Class: SE (Mech/Auto)

Exam: SE (Mech/Auto) Sem-III (Rev)Sum2010

Code : AN-2432

Date: May 25th ,2010

Q1.a)

Intensive propertiy: The properties which are independent of mass of system is called as intensive properties. Ex. Temperature, Pressure

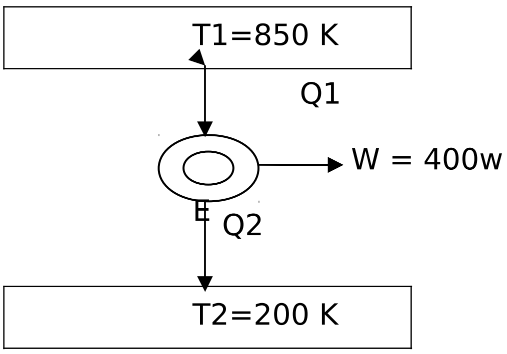
Extensive properties: The properties which are independent of mass of system is called as intensive properties. Ex. Density, Specific extensive property

b)

1. Practically it is not possible to bring in contact and remove alternately heat reservoir and adiabatic cover.

2. Large variation in speed cannot be obtained in practice.

c)



Rate of heat supplied ,

Qs = 35.5 kJ/min = 591w

Actual eff. Of engine

= Power output / heat suoolied

= 400/591

= 67.68 %

Carnot eff.

= 1- (T2/T1)

= 1- (200/850)

= 76.47 %

Since eff of engine is less than carnot eff, hence his claim is possible.

d)

m = 2 kg

P_0 = 8 bar

X = 0.8

from Molier chart

h = 2360 kJ/kg

v = 0.2 m3/kg

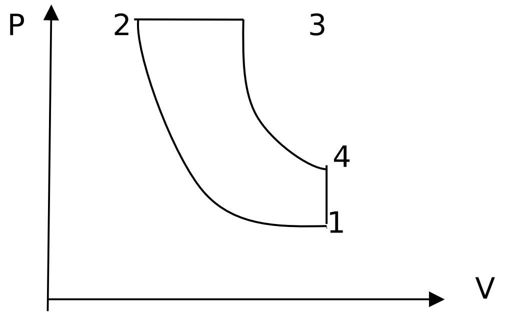
Hence for 2 kg

H = 4720 kJ

V = 0.4 m^3

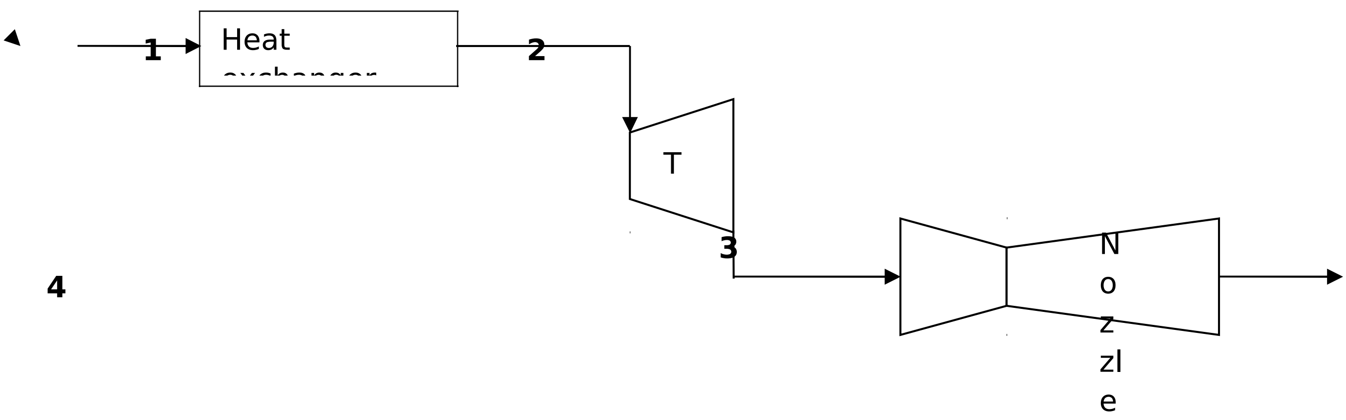
e)

Cut off ratio : It is ratio of volume of gas after heat addition to the volume before heat addition in diesel cycle.



Eff of diesel α (1 / cutoff ratio)

Q2.a)



$T1 = 20^0$ C

$V1$ = 40 m/s

$T2 = 820^0$C

$V2$ = 40 m/s

$T3 = 620\ ^0$C

$V3$ = 55 m/s

$T4 = 510^0$C

m = 2.5 kg/s

SFEE for heat exchanger

$Q_{12} = m(h2-h1)$

$= m*(T2-T1)$

$= 2 *1.005 (820-20)$

= 1608 kJ/sec

SFEE for Turbine,

$m ((V_2^2/2)+h2) = m ((V_3^2/2)+h3) + W_T$

$W_T = 2 ((40^2 - 55^2) * 1000/2) + 2 (1.005(800 - 620))$

$= -1.425 + 361.8$

= 360.37 kJ/sec

SFEE for nozzle,

$((V_3^2/2)+h3) = ((V_4^2/2)+h4)$

V_4 = 471.41 m/s

Q2.b)

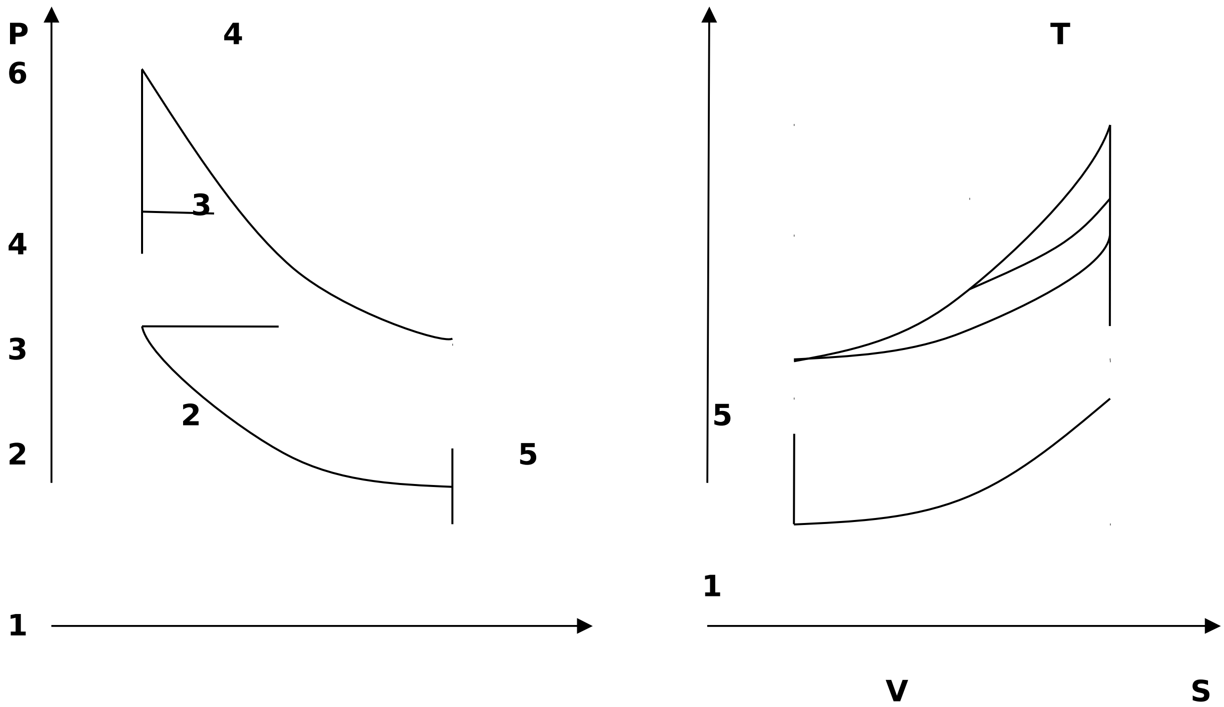
1. Availability: When system is subjected to state change maximum amount of work can be obtained eater than diesel

2. Dead State: When the system is in pressure and temperature equilibrium with surrounding and chemical equilibrium the state of system is known as dead state.

3. Irreversibility: The difference between reversible work and actual work called as irreversibility.

4. Effectiveness: Ratio of actual work to the reversible work called as effectiveness.

Q2.C)



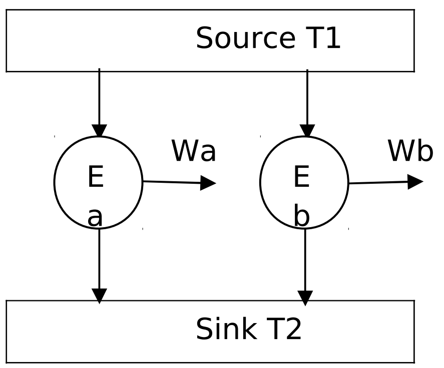
Effieiency of Otto cycle is greater than Efficiency of dual cycle greater than diesel.

Q3.a)

Carnot theorem: It state that none engine has higher efficiency than reversible engine working between same constant temperature source and sink.

$$\mu_{carnot} > \mu_{any\ engine}$$

Proof: Let two engines Ea and Eb operating between t1 and t2



Let Ea may be any engine, Eb may be reversible enging, let assume, $\mu a > \mu B$

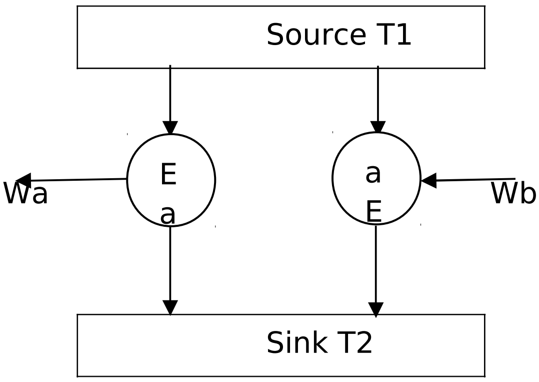
$Q_{1a} = Q_{1b} = Q_1$

Since, μa > μB

$W_a / Q_{1a} = W_b / Q_{1b}$

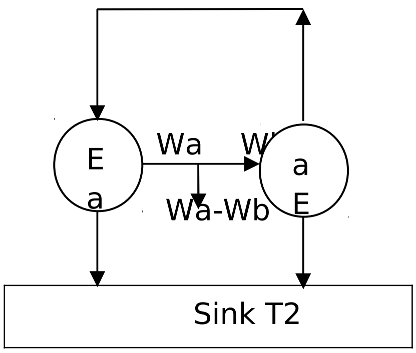
$W_a = W_b$

Now let Eb reversed. The magnitude of heat and work remain same but directions are changed.



Since, Wa > Wb

Some part of Wa (equal to Wb) may be fed to run enging.



This is not possible.

Hence, μb > μa .

Q3. b) Given

P1 = 15bar

P2 =0.01bar

From steam table at 15 bar pressure

$T_{sat} = 198.3^0C$

Initial temperature of steam

$T1 = 298.3^0C$

Also at 15bar and 298.3^0C

h1 = 3034.97kJ/kg.

And S1 = 6.913 kJ/kgK

At 0.01bar

$h_{f2} = h_{f3} =$ h3 = 29.3 kJ/kg

hfg2 = 2514.4 kJ/kg

but isentropic efficiency of expansion is 85%

hence, S2 = 0.85 S1

= 5.876 kJ/kgK

But

S2 = Sf2 + X2*Sfg2

5.876 = 0.106 + X2*8.977

X2 = 0.642

h2 = hf2 +X2*hfg2

= 29.3 + 0.642*2514.4

= 1645.43 kJ/kg

Pump work

Wp = Vf2 * (P1-P2)

= 0.001 * (15-0.01)*100000

= 1.499 kJ/kg

Turbine work

Wt = h1 – h2

= 3034.97 – 1645.54

= 1389.54 kJ/kg

Thermal Eff.

$\mu = (W / Qs)$

$= (Wt - Wp) / (h1 - h4)$

$= (1389.54 - 1.499) / (3034.97 - h4)$

Pump work

$Wp = h4 - h3$

$h4 = 30.79$

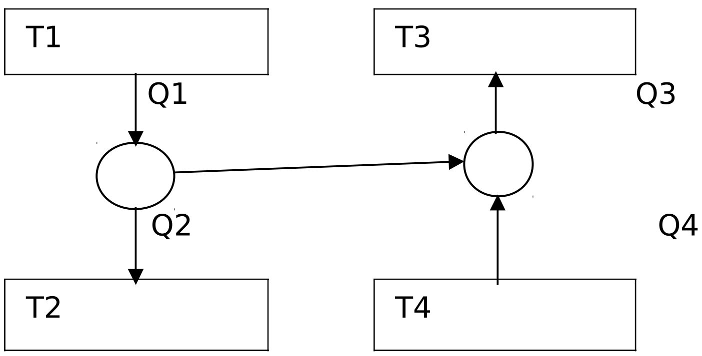
$\mu_{th} = 46.20$ %

Q3.C)

Joule Thomsom Coefficient : Throttling process is frequently encountered. In such case enthalpy remain constant. We could find $(\delta t / \delta p)h$ is a constant. This constant is called as Joule Thomson coefficient.

Region where it is positive is called as cooling region and region where it is negative called as heating region.

Q4.a)



Let output of engine will be W1,

$W1 = Q1 = Q2$ ---------------------------------------I

But, $(Q1 / T1) = (Q2 / T2)$

$Q2 = (T2 / T1) * Q1$

$W1 = Q1 - (T2 / T1) * Q1$ -------------------------------II

This work is supplied to heat pump

$Q3 = Q4 + W1$

$= Q4 + Q1 * (T2 / T1)$ ---------------------------------III

But (Q3 / T3) = (Q4 / T4)

Q3 =(T3 / T4)* Q4

Substituting in equation III

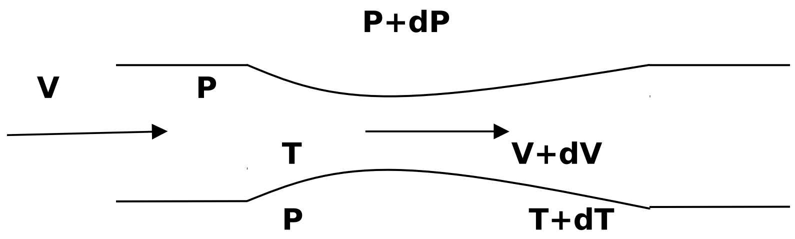
(T3 / T4)* Q4 = Q4 + Q1 (1 – (T2 / T1))

((T3 / T4) – 1)* Q4 = (1 – (T2 / T1)) * Q1

Q4 / Q3 = (1 - (T2/T1)) / ((T3 /T4) – 1)

Q4 / Q3 = T4 (T1 - T2) / T1 (T3 – T4)

Q4. b)



$Ho = h + (V^2 / 2)$

dh = -VdV

From property relation

Tds = dh – V dp

From isentropic flow

dh = dp / ρ

from above equation,

dp = - ρ v Dv

dp /dV < 0

continuity equation gives,

W = ρ *A*V

By algoriyhimic differentiation

(d ρ / ρ) + (dA / A) + (dV / V) = 0

(dA / A) = (dV / V) - (d ρ / ρ)

$(dA / A) = (dp / \rho * V2) (1 - V^2 (d\rho / dp))$

$(dA / A) = (dp / dV^2) (1 - M^2)$

$(dA / A) = (dV / V) (1 - M^2)$

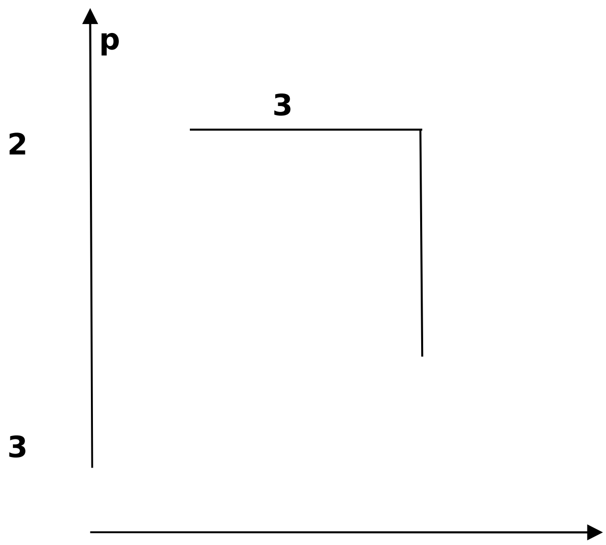
Q4.C)

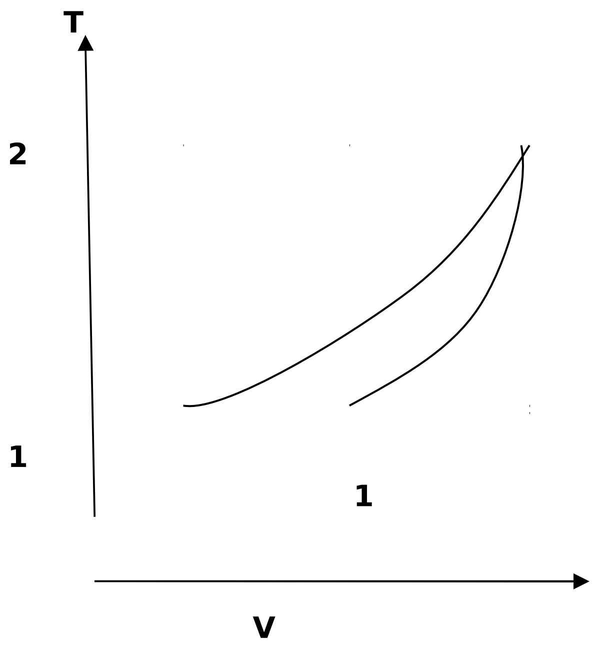
1)Wet steam : Steam containing mixture of dry steam and water moisture.

2)Quality of steam : It is percentage of dryness of steam.

3)Subcooled liquid: When liquid is cooled under its saturation temperature at certain pressure it is called as subcooled liquid.

Q5.a)





S

V1 = V2 = 0.05 m^3

P1 = 1.05 bar

T1 = T3 = 293 K

P2 = 4.5 bar

m = P1*V1 / R*T1 = 0.0312 kg

for the process 1-2

P1/T1 = P2/T2

T2 = 1255.7 K

Heat flow

$Q = Q_{1-2} + Q_{2-3}$

= m Cv (T2-T1) + m Cp (T3-T2)

= 21.56 – 30.18

Q = -8.62 kJ

Net entropy

dS = m (Cv ln(T2/T1) + Cp ln(T3/T2))

= 0.312 (1.044 – 1.462)

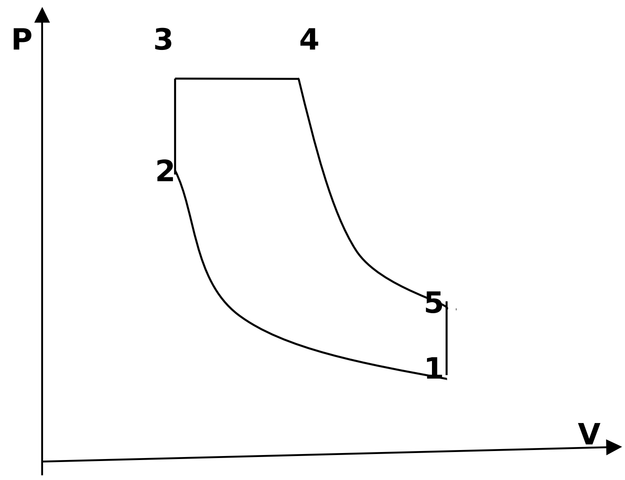
dS = - 0.013kJ/K

Q5.c)

Variation of back pressure in C-D nozzle

1. If P=0, no mass flow of gas
2. If back pressure is reduced as P2>P*, the mass flow rate increases.
3. If back pressure is further reduced P=P*, the mass flow rate is maximum and velocity at exit become sonic.
4. If back pressure is further lowered P<P*, mass flow rate remain maximum.

Q6.a)



P1= 1 bar

T1 = 363 K

r = 9

P4 = 68 bar

Q = 1750 kJ

Process 1-2,

$T2/T1 = (V1/V2)^{r-1} = 9^{0.4}$

$T2 = 874.18$ K

$P2 = P1 * (V1/V2)^{r}$

$P2 = 21.67$ bar

Process 2-3,

$T3/T2 = P3/P2$

$T3 = 874.18 * (68/21.67)$

$T3 = 2743.15$ K

$Q2\text{-}3 = Cv (T3-T2) = 0.718 (2743.15-874.18)$

$= 1342.92$ kJ/kg

But,

$Q3\text{-}4 = 1750 – Q2\text{-}3$

$= 408.07$ kJ/kg $= Cp (T4-T3)$

$= 1.005 (T4- 2743.15)$

$T4 = 3149.18$K

Process 3-4,

$V4/V3 = T4/T3 = 1.15$

$V5/V4 = V1/V2 * V3/V4 = 9 / 1.15$

$V5/V4 = 7.83$

Process 4-5,

$T5 = T4 *(V4/V5)^{r-1}$

$= 1382.58$ K

$P5 = P1 *(T5/T1)$

$= 1* (1382/363)$

$= 3.81$ bar

Efficiency,

$\mu = 1 – (Q2 / Q1)$

$= 1 – (Cv (T5-T1)/((Cv (T3-T2)) +(Cp(T4-T3))))$

= 58.16 %

Work done,

W = Q1 * μ

= 1017.18 kJ/kg.

Q6.b)

let denote x for the properties before shock and y for after shock.

mx = 2

Px = 26.5 kN/m2

ρx = 0.413 kg/m2

i) Py, Ty and ρy

From gas equation

Px = ρx* R* Tx

Tx = Px/(R-ρx)

Tx = 223.6 K

From table at m= 2

my = 0.5774, (Py/Px) = 4.5 , (ρy/ρx) = 2.6667, (Ty/Tx)= 1.6875

(Poy/Pox) = 0.7209 and (ay/ax) = 1.299

Pressure after shock,

Py = 4.5 Px

Py = 119.25 kPa

Density after shock,

ρy = 2.667*ρx

ρy = 1.1014 kg/m3

temperature after shock,

Ty = 1.6875*Tx

= 377.3K

ii) Cx and Cy (Velocities)

Sonic velocity before shock

$ax = SQRT(r*R*Tx) = SQRT(1.4*287*223.6)$

$= 299.7 m/s$

$Cx = mx * ax = 599.4$ m/s

$Cy = my*ay = 224.8$ m/s

iii) Stagnation pressure

$(Pox/Px) = (1 + (((r-1)/2)mx^2))$

Pox = 207.35 kN/m2

(Poy/Pox) = 72.09

Poy = 149.48 kN/m2.

Q7.a)

Absolute thermodynamic temperature scale:

Eff of Carnot engine is function of temperature alone.

Let consider heat engine working in three pairs of temperature (t2,t2), (t2,t3) and (t1,t3) when t1>t2>t3

µ of engine I

µ = 1 – (Q2/Q1) = f (t1,t2)

i.e.

(Q1/Q2) = f (t1,t2)

Similarly,

(Q2/Q3) = f (t2,t3)

And

(Q1/Q3) = f (t1,t3)

From above

Q1/Q3 = Q1/Q2 * Q2/Q3

f (t1,t2) = f (t1,t2) * f (t2,t3)

this equation will satisfied if,

Q1/Q2 = f(t1,t2) = ϕ(t1) / ϕ(t2)

It follows that if Q1>Q2, then $\phi(t1)$ $\phi(t2)$

Hence,

$t1 > t2$.

This function is depend on temperature scale.

Therefore we can define $\phi(t)$ itself as temperature on absolute temperature scale.

$T = \phi(t)$.

Q7.b)

Principle of increase of entropy:

for a process undergone by a system,

$dS >= dQ/T$

for isolated system,

$(dS)iso >= 0$

For reversible process,

$(dS)r = 0$

For irreversible process,

$(dS) > 0$

Thus entropy of isolated system like universe never decreases but always increases. This is called as principle of increase of Entropy.

Q7.c)

Rayleigh and Fanno flow:

The flow of comprissible gas in a constant area duct with friction and without heat and work transfer is called as Fanno flow.

Q7.d)

Clausius inequality:

Eff of any cycle is equal or less than reversible cycle.

$1 – (dQ2/dQ) <= [1 – (dQ2/dQ)]rev$

$(dQ2/dQ) >= (dQ2/dQ)rev$

$(dQ/dQ2) <= (dQ/dQ2)rev$

But

$$(dQ/dQ_2)_{rev} = T/T_2$$

$$(dQ_2/dQ) >= T/T_2$$

Or $$dQ/T <= dQ_2/T_2$$

For reversible process

$$dS = dQ_2/T_2$$

for any process

$$dS >= dQ/T$$

Hence,

$$\S(dQ/T) <= \S\, dS$$

Since entropy is a property,

$$\S(dQ/T) <= 0.$$

It is called as Clausius inequality.