

Solutions for class #14 from Yosunism website

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

Problem 8

Mechanics \Rightarrow } Damped Oscillations

One should remember that damped oscillations have decreasing amplitude according to an exponential envelope. As the amplitude shrinks, the period increases. The additional force instated in the problem is equivalent to damping, and thus the period increases, as in choice (A).

YOUR NOTES:

Problem 9:

Atomic \Rightarrow } Rydberg Energy

$\frac{1}{\lambda} = R \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$. Given the information that the Lyman Series is $n_f = 1$, and the Balmer series is $n_f = 2$, one forms the ratio $\lambda_L / \lambda_B = 0.25$ (taking $n_i = \infty$). This is closest to choice (A). (Recall that ETS wants the answer that best fits.)

YOUR NOTES:

Problem 10:

Advanced Topics \Rightarrow } Particle Physics

Recall that in gamma-ray production, the excited nucleus jumps to a lower level and emits a photon γ . In internal conversion, however, an orbital electron is absorbed and ejected along with an *X-ray*.

YOUR NOTES:

Problem 11:

Atomic \Rightarrow } Stern-Gerlach

Recall the Stern-Gerlach experiment, where (in its original set-up) a beam of *neutral* silver atoms are sent through an inhomogeneous magnetic field. The beam's split into two---classically, from the Lorentz force, one wouldn't expect anything to happen since all the atoms are neutral, but if one accounts for the Larmor precession, one would expect the beam to be deflected into a smear. Instead, however, the beam deflects into $2s+1$ beams, and thus this supports the idea that electrons are of spin-1/2. (Ag has one unpaired electron in its p orbital.)

With a beam of hydrogen atoms, one should also get a split into two, since $s = 1/2$ from the electron.

YOUR NOTES:

Problem 12:

Atomic \Rightarrow } Positronium

The positronium atom involves a positron-electron combination instead of the usual proton-electron combo for the H atom. Charge remains the same, and thus one can approximate its eigenvalue by changing the mass of the Rydberg energy (recall that the ground state of the Hydrogen atom is 1 Rydberg).

Recall the reduced mass $\mu = \frac{m_1 m_2}{m_1 + m_2}$, where for identical masses, one obtains $\mu = m/2$. The Rydberg in the regular Hydrogen energy eigenvalue formula $E = R \left(1/n_f^2 - 1/n_i^2 \right)$ is proportional to μ . Substitute in the new value of the reduced mass to get $E \approx R/2$. $R = -13.6\text{eV}$, and thus $E \approx -6.8\text{eV}$.

YOUR NOTES:

Problem 34:

Advanced Topics \Rightarrow } Particle Physics

Regularly, electrons are emitted in any direction. Thus, there is *infinite* symmetry. In the case of a magnetic field, electrons are more likely to be emitted in a direction opposite to the spin direction of the decaying atom. Place the atom in an x-y plane, with its spin-direction pointing along the z-axis. If the electron is mostly emitted in the -z axis, then reflection symmetry is violated since it's not (mostly) emitted in the +z axis, i.e., not mirrored across the x-y plane. Choice (D).

(This is due to Joe Bradley.)

YOUR NOTES:

Problem 35:

Quantum Mechanics \Rightarrow } Identical Particles

Because of the antisymmetric interchange of identical particles, one gets $\psi = 0$ if two fermions are in the same state. This is basically the foundation behind the familiar Pauli exclusion principle.

YOUR NOTES:

Problem 36:

Special Relativity \Rightarrow } Conservation of Energy

The rest mass for each mass is 4kg. They collide head-on with identical speeds pointing in opposite directions. This implies that the composite mass is at rest. Thus, recalling that the total energy is given by $E = \gamma mc^2$ and that the rest mass is given by $E = mc^2$, one has $2\gamma mc^2 = Mc^2$, where M is the composite mass.

The particle travels at $v = 3c/5$, which yields $\gamma = 5/4$. Plug this in to get $M = 10/4 \times 4 = 10kg$.

YOUR NOTES:

Problem 37:

Quantum Mechanics \Rightarrow }Symmetry

One recalls the simple harmonic oscillator wave functions to be symmetric about the vertical-axis (even) for the 0th energy level, symmetric about the origin (odd) for the first energy level, and so on.

If there is a wall in the middle of the well, then all the 0th energy level wave function would disappear, as would all even wave functions.

Recall the formula for SHO $E = \hbar\omega\left(n + \frac{1}{2}\right)$. The first few odd states (the ones that remain) are $E_1 = 3/2\hbar\omega, E_3 = 7/2\hbar\omega$, etc. This is choice (D).

YOUR NOTES:

Problem 38:

Quantum Mechanics \Rightarrow }Symmetry

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YOUR NOTES:

Problem 39:

Atomic \Rightarrow } Ionization Potential

Atoms with full shells have high ionization potentials---they would hardly want to lose an electron, and thus it would take a great amount of energy to ionize them. Atoms with close-to-full-shells have similarly high potentials, as compared to atoms that are in the middle of the spectrum, take Cs^{55} , for example.

- (A) He has a full orbital, and thus its ionization potential must be high.
- (B) N has a close-to-full orbital.
- (C) O has a close-to-full orbital.
- (D) Ar is a noble gas, and thus its orbital is full.
- (E) This is it. Cs has the lowest IP of all (of the above).

YOUR NOTES:

Problem 40:

Quantum Mechanics \Rightarrow } Bohr Theory

It's amazing how far one can get with the Bohr formula.

To start with, one should calculate the ground-state energy of the singly ionized Helium (i.e., the ionization energy). $E_1 = Z^2 E_{H1} = 4 \times 13.6 \text{ eV}$, since Helium has 2 protons. (The general formula is $E_n = Z^2/n^2 E_1$.)

The Bohr formula gives $E = E_1 \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right) = E_1 \left(\frac{1}{n_f^2} - \frac{1}{16} \right)$, since $n_i^2 = 4^2 = 16$.

$E = hc/\lambda \approx 1.24 E^{-6} / 4.7 E^{-7}$ gives $E \approx 2.5 \text{ eV}$.

The only unknown expression above is n_f . Plugging everything in and solving for that, $n_f^{-2} \approx 8^{-1} \Rightarrow n_f \approx 3$. This yields choice (A). One can check via $E_f = E_1/n_f^2 = 4 \times 13.6/9 \approx 6$, which verifies (A).

YOUR NOTES: