Summer Physics Name:
Quiz 1 on Radioactivity & Energy Conservation

Part 1: Radioactivity

1. You manage to acquire a dangerous sample of radioactive polonium.

   a. According to Wikipedia[1], polonium "has 27 known isotopes, all of which are radioactive." What does it mean to say that polonium has more than one "isotope"? Include in your response a sketch that helps explain your point – the sketch need only be suggestive of the underlying concept, not numerically precise.

   b. Again, according to Wikipedia, "^{210}Po is an alpha emitter that has a half-life of 138.376 days; it decays directly to [a] stable daughter isotope." (You'll recall that an alpha particle is a helium nucleus.) Write down the decay equation that shows the radioactive decay of ^{210}Po, and describe the element that is created through this radioactive decay.

   c. Suppose your sample consists of 4 grams of ^{210}Po. How long would you have to wait until your sample is reduced, through radioactive decay, to only 1 gram? Express your answer in days. Show your work.

   d. Alexander Litvinenko, a former member of the Soviet and Russian security services (FSB & KGB), was poisoned in London in 2006 with ^{210}Po and died within three weeks[2]. In fact, his tea cup was poisoned. Suppose you wanted to avoid exposure to radiation from the tea cup by moving from a distance of 1 m to a distance of 4 m away from the cup. According to the inverse-square law, how many times safer will you be at this new distance? Select one:

   ___ no safer ___ twice as safe ___ four times safer

   ___ eight times safer ___ sixteen times safer ___ sixty-four times safer

[1] http://en.wikipedia.org/wiki/Polonium
[2] http://en.wikipedia.org/wiki/Alexander_Litvinenko_poisoning

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2. A physicist might say that we should be thankful for naturally occurring radioactivity. Can you give one or more examples of situations in which radioactivity might not be a bad thing?

3. Recall that so-called "beta-particles" were later discovered to be the particle we call electrons. One radioactive element, ^{137}Cs (cesium), beta-decays with a half life of 30 years.

   a. What element is produced when ^{137}Cs beta-decays, and which isotope of this element is produced? Include in your answer the appropriate decay equation.

   b. You have a sample of 100 g of ^{137}Cs. After 90 years, how much of your sample would still remain? Show your work.

4. What, ultimately, is the *cause* of nuclear decay? Include in your answer a description of the four fundamental forces of nature, and what role (if any) each plays in radioactive decay.

5. Suppose, during the explosion of a nuclear bomb, 0.010 kg of uranium is converted *directly* into energy. Using Einstein's famous equation, calculate the amount of energy, in Joules, that is released as gamma-rays from this explosion.

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Part 2: Energy Conservation

1. Describe in words the difference between *kinetic* energy and *potential* energy. Use examples, and include at least one sketch. Explain as you would to a 5^{th} grader – someone who doesn't have the benefit you have of extensive practice with the topic.

2. Suppose you are crane operator and you're lifting a very heavy chunk of concrete. Right now, the concrete is up in the air and so has a potential energy of 10,000 J (but no kinetic energy).

   a. You use your crane to begin lifting the chunk of concrete even higher. In lifting the concrete, you do 15,000 J of work on it. How much total energy does the concrete have now?

   b. If, in doing that 15,000 J of work, you only lifted the chunk of concrete a distance of 1.5 m, how much *force* did you apply? Don't forget to include proper units in your answer!

   c. The chunk of concrete has a mass of 150 kg. The cable on your crane breaks! How *fast* is the chunk of concrete traveling when it hits the ground?

3. A train is racing along a horizontal track with 100 MJ (megajoules) of kinetic energy and no potential energy. Superman is going to push on the train to bring it to a stop before it runs over his sweetie. How much work (in Joules) will Superman have to do to bring the train to a stop?

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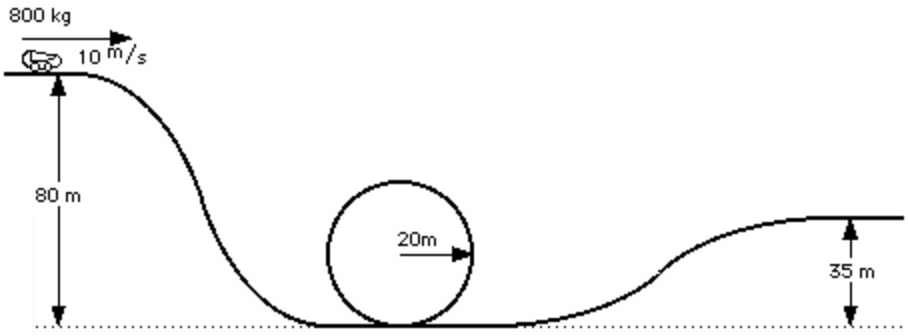

4. For this problem, consider the roller-coaster diagram shown above. (We will neglect friction – all energy in this problem will be in either kinetic or potential form.)

   a. The roller coaster begins at a height of 80 m with a speed of 10 m/s towards the right. Its mass is 800 kg. What is the initial *kinetic* energy of the coaster?

   b. What is the initial *potential* energy of the coaster?

   c. What is the initial *total* energy of the coaster?

   d. Calculate the speed of the coaster when it is ...

      i. ... at the top of the loop (note the loop has a radius of 20 m).

      ii. ... at the horizontal part of the track at the end (at height 35 m).

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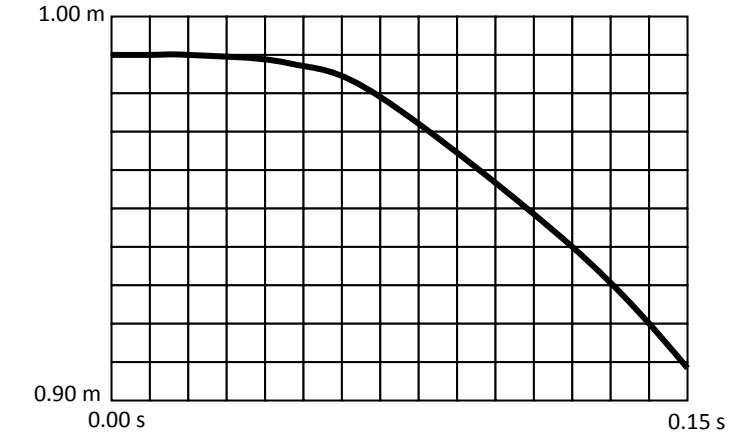
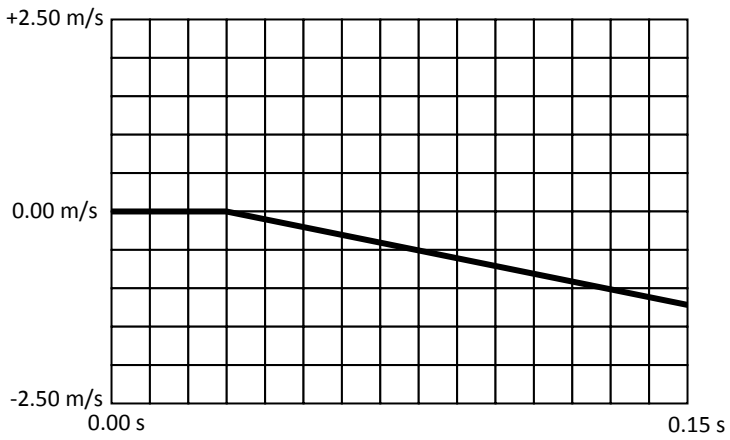
5. You carried out an experiment in our lab using the Lab Pro data acquisition system and the Logger Pro computer program. You dropped a cart of known mass (0.25 kg) onto a sonic range finder, producing the following position vs. time and velocity vs. time graphs:





Select two points in time (of your choosing) from the graph above and determine whether the total energy was *conserved* in this experiment. <u>If</u> there was a discrepancy between the energy at two points in time, calculate the % difference. (Note the formula for this is available on your blue equation sheet.) Be clear in your explanation & calculations below.