1. D For an observer to see that the entire train is in the tunnel at one time, that observer must see that the train is only 80 m long. At relativistic speeds, the length of objects contracts in the direction of their motion according to the formula , where l is the relativistic length of the train, is the rest length of the train, and v is the speed of the train relative to the tunnel. Knowing that = 100 m and l = 80 m, we can solve for v:

2. D Energy, frequency, and Planck’s constant are related by the formula E = hf. Solving this problem is a matter of plugging numbers into this formula:

3. B Most of the particles will pass through with little deflection. However, some of the particles will hit the nucleus of one of the gold atoms and bounce back in the direction they came.

4. C Answering this question is simply a matter of recalling what Bohr’s atomic model shows us. According to Bohr’s atomic model, electrons orbit the nucleus only at certain discrete radii, so C is the correct answer.

5. B This problem asks that you apply the formula relating de Broglie wavelength to linear momentum,

6. B Heisenberg’s uncertainty principle tells us that we can never know both the momentum and the position of a particle at the same time, since the act of measuring one will necessarily affect the other.

7. E An alpha particle is made up of two protons and two neutrons, so it is four times as massive as either a proton or a neutron. Further, protons and neutrons are nearly 2000 times as massive as an electron. A beta particle is the same thing as an electron.

8. C Both atomic number and mass number are conserved in nuclear reactions. Since the mass number is and the atomic number is 95 on the left side of the equation, the mass number must add up to 241 and the atomic number to 95 on the right side. Since the mass number of the Np atom is 237 and its atomic number is 93, the X atom must have a mass number of 4 and an atomic number of 2, which is the case with an alpha particle.

9. E The activity of a radioactive sample, A, at time t is given by the formula , where is the activity at time t = 0, e is the natural constant, and is the decay constant. This formula tells us that the activity of a radioactive sample decreases exponentially over time, as expressed in graph E.

10. A The half-life of a radioactive substance is the constant that determines how long it will take for half of a radioactive sample to decay. Since half-life is a constant, its value does not change, as represented in graph A.