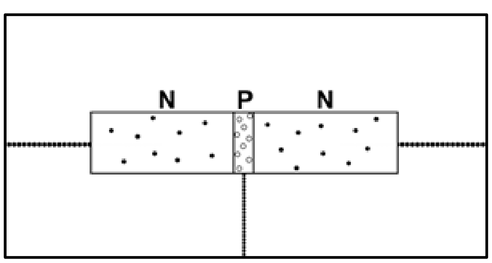
1. Which of the following statements about transistors is (or are) true?

1. Transistors amplify the current leaving the base layer.
2. Electrons in transistors move from the P layer to the N layer.
3. Removing the base layer changes a transistor into a diode.

(A) Only statement 1
(B) Only statement 2
(C) Only statement 3
(D) Statements 1 and 3
(E) Statements 2 and 3

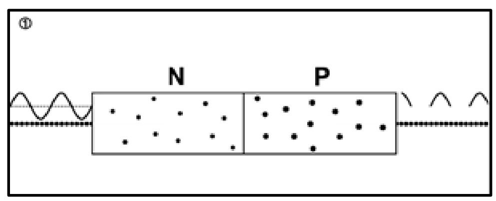
The amplitude of the base layer remains constant. Because you see a small current entering the base layer and a large current exiting the N layer, you think the current entering the base P layer is being amplified. All the base current is doing is modulating the current passing through the two N layers.

Electrons move from an area of excess electrons, the N layer, to an area of insufficient electrons, the P layer. Electrons cannot move from the P layer to the N layer because there are no extra electrons in the P layer available to move to the N layer.



A diode is an N layer abutting a P layer, and because current can only flow from the N layer to the P layer, an NP diode only allows current to flow in one direction.

When the electrical charge of the current is positive, which is above the midpoint of the sine wave, electrons are moving to the right in the transistor. Since electrons cannot move from the P layer to the N layer, current only exits the P layer when the input current is above the midpoint in the positive range of the sine wave.

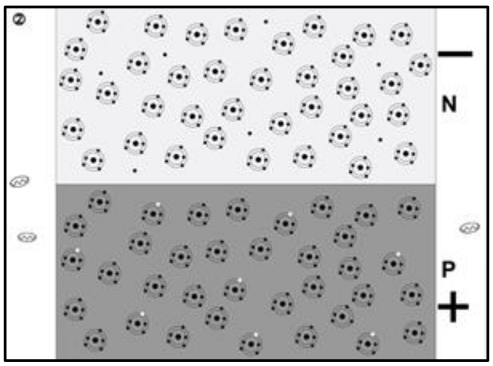


2. In a transistor, free-floating electrons in the emitter layer of the N semiconductor fall into holes within the P layer. Those holes are empty suborbitals of atoms within the P layer. When electrons fall, they accelerate and give off electromagnetic radiation.

If the electrons fall far enough, the photons have enough energy to produce visible light. Which of the following uses this mechanism of N and P semiconductors to produce light?

(A) laser light
(B) incandescent light
(C) light emitting diode
(D) fluorescent light
(E) arc lights

Light emitting diodes, or LED's, produce light by applying a voltage to a diode. A diode is an N layer next to a P layer. A positive voltage applied to the P layer attracts free electrons in the N layer to pass into the P layer and fall into suborbital slots, giving off visible photons of light.



3. The half-life of carbon 14 is 5730 years. 1 gram of carbon from a living plant undergoes 500 counts per minute. A 1 gram sample of carbon from a piece of dead wood undergoes 125 counts per minute. Approximately how old is the piece of dead wood?

(A) 1400 years
(B) 2800 years
(C) 5700 years
(D) 12,000 years
(E) 24,000 years

125 counts per minute is one-fourth the count rate of carbon from a living plant. In order for the count rate to decline to one-fourth its starting point, it must have undergone 2 half-lives, because one-half of a half is one-fourth.

Two half-lives is 12,460 years.

Mathematically, you're asking how many times must one-half be multiplied by itself to reach the fraction of its starting point.

In this problem, we're asking what n is: $(½)^n$ = ¼.

If we take the log of each side, we get:

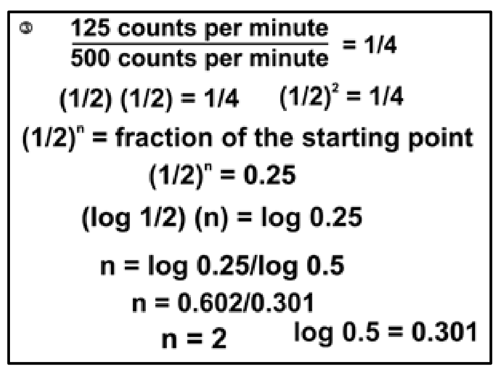
(log 1/2) (n) = log 0.25

n = log 0.25/log 0.5

n = 0.602/0.301

n = 2 – two half lives.

The log of one-half, 0.301, in the denominator remains the same in all half-life problems.



4. A radioactive isotope initially manifests 80 clicks per minute, but after 9 days is down to 10 clicks per minute. What is its half-life?

(A) 1 day
(B) 3 days
(C) 5 days
(D) 7 days
(E) 9 days

In declining from 80 to 10 clicks per minute, the isotope declined to 1/8 its staring click rate. In order to experience a rate of 1/8, it had to undergo 3 half-lives, because a half of a half of a half is 1/8, or $(1/2)^3 = 1/8$.
If the sample underwent 3 half-lives in 9 days, then it underwent 1 half-life in 3 days. Its half-life is 3 days.

④

$$\frac{\text{10 clicks per minute}}{\text{80 clicks per minute}} = 1/8$$

$$(1/2)\,(1/2)\,(1/2) = 1/8$$

$$(1/2)^3 = 1/8$$

$$\frac{\text{3 half-lives}}{\text{9 days}} = \frac{\text{1 half-life}}{\text{3 days}}$$

5. If the mass of a helium nucleus is 0.03037 atomic mass units, what is the binding energy of a helium nucleus? 1 atomic mass unit (amu) is 1.66×10^{-27} kg.

(A) 1.83×10^{-13} J
(B) 1.83×10^{-12} J
(C) 1.65×10^{-13} J
(D) 1.65×10^{-12} J
(E) 1.65×10^{-11} J

If: 1 amu = 1.66×10^{-27} kg,
Then: 0.03037 amu = X kg

X = 0.01829×10^{-27} kg, or 1.83×10^{-29} kg,

$E = mc^2$
$E = (1.83 \times 10^{-29}\text{ kg})\,(3.00 \times 10^{8}\text{ m/sec})^2$
$E = 1.65 \times 10^{-12}$ J

⑤

If: 1 amu = 1.66×10^{-27} kg
Then: 0.03037 amu = X kg

$$X = 0.01829 \times 10^{-27}\text{ kg}$$

$$X = 1.83 \times 10^{-29}\text{ kg}$$

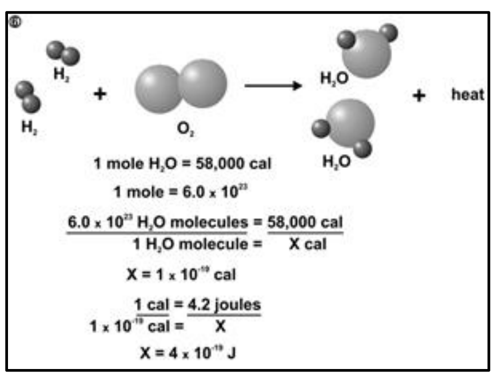
$$E = mc^2$$

$$E = (1.83 \times 10^{-29}\text{ kg})\,(3.00 \times 10^{8}\text{ m/sec})^2$$

$$E = 1.65 \times 10^{-12}\text{ J}$$

Introduction to Question 6

In the chemical reaction where hydrogen gas is burned to form water, 2 hydrogen molecules combine with a single oxygen molecule to form 2 molecules of water.



For every mole of water molecules produced in this chemical reaction, 58,000 calories are released.

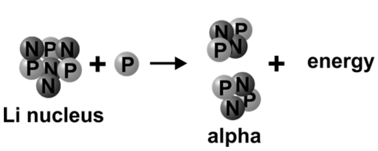
1 mole is 6.02 times 10^{23}, so if 6.02 times 10^{23} water molecules releases 58,000 calories, then 1 water molecule must release 1 x 10^{-19} calories.

1 calorie equals 4.2 joules of energy, so 1 x 10^{-19} calories must release 4 x 10^{-19} joules or energy.

How much more energy do you estimate is released when the nucleus of a lithium-7 atom is broken apart after being struck by a proton?

The nucleus of a lithium 7 atom contains three protons and four neutrons. When a proton strikes a lithium atom, the four protons and four neutrons break apart into two alpha particles, each consisting of two protons and two neutrons

6. The mass of a lithium nucleus is 11.65034 x 10^{-27} kg, and the mass of a proton is 1.67263 x 10^{-27} kg. The mass of an alpha particle is 6.64466 x 10^{-27} kg.



(A) 1000 times greater
(B) 100,000 times greater
(C) 1,000,000 times greater
(D) 10,000,000 times greater
(E) 1000,000,000 times greater

If the mass of a lithium 7 nucleus is 11.65034 x 10^{-27} kg, and the mass of a proton is 1.67263 x 10^{-27} kg, together their mass must be 13.32297 x 10^{-27} kg.

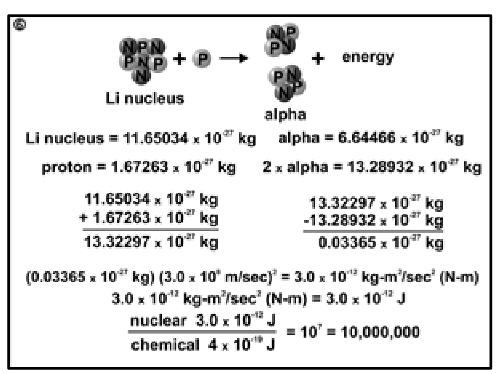
The mass of an alpha particle is 6.64466 x 10^{-27} kg, and for 2 alpha particles, 13.28932 x 10^{-27} kg.

Since we started out with 13.32297 x 10^{-27} kg and ended up with 13.28932 x 10^{-27} kg, we've lost 0.03365 x 10^{-27} kg. That mass was converted into energy. How much energy?

c squared worth of energy.

0.03365 x 10^{-27} kg times (3.0 x 10^8 m/sec$)^2$ = 3.0 x 10^{-12} (kg-m^2/sec^2), or 3.0 x 10^{-12} newton meters, or 3.0 x 10^{-12} N-m is 3.0 x 10^{-12} joules.

Compared to the 4.0 x 10^{-19} joules released in a hydrogen-oxygen chemical reaction, the energy released when a lithium nucleus breaks apart is 10 to the 7, or 10 million times greater than the energy released in a chemical reaction.



7. To a person standing still, what is the length of a 1.00 meter pipe when it speeds up to six-tenths the speed of light?

(A) 0.8 m
(B) 0.9 m
(C) 0.64 m
(D) 0.36 m
(E) 0.6 m

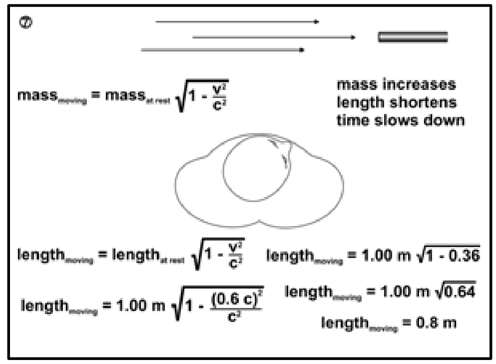
Einstein's theory of relativity says that as something moves, to a person standing still and watching that something speed up, the mass of that something increases, its length shortens, and time slows down. The amount that mass, length, and time change when an object moves at velocity, v, is described by the formula:

mass (or length or time) = mass at rest $\sqrt{(1-v^2/c^2)}$

To a person standing still and observing the stick traveling at six-tenths the speed of light, the stick shortens to a new length. The new length to a person standing equals its length at rest times the square root of $1-v^2/c^2$.

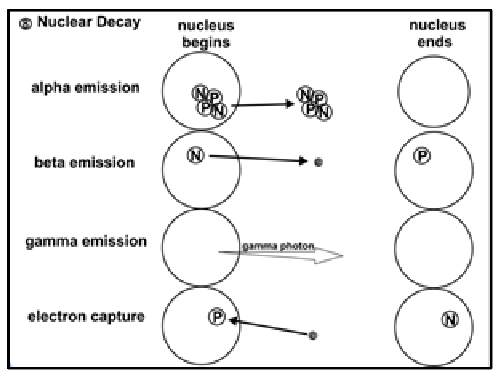
Since the velocity is six-tenths the speed of light, the moving length is 1 minus the square root of 1 minus 0.6 squared over 1squared.

L turns out to be 0.8 m. The 1 meter long stick appears to shorten to eight-tenths of meters.



Intro to Question 8

Four common methods of nuclear decay include alpha emission, beta emission, gamma emission, and electron capture.



In alpha emission, the nucleus releases an alpha particle consisting of 2 protons and 2 neutrons and ends up 4 atomic mass units lighter.

In beta emission, a neutron in the nucleus releases an electron and turns into a proton.

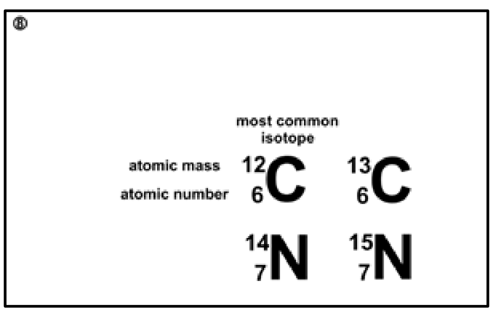
In gamma emission, the nucleus releases a gamma photon with no change in the number of protons or neutrons.

In electron capture, a proton captures an electron and becomes a neutron.

Elements in the periodic table are symbolized by letters and two numbers. The bottom number, called the atomic number, refers to the number of protons in the nucleus. The atomic number determines the element. A different atomic number means a different element.

Adding the number of neutrons in the nucleus to the bottom number gives the upper number, called the atomic mass.

Changing the number of protons in the nucleus changes the element. Changing the number of neutrons changes the isotope of that element.



8. Match the process of nuclear decay.

A= alpha decay
B= beta emission
C= gamma emission
D= electron capture

238U 234Th ______
92 90

210Po 206Pb ______
84 82

14C 14N ______
6 7

64Cu 64Ni ______
29 28

87Sr 87Sr ______
38 38

(A) A, A, C, D, B
(B) B, A, B, D, C
(C) B, D, C, A, D
(D) A, A, B, D, C
(E) A, D, C, A, C

In alpha decay, the nuclear mass drops by 4 – 2 protons and 2 neutrons, so the decay of uranium 238 and polonium 210 has to be by alpha decay.

In beta decay, a neutron turns into a proton, so the atomic number increases by 1. Since nitrogen 14 has 1 more proton than carbon 14, one of carbon 14's neutrons must have turned into a proton by losing an electron. A proton and neutron have nearly the same atomic mass so their atomic masses are considered the same.

In electron capture, a proton captures an electron and turns into a neutron, which reduces the atomic number by 1, but without changing the atomic mass. Copper 64 captured an electron to because nickel 64 with 1 less proton.

Gamma rays have no weight and no electrical charge, so gamma emission does not change the atomic weight or the atomic number. By emitting a gamma ray, strontium 87 only lost energy, but no mass.

Match the process of nuclear decay:

$^{238}_{92}U \rightarrow ^{234}_{90}Th$ A

$^{210}_{84}Po \rightarrow ^{206}_{82}Pb$ A

$^{14}_{6}C \rightarrow ^{14}_{7}N$ B

$^{87}_{38}Sr \rightarrow ^{87}_{38}Sr$ C

$^{64}_{29}Cu \rightarrow ^{64}_{28}Ni$ D

A. alpha decay
B. beta emission
C. gamma emission
D. electron capture