Experimental Physics - II
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Lecture - 06
Basic Analysis

Today I will discuss about the Error Analysis.

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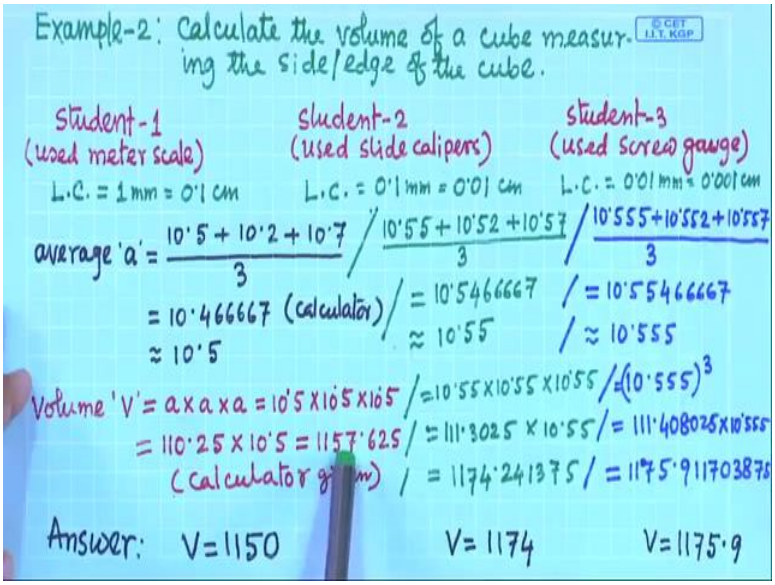

Whenever you will measure or you will do some experiments in laboratory, you will note down the data as well as you will calculate the results. How to write data and how to write result that I will discuss. In last class, I gave one example; if you have, say, 200 rupees and you want to equally divide this 200 rupees among 3 people. What would be the results? How much money each people will get that we have to find out.

Today I will give another example. Example 2: calculate the volume of a cube measuring the side or edge of the cube. This is a very simple example, all of you know. But following this example, actually we will learn how to write data and how to calculate and finally, how to write the results.

Say 3 students are doing this experiment. Student 1, he use the meter scale; least count of meter scale is 1 millimeter, 0.1 centimeter. Student 2, he used a slide calipers; least count of slide calipers is 0.1 millimeter or 0.01 centimeter. And student 3, he used screw

gauge; least count of screw gauge is a 0.01 millimeter, that is 0.001 centimeter. Now, they measured, they have taken 3 readings, 3 observations and then taking the average of these 3 observation, and finding out the average side a length, average side length that is a.

a equal to 10.5 one data, another data 10.2 and third data 10.7 divided by 3. If we use calculator, I have used calculator. The result is coming 10.466667. It can be 66667. It depends on the accuracy of the calculator. Better calculator, it gives more number of a digit if it can display more number of digits it is a better calculator. This is the result given by the calculator.

But now question is whether you will keep this just like this whatever calculator is given or there are some procedure how to write this, this result. One has to write 10 to the power 10.5. Why one should write this one? Why one should write this one? That you can say here this least count is 0.1, we can keep the maximum after this may just one digit we can keep that is 2, that is 2. It depends on least count since we are taking average of the similar, similar kind of a quantity. It is this unit of all of them are same. It is a result whatever you are getting that, it is unit also same as the unit of this parameters, this quantity. Following this that we can, we can keep the digit last digit or decimal point which we have to decide from the least count of the instrument, fine.

Similarly this second students say if he got the data 10.55, 10.52, then 10.57, then average just I have taken this for easier calculation just I have taken like this, divide by 3. average rate is coming again 10.5466667 etcetera. Here actually you have to write result not this one, you have to write 10.55. Again why? After decimal two digits are there, after decimal two digits are there. If you know the least count, if you know the least count, then only you can you can write this result. Then third students also it is a least count is 0.001 centimeter. After decimal 3, up to 3 digit we can keep. this is average side of the cube.

Now, volume of the cube you can find out V equal to a cube: a into a into a. This student will write 10.5 into 10.5 into 10.5. If we use calculator, calculator will give 1157 dot 625. This is the result given by the calculator. Similarly, this student 2, he will get result from calculator 1174.241375.

The third student, third student, he will get result from calculator 1175.911703875. exactly my calculator was giving this one. Again the same question that the volume we have to find out, we have to write the result, answer. Calculator is giving this, volume is this or second student this, third student this. But this he cannot keep it as a result.

You have to write [vocalize-noise] the result properly. How to write the result? How to write the result? Here 1175.625, 11 sorry 1175.625, and answer I have written 1150. whatever calculator is given, from there I have retain the result for this case or student one has retain the result volume is equal to 1150. Second student retain the result 1174, 1174. Third student is retain the result 1175.9, 0.9.

Now, you think in this case generally from my experiments I have seen the students write, students write the result keeping the at least keeping the one, one decimal point. Keeping one digit after decimal, in most cases I have seen that student will write the result answer 1157.6. For this case they will write 1174.24 and third case they will write 1175.912, it is a 7 is there, it is 2. but correct result is these whatever is written here.

Why student write this? Just in this case keep 1 decimal point, here 2 decimal point, here 3 decimal point up to 3 decimal point, because they will follow here, least count is 0.1, after decimal one digits are there, here two digit here, third digit, up to third decimal point of a least count. In result also they will write in same way and that is completely wrong. Result will be these. How result will be this? that is what we want to learn. I want to describe you. This is a just one example and this if you learn this example, it is applicable everywhere for any case. Let us learn how to write this result.

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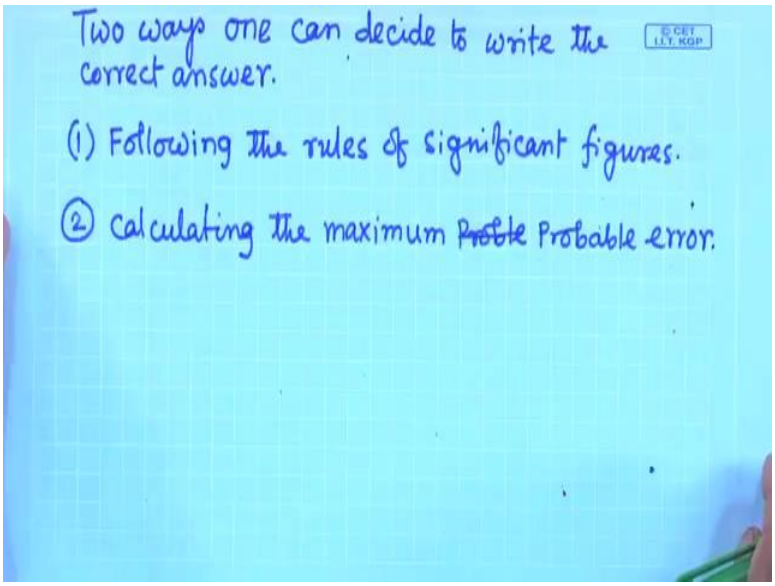

One can decide to write the correct answer. Following the rules of significant figures, one can write the correct answers and another we the calculating the maximum probable error. Calculating maximum probable error also one can write the correct answer. two ways, actually both ways, both we have to learn then only you can write correct answer complete answer.

Only following the rules of significant figure also you can write. We have to follow the rules of significant figures as well as we have to calculate the maximum probable error. let us discuss about the significant figures.

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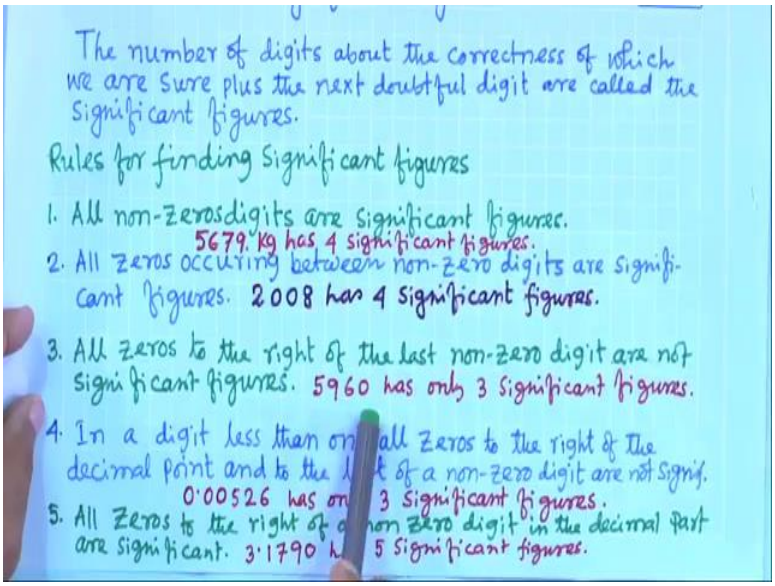

What is significant figures? What is significant figures? I have actually in experimental physics-I, I have I have discuss, but I again repeat because this is very important. what is significant figures? Actually the number, the number of digits about the correctness of which we are sure plus the next doubtful digit are called the significant figures. You have a number, of digits you have a number of a digits.

First few numbers, about few numbers you are sure about the correctness of that you are sure up to that number, up to that digits in that number. And after that the next digit it is even not sure, it tells a doubtful digit, there is uncertainty in the digit. That also we keep. After keeping that whatever the number in that number how many digits are there. That count is the significant figures,

Rules for finding the significant figures are the followings. All nonzero in a number in a number, all nonzero digits are significant figures. As for example, 5679 kg, kilo gram, or kilometer or whatever, in this number, all are non-digit nonzero numbers, all are significant. All digits are significant. How many how many nonzero digits are there? 4. For this number, we tell this number has 4 significant figures.

Second rule is all zeros occurring between nonzero digits are significant figures. zeros occurring between two nonzero numbers are significant figures. Example 2008, or this number, significant figures is 4. This 0 are counted as a significant figure. 1 2 3 4. this number has 4 significant figures.

Third rule is all zeros to the right of the last nonzero digit are not significant figures. What does it mean? All zeros to the right of the nonzero digit are not significant figure. As for example, 5960. This 0 it is at the right of this nonzero number, 6. This 0 will not be counted as a significant figures. This this number 5960 this number has only 3 significant figures.

Fourth rule is, in a digit less than one, means in decimal, in after decimal all zeros to the right of the decimal point and to the left of a non nonzero digit are not significant. In a digit less than one, means it is a decimal, it is a less than one, there will be decimal point, and before decimal it is a there will be nothing 0. All zeros to the right, to the right of the decimal point, to the right of the decimal point, but to the left of nonzero digit are not significant. To the right of the decimal point and to the left of the nonzero digit that whatever zeros are there, they are not significant. For this number 0.00526, this number has significant figure, this only 3,

Fifth rule is all zeros to the right of the nonzero digit in the decimal part are significant. All zeros to the right of the nonzero digit in the decimal part, are significant. That means, 3.1790, this 0 is significant. For this number the, it has 5 significant figures. This is the rule how to find out the significant figure of a number.

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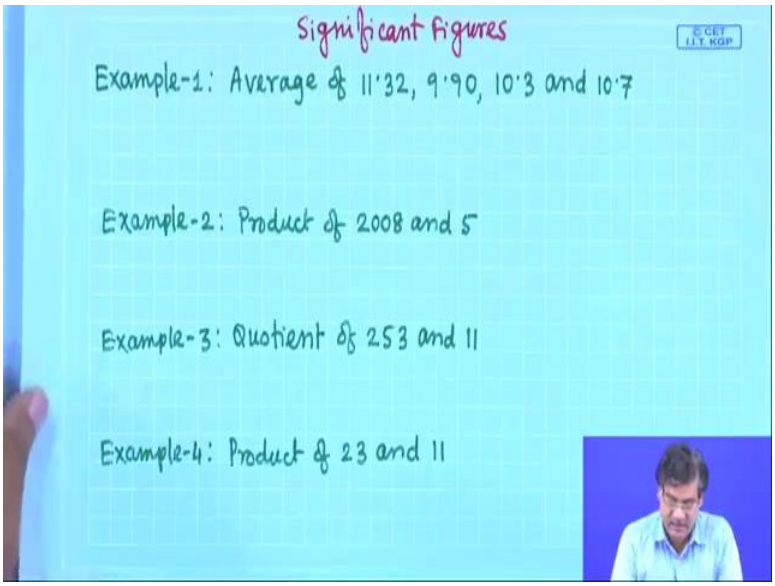

next, next see this a significant figure. for these I think this example I will take after telling this, this one. Yes, I think I should tell this one.

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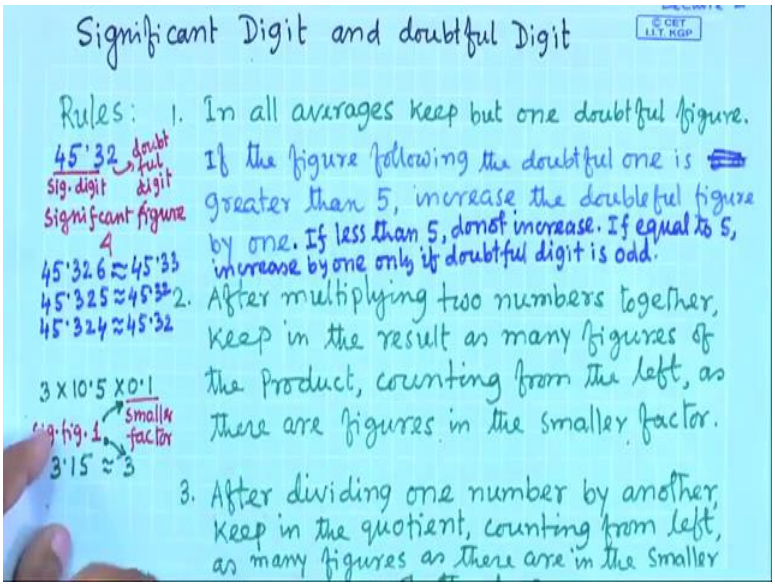

Now, if you have a number, then you can tell what the significant figure of that number is. That rules we have learnt. Now, when you will do some calculation, dealing with few numbers and then whatever the result you will get for writing the result, the result will have, again that is the result is a number, it will have again this, it will help the significant figures. That significant figures is related with the original terms, original numbers which we have used for calculation,

Rules are that how to write this result after summation or subtraction or after multiplication, after division. That is the important things. For this actually, here I have even significant digit and doubtful digit. In a number, in a number how many digits are there? That we are counting as a, that we are counting as a significant figure for that number. In that number that a first except the last one rest of the, rest of the digit to the to the left of that number, they are significant digit and last one is doubtful digit, and this together we tell this whatever number. That we tell the significant figure.

Rule 1 is, in all averages keep, but one doubtful figures. When you will do the average of few numbers, in the result, in the result you will you will keep, you will keep all significant digit as well as one doubtful digit. If there whatever figure you are keeping or you got and from there your writing you result, if the figures following the doubtful digit, we have already decided that that number, which have one doubtful digit, if the doubtful

digit if the figure following the doubtful one, after doubtful digit whatever the digit is there.

If that that digit is greater than 5 then increase the doubtful figure by 1, if less than 5 do not increase if equal to 5 increase by 1, only if doubtful digit is odd. If doubtful digit is even, we do not increase. If 5 is there, after doubtful digit if 5 is there, then whether you will increase the doubtful digit or not that will depend on whether this doubtful digit is even or odd.

As for example this a 45.32. This is the, this is the result we have written, this is the number. In this numbers, this two last number digit that is doubtful digit and this other 3 are significant digit. And together, we tell this significant figure and that number of digits in this in this number, in this quantity that is 4. Including the significant figure, including the significant, sorry doubtful digit, we take the number and that all digits in that number are counted as a significant figure.

Now, if 45.326 then you will write 45.33. This 2 will increase by 1 because this doubtful digit is 2. And 6, 6 is following this 2, it is greater than 5, it is increased by 1. Second number if 45.325. Now, it is 5, now, you have to see whether your doubtful digit, before that 5 that digit is even or odd. It is obviously even, it will not increase it will not be increase by 1. your result you have to write 45.32 ah, right. If 45.324, it is less than 5, , obviously, we will not increase this doubtful digit 2 by 1, 45.32. that is what the rule 1 that is what the rule 1.

We have done me average, of few numbers and you are getting this type of, you are getting this type of result after calculation. How you will round off? How you will round of? that is the rule is stated in this rule 1.

And rule 2, after multiplying two numbers together keep in the result as many figures of the product, counting from the left as there are figures in the smaller factor. What it is telling? After multiplying 2 numbers, it can be 3 numbers, 4 numbers also. Here example I have taken, I am multiplying say 3 into 10 to the power 5 into 0.1. Or if just take two of them then also fine, but 3 of them also fine, it will multiplying. Whatever the numbers you are multiplying.

Among them we have to we have to see the smaller factor. 3, 10.5, 0.1, so among these 3 which one is the smaller factor 0.1. This rule is telling that in your result, in your result, in your result, you have to is telling that there are figures in the smaller there are significant figures mean there are significant figures in the smaller factor.

In this smaller factor, what is the significant figure? It is 1. Significant factor for this smaller factor is 1. It is telling that in result, in result, whatever result you will get in that result you have to keep, you have to keep the significant figures as same as the significant figure of the smaller factor. That means, whatever result you will get in the result, result will help only one significant figure,

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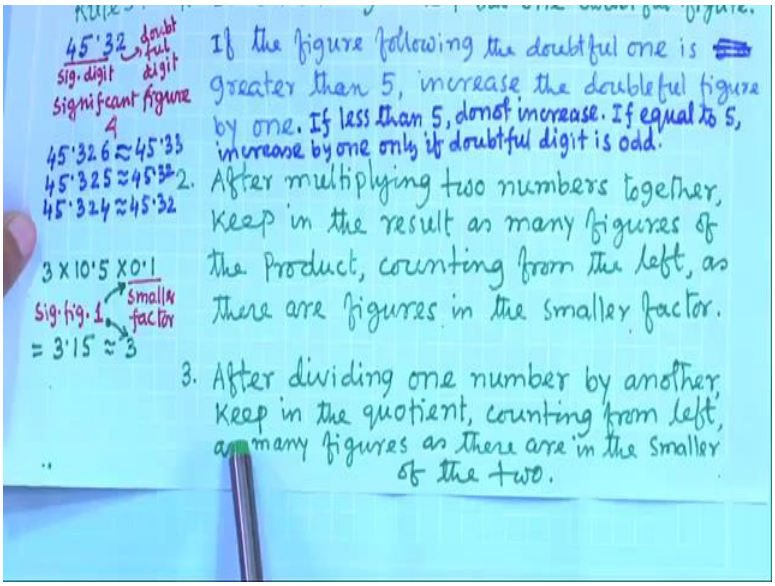

Here after multiplication we got the result what 3.15. This rule is telling that, this 3.15, it is 3 significant figure. But you cannot, you cannot keep. You can keep only one significant figure counting from the, counting from the left. That means, if we counting from the left this 1, this 3, if keep this 3 then is the significant figure of this is 1. Your result will be 3 not 3.15. This rule is telling after multiplication what will be the result. In that result you have to the, the results will have significant figure same as the significant figure of the smaller factor,

Similarly rule 3 is that after division or after dividing one number by another number, you will get the result your result is quotient. Keep in the quotient counting from the left again, counting from the left again, as many figure as there are in the smaller of the two,

again two numbers. If you divide one number by another number, among these two number, between these two numbers which one is smaller factor and what the significant figure of that smaller factor is? In your result in quotient, only you have to keep that many significant figure counting from the left,

Here I have not written example, but it is a similar of this one. This is the rule. this after multiplication, after division, after averaging, in averaging actually I should tell one more thing is there, in average, in average if you have different decimal, different decimal points are, different significant figure of different numbers then after averaging in result, among this all numbers which this from which your finding out the average. What is the smallest significant figure of among those numbers? In your result also you have to keep this significant figure of the result that will be as many as significant figure of this smallest significant figure is among those number.

This, what is significant figure? How to find out the significant figure of a number? And then after calculation either averaging or division or multiplication whatever the result you will get, how to write the result from the rules of the significant figure? that that is what I discussed. Now, let us go back to our example, our example. Here, I think.

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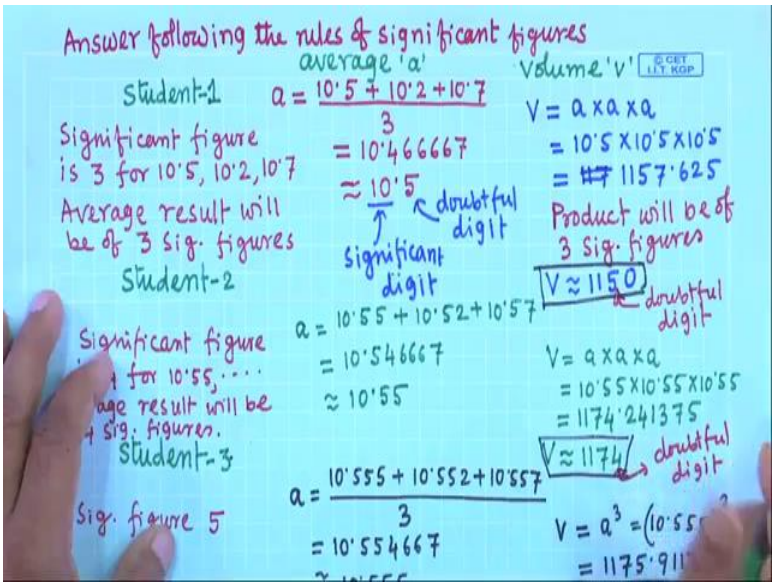

In our example I have shown the results, I have shown the results before hand, right. Now, let us let us see from following the, following the rules of the significant figures whether we can get that result or not,

Student 1, he found the average of that is 10.466667. Significant figure that rules 1 averaging, what it is telling? Actually it is telling it is whatever the number here, among them this which number have the smallest significant figure. In your result you have to keep that significant, in result you can keep that up to that significant figure. That is the meaning of this rule 1, it is not clear from that, but that is the meaning.

Here this all number have significant figure is 3. There is no complicacy. In our result also this significant the result have to have significant figure same significant figure 3, right. Obviously, we will write from here wherever calculator is given, obviously, we write this 10.4 that is doubtful actually and 6 is there, it will increased by 1, 10.5. As per rule it is a last one is doubtful one, doubtful digit. Then student 1 finds the volume, right. a is 10.5, a cube, 10.5 into 10.5 into 10.5. Result is 1157.625, right, earlier we have seen. This is the result.

Now, from this result, what it is telling? Rules is telling multiplication. Whatever the factors here we have to find out the smaller factor, but here all are equal, you can take any of them. And also each of them have the significant figure 3. No complicacy. Your result only will have 3 significant figure. Here whatever things is there, and that you have to take counting from the left. 1 2 3, 115, if you keep 115 then 115 will have the significant figure 3. this answer whether I should write 115, yes, I have to write 115. If I write, that will be wrong. Rule is that significant figure has to be has to be 3.

If I write this 115 then next 0. It will be close to this one. You have to find out, following the significant figure rules also we have to see that how close result you can keep of this your this one. 1150 if I write, it is not violating the significant figure rules. Also I am this one is close, close to this one. This result you have to write. Result is 1150.

And whatever the significant figure, last one is doubtful as first rule was telling that in result you have to keep the last one whatever result you will keep the last one will be the last significant figure digit, last digit in the number. That will be the significant that will be the doubtful digit. That means, in this number this 3 significant figure.

That significant figure 3, the third one, the third one will be the doubtful one. that means, in this number 11 is the significant digit and not significant number. Do not confuse with the significant digit and significant number. In this number, in this number

significant it has significant figure is 3 and in this 3 significant figure. First two digit are significant digit and third one is doubtful digit. That means, 5 is doubtful digit, right.

In these result in this result, if it is doubtful; that means, 1151, your result could be 11 1150, 1150, your result could be 1151 or 1152 or 1149. Generally, what would be the error? What will be the error? That about the error, these doubtful digit last doubtful digit, 0 is not the doubtful digit. 5, last one is doubtful digit. This order is the, order is a second order you know. Uncertainty, doubtful digit means a there is an uncertainty. Uncertainty in this result is in second this number, right. it is order of it is a is what I should tell, result can be can be 1150, 1160, 1170. uncertainty in 10th order.

Here you your rules significant rules from that significant rules you are writing the result also you are able to identify the uncertainty in which level in who is digit uncertainty is there. 5 can be 4, can be 6, can be 3, and can be 2 anything. Uncertainty is there. that how the two to know the actual uncertainty, to compare that one, that will learn later on for that we have to find out, we have to calculate the maximum probable error.

Without calculating also you can tell from here, but, but to verify this statement whatever I am telling, uncertainty it is not plus minus 1 or something is the plus minus 10, 20, 30 it can be in the error, , , up to 90, because this is a second order. 10 to the power 2. Here uncertainty is in which digit that also you can tell. That will verify after learning the how to calculate the maximum probable error,

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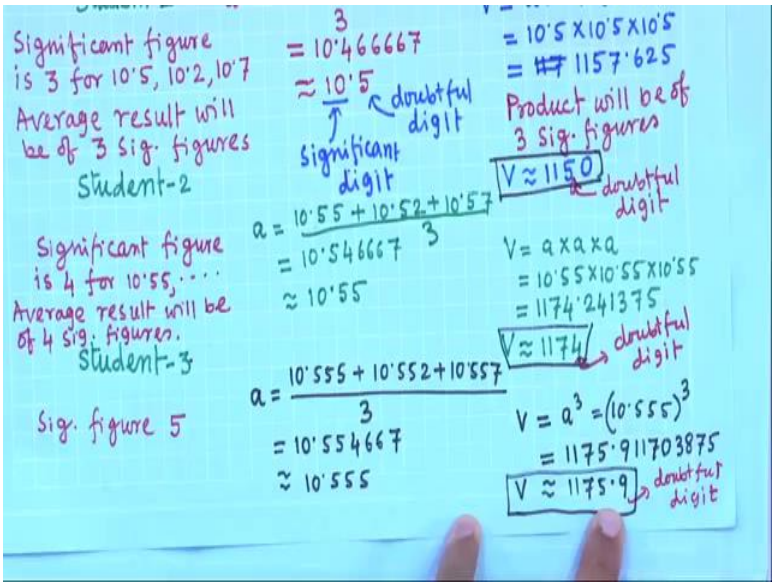

Similarly, that second student, second student here this average a, that is 10.55, right 10.55 as we have seen earlier. This is again average finding out the average of that one is it will be divided by 3. There are 4 digit, is each number have 4 digits, in the (Refer Time: 45:08) you have to keep 4 digits. that is what this error. And you are calculating the volume and it is a result is coming 1174.241375.

Again this smallest factor, all are equal factor and 4 significant figures are there, in your result you have to keep 4 significant figure counted from the left, 1174. Your result is 1174 and last one is doubtful digit and uncertainty in this result, uncertainty will be in this last digit, 4. it can be, it can be 4, it can be 5, it can be 6, it can be 9, it can be 1. in it is, is a first order. It is the in in first order, this error will be of first order in this case, It will be error of the second order,

And third student same way he calculated the average this 5 digit in result and this volume also calculated, it is a 5 digit, , 5, not 5 digit, 5 significant figure of this factors. In result also you have to keep 5 significant figure. 1 2 3 4 5, 1175.9. That is the result again this is the doubtful digit is 0.9. Error is in decimal point,

From here you can see that this student 1, he used he used the meter scale list count is 0.1, second student used slide calipers least count is 0.01, and third student use the screw gauge, and that is 0.001, right. If he used the better and from result as I from significant we found that error here in this level, in second order, it is 10, 20, 30, 40 up to 90 it can

be, error. And other case, it is a in first order 1, 2, 3, 4 up to 9 and third case, third students in decimal point error is a decimal point. It is a error can be point plus minus 0.1 or plus minus 0.2 or plus minus 0.3 etcetera,

Just learning the significant figurer and rules, we can write the number; when you are taking data, how to write the number and after calculation, that is very important. Generally, there, we will do mistake, most of us, we do mistake. That we have learnt how to write and in that result where is the uncertainty, which one is doubtful, what is the order of the uncertainty that also we can find out. I will stop here.

Thank you for your attention.