7. AVAILABILITY

AVAILABLE ENERGY: The maximum work which can be obtained in a cycle.
UNAVAILABLE ENERGY: The minimum heat which is rejected to the atmosphere.
AVAILABILITY: the maximum work which can be obtained in a process.
IRREVERSIBILITY: It's defined as difference between the maximum work and the actual work.

METHODS TO IMPROVE CARNOT CYCLE EFFICIENCY:

INCREASING SOURCE TEMPERATURE	DECREASING SICK TEMPERATURE
Efficiency increase per unit increase in temperature is less in comparison.	Efficiency increase per unit increase in temperature is more. So, it's best method to increase efficiency of Carnot cycle.
It depends on working fluid and it's calorific value. So, maximum value increase with quality of working fluid.	It depends on minimum possible heat rejection temperature. E.g. $T_2 = T_{min} = T_{amb} = T_{sur} = T_{atm} = T_0$

AVAILABLE ENERGY:

$\eta_{Carnot} = 1 - T_2/T_1 = W_{max}/Q_1$	$\therefore Available\ energy, W_{max} = Q_1[1 - T_2/T_1] = Q_1 - Q_2$
It can be increase by decreasing T_2 temperature.	It can be increase by increasing T_1 temperature.
1st Law of T.D. is Quantitative law.	**2nd Law of T.D. is Qualitative law.**

UNAVAILABLE ENERGY:

$Unavailable\ energy = Heat\ Rejection\ Area\ on\ T - S\ diagram = [Q_2]_{min} = [T_2]_{min}\Delta S$	
$\therefore Available\ energy, W_{max} = Q_1 - Q_2 = Q_1 - Unavailable\ Energy$	$\therefore \boldsymbol{Q_1 = A.E. + U.A.E.}$

AVAILABLE ENERGY BETWEEN FINITE BODY & THERMAL RESERVOIR:

$Q_1 = A.E. + U.A.E.$ $A.E. = Q_1 - T_0\Delta S$ $U.A.E. = [T_2]_{min}\Delta S = T_0\Delta S$	Q_1 Always consider magnitude. ΔS will be negative but consider magnitude in this equation. $\Delta S = mC\ln[T_2/T_1]$	Q_1	$T_1 \rightarrow T_2$	Finite Body
			HE	$\rightarrow W_{net}$
		Q_2	T_0	Reservoir

LOSS OF A.E. OR DECREASING A.E. OR INCREASING U.A.E.:

$A.E._1 = Q_1[1 - T_0/T_1]$	$A.E._2 = Q_1[1 - T_0/T_2]$	Here, $T_1 > T_2$	Hence, $A.E._1 > A.E._2$
$Loss\ of\ A.E. = A.E._1 - A.E._2 = U.A.E._2 - U.A.E._1 = Q_1T_0[(1/T_2) - (1/T_1)]$			

EXERGY: The maximum useful work which can be obtained from a system as it reversibly comes into equilibrium with its environment. It is combined word used for A.E. & Availability.
DEAD STATE: It's state at which system and surroundings are in equilibrium.

AVAILABILITY IN NON-FLOW PROCESS:

CHANGE IN AVAILABILITY ($\boldsymbol{W_{max}}$): $W_{max} = (U_1 - U_2) - T_0(S_1 - S_2) - d(K.E.) - d(P.E.) = a_1 - a_2$

$\because$	N.F.E.E.: $Q = dE + W$	$E = KE + PE + U$	$Q_{Loss} = T_0\Delta S$

AVAILABILITY/ WORK POTENTIAL AT A STATE "$\boldsymbol{i}$": $a_i = (U_i - U_0) - T_0(S_i - S_0)$
Availability/ work ability at a state *"i"* is composite property (extensive) of system and surroundings.

SURROUNDINGS WORK:	$W_{sys} = P_{sys}dV$	$W_{surr} = -P_{surr}dV$	$dV_{sys} = dV_{surr} = dV$	$P_{sys} > P_{surr}$

MAXIMUM USEFUL WORK:	$W_{useful} = W_{Utilised} = W_{sys} - W_{surr}$	$[W_{useful}]_{max} = [W_{sys}]_{max=Rev.} - W_{surr}$

AVAILABILITY FUNCTION: $\emptyset_i = U_i - T_0S_i + P_0V_i$

$[W_{useful}]_{max} = W_{max} - W_{surr} = \emptyset_1 - \emptyset_2$	$W_{max} = (U_1 - U_2) - T_0(S_1 - S_2)$

AVAILABILITY IN FLOW PROCESS:

CHANGE IN AVAILABILITY (w_{max}):

$$w_{max} = (h_1 - h_2) - T_0(s_1 - s_2) - (1/2)[V_1^2 - V_2^2] - g(z_1 - z_2) = b_1 - b_2$$

∵	S.F.E.E.	$q_{Loss}(in\ J/kg) = T_0 \Delta s$

SURROUNDINGS WORK: $w_{surr} = 0$ (∵ No atmospheric resistance)

MAXIMUM USEFUL WORK: $[w_{useful}]_{max} = w_{max} = (h_1 - h_2) - T_0(s_1 - s_2)$

AVAILABILITY/ WORK POTENTIAL AT A STATE "$\boldsymbol{i}$": $b_i = (h_i - h_0) - T_0(s_i - s_0)$

Availability/ work potential at a state *"i"* is composite property (intensive) of system and surroundings.

AVAILABILITY FUNCTION: $\psi_i = h_i - T_0 s_i$

$[w_{useful}]_{max} = w_{max} = \psi_1 - \psi_2$	$w_{max} = (h_1 - h_2) - T_0(s_1 - s_2)$

IRREVERSIBILITY (I): It represents loss of work or available energy or availability.

$I = W_{max} - W_{act}$	$I \propto \Delta S_{Univ.}$
$I = T_0 \Delta S_{Univ.}$	$I = T_0[\Delta S_{sys.} + \Delta S_{surr.}]$

IRREVERSIBILITY BETWEEN THERMAL RESERVOIRS:

$$I = T_0 \Delta S_{Univ.} = T_0[\Delta S_{sys.} + \Delta S_{surr.}] = T_0\left[\frac{-Q}{T_1} + \frac{Q}{T_2}\right] + 0$$

IRREVERSIBILITY IN FREE EXPANSION/ THROTTLING PROCESS:

$$I = T_0 \Delta S_{Univ.} = T_0[\Delta S_{sys.} + \Delta S_{surr.}] = T_0\left[mC_P \ln\left(\frac{T_2}{T_1}\right) - mR \ln\left(\frac{P_2}{P_1}\right)\right] + T_0 \frac{Q}{T_{Surr}}$$

IRREVERSIBILITY IN ADIABATIC MIXING PROCESS:

$$I = T_0 \Delta S_{Univ.} = T_0[\Delta S_{sys.} + \Delta S_{surr.}] = T_0[\Delta S_1 + \Delta S_1] + T_0 \frac{Q}{T_{surr.}}$$

$$Where, \Delta S_1 = m_1 C_{P1} \ln\left(\frac{T_f}{T_1}\right) - m_1 R_1 \ln\left(\frac{P_f}{P_1}\right) \ \& \ \Delta S_2 = m_2 C_{P2} \ln\left(\frac{T_f}{T_2}\right) - m_2 R_2 \ln\left(\frac{P_f}{P_2}\right)$$

IRREVERSIBILITY IN FLUID FRICTION IN AN ADIABATIC PIPELINE:

From, S.F.E.E.: $h_1 = h_2 \Rightarrow T_1 = T_2$	$h_1 = m_1 C_P dT$
$\dot{I}(in\ KW) = T_0 \Delta \dot{S}_{Univ.} = T_0[\Delta \dot{S}_{sys.} + \Delta \dot{S}_{surr.}] = -T_0 \dot{m} R \ln\left(\frac{P_2}{P_1}\right) = -T_0 \dot{m} R \ln\left(1 - \frac{\Delta P}{P_1}\right) = T_0 \dot{m} R \left(\frac{\Delta P}{P_1}\right) (Forier)$	

SECOND LAW EFFICIENCY:

FOR HEAT ENGINES,	**FOR TURBINES,**
$\eta_{II-LAW} = \frac{\eta_{act}}{\eta_{ideal}} = \frac{1 - Q_2/Q_1}{1 - T_2/T_1}$	$\eta_{II-LAW} = \frac{W_{act}(From\ SFEE)}{W_{ideal}(From\ \psi_1 - \psi_2)} = \eta_{ISE-T} = \frac{h_1 - h_2'}{h_1 - h_2}$
FOR REFRIGERATOR,	**FOR COMPRESSORS,**
$\eta_{II-LAW} = \frac{COP_{act}}{COP_{ideal}} = \frac{Q_2/(Q_1 - Q_2)}{T_2/(T_1 - T_2)}$	$\eta_{II-LAW} = \frac{W_{ideal}(From\ \psi_1 - \psi_2)}{W_{act}(From\ SFEE)} = \eta_{ISE-C} = \frac{h_2 - h_1}{h_2' - h_1}$
FOR HEAT PUMP,	**FOR HEATING COIL,**
$\eta_{II-LAW} = \frac{COP_{act}}{COP_{ideal}} = \frac{Q_1/(Q_1 - Q_2)}{T_1/(T_1 - T_2)}$	$\eta_{II-LAW} = \frac{COP_{act}}{COP_{ideal\ HP}} = \frac{1}{T_1/(T_1 - T_2)}$