IIT-JAM PHYSICS 2023

TEST : THERMODYNAMICS

Time : 60 Minutes **Date : 20-11-2022**

M.M. : 40

INSTRUCTIONS:

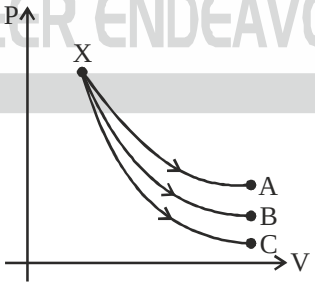
- **Part-A** contains **10** Multiple Choice Questions (MCQ). Each question has 4 choices (a), (b), (c) and (d), for its answer, out of which **ONLY ONE** is correct. For each correct answer you will be awarded **2 marks**. For each incorrect answered **0.5 mark** will be deducted.
- **Part-B** contains **5** Multiple Select Questions (MSQ). Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which **ONE or MORE than ONE** is/are correct. For each correct answer you will be awarded **2 marks**, there is no negative marking in this section.
- **Part-C** contains **5** Numerical Answer Type (NAT) questions which contain **2 Marks** for each, and there is no negative marking.

PART-A [Multiple Choice Questions]

1. When an ideal monoatomic gas is expanded adiabatically from initial volume V_0 to $3V_0$, its temperature changes from T_0 to T. Then the ratio T/T_0 is

(a) 1/3 (b) $(1/3)^{2/3}$ (c) $(1/3)^{5/3}$ (d) 3

2. An ideal gas is expanded adiabatically from X to B (as shown in figure below). If the same gas expands freely into vacuum in an adiabatic container from point X to one of the points out of A, B and C. The point will be



(a) A (b) B (c) C (d) Either A and C

3. An engine of efficiency η operates between two reservoirs at temperatures T_1 and T_2 with $T_1 > T_2$. All of the work delivered by the engine is used to drive a carnots heat pump of coefficient of performance β (working between the same temperature limits). Which relation is ***correct***?

(a) $\eta \cdot \beta = 1$ (b) $\frac{\eta}{\beta} = 1$ (c) $\eta \cdot \beta < 1$ (d) $\frac{\eta}{\beta} = 1$

4. Two moles of ideal diatomic gas at a temperature 300K was cooled isochorically so as the gas pressure reduced by one third of its initial value. The gas then was expanded isobarically till its temperature got back to its initial value of 300K. The total amount of heat absorbed by the gas in this process (in terms of gas constant) is

(a) 150 (b) 200 (c) 300 (d) 400

5. Two ideal gases is a box are initially separated by a partition. Let N_1, V_1 and N_2, V_2 be the number of particles and volumes occupied by the two systems, when the partition is removed, the pressure of the mixture at an equilibrium temperature T is

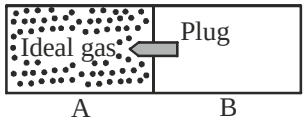
(a) $k_B T\left(\frac{N_1+N_2}{2(V_1+V_2)}\right)$ (b) $k_B T\left(\frac{N_1+N_2}{V_1+V_2}\right)$ (c) $k_B T\left(\frac{N_1}{V_1}+\frac{N_2}{V_2}\right)$ (d) $\frac{k_B T}{2}\left(\frac{N_1}{V_1}+\frac{N_2}{V_2}\right)$

6. A real gas with equation of state $b^3\left(P+\frac{a^2}{V^3}\right)=nRT$ (where 'a' and 'b' are constants) undergoes expansion from volume V_0 to $2V_0$ at constant temperature T_0. The change in internal energy in isothermal expansion is

(a) 0 (b) $\frac{a^2b^3}{V_0^3}\ln(2)$ (c) $\frac{a^2}{2V_0^2}$ (d) $\frac{3a^2}{8V_0^2}$

7. As shown in the figure, an ideal gas is confined to chamber A of an insulated container, with vacuum in chamber B, when the plug in the wall separating the chambers A and B is removed, the gas fills both the chambers. Which of the following statements is ***true***?

(a) Temperature of the gas decrease as it expands to fill the space in chamber B
(b) Internal energy of the gas increase as its atoms have more space to more around
(c) Internal energy of the gas decreases
(d) The temperature of the gas remains unchanged



8. $\left(\frac{\partial P}{\partial T}\right)_V$ can be given in terms of isobaric volume expansivity α_P and isothermal compressibility β_T as

(a) $\frac{\alpha_P}{\beta_T}$ (b) $\frac{-\alpha_P}{\beta_T}$ (c) $\frac{\beta_T}{\alpha_P}$ (d) $\frac{-\beta_T}{\alpha_P}$

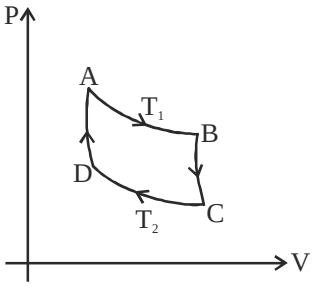
9. Consider an ideal gas initially occupying $1m^3$ at 1.5 bar, 20°C undergoes a reversible compression for which PV^n = constant to a final state where the pressure is 6 bar and the temperature is 120°C. Take $C_V = 0.718$ J mol^{-1} k^{-1}. Which one of the following is ***correct***?

(a) The given process is adiabatic process (b) $n=1.67$
(c) $n=1.27$ (d) $w\simeq 190$ kJ

10. For an ideal gas, AB and CD are two isotherms at temperatures T_1 and T_2($T_1 > T_2$), respectively. AD and BC represent two adiabatic paths as shown in the figure.

Let V_A, V_B, V_C and V_D be the volume of the gas at A, B, C and D respectively.

If $\frac{V_B}{V_A}=2$; then $\frac{V_C}{V_D}$ is

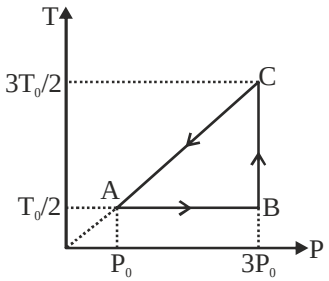


(a) 2 (b) $\frac{1}{2}$ (c) $\left(\frac{1}{2}\right)^r$ (d) 2^{r-1}

(where r is adiabatic exponent of ideal gas)

PART-B [Multiple Select Questions]

11. An ideal monatomic gas having two moles undergoes the following cyclic process:



Which of the following is/are **correct**(s)?

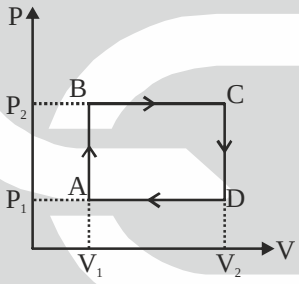
(a) Total work done in the cycle is $RT_0(1-\ln 3)$

(b) Total work done in the cycle is $RT_0(2-\ln 3)$

(c) Total heat absorbed by the gas in the cycle is $5RT_0$

(d) Total heat released by the gas in the cycle is $RT_0(3+\ln 3)$

12. An ideal gas cycle is represented by a rectangle on P–V diagram. If P_1 and P_2 are the lower and higher pressures, and V_1 and V_2 the smaller and larger volumes, respectively.



Identify which of the following is/are ***correct***?

(a) The work done per cycle is $(P_2-P_1)(V_2-V_1)$

(b) Amount of heat absorbed in the cycle is $\frac{C_V}{R}[P_2-P_1]V_1+\frac{C_P}{R}[V_2-V_1]P_2$

(c) Amount of heat rejected in the cycle is $\frac{C_V}{R}[P_2-P_1]V_2+\frac{C_P}{R}[V_2-V_1]P_1$

(d) Efficiency; $\eta=\frac{(r-1)}{\left(\frac{V_1}{V_2-V_1}\right)+\left(\frac{P_2}{P_2-P_1}\right)}$ (where r is adiabatic exponent)

13. A Carnot heat engine, working between the temperature limits T_0 and $T_0/3$, is used to run a Carnot heat pump working between the temperature limits T_0 and $T_0/4$. If the heat rejected to the cold reservoir of the heat engine is 100 cal/s. Which of the following is/are **correct(s)**?

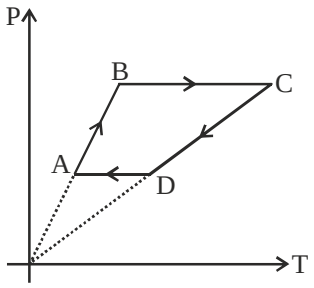
(a) Coefficient of performance of the heat pump is 7/3

(b) Heat extracted from the cold reservoir of the heat pump is 200/3 W

(c) Net heat exchanged by the reservoir at temperature T_0 in one cycle (of combined heat engine and heat pump) is 100W

(d) Net heat exchanged by the reservoir at temperature T_0 in one cycle (of combined heat engine and heat pump) is 140W

14. 3 moles of an ideal monoatomic gas performs a cycle shown in the figure. The gas temperature T_A = 400K, T_B = 800K, T_C = 2400K, T_D = 1200K.



Which of the following is/are ***correct***?

(a) The total work done is 2400R Joules, (where R is gas constant)

(b) The total heat goes out of engine in a cycle is 11400 R

(c) The efficiency of the engine is 0.17

(d) The efficiency of the engine is 0.21

15. The equation of state of a gas is $P\left(V-\frac{a^2}{V}\right)=nRT$. Which of the following is/are ***correct***?

(a) Work done by the gas when it is expanded isothermally at temperature T_0 from volume V_0 to $2V_0$ is

$$w=\frac{nRT_0}{2}\log_e\left[\frac{4V_0^2-a^2}{V_0^2-a^2}\right]$$

(b) Change in internal energy of the gas during an isothermal expansion at T_0 from V_0 to $2V_0$ is $\Delta U = 0$

(c) During an adiabatic process, the gas obeys PV^r = constant

(d) During an adiabatic process, the gas obeys $(V^2-a^2)T^{\frac{2C_V}{R}}=\text{Constant}$

PART-C [Numerical Answer Type]

16. A diatomic ideal gas is expanded adiabatically against the piston of a cylinder. As a result, the temperature of the gas drops from 1500K to 500K. What is the number of moles of the gas required to obtain 5000R Joules of work from the expansion? [where R is universal gas constant]

[Answer must be an integer]

17. Consider a Carnot refrigerator operating between temperatures of 600K and 400K. 500 J of work is done on the working substance during one cycle. The heat (in calories) extracted per cycle from the cold temperature reservoir is _____ [Specify your answer to two digits after the decimal point]

18. The smallest possible time taken by a refrigerator to freeze 2 kg of water at 0ºC if a 50W motor is available is _____ hr. [The outside temperature is 27ºC]

[Round off to two decimal places]

19. An iron piece of mass 0.1 kg at 940ºC is put in thermal contact with a substance of water equivalent 10gm at 20ºC. The resultant equilibrium temperature would be _____ºC.
(Specific heat of iron is 470 J/kg/ºC) [Specify nearest integer]

20. The molar heat capacity of a diatomic ideal gas taken through the process $T\sqrt{V}=$ constant in terms of universal gas constant R is _____ [Specify your answer upto two decimal place]

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ANSWER KEY

PART-A [Multiple Choice Questions]

1. (b)	**2.** (a)	**3.** (c)	**4.** (b)	**5.** (b)
6. (d)	**7.** (d)	**8.** (a)	**9.** (c)	**10.** (a)

PART-B [Multiple Select Questions]

11. (b, c, d)	**12.** (a, b, c)	**13.** (d)	**14.** (a, b, c)
15. (a, b, d)			

PART-C [Numerical Answer Type]

16. (2)	**17.** (238.00 to 239.50)	**18.** (0.35 to 0.37)
19. (505 to 508)	**20.** (0.50)	