Thermodynamics TIFR

https://snboseplc.com/thermodynamics-tifr/

Q.No:1 TIFR-2013

A certain amount of fluid with heat capacity C_F Joules/°C is initially at a temperature 0°C. It is then brought into contact with a heat bath at a temperature of 100°C, and the system is allowed to come into equilibrium. In this process, the entropy (in Joules/°C) of the Universe changes by

(A) $100C_F$

(B) 0

(C) $0.055C_F$

(D) $0.044C_F$

Q.No:2 TIFR-2013

A monatomic gas is described by the equation of state

$$p(V - bn) = nRT$$

where b and R are constants and other quantities have their usual meanings. The maximum density (in moles per unit volume) to which this gas can be compressed is

(A) $1/bn$

(B) b

(C) $1/b$

(D) infinity

Q.No:3 TIFR-2013

A classical ideal gas, consisting of N particles ($N \to \infty$) is confined in a box of volume V at temperature T and pressure p. The probability that, at any instant of time, a small sub-volume v_0 becomes totally void (i.e. no particles inside), due to a spontaneous statistical fluctuation, is

(A) $\exp(-v_0/V)$

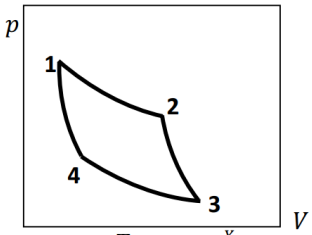
(B) $\exp(-Nv_0/V)$

(C) $\frac{v_0}{V}\exp(-pV/NT)$

(D) pv_0/NT

Q.No:4 TIFR-2013

The pV-diagram for a Carnot cycle executed by an ideal gas with $C_p/C_V = \gamma > 1$ is shown below. Note that 1, 2, 3 and 4 label the change-over points in the cycle.



$$\frac{T_2}{T_3} = \left(\frac{p_2}{p_3}\right)^X$$

If, for this cycle, then $X =$

(A) $1 - 1/\gamma$

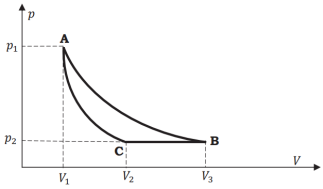
(B) 0

(C) 1

(D) $-1/\gamma$

Q.No:5 TIFR-2014

One mole of an ideal gas undergoes the cycle ACBA shown in the pV diagram below.



One of the curved lines in the cycle represents an isothermal change at temperature T, while the other represents an adiabatic change. The net heat gained by the gas in this cycle is

(A) $-p_2(V_3 - V_2) + RT\ln\frac{V_2}{V_1}$

(B) $-p_2(V_3 - V_2) + RT\ln\frac{V_3}{V_1}$

(C) $-p_2(V_3 - V_2) + \gamma RT(V_2^{1-\gamma} - V_1^{1-\gamma})$

(D) $(p_1V_1 - p_2V_2) - RT\ln\frac{V_3}{V_1}$

Q.No:6 TIFR-2014

An ideal gas at a temperature T is enclosed in a rigid container whose walls are initially at temperature T_1, where $T_1 < T$. The walls are covered on the outside with perfect thermal insulation and the system is allowed to come to equilibrium. The pressure exerted by the gas on the walls of the container

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(A) remains constant throughout.

(B) is lower at the initial stage than at the final stage.

(C) is higher at the initial stage than at the final stage.

(D) is the same at the initial and final stages.

Q.No:7 TIFR-2014

A thermally-insulated container of volume V_0 is divided into two equal halves by a non-permeable partition. A real gas with equation of state

$$b^3\left(p+\frac{a^2}{V^3}\right)=nRT$$

where a and b are constants, is confined to one of these halves at a temperature T_0. The partition is now removed suddenly and the gas is allowed to expand to fill the entire container. The final temperature of the gas, in terms of its specific heat C_V, will be

(A) $T_0-\frac{3a^2}{2C_VV_0^2}$

(B) $T_0-\frac{2a^2}{3C_VV_0^2}$

(C) $T_0+\frac{3a^2}{2C_VV_0^2}$

(D) $T_0+\frac{2a^2}{3C_VV_0^2}$

Q.No:8 TIFR-2015

The equation of state of a gas is given by

$$V=\frac{RT}{P}-\frac{b}{T}$$

where R is the gas constant and b is another constant parameter. The specific heat at constant pressure C_P and the specific heat at constant volume C_V for this gas is related by $C_P-C_V=$

(A) R

(B) $R\left(1+\frac{RT^2}{bP}\right)^2$

(C) $R\left(1+\frac{bP}{RT^2}\right)^2$

(D) $R\left(1-\frac{bP}{RT^2}\right)^2$

Q.No:9 TIFR-2015

An ideal diatomic gas is initially at a temperature $T=0°$C. Then it expands reversibly and adiabatically to 5 times its volume. Its final temperature will be approximately

(A) $-180°$C

(B) $-150°$C

(C) $-130°$C

(D) $0°$C

Q.No:10 TIFR-2016

In the temperature range 100–1000C, the molar specific heat of a metal varies with temperature T (measured in degree Celsius) according to the formula $C_p=(1+T/5)$ J-deg C^{-1} mol^{-1}. If 0.2 kg of the metal at 600C is brought in thermal contact with 0.1 kg of the same metal at 300C, the final equilibrium temperature, in deg C, will be

(A) 466

(B) 567

(C) 383

(D) 519

Q.No:11 TIFR-2016

The equation of state for a gas is given by

$$\left[p+\left(\frac{\alpha N}{V}\right)^2\right](V-\beta N)=Nk_BT$$

where $P, V, T, N,$ and k_B represent pressure, volume, temperature, number of atoms and the Boltzmann constant, respectively, while α and β are constants specific to the gas. If the critical point C corresponds to a point of inflexion of the $p-V$ curve, then the critical volume V_C and critical pressure p_C for this gas are given by

(A) $V_C=3\beta N, p_C=\alpha^2/3\beta^2$

(B) $V_C=3\beta N, p_C=\alpha/27\beta^2$

(C) $V_C=3\beta N, p_C=8\alpha^2/27\beta$

(D) $V_C=3\beta N, p_C=\alpha^2/27\beta^2$

Q.No:12 TIFR-2016

Two containers are maintained at the same temperature and are filled with ideal gases whose molecules have mass m_1 and m_2 respectively. The mean speed of molecules of the second gas is 10 times the r.m.s. speed of the molecules of the first gas. Find the ratio of m_1/m_2, to the nearest integer.

Q.No:13 TIFR-2017

A thermally isolated container stores N_2 gas at 27.24°C at one atmospheric pressure. Suddenly the pressure of the gas is increased to two atmospheric pressures. Assuming N_2 to behave as an ideal gas, estimate the change in temperature of the gas, in Celsius degrees (°C).

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Q.No:14 TIFR-2017

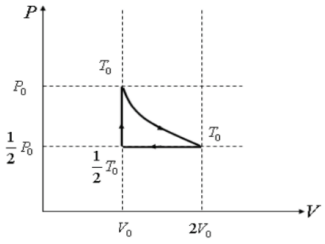
One mole of monoatomic ideal gas is initially at pressure P_0 and volume V_0. The gas then undergoes a three-stage cycle consisting of the following processes:

(A) An isothermal expansion till it reaches volume $2V_0$, and heat Q flows into the gas

(B) An isobaric compression back to the original volume V_0

(C) An isochoric increase in pressure till the original pressure P_0 is regained.

The efficiency of this cycle can be expressed as



(A) $\epsilon = \frac{4Q+2RT_0}{4Q+RT_0}$

(B) $\epsilon = \frac{4Q+2RT_0}{4Q-3RT_0}$

(C) $\epsilon = \frac{4Q-2RT_0}{4Q+RT_0}$

(D) $\epsilon = \frac{4Q-2RT_0}{4Q+3RT_0}$

Q.No:15 TIFR-2018

A heat engine is operated between two bodies that are kept at constant pressure. The constant-pressure heat capacity C_p of the reservoirs is independent of temperature. Initially the reservoirs are at temperature 300 K and 402 K. If, after some time, they come to a common final temperature T_f, the process remaining adiabatic, what is the value of T_f (in kelvin)?

Q.No:16 TIFR-2018

A many-body system undergoes a phase transition between two phases A and B at a temperature T_c. The temperature-dependent specific heat at constant volume C_V of the two phases are given by $C_V^{(A)} = aT^3 + bT$ and $C_V^{(B)} = cT^3$. Assuming negligible volume change of the system, and no latent heat generated in the phase transition, T_c is

(A) $\sqrt{\frac{2b}{c}}$

(B) $\sqrt{\frac{b}{c-a}}$

(C) $\sqrt{\frac{3b}{c-a}}$

(D) $\sqrt{\frac{4b}{c-a}}$

Q.No:17 TIFR-2019

A thermally-insulated coffee mug contains 500 g of warm coffee at 80°C. Assuming that the heat capacity of this liquid is 1 cal g^{-1} $°C^{-1}$ and the latent heat of fusion for ice is 80 cal g^{-1}, the amount of ice that must be dropped into the cup to convert it into cold coffee at 5°C is about

(A) 421 g

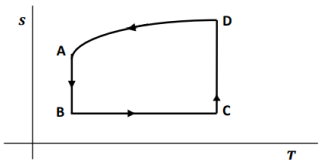
(B) 441 g

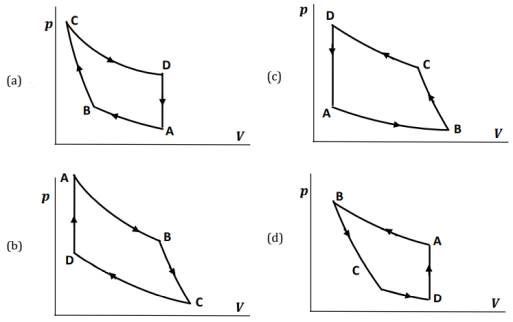
(C) 469 g

(D) 471 g

Q.No:18 TIFR-2019

An ideal gas engine is run according to the cycle shown in the $s-T$ diagram below, where the process from D to A is known to be isochoric (i.e. maintaining $V =$ constant).





Q.No:19 TIFR-2020

A gas has the following equation of state

$$U = \frac{aS^5}{N^2V^2}$$

where U is the internal energy, V is the volume and N is the number of particles. Here a is a constant of the appropriate dimension. It follows that the equation of state of this gas relating its pressure P to its temperature T and its density $\rho = N/V$ is given by

(A) $\frac{P^4}{T^5\rho^2} =$ constant

(B) $\frac{P^5}{T^4\rho^3} =$ constant

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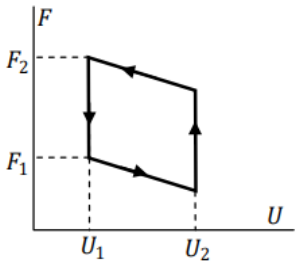
(C) $\frac{P}{T\rho} = \text{constant}$

(D) $\frac{P^3}{T^2\rho^3} = \text{constant}$

Q.No:20 TIFR-2020

An ideal gas is passed through a cyclic process where the corresponding changes in the thermodynamic potentials are plotted on the adjoining graph. Here U is the internal energy and F is the Helmholtz free energy.



The efficiency of this cycle is given by

(A) $1 - \frac{U_1}{U_2}$

(B) $1 - \exp\left(-\frac{F_2}{F_1}\right)$

(C) $1 - \frac{U_1}{U_2}\exp\left(-\frac{F_2}{F_1}\right)$

(D) $\exp\left(\frac{U_1}{U_2}\right) - \exp\left(-\frac{F_2}{F_1}\right)$

Q.No:21 TIFR-2020

The mean free path λ of molecules of a gas at room temperatures is given approximately by

$$\lambda = \frac{1}{n\sigma}$$

where n is the number density of the molecules and σ is the collision cross-section of two molecules. It follows that the mean free path of air molecules at normal temperature and pressure is of order

(A) 500 μm

(B) 50 nm

(C) 0.5 nm

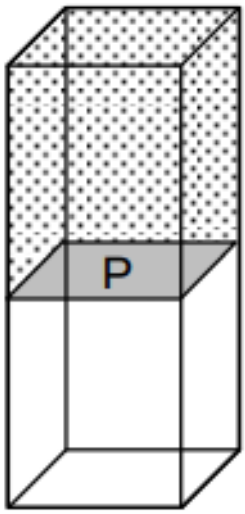
(D) 500 fm

Q.No:22 TIFR-2020

The volume V of a rectangular box is divided into two equal parts by a solid non-permeable partition P. On one side of the partition P there is a vacuum, while the other side is filled with a real gas having equation of state

$$pVe^{a/RTV} = nRT$$

where a and b are constants. The gas was initially at a uniform temperature T_0. Then the partition P was removed instantaneously, and the gas was allowed to expand to fill the full volume of the box and come to equilibrium.



The final temperature of the gas, in terms of its specific heat C_V will be

(A) $T - \left(\frac{na}{C_V}\right)\ln 2$

(B) $T + \left(\frac{na}{C_V}\right)\ln 2$

(C) $T - 2n\left(\frac{RTa}{C_V}\right)^{3/2}$

(D) $T + 2n\left(\frac{RTa}{C_V}\right)^{3/2}$

Q.No:23 TIFR-2021

A boiler of volume 1.7m^3, when filled with 1.0kg of steam at 100°C, has a pressure of 1.0atm. What will be the boiling point of water in this boiler when the pressure is 2.0atm? [The latent heat of vaporization of water is 2250×10^3J/kg; 1atm = 10^5N/m^2]

(A) 128°C

(B) 118°C

(C) 78°C

(D) 88°C

Q.No:24 TIFR-2021

A spherical balloon of radius R is made of a material with surface tension γ and filled with N particles of an ideal gas. If the outside air pressure is P, the pressure P_b inside the balloon is given by

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(A) $P_b = P + 2\gamma/R$

(B) $P_b = P$

(C) $P_b = P - 2\gamma/R$

(D) $P_b = P + 3\gamma/R$

Q.No:25 TIFR-2022

A bicycle tyre is pumped with air to an internal pressure of 6 atm at 20°C, at which point it suddenly bursts. Assuming the external pressure to be 1 atmosphere and the subsequent sudden expansion to be adiabatic, the temperature immediately after the burst is approximately

(A) -97.5°C

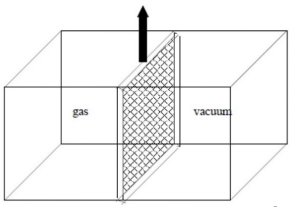
(B) -108.5°C

(C) 45.5°C

(D) 216.05°C

Q.No:26 TIFR-2023

Consider a sealed but thermally conducting container of total volume V, which is in equilibrium with a thermal bath at temperature T. The container is divided into two equal chambers by a thin partition, which is thermally conducting but impermeable to particles. One of the chambers contains an ideal gas, while the other is a vacuum.



If the partition is removed suddenly and the ideal gas is allowed to expand and fill the entire container, then, once equilibrium has been reached, the entropy per molecule will increase by an amount

(A) $+k_B \ln 2$

(B) $\frac{1}{2}k_B \ln 2$

(C) $2k_B$

(D) $-k_B \ln 2$

Q.No:27 TIFR-2024

An ideal heat pump delivers heat at a rate $\beta(T_H - T_S)$ from the colder surroundings (S) at a temperature T_S to a heater (H) kept at a constant temperature T_H. Here β is a constant. What is the power consumption of the heat pump?

(A) $\frac{\beta(T_H - T_S)^2}{T_H}$

(B) $\beta(T_H - T_S)$

(C) $\frac{\beta(T_H - T_S)^2}{T_S}$

(D) $\frac{\beta(T_H - T_S)T_H}{T_S}$

Q.No:28 TIFR-2024

An ideal gas on the Pressure (P)-Volume (V) diagram can be taken from point K to point N along three different paths, as shown below. K → L → N, K → N, and K → M → N. Which of the following options is a true statement?

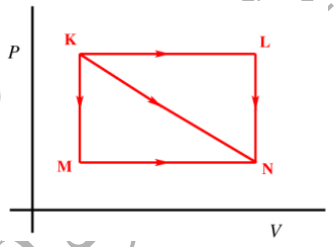


Figure 1: WPPB Image Addons

(A) The change in internal energy is the same along each path

(B) The same work is done along each path

(C) The same amount of heat is added to each the gas along each path

(D) There is no work done along the path K → N

Q.No:29 TIFR-2024

A mass of M kg of water at temperature T_a is isobarically and adiabatically mixed with an equal mass of water at temperature T_b. The specific heat of water at constant pressure is C_p. What is the entropy change (ΔS) of the system?

(A) $\Delta S = MC_p \left[\ln\left(1 + \frac{(T_a - T_b)^2}{4T_aT_b}\right)\right]$

(B) $\Delta S = MC_p \left[\ln\left(1 - \frac{(T_a + T_b)^2}{4T_aT_b}\right)\right]$

(C) $\Delta S = MC_p \left[\ln\left(1 + \frac{4T_aT_b}{(T_a - T_b)^2}\right)\right]$

(D) $\Delta S = MC_p \left[\ln\left(\frac{T_a + T_b}{\sqrt{T_aT_b}}\right)\right]$

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Q.No:30 TIFR-2025

Two types of particles A and B have the same mass, but are distinguished by an internal degree of freedom. A classical ideal gas in a volume V at temperature T contains (X) $2N$ particles of A-type and (Y) N particles of A-type and N particles of B-type. Which of the following is true?

(A) Pressure of (X) and (Y) are same; (Y) has more entropy than (X)

(B) Pressure of (X) and (Y) are same; (X) has more entropy than (Y)

(C) Pressure of (X) is greater than pressure of (Y); (X) has more entropy than (Y)

(D) Pressure of (X) is greater than pressure of (Y); (Y) has more entropy than (X)

Q.No:31 TIFR-2026

The equation of state of a gas is given by:

$$\left(p + \frac{a}{v^2}\right)(v - b) = RT,$$

where v is the volume per mole and R, a, b are constants. The internal energy per mole of the gas is given by:

$$U(T, v) = \frac{3}{2}RT - \frac{a}{v}$$

Which of the following gives the adiabatic equation of state at fixed particle number for the gas?

(A) $(v - b)^2 T^3 = \text{constant}$

(B) $(v - b)^2 T^{-3} = \text{constant}$

(C) $(v - b)^2 T^{3/2} = \text{constant}$

(D) $(v - b)^2 T^{-3/2} = \text{constant}$

Q.No:32 TIFR-2026

A non-interacting, classical gas is made up of N Nitrogen molecules. The specific heat at constant volume is C_v. $C_v/(Nk_BT)$ is given by:
(Ignore rotations about the axis of symmetry.)

(A) 3/2 for some very low T, 5/2 for temperatures around the room temperature, 7/2 for some high temperatures

(B) 7/2 for some very low T, 5/2 for temperatures around the room temperature, 3/2 for some high temperatures

(C) 3/2 for some very low T, 2 for temperatures around the room temperature, 5/2 for some high temperatures

(D) 3/2 for some very low T, 2 for temperatures around the room temperature, 3 for some high temperatures

Q.No:33 TIFR-2026

A cycle for an ideal gas consists of the following three reversible processes:

i. Isothermal expansion at T_H from V_1 to V_2.

ii. Isochoric (constant volume) cooling from T_H to T_C.

iii. Adiabatic compression from T_C and V_2 back to the initial state (T_H, V_1).

If C_V is the constant volume heat capacity of the gas, the efficiency η of this cycle is:

(A) $\eta = 1 - \frac{C_V(T_H - T_C)}{RT_H \log(V_2/V_1)}$

(B) $\eta = 1 - \frac{T_C}{T_H}$

(C) $\eta = 1 - \frac{C_V(T_H - T_C)}{C_P T_H}$

(D) $\eta = 1 - \frac{C_V T_C}{RT_H \log(V_2/V_1)}$

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Q.No	Year	Answer
Q1	TIFR-2013	Option D
Q2	TIFR-2013	Option C
Q3	TIFR-2013	Option B
Q4	TIFR-2013	Option A
Q5	TIFR-2014	Option B
Q6	TIFR-2014	Option C
Q7	TIFR-2014	Option A
Q8	TIFR-2015	Option C
Q9	TIFR-2015	Option C
Q10	TIFR-2016	Option D
Q11	TIFR-2016	Option D
Q12	TIFR-2016	118
Q13	TIFR-2017	66
Q14	TIFR-2017	Option D
Q15	TIFR-2018	347
Q16	TIFR-2018	Option C
Q17	TIFR-2019	Option B
Q18	TIFR-2019	Option A
Q19	TIFR-2020	Option A
Q20	TIFR-2020	Option A
Q21	TIFR-2020	Option B
Q22	TIFR-2020	Option A
Q23	TIFR-2021	Option A
Q24	TIFR-2021	Option A
Q25	TIFR-2022	Option A
Q26	TIFR-2023	Option A
Q27	TIFR-2024	Option A
Q28	TIFR-2024	Option A
Q29	TIFR-2024	Option A
Q30	TIFR-2025	Option A
Q31	TIFR-2026	Option A
Q32	TIFR-2026	Option A
Q33	TIFR-2026	Option A

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