Master Testing Agency
Practice papers, exam-standard · www.mastertestingagency.com

Thermodynamics — JEE (Main) Pattern Topic Test

FREE SAMPLE TEST · PHYSICS · PATTERN OF JEE (MAIN)

DURATION	MAXIMUM MARKS	QUESTIONS	NAME / ROLL NO.
60 minutes	100	25 (20 + 5)	

GENERAL INSTRUCTIONS

1. This question paper has two sections, A and B. All 25 questions are compulsory.
2. Section A has TWENTY (20) multiple-choice questions. Each has FOUR options, (1), (2), (3) and (4), of which ONLY ONE is correct.
3. Section B has FIVE (05) questions whose answer is a numerical value. Enter the value rounded off to the nearest integer.
4. Marking scheme for both sections: +4 for a correct answer, −1 for an incorrect answer, 0 if the question is not attempted.
5. Treat all gases as ideal; R = 8.314 J/mol K unless stated otherwise. Use of a calculator, log tables or any other aid is not allowed.
6. The answer key and worked solutions are at the end of this booklet. Attempt the paper in 60 minutes before you look at them.

All questions are original and © Master Testing Agency. Free to download and use for personal practice; not for resale. Master Testing Agency is an independent test-prep publisher, not affiliated with, endorsed by or connected to the National Testing Agency (NTA), the IITs or any other exam-conducting body.

Topics covered: Thermal equilibrium · Work done by a gas · First law of thermodynamics · Isothermal process · Adiabatic process · Reversible and irreversible processes · Second law of thermodynamics · Heat engines · Refrigerators

SECTION A (Q1–20) · Multiple choice · +4 / 0 / −1

Each question has FOUR options. ONLY ONE of them is correct.

1. An ideal gas is taken round a cycle that is a rectangle on the P–V diagram, with pressures P_0 and $2P_0$ and volumes V_0 and $3V_0$. It expands at the higher pressure and is compressed at the lower pressure. The net work done by the gas in one cycle is

(1) P_0V_0

(2) $2P_0V_0$

(3) $4P_0V_0$

(4) $6P_0V_0$

2. A diatomic ideal gas (rigid molecules) is heated at constant pressure. The fractions of the heat supplied that go into work done by the gas and into its internal energy are

(1) 2/5 and 3/5

(2) 5/7 and 2/7

(3) 2/7 and 5/7

(4) 1/2 and 1/2

3. Two moles of an ideal gas at 300 K expand isothermally and reversibly from 10 L to 20 L. The work done by the gas is about (R = 8.314 J/mol K)

(1) 1.73 kJ

(2) 4.99 kJ

(3) 6.92 kJ

(4) 3.46 kJ

4. A monoatomic ideal gas at temperature T and pressure P is compressed adiabatically and reversibly to one-eighth of its volume. Its final temperature and pressure are

(1) 4T and 32P

(2) 8T and 64P

(3) 2T and 16P

(4) 4T and 8P

5. One mole of a monoatomic ideal gas at 300 K expands adiabatically until its temperature falls to 200 K. The work done by the gas is about (R = 8.314 J/mol K)

(1) 831 J

(2) 1247 J

(3) 2079 J

(4) 1663 J

6. Statement I: Through any point on the P–V diagram of an ideal gas, the adiabatic curve is steeper than the isothermal curve.
Statement II: At any point, the slope of the adiabatic curve is γ times the slope of the isothermal curve, and $\gamma > 1$.
In the light of the above statements, choose the correct answer from the options given below:

(1) Statement I is true but Statement II is false

(2) Statement I is false but Statement II is true

(3) Both Statement I and Statement II are false

(4) Both Statement I and Statement II are true

7. A monoatomic ideal gas expands in a process in which PV^2 stays constant. The molar heat capacity of the gas in this process is

(1) $R/2$

(2) $3R/2$

(3) $5R/2$

(4) $-R/2$

8. Consider the following statements about an ideal gas.
(A) In a free expansion into a vacuum, the temperature of the gas does not change.
(B) A free expansion is a reversible process.
(C) In an isothermal process, all the heat supplied to the gas is converted into work done by it.
(D) In an adiabatic expansion, the internal energy of the gas increases.
(E) The internal energy of a given amount of the gas depends only on its temperature.
Choose the correct answer from the options given below:

(1) (A), (B) and (E) only

(2) (A), (C) and (E) only

(3) (C), (D) and (E) only

(4) (A), (C), (D) and (E) only

9. A Carnot engine works between a source at 500 K and a sink at 300 K. Keeping the sink at 300 K, by how much must the temperature of the source be raised to increase the efficiency to 50%?

(1) 50 K

(2) 200 K

(3) 100 K

(4) 125 K

10. An ideal (Carnot) refrigerator keeps its cold compartment at 270 K in a room at 300 K. To remove 900 J of heat from the cold compartment, the work needed and the heat delivered to the room are

(1) 100 J and 1000 J

(2) 100 J and 800 J

(3) 900 J and 1800 J

(4) 300 J and 1200 J

11. An inventor claims that an engine working between reservoirs at 600 K and 400 K takes in 1000 J of heat from the hot reservoir in each cycle and does 500 J of work. The claim is

(1) possible, since it obeys the first law

(2) possible only if the engine is reversible

(3) impossible, since the most work it could do is about 333 J per cycle

(4) impossible, since it would reject heat to the cold reservoir

12. One mole of a monoatomic ideal gas at 300 K and one mole of a diatomic ideal gas at 400 K are in two parts of a rigid, insulated vessel separated by a partition. The partition is removed and the gases mix. The final temperature is

(1) 350 K

(2) 362.5 K

(3) 337.5 K

(4) 375 K

13. One mole of a monoatomic ideal gas is taken round the cycle A → B → C → A. A (P_0, V_0) to B ($2P_0$, V_0) is at constant volume, B to C ($2P_0$, $2V_0$) is at constant pressure, and C returns to A along the straight line joining them on the P–V diagram. The net work done in one cycle and the efficiency of the cycle are

(1) P_0V_0 and 2/13

(2) $P_0V_0/2$ and 1/6

(3) $P_0V_0/2$ and 1/13

(4) $P_0V_0/2$ and 1/12

14. A gas is taken from state A to state B along path 1, absorbing 80 J of heat and doing 50 J of work. Along path 2 from A to B it does 20 J of work. It is then returned from B to A along a third path, on which 30 J of work is done on the gas. The heat absorbed along path 2, and the heat exchanged on the return path, are

(1) 50 J absorbed, and 60 J released

(2) 110 J absorbed, and 60 J released

(3) 50 J absorbed, and 0 J

(4) 80 J absorbed, and 30 J released

15. The adiabatic bulk modulus of a diatomic ideal gas (rigid molecules) at a pressure of 1.0×10^5 Pa is

(1) 1.0×10^5 Pa

(2) 1.67×10^5 Pa

(3) 0.71×10^5 Pa

(4) 1.4×10^5 Pa

16. An ideal gas with ratio of specific heats γ, initially at pressure P_0 and volume V_0, expands isothermally to volume $2V_0$, and is then compressed adiabatically back to volume V_0. Its final pressure is

(1) $2^{(1-\gamma)} P_0$

(2) $2^{\gamma} P_0$

(3) P_0

(4) $2^{(\gamma-1)} P_0$

17. From the same initial state, an ideal gas expands to the same final volume in three ways: at constant pressure, isothermally, and adiabatically. The work done by the gas is

(1) greatest in the isothermal expansion

(2) the same in all three

(3) greatest in the isobaric expansion and least in the adiabatic expansion

(4) greatest in the adiabatic expansion

18. Two Carnot engines work in series: the first takes heat from a source at 900 K and rejects it to a reservoir at temperature T, and the second takes that heat from the reservoir and rejects heat to a sink at 400 K. If the two engines have equal efficiencies, T is

(1) 600 K

(2) 650 K

(3) 500 K

(4) 750 K

19. A monoatomic ideal gas at a pressure of 3.2×10^6 Pa and volume 1 L expands adiabatically and reversibly to 8 L. The work done by the gas is

(1) 2400 J

(2) 6650 J

(3) 3600 J

(4) 1600 J

20. Which of the following is NOT allowed by the laws of thermodynamics?

(1) A refrigerator that moves heat from a cold body to a hot body, using work

(2) An engine that, in a cycle, takes heat from one reservoir and converts all of it into work

(3) A gas that absorbs heat and converts all of it into work in a single isothermal expansion

(4) A process in which work is converted completely into heat

---

SECTION B (Q21–25) · Numerical value · +4 / 0 / −1

The answer to each question is a NUMERICAL VALUE. Enter it rounded off to the nearest integer.

---

21. The heat (in J) needed to raise the temperature of one mole of a monoatomic ideal gas by 100 K at constant pressure is _____ (R = 8.3 J/mol K).

Answer: _____

22. A Carnot engine has an efficiency of 25% when its sink is at 27 °C. The temperature of its source (in °C) is _____.

Answer: _____

23. A gas is taken round a cycle that is a rectangle on the P–V diagram, between pressures of 100 kPa and 300 kPa and volumes of 2 L and 5 L, expanding at the higher pressure. The net work done by the gas (in J) in one cycle is _____.

Answer: _____

24. Air ($\gamma = 1.4$) at 27 °C is compressed adiabatically and reversibly to 1/32 of its volume. Its final temperature (in K) is _____.

Answer: _____

25. A gas absorbs 500 J of heat and its internal energy increases by 200 J, while it expands against a constant pressure of 1.0×10^5 Pa. The increase in its volume (in cm^3) is _____.

Answer: _____

END OF THE QUESTION PAPER

ANSWER KEY

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
(2)	(3)	(4)	(1)	(2)	(4)	(1)	(2)	(3)	(1)

Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
(3)	(2)	(3)	(1)	(4)	(4)	(3)	(1)	(3)	(2)

Q21	Q22	Q23	Q24	Q25
2075	127	600	1200	3000

WORKED SOLUTIONS

Q1. Answer (2). The net work is the area enclosed: $(2P_0 - P_0)(3V_0 - V_0) = 2P_0V_0$. It is positive because the expansion happens at the higher pressure (the cycle runs clockwise on the P–V diagram). The two vertical sides do no work.

Q2. Answer (3). $Q = nC_p\Delta T = (7/2)nR\Delta T$, $\Delta U = nC_v\Delta T = (5/2)nR\Delta T$ and $W = P\Delta V = nR\Delta T$. So $W/Q = 2/7$ and $\Delta U/Q = 5/7$. (2/5 and 3/5 are the fractions for a monoatomic gas.)

Q3. Answer (4). $W = nRT\ln(V_2/V_1) = 2 \times 8.314 \times 300 \times \ln 2 \approx 3458$ J ≈ 3.46 kJ. All of it is supplied as heat, since $\Delta U = 0$ at constant temperature.

Q4. Answer (1). $\gamma = 5/3$. TV^(γ−1) is constant: $T_2 = T \times 8^{(2/3)} = 4T$. PV^γ is constant: $P_2 = P \times 8^{(5/3)} = 32P$. (Check: $P_2V_2/T_2 = 32P(V/8)/(4T) = PV/T$.) 8P would be the isothermal result.

Q5. Answer (2). No heat enters, so $W = -\Delta U = nC_v(T_1 - T_2) = 1.5 \times 8.314 \times 100 \approx 1247$ J. 831 J (= $R\Delta T$) would be the work in an isobaric process; 2079 J uses C_p.

Q6. Answer (4). Isothermal: PV = constant gives $dP/dV = -P/V$. Adiabatic: PV^γ = constant gives $dP/dV = -\gamma P/V$. Since $\gamma = C_p/C_v > 1$, the adiabatic curve is steeper. Both statements are true (and II explains I).

Q7. Answer (1). With $PV^2 = k$ and $PV = nRT$, $T \propto 1/V$, so the gas cools as it expands. For PV^n = constant, $C = C_v + R/(1 - n) = 3R/2 + R/(1 - 2) = R/2$. Check: on expansion $W > 0$ but $\Delta U < 0$, and $Q = \Delta U + W$ comes out as $(R/2)n\Delta T$, which is negative, as ΔT is.

Q8. Answer (2). (A) In a free expansion $Q = 0$ and $W = 0$, so $\Delta U = 0$ and, for an ideal gas, T is unchanged. True. (B) It cannot be reversed without outside changes: false. (C) $\Delta U = 0$, so $Q = W$. True. (D) $Q = 0$ and $W > 0$, so $\Delta U = -W < 0$: false. (E) True for an ideal gas.

Q9. Answer (3). Now $\eta = 1 - 300/500 = 40\%$. For 50%, $1 - 300/T = 0.5$, so $T = 600$ K: the source must be raised by 100 K.

Q10. Answer (1). Coefficient of performance $= T_c/(T_h - T_c) = 270/30 = 9$. Work = 900/9 = 100 J, and the room receives 900 + 100 = 1000 J.

Q11. Answer (3). No engine between these temperatures can beat the Carnot efficiency $1 - 400/600 = 1/3$, so at most 333 J of work per 1000 J of heat. Claiming 50% breaks the second law, though it obeys the first.

Q12. Answer (2). No heat or work enters, so the total internal energy is unchanged: $(3/2)R \times 300 + (5/2)R \times 400 = (3/2 + 5/2)R\,T$. So $450 + 1000 = 4T$ and $T = 362.5$ K, nearer the temperature of the gas with the larger heat capacity.

Q13. Answer (3). Net work = area of the triangle = $\frac{1}{2}P_0V_0$. Heat taken in: A → B, $Q = (3/2)R(T_B - T_A) = (3/2)(2P_0V_0 - P_0V_0) = 1.5P_0V_0$; B → C, $Q = (5/2)(4P_0V_0 - 2P_0V_0) = 5P_0V_0$. On C → A ($P \propto V$) the temperature falls all the way and heat leaves. Efficiency $= 0.5/6.5 = 1/13 \approx 7.7\%$.

Q14. Answer (1). $\Delta U(A \to B) = 80 - 50 = 30$ J, the same for every path. Path 2: $Q = 30 + 20 = 50$ J absorbed. Return: $\Delta U = -30$ J and $W = -30$ J, so $Q = -60$ J: 60 J released.

Q15. Answer (4). $B = -V\,dP/dV$. For an adiabatic change $dP/dV = -\gamma P/V$, so $B = \gamma P = 1.4 \times 10^5$ Pa (the isothermal bulk modulus is $P = 1.0 \times 10^5$ Pa).

Q16. Answer (4). After the isothermal expansion the pressure is $P_0/2$. The adiabatic compression to half the volume multiplies it by 2^{γ}: $P = (P_0/2)2^{\gamma} = 2^{(\gamma-1)}P_0$, more than P_0 (the gas is now hotter).

Q17. Answer (3). Work is the area under the P–V curve. At constant pressure the pressure stays at its initial value; isothermally it falls as $1/V$; adiabatically it falls faster still (as $1/V^{\gamma}$). So $W_{isobaric} > W_{isothermal} > W_{adiabatic}$.

Q18. Answer (1). Equal efficiencies: $1 - T/900 = 1 - 400/T$, so $T^2 = 900 \times 400$ and $T = 600$ K (the geometric mean). Equal work outputs would instead give the arithmetic mean, 650 K.

Q19. Answer (3). $P_2 = P_1(V_1/V_2)^{\gamma} = 3.2 \times 10^6 \times 8^{(-5/3)} = 3.2 \times 10^6/32 = 10^5$ Pa. $W = (P_1V_1 - P_2V_2)/(\gamma - 1) = (3200 - 800)/(2/3) = 3600$ J. 6650 J ($= P_1V_1 \ln 8$) would be the isothermal work.

Q20. Answer (2). Kelvin–Planck statement of the second law: no engine working in a cycle can convert all the heat taken from a single reservoir into work. A single isothermal expansion is not a cycle, so (3) is allowed; (1) uses work, as the Clausius statement requires; (4) happens in friction.

Q21. Answer 2075. $Q = nC_p\Delta T = (5/2) \times 8.3 \times 100 = 2075$ J (of which 1245 J raises the internal energy and 830 J is the work done).

Q22. Answer 127. $\eta = 1 - T_2/T_1$: $0.25 = 1 - 300/T_1$, so $T_1 = 400$ K = 127 °C.

Q23. Answer 600. Net work = area enclosed = $(300 - 100) \times 10^3$ Pa $\times (5 - 2) \times 10^{-3}$ m³ = 600 J.

Q24. Answer 1200. $T_2 = T_1(V_1/V_2)^{(\gamma-1)} = 300 \times 32^{0.4} = 300 \times 4 = 1200$ K ($32^{0.4} = 2^2 = 4$).

Q25. Answer 3000. $W = Q - \Delta U = 300$ J $= P\Delta V$, so $\Delta V = 300/10^5 = 3 \times 10^{-3}$ m³ = 3000 cm³.

All questions are original and © Master Testing Agency. Free to download and use for personal practice; not for resale. Every answer in this paper was checked independently by computer: work as the numerical integral of P dV along each path, heat by applying the first law step by step along the path, and adiabats by integrating $dP/dV = -\gamma P/V$.