1. According to Planck's quantum hypothesis: (a) How many charged particles must oscillate at frequency 525 THz to emit precisely 1.0 pJ of energy? (b) Use the least number of particles to produce 1.0 pJ over the visible range of frequencies 400 – 750 THz – how many and what frequency? (c) How many more at the other end of the spectrum?

2. A certain laser pointer creates light with wavelength 532 nm in the form of a plane wave with power 5.0 mW and beam of diameter 1.0 mm. (a) Use the formulas $I = P/A$, $I = EB/2\mu_0$ $E = cB$ to determine amplitude of the classical wave. (b) Use $E = hf$ to determine the number of photons per second emitted by the laser. (c) What is the greatest *possible* current that this laser could conceivably produce by the photoelectric effect?

3. The laser described in the previous problem shines on a mirror and reflects in the opposite direction. What force does the light exert on the mirror?

4. Spacecraft may one day be propelled by “solar sails” – like a sailboat in the solar wind. Sunlight reaching the Earth has intensity 1360 W/m^2. A square sail of what minimum size would provide a force of propulsion equal to 92 mN (same as DAWN’s ion engine)?

5. The ground state of the hydrogen atom is –13.6 eV. This is sometimes described as the “binding energy”. (a) Determine the frequency of light necessary to ionize a hydrogen atom. (b) Suppose a photon with wavelength 60.0 nm causes ionization – determine the kinetic energy and speed of the emitted electron.

6. Derive the Bohr radius and energy levels associated with principal quantum numbers 2 and 3. Assume the electron has orbital resonance based on the De Broglie wavelength.

7. Electrons moving along parallel paths are fired with speed 2.0 Mm/s through a slit of width 0.10 μm at a target 0.50 m away. (a) Most of the electrons hit the target within a band of what width? (b) What happens to the pattern if the width of the slit is greater? smaller?

8. A muon has a half-life of 1.5 μs (proper time). Suppose one thousand muons traveling at $0.99c$ travel a distance 1.90 km downward through the atmosphere. (a) Determine the time for the journey in the Earth frame. (b) Calculate the number of muons expected to remain. (c) Determine the time in the muon's frame and the number remaining using time dilation.

9. Consider the equation $K = mc^2 - m_0c^2$. (a) Use the binomial approximation $(1 + x)^n \approx 1 + nx$ ($x << 1$) to show that $K = \frac{1}{2} mv^2$ at low speeds – using which mass? (b) Calculate the kinetic energy both ways for a proton moving at one tenth the speed of light. (c) Under what circumstances is $m = m_0$?

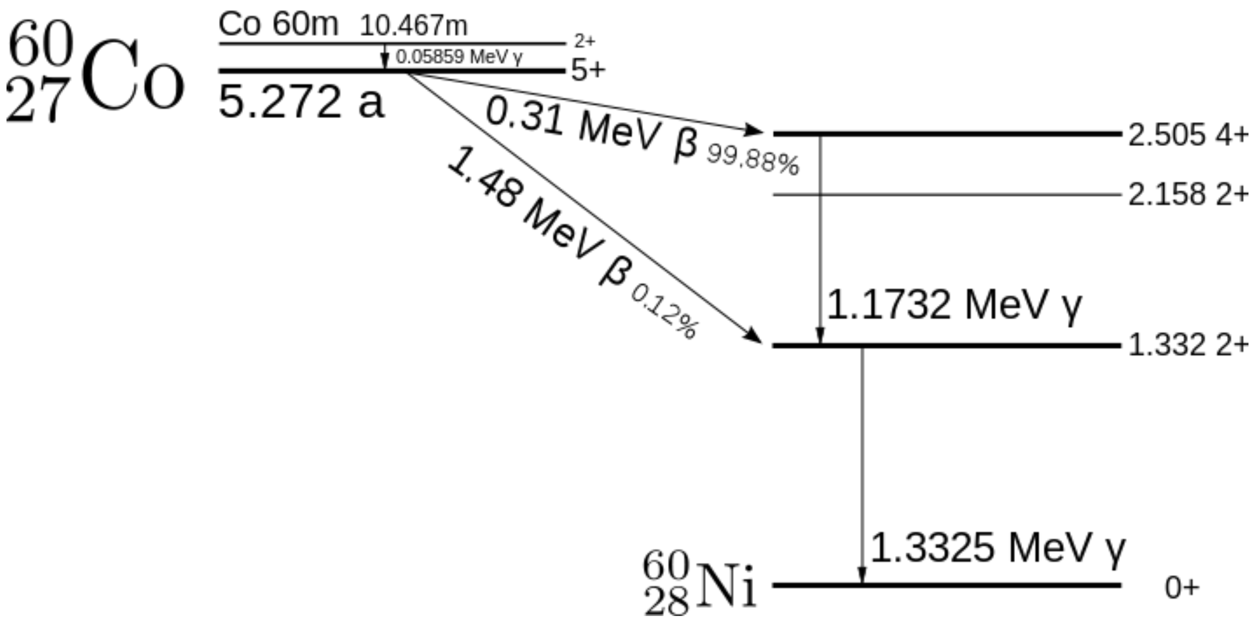
10. Determine the relativistic increase in mass for a car of mass 1500 kg traveling at 30.0 m/s. In what frame of reference is this increase observed?

11. In nuclear reactions the mass of the products is different than the mass of the reactants. Any "missing" atomic mass units must be "converted" to energy. One u equates with how much energy?

12. The "Little Boy" nuclear bomb detonated with a release of energy equal to 6.2×10^{13} J. Determine the change in mass corresponding to this reaction.

13. A radium-226 atom undergoes decay and emits an alpha. (a) Determine the energy released. (b) Show why most of the energy released must go to the alpha and estimate its speed – is it relativistic?

14. Cobalt-60 has a half-life of 5.27 years and undergoes a decay process leaving nickel. Most of the time a single decaying cobalt atom results in releases of a photon of frequency 2.84×10^{20} Hz and another at 3.22×10^{20} Hz. (a) Determine the type of decay and write the equation. (b) Determine the energy and speed of the emitted particle.



15. A positron collides with an electron releasing gamma radiation. (a) How much energy is released? (b) Find the frequency of the photons.