AKTU

B. Tech I-Year

Gateway Classes

GATEWAY CLASSES

Semester -I & II

Common to All Branches

BAS101 / BAS201: ENGINEERING PHYSICS

Unit-5 :Superconductors & Nano-Materials

Gateway Series for Engineering

- Topic Wise Entire Syllabus
- Long - Short Questions Covered
- AKTU PYQs Covered
- DPP
- Result Oriented Content

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AKTU

B. Tech I-Year

Gateway Classes

GATEWAY CLASSES

BAS101 / BAS201: ENGINEERING PHYSICS

Unit-5

Introduction to : Superconductors & Nano-Materials

Syallbus

Superconductors: Temperature dependence of resistivity in superconducting materials, Meissner effect, Temperature dependence of critical field, Persistent current, Type I and Type II superconductors, High temperature superconductors, Properties and Applications of Super-conductors.

Nano-Materials: Introduction and properties of nano materials, Basics concept of Quantum Dots, Quantum wires and Quantum well, Fabrication of nano materials -TopDown approach (CVD) and Bottom-Up approach (Sol Gel), Properties and Application of nano materials.

AKTU

B.Tech. 1st Sem

Engineering Physics

Unit-5 Lec-1

Dr. Neeti Bansal Ma'am

GATEWAY CLASSES

I-Sem (BAS101 – ENGINEERING PHYSICS)

AKTU : Syllabus

Unit-V

(2)

Superconductors: Temperature dependence of resistivity in superconducting materials, Meissner effect, Temperature dependence of critical field, Persistent current, Type I and Type II superconductors, High temperature superconductors, Properties and Applications of Super-conductors.

(2)

Nano-Materials: Introduction and properties of nano materials, Basics concept of Quantum Dots, Quantum wires and Quantum well, Fabrication of nano materials -Top-Down approach (CVD) and Bottom-Up approach (Sol Gel), Properties and Application of nano materials.

I-Sem (BAS101 – ENGINEERING PHYSICS)

Unit-V Lec-1

Today's Target

Superconductors

- Introduction
- Temperature dependence of resistivity in superconducting materials
- Temperature dependence of critical field
- Meissner effect
- Persistent current
- AKTU PYQs

AKTU QUESTIONS

Q1	What do you mean by super conductivity? Discuss the effect of external magnetic field on superconductors. The transition temperature for Pb is 7.2K, however, at 5K it loses the superconducting property subjected to a magnetic field of 3.3×10^4 A/m. Find the maximum value of H which allow the metal to retain its superconductivity at 0K. Ans: 6.37×10^4 A/m Explain the Meissner effect and persistent current in superconductivity	AKTU 2022-23
Q2	Explain the effect of temperature on electrical resistivity of superconducting materials. Discuss Meissner effect.	AKTU 2017-18

Superconductors: Introduction

SUPER + CONDUCTOR

- Superconductivity is a phenomenon of disappearance of electrical resistance in some materials when cooled to a very low temperature.

Resistivity (ρ) = $\frac{1}{\text{conductivity } (\sigma)}$

- There are certain materials or alloys whose electrical resistivity suddenly drops to zero (or conductivity increases to infinite) when they are cooled to a very low temperature nearly absolute zero (often called liquid helium temperature range); these materials/alloys are called superconductors.

- The temperature at which the resistivity becomes zero or material becomes superconductor is called transition temperature or critical temperature. T_c

- This phenomenon was discovered by Dutch physicist Heike Kamerlingh Onnes on April 8, 1911 in Leiden.

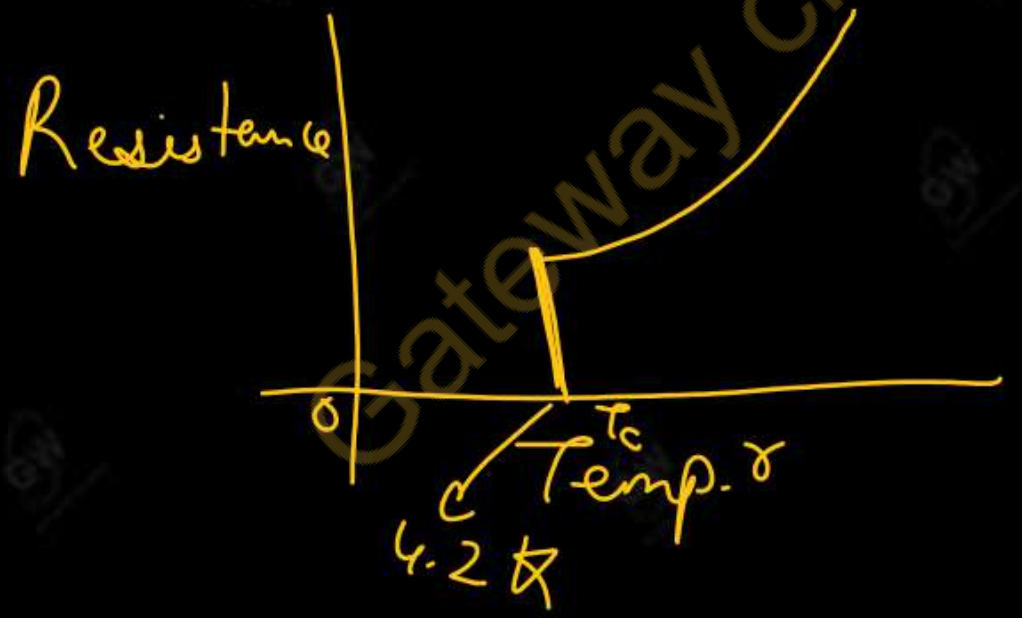
Superconductors: Introduction

T_c

Thus, when a substance is cooled below a certain temperature (called transition temperature or critical temperature), the electrical resistance of the substance suddenly drops to zero; this phenomenon is known as superconductivity and the substances which exhibit this property are known as superconductors.

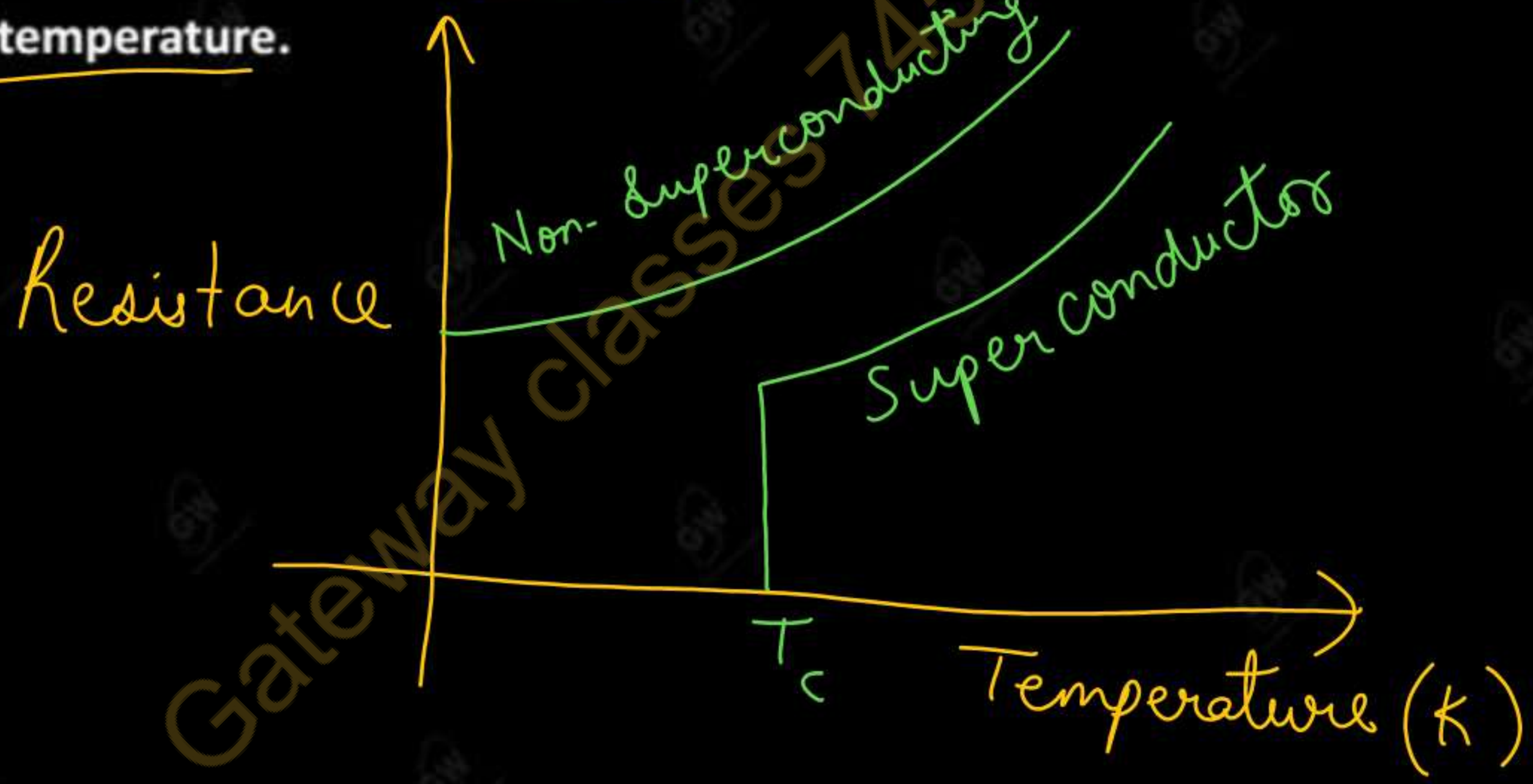
Temperature dependence of resistivity in superconducting materials

- During the study of electrical resistance of mercury at very low temperature, Onnes in 1911 observed that the electrical resistance of a pure mercury at very low temperatures decreases regularly like that of any other metal but at temperature about 4.2 K, it suddenly drops to zero.
- *The temperature at which the normal material changes into superconducting state is called the critical temperature Tc.*
- *Other substances* which exhibit this phenomenon are aluminium, silver, cadmium, lead, gallium, iridium, etc.
- There are so many other alloys and ceramics that behave as superconductors. It may be possible that individual elements may not be the superconductor but their alloy can be superconductor.



Temperature dependence of resistivity in superconducting materials

- This critical temperature and its range are different for different materials and are affected very much by the impurity in the material.
- A small amount of impurity can change from steep fall of resistivity to gradual fall.
- Further, this transition of material is reversible and the material transforms to normal state when temperature rises above critical temperature.



Temperature dependence of critical field

(T) (H) (Magnetic field)

- When the superconducting materials are subjected to a strong magnetic field, it will result in the destruction of the superconducting property below the critical temperature, that is, they return to the normal state.
- *Thus, the minimum field required to destroy the superconducting property is called the critical field Hc.* H_c
- *Its value* depends upon the nature of the material and its temperature
- The variation of *Hc with* temperature is nearly parabolic and can be expressed by the equation

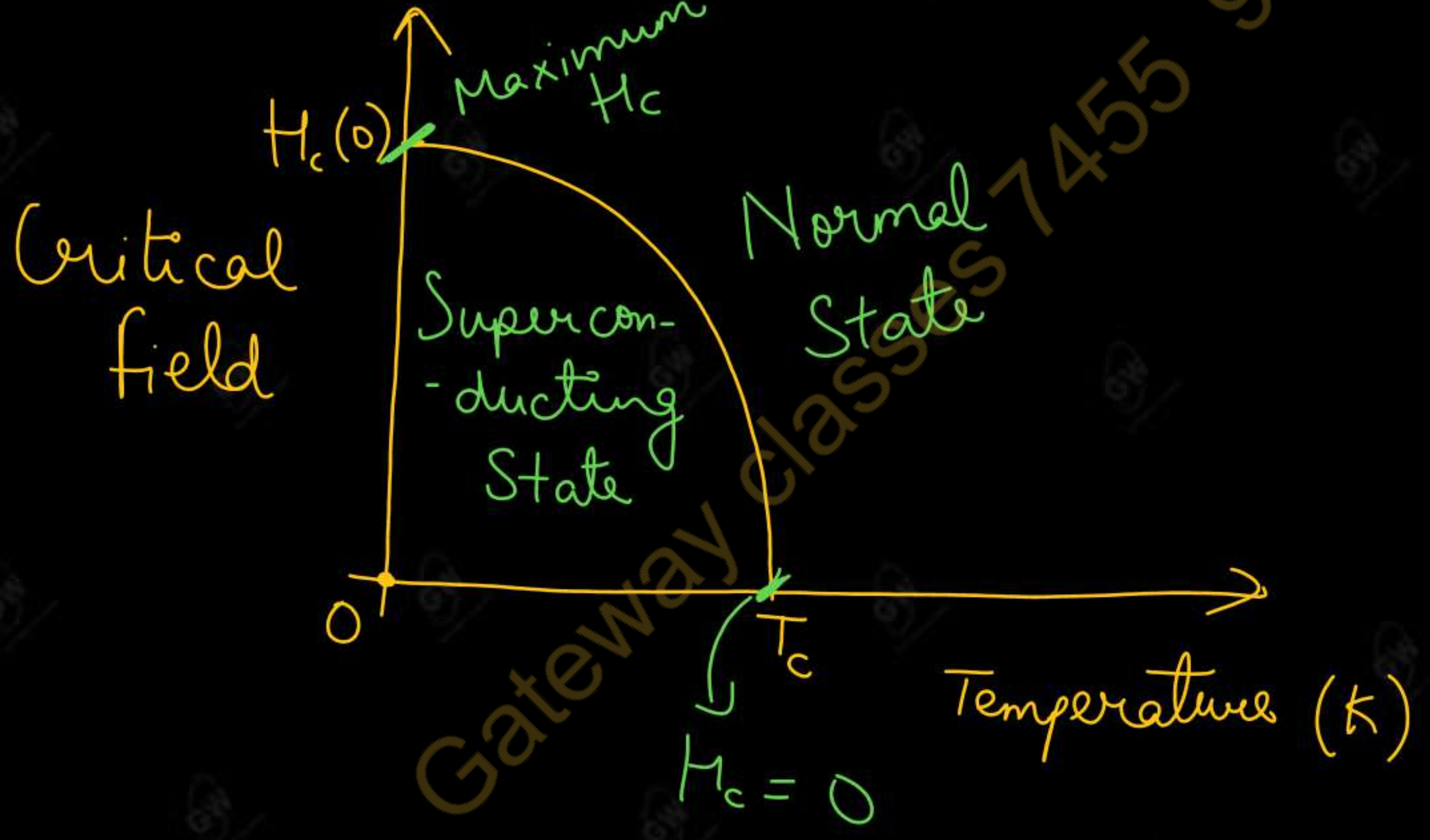
$$H_c(T) = H_c(0)\left[\left(1 - \frac{T}{T_c}\right)^2\right]$$

Critical field at Temp. T

field at Temp. 0K

Temperature dependence of critical field

- Below critical temperature, the critical field decreases with increase of temperature.
- It is maximum at absolute zero and zero at critical temperature.
- It means that no field is required for transition from superconductor to normal state at critical temperature.



Critical Current and Current Density

$\downarrow I_c$ $\rightarrow J_c$

- The application of a large value of electric current to a superconducting material destroys its superconducting property.
- The current required for this is called critical current (I_c) and the corresponding current density is
- called critical current density. J_c
- If a superconducting wire of radius *r carries current I then critical current Ic is given by*

$$\boxed{I_c = 2\pi r H_c}$$

$r \rightarrow$ Radius of superconducting wire

$H_c \rightarrow$ Critical field

Critical Current and Current Density

H_c, I_c $\rightarrow$ Superconductivity X

At $I = I_c$ superconductivity will be destroyed. In presence of applied transverse magnetic field H, the value of critical current decreases and expressed as

$$\boxed{I_c = 2\pi r (H_c - 2H)}$$

This is called Silsbee's rule.

Current Density $\longrightarrow$ $J_c = \frac{I_c}{A} = \frac{I_c}{\pi r^2}$ A/m^2

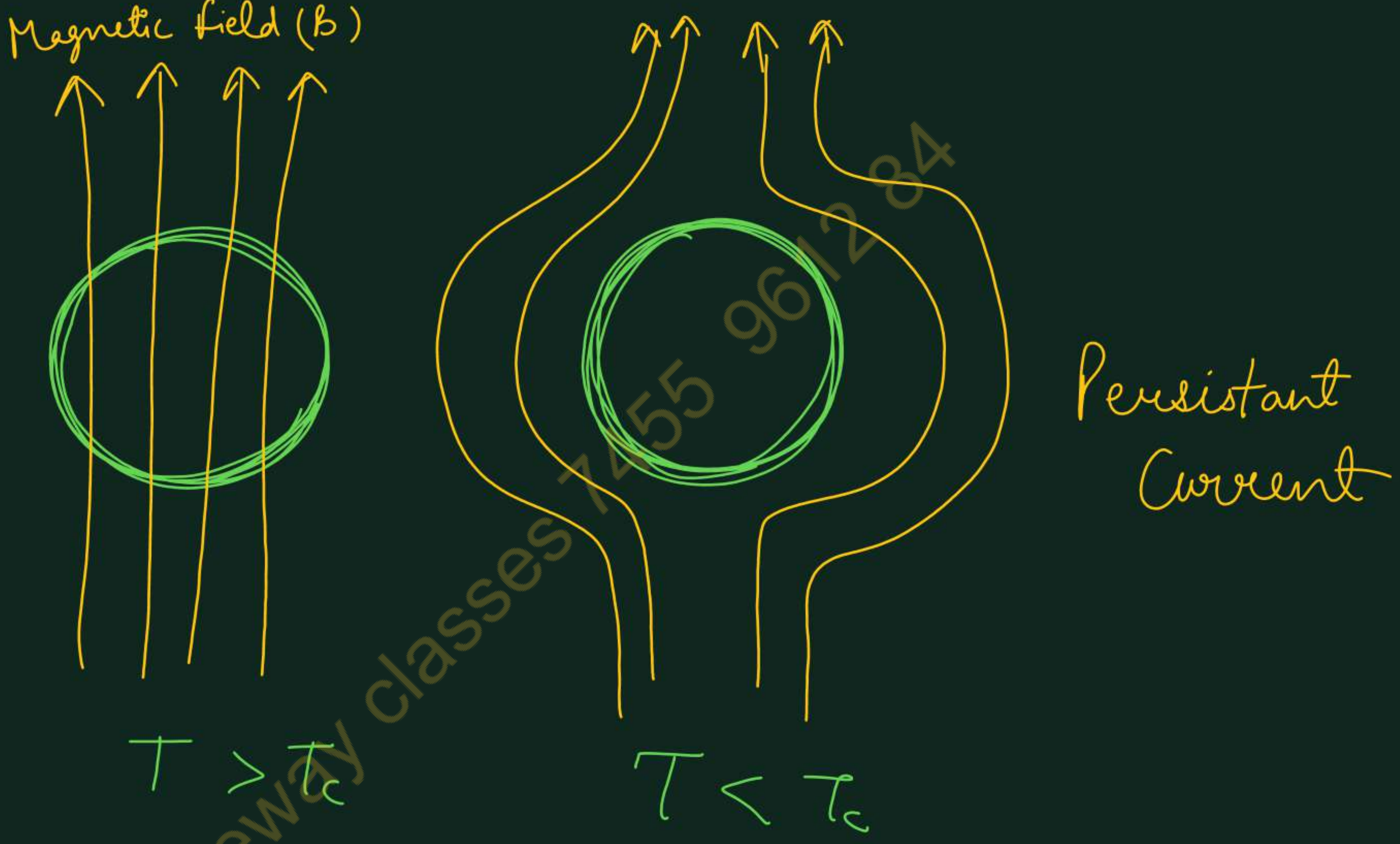
Effect of Magnetic Field (Meissner Effect)

- The Meissner effect is an expulsion of a magnetic field from a material during its transition to the superconducting state. $T < T_c$

- German physicists Walther Meissner and Robert Ochsenfeld discovered the phenomenon in 1933 by measuring the magnetic field distribution outside superconducting tin and lead specimen.

- The specimens, in the presence of an applied magnetic field, were cooled to a temperature below the superconducting transition temperature. T_c

- Until the transition temperature, the magnetic lines of force penetrate the interior of specimen; however as the temperature decreases below the transition temperature, the magnetic flux is expelled out from the interior and goes round of the specimen. $T < T_c$


Magnetic field (B)
T > Tc
T < Tc
Persistant Current

Effect of Magnetic Field (Meissner Effect)

- In the presence of magnetic field below the critical temperature, currents on the surface of the material (called persistent current) are generated which actually cancel the interior flux density of the superconductor.

- Below the transition temperature the material becomes perfectly diamagnetic

Thus, when a superconductor is placed in an external magnetic field and cooled below the critical temperature, all the magnetic flux is expelled or pushed out of it; this is called Meissner's effect.

Effect of Magnetic Field (Meissner Effect)

➢ If inside the specimen *B = 0, then the* relation between magnetizing field *H, magnetic induction B and intensity of magnetization I is expressed as*

$$B = 0$$

$$B = \mu_0 (H + I) = 0$$

$$H + I = 0$$

$$H = -I$$

$$\boxed{\chi_m = \frac{H}{I} = -1} \rightarrow \text{negative}$$

$\Rightarrow$ diamagnetic

AKTU QUESTIONS

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$T_c = 7.2K$

$H_c(5) = 3.3 \times 10^4 \, A/m$

$H(0) = ?$

$$H_c(T) = H_c(0)\left[1 - \left(\frac{T}{T_c}\right)^2\right]$$

$T = 5K$

$T_c = 7.2K$

Unit-V Lec-2

Today's Target

Superconductors

- Type I and Type II superconductors
- High temperature superconductors
- Properties and Applications of Super-conductors
- AKTU PYQs

Type I and Type II superconductors

- Superconducting materials are classified as Type I (soft) and Type II (hard) superconductors depending on their characteristic behaviors in the presence of an external magnetic field.

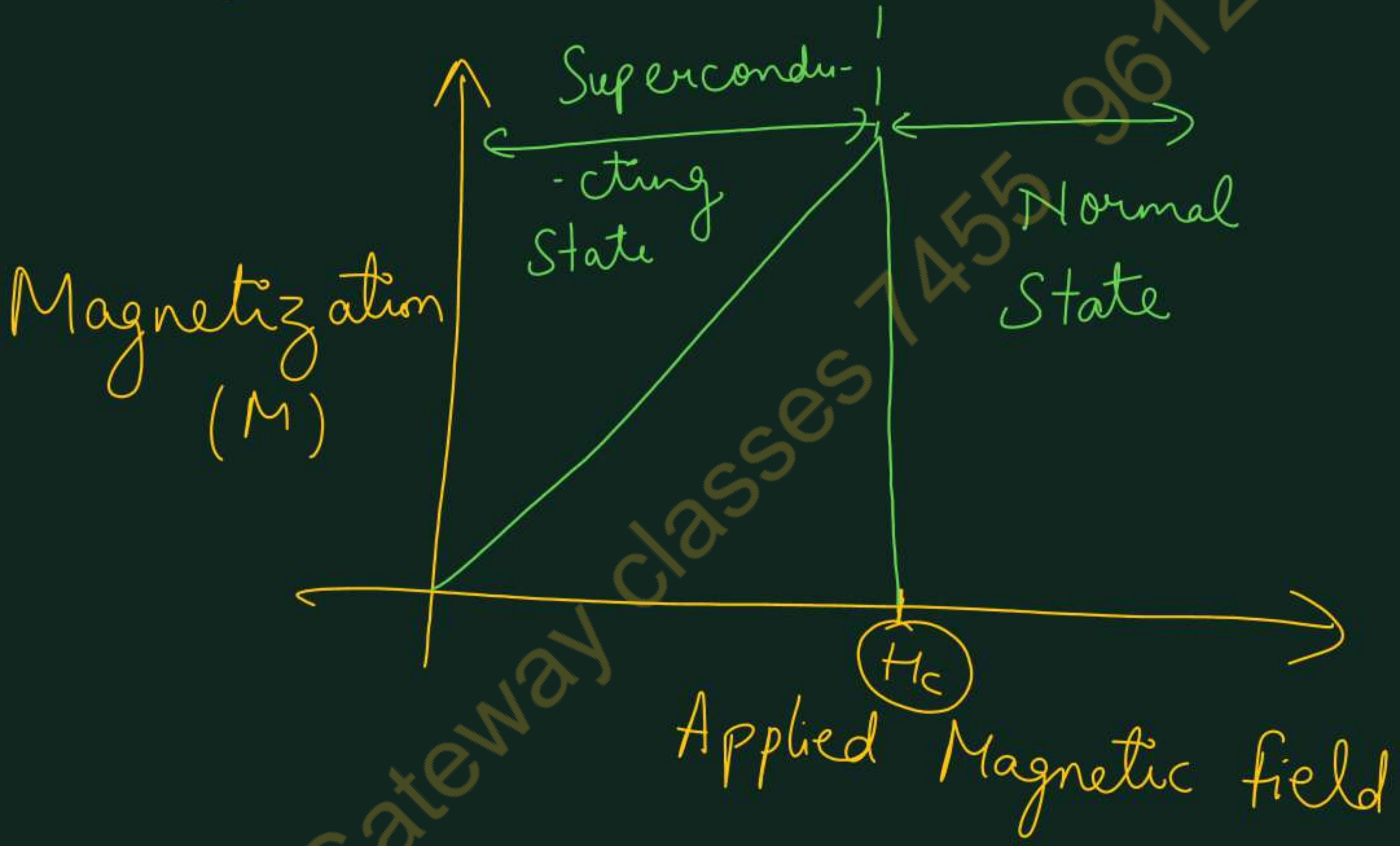
- Type I superconductors exhibit complete Meissner effect, that is below critical field H_c *they are superconductors and at* H_c *they become* normal.

- The value of H_c *is very small and is of the order of 0.1 T.*

- *This type of superconductivity* is normally exhibited by pure metals, for example, aluminium, lead, indium and mercury.

- Type I superconductor is one in which the transition from superconducting state to normal state in presence of magnetic field occurs sharply at the critical value H_c

Type I Superconductor (Soft Superconductor)

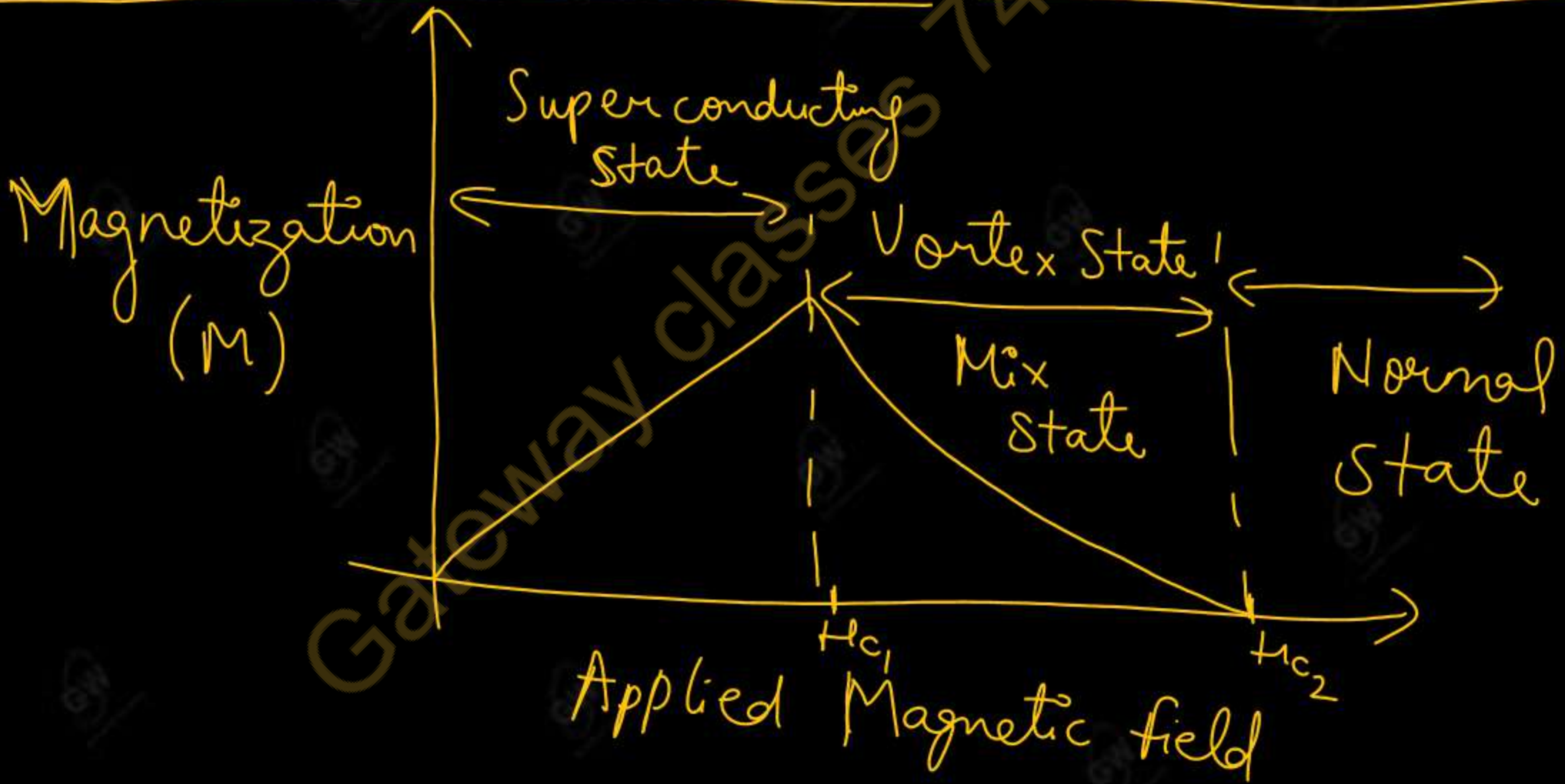


Type I and Type II superconductors

- **Type I superconductors** : Upto the critical field strength H_c the magnetization of superconductor grows in proportion to the external field. As soon as the applied field H exceeds H_c the magnetization abruptly drops to zero.

Type I and Type II superconductors

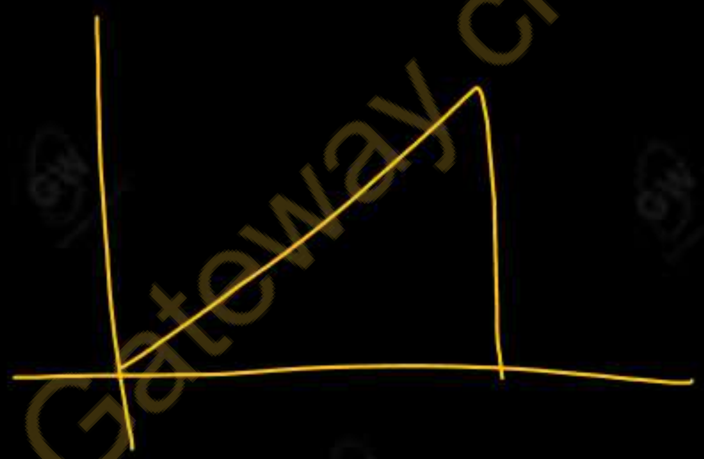
- **Type II superconductors** exhibit two critical magnetic fields H_{c1} *and* H_{c2} *as materials* behave in different ways.
- Below critical field H_{c1} , *the magnetization increases linearly, the* material is superconductor and exhibits complete Meissner effect that is complete expulsion of magnetic line of forces from the bulk material.
- Above H_{c1} , *the magnetization decreases gradually and magnetic lines* start penetrating the material.



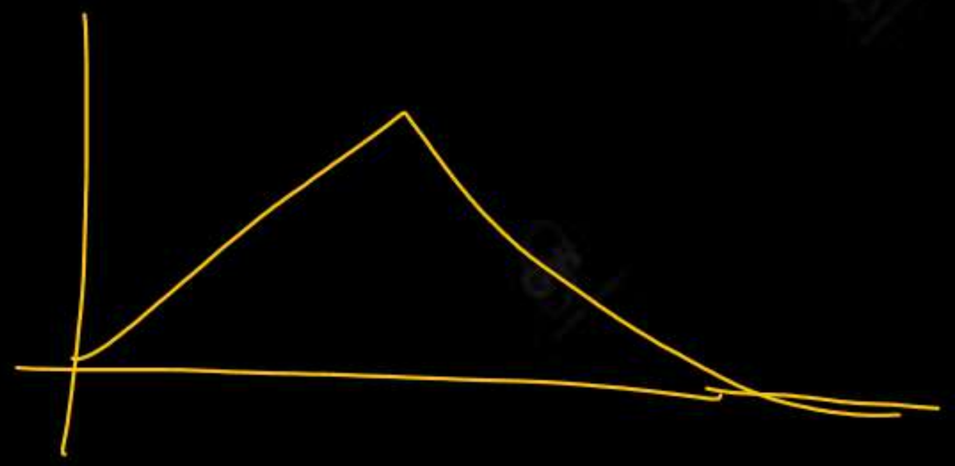
Type I and Type II superconductors

- The material loses its superconducting state and comes to normal sate at H_{c2}.
- The region between H_{c1} *and* H_{c2} *is called mix state. The superconductor is said to be in a mixed state which is commonly known as vortex state.*
- *If we compare with Type I superconductor, there is* abrupt fall in magnetization wherein Type II fall is gradual.
- Transition metals and alloys consisting of niobium and aluminium are examples of Type II superconductors.

Type I



Type II



Type I and Type II superconductors

- A material can change from Type I to Type II on addition of some impurities.

- For example, lead is a Type I superconductor. *On adding 20% of indium* in lead it becomes type II superconductor.

- *Magnetization curves for both Type I and Type II* materials are reversible in case of the ideal superconductors.

Type I → Pure metals

\+ Impurity

⇓

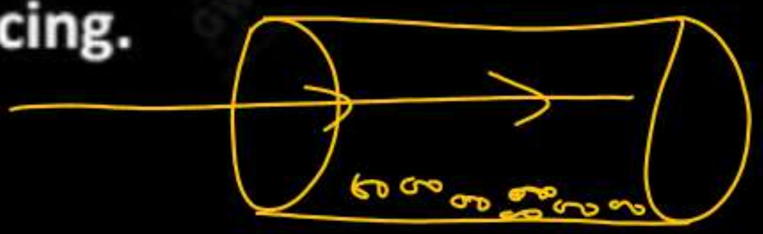
Type II

BCS Theory

- John Bardeen, Leon N. Cooper and John R. Schrieffer (BCS) developed the quantum theory of superconductivity

- It is based on interaction of two electrons through the intermediary of phonons.

- The behavior of *superconductors* suggests that electron pairs are coupling over a range of hundreds of nanometers, there orders of magnitude larger than the lattice spacing.



- These pairs are called Cooper pairs.

- These coupled electrons can take the character of a boson and condense into the ground state.

- BCS showed that the basis of interaction responsible for superconductivity to be a pair of electron is by means of interchange of virtual phonons.

- Usually the electrons repel each other by the columbic force but in special case when temperature is lower than critical value, the attraction of electron is stronger than electrons columbic force.

High-Temperature Superconductivity

- Until 1986, physicists had believed that BCS theory forbade superconductivity at temperatures above about 30 K.

- It was a great achievement for discoverer to have the superconductors above 10 K transition temperature and the new nomenclature of high temperature superconductor was introduced.

- It was soon found that replacing lanthanum with yttrium (i.e., making YBCO) raised the critical temperature to 92 K.

- This temperature jump is particularly significant, since it allows liquid nitrogen as a refrigerant, replacing liquid helium.

- This can be commercially important because liquid nitrogen can be produced relatively cheap, even on-site, avoiding some of the problems (such as so-called 'solid air' plugs) which arise when liquid helium is used in piping.

High-Temperature Superconductivity

- Since about 1993, the highest temperature superconductor was a ceramic material consisting of mercury, thallium, barium, calcium, copper, and oxygen ($Hg_{12}Tl_3Ba_{30}Ca_{30}Cu_{45}O_{125}$) with $T_c = 133 - 138\ K$.

- *In February 2008,* an iron-based family of high-temperature superconductors was discovered.

Properties and Applications of Super-conductors

- **Properties**

The following are the important characteristics of superconductors:

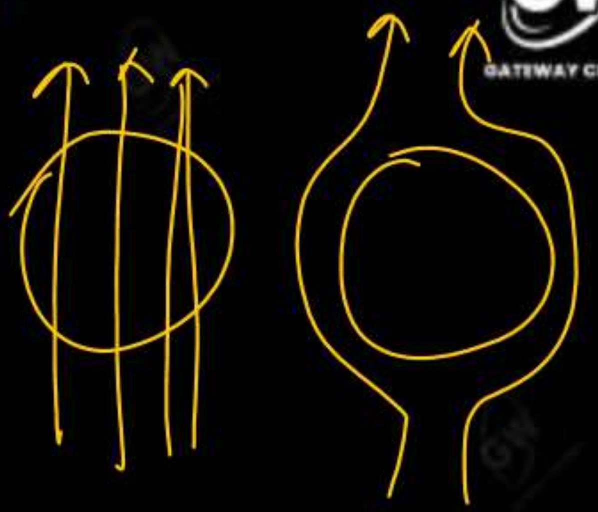
- Materials having high normal resistivity exhibit superconductivity.
- Materials for which $Z\rho = 10^6$ exhibit superconductivity.

$Z\rho = 10^6$

Resistivity

Atomic number

- For chemically pure and structurally perfect specimen, the superconductivity is very sharp.
- The current in superconductors can be sustained for a long period.
- Magnetic field does not penetrate the superconductor.
- Above critical magnetic field, a superconductor becomes normal metal.
- Ferromagnetic and anti-ferromagnetic materials are not superconductors.



Superconductor

H_c

Properties and Applications of Super-conductors

- **Applications**

- **Power transmission** using superconductors power transmission can be done at a lower voltage level without any energy loss.
- **Superconducting magnets** are some of the most powerful electromagnets. They are used in MRI/NMR machines, mass spectrometers, etc. The beam-steering magnets are used in particle accelerators. They can also be used for magnetic separation in the pigment industries.
- In the 1950s and 1960s, superconductors were used to build **experimental digital computers** using

Cryotron switches. More recently, superconductors have been used to make **digital circuits** based on rapid single flux quantum technology and RF and microwave filters for mobile phone base stations.

Properties and Applications of Super-conductors

- Applications

•Superconductors are used to build Josephson junctions which are the building blocks of SQUIDs (superconducting quantum interference devices), the most sensitive magnetometers known. Josephson junction can be used as a photon detector or as a mixer.

•Promising future applications include high-performance smart grid, electric power transmission transformers, power storage devices, electric motors, fault current limiters.

AKTU QUESTIONS

Q.1	Discuss high temperature superconductors and some potential applications. Explain Type I and Type II superconductors briefly.	AKTU 2022-23
Q.2	Explain superconductivity on the basis of BCS theory. Determine the critical current and current density which can flow through a long thin superconducting wire of diameter 2 mm if critical field for the material is 1.2×10^4 A/m.	AKTU 2017-18

$d = 2$ mm

$= 2 \times 10^{-3}$ m

$r = d/2$

$I_c = 2\pi r H_c$

$J_c = I_c / \pi r^2$

$H_c = 1.2 \times 10^4$ A/m

Unit-V Lec-3

Today's Target

Nano-Materials

- Nano-Materials: Introduction
- Properties of nano materials
- Quantum well
- Quantum wires
- Quantum Dots
- AKTU PYQs

Nano-Materials: Introduction

- Nano is a Greek word that means dwarf (small).

$1\,nm = 10^{-9}\,m$

- On the other hand, nanotechnology is a branch in which we study the design, characteristics, production, and application of structures, devices, and systems on the nanoscale.

- Nanoscience is the branch of physics in which we study the phenomenon and manipulation of materials at atomic, molecular, and micromolecular scales.
- The growth of nanoscience and nanotechnology is in line with the tendency towards miniaturization.
- It is a cutting-edge technology where objects or devices behave as a whole unit that has a size from 1 to 100 nanometers.

1 nm to 100 nm

Nano-Materials: Introduction

•The materials developed under nanotechnology show very different properties at the nanoscale in comparison to the macroscale though the properties hardly change at the microscale.

large scale

small scale

•For instance, opaque substances at the macroscale become transparent at the nanoscale (Cu). Materials having inert properties attain catalytic properties (Pt), stable materials turn into combustible materials (Al), solids turn into liquids (Au), insulators become conductors (Si), etc.

•Nanomaterials in powder forms (known as nanoparticles) are potentially important in ceramics, powder metallurgy, the achievement of uniform nanoporosity, and similar applications.

•The differences in properties of the same materials are due to their structure and bonding.

Nano-Materials: Introduction

- **Nanomaterials** are materials that are developed, designed, fabricated, or manipulated at the nanometer scale.
- The various physical, electrical, mechanical, and magnetic properties of material at this scale change drastically.
- These are fabricated from carbon, ceramics, ferrites, metals, polymers, semiconductors, and silicas.
- For example, buckyballs, the structure of C_{60} atoms, nanotubes, nanogels, nanocrystals, Quantum dots, etc.

Properties of nano materials

There are some useful properties of nanomaterials which are as follows:

1. Nanomaterials are hard.
2. Nanomaterials are exceptionally strong.
3. Nanomaterials are ductile at high temperature.
4. Nanomaterials are chemically very active.
5. Nanomaterials are wear resistant.

Quantum well

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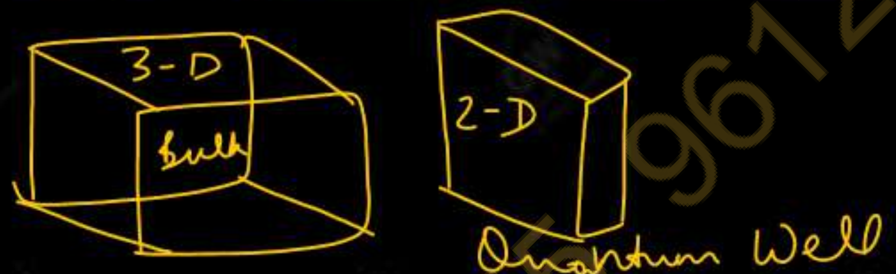
•If one dimension is reduced to the nano range while other dimensions remain large, then the structure formed is known as a **Quantum Well**



•A Quantum well is a nanometer-thin layer that can confine particles in the dimension perpendicular to the layer surface, whereas the movement in other dimensions is not restricted.

•Quantum wells are used widely in diode LASERS, including red LASERS for DVDs and LASER printers, infrared LASERS, and also to make HEMTs (High Electron Mobility Transistors) which are used in low noise electronics.

•They can be made to a high degree of precision by modern epitaxial crystal growth techniques.

Quantum wire

- If two dimensions are reduced to the nanorange while the third remains the same, then the structure formed is known as **Quantum Wire**

- A Quantum wire is a cable or a wire often similar in function to copper wire, but made with carbon nanotubes usually.

- Quantum wires are usually conductors, but may be made as insulators or semiconductors.

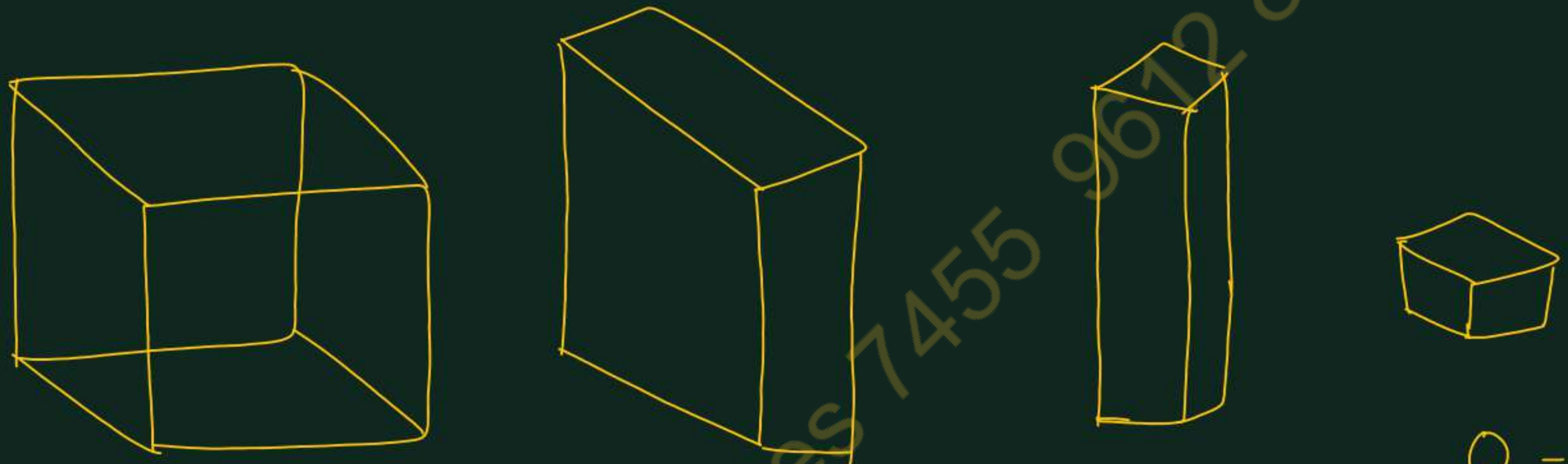
- Nanowires have two quantum confined directions but one unconfined direction available for electrical conduction.

Quantum dots

- If all three dimensions of the material are reduced to the nano range ~~while the third remains the same~~, then the structure formed is known as **Quantum dot.**
- Quantum dots have properties intermediate between bulk semiconductors and discrete atoms or molecules.
- These are semiconductor particles a few nanometers in size having optical and electrical properties. Eg. larger quantum dots (5-6 nm) emit longer wavelengths while smaller quantum dots (2-3 nm) emit shorter wavelengths.

- Examples of quantum dots are: Cadmium Selenide (CdSe), Cadmium Tellunide (CdTe), Zinc Selenide (ZnSe), Indium Phosphide (InP)

- These are zero-dimensional nanostructures.



3 - D

Bulk Material

2 - D

Quantum Well

1 - D

Quantum Wire

0 - D

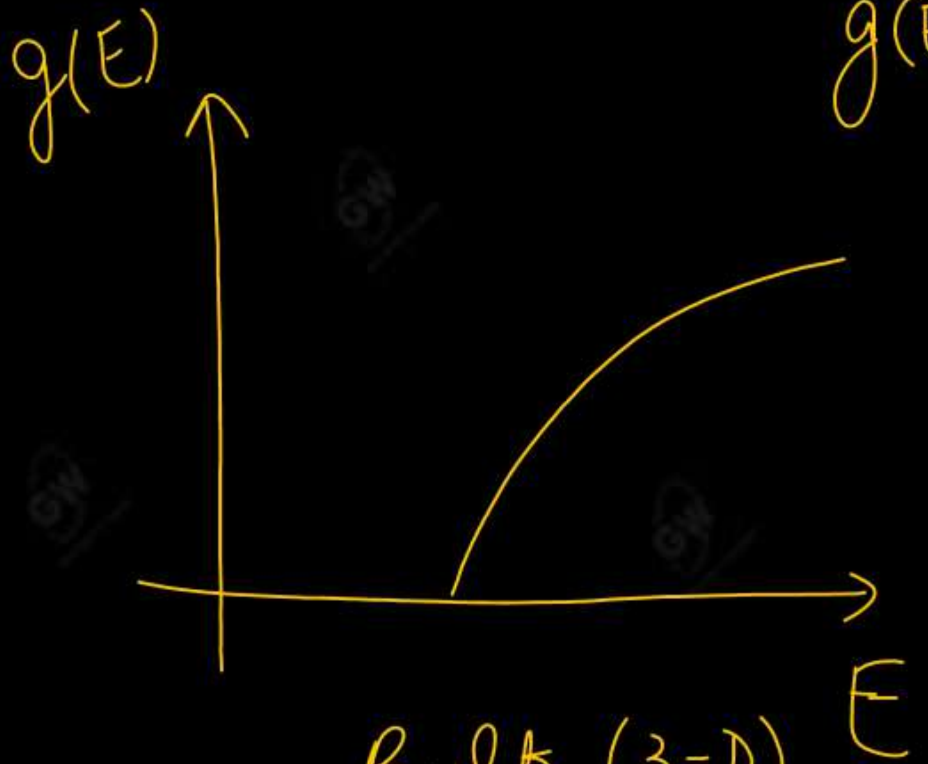
Quantum Dot

Nano-materials

Density of States

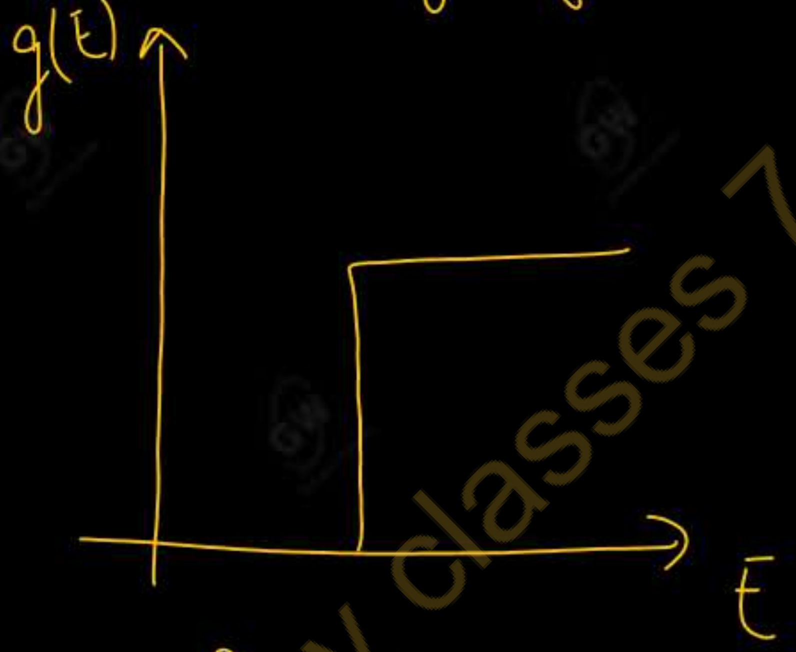
- It is defined as number of states per unit Energy per unit volume that electrons are allowed to occupy.

$g(E) \rightarrow$ Density of State



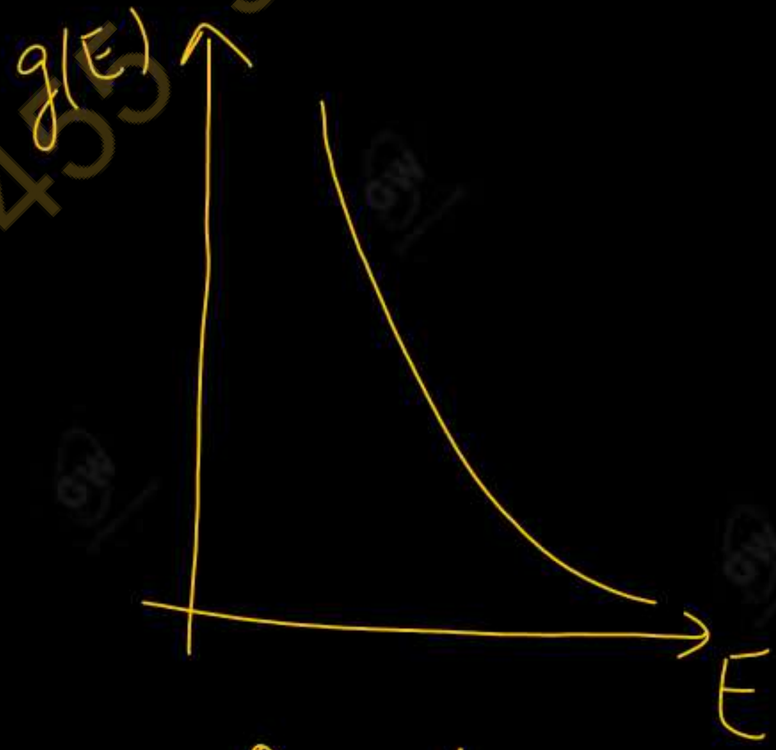
Bulk (3-D)

$g(E) \propto E^{1/2}$



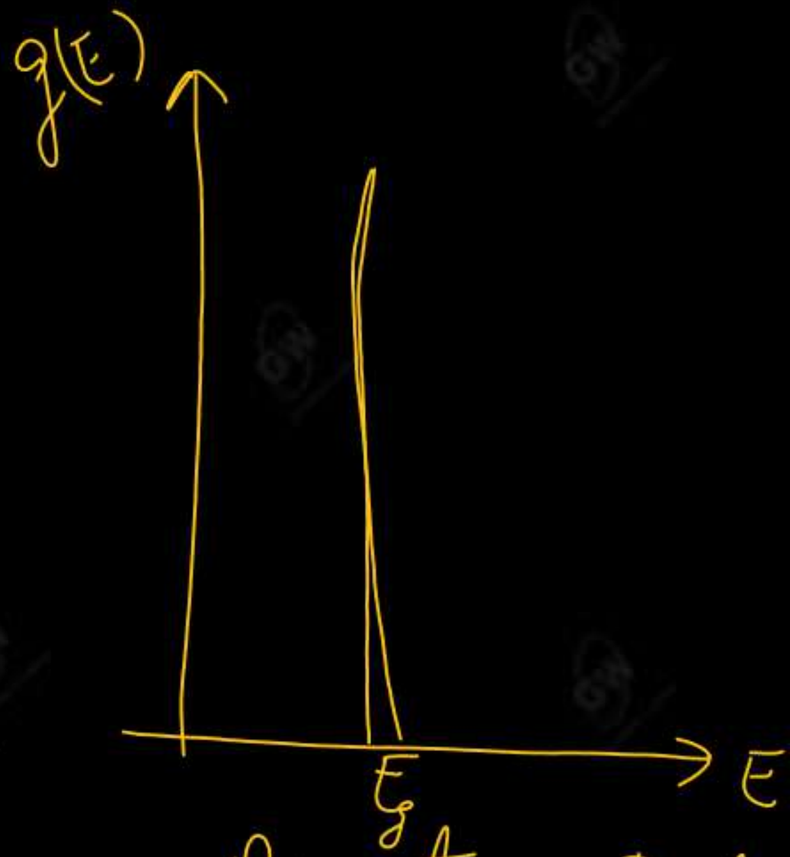
Quantum Well (2-D)

$g(E) \propto E^{0} = \text{constant}$



Quantum Wire (1-D)

$g(E) \propto E^{-1/2}$



Quantum Dot (0-D)

$g(E) \propto \delta(E_g - E)$

AKTU QUESTIONS

Q.1	What do you mean by a Quantum Well? What are Nano materials? Explain briefly the basic concepts of Quantum Dots, Quantum wires and Quantum well.	AKTU 2022-23

Unit-V Lec-4

$1\ nm = 10^{-9}\ m$

Today's Target

Nano-Materials

- Fabrication of Nanomaterials
- Top-down approach (CVD)
- Bottom-Up approach (Sol-Gel)
- Properties of Nanomaterials
- Application of Nanomaterials
- AKTU PYQs

Fabrication of Nano materials

- The following two main techniques are used for the fabrication of Nanomaterials:
- Bottom-up technique
- Top-down technique

Bottom-up technique

- This is a technique in which materials and devices are built up atom by atom.
- A technique to collect consolidate and fashion individual atoms and molecules into the structure.
- This is carried out by a sequence of chemical reactions controlled by a series of catalyst

Fabrication of Nano materials

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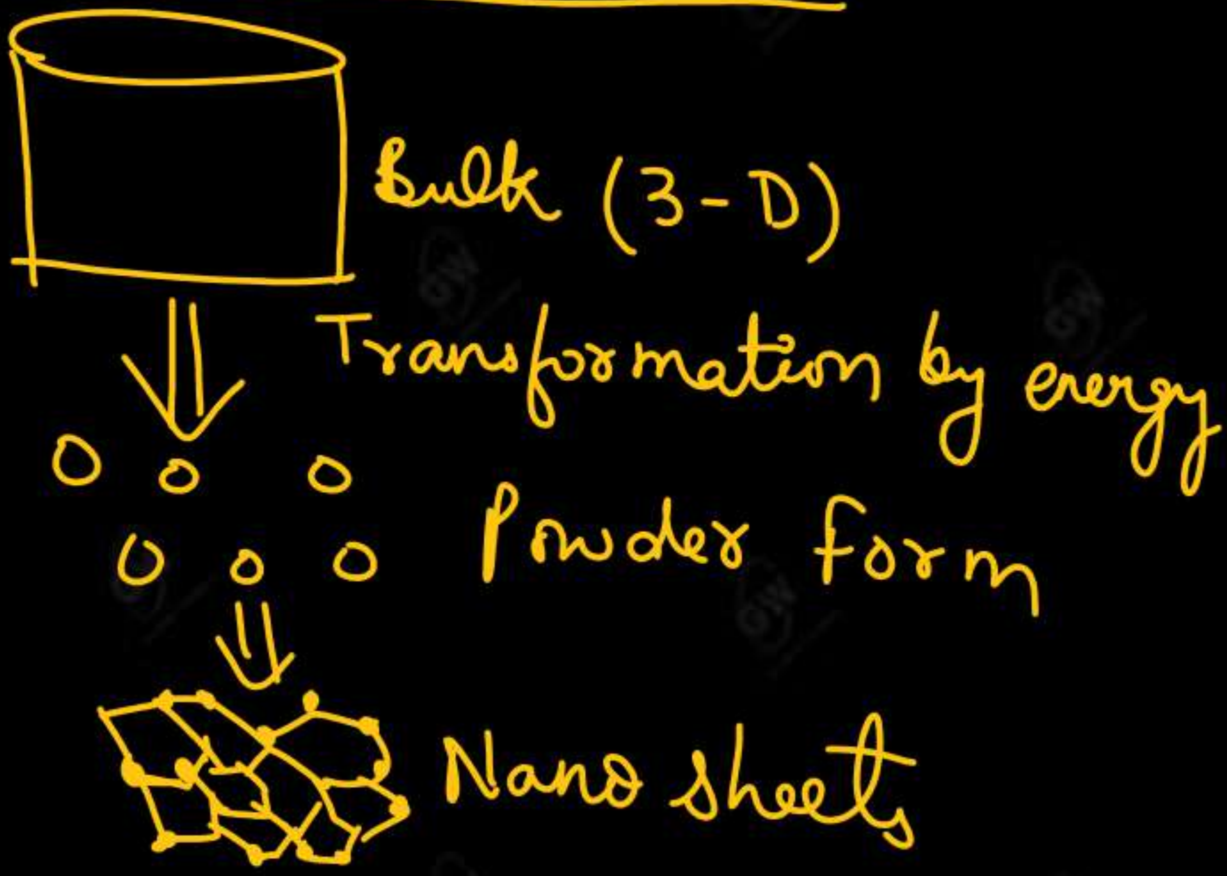
Top-down technique

- This is a technique in which materials and devices are synthesized or constructed by removing existing material from larger entities.

- Therefore, in this technique, a large-scale object or pattern is gradually reduced in dimension to a nanoscale pattern.

- This can be accomplished by a technique called lithography.



Top-Down approach (CVD)

- Chemical vapor deposition (CVD)

- In this method, a substrate is prepared with a layer of metal catalyst particles, such as nickel, cobalt, or iron.

- The substrate is heated to approximately 700°C in a chamber.

- To initiate the growth of nanotubes, two gasses are blown into the chamber (precursors) which are methane (Carbon containing gas) and other is process gas (ammonia nitrogen, or hydrogen)

CH_4

- The high temperature breaks the bonds between the carbon atoms and hydrogen atoms in the methane molecules.

CH_4

Top-Down approach (CVD)

- Chemical vapor deposition (CVD)

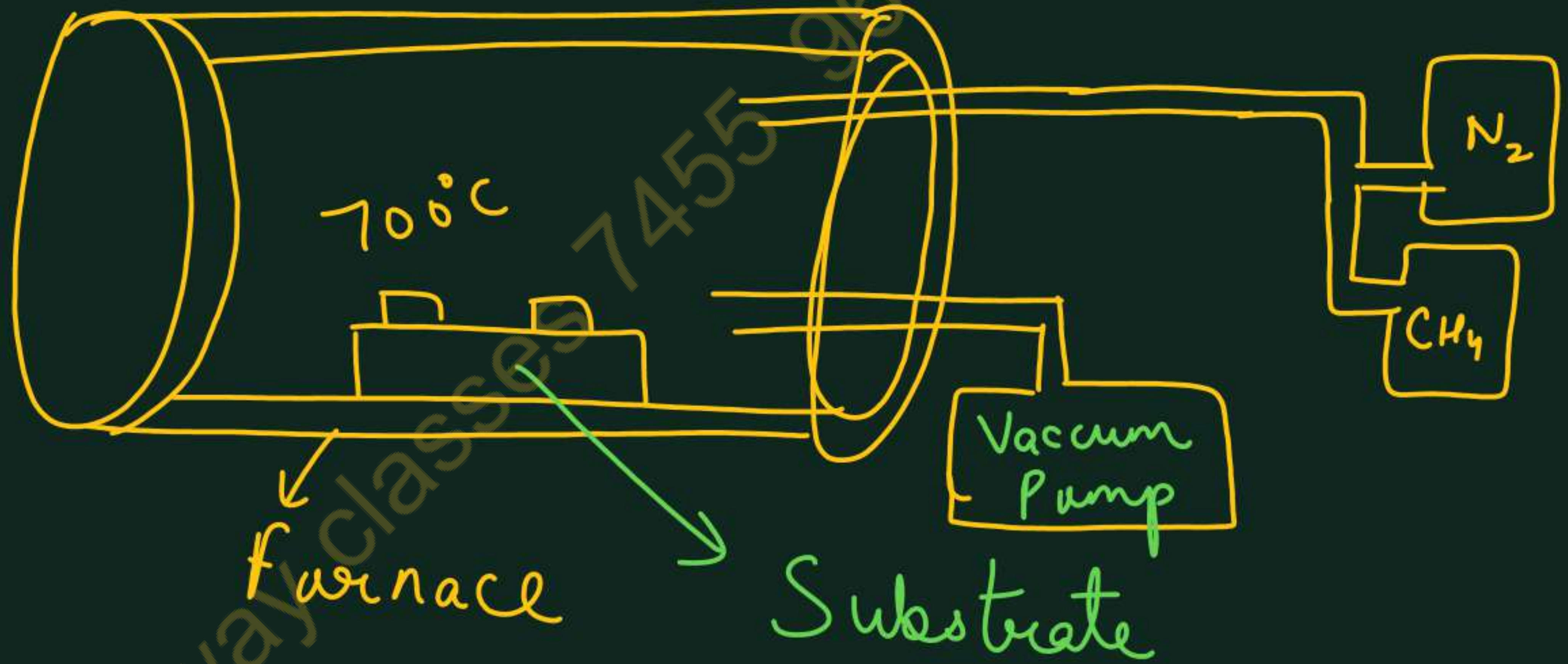
- This results in carbon atoms with no hydrogen atoms attached.

- These carbon atoms attach to the catalyst particles where they bond to other carbon atoms.

- This results in formation of nanotube.

- Nanotubes formed can be single walled nanotubes (SWNT) or multi walled nanotubes (MWNT).

CVD (Top Down Approach)



Top-Down approach (CVD)

- Chemical vapor deposition (CVD) Advantages

- It is used to produce high purity, high performance solid materials.
- By-products are removed by carrier gas flow through the reaction chamber.
- Substrate is exposed to one or more volatile precursors which reacts or decompose on substrate surface to produce desired compound.

CH_4, N_2

- This is widely applied to produce coatings, powders, fibers and monolithic components.

Bottom-Up approach (Sol Gel)

- Sol-Gel Method

- It is a bottom-up approach and chemical-based method to synthesize Nanomaterials.
- This method is used to synthesize metal oxide Nanoparticles.
- A Sol is a colloidal (the dispersed phase in which the size of particles is so small that gravitational forces do not exist).
- A Gel is a semi-rigid mass that forms when the solvent from the sol begins to evaporate and the particles left behind begin to join together in a continuous network.
- This is accomplished by sedimentation or centrifugation

$\boxed{\text{Sol}} \rightarrow \boxed{\text{Gel}}$

Bottom-Up approach (Sol Gel)

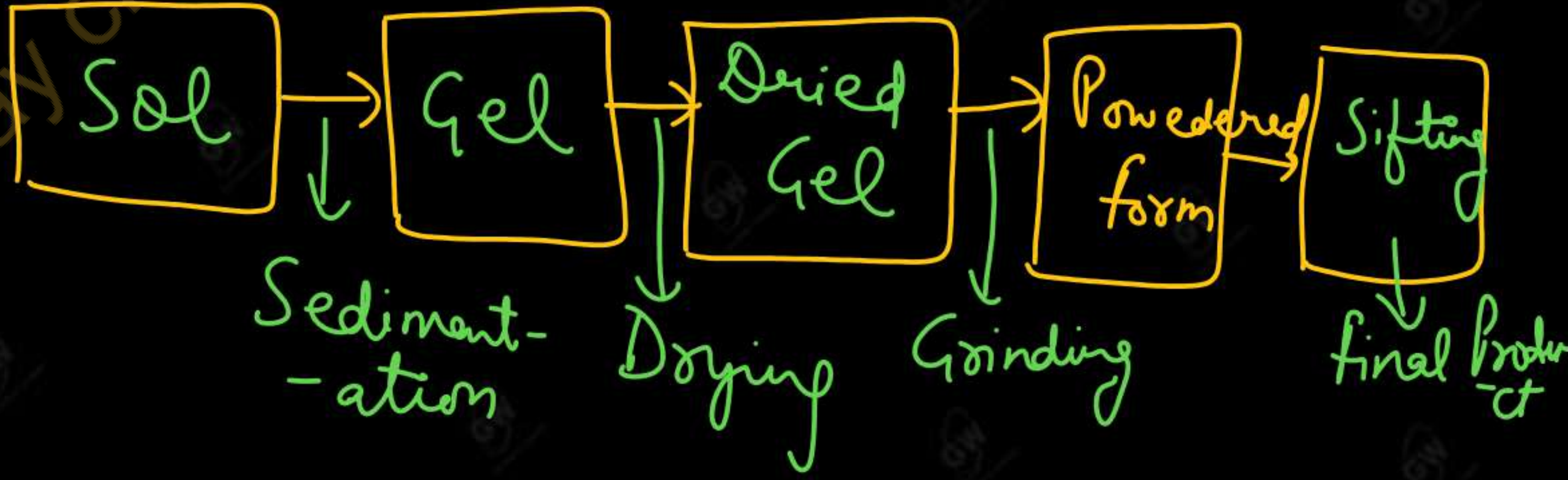
- Sol-Gel Method

- The remaining liquid is removed using the drying process accomplished by thermal treatment and the remaining is left as a dried gel. This further enhances the mechanical stability

- The dried gel is ground to get the material into powdered form.

- The powder is then sifted (the process of removing lumps) to get the final product

- This final product can be deposited on a substrate to get a thin film or we can cast it into desired shapes



Bottom-Up approach (Sol Gel)

- **Sol Gel Method Advantages**

- It is a cheap and low temperature technique.
- It gives us fine control of product's chemical composition
- Rate of reaction can be easily controlled.
- Even small quantities of dopants can be uniformly dispersed in the final product.

Properties of nano materials

Mechanical Properties:

- Very small nanoparticles have almost all their atoms on the surface which gives them more freedom to go larger from their equilibrium positions.

- Nano-phase metals with their exceptionally small grain size are found to be exceptionally strong

- The melting point of the cluster depends upon the number of atoms in the crystal. It increases with an increase in the number of atoms and attains the value of bulk material when the cluster contains greater than one thousand atoms

Properties of Nano materials

Optical Properties:

- The absorption of photons occurs because electrons move from lower energy states to higher energy states.

- It is observed that clusters of different sizes have different energy level separations. So their absorption is different for different clusters, hence the different colors.

higher

lower

Magnetic Properties:

- The Nanoparticles of magnetic solids exhibit a new class of magnetic properties. The smaller particles are more magnetic than bulk material

Properties of nano materials

Electronic Properties:

•The electronic structure of Nanoparticles can be studied by UV photoelectron spectroscopy.

•When a UV photon strikes an electron in the valence band of an atom, the electron is ejected from the atom.

•The emitted electrons are counted by the spectroscope.

Applications of Nano materials

- **Electronics:** The electronic devices with typical dimensions of Nanometers in either of the three directions display many unique properties. Single electron transistor (SET), spin values and magnetic tunnel junctions (MTJ) are conceptually new devices based on nanotechnology.
- **Optics:** Nanoscience has entered the field of light emission by the use of light emitting diode. The phenomenon of luminescence is also of substantial interest in a number of applications. Example: Luminescent barcode structures, Photovoltaics is one of the most immediately attractive application of nanostructures.

  LED
- **Diagnostics:** Nanotechnology is helpful in medical diagnostics by providing faster, cheaper and portable diagnostic equipments.

Applications of Nano materials

- **Novel drugs:** They aid in the delivery of just the right amount of medicine to the exact spots of the body that need it.

- **Energy:** It provides new methods to effectively utilize our current energy resources. Mono and polycrystalline silicon are widely used in solar cells

- **Sensors:** Sensors based on nanotechnology are more sensitive and hence more effective

- **Superior lightweight materials:** The strength and lightweight of Nanomaterials make them widely used in tear-resistant clothes, spout materials, bulletproof clothing, carbon fiber, etc.

AKTU QUESTIONS

Q1	Discuss the properties and the potential applications of Nano materials. What are the risks of using Nano materials to human body ?	AKTU 2022-23

→ Toxicity
→ Bioaccumulation
→ Inhalation Hazard
→ Skin Penetration

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Thank You