

Concepts of Thermodynamics
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Lecture – 68
Supplementary Lecture: Problem Solving with the Aid of a Computer

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The screenshot displays a MATLAB script on the left side of the screen, which defines the initial state (p1 = 95; t1 = 290; v1 = volume(air, t = t1, p = p1); v2 = v1/20; s2 = s1; s1 = entropy(air, t = t1, p = p1); p2 = pressure(air, v = v2, s = s2); t2 = temperature(air, v = v2, s = s2); p3 = p2; t3 = 1800; s3 = entropy(air, p = p3, t = t3); s4 = s1; v4 = v1) and calculates heat input (qh = h3 - h2) and heat output (ql = u1 - u4). On the right side, a p-v diagram is shown with a cycle consisting of four states: 1 (bottom-left), 2 (top-left), 3 (top-right), and 4 (bottom-right). The process 1-2 is isentropic compression, 2-3 is constant pressure heat addition, 3-4 is isentropic expansion, and 4-1 is constant pressure heat rejection. Handwritten notes include the equation $\oint \delta Q = \oint \delta W$ and a list of state conditions: 1) 95 kPa, 290 K (P, T); 2) $v_2 = \frac{v_1}{20}, s_2 = s_1$ (v, s); 3) T = 1800, P3 = P2 (T, P); 4) $s_4 = s_3, v_4 = v_1$ (s, v).

Hello and welcome to this session in which we are going to analyse a diesel engine. So, we have been given that we have a diesel engine with a compression ratio of 20 is to 1 ratio. So, let me first draw the p v diagram. So, we have a compression like this and then a heat addition at constant pressure and then an isentropic heat rejection, an isentropic expansion and followed by heat rejection. So, 1 to 2 is the isentropic compression, 2 to 3 is the constant pressure heat addition, 3 to 4 is the isentropic expansion and 4 to 1 is the heat rejection.

So, state 1 is given as 95 kilo Pascal 290 Kelvin slightly below the atmosphere because it is a suction process. State 2 so, because compression ratio is given as 20 is to 1 the specific volume at state 2 will be 1 20th the specific volume at state 1 ok. Moreover, the entropy at state 2 will be the same as the entropy at state 1 because it is an isentropic process; it is an isentropic compression process.

A state 3 because we are adding heat so, state 3 will be at a temperature of 1800 Kelvin which is the maximum temperature given. And, the pressure at point 3 will be the same

as pressure at point 2. Coming to state point 4 the space, the entropy at state point 4 will be equal to the entropy at state point 3. And, the specific volume at state point 4 will be equal to specific volume at state point 1.

So, the first point is quantified in terms of the pressure and temperature, the second in terms of specific volume and entropy, third in terms of temperature and pressure and the fourth in terms of entropy and specific volume. Let us proceed to the computer and see what we can get out of this.

So, p_1 is 95 t_1 is 290, so I have set the units in e s to be in Kelvin, v_1 will be the volume of air at t equal to t_1 and p equal to p_1 . As per the information about the compression ratio v_2 will be v_1 by 20 and s_2 equal to will be equal to s_1 where, s_1 equal to entropy of air t equal to t_1 and p equal to p_1 so far so good. So now, with the help of s_2 and v_2 we can find out p_2 ; p_2 is pressure of air at v equal to v_2 and s equal to s_2 .

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The screenshot shows a software interface with two panes. The left pane displays the following data:

```

p1 = 95; t1 = 290;
v1 = volume(air, t = t1, p = p1);
v2 =
s2 =
Unit Settings: SI K kPa kJ mass deg
s1 =
p1 = 95          p2 = 5929
s1 = 5.686      s2 = 5.686
t1 = 290        v1 = 0.8762
v2 = 0.04381
3 potential unit problems were detected
Calculation time = .0 sec.

```

The right pane contains a P-v diagram and a list of state conditions:

A diesel engine has a compression ratio of 20 with an inlet of 95 kPa, 290 K, state 1, with volume 0.5 L. The maximum cycle temperature is 1800 K. Find the maximum pressure, the net specific work and the thermal efficiency.

① 95 kPa, 290 K (P, T)
 ② $v_2 = \frac{v_1}{20}$, $s_2 = s_1$ (v, s)
 ③ $T = 1800$, $p_3 = p_2$ (T, p)
 ④ $s_4 = s_3$, $v_4 = v_1$ (s, v)

So, let us see what the pressure is; so, the pressure comes out to be approximately 5.9 mega Pascal that is a lot of pressure. So, p_3 will also be correspondingly equal to p_2 and t_3 will be also equal to 1800 Kelvin. So, then s_3 will be entropy of air at p equal to p_3 and t equal to t_3 and s_4 will be equal to s_1 , v_4 will be equal to v_1 .

So, now that we have all the points let us find out the network. So, if you recall the first law for a cycle closed integral of the total heat added will be equal to the closed integral of the total work done. So, because of this we can write q_h plus q_l will be equal to the network where, we will account for the sign of q appropriately. So, the heat added is during the process 2 to 3. So, q_h will be equal to h_3 minus h_2 because it is a constant pressure process. The heat addition will not be simply the difference in the internal energies. So, this should have been covered in theory class.

In case of a constant pressure process the heat added will be equal to the difference in enthalpies and not the internal energies because, you are already accounting for the constant pressure work as $p \cdot v$. So, u plus $p \cdot v$ will become h , this should be clear by now, but the q_l will be equal to u_1 minus u_4 because, the heat rejection is going on during process 1 to 4. So, during 1 to 4 the process is constant volume and as a result it will be simply u_1 minus u_4 . So, the task now remains is to find the internal energies and the enthalpies.

So, u_1 will be internal energy air, t equal to t_1 . So, let us write down the expression for t_2 because, we will need the temperature to find out the internal energy at point 2 or rather the enthalpy at point 2. So, h_3 is simply known because the temperature at point 3 is given as the highest temperature achievable in the cycle which is t_3 which is 1800 Kelvin.

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A diesel engine has a compression ratio of 20:1 with an inlet of 95 kPa, 290 K, state 1, with volume 0.5 L. The maximum cycle temperature is 1800 K. Find the maximum pressure, the net specific work and the thermal efficiency.

$\oint \delta Q = \oint \delta W$

$\eta = w/q_h$

① 95 kPa, 290 K (P, T)
 ② $v_2 = \frac{v_1}{20}, s_2 = s_1$ (v, s)
 ③ $T = 1800, P_3 = P_2$ (T, P)
 ④ $s_4 = s_3, v_4 = v_1$ (s, v)

And u_4 is the; so t_4 we can find out using s_4 and v_4 . So, with the help of this and the heat we have η is equal to w by q_h , this defines the thermal efficiency.

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Unit Settings: SI K kPa kJ mass deg

$\eta = 1$	$h_2 = 938.8$
v_4	$h_3 = 2003$
t_4	$p_1 = 95$
q_h	$p_2 = 5929$
q_h	$p_3 = 5929$
q_h	$q_h = 1065$
$q_l = 0$	$q_l = 0$
$s_1 = 5.686$	$s_2 = 5.686$
$s_3 = 6.499$	$s_4 = 5.686$
$t_1 = 290$	$t_2 = 905$
$t_3 = 1800$	$t_4 = 290$

$\eta = w/q_h$

A diesel engine has a compression ratio of 20:1 with an inlet of 95 kPa, 290 K, state 1, with volume 0.5 L. The maximum cycle temperature is 1800 K. Find the maximum pressure, the net specific work and the thermal efficiency.

$\oint \delta Q = \oint \delta W$

1) 95 kPa, 290 K (P, T)
 2) $v_2 = \frac{v_1}{20}$, $s_2 = s_1$ (v, s)
 3) $T = 1800$, $p_3 = p_2$ (T, P)
 4) $s_4 = s_3$, $v_4 = v_1$ (s, v)

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$q_l = 1065$	$q_l = 0$
$s_1 = 5.686$	$s_2 = 5.686$
$s_3 = 6.499$	$s_4 = 5.686$
$t_1 = 290$	$t_2 = 905$
$t_3 = 1800$	$t_4 = 290$
$u_1 = 207.1$	$u_4 = 207.1$
$v_1 = 0.8762$	$v_2 = 0.04381$
$v_4 = 0.8762$	$w = 1065$

$\eta = w/q_h$

A diesel engine has a compression ratio of 20:1 with an inlet of 95 kPa, 290 K, state 1, with volume 0.5 L. The maximum cycle temperature is 1800 K. Find the maximum pressure, the net specific work and the thermal efficiency.

$\oint \delta Q = \oint \delta W$

1) 95 kPa, 290 K (P, T)
 2) $v_2 = \frac{v_1}{20}$, $s_2 = s_1$ (v, s)
 3) $T = 1800$, $p_3 = p_2$ (T, P)
 4) $s_4 = s_3$, $v_4 = v_1$ (s, v)

So, the net specific work of the engine is 1065; there seems to be a small mistake because, q_l appears to be 0. So, let us have a look what is wrong. So, t_4 has come out surprisingly to be 290.

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The screenshot shows a software window with MATLAB code on the left and a handwritten diagram and notes on the right.

Code (Left):

```

v2 = v1/20
s2 = s1
s1 = entropy(air, t = t1, p = p1);
p2 = pressure(air, v = v2, s = s2);
t2 = temperature(air, v = v2, s = s2);
p3 = p2; t3 = 1800
s3 = entropy(air, p = p3, t = t3)
s4 = s3
v4 = v1
t4 = temperature(air, s = s4, v = v4)
qh + ql = w

qh = h3 - h2
ql = u1 - u4
u1 = interenergy(air, t = t1)
h2 = enthalpy(air, t = t2)
h3 = enthalpy(air, t = t3)
u4 = interenergy(air, t = t4)

```

Diagram and Notes (Right):

A P-v diagram for a Diesel cycle with states 1, 2, 3, and 4. The vertical axis is pressure (P) and the horizontal axis is volume (v). The cycle consists of: 1-2 (compression), 2-3 (constant pressure heat addition), 3-4 (expansion), and 4-1 (constant volume heat rejection). The area under 2-3-4-1 is shaded, representing net work. The equation $\oint \delta Q = \oint \delta W$ is written above the diagram.

Handwritten notes below the diagram:

- ① $95 \text{ kPa}, 290 \text{ K}$ (P, T)
- ② $v_2 = \frac{v_1}{20}, s_2 = s_1$ (v, s)
- ③ $T = 1800, p_3 = p_2$ (T, P)
- ④ $s_4 = s_3, v_4 = v_1$ (s, v)

So, let us see what is wrong. So, this is the mistake s_4 is not equal to s_1 rather it is equal to s_3 . So, because this is small mistake we were able to get points 4 and 1 identical ok. So, the q_l is equal to minus 430. So, we already seen that we are did not account for the sign and rotate simply $s q h$ plus $q l$. But, because q_l is negative we understand that the process from 4 to 1 is losing heat instead of gaining heat.

The heat gained is 1065 kilo Joule during process 2 to 3, as a result the work is 634.1 kilo Joule per kg and the thermal efficiency of the cycle is 59.56 percent. So, with this we conclude this session on diesel engine and I hope it will be clear on how to solve such kinds of questions in as and when you encounter them. So, with this we close the session I will see you next time bye.