CHAPTER 5

X-ray Production

LEARNING OBJECTIVES

- Describe a simple x-ray tube and label its parts
- Describe both the composition and the function of the basic parts of the x-ray tube
- Associate the terms *anode* and *cathode* with the appropriate parts of the x-ray tube
- Describe the production of bremsstrahlung and characteristic radiation and explain what determines the wavelength of each

LEARNING OBJECTIVES

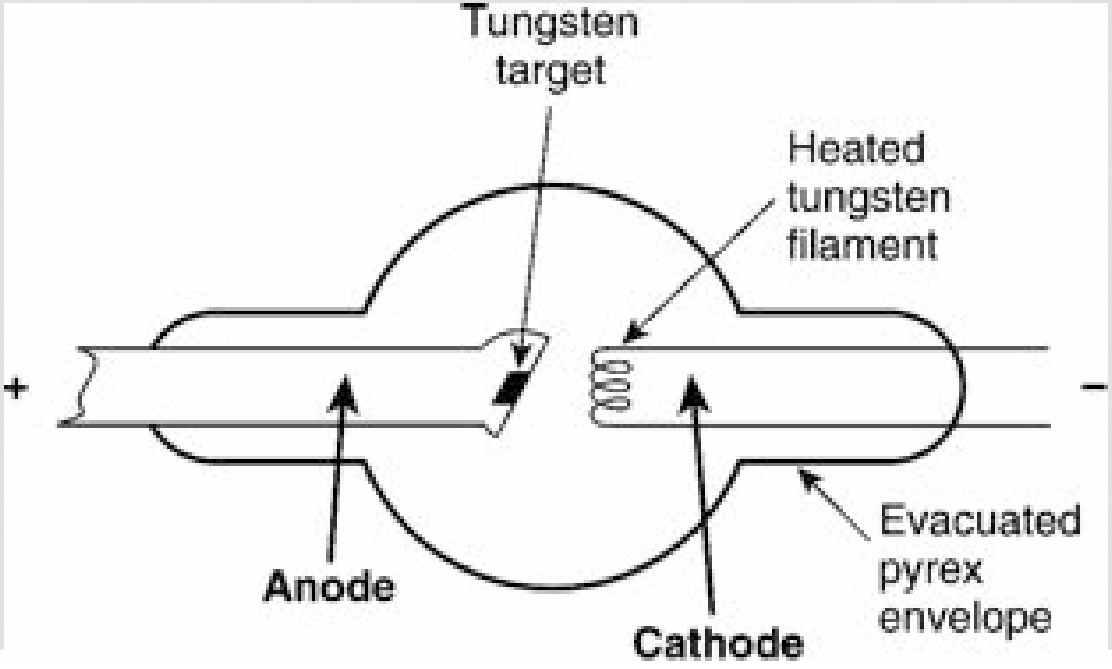
- Explain what is meant by a dual-focus tube and describe its advantages
- Explain the significance of the target angle with respect to the line focus principle and the maximum field size
- Define *effective focal spot* and state its significance with respect to the radiographic image

LEARNING OBJECTIVES

- Explain the function of a rotating anode and state its purpose
- State the effect of changes in milliamperage (mA) and kilovolt (kVp) levels on the resulting x-ray beam

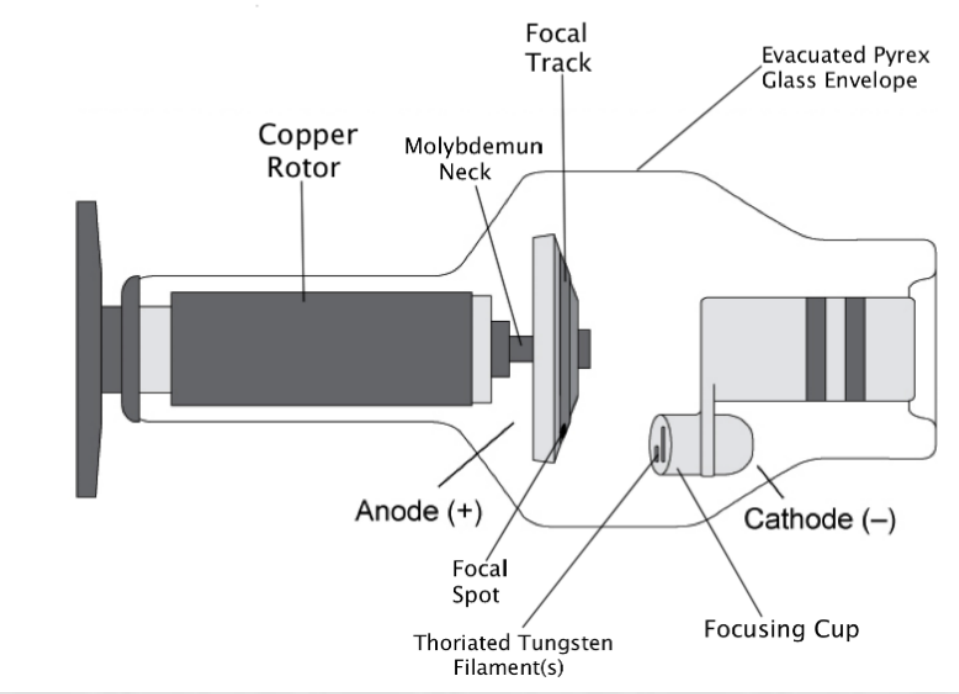
X-RAY TUBE

- Vacuum Pyrex Envelope
  - Houses the anode and cathode
- Anode
  - Positive end of the x-ray tube
  - Contains the tungsten target
- Cathode
  - Negative end of the x-ray tube
  - Contains the tungsten filament



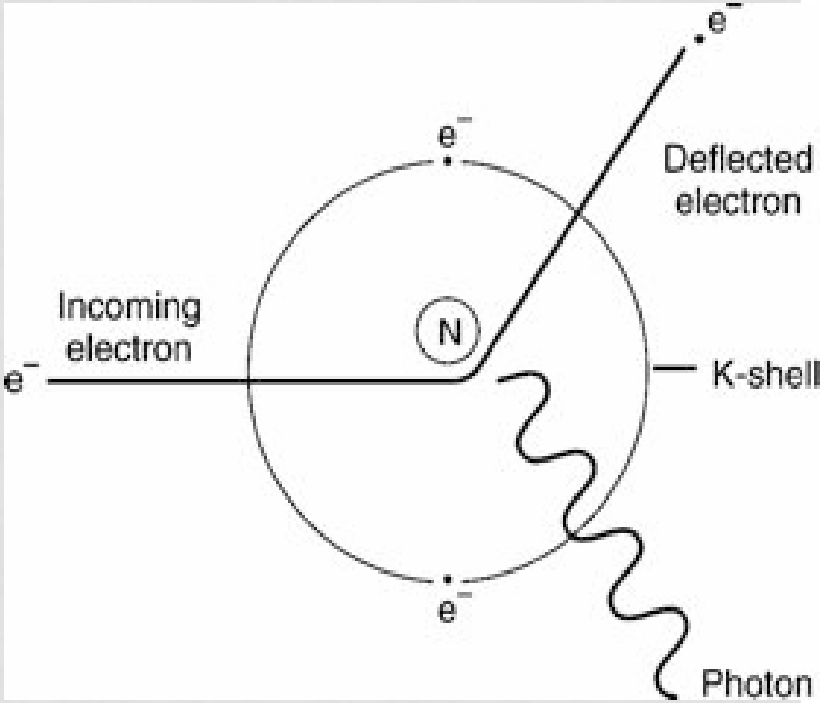
X-RAY PRODUCTION

- Tungsten filament is heated to produce thermionic emission or the release of negatively charged electrons
- Step-up transformer provides a high voltage source to the current that goes through the tube
- Upon striking the target, the kinetic energy or movement of the electrons is converted to x-rays (1%) and heat (99%)



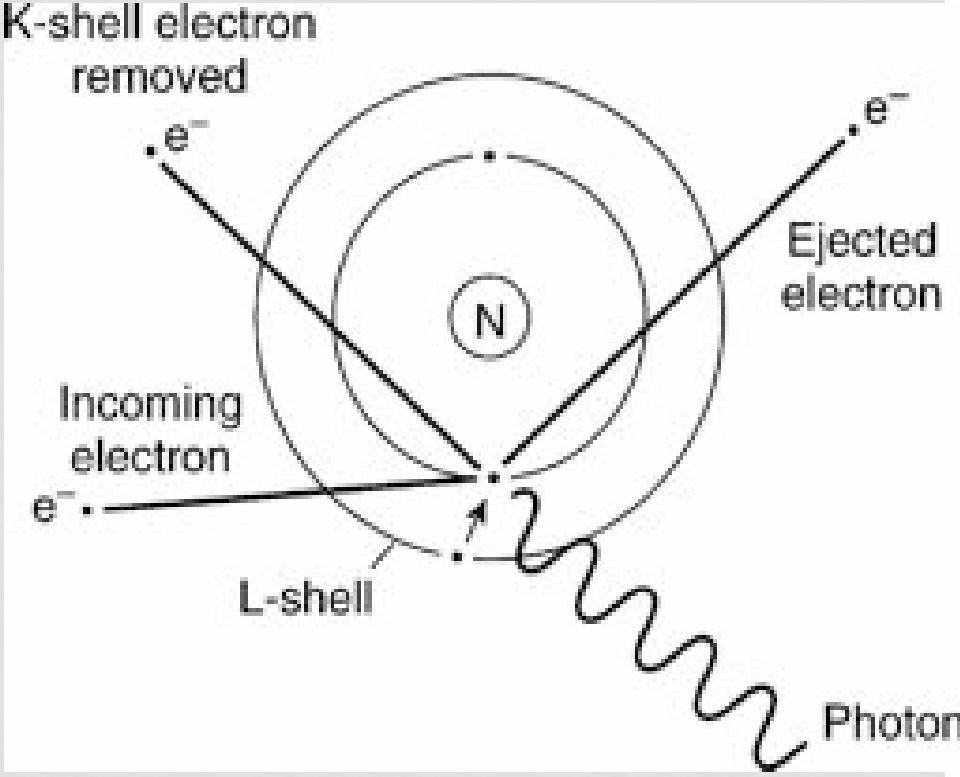
BREMSSTRAHLUNG RADIATION

- Occurs when an electron passes close to the nucleus of a target atom
- Positively charged nucleus attracts the negative electron causing it to slow and lose energy
- Lost electron kinetic energy is converted to an x-ray photon



CHARACTERISTIC RADIATION

- Occurs when an electron collides with a K-shell electron of a target atom
- K-shell electron is knocked out creating a vacancy
- Energy in the form of an x-ray photon is released when an electron from the atom fills the K-shell vacancy

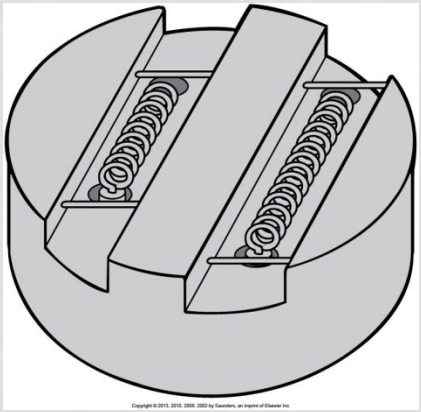


RADIATION

- Bremsstrahlung Radiation
  - Makes up the majority of the x-ray beam
  - Below 70 kVp, 100% of photons in x-ray beam
- Characteristic Radiation
  - Minimum of 70 kVp is needed for characteristic x-rays to be produced
  - Above 70 kVp, 15% of photons in x-ray beam

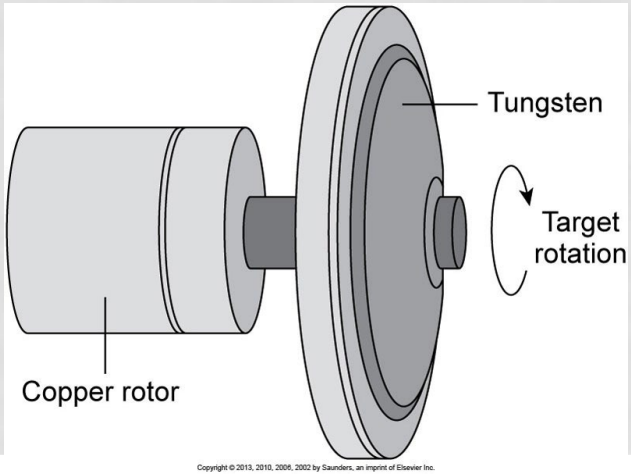
CATHODE AND ANODE

- Cathode
  - Frequently contains a large and a small filament (dual-focus) within a focusing cup
  - Focusing cup propels electrons toward a specific area of the anode target



- Anode
  - The focal spot is the area of target with which electrons interact
  - Rotates during exposure to distribute and dissipate heat from electron interaction

*Rotates at about 3600 rpm during exposure; most modern x-ray tubes also have a high speed rotation of 10,000 rpm



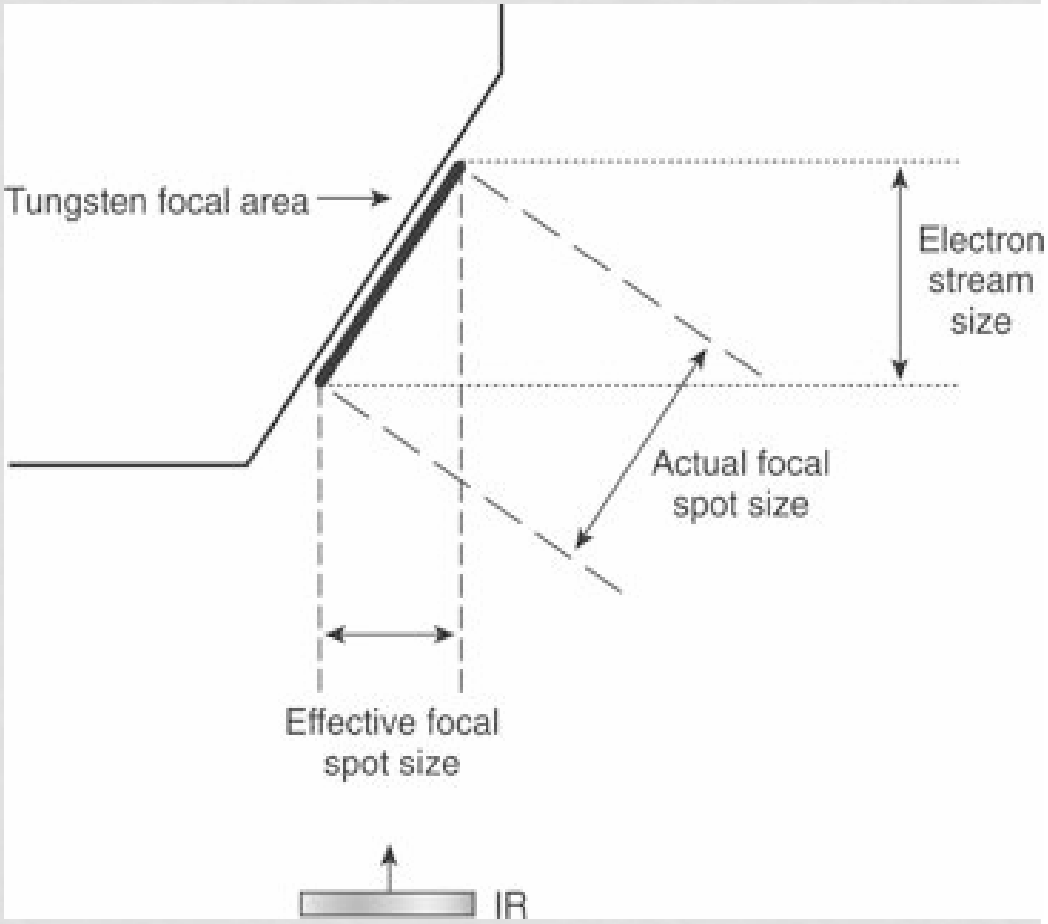
DUAL FOCUS X-RAY TUBES

- Small Filament
  - Smaller stream of electrons results in fewer x-rays, less heating of the anode, and greater image detail
  - Use for medium and small patients
- Large Filament
  - Larger stream of electrons results in more x-rays, greater anode heating, and less image detail
  - Use for large patients

LINE FOCUS PRINCIPLE

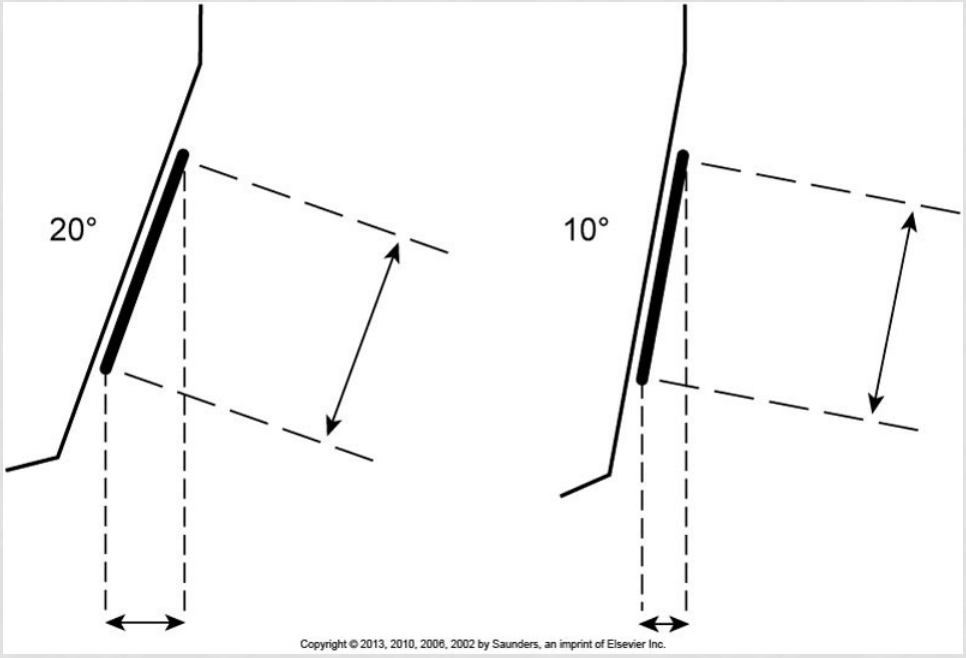
- Relationship between actual and effective focal spots
  - Actual focal spot is the target area struck by electrons during an exposure
  - Effective focal spot is the target area from which x-rays are projected toward the IR

*The slanted anode angle is called the target angle; can range from 7 to 17 degrees; 12 degrees is the most common

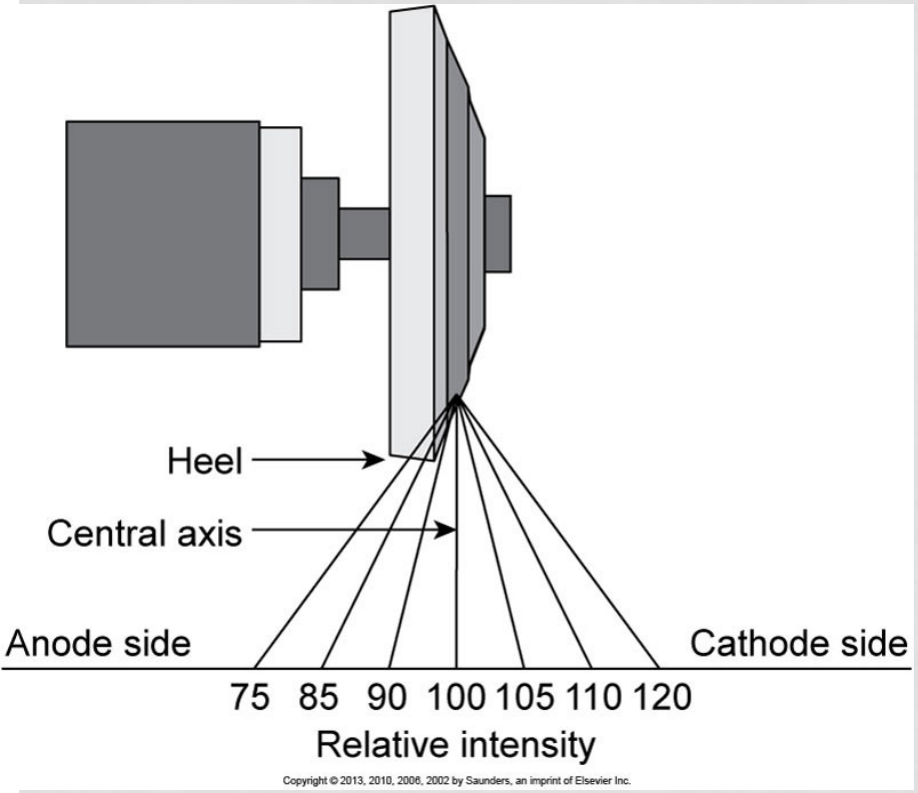


LINE FOCUS PRINCIPLE

- Because of the anode angle, the effective focal spot is always smaller than the actual focal spot
- A smaller target angle results in a smaller effective focal spot with a given actual focal spot size.



ANODE HEEL EFFECT



- Refers to the absorption of x-rays by the anode target's heel
- Radiation intensity is greater at the cathode and less at the anode ends of the x-ray beam
- Use to produce more uniform radiographic density of body parts such as the thoracic spine by placing the thicker portion under the cathode end of the beam and the thinner portion under the anode portion

KILOVOLTAGE AND X-RAY PRODUCTION

- The amount of voltage applied to the x-ray tube will control the speed and the power of the electrons in the electron stream
- Higher kVp increases electron speed during x-ray production resulting in x-rays with shorter wavelengths, more energy, and greater penetrating ability
- Use higher kVp for larger and/or denser body parts

kVp controls the *penetration* and the *contrast* of the image

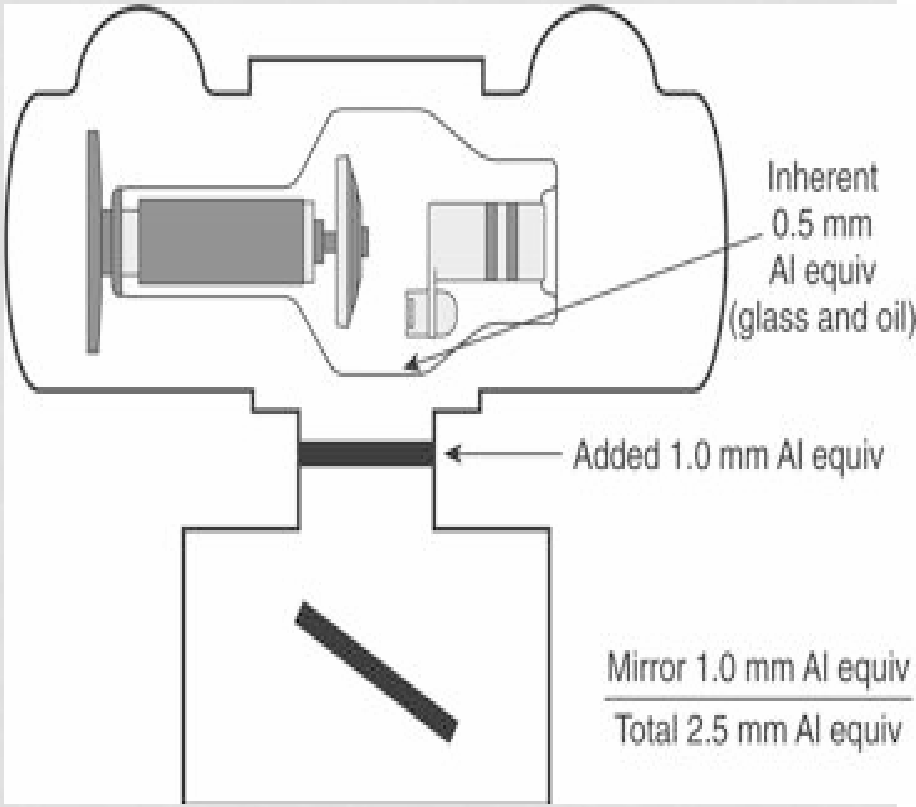
MILLIAMPERAGE, TIME, AND X-RAY PRODUCTION

- Milliamperage – measure of the rate of current flow across the x-ray tube
  - Higher mA results in more x-rays produced per seconds of exposure
  - Use higher mA for larger body parts
- Time – exposure time
  - Amount of time x-rays are being produced
  - Most exposure times are < 1 second
- mAs – milliampere-seconds
  - Product of mA × time
  - Indicates the total quantity of the exposure

mAs controls the quantity of exposure and the *density* of the image

FILTRATION

- Removes low energy, long-wavelength x-ray photons that cause unnecessary patient exposure
- Classified as inherent and added
- Total filtration is a combination of inherent and added and is equivalent to 2.5 mm of aluminum as required by federal law



SUMMARY

- The x-ray tube has a positive anode (target) and negative cathode (filament)
- When high-speed electrons from the filament interact with the target bremsstrahlung, characteristic x-rays are produced
- Dual-focus x-ray tubes have a large and a small filament

SUMMARY

- Small filaments result in smaller focal spots with better image detail but less heat loading capacity
- Because of the anode angle, the effective focal spot is always smaller than the actual focal spot
- Anode heel effect refers to a variation in radiation intensity between the anode and cathode ends of the x-ray beam

SUMMARY

- kVp affects the penetrating ability of the x-rays
- mA affects the number of x-rays produced per second
- Time is how long x-rays are produced
- mAs is the product of time and indicates the total exposure
- Filtration removes long wavelength, low energy x-rays that would be absorbed by the patient