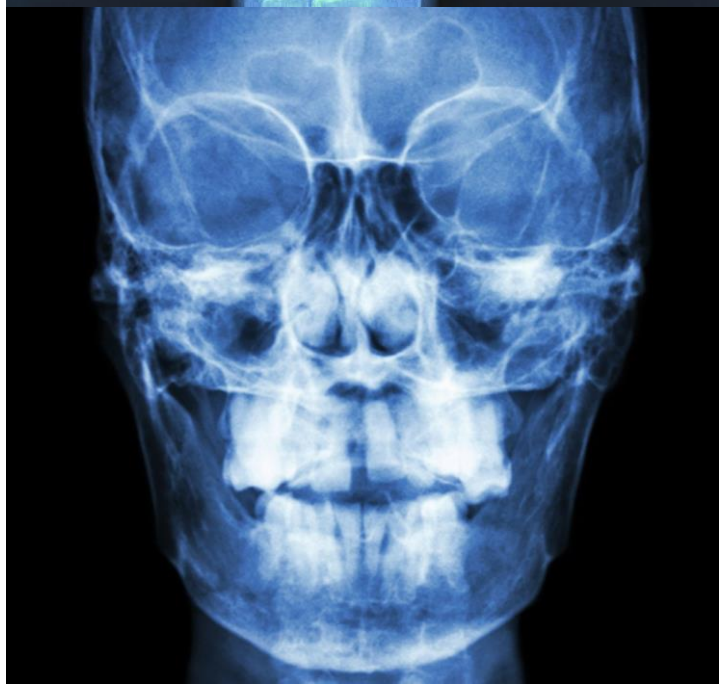
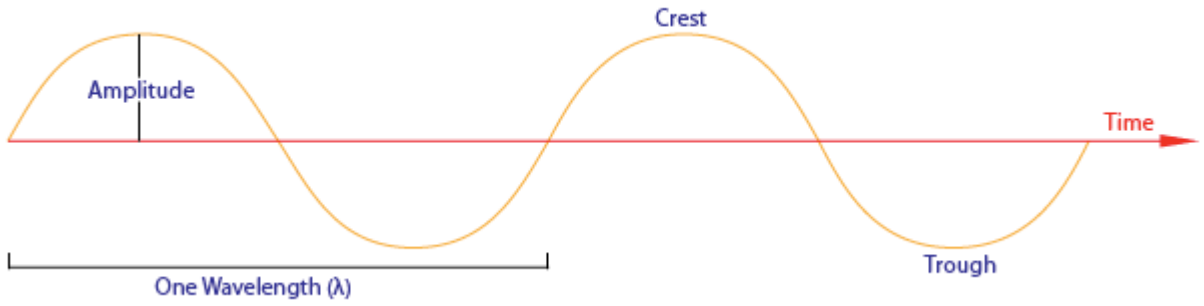


Basic principles of X-ray imaging

Assoc. Prof. Erkan Tuncay

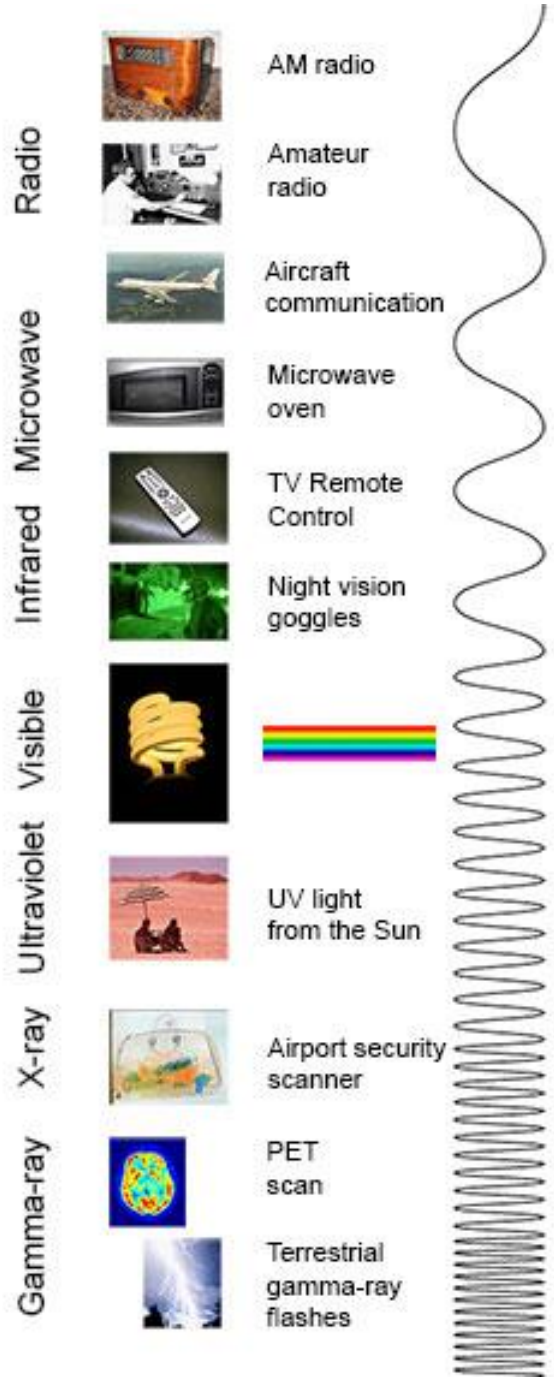
Basic properties of waves: Amplitude, wavelength, and frequency

- A wave has a *trough* (lowest point) and a *crest* (highest point). The vertical distance between the tip of a crest and the wave's central axis is known as its *amplitude*. This is the property associated with the brightness, or intensity, of the wave. The horizontal distance between two consecutive troughs or crests is known as the *wavelength* of the wave. These lengths can be visualized as follows:



What is Electromagnetic Radiation?

- Electromagnetic (EM) radiation is a form of energy that is all around us and takes many forms, such as radio waves, microwaves, X-rays and gamma rays. Sunlight is also a form of EM energy, but visible light is only a small portion of the EM spectrum, which contains a broad range of electromagnetic wavelengths.



Production of non ionized and ionized radiation

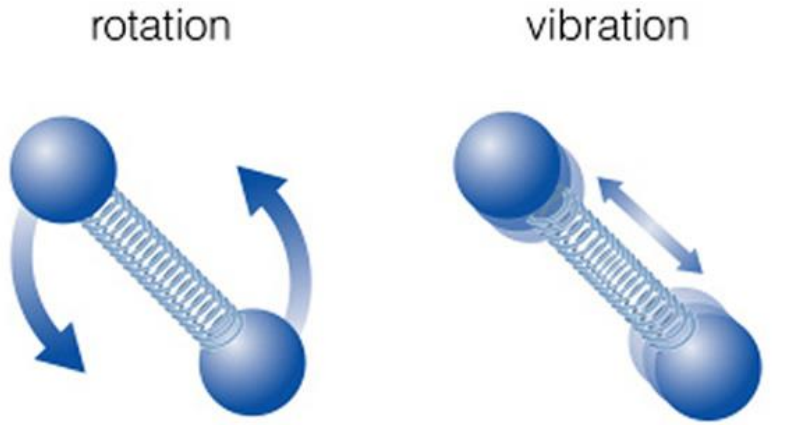
- A type of low-energy radiation that does not have enough energy to remove an electron (negative particle) from an atom or molecule. Non-ionizing radiation has enough energy to move atoms in a molecule around or cause them to vibrate, but not enough to remove electrons from atoms. Examples of this kind of radiation are radio waves, visible light and microwaves.

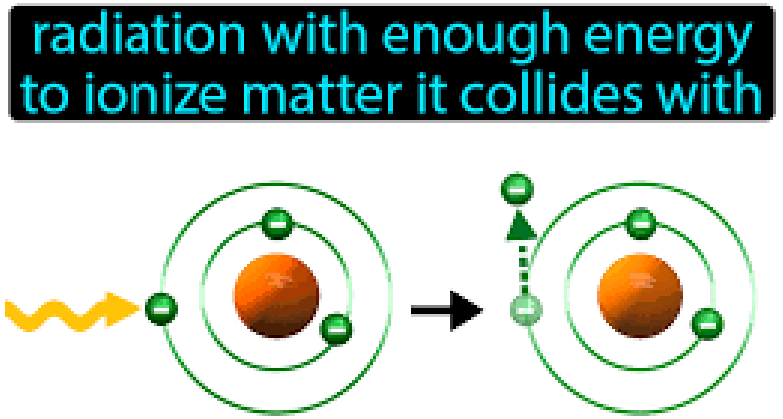
- Ionizing radiation has so much energy it can knock electrons out of atoms, a process known as ionization. Ionizing radiation can affect the atoms in living things, so it poses a health risk by damaging tissue and DNA in genes. Ionizing radiation comes from x-ray machines, cosmic particles from outer space and radioactive elements. Radioactive elements emit ionizing radiation as their atoms undergo radioactive decay.

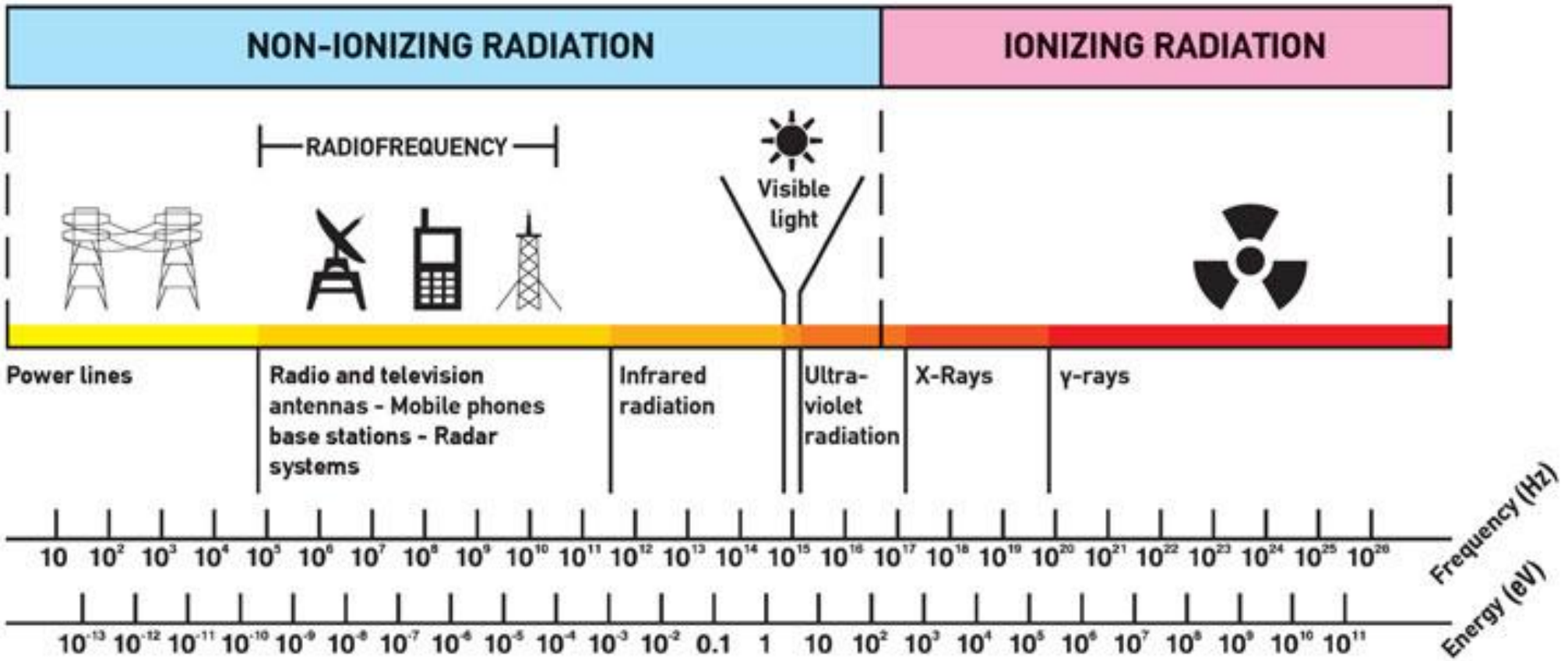
Production of non ionized and ionized radiation

- **Non-ionizing (or non-ionising) radiation refers to any type of electromagnetic radiation that does not carry enough energy per quantum (photon energy) to ionize atoms or molecules—that is, to completely remove an electron from an atom or molecule**. Visible light is produced by vibrations and rotations of atoms and molecules, as well as by electronic transitions within atoms and molecules. We say the atoms and molecules are excited when they absorb and relax when they emit through electronic transitions.

- Ionising radiation is the energy produced from natural or artificial sources. It has more energy than non-ionising radiation, enough to cause chemical changes by breaking chemical bonds. This effect can cause damage to living tissue.

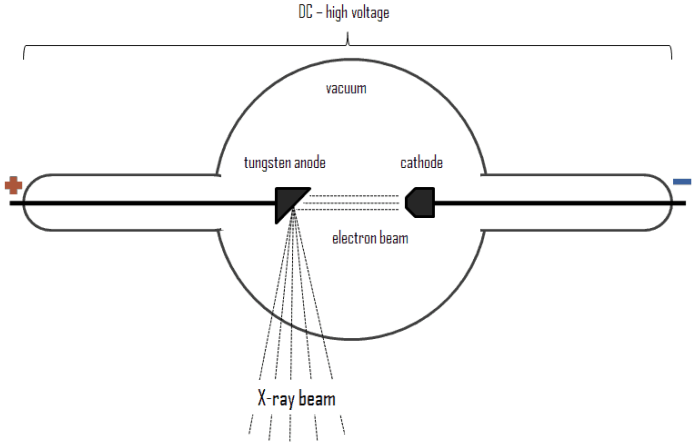


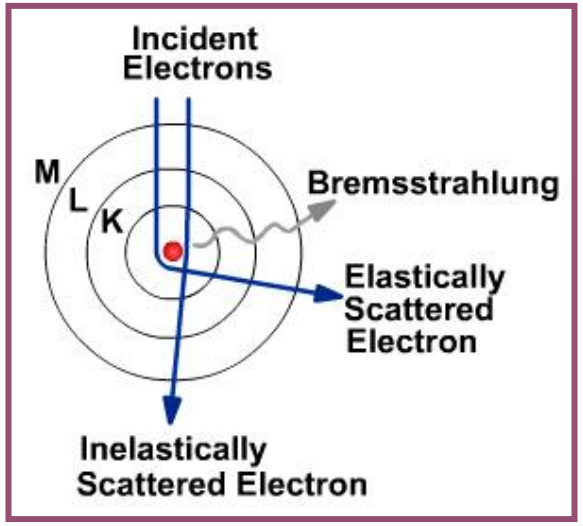



NON-IONIZING RADIATION
IONIZING RADIATION
RADIOFREQUENCY
Visible light
Power lines
Radio and television antennas - Mobile phones base stations - Radar systems
Infrared radiation
Ultra-violet radiation
X-Rays
γ-rays
10 10² 10³ 10⁴ 10⁵ 10⁶ 10⁷ 10⁸ 10⁹ 10¹⁰ 10¹¹ 10¹² 10¹³ 10¹⁴ 10¹⁵ 10¹⁶ 10¹⁷ 10¹⁸ 10¹⁹ 10²⁰ 10²¹ 10²² 10²³ 10²⁴ 10²⁵ 10²⁶
Frequency (Hz)
10⁻¹³ 10⁻¹² 10⁻¹¹ 10⁻¹⁰ 10⁻⁹ 10⁻⁸ 10⁻⁷ 10⁻⁶ 10⁻⁵ 10⁻⁴ 10⁻³ 10⁻² 0.1 1 10 10² 10³ 10⁴ 10⁵ 10⁶ 10⁷ 10⁸ 10⁹ 10¹⁰ 10¹¹
Energy (eV)

Principle of X-Ray imaging

- X-rays are one of the main diagnostic tools in medicine since its discovery by Wilhelm Roentgen in 1895.
- X-rays are produced when high energetic electrons interact with matter.
- The kinetic energy of the electrons is converted into electromagnetic energy by atomic interactions



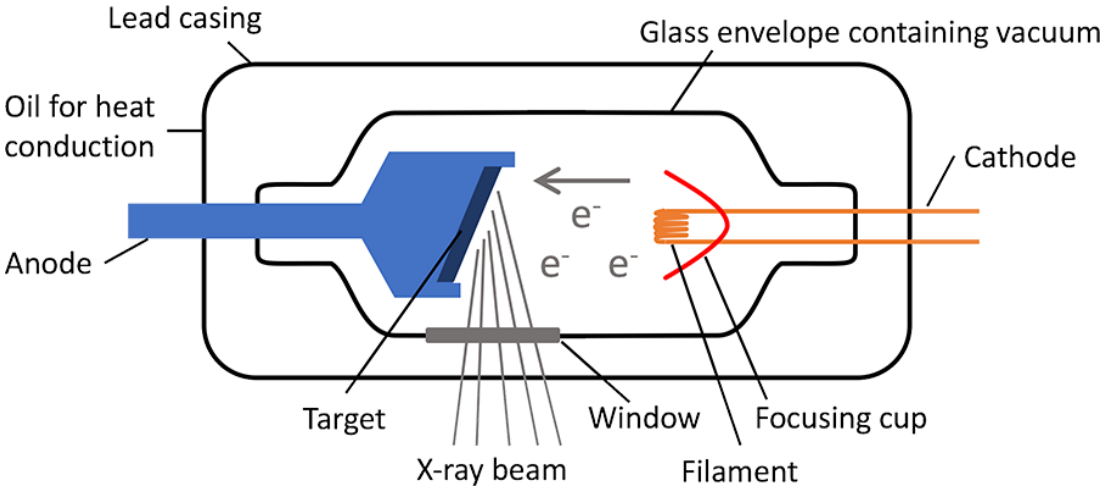


Principle of X-Ray imaging

- The major components of the modern X-ray tube are:
  - cathode (electron source)
  - anode (acceleration potential)
  - rotor/stator (target device)
  - glass/metal envelope (vacuum tube)

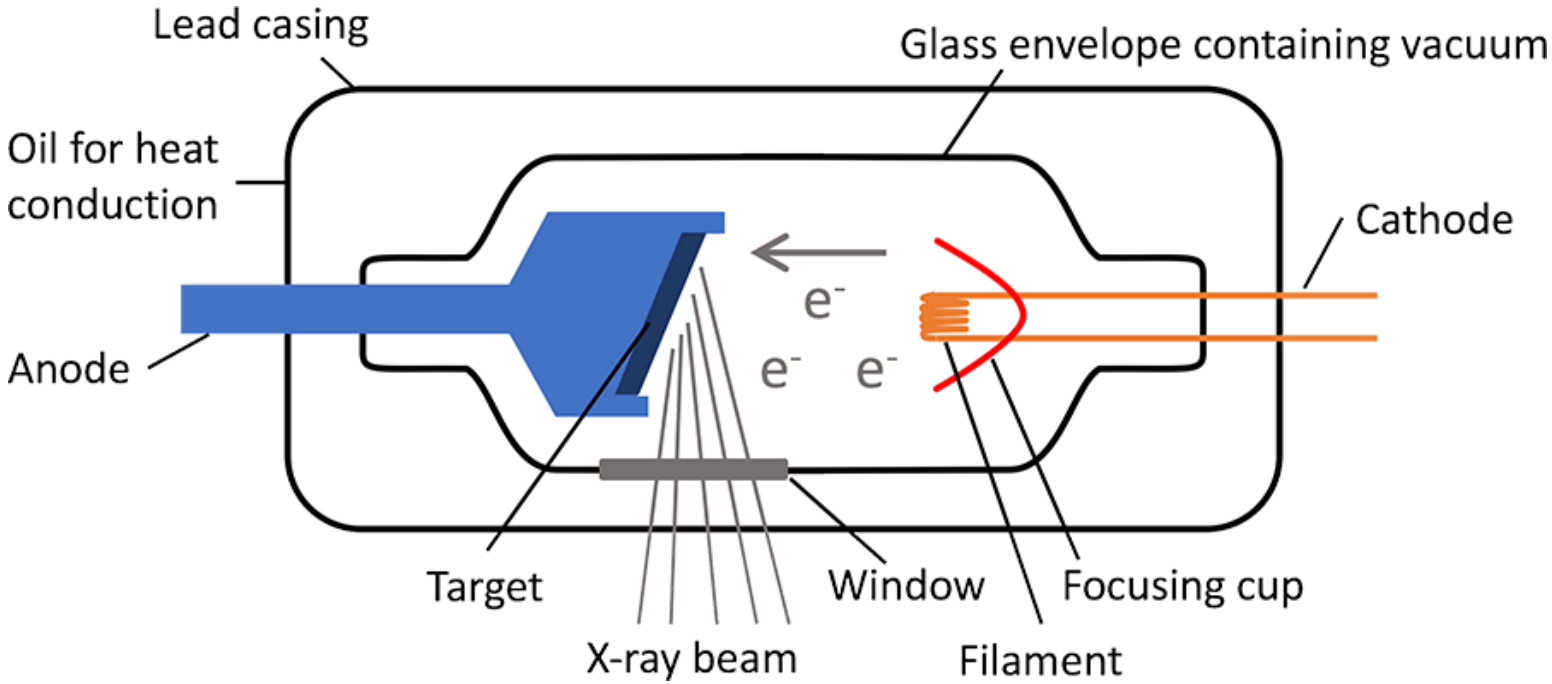
X-Ray production

- Since the quantum energies of x-ray photons are much too high to be absorbed in electron transitions between states for most atoms, they can interact with an electron only by knocking it completely out of the atom. That is, all x-rays are classified as ionizing radiation. This can occur by giving all of the energy to an electron (photoionization) or by giving part of the energy to the electron and the remainder to a lower energy photon (Compton scattering). At sufficiently high energies, the x-ray photon can create an electron positron pair.



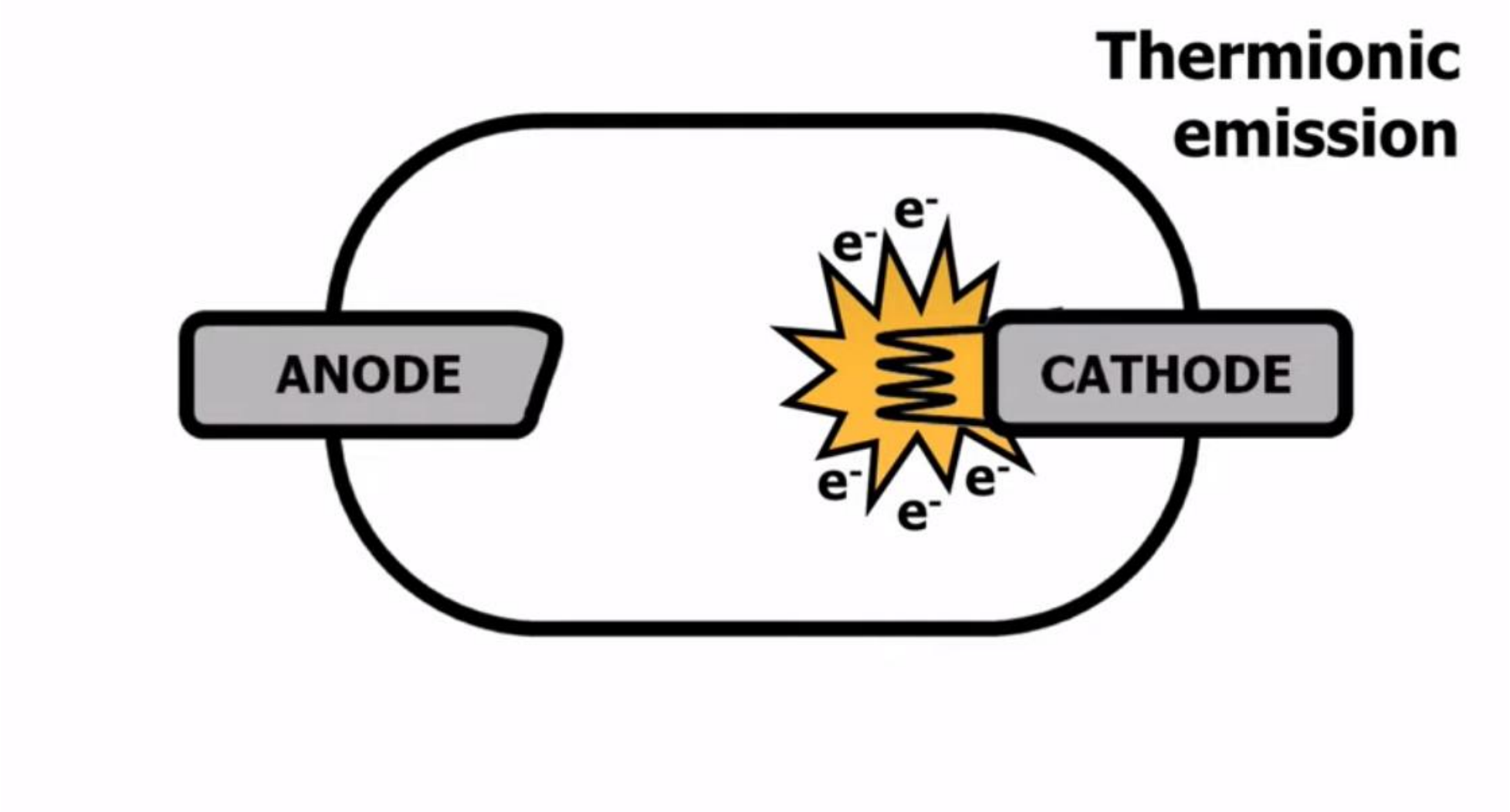
X-Ray production

- Characteristic x rays and low energy bremsstrahlung produced in x-ray tubes are used extensively in diagnostic imaging while high energy x rays produced in linear accelerators provide the basis of modern radiotherapy.

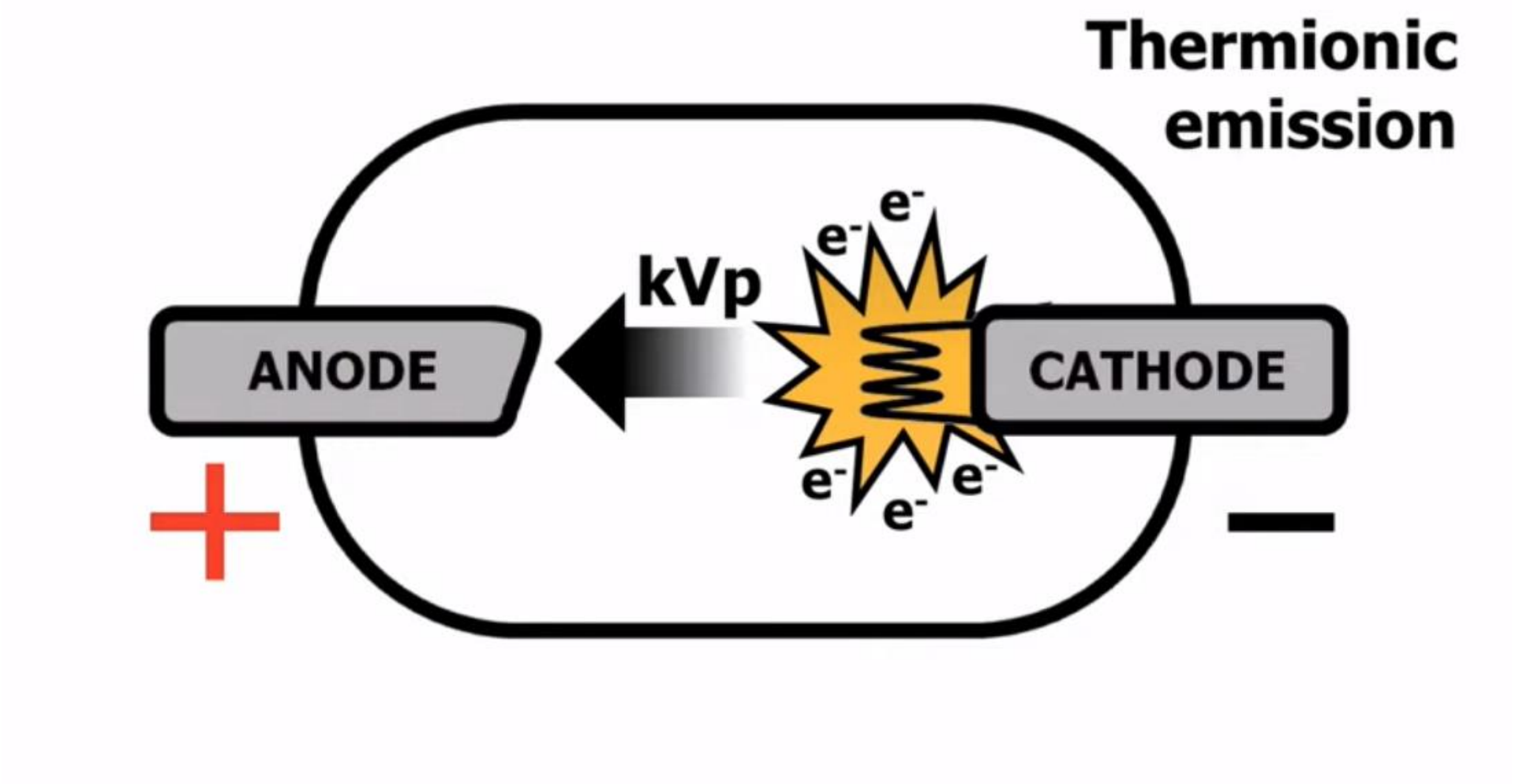


https://www.youtube.com/watch?v=uPoD0jv93Ks

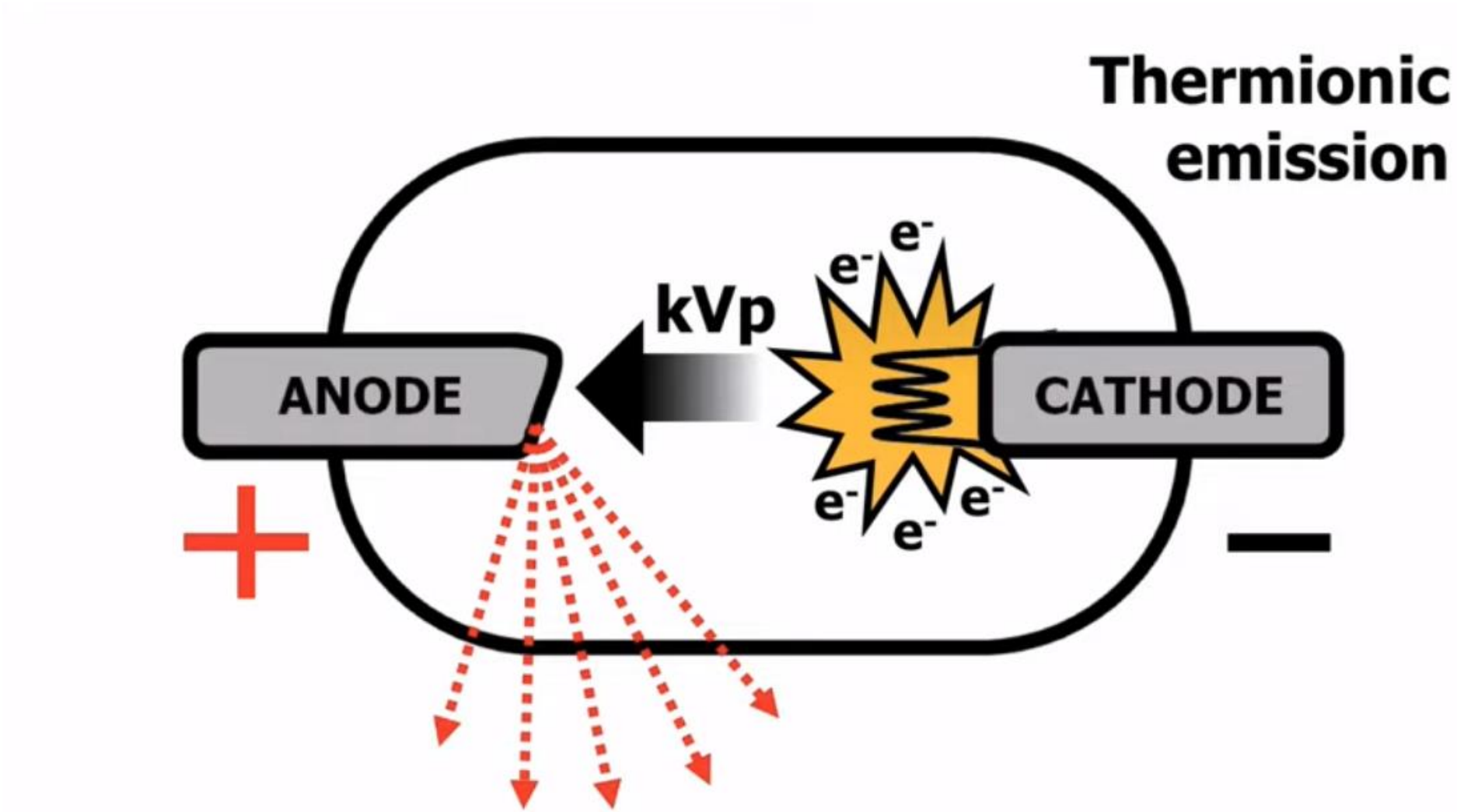
Thermionic emission



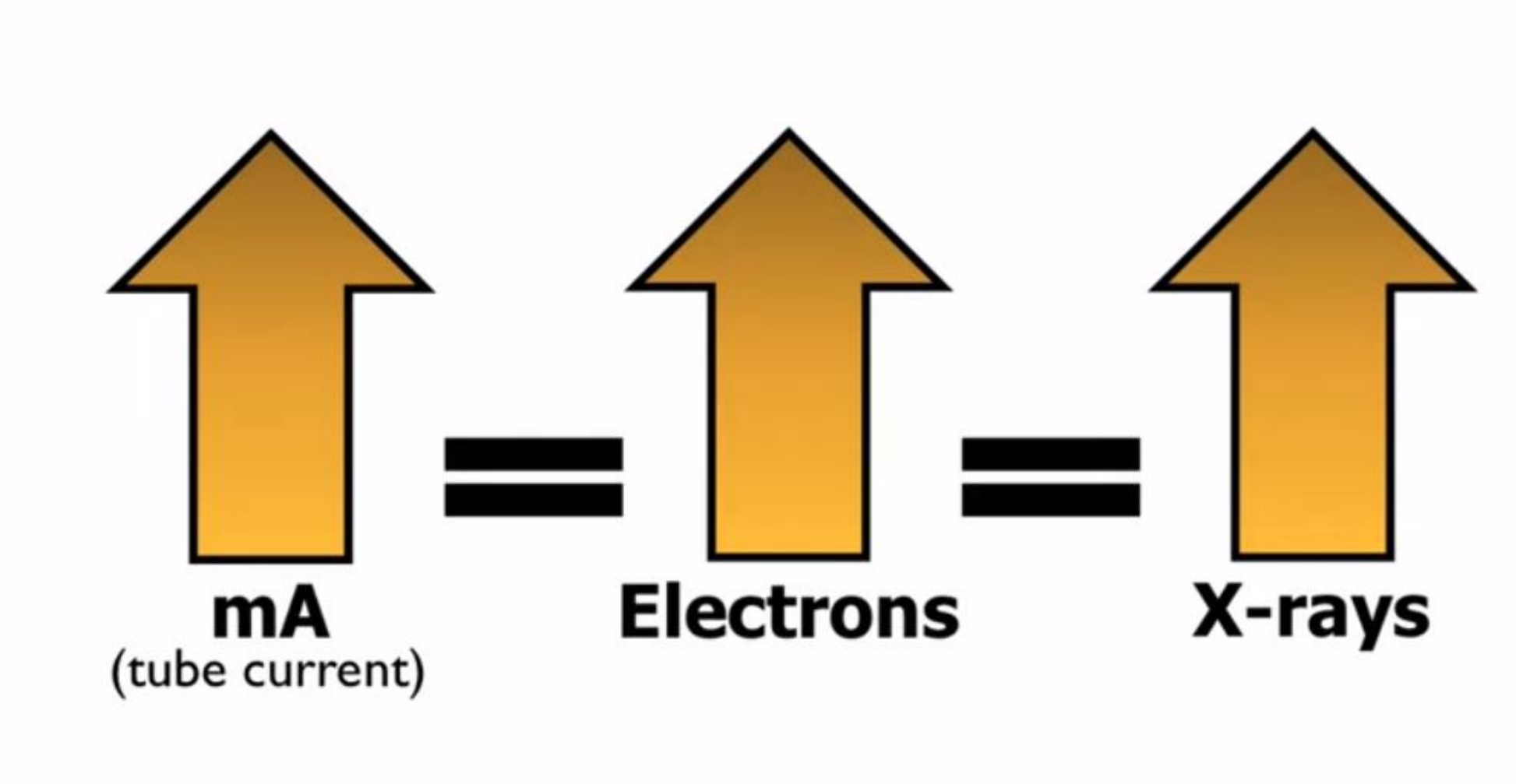
Accelerating the electrons

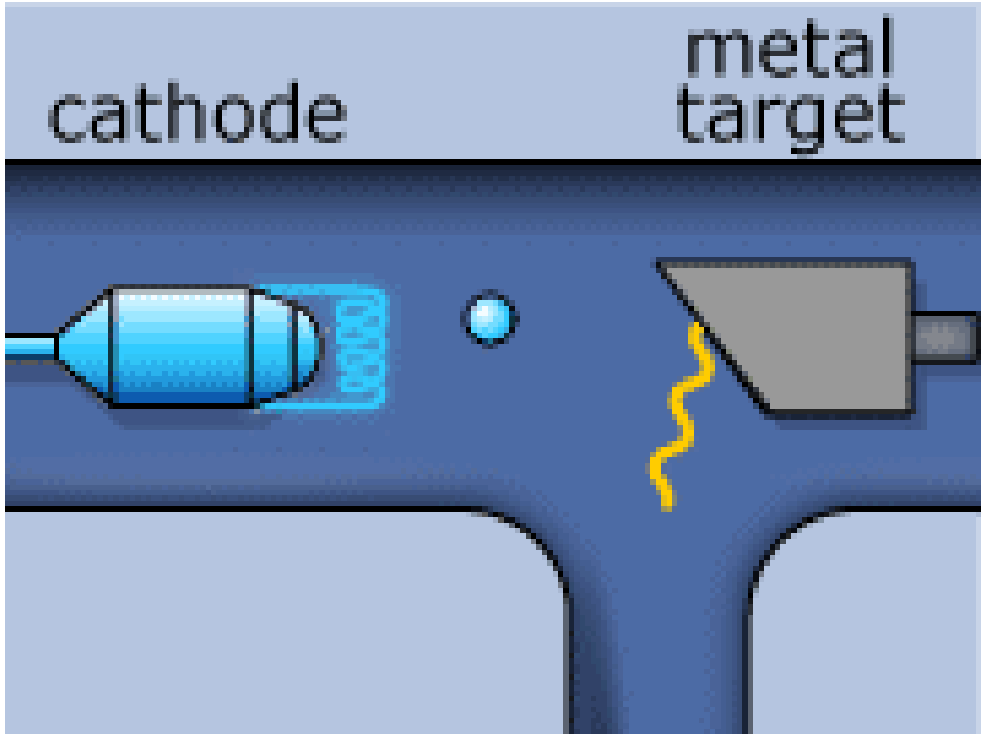


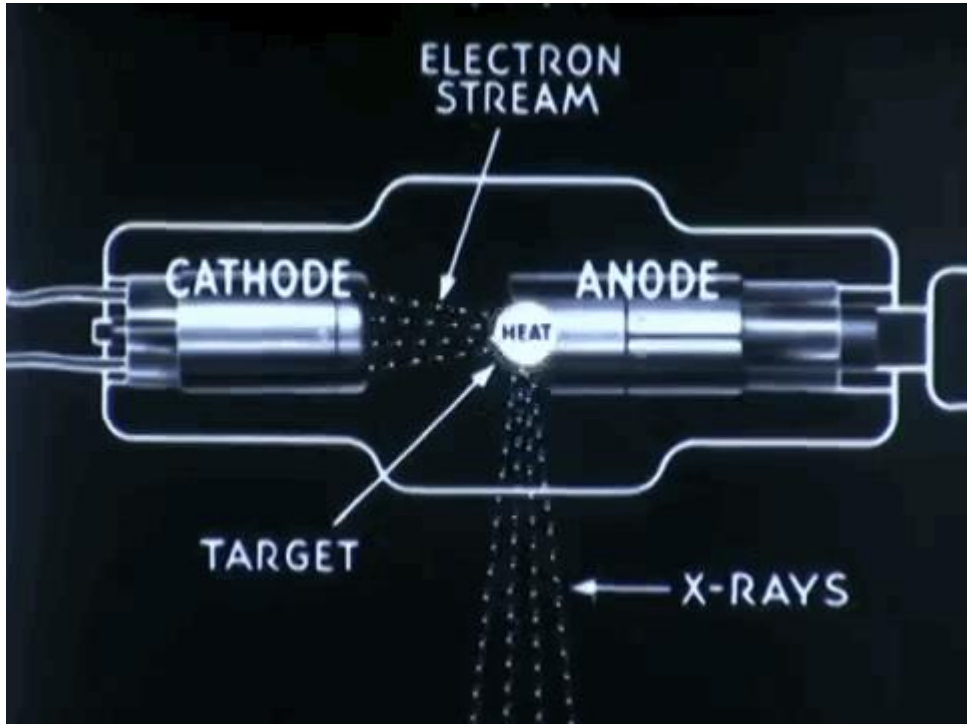
X-Ray production by deaccelerating the electrons



How to increase the intensity?

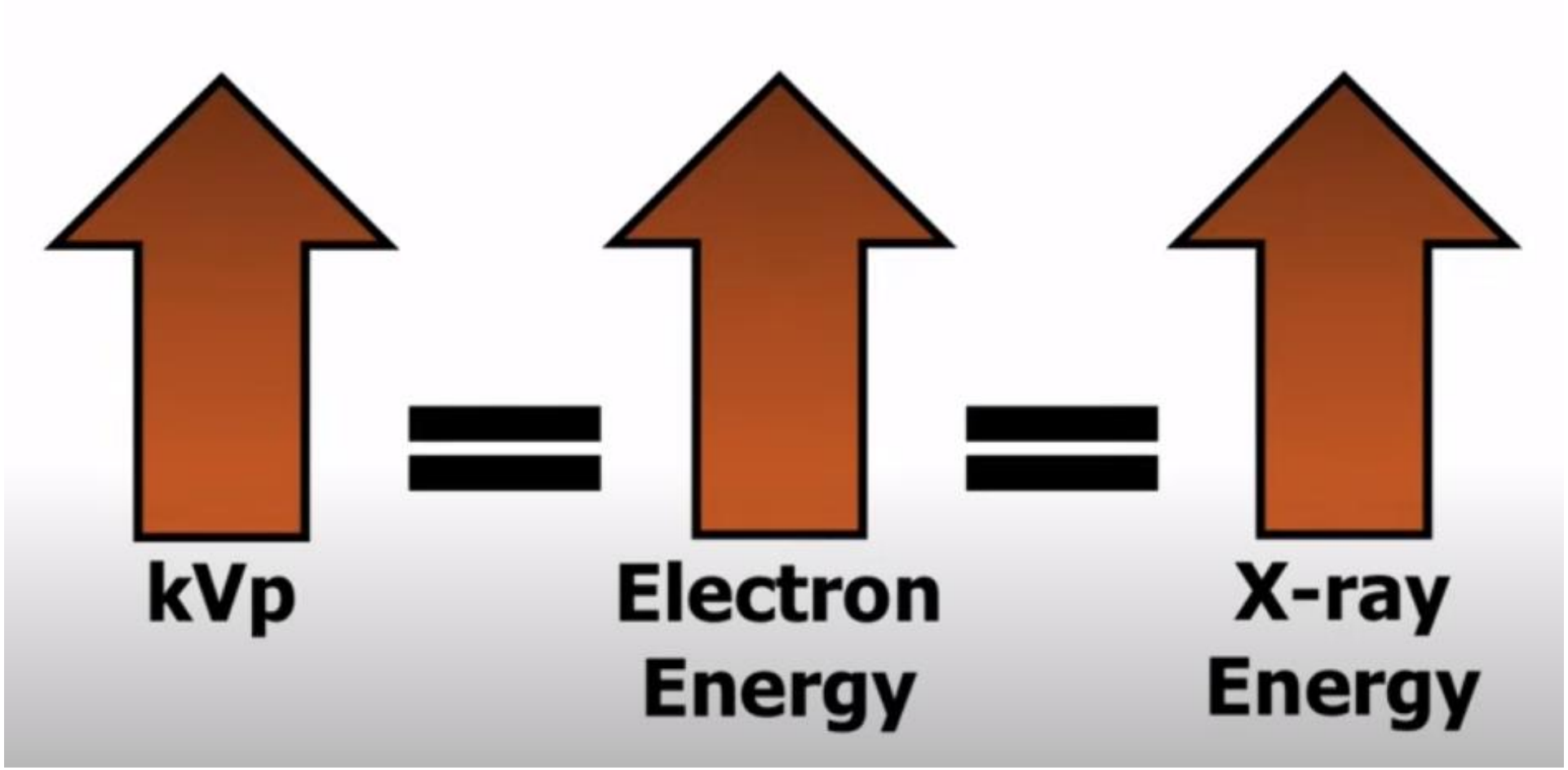




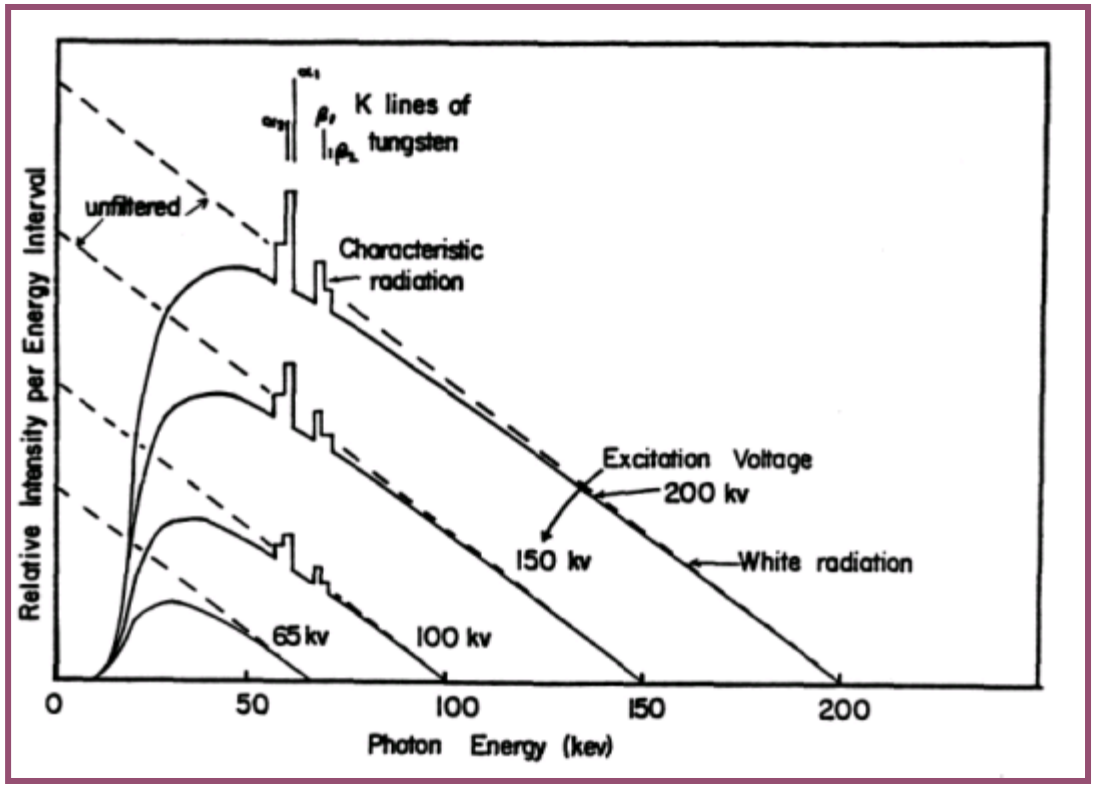


https://www.youtube.com/watch?v=jgc6YYAbR0E

How to increase the energy?



The intensity of the electron beam determines the intensity of the X-ray radiation. The electron energy determines the shape of the bremsstrahlungs spectrum, in particular the endpoint of the spectrum. Low energy X-rays are absorbed in the tube material.



The spectrum of characteristic x-ray photons

- The spectrum of characteristic x-ray photons is discrete and characteristic of the absorber material; the spectrum of bremsstrahlung is continuous and contains photons with energy from 0 to the kinetic energy of the light charged particle that produced the photon.

X-Ray emmison spectrum