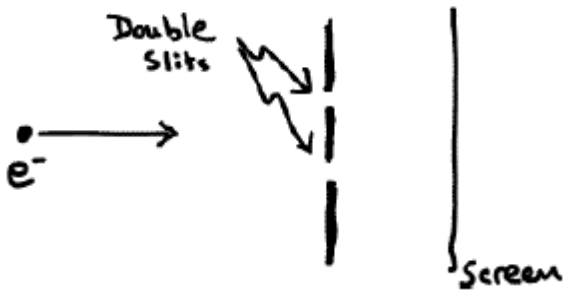
In the Standard Model of particle physics there are how many distinct types of quarks?

a) 2
b) 4
c) 6
d) Just over 100
e) There are no quarks in the Standard Model.

Problem 3 (4 pts, no need to show work):

In a double-slit experiment with an electron beam, quantum mechanics enables scientists to predict

f) which slit the electron will come through.
g) the place at which each electron will hit on the screen.
h) the precise position and velocity of each electron.
i) the pattern that a single electron will produce when it hits the screen.
j) the overall pattern made by a large number of electron impacts on the screen.



Scores
1. ___/4
2. ___/4
3. ___/4
4. ___/4
5. ___/4
6. ___/4
7. ___/4
8. ___/4
9. ___/4
10. ___/4
11. ___/30
12. ___/10
13. ___/10
14. ___/10

Total ___/100

Problem 4 (4 pts, no need to show work):

Roughly how many chemical compounds exist in nature?

a) 6
b) 25
c) Just over 100
d) Just over 500
e) A very large number, much greater than 500

Problem 5 (4 pts, no need to show work):

An atom has four distinct energy levels that can be occupied by an electron. The number of spectral lines produced by this atom is

a) 3
b) 4
c) 6
d) 10
e) Many more than 10

Problem 6 (4 pts, no need to show work):

In what way or ways do ^{3}H and ^{3}He differ?

a) They have different numbers of protons.
b) They have different number so neutrons.
c) Both of the above.
d) They have different atomic mass numbers.
e) The numbers of protons, neutrons and atomic mass all differ.

Problem 7 (4 pts, no need to show work):

$_{92}{}^{238}U$ alpha decays producing which daughter nucleus

a) $_{92}{}^{234}U$
b) $_{93}{}^{238}Np$
c) $_{90}{}^{236}Th$
d) $_{90}{}^{234}U$
e) $_{90}{}^{234}Th$

Problem 8 (4 pts, no need to show work):

What is the source of the energy for the creation of the heavy elements (heavier than iron)?

a) hydrogen fusion
b) fission
c) gravitational collapse
d) helium fusion
e) the shock of a supernova explosion

Problem 9 (4 pts, no need to show work):

To an astronomer, a white dwarf is

a) The end stage in the life cycle of a star with a mass between 0.8 and 1.4 solar masses where fusion has largely ceased and the star is held up by bare nuclei and electrons.
b) A term for a 'star' with a mass less than 0.8 solar masses where fusion reactions never began in earnest.
c) The name of Snow White's love child.
d) The end stage in the life cycle of a star with a mass between 1.4 and 2.5 solar masses where fusion has largely ceased and the star is held up by a core of neutrons.
e) The end stage in the life cycle of a large star where fusion has largely ceased and the star collapses to such a degree that even light cannot escape.

Problem 10 (4 pts, no need to show work):

A physicist cannot predict the exact time that a single ^{14}C nucleus will decay because

a) of the fact that we do not yet have powerful enough computers.
b) of fundamental uncertainties associated with quantum mechanics.
c) it is too difficult to determine the precise initial state of the protons and neutrons inside a nucleus.
d) it depends on the exact origin of the nucleus, which is generally unknown.
e) of the fact that the protons and neutrons exhibit quantum entanglement.

Problem 11 (30 pts, true or false, each part is worth 2 points):

a) _____ Baryons are a bound state of three leptons.
b) _____ The Higgs particle has yet to be discovered.
c) _____ Quarks are the virtual particles that convey the strong force in quantum field theory.
d) _____ The force of gravity is by far and away the weakest force yet observed in nature.
e) _____ Due to their large electric charge, alpha particles are the most dangerous form of natural radiation from sources outside one's body.
f) _____ The W and Z particles have zero mass.
g) _____ A particle formed from a quark and an anti-quark is known as a meson.
h) _____ Nuclear fusion is the power source for stars.
i) _____ The process of small nuclei joining to form larger nuclei is known as fission.
j) _____ In the Standard Model, photons are the virtual particles that hold electrons in atoms.
k) _____ Neutrinos only interact with other particles via the weak nuclear force.
l) _____ The heaviest element likely to be found at the center of a massive stars is nitrogen.
m) _____ Clocks on the moon move at a slightly slower rate than clocks at the surface of the earth.
n) _____ Benzene (C_6H_6) is a chemical compound consisting of 12 atoms.
o) _____ ${}_{93}{}^{238}\mathrm{Np}$ is a nucleus that has 93 protons and 238 neutrons.

Problem 12 (10 pts):

Suppose that you measure the frequency of carbon-14 decays in an old scroll said to contain a description of a story similar to one in the Bible. You find that the frequency of decays are roughly 6% of that measured in a freshly cut piece of wood. Is this document likely to have come from biblical times? Why or why not? *(Potentially useful information: the decay constant for carbon-14 is 1.4×10^{-4} year^{-1} and the half-life of carbon-14 is 5730 years.)*

Problem 13 (10 pts):

Phosphors (a type of chemical) on the inside of fluorescent lamps convert ultraviolet light to visible light. Briefly explain how this might work and why are there no substances that convert visible light to ultraviolet light. (Take the average wavelength of visible light to be 10^{-7} meters and that for ultraviolet light to be 10^{-8} meters.)

Problem 10 (10 pts):

What is meant by the 'enrichment' of uranium and why is this technical process important to society?

hydrogen 1 H 1.0079																	helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122											boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305											aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 **	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]		ununquadium 114 Uuq [289]				

*Lanthanide series	lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
**Actinide series	actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

Some potentially useful formulas

$F = \frac{G m_1 m_2}{r^2}$ [m_1 and m_2 in kg, r in meters, F in Newtons] $\rightarrow G = 6.7 \times 10^{-11}$

$F = \frac{k q_1 q_2}{r^2}$ [q_1, q_2 in Coulombs, r in meters, F in Newtons] $\rightarrow k = 9 \times 10^9$

$F = ma$

(distance) = (speed)(time)

1 Joule $= 1.6 \times 10^{-19}$ eV

speed of sound = 330 M/s

$c = 3 \times 10^8$ M/s

$h = 6.6 \times 10^{-34}$ J·s
or
4.5×10^{-15} eV·s

$v = \frac{\Delta x}{\Delta t}$

$a = \frac{\Delta v}{\Delta t}$

work = force × distance

Momentum = $p = mv$

$\lambda = \frac{h}{p} = \frac{h}{mv}$

$v = \lambda \nu$

$\nu = \frac{1}{T}$ (T = period)

$E = h\nu$

$\Delta x' = \gamma \Delta x$, Δx longest in proper frame

$\Delta t' = \gamma \Delta t$, Δt shortest in proper frame

$\gamma = \frac{1}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$

$\Delta x \Delta p \geq h/2\pi$ $\Delta E \Delta t \geq h/2\pi$

$\frac{\Delta N}{\Delta t} = \lambda N$ $t_{1/2} = 0.693/\lambda$