Basic Thermodynamics

Prof. S. K. Som

Department of Mechanical Engineering

Indian Institute of Technology, Kharagpur

Lecture - 05

First Low– III

Good morning, I welcome you all to this session. In the last two classes, we have discussed the analysis of first law of thermodynamics to closed and open systems. In this class, we will solve some problems to clear our concept about this analysis of first law to closed and open systems. Through some practical problems, we will see how these analyses are being utilized.

Well, so let us start with the problems.

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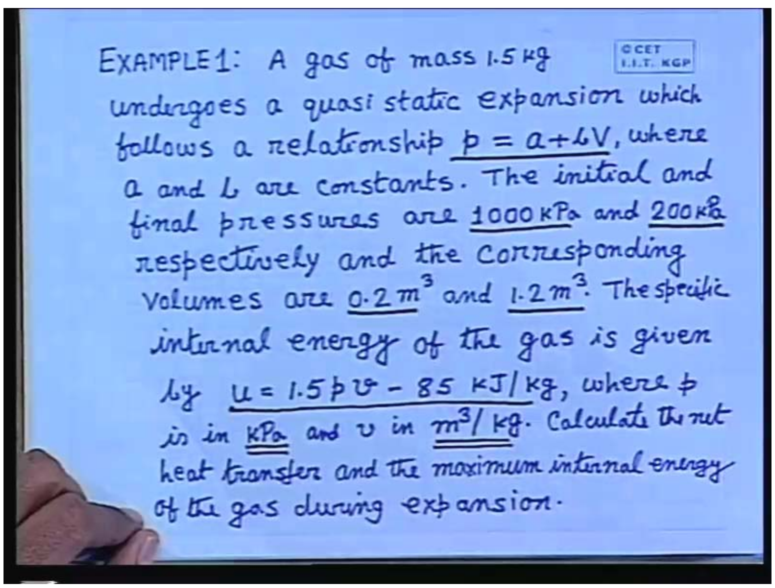

First problem, example one: This is a problem relating to the application of first law in a closed system and we start with a very simple problem - straightforward application. A gas of mass 1.5 kg undergoes a quasi static expansion, you may or may not write the entire problem, you can write only the pertinent points.

For example, a gas the mass of which is 1.5 kg, undergoes a quasi static expansion, already we know that is pdV work, which follows a relationship p is equal to a plus bv, that is the relationship p and V, p is equal to a plus bV, where a and b are constants. This is the law of the process displacement work, where the pressure and volume changes. The initial and final pressures are 1000 kiloPascals and 200 kiloPascals respectively. The initial pressure is 1000 kiloPascals and the final pressure is 200 kiloPascals. That means it is an expansion process where the pressure decreases. The corresponding volumes are 0.2 meter cube - that is the initial volume and 1.2 meter cube - that is the final volume. The specific internal energy of the gas is given by….I told you earlier that regarding this internal energy, how does it relate with the pressure volume, this we will see afterwards, but at the present moment we will assume some relationship which will be given as u is equal to 1.5 pv where V is the specific volume and p is the pressure minus 85 kilo Joule per kg. This u is expressed in kilo Joule per kg provided we substitute p in this equation in kiloPascals; these things are very important utilizing this equation. If you do a mistake, so you will lose marks in examination.

Concept remains the same, but to get the correct answer we have to be very careful. v in meter cube per kg; that means, if you express p and v in these units, then u will be given by kilo Joule per kg according to this relationship. These constants - the numerical values - are adjusted like that.

Calculate the net heat transfer and the maximum internal energy of the gas during the expansion. The problem is clear to you? So, now, how to solve the problem? First of all, we will have to find out the net heat transfer. So, this is a problem of a closed system.

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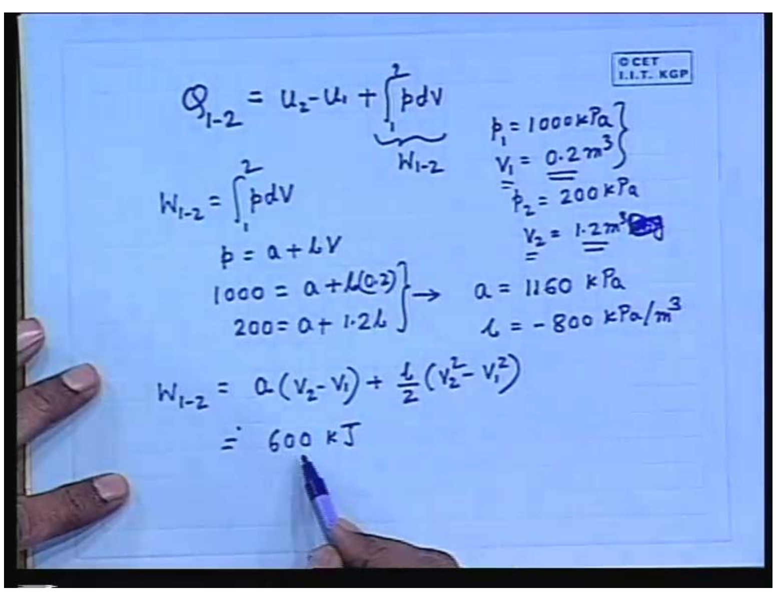

For a closed system, we will always write the first law in this fashion, as we know already what to write; $Q_{1-2,}$ let 1 and 2 be the initial and final state points is equal to u_2 minus u_1 plus integral of pdV, that is the work 1 to 2, this is the work transfer W. That means W_{1-2} is integral of pdV. It is the very simple problem straightforward applications. (Refer Slide Time: 05:37)

Now we know this p is a liner function of v, a plus bv; so we can straightforward integral d. But to get a numerical value, we have to know the numerical values of these constants a and b and it is very simple; it is found from these two conditions; that means, it is written; when p_1 is equal to 1000 kiloPascals, what is V1? V_1 is equal to 0.2 meter cube; this is one set. Another is p_2; p_2 is how much? p_2 is equal to 200 kiloPascals. What is V2? V2 is equal to 1.2 meter cube. Now if we substitute this p, not meter cube per kg only meter cube, very good, P is equal to a plus bv; this is the relation. That means, we will write this 1000 in kiloPascals, I am writing, accordingly the unit will come. 1000 is equal to a plus b, 0.2 because, I am not converting into Pascals by multiplying with 10 cube unnecessarily, the number will be very high, so b in meter cube. Then we write 200 is equal to a plus 1.2b. If you solve these two equations, you will get a is equal to 1160 kiloPascals. You have done this problem? Just now you are doing? Very good. The unit of a has to be kiloPascals because it is pressure.

What is the value of b? b is equal to minus 800 kiloPascals per meter cube. Very simple problem that is why you are so prompt. Therefore, I get av. Now, what is W_{1-2}? Tell me. W_{1-2} is equal to a into V_2 minus V_1 plus b by 2 into V_2 square minus V_1 square. All this students may not catch so fast as for wide spectrum of the students, so we will go slow.

Now we have got the values V_2 is equal to 1.2 meter cube, V_1 is equal to 0.2 meter cube and 'a' is in kiloPascals, 'b' is in kiloPascals per meter cube. If you substitute this value, you get the value of W as 600 kiloJoule. If you just substitute the value a in kiloPascals and V_2 minus V_1 in meter cube, so kiloPascals into meter cube will be kiloJoule. Here also (Refer Slide Time: 08:46 min), if you substitute kilopascals per meter cube and this is V_2 square; therefore, you get the value 600 kiloJoule.

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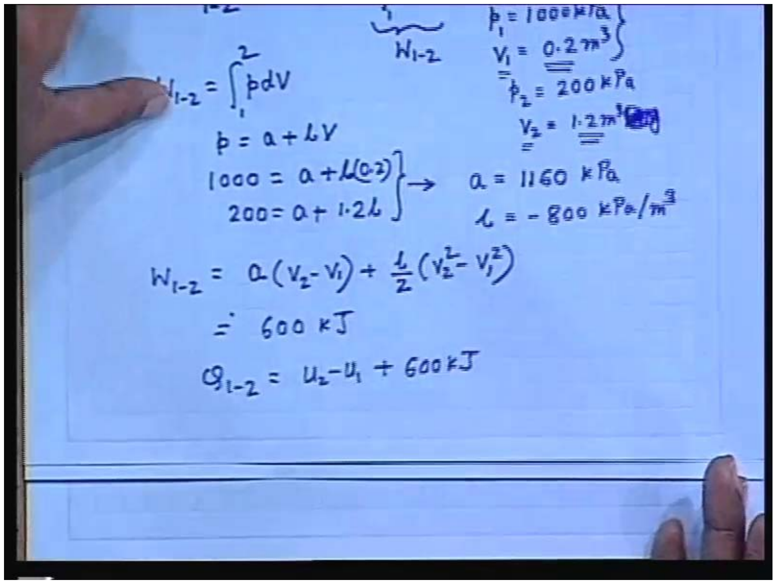

Now what is $Q_{1-2?}$ $Q_{1-2}$is equal to u_2 minus u_1 plus 600 kiloJoule. Now, here W is coming to be plus; so this sign automatically comes when you integrate this. We put the limit final minus initial. So, final is the upper limit; initial is the lower limit. Depending upon the final and initial values of V the sign of this quantity is determined. So it is determined as a positive quantity which physically signifies that work is coming out of the system. Now how to find out u_2 minus u_1? From the property relation, School level problems in fact. What is this property relation? This is kiloJoule per kg.

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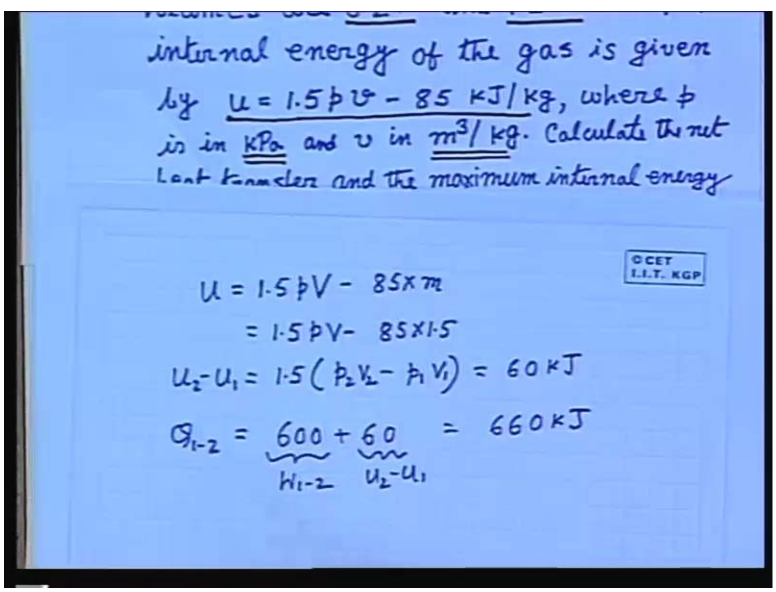

If I want to find out capital U, we will have to multiply with the mass; that means, V will be the volume; this V is also in meter cube per kg. That means, I will write the equation rather in this fashion.

U is equal to 1.5 pV minus 85 into mass of the gas. This is the relationship between the pressure volume and the total internal energy of this system. Then the equation becomes U is equal to 1.5 pV minus 85 into 1.5, but this part is constant, it is not required in finding out the change. So, change will be given by U_2 minus U_1 is equal to 1.5 into p_2V_2 minus p_1V_1, which is equal to 60 kiloJoule. Therefore, Q_{1-2} is equal to 600 plus 60, that means 600 is W_{1-2} and 60 is u_2 minus u_1, is equal to 660 kiloJoule.

What is the next part? The maximum internal energy. How do you do this part? Calculate the maximum internal energy of the gas during the expansion. How do you do it? Tell me.

[Conversation between Student and Professor – Not audible ((00:11:32 min))]

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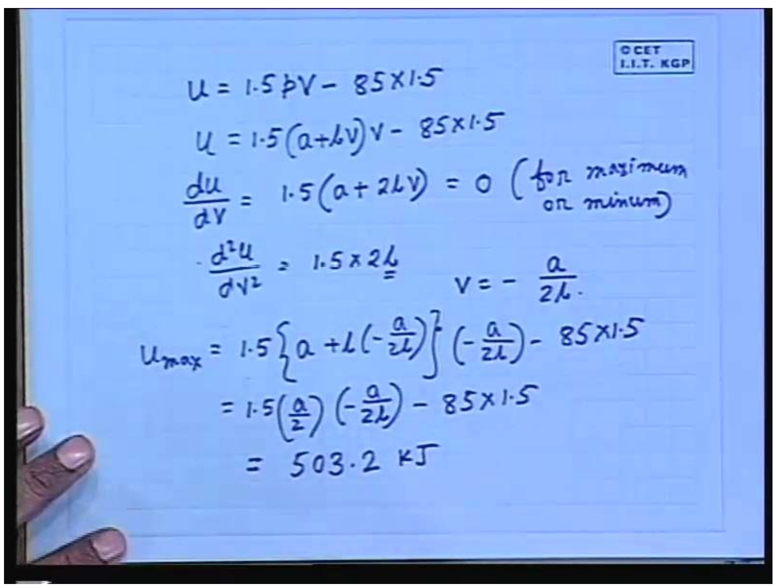

Let us first write u. What is u? u is equal to 1.5 pV minus 85 into1.5. So, you express this in one variable. That is p is a plus bV, then we get u is equal to 1.5 into a plus bV into V minus 85 into 1.5. It does not matter whatever it is until and unless we are interested in finding out them. It will be required when we find out the maximum internal energy. Let us make du by dv. What is du by dv? du by dv is equal to 1.5 into a plus 2bV and said this is equal to 0 for maximum, but this curve has only a maximum with the values of a and b, how?

d square u by dv square is negative. What is d square u by dv square? That is equal to 1.5 into 2b and b is negative in this problem; minus 800 kiloPascals per meter cube. Therefore, this shows with these values of ab, this curve, that means the relationship between u and V, shows only a maximum (Refer Slide Time: 13:03 min). So, this is the condition for maximum not a minimum. So that maximum condition is given. So that Vis equal to minus a by 2b.

Therefore maximum internal energy will be found out u_{max} is equal to 1.5 into a plus b into minus a by 2b into minus a by 2b minus 85 into 1.5. By substituting the values this we can simplify into 1.5 into a by 2 into minus a by 2b minus 85 into 1.5. So, the minus in the a will get cancelled with the minus in the b. Ultimately, I do not know the sign of this, but it will be composite. What is the value? The value will come is 503.2 kiloJoule; this is the change in the maximum internal energy.

[Conversation between Student and Professor – Not audible ((00:14:23 min))]

Maximum internal energy.

It is the maximum internal energy during the expansion. Any query? It is a very straightforward problem applied to a closed system. Straightforward application of the law that Q is equal to u_2 minus u_1 or delta u plus w which is pdV work incase pdV work it is the integration of pdV.

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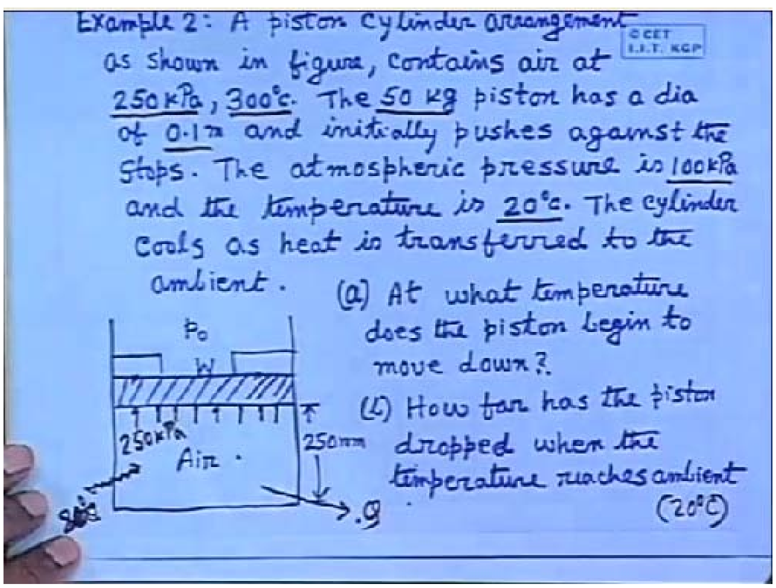

Now, let us go to the second problem number 2; example 2: A piston cylinder arrangement as shown in figure contains air at 250 kiloPascals - that means, the initial pressure of the air - and

300 degree Celsius. This is the piston cylinder (Refer Slide Time: 15:36 min). The 50 kg piston, that means, the piston has a weight of 50 kg and it has a diameter of 0.1 meter and initially pushes against the stops - that means, physically. What is this? There is a pressure of 250 kiloPascals. This pressure exerts a force which balances the wet plus the atmospheric pressure and the reaction against these stops (Refer Slide Time: 16:23 min), so that piston is kept fixed with this stop. The atmospheric pressure is 100 kiloPascals and the temperature is 20 degreeCelsius, which is the initial temperature.

[Conversation between Student and Professor – Not audible ((00:16:39 min))]

It is atmospheric temperature. . The atmospheric temperature is 20 degree Celsius. Now, the cylinder cools as heat is being transferred from the cylinder Q to the ambient. At what temperature does the piston begin to move down? That is part one. How far has the piston dropped when the temperature reaches ambient? That means 20 degree Celsius.

Now, you see what is the problem? Try to understand the problem physically. Now the piston is fixed to this (Refer Slide Time: 17:25 min). When we cool it, this will be cooling at a constant volume, so pressure will be reduced. When you take the heat from this at a constant volume the pressure will be reduced. When the pressure will be reduced, both pressure and temperature will be reduced, but the volume will remain same, because piston is fixed to this. When pressure will reach a value, the piston will try to descend downward direction. So, from the mechanics point of view, what will happen at the point when piston is just trying to descend down?

[Conversation between Student and Professor – Not audible ((00:18:01 min))]

No.

[Conversation between Student and Professor – Not audible ((00:18:03 min))]

No.

[Conversation between Student and Professor – Not audible ((00:18:07 min))]

Pressure plus atmospheric pressure plus.

[Conversation between Student and Professor – Not audible ((00:18:14 min))]

Will be equal to the atmospheric it is the pressure inside the gas very good, but now what it is?

It is not like that now at this condition one.

[Conversation between Student and Professor – Not audible ((00:18:21 min))]

Why?

[Conversation between Student and Professor – Not audible ((00:18:23 min))]

Normal forces are added, the reaction will be 0, the forces on both the sides except this reaction forces, that means pressure and the weight and the pressure forces will be equal to each other. These normal forces here will be 0 (Refer Slide Time: 18:44 min). Then, if you reduce the pressure any more it will automatically descend down. Therefore, we have to find that pressure and if we know the pressure, we can find out the temperature. This is the problem. This part is more of mechanics than of thermodynamics. What is this pressure? Calculate. What is this atmospheric pressure? Let me write in terms of atmospheric with pressure p and all these things.

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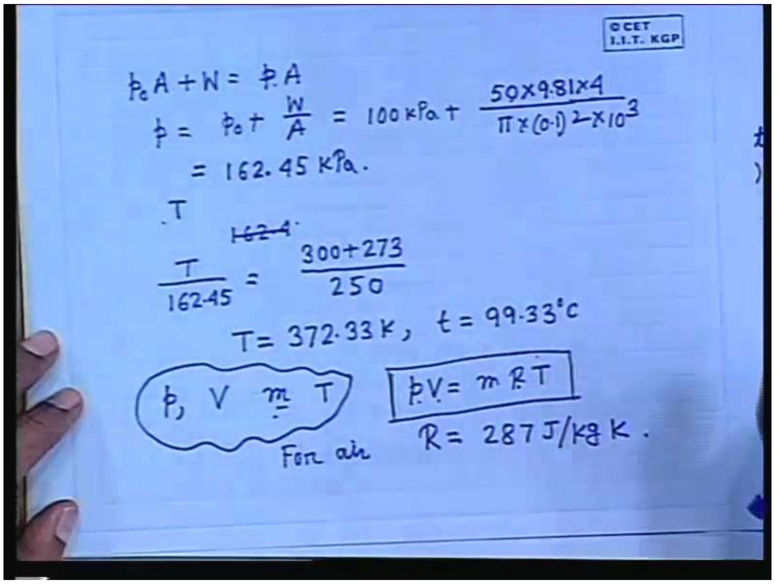

Let the weight of the piston be W. I can write this as p_0A plus W is equal to p into A, where A is the area of this piston and p is the pressure when the piston will be in a position to descend down. So therefore, p is equal to p_0 plus W by A; the atmospheric pressure due to the weight of the piston. The pressure of the air at which the piston will just try to descend down will be p_0 plus W by A. Now substitute the values. What is p_0? What is the value? 100 kiloPascals. This part also has to be expressed in kiloPascals. We get p_0 is equal to 100 kiloPascals plus 50 kg into mass 9.81 Newton into 4 divided by area, what is the diameter of area? pi into 0.1 square into 1000. Wm into G, that is the weight expressed in Newton, pi d square by 4 is the area kilopascals; that means, kilo Newton per meter square. So, this becomes equal to what? 162.45 kiloPascals. This is the pressure when the pressure will be reduced from 250 kiloPascals to

162.45 kiloPascals, the piston will try to descend, but the question is, at what temperature does the piston begin to move down? Now question is that I know the pressure, but how can I know the temperature?

[Conversation between Student and Professor – Not audible ((00:21:39 min))]

Constant volume p_1 pi. Therefore, let T be the temperature, then p by t, that is 162.45; rather I write this way - T by p is 162.45; this is equal to what? The initial temperature is 300 degree Celcius.

[Conversation between Student and Professor – Not audible ((00:22:08 min))]

Actually, it is 273.15, but for our practical purpose we will take it as 273 divided by p. What is p? p is 250 kiloPascals, p is to be in kilo Pascals. This gives T is equal to what? 99.. Therefore, we get T is equal to 372.33 k which gives t is equal to 99.33 degree Celsius. Now where from you got p_1 by T_1 is p_2 by T_2?

[Conversation between Student and Professor – Not audible ((00:22:49 min))]

Volume, but you are not supposed to know the first law, so that I tell that sometimes it will be given; if it is not given, then for air I recapitulate the earlier things: you always know that if p is the pressure, V is the volume, m is the mass and T is the temperature of a certain mass of gas M. Then for any ideal gas this is the relationship: pV is equal to mRT. For any ideal gas, pressure, volume, temperature and mass is related by this equation where R is a constant for that particular gas and is known as characteristic gas constant. We will see afterwards if this mass is changed to another unit – moles - which is nothing but the mass scaled with the molecular rate, then this constant is same for all ideal gases. But if you do not scale the mass by the molecular way rather mass simply has the amount in terms of kg, then it is the constant which is varying from gas to gas and is known as characteristic gas constant. For many other problems, you have to use this equation. So you have to remember one thing - the value of R; this may not be given. Even for the examinations also because you are supposed to know certain values; so, R is one of such. For air, this value is 287 Joule per kg, in SI unit it is 287 Joule per kgk. This we will always remember that pV is equal to 287 mRT where p is in basic unit Newton per meter square, V is in meter cube, m in kg and T in Kelvin.

Now let us come to the next part. How far has the piston dropped when the temperature reaches ambient how do you find out?

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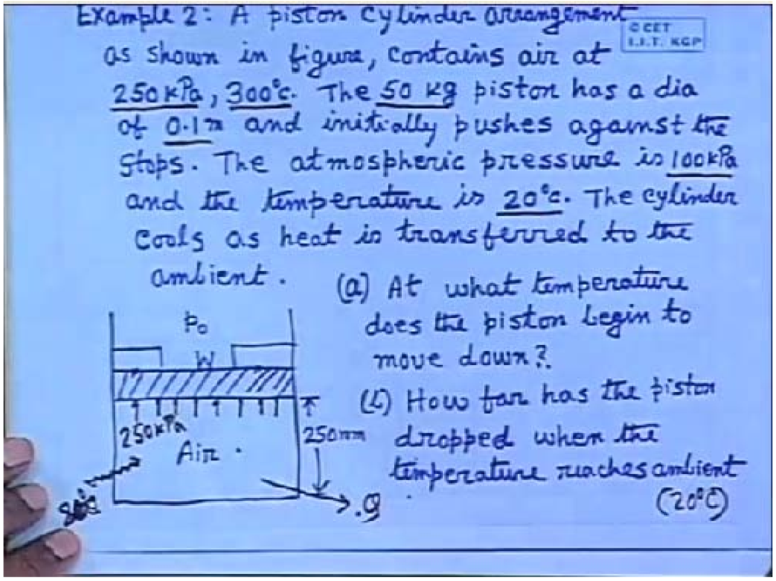

[Conversation between Student and Professor – Not audible ((00:25:13 min))]

[Conversation between Student and Professor – Not audible ((00:25:16 min))]

So how to p_2V_2 correct, but temperature is changing why temperature will be constant, which is 20 degree Celsius.

[Conversation between Student and Professor – Not audible ((00:25:26 min))]

V by T is constant.

[Conversation between Student and Professor – Not audible ((00:25:32 min))]

One solution is that V by T is constant, so you can find out the V, pressure remains constant that is one. Another person is telling that T will remain constant. T is not constant because it is given there.

[Conversation between Student and Professor – Not audible ((00:25:48 min))]

Pressure is remaining constant is the answer for it; that means, we will have to find the V by making the pressure constant, so that you can use the same equation pV.

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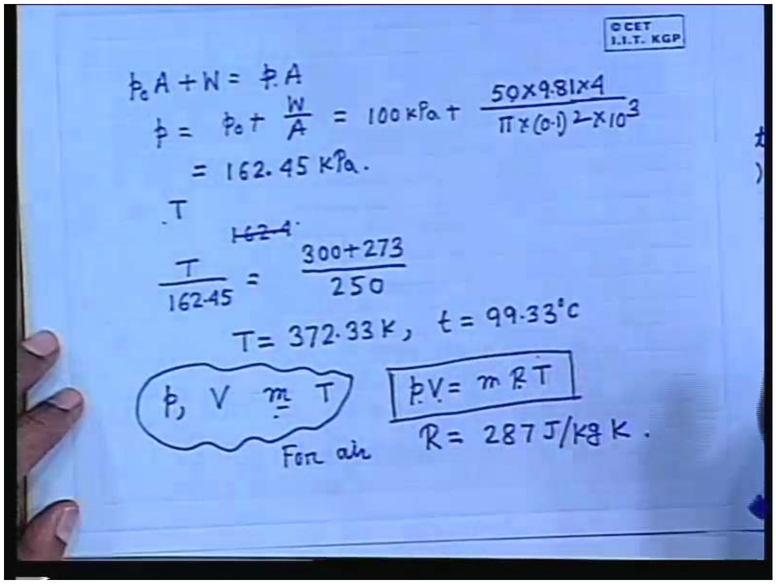

If pressure remains constant V by T is constant, you can find out the volume.

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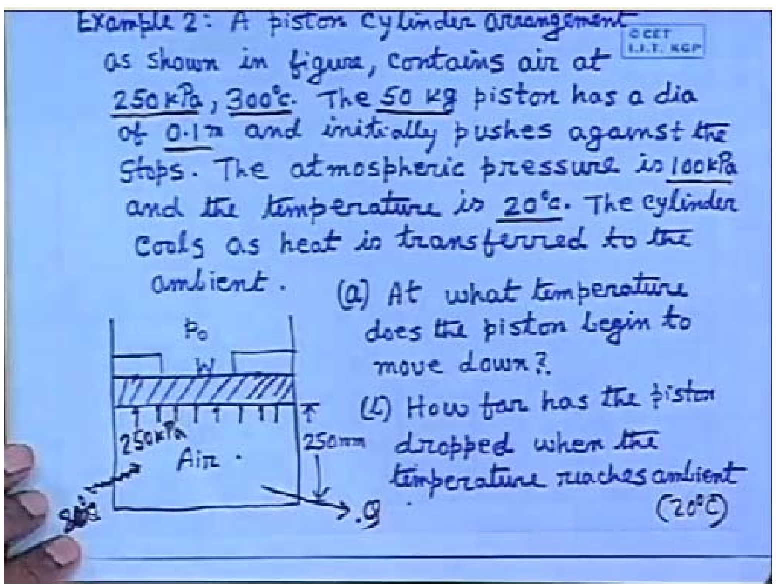

Why the pressure will remain constant? Can you tell me those who have told that pressure will remain constant that will come from the physical concept?

[Conversation between Student and Professor – Not audible ((00:26:22 min))]

Atmospheric, but inside pressure of the gas, why it will be constant?

[Conversation between Student and Professor – Not audible ((00:26:28 min))]

Because always we will consider that the piston descends in an equilibrium condition, where we will neglect the inertia of the piston in a sense that is the acceleration will be neglected. It is slowly moving. If it moves with a uniform velocity there also there is an equilibrium of forces, but in this case of thermodynamics all such problems of this sort will always be considered when the piston descends down or goes up it is always in equilibrium; the total force acting on both the sides of the pistons are equal. We neglect the acceleration of the piston. If we make so then atmospheric pressure is constant, then the weight of the piston is constant; that means, gas pressure has to be same. It is a displacement work at constant pressure, but we do not have to use the pdV formula; only thing is that we have to use that now V by t. So, we have to find out the volume.

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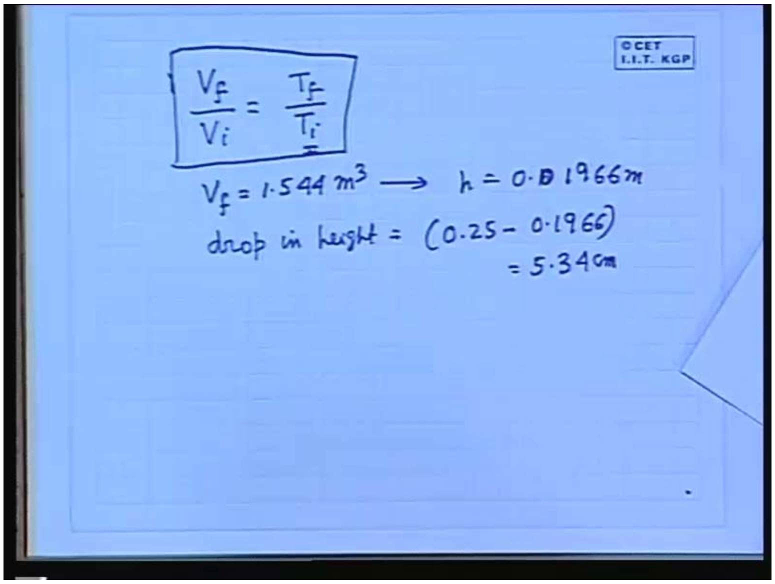

Let this volume is V_f by V_i is equal to T_f by T_i. So you find out V and what we will get, but we have to find out what?

[Conversation between Student and Professor – Not audible ((00:27:54 min))]

What is the value of V? Just a moment.

[Conversation between Student and Professor – Not audible ((00:28:03 min))]

You know V_i; V_i is not known.

[Conversation between Student and Professor – Not audible ((00:28:16 min))]

Initial V_i is not known. Just a minute.

[Conversation between Student and Professor – Not audible ((00:28:29 min))]

So initial V_i is known; therefore, we can find out the V_f. The value of $V_{f,}$ is 1.544 meter cube, which gives h as 0.01966. How do you get it? So, the drop in height will be 0.25 minus 0.1966 that is 5.34 centimeter. So, this temperature is which temperature (Refer Slide Time; 29:28 min)? T_i is the temperature at which it starts falling. So we know this temperature, we know the final temperature, it is told in the problem that it will reach ambient temperature, we can very well use this, pressure remaining constant. This is another type of problem. There are few more complicated problems, which I will be solving in tutorial classes. I do not know how much I can do for these sessions, these audiovisual classes.

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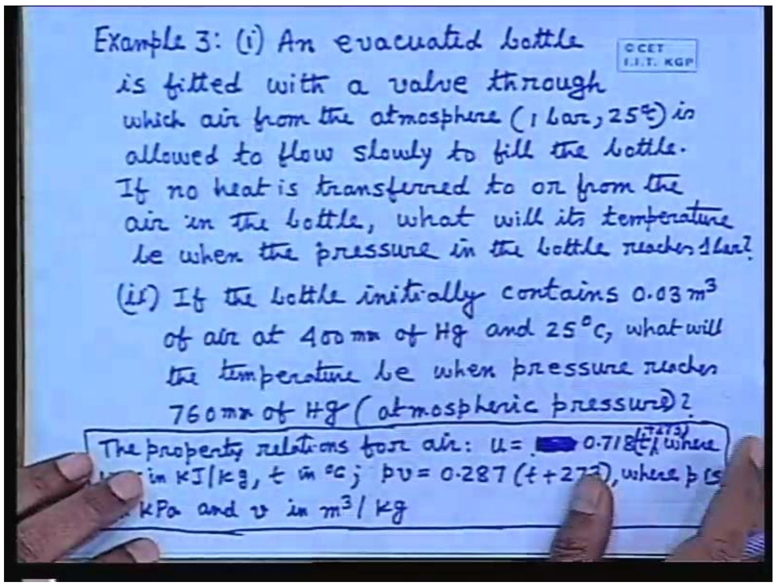

Now, I come to another interesting problem. This is a very standard problem for an open system on control volume. First law for an open system on control volume is known as problem of charging of a bottle. How it is done? First of all, you see that problem. Before going through this problem, I should better discuss.

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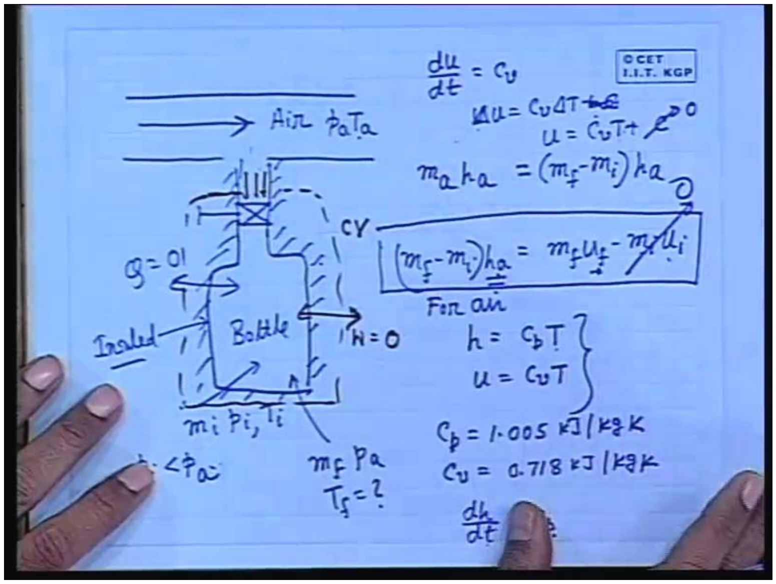

Let us consider a bottle here. This is a typical problem of charging a bottle which is being charged. Let us consider there is a valve, which is being connected to a pipeline which contains air. This is the practical problem; there is a main pipeline through which air flows at a constant p_a and T_a, and these are pressure and the temperature of the air which is flowing. There is a valve and there is a bottle which contains initially a mass m_i and its pressure is p_i, its temperature is T_i. If p_i is less than p_a then what will happen? If I open this valve, then air will gradually flow in this bottle. Let us consider the entire thing is adiabatic; that means, insulated or no heat transfer. In thermodynamic sense, the heat transfer is 0 in either direction. Now what will happen practically? The air will continue to flow or to charge the bottle.

When the mass of air will increase in this bottle of fixed volume, what will happen? The pressure and temperature both will increase. This process will automatically stop, naturally stop. This is not a continuous process; so, it will be automatically stopped when the pressure inside the bottle will reach the value of p_a; no flow will take place in that pressure equalization case; the process will naturally stop. Parameter of interest to be known is the temperature. At that condition, what will be the temperature in the bottle, if we do not allow any heat to come out or go in. Because pressure will be equal to p_a, that means what will be the final temperature of the bottle when the process naturally stops. How to solve this problem?

This is a problem of application of first law to a control volume and unsteady state. How you would do the problem? You take this (Refer Slide Time: 33:05 min) bottle as a control volume.

There is an inflow to the control volume but outflow is 0 and you write for a finite time, not in the rate form, the equation which I develop in the rate form, if we integrate that we will get in the finite form. The work transfer is also 0; here there is no work interaction.

Let us consider at the end of this process the mass in the bottle is m_f, pressure is automatically p_a, and T_f is to be found out. Now what is the energy influx to this control volume during the entire process is the mass of the air which has come. Let this is m_a times the specific enthalpy of the air associated with this pressure and temperature and this $m_a h_a$ is equal to m_f minus m_i into h_a. I am not writing everything like that. This is the influx of energy to the control volume. It is a very simple problem m_f minus m_i into h_a will be equal to the change in the internal energy of the control volume that is $m_f u_f$ minus $m_i u_i$. Now you can ask me: sir, you are telling the most practical problem is that engineers are interested to know what is the temperature? But this equation, where it is temperature from the property relations, we will know how h relates with the temperature for air and how u relates with the temperature for air. From this equation we can find out what is u_f knowing m_i, u_i and h_a. So, we can find out u_f and from u_f we can find out the temperature. In this connection, I like to tell you that for air if it is not otherwise given.

You will always assume h is equal to c_p into T and u is equal to c_v into T for air, where the values of c_p is 1.005 kiloJoule per kgK if it is not otherwise given. If the properties relationships are given, you do not use that, we use the property relationship. C_v is equal to 0.718 these are the values of c_p c_v. This comes from the fact that for any ideal gas, internal energy is a function of temperature; enthalpy is a function of temperature; that means, they are function of temperatures only not of any other property. That means, one can write if you follow the definition that du by dt, because u is a function of temperature there is no question of writing delta u divided by delta t is equal to c_v. So you integrate it, you get delta u is c_v delta T plus constant. If you make it delta u is delta T, but if you just integrate to give u is $c_v T$ plus C constant. So if you make the assumption that at T is equal to 0 internal energy is 0 that is C is 0. In the similar way, we can write using this equation, dh by dt for ideal gas is c_p. I am not writing delta h divided by delta t at constant pressure, because h is not a function of pressure it is only the temperature.

Therefore, I can write dh by dt and it becomes c_p this will be taught afterwards for an ideal gas. If we integrate it, we get delta h is c_p delta t or h is simply c_p into t at T is equal to 0, we consider the h is also equal to 0, so that h is $c_p T$ and u is cvT. If these property relationships are known, I can utilize this formula to find out the temperature. In case of an evacuated bottle if the bottle contains 0 mass at 0 pressure; so, this will be 0.

So the application of this equation is there in this problem three.

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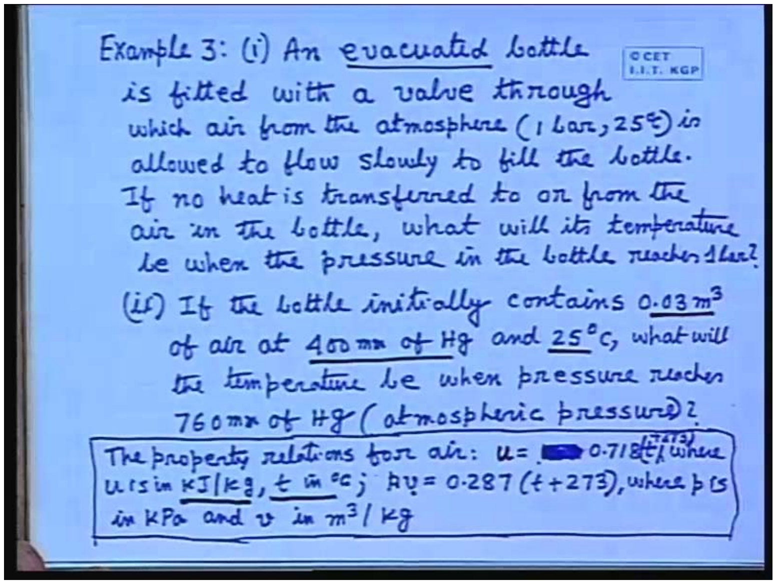

Now you read this problem (Refer Slide Time: 38:02 min) which appears to be very simple. An evacuated bottle is fitted with a valve through which air from the atmosphere, that means the condition of the flowing air at 1 bar. What is bar? Bar is 100000 Newton per meter square at 25 degree Celsius and this is precised at the the atmospheric pressure and temperture. Atmospheric pressure is little more 1.01 bar, however is allowed to flow slowly to fill the bottle.

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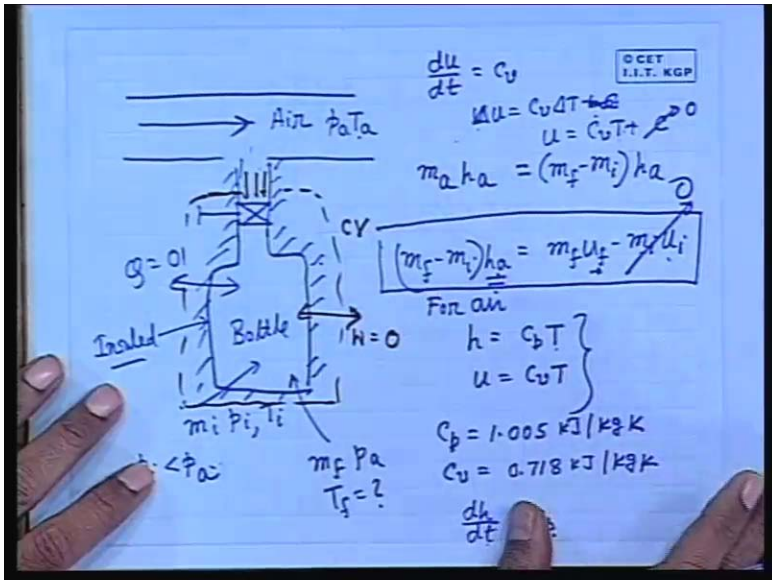

Now here question comes: sir, why you have neglected kinetic enegry associated with this? (Refer Slide Time: 38:39 min) We go slowly, here also I have use that slowly filling up. That means the velocity is neglected, velocity is so small that the kinetic energy part is much small compare to this enthalpy part. So that I am only using the enthalpy part as the total energy; kinetic energy is neglected.

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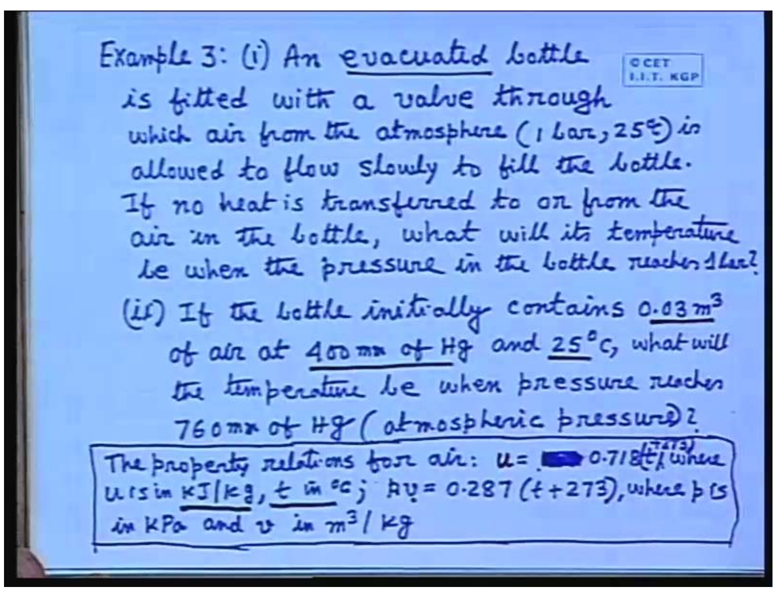

Air from the atmosphere is allowed to flow slowly to fill the bottle. If no heat is transferred to or from the air in the bottle that means bottle is totally insulated. What will its temperature be when the pressure in the bottle reaches 1 bar? The pressure will be same as that one that is the process will be automatically stop. If the bottle initially contains 0.03 meter cube of air at 400 millimeter f Hg and 25 degree Celsius where first bottle is evacuated. Here you see the property relationship is like this; this is the value of c_v what we have told T plus 273. So when this relationship is given one student may not know what is ideal gas? What is c_p? What is c_v?

In ideal gas what is the value of c_p? How it does it relate? He will use this simply as a mathematical formula. That u is equal to 0.718 into t plus 273 and he will leave simply this as a mathematical formula as far as the property relationship is concerned. That pv is equal to 0.287, t is equal to 273, where u is in kiloJoule per kg it is given. These types of equation where these numerical constants are there are always specified like that. If you substitute this variable, that is independent variable, in this unit we get the dependent variable in this unit. So this type of equation are always specified; otherwise there is no meaning to these equations. So pv is this, where p is in kilo Pascals and v is in meter cube per kg and t is in degree Celsius. If you add these two we get the h, h is u plus pv that is h is equal to 1.005 into t plus 273.

[Conversation between Student and Professor – Not audible ((00:41:02 min))]

Please write it. So, how to solve this problem? Just we apply this equation. What is the equation? That t is equal to 144. Do you have written it? This equation (Refer Slide Time: 41:24 min). Now we will be solving; that means, I write this equation.

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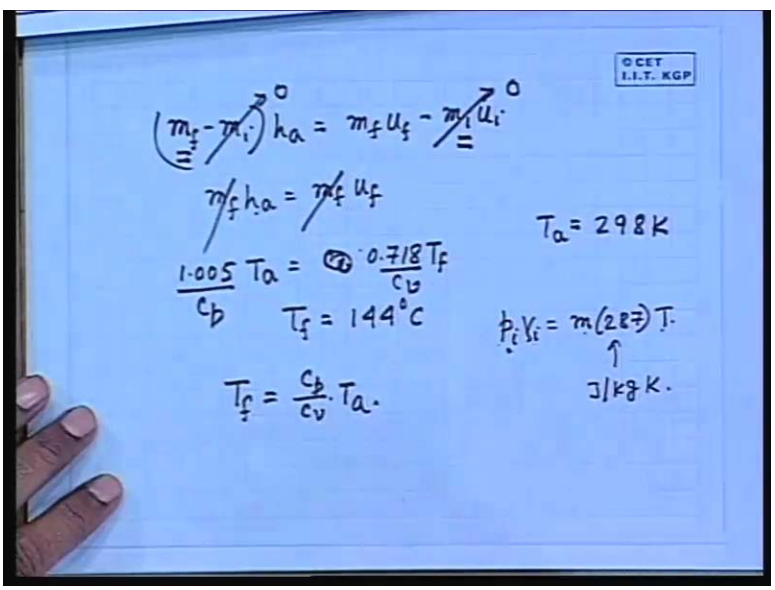

m_f minus m_i into h_a is equal to m_f u_f minus m_i u_i; very interesting result will come out; that is, now h_a is equal to u_f. Therefore, h_a is 1.005 as far as the property relationship are given. Therefore we get $1.005T_a$ is equal to $0.718T_f$. T_a is equal to what?

[Conversation between Student and Professor – Not audible ((00:42:29 min))]

The air temperature is 25 degree Celsius - 298k. With this I get T_f is 144 degree Celsius. It is very interesting thing that we know this for air, for any ideal gas, h is c_p that means 1.005 is c_p and 0.718 is c_v. That means the final temperature, if the bottle is evacuated will be the ratio of specific heat times the temperature of the air which is greater than 1; the air temperature will be multiplied by the ratio of the specific heat, for air we know this is 1.41. So, if the ambient temperature is 25 degree Celsius, the inside temperature will be 1.41 into 298. So, it is the ratio or specific heat which will be multiplied with the air temperature to get the final temperature of the evacuated is the thermal rule, but it is true. When we deal with an ideal gas and the bottle is evacuated, but if the bottle is not evacuated, then we will have to take care of m_i and we will have to find out the m_f also. Then you can find out the value of u.

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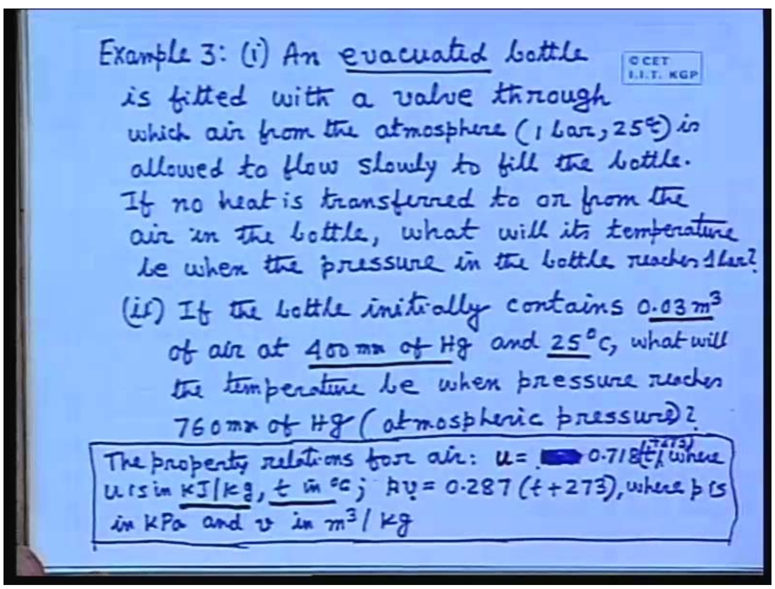

In the second case, the bottle initially contains 0.3 meter cube. This will give the value of m_i because initial pressure is given, initial temperature is given. How can you find out m_i?

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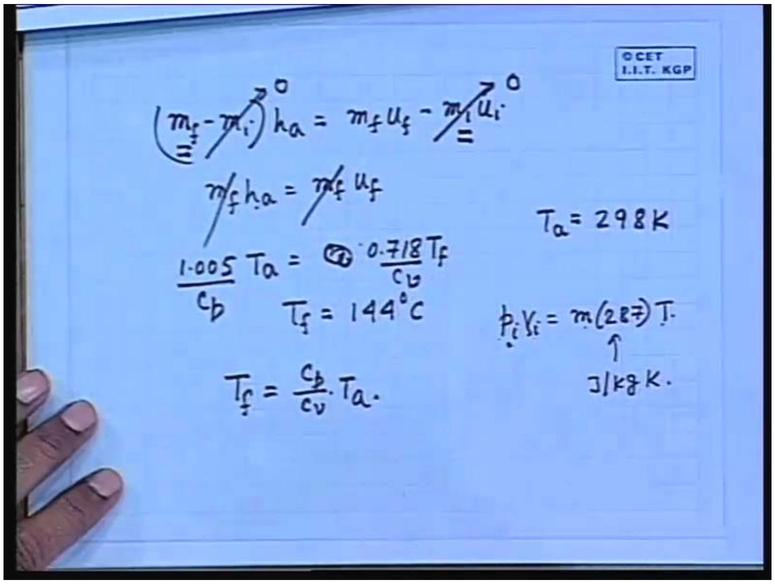

Because we know p_v is equal to mRT I have already told, so p_iv_i is equal to m into 287 into T. This is Joule per kg. So that these things are to be in consistent unit Newton per meter square meter cube per kg and Kelvin and m is in kg. This is meter cube not meter cube per kg; this is meter cube this is kg. Now from this, we can find out the value of m_i and we can apply these equations to find out the T_f. This I am giving you as an exercise with the answer for T_f. What is the answer for T_f? In that case, what is the problem? I will give you the answer for this, just wait for sometime. Let me see the answer for it, whether I do have or not, just wait.

This is exercise for you; so, I must give you the answer for it. Well, just wait. Okay, you do it. I will tell you the answer in the next class. This is your home exercise. I have misplaced the answer somewhere; so, I will tell you the answer in the next class.

[Conversation between Student and Professor – Not audible ((00:45:42 min))]

Which one? Yes, the volume will remain constant.

Volume will remain constant. The simple algebraic manipulations then I will come to problem number four. Time is up? What is the time?

[Conversation between Student and Professor – Not audible ((00:46:04 min))] okay

Do you have a class now?

[Conversation between Student and Professor – Not audible ((00:46:08 min))]

Lunch. Just wait because they have some time for them. So, wait.

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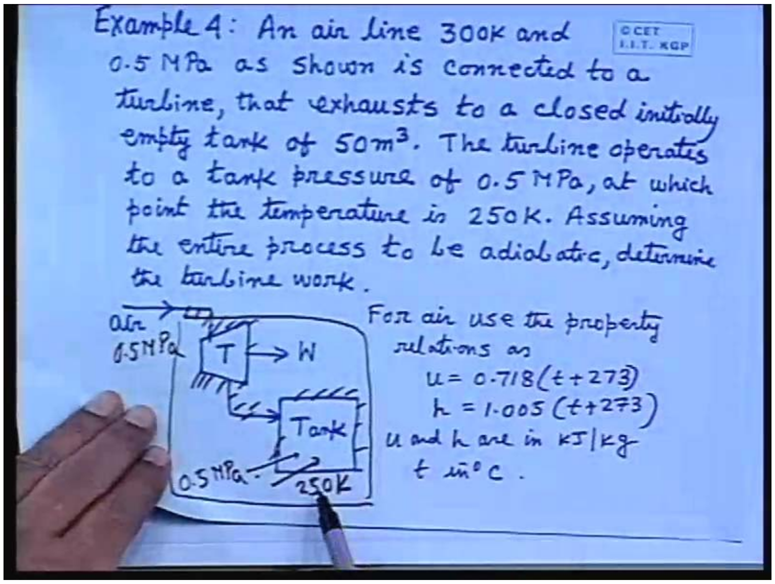

Problem four: an air line at 300 k and 0.5 MegaPascals as shown is connected to a turbine. This is the airline, this is connected to a turbine (Refer Slide Time: 46:32 min), that exhausts to a closed initially empty tank of 50 meter cube. Almost the similar problem, but we ask a different quantity. The turbine operates to a tank pressure of 0.5 MegaPascals. Now what happens this air line is at 0.5 MegaPascals, that means here the pressure is 0.5 MegaPascals and the turbine operates to a tank; the turbine operates till the tank pressure is 0.5 MegaPascals, at which point the temperature is 250 k; the temperature of the tank becomes 250 k that means, this is the point when the process terminates automatically the same thing. Assuming the entire process to be adiabatic, both the turbines and the tank along with the pipelines are adiabatic, determine the turbine work. We have to find out what is the turbine work? Tell me which one you will consider as a control volume place, any one of you?

[Conversation between Student and Professor – Not audible ((00:47:56 min))]

Only turbine.

[Conversation between Student and Professor – Not audible ((00:47:58 min))]

Turbine and tank together. We take turbine and tank together; what will be the equations? Then in that case also there is an inflow only. It is a definite process over a finite time.

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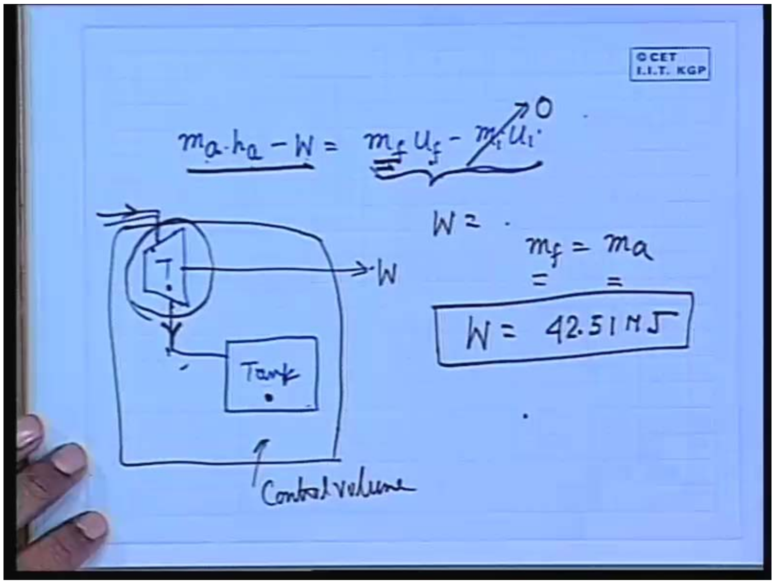

The mass of air which has come into the enthalpy of air, that is the mass coming in, energy coming in minus the work done W control volume will be equal to m_f u_f minus $m_i u_i$ because this is nothing but the change in internal energy of the control volume. If we look back to our steady flow energy equations integrate it with respect to dt. Then we get these values that finite quantity of mass times the specific stored energy. Finite quantity of work, finite quantity of heat and the change in the internal energy. That means, it is written over a finite time period for definite quantity of matter for a given process. Not in the rate basis.

Therefore here also (Refer Slide Time: 49:23 min) you can write this that means, if I again draw the picture this is the turbine, this is the tank. I am considering this as the control volume. Now here one point is very important, now this is the energy entering to control volume there is no exit to the control volume (Refer Slide Time: 49:50 min). This is the work done by the control volume that means, this is this minus this must be equal to the increase in internal energy of the control volume, but turbine part of the control volume does not undergo any change in the internal energy because it is a steady state device. So, within the turbine things are steady the mass which is coming in is going out that means energy which is coming in equal to going out in the form of work and in the form of energy going to with this mass which is coming to this tank.

Therefore, as far as turbine part is considered, there is no change in the internal energy. Internal energy is changing only in the tank part which is in unsteady mode. Therefore, if we consider this as a control volume, the change in the internal energy is contributed only by the tank. This is the only key point of this problem; so that you can write this any query; you can ask me which will give the W. Now what is the value in this case? This is an evacuated bottle or the tank is empty. Therefore this is 0 (Refer Slide Time: 51:05 min), you can find out m_f and this m_f is equal to m_a, because there was no mass. So final mass is the mass which has come during that interval of time through the control volume; that means, the entire control volume system. So, m_f is equal to m_a. You can find out m_a,; here m_a does not cancel out because work is there. Otherwise, we have to find out the work per unit mass that is all right, but here m_a we can find out because the final temperature and pressure of the tank is given and volume of the tank is also given or not 50 meter cube. We can find out the mass by the same formula; for the air pv is equal to m into RT. You know the mass; you know the internal energy at the final point, because final temperature is given. When the mass pressure reaches 0.5 megaPascal, temperature is 250 k. We utilize this equation; so if we know uf and h_a we can find out by using this equation where t plus 273 this is given 300 k that means t plus 273 is already given in that form 300 k. We can find out the value of this. Finally work comes out to be 42.51 MegaJoule. You do it and you will see this is the final work done by the turbine that is 42.51 MegaJoule.

These are the four problems, where you can have an idea how this concepts of first law applied to closed system and open systems are utilized. Well, any query? This is the lunch time so, I think there will be no query. Problems are simple. Okay then, thank you.

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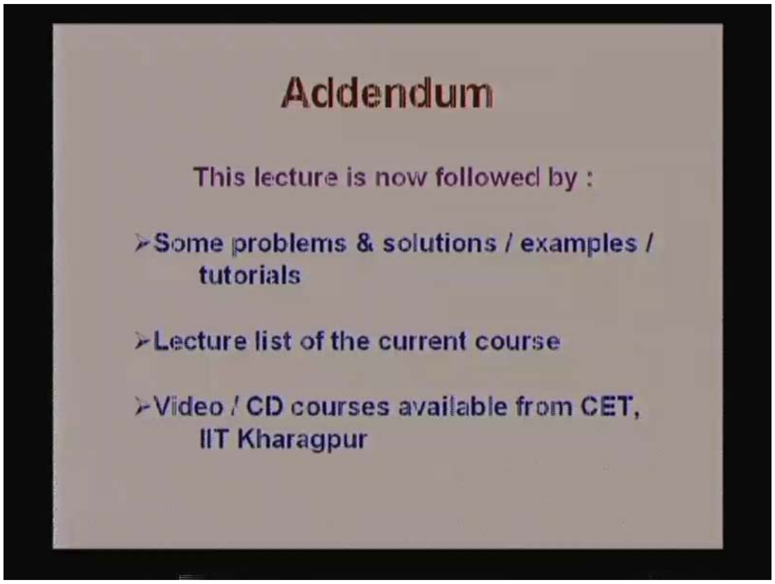

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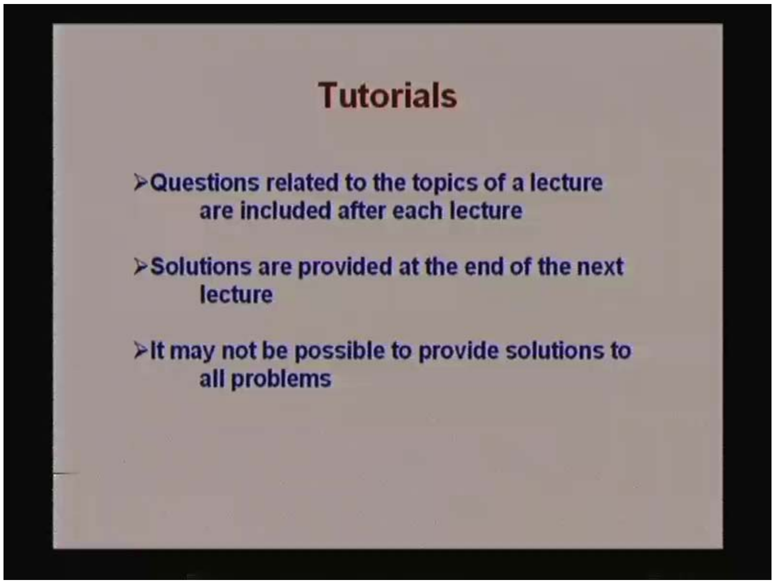

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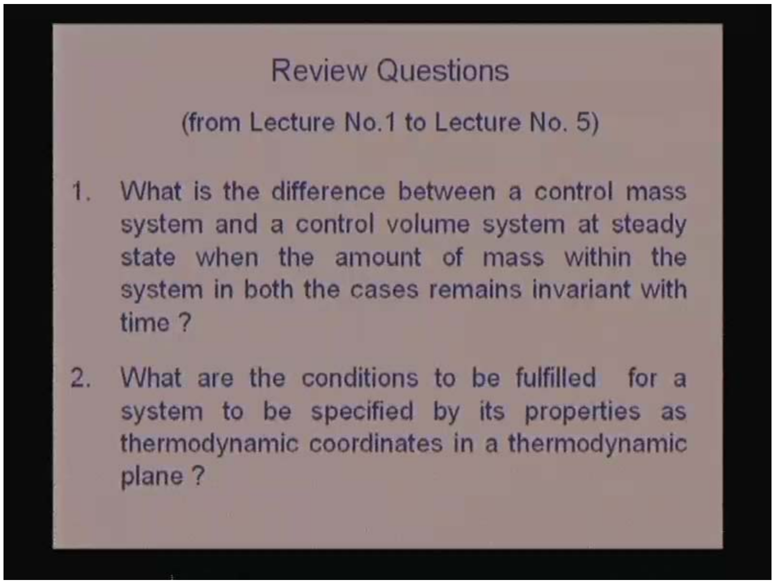

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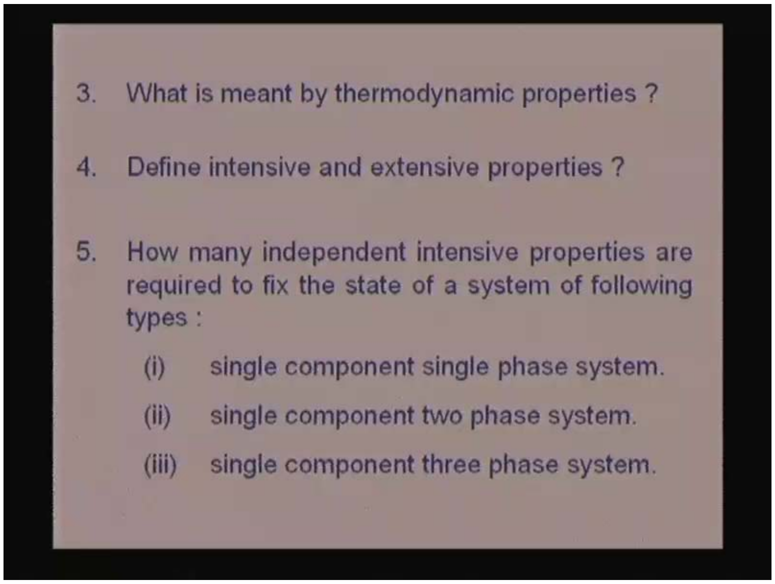

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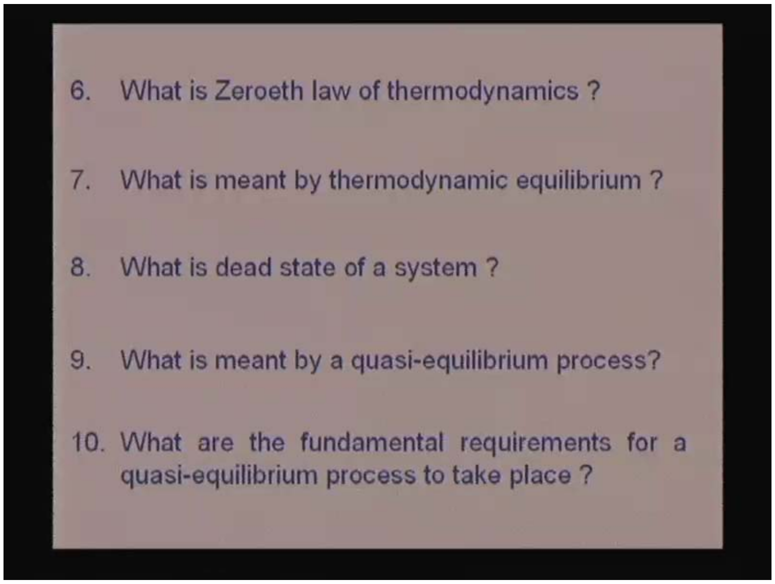

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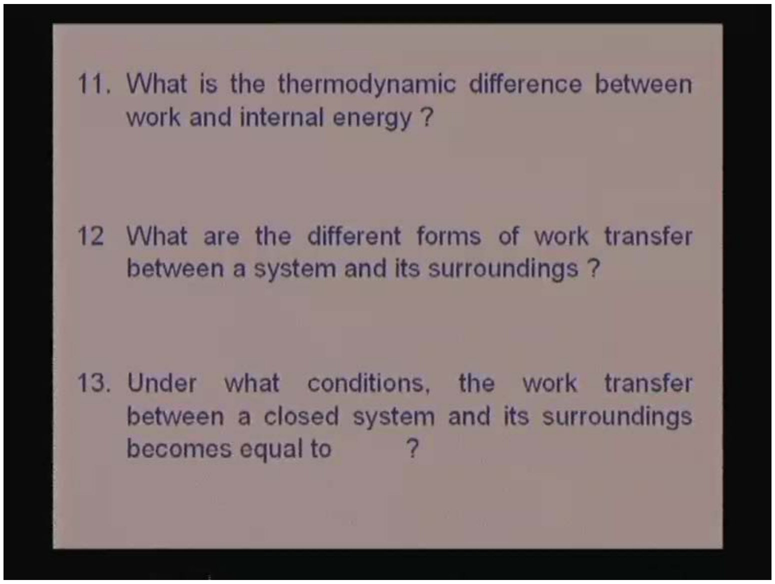

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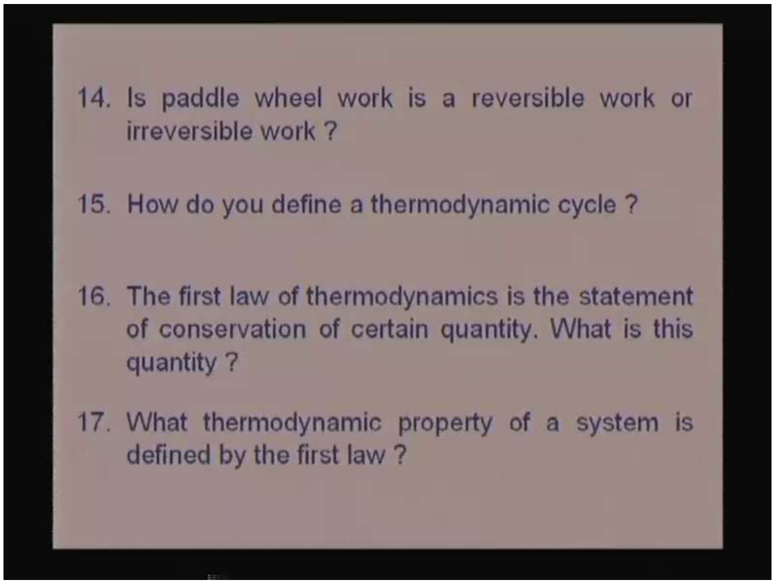

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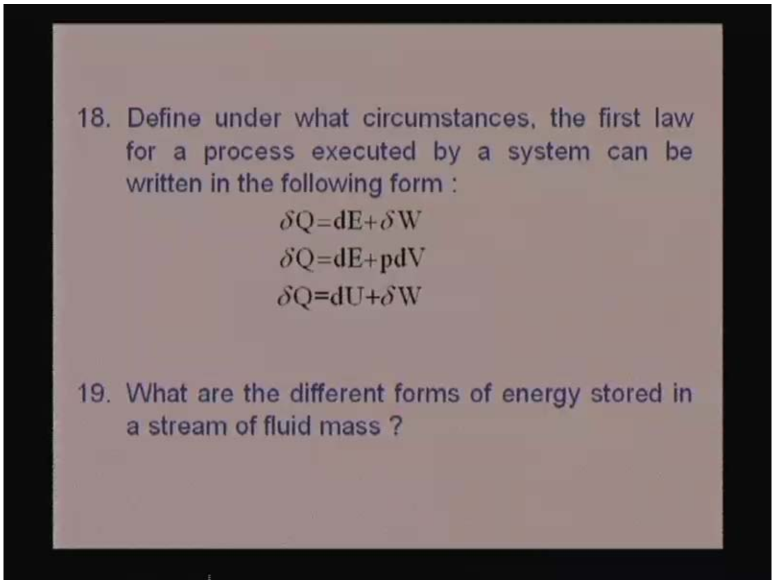

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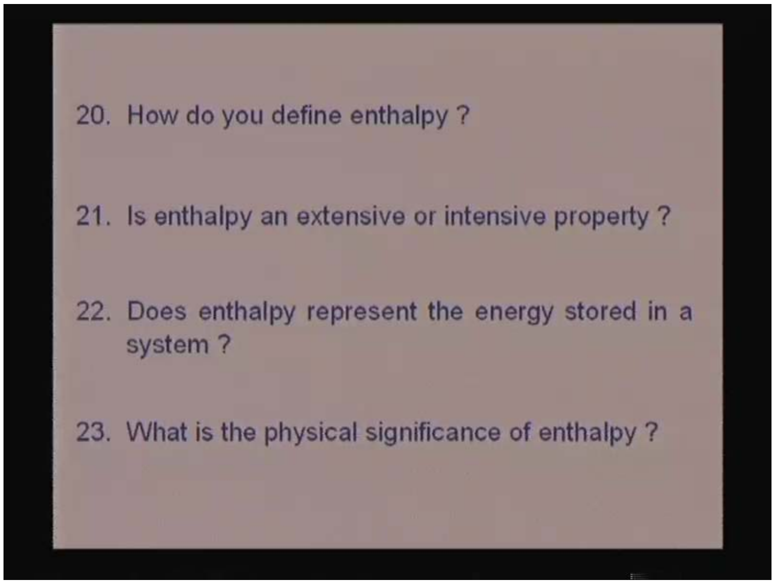

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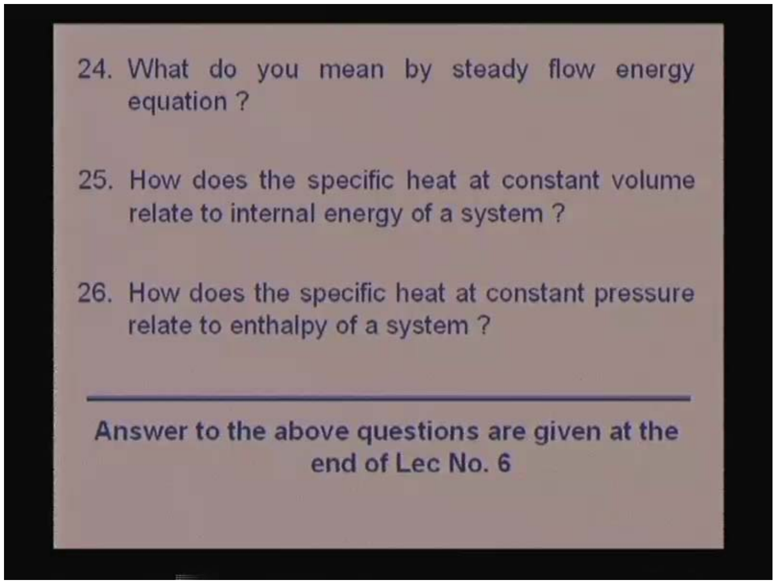

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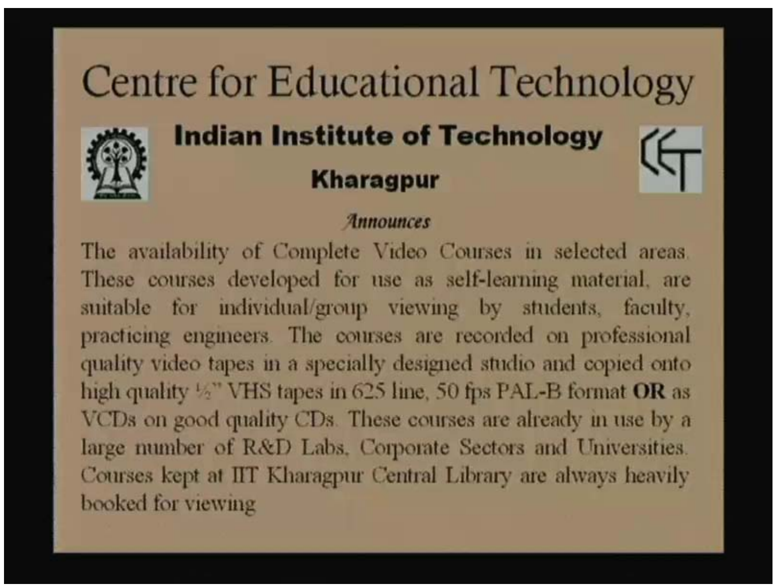

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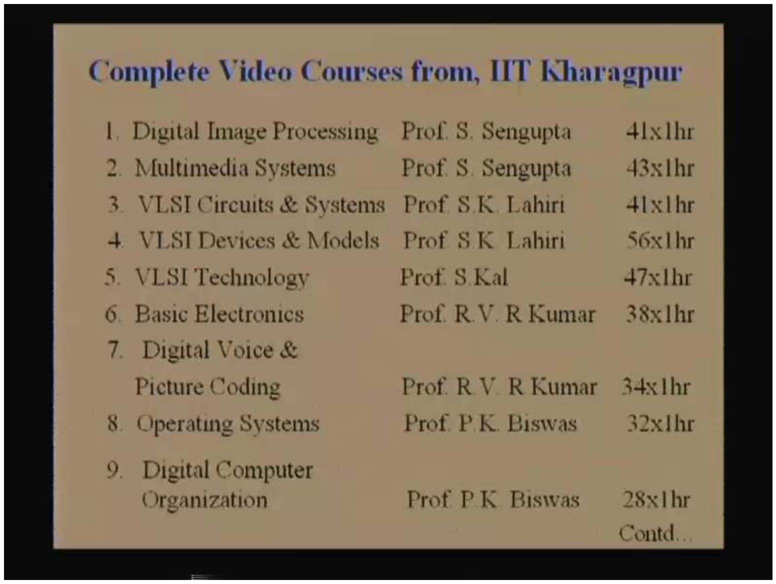

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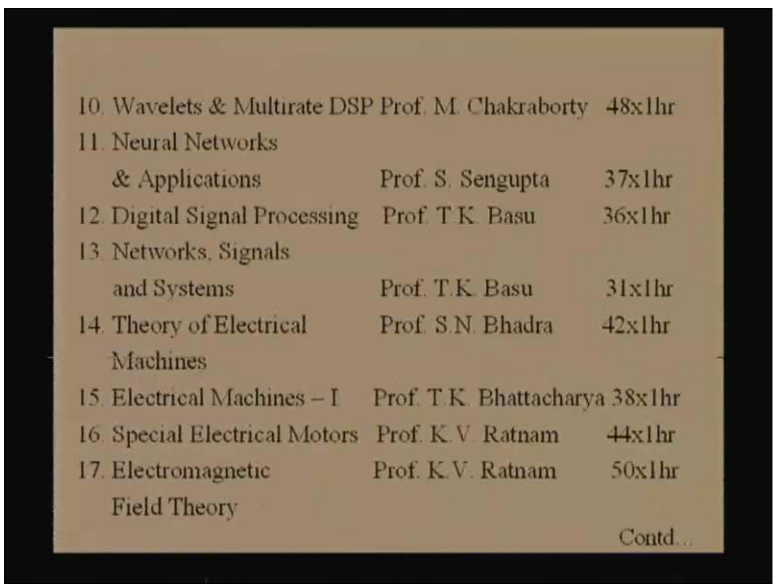

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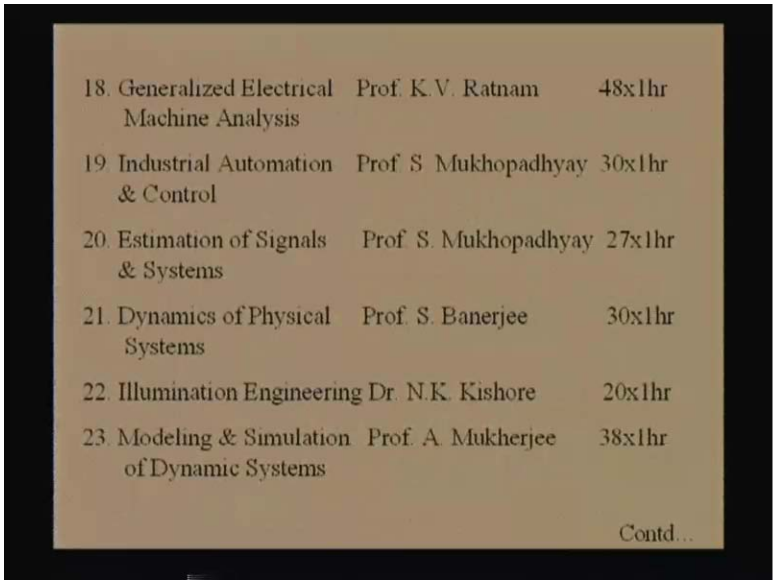

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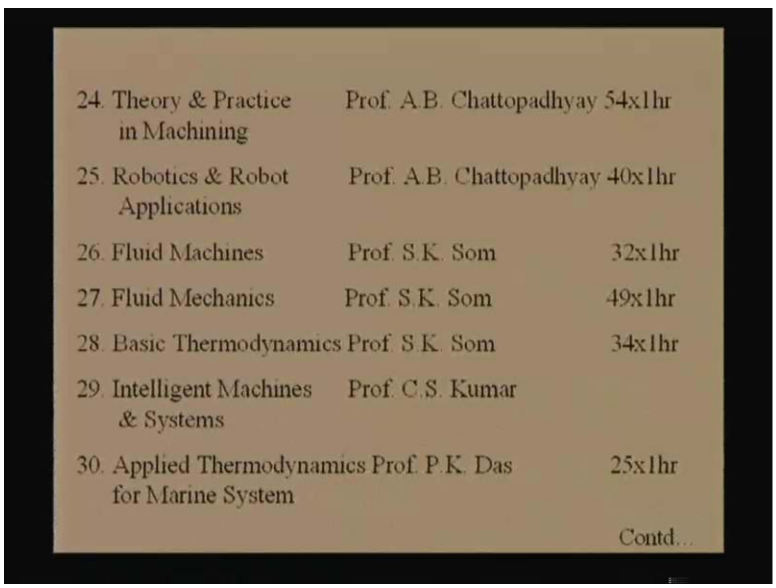

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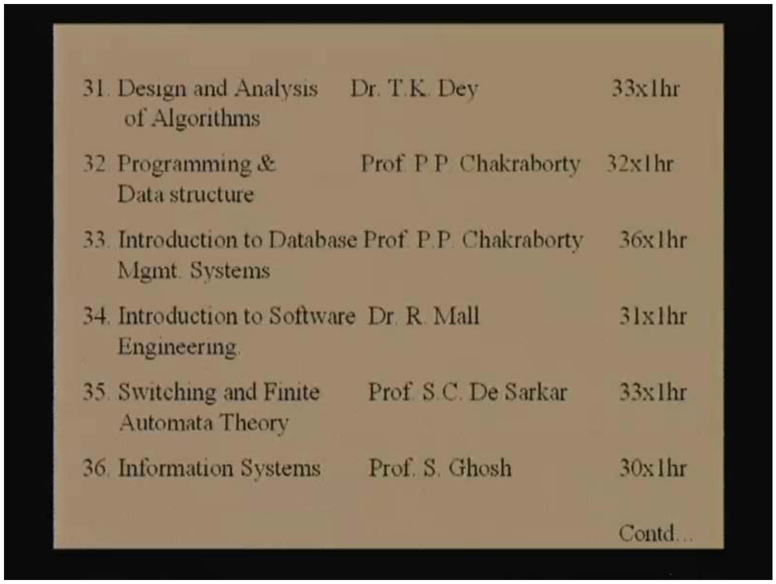

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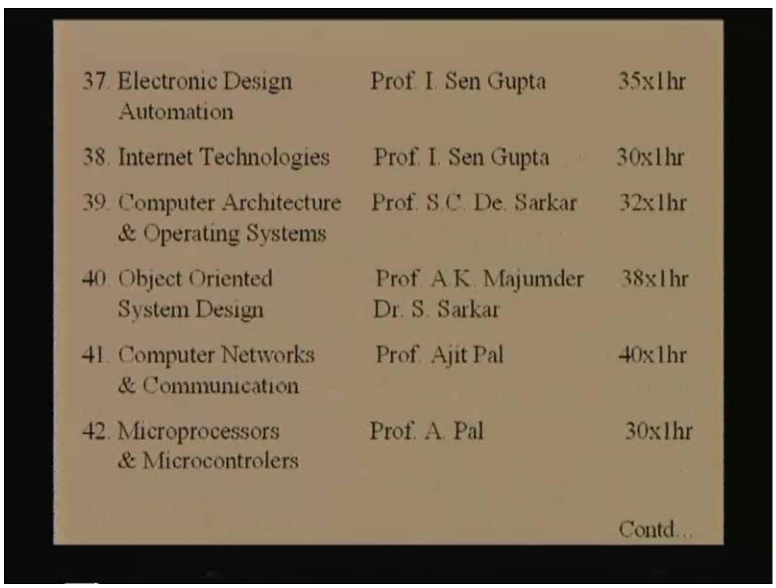

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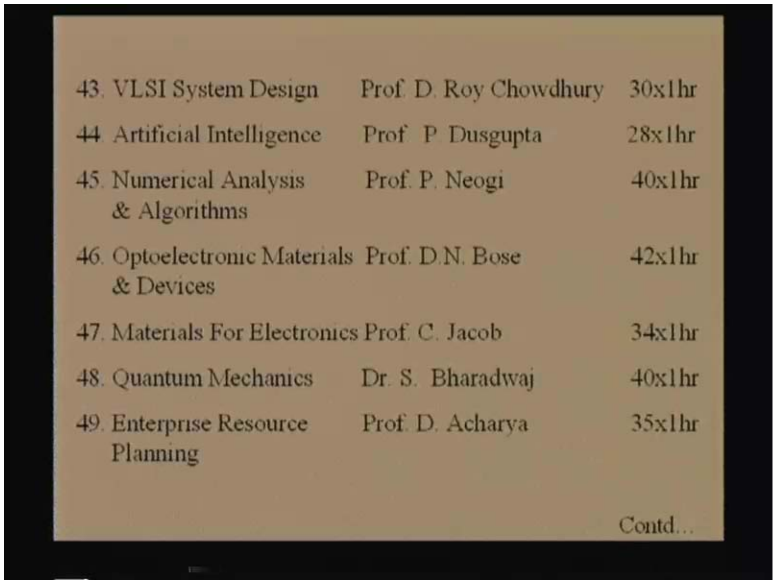

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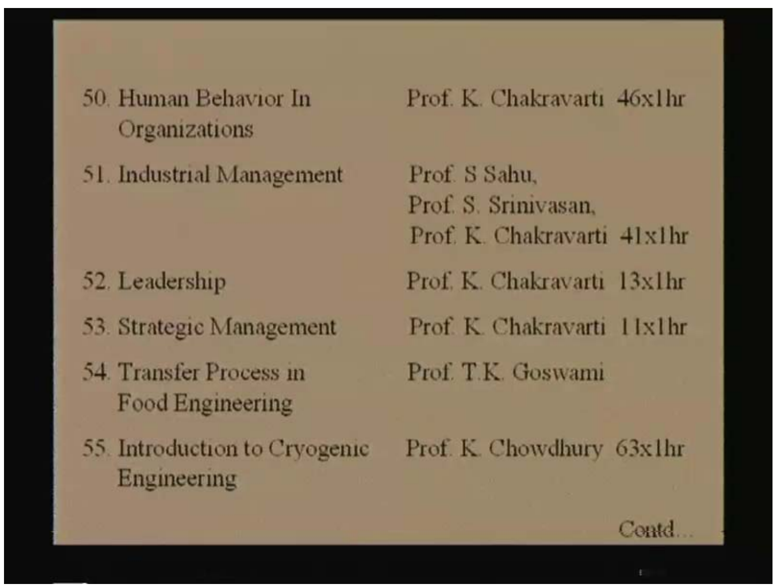

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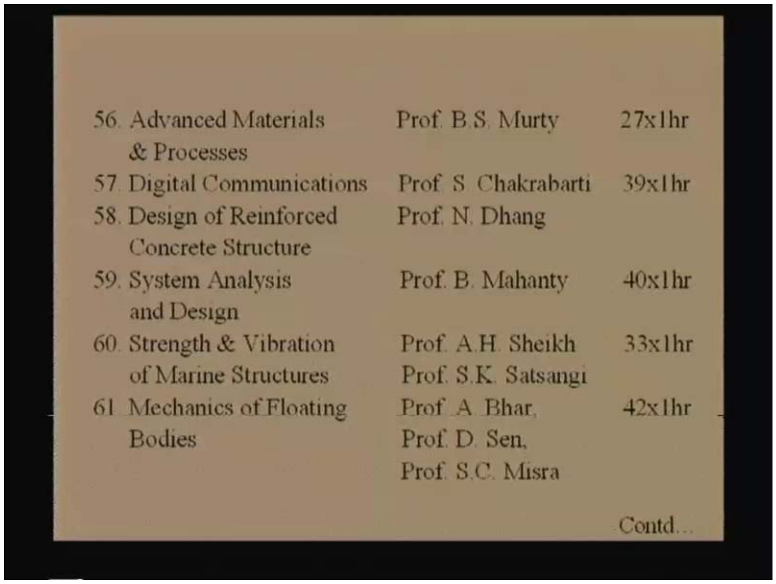

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