Radiological Equipment Techniques (Lec 4)

Autotransformation

1. Autotransformation

The autotransformer has a single winding and is designed to supply a precise voltage to 1-the filament circuit and to 2-the high-voltage circuit of the x-ray imaging system.

This single winding has a number of connections along its length (Figure below).

Two of the connections (A and A′ as shown in the figure below) conduct the input power to the autotransformer and are called primary connections.

Some of the secondary connections, such as C in the figure below, are located closer to one end of the winding than are the primary connections. This allows the autotransformer to increase voltage. Other connections, such as D and E in the figure below, allow a decrease in voltage. The autotransformer can be designed to step up voltage to approximately twice the input voltage value.

Because the autotransformer operates as an induction device, the voltage it receives (the primary voltage) and the voltage it provides (the secondary voltage) are related directly to the number of turns of the transformer enclosed by the respective connections.

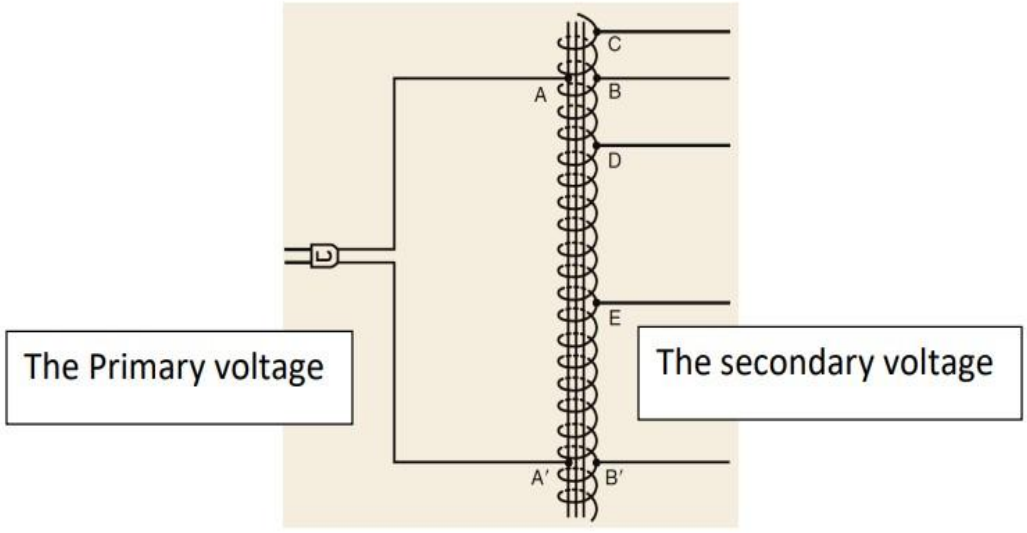


Figure (1): show the primary and secondary voltage.

Autotransformer Law

$$V_s/V_p = N_s/N_p$$

Where:

V_p = the primary voltage

V_S = the secondary voltage

N_P = the number of windings enclosed by primary connections

N_S = the number of windings enclosed by secondary connections

Q/ If the autotransformer in Figure (1) is supplied with 220 V to the primary connections AA′, which enclose 500 windings, what is the secondary voltage across BB′ (500 windings), CB′ (700 windings), and DE (200 windings)?

S/

$$\text{BB: } V_S = V_P\left(\frac{N_S}{N_P}\right)$$

$$= (220\text{ V})\left(\frac{500}{500}\right) = 220\text{ V}$$

$$\text{CB: } V_S = (220\text{ V})\left(\frac{700}{500}\right)$$

$$= (220\text{ V})\,(1.4) = 308\text{ V}$$

$$\text{DE: } V_S = (220\text{ V})\left(\frac{200}{500}\right)$$

$$= (220\text{ V})\,(0.4) = 88\text{ V}$$

Q1/ An autotransformer connected to a 440-V supply contains 4000 turns, all of which are enclosed by the primary connections. If 2300 turns are enclosed by secondary connections, what voltage is supplied to the high-voltage generator?

S/

$$V_S = V_P\left(\frac{N_S}{N_P}\right)$$
$$= (440\ \text{V})\left(\frac{2300}{4000}\right)$$
$$= (440\ \text{V})(0.575)$$
$$= 253\ \text{V}$$

2. kVp Adjustment Peak

kilovoltage (kVp) is the maximum voltage applied across an X-ray tube, it determines the kinetic energy of the electrons accelerated in the X-ray tube and the peak energy of the X-ray spectrum.

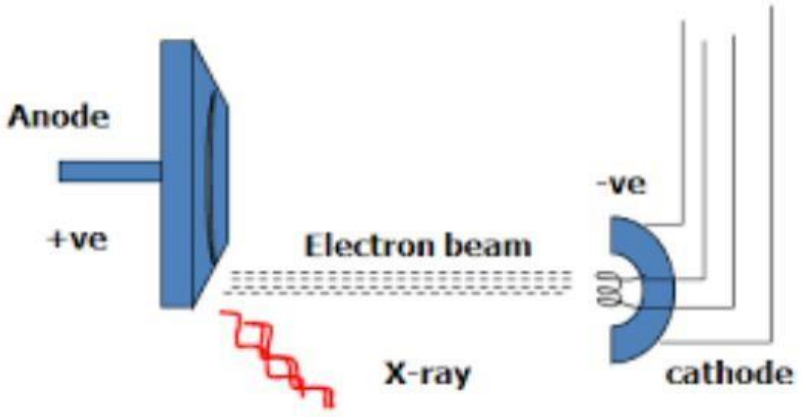


Figure (2): show the KVp.

2.1 kVp effect on x-ray beam

The X-ray beam is polyenergetic (many energies), increasing kVp will increase the average energy of photons in the beam and increase x-ray beam quality. Increase kVp will increase both quantity and quality of X-ray beam.

Increasing the kVp from 72 to 82 shows an increase in the quantity of x-rays (amplitude), and the x-ray emission shifts toward the right, indicating an increase in the energy or quality of the beam. (see figure below).

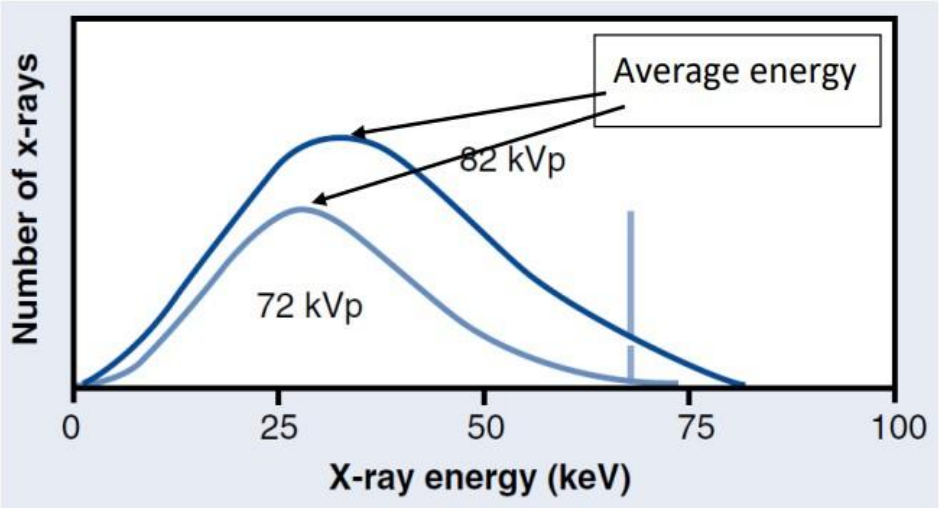
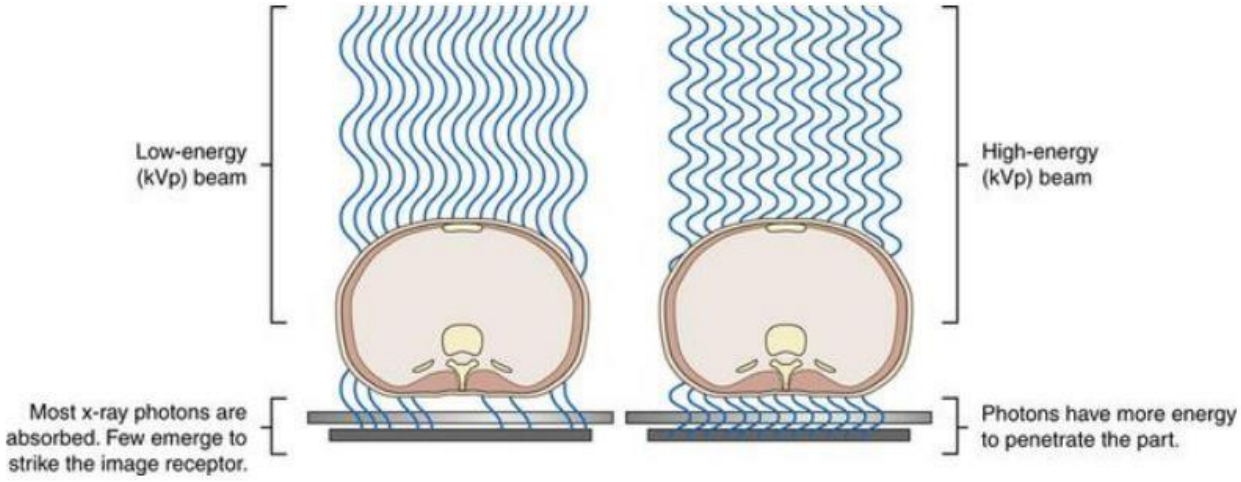


Figure (3): kVp effect on x-ray beam.

Radiation quantity refers to the number of x-rays in an x-ray beam. Radiation quantity is usually expressed in milligray (mGy) or milligray/milliampere-second (mGy/mAs). Radiation quality refers to the energy of the x-ray beam and is expressed in kilovolt peak (kVp) or, more precisely, half-value layer (HVL). A higher quality x-ray beam is (higher energy) leads to more penetration to the anatomy of interest and better reach to the image receptor.



2.2 How increasing kVp affects

X-ray Quality; 1. Higher kVp leads to faster electrons in the tube current from the cathode to the anode. 2. The faster the movement of the electrons in the tube current, the greater the energy of the x-rays produced. 3. The greater the energy of the x-rays produced, the greater the penetrability of the X-ray beam.

2.3 Percentage of x-ray interactions

As x-ray energy is increased, the absolute number of Compton interactions decreases, but the number of photoelectric interactions decreases much more rapidly. Therefore, the relative number of x-rays that undergo Compton scattering increases.

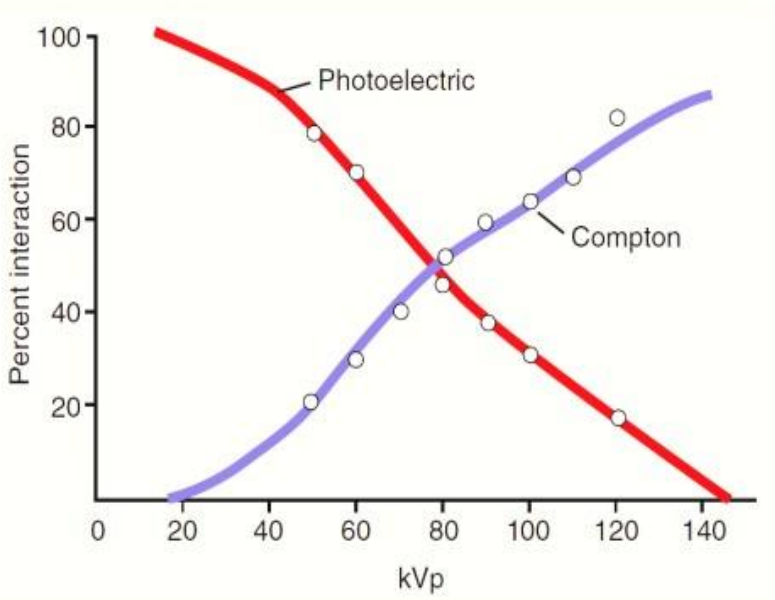


Figure (5): show the percentage of x-ray interactions.

2.4 kVp effect on image quality

Because x-rays have higher energy, they also interact more by Compton effect and produce more scatter radiation, which results in reduced image contrast. The kVp controls the scale of contrast on the finished radiograph because when kVp increases, there will be less differential absorption occurs. Therefore, high kVp results in reduced image contrast.

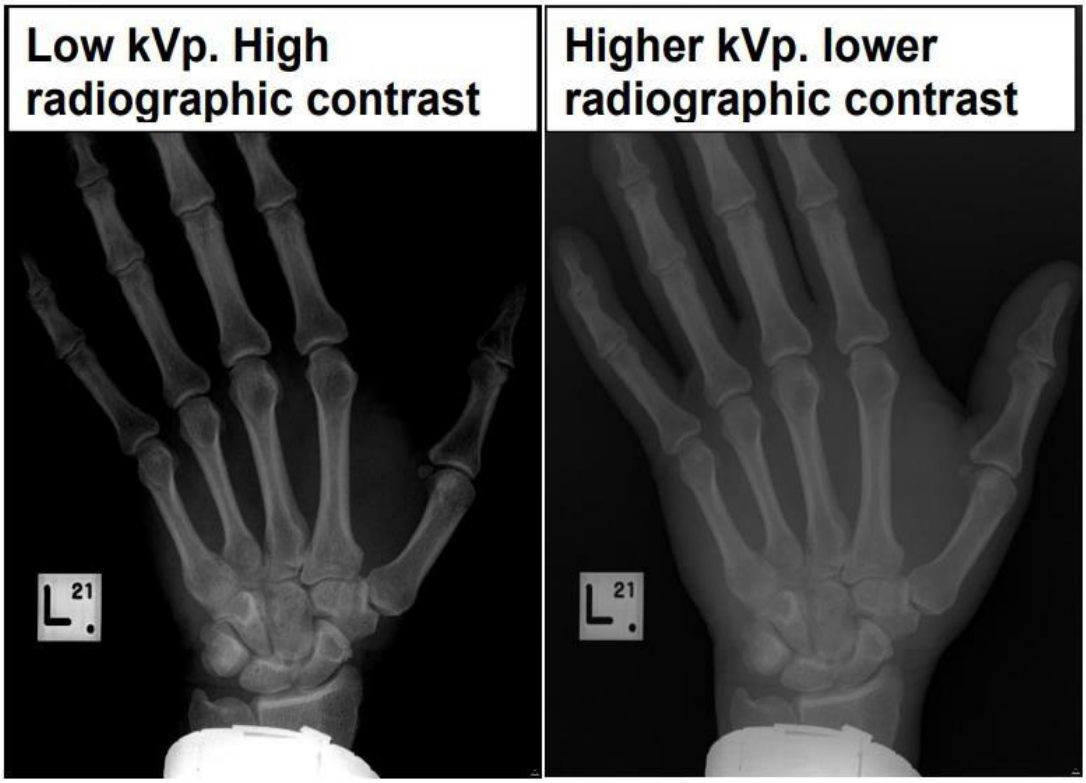


Figure (6): show the kVp effect on image quality