MARINE ENGINEERING

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Lecture3

Work and Heat transfer

Hello good morning. Now this topic is based on work and heat transfer. It is part of thermodynamics. So basic content is taken from P.K. Nag book, Basic and Applied Thermodynamics, Tata McGraw-Hill book.

First we will start with thermodynamic laws. Thermodynamic laws, there are different laws. First law. Second law. Third law.

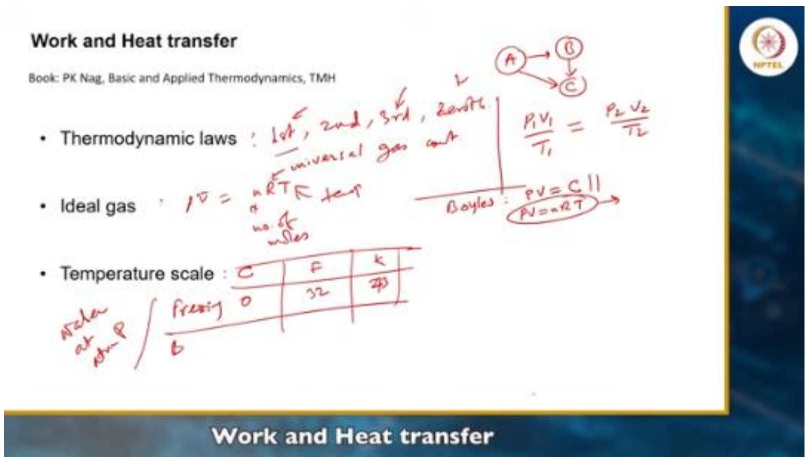
and zeroth law. There are four laws. So zeroth law says like if A is in equilibrium with B and B is equilibrium with C, so A and C must be in equilibrium. First law says that energy and work can be convertible. Second law says 100% work or energy cannot be converted because whenever heat is converted into work, so some energy will be lost.

Third law says like it is for absolute, a perfect crystal will have zero entropy at zero Kelvin. So, ideal gas. So, in ideal gas, formula is that PV equals nRT, universal gas constant. n number of mole, T is temperature. For two states P1 V1 by T1 equals P2 V2 by T2.

These are coming from your basic equation Boyle's law, Charles' law. So, Boyle's law says Boyle's law says PV equals constant and there is criteria. This Boyle's law will be holding true if the process is very slow and isothermal and for low pressure application. So when Boyle's developed this formula, so that time there is no machine to create a very high pressure.

So because high pressure was not created, ah so this can be applicable for low pressure application and it must be very slow process not very fast process okay and charles law charles says p v equals n r t okay so when pressure volume and temperature link that become that is coming from charles law okay now temperature scales so temperature scale i already told centigrade is there Fahrenheit is there and Kelvin. Basically, these three scales are common and there will be a Rankine also. So, I am not going to Rankine now.

So, centigrade like freezing temperature 0 degree, Fahrenheit freezing temperature 32 degree and Kelvin will be 273 Kelvin and freezing. And if I go to boiling point of water, freezing point, actually water at atmospheric pressure. If pressure is changing, the freezing temperature, boiling temperature will change. So whenever you are talking about freezing temperature or boiling temperature of water, you have to specify pressure also. So boiling water.



This is 100 degree, this is 212 degree and this is 373 degree. So C to K conversion is very easy just add 273. C plus 273 is your Kelvin. But C to Fahrenheit formula is that C by 5 equals F minus 32 by 9. So, this is the conversion formula.

So, if you know certain temperature in Fahrenheit and you want to convert into Kelvin. So, this is simply you convert to Celsius then add 273. So, that will be easiest process. If I can write directly F F minus 32 by 9 equals K minus 273 by 5.

So, this also can be possible. A closed system, a closed system and its surrounding can interact in two ways, by work transfer or by heat transfer. This may be called as energy interaction. Energy interaction in closed system. In previous lecture we have seen this flow system is mass cannot enter or exit rather energy can enter and exit.

So two way it can interact work transfer or heat transfer. Now surrounding if I have surrounding this is system work will be going surrounding. surrounding. So, what is going out? So, W is positive.

But system work incoming. So, in that case surrounding. So, W will be negative. The work in PDV work and displacement.

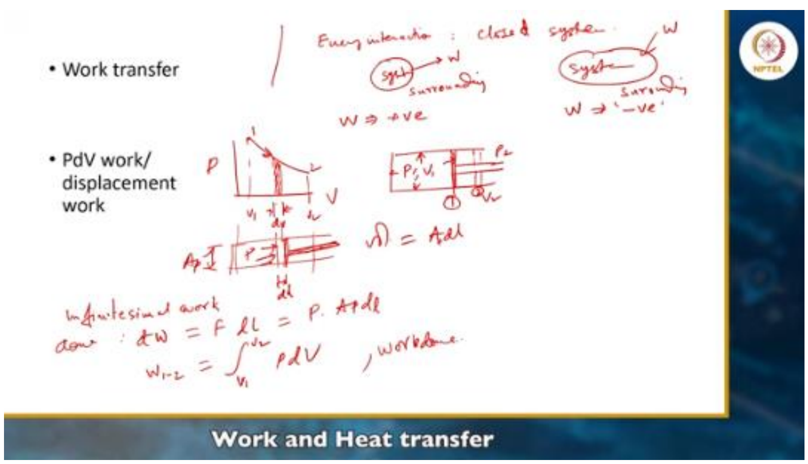
So first you draw the figure PV and let us see what process is happening like this 1 to 2. Take very small amount of volume change. So this is volume V1, this is volume V2 and this is DV. And this process is happening like this. I have got piston cylinder alignment and P will be acting in all direction because of Pascal's law P1 and V1 is here.

P2 is here and piston is here. V2 is here. This is process 1. Piston is here. Piston in point 1 position.

This is 2 position. Now, if I draw this one on piston, it will be like this. And piston initially here. Piston is here. And P is working here.

P. P. then this is dV, actually this is dV and the piston is here. When the piston moves an infinitesimal amount dL, so it is dL moved, dL, AP is the area, so this piston area is AP, so volume will be ADP, so volume will be ADP, because A is not changing area piston A, is not changing only the motion is changing so the volume will be ADP sorry ADL infinite now infinite work DW equals F into DL equals P into AP piston and DL.

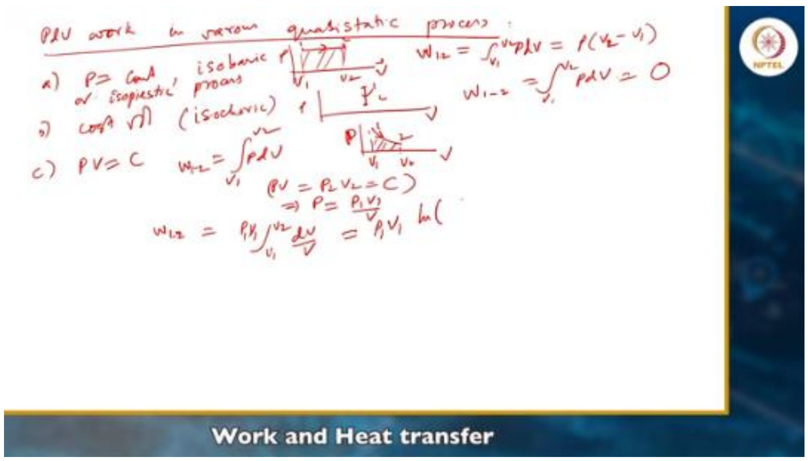
Piston area I say AP. So, W1 to 2 PDV. This is work done. So PDV work PDV work in various quasi-static processes.



So, a constant P, P equals constant isobaric, it is called isobaric or isopiastic. isopiestic process. So, it is like this. P, process is here, constant pressure, P is not changing, 1 to 2. So, this area, V1, V2, V. So, W12, 1 to 2.

dv equals e into v1 minus v2 minus v1 because pressure is not changing so it becomes v2 minus v1 another condition is that constant volume or isobaric isochoric isochoric process so they are is like this P V processes like this 1 to 2. So, this is P and W12 integration of P V1 V2 PDV. So, volume is not changing. So, it is becoming 0.

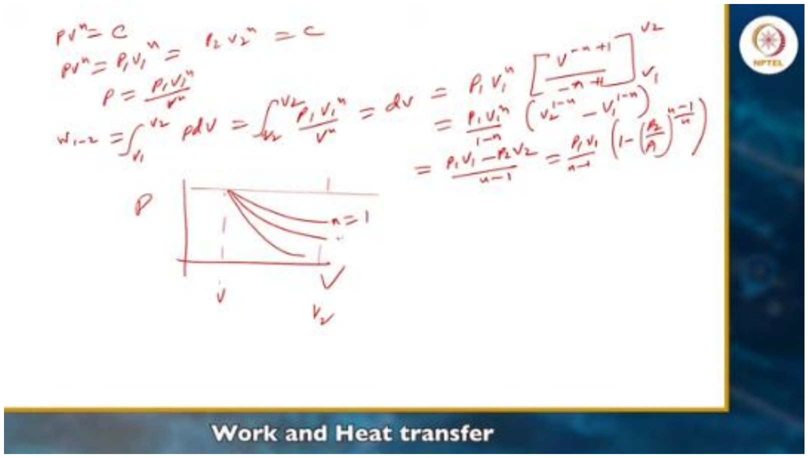
C process with PV equals constant so this is Boyle's law when it is system is isothermal so it is like W 1 to 2 so process will be like this 1 to 2 PV this is V this is P this is V 1 V 2 okay integration of p dv v1 v2 equals p um we know p v equals p2 v2 equals constant okay so this implies p equals P1V1 by V. Or I can write PV only. Now, W12122 equals P1V1 integration of V1V2 DV by V equals P1V1 natural log dv by v no natural log v2 by v1 ok because this is coming logarithm and if I replace p and v v by p then it will be like p1 v1 natural log p1 by



if pv equals pv power n equals c is is adiabatic process or polytrophic process let's say as in polytrophic so pv power n equals p1 v1 power n equals p2 v2 power n equals constant so p equals p1 v1 power n by v power n so w1 to 2 integration of v1 v2 P dV equals V1 V2 P1 V1 power n V power n equals dV. Now we replace P by P P1 V1. So it is becoming like this. P1 V1 power n V minus n plus 1 minus n plus 1 V2 by V1

P1, V1 power n, 1 minus n, V2, 1 minus n, minus V1, 1 minus n. So, it is P1, V1, minus P2, V2, n minus 1. So, it is P1, V1, n minus 1, 1 minus P2 by P1, n minus 1 by n. So figure will be like this. P, V. 1, 2. So just different line I am showing.

This is V1. This is V2. N equals 1. N equals 2. N equals 3.



So this is a process. This is process P, V, N equals constant. And here, okay, so if N equals 1, it's becoming P equals C. So that becomes Boyle's law. So PV energy work when you are calculating so we need to know we need to go through integrated diagram. Integrated diagram first you draw one slider crank mechanism.

I have one cylinder. Cylinder is like this. Two valves are there and there will be one port here. Port will have another piston. Piston is here.

And piston is connected to one stylus. And this cylinder is having one piston. Piston is connected to one slider crank mechanism. Slider crank mechanism like this. So this is crank.

Later stage when we will discuss IC engine there we will explain much more details. So just here if you rotate the crank this piston-like thing it will be moving forward backwards. So this is called crosshead. And this is a connecting rod. Then piston, this is also one piston.

It is similar to an ICE engine. And piston, this crosshead will be connected to one stylus. Crosshead is connected with R. Now this I am putting some dots, there we will get an indicator diagram. If piston is moving forward backward, because of crank is rotating, crank rotating, that is why cross head will be moving forward backward.

When cross head is moving forward backward, this will be pushing piston also move forward backward. When piston is moving forward backwards, inside this area, it will be compressed or expanded. When you are compressing, let us say both right side valves, right side valves are closed, Then when you are compressing, pressure will increase. So pressure will be increasing, temperature will be increasing.

So that will be indicated in your indicator diagram. So I have written this diagram indicator. So the top section indicator diagram is there. So there we can get a diagram actually. When pressure is increasing the volume will be compressed.

When volume is compressed so you will get certain curve. When you are expanding you will get certain curve. PV if I draw PV normally indicator diagram will be coming like this going like this it will begin expanding and if there is no heat transfer is happening or no work transfer happening. So, 1 2 1 it will be happening like this but if work transfer heat transfer happening then curve will be little bit different this is called indicator diagram. And this inside area of indicator diagram there is a work done.

Work done in one engine cycle, in one, this thing I will discuss later also in details when I will be discussing about IC engines. The area of the indicator diagram represents the magnitude of net work done by system in one engine cycle. So this area will be showing that how much work done by the system. Now, if I have two-stroke engine, four-stroke engine, IC engine, so I am not going into details of IC engine now. Just here you can see this indicator diagram we can draw and the curve in between that area is called how much work, the intensity of work we are producing.

So, for two-stroke engine work done, we will discuss later. Two-stroke Work done per minute. So, it is P, M, A, L, N. What is A? A means area of piston.

Area of piston. N, number of stroke. And L is stroke length. So total volume into P is the average pressure. Average pressure in the cylinder and total volume how much composition decomposing.

That if you know then you can get per minute work done. And number of stroke per minute actually. N is number of stroke per minute. Number of strokes per minute. That way you can calculate two stroke engine work done per minute.

But if you have four stroke engine then it will be divided by two. For four stroke engine, it will be like work done per minute. What happens in two-stroke engine in IC engine or internal combustion engine motorcycle, bus, trucker your crank is rotating so when it is rotating one time it is giving power one rotation one time power but in four stroke engine what is happen the crank will be rotating two times and you will get one time power that is why divided by two is coming. Later we will discuss details when we will be discussing IC engine. Power developed inside the cylinder of the engine is called indicated power or IP.

Power developed inside the cylinder is called indicated power. Indicated power IP. So, the formula is that PMALN or N by 2. Because of 2 stroke or 4 stroke engine divided by 60 in kilowatt, power in kilowatt unit. So, Pm in kPa, Pm kPa and n number of cylinder, n also you can put, so n number of cylinder.

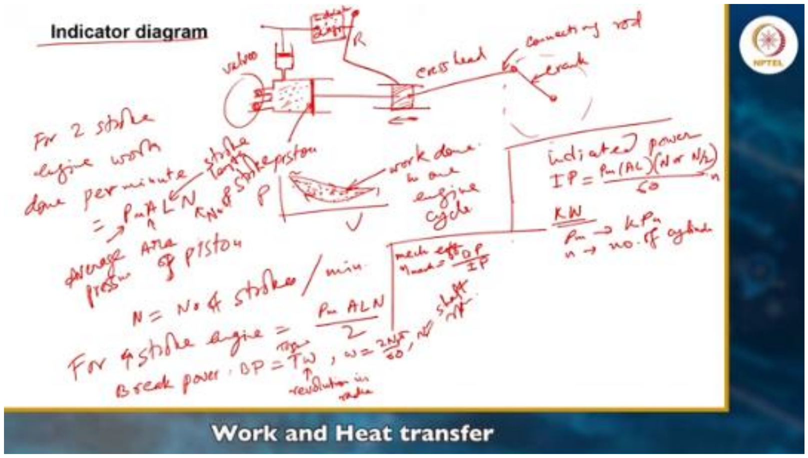
Here I am using N but I have used another N in PV power N. So both are different actually do not mix up. N is a number of cylinders. If I have one cylinder then N is 1. If I have multiple cylinders then number of cylinders will be 2. Many marine engines will have multiple cylinders.

Normally there will be no single cylinder for very heavy ships. Cargo ships or passenger ships or big cruise ships, they will have multiple cylinders. But small engine, for example, motorcycle, bike, scooter and the small fishing boats, they may have only one engine. Yeah, one cylinder. Brake power.

Another term is brake power. Brake power is equals BP or torque into omega. Torque means sharp torque, how much torque is there and how much rotation is there. Rotation means regulation in radian and T is torque and omega equals 2 n pi by 60. n here n is shaft rotation n equals shaft rpm okay so here I am using n for other purpose also please don't miss that okay n means n nr I can put some suffix so that it will be different okay mechanical efficiency

Mechanical efficiency eta mech equals bt by ip. integrated power, integrated power means inside engine how much power we are getting. that is higher and brake power means after engine lots of friction will be there then you are getting power. engine is giving higher power then there will be certain losses because second law already we discussed the second law means there will be certain loss every time. integrated power is higher then you are getting shaft power, shaft power means brake power.

that brake power is lower than your integrated power. what is the mechanical efficiency? Whatever you are getting divided by your engine power. That is called your mechanical efficiency. So, BP by IP.

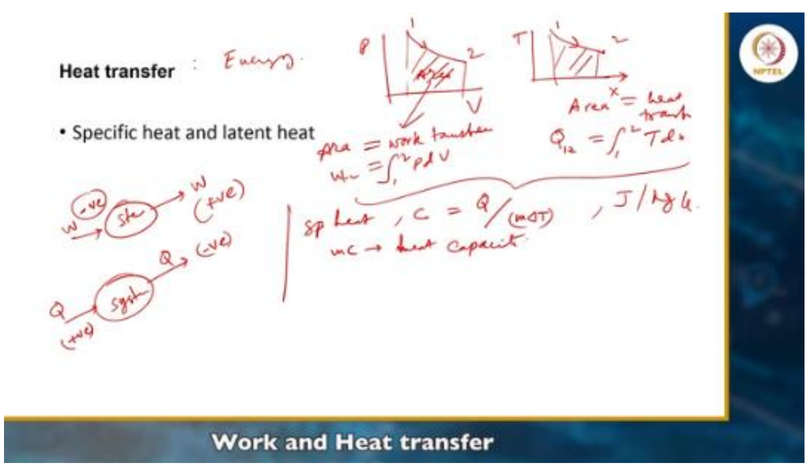


Heat transfer. Heat is a form of energy. This is also energy. So, let us see PV diagram. P and V, V means volume, pressure P and T means temperature, X means distance, okay.

So, 1 to 2, one process is happening, another process is happening, 1 to 2 but it is represented on TX coordinate system. So, area, this is area. This area is equals walk transfer actually. heat transfer,equals W12, 122 P dV. area equals heat transfer.

this is heat transfer area. Q 1 to 2 equals 1 to 2 T dx. representation of work transfer and heat transfer in quasi-static process on PV diagram, TS diagram it is there. So, here system and work is given to the system that is negative. We have to use negative sign.

When work is going out of the system will be using this is negative will be using positive sign and heat transfer case system this is also system Q entering this is positive Q exiting negative. Specific heat, specific heat means C equals Q by m delta T. So, unit will be joule per kg K. m C called heat capacity. Later we will discuss in details of these terms and we will do some calculation also in future lectures. Laws of thermodynamics.



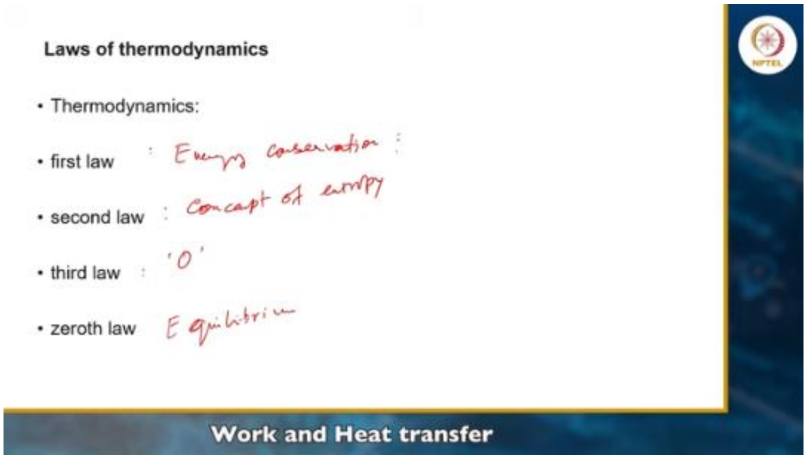
first law. first law is it is energy conservation law. First law is the energy conservation law. Energy conservation law. Second law says energy loss, which is concept of entropy it will give.

Concept of entropy. And third law, a perfect crystal should have 0 Kelvin temperature. 0 Kelvin concept it will give. Zeroth law, it will be talking about equilibrium. Equilibrium.

In first law, energy can be converted to work, work can be converted to energy. And they just now say how it will be done and whether there will be energy loss or anything. But in second law says energy 100% cannot be converted actually, there will be certain losses every time. So this second law is very much important for all calculation engineering because Whenever there will be one boiler, boiler transferring heat or transferring steam to turbine, turbine is giving power, that power is being transferred through shaft to propeller.

So, every time there will be energy losses. We cannot generate any system which will be self-sustaining. So, we cannot design any perpetual motion machine. So, any machine will be running by itself without taking outside any energy. This second law confirms that.

But first law does not say that. First law says energy can be converted. But how it will be converted, how much converted that does not say anything. So first law formulation if I write it will be like summation of W cycle equals some conversion factor summation of Q cycle. So Q minus W equals delta E.

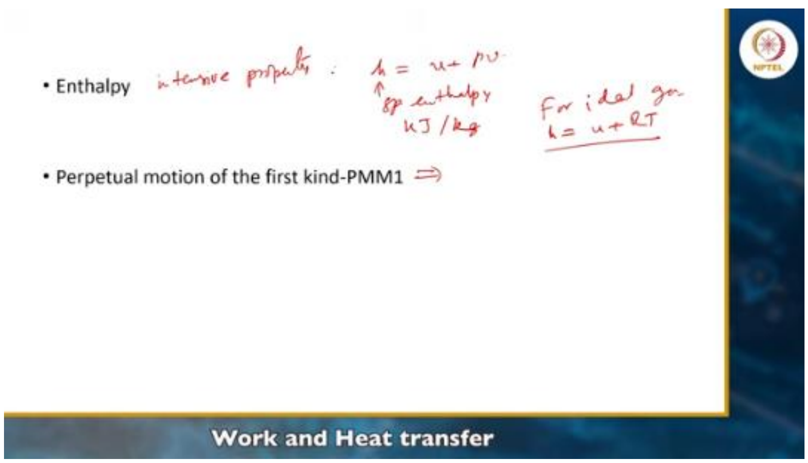


internal energy, increase in internal energy. This is increase in internal energy and this is net energy transfer. So, regarding second law, the entropy we will discuss later. Enthalpy. So, enthalpy is the intensive property.

And the formula is like H equals U plus PV. U means internal energy. So, this is called specific energy. And PV is pressure and volume and unit will be kJ per kg for ideal gas. H equals U plus RT.

Perpetual motion machine of first kind, there are two types of perpetual motion machine. This is first kind, it is coming from first law. And another is there, PMM2, perpetual motion machine of second, of the second kind, this is coming from second law of thermodynamics. So, first law says that energy cannot be destroyed or created. And there will be certain losses actually.

And from same source, you cannot take and give back energy. So, when you cannot take and give back, so that means you cannot get work also. So, Foslow says that. Helium gas actually. Helium gas from a bottle.



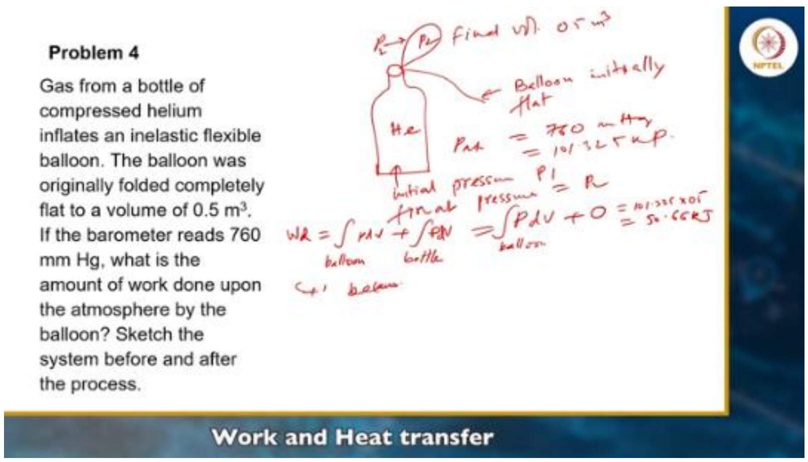
Inflated elastic balloon. It is inflating. The balloon was originally folded completely flat to vacuum of 0.2. To a volume of 0.05 meter cube. If the barometric pressure is 760 millimeter Hg and mercury, what is the amount of work done upon the atmosphere by the balloon?

This is the system before and after the process. So, first you draw the bottle. Bottle means, we are assuming glass bottle, so there will be no change in volume or shape or the boundary, system boundary. And initially it was flat like this. So this is balloon initially flat.

And after blowing it, it will be P2 and final volume 0.5 meter cube. This is helium gas is here and atmospheric pressure P atmospheric pressure 760 millimeter Hg. So it is becoming like almost 101.825 kPa. So initial Pa initial pressure P1 final pressure P2.

Now work done WD equals integration of PDV plus PDV and first PDV is a balloon, second is a bottle. And second V volume is not changing so that is equal to 0. So it is becoming like P dV balloon plus 0. So 101.325 equals 0.5. It is becoming 50.66 kg.

So plus sign becomes because work is done by the system. because work is done by the system, minus five zero point six six k j if you write then it will be work done by the atmosphere work done by the atmosphere So problem, another problem, the piston of an oil engine of area 0.5 square meter moves piston surface area moves downward 75 minute drawing 0.00028 meter cube of fresh air from the atmosphere. The pressure of cylinder is uniform during the process at 80 kilopascal while atmospheric pressure is 101.325 kilopascal. The difference between the being due to the flow resistance in the induction pipe and the inlet valve.



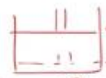
Estimate the displacement work done by the air and finally the cylinder. So, first, draw this cylinder. So, initially it was here. So, volume was 0 and final volume become like 3.375 into 10 power minus 4 meter cube. So, piston stroke equals 0.0045 into 0.075.

It is becoming 0.00003375 meter cube. Now, del V we got. Now, this is not piston, this is volume of piston stroke. So, actually this is delta V. Now, as P is constant, it is 80 kPa given this data. work done.

work done equals P dV. So, equals 80 pressure into dV, 0.0003375 kJ. So, it is becoming 0.027 kJ equals 27 joule. So, this is the energy we get.

Problem 5

The piston of an oil engine, of area 0.0045 m^2, moves downwards 75 mm drawing in 0.00028 m^3 of fresh air from the atmosphere. The pressure in the cylinder is uniform during the process at 80 kPa, while the atmospheric pressure is 101.325 kPa, the difference being due to the flow resistance in the induction pipe and the inlet valve. Estimate the displacement work done by the air finally in the cylinder.



$\leftarrow 3.375 \times 10^{-4}\ m^3$

$V = 0$

Vol. piston stroke = 0.0045 × 0.075
= 0.000 3375 m^3 = ΔV

As p in cyl. = 80 kPa

work done = pdV
= 80 × 0.000...