Chemical Process Instrumentation
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Lecture – 59
GATE Questions

Welcome to lecture 59. What will do in this lecture as well as in the following lecture is review of GATE questions that are related to this particular course. So, we have planned that we will review the questions during the span of 2018 to year 2000. So, you will go through quickly each question, and see how to solve those questions.

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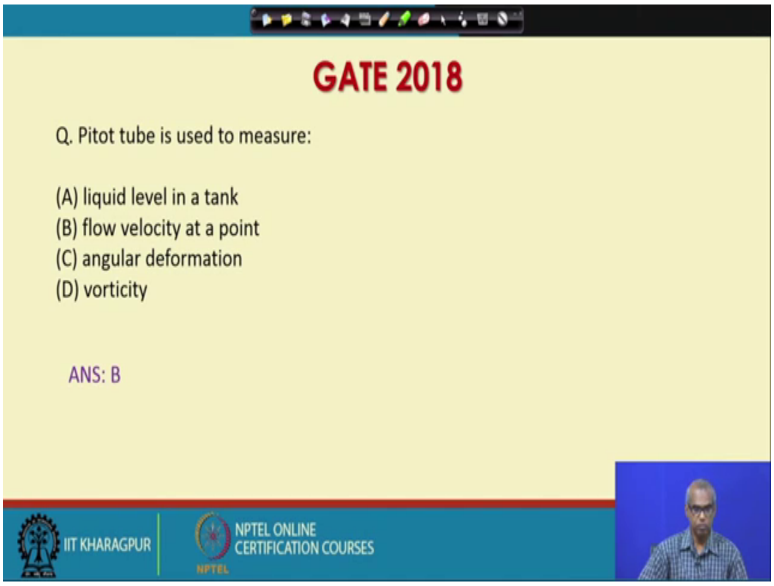

So, this is the question that appeared in 2018. Pitot tube is used to measure; liquid level in a tank, flow velocity at a point, angular deformation, vorticity. So, the correct answer is flow velocity at a point. We have seen this before when we talked about flow measurements.

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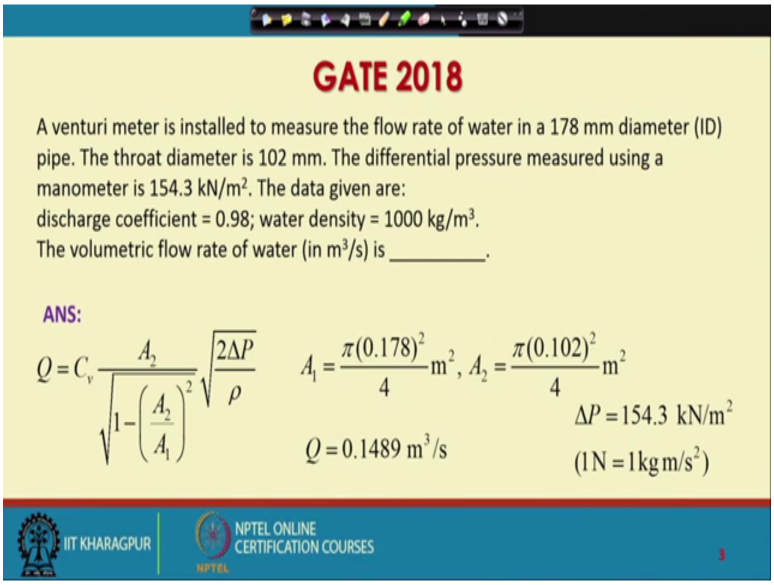

Next question again on GATE 2018: A venturi meter is installed to measure the flow rate of water in a 178-millimeter diameter ID pipe.

The throat diameter is 102 millimeter; the differential pressure measured using a manometer is 154.3 kilo Newton per meter square. The data given are discharge coefficient equal to 0.98 water density equal to 1000 kg per meter cube. The volumetric flow rate of water in meter of a second cube is we have to find out the volumetric flow rate. So, basically this is the straight forward application of the formula that relates flow rate with the pressure drop across the flow restriction.

Say you know this formula we have talked about. In fact, we have seen similar problems in assignments. So, Q equal to Cv into A2 divided by square root of 1 minus A2 by one whole square into square root of 2 delta P into rho. So, just put the appropriate values A 1 you can find out as pi d square by 4. Similarly A2 can also be used as pi into diameter square divided by 4 take care of unit, delta P is given as 154.3 kilo Newton per meter square.

So, take it as 154.3 into 1000 Newton per meter square. Remember, one Newton is 1 kg meter per second square so, the unit of flow rate will come as meter cube per second. So, put all these values of A 1 A2 delta P as 154.3 into 10 to the power 3 Newton per meter square, and rho as 1000 kg per meter square, you will get Q equal to 0.1489-meter cube per second.

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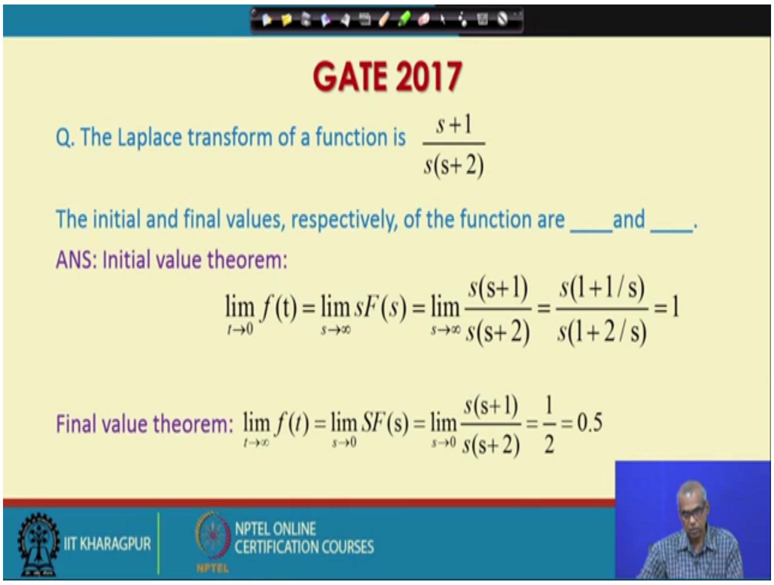

Next the question from 2017; the Laplace transform of a function is s plus 1 divided by s into s plus 2.

We have to find out the initial and final values of the function. So, we have to make use of initial value theorem and final value theorem. So, the initial value theorem can be used to find out, the initial value of a function which can be found out as finding out limit x tends to infinity S F s where F s is the Laplace transformation of the function f t.

So, that Laplace transformation is given as s plus 1 divided by s into s plus 2. So, you have to find out the limit s tends to infinity which can be evaluated as 1. So, the initial value is one, similarly, let us make use of final value theorem to find out final value theorem what you do is you find out limit x tends to 0 s F s and this is computed as half or 0.5.

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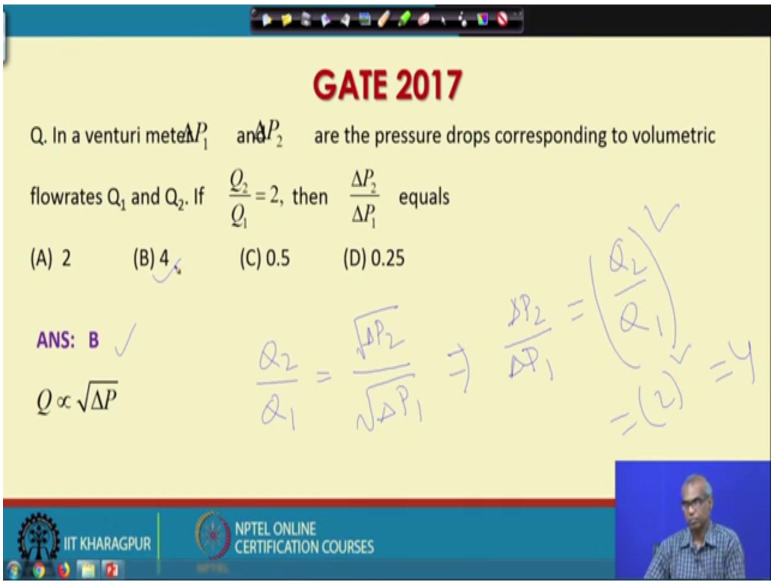

Again, a question on venturi meter from year GATE 2017. In a venturi meter delta P 1 and delta P 2 at the pressure drops corresponding to the volumetric flow rates Q 1 and Q 2. If Q 2 by Q 1 equal to 2, then delta P 2 by delta P 1 equals 2 4.5 or 0.25. Again if you remember the relationship between the flow rate and pressure drop you can easily find out the answer to this question. You know Q is proportional to square root of delta P. So, here you can write Q 2 by Q 1 is equal to square root of delta P 2 by square root of delta P 1.

So, this gives you delta P 2 by delta P 1 equal to Q 2 by Q 1 whole square. Since, Q 2 by Q 1 is given as 2 so, the answer is 4 b.

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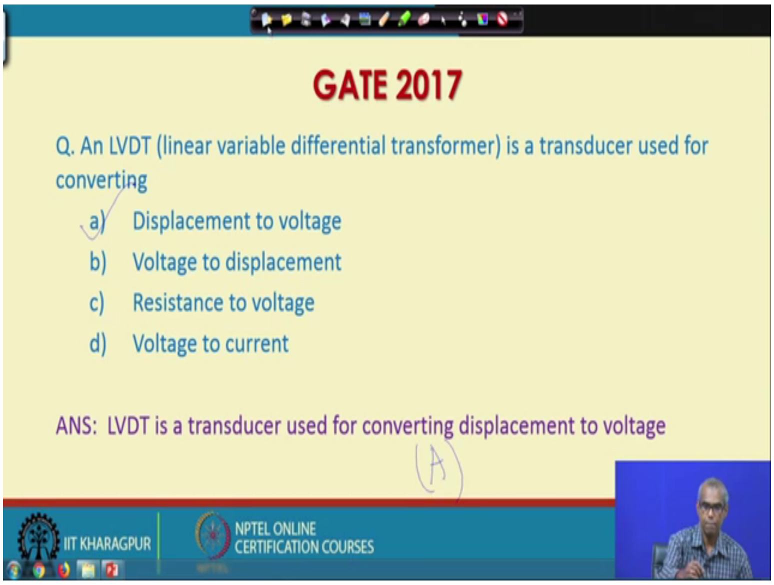

A question on LVDT linear variable differential transformer from GATE 2017 and LVDT linear variable differential transformer is a transducer used for converting displacement to voltage, voltage to displacement resistance to voltage, voltage to current. If you remember LVDT is nothing but a displacement transducer. So, LVDT is a transducer used for converting displacement to voltage.

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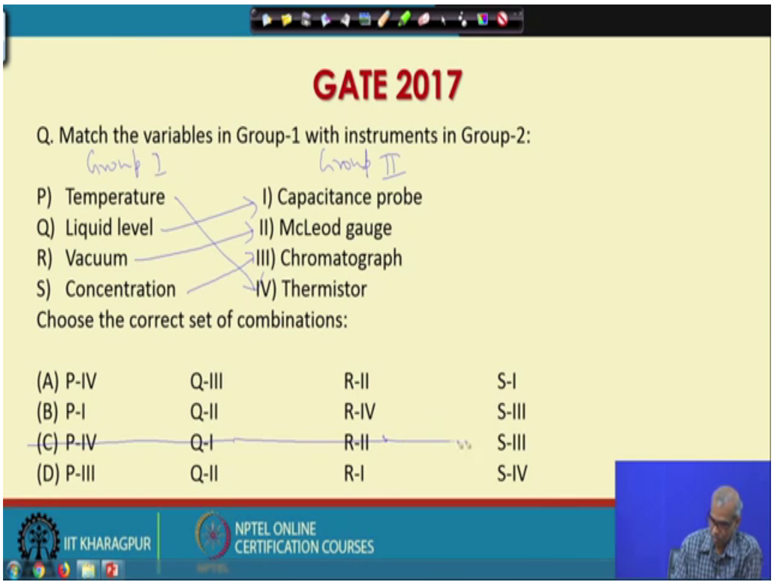

So, the correct answer is option a match the variables in group one with instruments in group 2. So, this is group one and this is group 2, temperature liquid level vacuum concentration, capacitance probe McLeod gauge chromatograph and thermistor.

Temperature can be measured using thermistor, liquid level can be measured using capacitance probe, vacuum can be measured using McLeod gauge, concentration can be measured using chromatography. So, the correct answer should be P 4 Q 1 P 4 Q 1 R 2 R 2 and S 3 S 3.

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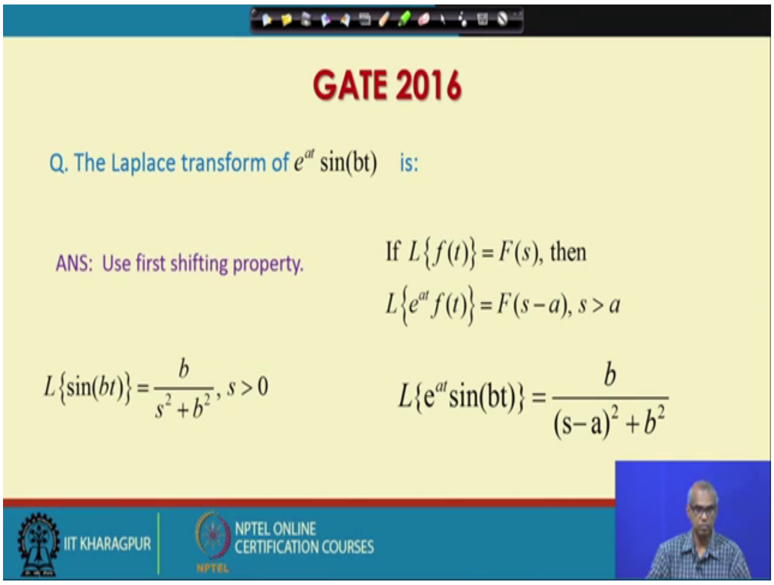

So, correct answer should be option C, answer option c. A question on Laplace transformation from GATE 2016, the Laplace transform of e to the power a t sin bt is; to evaluate this you have to make use of first shifting property. So, use first shifting property which says if Laplace transformation of ft is Fs, then Laplace transformation of e to the power a t into f of ft is f of s minus a, s is greater than a. So, Laplace transformation of sin b t we know b by s square plus b square.

So, Laplace transformation of e to the power sin b t will become b by s minus a whole square plus b square. So, if you remember the first shifting property, you will be able to find out the Laplace transform of e to the power a t sin bt very easily as shown.

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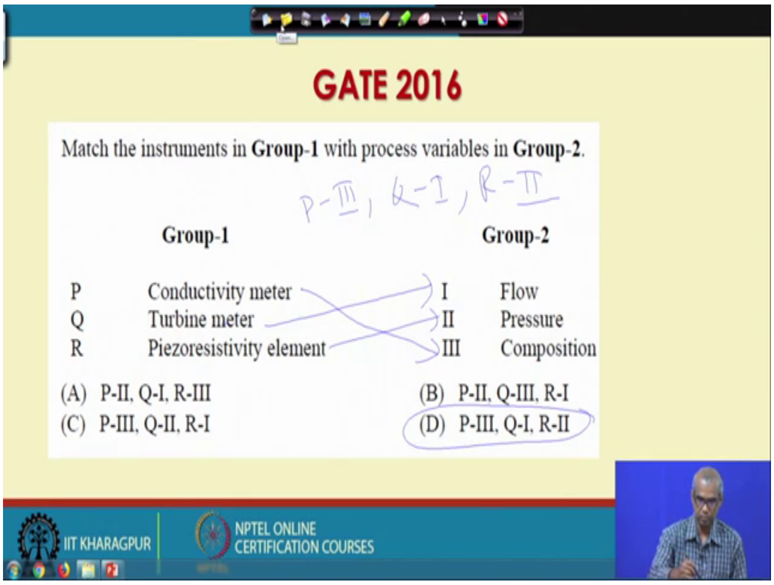

A question from GATE 2016: match the instruments in group 1 with process variables in group 2; conductivity meter turbine meter and piezo resistivity element. Conductivity meter can be used to measure composition. If you remember we have discussed this during our discussion on concentration measurement, turbine meter can be used to measure flow and piezo resistivity element can be used to measure pressure.

So, the correct answer should be P 3 Q P 3 Q 1 and R 2, which is option D. What is the order of response exhibited by u tube manometer?

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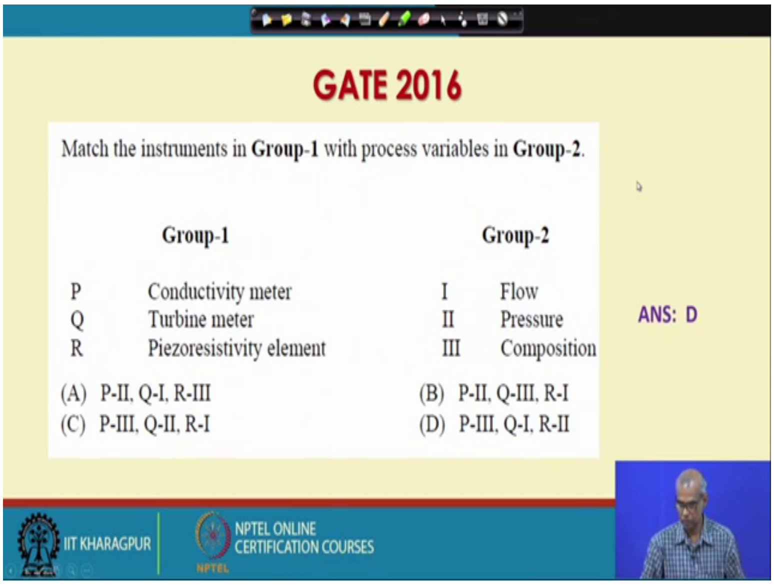

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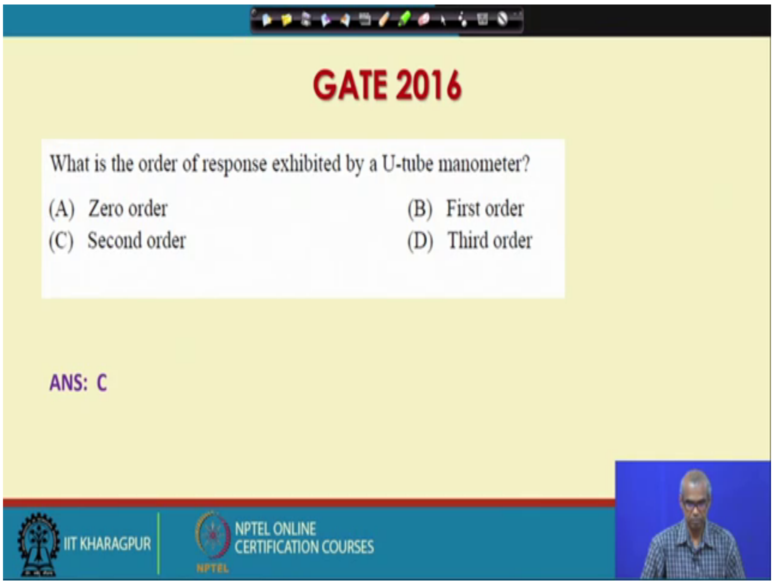

Zero order, first order, second order, third order. We have discussed this that u tube manometer shows second order dynamic. So, this is an example of second order response option C.

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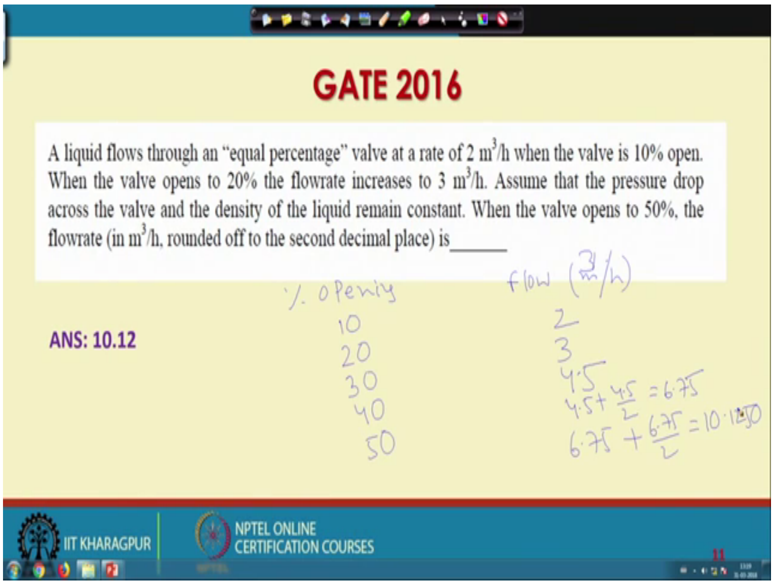

A liquid flows though an equal percentage valve at a rate of 2-meter cube per hour when the valve is 10 percent open. When the valve opens to 20 percent the flow rate increases to 3-meter cube per hour.

Assuming that the pressure drop across the valve and the density of the liquid remain constant, when the valve opens to 50 percent, the flow rate in meter cube per hour rounded off to the second decimal place is so, basically what you have to do is, you have been given an equal percentage valve.

And if percentage opening is 10 percent opening the flow rate is 2 meter cube per hour. When it is 20 percent opening it is 3-meter cube per hour. So, you know that for an equal percentage valve for each increment in valve lift, the flow rate increases by percentage of the previous flow rate.

So, for 10 percentage opening the flow rate increases from 2 to 3; that means, 50 percent. So, if it is 30 it should be again 50 percent so, that will become 4.5. When it is 40, it will increase by 50 percent. So, 4.5 plus 4.5 by 2 equal to 6.75-meter cube per hour. Similarly, when is 50 percent opening, they will again the 50 percent hike in the flow rate. So, 6.75 plus 6.75 by 2 which is 10.1250-meter cube per hour.

So, if you wish to round off to the second decimal place we can write as 10.12.

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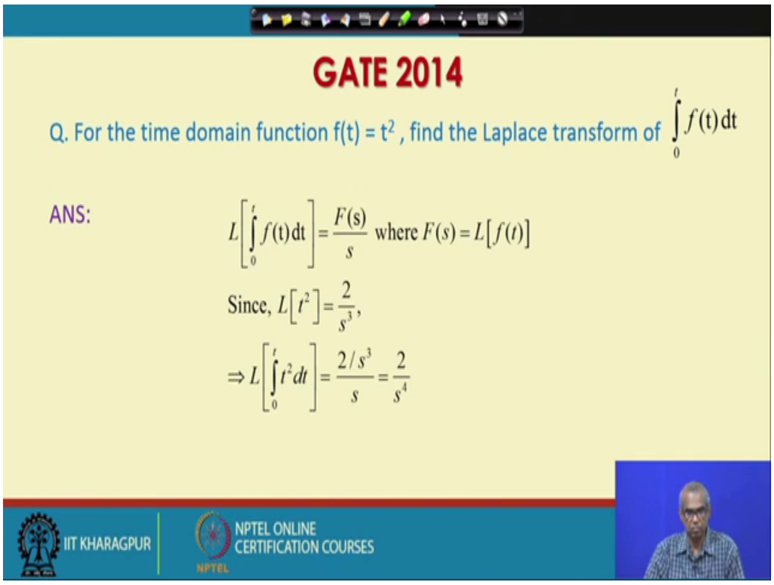

For the time domain function ft equal to t square find the Laplace transform of integral 0 to 2 ft dt so, we can evaluate it as shown.

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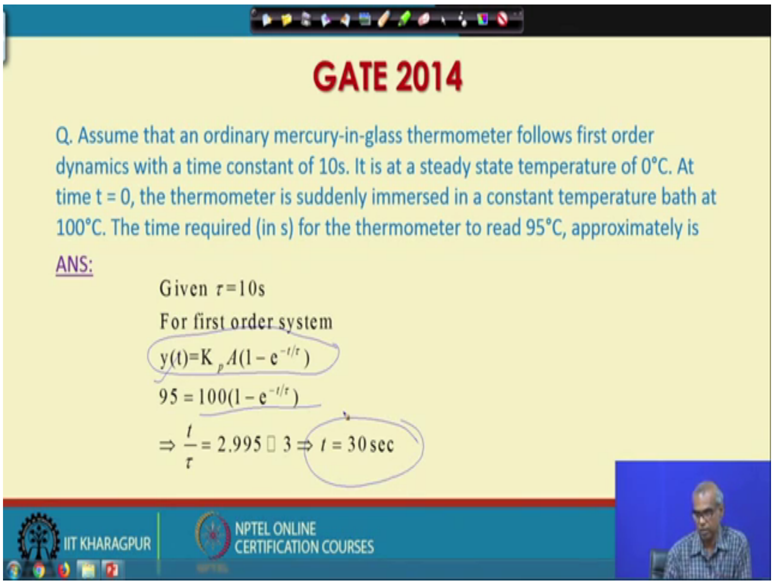

Next the question from year 2014, assume that an ordinary mercury in glass thermometer follows first order dynamics with a time constant of 10 seconds. It is at study state temperature of 0 degree Celsius, at time t equal to 0, the thermometer is suddenly emerged in a constant temperature bath at 100 degree Celsius.

The time required in second for the thermometer to read 95 degree Celsius approximately is so, what the problem says that, you have an ordinary mercury in glass thermometer, and it follows first order dynamics.

So, the response of this ordinary mercury in glass thermometer is first order. It has a time constant of 10 seconds. It was at a study state temperature of 0 degree Celsius, and then at time t equal to 0, the thermometer is suddenly immersed in a constant temperature bath at 100 degree Celsius. So, how much time will be elapsed before the thermometer reads approx. 95 degree Celsius?

So, again if you remember, the expression for the response of a first order systems for step input. The problem can be solved in a straight forward manner. Note that the thermometer was study at 0 degree Celsius, then suddenly you put the thermometer into 100 degree Celsius.

So, basically you give us step input of magnitude 100. So, time constant tau is given as 10 seconds. So, this is the expression for first order systems response for a step input y t equal to Kp into A into 1 minus 1 minus e to the power minus t by tau.

So, y t equal to 95, and then this is Kp equal to 1, A equal to 100 1 minus e to the power minus t by tau, tau is 10. So, everything is known accept t, and you can find out t as approximately 30 second.

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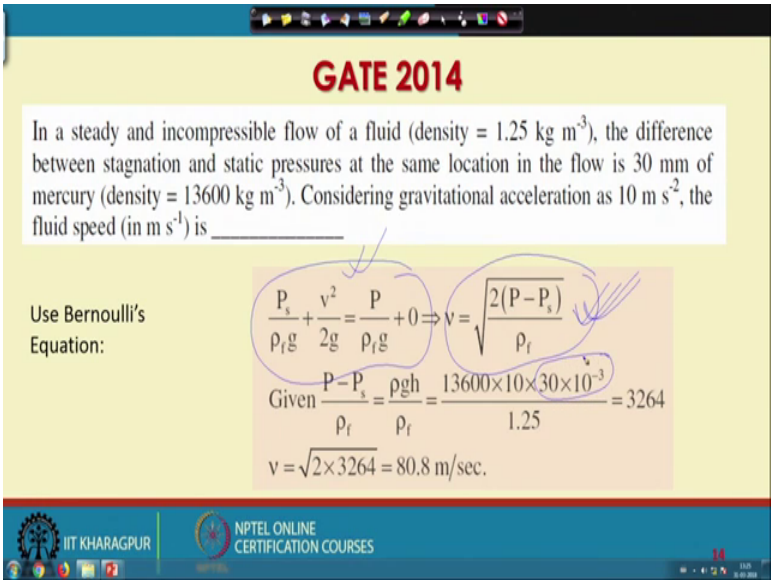

This question is also from GATE 2014. In a steady and incompressible flow of a fluid density equal to 1.25 kg per meter cube the difference between stagnation and static pressures at the same location in the flow is 30 millimeter of mercury. Density is equal to 13600 kg per meter cube. Considering gravitational acceleration is 10 meter per second square, the fluid speed is in meter per second we have to calculate, ok.

Although this question is from fluid dynamics, but this can be answered from the knowledge of Bernoulli's equation we have talked about Bernoulli's equations.

So, let us try to solve this is in Bernoulli's equation. So, this is the Bernoulli's equation from here you can find out v as this. So, note the Bernoulli's equation Ps by rho f g plus b square by 2 g equal to P by rho f g plus 0. From this you get an expression of v which is square root of 2 into P minus, P s by rho f P minus P s can be written as rho g h.

Rho is given as 13600 kg per meter cube, and 30 millimeter of mercury that has to be converted in 2 meter so, multiply 30 by 10 to the power minus 3. So, rho g and h divided by the density of the fluid is 1.25 kg per meter cube.

So, by plugging in these values you get v equal to 80.8 meter per second. So, this is state forward application of Bernoulli's equation.

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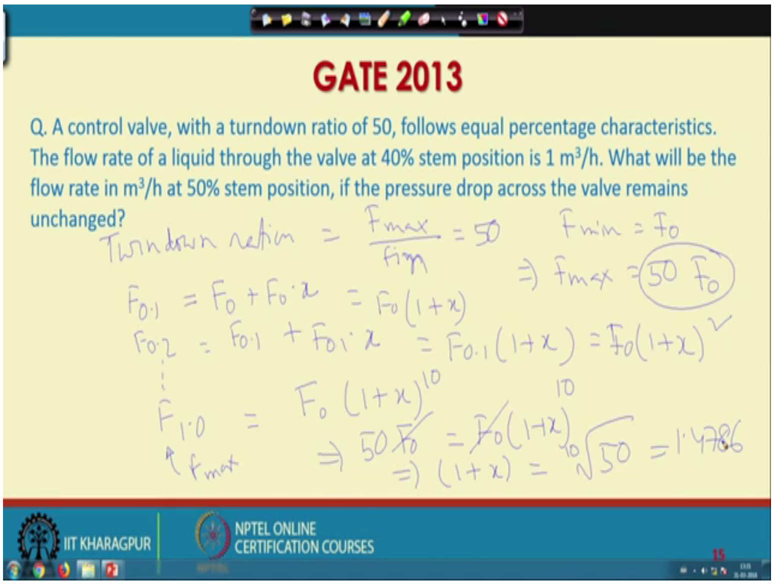

A control valve with a turndown ratio of 50 follows equal percentage characteristics. The flow rate of a liquid through the valve at 40 percent stem position is one-meter cube per hour. What will be the flow rate in meter cube per hour at 50 percent stem position is the pressure drop across the valve remains unchanged. This is an interesting question which is slightly more in valve then a similar question that we discussed few slides back.

In the previous problem, flow rates for 2 bulk opening instances were given here what is given is flow rate in a particular stem position or valve opening and the turndown ratio. So, a control valve with a turndown ratio of 50 follows equal percentage characteristics.

The flow rate of a liquid through the valve at 40 percent stem position is one-meter cube per hour, what will be the flow rate in meter cube per hour at 50 percent stem position, if the pressure drop across the valve remains unchanged. So, again remember the characteristics of equal percentage valve, that for each increment in the valve lift the flow rate increases by a fixed percentage of the previous flow rate.

Turndown ratio we know has maximum flow divided by minimum flow, which is given as 50. If I say minimum flow is Fo maximum flow is 50 times Fo. So, in the valve opening is 10 percent so, F 0.1 flow at 10 percent opening is Fo plus Fo into x. Because we know that for each increment involve if the flow rate will increases by a fixed percentage of the previous flow rate.

Let us consider that factor as x. So, this will be Fo into 1 plus x. Similarly, for 20 percent it will be F of 0.1; that means, flow at 10 percent opening plus F of 0.1 into x. So, F of 0.1 into 1 plus x, but F of 0.1 is F 0 into 1 plus x. So, this is F 0 into 1 plus z whole square. By doing this what will get is F of 1 0 is equal to F 0 into 1 plus x to the power 10. Also note this is nothing but F max maximum flow if because there is 100 percent opening.

So, F max is also nothing but 50 times F 0 so, what we can write is 50 F 0 is equal to F 0 into 1 plus x to the power 10. So, f 0 f 0 cancels out, and 1 plus x is nothing but, this is equal to 1.4786. So, what I get is, 1 plus x equal to 1.4786. So, what I have got is 1 plus x equal to 1.4786.

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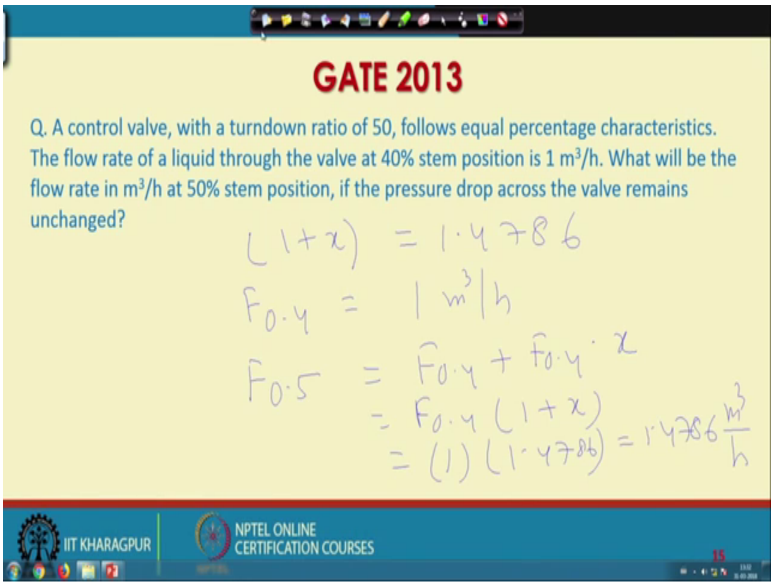

Now, given that 40 percent bulb opening or at 40 percent stem position the flow rate is 1-meter cube per hour, and I have to find out at 50 percent stem position.

So, F of 0.5 I know will be F of 0.4 plus F of 0.4 into x, which is F of 0.4 into 1 plus x, but F of 0.4 is nothing but 1 meter cube per hour and 1 plus x is 1.4786 which is 1.4786 meter cube per hour so, that is the answer. So, the flow rate at 50 percent stem position will be 1.4786-meter cube per hour.

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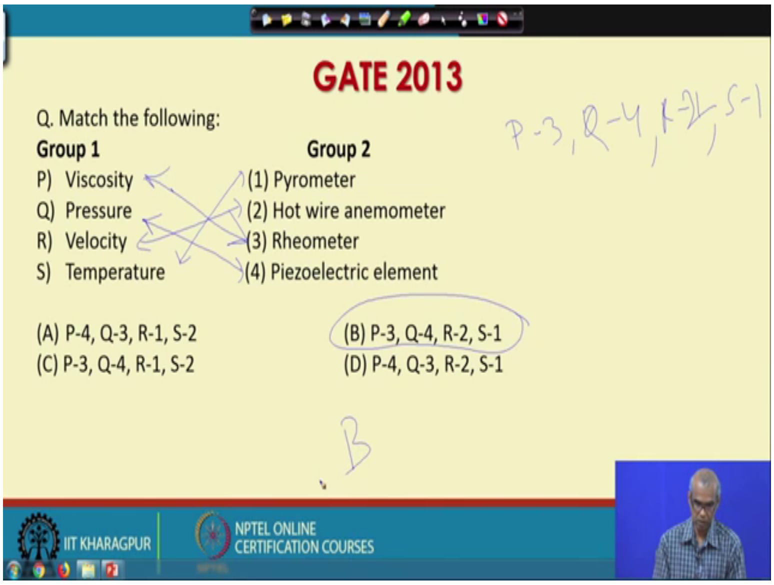

Match the following, question from 2013, viscosity you can use rheometer, pressure, you can use piezoelectric element.

Velocity we can use hot wire anemometer, temperature you can use pyrometer; so P 3 Q 4 R 1 S, sorry, R 2 S 1, P 3 Q 4 R 2 S 1. So, answer B, option B is the answer.

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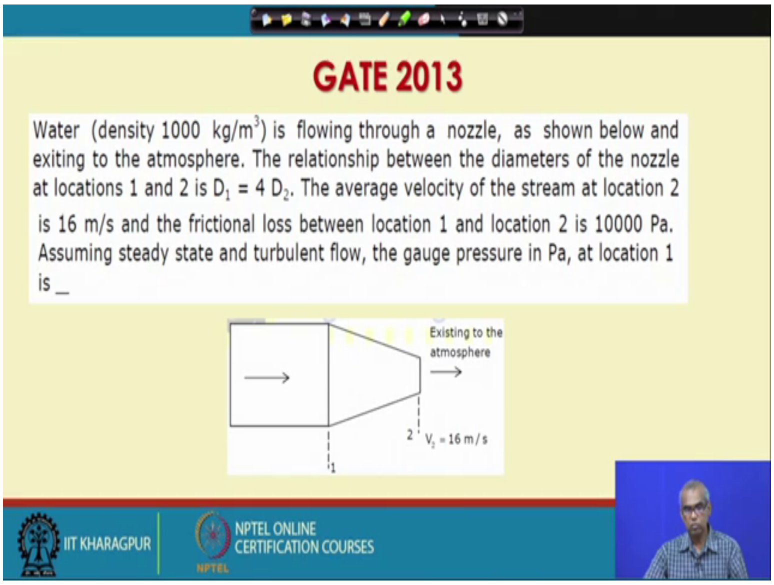

Another question on 2013 water density 1000 kg per meter cube is flowing through a nozzle, as shown below and exiting to the atmosphere. The relationship between the diameter of the nozzle at locations 1 and 2 is D1 equal to 4 D2, the average velocity of the stream at location 2 is 16 meter per second, and the frictional loss between location one and location 2 is 10000 Pascal.

Assuming steady state and turbulent flow, the gauge pressure in Pascal and location one is, again you have to apply the Bernoulli's equation.

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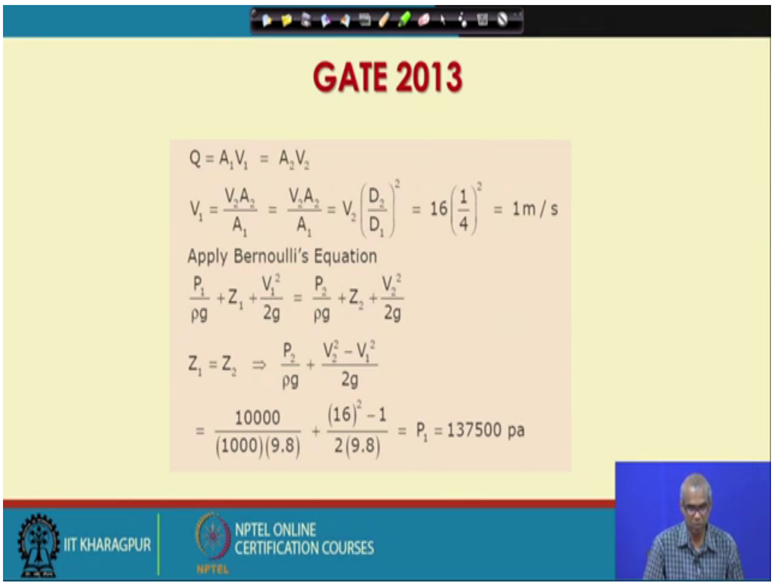

So, it is also a state forward application of Bernoulli's equation. If you apply Bernoulli's equation will get the value of P 1 as 137500 Pascal.

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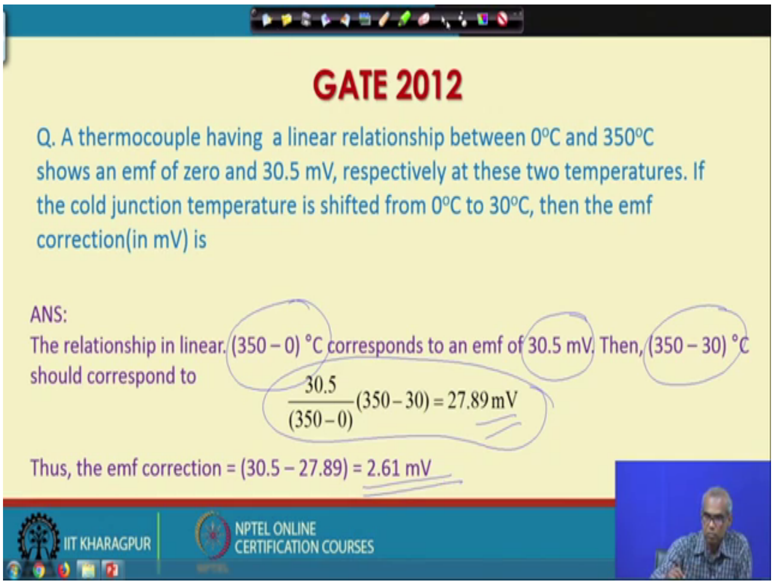

A question on thermocouple from GATE 2012: a thermocouple having a linear relationship between 0 degree Celsius on 350 degree Celsius shows an emf of 0 and 30.5 mill volt respectively at this 2 temperatures. If the cold junction temperature is shifted from 0 degree Celsius to 30 degree Celsius, then the emf correction in millivolt is; the relationship is linear.

So, 350 minus 0 degree Celsius corresponds to an emf of 30.5 millivolt then 350 to 30 degree Celsius should correspond to this which is computed as 27.89 millvolt. So, the emf correction is 30.5 millivolt minus his millivolt which is 2.61 millivolt. The thermometer initially at 100 degree Celsius is dipped at t equal to 0 into an oil bath maintained at 150 degree Celsius.

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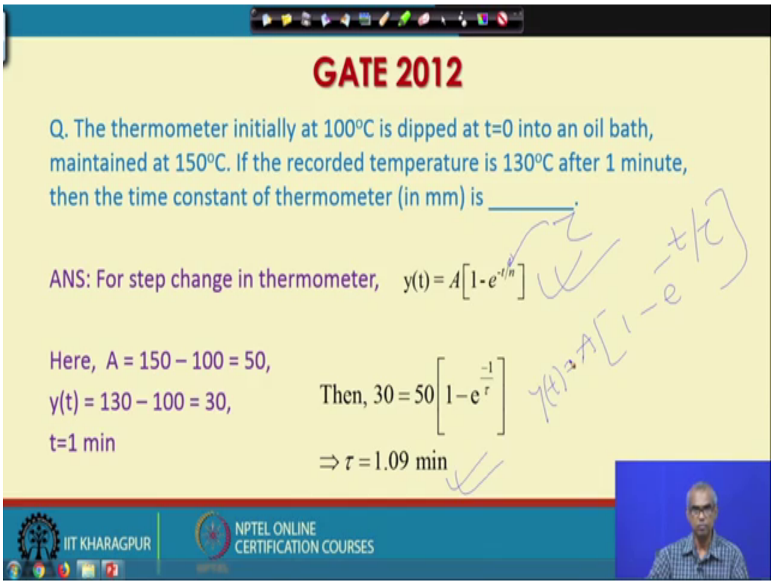

If the recorded temperature is 130 degree Celsius after 1 minutes, then the time constant of the thermometer is for a step change in thermometer, y t equal to A into 1 minus c to the power minus t by tau is A n is (Refer Time: 33:48) is tau. Here A equal to 150 minus 100 equal to 50 y t equal to 1 30 minus 100 equal to 30, t equal to 1 minute, then putting the values in the equation y t equal to a into 1 minus e to the power minus t by tau we get tau equal to 1.01 minute please read this as tau, A into 1 minus e to the power minus t by tau y t equal to.

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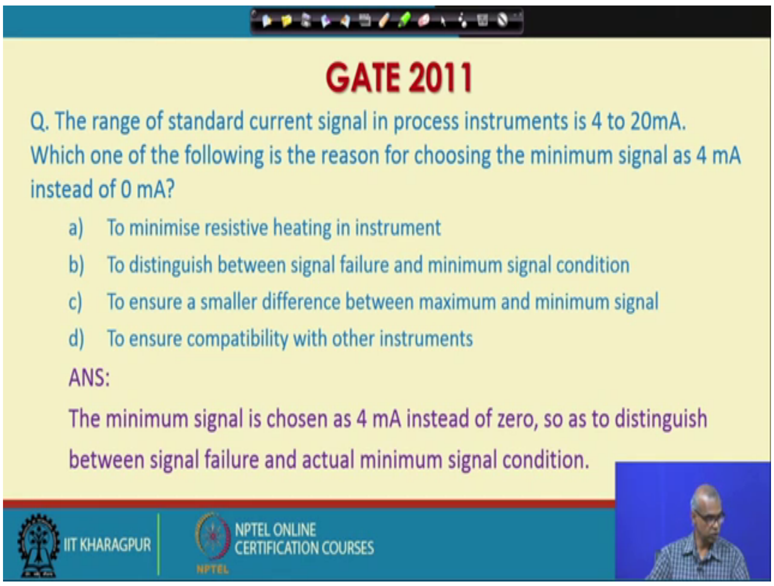

A question from 2011; the range of a standard current signal in process instrument is 4 to 20 milliampere, which one of the following is the reason for choosing the minimum signal as 4 milliampere instead of 0 milliampere. To minimize the resistive heating an instrument to distinguish between signal failure and minimum signal condition, to ensure as smaller difference between maximum minimum signal, to ensure compatibility with other instruments.

To distinguish between signal failure and minimum signal conditions, we use 4 to 20 milliampere instead of 0 to 20 milliampere. So, answer is b, the minimum signal is chosen as 4 milliampere instead of 0 so, as to distinguish between signal failure and actual minimum signal condition.

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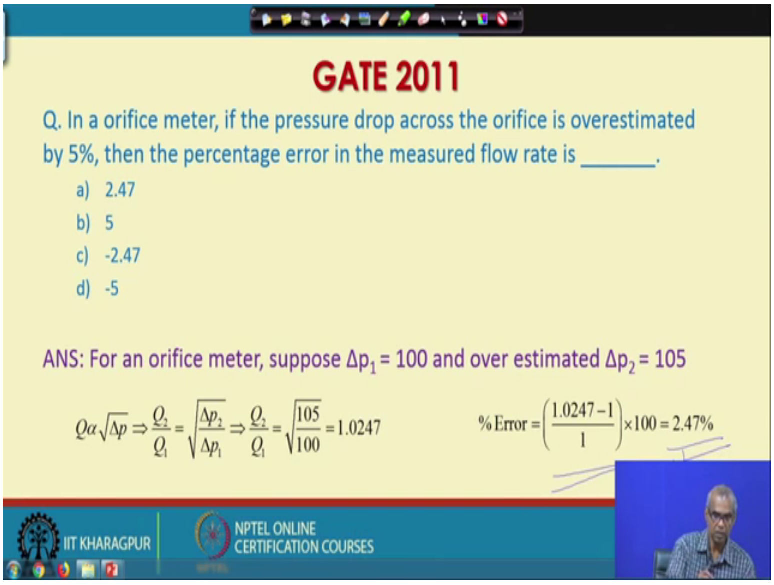

A question and GATE 2011 in a orifice meter if the pressure drop across the orifice is over estimated by 5 percent, then the percentage error in the measure flow rate is 2.475 minus 2.47 minus 5. For an orifice meter suppose delta P 1 equal to 100 and over estimated delta P 2 equal to 105 is 5 percent overestimation.

We know flow rate Q is proportional to square root of delta P. So, Q 2 by Q 1 is square root of delta P 2 by delta P 1. So, Q 2 by Q 1 is square root of 105 by 1, which is 1.0247. So, percentage error is 1.247 minus 1 by 1 into 100 is 2.47 percentage.

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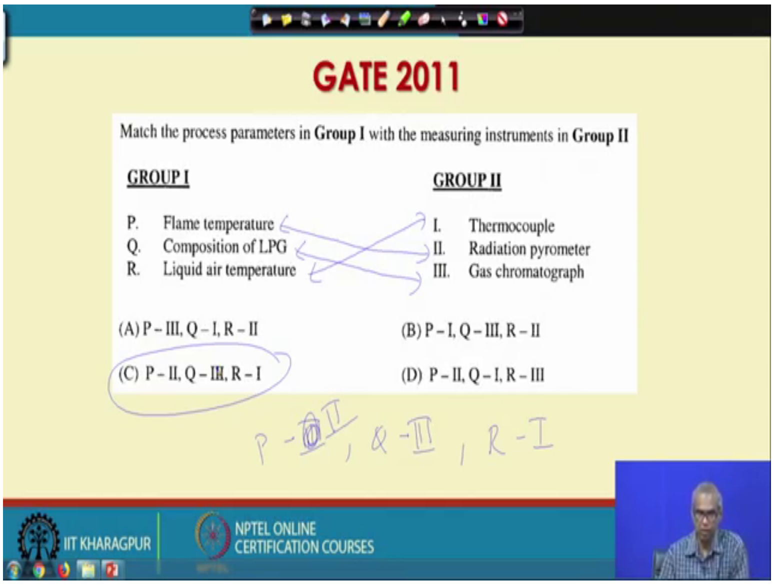

Match the process parameters in group one with the measuring instrument in group 2. Flame temperature, you want to measure using radiation pyrometer. Composition of LPG, you want to measure using gas chromatograph. Liquid air temperature, you want to measure using thermocouple: so P 3 Q P 2 P 2 Q 3 R 1. C is the correct answer.

So in the next lecture, we will see some more examples from previous year gauge question papers.