MARINE ENGINEERING

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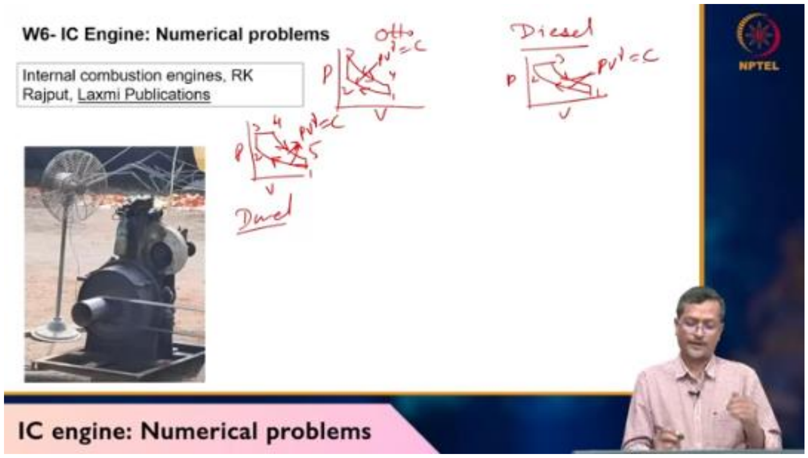
Lecture41

IC engine: Numerical problems

good morning we have gone through our basic understanding on ic engine ic engine will have one piston we'll have crank we'll have crankcase we'll have exhaust port inlet port compression system flywheel cam so many things we have discussed now we should we should solve some problems so that we'll understand how thermodynamics is happening in the ic engine and we are getting power fuel will be burned and it will giving it will be giving heat energy that energy will be converted into your torque on the shaft so we basically we discussed two type of engine auto cycle and diesel cycle so auto cycle will have constant volume heat addition process one two three four and diesel cycle will have my constant pressure heat addition process other processes are almost same okay PV PV now another cycle also there called dual cycle so people thought like say take two stroke benefit take four stroke benefit

and make another cycle called dual cycle dual cycle is like this some portion will be constant volume heat addition process some will be constant pressure heated addition process then you get expansion okay so one two three four five so two three four that part is different this is called dual cycle this is called auto cycle auto cycle already written this is dual cycle fluid where compression will be happening expansion will be happening so we are getting power p v power gamma equals constant here also p v for gamma equals constant they are also same same thing happening p v power gamma equals constant here also p v power gamma equals constant now through the problem we will try to solve this problem like what is the temperature pressure different point with the efficiency and different other parameter also try to calculate let us try to solve first two stroke engine or spark ignition engine



one spark ignition engine has or auto cycle auto cycle has compression ratio 10 So, many books they are writing Rk, many books are writing R, many books have they have written Cr also. So, just in this problem I have used the term Cr means compression ratio of 10, it operates with a low temperature so that means first I have to draw my PV diagram. draw the PV diagram, this is curved line, this is curved line 1, 2, 3, 4. SI engine compression ratio is 10.

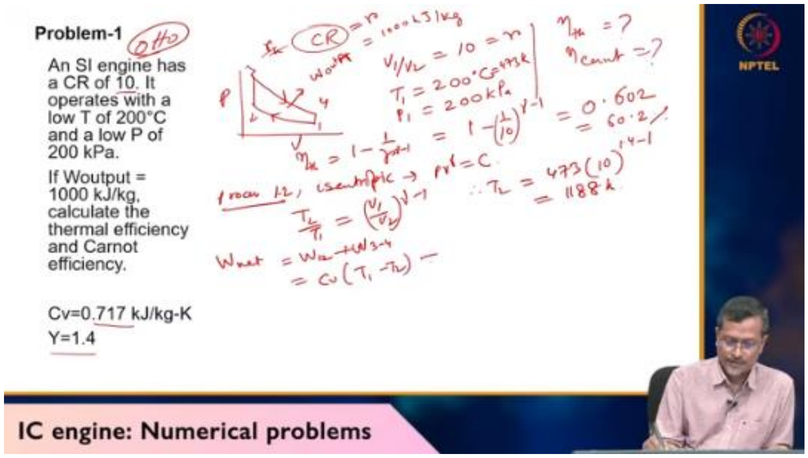
So, that means V1 by V2 equals 10 and operation with a low temperature 200 degree. So, T1 equals 200 degree centigrade and low pressure P1 equals 200 kPa kilopascal work output is given W output 1000 kg per kg, kg per kg means per kg of air or mass. Calculate the thermal efficiency. So, we have to calculate eta thermal eta Carnot.

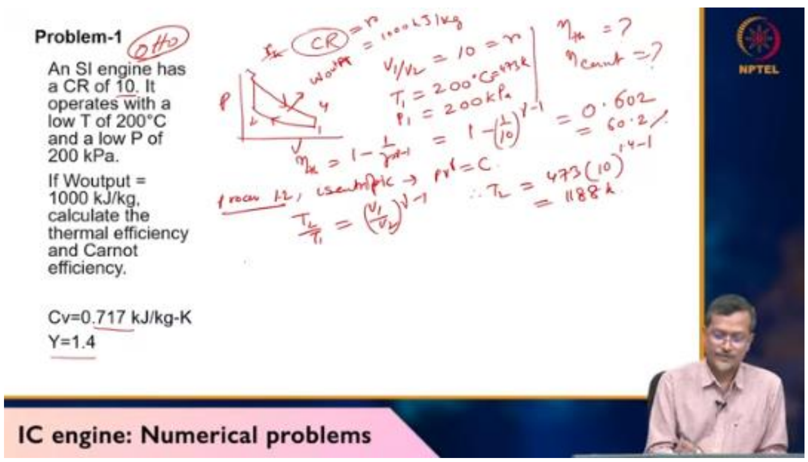
Given data Cv equals 0.717 gamma value also given. So, using this one we have to solve. So, first we have to see this temperature is given in centigrade. So, all the calculation will be done using Kelvin scale. So, T1 will be then 473 K, 200 plus 273.

Now, thermal efficiency eta thermal equals 1 minus 1 by gamma R power gamma minus 1 Cr or R. So, 1 minus 1 by 10 gamma minus 1. So, it is gamma means 1.4. So, the value will be coming 0.602 or 60.2 percent. Directly this formula is discussed, was discussed in previous lecture.

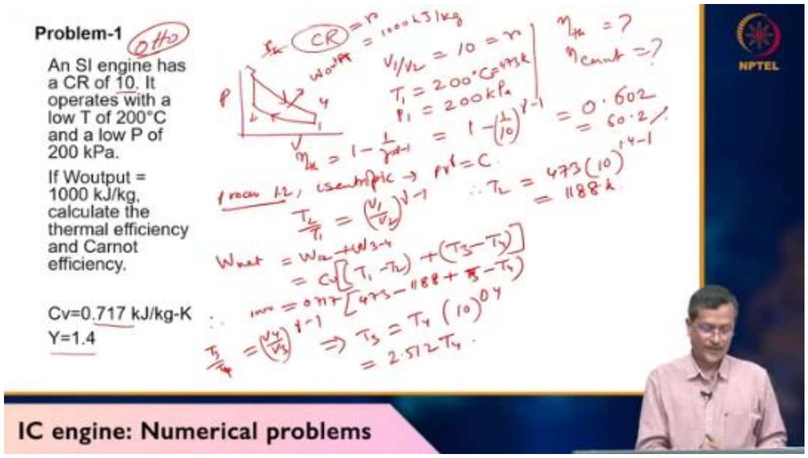
So, now process 1 to 2. is isentropic process. Isentropic process means PV per gamma equals constant. Now, T2 by T1 equals V1 by V2 gamma minus 1. Therefore, T2 equals T1, T1 is 473 and V1 by V2, you see V1 by V2 is compression ratio

it is 10, gamma means 1.4 minus 1, this value is coming 1188K. So, W net work output plus W 1 to 2 process compression work plus W 3 to 4 process. Now, 1 to 2 process CV T1 minus T2 plus T3 minus T4 we are assuming CV is constant okay now this value will be giving like this 1000 equals 0.717 T1 is given 473 minus 1188 we got plus T3 minus T4 okay now T3 by T4, T3 by T4 equals V3 by V4 by V3 gamma minus 1.





So, this will be giving T3 equals T4 10 0.4 equals 2.512 T4. So, we got this T4. Now, if I put numbering 1 and 2, now 1 and 2 gives, what will it give? 1000 divided by 0.717 plus 1188 minus 478 equals to 0.512 T4 minus T4. So, this will give

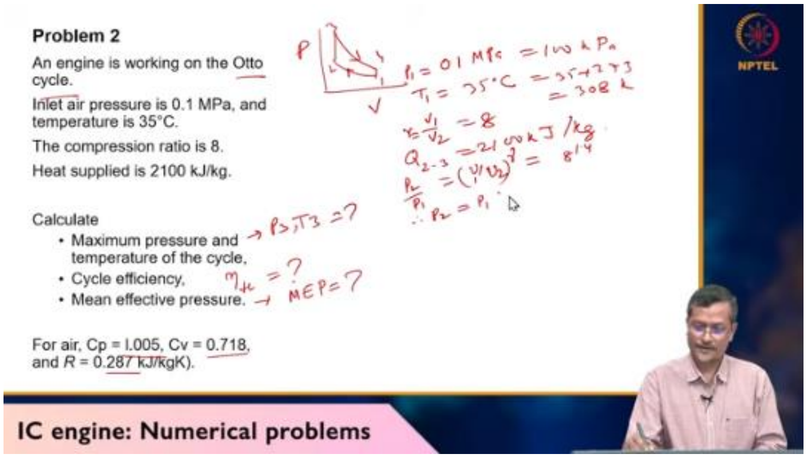


T4 equals 1395 k. So, now, therefore, T3 equals 2.512 T4 implies T3 equals 3505 k. Now, eta carnot equals 1 minus T low minus T high, 1 minus T low, low means 473, 473 minus, divided by T high 35, 3508, 3505, so 86.5 percent. Now, we will go to another problem, similar auto cycle problem. Here again, then PV you drop, 1, 2, 3, 4. There will be many IC engine books.

So, a student can follow the any IC engine book. So, I am using the Rajput book. So, they are in that book also there are lots of example problems are there student can solve. So, an engine working on the motorcycle inlet air pressure is given P1 is given 0.1 Mpa equals 100 kPa and Inlet temperature also given T1 equals 35 degrees centigrade equals 35 plus 273 equals 308 Kelvin.

And the compression ratio is given V1 by V2 equals 8. Now, heat supplied Q 223 is supplied 2100 kg per kg per kg of mass flow rate through the system r value is given 0.287 cp value also given cv value also given we have to calculate maximum pressure just p3 and temperature maximum pressure and temperature so t3 you have to calculate cycle efficiency eta thermal efficiency you have to calculate mean effective pressure, we have one formula I will show, we will see. So, P1 is 100 kilo Newton.

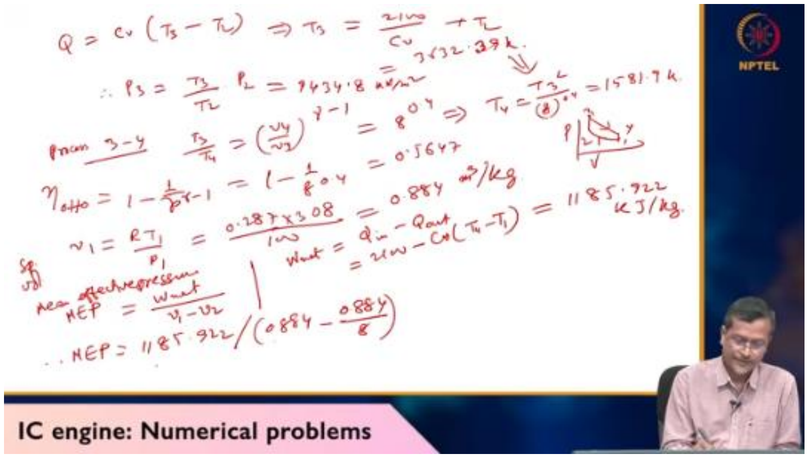
So, Q1 also given 20, 100. So, P2 by P1, P2 by P1 equals V1 by V2 divided by gamma equals 8 by 1.4. Therefore, P2 equals P1 into eight one point four okay so this uh this value is giving one eight three seven point nine one seven kilo newton per meter square so kpa or kilo newton per meter square okay t 2 by t 1 equals v 1 by v 2 equals 8 power 0.8 therefore t 2 is coming 707.59 k now p 2 v 2 by t 2 equals p 1 v 1 by t 1



equals p3 implies p3 equals t2 by t3 by t2 p2 okay now q equals cv t3 minus t2 equals implies t3 equals 2100 cv plus t2 okay so now So, it is coming like 3632.39 k, 39 k. Now, P3 T3 by T2 P2 equals 9434.8 kilo Newton per meter square. Now, process. T3 by T4 equals V4 by V3 power gamma minus 1 equals 80.4 implies T4 equals T3 8 power 0.4 equals 1581.9 k because T3 value already known. t 3 value is already calculated here t 3 is coming from here okay now now it out of cycle or thermal efficiency equals 1 minus 1 by r gamma minus 1 pressure ratio gamma minus 1 minus 1 by 8 0.4 equals 0.5647

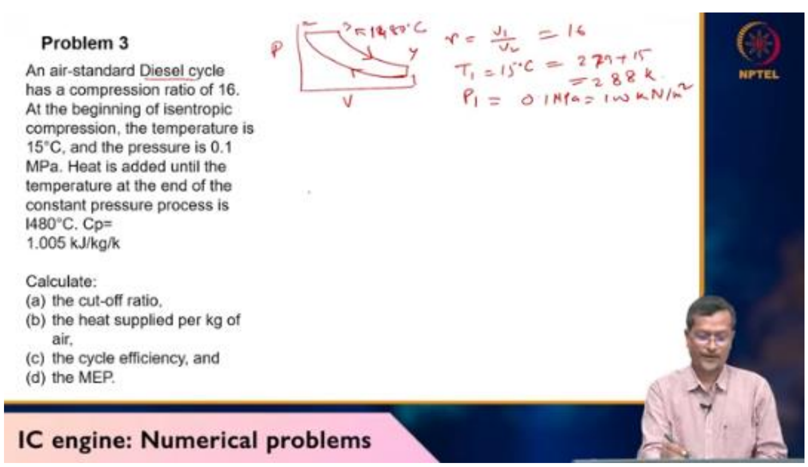
so V1 equals RT1 by P1 equals 0.287 into 308 divided by 100 equals 0.884 equals 0.884 meter cube per kg okay this is the specific volume this is specific volume okay now mean effective pressure mean effective pressure mep equals w net yet how much power we are getting and divide by specific volume v1 minus v2 so now w net equals q in minus q out so 2100 minus cv t4 minus t1 you see pv diagram pv It is like this, 1, 2, 3, 4. So, 4 and 1, this one heat exhaust. So, CV T4 minus T1.

Now, this value will be coming as 1185.922 kg per kg. So, therefore, MEP equals 1185.922 divided by 0.884 minus 0.884 divided by compression ratio that is 8. So, this is giving 1533 kilonewtons per meter square. So, this is your answer.



Now, we will go to another problem called diesel cycle. So, here in standard diesel cycle when you are talking about diesel cycle first you draw PV diagram. Then it is horizontal combustion and other points you connect 1, 2, 3, 4. And air standard diesel cycle has compression ratio 16. So, R equals V1 by V2 equals 16.

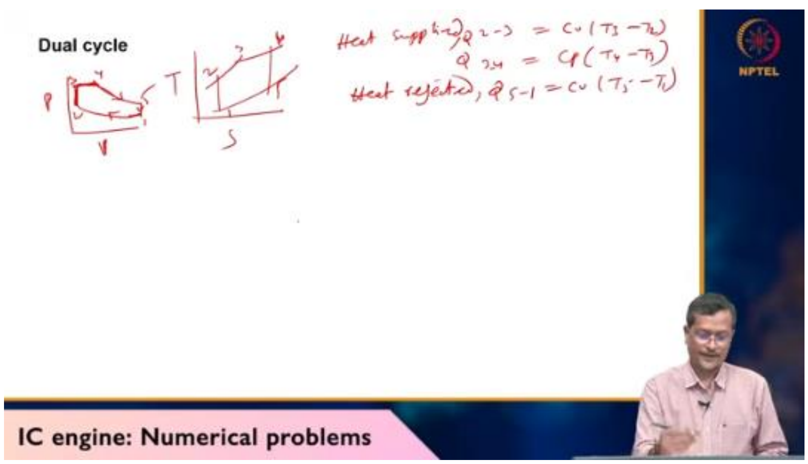
At the beginning of isentropic compression, the temperature is T1 is 15 degrees centigrade equals 273 plus 15 equals 288 K. Now, pressure pressure also given 0.1 mpa equals 100 kilo newton per meter square now heat is added at added until the temperature at the end of the constant pressure pulses is 1480 degrees centigrade okay this is 1480 degrees centigrade cp given calculate cutoff ratio cutoff ratio means v3 by v2 equals rc now cycle efficiency cycle efficiency eta equals eta equals 1 minus q2 by q1 heat rejection divided by heat addition so 1 minus 343.2 divided by 884.4 equals 0.62 or 61.2 percent so it can be obtained from other equation also like eta cycle from formula so let us ignore that one w net equals q 1 into eta cycle So, W net means net output will be lower than whatever heat input you have given.

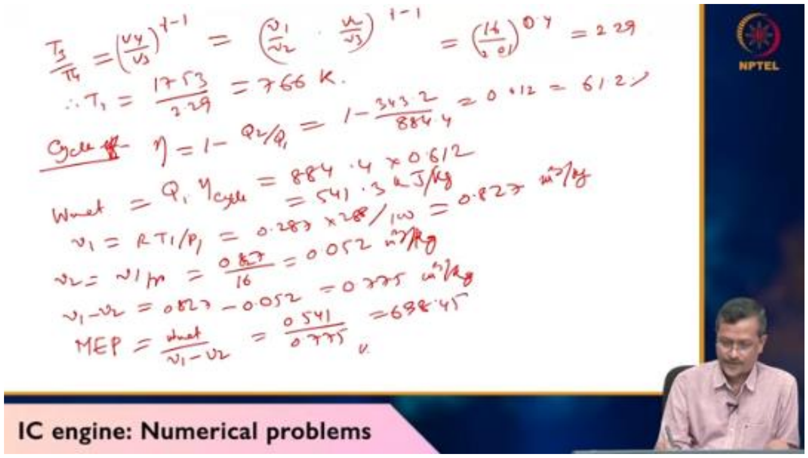


So, that is why multiplied by efficiency. So, 884.4 into 0.612. So, it is coming 541.3 kg per kg. Now, V1 RT1 by P1 0.287 into 288 divided by 100.

So it is giving 0.827 meter cube per kg. V2 equals V1 by R. R means compression ratio 0.827 divided by compression ratio 16. So it is giving 0.052 meter cube per kg. Now, V1 minus V2 equals 0.827 minus 0.052 equals 0.775 meter cube per kg. So, mean effective pressure MEP is W net divided by V1 minus V2 equals 0.541 0.775 equals 698.45

kpa this is your answer now dual cycle dual cycle i already told that auto cycle diesel cycle both you mix and you make another cycle called dual cycle so p v diagram so constant pressure you divide into two constant pressure and constant volume and you make the cycle one two three four so some portion constant volume process some portion constant pressure process then other portion other processes are same they call dual cycle If I draw TS diagram, it will be like this, vertical, vertical, 1, 2, 3, 4, 5, 2, 2, 3, 3, 2, 4, heat addition happening, so as I said 2, 2, 3, 3, 2, 4. So, heat supplied 2, 2, 3 equals Cv T3 minus T2 q 3 4 3 to 4 heat supplied c p constant pressure process t 4 minus t 3 okay heat rejected heat rejected heat q 5 to 1 so 5 4 5 5 to 1 c v t 5 minus t 1 Now, eta work done by heat supplied.





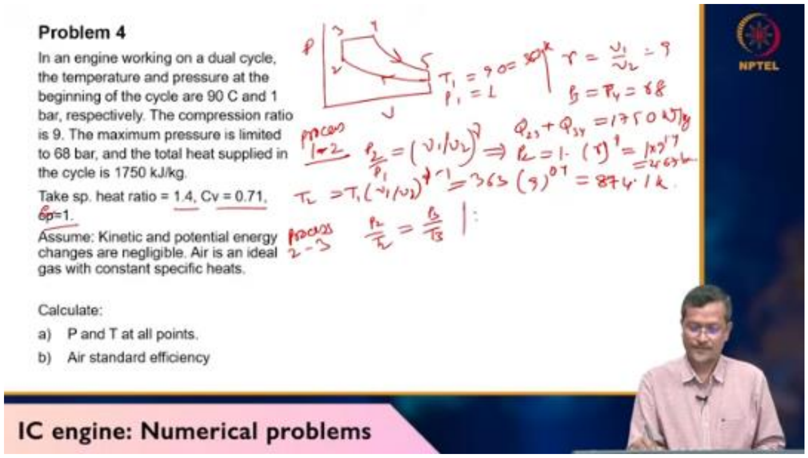
So, that formula we will use later. Let us see first one problem on dual cycle. So, in an engine working on dual cycle. So, PV 1, 2, 3, 4, 5. So, in walking dual cycle, temperature and pressure at the beginning, so T1 is given 90, P1 is 1 bar.

Now, compression ratio is given, R is given V1 by V2 is 9, maximum pressure limited to 68 bar. So, P3 equals P4 equals 68. The total heat supplied cycle, So, Q2 to 3 plus Q3 to 4 equals 1750 kJ per kg. Specific heat ratio given, Cv given, Cp given.

Assume kinetic and potential energy change is negligible, air is an ideal gas, constant specific heat. So, gamma is given 1.4, T1 is given 90. So, it will be like 90. 273, so 363K, P1 1 bar, RK 9, Q1 is given, P3 given. Now, 1, 2, 2 process, P2 by P1, V1 by V2 per gamma implies P2 equals 1 into RK

divided by gamma equals 1 9 power 1.4 is coming 21.67 bar okay so T2 T1 V1 by V2 gamma minus 1 so T1 is temperature is given 363 V1 by V2 is given pressure ratio 9 by 0.4 So, this is giving T2 value 874. Now, process 2 to 2. Process, this is process. Process 2 to 3.

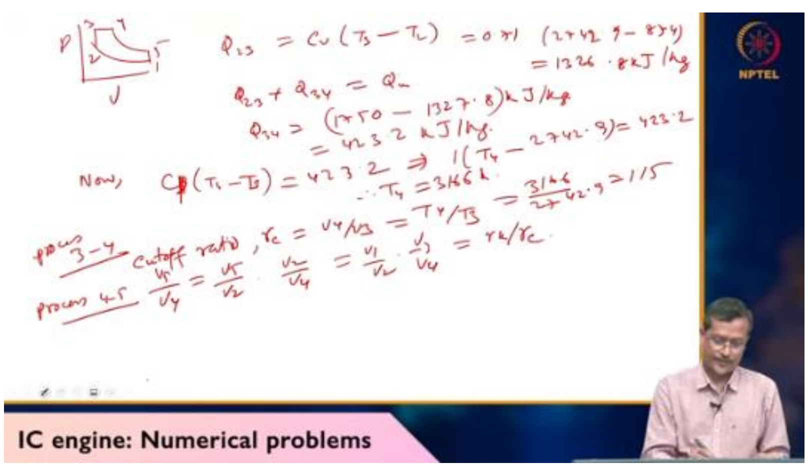
So, P2 by T2 equals P3 by T3. V is constant. So, V is cancelled out already. pv by t equals constant okay so t3 is giving t2 p3 by p2 equals 8741.168 divided by 21.67 equals 2742.9 k okay So, heat added constant volume, again I have to draw the PV 1, 2, 3, 4, 5.



So, heat added constant volume process is 2 to 3, Q 2 to 3 equals Cv T3 minus T2 equals 0.71 2742.9 minus 874 equals 1326.8 kJ per kg, Q23 plus Q34 equals Q total heat input. So, Q34 equals total heat input 1750 given minus 1326, 1326 we got already 0.8 kJ per kg. so this should be giving 423.2 kj per kg now cv equals a cv t4 minus t3 equals 423.2 so cv value is 1 is given there in the problem You see CP value is given 1, CV is 0.707.

Not CV, this is CP. So, CP value is 1 given, so 423. So, whatever data is given, you use that same data, you do not use another data, otherwise there will be error in result. So, 1 T4 minus 2742.9 equals 423.2. So, this is giving T4 equals 3166K.

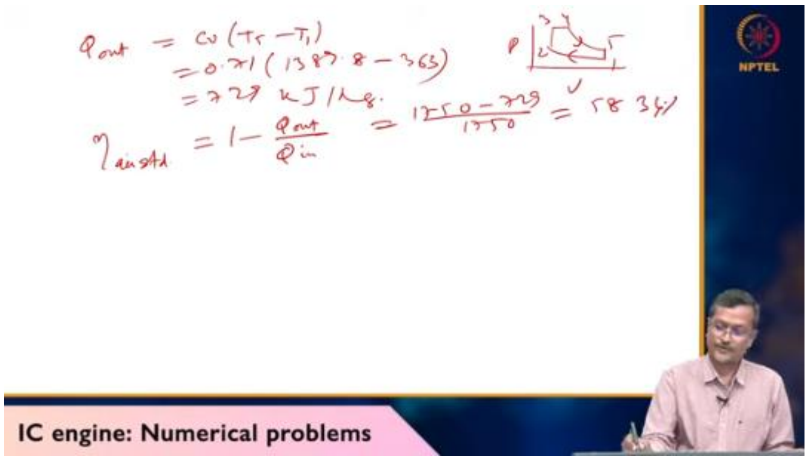
For constant pressure process 3 to 4 process cutoff ratio cutoff ratio RC equals V4 by V3 equals T4 by T3 equals 31662742.9 equals 1.15. Now, process 4 to 5. V5 by V4 equals V5 by V2, V2 by V4 equals V1 by V2 into V3 by V4 equals RK by RC. Now, P4 V4 per gamma equals P5 V5 per gamma.



Therefore, P5 equals V4, V5, P4 equals 68.RC by RK per gamma equals 68 into 1.15 divided by 9, 1.4 equals 3.81 bar. now T5 by T4 T5 by T4 equals V4 by V5 gamma minus

1 equals RC RK gamma minus 1 equals 1.15 by 9 0.4 plus 0.439 now T5 equals T4 0.439 equals 3166 into 0.439 because 1389.8 K so Q out output your exhaust heat CV constant volume process 1, 2, 3, 4, 5 PV. So, T5 minus T1 this constant volume process.

So, it is giving 0.71 1389.8 minus 363 equals 729 kg per kg. So, eta air standard efficiency 1 minus Q out divided by q in equals 1750 minus 729 by 1750. So, this is giving 58.34 percent. So, this is the solution.



Thank you very much for watching this lecture of IC engine. Next day we will start next topic. Thank you very much.