CHAPTER 11

Thermodynamics

1. Which statement is incorrect? **[2002]**
(a) All reversible cycles have same efficiency
(b) Reversible cycle has more efficiency than an irreversible one
(c) Carnot cycle is a reversible one
(d) Carnot cycle has the maximum efficiency in all cycles

2. Even Carnot engine cannot give 100% efficiency because we cannot **[2002]**
(a) prevent radiation
(b) find ideal sources
(c) reach absolute zero temperature
(d) eliminate friction

3. "Heat cannot by itself flow from a body at lower temperature to a body at higher temperature" is a statement or consequence of **[2003]**
(a) second law of thermodynamics
(b) conservation of momentum
(c) conservation of mass
(d) first law of thermodynamics

4. During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its absolute temperature. The ratio C_P/C_V for the gas is **[2003]**
(a) $\frac{4}{3}$ (b) 2
(c) $\frac{5}{3}$ (d) $\frac{3}{2}$

5. Which of the following parameters does not characterize the thermodynamic state of matter? **[2003]**
(a) Temperature (b) Pressure
(c) Work (d) Volume

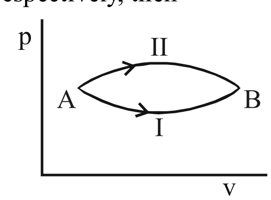
6. A Carnot engine takes 3×10^6 cal of heat from a reservoir at 627°C, and gives it to a sink at 27°C. The work done by the engine is **[2003]**
(a) 4.2×10^6 J (b) 8.4×10^6 J
(c) 16.8×10^6 J (d) zero

7. Which of the following statements is **correct** for any thermodynamic system ? **[2004]**
(a) The change in entropy can never be zero
(b) Internal energy and entropy are state functions
(c) The internal energy changes in all processes
(d) The work done in an adiabatic process is always zero.

8. Two thermally insulated vessels 1 and 2 are filled with air at temperatures (T_1, T_2), volume (V_1, V_2), and pressure (P_1, P_2) respectively. If the valve joining the two vessels is opened, the temperature inside the vessel at equilibrium will be **[2004]**
(a) $T_1T_2(P_1V_1 + P_2V_2)/(P_1V_1T_2 + P_2V_2T_1)$
(b) $(T_1 + T_2)/2$
(c) $T_1 + T_2$
(d) $T_1T_2(P_1V_1 + P_2V_2)/(P_1V_1T_1 + P_2V_2T_2)$

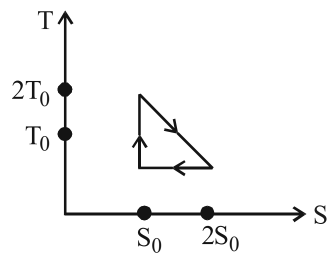
9. Which of the following is **incorrect** regarding the first law of thermodynamics? **[2005]**
(a) It is a restatement of the principle of conservation of energy
(b) It is not applicable to any cyclic process
(c) It introduces the concept of the entropy
(d) It introduces the concept of the internal energy

10. A system goes from A to B via two processes I and II as shown in figure. If ΔU_1 and ΔU_2 are the changes in internal energies in the processes I and II respectively, then **[2005]**



(a) relation between ΔU_1 and ΔU_2 can not be determined
(b) $\Delta U_1 = \Delta U_2$
(c) $\Delta U_2 = \Delta U_1 \, \Delta U_2 < \Delta U_1$
(d) $\Delta U_2 > \Delta U_1$

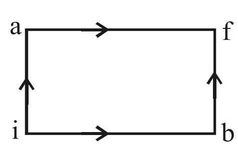
11. The temperature-entropy diagram of a reversible engine cycle is given in the figure. Its efficiency is **[2005]**



(a) $\frac{1}{4}$ (b) $\frac{1}{2}$
(c) $\frac{2}{3}$ (d) $\frac{1}{3}$

12. The work of 146 kJ is performed in order to compress one kilo mole of gas adiabatically and in this process the temperature of the gas increases by 7°C. The gas is
($R = 8.3$ J mol^{-1} K^{-1}) **[2006]**
(a) diatomic
(b) triatomic
(c) a mixture of monoatomic and diatomic
(d) monoatomic

13. When a system is taken from state i to state f along the path iaf, it is found that $Q = 50$ cal and $W = 20$ cal. Along the path ibf $Q = 36$ cal. W along the path ibf is **[2007]**



(a) 14 cal (b) 6 cal
(c) 16 cal (d) 66 cal

14. A Carnot engine, having an efficiency of $\eta = 1/10$ as heat engine, is used as a refrigerator. If the work done on the system is 10 J, the amount of energy absorbed from the reservoir at lower temperature is **[2007]**
(a) 100 J (b) 99 J
(c) 90 J (d) 1 J

15. An insulated container of gas has two chambers separated by an insulating partition. One of the chambers has volume V_1 and contains ideal gas at pressure P_1 and temperature T_1. The other chamber has volume V_2 and contains ideal gas at pressure P_2 and temperature T_2. If the partition is removed without doing any work on the gas, the final equilibrium temperature of the gas in the container will be **[2008]**

(a) $\dfrac{T_1T_2(P_1V_1 + P_2V_2)}{P_1V_1T_2 + P_2V_2T_1}$

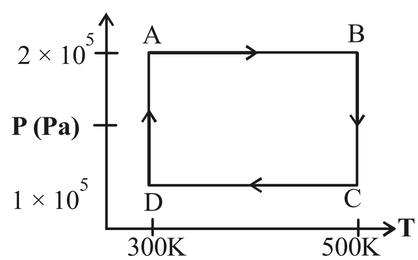
(b) $\dfrac{P_1V_1T_1 + P_2V_2T_2}{P_1V_1 + P_2V_2}$

(c) $\dfrac{P_1V_1T_2 + P_2V_2T_1}{P_1V_1 + P_2V_2}$

(d) $\dfrac{T_1T_2(P_1V_1 + P_2V_2)}{P_1V_1T_1 + P_2V_2T_2}$

Directions for questions 16 to 18 : *Questions are based on the following paragraph.*

Two moles of helium gas are taken over the cycle $ABCDA$, as shown in the P-T diagram. **[2009]**



16. Assuming the gas to be ideal the work done on the gas in taking it from A to B is
(a) 300 R (b) 400 R
(c) 500 R (d) 200 R

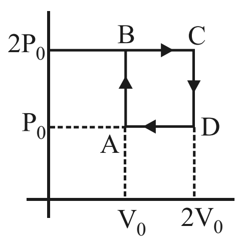
17. The work done on the gas in taking it from D to A is
(a) +414 R (b) –690 R
(c) +690 R (d) –414 R

18. The net work done on the gas in the cycle $ABCDA$ is
(a) 276 R (b) 1076 R
(c) 1904 R (d) zero

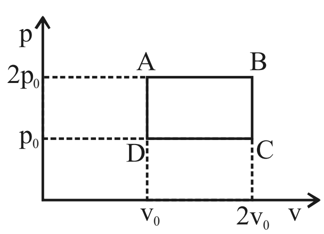
19. A diatomic ideal gas is used in a Carnot engine as the working substance. If during the adiabatic expansion part of the cycle the volume of the gas increases from V to $32\ V$, the efficiency of the engine is **[2010]**
(a) 0.5 (b) 0.75
(c) 0.99 (d) 0.25

20. A Carnot engine operating between temperatures T_1 and T_2 has efficiency $\frac{1}{6}$. When T_2 is lowered by 62 K its efficiency increases to $\frac{1}{3}$. Then T_1 and T_2 are, respectively: **[2011]**
(a) 372 K and 310 K (b) 330 K and 268 K
(c) 310 K and 248 K (d) 372 K and 310 K

21. Helium gas goes through a cycle ABCDA (consisting of two isochoric and isobaric lines) as shown in figure. The efficiency of this cycle is nearly : (Assume the gas to be close to ideal gas) **[2012]**
(a) 15.4 % (b) 9.1 %
(c) 10.5% (d) 12.5 %



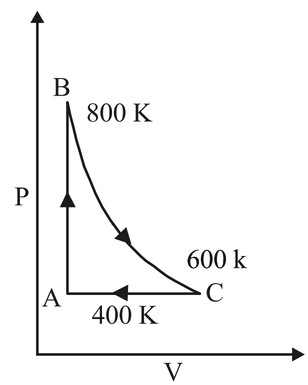
22. A Carnot engine, whose efficiency is 40%, takes in heat from a source maintained at a temperature of 500K. It is desired to have an engine of efficiency 60%. Then, the intake temperature for the same exhaust (sink) temperature must be : **[2012]**
(a) efficiency of Carnot engine cannot be made larger than 50%
(b) 1200 K
(c) 750 K
(d) 600 K

23.


The above p-v diagram represents the thermodynamic cycle of an engine, operating with an ideal monatomic gas. The amount of heat, extracted from the source in a single cycle is **[2013]**

(a) p_0v_0 (b) $\left(\frac{13}{2}\right)p_0v_0$
(c) $\left(\frac{11}{2}\right)p_0v_0$ (d) $4p_0v_0$

24. One mole of a diatomic ideal gas undergoes a cyclic process ABC as shown in figure. The process BC is adiabatic. The temperatures at A, B and C are 400 K, 800 K and 600 K respectively. Choose the correct statement: **[2014]**



(a) The change in internal energy in whole cyclic process is 250 R.
(b) The change in internal energy in the process CA is 700 R.
(c) The change in internal energy in the process AB is -350 R.
(d) The change in internal energy in the process BC is – 500 R.

25. A solid body of constant heat capacity 1 J/°C is being heated by keeping it in contact with reservoirs in two ways : **[2015]**
(i) Sequentially keeping in contact with 2 reservoirs such that each reservoir supplies same amount of heat.
(ii) Sequentially keeping in contact with 8 reservoirs such that each reservoir supplies same amount of heat.

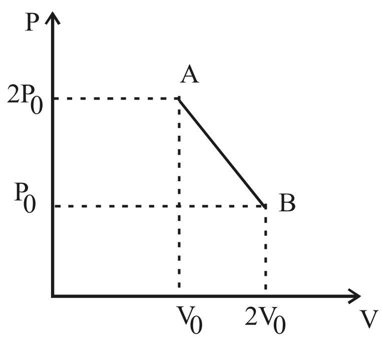
In both the cases body is brought from initial temperature 100°C to final temperature 200°C.

Entropy change of the body in the two cases respectively is :

(a) $ln2,\ 2ln2$ (b) $2ln2,\ 8ln2$

(c) $ln2,\ 4ln2$ (d) $ln2,\ ln2$

26. 'n' moles of an ideal gas undergoes a process $A \rightarrow B$ as shown in the figure. The maximum temperature of the gas during the process will be : **[2016]**



(a) $\dfrac{9P_0V_0}{2nR}$ (b) $\dfrac{9P_0V_0}{nR}$

(c) $\dfrac{9P_0V_0}{2nR}$ (d) $\dfrac{3P_0V_0}{2nR}$

27. An ideal gas undergoes a quasi static, reversible process in which its molar heat capacity C remains constant. If during this process the relation of pressure P and volume V is given by PV^n = constant, then n is given by (Here C_P and C_V are molar specific heat at constant pressure and constant volume, respectively) : **[2016]**

(a) $n = \dfrac{C_P - C}{C - C_V}$ (b) $n = \dfrac{C - C_V}{C - C_P}$

(c) $n = \dfrac{C_P}{C_V}$ (d) $n = \dfrac{C - C_P}{C - C_V}$

Answer Key

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(a)	(c)	(a)	(d)	(c)	(b)	(b)	(a)	(b, c)	(b)	(d)	(a)	(b)	(c)	(a)
16	17	18	19	20	21	22	23	24	25	26	27			
(b)	(a)	(a)	(b)	(d)	(a)	(c)	(b)	(d)	(d)	(c)	(d)			

SOLUTIONS

1. **(a)** All reversible engines working for the same temperature of source and sink have same efficiencies. If the temperatures are different, the efficiency is different.

2. **(c)** In Carnot's cycle we assume frictionless piston, absolute insulation and ideal source and sink (reservoirs). The efficiency of carnot's cycle is given by $\eta = 1 - \dfrac{T_2}{T_1}$

For $\eta = 1$ or 100 %, $T_2 = 0$ K.

The temperature of 0 K (absolute zero) can not be obtained .

3. **(a)** This is a statement of second law of thermodynamics

4. **(d)** $P \propto T^3 \ \Rightarrow PT^{-3} = \text{constant}$ ....(i)

But for an adiabatic process, the pressure temperature relationship is given by

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

$\Rightarrow PT^{\frac{\gamma}{1-\gamma}} = \text{constt.}$ ....(ii)

From (i) and (ii) $\dfrac{\gamma}{1-\gamma} = -3$

$\Rightarrow \gamma = -3 + 3\gamma \ \Rightarrow \gamma = \dfrac{3}{2}$

5. **(c)** Work is a path function. The remaining three parameters are state function.

6. **(b)** $\eta = 1 - \dfrac{T_2}{T_1} = 1 - \dfrac{(273+27)}{(273+627)}$

$= 1 - \dfrac{300}{900} = 1 - \dfrac{1}{3} = \dfrac{2}{3}$

But $\eta = \dfrac{W}{Q}$

$\therefore \dfrac{W}{Q} = \dfrac{2}{3} \Rightarrow W = \dfrac{2}{3} \times Q = \dfrac{2}{3} \times 3 \times 10^6$

$= 2 \times 10^6 \text{ cal}$

$= 2 \times 10^6 \times 4.2 \text{ J} = 8.4 \times 10^6 \text{ J}$

7. **(b)** Internal energy and entropy are state function, they do not depend upon path taken.

8. **(a)** Here $Q = 0$ and $W = 0$. Therefore, from first law of thermodynamics $\Delta U = Q + W = 0$

$\therefore$ Internal energy of the system with partition = Internal energy of the system without partition.

$$n_1 C_v T_1 + n_2 C_v T_2 = (n_1 + n_2) C_v T$$

$$\therefore \quad T = \frac{n_1 T_1 + n_2 T_2}{n_1 + n_2}$$

But $n_1 = \dfrac{P_1 V_1}{RT_1}$ and $n_2 = \dfrac{P_2 V_2}{RT_2}$

$$\therefore \quad T = \frac{\dfrac{P_1 V_1}{RT_1} \times T_1 + \dfrac{P_2 V_2}{RT_2} \times T_2}{\dfrac{P_1 V_1}{RT_1} + \dfrac{P_2 V_2}{RT_2}}$$

$$= \frac{T_1 T_2 \,(P_1 V_1 + P_2 V_2)}{P_1 V_1 T_2 + P_2 V_2 T_1}$$

9. **(b, c)** First law is applicable to a cyclic process. Concept of entropy is introduced by the second law.

10. **(b)** Change in internal energy do not depend upon the path followed by the process. It only depends on initial and final states i.e.,

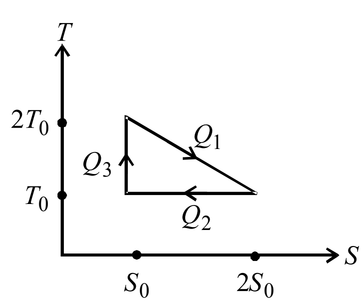
$$\Delta U_1 = \Delta U_2$$

11. **(d)** $Q_1 = T_0 S_0 + \dfrac{1}{2} T_0 S_0 = \dfrac{3}{2} T_0 S_0$

$Q_2 = T_0 (2S_0 - S_0) = T_0 S_0$

and $Q_3 = 0$

$$\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$$



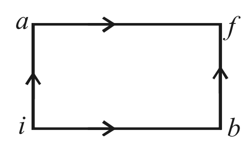
$$= 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_0 S_0}{\frac{3}{2} T_0 S_0} = \frac{1}{3}$$

12. **(a)** $W = \dfrac{nR\Delta T}{1-\gamma} \Rightarrow -146000 = \dfrac{1000 \times 8.3 \times 7}{1-\gamma}$

or $1 - \gamma = -\dfrac{58.1}{146} \Rightarrow \gamma = 1 + \dfrac{58.1}{146} = 1.4$

Hence the gas is diatomic.

13. **(b)** For path iaf, $Q = 50$ cal, $W = 20$ cal



By first law of thermodynamics,

$\Delta U = Q - W = 50 - 20 = 30$ cal.

For path ibf

$Q = 36$ cal

$W = ?$

or, $W = Q - \Delta U$

(Since, the change in internal energy does not depend on the path, therefore $\Delta U = 30$ cal)

$\therefore$ $W = Q - \Delta U = 36 - 30 = 6$ cal.

14. **(c)** The efficiency (η) of a Carnot engine and the coefficient of performance (β) of a refrigerator are related as

$\beta = \dfrac{1-\eta}{\eta}$ Here, $\eta = \dfrac{1}{10}$

$$\therefore \quad \beta = \frac{1 - \frac{1}{10}}{\left(\frac{1}{10}\right)} = 9.$$

Also, Coefficient of performance (β) is given by $\beta = \dfrac{Q_2}{W}$, where Q_2 is the energy absorbed from the reservoir.

or, $9 = \dfrac{Q_2}{10}$ $\qquad \therefore\ Q_2 = 90$ J.

15. **(a)** Here $Q = 0$ and $W = 0$. Therefore from first law of thermodynamics $\Delta U = Q + W = 0$

$\therefore$ Internal energy of the system with partition = Internal energy of the system without partition.

$$n_1 C_v T_1 + n_2 C_v T_2 = (n_1 + n_2) C_v T$$

$$\therefore T = \frac{n_1 T_1 + n_2 T_2}{n_1 + n_2}$$

But $n_1 = \frac{P_1V_1}{RT_1}$ and $n_2 = \frac{P_2V_2}{RT_2}$

$$\therefore\ T = \frac{\frac{P_1V_1}{RT_1} \times T_1 + \frac{P_2V_2}{RT_2} \times T_2}{\frac{P_1V_1}{RT_1} + \frac{P_2V_2}{RT_2}}$$

$$= \frac{T_1T_2\ (P_1V_1 + P_2V_2)}{P_1V_1T_2 + P_2V_2T_1}$$

16. (b) A to B is an isobaric process. The work done

$W = nR(T_2 - T_1)$

$= 2R(500 - 300) = 400R$

17. (a) Work done by the system intheisothermal process

DA is $W = 2.303\,nRT\ \log_{10} \frac{P_D}{P_A}$

$= 2.303 \times 2\ R \times 300$

$\log_{10} \frac{1 \times 10^5}{2 \times 10^5} - 414\text{R}.$

Therefore, work done on the gas is $+ 414\,R$.

18. (a) The net work in the cycle $ABCDA$ is

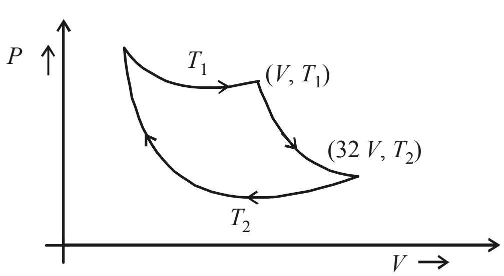
$W = W_{AB} + W_{BC} + W_{CD} + W_{DA}$

$= 400R + 2.303nRT \log \frac{P_B}{P_C} + (-400R) - 414R$

$= 2.303 \times 2R \times 500 \log \frac{2 \times 10^5}{1 \times 10^5} - 414\,R$

$= 693.2\,R - 414\,R \quad = 279.2\,R$

19. (b)



We have, $TV^{\gamma - 1}$ = constant

$\Rightarrow T_1V^{\gamma-1} = T_2(32V)^{\gamma-1}$

$\Rightarrow T_1 = (32)^{\gamma-1}.T_2$

For diatomic gas, $\gamma = \frac{7}{5}$

$\therefore \gamma - 1 = \frac{2}{5}$

$\therefore T_1 = (32)^{\frac{2}{5}}.T_2 \ \Rightarrow T_1 = 4T_2$

Now, efficiency $= 1 - \frac{T_2}{T_1}$

$= 1 - \frac{T_2}{4T_2} = 1 - \frac{1}{4} = \frac{3}{4} = 0.75.$

20. (d) Efficiency of engine

$\eta_1 = 1 - \frac{T_2}{T_1}$

$\Rightarrow \frac{T_2}{T_1} = \frac{5}{6}$ ....(i)

Again, $\eta_2 = 1 - \frac{T_2 - 62}{T_1} = \frac{1}{3}$ ....(ii)

Solving (i) and (ii), we get,

$\text{T}_1 = 372\text{ K and T}_2 = \frac{5}{6} \times 372 = 310\text{ K}$

21. (a) The efficiency $\eta = \frac{\text{output work}}{\text{input work}}$

Input work = Work done in going A to B + workdone in going B to C and the work done in going C to D.

$\text{W}_\text{i} = \frac{\text{n}}{2}(P_0V_0) + \frac{n}{2}(2P_0V_0) + 2P_0V_0$

where n = degree of freedom

which is 3 for mono-atomic gases like He

$= \left(\frac{3}{2} + \frac{3}{2}.2 + 2\right)\text{P}_0\text{V}_0$

$= \left(\frac{3+10}{2}\right)\text{P}_0\text{V}_0 = \frac{13}{2}\text{P}_0\text{V}_0$

and $W_0 = P_0V_0$

$\eta = \frac{P_0V_0}{\frac{13}{2}P_0V_0} = \frac{2}{13}$

Efficiency in %

$\eta = \frac{2}{13} \times 100 = \frac{200}{13} \simeq 15.4\%$

22. **(c)** The efficiency of the engine is given as

$$\eta = \left(1 - \frac{T_2}{T_1}\right) \times 100$$

For first case

$T_1 = 500\,\text{K};\ \eta = 40$

$$40 = \left(1 - \frac{T_2}{500}\right) \times 100$$

$$\Rightarrow \frac{40}{100} = 1 - \frac{T_2}{500}$$

$$\Rightarrow \frac{T_2}{500} = \frac{60}{100} \Rightarrow T_2 = 300\,\text{K}$$

For second case :

$$\frac{60}{100} = \left(1 - \frac{300}{T_2}\right) \frac{300}{T_2} = \frac{40}{100}$$

$$\Rightarrow T_2 = \frac{100 \times 300}{40} \Rightarrow T_2 = 750\,\text{K}$$

23. **(b)** Heat is extracted from the source in path DA and AB is

$$\Delta Q = \frac{3}{2} R \left(\frac{P_0 V_0}{R}\right) + \frac{5}{2} R \left(\frac{2 P_0 V_0}{R}\right)$$

$$\Rightarrow \frac{3}{2} P_0 V_0 + \frac{5}{2} 2 P_0 V_0 = \left(\frac{13}{2}\right) P_0 V_0$$

24. **(d)** In cyclic process, change in total internal energy is zero.

$\Delta U_{cyclic} = 0$

$$\Delta U_{BC} = n C_v \Delta T = 1 \times \frac{5R}{2} \Delta T$$

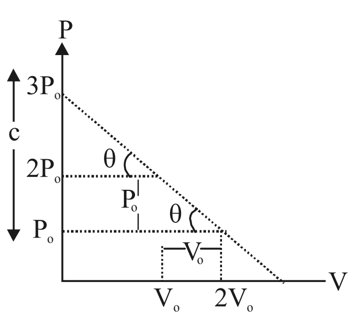
Where, C_v = molar specific heat at constant volume.

For BC, $\Delta T = -200\,\text{K}$

$\therefore \quad \Delta U_{BC} = -500R$

25. **(d)** The entropy change of the body in the two cases is same as entropy is a state function.

26. **(c)** The equation for the line is



$$P = \frac{-P_0}{V_0} V + 3P$$

$$\left[\text{slope} = \frac{-P_0}{V_0},\ c = 3P_0\right]$$

$$PV_0 + P_0 V = 3P_0 V_0 \quad \text{...(i)}$$

But $\quad pv = nRT$

$$\therefore p = \frac{nRT}{v} \quad \text{...(ii)}$$

From (i) & (ii) $\dfrac{nRT}{v} V_0 + P_0 V = 3P_0 V_0$

$$\therefore nRT\, V_0 + P_0 V^2 = 3P_0 V_0 \quad \text{...(iii)}$$

For temperature to be maximum $\dfrac{dT}{dv} = 0$

Differentiating e.q. (iii) by 'v' we get

$$nRV_0 \frac{dT}{dv} + P_0(2v) = 3P_0 V_0$$

$$\therefore nRV_0 \frac{dT}{dv} = 3P_0 V_0 - 2P_0 V$$

$$\frac{dT}{dv} = \frac{3P_0 V_0 - 2P_0 V}{nRV_0} = 0$$

$$V = \frac{3V_0}{2} \ \therefore\ p = \frac{3P_0}{2} \quad \text{[From (i)]}$$

$$\therefore T_{max} = \frac{9P_0 V_0}{4nR} \quad \text{[From (iii)]}$$

27. **(d)** For a polytropic process

$$C = C_v + \frac{R}{1-n} \quad \therefore\ C - C_v = \frac{R}{1-n}$$

$$\therefore\ 1 - n = \frac{R}{C - C_v} \quad \therefore\ 1 - \frac{R}{C - C_v} = n$$

$$\therefore\ n = \frac{C - C_v - R}{C - C_v} = \frac{C - C_v - C_p + C_v}{C - C_v}$$

$$= \frac{C - C_p}{C - C_v} \ (\because C_p - C_{v=R})$$