Summer Physics Name:

Midterm Exam Part A: Nuclear Physics, Energy Conservation, and Kinematics

Part 1: Nuclear Physics (Step 4)

1. In this unit, we studied just three simple types of radioactive decay: alpha, beta, and gamma decay. Of course, nuclear physics is actually more complicated and involves about fifteen different types of decays.

   One such decay is known as *electron capture*[1]. Essentially what happens is that a proton in the nucleus captures one of the electrons orbiting the nucleus; as a result, the proton "ingests" this electron, turns into a neutron, and emits a neutrino.

   The decay equation for the electron capture decay of ^{59}Ni is shown below. The daughter isotope is not shown – it will be your job to provide it:

   ^{59}Ni + electron $\Rightarrow$??? + neutrino

   a. What type of element is produced when nickel decays in this way?

   b. Which isotope, specifically, is produced?

   c. Suppose a neutral ^{59}Ni atom decays in this way. What is the net electrical charge of the atom after the decay?

2. The process detailed in question #1 has a half-life of 6.10 days. Suppose you have 50 mg of ^{59}Ni in your laboratory. How long would you have to wait until you only had 6.25 mg left?

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[1] http://en.wikipedia.org/wiki/Electron_capture

3. Suppose you had a machine that could convert matter into energy directly. Suppose that you wanted to generate about 10 J of energy (roughly the amount of energy contained in a good, solid punch in the face) in this manner.

   a. How much matter are we talking about? Express your answer in kilograms, then in grams.

   b. How many hydrogen atoms would it take to make up the amount of mass required for part (a). Is this a lot? Explain.

4. Exposure to poisonous radiation from nuclear decays is a tricky thing to quantify. It depends not only on what is emitted, but also how this emitted particle interacts with biological tissue. The standard unit is the rem (Rontgen equivalent in man)[2], where a dose of more than 100 rem is quite dangerous. In the United States, the federal government limits those who work with radioactive sources to no more than 5 rem of exposure per year.

   Suppose, for reasons of urgent public safety, you need to do precisely one hour of work near a very dangerous radiation source. You know that if you work a distance of 10 m away from the source, in that one hour you would receive only about 1 rem. How close could you work (again, just for this one hour) without going over the 5 rem exposure limit mandated by the government? Express your answer in meters.

[2] http://en.wikipedia.org/wiki/Roentgen_equivalent_man

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Part 2: Energy Conservation (Step 4)

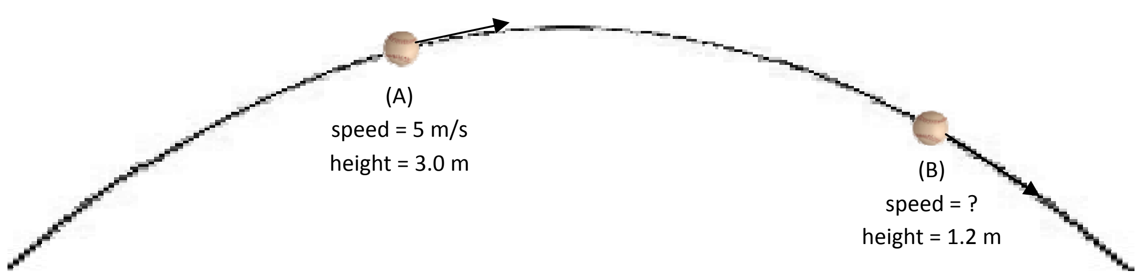
Please use g = 10 m/s^2 instead of 9.8 m/s^2 for this part. Neglect friction and air resistance. Note that some of these problems can be solved through the 'Newtonian' / force / kinematics perspectives. This section is not assessing your abilities in that framework – please use Energy Conservation concepts & skills throughout.

1. A butterfly has 0.02 J of kinetic energy and 0.04 J of potential energy. It flaps its wings vigorously, doing work, and later has 0.03 J of kinetic energy and 0.08 J of potential energy.

    a. How much work (if any) did the butterfly do?

    b. If the butterfly had a mass of 1.5 grams, approximately how fast was it going, and how high was it flying, after it finished flapping its wings?

2. You throw a 0.20 kg softball into the air along the trajectory shown below. The height and speed of the softball is shown at point (A). Your job is to determine the speed of the softball at point (B). (Use an energy analysis, not 2D kinematics.) <u>Please include an energy bar graph or pie chart</u> that allows the grader a quick & accurate look at the division between kinetic energy and potential energy at these two points in time.



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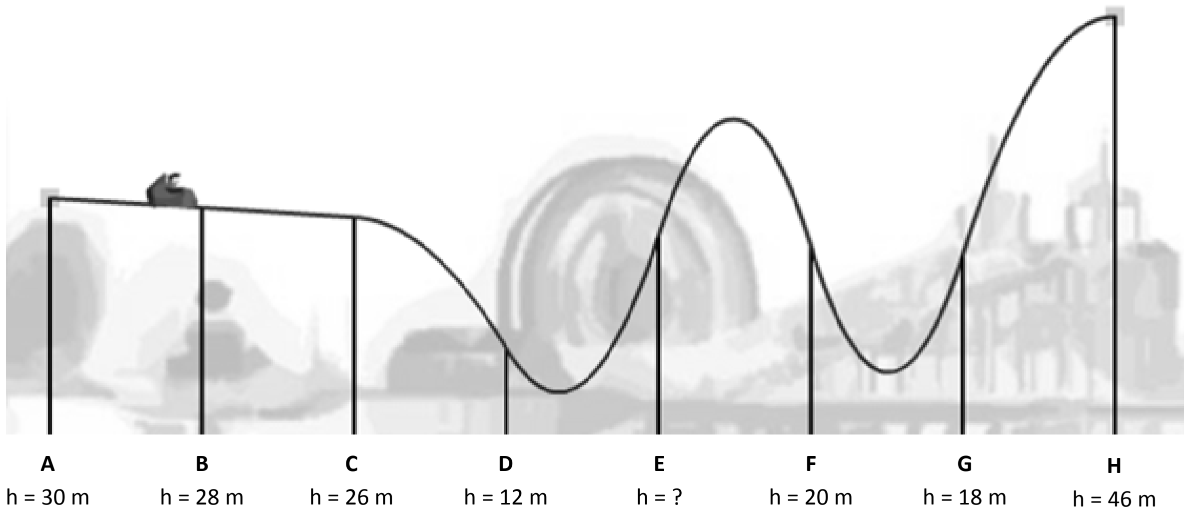
3. Consider the following roller coaster system track. Each point along the track is labeled A – H. The height of the track at most points is shown. (Image is not to accurate scale.)



a. An empty coaster is released from rest at point (A). How fast should the coaster be going at point (D)? Neglect friction. The mass of the coaster is (intentionally) not provided for you.

b. How far will the roller coaster "make it" along this track if released from rest at A? Indicate the right-most position the roller coaster reaches along the track with an arrow and the label 'b'. Explain your thinking below.

c. We'd like the coaster to make it to the top of hill 'H' with a speed of 5 m/s. How fast should we launch the thing at point A in order for it to achieve this goal?

d. Some students, when first learning energy conservation, want to just set $\frac{1}{2}mv^2 = mgh$ as much as possible. In which situations is such a mindset going to lead to trouble? Give a clear example that refers to the roller coaster above.

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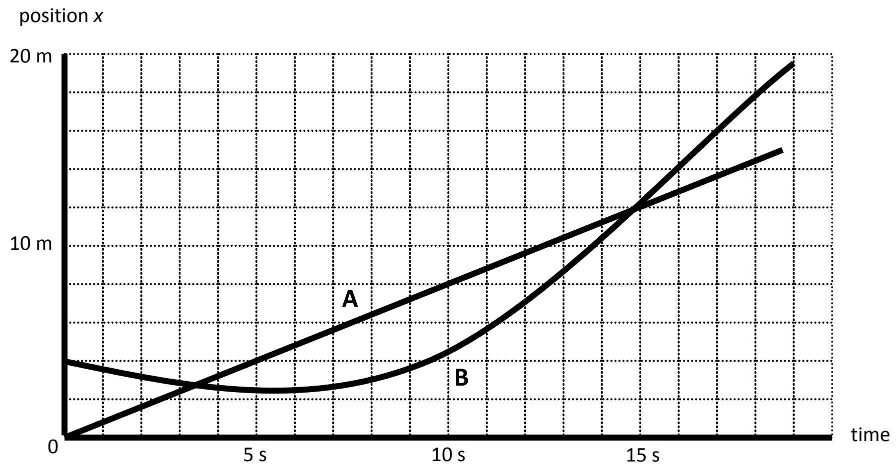
Part 3: Kinematics in 1D & 2D (Step 4)

Please use g = 10 m/s^2 instead of 9.8 m/s^2 for this part. Neglect friction and air resistance.

1. Consider the following position vs. time graph. Two curves are shown on the same graph – the first, curve A, represents the motion of a big dog named Abercrombie. The second curve, B, represents the motion of a little dog named Beauregard.



   a. Abercrombie is the more serious dog – he just started running at *t*= 0 and kept running with the same speed throughout. What was his speed? Explain how you know.

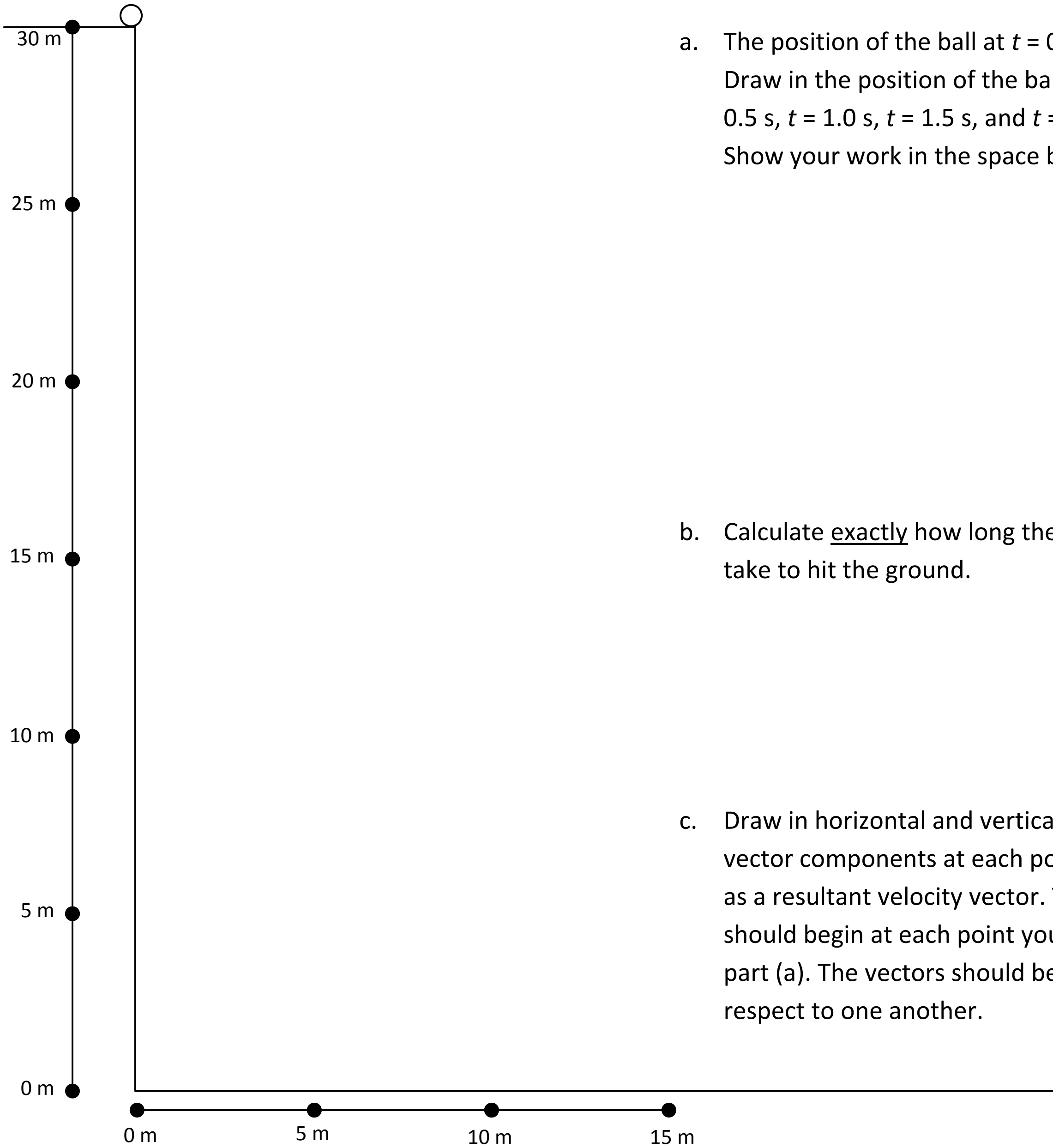
   b. Beauregard is a little crazy. Some of the race he was running backwards (the opposite direction that Abercrombie was running). During which time intervals was this happening?

   c. At what time, if any, did Beauregard stop running?

   d. Which dog, if either, was running faster at *t* = 15 seconds? Explain your thinking.

   e. Sketch in the trajectory of a third dog, Cassiopeia, who spends the first 10 s of the “race” at rest at *x* = 10 m, then begins running towards the origin (that is, with a negative velocity) at a constant speed of 2 m/s.

2. You roll a ball off the edge of a 30 m tall cliff. The ball falls freely. The initial horizontal speed of the ball is 5 m/s at the moment it leaves the cliff.



a. The position of the ball at t = 0 is shown. Draw in the position of the ball at t = 0.5 s, t = 1.0 s, t = 1.5 s, and t = 2.0 s. Show your work in the space below.

b. Calculate <u>exactly</u> how long the ball should take to hit the ground.

c. Draw in horizontal and vertical velocity vector components at each point as well as a resultant velocity vector. The vectors should begin at each point you drew in part (a). The vectors should be scaled with respect to one another.

3. If you were asked to "tweet" (that is, write in 140 characters or less – like a text message) the <u>fundamental point</u> or Big Idea of projectile motion / kinematics in 2D, what would you say?

4. An erratic fly is located at position x = 0 m, y = 5 m, as shown in the diagram below. At *t* = 0, the fly has an instantaneous horizontal velocity of v_x = 2 m/s and no horizontal acceleration. At the same instant in time, the fly has an instantaneous vertical velocity of v_y = +1 m/s but also has a constant vertical <u>acceleration</u> of –3 m/s^2. Assuming no changes in the forces acting on the fly over the short time interval which follows, which of the walls, marked in **solid black line**, will the fly hit first? Show your work / explain your thinking in the blank space provided. (*Hint*: calculate the horizontal and vertical positions of the fly at various times *t* and plot a trajectory.)