

## Solutions from Yosunism website

Yosunism website: <http://grephysics.yosunism.com>

### Problem 41:

Atomic  $\Rightarrow$  } Spectroscopic Notations

Recall the selection rules  $\Delta m = 0, \pm 1$  and  $\Delta l = \pm 1$  for the electric dipole approximation in time-dependent perturbation theory.

- (A) This is allowed since  $\Delta l = -1$  and  $\Delta m = 1$
- (B) This is *not* allowed since  $\Delta l = 0$ , which goes against the condition that  $\Delta l = \pm 1$ .
- (C)  $l = 1$  for p orbitals. Recall  $(s, p, d, f) = (0, 1, 2, 3)$
- (D) An electron has  $s = 1/2$ , thus one can't have  $j = l$  or  $s = 3/2$ .
- (E) One does not know this for sure. Choice (A) is the best choice.

YOUR NOTES:

### Problem 42:

Quantum Mechanics  $\Rightarrow$  } Photoelectric Effect

Recall the photoelectric equation relating the incident electromagnetic wave to the kinetic energy and the work function

$hc/\lambda = K + \phi$  approx  $12\text{E} - 7/500\text{E} - 9 = K + 2.28 \Rightarrow K = 12\text{E} - 7/5\text{E} - 7 - 2.28 \approx 0.20\text{eV}$ , as in choice (B).

YOUR NOTES:

### Problem 48:

Special Relativity  $\Rightarrow$  } Half Life

The halflife of the mesons is given. Since only half of the mesons reach point B 15 meters away, one presumes that it takes 1 halflife of proper time to get there.

The proper time is  $t_0 = 2.5 \times 10^{-8}$ . The length  $L = 15 = vt$  is in the lab frame, and since the time dilation equation gives  $t = \gamma t_0$ , one has  $L = vt = v\gamma t_0 = vt_0 / \sqrt{1 - (v/c)^2} \Rightarrow L/t_0 = \frac{v}{\sqrt{1 - (v/c)^2}}$ .

Now, the gory arithmetics. No calculators allowed; 12 years of American public school mathematics wasted!  $\frac{15}{2.5 \times 10^{-8}} = \frac{15}{2.5 \times 10^{-8}} = 6 \times 10^8 = \frac{v}{\sqrt{1 - (v/c)^2}} = \frac{vc}{\sqrt{c^2 - v^2}}$ . Multiply things out to get  $\frac{6^2(c^2 - v^2)}{c^2} = \frac{v^2}{c^2} \Rightarrow 6^2 c^2 = v^2(c^2 + c^2)$ . Plug in numbers to get  $v = \frac{6^2 c^2}{\sqrt{6^2 c^2 + c^2}} = \frac{36 c^2}{\sqrt{37} c} = \frac{36}{\sqrt{37}} c$ , which is choice (C). Whew!

**YOUR NOTES:**

### Problem 50:

Special Relativity  $\Rightarrow$  } Spacetime Interval

The spacetime interval is defined by the metric that negates spatial and time variables as  $dS^2 = (cdt)^2 - (dx)^2$ .  $dS$  is invariant. One has thus  $dS^2 = dS'^2 \Rightarrow (3c)^2 = (5c)^2 - (x)^2 \Rightarrow ct = 4c$  minutes, as in choice (C).

**YOUR NOTES:**

### Problem 53:

Advanced Topics  $\Rightarrow$  } Particle Physics

One can ignore baryon numbers and lepton numbers and all that and just deal with spin conservation. For the positronium-electron spin singlet state, one has, initially,  $s_i = 0$ . The decay *must* conserve spin. Thus, one must have the final spin as  $s_f = 0$ . Since a photon is its own antiparticle (and antiparticles have the negation of the usual particle's quantum number), the photon has spin  $s_p = 1$  and the antiphoton (just another photon) has spin  $s_{\bar{p}} = -1$ . Thus, two photons are emitted to conserve spin.

(Wheee... can one get more ad hoc than the Standard Model?)

YOUR NOTES:

### Problem 63:

Advanced Topics  $\Rightarrow$  } Particle Physics

If one knows little about particle physics, one can make (at least) the following deductions, wherein one recalls the composites of each particle:

- (A) A muon is a lepton. Leptons, along with quarks, are considered the fundamental particles.
- (B) Pi-Meson consists of a quark and its antiparticle. (Contribution to this part of the solution is due to user danty.) Moreover, a pi-meson is a hadron. Hadrons interact with the strong-force, and all of them are composed of combinations of quarks. (The fundamental particles are classified as quarks and leptons.)
- (C) A neutron is made up of 3 quarks.
- (D) A deuteron consists of a proton and a neutron. (tritium is two neutrons and a proton, while regular Hydrogen is just an electron and proton)
- (E) An alpha particle consists of electrons and protons and neutrons.

Choice (A) remains. Choose that.

If one has some time, one might want to remember the elementary particles involved in the Standard Model. There are six quarks and six leptons. Three of the leptons are neutrinos and the other three are the electron, the tau, and the muon. (Also, in a decay similar to beta-decay, a muon is emitted instead of an electron. Charge conservation works since a muon is like an electron except it is about 200 times more massive.)

Wikipedia has a good reference on this:

`\begin{verbatim} http://en.wikipedia.org/wiki/Fundamental_particle`  
`\end{verbatim}`

*YOUR NOTES:*

### Problem 64:

Advanced Topics  $\Rightarrow$  } Nuclear Physics

In symmetric fission, the change in kinetic energy is just the change in binding energy. The change in binding energy for a  $N$ -nucleon heavy nucleus is the difference in energy between the initial un-fissioned heavy nucleus and the final 2 medium-sized nuclei,

$$\Delta E = 2 \times 0.5N \times 8.1 \text{ MeV/nucleon} - N \times 7.1 \text{ MeV/nucleon} = N \times 1.1 \text{ MeV/nucleon}$$

For a heavy nucleus, one has  $N \approx 200$ , and thus one arrives at choice (C).  
 (This is due to David Schaich.)

*YOUR NOTES:*

### Problem 67:

Advanced Topics ⇒ } Schwarzschild Radius

Using quite a bit of handwaving, the current author has seen an astrophysicist derive the Schwarzschild Radius (radius at which the curvature of space mooches and eats up light completely) via  $\frac{1}{2}mc^2 = \frac{GMm}{r}$ . (The guy totally neglected relativity, assuming that kinetic energy has the same form in the relativistic regime, but anyway...)

Handwaving like a good astrophysicist, one finds that

$$r = \frac{2GM}{c^2} = \frac{2 \times 7.5 \times 10^{24}}{9 \times 10^{16}} = 1.67 \text{ cm}$$

(Note: the author is currently declared as an astrophysics major, and if the above comment is to be interpreted as pejorative towards astrophysicists, then she has thus implicitly insulted herself.)

**YOUR NOTES:**

### Problem 78:

Advanced Topics ⇒ } Solid State Physics

A n-type semiconductor is a material with *negative*-charge carriers, such as electrons. A p-type semiconductor is a material with *positive*-charge carriers, such as holes (positrons).

In band theory, n-type semiconductor impurities are (electron) donors, while p-type semiconductor impurities are (electron) acceptors.

The setup is as follows:

Impurities add in more levels to the energy bands. Without impurities, one has just a valance band and a conduction band with an energy gap in between. The impurities supply an extra energy level in between the conduction and valance bands. In an n-type semiconductor, the material becomes conducting when there are electrons in the conduction band; the impurity helps the material become conducting by supplying it with electrons.

Essentially, one starts with a lattice of pure semiconductor atoms, say Silicon. Silicon has four valance electrons and forms a decent crystal lattice. Pluck out a few silicon atoms and replace them with some impurities, like Arsenic, which five valance electrons. The extra electron from each impurity atom is free to roam around. In fact, these extra electrons act as *donors* to the conduction band. This is choice (E).

**YOUR NOTES:**

### Problem 95:

Advanced Topics  $\Rightarrow$  } Solid State Physics

The specific heat of a superconductor jumps at the critical temperature (c.f. with its resistivity jump).

Ordinarily, the specific heat of a metal is  $c = c_{ph} + c_{el}$ . When it is superconducting, the first term, the electronic-contribution, is replaced by  $c_{el} = c_0 e^{-\frac{2T_c}{T}}$ . The revised plot of the specific heat has a jump from an exponentially increasing specific heat to a much lower value somewhere in the range for positive T.

Reference: Ibach and Luth p 270ff

**YOUR NOTES:**

### Problem 96:

Special Relativity  $\Rightarrow$  } Maximal Velocity

Conservation of momentum yields  $p = \frac{E}{c}$ , where p is the momentum of the photon.

Conservation of energy yields  $E = \gamma m_e c^2$ . Plug in the above equation for momentum to get  $\frac{E}{c} = \gamma m_e v$ . This occurs when  $v = c$ . Since v is the velocity of the electron, and since according to relativity, only a photon (to wit: a massless particle) can move at the speed of light--one of the conservation laws is not conserved!

This is choice (A).

**YOUR NOTES:**