Thermodynamics JEE Main PYQ - 1

Total Time: 25 Minute **Total Marks:** 40

Instructions

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1. Test will auto submit when the Time is up.
2. The Test comprises of multiple choice questions (MCQ) with one or more correct answers.
3. The clock in the top right corner will display the remaining time available for you to complete the examination.

Navigating & Answering a Question

1. The answer will be saved automatically upon clicking on an option amongst the given choices of answer.
2. To deselect your chosen answer, click on the clear response button.
3. The marking scheme will be displayed for each question on the top right corner of the test window.

Thermodynamics

1. The shown p- V diagram represents the thermodynamic cycle of an engine, operating with an ideal monoatomic gas. The amount of heat, extracted from the source in a single cycle is **(+4, -1)**
[2010]

a. $p_0 v_0$

b. $\left(\frac{13}{2}\right) p_0 v_0$

c. $\left(\frac{11}{2}\right) p_0 v_0$

d. $4 p_0 v_0$

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2. Consider a spherical shell of radius R at temperature T. The black body radiation inside it can be considered as an ideal gas of photons with internal energy per unit volume $u = \frac{U}{V} ? T^4$ and pressure $p = \frac{1}{3}\left(\frac{U}{V}\right)$ If the shell now undergoes an adiabatic expansion, the relation between T and R is **(+4, -1)**
[2015]

a. $T ? e^{-R}$

b. $T ? \frac{1}{R}$

c. $T ? e^{-3R}$

d. $T ? \frac{1}{R^3}$

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3. Consider an ideal gas confined in an isolated closed chamber. As the gas undergoes an adiabatic expansion, the average time of collision between molecules increases as V^q , where V is the volume of the gas. The value of q is $\left(\gamma = \frac{C_p}{C_v}\right)$ **(+4, -1)**
[24-Jan-2023 Shift 2]

a. $\frac{3\gamma+5}{6}$

b. $\frac{\gamma+1}{2}$

c. $\frac{3\gamma-5}{6}$

d. $\frac{\gamma-1}{2}$

---

4. A solid body of constant heat capacity $1\,J/^{\circ}C$ is being heated by keeping it in contact with reservoirs in two ways (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 $100^{\circ}C$ to final temperature $200^{\circ}C$. Entropy change of the body in the two cases respectively, is [2015] **(+4, -1)**

a. In (2), In 2

b. In 2, 2 In 2

c. 2 In 2, 8 In 2

d. In 2,4 In 2

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5. During an adiabatic compression, $830\,J$ of work is done on 2 moles of a diatomic ideal gas to reduce its volume by 50%. The change in its temperature is nearly : $(R = 8.3JK^{-1}\,mol^{-1})$ [27-Jan-2024•Shift•2] **(+4, -1)**

a. 40 K

b. 33 K

c. 20 K

d. 14 K

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6. An ideal gas undergoes a quasi static, reversible process in which its molar heat capacity Cremains 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] **(+4, -1)**

a. $n = \frac{C_P}{C_V}$

b. $n = \frac{C-C_P}{C-C_V}$

c. $n = \frac{C_P-C}{C-C_V}$

d. $n = \frac{C-C_V}{C-C_P}$

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7. $'n'$ 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 : [10 Apr. 2019 I] (+4, -1)

a. $\frac{9\, P_0\, V_0}{4nR}$

b. $\frac{3\, P_0\, V_0}{2nR}$

c. $\frac{9\, P_0\, V_0}{2nR}$

d. $\frac{9\, P_0\, V_0}{nR}$

---

8. C_p and C_v are specific heats at constant pressure and constant volume respectively. It is observed that $C_p - C_v$ = a for hydrogen gas $C_p - C_v$ = b for nitrogen gas The correct relation between a and b is : [27-Jan-2024•Shift•1] (+4, -1)

a. $a = \frac{1}{14}b$

b. $a = b$

c. $a = 14\,b$

d. $a = 28\,b$

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9. A certain amount of gas of volume V at $27^{\circ}C$ temperature and pressure $2 \times 10^7 Nm^{-2}$ expands isothermally until its volume gets doubled Later it expands adiabatically until its volume gets redoubled The final pressure of the gas will be (Use $\gamma = 15$) [25-Jul-2022-Shift-1] (+4, -1)

a. $3.536 \times 10^5 Pa$

b. $3.536 \times 10^6 Pa$

c. $1.25 \times 10^6 Pa$

d. $1.25 \times 10^5 Pa$

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10. Match List -I with List -II **(+4, -1)**

List - I		List -II	
a	Isothermal	i	Pressure constant
b	Isobaric	ii	Temperature constant
c	Adiabatic	iii	Volume constant
d	Isobaric	iv	Heat content is constant

[25-Jan-2023 Shift 2]

Choose the correct answer from the options given below

a. $(a) \rightarrow (i), (b) \rightarrow (iii), (c) \rightarrow (ii), (d) \rightarrow (iv)$

b. $(a) \rightarrow (ii), (b) \rightarrow (iii), (c) \rightarrow (iv), (d) \rightarrow (i)$

c. $(a) \rightarrow (ii), (b) \rightarrow (iv), (c) \rightarrow (iii), (d) \rightarrow (i)$

d. $(a) \rightarrow (iii), (b) \rightarrow (ii), (c) \rightarrow (i), (d) \rightarrow (iv)$

Answers

1. **Answer: b**

Explanation:

Heat is extracted from the source means heat is given to the system (or gas) or Q is positive. This is positive only along the path ABC.
Heat supplied

$\therefore \quad Q_{ABC}+W_{ABC}$

$=nC_v(T_f-T_i)+$ Area under p-V graph

$=n\left(\frac{3}{2}R\right)(T_C-T_A)+2p_0v_0$

$=\frac{3}{2}(nRT_C-nRT_A)+2p_0v_0$

$=\frac{3}{2}(p_CV_C-p_AV_A)+2p_0V_0$

$=\frac{3}{2}(4p_0V_0-p_0V_0)+2p_0V_0$

$=\left(\frac{13}{2}\right)p_0V_0$

Concepts:

1. **Thermodynamics:**

Thermodynamics in physics is a branch that deals with heat, work and temperature, and their relation to energy, radiation and physical properties of matter.

Important Terms

System

A thermodynamic system is a specific portion of matter with a definite boundary on which our attention is focused. The system boundary may be real or imaginary, fixed or deformable.

There are three types of systems:

- **Isolated System –** An isolated system cannot exchange both energy and mass with its surroundings. The universe is considered an isolated system.
- **Closed System –** Across the boundary of the closed system, the transfer of energy takes place but the transfer of mass doesn't take place. Refrigerators and

compression of gas in the piston-cylinder assembly are examples of closed systems.
- **Open System –** In an open system, the mass and energy both may be transferred between the system and surroundings. A steam turbine is an example of an open system.

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Laws of Thermodynamics

Zeroth Law of Thermodynamics

The Zeroth law of thermodynamics states that if two bodies are individually in equilibrium with a separate third body, then the first two bodies are also in thermal equilibrium with each other.

First Law of Thermodynamics

The First law of thermodynamics is a version of the law of conservation of energy, adapted for thermodynamic processes, distinguishing three kinds of transfer of energy, as heat, as thermodynamic work, and as energy associated with matter transfer, and relating them to a function of a body's state, called internal energy.

Second Law of Thermodynamics

The Second law of thermodynamics is a physical law of thermodynamics about heat and loss in its conversion.

Third Law of Thermodynamics

Third law of thermodynamics states, regarding the properties of closed systems in thermodynamic equilibrium: The entropy of a system approaches a constant value when its temperature approaches absolute zero.

---

2. Answer: b

Explanation:

$u = \frac{U}{V} \propto T^4$

$P = \frac{1}{3}\left(\frac{U}{V}\right)$

Adiabatic expansion

$TV^{\gamma-1} = K$

$TV^{\frac{\gamma}{4}} = C$

$\gamma - 1 = \frac{\gamma}{4}$

$\frac{3\gamma}{4} = 1$

$\gamma = \frac{4}{3}$

$TV^{\frac{\gamma}{4}} = C$

$TV^{\frac{1}{3}} = C$

$T\left(\frac{4}{3}\pi R^3\right)^{\frac{1}{3}} = C$

$T \propto \frac{1}{R}$

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3. **Answer: b**

Explanation:

mean free path

$\lambda = \frac{1}{\sqrt{2}\,\pi d^2 n}$

$n = \frac{\text{no. of molecules}}{\text{volume}}$

$v_{\text{avg.}} \propto \sqrt{T} \quad T.V^{\gamma-1} = C$

$t = \frac{\lambda}{V_{\text{avg.}}} \propto \frac{V}{\sqrt{T}} \qquad v \rightarrow$ is volume

$\frac{V}{\sqrt{\frac{C}{v^{r-1}}}} \propto V^{\frac{\gamma+1}{2}}$

$v^q \propto v^{\frac{\gamma+1}{2}}$

$q = \frac{\gamma+1}{2}$

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4. **Answer: a**

Explanation:

(i) $\Delta S_1 = \int \frac{dQ}{T} = ms \int_{100}^{150} \frac{dT}{T} + ms \int_{150}^{200} \frac{dT}{T}$

$= \ln\left(\frac{150}{100}\right) + \ln\left(\frac{200}{150}\right)$

$= \ln\left(\frac{3}{2}\right) + \ln\frac{4}{3}$

$\Delta S_1 = \ln 2$

(ii) $\Delta s_2 = \int \frac{dQ}{T} = \int_{100}^{112.5} \frac{dQ}{T} + \int_{112.5}^{125} \frac{dQ}{T} + \ldots\ldots$

$= \ln\left(\frac{112.5}{100}\right) + \ln\left(\frac{125}{112.5}\right) + \ldots..$

$= \ln\left(\frac{9}{8}\right) + \ln\left(\frac{10}{9}\right) + \ln\left(\frac{16}{15}\right)$

$= \ln\left(\frac{16}{8}\right) = \ln 2$

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5. **Answer: c**

Explanation:

The work done in adiabatic process is given as

$$W=\frac{n R \Delta T}{\gamma-1}$$

or

$830=\frac{2\times 8.3\times \Delta T}{1.4-1}$

$$\Delta T=20 K$$

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6. **Answer: b**

Explanation:

$$C = C_V + \frac{R}{1-\eta}$$
$$\Rightarrow 1 - n = \frac{R}{C-C_V}$$
$$n = 1 - \frac{R}{C-C_V} = \frac{C-(C_V+R)}{C-C_V} = \frac{C-C_P}{C-C_V}$$

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7. **Answer: a**

Explanation:

Equation of line AB

$y - y_1 = \frac{y_2 - y_1}{x_2 - x_1}(x - x_1)$

$P - P_0 = \frac{2P_0 - P_0}{V_0 - 2V_0}$

$(V - 2V_0) = -\frac{P_0}{V_0}(V - 2V_0)$

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

$PV = -\frac{P_0}{V_0}V^2 + 3P_0V$

$nRT = -\frac{P_0}{V_0}V^2 + 3P_0V$

$T = \frac{1}{nR}\left(\frac{P_0}{V_0}V^2 + 3P_0V\right)$

$\frac{dT}{dV} = 0$ (For maximum temperature)

$\frac{P_0}{V_0}2V + 3P_0 = 0$

$\frac{P_0}{V_0}2V = -3P_0$

$V = \frac{3}{2}V_0$ (Condition for maximum temperature)

$T_{max} = \frac{1}{nR}\left(-\frac{P_0}{V_0} \times \frac{9}{4}V_0^2 + 3P_0 \times \frac{3}{2}V_0\right)$

$= \frac{1}{nR}\left(-\frac{9}{4}P_0V_0 + \frac{9}{2}P_0V_0 0\right) = \frac{9}{4}\frac{P_0V_0}{nR}$0

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8. Answer: c

Explanation:

Let molar heat capacity at constant pressure = X_p
and molar heat capacity at constant volume = X_v
$X_p - X_v = R$
$MC_p - MC_v = R$
$C_p - C_v = \frac{R}{M}$
For hydrogen; $a = \frac{R}{2}$
For $N_2; b = \frac{R}{28}$

$\frac{a}{b} = 14$

$a = 14b$

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9. **Answer: b**

Explanation:

The correct option is (B)

Concepts:

1. Laws of Thermodynamics:

Thermodynamics in physics is a branch that deals with heat, work and temperature, and their relation to energy, radiation and physical properties of matter.

The First Law of Thermodynamics:

The first law of thermodynamics, also known as the Law of Conservation of Energy, states that energy can neither be created nor destroyed; energy can only be transferred or changed from one form to another.

The Second Law of Thermodynamics:

The second law of thermodynamics says that the entropy of any isolated system always increases. Isolated systems spontaneously evolve towards thermal equilibrium—the state of maximum entropy of the system. More simply put: the entropy of the universe (the ultimate isolated system) only increases and never decreases.

The Third Law of Thermodynamics:

The third law of thermodynamics states that the entropy of a system approaches a constant value as the temperature approaches absolute zero. The entropy of a system at absolute zero is typically zero, and in all cases is determined only by the number of different ground states it has. Specifically, the entropy of a pure crystalline substance (perfect order) at absolute zero temperature is zero

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10. Answer: b

Explanation:

(a) Isothermal $\Rightarrow$ Temperature constant
(a) $\rightarrow$ (ii)
(b) Isochoric $\Rightarrow$ Volume constant
(a) $\rightarrow$ (iii)
(c) Adiabatic $\Rightarrow \Delta Q = 0$

$\Rightarrow$ Heat content is constant

$(c) \rightarrow (iv)$

(d) Isobaric $\Rightarrow$ Pressure constant

$(d) \rightarrow (i)$

Concepts:

1. Thermodynamics:

Thermodynamics in physics is a branch that deals with heat, work and temperature, and their relation to energy, radiation and physical properties of matter.

Important Terms

System

A thermodynamic system is a specific portion of matter with a definite boundary on which our attention is focused. The system boundary may be real or imaginary, fixed or deformable.

There are three types of systems:

- **Isolated System –** An isolated system cannot exchange both energy and mass with its surroundings. The universe is considered an isolated system.
- **Closed System –** Across the boundary of the closed system, the transfer of energy takes place but the transfer of mass doesn't take place. Refrigerators and compression of gas in the piston-cylinder assembly are examples of closed systems.
- **Open System –** In an open system, the mass and energy both may be transferred between the system and surroundings. A steam turbine is an example of an open system.

Thermodynamic Process

A system undergoes a thermodynamic process when there is some energetic change within the system that is associated with changes in pressure, volume and internal energy.

There are four types of thermodynamic process that have their unique properties, and they are:

- **Adiabatic Process** – A process in which no heat transfer takes place.
- **Isochoric Process** – A thermodynamic process taking place at constant volume is known as the isochoric process.
- **Isobaric Process** – A process in which no change in pressure occurs.
- **Isothermal Process** – A process in which no change in temperature occurs.

Laws of Thermodynamics

Zeroth Law of Thermodynamics

The Zeroth law of thermodynamics states that if two bodies are individually in equilibrium with a separate third body, then the first two bodies are also in thermal equilibrium with each other.

First Law of Thermodynamics

The First law of thermodynamics is a version of the law of conservation of energy, adapted for thermodynamic processes, distinguishing three kinds of transfer of energy, as heat, as thermodynamic work, and as energy associated with matter transfer, and relating them to a function of a body's state, called internal energy.

Second Law of Thermodynamics

The Second law of thermodynamics is a physical law of thermodynamics about heat and loss in its conversion.

Third Law of Thermodynamics

Third law of thermodynamics states, regarding the properties of closed systems in thermodynamic equilibrium: The entropy of a system approaches a constant value when its temperature approaches absolute zero.