Tutorial Foundations Week 12

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1 Light

This section may require the use of the internet.

a) What is the wavelength of red light? What is the corresponding frequency? What energy does each photon carry?

b) What is the frequency of red light travelling through water? How does the energy of a red photon travelling through glass compare to a red photon travelling through water? The vacuum?

c) What is your favourite free-to-air TV station? What wavelength does it broadcast in? Which region of the EM spectrum is this?

d) How much energy does a UV photon from the sun carry? What is it's wavelength?

e) What is the wavelength of an photon used in medical x-rays? How much energy does each photon carry? Why would you want to limit the number of x-rays you have?

f) A photon has energy 0.1 eV, which part of the EM spectrum does it belong to?

2 Matter Waves

a) What is the deBroglie Wavelength of an electron with a kinetic Energy of 1 eV?

b) Relativistic effects become important when velocities approach the speed of light, $v \sim 0.1c$. What is the kinetic energy carried by an electron travelling at 10% of the speed of light? What is it's wavelength?

c) What experiment shows that matter also behaves like a wave?

3 The Hydrogen Atom

a) Lyman alpha (Ly-α) is a very important photon in observational astronomy. It results from an electron in a Hydrogen atom moving from the $n = 2$ energy level to the $n = 1$ energy level. What is the energy of this photon? Which part of the spectrum does it belong to?

4 The Atomic Nucleus

a) What is nuclear fission? What is nuclear fusion? Which of the two is more energy efficient? Which results in less hazardous waste? Which can provide us with unlimited energy? Which powers the sun?

b) Consider the following Uranium decay:

$$\mathrm{n} + {}^{235}\mathrm{U} \rightarrow {}^{140}\mathrm{Xe} + {}^{94}\mathrm{Sr} + 2\mathrm{n} \tag{1}$$

^{235}U 7.6 MeV per nucleon

^{140}Xe 8.4 MeV per nucleon

^{94}Sr 8.6 MeV per nucleon

What is the energy released through this equation? Where does it go? What is the energy released by 1kg of Uranium 235 at 10% conversion efficiency? What is the volume of a 1kg block of Uranium?

c) Which has greater mass? A bound proton and neutron (Deuterium), a proton and neutron well-separated in space, or is the mass the same?

d) How does the the energy of an atomic nucleus compare to the sum of its constituent protons and neutrons? ie. is the rest mass of an atomic nucleus greater, less than, or equal to the sum of the rest masses of these nucleons?

5 Radioactive Decay

a) What is the difference between alpha decay, beta decay, and gamma decay? What types of particles are emitted? What types of charge can they carry?

b) A radioactive isotope undergoing γ decay is placed in a magnetic field $B = 1$ T. Are the decay products affected by this field?

c) Consider the following Uranium decay:

$$^{238}\mathrm{U} \rightarrow {}^{234}\mathrm{Th} + {}^{4}\mathrm{He}^{2+} \tag{2}$$

In a magnetic field of $B = 0.5$ T, what happens to the alpha particle if it is ejected with kinetic energy $E = 50$ keV? Describe its motion.

d) In a Moon rock sample, the ratio of the number of (stable) ^{40}Ar atoms present to the number of (radioactive) ^{40} K atoms is 10.3. Assume that all the argon atoms were produced by the decay of potassium atoms, with a half-life of 1.25×10^9y. How old is the rock?