Solutions for class #2 from Yosumism website

Problem 2:

Atomic$\Rightarrow$}Bragg Diffraction

Recall the Bragg Diffraction dispersion relation,

$\lambda = 2d\sin\theta$,

thus the maximal wavelength λwould be $2d$, choice (D). (One can derive that even if one does not remember the formula. Consider two lattice planes. View them from the side so that they appear as two parallel lines. A wave would hit the both planes at, say, an angle $\theta$from the normal. The wave that reflects off the bottom lattice will have to travel an extra distance, relative to the wave hitting the top plane, equal to $2d\sin\theta$.)

YOUR NOTES:

Problem 3:

Quantum Mechanics$\Rightarrow$}Bohr Theory

Recall the Bohr Equation, $E_n = Z^2/n^2 E_1$, which applies to both the Hydrogen atom and hydrogen-like atoms. One can find the characteristic X-rays from that equation (since energy is related to wavelength and frequency of the X-ray by $E = \lambda f$).

The ratio of energies is thus $E(Z=6)/E(Z=12) = 6^2/12^2 = 1/4$, as in choice (A).

YOUR NOTES:

Problem 14:

Statistical Mechanics$\Rightarrow$}Blackbody Radiation Formula

Recall

$P = ut \propto T^4$,

where P is the power and u the energy and T the temperature.

So, initially, the blackbody radiation emits $P_1 = kT^4$. When its temperature is doubled, it emits $P_2 = k(2T)^4 = 16kT^4$.

Recall that water heats according to $Q = mc\Delta T = \kappa \Delta T$. So, initially, the heat gain in the water is $Q_1 = \kappa(0.5^\circ)$. Finally, $Q_2 = \kappa x$, where x is the unknown change in temperature.

Conservation of energy in each step requires that $kT^4 t = \kappa/2$ and $16kT^4 t = \kappa x$, i.e., that $P_i t = Q_i$. Divide the two to get $\frac{1}{16} = \frac{2}{x} \Rightarrow x = \Delta T = 8^\circ$. Assuming the experiment is repeated from the same initial temperature, this would bring the initial 20° to 28°, as in choice (C).

YOUR NOTES:

Problem 23:

Statistical Mechanics$\Rightarrow$}Fermi Temperature

(Much of the stuff I classified as Stat Mech might also be considered Condensed Matter or Solid State Physics. They are classified as thus because the Stat Mech book I mentioned in the booklist on the site *http://grephysics.yosunism.com* is perhaps the best intro to all this.)

The Fermi velocity is related by $\epsilon_F = kT_F = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2kT_F}{m}}$, where $\epsilon_F$is the fermi energy, and $T_F$is the Fermi temperature.

One should know by heart the following quantities, $k = 1.381E-23$and $m = 9.11E-31$ (but then again, they are also given in the table of constants included with the exam). Plug these numbers into the expression above to find v,

the choice that comes closest to this order is choice (E).

Note that the hardest part of this problem is the approximation bit. No calculators allowed. Sadness.

YOUR NOTES:

Problem 24:

Atomic⇒}Bonding

Solid Argon is a Nobel gas. It has a full shell of outer electrons, and thus it cannot bond in anything but van der Walls bonding, which isn't really bonding, but more weak like charge-attraction.

One can arrive at this choice by elimination:
(A) Ionic bonding occurs when one atom is a positive ion and the other the compensating negative ion. Since solid Argon isn't an ion, it can't do this.

(B) Covalent bonding occurs when electrons are shared between atoms. This only happens when the atom has unfilled orbitals. (Incidentally, it only occurs when two electrons are of opposite spins due to the Pauli Exclusion Principle. That is, they must have different quantum numbers so that they can both remain stable in a low energy state.)

(C) No partial charge-analysis needed.

(D) Argon isn't a metal.

(E) This is the one that remains.

YOUR NOTES:

Problem 25:

Advanced Topics⇒}Particle Physics

Choice (A) and (C) involve atoms, which are quite massive. Choice (B) involves protons, which are also pretty massive. Massiveness eliminates three choices, leaving just (D) and (E).

Neutrinos are massless, but muons aren't. Both positrons and electrons have the same mass. Massiveness has lost its charm. (No pun intended.)

According to David Schaich, the Super-Kamiokande
and the Antarctic Muon and Neutrino Detector Array (AMANDA) are both located deep down underground to avoid interaction with other particles. Thus, with the hindsight of this bit of trivia, choice (D) is correct.

YOUR NOTES:

Problem 26:

Lab Methods⇒}Log-Log graph

Since initially, the counts per minute is $6E3$, the half-count amount would be $3E3$. This occurs between 5 and 10 minutes. Choice (B) seems a good interpolation.

YOUR NOTES:

Problem 30:

Quantum Mechanics ⇒ }Bohr Theory

The ground state binding energy of positronium is half of that of Hydrogen. This is so because the energy is proportional to the reduced mass, and that of the positronium has a reduced mass of half that of Hydrogen.

Thus, from the Bohr formula, one has $E=Z^2E_1/n^2$, where $E_1=E_0/2$ and E_0 is the ground state energy of Hydrogen. (The ground state energy of positronium is half that of Hydrogen because its reduced mass is half that of Hydrogen's.)

Since $Z=1$, then for $n=2$, the energy is $E=E_0/8$, as in choice (E).

YOUR NOTES:

Problem 31:

Atomic⇒ }Spectroscopic Notations. Spectroscopic notation is given by $^{2s+1}L_j$, and it's actually quite useful when one is dealing with multiple particles. $L\in(S,P,D,F)$, respectively, for orbital angular momentum values of $0,1,2,3$. $s=1/2$ for electrons. j is the total angular momentum.

Knowing the convention, one can plug in numbers to solve $3=2s+1\Rightarrow s=1$. Since the main-script is a S, $l=0$. The total angular momentum is $j=s+l=1$.

YOUR NOTES:

Problem 37:

Special Relativity $\Rightarrow$}Maximal Velocity

The maximal velocity of any object, even light itself, is the speed of light. Moreover, light always travels at light speed (c). This is true in all frames, and in fact, it is one of the two postulates of Special Relativity (the other being the equivalence of inertia frames).

There's no need to chunk out the addition of velocity formula for this. The only possibilities are choices (A) and (D). Since $\gamma_2$is emitted backwards, according to the coordinate system in the diagram, its velocity would be $-c\hat{k}$, as in choice (A).

YOUR NOTES:

Problem 38:

Special Relativity $\Rightarrow$}Time Dilation Formula

The time dilation formula is given by $t=\gamma t_0=\frac{\Delta t_0}{\sqrt{1-\beta_{ij}^2}}$, where time is dilated (lengthened) in all but the frame at rest (proper-time t_0). Note that $\beta_{ij}=v_{ij}/c$.

So, from that alone, one can deduce the following relations (without looking at the choices yet):

$$\Delta t_2=\frac{\Delta t_1}{\sqrt{1-\beta_{12}^2}}$$

$$\Delta t_3=\frac{\Delta t_1}{\sqrt{1-\beta_{13}^2}}$$

The latter deduction is just choice (B).

YOUR NOTES: