Ministry of Higher Education and Scientific Research
University of Al-Mustaqbal
College of Health and Medical Technologies

General Physics

Frist Stage

A Lecture Two Title / Practical

Introduction to X-Ray Production

AN

By

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General guidelines:

- **Keep your mobile phone on silent mode during the lecture.**
- **Maintain quiet and avoid noise inside the hall.**

Structure Path

General Objective of the Lecture

To provide students with a foundational understanding of how X-rays are produced, including the role of electrical circuits, energy conversion in the X-ray tube, and the physical properties that determine their clinical use and safety requirements.

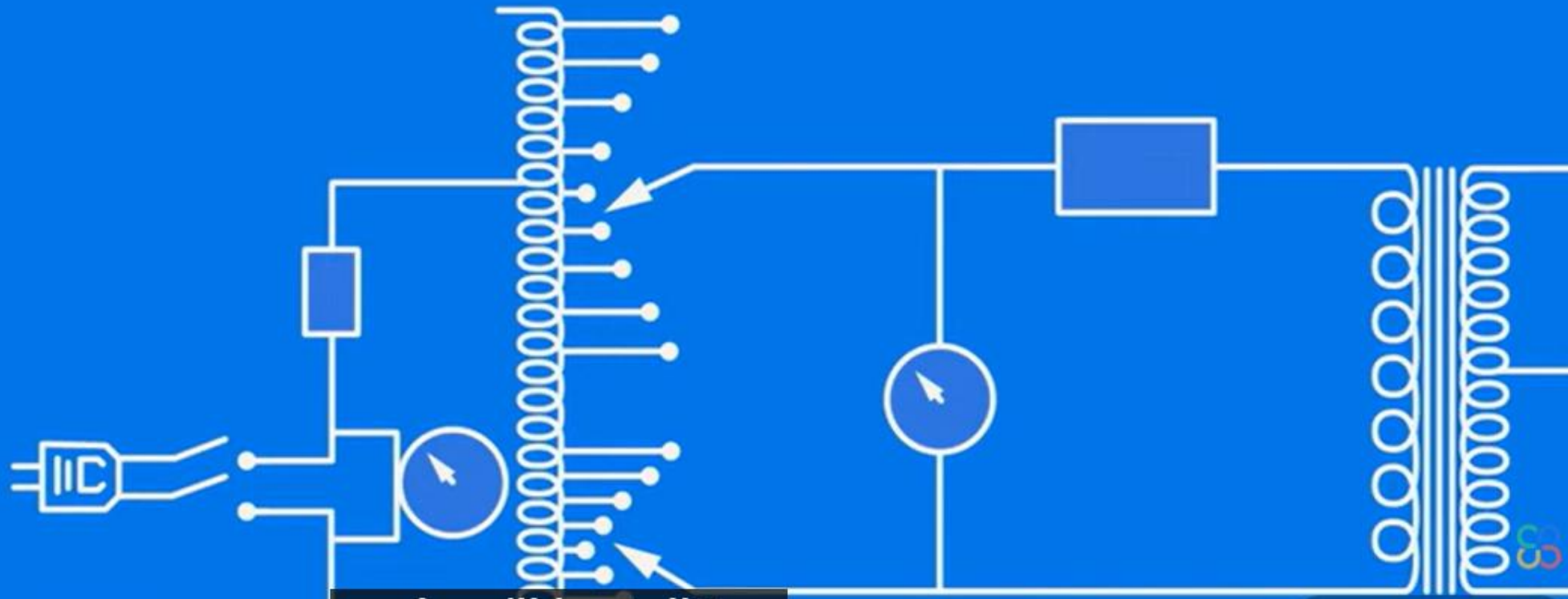
Behavioral (Performance/Learning) Objectives: By the end of this research/presentation, the candidate is expected to demonstrate the ability to:

- **(Remembering) the basic principle of X-ray production by the end of the lecture.**
- **(Understanding) That the student explains the function of the key components in the primary, secondary, and filament circuits by the end of the lecture**
- **(Applying) That the student applies the power formula (P = IV) and Ohm's Law (V = IR) to calculate power by the end of the lecture.**

The primary function of an X-ray imaging system (Figure 1) is to convert electric energy into electromagnetic energy. Electric energy is supplied to the x-ray imaging system in the form of a well-controlled electric current. A conversion takes place in the x-ray tube, where most of this electric energy is transformed into heat, some of it into x-rays.

The Primary Circuit - X Ray Physics

Primary Circuit



and we'll be talking
about the primary circuit.

0:09 / 4:43

Clover Learning

Components of the primary circuit

Component	Function / Working Principle
1. Main Power Switch	It is the first control element in the primary circuit. Turns the power on/off for the entire X-ray machine.
2. Circuit Breaker / Fuse	A protective device that stops electrical current if there is overload or fault.
4. Autotransformer (kVp Selector)	A transformer with a single winding is used to select the desired kilovoltage peak (kVp) setting.
5. Exposure Timer / Control	Controls how long the X-ray exposure lasts.
6. Primary Side of Step-Up Transformer	The part of the high-voltage transformer that receives controlled low voltage from the autotransformer.

Quick Quiz – 3 Minute! (Individual activity)

Total score: 0.5 point

Scan → Think → Submit

Question (1) ❓ What is the last part of the first electrical circuit?

1. Main Power Switch
2. Fuse
3. Exposure Timer
   Primary Side of Step-Up Transformer

Google forms

Electric Power

Electric power is measured in watts (W).

Electric Power

$P = IV$

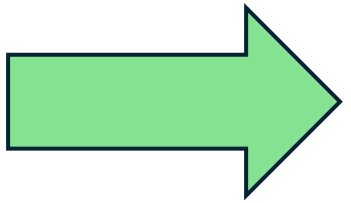
where P is the power in watts, I is the current in amperes, and V is the electric potential in volts; alternatively,

$P = IV = I(IR)$

therefore,

$P = I^2R$

where R is resistance in ohms.



Ohm's Law

$V = IR$

Question: An x-ray imaging system that draws a current of 80 A is supplied with 220 V. What is the power consumed?

Answer:

$$P = IV$$
$$= (80\ A)(220\ V)$$
$$= 17{,}600\ W$$
$$= 17.6\ kW$$

Question: The overall resistance of a mobile x-ray imaging system is 10Ω. When plugged into a 110-V receptacle, how much current does it draw and how much power is consumed?

Answer:

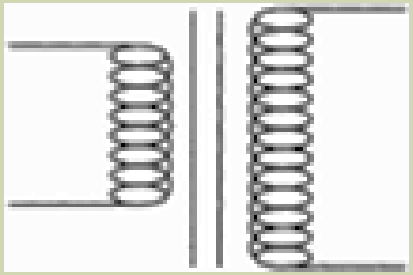
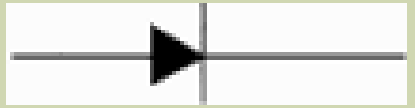
$$P = IV$$
$$= (11A)(110\ V)$$
$$= 1210\ W$$

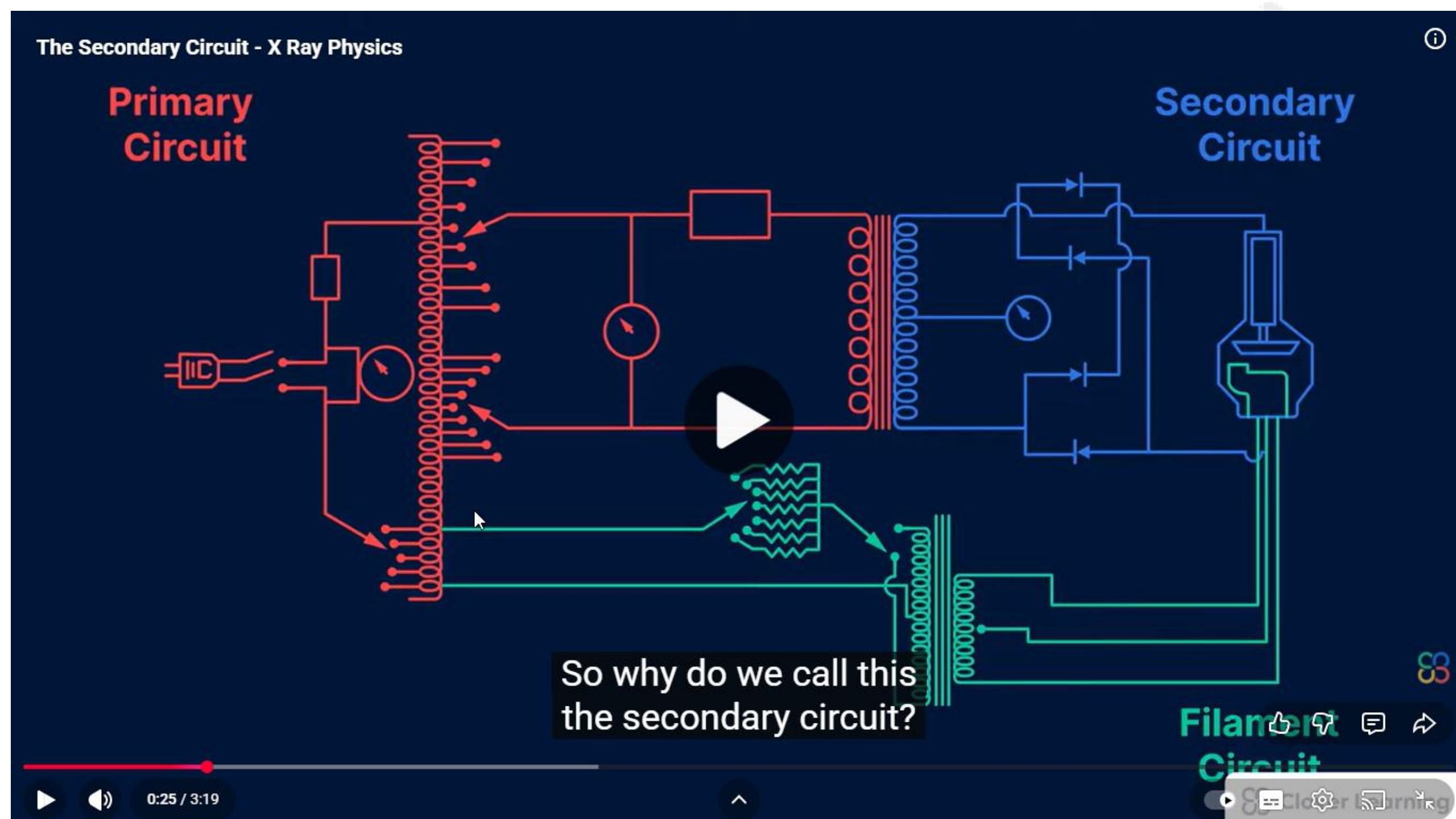
or

$$P = I^2R$$
$$= (11A)^2 10$$
$$= 1210\ W$$

X-ray circuits are also complicated and contain a number of different types of circuit elements. Table 1 identifies some of the important types of circuit elements, the functions of each, and their symbols.

TABLE 4-2 Symbol and Function of Electric Circuit Elements

Circuit Element	Symbol	Function
Resistor		Inhibits flow of electrons
Battery		Provides electric potential
Capacitor		Momentarily stores electric charge
Transformer		Increases or decreases voltage by fixed amount (AC only)
Diode		Allows electrons to flow in only one direction


The Secondary Circuit - X Ray Physics
Primary Circuit
Secondary Circuit
So why do we call this the secondary circuit?
Filament Circuit
0:25 / 3:19

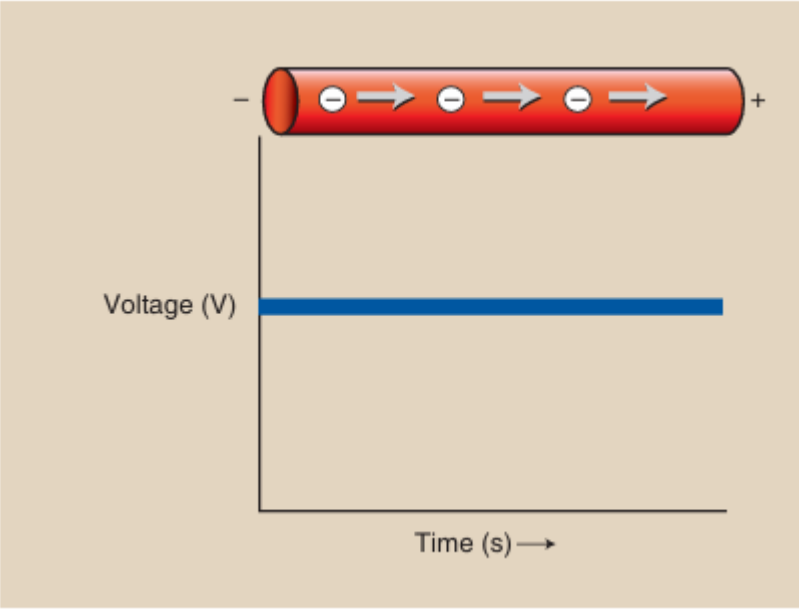
Components of the Secondary circuit

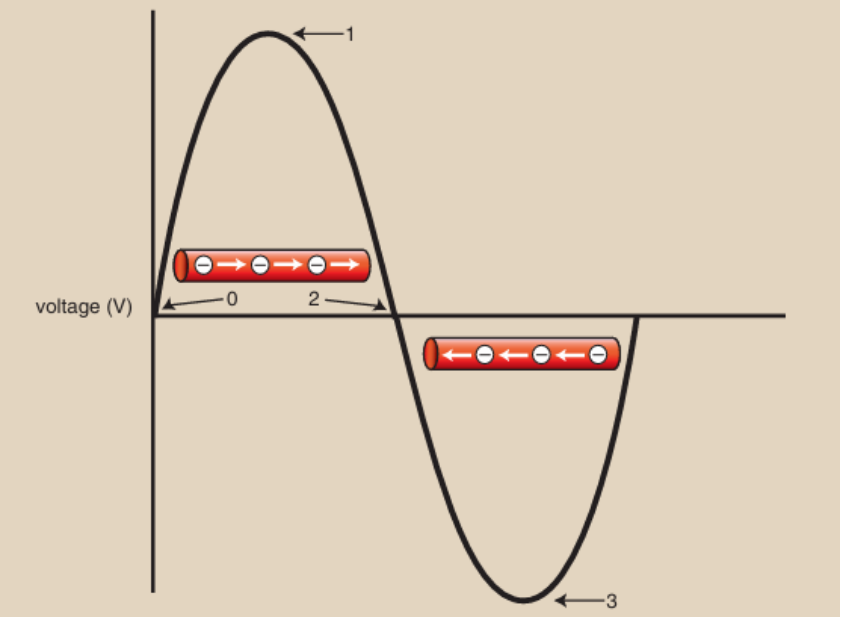
Component	Function / Working Principle
High-Voltage Transformer (Secondary Winding)	Steps up the voltage from the primary circuit to a very high voltage (kV) required to accelerate electrons across the X-ray tube.
Rectifier	Converts high-voltage alternating current (AC) into high-voltage direct current (DC) so that electrons flow in only one direction (from cathode to anode).
X-Ray Tube	The site of X-ray production.

Direct current (DC), Alternating current (AC).

Electric current, or electricity, is the flow of electrons through a conductor. These electrons can be made to flow in one direction along the conductor, in which case the electric current is called direct current (DC). Most applications of electricity require that the electrons be controlled so that they flow first in one direction and then in the opposite direction. Current in which electrons oscillate back and forth is called alternating current (AC).

Electrons that flow in only one direction constitute DC; electrons that flow alternately in opposite directions constitute AC.





Quick Quiz – 3 Minutes! (Group activity)

Total score: 0.5 points

Scan → Decide → Submit

Google forms

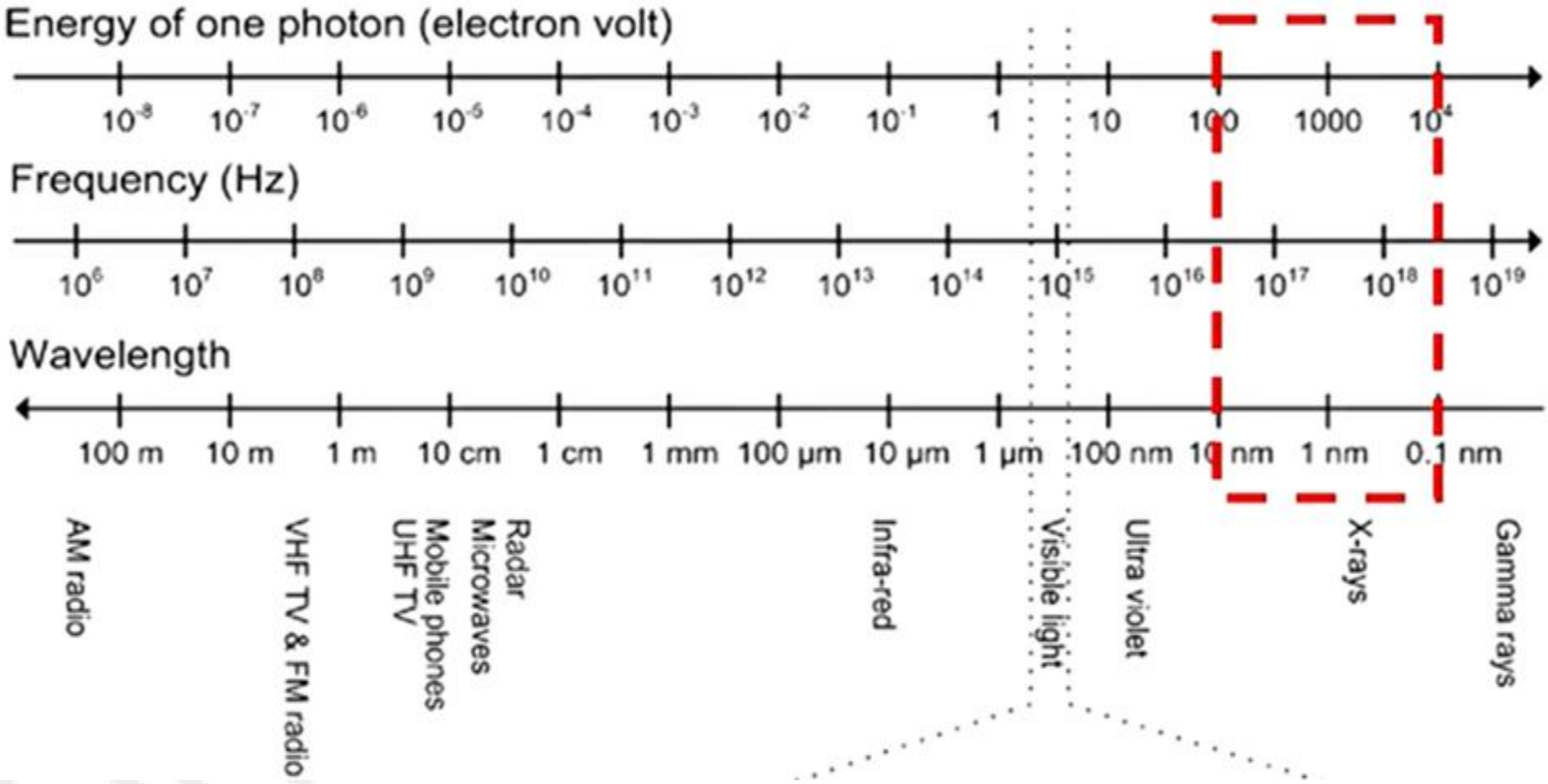
Question (2) Converts high-voltage AC into DC so electrons flow only from cathode to anode ?

1. HV Transformer
2. X-ray Tube
3. Rectifier
4. Autotransformer

Requirements of X-Ray Production

Source of electrons

a source of electrons, a
means of rapidly accelerating


Energy of one photon (electron volt)
10-8 10-7 10-6 10-5 10-4 10-3 10-2 10-1 1 10 100 1000 10^4
Frequency (Hz)
10^6 10^7 10^8 10^9 10^10 10^11 10^12 10^13 10^14 10^15 10^16 10^17 10^18 10^19
Wavelength
100 m 10 m 1 m 10 cm 1 cm 1 mm 100 µm 10 µm 1 µm 100 nm 10 nm 1 nm 0.1 nm
AM radio
VHF TV & FM radio
Mobile phones
UHF TV
Radar
Microwaves
Infra-red
Visible light
Ultra violet
X-rays
Gamma rays

Properties of X-Rays

Property	Explanation
Electromagnetic Nature	X-rays are a form of **electromagnetic radiation** that propagate as waves of electric and magnetic fields at the **speed of light (≈ 3×10^8 m/s)**.
High Energy & Short Wavelength	X-rays have **high photon energy** (few keV to hundreds of keV) and **short wavelengths (0.01–10 nm)**, allowing them to **penetrate matter**.
Ionizing Radiation	X-rays are **ionizing photons** that can remove electrons from atoms and molecules. This makes them **useful for imaging** but potentially **harmful** at high doses.
Invisible & Undetectable by Human Senses	X-rays cannot be seen, felt, or heard. Detection requires **film, digital detectors, or ionization chambers**.
No Mass or Charge (Photons)	X-rays consist of **neutral photons**, not electrons. They have **no rest mass**, **no electric charge**, and interact with matter through **energy transfer**, not direct contact.

Summary

Topic	Key Points
X-ray Production	X-rays are produced in the tube when fast electrons hit the anode; >99% of energy becomes heat and <1% becomes X-rays
Primary Circuit	Controls kVp and exposure time using low-voltage components (switch, fuse, autotransformer, timer).
Secondary Circuit	Steps up voltage and uses a rectifier to convert AC to DC for one-way electron flow (cathode → anode).
X-ray Properties	X-rays are invisible, ionizing, massless, chargeless, high-energy, short-wavelength EM waves.
Radiation Safety	Stay behind shielding, wear lead apron/thyroid collar, and inspect equipment before use.


Any
Question

Homework // Q//Solve the question and submit your answer via the Classroom platform

Q /Based on what you have learned about the nature of X-rays (e.g., they are ionizing, penetrate tissues, massless and chargeless, high-energy, short-wavelength, and invisible), and considering the high-voltage circuits used in X-ray production:

List THREE practical safety measures you would recommend to protect radiology staff during X-ray equipment operation?

References

- Science Introduction to Physics in Modern Medicine, (Suzanne Amador 2002), Radiation Physics for Medical Physicists (Ervien B, Poodgorasak.2006)
- Physics Utah Science Standards, 2019
- Science Direct, Google Scholar. Web of Science

Thank you for listening