

20. (b) $\Delta Q = \Delta U + \Delta W$; $\Delta Q = 200\text{ J}$ and $\Delta W = -100\text{ J}$
 $\Rightarrow \Delta U = \Delta Q - \Delta W = 200 - (-100) = 300\text{ J}$
21. (a) During free expansion of a perfect gas no, work is done and also no heat is supplied from outside. Therefore, no change in internal energy. Hence, temperature remain constant.
22. (d) $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta U = \Delta Q - \Delta W = 150 - 110 = 40\text{ J}$
23. (b) From FLOT $\Delta Q = \Delta U + \Delta W$
 \therefore Heat supplied to the system so $\Delta Q \rightarrow$ Positive
 and work is done on the system so $\Delta W \rightarrow$ Negative
 Hence $+\Delta Q = \Delta U - \Delta W$
24. (a)
25. (d) State of a thermodynamic state cannot determine by a single variable (P or V or T)
26. (d) R is the universal gas constant.
27. (a) From FLOT
 $\Rightarrow dU = dQ - dW \Rightarrow dU = dQ (< 0)$ ($\therefore dW = 0$)
 $\Rightarrow dU < 0$ So temperature will decrease.
28. (b) From FLOT $\Delta Q = \Delta U + \Delta W$
 Work done at constant pressure
 $(\Delta W)_P = (\Delta Q)_P - \Delta U$
 $(\Delta Q)_P - (\Delta Q)_V$ (As we know
 $(\Delta Q)_V = \Delta U$)
 Also $(\Delta Q)_P = mc_p \Delta T$ and $(\Delta Q)_V = mc_v \Delta T$
 $\Rightarrow (\Delta W)_P = m(c_p - c_v) \Delta T$
 $\Rightarrow (\Delta W)_P = 1 \times (3.4 \times 10^3 - 2.4 \times 10^3) \times 10 = 10^4\text{ cal}$
29. (d)
30. (a) Ideal gas possess only kinetic energy.
31. (b) The internal energy and entropy depend only on the initial and final states of the system and not on the path followed to attain that state.
32. (c) $\Delta Q = \Delta U + \Delta W$
 $\therefore \Delta Q = 200\text{ cal} = 200 \times 4.2 = 840\text{ J}$ and $\Delta W = 40\text{ J}$
 $\Rightarrow \Delta U = \Delta Q - \Delta W = 840 - 40 = 800\text{ J}$
33. (c) $\Delta Q = \Delta U + \Delta W = (U_f - U_i) + \Delta W$
 $\Rightarrow 30 = (U_f - 40) + 10 \Rightarrow U_f = 60\text{ J}$
34. (a) With rise in temperature, internal energy also increases.
35. (a)
36. (b) Heat supplied to a gas raise its internal energy and does some work against expansion, so it is a special case of law of conservation of energy.
37. (c) Change in internal energy is always equal to the heat supplied at constant volume.
i.e. $\Delta U = (\Delta Q)_V = \mu C_V \Delta T$
 For monoatomic gas $C_V = \frac{3}{2} R$
 $\Rightarrow \Delta U = \mu \left(\frac{3}{2} R \right) \Delta T = 1 \times \frac{3}{2} \times 8.31 \times (100 - 0)$
 $= 12.48 \times 10^2\text{ J}$
38. (c) $\Delta U = \mu C_V \Delta T = n \left(\frac{R}{\gamma - 1} \right) \Delta T$
 $\Rightarrow \Delta U = \frac{P \Delta V}{(\gamma - 1)} = \frac{P(2V - V)}{\gamma - 1} = \frac{PV}{(\gamma - 1)}$
39. (b) $\Delta U = \mu C_V \Delta T = 2 \times 4.96 \times (342 - 340) = 19.84\text{ cal}$
40. (a)
41. (c) According to FLOT
 $\Delta Q = \Delta U + P \Delta V \Rightarrow \Delta U = \Delta Q - P \Delta V$
 $= 1500 - (2.1 \times 10^5)(2.5 \times 10^{-3}) = 975\text{ Joule}$
42. (a) $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta U = \Delta Q - \Delta W$
 $= 6 \times 4.18 - 6 = 19.08\text{ kJ} \approx 19.1\text{ kJ}$
43. (a) Given $\Delta Q = -20\text{ J}$, $\Delta W = -8\text{ J}$ and $U_i = 30\text{ J}$
 $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta U = (\Delta Q - \Delta W)$
 $\Rightarrow (U_f - U_i) = (U_f - 30) = -20 - (-8) \Rightarrow U_f = 18\text{ J}$
44. (c) Change in internal energy $\Delta U = \mu C_V \Delta T$
 it doesn't depend upon type of process. Actually it is a state function
45. (c)
46. (a) In first process using $\Delta Q = \Delta U + \Delta W$
 $\Rightarrow 8 \times 10^5 = \Delta U + 6.5 \times 10^5 \Rightarrow \Delta U = 1.5 \times 10^5\text{ J}$
 Since final and initial states are same in both process
 So ΔU will be same in both process
 For second process using $\Delta Q = \Delta U + \Delta W$
 $\Rightarrow 10^5 = 1.5 \times 10^5 + \Delta W \Rightarrow \Delta W = -0.5 \times 10^5\text{ J}$
47. (c) $\Delta W = P \Delta V$, here ΔV is negative so ΔW will be negative

48. (b) Entropy is related to second law of thermodynamics.

Isothermal Process

1. (c) In isothermal process temperature remains constant.
2. (a) If isothermal curves cut each other then at equilibrium two temperature will be there which is impossible.
3. (c) In isothermal expansion temperature remains constant, hence no change in internal energy.
4. (d) $W = \mu RT \log_e \frac{V_2}{V_1}$

$$= \left(\frac{m}{M}\right) RT \log_e \frac{V_2}{V_1} = 2.3 \times \frac{m}{M} RT \log_{10} \frac{V_2}{V_1}$$

$$= 2.3 \times \frac{96}{32} R (273 + 27) \log_{10} \frac{140}{70} = 2.3 \times 900 R \log_{10} 2$$
5. (b) $0.8 \times 5 = P \times (3 + 5) \Rightarrow P = 0.5 m$
6. (b) Differentiate $PV = \text{constant}$ w.r.t V
 $\Rightarrow P \Delta V + V \Delta P = 0 \Rightarrow \frac{\Delta P}{P} = -\frac{\Delta V}{V}$
7. (c)
8. (d) $W = -\mu RT \log_e \frac{V_2}{V_1} = -1 \times 8.31 \times (273 + 0) \log_e \left(\frac{22.4}{11.2}\right)$
 $= -8.31 \times 273 \times \log_e 2 = -1572.5 J$
 $[\because \log_e 2 = 0.693]$
9. (a) $E_\theta = P$, if $P = \text{constant}$, $E_\theta = \text{constant}$
10. (c) For isothermal process $PV = RT \Rightarrow P = \frac{RT}{V}$
 $\therefore W = PdV = \int_{V_1}^{V_2} \frac{RT}{V} dV = RT \log_e \frac{V_2}{V_1}$
11. (a) $E_\theta = P$
12. (b) For such a case, pressure = $\frac{1}{\text{Compressibility}}$
13. (a) $E_\theta = P = 1.013 \times 10^5 \text{ N/m}^2$
14. (a) In isothermal process, compressibility $E_\theta = \rho$.
15. (c) In isothermal process, exchange of energy takes place between system and surrounding to maintain the system temperature constant.
16. (c) No change in the internal energy of ideal gas but for real gas internal energy increases

because work is done against intermolecular forces.

17. (a) In isothermal process temperature remains constant. i.e., $\Delta T = 0$. Hence according to $C = \frac{Q}{m \Delta T} \Rightarrow C_{iso} = \infty$
18. (c) This is the case of free expansion of gas. In free expansion $\Delta U = 0 \Rightarrow$ Temp. remains same.
19. (a) An isothermal process takes place at constant temperature, must be carried out in a vessel with conducting wall so that heat generated should go out at once.
20. (c) For isothermal process
 $dU = 0$ and work done = $dW = P(V_2 - V_1)$
 $\therefore V_2 = \frac{V_1}{2} = \frac{V}{2} \therefore dW = -\frac{PV}{2}$
21. (b) In isothermal process, temperature remains constant.
22. (b) In isothermal process, heat is released by the gas to maintain the constant temperature.
23. (a) In isothermal compression, there is always an increase of heat. which must flow out the gas.
 $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta Q = \Delta W (\because \Delta U = 0)$
 $\Rightarrow \Delta Q = -1.5 \times 10^4 J = \frac{1.5 \times 10^4}{4.18} \text{ cal} = -3.6 \times 10^3 \text{ cal}$
24. (a) In isothermal change, temperature remains constant, Hence $\Delta U = 0$.
 Also from $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta Q = \Delta W$
25. (a) It is an isothermal process. Hence work done = $P(V_2 - V_1)$
 $= 1 \times 10^5 \times (1.091 - 1) \times 10^{-6} = 0.0091 J$
26. (c) $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta U = \Delta Q - \Delta W = 2240 - 168 = 2072 J$.
27. (b) Amount of heat given = 540 calories
 Change in volume $\Delta V = 1670 \text{ c.c}$
 Atmospheric pressure $P = 1.01 \times 10^6 \text{ dyn/cm}^2$
 Work done against atmospheric pressure
 $W = P \Delta V = \frac{1.01 \times 10^6 \times 1670}{4.2 \times 10^7} \approx 40 \text{ cal}$
28. (b) $W_{iso} = \mu RT \log_e \frac{V_2}{V_1} = 1 \times 8.31 \times 300 \log_e \frac{20}{10} = 1728 J$

29. (b) $W = \mu RT \log_e \left(\frac{V_2}{V_1} \right) = 0.2 \times 8.3 \times \log_e 2 \times (27 + 273)$

$= 0.2 \times 8.3 \times 300 \times 0.693 = 345 J$

30. (a) For isothermal process $P_1 V_1 = P_2 V_2$

$\Rightarrow P_2 = \frac{P_1 V_1}{V_2} = \frac{72 \times 1000}{900} = 80 \text{ cm}$

Stress $\Delta P = P_2 - P_1 = 80 - 72 = 8 \text{ cm}$

31. (d) During isothermal change $T = \text{constant} \Rightarrow \Delta U = 0$

also from FLOT, $\Delta Q = \Delta W$.

Adiabatic Process

1. (c) Gas cylinder suddenly explodes is an irreversible adiabatic change and work done against expansion reduces the temperature.

2. (c) Work done in adiabatic change $= \frac{\mu R (T_1 - T_2)}{\gamma - 1}$

3. (b) In case of adiabatic expansion $\Delta W = \text{positive}$ and $\Delta Q = 0$

from FLOT $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta U = -\Delta W$
i.e., ΔU will be negative.

4. (d) For adiabatic process $\frac{T^\gamma}{P^{\gamma-1}} = \text{constant}$

$\Rightarrow \frac{T_2}{T_1} = \left(\frac{P_1}{P_2} \right)^{\frac{1-\gamma}{\gamma}} \Rightarrow \frac{T_2}{300} = \left(\frac{4}{1} \right)^{\frac{(1-1.4)}{1.4}} \Rightarrow$

$T_2 = 300(4)^{\frac{-0.4}{1.4}}$

5. (c) $PV^\gamma = \text{constant} \Rightarrow \frac{P_2}{P_1} = \left(\frac{V_1}{V_2} \right)^\gamma \Rightarrow \frac{P_2}{1} = \left(\frac{V_1}{V_1/4} \right)^{3/2} = 8$

$\Rightarrow P_2 = 8 \text{ atm}$.

6. (d) $PV^\gamma = \text{constant} \Rightarrow$

$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2} \right)^\gamma \Rightarrow P_2 = (8)^{5/3} P_1 = 32 P_1$

7. (c) Volume of the gas $V = \frac{m}{d}$ and using $PV^\gamma = \text{constant}$

We get $\frac{P}{d} = \left(\frac{V}{d} \right)^\gamma = \left(\frac{m}{d} \right)^\gamma = (32)^{7/5} = 128$

8. (b) $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2} \right)^{\gamma-1} \Rightarrow T_2 = 300 \left(\frac{27}{8} \right)^{\frac{5}{3}-1} = 300 \left(\frac{27}{8} \right)^{\frac{2}{3}}$

$= 300 \left\{ \left(\frac{27}{8} \right)^{1/3} \right\}^2 = 800 \left(\frac{3}{2} \right)^2 = 675 K$

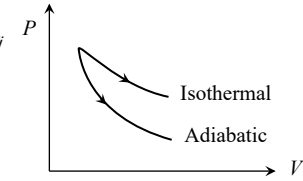
$\Rightarrow \Delta T = 675 - 300 = 375 K$

9. (a) In thermodynamic processes.

Work done = Area covered by PV diagram with V -axis

From graph it is clear that $(\text{Area})_{iso} > (\text{Area})_{adi}$

$\Rightarrow W_{iso} > W_{adi}$



10. (a) Since $PV = RT$ and $T = \text{constant}$;
 $\therefore PV = \text{constant}$.

11. (c) For Isothermal process $PV = \text{constant}$

$\Rightarrow \left(\frac{dP}{dV} \right) = \frac{-P}{V} = \text{Slope of Isothermal curve}$

For adiabatic $PV^\gamma = \text{constant}$

$\Rightarrow \frac{dP}{dV} = \frac{-\gamma P}{V} = \text{Slop of adiabatic curve slope}$

Clearly, $\left(\frac{dP}{dV} \right)_{\text{adiabatic}} = \gamma \left(\frac{dP}{dV} \right)_{\text{isothermal}}$

12. (d) $PV^\gamma = \text{constant} \Rightarrow P \left(\frac{RT}{P} \right)^\gamma = \text{constant}$

$\Rightarrow P^{1-\gamma} T^\gamma = \text{constant}$.

13. (b) $W_{adi} = \frac{R}{\gamma-1} (T_1 - T_2) = \frac{R}{\gamma-1} (T - T_1)$

14. (d) $dQ = 0 = -2 + dW \Rightarrow dW = 2 J$

$\Rightarrow \text{Work done by the gas} = 2 J$

$\Rightarrow \text{Work done on the gas} = -2 J$

15. (d) $E_\phi = \gamma P = 1.4 \times (1 \times 10^5) = 1.4 \times 10^5 \text{ N/m}^2$

16. (b) Slope of adiabatic curve = $\gamma \times$ (Slope of isothermal curve)

17. (a) Due to compression the temperature of the system increases to a very high value. This causes the flow of heat from system to the surroundings, thus decreasing the temperature. This decrease in temperature results in decrease in pressure.

18. (c) $\Delta Q = \Delta U + \Delta W = 0 \Rightarrow \Delta W = -\Delta U$

if ΔW is positive i.e., gas does work then ΔU should be negative meaning internal energy is used in doing work.

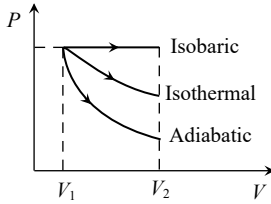
19. (a) $W = \frac{R}{\gamma-1} (T_1 - T_2)$

$= \frac{8.31 \times \{(273 + 27) - (273 + 127)\}}{1.4 - 1} = -2077.5 \text{ joules}$

20. (c) Pressure is reduced, so the temperature falls.
21. (d) Adiabatic Bulk modulus $E_\phi = \gamma P$
22. (c) In adiabatic process, no heat transfers between system and surrounding.
23. (b) $\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^\gamma \Rightarrow P_2 = P_1 \left(\frac{V_1}{V_2}\right)^\gamma = P_0(8)^{4/3} = 16P_0$.
24. (c) In adiabatic process $PV^\gamma = \text{constant}$
 $\Rightarrow \left(\frac{RT}{V}\right) V^\gamma = \text{constant} \Rightarrow TV^{\gamma-1} = \text{constant}$
25. (a) $TV^{\gamma-1} = \text{constant} \Rightarrow \frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^\gamma \Rightarrow T_2 = T_1 \left(\frac{V_1}{V_2}\right)^\gamma$
 $\Rightarrow T_2 = 300 \left(\frac{1}{2}\right)^{0.4} = 227.36 \text{ K}$
26. (b) In adiabatic change $Q = \text{constant} \Rightarrow \Delta Q = 0$
 So $\Delta W = -\Delta U (\because \Delta Q = \Delta U + \Delta W)$
27. (d) For adiabatic process from FLOT
 $\Delta W = -\Delta U \quad (\because \Delta Q = 0)$
 $\Rightarrow \Delta W = -(-100) = +100 \text{ J}$
28. (a) $\Delta U = -\Delta W = -\frac{R(T_1 - T_2)}{(\gamma - 1)} = \frac{R(T_2 - T_1)}{\gamma - 1}$
29. (d) $TV^{\gamma-1} = \text{constant} \Rightarrow T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{\gamma-1} = 927^\circ \text{C}$
30. (d) The process is very fast, so the gas fails to gain or lose heat. Hence this process is adiabatic
31. (a) $\Delta U = \mu C_V \Delta T = 1 \times C_V (T_f - T_i) = -C_V (T_i - T_f)$
 $\Rightarrow |\Delta U| = C_V (T_i - T_f)$
32. (c) $T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{\gamma-1} = 273(2)^{0.41} = 273 \times 1.328 = 363 \text{ K}$
 $W = \frac{R(T_1 - T_2)}{\gamma - 1} = \frac{8.31(273 - 363)}{1.41 - 1} = -1824$
 $\Rightarrow |W| \approx 1815 \text{ J}$
33. (d)
34. (c) $TV^{\gamma-1} = \text{constant}$
 $\Rightarrow T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{\gamma-1} = (273 + 18) \left(\frac{V}{V/8}\right)^{0.4} = 668 \text{ K}$
35. (a) $\Delta Q = mc\Delta\theta$. Here $\Delta Q = 0$, hence $c = 0$
36. (d) In adiabatic process, no transfer of heat takes place between system and surrounding.
37. (b) $W = \frac{\mu R(T_1 - T_2)}{(\gamma - 1)} = \frac{\mu R T_1}{(\gamma - 1)} \left[1 - \frac{T_2}{T_1}\right]$
 $= \frac{\mu R T_1}{(\gamma - 1)} \left[1 - \left(\frac{V_1}{V_2}\right)^{\gamma-1}\right]$
 $= \frac{2 \times 8.31 \times 300}{\left(\frac{5}{3} - 1\right)} \left[1 - \left(\frac{1}{2}\right)^{5-1}\right] = +2767.23 \text{ J}$
38. (d) $T^\gamma P^{1-\gamma} = \text{constant} \Rightarrow T \propto P^{\frac{\gamma-1}{\gamma}}$
 $\Rightarrow \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{1}{8}\right)^{\frac{5/3-1}{5/3}}$
 $T_2 = 300 \times \left(\frac{1}{8}\right)^{0.4} = 131 \text{ K} = -142^\circ \text{C}$
39. (a) In adiabatic process $\Delta Q = 0 \Rightarrow \Delta U + \Delta W = 0$
 $(\because \Delta Q = \Delta U + \Delta W)$
40. (d) Using relation $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = (8)^{\frac{3/2-1}{3/2}} = 2$.
 $\Rightarrow T_2 = 2T_1 \Rightarrow T_2 = 2(273 + 27) = 600 \text{ K} = 327^\circ \text{C}$
41. (c) $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} \Rightarrow \frac{T_2}{T_1} = \left(\frac{1}{8}\right)^{\frac{1.5-1}{1.5}} = \left(\frac{1}{8}\right)^{\frac{1}{3}} = \frac{1}{2}$
 $\Rightarrow T_2 = \frac{T_1}{2} = \frac{300}{2} = 150 \text{ K}$.
42. (c) $\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^\gamma \Rightarrow \frac{P}{P} = (8)^{5/2} \Rightarrow P = P \times (2)^{15/2}$
43. (a)
44. (a) Given $P \propto T^3$, but we know for an adiabatic process, the pressure $P \propto T^{\gamma/\gamma-1}$
 So $\frac{\gamma}{\gamma-1} = 3 \Rightarrow \gamma = \frac{3}{2} \Rightarrow \frac{C_p}{C_v} = \frac{3}{2}$
45. (b)
46. (d) $W = \frac{R(T_i - T_f)}{\gamma - 1} \Rightarrow 6R = \frac{R(T - T_f)}{\left(\frac{5}{3} - 1\right)} \Rightarrow T_f = (T - 4) \text{ K}$.
47. (a) $\because TV^{\gamma-1} = \text{constant} \Rightarrow T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$
 $\Rightarrow T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{\gamma-1} = T_1 (4)^{1.5-1} = 2T_1$
 $\therefore \text{change in temperature}$
 $= T_2 - T_1 = 2T_1 - T_1 = T_1 = 273 \text{ K}$

48. (b) $\because PV = k(\text{constant}) \Rightarrow P_1 V_1 = P_2 V_2$
 $\Rightarrow P_2 = P_1 \left(\frac{V_1}{V_2} \right)^\gamma = 10^5 \times (2)^{1.3} \quad (\because V_2 = \frac{V_1}{2})$
49. (b) In adiabatic process $\Delta U = -\Delta W$. In compression ΔW is negative, so ΔU is positive i.e. internal energy increases.
50. (a) According to the first law of thermodynamics
 $\Delta Q = \Delta U + \Delta W$
 In adiabatic process $\Delta Q = 0$, hence $\Delta U = -\Delta W$
51. (b) $PV = \text{constant} \Rightarrow \frac{P_2}{P_1} = \left(\frac{V_1}{V_2} \right)^\gamma = \left(\frac{V_1}{V_1/4} \right)^\gamma = 4^\gamma$
 $\Rightarrow P_2 = 4^\gamma P$
 As γ is always greater than one so $4^\gamma > 4 \Rightarrow P_2 > 4P$
52. (d) $P_1 V_1 = P_2 V_2 \Rightarrow \frac{P_2}{P_1} = \left[\frac{V_1}{V_2} \right]^\gamma = \left[\frac{4}{1} \right]^{3/2} = \frac{8}{1}$
53. (b) Change in internal energy of the gas
 $\Delta U = -\Delta W = \frac{R}{\gamma-1} [T_2 - T_1] = \frac{8.3}{(1.4-1)} [308 - 300] = 166 \text{ J}$
54. (b) For adiabatic change $TV^{\gamma-1} = \text{constant}$
 $\Rightarrow \frac{T_2}{T_1} = \left(\frac{V_1}{V_2} \right)^{\gamma-1} \Rightarrow T_2 = \left(\frac{V_1}{V_2} \right)^{\gamma-1} \times T_1$
 $\Rightarrow T_2 = \left(\frac{V}{V/4} \right)^{1.4-1} \times 300 = 300 \times (4)^{0.4} \text{ K}$
55. (d) For adiabatic forces $\Delta W = -\Delta U \quad (\because \Delta Q = 0)$
 $\Rightarrow \Delta W = -(-50) = +50 \text{ J}$
56. (b) $\frac{\text{Adiabatic elasticity } (E_\theta)}{\text{Isothermal elasticity } (E_\theta)} = \gamma \Rightarrow E_\theta = \frac{E_\theta}{\gamma}$
 $\Rightarrow E_\theta = \frac{2.1 \times 10^5}{1.4} = 1.5 \times 10^5 \text{ N/m}^2$
57. (c) $PV = \text{constant}$: Differentiating both sides
 $P\gamma V^{\gamma-1} dV + V^\gamma dP = 0 \Rightarrow \frac{dP}{P} = -\gamma \frac{dV}{V}$

$$\text{Increase} = \frac{274 \text{ V}}{273} - V = \frac{V}{273}$$

4. (a) From FLOT $\Delta Q = \Delta U + \Delta W = \Delta U + P\Delta V$
 $\Rightarrow 100 = \Delta U + 50 \times (4 - 1) \Rightarrow \Delta U = 400 \text{ J}$
5. (a) $W = P \times \Delta V = 2 \times 10^5 (150 - 50) \times 10^{-3} = 2 \times 10^4 \text{ J}$
6. (c) $W = P\Delta V = nR\Delta T = 0.1 \times 2 \times 300 = 60 \text{ cal}$
7. (c) $\Delta Q = \Delta V + P\Delta V \Rightarrow mL = \Delta U + P(V_2 - V_1)$
 $\Rightarrow \Delta U = L - P(V_2 - V_1) \quad (\because m = 1)$
8. (b) $\Delta W = P\Delta V = 10^3 \times 0.25 = 250 \text{ J}$
9. (d) $W = P\Delta V = 1.01 \times 10^5 (3.34 - 2 \times 10^{-3})$
 $= 337 \times 10^3 \text{ J} \approx 340 \text{ kJ}$
10. (c) $\frac{T_2}{T_1} = \frac{V_2}{V_1} = 2 \Rightarrow T_2 = 2 \times T_1 = 2 \times 300 = 600 \text{ K} = 327^\circ \text{ C}$
11. (c) $V \propto T$ at constant pressure
 $\Rightarrow \frac{V_1}{V_2} = \frac{T_1}{T_2} \Rightarrow V_2 = \frac{V_1 T_2}{T_1} = \frac{300 \times 280}{300} = 280 \text{ ml.}$
12. (a) In thermodynamic process, work done is equal to the area covered by the PV curve with volume axis.
 Hence, according to graph shown
 $W_{\text{adiabatic}} < W_{\text{isothermal}} < W_{\text{isobaric}}$
- 
13. (b) (Similar to previous question)
14. (a)
15. (d) $W = P\Delta V = 2.4 \times 10^{-4} \times 1 \times 10^5 = 24 \text{ J}$
16. (b) At constant pressure
 $W = P\Delta V = \mu R\Delta T = 1 \times 8.31 \times 100 = 831 \approx 814 \text{ J}$
17. (a) $\Delta V = 0 \Rightarrow P\Delta V = 0 \Rightarrow \Delta W = 0$
18. (d) Entropy of a reversible process does not change.
19. (c) $W = P\Delta V = 0 \quad (\text{As } \Delta V = 0)$
20. (d)
21. (d) At constant volume $P \propto T \Rightarrow \frac{P_1}{P_2} = \frac{T_1}{T_2} \Rightarrow \frac{P_1}{P_2} = \frac{300}{400} = \frac{3}{4}$
22. (d) In isothermal process $\Delta Q \neq 0$.

Isobaric and Isochoric Processes

1. (a) Work done $= P\Delta V = P(V_2 - V_1)$
2. (c) When heat is supplied at constant pressure, a part of it goes in the expansion of gas and remaining part is used to increase the temperature of the gas which in turn increases the internal energy.
3. (c) For isobaric process $\frac{V_2}{V_1} = \frac{T_2}{T_1} \Rightarrow V_2 = V_1 \times \frac{274}{273}$

23. (a) For isochoric process $\Delta V = 0 \Rightarrow \Delta W = 0$
From FLOT $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta Q = \Delta U$

**Heat Engine, Refrigerator and
Second Law of Thermodynamics**

1. (d) $\eta = \frac{T_1 - T_2}{T_1} = \frac{W}{Q} \Rightarrow Q = \left(\frac{T_1}{T_1 - T_2} \right) W$
 $= \frac{600}{(600 - 300)} \times 800 = 1600 \text{ J}$
2. (c) Coefficient of performance
 $K = \frac{T_2}{T_1 - T_2} = \frac{273}{303 - 273} = \frac{273}{30} = 9$
3. (b) In a refrigerator, the heat dissipated in the atmosphere is more than that taken from the cooling chamber, therefore the room is heated if the door of a refrigerator is kept open.
4. (c) Internal energy is a state function.
5. (b)
6. (d) For a reversible process $\int \frac{dQ}{T} = 0$
7. (b) For cyclic forces $\Delta U = 0$ So, $\Delta Q = \Delta W$
8. (d) $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{400}{500} = \frac{1}{5} \therefore \eta = \frac{W}{Q} \Rightarrow \frac{1}{5} = \frac{W}{Q}$
 $\Rightarrow W = \frac{Q}{5} = \frac{6}{5} \times 10^4 = 1.2 \times 10^4 \text{ J}$
9. (b) $\eta = 1 - \frac{T_2}{T_1} \Rightarrow \frac{30}{100} = 1 - \frac{350}{T_1}$
 $\Rightarrow \frac{350}{T_1} = 1 - \frac{50}{100} = \frac{70}{100} = \frac{7}{10} \Rightarrow$
 $T_1 = 500 \text{ K} = 227^\circ \text{C}$
10. (b) $\eta = 1 - \frac{T_2}{T_1}$ for 100% efficiency $\eta = 1$ which gives $T_2 = 0 \text{ K}$.
11. (c) $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{(273 + 69)}{(273 + 411)} = 0.5$
 $\Rightarrow \text{Work done} = \eta \times Q = 0.5 \times 1000 = 500 \text{ J}$
12. (b) $\therefore \eta = 1 - \frac{T_2}{T_1} = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$
where $Q_1 =$ heat absorbed, $Q_2 =$ heat rejected
 $\Rightarrow 1 - \frac{T/3}{T} = \frac{W}{Q_1} \Rightarrow \frac{2}{3} = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$
 $\Rightarrow \frac{2}{3} = 1 - \frac{Q_2}{Q_1} \Rightarrow \frac{Q_2}{Q_1} = \frac{1}{3} \Rightarrow Q_2 = \frac{Q_1}{3} = \frac{Q}{3}$

13. (c) $\eta = 1 - \frac{T_2}{T_1} \Rightarrow \frac{25}{100} = 1 - \frac{300}{T_1} \Rightarrow \frac{1}{4} = 1 - \frac{300}{T_1}$
 $T_1 = 400 \text{ K} = 127^\circ \text{C}$
14. (a) $\eta = 1 - \frac{T_2}{T_1} \Rightarrow \frac{70}{100} = 1 - \frac{T_2}{1000} \Rightarrow T_2 = 300 \text{ K}$
15. (a) $\eta = 1 - \frac{T_2}{T_1} = \frac{T_1 - T_2}{T_1} \Rightarrow \eta_1 = \frac{(473 - 273)}{473} = \frac{200}{473}$
and $\eta_2 = \frac{273 - 73}{273} = \frac{200}{273}$
So required ratio $\frac{\eta_1}{\eta_2} = \frac{273}{473} = 0.577$
16. (a) $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{(273 + 123)}{(273 + 27)} = 1 - \frac{150}{300} = \frac{1}{2} = 50\%$
17. (b) $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{300}{500} = \frac{2}{5}$
18. (d)
19. (b) In first case, $(\eta_1) = 1 - \frac{500}{800} = \frac{3}{8}$
and in second case, $(\eta_2) = 1 - \frac{600}{x}$
Since $\eta_1 = \eta_2$, therefore $\frac{3}{8} = 1 - \frac{600}{x}$
or $\frac{600}{x} = 1 - \frac{3}{8} = \frac{5}{8}$ or $x = \frac{600 \times 8}{5} = 960 \text{ K}$
20. (a) $\eta_{\text{max}} = 1 - \frac{T_2}{T_1} = 1 - \frac{300}{400} = \frac{1}{4} = 25\%$
So 26% efficiency is impossible
21. (b) In first case $\eta_1 = 1 - \frac{T_2}{T_1} = 1 - \frac{(273 + 0)}{(273 + 200)} = \frac{200}{473}$
In second case $\eta_2 = 1 - \frac{(273 - 200)}{(273 + 0)} = \frac{200}{273}$
 $\Rightarrow \frac{\eta_1}{\eta_2} = \frac{1}{\left(\frac{473}{273} \right)} = 1 : 1.73$
22. (b) $\eta = 1 - \frac{T_2}{T_1} \Rightarrow \frac{1}{2} = 1 - \frac{500}{T_1} \Rightarrow \frac{500}{T_1} = \frac{1}{2} \dots\dots(i)$
 $\frac{60}{100} = 1 - \frac{T_2'}{T_1} \Rightarrow \frac{T_2'}{T_1} = \frac{2}{5}$
Dividing equation (i) by (ii), $\frac{500}{T_2'} = \frac{5}{4} \Rightarrow$
 $T_2' = 400 \text{ K}$
23. (c)
24. (a)
25. (b) $\eta = 1 - \frac{T_2}{T_1} = \frac{W}{Q} \Rightarrow$
 $W = \left(1 - \frac{T_1}{T_2} \right) Q = \left\{ 1 - \frac{(273 + 27)}{(273 + 627)} \right\}$
 $\Rightarrow W = \left(1 - \frac{300}{900} \right) \times 3 \times 10^6 = 2 \times 10^6 \times 4.2 \text{ J} = 8.4 \times 10^6 \text{ J}$

26. (a)
27. (d) $\eta = 1 - \frac{T_2}{T_1}$; for η to be max. ratio $\frac{T_2}{T_1}$ should be min.
28. (a)
29. (b) In first case $\eta_1 = \frac{T_1 - T_2}{T_1}$
 In second case $\eta_2 = \frac{2T_1 - 2T_2}{2T_1} = \frac{T_1 - T_2}{T_1} = \eta$
30. (c) Coefficient of performance

$$K = \frac{T_2}{T_1 - T_2} \Rightarrow 5 = \frac{(273 - 13)}{T_1 - (273 - 13)} = \frac{260}{T_1 - 260}$$

$$\Rightarrow 5T_1 - 1300 = 260 \Rightarrow 5T_1 = 1560$$

$$\Rightarrow T_1 = 312K \rightarrow 39^\circ C$$
31. (a) Coefficient of performance $K = \frac{T_2}{T_1 - T_2}$

$$= \frac{(273 - 23)}{(273 + 27) - (273 - 23)} = \frac{250}{300 - 250} = \frac{250}{20} = 5$$
32. (a) $\eta = \frac{T_1 - T_2}{T_1} = \frac{(273 + 727) - (273 + 227)}{273 + 727} = \frac{1000 - 500}{1000} = \frac{1}{2}$
33. (c) $\eta = \frac{T_1 - T_2}{T_1} = \frac{W}{Q} \Rightarrow W = \frac{Q(T_1 - T_2)}{T_1}$

$$= \frac{6 \times 10^4 [(227 + 273) - (273 + 127)]}{(227 + 273)}$$

$$= \frac{6 \times 10^4 \times 100}{500} = 1.2 \times 10^4 \text{ cal}$$
34. (d) Slow isothermal expansion or compression of an ideal gas is reversible process, while the other given process are irreversible in nature.

Critical Thinking Questions

1. (d) Fraction of supplied energy which increases the internal energy is given by

$$f = \frac{\Delta U}{(\Delta Q)_p} = \frac{(\Delta Q)_V}{(\Delta Q)_p} = \frac{\mu C_V \Delta T}{\mu C_p \Delta T} = \frac{1}{\gamma}$$
 For diatomic gas $\gamma = \frac{7}{5} \Rightarrow f = \frac{5}{7}$
2. (c) $\Delta Q = \Delta U + \Delta W$

$$\therefore \Delta U = \Delta Q - \Delta W = 540 - \frac{P(V_2 - V_1)}{J}$$

$$= 540 - \frac{1.013 \times 10^5 \times [(1671 - 1) \times 10^{-6}]}{4.2}$$

$$= 540 - 39.7 = 500 \text{ calories}$$
3. (b,c) There is a decrease in volume during melting on an ice slab at 273K. Therefore, negative work is done by

ice-water system on the atmosphere or positive work is done on the ice-water system by the atmosphere. Hence option (b) is correct. Secondly heat is absorbed during melting (*i.e.* ΔQ is positive) and as we have seen, work done by ice-water system is negative (ΔW is negative). Therefore, from first law of thermodynamics $\Delta U = \Delta Q - \Delta W$.

Change in internal energy of ice-water system, ΔU will be positive or internal energy will increase.

4. (c) Process is isothermal. Therefore, $T = \text{constant}$,
 $\left(P \propto \frac{1}{V}\right)$ volume is increasing, therefore pressure will decrease.
 In chamber A:

$$\Delta P = P_i - P_f = \frac{\mu_A RT}{V} - \frac{\mu_A RT}{2V} = \frac{\mu_A RT}{2V} \dots (i)$$
 In chamber B:

$$1.5 \Delta P = P_i - P_f = \frac{\mu_B RT}{V} - \frac{\mu_B RT}{2V} = \frac{\mu_B RT}{2V} \dots (ii)$$
 from equations (i) and (ii) $\frac{\mu_A}{\mu_B} = \frac{1}{1.5} = \frac{2}{3}$

$$\Rightarrow \frac{m_A / M}{m_B / M} = \frac{2}{3} \Rightarrow 3m_A = 2m_B$$
5. (d) $T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1} \Rightarrow \frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1} = \left(\frac{L_2 A}{L_1 A}\right)^{\frac{5}{3}-1} = \left(\frac{L_2}{L_1}\right)^{\frac{2}{3}}$
6. (d) Using Boyle's law, we have $\frac{V}{T} = \text{constant}$

$$\Rightarrow \frac{l}{2+5} = \frac{l}{273}$$

As the piston moves 5 cm, the length of one side will be $\left(\frac{l}{2} + 5\right)$ and other side $\left(\frac{l}{2} - 5\right)$.
 On solving this equation, we get $l = 64.6$ cm.