welcome to today's lecture will start again as
usual our practice is by recapitulating what we   discussed in the last lecture namely work done
in different thermodynamical processes
 so we   talked about isothermal process isobaric process
isochoric process and most complicated of all is   the adiabatic process
 so different thermodynamical
processes which i am going to discuss now again   just to emphasize the physical aspect of
the calculations i did in the last lecture   well all these processes i will be talking about
are quasi static processes i repeatedly told you   what do i mean by a quasi static process that
means changes are in decimal small i make very   small change in my thermodynamic variables
so that the system can always be thought   to be in equilibrium
 so i will be considering
ideal gas for every instant of time   i can write pv is equal to nrt if i consider n
moles of ideal gas if not otherwise mentioned   i will be considering mono atomic ideal gas
okay
 so i will consider different quasistatic   thermodynamic processes and my working
substance is an ideal gas and will verify   or rather will use first law of thermodynamics
namely the conservation of energy   to justify different situation whether there is
a change in internal energy whether heat absorbed   or heat released these are the things i
am going to do in coming 20 25 minutes   before i do the adiabatic process at some length
ok
 so first process which we are going to discuss   is very simple isothermal process by the way
we have done mathematics in gory details in   the previous lecture
 so today i will just code the
results
 so isothermal process is temperature fixed   well temperature remains fixed if i can
draw a pv diagram this is my pressure   this is my volume this is an isothermal process
that means temperature constant which immediately   implies that $p_i v_i$ is c ci this subscript i this
denotes i am talking about an isothermal process   this is very very important its not the initial
value it depends on the process ok
 so this is an   isothermal process $p_i v_i$ is equal to c_i which
is equal to n r t t is a constant
 so this n r t   is a constant which is denoted here by c_i
 so in
an isothermal process i am going from $p_1 v_1 t$ to $p_2 v_2 t$ ok i can think of this is an isothermal
process in which i go from $p_1 v_1$ to p_2 v_2 obviously here you can see that

v 2 is greater
than v one which immediately implies that p one is   greater than p two ok
 so i am increasing pressure
volume decreases and these i am going from   high pressure to low pressure okay
and
this i will often call as expansion ok
 so isothermal process temperature remains
fixed internal energy does not change   but pressure and volume change i am
talking
about ideal gas internal energy is a function of temperature and since
temperature
is kept fixed in an isothermal process   internal energy does not change ok but
pressure
and volume do change we calculated the work done   the calculated work done is
pdv which is nothing
but if you go back to the previous slide we are   calculating the area under
this curve as i said
in the very beginning of this set and this work   done can be easily calculated
which is n r t
log v two by v one this is the final expression   for work done in an isothermal
process if i
consider expansion that means v two is greater   than v one which is the picture
i have shown here
you can immediately see work done is positive   which is this one okay what does
it mean let
us recall first law these i will keep writing   again and again almost in every
slide okay
this is my first law or conservation of energy   i have said d u is equal to
zero in this process
so delta q is equal to delta w work done is   positive that means delta q is
also positive
which implies system absorbs heat and converts to   work ok this is expansion
isothermal expansion in
which work done is positive system absorbs heat   and converts it to work now if
i think of
contraction what do we mean by contraction   contraction is v one is greater
than v two work
done is negative that means i am doing work on the   system ok work is done on
the system and heat so
delta q is negative delta w is negative and system   releases heat it does not
absorb it remember our
convention was whenever system absorbs heat ok   then delta q is positive and
system
does some work delta w is positive here   work is done on the system because
work done
is negative as a result system releases heat   these things will be very very
important when
we go to engine and refrigerator those things   have multiple thermodynamic
processes
 so we have
to be careful about the sign convention and we   should know when heat is
absorbed or when heat is
released ok now proceed we can do this isothermal   process calculation in an
alternative way which is

the same result you know p v this is the thing we are calculating p d v and how do you get p d v

i just use this equation p v is equal to n r t ok just to tell you something interesting

mathematically let us try to see what is v v is nothing but n r t over p so what

is change in v dv which is nothing but i am doing a differentiation n r t over p

square d p i put it back in this equation i want to calculate the work done i put

it back in this equation i get n r t now integral is not over d v i want to write

it in terms of d p

so i will be having a p e down by a factor of p square which i get from here and then d p

so i have changed the integration

from d v to d p and it goes from p one to p two ok

so there is a minus sign all together so

what you are getting you are getting n r t log of if we integrate one

p cancels out log of p two by p one ok

so now i have p two v

two is equal to p one by v one okay

so what do i get my work done as you see what i

have done i am writing again the same integral work done p d v from v one to v two p v is

equal to n r t

so i get v is equal to n r t over p t v is equal to minus n r t over p

square d p i am just taking the differentiation

so minus n r t p by p square d p and now

i integrate from the initial value of the pressure to the final value of pressure which

i get p two by p one and now use this result now use this return p two by p one is actually v

one by v two n r t log v one by v two ok this is always equal to n r t which is equal to the

constant c i i mentioned

so you see you just take care of this minus sign you get n r t log v 2 y v one ok if you compare with the previous light this is precisely the result we obtained

so you see

this result can be obtained in an alternative way i did it only to give you a different mathematical

procedure

so this is all about isothermal processes ok you should remember when work done is

positive which means system absorbs heat and when work done is negative which means the contraction

process in which work done is negative and the system releases heat and internal energy never

changes because i am considering an ideal gas in an ideal gas internal energy is entirely

a function of temperature t

so lets proceed we now have isochronic process volume is kept

fixed ok let us go slowly if volume kept fixed temperature and pressure they

do change and
so does internal energy because temperature changes means internal energy must change ok but
no work done because again work done is p d v and i have said in the beginning change in volume
d v is equal to 0.

so now i ask the question whether the system absorbs it or it releases
it ok that will be determined by the change in internal energy again as i told you recall the
first law delta q is equal to d u plus delta w this fellow is 0 in the present case so
you see internal energy dictates whether delta q is positive or delta q is negative so
heat absorbed that means increase in temperature as soon as you know there is an increase in
temperature and which always implies pressure is also increases because we know p
is proportional to t if v is constant then internal energy increases because temperature
has increased internal energy must increase now if heat released delta q is negative
d u is negative internal energy decreases
so again repeat isochoric process volume is
kept fixed no work done you are going from p 1 v t 1 to p 2 v t 2 since no work done delta q is
entirely determined by d u heat absorbed system temperature increases which also means pressure
also increases and internal energy increases since temperature increases in the reverse process
if delta u is negative or heat is released that means delta q is negative then d u will
be negative internal energy will decrease temperature will go down and
so does the pressure
so this is isochoric process now we go to the next process isobaric process isobaric
process means pressure is kept constant ok here pressure is kept constant volume and
temperature they do change ok as soon as you know the temperature change there is a change in
internal energy ok this is your isobaric process in which you go from p v 1 t 1 to p v 2 t 2.
so
pressure is kept fixed
so calculation of work done becomes very very simple and this is simply
given by this in going from this step to this step we have simply use the fact that p v is equal
to n r t initially it was p v one is equal to n r t one finally p v two is equal to n r t
two
so this expression is very transparent if i consider an isobaric expansion
so if you
consider your isobaric process and try to show it in the pv diagram you see pressure is constant

let us say this is some value and volume goes from v one to v two
 so this is your work done this area under the curve is work done and
that is this is v two v one
 so you know area   under this curve is p v two minus v1 which i
can write also in terms of temperature only   ok if there is an expansion that
means v2 i am
going this way if i go this way v2 is greater   than v1 which implies t two is
greater than t
one again if pressure is kept constant volume   is proportional to temperature
ok because p v is
equal to n r t for an ideal gas and you know that   pressure is kept constant
volume is proportional
to temperature
 so v two greater than v one implies   t two is greater than t one
 so work done is
positive there is a change in internal energy   which is also positive because
temperature has
gone off internal energy being proportional   to temperature for an ideal gas
must also
go up and system absorbs it ok
 so delta q   is equal to d u plus delta w it
 so happens
this fellow is positive work done is positive   d u is also positive
 so i must have delta q
positive which means system absorbs it ok so   now we think of contraction
contraction
means remember your v 2 is final value and v   1 is the initial value
 so contraction
process if i draw in p v diagram you are coming from v one to v two
 so you see work done definitely work done
here since v 1 is greater than v 2 work done   is negative change in internal
energy is negative
and system releases heat because in this first law   d u is negative delta w is
negative
 so delta q
is also negative
 so so far we have summarized   three processes first isothermal isothermal
what is important about isothermal   temperature is kept fixed whereas pressure
and
volume change satisfying the relation p v is equal   to n r t which i have
denoted by a constant c sub
i ok internal energy does not change and you can   calculate the work done and
you can find out very
easily when work done is positive system absorbs   heat and wherever work is
done on the system which
releases heat ok this is isothermal and then i   gave you an alternative way of
same derivation
just to show you some mathematical trick   finally isochoric and isobaric
processes isochoric
process volume is kept fixed but temperature and   pressure change and
 so does internal energy
and hence you can calculate very easily   the expression for the heat absorbed
or released
which is simply given in terms of the change   in internal energy there is no

work done in an isochoric process whereas in the isobaric process pressure is constant but volume temperature can change but they change in such a way that v is proportional to temperature it must happen because pv is equal to nrt okay pressure is kept constant now here also internal energy changes and you can talk about two processes one is expansion and one is contraction here one has to be careful you always be careful remember v two is my final volume v one is my initial volume and i am going from p v one t one to p v two t two these three processes are unique in one sense or they have something common in some sense what is that i have three thermodynamic variables pressure volume and temperature in all these three processes i mentioned here i see two of them are changing one is kept fixed now i will go to the most complicated one which is called the adiabatic process in an adiabatic process there is no heat exchange

so i can write delta q is zero
so it will be an interplay between the internal energy and the work done what is most important here that pressure temperature and volume all the thermodynamic variables change

so p 1 v 1 t 1 p 2 v 2 t 2 i am starting from p 1 v 1 t 1 i am going to p 2 v 2 t 2 ok in deriving the work done in an adiabatic process i proved c p minus c v is equal to r for ideal gas throughout this discussion we are considering n moles of ideal gas for example or n is equal to one you can set if you

so is cp minus cv is equal to r and the process is characterized by pv gamma is equal to constant it is not pv is equal to constant pv is equal to constant is a characteristic of an isothermal process in which temperature is constant pv is equal to energy for ideal gas if temperature is constant pv must be equal to constant but here temperature is not constant hence we have a different process equation describing my pv diagram which is pv gamma is equal to constant where gamma is equal to cp over cv

so in an isothermal process p i v i is equal to c i for an adiabatic process p a v a to the power gamma is equal to c a please remember gamma is always greater than one ok c p always exceeds c v thanks to this relationship ok

so now i can draw things in a pv diagram i give you two curves ok these two curves intersect at some point which i am denoting by v naught and p naught i am asking the question by looking at these two curves can you tell me which one is isothermal and which

one is adiabatic
remember one is characterized by the equation $p_i v_i$ is equal to c_i whereas the other
namely the adiabatic process is characterized by this equation here ok now you have to think
a little bit but i can tell by just looking at these two pv diagrams this is adiabatic process
this is isothermal process how do you do that they intersect at the point p_0 v_0
v naught you can immediately see that the curve which i denoted by adiabatic
ok this is steeper this is steeper ok
 so you should look at this slope you can
look at the slope and see which curve is steeper adiabatic is always steeper than the
isothermal which i am going to show in few lines in the coming slide ok
 so question is
i have two curves in the pv plane they intersect at a point p naught v naught i am
asking the question which curve do you think represents an isothermal process and
which represents an adiabatic process i am saying this one which has a steeper slope at the point of
intersection is representing an adiabatic process the other one is an isothermal process
let me give you a very quick proof of this thing please remember this picture in
your mind ok
 so isothermal process isothermal in isothermal process i have $p_i v_i$ is
equal to c_i whereas in the adiabatic process i have $p_a v_a$ raise to the power gamma is equal
to c_a ok now let us refer to isothermal process p_i is equal to c_i by v_i lets calculate the
slope in an isothermal process $\frac{\partial}{\partial v_i}$ which is nothing but c_i by v_i square but at the point v naught what is
v naught let us go to the previous light this point of intersection i am calculating
this slope here ok
 so this quantity now thanks to this equation
i can write c_i as minus p_i v_i by v_i square at the point v naught i got rid
of the constant c_i completely and i can find out what is the expression i can
immediately find out this is nothing but $p_i v_i$ by v_i square i cancel one of this and this is getting at p naught v naught
 so this slope is given by
p naught v naught this is the slope of the isothermal curve at the point of
intersection now let us go to the adiabatic let us go to the adiabatic process in an adiabatic
process on the other hand i have that equation ok let me rewrite it is equal to c_a i want to
calculate what is $\frac{\partial p_a}{\partial v_a}$ again at the point p naught v naught point of intersection if you
calculate this this turns out to be gamma c_a v_a gamma plus one now what is c_a
c_a is p

a v a gamma and remember i am calculating at   p naught v naught here also its better
to mention that it is p naught v naught   ok
 so if i do that immediately one can
calculate i will not show all these steps gamma   p naught v naught
 so you compare these two
this is the slope of the isothermal curve   this is the slope of the adiabatic curve where at the point of at the point of intersection which is designated by the
coordinates p naught and v naught you see   this is two curves
 so whatever is steeper
is adiabatic whatever is not
 so stiff   is isothermal
 so slope of the adiabatic is
gamma times this is i write it separately gamma   times p naught v naught which is nothing but this slope of the isothermal
 so this is the question i
posed in the last class i gave you hints also   that calculate the slope slope of the adiabatic
at the point of intersection is gamma times more   the slope of the isothermal that is why i am
saying that adiabatic curve is steeper than the   isothermal curve now we can
ask the question that given two curves on the pv diagram ok lets say i know this is my adiabatic   this is my isothermal this is my adiabatic
this is my isothermal lets call this point of   intersection as o which has coordinates p naught
v naught ok now lets consider an expansion process that means from v naught i go to some v two
which is here let us say this is my v two and also a contraction process start from v zero and go to some v one so
this is your v two lets say this is your v one ok this is your v zero ok now ask the question if i consider an expansion
process work done is more in which process   adiabatic or isothermal if i start from saying
v naught ok let me address this question   i have defined an expansion process
i have defined a contraction process   and work done will be more in
which process in both the cases   in adiabatic or in isothermal the picture itself
has the answer lets discuss this let us start by   considering the expansion process starting from v
naught to v two ok and i have an adiabatic process   and also an isothermal process what is the work
done in the adiabatic process this is simply the the area under this curve ok
 so you can easily look at this area under
the curve and that is your work done   now what is the work done in an isothermal
process this will be this area plus this area
 so in this expansion process you can see wagdon in the isothermal process is more ok whereas if you look at the contraction process
you see your isothermal carbs lies lower than the   adiabatic curve
 so this is the work done in the
isothermal process whereas this is the work done in the adiabatic process which includes the
smaller part and also this bigger parts

so in the contraction process remember both the processes i am starting from v naught
so you have to consider the area starting from here okay
so contraction process on the other hand adiabatic work is more work is more is more please note in an expansion process
work done is positive while in a contraction or compression process work done is negative which means work is being done on the system
so when i say that work done is more in the adiabatic process in a contraction from v 0 to v 1 i refer to the
magnitude of the work it means i need to do more work on the system in the idea basic process
so what we learnt in these two slides that adiabatic curve is steeper slope of
the adiabatic curve is gamma times more the slope of the isothermal curve at the point of
intersection please remember gamma is greater than one what is the consequence from the intersection
point which is at p naught v naught you consider an expansion of to a volume v two work
done in the isothermal process is more in comparison to the work done in the adiabatic
process because isothermal process has this additional area on the other hand it is reverse
if you consider contraction process in which adiabatic curve lies above the isothermal curve
and adiabatic work done is more because you have to include these area this small area also
this is what i wanted to say about to subtle issues about the adiabatic process i repeat it
is the most complicated because you are changing all the thermodynamic variables you have at
hand namely pressure volume and temperature now we calculated the work done work done is of
this form which is n r t one minus t2 gamma y1 t2 is your final temperature t1 is your
initial temperature that is how we have fixed our notation if t1 is greater than t2 okay
that means you are going to a lower temperature internal energy definitely will decrease
because it is a function of temperature rather proportional to temperature work
done is positive t 2 is greater than t 1 which means you are going to a higher
temperature starting from the lower temperature internal energy will increase and work done
is negative well remember here delta q is zero which tells me delta w this is very important i just wanted
to show few more mathematical steps since we have this relation all
through in an adiabatic process we always have this relation satisfied p one v one
gamma is equal to p two v two gamma is equal to c a i can express this entire work

done in terms of volume only c a   carries the information about the pressure
so
this is the expression which you can also write   in terms of c a this may be
useful in our later
discussions
 so this completes our recapitulation   thorough discussion of work done in
different
thermodynamic processes mathematics i have not   done this class because all
these mathematical
steps were done in the previous class but but   this subtle issues which i
didn't consider in the
previous lecture i have unfolded them
 so that you   understand this processes by heart we need to
use these processes in the definition of engine   and refrigerator to which i am
going to proceed
now okay before that i have to bring in notion of   reversibility what do you
mean by a reversible
process we have been talking about quasi static   process
 so whatever process we have used
 so far
are quasi static small changes system is always   in equilibrium or at least i
can assume
within the time scale of experiment the   system is in equilibrium if it is an
ideal gas i
can write pv is equal to nrt furthermore i will   now assume that it is
non-dissipative no friction
or viscosity there is no dissipative force ok so   i have already given these
hints that you can have
a forward process or a backward process once again   i do a p b diagram i do not
care whether it is
isotherm or whether it is adiabatic i just draw   a preview diagram
 so this is my volume and this
is my pv diagram i am going from let us say a   to b what do a and b imply those
imply that
initial values p i v i t i b 1 v 1 t 1 or p 2 v 2   2 which is b ok
 so this is my forward process let
us say ok forward process takes me to something   p one v one t one two p two v
two t two ok now if
i revert the direction of arrow what does it mean   i mean that i am going from
p two v two t
two to p one v one t one
 so forward process   means i am going from p one v one t one two
p two v two t two whereas backward process   implies the reverse i am going from
p p2 v2 t2
to p1 v1 and t1 okay a reversible process means   this forward and backward
processes are completely
equivalent what does it mean if in this process let us say forward process in
the forward process i have delta cube heat supplied or heat
released delta w is the total work done   on the system or by the system delta
u   is the change in internal energy if this represent
my forward process in the backward process i should have minus delta cube minus
delta w minus
delta u ok that is what i mean when i say forward   and backward processes are
completely equivalent

if i go from a to b delta q is heat supplied   or is extracted from the system delta w is work
done net work done on the system or by the system   delta u is net change in the internal
energy in the reverse process when i go from   b two a everything should be negative delta q goes
to minus delta q if i absorb a heat delta q in the   forward process i must release an amount of it
which is minus delta q in the reverse process   similarly for work similarly for internal
energy if internal energy change net change   is positive and amount is delta u in
the reverse process it will decrease   by an amount delta u same amount this is what
i mean by forward and backward process and in a   reversible process these are equivalent in the
following sense which i have elaborated here   now if you consider a finite process from
a to b which i have drawn here you can take   any section of this let us say this is from
c to d a small part of the entire p v diagram   this small part should also be reversible ok what
do we mean by that in this small part again i have   delta q delta w and delta u if i do a
reverse
 so i can go from c to d or d two c   ok the same equivalence that delta q goes to
minus delta q delta w goes to minus delta w   and delta u goes to minus delta u in the backward
process which is here from c to d holds true   ok
 so what i mean to say here if i
have a reversible process every small   segment of this process must be reversible
so this equivalence what i have said is valid   obviously it should be quasi static
otherwise i cannot define internal energy   work done in the intermediate processes my
system should be at equilibrium at every instant   of time
 so it is quasi static and secondly this
connection this equivalence i have presented here   ok we hold true only i have no dissipative
force no friction no viscosity then i can have   a reversible process ok
 so all the processes
i will talk about
 so far its quasi static class reversible ok with an advantage what is the advantage of
reversible process if i know the forward process   i know delta q delta w and delta u for a forward
process i know it for the backward process also   similarly if i pick up a small segment of
the process as i have shown it here c d   ok in this small segment also if i know
the quantities for the forward process   i will immediately know the
quantities for the reverse process   ok

so forward and backward process or i call it sometimes forward and reverse process they are equivalent they have a connection i know about the one process i immediately get to know about other processes
so the concept of reversibility is very very important throughout thermodynamics and it turns out to be very important in the next set in which i am going to define engine and refrigerator ok
so now brings in the concept of heat engine why thermodynamics is a very important subject ok its very important subject because of this possibility of constructing heat engines and reservoirs ok if you go back to history you will see entire industrial revolution started from steam engine ok
so engines are very very important because i need work i need to extract work and work i can get from heat engines i need refrigerator in hot weather and the principle of refrigerator refrigerator works based on the laws of thermodynamics
so what do we mean by engine and engine i will have a working substance for example i gave you the example of stem engine steam in stem engine is the working substance but in our case we have calculated work done from ideal gas in various thermodynamic processes
so we will consider ideal gas okay it works in a closed cycle what does it mean if i start from p t v these are my initial thermodynamic variables at the end of one cycle i should come back to pvt or rather this defines a cycle for me i start from initial value values of pressure temperature and volume my final value should also be the same p t and v this is a cycle and engine goes in a closed cycle that is obvious it has to go in a closed cycle
so that we can keep on getting work from the engine but also what is obvious that involves multiple thermodynamic processes why multiple we have seen four thermodynamic processes none of the processes which we have discussed so far can bring you back to same p v and t ok
so you involve multiple thermodynamic processes then only you can come back to your initial thermodynamic variables someone talks about isothermal temperature fixed but pressure and volume will always change in the isothermal process
so i must have some other process which you will soon see an adiabatic process to bring pressure and volume to an initial initial parameters but not a single adiabatic not a single isothermal will do the job for me i need multiple processes how many will soon see when we discuss about

carnal engines

so i have an working substance   this working or the working goes in a closed cycle thats multiple thermodynamic process i start   from p t v i should come back to p t v works

in a closed loop between two heat reservoirs   ok

so engine assumes the existence of

two heat resolvers one is hot which is   at temperature t one another is cold which is

temperature t two

so i write it t one greater than   t two

so this working stuff substance will work

in a cycle between these two heat reservoirs   with temperature t one and t two the

reservoirs they are very big if you   like they have infinite heat capacity how much heat you may extract from them   their temperature do not change

so t one and

t two are fixed t one and t two are fixed   an engine absorbs a heat which is amount q

one from the hot reservoir and it releases   some heat which is q two to the cold reservoir and

you know conservation of energy is tells us w is   equal to q one minus q two what about internal

energy internal energy cannot change i told you   i am coming back to the same state

same thermodynamic state means same   thermodynamic state of variables

so initial

temperature and final temperature after a   closed loop they are the same and internal energy

for an ideal gas is proportional to temperature

so d u or change in internal energy is zero so

we do not care about the internal energy here   ok

so what is the essence i have a working

substance which i choose to be ideal gas works   in a closed loop ok between two heat resolvers

one is having temperature t one other is having   temperature t two t one is greater than t

two it absorbs heat from the hot reservoir   the amount is q one and releases some heat

to the cold reservoir with lower temperature   ok is q two

so work done by the system is w q one

minus q two this is conservation of energy but   change in internal energy is zero because initial

temperature and final temperature happen to be the   same

so lets do it pictorially

so lets say this is

my hot resolver t1 this is my cold resort wire t2 this is my working substance and it goes in

a cycle ok it goes in a cycle means again i   am saying initial value of thermodynamic

parameters at a p v t after a closed loop   the value is again p v t and it going over many

many cycles ok

so it is the heat absorbed which   i show by this arrow is q one it released to this

is q two ok and then w is the work i can extract   from the engine over a cycle ok is w and
conservation of energy tells me this one
 so heat absorbed in a closed cycle one
cycle is q one heat release to t two   again in a closed cycle is q two and work done
is q one minus q two
 so i am extracting some work   from the engine and this is the work done
over one complete cycle now one can define   efficiency of an engine efficiency is defined
in the following work done by heat absorbed   in a complete cycle ok that is simply q 1
minus q 2 over q 1.

 so this is the expression   this is the expression
 so what could
be the maximum value of this ok   what is the maximum value of it i can write
is w by q 1 maximum value possible value when i can set q two is equal to zero ok
then eta will be one now it is a big question
 so you see that i make q two smaller and smaller
efficiency of the engine goes higher and higher   okay question is can i make u two
disappear completely from the problem
 so system absorbs heat q one and converts
it to work then the efficiency will be   identity and that is a fantastic situation amount
of heat is applied is entirely gets converted   to the work done question is is it
possible construct an engine whose   efficiency is perfectly one will come to the answer to this question very shortly
 so this is engine what is engine in a
nutshell it absorbs heat from a hot reservoir   releases heat to a cold reservoir and rest of
the mount q one minus q two is converted to   work at least engine provides us work at the
cost of heat energy i supply to the engine   now one can operate the engine in reverse order
and that gives what we call the refrigerator
 so i should not call it heat refrigerator
i call it simply refrigerator ok hot reservoir and cold reservoir i again have two
reservoirs one is hot one is cold and i am asking   the question what happens in a complete cycle
ok heat absorbed from the cold reservoir q2 note   earlier in the case of engine heat
was absorbed from the hot reservoir   which was having a temperature t one
refrigerator does the other way round   i told you refrigerator works in a reverse way
so heat absorbed from the cold reservoir wire   is q2 it is taking heat from the
cold reservoir and released heat   to the hot reservoir
 so it is releasing heat to
the hot reservoir and this is funny

so it takes   heat from the cold reservoir
so cold reservoir it
takes heat and dumps it to the hot reservoir ok   now this is an abnormal
process engine it was
fine it was taking heat from the hot reservoir   releasing into the cold
reservoir and in
the process it was giving us some work   here since it is the other way around i
have
to do some work on the refrigerator ok please   note work done on the system
these are all in a
complete cycle in a complete cycle work done on   the system is w
so one can define a coefficient
of performance heat absorbed by work done   ok
so heat absorbed from the cold reservoir heat
release to the hot reservoir this difference   with the heat engines one should
bear in mind
furthermore this time i am not getting work out   of the system rather work is
done on the system
okay now proceed again pictorially if i draw it this is my hot reservoir t one
this is my
cold reservoir t two this refrigerator fellow   again i will choose to be ideal
gas if you like it
could be anything ok now it absorbs heat from here   follow the arrows i have
drawn q 2 amount of
heat it absorbs q one amount of heat it comes   and then q one should be equal
to the work done
on it q two plus w this satisfies my conservation   ok i take q two amount of
hit and dump it to
this now i have a coefficient of performance   which i have defined heat
absorbed by work done so
q two by q one minus q two what will be my purpose   i want to have w is equal
to
zero ideal situation ideal   i would like to have w is equal to zero if w
is equal to zero you see phi tends to infinity
so what i will do i will extract heat from a cold
reservoir and i will dump it to a hot resorb wire   but no work is required ok
or rather i
will keep on working in a closed cycle   i will keep on extracting heat from the
cold
reservoir and no work is necessary to be done on   the system if that ideal
situation i can achieve
then w will be equal to 0 and phi will be infinity
so in engine case ideal situation maximum value
of eta was one we asked the question can i have   an engine which has efficiency
unity
similarly here i live with the question   can i construct a refrigerator whose
coefficient of performance will be infinity   no work will be needed it will
extract heat from the cold reservoir   and i will keep on continuing doing that
in a
cycle answer is both the cases answer is no why no   that you will discuss in
the next lecture when i
introduce you to the second law of thermodynamics   in the process i will tell
you about two processes
or two possible machines one perpetual motion of   first kind and secondly

perpetual motion of
second kind will show both are impossible   one because of the first law and other because of
the second law
 so i stopped the class here today you