Week 4 Problems

1. You have a great summer job working in a cancer research laboratory. Your team is trying to construct a gas laser that will give off light of an energy that will pass through the skin but be absorbed by cancer tissue. You know that an atom emits a photon (light) when an electron goes from a higher energy orbit to a lower energy orbit. Only certain orbits are allowed in a particular atom. To begin the process, you calculate the energy of photons emitted by a Helium ion in which the electron changes from an orbit with a radius of 0.30 nanometers to another orbit with a radius of 0.20 nanometers. A nanometer is 10^{-9} m. The helium nucleus consists of two protons and two neutrons.

2. You are working in cooperation with the Public Health department to design an electrostatic trap for particles from auto emissions. The average particle enters the device and is exposed to ultraviolet radiation that knocks off electrons so that it has a charge of $+3.0 \times 10^{-8}$ C. This average particle is then moving at a speed of 900 m/s and is 15 cm from a very long negatively charged wire with a linear charge density of -8.0 x 10-6 C/m. The detector for the particle is located 7.0 cm from the wire. In order to design the proper kind of detector, your colleagues need to know the speed that an average emission particle will have if it hits the detector. They tell you that an average emission particle has a mass of 6.0×10^{-9} kg.

3. You are reading a newspaper report of a lightning strike in Jacksonville, Florida. Two men were sitting at a table outside a small cafe on a beautiful 30^{o}C day when a thunderstorm approached. Suddenly, a bolt of lightning struck a large aspen tree near their table. Needless to say, the men were very startled. One of the men remarked, "It just about scared the espresso out of me." They reported that when the bolt hit the tree and there was a loud hiss and a release of much steam from the tree. The lightning had boiled away some of the tree's sap. You are curious, and wonder how much water could be evaporated in this manner. So, you study your physics book and make a few estimates and assumptions. You estimate that the electric potential difference between the tree and the thunderhead cloud was about 108 volts, and the amount of charge released by the bolt was about 50 Coulombs. You also assume that about 1% of the electrical energy was actually transferred into the sap, which is essentially water. The specific heat capacity of water is 4200 J/(kg ^{o}C) and its heat of vaporization is 2.3 x 10^{6} J/kg.

4. NASA has asked your team of rocket scientists about the feasibility of a new satellite launcher that will save rocket fuel. NASA's idea is basically an electric slingshot that consists of 4 electrodes arranged in a horizontal square with sides of length d at a height h above the ground. The satellite is then placed on the ground aligned with the center of the square. A power supply will provide each of the four electrodes with a charge of +Q/4 and the satellite with a charge -Q. When the satellite is released from rest, it moves up and passes through the center of the square. At the instant it reaches the square's center, the power supply is turned off and the electrodes are grounded, giving them a zero electric charge. To test this idea, you decide to use energy considerations to calculate how big Q will have to be to get a 100 kg satellite to a sufficient orbit height. Assume that the satellite starts from 15 meters below the square of electrodes and that the sides of the square are each 5 meters. In your physics text you find the mass of the Earth to be 6.0×10^{24} kg.