Analog Electronic Circuits
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Lecture no 12
Module no 01
Problem Session 3 on Mid-Frequency Analysis of CE Amplifier

This is the 12th lecture and this our problem session 3, we will work out problems on mid-frequency analysis of common emitter amplifiers, the theory that we developed yesterday. We will see its applications in calculating figures for practical problems, but before that we want to take up a couple of problems couple of interesting problems about BJT biasing and current mirrors which we had not done earlier and the 1st problem is this.

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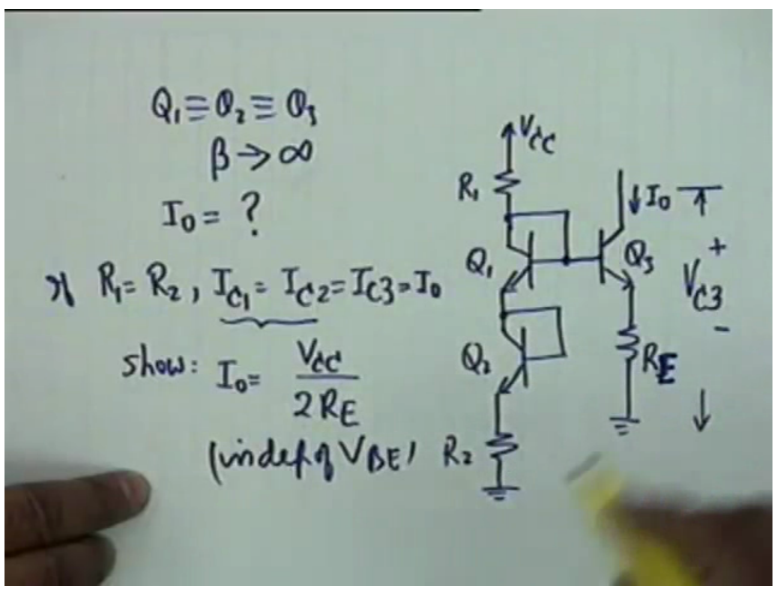

We had a fairly elaborate circuit, try to draw with me, this is Q 1 and its base is connected to to the collector, we have a 2nd transistor like this Q 2 whose base is also connected to the collector and then we have a resistance R 2 which goes to ground and this transistor Q 1 drives another transistor Q 3, the current here is I 0 and the resistance here is R E connected to the emitter it is R E and the voltage measured from here to ground is V C3 okay, it is not V CE because from collector to ground V C3 this is the circuit, it is not the ordinary circuit it is not the ordinary current mirrors circuit, it is not the (())(2:53) either, there is an extra transistor and let us see what the question says.

The question says in this circuit assume all transistors to be identical, Q 1, Q 2, Q 3, there are 3 transistors made on the same chip and therefore they are identical. And the Betas are so large that they can be assumed to go to infinity, which means that the base current is negligible compared to the collector current and the collector current and emitter current are the same okay alright, beta tends to infinity, the question is to find an expression for I 0, this current the current that is drawn by the load transistor, it is this current which is required to be stabilized okay, so find I 0 this is the 1st part of the question and then it says that if R 1 = R 2, if these 2 resistors are equal if R 1 = R 2 and all collector currents are equal that is I C1 = I C2 = I C3, now obviously this does not require a stipulation, I C1 must be the same as I C2 because they flow like this.

The base current, the only diversion is this base current, this is negligible and therefore I C1 = I C2 is is given by this circuit, what you want to do is I C3 which = I 0, I C3 = I 0, you want this current to be a mirror of this current alright, you want I 0 to be a mirror of I C1, I C1 is the same as current through R 1 because the base currents are negligible.

Student: But there is base current in Q 2 also.

Professor: That is correct, all base currents are negligible.

Beta tends to infinity and therefore what you want is this current which is the reference current should flow in the load transistor also so it says if this is so then show that I 0 = V CC divided by twice R E, the idea is you remember in the ordinary current mirror, the reference current is V CC – V BE divided by the reference resistance R 1, here you see this is independent of V BE and this is the purpose of this circuit, this is also a current mirror, you wanted to make I 0 even if V BE is small compared to V CC, V BE decreases with temperature, it is a temperature sensitive element and therefore what you want to do is this current you want to make independent of V BE and this is the purpose of this circuit okay.

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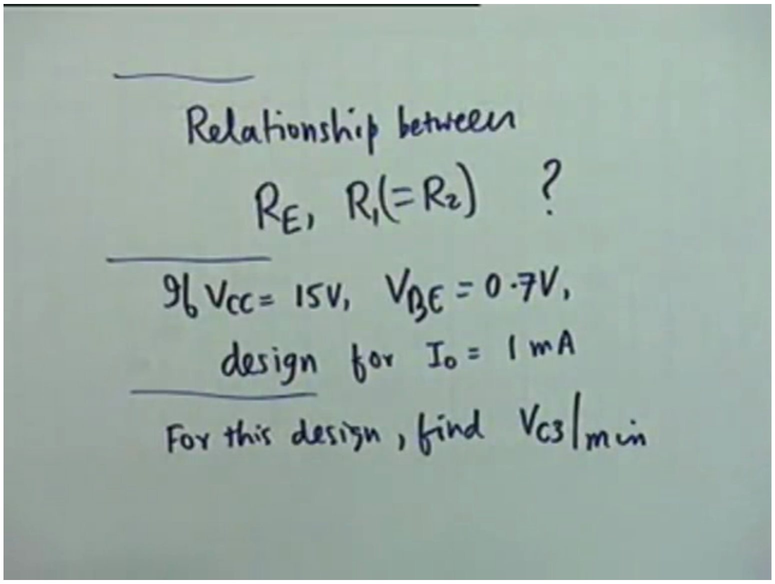

Under this condition the next question is, what is the relationship between, this is also wanted, relationship between R E, R 1 and R 2, R 1 and R 2 are equal given so what is the relationship that is wanted that means what is the value of R E required to satisfy this condition that all collector currents are equal then a numerical part, if V CC = 15 volts and V BE can be taken as 0.7 volts, design the circuit to have... Design means you find out these resistors R E, R 1 and R 2 okay, design the circuit to have I 0 = 1 milliampere alright, this is third-party. And the 4^{th} part is, under this condition that is for this design for this design, what is the lowest voltage that can be applied to the collector of Q 3 that is find V C3 minima, what is the lowest voltage required for the current mirror to operate?

Is there a lowest voltage? Why cannot we apply any voltage that we like? Why is this question, find the lowest V C3? Pardon me... Saturation that is right, we do not want Q 3 to be in saturation, we want Q 3 to be in the active region that is V CB must be... A quantity like voltage being reversed bias does not makes sense, V CB should be either positive or negative, what do you require V CB to be?

“Professor–student conversation starts”

Student: Negative.

Professor: No.

Student: Positive.

Professor: Positive because it is to be reverse bias, it is an NPN transistor okay, so you want V CB to be positive. Now what is V CB? Just a minute, V CB = V CE + V EB no, let us put it the other way round. V CE = V CB + V BE right, so lowest V CE that is required is V CB at the most can be 0, it should be positive so V CB is greater than = 0 and therefore V CE must be greater than = V BE that means the collector emitter voltage must be no less than V BE no less than 0.7 okay that is the meaning of the 4th question, is the question clear? Yes.

Student: Sir (())(9:26)

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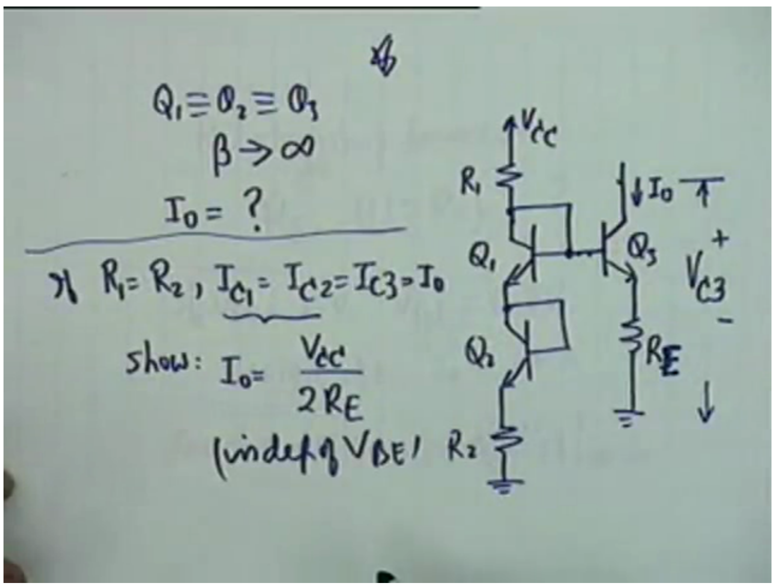

Professor: Oh we have to find a lots of things okay, let me go bag. 1st thing is we have to find I 0 general expression okay, 2nd is R 1 and R 2 and all collector currents are made equal then show that I 0 is this okay. Now if this is to be true then what is the relationship between R E and R 1, if all collector currents have to be equal what is the relationship, then a numerical part design the circuit for a given load current of 1 milliampere.

Student: I 0 = V CC by 2 R E is also a condition for (())(10:12)

Professor: That is correct that is correct, that is if all collector currents have to be equal, what is the relationship between R E and R 1, it is only under that condition that I 0 = V CC by 2 R E alright. Then this is the numerical part and then finally for this design what is the minimum V C3 and that I have already explained, , why a minimum is needed. Now if you look at this circuit carefully, you can see that this voltage the voltage from here to ground can be calculated by 2 roots, one is via Q 3 and the other is via Q 1 Q 2 R 2 alright.

"Professor–student conversation ends"

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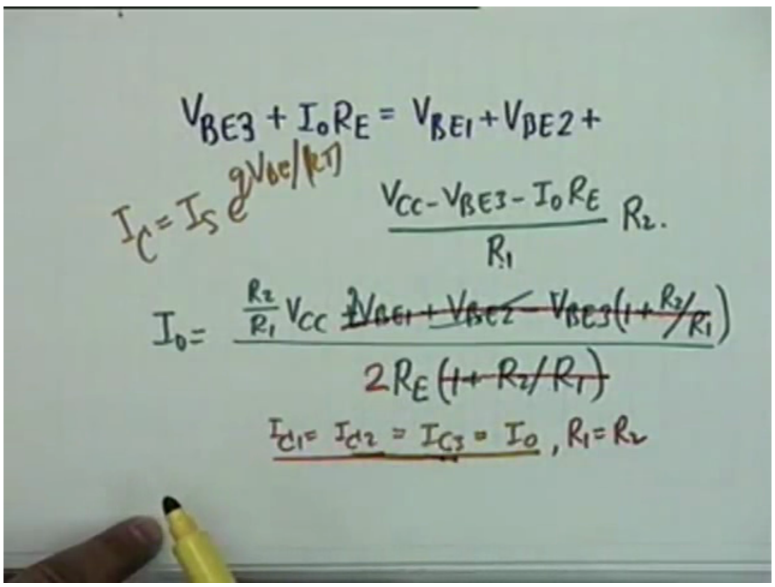

If I do that then you notice that V BE3 + I 0 R E that is the voltage drop across R E this should be = V BE1 + V BE2 + the current through R 2 multiplied by R 2, now what is the current through R 2? If you look at this well, we do not... I want 1st an expression for I 0 so I cannot assume that I 0 = this, I C2 okay now I do not want I C2 because this is another variable. Even I C1 is not guaranteed in general I C1 is not guaranteed to be I 0 so what I do is, look at this I find out current in this, what is this current? This is V CC - this drop which contains I 0, these are tricks of the trade, I do not want extra variables I want I 0 so I do not want to write in terms of any... so V CC – this drop divided by R 1 is the current...

Student: We should get it directly Sir, V CC – V BE was – V BE2 divided by R 1 + R 2.

Professor: Yeah that also I can do yes that also I can do, I prefer to do it this way because I 0 is involved here okay, let us try this. So this current is, let me use a different colour, this currently is V CC – V BE3 – I 0 R E divided by R 1 and this is the current that flows through R 2 and therefore the drop in R 2 would be = V CC – V BE3 – I 0 R E divided by R 1 multiplied by R 2, why did not I do it the other way that this gentleman suggested because V BE1 and V BE2 are already there and this would be an identity okay. I want I 0, I want to find an expression for I 0 in terms of known quantities V BE, I 0 that is the load current and V CC.

If I... obviously now I get a general expression for R E, if you clear the algebra then I get I will skip this algebra, what I get is I 0 = R 2 by R 1 multiplied by V CC which you can see R 2 by R 1 multiplied by V CC + V BE1 + V BE2 - this V BE3 comes on the other side, it comes on the other side, V BE3 1 +... 1 comes from here and R 2 to by R 1 is here so 1 + R 2 by R 1 whole divided by R E, I 0 R E and here I 0 R E R 2 by R 1 so R E, 1 + R 2 by R 1, this is the general expression alright. Now if I C1 the collector current of the 1st transistor, I C1 and I C2 are obviously equal, if I C1 and I C2 are equal, obviously their V BE must be identical, collector current is I s exponential e to the power V BE by k t, so V BE1 and V BE2 can be written as twice V BE1 agreed we have eliminated one of the unknown quantities.

And then if it says that I C1 = I C2 this is given and if it is required if it is forced to be = I C3 that is I 0, this implies that V BE3 is also = V BE1 alright, and in addition...

“Professor–student conversation starts”

Student: Under what conditions it = that?

Professor: Under what conditions... If the collector currents of 2nd and 3rd transistors are same, if collector currents of the 2 transistors are same their V BE must be identical.

Student: Only then?

Professor: Yes because they are identical transistors, their situation current I s are equal. You remember I sub C is approximately = I sub E is given by I S e to the power q C Be by k T.

Student: Sir in this case there is no quantity as I C3, why are we including other variables unnecessarily?

Professor: I C3 is same as I 0, just to indicate that it is the collector current of 3rd transistor that is all Okay, any other questions? No.

“Professor–student conversation ends”

So what I get is under the special condition that all collector currents are equal and also R 1 = R 2 then you see twice V BE1 shall cancel with this quantity, is not that right? This is 1, 1 + 1 = 2, 2 V BE3, V BE3 is same as V BE1, so these 2 quantities shall cancel with each other under the special condition and this will become a 2 alright, so and R 2 and R 1 are equal for this also becomes unity.

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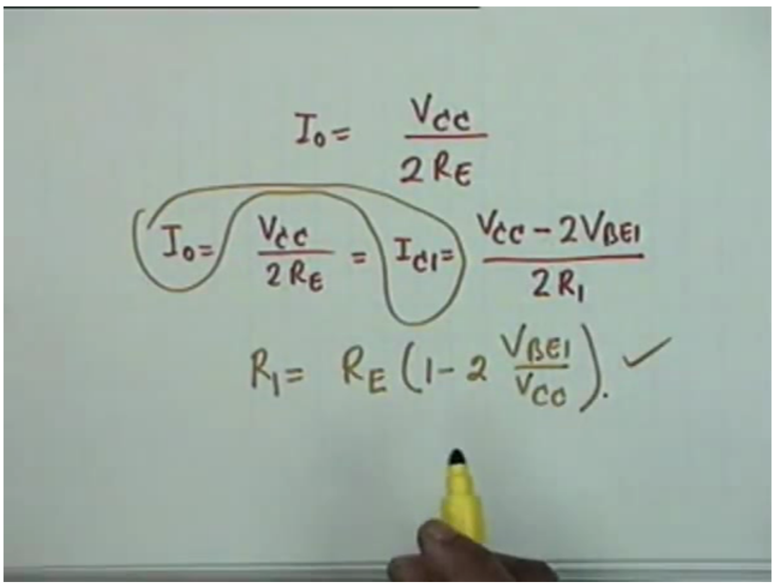

In other words I get I 0 = V CC by 2 R E which was the 2nd partof the question okay, V CC by 2 R E and obviously you see this is independent of V BE, this was the purpose of the current mirror, this is the current mirror this is the purpose of the current mirror. Then the relationship between R E and R 1, you see I 0 = V CC divided by twice R E, this is also = I C1, which is I C1 if V CC – now the resistors are equal and Q 1 and Q 2 identical so twice V BE1 divided by 2 R 1, now we use this formula because I want the relationship between R E and R 1, obviously if you take these 2 quantities off you get a relationship between R 1 and R E and this relation after clearing the algebra will become R 1 = R E 1 – 2 V BE1 divided by V CC, this is the required relationship okay.

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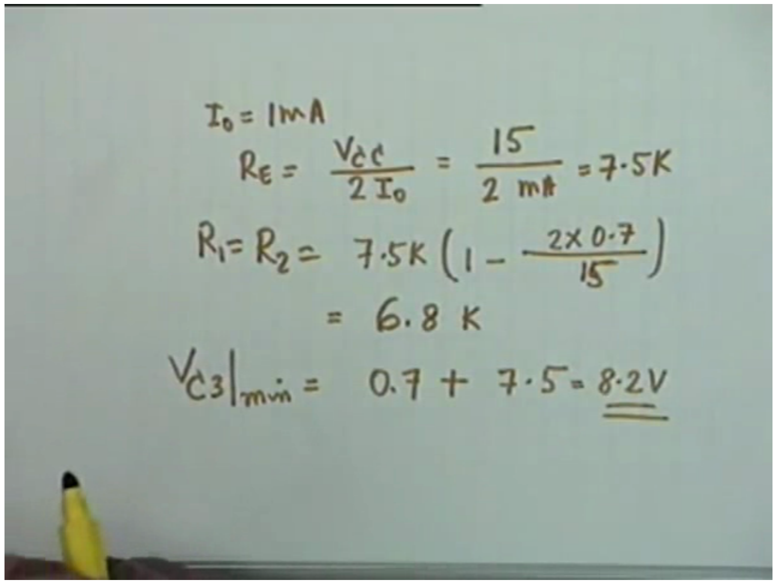

Now as far as design is concerned is very simple, design is I 0 is required to be 1 milliampere, therefore R E shall be = V CC divided by twice I 0 this is the relationship that we have obtained, I 0 was V CC by 2 R E so this is 15 volts. Did I give you V CC? V CC is 15 volts divided by 1 milliampere is required the current so this is 2 milliampere and that becomes 7.5 K and from the relationship between R 1 and R E, I get R 1 = R 2 = R E, which is 7.5 K multiplied by 1 - 2 times 0.7 divided by 15 and this calculates out to 6.5 K. Finally the V C3 min what would this be... Not 0.2... 0.7 + I 0 R E which is which is 7.5 volts, R E is 7.5 K and 1 milliampere so this = 8.2 volts, this is the minimum voltage that is required to be maintained between the collector and ground, if it falls below this, Q 3 shall go into the saturation region agreed? That completes the question.

“Professor–student conversation starts”

Professor: Any questions on this relation? No.

Student: Sir.

Professor: Yes please.

Student: Like V BE for the saturation and active phase you have taken it to be 0 or positive?

Professor: V BE we have taken as 0.7 for the active region yes... No, I have not taken it 0, I must explain that.

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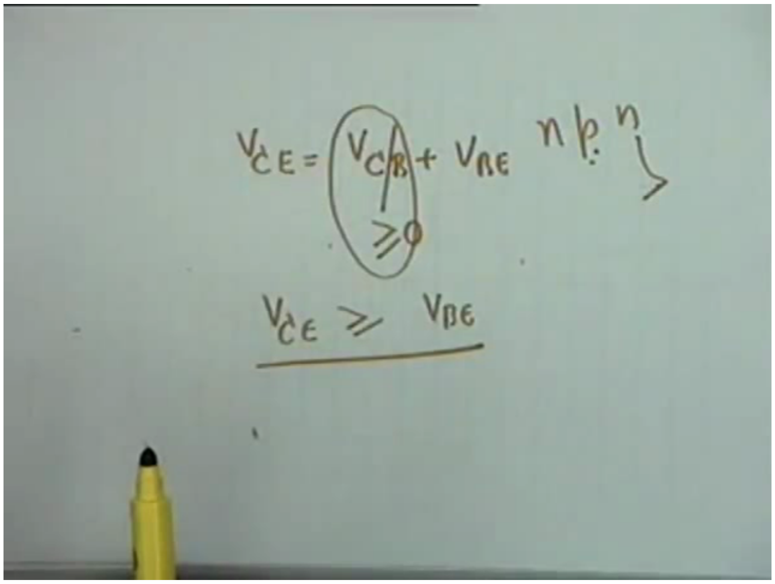

You see what I said was V CE alright, let us go back is V CB + V BE alright, and V CB has to be greater than = 0 therefore V CE has to be greater than = V BE that is what I said.

Student: Why did you take V CB greater than = 0.

Professor: Because the collector base junction must be reversed bias and since it is an NPN transistor...

Student: Sir but it would be reversed bias for (())(21:16).

Professor: No, collector has to be positive with respect to the base, V CB cannot be negative that is what we are saying.

Student: There is specific voltage for active cut in also.

Professor: No, that is not what we are considering, we are only saying that V CB must be reverse biased, V CB cannot be negative V CB must be positive, collector must be positive with respect to the base so V CB is greater than 0 greater than = 0 so V CE must be greater than = V BE, mind you we are finding the lowest voltage okay. It is only when V CE is greater than = V BE that it will go into the active region otherwise it will not, this is the lowest, you cannot go below this.

“Professor–student conversation ends”

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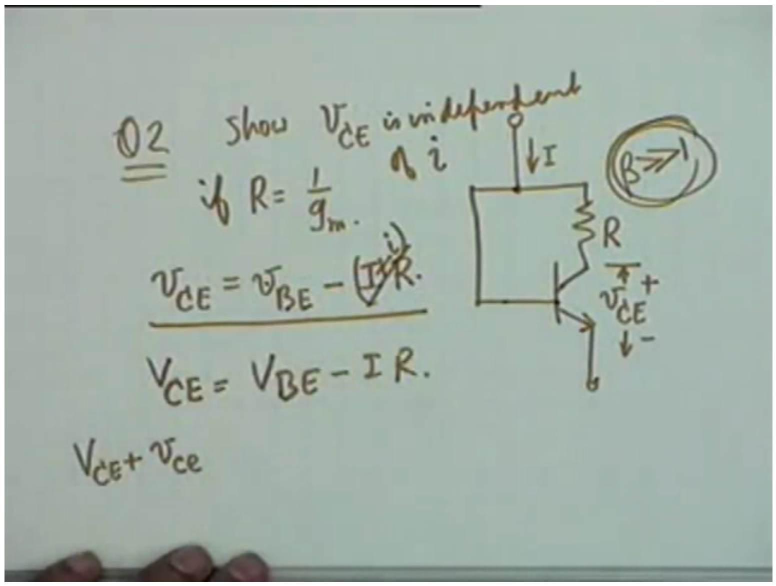

Question 2 is a mixture of AC and DC and it is a tricky question, a simple question but a tricky question. It says a very simple circuit, a current I flows here and a single transistor with a resistance R this voltage is V CE + - and the supply is connected directly to the base, this is the circuit very simple circuit. It says that the question is the following, listen to the question carefully. The question is, with change in I if I changes, show that V CE is a constant show that V CE is independent of I provided R = 1 by g m okay, show that V CE is independent of small changes in I provided this resistance is carefully chosen okay. Now to look at this v CE = pardon me...

Question is complete Question is complete, you have to show that small v CE is independent of... Variation in capital I we will write as small i okay. If capital I changes, show that v CE does not change provided R = 1 by g m this is the question, how do we solve it?

“Professor–student conversation starts”

Student: Sir is the emitter connected to ground?

Professor: It does not matter, it could be connected to ground, it could be connected to a negative supply, it could be connected to a resistance and ground it does not matter, wherever it is connected.

Student: (())(24:46)

Professor: Pardon me.

Student: If it does not matter where it is connected, we can use it as (())(24:52) any circuit.

Professor: Yeah, you can use it as part of any circuit provided there is a flow of, there is a path for flow of current, it cannot be hanging okay, it must be connected to ground through a supply through a resistance whatever it is alright. Now how do we solve the circuit? You if you look at V CE, this point is same as this point so it is v BE - the drop in R, is not that right? Okay, so it is v BE – what is the drop in R? Capital I R is the total...

Student: Sir there will be base current also.

Professor: There is a base current, we assume that Beta is much greater than 1, this condition is required alright.

“Professor–student conversation ends”

Now small v CE is the total collector emitter voltage, small v BE is the total base emitter voltage so I must include in I if I is taken of the DC part small variations that is I + i, is the point clear? If we write the V CE, V CE is fine V CE is this V BE – I R, if I write the total what is the total? This is V CE + small v CE okay the total voltage, similarly V BE the total voltage is capital V BE + small v be, similarly I must include the total current here that is small changes in I therefore I changes to I + i.

Student: (())(26:56)

Professor: Yes if Beta is much greater than... Not 1 not just greater, much greater therefore we ignore this current okay, we ignore this current. Now let us let us take the incremental part of this equation this totally equation, I can write v CE is V CE + v ce similarly, v BE is some of the DC part + AC part, then obviously because the circuit is linear, the DC part will balance and AC parts will balance alright.

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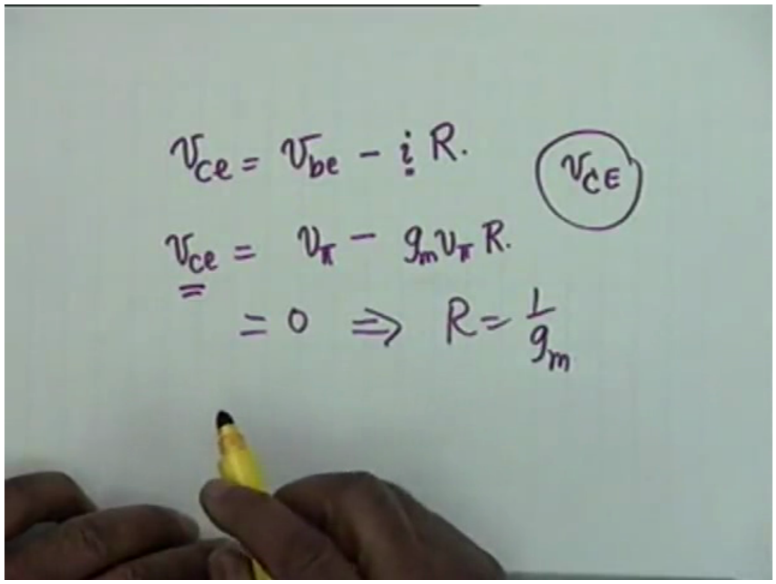

So if I write the AC part of this equation, what I get is, I get v ce = v be – i R okay, now what is the relationship between v be and v Pi? They are equal approximately ignoring r x okay. And what is the relationship between this incremental collector current and v Pi? g m v Pi okay g m v Pi R, so I get v ce = this agreed. What I want is that that v CE should be independent of small i the total collector emitter voltage should not depend on small i, so what I want is even if there is an i the v ce should be = 0 so this is 0 which leads to R = 1 by g m.

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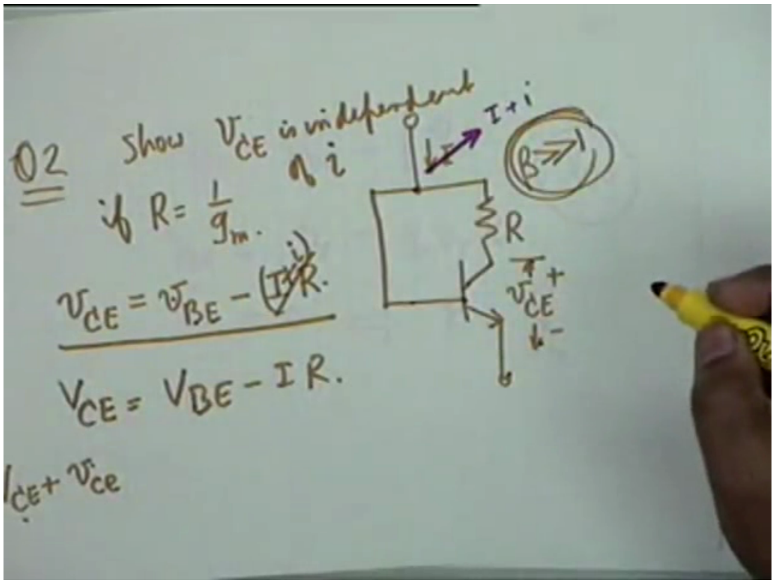

My question was that even if this I changes, this should be independent of this change. In other words if R I changes to I + i, v CE should remain as V CE, it should not contain any AC part, which means that the AC part of this should be = 0 which is what I have done here. So I proved that it R = 1 by g m, the collector emitter voltage remains steady, it is independent of variations of the collector current, question 3 is a question on common emitter amplifier.

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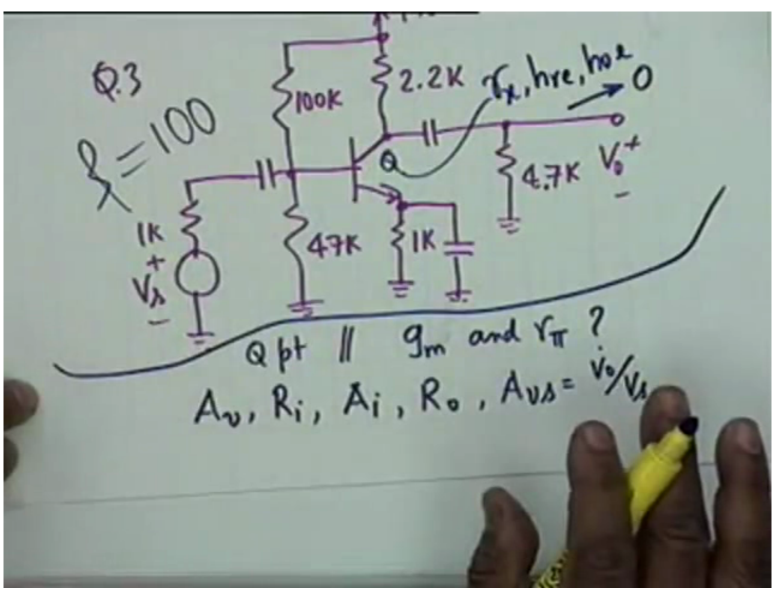

Question 3, draw the amplifier with me, there is a + 10 volts supply, 2.2K the transistor with an emitter resistance of 1K, there is a capacitor goes to 4.7K, there is a capacitor here also which I forgot to draw, there is a capacitor here also and the base biasing is through 100K and 47K , there is a capacitor here coupling and the source resistance is 1K, you have a V s here and this is V 0, this is a simple common emitter amplifier okay. The questions are the following, have you been able to draw?

Firstly we have to find the Q point of the transistor Q that means you have to find out I sub C and V CE okay Q point. And from that you have to estimate g m and r Pi, it is given Beta for the transistor is given as 100 and 25 degree C and it is also given that for the transistor r x now note the way it is specified, r x, hre now we are mixing hybrid Pi parameters with hybrid parameters because these are what are specified by the manufacturers. It says r x, hre and hoe these 3 quantities are specified to be negligible they go to 0, this is the total specification of the amplifier of the transistor, beta is 100, r x, hre and hoe can be neglected okay, we will see what this means.

Now you are required to find out Q point then g m and r Pi and also these quantities A v voltage gain, input resistance R i, current gain A i, output resistance R 0 and A vs, which is as I said V 0 by V s okay, this is the complete question now let us see let us proceed step-by-step. The 1st thing we have noticed is we have to calculate the base current, to determine the Q point you require collector current and collector emitter voltage, how do you calculate the collector current, you 1st require the base current. Now as far as the base current is concerned, you have to find out V BB which is 10 multiplied by 47 divided by 147 okay that is V BB. You have to find out R B, 100 K parallel 47, I will give you the numerical values I have calculated them 100K parallel 47K. Then I B would be V BB – V BE, which you shall take as 0.7 divided by R B which is the parallel combination of these 2 + Beta + 1, 101 times 1K okay very good, so the biasing has gone in I am very happy at this.

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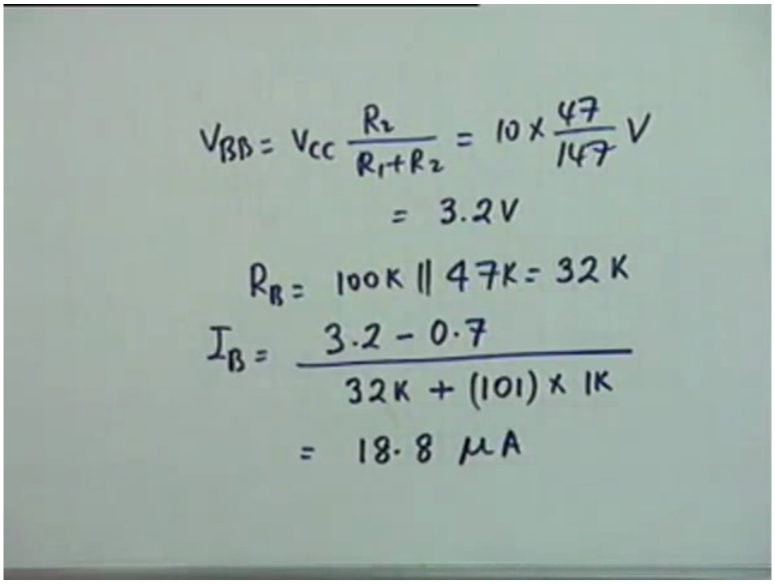

V BB is V CC R 2 by R 1 + R 2 and as I said this is 10 times 47 divided by 147 volts and this comes out as 3.2 volts. R B which is 100k parallel 47K, this calculates out to 32K in my calculations I often make approximations which I do not advise that you do okay. Therefore, I sub B = 3.2 V BB - 0.7 V BE divided by R b which is 32K + 101 multiplied by R E which is 1K and this comes out as 18.8 microampere.

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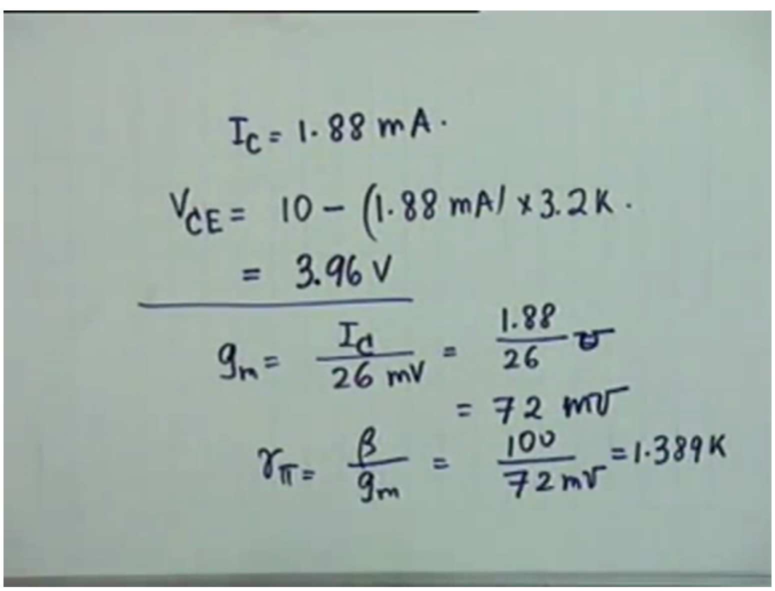

Therefore the collector current I sub C would be simply Beta times this which means 1.88 milliamperes. And if this is so then V CE, the collector emitter voltage the DC part shall be ably V CC - the collector current multiplied by 3.2 R C + R E this you must not forget, 3.2K and this comes out as 3.96 volts. Now this is the Q point the question is to find g m and r Pie, now g m is I sub C by 26 millivolt and I sub C is 1.88 divided by 26, this is so many mhos and this comes out as 72 millimho, we do not want to write 72 multiplied by 10 to the - 3 or 0.072, right it in this form it is your choice. Therefore, r Pi which is Beta by g m can be very easily found out, 100 by 72 millimhos and therefore this will come out in K, 1.389K so we have found out the answer to the 2nd part of the question.

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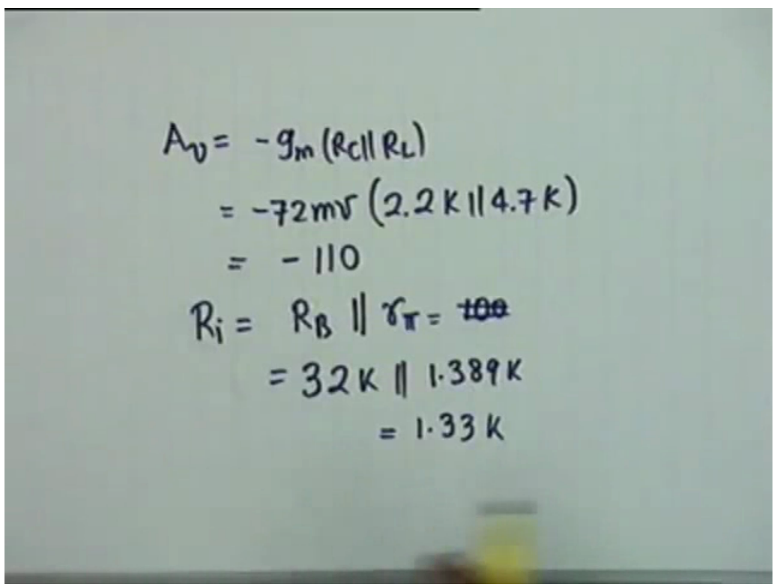

The 3rd part is to calculate all those gains, 1st A v Beta is given as 100, Beta was given as 100 okay. The voltage gain is – g m approximately RC parallel R L so it is RC parallel R L, g m is 72 millimhos, 2.2K, 4.7K that is the load okay so this is - 72 millimho multiplied by 2.2 K parallel 4.7 K and this my calculation gives this is - 110 a good figure, a voltage you know 110 okay 1 millivolt becomes how much, 0.1. The R i input resistance will be R B parallel, r x is ignored so it is R B parallel r Pi, which = 100 K, we had already found out R B 32 K parallel 1.389 K which will be approximately 1.389, this is 1.33 K that is not too different.

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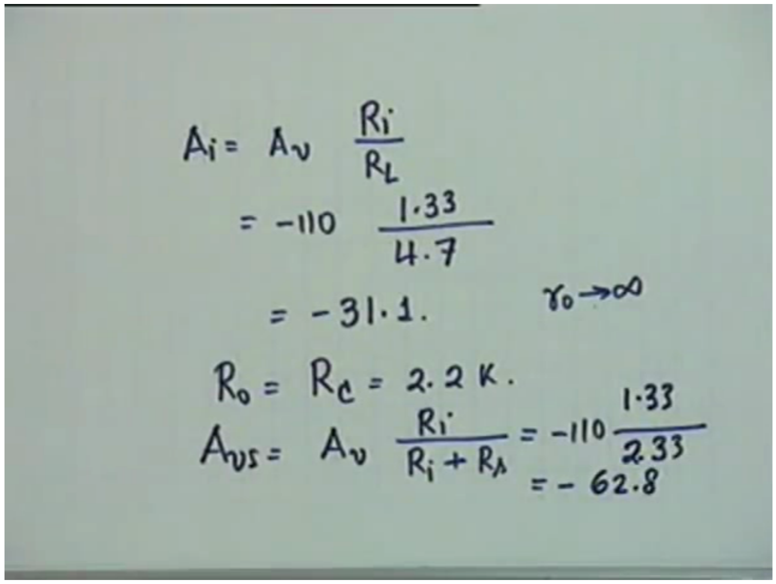

The current gain A i as you remember the current if the voltage gain is known then the current gain is known, A i is A v voltage gain multiplied by R i divided by R L therefore this = – 110, this is 1.33 divided by R L is 4.7 okay this becomes - 31.1, R 0 your hoe was given as 0 and therefore r 0 tends to infinity r 0 tends to infinity therefore output resistance will be simply = R C which = 2.2 okay. And finally A vs = A v multiplied by V i divided by V s which is R i divided by R i + R s, therefore this is – 110 1.33 divided by 2.33, R s is given as 1K and this comes out as – 62.8 that completes the question, now let us complicates matters.

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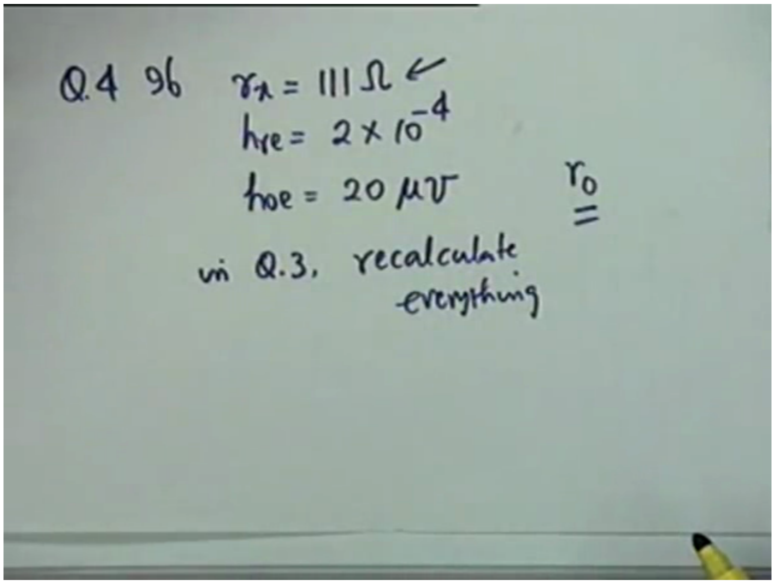

This was simple this was simple, in this problem in the same problem question 4 says in problem 3 if r x, hoe and hre are not neglected how do the things change, this is the basic theme of question number 4, r x is given in question 3, we had assumed r x = 0, hre = 0 and hoe = 0. Now r x is given as 111 Ohms, hre from the manufacturers data is given as 2 times 10 to the - 4 and hoe is given as 20 Micromhos, if that is so in question 3 recalculate everything. Now you do not ignore, let us see how this transform into the hybrid Pi model, r x can be taken directly, r x obviously measured from hie okay and finding out g m and r Pi then r x is hie – r Pi that is correct so I know r x, how to take care of hre and hoe okay.

What is it that we are missing in the hybrid Pi model, the value of small r 0 that is all that we are missing, r Mu anyway we do not want to go anywhere near r Mu, why? Because that complicates the analysis, it makes a 3 by 3 matrix inversion we do not want that. So hopefully deserve Pious thought that r Mu would be very large okay, so let us see how r 0 can be calculated from these 2 alright.

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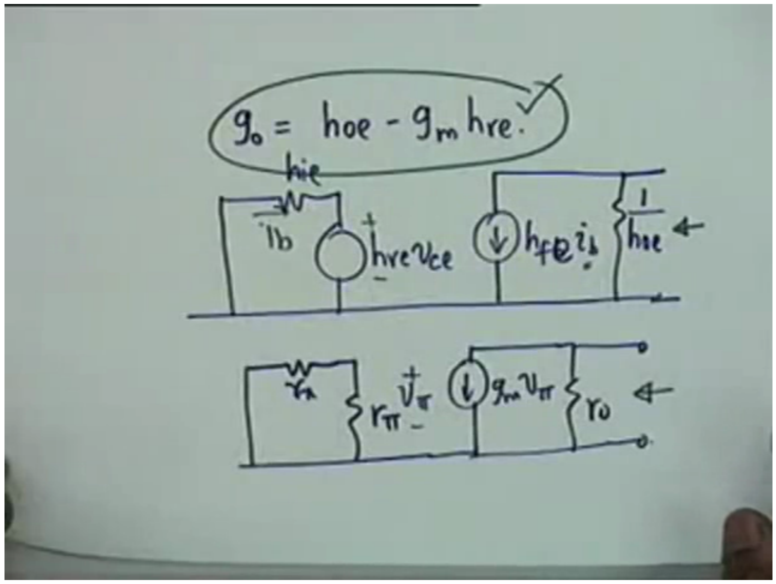

If you remember we derived this, we did not derive we simply say the relationship between g 0 and h parameters is hoe – g m hre, this is what will give you r 0 okay. Now we did not derive it, I ask you to derive it yourself let me give you a hint as to how to derive this okay. What we want is from the h parameter model hie, hre v ce, hfe i b is the h parameter model and hoe, the corresponding hybrid Pi parameter is r x, these 2 should be identical you see r x.

Student: Should not it be 1 by hoe.

1 by hoe wonderful, r x, r Pi and this is v Pi and then you have g m v Pi, r 0, we do not want r Mu okay, if r Mu come then things become a little more complicated. But if these 2 if these 2 are to be identical then obviously if we measure a resistance here with the input shorted it should be the same as the resistance here with the input shorted out you. Now what do you get here if you measure the resistance here? These 2 this is the hybrid parameter model and this is the hybrid Pi, we want to find out the hybrid Pi parameters in terms of hybrid parameters. Since these are identical, if the inputs are shorted in both the output resistance would be the same, if you calculate these 2 output resistances you shall see that this is precisely what you get.

You have to figure out what you should do, either open circuit or short-circuit somewhere and since the 2 circuits are identical wherever you measure voltage or current they should be identical, terminal voltages and currents should be identical alright, so this is the trick for proving his relationship Pardon me... Oh I wanted to establish this relationship okay, how do I do that, g 0 obviously g 0 is 1 by r 0 and if we measure the resistance here r 0 figures here. Now I can measure it under open circuit, short-circuit, whatever condition I will do it under short-circuit condition because if I keep it open circuit then hre v ce does not come into the Picture at all is not that right so I make it a short-circuit I make it a short-circuit then v Pi is 0 so here it is simply 1 by simply r 0, here hre and hfe, hoe all the 3 quantity shall be involved and you shall see that they conspire to give a simple relation like this, it is a very simple exercise.

Student: Why all 3 will come?

Professor: Why all 3 will come... You do it and then you shall know... Because I b is here and I b is this current do not you see the coupling, I b is this current, this is not 0 so this drives the current in the other direction, you think about it I cannot do everything.

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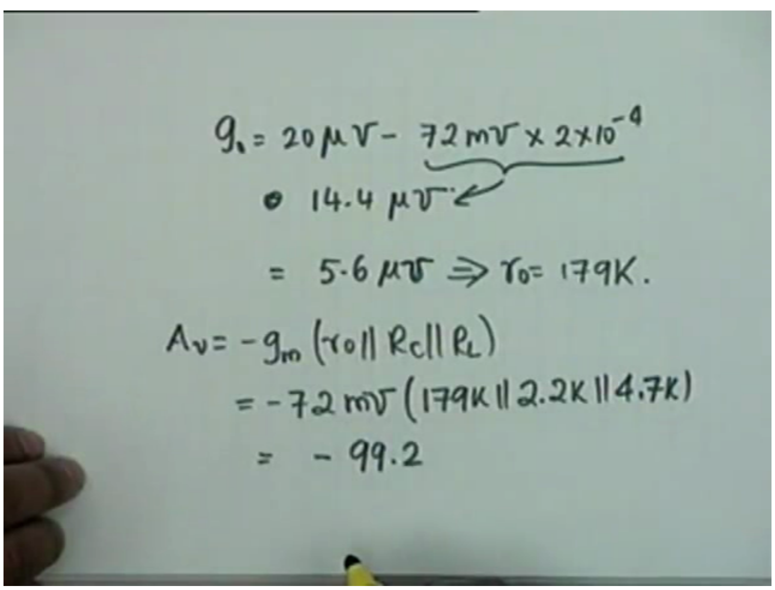

Okay now if I use this relationship then g 0 is 20 Micromho, hoe is given, - g m is found out oh incidentally since r 0, r x, hoe and hre are not ignored, do they change the DC conditions at Q point? No, so g m remains the same alright so I use the same g m multiplied by hre is given as 2 times 10 to the – 4 and this comes out as 14.4 micromho no, this calculates to 14.4 this part, is not it? 144 milli is 10 to the – 3 so 10 to the - 7 and therefore g 0 becomes = 5.6 micromho, which leads to r 0 = 1 by g 0 and that becomes 179K, pretty large let us see how this affects.

A v the voltage gain is now – g m, instead of R L flying we must also include r 0 so – g m r 0 parallel R C parallel R L. And if you substitute the values, 72 millimhos multiplied by 179K 2.2 K and the 3rd one was 4.7K alright and this calculates to – 99.2, what was it earlier? 110 so it has reduced. Why has it reduced? Because of r 0 because of shunting effect of r 0 okay.

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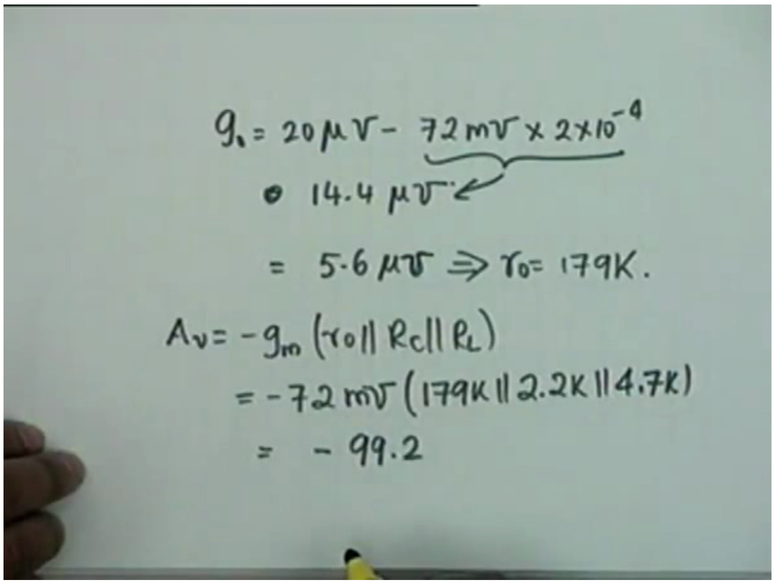

What about R i how does it change? It would be R B parallel since r x is not ignored, r x shall come r x + r Pi and this is 32K parallel 1.389 that is r Pi + 0.111K, this is 1.5 as you can see so 32K and 1.5K they become 1.43K it is I am now why, because the shunting effect is reduced due to the introduction of r x, previously it was 1.33 K it is slightly larger. The current gain A sub i is A v divided by R L so this is – 99.2, R i has increased to 1.43K this has decreased but R i is increased, but we still see the gain goes down, divided by 4.7K and that is - 30.2, not too much, the earlier value was 31.1 so that is not too much, our output resistance also changes yes...

Student: Previous concept... Should not A i be positive?

Professor: No... What is A i? A is the collector current... A i is not the collector current, A i is the load current and load current was taken as flowing into the load that is why this sign is negative.

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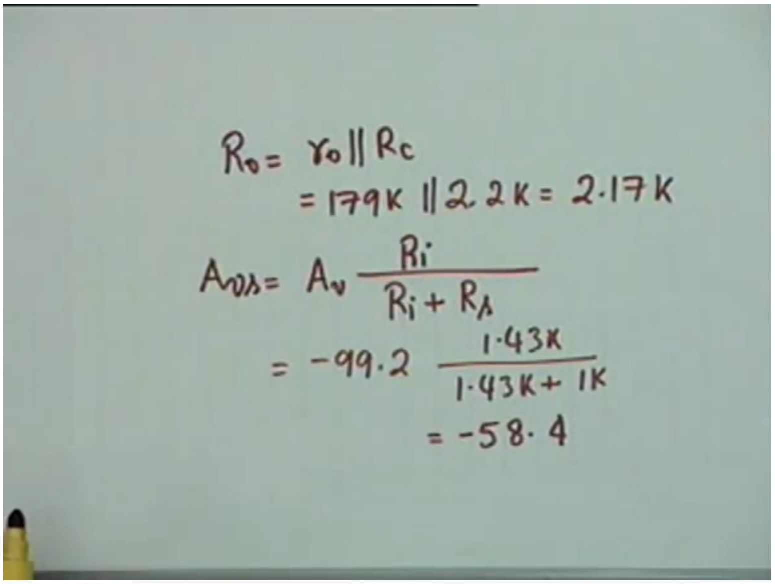

Okay the output resistance R 0, which is r 0 parallel R C now becomes 179K parallel 2.2 K and this becomes 2.17K not too much difference. The gain from the source that is A vs is given by A v multiplied by R i divided by R i + R s, when you do such problem the equivalent circuit should be flashing in your mental Picture okay, Source R s then what does it see is R i so the division between V i and V s is R i divided by R y + R s, you must make this imprinted in your mind – 99.2 1.43K by 1.43K + 1K and this is - 58.4 this gain is also reduced, previously it was 62.8 alright that completes this question.

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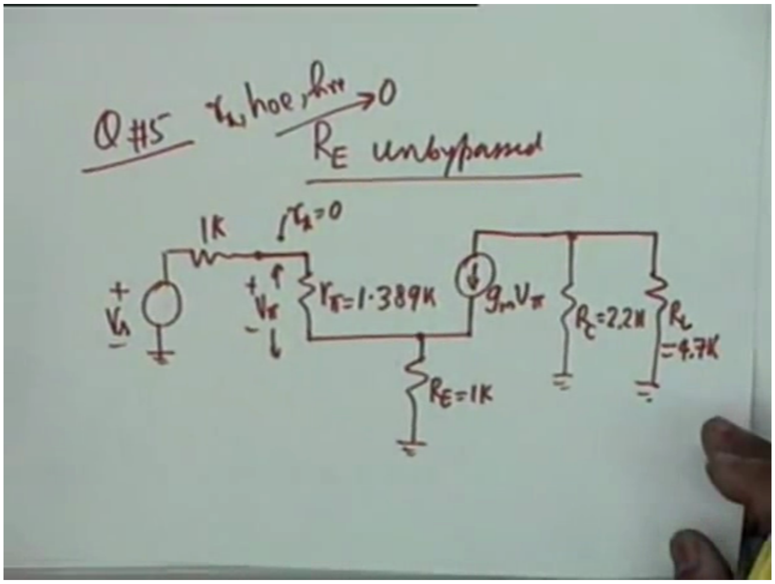

The last one question no 5 says, repeat the same problem with R E unbypassed okay R E unbypassed, now if R E is unbypassed and you remember the equivalent circuit, we have V S 1 k then we have let us ignore r x alright, we put r x = 0, we can include it for a change let us ignore this, this is 1.389K then you have an R E which = 1 K it is unbypassed then this is g m...

Student: (())(51:56)

Professor: No but v Pi is across r Pi, we will enter into unnecessary complications let us work this out under the conditions of problem 3 where r x, hre and hoe are 0, r x, hre and hoe all of them tend to 0, r 0 tends to 0 so this is simply g m v Pi, this is v Pi, r 0 tends to infinity and so what we have here is R C which is 2.2 K and R L and we shall do things almost by inspection as you will see R L is 4.7K. This is the equivalent circuit so all that changes is that this R E as far as input side is concerned it reflects the resistance of Beta + 1 R E, if you take care of this everything else fits into place, as you will see we will do it almost by inspection.

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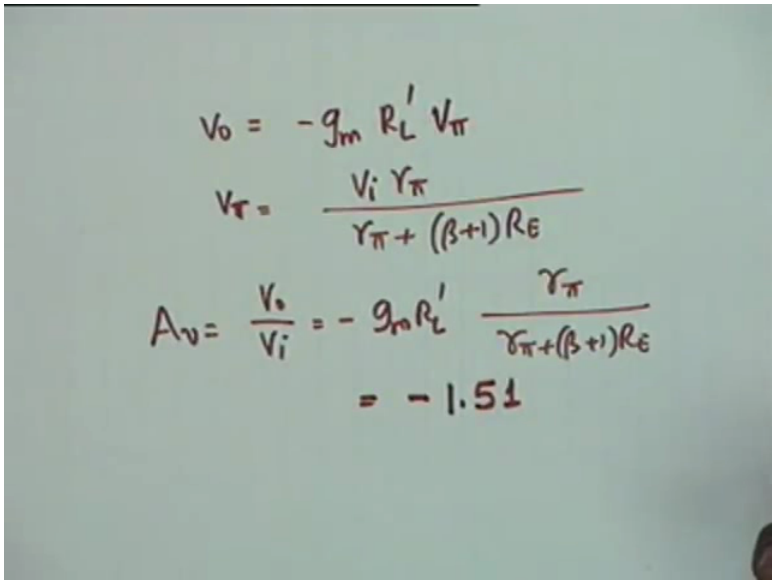

The output voltage is – g m R L prime times V Pi okay g m V Pi times R L prime and V Pi = V i this is V i, V Pi is V i potential division between r Pi and Beta + 1 R E and therefore V Pi is V i R Pi divide by r Pi + Beta + 1 R E. Therefore, A v which is V 0 by V i would be = - g m R L prime multiplied by r Pi divided by r Pi + Beta + 1 R E. And if you put the numerical values, (()) (54:18) gain becomes - 1.51. All that you had the gain in – g m R L prime has been killed by this factor okay because there is a large quantity here Beta + 1 R E, 1.51 only as compared to 110 earlier okay – 110.

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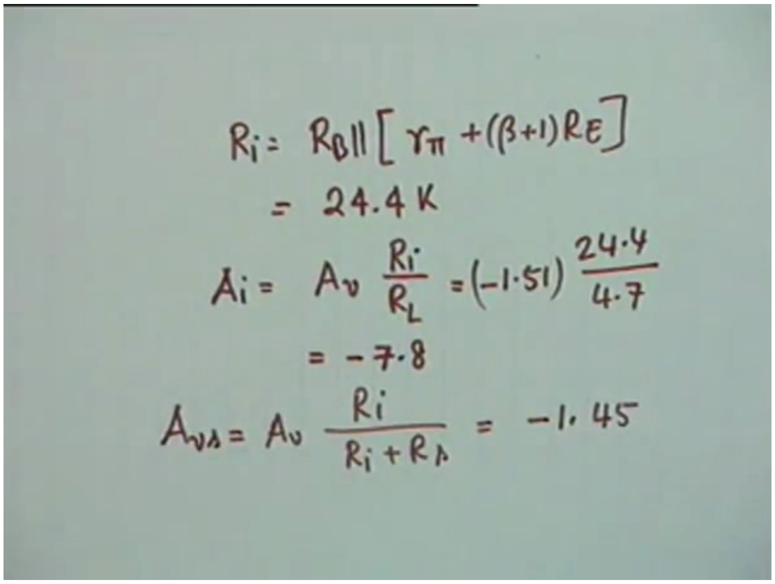

But what it does is the input resistance R sub i it becomes parallel now no longer r Pi it becomes r Pi + Beta + 1 R E and if you calculate the values this comes as 24.4 K which is about 20 times the previous value okay. The input resistance has increased, the current gain usual thing A v R i divided by R L, R i is now increased and this will become - 1.51 24.4 divided by 4.7 and this becomes - 7.8, current gain is also reduced. And A vs you did not make any further analysis, just that factor that R E reflects is reflects is Beta + 1 R E solves everything okay, and A vs is A v times again that Picture in mind R i divided by R i + R s and if you put down numerical values this is – 1.45, the gain is slightly greater than 1 and that brings us to the close of this session.