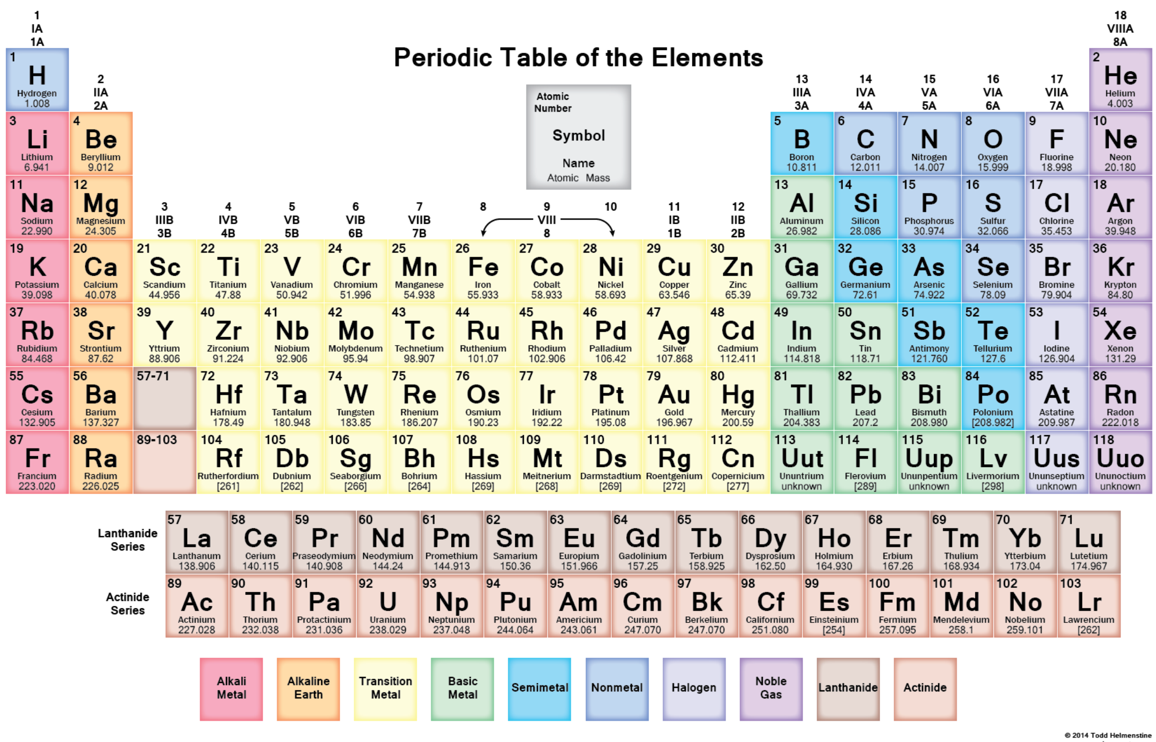
Name: ______________________________

Date: ______________________________

Cornell University
Prison Education Program

Conceptual Physics
Class 9 Questions
April 6th, 2018

The following might be useful for today's class questions:



1. The following is a wave of light:

(a) Draw the light-wave *red-shifted*.

- What happens to the frequency? (Increase, decrease, stay the same):
- What happens to the wavelength? (Increase, decrease, stay the same):
- What happens to the energy? (Increase, decrease, stay the same):
- What happens to the intensity? (Increase, decrease, stay the same):

(b) Draw the light-wave *blue-shifted*

- What happens to the frequency? (Increase, decrease, stay the same):
- What happens to the wavelength? (Increase, decrease, stay the same):
- What happens to the energy? (Increase, decrease, stay the same):
- What happens to the intensity? (Increase, decrease, stay the same):

2. In the Doppler effect, light is red-shifted or blue-shifted depending on whether objects are moving away from each other or closer together.

   (a) When two objects come together, light is *blue-shifted* between them. What happens to:

      1. The wavelength of the light? (Increase, decrease, stay the same):

      2. The frequency of the light? (Increase, decrease, stay the same):

      3. The energy of the light? (Increase, decrease, stay the same):

      4. The intensity of the light? (Increase, decrease, stay the same):

   (b) When two objects move away from each other, light is *red-shifted* between them. What happens to:

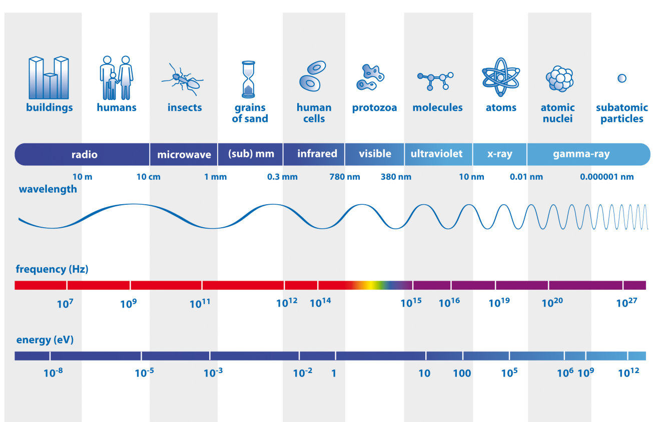
      1. The wavelength of the light? (Increase, decrease, stay the same):

      2. The frequency of the light? (Increase, decrease, stay the same):

      3. The energy of the light? (Increase, decrease, stay the same):

      4. The intensity of the light? (Increase, decrease, stay the same):

3. The following diagram represents the EM spectrum of light.



   (a) Order the following photons in terms of *increasing energy:* x-rays, microwaves, infrared, visible light

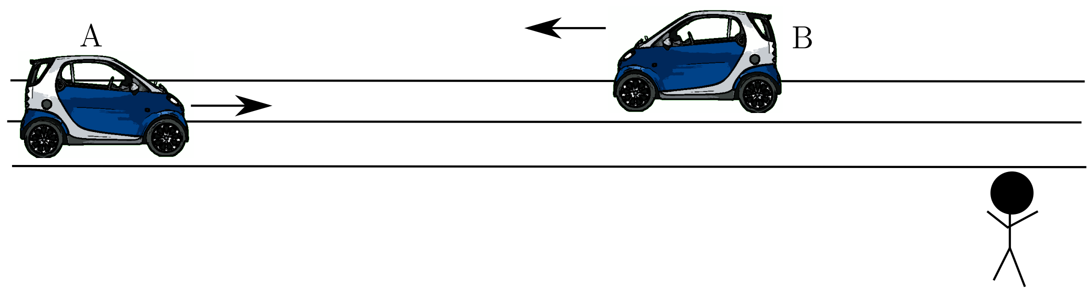
   (b) Which has the greater *wavelength*: Radiowaves or infrared?

   (c) Which has the greater *frequency*: Visible light or gammarays?

4. When light is reflected from a mirror, perhaps only 80% of the energy comes back. The rest is converted to heat. One could try to explain this in two different ways: (1) 80% of the photons are reflected, or (2) all the photons are reflected, but each loses 20% of its energy. Based on your everyday knowledge about mirrors, how can you tell which interpretation is correct?

   From *Light and Matter*, Chapter 34 Question 3

5. Two cars are driving in opposite directions on a road, by a pedestrian.



   (a) To the pedestrian on the road, the lights from car A appear
      1. Red-shifted
      2. Blue-shifted
      3. Unchanged

   (b) To the pedestrian on the road, the lights from car B appear
      1. Red-shifted
      2. Blue-shifted
      3. Unchanged

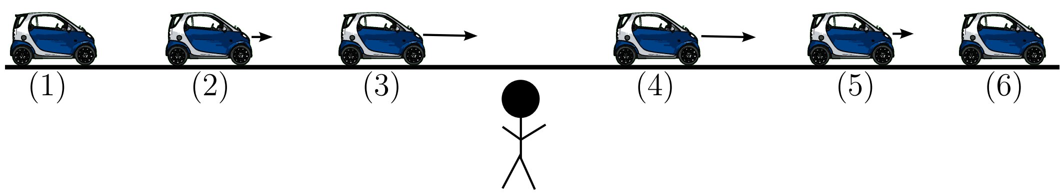
   (c) To car A, the lights from car B appear:
      1. Red-shifted
      2. Blue-shifted
      3. Unchanged

   (d) To car B, the lights from car A appear:
      1. Red-shifted
      2. Blue-shifted
      3. Unchanged

   (e) Compare and contrast the light from car A, as it appears to car B and the pedestrian.

   (f) Compare and contrast the light form car B, as it appears to car A and the pedestrian.

6. You are standing by the side of the road, and West of you is a stationary car with its lights on, labelled as (1) in the image below. The car then begins to move, and accelerates East. Part (2) shows the car some time later, moving East and still accelerating. Part (3) shows the car at its highest velocity, which it maintains as it moves past you to part (4). The car then begins to slow down, and so has the same velocity in part (5) as in part (2), and then comes to a complete stop again at point (6). The image bellow illustrates this, where the car's velocity is indicated by the arrows. Use this to answer the following questions.



(a) At which point(s) if any do the car's lights appear red-shifted to you?

(b) At which point(s) if any do the car's lights appear blue-shifted to you?

(c) At which point(s) if any are the car's light neither red nor blue-shifted?

7. Carbon comes in 3 main isotopes, carbon-12, carbon-13 and carbon-14.
   (a) How many protons are in a carbon-12 atom?

   (b) How many protons are in a carbon-13 atom?

   (c) How many protons are in a carbon-14 atom?

   (d) How many neutrons are in a carbon-12 atom?

   (e) How many neutrons are in a carbon-13 atom?

   (f) How many neutrons are in a carbon-14 atom?

8. The weak nuclear force mediates a form of nuclear decay, where a neutron turns into a proton and in the process emits an electron and an *anti*-neutrino. This is called *beta decay*:

$$n \to p^+ + e^- + \bar{\nu}$$

   (a) What is the total electrical charge on the left hand side of this reaction (just the neutron?)

   (b) What is the total electrical charge on the right hand side of this reaction (proton, electron, anti-neutrino) if the anti-neutrino has no charge?

   (c) A comparable decay mediated by the weak force is one where the proton decays. However, in this process a proton decays to a neutron by forming a *positron*, a particle of anti-matter which is the exact opposite of the electron, and a neutrino

$$p^+ \to n + e^+ + \nu$$

   What is the total electrical charge on the left hand side of this reaction (just the proton)?

   (d) What is the total electrical charge on the right hand side of this reaction (neutron, positron, neutrino)?

   (e) From the above two reactions, you should notice that the amount of charge is the same on both sides. This is because electrical charge is a conserved quantity in nature (think back to Noether's theorem, there's a symmetry in the electric field that makes this true). Knowing this, explain whether or not the following decay is possible:

$$p^+ \to n + e^- + \nu$$

(f) *Electron capture* is the process by which an electron an proton come together to form a neutron (releasing a neutrino in the process). Using the idea of conservation of charge, explain why this is possible:

$$p^+ + e^- \rightarrow n + \nu$$

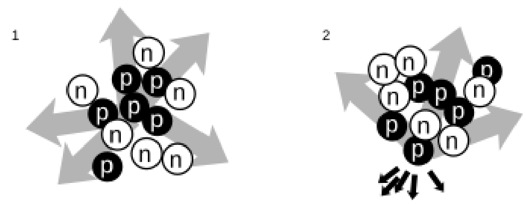
9. The following isotopes undergo either *beta decay* or *electron capture* (described in the previous question). What do they turn into?
   (a) Cobalt-57 undergoes electron capture
   (b) Carbon-14 undergoes beta decay
   (c) Aluminum-26 undergoes electron capture
   (d) Cesium-137 undergoes beta decay
   (e) Sodium-22 undergoes electron capture
   (f) Beryllium-7 undergoes electron capture
   (g) Iron-55 undergoes electron capture

10. When an antielectron and an electron come together, they annihilate causing a gamma ray to be released:

$$e^- + e^+ \rightarrow \gamma$$

Is charged conserved in this reaction?

11. In very heavy elements (with lots of neutrons and protons in a nucleus), there are many ways in which the nucleus can be arranged.



The image is taken from *Light and Matter*, Chapter 26.

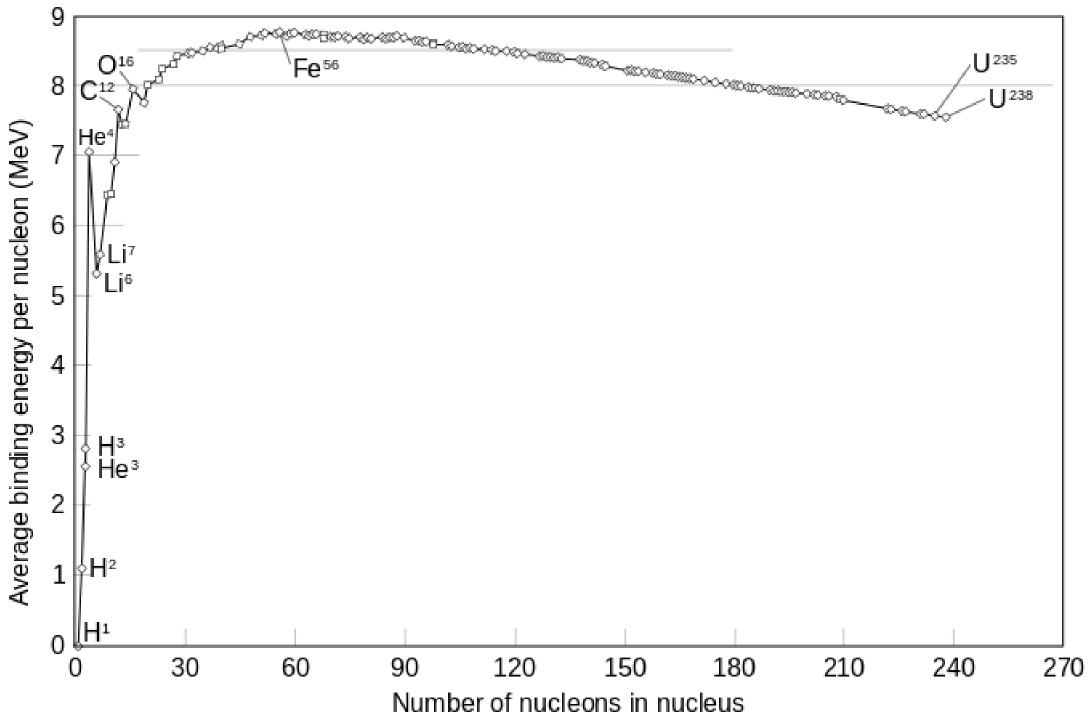
(a) What are the two dominant forces acting on the protons in the two figures?

(b) Very heavy elements tend to be *neutron rich*, meaning that they have far more neutrons than protons. Using the above figure and the forces you listed in part (a), explain why.

12. *Nuclear fusion* is the process by which atomic nuclei come together to create heavier elements.

Nuclear fission is the process by which atomic nuclei break apart to create lighter elements.

The amount of energy released is related to the *binding energy* of the atom: It is the amount of energy needed to disassemble the nucleus into free protons and neutrons.



(a) When hydrogen-1 (^{1}H) comes together with free neutrons to create helium-3 (^{3}He), would the process release or require energy?

(b) If helium-4 (^{4}He) broke into hydrogen-2 (^{2}H), would the process release or require energy?

(c) Why does the sun release energy by fusing lighter elements (hydrogen, helium) whereas nuclear reactors release energy by breaking apart heavier elements (uranium, plutonium)?

(d) Following this argument, why is iron-56 (^{56}Fe) the most stable nucleus?