THERMODYNAMICS

FIRST LAW OF THERMODYNAMICS

2011

1. When 1 kg of ice at 0^0C melts to water at 0^0C, the resulting change in its entropy, taking latent heat of ice to be $80\,cal/{}^0C$, is

a) $8\times10^4 cal/K$ b) 80 cal/K c) 293 cal/K d)273 cal/K

2010

2. A cylinder of fixed capacity (of 44.8 L) contains 2 moles of helium gas at STP. What is the amount of heat needed to raise the temperature of the gas in the cylinder by 20^0C?

(Use $R = 8.31 J\,mol^{-1} K^{-1}$)

a) 996J b) 831 J c) 498 J d) 374 J

3. Ten moles of an ideal gas at constant temperature 600K is compressed from 100L to 10L. The work done in the process is

a) $4.11\times10^4 J$ b) $-4.11\times10^4 J$ c) $11.4\times10^4 J$ d) $-11.4\times10^4 J$

4. A perfect gas goes from state A to state B by absorbing $8\times10^5 J$ of heat and doing $6.5\times10^5 J$ of external work. It is now transferred between the same two states in another process in which it absorbs $10^5 J$ of heat. In the second process

a) work done on gas is $10^5 J$ b) work done on gas in $0.5\times10^5 J$

c) work done by gas is $10^5 J$ d) work done by gas is $0.5\times10^5 J$

5. A constant volume gas the thermometer work on

a) Archimedes principle b) Pascal's law

c) Boyle's law d) Charles' law

2008

6. If Q, E and W denote respectively the heat added change in internal energy and the work done in a closed cycle process then

a) W = 0 b) Q = W = 0 c) E = 0 d) Q = 0

7. Two rigid boxes containing different ideal gases are placed on table. Box A contains one mole of nitrogen at temperature T_0, while box B contains one mole of helium at temperature $(7/3)T_0$. The boxes are then put into thermal contact with each other, and heat flows between them until the gases reach a common final temperature (ignore the heat capacity of boxes). Then, the final temperature of the gases, T_f, in terms of T_0 is

a) $T_f = \frac{3}{7}T_0$ b) $T_f = \frac{7}{3}T_0$ c) $T_f = \frac{3}{2}T_0$ d) $T_f = \frac{5}{2}T_0$

8. An ideal gas is taken through a cyclic thermo dynamical process through four steps. The amounts of heat involved in these steps are $Q_1 = 5960J$ b, $Q_2 = 5585J$, $Q_3 = -2980J$; $Q_4 = 3645J$; **respectively. The corresponding works involved are** $W_1 = 2200J$, $W_2 = -825J$, $W_3 = -1100J$ **and** W_4 **respectively. The value of** W_4 **is**

a) 1315 J b) 275 J c) 765 J d) 675 J

2007

9. A gas is heated at constant pressure. The fraction of heat supplied used for external work is

a) $\frac{1}{\gamma}$ b) $\left(1-\frac{1}{\gamma}\right)$ c) $\gamma - 1$ d) $\left(1-\frac{1}{\gamma^2}\right)$

10. $1cm^3$ **of water at its boiling point absorbs 540 cal of heat of become steam with a volume of** $1671cm^3$**. If the atmospheric pressure** $= 1.013\times10^5\, Nm^{-2}$ **and the mechanical equivalent of heat = 4.19J cal the energy spent in this process in overcoming intermolecular forces is**

a) 540 cal b) 40 cal c) 500 cal d) zero

2004

11. Assertion (A): Thermodynamic processes in nature are irreversible
Reason (R): Dissipative effects cannot be eliminated

a) Both assertion and reason are true and reason is the correct explanation of assertion
b) Both assertion and reason are true but reason is not the correct explanation of assertion
c) Assertion is true but reason is false
d) Both assertion and reason are false

12. Air is expanded from 50L to 150L at 2 atm pressure. The external work done is (1 atm $1\times10^5\, Nm^{-2}$)

a) $2\times10^{-8}J$ b) $2\times10^4 J$ c) 200J d) 2000J

13. The amount of work, which can be obtained by supplying 200cal of heat, is

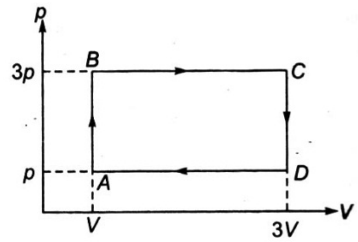
a) 840 J b) 840 erg c) 840 W d) 840 dyne

2003

14. The intensive property among the following is

a) Energy b) volume c) entropy d) temperature

15. An ideal monatomic gas is taken around the cycle ABCDA as shown in figure. The work done during the cycle is given by



a) 8 pV   b) pV   c) 4 pV   d) 2 pV

Thermodynamic Processes

2010

16. During an adiabatic expansion the increase in volume is associated with which of the following possibilities w.r.t. pressure and temperature?

Pressure	**Temperature**
a) increase	increase
b) increase	decrease
c) increase	decrease
b) decrease	increase

17. A mono-atomic gas is suddenly compressed to (1/8)th of its initial volume adiabatically. The ratio of its final pressure to the initial pressure is (given the ratio of the specific heats of the given gas to be 5/3)

a) 32   b) 40/3   c) 24/5   d) 8

18. Assertion (A): The isothermal curve intersects each other at a certain point.

Reason (R): The isothermal change takes place rapidly, so the isothermal curve have very little slope.

a) Both assertion and reason are true and reason is the correct explanation of assertion

b) Both assertion and reason are true but reason is not the correct explanation of assertion

c) Assertion is true but reason is false   d) Both assertion and reason are false

19. In an adiabatic process where pressure is increased by $\frac{2}{3}\%$. If $\frac{C_p}{C_v} = \frac{3}{2}$, then the volume decreases by about

a) $\frac{4}{9}\%$ b) $\frac{2}{3}\%$ c) 4%   d) $\frac{9}{4}\%$

2007

20. The internal energy of an ideal gas increases during an isothermal process when the gas is

a) expanded by adding more molecules to it
b) expanded by adding more heat to it
c) expanded against zero pressure
d) compressed by doing work on it

21. A sample of gas expands from volume V_1 to V_2 . The amount of work done by the gas is greatest when the expansion is

a) adiabatic
b) isobaric
c) isothermal
d) equal in all above cases

2005

22. Assertion (A): Air quickly leaking out of a balloon becomes cooler
Reason (R): The leaking air undergoes adiabatic expansion

a) Both assertion and reason are true and reason is the correct explanation of assertion
b) Both assertion and reason are true but reason is not the correct explanation of assertion
c) Assertion is true but reason is false
d) Both assertion and reason are false

23. A perfect gas is found to obey the relation $PV^{3/2} =$ constant during an adiabatic process, if such a gas initially at a temperature T, is compressed to half of its initial volume, then its final temperature will be

a) 2T
b) 4T
c) $(2)^{1/2}T$
d) $2(2)^{1/2}T$

2004

24. A gas is compressed at a constant pressure of $50\,Nm^{-2}$ from a volume of $10m^3$ to a volume of $4m^3$. Energy of 100J, then added to gas by heating. Its internal energy is

a) Increased by 400J
b) increased by 200J
c) increased by 100J
d) decreased by 200J

25. If the ratio of specific heats of a gas constant pressure to that at constant volume is γ the change in internal energy of a gas when the volume changes from V to 2V at constant pressure p, is

a) pV
b) $\frac{R}{\gamma-1}$
c) $\frac{pV}{\gamma-1}$
d) $\frac{\gamma pV}{\gamma-1}$

Second Law of Thermodynamics and Entropy

2010

26. Choose the incorrect statement from the following

S1: the efficiency of a heat engine can be 1, but the coefficient of performance of a refrigerator can never infinity

S2: The first law of thermodynamics is basically the principle of conservation of energy

S3: The second law of thermodynamics does not allow several phenomena consistent with the first law

S4: A process whose sole result is the transfer of heat from a colder object to a hotter object is impossible

a) S1 b) S3 c) S2 d) S4

27. Which of the following statement is correct for any thermodynamics system

a) The internal energy changes in all processes

b) Internal energy and entropy are state functions

c) The change in entropy can never be zero

d) The work done in an adiabatic process is always zero

2008

28. The freezer in a refrigerator is located at the top section so that

a) the entire chamber of the refrigerator is cooled quickly due to convection

b) the motor is not heated

c) the heat gained from the environment is high

d) the heat gained from the environment is low

29. A Carnot engine takes heat from a reservoir at $627^0 C$ and rejects heat to a sink at $27^0 C$. Its efficiency will be

a) 3/5 b) 1/3 c) 2/3 d) 200/209

2007

30. An engine has an efficiency of $\frac{1}{6}$. When the temperature of sink is reduced by $62^0 C$, its efficiency is doubled. Temperature of the source is

a) $124^0 C$ b) $37^0 C$ c) $62^0 C$ d) $99^0 C$

31. An ideal gas heat engine operates in a Carnot cycle between $227^0 C$ and $127^0 C$. It absorbs 6 kcal at the higher temperature. The amount of heat (in kcal) converted into work is equal to

a) 1.6 b) 1.2 c) 4.8 d) 3.5

2006

32. Assertion (A) : In an isolated system the entropy increases.

Reason (R) : The process in an isolated system are adiabatic

a) Both assertion and reason are true and reason is the correct explanation of assertion

b) Both assertion and reason are true but reason is not the correct explanation of assertion

c) Assertion is true but reason is false d) Both assertion and reason are false

33. Assertion (A) : The Carnot cycle is useful in understanding the performance of heat engines

Reason (R) : The Carnot cycle provide a way of determining the maximum possible efficiency achievable with reservoirs of given temperature

a) Both assertion and reason are true and reason is the correct explanation of assertion

b) Both assertion and reason are true but reason is not the correct explanation of assertion

c) Assertion is true but reason is false d) Both assertion and reason are false

34. The inside outside temperatures of a refrigerators are 273K and 303K respectively. Assuming that refrigerator cycle is reversible, for every joule of work done the heat delivered to the surrounding will be

a) 10 J b) 20 J c) 30 J d) 50 J

35. A Carnot engine has efficiency 1/5. Efficiency becomes 1/3 when temperature of sink is decreased by 50K. What is the temperature of sink

a) 325 K b) 375 K c) 300 K d) 350 K

36. Consider the statement (A) and (B) and identify the correct answers

A : First law of thermodynamics specifics the conditions under which a body can use its heat energy to produce the work

B : Second law of thermodynamics states that heat always flows from hot body to cold body the itself

a) Both A and B are true b) Both A and B are false

c) A is true but B is false d) A is false B is true

37. Efficiency of engine working at 40^0C , 20^0C **is**

a) 0.064 % b) 0.645 c) 64% d) 6.4%

2005

38. Carnot engine cannot give 100% efficiency, because we cannot

a) eliminate friction b) find ideal sources

c) prevent radiation d) reach absolute zero temperature

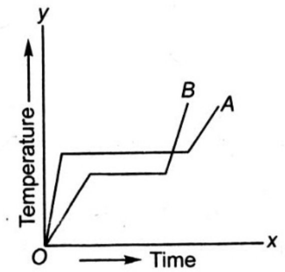
39. In heat engine sink is fitted at temperature 27^0C **and heat of 100 kcal is taken from source at temperature** 677^0C **. Work done in (joule) is**

a) 0.28×10^6 b) 2.8×10^6 c) 28×10^6 d) 0.028×10^6

Calorimetry

2009

40. Equal masses of two liquids A and B contained in vessels of negligible heat capacity are supplied heat at the same rate. The temperature-time graphs for the two liquids are shown If S represents specific heat and L represents latent heat of liquid then



a) $S_A > S_B, L_A < L_B$ b) $S_A > S_B, L_A > L_B$ c) $S_A < S_B, L_A < L_B$ d) $S_A < S_B, L_A > L_B$

41. 19g of water at 30^0C and 5g of ice at -20^0C are mixed together in a calorimeter. What is the final temperature of the mixture? (Given specific heat of ice = 0.5cal $g^{-1}(^0C)^{-1}$ and latent heat of fission of ice $=80cal g^{-1}$)

a) 0^0C b) -5^0C c) 5^0C d) 10^0C

42. The height of a waterfall is 30m.($g = 9.8ms^{-2}$) the difference between the temperature at the top and the bottom of the waterfall is

a) 1.17^0C b) 2.17^0C c) 0.117^0C d) 1.43^0C

2006

43. In an energy recycling process, X g of steam at 100^0C becomes water at which converts Y g of ice 0^0C into water at 100^0C . The ratio of X and Y will be

a) $\frac{1}{3}$ b) $\frac{2}{3}$ c) 3 d) 2

2005

44. Assertion (A): In pressure temperature (P-T) phase diagram of water, the slope of the melting curve is found to be negative

Reason (R): Ice contracts on melting to water

a) Both assertion and reason are true and reason is the correct explanation of assertion

b) Both assertion and reason are true but reason is not the correct explanation of assertion

c) Assertion is true but reason is false d) Both assertion and reason are false

KEY

1) c	2) c	3) b	4) d	5) d	6) c	7) c	8) c	9) b	10) c
11) a	12) b	13) a	14) d	15) c	16) b	17) a	18) d	19) a	20) a
21) b	22) a	23) c	24) a	25) c	26) a	27) d	28) a	29) c	30) d
31) b	32) b	33) a	34) a	35) c	36) a	37) d	38) d	39) a	
40) d	41) c	42) c	43) a	44) a					

HINTS

First Law of Thermodynamics

1. $\Delta S = \frac{ml}{T} = \frac{1000\times 80}{273} = 293\,cal\,K^{-1}$

2. Internal energy $= \mu C_V \Delta T$

$U = \frac{1}{2} f\,\mu R\Delta T \left[\because C_v = \frac{1}{2} fR\right]$

$U = \frac{1}{2}\times 3\times 2\times 8.31\times 20 = 498.6\text{J}$

3. $W = 2.3026 n\,RT\log_{10}\left(\frac{V_2}{V_1}\right)$

$= 2.3026\times 10\times 8.3\times 600\log_{10}\left(\frac{10}{100}\right) = -11.4\times 10^4\,J$

4. From first law of thermodynamics

dU = dQ – dW

$dU = 8\times 10^5 - 6.5\times 10^5$

$dU = -0.5\times 10^5\,J$

In the second process, dU remains the same

$\therefore dW = dQ - dU = 1\times 10^5 - 1.5\times 10^5$

$dW = -0.5\times 10^5\,J$

7. $\Delta U_A = 1\times\frac{5R}{2}(T_f - T_0)$

$\Delta U_B = 1\times\frac{3R}{2}(T_f - \frac{7}{3}T_0)$

Now, $\Delta U_A + \Delta U_B = 0$

$\frac{5R}{2}(T_f - T_0) + \frac{3R}{2}\left(T_f - \frac{7T_0}{3}\right) = 0$

$5T_f - 5T_0 + 3T_f - 7T_0 = 0$

$= 8T_f = 12T_0$

$\Rightarrow T_f = \frac{12}{8}T_0 = \frac{3}{2}T_0$

8. $\Delta Q = Q_1 + Q_2 + Q_3 + Q_4$

= 5960 – 5585 – 2980 + 3645 = 1040J

$\Delta W = W_1 + W_2 + W_3 + W_4$

$= 2200 - 825 - 1100 + W_4 = 275 + W_4$

For a cyclic process $\Delta U = 0$

Ie, $U_f - U_i = 0$

From first law of thermodynamics,

$\Delta Q = \Delta U + \Delta W$

$1040 = 0 + 275 + W_4$

Or $W_4 = 765J$

12. Work done $W = p \times \Delta V = 2\times10^5 \times (150-50)\times10^{-3} = 2\times10^4 J$

13. Work done = heat supplied

W = 200 x 4.2

W = 840 J

15. The work done = area of p-V rectangle

W = AD x CD = (3V – V) (3p-p) = 2V x 2p = 4pV

Thermodynamics Processes

16. $\Delta Q = \Delta U + \Delta W$

For an adiabatic process

$\Delta Q = 0$

$\Delta U = -W$

In adiabatic process

$p \propto \frac{1}{V^r}$ and $T \propto \frac{1}{V^{r-1}}$

$\gamma > 1$, because volume increases

Then, p and T will decreases

17. $pV^{\gamma} = \text{constant}$

$$\Rightarrow \frac{p_1}{p_2} = \left(\frac{V_2}{V_1}\right)^{\gamma}$$

$$\Rightarrow \frac{p_1}{p_2} = \left(\frac{1}{8}\right)^{5/3}$$

$$\Rightarrow \frac{p_1}{p_2} = \left(\frac{1}{2^3}\right)^{5/3} = \frac{1}{32}$$

$$\therefore \frac{p_2}{p_1} = 32$$

19. $pV^{\gamma} =$ constant (Say C)

Here $\gamma = \frac{C_p}{C_v} = \frac{3}{2}$

$$\therefore pV^{3/2} = C$$

$$\Rightarrow \log p + \frac{3}{2}\log V = \log C$$

$$\Rightarrow \frac{\Delta p}{p} + \frac{3}{2}\frac{\Delta V}{V} = 0$$

$$\therefore \frac{\Delta V}{V}\times 100 = -\left(\frac{2}{3}\right)\left(\frac{\Delta p}{P}\times 100\right) = -\frac{2}{3}\times\frac{2}{3}\% = -\frac{4}{9}\%$$

Thus, volume decreases by $\frac{4}{9}\%$.

23. pV = RT where R is gas constant

Also, given $pV^{3/2} =$ constant

$\therefore$ Putting the value of $p = \frac{RT}{V}$, we have

$$\frac{RT}{V}V^{3/2} = \text{constant}$$

$$TV^{1/2} = \text{constant}$$

$$T_1V_1^{1/2} = T_2V_2^{1/2}$$

$$\therefore TV^{1/2} = T_2\left(\frac{V}{2}\right)^{1/2}$$

$$\Rightarrow T_2 = (2)^{1/2}T$$

24. $\Delta Q = \Delta U + \Delta W = \Delta U + \Delta W$

$$\Rightarrow 100 = \Delta U + 50\times(4-10)$$

$$\Rightarrow \Delta U = 400J$$

Second Law of Thermodynamics and Entropy

29. Efficiency $\eta = 1 - \frac{T_2}{T_1}$

$\therefore \eta = 1 - \frac{(27+273)}{(273+627)} = 1 - \frac{300}{900} = \frac{600}{900} = \frac{2}{3}$

30. $\eta = 1 - \frac{T_2}{T_1}$

$\therefore \frac{T_2}{T_1} = 1 - \eta = 1 - \frac{1}{6} = \frac{5}{6}$ ……………………(i)

In other case

$\frac{T_2 - 62}{T_1} = 1 - \eta = 1 - \frac{2}{6} = \frac{2}{3}$ ……………….(ii)

Using eq (i)

$T_2 - 62 = \frac{2}{3}T_1 = \frac{2}{3} \times \frac{6}{5}T_2$ or $\frac{1}{5}T_2 = 62$

$T_2 = 310K = 310 - 273^0 C$

$= 37^0 C$

Hence, $T_1 = \frac{6}{5}T_2 = \frac{6}{5} \times 310$

= 372 K

= 372 – 273

$= 99^0 C$

Hence, temperature of source is $99^0 C$

31. $\eta = 1 - \frac{T_2}{T_1}$

Or $\frac{W}{Q_1} = 1 - \frac{T_2}{T_1}$

Here $Q_1 =$ heat absorbed from the source of heat = 6 kcal

$T_1 =$ 227 + 273 = 500 K

And $T_2 =$ 127 + 273 = 400 K

Hence, $\frac{W}{6} = 1 - \frac{400}{500}$

Or $\frac{W}{6} = \frac{100}{500}$ or W = 1.2 kcal

34. Coefficient of performance $\beta = \frac{Q_2}{W} = \frac{T_L}{T_H - T_L}$

$$Q_2 = \frac{273 \times 1}{303 - 273} = \frac{273}{30} = 9J$$

Heat delivered to the surrounding

$$Q_1 = Q_2 + W = 9 + 1 = 10J$$

35. $\eta = 1 - \frac{T_L}{T_H}$

Where, T_L is temperature of sink and T_H is temperature of hot reservoir

According to question

$\frac{1}{5} = 1 - \frac{T_L}{T_H}$ …………….. (i)

And $\frac{1}{3} = 1 - \frac{T_L - 50}{T_H}$ ……………… (ii)

From eq (i)

$$\frac{T_L}{T_H} = \frac{4}{5} \Rightarrow T_H = \frac{5}{4} T_L$$

Substituting value of T_H in eq (ii) we get

$$\frac{1}{3} = 1 - \frac{T_L - 50}{\frac{5}{4} T_L}$$

Or $\frac{4(T_L - 50)}{5T_L} = \frac{2}{3}$

Or $T_L - 50 = \frac{2}{3} \times \frac{5}{4} T_L$

Or $T_L - \frac{5}{6} T_L = 50$

$\therefore T_L = 50 \times 6 = 300K$

37. $n = \left(1 - \frac{T_2}{T_1}\right) \times 100 = \left(1 - \frac{273 + 20}{273 + 40}\right) \times 100$

$= \left(1 - \frac{293}{313}\right) \times 100 = 0.064 \text{ x } 100 = 6.4\%$

39. $\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$

Given, $T_2 = 27^0 C = 273 + 27 = 300K$,

$T_1 = 677^0 C = 677 + 273 = 950K$

$\therefore \eta = 1 - \frac{T_2}{T_1} = 1 - \frac{300}{950} = \frac{13}{19}$

$\therefore W = \eta Q_1 = 100 \times 10^3 \times \frac{13}{19} cal$

Also 4.2 J -= 1cal

$\therefore W = 100 \times 10^3 \times \frac{13}{19} \times 4.2$

$W = 2.87 \times 10^5$

$W = 0.28 \times 10^6 J$

Calorimetry

41. Let the final temperature of mixture be $t^0 C$. Heat lost by water in calories,

$H_1 = 19 \times 1 \times (30 - t)$

= 570 – 19 t

Heat taken by ice, $H_2 = ms_i \Delta t + mL + mswt$

= 5 x (0.5) 20 + 5 x 80 + 5 x 1 x t

But, $H_1 = H_2$

5 x (0.5) x 20 + 5 x 80 + 5t = 570 – 19t

$\Rightarrow 24t = 570 - 450 = 120 \Rightarrow t = 5^0 C$

43. Specific heat of water $= 4200\, J\, kg\, K^{-1}$

Specific latent heat of fusion $= 3.36 \times 10^5\, J\, kg^{-1}$

Specific latent heat of vaporization $= 22.68 \times 10^5\, J\, kg^{-1}$

$= X \times 10^{-3} \times 22.68 \times 10^5$

$= Y \times 10^{-3} \times 3.36 \times 10^5 + Y \times 10^{-3} \times 4200 \times 100$

$\therefore \frac{X}{Y} = \frac{7.56}{22.68} = \frac{1}{3}$