Engineering Thermodynamics
Professor Jayant K Singh
Department of Chemical Engineering
Indian Institute of Technology Kanpur
Lecture 07
Efficiency of mechanical and electrical devices

In the last class we were working on some part of energy and energy transfer is started with the first law of thermodynamics.

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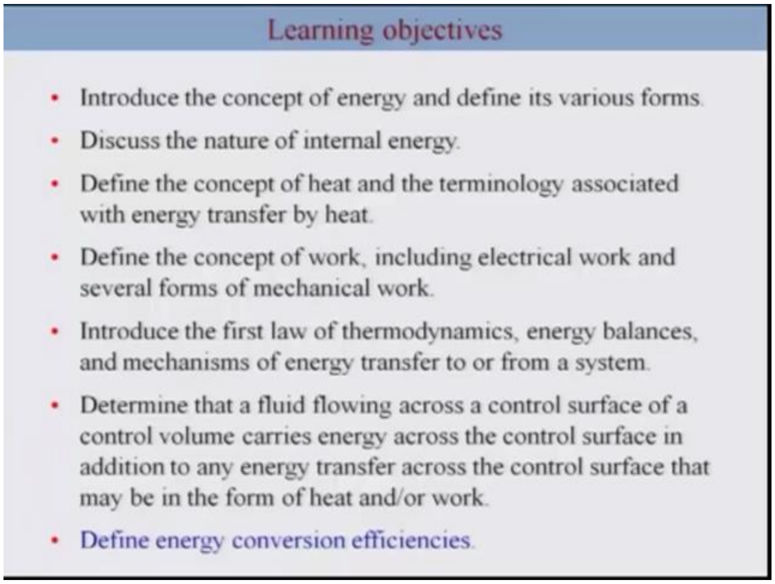

Learning objectives

- Introduce the concept of energy and define its various forms.
- Discuss the nature of internal energy.
- Define the concept of heat and the terminology associated with energy transfer by heat.
- Define the concept of work, including electrical work and several forms of mechanical work.
- Introduce the first law of thermodynamics, energy balances, and mechanisms of energy transfer to or from a system.
- Determine that a fluid flowing across a control surface of a control volume carries energy across the control surface in addition to any energy transfer across the control surface that may be in the form of heat and/or work.
- Define energy conversion efficiencies.

Now we will continue with the discussion and in this lecture we are going to talk the energy conversion efficiency. Now this is something quite relevant for a daily life when we look at any devices whether it is a refrigerator, whether is oven okay, whether it you buying a bike or car, you look at efficiency like how efficient the device is or the machine is.

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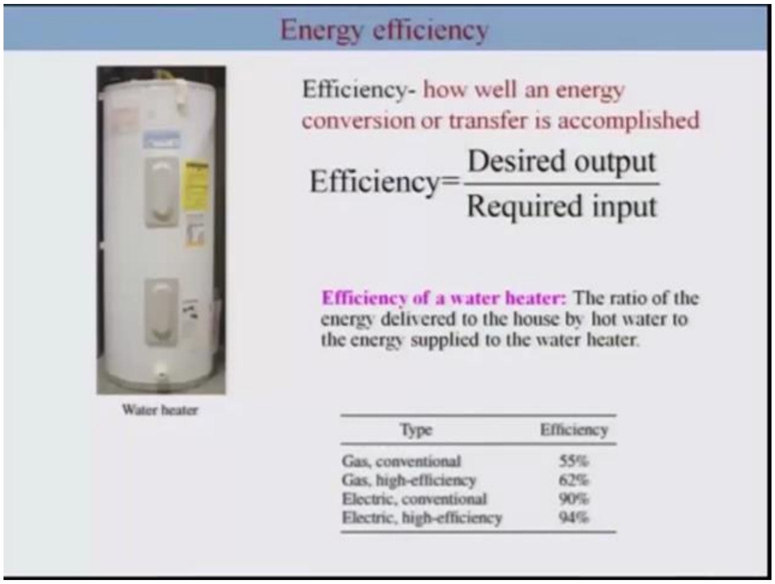

Energy efficiency

Water heater

Efficiency- how well an energy conversion or transfer is accomplished

$$\text{Efficiency} = \frac{\text{Desired output}}{\text{Required input}}$$

Efficiency of a water heater: The ratio of the energy delivered to the house by hot water to the energy supplied to the water heater.

Type	Efficiency
Gas, conventional	55%
Gas, high-efficiency	62%
Electric, conventional	90%
Electric, high-efficiency	94%

And the one the daily usage at our home is water heater. So, we will go through different expect of this different devices and is there efficiency. So, let us first define what is efficiency and this is a generate term, it is not a term relevant only to engineering but our other on daily life activities. So, efficiency is nothing but the ratio of the desired output and required input. Now this desired output and required input would be different for different contexts, in case of thermodynamics is always related to some form of energy.

So, let us take the different kind of water heater now what you have typically in at home, the efficiency is defined as the ratio of the energy delivered to the house by hot water to the energy supply to the water heater. So, whatever the water being heated up and how much energy it contains what use it that divided by the energy supplied to the water heater. So, is a simple ratio, the issue is that how do you compare with other system, so because it is not always the electrical based heater.

It could be gas based heater, it could be some other form of heater and the efficiency vary, so how do you really compare. So this efficiency for example gas is quite lower compare to the conventional electric pressure is very high, okay. The loss is quite limited and you know, when you go to the market and you talk about it and you always get confused. Because this some guys we will says very high efficiency. You do not what they are using it, if you aware of it then you can quantify and you can calculate its cost and cost does vary a lot okay.

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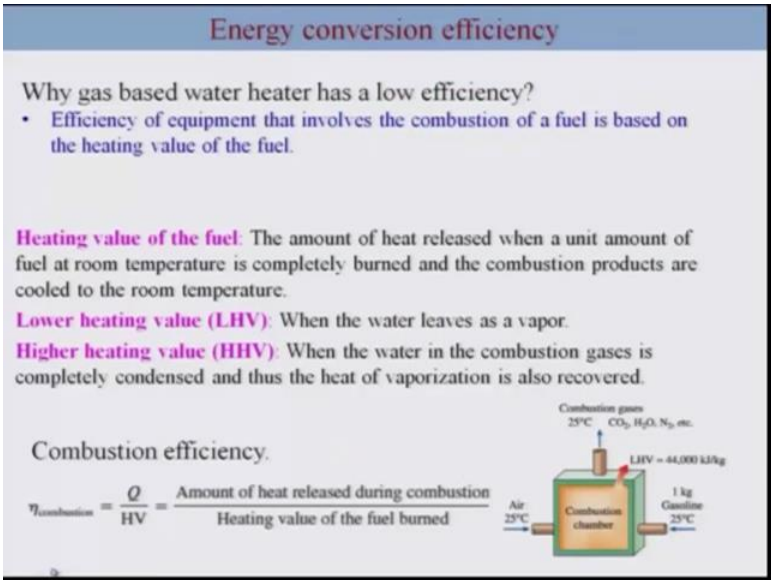

Energy conversion efficiency

Why gas based water heater has a low efficiency?

- Efficiency of equipment that involves the combustion of a fuel is based on the heating value of the fuel.

Heating value of the fuel: The amount of heat released when a unit amount of fuel at room temperature is completely burned and the combustion products are cooled to the room temperature.

Lower heating value (LHV): When the water leaves as a vapor.

Higher heating value (HHV): When the water in the combustion gases is completely condensed and thus the heat of vaporization is also recovered.

Combustion efficiency.

$$\eta_{\text{combustion}} = \frac{Q}{\text{HV}} = \frac{\text{Amount of heat released during combustion}}{\text{Heating value of the fuel burned}}$$

So, let us look at why the gas based water heater has a low efficiency okay, the reason being that this efficiency is being calculated based on the combustion of fuel, okay. And that is related to heating value of the fuel. So, what is a heating value of the fuel is the amount of heat released when a unit amount of fuel at room temperature is completely burned and the combustion products are cooled to the room temperature.

This is an example of a combustion chamber, you have an air which pass through let say Gasoline which is passed here, it burns and after the burning the gasses, the combustion gasses consists of CO2, S2O, N2 etc. H2O is in the vapor state and thus this is an example of low heating value. It says that when the water leaves as a vapor the energy associated of this combustion would be low heating value, the reason being water takes lot of energy out of heat. Now you are heating it water comes as a vapor, it contains lot of energy hence whatever is useful energy remains is going to be a low quality, okay.

But when you condense this water vapor and then you used this heat of vaporization as a part of your output desired output, then the corresponding heating value would be so higher heating value, okay. So, when the water in the combustion gas is completely condensed thus heat of vaporization is also recovered in such case high rating value, okay. So, the how we defined this combustion efficiency, amount of heat released during combustion dived by heat value of the fuel bud, so that is a ratio is the Q divided by H V.

So, this HV could be HHV Higher Heating Value or LHV depending on what is the state of the combustion gas.

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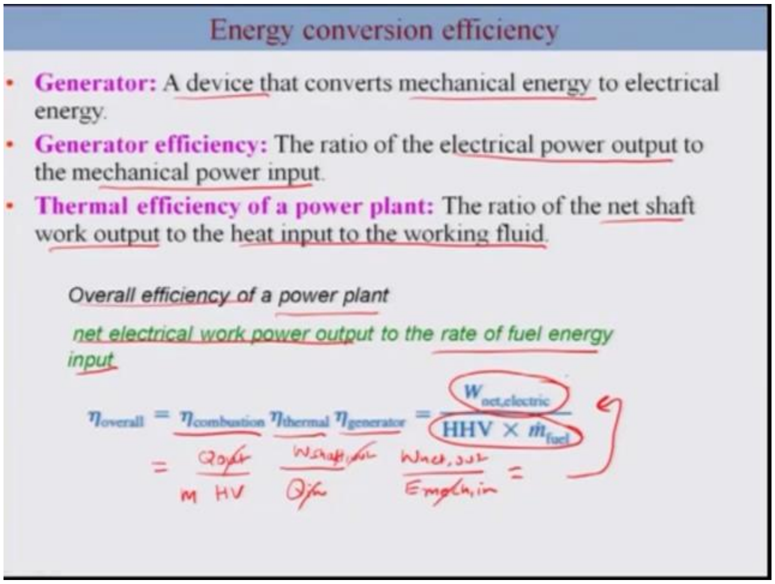

Energy conversion efficiency

- **Generator:** A device that converts mechanical energy to electrical energy.
- **Generator efficiency:** The ratio of the electrical power output to the mechanical power input.
- **Thermal efficiency of a power plant:** The ratio of the net shaft work output to the heat input to the working fluid.

Overall efficiency of a power plant

net electrical work power output to the rate of fuel energy input

$$\eta_{\text{overall}} = \eta_{\text{combustion}}\,\eta_{\text{thermal}}\,\eta_{\text{generator}} = \frac{W_{\text{net,electric}}}{\text{HHV} \times \dot{m}_{\text{fuel}}}$$

$$= \frac{Q_{out}}{m\ HV}\ \frac{W_{shaft,out}}{Q_{in}}\ \frac{W_{net,out}}{E_{mech,in}} =$$

So, let us further look into more efficiency what about generator . So, the generator is device that converts mechanical energy to electrical energy. It is gets a shaft work okay output from the turbine and converts that into electrical energy and how we are going to define the efficiency of a generator. It is a ratio of electrical power output to the mechanical power input and what about the thermal efficiency of a power plant.

So, it is a ratio of the net shaft work output to the heat input to the work working fluid. So, in a power plant it is like the thermal efficiency is related to the turbine, okay. Because you already heated the water, then the steam is given to the as a input to the turbine and turbine high pressure it expands, this steam goes to the law pressure. While doing this process it actually generates a work. So, what is the thermal efficiency of a power plant, it is a ration of the net shaft work output to the heat input to the to the working fluid

So, when you consider the power plant as a whole you have to take different components and is and their efficiency and you multiply them. So, the overall efficiency would be the net electrical power output because that is the desired output of the whole power plant to the rate of the fuel energy input, in this case you are going to burn the fuel, use that energy to heat up the water, convert to steam and steam is used to do the work through turbine.

So, this whole cycle you have to consider the combustion chamber, you have to consider the turbine, you have to the generator, all three of them. So, this this is going to be the overall efficiency Eta combustion, Eta thermal and efficiency of generator. You can make use of definition of each of them, for example here what is a compulsion, this would be Q out divided by the heating value. But now we are going to multiply I am also because heating value is typically per unit mass.

So, we are going to multiply by m, so that becomes the combustion efficiency. What about the thermal as I already mentioned, thermal is on the net shaft work output. So, that would be W shaft out divided by Q in, okay, Q in is basically same as Q out okay. And Eta generator would be net out which is electrical power output divided by the mech-in mechanical energy which we using here. So, this you can write all of them in the rate form converting into the power.

So, this effectively should give you this because this should cancel. If it is a perfect conversion and effectively you can write this that this is our that input. So, W net electric would be the desired output and this is desired input.

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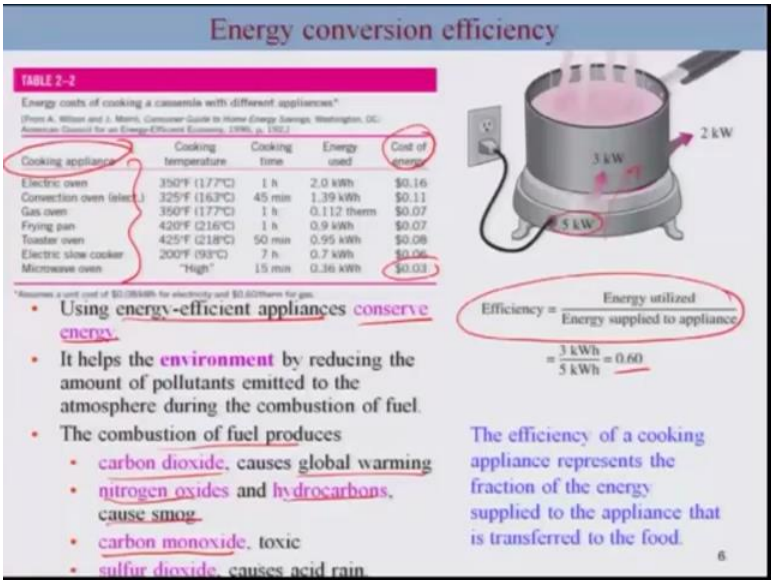

Energy conversion efficiency

TABLE 2–2

Energy costs of cooking a casserole with different appliances*

(From A. Wilson and J. Morril, Consumer Guide to Home Energy Savings, Washington, DC: American Council for an Energy-Efficient Economy, 1996, p. 192.)

Cooking appliance	Cooking temperature	Cooking time	Energy used	Cost of energy
Electric oven	350°F (177°C)	1 h	2.0 kWh	$0.16
Convection oven (elect.)	325°F (163°C)	45 min	1.39 kWh	$0.11
Gas oven	350°F (177°C)	1 h	0.112 therm	$0.07
Frying pan	420°F (216°C)	1 h	0.9 kWh	$0.07
Toaster oven	425°F (218°C)	50 min	0.95 kWh	$0.08
Electric slow cooker	200°F (93°C)	7 h	0.7 kWh	$0.06
Microwave oven	"High"	15 min	0.36 kWh	$0.03

*Assumes a unit cost of $0.084/kWh for electricity and $0.60/therm for gas.

- Using energy-efficient appliances conserve energy.
- It helps the environment by reducing the amount of pollutants emitted to the atmosphere during the combustion of fuel.
- The combustion of fuel produces
  - carbon dioxide, causes global warming
  - nitrogen oxides and hydrocarbons, cause smog
  - carbon monoxide, toxic
  - sulfur dioxide, causes acid rain.

$$\text{Efficiency} = \frac{\text{Energy utilized}}{\text{Energy supplied to appliance}}$$

$$= \frac{3\ \text{kWh}}{5\ \text{kWh}} = 0.60$$

The efficiency of a cooking appliance represents the fraction of the energy supplied to the appliance that is transferred to the food.

So, take an example of some common case appliance this is an example of simple appliance, so you are using this device okay which is using electrical power, cooking appliance here, which is simply utensil having some fluid.

So, it is 5 kilo what you have taken from the electrical point and it is only 3kilo what is being transferred. So, thus the efficiency of this particular appliance is 0.6 and similarly you can come up with a different kind of cooking appliances okay and which may be based on the electric, based on gas and based on other forms, and this is a summary of this appliances the cost of the energy used based on (())(8:18) states datas, and you can clearly see the some are extremely small compare to others. The cost being low does not mean it efficient, okay. And is also does not means it is you getting a good food, for example if you are related to the food I mean.

So, but otherwise it is important to be aware of the few energy efficient appliances, because at the end if you are using a high efficient appliance you are conserving the energy in some form. And if you can reduced the combustion of fuel by any mean is going to help the environment because the combustion of fuel produces various different gases such as carbon dioxide which causes global warming, nitrogen oxides and hydrocarbons which cause smog, carbon monoxide which is toxic and sulfur dioxide which cause acid rain. Thus if you are using energy efficient even if it little higher cause is good for the environment.

Now as an engineer you need to develop this kind of highest higher energy efficient devices. And that is of course the challenge okay, that’s also the challenge for power plants, for other many petroleum industry to increase the output, desired output with a lower possible input okay.

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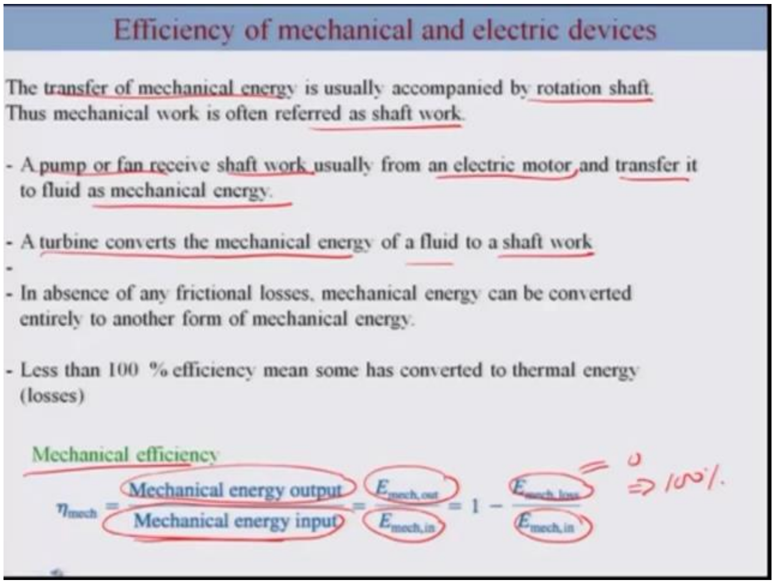

Efficiency of mechanical and electric devices

The transfer of mechanical energy is usually accompanied by rotation shaft. Thus mechanical work is often referred as shaft work.

- A pump or fan receive shaft work usually from an electric motor and transfer it to fluid as mechanical energy.
- A turbine converts the mechanical energy of a fluid to a shaft work
-
- In absence of any frictional losses, mechanical energy can be converted entirely to another form of mechanical energy.
- Less than 100 % efficiency mean some has converted to thermal energy (losses)

Mechanical efficiency

$$\eta_{mech} = \frac{\text{Mechanical energy output}}{\text{Mechanical energy input}} = \frac{E_{mech,out}}{E_{mech,in}} = 1 - \frac{E_{mech,loss}}{E_{mech,in}}$$

$= 0 \Rightarrow 100\%$.

Now we will continue with the discussion of efficiency of mechanical and electrical devices. Now any transfer of mechanical energy is usually accompanied by rotation a shaft and thus is typically the mechanical energy is often referred as shaft work.

So, imagine the again the mechanical energy of the fluid in your damp, you are transferring the mechanic in some form of turbine shaft work. So, this is a popular thing or pump for example okay. That is also mechanical heat transfer the mechanical energy or from the motor it transfer to the fluid in some form. So, let us to take an example again of a pump and turbine, a pump or fan receive shaft work usually from an electrical motor. And the job is to transfer it to fluid as a mechanical energy.

So, the pump is used to increase the pressure and thus so it increase the mechanical energy. Because mechanical energy has a pressure heat, is a pressure component, pressure energy or the flow energy p by Rho. A turbine converts the mechanical energy of a fluid to a shaft work, it is simply a mechanical energy output divided by mechanical energy input. You can write this in this form E mech out divided by E mach in and also in this form, where this is nothing but 1 minus E mech loss divided by E mech in.

If the loss is closed to zero, then you will get almost 100% conversions. So, you can convert a mechanical form to another mechanical form theoretically 100%.

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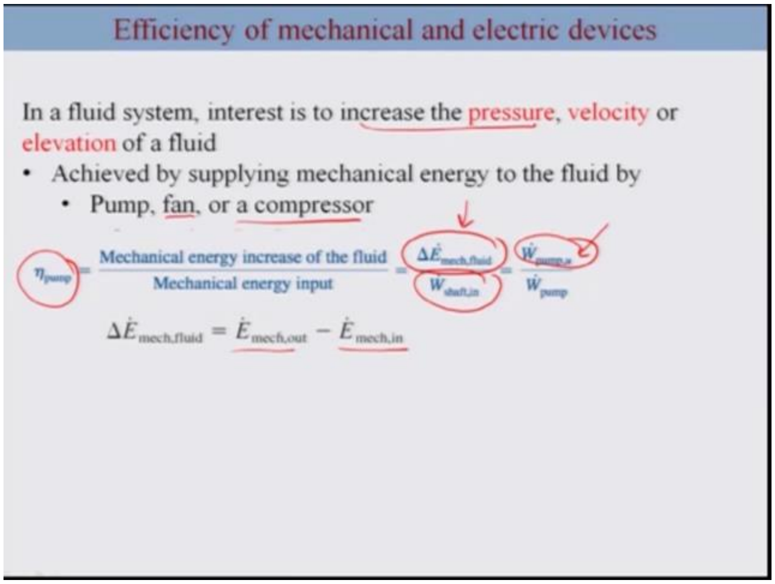

Efficiency of mechanical and electric devices

In a fluid system, interest is to increase the pressure, velocity or elevation of a fluid

- Achieved by supplying mechanical energy to the fluid by
  - Pump, fan, or a compressor

$$\eta_{pump} = \frac{\text{Mechanical energy increase of the fluid}}{\text{Mechanical energy input}} = \frac{\Delta \dot{E}_{mech,fluid}}{\dot{W}_{shaft,in}} = \frac{\dot{W}_{pump,u}}{\dot{W}_{pump}}$$

$$\Delta \dot{E}_{mech,fluid} = \dot{E}_{mech,out} - \dot{E}_{mech,in}$$

So, further we can look it little more detail with the further case of pump and turbine. So, what is a job a pump is to increase the pressure okay. And that is the pump can do, the fan or compressor also can increase the pressure of the system and that means it increases the mechanical energy of the system.

So, this is the if you want to find out the efficiency of pump it will be the ratio of the mechanical energy increase of the fluid divided by mechanical energy input. So, what is a input in this case, is W shaft in for the pump and what is output, so it is mechanical energy increase of the fluid, and that we are going to say as WE mech fluid okay. We using dot because we serrate this, so it is basically power mode. And this is equivalent to useful pumping power for pump okay.

So, that is why this use stand for here, it means useful. So, what is at change in the mechanical energy a fluid is simply E mech out minus E mech in. So, you will remember in for the pump E mech out is greater than the E mech in because it is already increase.

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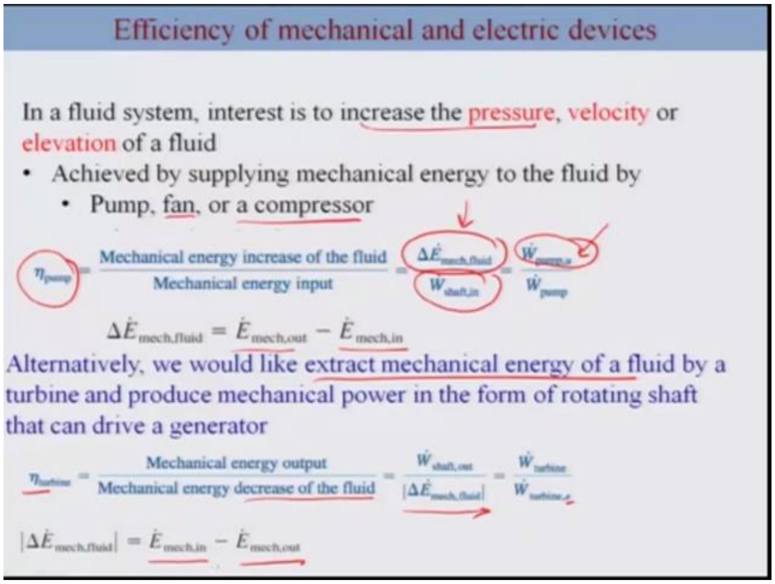

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$$\Delta \dot{E}_{mech,fluid} = \dot{E}_{mech,out} - \dot{E}_{mech,in}$$

Alternatively, we would like extract mechanical energy of a fluid by a turbine and produce mechanical power in the form of rotating shaft that can drive a generator

$$\eta_{turbine} = \frac{\text{Mechanical energy output}}{\text{Mechanical energy decrease of the fluid}} = \frac{\dot{W}_{shaft,out}}{|\Delta \dot{E}_{mech,fluid}|} = \frac{\dot{W}_{turbine}}{\dot{W}_{turbine,e}}$$

$$|\Delta \dot{E}_{mech,fluid}| = \dot{E}_{mech,in} - \dot{E}_{mech,out}$$

So, what about the turbine the turbine job is to extract mechanical energy of the fluid, because it turbine there fluid extracts the pressure it drops. So, it basically it extracts the mechanical energy of the fluid in that case the way we are going to define the efficiency of turbine is mechanical energy output divided by mechanical energy decrease of the fluid.

Now this is the positive value and thus we are going to use here the absolute value of delta E mech. So, and this E stand for gain is E extract, we are trying to extract the mechanical energy of the fluid, that is why we are going to use this absolute value in this form, E mech in minus E mech out. So, remember this is little different from the pump, pump we use E mech out minus E mech in. Because it was all like E mech out was greater than E mech in, in this case E mech in is more than E mech out.

So, once you do this absolute value we using the absolute value of this decrease in the mechanical energy of the fluid.

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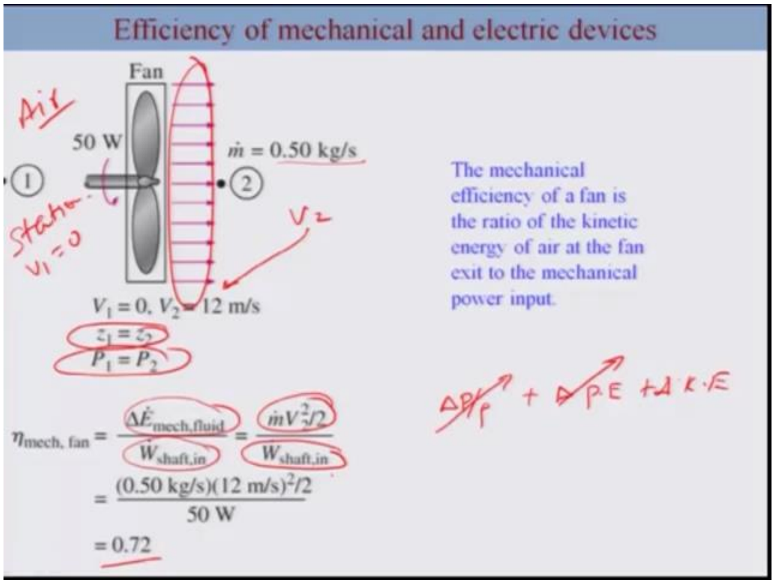

Efficiency of mechanical and electric devices

$V_1 = 0,\ V_2 = 12$ m/s

$z_1 = z_2$

$P_1 = P_2$

The mechanical efficiency of a fan is the ratio of the kinetic energy of air at the fan exit to the mechanical power input.

$$\cancel{\Delta P/\rho} + \cancel{\Delta PE} + \Delta K.E$$

$$\eta_{\text{mech, fan}} = \frac{\Delta \dot{E}_{\text{mech,fluid}}}{\dot{W}_{\text{shaft,in}}} = \frac{\dot{m}V_2^2/2}{\dot{W}_{\text{shaft,in}}}$$

$$= \frac{(0.50\text{ kg/s})(12\text{ m/s})^2/2}{50\text{ W}}$$

$$= 0.72$$

So, let us take an example, so this is a fan and fan uses a shaft a work of 50watt. And then the air here has a the mass rate is given is a 0.5 kilojoules per second and we need to find the mechanical efficiency of this fan. So, how we are going to do that, we going to use the expression what we are used for pump, delta E mech fluid divided by W shaft in. Because here there is, the air here is stationary, okay, this is stationary which means the velocity is would be zero here, here the velocity is given as 12 meter per second, there is no change in the elevation there is no change in the pressure.

So, mechanical energy of the fluid we will have only the kinetic energy part, there is no change in the pressure part because there is no delta P by Rho and there is no delta P E, the only thing which we has is delta KE. So, this is going to be zero, this is going to be zero and thus you have only this kinetic energy and that what you want to use okay. And the shaft work is already given to you as 50watt. So, you replace this value and this terms out to be 0.72 okay.

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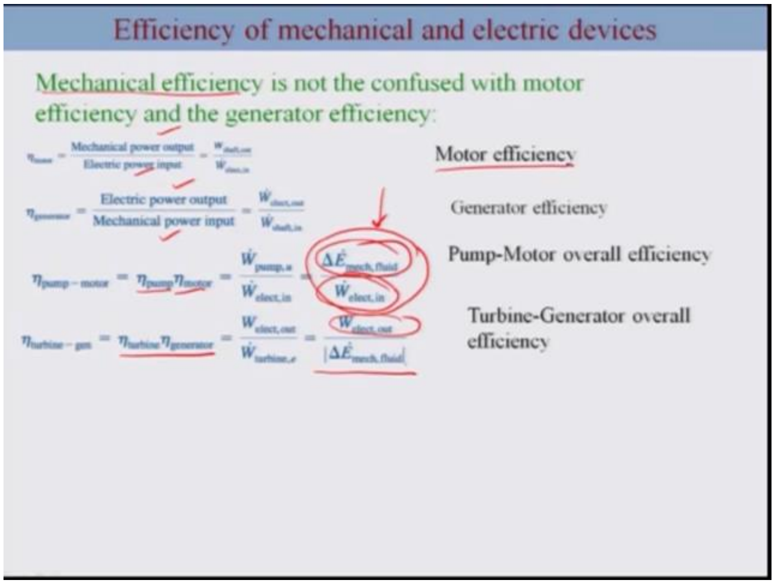

Efficiency of mechanical and electric devices

Mechanical efficiency is not the confused with motor efficiency and the generator efficiency:

$$\eta_{motor} = \frac{\text{Mechanical power output}}{\text{Electric power input}} = \frac{\dot{W}_{shaft,out}}{\dot{W}_{elect,in}}$$ Motor efficiency

$$\eta_{generator} = \frac{\text{Electric power output}}{\text{Mechanical power input}} = \frac{\dot{W}_{elect,out}}{\dot{W}_{shaft,in}}$$ Generator efficiency

$$\eta_{pump-motor} = \eta_{pump}\eta_{motor} = \frac{\dot{W}_{pump,u}}{\dot{W}_{elect,in}} = \frac{\Delta\dot{E}_{mech,fluid}}{\dot{W}_{elect,in}}$$ Pump-Motor overall efficiency

$$\eta_{turbine-gen} = \eta_{turbine}\eta_{generator} = \frac{\dot{W}_{elect,out}}{\dot{W}_{turbine,e}} = \frac{\dot{W}_{elect,out}}{|\Delta\dot{E}_{mech,fluid}|}$$ Turbine-Generator overall efficiency

So, many times we are interested in the combined effect, so for example motor is connected to your pump or general or generator has a turbine. So, having just efficiency of a turbine is not sufficient, you are interested in the (com) combo or combination of both the things. So, as mechanical efficiency should not be just confused with a motor efficiency, it has a different definition. So, motor efficiency here would be simply the ratio of the mechanical power output and electrical power output. On the other hand generator would be electrical power output divided by mechanical power input.

So, what about the combined pump motor efficiency, you are going to just multiply the individual efficiency, or in other word you can come up with this direct form where you are saying that pump a motor combined has a effect of increasing the mechanical energy of the fluid and is divided by the power it takes, okay. And the effect is directly reflected on the mechanical energy, energy of the fluid.

Similarly you can do that what a turbine a generator and so here the turbine and generator is given by your the electrical power output divided by the decrease in the mechanical energy of the fluid okay. That is a turbine generator overall efficiency.

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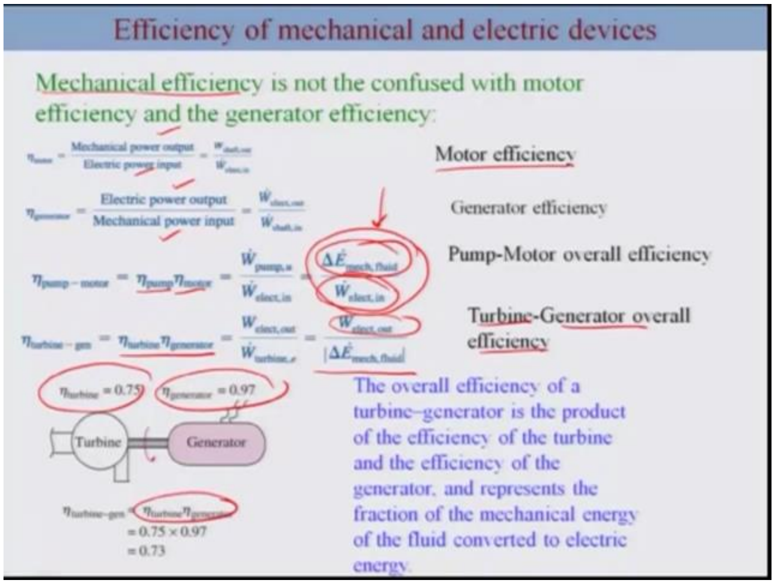

Efficiency of mechanical and electric devices

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$\eta_{turbine-gen} = \eta_{turbine}\eta_{generator} = \frac{\dot{W}_{elect,out}}{\dot{W}_{turbine,e}} = \frac{\dot{W}_{elect,out}}{|\Delta\dot{E}_{mech,fluid}|}$ Turbine-Generator overall efficiency

$\eta_{turbine} = 0.75$ $\eta_{generator} = 0.97$

$\eta_{turbine-gen} = \eta_{turbine}\eta_{generator}$
$= 0.75 \times 0.97$
$= 0.73$

The overall efficiency of a turbine–generator is the product of the efficiency of the turbine and the efficiency of the generator, and represents the fraction of the mechanical energy of the fluid converted to electric energy.

So, this is an example here, so this is a combination of a turbine and generator individual efficiencies are given. So, turbine is generator efficiency would be simply the multiplication of individual efficiency of turbine and generator.

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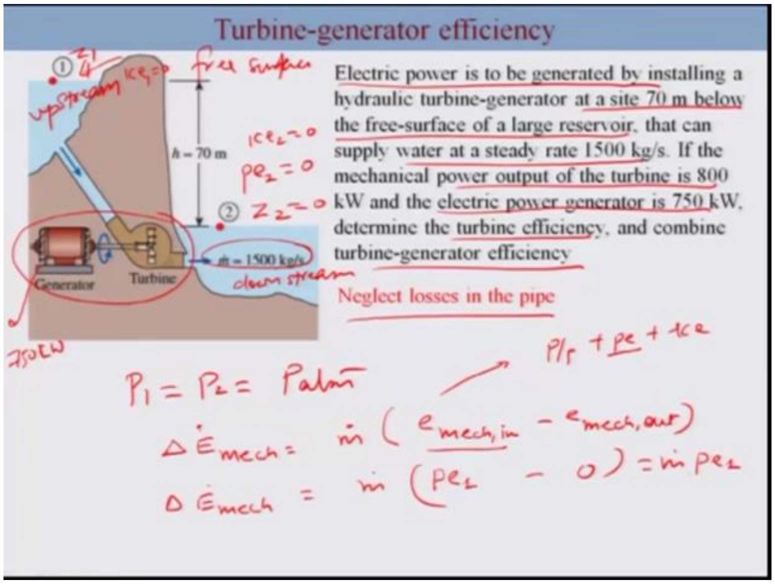

Turbine-generator efficiency

Electric power is to be generated by installing a hydraulic turbine-generator at a site 70 m below the free-surface of a large reservoir, that can supply water at a steady rate 1500 kg/s. If the mechanical power output of the turbine is 800 kW and the electric power generator is 750 kW, determine the turbine efficiency, and combine turbine-generator efficiency

Neglect losses in the pipe

$P/\rho + pe + ke$

$P_1 = P_2 = P_{atm}$

$\Delta\dot{E}_{mech} = \dot{m}\,(e_{mech,in} - e_{mech,out})$

$\Delta\dot{E}_{mech} = \dot{m}\,(pe_2 - 0) = \dot{m}\,pe_2$

Now we will end this lecture by doing this energy analysis okay. So, this is a turbine generator efficiency problem electrical power is to be generated by installing a hydraulic turbine generator. So, this is the hydraulic (())(16:35) turbine generator which is at a site 70 meter below the free surface, the free surface you see this, okay of the larger reservoir, so this is a larger reservoir, this is a upstream this is a downstream. So, this is would be down stream. So, this is up stream, so larger reservoir here okay. So, is saying that it should be installed at a site 70 meter below the free surface of the larger reservoir. That can supply water at a steady state of 1500 kilo gram per second which means the m dot here the fluid which is flowing out of heat is 1500 kilogram per second.

If the mechanical power output of the turbine is 800 and the electrical power generate a 750 which means this generator is generating 750 kilowatt of electrical power. Then what is the turbine efficiency on an the combine turbine generator efficiency. So, that is question which we have to solve, so we have to neglect the losses in the pipe. The first thing is we should write down the basic steps here. So, let us say we are going to consider this Z 2 and the point 2 which is written here and Z 1 and Z 2 we are going to says to be zero make this as a reference.

So, we know Z 1 is 70 meter, so considering Z 2 zero p2 should be zero right. These are stationary there is no velocity, so the kinetic energy here should be zero and same is the case for here. So, the kinetic energy is of this point one is zero. Now what about the P1 and P2, we can assume these are both atmosphere right okay. So, let us first calculate the delta E mechanical change in a mechanical energy of the fluid, so what about a delta E mech, so this would m dot because m considering the rate here this would be E mech in minus E mech out, okay.

Now since we know E is nothing but your P by Rho plus P e plus K e, right. Now what about in here and out, out is of course 2 and in is 1. So, in this case E mechanical energy in is we going to considered only the potential energy, so this would be simply Pe1 and this is going to be zero because of the fact that P e2 is zero, K e2 is zero and of course there is no flow energy okay. So, this is nothing but M, so you have the information of change in mechanical energy of the fluid okay.

So, you can calculate what is P e is nothing but g times the Z1 and so you can write the expression.

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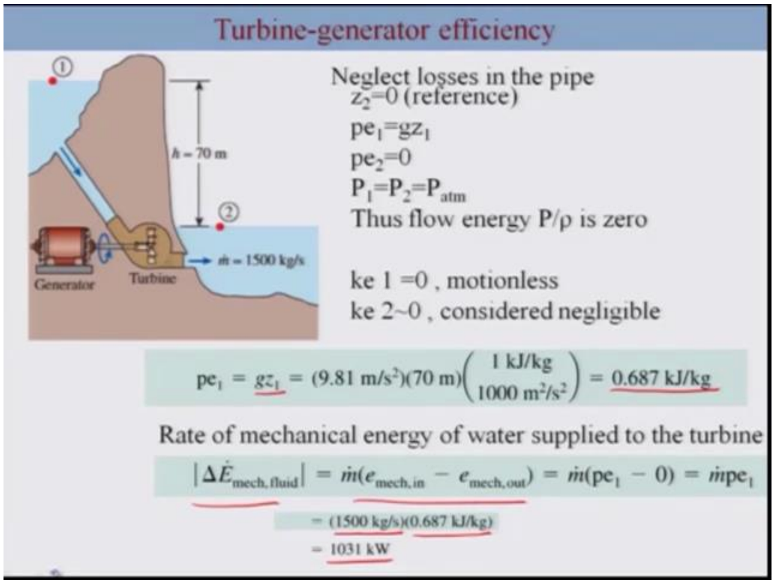

Turbine-generator efficiency

Neglect losses in the pipe
z_2=0 (reference)
$pe_1 = gz_1$
$pe_2 = 0$
$P_1 = P_2 = P_{atm}$
Thus flow energy P/ρ is zero

ke 1 =0 , motionless
ke 2~0 , considered negligible

$$pe_1 = gz_1 = (9.81\ \text{m/s}^2)(70\ \text{m})\left(\frac{1\ \text{kJ/kg}}{1000\ \text{m}^2/\text{s}^2}\right) = 0.687\ \text{kJ/kg}$$

Rate of mechanical energy of water supplied to the turbine

$$|\Delta\dot{E}_{\text{mech, fluid}}| = \dot{m}(e_{\text{mech, in}} - e_{\text{mech, out}}) = \dot{m}(pe_1 - 0) = \dot{m}pe_1$$
$$= (1500\ \text{kg/s})(0.687\ \text{kJ/kg})$$
$$= 1031\ \text{kW}$$

So, here is a expression finally. So, this is the expression 1500 kilogram per second multiplied by P e, P e is calculate is a gZ1 and this is the value which you getting as change in mechanical energy of the system. Remember that what I did was the absolute change, so this actually should be absolute change, okay because I am using E in minus E out there is drop in mechanical energy. And that is what it is used so absolute change here.

So, now be once you have this information how do you calculate thermal efficiency.

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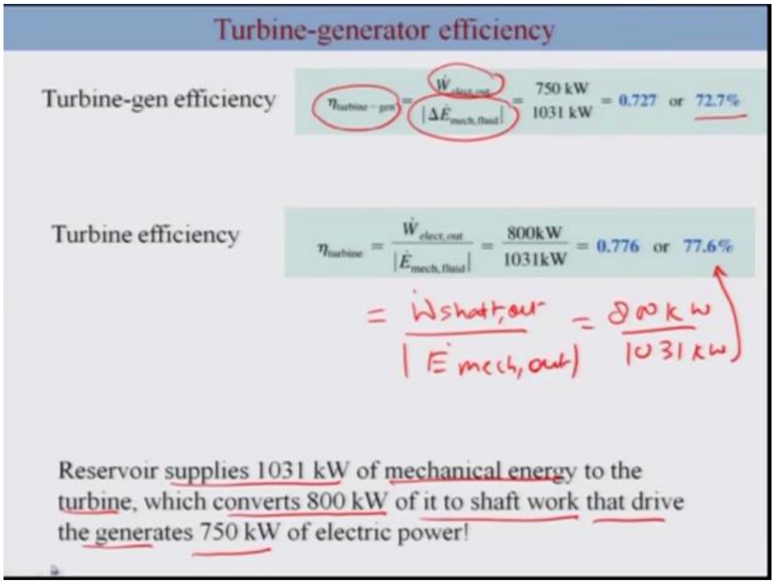

Turbine-generator efficiency

Turbine-gen efficiency
$$\eta_{\text{turbine-gen}} = \frac{\dot{W}_{\text{elect, out}}}{|\Delta\dot{E}_{\text{mech, fluid}}|} = \frac{750\ \text{kW}}{1031\ \text{kW}} = 0.727 \text{ or } 72.7\%$$

Turbine efficiency
$$\eta_{\text{turbine}} = \frac{\dot{W}_{\text{elect, out}}}{|\dot{E}_{\text{mech, fluid}}|} = \frac{800\text{kW}}{1031\text{kW}} = 0.776 \text{ or } 77.6\%$$

$$= \frac{\dot{W}_{\text{shaft, out}}}{|\dot{E}_{\text{mech, out}})} = \frac{800\ \text{kW}}{1031\ \text{kW}}$$

Reservoir supplies 1031 kW of mechanical energy to the turbine, which converts 800 kW of it to shaft work that drive the generates 750 kW of electric power!

You can directly use the expression of what we have gone through thermal efficiency of turbine generator combination would be simply the electrical work output from the generator divided by the change in the mechanical energy of the fluid. That would be the combine the effect of turbine and generator. So, that turns out to be 72.7%, what about turbine, turbine would be the, this should not be electrical this should be shaft work. So, because if you recall the question had 800 was the mechanical power output was nothing but shaft work okay.

So, this should be a simply 800 kilowatt by 1031 so that answers to be 77.6 %. So, what this reservoir does, so reservoir supplied 1031 kilowatt of mechanical energy. Because that was the mechanical energy to the turbine which converts 800 kilowatt of it to a shaft work and that drives the generator generating 750 kilowatt of electrical power, remaining amount is lost. So, this is how we are going to calculate and make use of efficiency to find out solve of such kind of problems.

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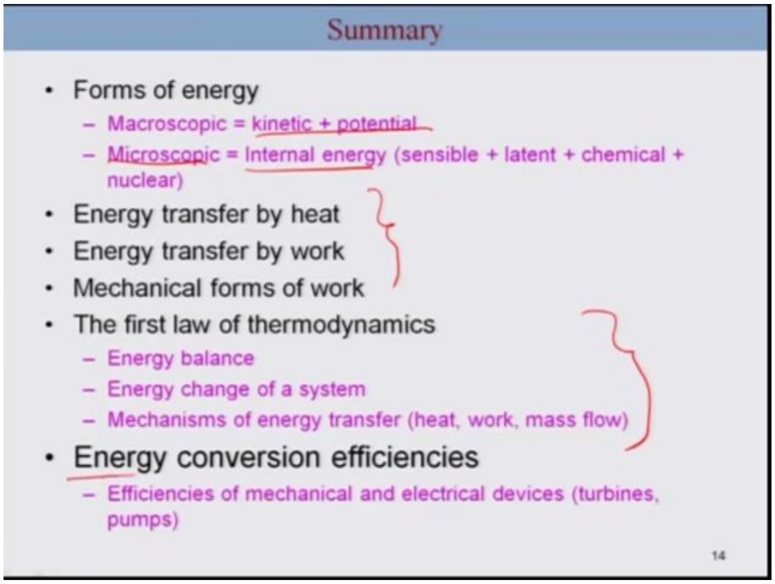

Summary

- Forms of energy
  - Macroscopic = kinetic + potential
  - Microscopic = Internal energy (sensible + latent + chemical + nuclear)
- Energy transfer by heat
- Energy transfer by work
- Mechanical forms of work
- The first law of thermodynamics
  - Energy balance
  - Energy change of a system
  - Mechanisms of energy transfer (heat, work, mass flow)
- Energy conversion efficiencies
  - Efficiencies of mechanical and electrical devices (turbines, pumps)

So, let me summarized what we gone through in this module, we defined energy defined the microscopic and the microscopic energies, we also defined that energy can be transferred by heat, mass and work okay. These are different form of transfer of energy. And particularly heat and work will be recognized only at the boundary.

We went through the first law of thermodynamics, went it a details, went to the expression applied this particular expression or them analysis to a system and eventually we under this module with energy conversion efficiency and some examples. So, that would be the end of this lecture next lecture we are going to go through the property of the fluid and will understand the phase change in other aspect of it.