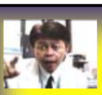


Thermodynamics Lecture Series

Assoc. Prof. Dr. J.J.

First Law of Thermodynamics & Energy Balance – Control Mass, Open System

Applied Sciences Education Research Group (ASERG)
Faculty of Applied Sciences
Universiti Teknologi MARA
email: drjlanita@hotmail.com
http://www.uitm.edu.my/staff/drjj/

Quotes

"One who learns by finding out has sevenfold the skill of the one who learned by being told." - Arthur Gutterman

"The roots of education are bitter, but the fruit is sweet." -Aristotle

Research Findings

Research Findings – Retention % of Learning After 3 days period

Read only – 10%

See only 30%

Hear only – 20%

See + hear – 50%

Say only – 70%

Say & do simultaneously - 90%

CHAPTER 4

The First Law of Thermodynamics

Goal: Identifying sources of energy interactions and write energy balances thermodynamic processes

8/22/2005 Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005

Introduction

Objectives:

1. *State the conservation of energy principle.*
2. *Write an energy balance for a general system undergoing any process.*
3. *Write the unit-mass basis and unit-time basis (or rate-form basis) energy balance for a general system undergoing any process.*
4. *Identify the energies causing the system to change.*

Introduction

Objectives:

5. *Identify the energy changes within the system.*
6. *Write the energy balance in terms of all the energies causing the change and the energy changes within the system.*
7. *Write a unit-mass basis and unit-time basis (or rate-form basis) energy balance in terms of all the energies causing the change and the energy changes within the system.*

Introduction

Objectives:

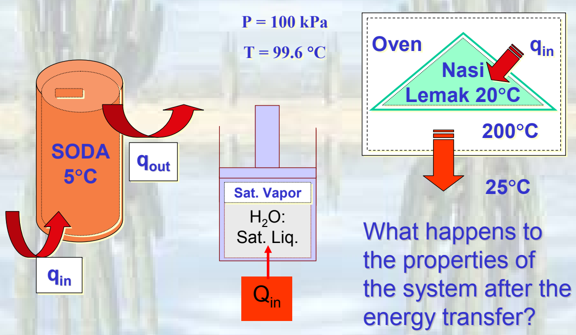
8. *State the conditions for stationary, closed system and rewrite the energy balance and the unit-mass basis energy balance for stationary-closed systems.*
9. *Apply the energy conservation principle for a stationary, closed system undergoing an adiabatic process and discuss its physical interpretation.*

Introduction

Objectives:

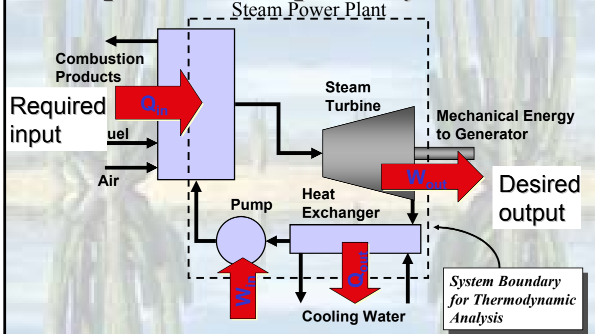
10. *Apply the energy conservation principle for a stationary, closed system undergoing an isochoric, isothermal, cyclic and isobaric process and discuss its physical interpretation.*
11. *Give the meaning for specific heat and state its significance in determining internal energy and enthalpy change for ideal gases, liquids and solids.*
12. *Use the energy balance for problem solving.*

Energy Transfer -Heat Transfer



What happens to the properties of the system after the energy transfer?

Example: A steam power cycle.



The net work output is $\dot{W}_{net,out} = \dot{W}_{out} - \dot{W}_{in}, kW$

Energy Transfer – Work Done

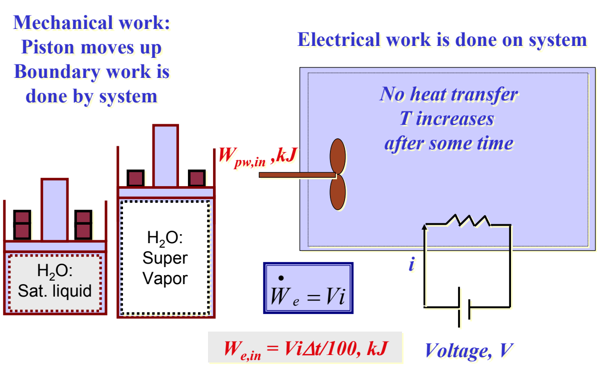
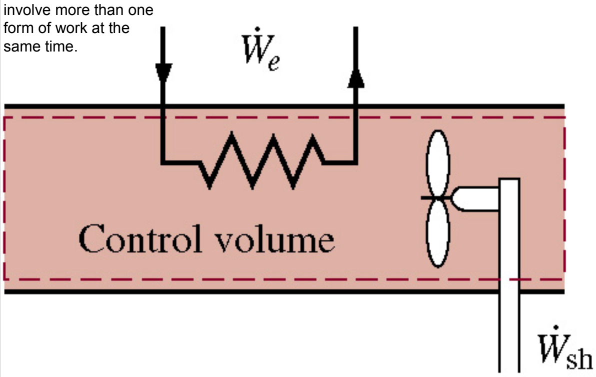
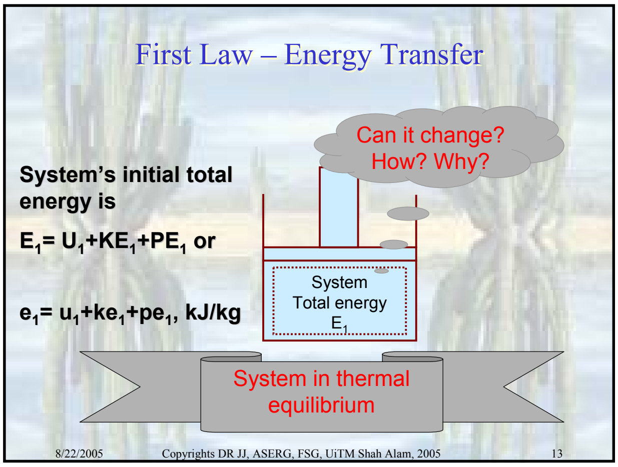
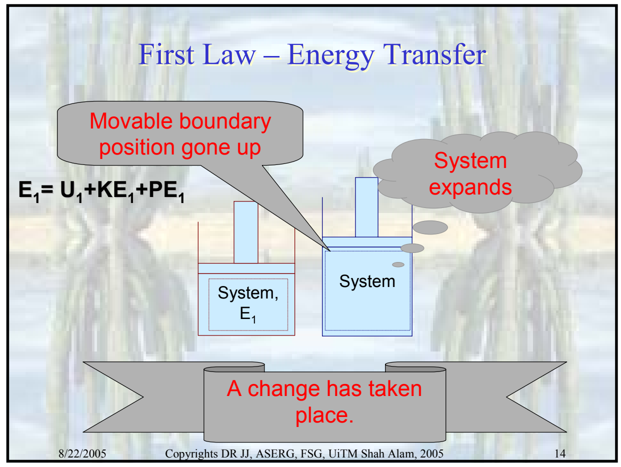
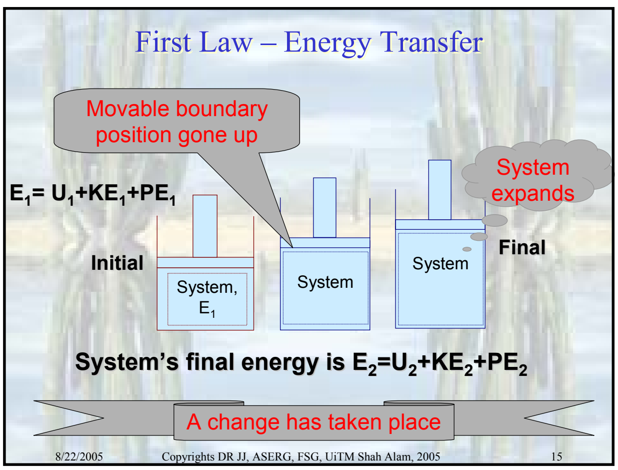


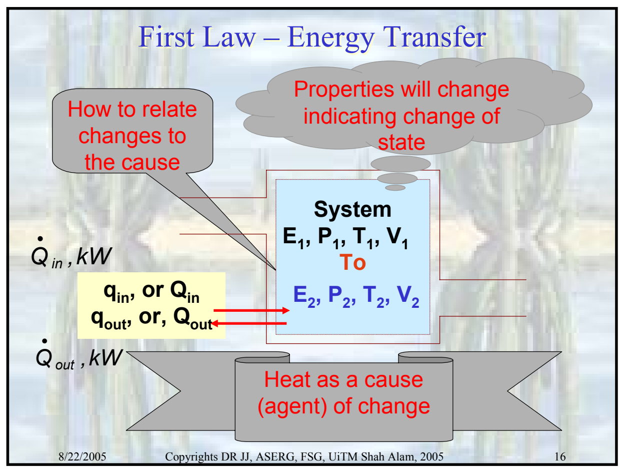
FIGURE 4-46
Pipe or duct flow may involve more than one form of work at the same time.

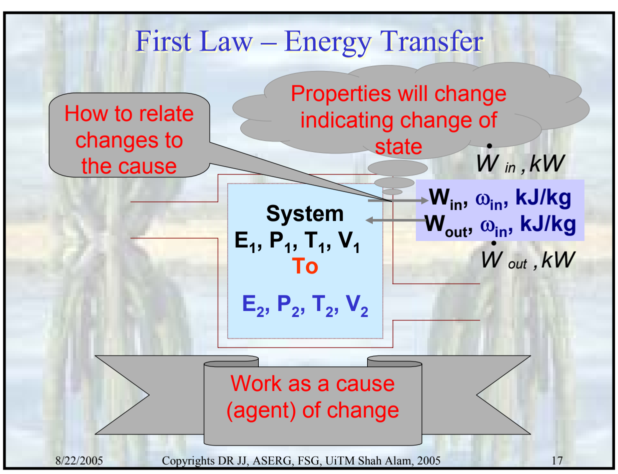


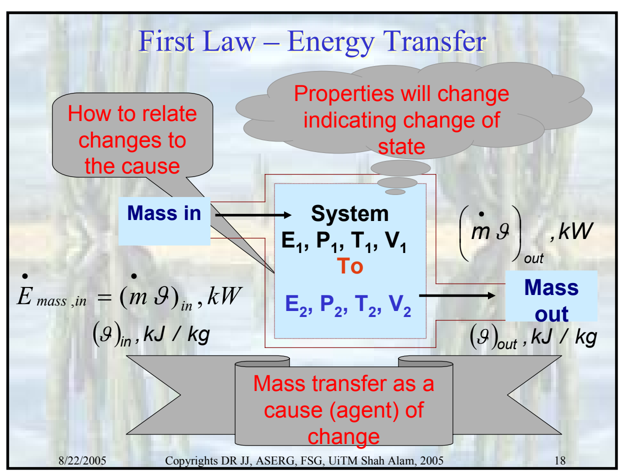

First Law – Energy Transfer
Can it change? How? Why?
System's initial total energy is
$E_1 = U_1 + KE_1 + PE_1$ or
$e_1 = u_1 + ke_1 + pe_1$, kJ/kg
System Total energy E_1
System in thermal equilibrium
8/22/2005 Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005 13

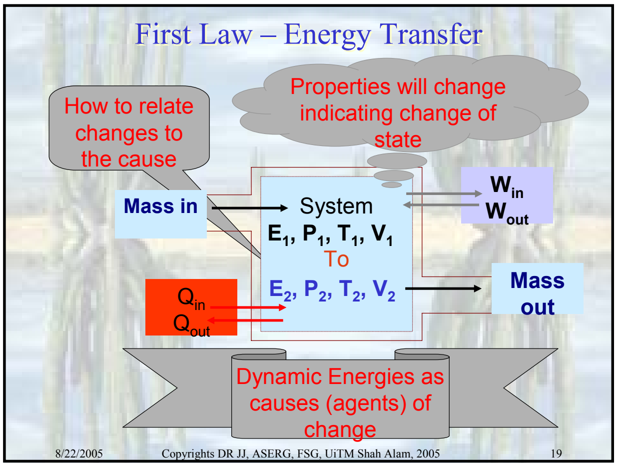

First Law – Energy Transfer
Movable boundary position gone up
System expands
$E_1 = U_1 + KE_1 + PE_1$
System, E_1
System
A change has taken place.
8/22/2005 Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005 14

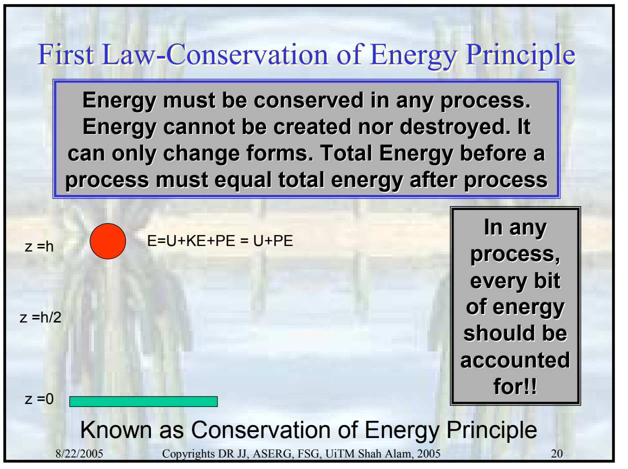

First Law – Energy Transfer
Movable boundary position gone up
System expands
$E_1 = U_1 + KE_1 + PE_1$
Initial
System, E_1
System
System
Final
System's final energy is $E_2 = U_2 + KE_2 + PE_2$
A change has taken place
8/22/2005 Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005 15

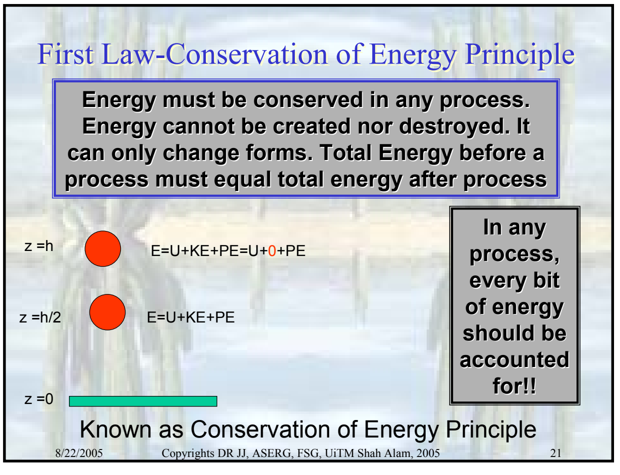

First Law – Energy Transfer
How to relate changes to the cause
Properties will change indicating change of state
System
E_1, P_1, T_1, V_1
To
E_2, P_2, T_2, V_2
$\dot{Q}_{in}, kW$
q_{in}, or Q_{in}
q_{out}, or, Q_{out}
$\dot{Q}_{out}, kW$
Heat as a cause (agent) of change
8/22/2005 Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005 16

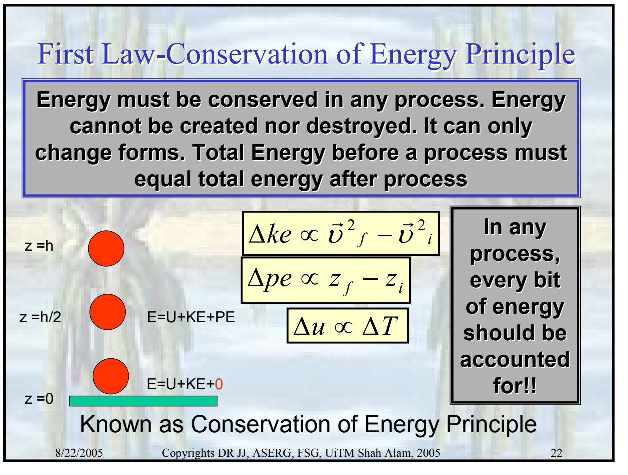

First Law – Energy Transfer
How to relate changes to the cause
Properties will change indicating change of state
$\dot{W}_{in}, kW$
W_{in}, ω_{in}, kJ/kg
W_{out}, ω_{in}, kJ/kg
$\dot{W}_{out}, kW$
System
E_1, P_1, T_1, V_1
To
E_2, P_2, T_2, V_2
Work as a cause (agent) of change
8/22/2005 Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005 17

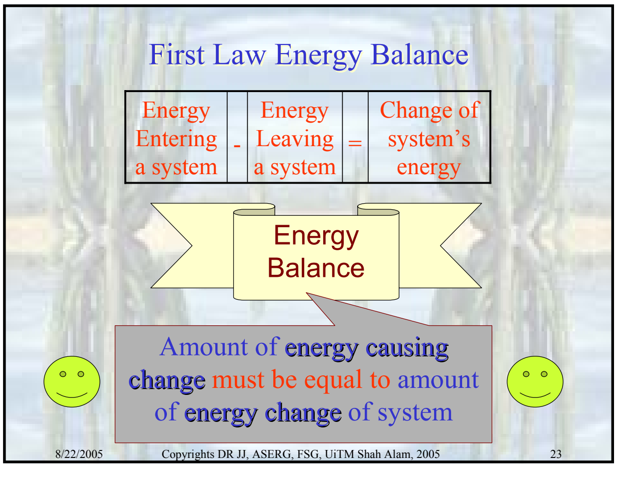

First Law – Energy Transfer
How to relate changes to the cause
Properties will change indicating change of state
Mass in
System
E_1, P_1, T_1, V_1
To
E_2, P_2, T_2, V_2
$\dot{E}_{mass,in} = (\dot{m}\vartheta)_{in}, kW$
$(\vartheta)_{in}, kJ/kg$
$(\dot{m}\vartheta)_{out}, kW$
Mass out
$(\vartheta)_{out}, kJ/kg$
Mass transfer as a cause (agent) of change
8/22/2005 Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005 18

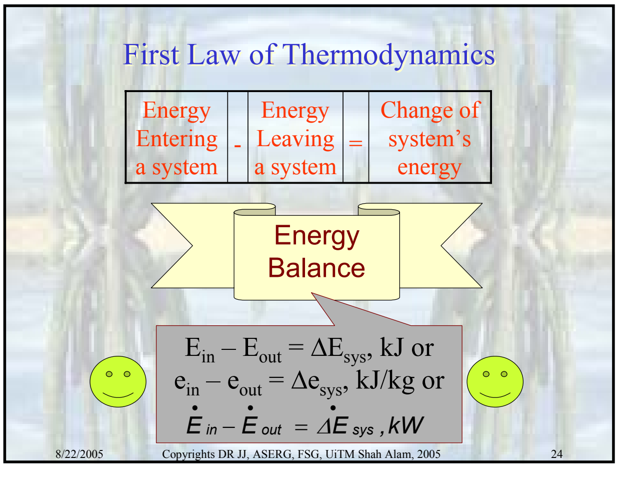

First Law – Energy Transfer
How to relate changes to the cause
Properties will change indicating change of state
Mass in
System
E1, P1, T1, V1
To
E2, P2, T2, V2
Win
Wout
Mass out
Qin
Qout
Dynamic Energies as causes (agents) of change
8/22/2005
Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005
19


First Law-Conservation of Energy Principle
Energy must be conserved in any process. Energy cannot be created nor destroyed. It can only change forms. Total Energy before a process must equal total energy after process
z =h
E=U+KE+PE = U+PE
z =h/2
z =0
In any process, every bit of energy should be accounted for!!
Known as Conservation of Energy Principle
8/22/2005
Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005
20


First Law-Conservation of Energy Principle
Energy must be conserved in any process. Energy cannot be created nor destroyed. It can only change forms. Total Energy before a process must equal total energy after process
z =h
E=U+KE+PE=U+0+PE
z =h/2
E=U+KE+PE
z =0
In any process, every bit of energy should be accounted for!!
Known as Conservation of Energy Principle
8/22/2005
Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005
21


First Law-Conservation of Energy Principle
Energy must be conserved in any process. Energy cannot be created nor destroyed. It can only change forms. Total Energy before a process must equal total energy after process
z =h
$\Delta ke \propto \vec{v}^2_f - \vec{v}^2_i$
$\Delta pe \propto z_f - z_i$
$\Delta u \propto \Delta T$
z =h/2
E=U+KE+PE
z =0
E=U+KE+0
In any process, every bit of energy should be accounted for!!
Known as Conservation of Energy Principle
8/22/2005
Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005
22


First Law Energy Balance
Energy Entering a system - Energy Leaving a system = Change of system's energy
Energy Balance
Amount of energy causing change must be equal to amount of energy change of system
8/22/2005
Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005
23


First Law of Thermodynamics
Energy Entering a system - Energy Leaving a system = Change of system's energy
Energy Balance
$E_{in} - E_{out} = \Delta E_{sys}$, kJ or
$e_{in} - e_{out} = \Delta e_{sys}$, kJ/kg or
$\dot{E}_{in} - \dot{E}_{out} = \Delta \dot{E}_{sys}$, kW
8/22/2005
Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005
24

First Law of Thermodynamics

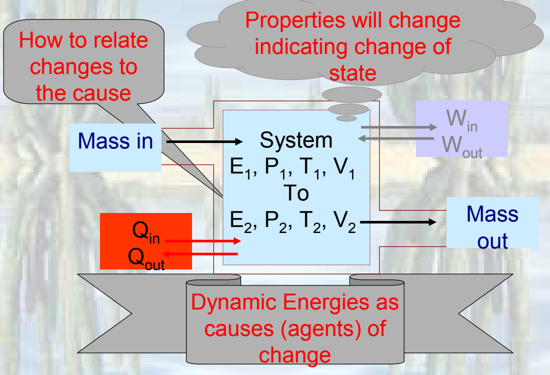
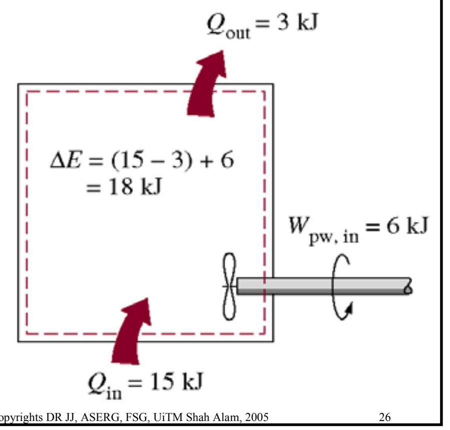


FIGURE 4–7
The energy change of a system during a process is equal to the *net* work and heat transfer between the system and its surroundings.



First Law – Interaction Energies

Energy Balance – The Agent

$E_{in} = Q_{in} + W_{in} + E_{mass,in}$,kJ

$e_{in} = q_{in} + \omega_{in} + \theta_{in}$, kJ/kg

$\dot{E}_{in} = \dot{Q}_{in} + \dot{W}_{in} + \dot{E}_{mass,in}$; kW

For Closed system: $E_{mass,in} = 0$, kJ, $\theta_{in} = 0$, kJ/kg

$\dot{E}_{mass,in} = 0$, kW

First Law - Interaction Energies

Energy Balance – The Agent

$E_{out} = Q_{out} + W_{out} + E_{mass,out}$,kJ

$e_{out} = q_{out} + \omega_{out} + \theta_{out}$, kJ/kg

$\dot{E}_{in} = \dot{Q}_{out} + \dot{W}_{out} + \dot{E}_{mass,out}$; kW

For Closed system: $E_{mass,out} = 0$, kJ, $\theta_{out} = 0$, kJ/kg

$\dot{E}_{mass,out} = 0$, kW

First Law - System's Energy

Energy Balance – The Change WIthin

Energy change within the system, $\Delta E_{sys} = E_2 - E_1$

is the sum of

Internal energy change, $\Delta U = U_2 - U_1$

kinetic energy change, $\Delta KE = KE_2 - KE_1$

potential energy change, $\Delta PE = PE_2 - PE_1$

First Law – Energy Change

Energy Balance – The Change WIthin

$\Delta E_{sys} = \Delta U + \Delta KE + \Delta PE$, kJ

$\Delta e_{sys} = \Delta u + \Delta ke + \Delta pe$, kJ/kg

$\Delta \dot{E}_{sys} = \Delta \dot{U} + \Delta \dot{KE} + \Delta \dot{PE}$, kW

For Stationary system: $\Delta KE = \Delta PE = 0$, kJ

$\Delta ke = \Delta pe = 0$, kJ/kg $\Delta \dot{KE} = \Delta \dot{PE} = 0$

First Law – General Energy Balance

Energy Entering a system	-	Energy Leaving a system	=	Change of system's energy

Energy Balance

$E_{in} - E_{out} = \Delta E_{sys}$, kJ or
$e_{in} - e_{out} = \Delta e_{sys}$, kJ/kg or
$\dot{E}_{in} - \dot{E}_{out} = \Delta \dot{E}_{sys}$, kW

8/22/2005 Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005 31

First Law – General Energy Balance

Energy Balance – General system

$Q_{in} + W_{in} + E_{mass,in} - Q_{out} - W_{out} - E_{mass,out}$
$= \Delta U + \Delta KE + \Delta PE$, kJ

$q_{in} + \omega_{in} + \theta_{in} - q_{out} - \omega_{out} - \theta_{out}$
$= \Delta u + \Delta ke + \Delta pe$, kJ/kg

$\dot{Q}_{in} + \dot{W}_{in} + \dot{E}_{mass,in} - \dot{Q}_{out} - \dot{W}_{out} - \dot{E}_{mass,out}$
$= \Delta \dot{U} + \Delta KE + \Delta PE$, kW

8/22/2005 Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005 32

First Law – Stationary System

Energy Balance – Stationary system

$Q_{in} - Q_{out} + W_{in} - W_{out} + E_{mass,in} - E_{mass,out} = \Delta U + 0 + 0$

$q_{in} - q_{out} + \omega_{in} - \omega_{out} + \theta_{in} - \theta_{out} = \Delta u + 0 + 0$, kJ/kg

$\dot{Q}_{in} - \dot{Q}_{out} + \dot{W}_{in} - \dot{W}_{out} + \dot{E}_{mass,in} - \dot{E}_{mass,out}$
$= \Delta \dot{U} + 0 + 0$

8/22/2005 Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005 33

First Law – Closed System

Energy Balance – Closed system

$Q_{in} - Q_{out} + W_{in} - W_{out} + 0 - 0$
$= \Delta U + \Delta KE + \Delta PE$, kJ

$q_{in} - q_{out} + \omega_{in} - \omega_{out} + 0 - 0$
$= \Delta u + \Delta ke + \Delta pe$, kJ/kg

$\dot{Q}_{in} - \dot{Q}_{out} + \dot{W}_{in} - \dot{W}_{out} + 0 - 0$
$= \Delta \dot{U} + \Delta \dot{KE} + \Delta \dot{PE}$, kW

8/22/2005 Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005 34

First Law – Stationary & Closed

Energy Balance – Stationary Closed system

$Q_{in} - Q_{out} + W_{in} - W_{out} + 0 - 0 = \Delta U + 0 + 0$

$q_{in} - q_{out} + \omega_{in} - \omega_{out} + 0 - 0 = \Delta u + 0 + 0$, kJ/kg

$\dot{Q}_{in} - \dot{Q}_{out} + \dot{W}_{in} - \dot{W}_{out} + 0 - 0 = \Delta \dot{U} + 0 + 0$

8/22/2005 Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005 35

First Law – Historical Perspective

Energy Balance – Stationary Closed system-History

$(Q_{in} - Q_{out}) + (W_{in} - W_{out}) = (Q_{in} - Q_{out}) - (W_{out} - W_{in})$
$= Q_{net,in} - W_{net,out}$
$= Q - W$

$q - \omega = q_{net,in} - \omega_{net,out} = (q_{in} - q_{out}) - (\omega_{out} - \omega_{in})$

8/22/2005 Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005 36

First Law – Adiabatic Process

Energy Balance Stationary Closed system - Special

Adiabatic: $0 - 0 + W_{in} - W_{out} + 0 - 0 = \Delta U + 0 + 0$

$0 - 0 + \omega_{in} - \omega_{out} + 0 - 0 = \Delta u + 0 + 0$, kJ/kg

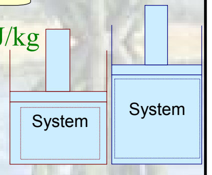
$\omega_{in} = \omega_{elec} + \omega_{pw} + \omega_{b,compress}$ and $\omega_{out} = \omega_{b,expand}$ kJ/kg

First Law – Adiabatic Process

Energy Balance Closed Stationary system - Special

Adiabatic: $\omega_{in} - \omega_{out} = \Delta u + 0 + 0$, kJ/kg

Spontaneous Expansion: piston-cylinder device



$\omega_{in} = 0$, and $\omega_{out} = \omega_{b,expand}$ kJ/kg

Work is expansion work: $0 - \omega_{out} = -\omega_{b,expand} = \Delta u < 0$

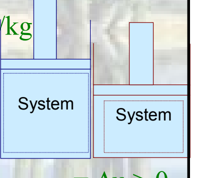
$u_2 < u_1$. Final u is smaller than initial u, T drops

First Law – Adiabatic Process

Energy Balance Closed Stationary system - Special

Adiabatic: $\omega_{in} - \omega_{out} - 0 = \Delta u + 0 + 0$, kJ/kg

Compression: piston-cylinder device



$\omega_{out} = 0$, and $\omega_{in} = \omega_{b,compress}$ kJ/kg

Work is compression work: $\omega_{in} = \omega_{b,compress} = \Delta u > 0$

$u_2 > u_1$. Final u is bigger than initial u; T increases

First Law – Cyclic Process

Energy Balance Closed Stationary system - Special

Cyclic: $Q_{in} - Q_{out} + W_{in} - W_{out} + 0 - 0 = \Delta E_{sys} = 0$

$q_{in} - q_{out} + \omega_{in} - \omega_{out} + 0 - 0 = \Delta e_{sys} = 0$, kJ/kg

$q_{in} - q_{out} = \omega_{out} - \omega_{in}$ or $q_{net,in} = \omega_{net,out}$

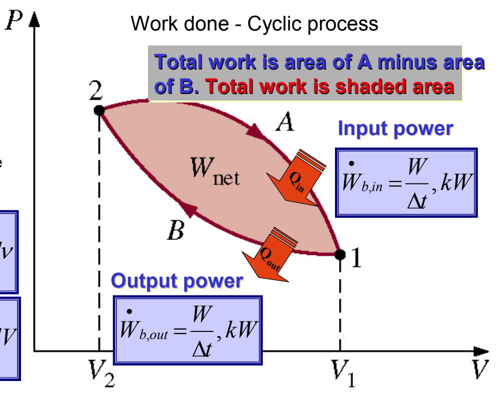
Expansion: $q_{in} - 0 = \omega_{out} = \omega_{b,expand}$

All heat absorbed is used to do expansion work

FIGURE 3-22 The net work done during a cycle is the difference between the work done by the system and the work done on the system.

$$\omega_b = \int_i^f P dv$$

$$W_b = \int_i^f P dV$$



First Law – Cyclic Process

Energy Balance Closed Stationary system - Special

Cyclic: $Q_{in} - Q_{out} + W_{in} - W_{out} + 0 - 0 = \Delta E_{sys} = 0$

$q_{in} - q_{out} + \omega_{in} - \omega_{out} + 0 - 0 = \Delta e_{sys} = 0$, kJ/kg

$q_{in} - q_{out} = \omega_{out} - \omega_{in}$

Compression: $0 - \omega_{in} = -\omega_{b,compress} = q_{in} - q_{out} = -q_{out}$

All compression work is removed as heat

First Law – Isochoric Process

Energy Balance
Closed Stationary
system - Special

Isochoric
Rigid Tank : $Q_{in} - Q_{out} + W_{in} - W_{out} + 0 - 0 = \Delta U$

$q_{in} - q_{out} + \omega_{in} - \omega_{out} + 0 - 0 = \Delta u$, kJ/kg

Since, $\omega_{in} - \omega_{out} = \omega_{others} + 0 = \omega_{elec} + \omega_{pw} + 0 + 0$

Then, $q_{in} - q_{out} + \omega_{elec} + \omega_{pw} + 0 + 0 = \Delta u$

First Law - Isobaric Process

Energy Balance
Closed Stationary
system - Special

Isobaric
Piston-Cyl : $Q_{in} - Q_{out} + W_{in} - W_{out} + 0 - 0 = \Delta U$

$q_{in} - q_{out} + \omega_{in} - \omega_{out} + 0 - 0 = \Delta u$, kJ/kg

For expansion, $\omega_{in} - \omega_{out} = \omega_{elec} + \omega_{pw} - \omega_{b,expand}$

$q_{in} - q_{out} + \omega_{elec} + \omega_{pw} + 0 - 0 = \omega_{b,expand} + \Delta u$, kJ/kg

First Law - Isobaric Process

Energy Balance
Closed Stationary
system - Special

Isobaric
expansion $q_{in} - q_{out} + \omega_{in} - \omega_{out} + 0 - 0 = \Delta u$, kJ/kg

$q_{in} - q_{out} + \omega_{elec} + \omega_{pw} + 0 - 0 = \omega_{b,expand} + \Delta u$, kJ/kg

$$q_{in} - q_{out} + \omega_{elec} + \omega_{pw} = \int_{initial}^{final} P\,dv + \Delta u = P\int_1^2 dv + \Delta u$$

$$q_{in} - q_{out} + \omega_{elec} + \omega_{pw} = P_2 v_2 - P_1 v_1 + u_2 - u_1$$

First Law - Isobaric Process

Energy Balance
Closed Stationary
system - Special

Isobaric expansion

$$q_{in} - q_{out} + \omega_{elec} + \omega_{pw} = \int_{initial}^{final} P\,dv + \Delta u = P\int_1^2 dv + \Delta u$$

$$q_{in} - q_{out} + \omega_{elec} + \omega_{pw} = P_2 v_2 - P_1 v_1 + u_2 - u_1$$

$$q_{in} - q_{out} + \omega_{elec} + \omega_{pw} = P_2 v_2 + u_2 - (P_1 v_1 + u_1)$$

$$q_{in} - q_{out} + \omega_{elec} + \omega_{pw} = h_2 - h_1 = \Delta h$$

First Law - Closed System

Energy Balance
Closed Stationary
system

$q_{in} - q_{out} + \omega_{in} - \omega_{out} + 0 - 0 = \Delta u$, kJ/kg

For pure substances, use property table and mathematical manipulations to determine u_2 and u_1. Then $\Delta u = u_2 - u_1$.

And h_2 and h_1, . Then $\Delta h = h_2 - h_1$.

First Law –Specific Heat

Energy Balance
Closed Stationary
system C_v, C_p,

Specific heats to find ΔU and ΔH

Specific Heat Capacity
C_v at constant volume, C_p, at constant pressure

Amount of heat necessary to increase temperature of a unit mass by 1K or 1degree Celcius

First Law –Specific Heat

Energy Balance Closed Stationary system C $_v$, C$_p$,

For Ideal Gases: Estimate internal energy change and enthalpy change

Assume smooth change of C with T, & approximate to be linear over small ΔT (approx. a few hundred degrees)

$$\Delta u = \int_1^2 C_V dT \cong C_{V,avg}(T_2 - T_1) = C_{V,avg}\Delta T$$

$$\Delta h = \int_1^2 C_P dT \cong C_{P,avg}(T_2 - T_1) = C_{P,avg}\Delta T \quad , \frac{kJ}{kg \bullet K}$$

First Law –Specific Heat

Energy Balance Closed Stationary system C $_v$, C$_p$,

For Ideal Gases : Estimate internal energy change and enthalpy change

Assume smooth change of C with T, & approximate to be linear over small ΔT (approx. a few hundred degrees)

$C_{v,\,avg}$ is determined using interpolation technique & use Table A-2b

First Law –Specific Heat

Energy Balance Closed Stationary system C $_v$, C$_p$,

For solids & Liquids: May consider as incompressible or constant volume

$C_v = C_p = C$, kJ/kg •K , $\Delta u = C_{av}(T_2 - T_1)$, kJ/kg

Enthalpy h = u + Pν, So, dh =du + νdP +Pdν, kJ/kg

Hence the enthalpy change,

$\Delta h = \Delta u + \nu\Delta P + P\Delta\nu$, kJ/kg

$\Delta h = C_{av}\Delta T + \nu\Delta P + P\Delta\nu$, kJ/kg

First Law –Specific Heat

Energy Balance Closed Stationary system C $_v$, C$_p$,

For solids & liquids: $\Delta u = C_{av}(T_2 - T_1)$, kJ/kg

$C_v = C_p = C$, kJ/kg •K ,

For solids: Enthalpy, $\Delta h = C_{av}\Delta T + \nu\Delta P + 0$, kJ/kg

Since, $\nu\Delta P = 0$, Then, $\Delta h \cong C_{av}\Delta T$, kJ/kg

First Law –Specific Heat

Energy Balance Closed Stationary system C $_v$, C$_p$,

For Liquids: $\Delta u = C_{av}(T_2 - T_1)$, kJ/kg

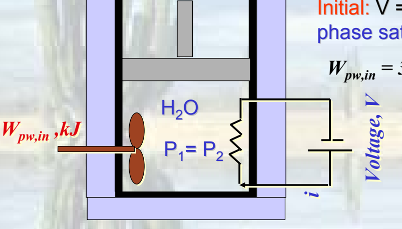
Enthalpy, $\Delta h = C_{av}\Delta T + \nu\Delta P + 0$, kJ/kg

Heaters where $\Delta P = 0$, $\Delta h = \Delta u \cong C_{av}\Delta T$, kJ/kg

Pumps where $\Delta T = 0$, $\Delta h = \nu\Delta P$, kJ/kg

Or written as $h_2 - h_1 = \nu(P_2 - P_1)$

First Law –Example – Prob 4-20



Initial: V = 5 L phase sat. liq. P = 150 kPa,

$W_{pw,in}$ = 300 kJ,

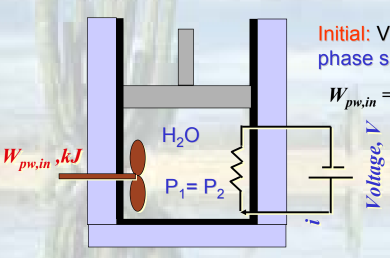
Δt = 45 min x 60s/min

Δt = 45 x 60s

Current, i = 8 A,

Final phase is sat. liq.-vapor mix at 150 kPa. Quality of steam is 0.5. Since $m_g = m/2$, hence $x = m_g/m = m/2m$ =0.5.

First Law –Example – Prob 4-20



Initial: V = 5 L

phase sat. liq. P = 150 kPa,

$W_{pw,in}$ = 300 kJ,

Δt = 45 min x 60s/min

Δt = 45 x 60s

Current, i = 8 A,

$x_2 = 0.5$

$v_1 = v_{f@150\ kPa}$, = 0.0010528 m³/kg

$h_1 = h_{f@150\ kPa}$, = 467.1 kJ/kg

$v_2 = [v_f + x_2 v_{fg}]_{@150\ kPa}$, = 0.579938 m³/kg

$h_2 = [h_f + x h_{fg}]_{@150\ kPa}$ =1580 kJ/kg

8/22/2005 Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005 55

First Law –Example – Prob 4-20

Energy balance,

$E_{in} - E_{out} = \Delta E_{sys}$

$0 + W_{in} + 0 – 0 – W_{out} - 0 = \Delta U + 0 + 0$, kJ

$W_{pw,in} + W_{e,in} = \Delta U + W_{out}$ where $W_{b,out} = \int_1^2 PdV$

Then $W_{e,in} = U_2 - U_1 + P_2V_2 - P_1V_1 - W_{pw,in}$

$W_{e,in} = U_2 + P_2V_2 - (U_1 + P_1V_1) - W_{pw,in}$

$W_{e,in} = H_2 - H_1 - W_{pw,in} = \Delta H - W_{pw,in}$

8/22/2005 Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005 56

First Law –Example – Prob 4-20

Energy balance,

$E_{in} - E_{out} = \Delta E_{sys}$

Since $W_{e,in} = H_2 - H_1 - W_{pw,in} = \Delta H - W_{pw,in}$

Electrical work done is $\frac{Vi\Delta t}{1000} = m\Delta h - W_{pw,in}, kJ$

Voltage source is $V = \frac{1000\ (m\Delta h - W_{pw,in})}{i\Delta t}, kJ$

8/22/2005 Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005 57

First Law –Example – Prob 4-20

Energy balance,

$E_{in} - E_{out} = \Delta E_{sys}$

Voltage source is

$$V = \frac{1000\ [(\frac{5\ L * 10^{-3} m^3 / L}{0.0010528\ \ m^3/kg})(1580.36 - 467.11)\ kJ / kg - 300\ kJ]}{(8\ A)(45\ \min\ x60\ s / \min)}$$

Note that the unit kJ/s = Volts-Ampere or VA

$$V = \frac{230.9\ kJ}{As} = 230.9\frac{AV}{A} = 230.9\ V$$

8/22/2005 Copyrights DR JJ, ASERG, FSG, UiTM Shah Alam, 2005 58