

## Dangerous vs. Not Dangerous Waves and the word “radiation”

### The word Radiation

When people see the word “radiation” they often think of something very dangerous. But, in physics, “radiation” is not dangerous at all. In fact, you are surrounded by completely safe radiation right now.

In physics, the word “Radiation” typically means “any electromagnetic wave.”

Oftentimes, it is called “electromagnetic radiation”

The word “radiation” comes from the same root as the word “radius,” as in the radius of a circle. If you have some source of electromagnetic waves, such as a light bulb, it sends electromagnetic waves out in every single direction, just like the *radii* come out in every direction from the center of a circle or sphere.

Questions:

True or false: all radiation is dangerous.

True or false: light is radiation.

Is there radiation in the room right now?

What kinds of radiation are in the room right now?

### Ionizing vs. Non-ionizing Radiation

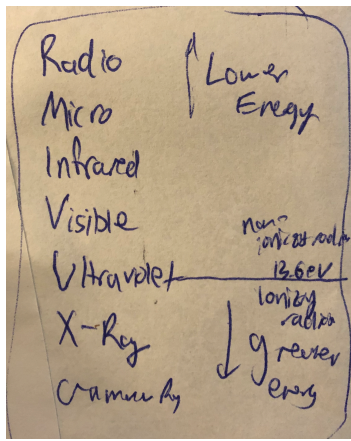
In the unit on quantitative electromagnetic radiation, we learned that all electromagnetic radiation comes in tiny pieces called *photons*. Every photon has a certain amount of energy. There

In chemistry class, you learned that an **ion** is an atom that has either gained or lost an electron.

Sometimes, a photon will strike an atom, and if the photon has enough energy, it will knock an electron out of the atom. At that point, the atom will become an *ion*. The photon that did this **ionized** the atom.

The simplest atom is hydrogen and has only one proton and one electron. It takes 13.6 electron volts of energy to knock the electron out of the hydrogen atom. Thus, all electromagnetic photons with an energy greater than 13.6 electron Volts are called **ionizing radiation**. All electromagnetic waves with an energy less than 13.6 electron Volts are called **non-ionizing radiation**.

A photon with precisely 13.6 electron volts comes in the ultraviolet region of the spectrum.



For each electromagnetic wave say if this is:

- ionizing radiation
- Non-ionizing radiation
- Partly ionizing radiation and partly non-ionizing radiation

- Infrared
- Microwaves
- Gamma rays
- Ultraviolet Rays
- Radio waves
- X-Ray
- Visible Light

For each electromagnetic wave say if this is:

- ionizing radiation
- Non-ionizing radiation
- Partly ionizing radiation and partly non-ionizing radiation

- Light from a light bulb
- Light from the sun\*
- A signal from a radio transmitter
- A pulse from an X-Ray machine
- Radiation used in a microwave oven
- Radiation used by a wifi signal
- Radiation from a remote control (typically infrared)
- Radiation emitted by a gamma ray burst

\* Light from the sun is primarily infrared, visible, and ultraviolet light

In physics, as stated above, the word “radiation” does not mean something dangerous, but rather means any electromagnetic wave.

There is both non-dangerous radiation and dangerous radiation.

The dangerous radiation is the *ionizing radiation* and the non-dangerous radiation is the *non-ionizing radiation*.

### **What causes cancer (a review of basic biology)**

- Your Body is made of cells.
- Every single cell 32 molecules of Deoxyribonucleic acid (DNA) called chromosomes. These 32 chromosomes together are called the *genome*. The genome gives instructions to your cell on how to build proteins and do its job correctly.
- Every cell in your body goes through process called the *cell cycle*. The cell cycle consists of four phases:
  - G1: The cell grows
  - S: The cell's DNA duplicates, it now has two copies of your entire genome.
  - G2: The cell grows some more
  - mitosis: The cell divides into two identical copies that have the same DNA.

Your body regulates each cell's cycle. For example, you want skin cells to grow continuously and replace skin cells that have rubbed off, but you don't want them to grow so much that your skin becomes deformed.

However, it is possible that a cell's DNA is *damaged* during DNA replication (stage S). If so, this damage may cause your cell's cycle to no longer be properly regulated.

Thus, instead of growing at a safe rate, your cells begin growing at an *extremely fast rate*. This forms a *tumor*.

If the tumor remains in one part of your body, it is called a *benign tumor*.

If the tumor cells begin spreading to other parts of your body, they are then called *malignant*. If the tumor cells continue to spread, then they can begin taking over your body, similarly to a virus, but in this case, the cells taking over are not an invader but *your own cells*. This issue is why cancer is so difficult for doctors to treat.

### **What do electromagnetic waves have to do with this?**

The three types of *ionizing radiation* present a risk for cancer because of their ability to knock electrons out of atoms. If an ionizing photon strikes a DNA molecule that is replicating, then it could damage the DNA molecule. This damage can eventually result in a disrupted cell-cycle and a malignant tumor.

## What are the main sources of ionizing radiation?

- The sun (high energy ultraviolet light)
- Radon (a gas that seeps out of the ground into people's basements and emits high energy radiation)

<https://www.nj.gov/dep/rpp/llrw/download/fact03.pdf>

### Questions:

You may have a broken bone! Your doctor recommends an X-Ray to see if you have a broken bone. Which of the following:

- There is absolutely no risk of an X-Ray.
- There is an extremely dangerous health risk of receiving an X-ray and you should never get one
- There is a health risk of receiving an X-Ray, but this risk is much much lower than the risk of having an undiagnosed broken bone. So you should receive the X-Ray when a doctor recommends it.

## Gamma Rays: very very dangerous

The three types of *ionizing radiation* are high energy ultraviolet rays, X-Rays, and gamma rays. However, gamma rays photons, because they have the highest energy of any photon, are much more dangerous.

The risk is not that they will simply knock electrons out of atoms and distrust your cells, but that they will completely eradicate human cells entirely! They have enough energy to break apart the chemical bonds that hold your molecules together. If there were ever a massive amount of gamma rays (such as in a gamma ray burst), it would be like the guns fired by aliens in a sci-fi movie, and simply vaporize everything in their path.

However, humans also use gamma rays to their own advantage. They do this by firing gamma rays at a tumor, in order to potentially destroy the tumor.

## Are microwaves dangerous?

Many people believe that a microwave oven sends out “dangerous radiation” into the kitchen, or even into your food.

A microwave oven works because microwaves have precisely the correct amount of energy to vibrate water molecules very fast. Because nearly all food involves water, microwaves give a much more efficient way to heat food than the more traditional method of using *infrared waves* (heat from your oven).

But are the microwaves made by the oven dangerous? Well, they are certainly non-ionizing radiation, and have even less energy than visible light! So, no.

If you search online, you will find plenty of weird side effects of heating with a microwave you can read about. You will need to decide about that for yourself. But, the important thing to know for physics class is this: microwave ovens produce non-ionization radiation, so there is no reason to assume they'd be dangerous.

True or false:

Microwaves are ionizing radiation.

Standing next to a microwave oven when heating up a pizza means that very dangerous radiation is moving through your body.

When you heat up food in a microwave oven, the microwaves go into your food and make it poisonous.

Microwaves work because they cause water molecules to vibrate very fast.

You should be metal in your microwave. It is safe and fun.

### **Are Cell Phones Dangerous?**

Cell Phones use microwaves to communicate.

Therefore, everything just stated about microwave ovens is also true about cell phones: Cell phones emit non-ionizing radiation unlikely to cause any damage.

However, there is one potential cause for concern:

Microwaves, though they do not damage DNA or cells, do *heat up water* very effectively, and your body is made primarily of water. Thus, a cell phone held near any part of your body (particularly your brain) for a long period of time can cause that body part to increase slightly in temperature. This could have potentially cause negative health effects.

Scientists are continuing to study this risk. There is still disagreement. Clearly, the risk is not enormous, otherwise it would be obvious.

To understand physics, it is important that you know that the risk of cell phones comes from *heating of water in your body* and NOT from *high energy electromagnetic radiation*.

True or false:

- Cell phones produce ionizing radiation.
- Cell phones produce radiation with less energy than visible light.
- Cell phones can potentially heat up your body.
- There is a potential, though not definite, health risk of constant cell phone use.

Update April 2020:

Apparently, some people are putting they're mail in the microwave oven to try to kill coronavirus on their mail...

First of all, it isn't very likely there is coronavirus on your mail, but separate from that, let's evaluate the physics of it...

a) Can microwaves kill cells?

NO! Microwaves are non-ionizing radiation. For they same reason they are not dangerous to you, they are not dangerous to coronavirus cells.

b) What do microwaves do?

They HEAT UP THINGS.

c) Can heating up your mail kill coronavirus on your mail?

Potentially, yes it could. But you know what else heating up your mail will do? START A FIRE!!!

In conclusion, seriously, don't put your mail in the microwave. Not that you were...but it is a good illustration of the misconceptions people have about the physics of microwaves.