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.
4 – c) higher frequency.
d) all of the above.
e) none of the above.

$E = h\nu$

$c = \nu\lambda$

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

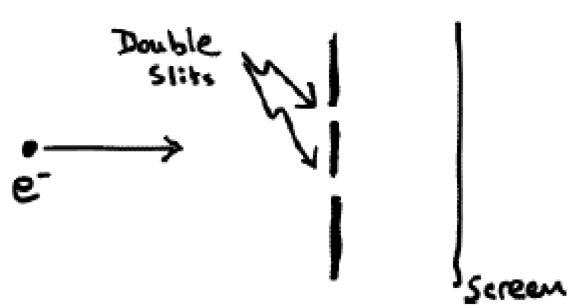
In the Standard Model of particle physics there are how many distinct types of quarks?

a) 2
b) 4
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.
4 – 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):

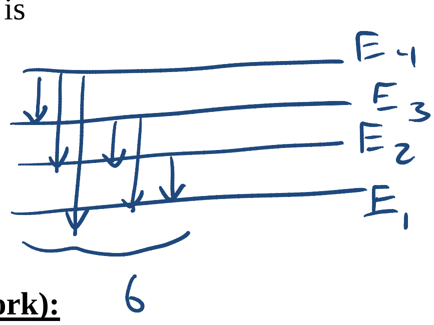
Roughly how many chemical compounds exist in nature?

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

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

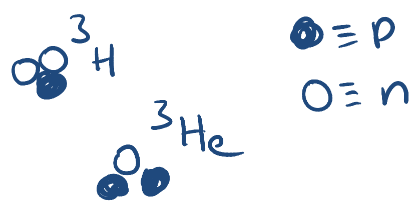
An atom has four distinct energy levels that can be occupied by an electron. The number of spectral lines produced by this atom is

a) 3
b) 4
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?



2 — a) They have different numbers of protons.
2 — b) They have different number so neutrons.
4 — 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) $_{90}^{236}Th$
2 — d) $_{90}^{234}U$
4 — e) $_{90}^{234}Th$

$$_{92}^{238}U \rightarrow \underbrace{_{2}^{4}He}_{\text{this is an } \alpha} + _{90}^{234}Th$$

Know it is NOT $_{90}^{234}U$ because # protons changes or look at periodic chart

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)?

1 a) hydrogen fusion
b) fission
4 c) gravitational collapse
1 d) helium fusion
4 **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.

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

a) F Baryons are a bound state of three leptons.
b) T The Higgs particle has yet to be discovered.
c) F Quarks are the virtual particles that convey the strong force in quantum field theory.
d) T The force of gravity is by far and away the weakest force yet observed in nature.
e) F Due to their large electric charge, alpha particles are the most dangerous form of natural radiation from sources outside one's body.
f) F The W and Z particles have zero mass.
g) T A particle formed from a quark and an anti-quark is known as a meson.
h) T Nuclear fusion is the power source for stars.
i) F The process of small nuclei joining to form larger nuclei is known as fission.
j) T In the Standard Model, photons are the virtual particles that hold electrons in atoms.
k) T Neutrinos only interact with other particles via the weak nuclear force.
l) F The heaviest element likely to be found at the center of a massive stars is nitrogen.
m) F Clocks on the moon move at a slightly slower rate than clocks at the surface of the earth.
n) T Benzene (C_6H_6) is a chemical compound consisting of 12 atoms.
o) F $_{93}^{238}Np$ is a nucleus that has 93 protons and 238 neutrons.

Problem 12 (10 pts):

"Biblical" times refers to the period around 2000 years ago surrounding the time that Jesus purportedly lived. If student assumes "Biblical Times" means "very old" We will accept Answer if consistent with that.

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.)*

Living things ingest a (roughly) constant amount of naturally radioactive carbon-14 while they are alive. Upon death the carbon-14 slowly decays away.

The material used in the scroll is from an object that lived approximately

1	2	3	4
50%	25%	12%	6%

4 carbon-14 half-lives ago or (4)5730 years ago — It is very unlikely

~23,000

that the artifact comes from biblical times.

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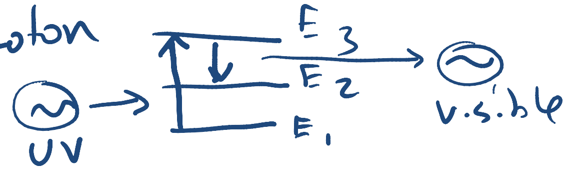
Problem 13 (10 pts):

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.)

(UV)
ultraviolet photons are more energetic than visible light photons. an atom (or chemical) can absorb a UV photon and then emit a visible photon



. If an atom absorbs a visible light photon, it still does not have enough energy to emit a UV photon

Problem 10 (10 pts):

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

Naturally occurring uranium is a mix of two isotopes, ^{235}U and ^{238}U, with the vast majority of the atoms being ^{238}U. This is important because, of the two isotopes, only ^{235}U can sustain a chain reaction — which is required for it to be useful as a fuel for a nuclear reactor or a nuclear bomb. "Enrichment" refers to any process that enriches the fraction of ^{235}U relative to ^{238}U in a sample of uranium. It is a difficult thing to do since ^{235}U and ^{238}U are chemically identical. It takes a certain degree of enrichment to make a sample of uranium useful as a fuel for a nuclear reactor and a greater amount of enrichment to be used in a nuclear bomb. The chain reaction is made possible because ^{235}U emits two neutrons when it fissions and each of these neutrons can cause a ^{235}U atom to fission.

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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)

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

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

work = force × distance

Momentum = $p = mv$

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

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

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

1 Joule = 1.6×10^{-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

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

$v = \lambda \nu$

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

$E = h\nu$

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

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