THERMODYNAMICS

NJ-OER TOPIC-15

Learning Outcomes

Differentiate states from processes
Relate change of internal energy to heat given to the system and work done by the system
Identify properties of isothermal, adiabatic, isobaric and isovolumic(isochoric) processes
Complete a P V T table of states
Complete a U Q W table for processes and cycles
Draw and interpret a PV diagram for a process
Apply conservation of energy to heat cycles
Calculate efficiency of different heat cycles including Carnot cycle

Concepts

U=Internal Energy
Q = Heat
Q is positive when heat is given to the system
Q is negative when heat is exhausted
W= Work done by the system
W is positive when work is done by the system
W is negative when work is done to the system
Cp= specific heat at constant pressure
Cv= specific heat at constant volume
e=efficiency
S=Entropy

Units

SI UNITS

Heat, internal energy and work done are in Joules

Efficiency and Entropy are dimensionless

Formulas and Constants

U= 3/2 NkT =3/2 nRT monatomic gas
ΔU = 3/2 n R ΔT monatomic gas

ΔU = Q + Won (First Law of Thermodynamics)
or ΔU = Q – WBy
Wby = - Area under PV graph

SPECIAL CASES
Wby= −PΔV (only for $isobaric\ process$)
ΔU = 0 (only for isothermal process)
W = 0 (only for isovolumetric $process$)
Q =0 (only for adiabatic process)
ΔU = 0 (For all cycles)

KEY STRATEGIES

- Label the states with A,B,C,D index
- Label processes with AB, BC, CD, DA index
- If any of the P,V,T values are not given, estimate them using the ideal gas law
- Write the zeroes of the processes using the properties of isothermal, adiabatic, isovolumic processes
- Using U=Q-W find the unknowns for each process
- deltaU = 0 for a cycle
- For a heat engine, identify Qin, Qout, Wnet and find efficiency

CLASSWORK FOR U Q W TABLE

An ideal gas goes through a cycle with 4 process starting from a state "A"
A->B is an isothermal expansion and 30J work is done
B->C is an isobaric contraction where internal energy is decreased by 25J and 40J of heat is exhausted. (deltaU=-25 , deltaQ=-40)
C->D is adiabatic where internal energy is increased by 20J
D->A is isovolumic where 5J heat is given to the system

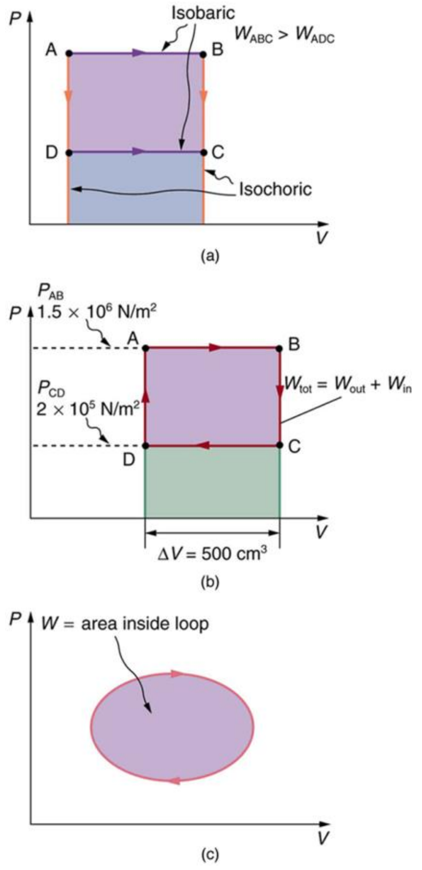
Process	U	Q	W
isothermal	0		
adiabatic		0	
isovolumic			0

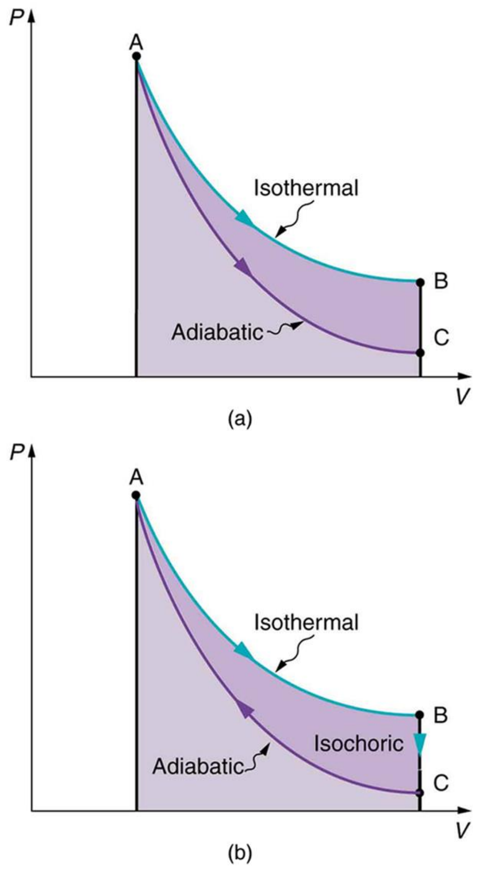
Complete the U Q W Table and find the missing values. Verify that this is a cycle by adding change of internal energy. Identify Qin, Qout and Wnet. Consider the zeroes of the table on the right. Efficiency is Qin/Wnet

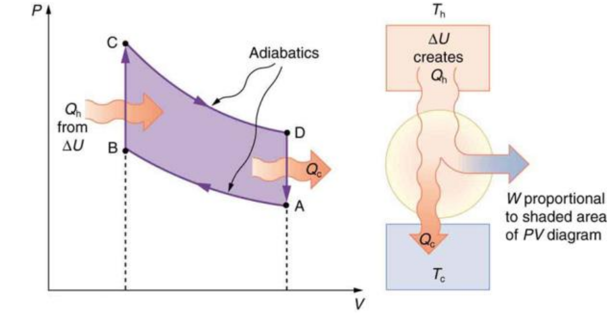
U = Q - W

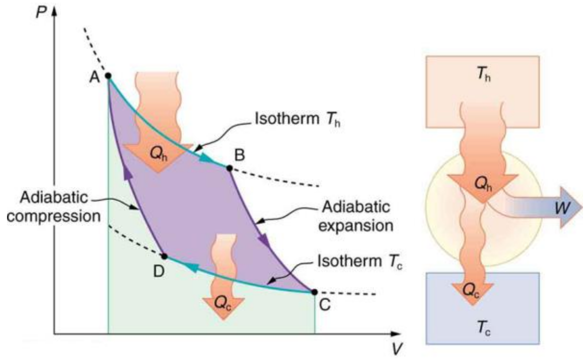
PROCESS	U	Q	W
A->B isothermal			30
B->C isobaric	-25	-40	
C->D adiabatic	20		
D->A isochoric		5	
TOTAL FOR THE CYCLE:	0	|Qin|-|Qout|	Wnet

TYPICAL PV GRAPHS FOR PROCESSES / CYCLES









ACTIVITY

- Open https://www.geogebra.org/m/KAZHEN8c
- Start your cycle (Point 1) at P1=40 kPa and V1= 1m^3
- Construct the following 4 step cycles and complete an approximate PVT table using the values that you measure from the graph

A) Isothermal expansion, isovolumic pressure drop, isochoric compression, isobaric back to Point 1

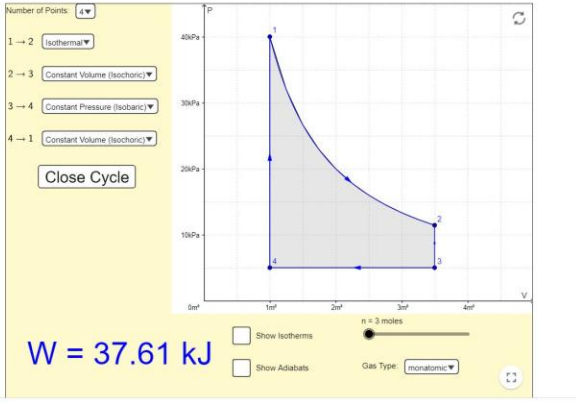
B) Otto cycle (adiabatic, isochoric, adiabatic, isochoric)

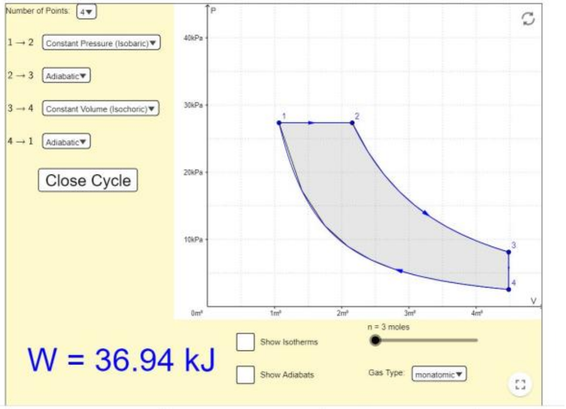
C) Diesel cycle (Isobaric, adiabatic, isochoric, adiabatic)

D) Carnot cycle (isothermal, adiabatic, isothermal, adiabatic)

E) Come up with your own cycle

You have to move the points closer in the beginning and adjust them so that the cycle is complete without the need of a fifth process.





CLASSWORK FOR PV GRAPH

Draw an approximate PV graph for each of the following process. Make sure you indicate the direction using an arrow

Q1) Isobaric expansion at 30kPa pressure from 2m^3 volume to 3m^3 volume
Q2) An ideal gas is heated in a locked piston with 4m^3 volume. As a result, its pressure is increased from 40 kPa to 60kPa
Q3) A diatomic ideal gas goes through an adiabatic expansion from 20.0 kPa pressure and 1.0 m^3 volume to 1.5 m^3 volume. (gamma=1.4 Pf=11.3 kPa)
Q4) The pressure of a gas is increased from 25 kPa to 50kPa isothermally. (Use Vi Vf on the graph)
Q5) The pressure of an ideal gas is increased linearly from 15 kPa to 30 kPa during the process its volume increased from 3.2 m^3 to 4.8m^3

PV DIAGRAM
FOR CARNOT CYCLE

Heat entered to the system Qh and,
heat exhausted from the system Qc
can be shown in PV diagram

For all cycles

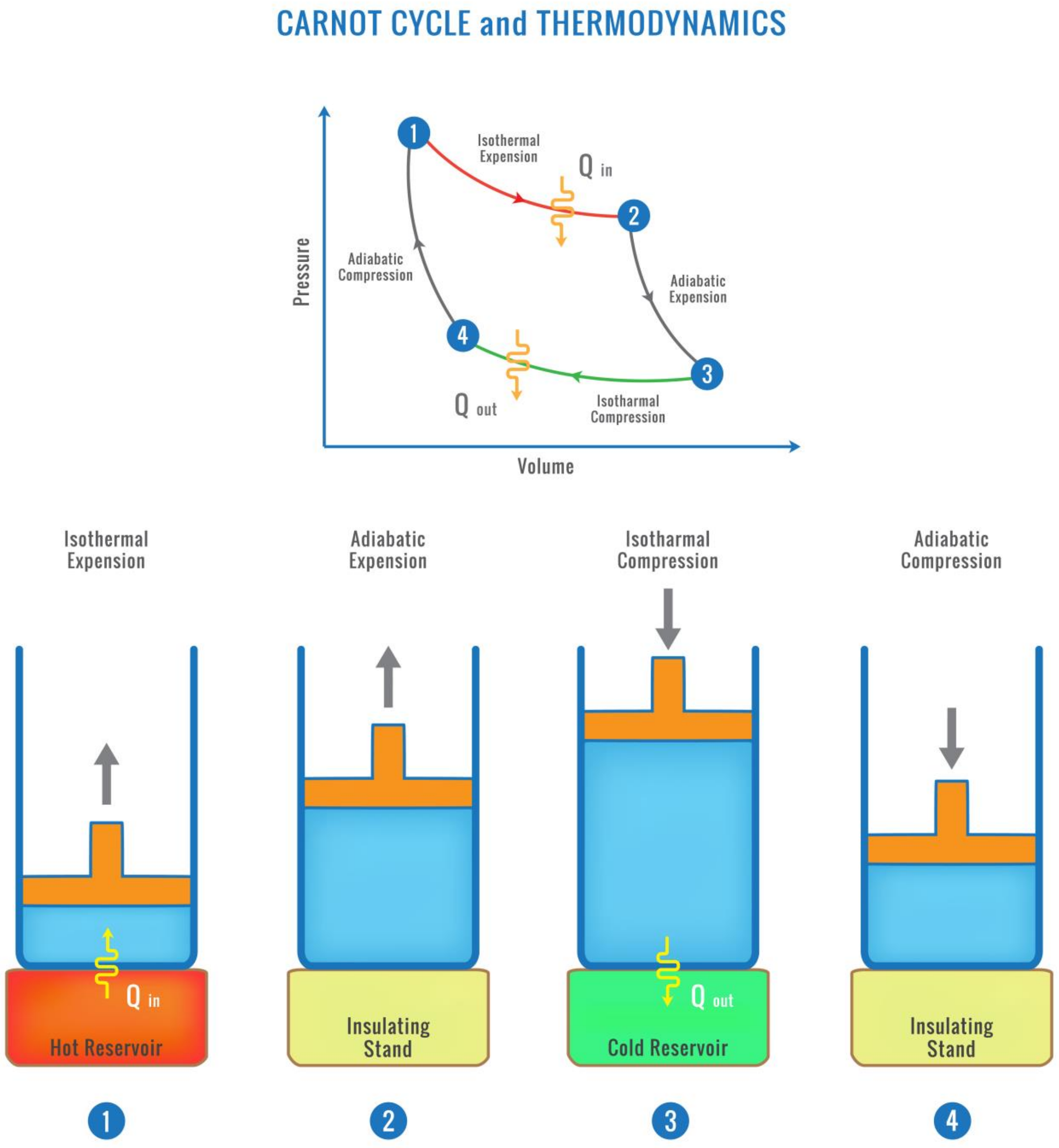
e= 1-[Qc/Qh]

e= W/Qh

Qh-Qc=W

For Carnot Cycle only

e=1-[Tc/Th]



CLASSWORK FOR THE SECOND LAW OF THERMODYNAMICS AND EFFICIENCY

Q1) During a heat cycle 40J of work is done and 30J of heat is exhausted. Find the efficiency

Q2) A carnot engine operates at a hot temperature of 500 Kelvin and a cold Temperature of 350 Kelvin. Find the efficiency. Find the work done if the Qhot=6000J

Q3) We want to build the following cycle

First the gas expands adiabatically and doing 20J of work

Later the gas expands isobarically doing 20J of work using 30J of heat

In the third phase 10J of heat given isovolumically

Finally the system is brought back to the original state isothermally with W=-25J

Complete the table

Find Qhot

Find Qcold

Find W

Find the efficiency

PROCESS FOR Q3	U	Q	W
A->B			
B->C			
C->D			
D->A			

CLASSWORK FOR ENTROPY

Q1) 4 kg Ice melts. Find the change in its Entropy

Q2) In the morning 0.050 kg air vapor condensates to dew. Find the change in Entropy

Q=+m L or Q=-mL Lf=334,000 Lv=2,260,000

Q3) Calculate the change in Entropy for an isothermal expansion of a 30 moles of monatomic ideas gas at 40,000 Pascal pressure when it expands from 3 m^3 volume to 6 m^3 of volume. Find the temperature first using PV=nRT. Find the Workdone using W=nRT ln (Vf/Vi). Find the heat given to the system using U=Q-W. Using Q and T, find the entropy.

HINTS: For Q1 there are two processes. For Q2, although there are two objects, there are three processes. Melted ice must be heated up too. For Q3-Q4 there are 4 processes.

REFERENCES

- Slide 1-8: Open Stax College Physics online textbook
- Slide 9: Screenshot from Ophysics and Geogebra by Tom Walsh using P-V Diagram and Work Author: Dave Nero
- Slide 11: Adobe id= 464626242 carnot cycle vector illustration labeled educational thermodynamic scheme explained with the steps
  By Nandalal