

Condensed Matter Physics
Prof. G. Rangarajan
Department of Physics
Indian Institute of Technology, Madras


Lecture - 33
Superconductor-Worked Example

(Refer Slide Time: 00:17)

Worked Example 70

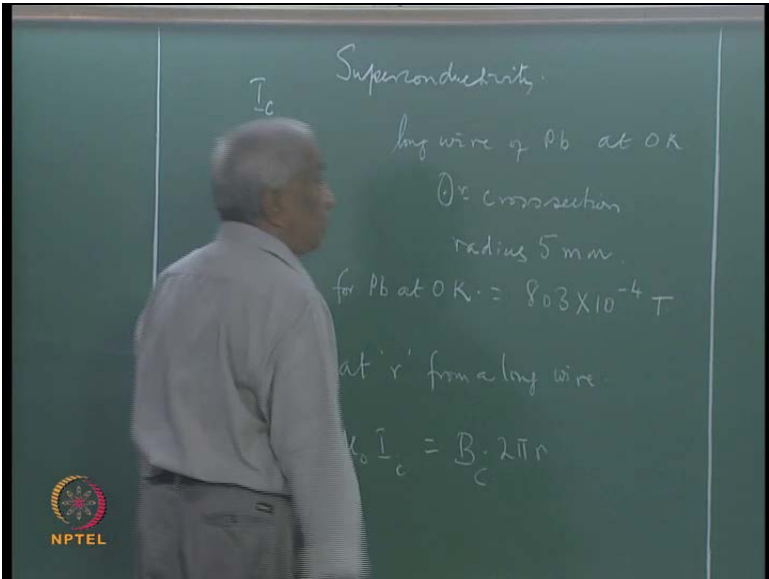
Problem

Calculate the critical current and the critical current density at 0 K, for a long wire of lead which has a circular cross section of radius 5 mm. Critical field for Pb at 0 K = 803×10^{-4} Tesla.



Today, we will consider some solved examples on the topic of superconductor. The first example, concerns the critical current and critical current density.

(Refer Slide Time: 00:31)



So, the critical current density and the critical current for a long wire of lead at 0 Kelvin, long means the length is very long in comparison to the lateral dimensions. It is a wire of circular cross-section and radius 5 millimeter. We are told to the critical field at zero kelvin for length is 803×10^{-4} Tesla.

(Refer Slide Time: 02:02)

Solution

The magnetic field at a distance r from a long wire carrying current I is given by


$$B = \mu_0 I / 2\pi r$$

The critical current I_c generates critical magnetic field, B_c , near the superconductor which destroys the superconductivity.

Therefore

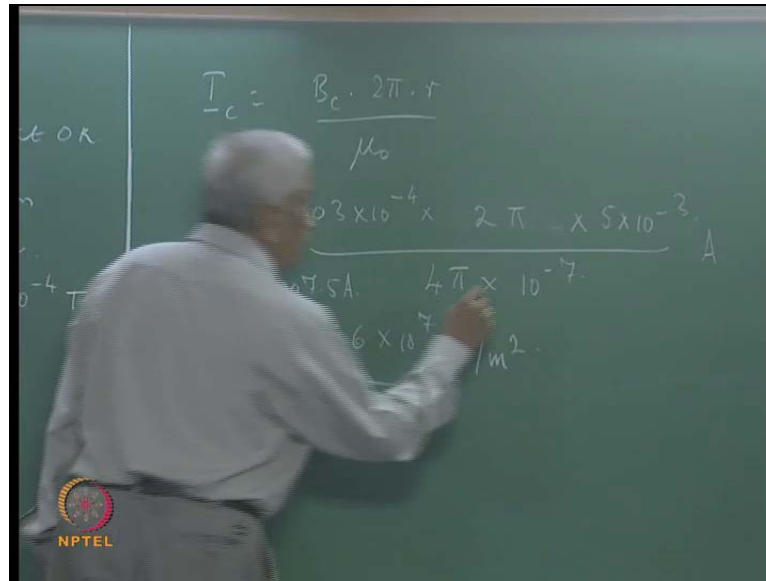
$$I_c = 2\pi r B_c / \mu_0$$

where r is the radius of the wire.



So, this is the data given and we have to find the critical current for which we go back to the ampere's theorem which gives the magnetic field at a distance r from a long wire. So, this is given by ampere's circuital theorem $\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I$ is the current. And in this case, obviously, the $d\mathbf{l}$ is going to give you B is constant. So, this will be B times $2\pi r$. So, this is the critical field this will be the corresponding critical current.

(Refer Slide Time: 03:03)



So, I_c will be B_c into two pi r divided by mu naught, so that we have to simply substitute the values the radius is given a 5 millimeters divided by 4 pi minus 7 and appears.

(Refer Slide Time: 04:08)

The slide contains the following calculations:

$$I_c = 2\pi \times 5 \times 10^{-3} \times 803 \times 10^{-4} / 4\pi \times 10^{-7}$$
$$= 2007.5 \text{ A}$$

Critical current density

$$J_c = I_c / \pi r^2$$
$$= 2007.5 / \pi \times (5 \times 10^{-3})^2$$
$$= 2.56 \times 10^7 \text{ A/m}^2$$

The NPTEL logo is in the bottom left corner.

So, this in simplified works out to the critical current is 2007.5 amperes in the corresponding critical current density works to be this.

(Refer Slide Time: 04:28)


Worked Example 71

Problem

In the above problem, calculate the critical current density at 4 K. T_c for Pb is 7.193 K.

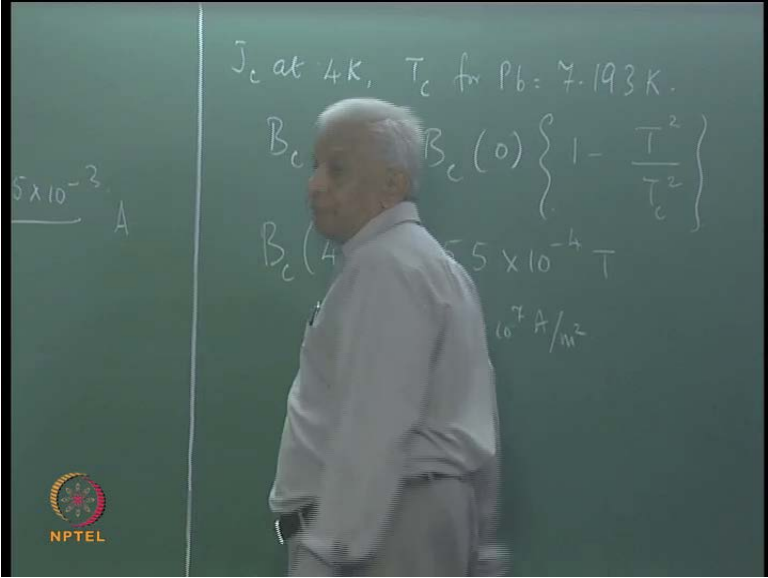
Solution

Temperature dependence of B_c is given by

$$B_c(T) = B_c(0) \left[1 - \left(\frac{T}{T_c} \right)^2 \right]$$
$$B_c(4) = 803 \times 10^{-4} \left[1 - \left(\frac{4}{7.193} \right)^2 \right]$$
$$B_c(4) = 555 \times 10^{-4} \text{ Tesla}$$


The next problem is a continuation of this where we are asked to calculate the critical current density at 4 k which was 0 k.

(Refer Slide Time: 04:44)




J_c at 4k, T_c for Pb = 7.193 K.

$$B_c = B_c(0) \left\{ 1 - \frac{T^2}{T_c^2} \right\}$$
$$B_c(4) = 55 \times 10^{-4} \text{ T}$$


$5 \times 10^{-3} \text{ A}$

10^7 A/m^2




And for this we need the additional data regarding the transition temperature for lead that is given to be 7.193 Kelvin. So, we start from the expressions for the critical magnetic field at any temperature in terms of the critical magnetic fields at 0 K that is the parabolic law. So, substituting these values B_c at 4 K works out to be 555×10^{-4} Tesla.

(Refer Slide Time: 05:52)


$$\begin{aligned}\text{Critical current at 4 K } I_c &= 2\pi r B_c(4) / \mu_0 \\ &= 2\pi \times 5 \times 10^{-3} \times 555 \times 10^{-4} / 4\pi \times 10^{-7} \\ &= 1387.5 \text{ A} \\ \text{Critical current density } J_c &= 1387.5 / \pi (5 \times 10^{-3})^2 \\ &= 1.77 \times 10^7 \text{ A/m}^2\end{aligned}$$

So, while working back at the critical current density in the same way as in the last problem beget this as 1.77 into 10 to the 7 ampere for mu square.

(Refer Slide Time: 06:16)



Superconductivity.

Hg $A = 202 \cdot (M)$

$M^\alpha T_c = \text{Constant}$

$\alpha = 0.5 \rightarrow$ Phonon Mechanism

$T_c = 4.153 \text{ K}$

$$(202)^{0.5} \times 4.153 = (200)^{0.5} T_c$$
$$T_c = 4.174 \text{ K}$$


Next problem, these about this sample of mercury we are given the mass number is 202, and we are also told that there is an isotropic dependence of the form M to the power alpha let us use the same symbol m here isotropic mass T c is constant, where alpha is also given to the 0.5 the transition temperature is given as 5.153 k.

(Refer Slide Time: 06:55)

Worked Example 72

Problem
For mercury of mass number 202, it is found that
 $M^\alpha T_c = \text{constant}$ where
 $\alpha = 0.50$ and the transition temperature is 4.153 K. Find
the transition temperature for the isotope of mercury of
mass number 200.

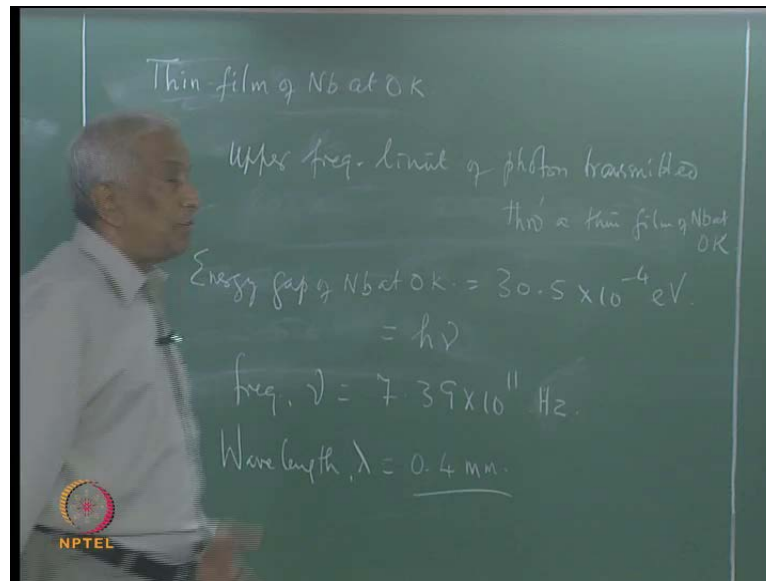
Solution

$$(202)^{0.5} \times 4.153 = (200)^{0.5} T_c$$
$$T_c = (202/200)^{0.5} \times 4.153$$
$$= 4.174 \text{ K}$$


So, with all these values be as the relation $202^{0.5} \times 4.153$ is equal to we are all as to find the transition temperature for the isotropic of mass 200. So, substituting the values we get a number there is a result is T_c is 4.174 Kelvin. It is this isotropic dependence of the critical temperature which gave a clue especially in this value of alpha equal to point five which gave a clue to the mechanism of superconductivity the phonon mechanism. Because the phonon are involves then the mass there will be a mass dependence is given by this the simple harmonic oscillator model as 0.5.

Of course, there are many instances where this isotropic dependence is satisfied with the different value of alpha. This is because there can be many mechanism rather than phonon mechanisms and they can be and un harmonistic as well. So, this is not a very these not always the case that this relation is satisfied, but in the case of mercury this relation is found to be satisfied to a considerable degree of accuracy.

(Refer Slide Time: 09:08)




Then the next problem is about as thin film of niobium at zero k. Again we are asked to find the upper frequency limit of photon is transmitted through a thin film through a thin film at zero k.

(Refer Slide Time: 09:56)

Worked Example 73

Problem

Calculate the upper frequency limit of a photon that is transmitted through a thin film of Nb at 0 K. The energy gap of Nb at 0 K is 30.5×10^{-4} eV. Find the corresponding wavelength.



For which we are given the data the energy of niobium at zero k is given as thirty point five into ten to power minus four electron walls.


(Refer Slide Time: 10:19)

Solution

The energy gap $E_g = h\nu = 30.5 \times 10^{-4} \times 1.6 \times 10^{-19} \text{ J}$

$$\nu = (30.5 \times 10^{-4} \times 1.6 \times 10^{-19}) / 6.6 \times 10^{-34}$$
$$= 7.39 \times 10^{11} / \text{sec}$$

The corresponding wavelength

$$\lambda = c/\nu = 3 \times 10^8 / 7.39 \times 10^{11}$$
$$= 4.06 \times 10^{-4} \text{ m}$$
$$= 0.4 \text{ mm}$$



So, we are given this energy now we have to simply set it equal to $h\nu$. So, the upper frequency limit corresponds to the frequency at which the energy of the photon just equals that of the energy gap. So, the corresponding h is the constant. So, that the upper frequency limit works out to be second inverse are hertz. We also have to find the corresponding wavelengths and that works out to be two point four millimeters which is in the microwave range. So, it is the microwave photon which can be transmitted.

(Refer Slide Time: 11:27)

Worked Example 74

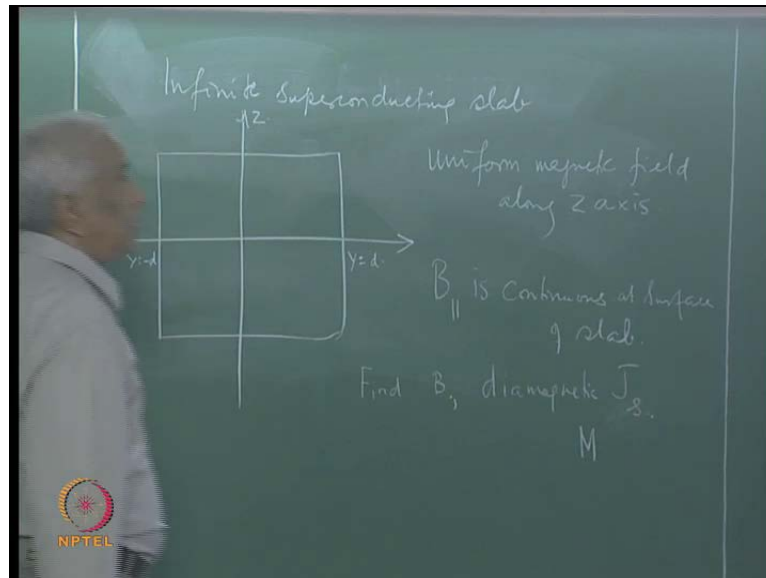
Problem

Consider an infinite superconducting slab bounded by two parallel planes perpendicular to the Y-axis at $Y = \pm d$. Let a uniform magnetic field be applied along the Z-axis. Taking the boundary condition that the parallel component of B be continuous at the surface, find the induction B , the diamagnetic current density J and the magnetization density M at a point within the superconductor. Hence get the limiting form for the susceptibility for a thick and a thin slab.



The next problem talks about a general superconductor and infinite superconducting slab.

(Refer Slide Time: 11:38)



So, we have the next figure shows the geometry you have it is bounded by 2 parallel planes perpendicular to the y axis at y equal to plus minus d. So, this is y is the and this is y is the minus. So, there is a magnet uniform magnetic fields applied along the z axis.

(Refer Slide Time: 12:57)

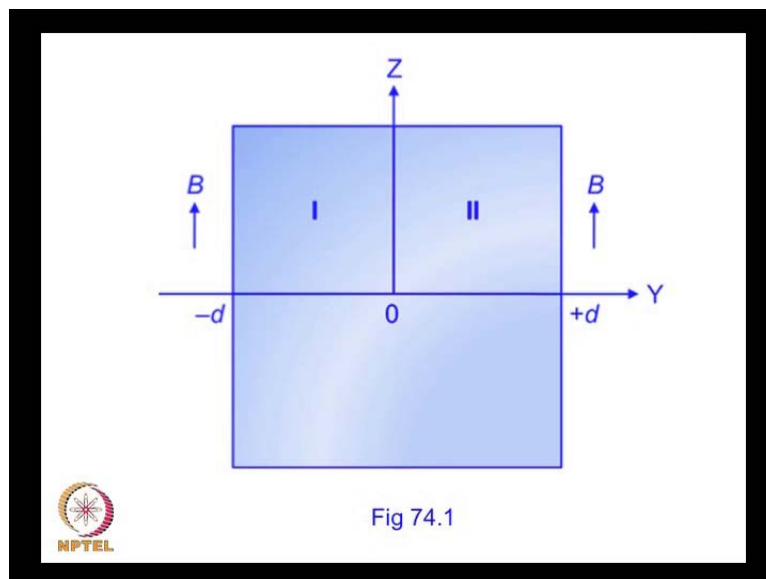


Fig 74.1

We are ask to take a boundary condition that the b parallel the parallel component of this field is continuous at the interface. So, that is the boundary conditions. So, we are asked

to find the magnetic induction b the diamagnetic current density j_s and the magnetization density at a point within this superconductor.

(Refer Slide Time: 14:05)

Solution


The equation for B inside the superconductor is

$$\nabla^2 B = \frac{B}{\lambda_L^2} \quad (74.1)$$

In one dimension,

$$\frac{d^2 B}{dy^2} = \frac{B}{\lambda_L^2} \quad (74.2)$$

Solution to the equation is,

$$B(y) = B_1 \exp\left(\frac{y}{\lambda_L}\right) + B_2 \exp\left(-\frac{y}{\lambda_L}\right) \quad (74.3)$$


So, this is a problem which concerns the application of the London equation.


(Refer Slide Time: 14:21)

Superconductivity.

In region I,

eqn: $\nabla^2 B = \frac{B}{\lambda_L^2}$

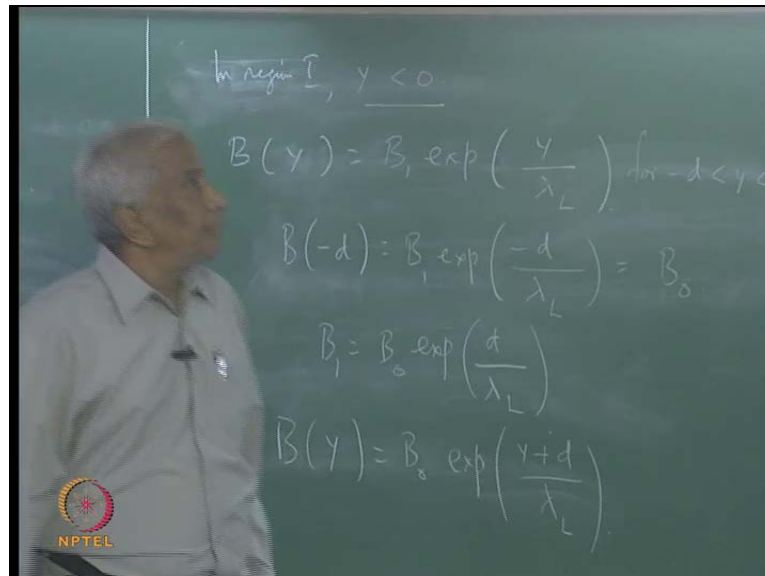
$$\frac{d^2 B}{dy^2} = \frac{B}{\lambda_L^2}$$

$$B_1 \exp\left(\frac{y}{\lambda_L}\right) + B_2 \exp\left(-\frac{y}{\lambda_L}\right)$$


So, restart from the London equation $\nabla^2 b = \frac{b}{\lambda_L^2}$ the corresponding one-dimensional equation is $\frac{d^2 b}{dy^2} = \frac{b}{\lambda_L^2}$. So, this is a second-order differential equation for which the solution is known to be $b = B_1 \exp\left(\frac{y}{\lambda_L}\right) + B_2 \exp\left(-\frac{y}{\lambda_L}\right)$. So, that is the

expression for the magnetic induction as a function of y within the superconductor now we apply the boundary conditions.

(Refer Slide Time: 15:41)



So, in region one in the figure y is negative in y is negative in region one y is less than zero. So, if that is. So, the first term in this solution will be bounded while the second term will not be bounded. So, this will go, so we have b of y you will have only b one exponential y by λ_L for minus b less than y less than zero. And they can also apply the boundary condition b of y minus d is b one exponential minus d by λ_L equals b zero.


(Refer Slide Time: 16:51)

so that $[B(y)]_I = B_0 \exp\left[\frac{(d+y)}{\lambda_L}\right]$ for $-d < y < 0$ (74.7)

Similarly for region II, we get,

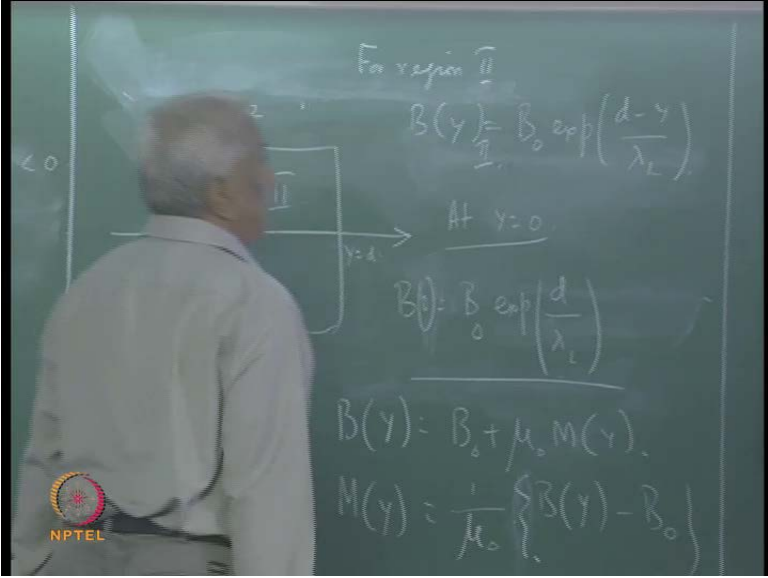
$$[B(y)]_{II} = B_0 \exp\left[\frac{(d-y)}{\lambda_L}\right] \text{ for } 0 < y < d \quad (74.8)$$

At $y = 0$,

$$B(0) = B_0 \exp\left[\frac{d}{\lambda_L}\right] \quad (74.9)$$


So, B_1, B_0 exponential d by λ_L by a similar argument, so that we can also write $b f y$ as b zero here substituting exponential in this, so y plus d y λ_L we can follow a similar line of argument for region two.

(Refer Slide Time: 17:28)




For region II

$$B(y) = B_0 \exp\left(\frac{d-y}{\lambda_L}\right)$$

At $y=0$

$$B(0) = B_0 \exp\left(\frac{d}{\lambda_L}\right)$$

$$B(y) = B_0 + \mu_0 M(y)$$

$$M(y) = \frac{1}{\mu_0} \{B(y) - B_0\}$$


And get the solution as $b f y$ is p zero exponential p minus y by λ_L . So, you have to know match it match these two solutions at y equal to zero. So, b zero is $b f$ zero b at y equal to zero is two are exponential d by λ_L .

(Refer Slide Time: 18:22)


The magnetization:

$$B(y) = B_0 + \mu_0 M(y) \quad (74.10)$$

So that $M(y) = \frac{1}{\mu_0} [B(y) - B_0]$

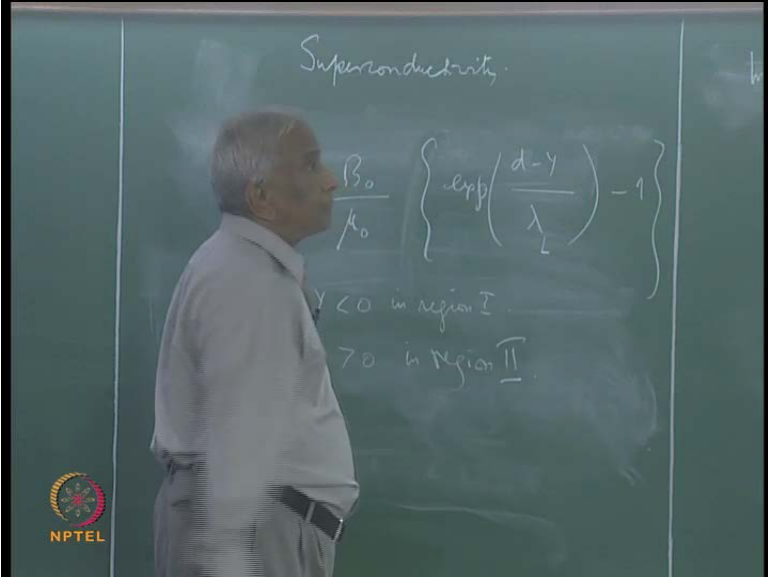
$$M(y) = \frac{B_0}{\mu_0} \left[\exp\left(\frac{d-y}{\lambda_L}\right) - 1 \right] \quad (74.11)$$

with y negative in region I
and y positive in region II



So, that is the magnetic induction which was asked to be found. So, correspondingly the magnetization is $B(y) = B_0 + \mu_0 M(y)$. It gives the standard result $M(y) = \frac{1}{\mu_0} [B(y) - B_0]$. So, plugging the value by expressions for $B(y)$.

(Refer Slide Time: 19:18)



The magnetization $M(y)$ is $\frac{B_0}{\mu_0} \left[\exp\left(\frac{d-y}{\lambda_L}\right) - 1 \right]$ where y is negative in region one when positive in region two.


(Refer Slide Time: 19:58)

Susceptibility: $\chi = \frac{\mu_0 M(y)}{B_0} = \frac{B(y)}{B_0} - 1$ (74.12)

Limiting conditions:

For $d \ll \lambda_L$ $B(y) \approx B_0$ so $\chi \approx 0$ (74.13)

For $d \gg \lambda_L$ $B(y) \approx 0$ so $\chi \approx -1$ (74.14)



We also asked to find delimiting form for the susceptibility the magnetic susceptibility is related to the magnetization.


(Refer Slide Time: 20:13)

Susceptibility

$$\chi = \frac{\mu_0 M(y)}{B_0} = \frac{B(y)}{B_0} - 1$$

$d \ll \lambda_L$ $B(y) \approx B_0$ so $\chi \approx 0$

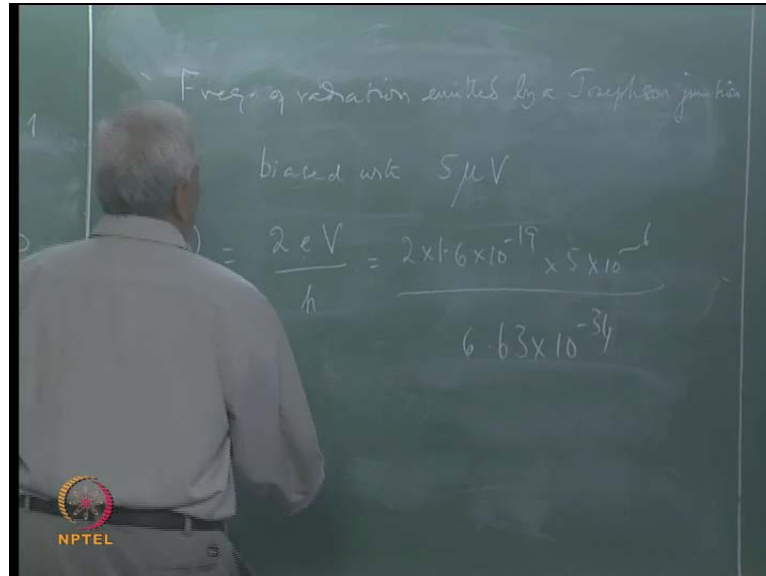
$d \gg \lambda_L$ $B(y) \approx 0$ so $\chi \approx -1$



How the susceptibility is given by the standard relation $\mu_0 M(y) / B_0$. So, that will be $B(y) / B_0 - 1$. So, for d very small compared to the London penetration for λ_L $B(y)$ is almost same as B_0 . So, χ is zero that is just outside just within short distance inside whereas, for d very large is compatible to London penetration have $B(y) \approx 0$ is minus that effect complete flux it

fusion and xi chance out have a perfect diamagnetic value minus of minus one v p pass on to another question.

(Refer Slide Time: 21:35)



Which we are asked to calculate the frequency radiation emitted by Josephson junction when the junction is by a as two the voltage of five micro volts in solution has straight forward from the Josephson equation. The frequencies two e v by h, where v is the voltage and then e is electronic h, h is the Planck constant.


(Refer Slide Time: 22:41)

Worked Example 75

Problem

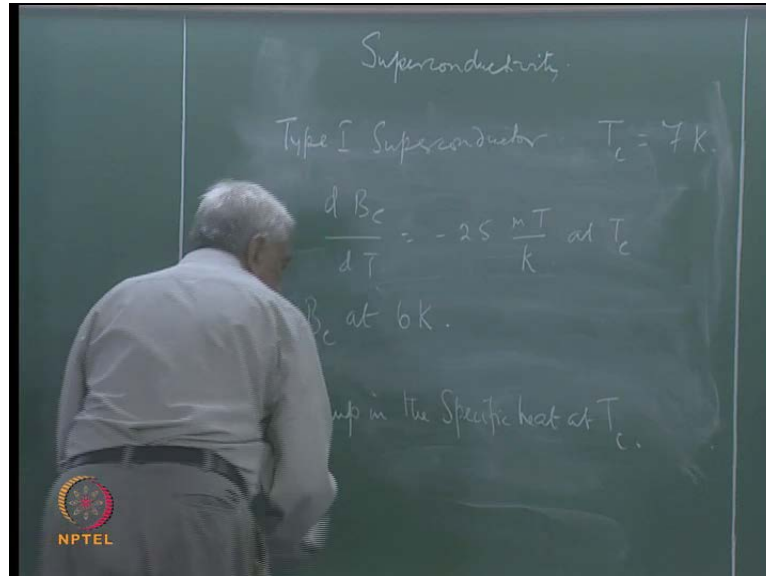
Calculate the frequency of radiation which a Josephson junction would emit when the voltage across the junction is $5 \mu\text{V}$.

Solution

$$\nu = \frac{2eV}{h} = \frac{2 \times 1.6 \times 10^{-19} \times 5 \times 10^{-6}}{6.63 \times 10^{-34}} = 2.41 \times 10^9 \text{ Hz}$$


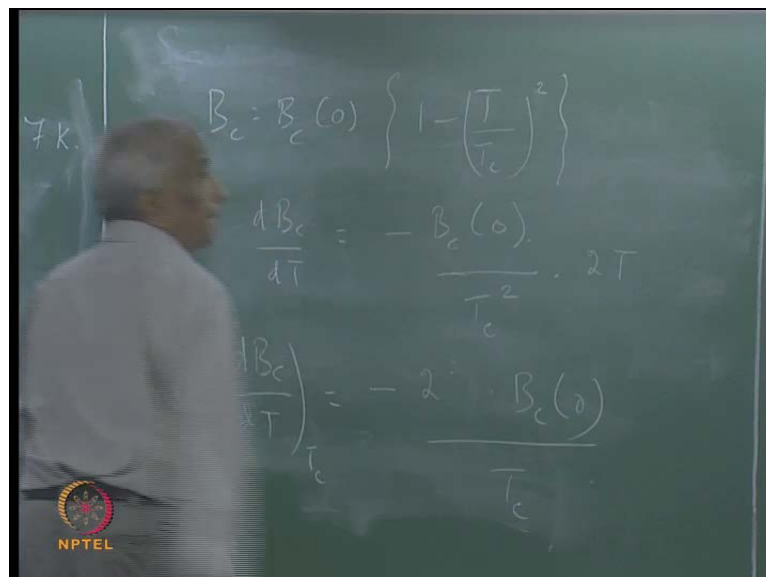
The substituting for all the numbers and that would be two point four one this will be a micro volts frequency gigahertz.

(Refer Slide Time: 22:55)



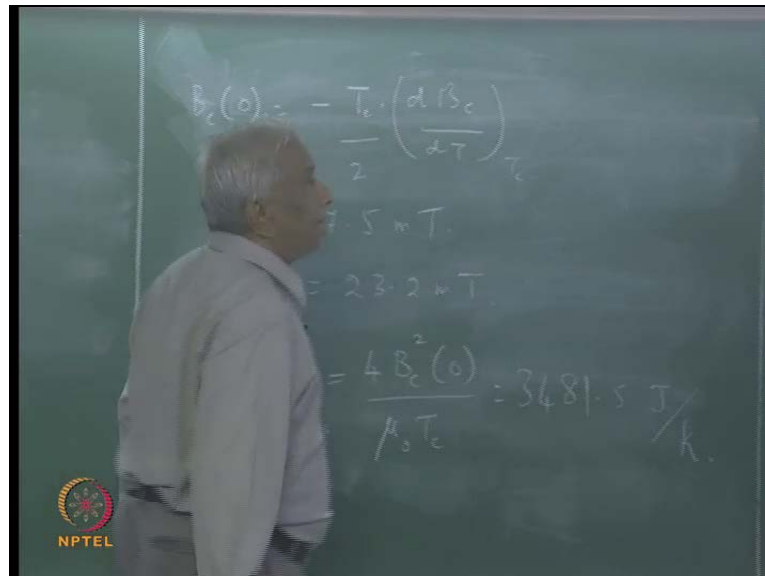
We next consider a type one superconductor in which transition temperature is given to be seven k probably late as a slope $d B_c / d T$ - the rate of change. The critical magnetic fields is minus 25 million meters law per k at T_c with this data are the are all as to estimate the critical field that six k and then calculate the than jumping the specific heat at T_c .

(Refer Slide Time: 24:06)



To do this we start from again the parabolic law and B_c by dT differentiating is minus B_c at T_c is T_c square into $2T_c$, now dB_c by dT at T_c is given.

(Refer Slide Time: 24:59)



So, substituting this, so B_c zero at absolute zero is just minus T_c times dB_c by dT at T_c divided by 2. So, substituting value this works as to eighty seven point five millimeters therefore, using the parabolic law it is quite easy to find the critical magnetic field at six k substituting the values it works out to be twenty three point two using this law the jumping the specific heat at T_c .

(Refer Slide Time: 25:50)

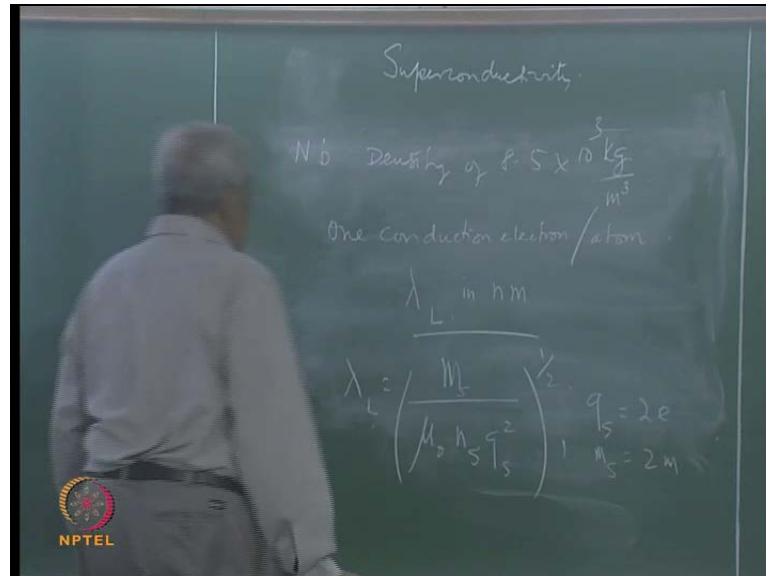
$$B_c(0) = -\frac{T_c}{2} \left(\frac{dB_c}{dT} \right)_{T_c} = -\frac{7}{2} (-25 \times 10^{-3}) = 87.5 \text{ mT}$$

$$B_c(6K) = B_c(0) \left[1 - \left(\frac{6}{7} \right)^2 \right] = 87.5 \text{ mT} \times 0.265 = 23.2 \text{ mT}$$

$$(C_N - C_S)_{T_c} = -\frac{4B_c^2(0)}{\mu_0 T_c} = -\frac{4 \times (87.5 \times 10^{-3})^2}{4\pi \times 10^{-7} \times 7} = -3481.5 \text{ J/K}$$

This subscript n and s means normal and superconducting and this was done in the lecture in given has . So, substituting all these values, this use the thirty four minus one five.

(Refer Slide Time: 26:21)



We next consider niobium. We already told that it has the density of eight point five into ten to power three kilogram per meter cube and it is donuts one conduction electron per atom. So, we are asked to calculate at the London penetration that lambda l of superconducting niobium in nanometers.

(Refer Slide Time: 27:06)

Worked Example 77


Problem

Nb has a density of $8.5 \times 10^3 \text{ kg/m}^3$ and has one conduction electron per atom. Its atomic weight is 93. Calculate the London penetration depth of superconducting Nb in nm.

Solution

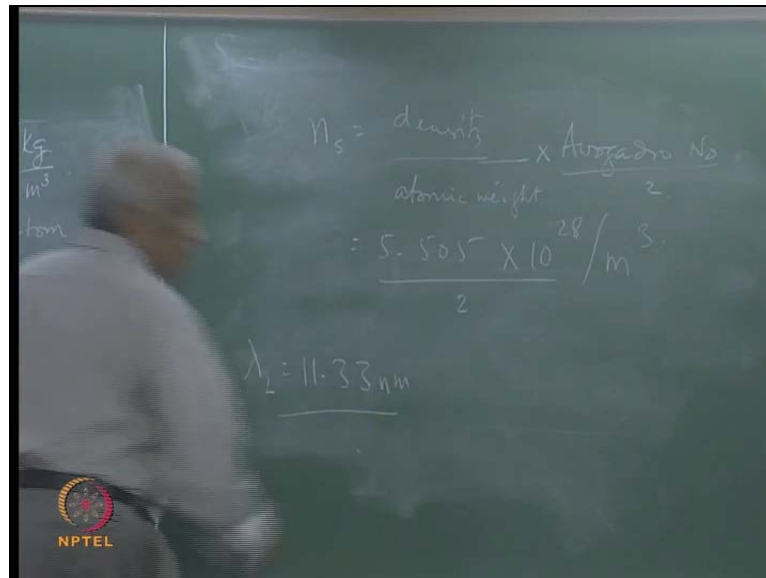
$$\lambda_L = \left[\frac{m}{\mu_0 n_s q^2} \right]^{1/2}$$

where $q = 2e$



Again it is a substitution will problem in which we using expression for the London penetration that as where q is q s is to e and m is also two m where e m stands for the electronic charge in mass effectiveness, n is the concentration of super current carriers cooper pairs.

(Refer Slide Time: 27:45)



In order to find the concentration of cooper pairs, we just take the density by atomic weight times the other Avogadro number. So, that works out to be if I point five zero five into twenty four twenty eight per meter cube well it should strictly by divided by 2. So, the London penetration left works out to be 11.33.

(Refer Slide Time: 28:34)

Worked Example 78


Problem
To what temperature should lead be cooled for it to be superconducting in a magnetic field of 20,000 A/m?

Solution

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

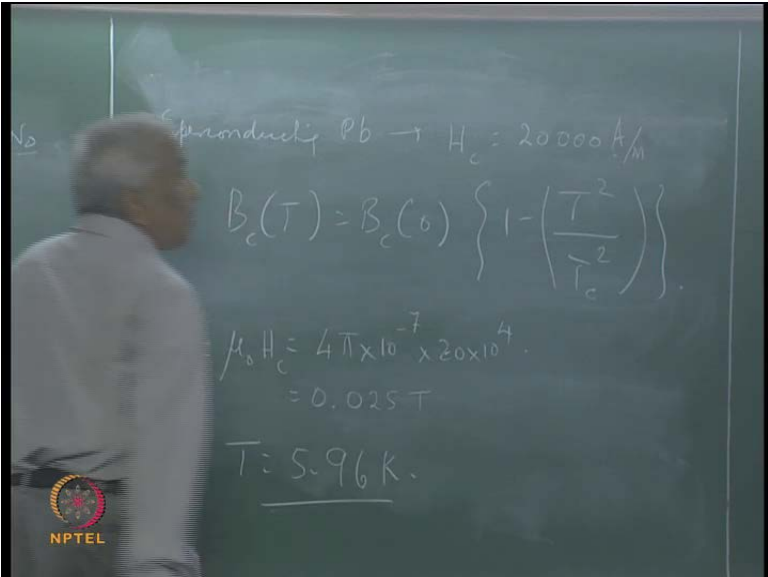
The field applied $H = 20,000 \text{ A/m}$

The field in Tesla: $B = \mu_0 H = 4\pi \times 10^{-7} \times 20,000 = 0.025 \text{ T}$




Next is equation and about a superconductor which is in a magnetic field superconducting led in a magnetic field of twenty thousand ampere per meters.

(Refer Slide Time: 28:47)



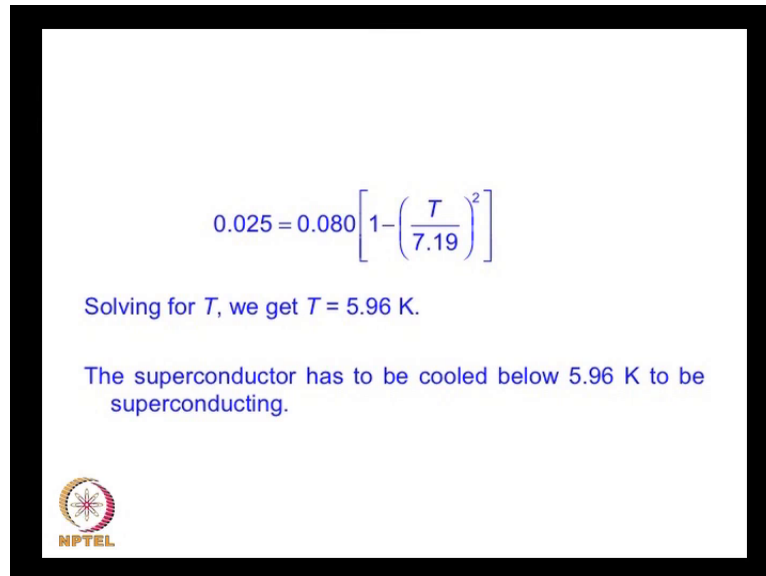
Superconductivity Pb $\rightarrow H_c = 20000 \text{ A/m}$

$$B_c(T) = B_c(0) \left\{ 1 - \left(\frac{T}{T_c} \right)^2 \right\}$$
$$\mu_0 H_c = 4\pi \times 10^{-7} \times 20 \times 10^4 = 0.025 \text{ T}$$
$$T = 5.96 \text{ K}$$


Because of the unit have used a H c i naught B c. So, what temperature should be cold for this to be superconducting in this magnetic field saw gained the critical magnetic field. So, we know the critical finance pressure and temperature of led and we have to find the t that is the temperature should which you should be cold and the field is twenty thousand ampere per meter which corresponds to b c corresponds to in Tesla mu naught

h c. So, it will be four pi into 10 to power minus seven into twenty two into twenty thousand. So, that works out to be naught point naught two pi Tesla.


(Refer Slide Time: 30:15)



$$0.025 = 0.080 \left[1 - \left(\frac{T}{7.19} \right)^2 \right]$$

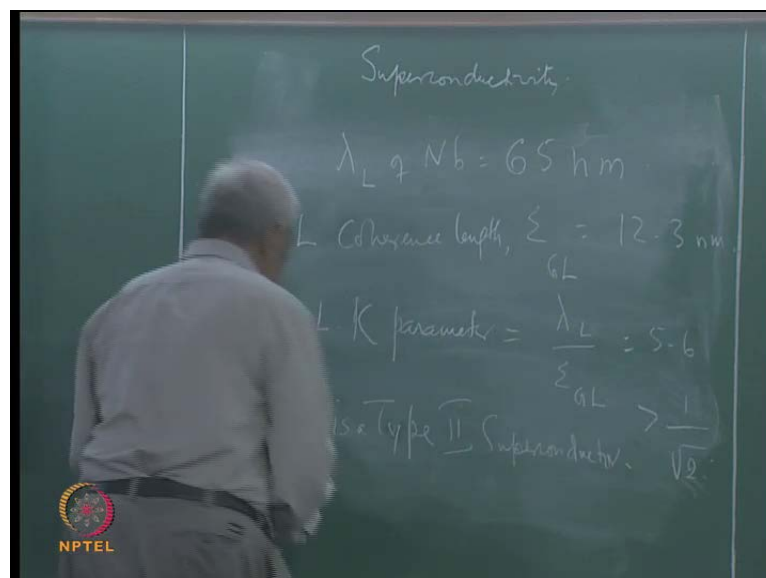
Solving for T , we get $T = 5.96$ K.

The superconductor has to be cooled below 5.96 K to be superconducting.



Substituting this value is readily found to be 5.96 k, we have to cool the led sample below five point nine six k in order that to be superconducting.

(Refer Slide Time: 30:39)




Superconductivity

λ_L of Nb = 65 nm

L coherence length, $\xi = 12.3$ nm

L K parameter = $\frac{\lambda_L}{\xi} = 5.6$

is a Type II Superconductor. $\frac{\lambda_L}{\xi} > \frac{1}{\sqrt{2}}$



Next we are given the London penetration is that of niobium as sixty five nanometers and its Ginsburg Glandau coherence length standard for symbol for s t c l it is given to be twelve point three nano meters. So, the Ginsburg Galndau kappa parameters which is

crucial for determining other it is a type one or type two superconductor is the ratio of κ . So, that works out to be 5.6.


(Refer Slide Time: 31:26)

Solution

The GL parameter of Nb = $\lambda_L/\xi_{GL} = 65/12.3 = 5.6 > 1/\sqrt{2}$

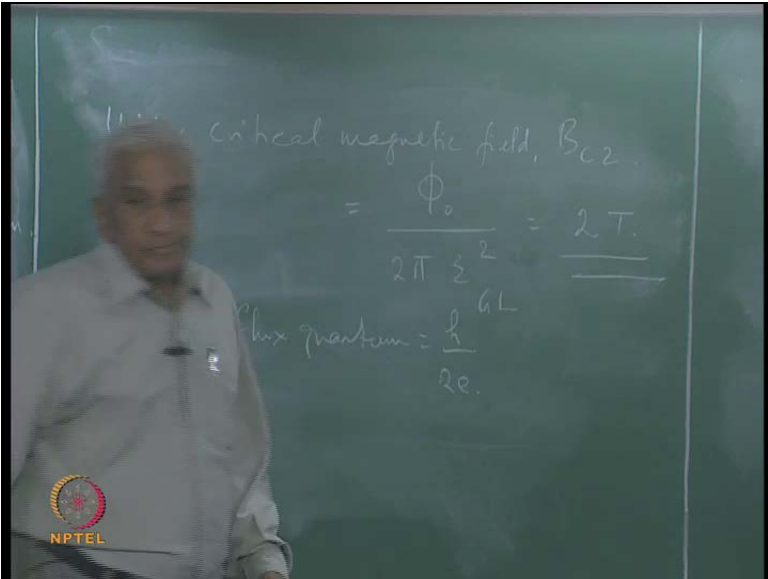
Hence Nb is a type II superconductor

Its upper critical magnetic field is:

$$B_{c2} = \phi_0/2\pi\xi_{GL}^2 = 6.6 \times 10^{-34}/(2 \times 1.6 \times 10^{-19} \times 2 \times 3.14 \times (12.3)^2 \times 10^{-18})T = 2 T$$


In this case, which is greater than $1/\sqrt{2}$, so the Ginsburg Glandau criterion for a type two behavior is that this κ should be greater than $1/\sqrt{2}$ which is the case so it is a type two superconductor that are also ask to find the magnetic field for which the flexible completely secluded from the type two superconductor.


(Refer Slide Time: 32:22)



Upper critical magnetic field, B_{c2} .

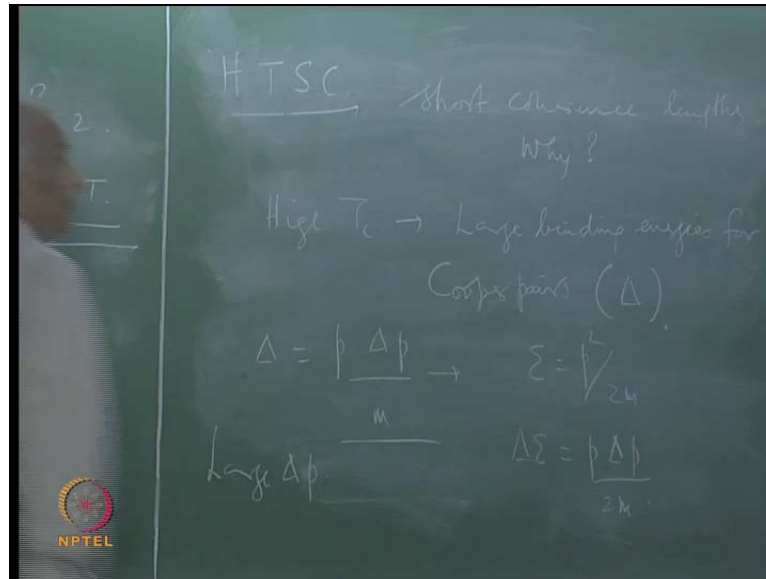
$$= \frac{\phi_0}{2\pi \xi_{GL}^2} = \underline{\underline{2 T}}$$

flux quantum = $\frac{h}{2e}$



And the magnetic field b the upper critical field b_{c2} and that was found from the discussion on the Ginsburg Glandau theory a five naught by $2\pi\psi_0$ by $2\pi f$ square where five naught is the flux quantum equal to h by $2e$ and size g l is already given. Now plugging these number in obtain the critical magnetic field upper critical magnetic field, so that turns out to be to Tesla.

(Refer Slide Time: 33:26)




Next we go to the question about high temperature superconductors, they have very short coherence link. This is an experimental finding they are asked to explain why we know on the b c s theory a that if we have a high t_c which is the case in the superconductor this means large binding energies for cooper pairs standard symbol is delta. Now the delta is given by $p \Delta p$ by 1 because we know the kinetic energy is p square by $2m$. So, $\Delta = \frac{p \Delta p}{2m}$. So, this is the relation between delta and p . So, this large value of the delta this is a large uncertainty in Δp .

(Refer Slide Time: 35:02)

Worked Example 80

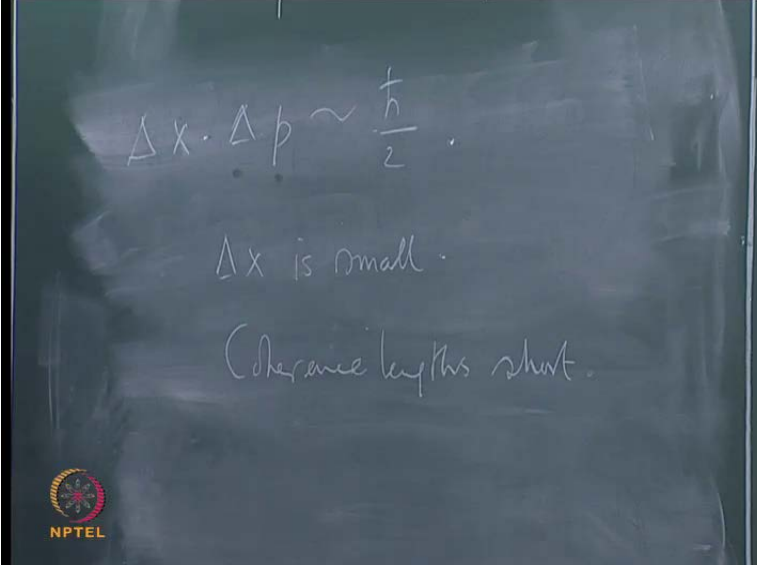
Problem
High T_c superconductors have very short coherence lengths. Explain why.

Solution
High transition temperatures indicate large binding energies for Cooper pairs and hence high energy gaps. This means correspondingly large uncertainties in the linear momenta, because $\Delta = p \Delta p/m$. Because of the uncertainty principle this would lead to short coherence lengths.



And the uncertainty relationship tells us that the product of the uncertainty in the moment and the position $\Delta x \Delta p$ is in order of h cross 2.


(Refer Slide Time: 35:12)



$\Delta x \cdot \Delta p \sim \frac{\hbar}{2}$

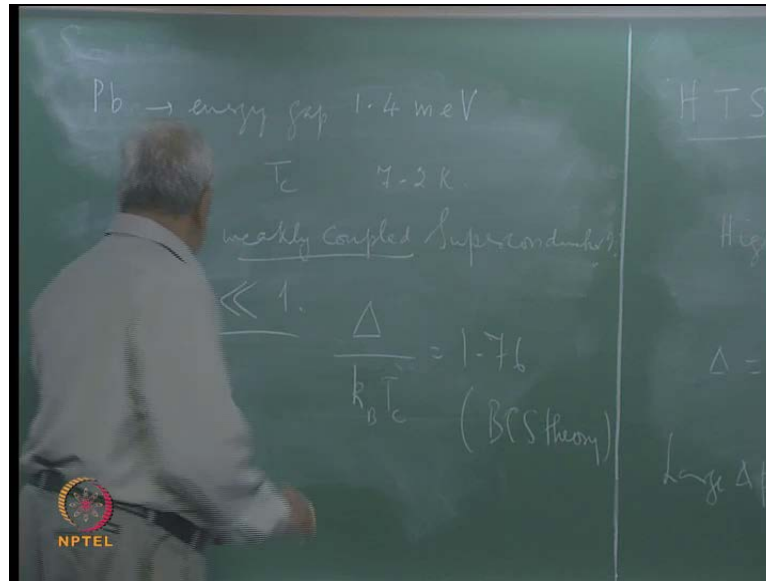
Δx is small.

Coherence lengths short.



So, if the uncertainty the momentum p is large, the uncertainty the portion is small this explains y the coherence links short.

(Refer Slide Time: 35:50)



Now, consider a question again regarding P b we are given the energy gap of led as 1.4 milli electron volt.

(Refer Slide Time: 36:06)

Worked Example 81

Problem
Pb has an energy gap of 1.4 meV and a superconducting transition temperature of 7.2 K. Determine whether it is a weakly coupled superconductor.

Solution
According to BCS theory , in the weak coupling limit
$$\frac{\Delta}{k_B T_c} = 1.76.$$

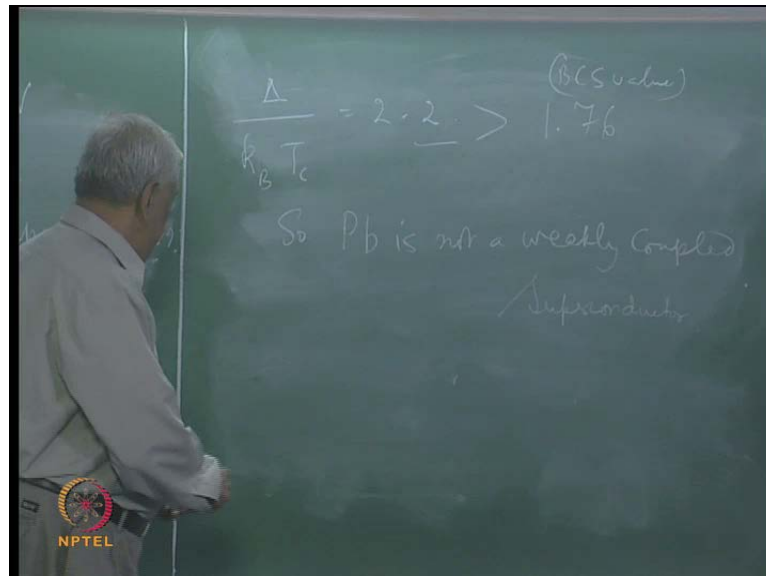
For Pb this ratio is $1.4 \times 10^{-3} \times 1.6 \times 10^{-19} / 1.38 \times 10^{-23} \times 7.2$
$$= 2.2$$

So it is not a weakly coupled superconductor.

And the transition temperature is 7.2 k as we already know. So, we are ask to find is it a weakly coupled superconductor. We know the condition for the v coupling if the b c s theory is that the condition for the v coupling. And the v coupling limit, we also know that the ratio of weld are the energy gap to k B T c is 1.76 according to BCS theory. So,

we are given the values of delta and T c. So, it is a simply checking how is values compare.

(Refer Slide Time: 37:14)



So, taking this ratio delta by k B T c for led, so the given data is comes to be 2.2 certainly much higher than 1.76 BCS value. So, the conclusion is led is not their weakly coupled superconductor, it is what is called the intermediate coupling.