# EXPERIMENT 1
# ELECTROSCOPE RADIATION DETECTOR

1. The leaves repel each other because their electrostatic charges are the same. The alpha source produces charged particles, which collide with atoms in the electroscope and neutralize its charges. The decreased charge results in less repulsion.

2. As the source is brought closer, more of the radiation from the source hits the electroscope. This is the same idea as a lighthouse, which is seen only dimly at a distance but seems very bright when viewed from close range.

3. The alpha particle is relatively heavy, but it is greatly attenuated by just a sheet of paper. This explains why ingesting alpha radioactivity (swallowing or breathing) is considered more of a hazard than an external alpha exposure.

# EXPERIMENT 2
# CLOUD CHAMBER

1. An alpha source would produce short trails due to the low penetrating power of the heavy alpha particle (helium nucleus). A beta source would give longer, thinner trails because the lighter beta particles (electrons) have more penetration. A gamma source produces only high energy rays, which are very penetrating but interact with fewer atoms in their path, so the vapor trails might be much longer but very difficult to see.

2. The rays and particles produced by radioactive decay interact with atoms in their path removing an electron to produce charged particles called ions.

3. Alcohol has a higher vapor pressure and lower condensation and freezing temperature than water. The water vapor in the chamber would form ice and be ineffective in showing vapor trails. The more plentiful alcohol vapor can be supercooled below its condensation temperature so that it will readily condense on any charged particles formed by ionization.

# EXPERIMENT 3
# RADIOACTIVITY HUNT

1. Radioactivity is the disintegration of the unstable nucleus of an atom. The energetic neutrons, alpha particles, beta particles, gamma rays, or x-rays released by these disintegrations are called radiation. The instrument detects radiation.

2. Ionizing radiation (described in Question 1) is produced from radioactive material like uranium. It transfers energy to atoms in the matter it penetrates, producing ions by removing electrons from the atom. Nonionizing radiation, such as the flashlight beam, does not have enough energy when it interacts with matter to create ions.

3. Background radiation comes from outer space (cosmic radiation), from rocks and soil, and building materials.

4. A Geiger counter uses a tube filled with gas which ionizes as radiation passes through it. The charged ions are attracted to electrodes operating with a potential of around 1000 volts. The electron motion toward the electrodes results in an "avalanche," discharging the tube momentarily until the potential can build back up. Each of these events produces a "click" which can be amplified and heard on earphones or speakers, or stored and displayed as a meter reading.

5. In general, materials exposed to radiation do not become radioactive. People receiving x-rays are not made radioactive; food and instruments sterilized by very high gamma doses are not made radioactive. Certain types of radiation, generally neutron radiation, can cause certain elements to change to radioactive isotopes. This is one way that radioactive isotopes for medical diagnosis and treatment are created. Exposure of living cells to high enough levels of ionizing radiation can kill the cells, which in the case of harmful bacteria, etc., can be helpful in sterilizing surgical instruments or preventing spoilage of food.

# EXPERIMENT 4
# ATOMIC MASS OF "BEANIUM"

1. The average atomic mass times the total number of beans in the sample should equal the total sample mass.

2. An isotope is an atom of an element containing a different number of neutrons. Neon-20 has 10 protons (Atomic number 10) and 10 neutrons; Neon-19 has 10 protons but only 9 neutrons; Neon-22 has 10 protons and 12 neutrons.

3. Magnesium has an average atomic mass of 24.32.

# EXPERIMENT 5
# OIL-DROP MODEL OF PLASMA

1. The spherical shape of the initial and final "nuclei" represent the most stable energy condition of a nucleus with its protons and neutrons tightly held by the strong force.

2. The bombarding neutron carries energy into the nucleus, upsetting its stable condition, resulting in distortion of the sphere and weakening of the strong force attractions. If parts of the nucleus move far enough apart, their attractions are overcome by the weaker but longer range repulsive forces between positively charged protons. The nucleus separates into two smaller nuclei, which attempt to achieve stability usually by the release of alpha, beta, or gamma radiation energy.

3. Fission products are rarely identical in size, given the randomness and violence of the splitting action. What matters is that all the particles and resulting neutrons produced by the fission total almost the same as the initial mass. The very slight amount of mass lost in the process (mass defect) is converted into energy. *Remember* $E = mc^2$?

# EXPERIMENT 6
# DOMINO CHAIN REACTION MODEL

1. Once initiated, the uncontrolled chain reaction proceeds until either all the fuel is used up or the rapidly expanding fissionable material is blown apart so neutrons cannot reach more nuclei. This depends on mass and geometry.

2. Neutron absorbing poisons limit the available neutrons for the next generation's bombardment.

3. If control rods are raised from a critical reactor, more heat energy will be produced, raising the temperature and expanding the core to "lose" more neutrons. The power level will decrease until the reactor is once more just critical. Essentially raising control rods raises the operating temperature.

# EXPERIMENT 7
# DETERMINING HALF-LIFE WITH PENNIES

1. Approximately 50% of the "heads" remain after each shaking. This is because there are only two possible results for each flip of a coin. Therefore, half of the "atoms" in the sample will decay in this time period.

2. Once an atom has "decayed" to its nonradioactive daughter product, it can no longer contribute to further decays. This is an artificiality, since daughter products do remain mixed with the original atoms and contribute their mass, but they cannot revert to become a parent atom and repeat their decay pattern as a coin could do if left in the box.

3. After 1 period, about 50 "heads" would be left; 25 after the second period; 12 or 13 after the third period; 6 after the fourth period; and about 3 after the fifth period. So it should take 5 half-lives to drop below 5 remaining "heads."

4. This shows the statistics or randomness of the event. Just as radioactive decay is random, so is flipping a penny. Only for samples with a large number of pennies or a large number of radioactive atoms will the measured decay be close to the theoretical value of 50% for penny flipping or the half-life of the radioactive isotope.

# EXPERIMENT 8
# HALF-LIFE DEMONSTRATION WITH WATER

1. The times should be approximately equal for each segment; it may be easier to see with average values of several trials.

2. The decreasing flow rate simulates diminishing decay rate as the parent isotope transmutes to the daughter. In each segment, half of the remaining quantity disappears.

3. The indicator solution should turn pink as it enters the ammonia in the bucket, simulating the formation of a new substance.

# EXPERIMENT 9
# TIME, DISTANCE, AND SHIELDING

1. Background counts or background dose rates result from the radiation that is always present around us such as cosmic radiation from the sun and outer space, building materials, and even our classmates (very small level).

2. Since the instrument reading represents a dose rate (in mrem/hour), the total dose received is simply the dose rate times the time spent at that rate. For example: if a worker spent a half hour in a 100 mrem/hour area, the total dose would be

   $$100 \text{ mrem/hour} \times 1/2 \text{ hour} = 50 \text{ mrem}.$$

   Radiation workers plan their work to minimize the amount of time they spend in high radiation areas.

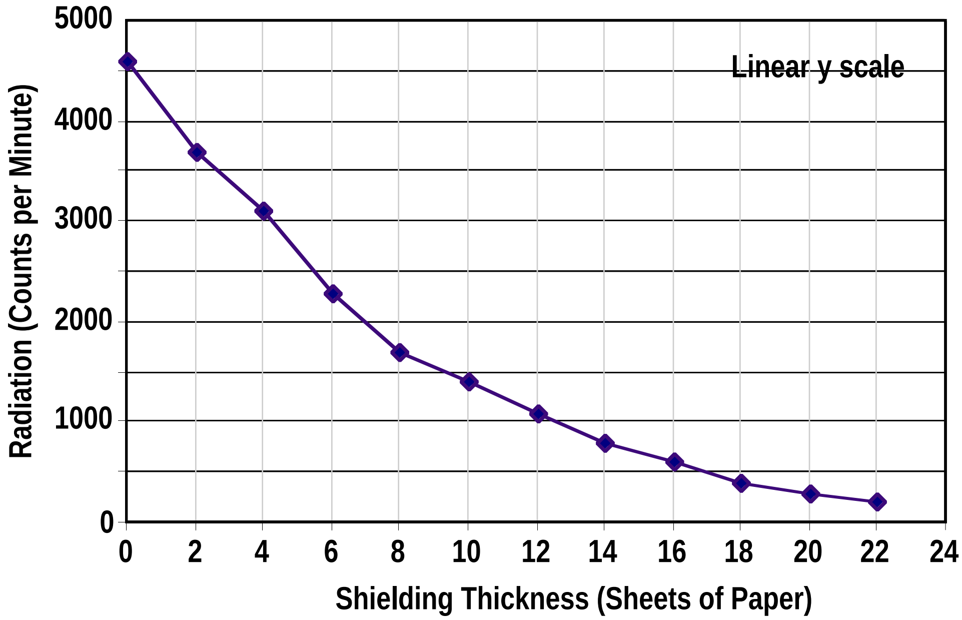
3. The relationship between radiation levels and distance from the source is nonlinear, specifically, the level is inversely proportional to the square of the distance ($1/d^2$) due to the spherical spreading characteristics of radiation (similar to light from a light bulb).

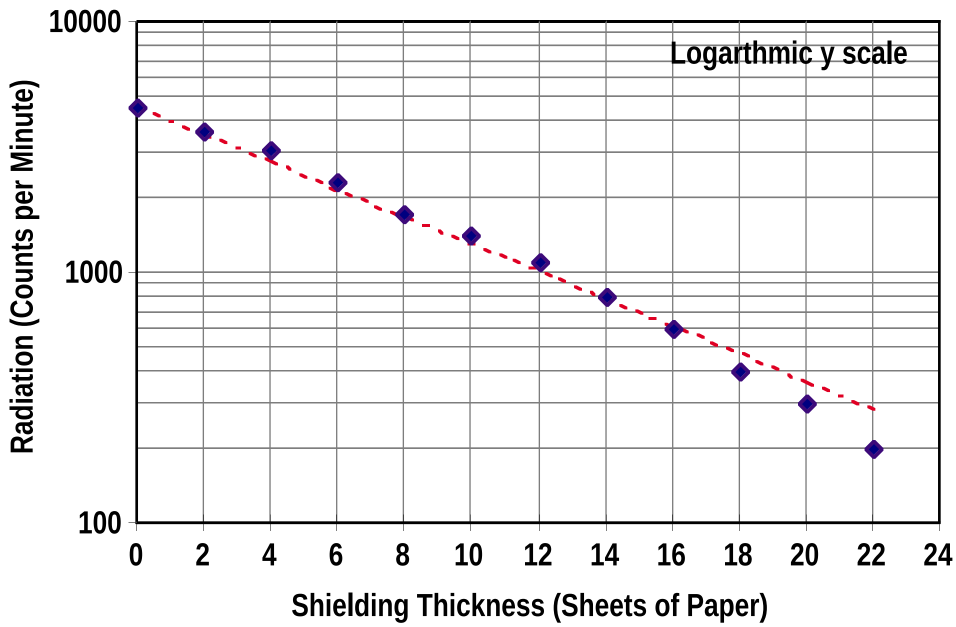
4. The beta particles can be greatly attenuated by a single aluminum sheet while the more energetic gamma rays require much denser material such as lead to be attenuated. The relationship between radiation levels and shielding thickness is also a nonlinear inverse function; not a square function but rather an exponential function. Quantities which decrease by the same factor for each additional sheet of shielding will plot as an exponential decay curve on a linear graph and as a straight line on a semilog graph. See the attached sample graphs. It is convenient to refer to "half-thickness" or "tenth-thickness" (the thickness that reduces the radiation by one-half or one-tenth) when comparing shielding effectiveness. A half-thickness of aluminum would be much less than a half-thickness of paper for example.

5. These results would vary, but should be comparable between participating teams.

## Measuring Radiation Shielding

### Sample Graphs



# EXPERIMENT 10
# RADIOACTIVE CONTAMINATION SIMULATION

1. Discussion could include compacting dry waste and sealing in drums or concrete for burial. Liquids could be evaporated to leave dry residue for packaging.

2. Open-ended question. The more cleanup material used, the more contaminated waste generated.

3. Possibilities might include high efficiency vacuums or chemical treatment with chelating compounds such as EDTA. EDTA chemically binds metals that may be radioactive and in a solution makes their extraction easier.

4. It will decay to nonradioactive material. In the case of isotopes with long half-lives, this may take quite a while. Chemical contamination, on the other hand, does not decay but remains forever.