Cornell University
Prison Education Program

Conceptual Physics
Homework Packet 6
Solutions

Score: / 20 points

1. (6 points) Suppose you have a fair coin (*i.e.* $P(\text{heads}) = 0.5$, $P(\text{tails}) = 0.5$).
   (a) What are the sixteen possible outcomes to tossing the coin four times? You can abbreviate, *e.g.* HHTH as opposed to "two heads followed by one tails followed by one heads."

   Solution:

HHHH	HTHH	THHH	TTHH
HHHT	HTHT	THHT	TTHT
HHTH	HTTH	THTH	TTTH
HHTT	HTTT	THTT	TTTT

   (b) What is the probability of getting all tails?

   Solution: $1/2 \times 1/2 \times 1/2 \times 1/2 = 1/16$

   (c) What is the probability of getting two heads and two tails in no particular order?

   Solution: There are 6 possible ways of getting two heads and two tails, out of 16 equally likely outcomes: P(two heads, two tails) $= 6/16 = 3/8$.

2. (2 points) If a radioactive substance has a half-life of one year, does this mean that it will be completely decayed after two years? Explain.

   From *Light and Matter,* Chapter 33 Question 1.

   Solution: No, it means that after 2 years you would expect about $1/2 \times 1/2 = 1/4$ of the substance to remain.

3. (6 points) Suppose you have a sample of a radioactive substance that has a half-life of one year.
   (a) What fraction of the sample will have decayed after one year?

   Solution: One half.

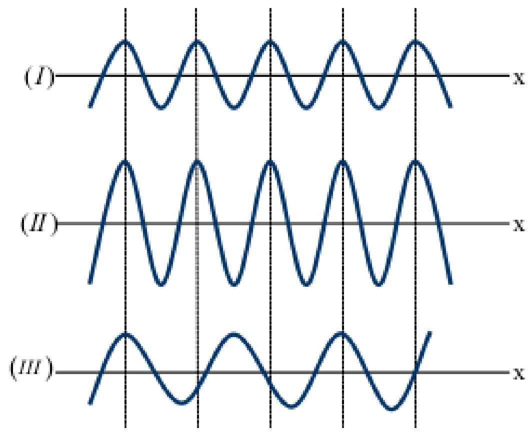
   (b) What fraction of the sample will have decayed after two years?

   Solution: One half decays after one year; during the next year, one half of the remaining half decays, leaving one fourth of the radioactivity. This means three fourths of the sample will have decayed.

   (c) What fraction of the sample will have decayed after five years?

   Solution: $\frac{1}{2} \cdot \frac{1}{2} \cdot \frac{1}{2} \cdot \frac{1}{2} \cdot \frac{1}{2} = \frac{1}{32}$ of the radioactivity is left, meaning $\frac{31}{32}$ has decayed.

4. (2 points) Three particles are traveling at the **same speed**. The waves of the three particles are as shown.



Rank the **masses** of the particles (I), (II) and (III) by circling one of these six possibilities.

(a) $m_{II} > m_I > m_{III}$

(b) $m_{II} > m_{III} > m_I$

(c) $m_I = m_{II} > m_{III}$

(d) $m_I = m_{II} < m_{III}$

(e) $m_{II} > m_I = m_{III}$

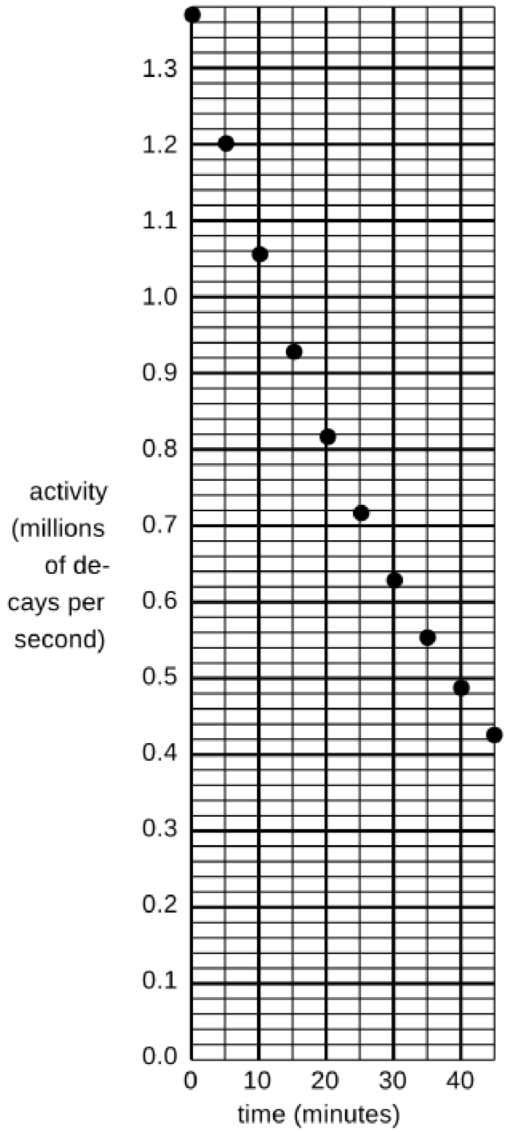
(f) $m_{II} < m_I = m_{III}$

Solution: C. Since the velocities are all the same, the mass will impact the energy the particle has. The greater the energy, the smaller the wavelength: Therefore the greater the mass, the smaller the wavelength. Since (I) and (II) have the same wavelength (amplitude is irrelevant here) they must have the same mass. Since their wavelength is greater than (III), this means that they must have a greater mass than (III)

5. (4 points) A nuclear physicist is studying a nuclear reaction caused in an accelerator experiment, with a beam of ions from the accelerator striking a thin metal foil and causing nuclear reactions when a nucleus from one of the beam ions happens to hit one of the nuclei in the target. After the experiment has been running for a few hours, a few billion radioactive atoms have been produced, embedded in the target. She does not know what nuclei are being produced, but she suspects they are an isotope of some heavy element such as Pb, Bi, Fr or U. Following one such experiment, she takes the target foil out of the accelerator, sticks it in front of a detector, measures the activity every 5 min, and makes a graph (bottom figure). Which element is it, given the following options? **Please explain your reasoning.**

From *Light and Matter*, Chapter 33 Question 8

isotope	half-life (minutes)
^{211}Pb	36.1
^{214}Pb	26.8
^{214}Bi	19.7
^{223}Fr	21.8
^{239}U	23.5



Solution: Lead-214. The sample starts off with just under 1.4 million decays per second, so at its half-life it will have decayed to just under 0.7 million decays per second. This happens somewhere between 25 and 30 minutes, so $^{214}\texttt{Pb}$, which has a half-life of 26.8 minutes, is the most likely candidate.