Thermodynamics

Standard difficulty · 20 questions · 40 marks · Time: 36 minutes

Name: _____ Date: _____ Score: ____ / 40

Show your working for Sections B and C. Answers are on the last page — try every question first!

Section A — Choose the correct answer 8 × 1 = 8 marks

1. 800 J of heat is given to a gas, and the gas does 600 J of work on its surroundings. The change in its internal energy is:
   (a) −200 J **(b)** 1400 J **(c)** 800 J **(d)** 200 J

2. A gas expands at a constant pressure of 10×10^5 N/m^2 from 4 L to 22 L. The work done by the gas is:
   (a) 18,000,000 J **(b)** 18 J **(c)** 18,000 J **(d)** 180,000 J

3. A heat engine takes in 4100 J from the hot source and does 600 J of work in each cycle. Its efficiency is:
   (a) 683.33% **(b)** 0.15% **(c)** 85.37% **(d)** 14.63%

4. A Carnot engine works between 870 K and 250 K. Its efficiency is:
   (a) 71.26% **(b)** 28.74% **(c)** 248% **(d)** 0.71%

5. The zeroth law of thermodynamics leads to the idea of:
   (a) temperature **(b)** internal energy
   (c) work **(d)** entropy

6. A Carnot refrigerator keeps its inside at 270 K in a room at 310 K. Its coefficient of performance is:
   (a) 7.75 **(b)** 6.75 **(c)** 0.15 **(d)** 0.87

7. A gas goes round a rectangular cycle on a p–V diagram between 3×10^5 and 6×10^5 N/m^2 and between 1 L and 5 L. The net work done in one cycle is:
   (a) 1,200 J **(b)** 0 J **(c)** 3,000 J **(d)** 2,400 J

8. Assertion (A): A gas goes through a complete cycle and does 1000 J of work. The net heat it absorbs in the cycle is 1000 J.
   Reason (R): In a cyclic process no heat is exchanged, because the gas returns to its initial state.
   (a) Both A and R are true, and R is the correct explanation of A.
   (b) Both A and R are true, but R is not the correct explanation of A.
   (c) A is true, but R is false.
   (d) A is false, but R is true.

Section B — Short answer 8 × 2 = 16 marks

9. A system absorbs 1200 J of heat and does 1200 J of work. Find the change in its internal energy.

10. 4 mol of an ideal gas expands isothermally at 400 K to 2 times its volume. Find the work done by the gas. (R = 8.31 J/mol K, ln 2 = 0.693) (2 decimal places where needed.)

11. A Carnot engine takes in 5,000 J per cycle from a source at 650 K and rejects heat to a sink at 580 K. Find its efficiency, the work done per cycle and the heat rejected. (2 decimal places where needed.)

12. A refrigerator with coefficient of performance 5 uses 1700 J of electrical work. How much heat does it remove from the inside, and how much does it give out to the room?

13. 5 mol of a monatomic ideal gas is heated at constant volume through 80 K. Find the heat supplied, the work done and the change in internal energy. (R = 8.31 J/mol K) (2 decimal places where needed.)

14. 5 mol of a diatomic ideal gas is heated at constant pressure through 45 K. Find the work done by the gas, the change in internal energy and the heat supplied. (R = 8.31 J/mol K) (2 decimal places where needed.)

15. In an adiabatic expansion, a gas goes from 8×10^5 N/m^2, 1 L to 3×10^5 N/m^2, 9 L. Taking $\gamma = 7/5$, find the work done by the gas. Does its temperature rise or fall? (2 decimal places where needed.)

16. A gas is taken round a rectangular cycle: pressures 2×10^5 and 5×10^5 N/m^2, volumes 1 L and 6 L, going clockwise on a p–V diagram. Find the net work done, the net heat absorbed and the change in internal energy per cycle.

Section C — Word problems — 4 × 4 = 16 marks

17. A Carnot engine works between 820 K and 280 K and takes in 15,000 J per cycle. (a) Find its efficiency, the work done and the heat rejected per cycle. (b) To what temperature must the sink be lowered for an efficiency of 60%? (2 decimal places where needed.)

18. 2 mol of a monatomic ideal gas expands at constant pressure from 340 K to 690 K. Find (a) the work done by the gas, (b) the change in internal energy, (c) the heat supplied, (d) the ratio of work done to heat supplied. (R = 8.31 J/mol K) (2 decimal places where needed.)

19. A Carnot refrigerator keeps food at 280 K in a kitchen at 290 K. It removes 16,000 J of heat from the food. Find (a) its coefficient of performance, (b) the work needed, (c) the heat given out to the kitchen. (2 decimal places where needed.)

20. A gas is taken round a triangular cycle on a p–V diagram (V across, p up) with corners at (3 L, 5×10^5 Pa), (6 L, 6×10^5 Pa) and (6 L, 5×10^5 Pa), in that order and back (clockwise). Find the net work done by the gas in one cycle, the net heat absorbed and the change in internal energy.

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Answer key

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Q	Answer	Working
1	**(d) 200 J**	$\Delta U = Q - W$
2	**(c) 18,000 J**	$W = p\Delta V$, with 1 L = 10^{-3} m^3
3	**(d) 14.63%**	$\eta = W/Q_1$
4	**(a) 71.26%**	$\eta = 1 - T_2/T_1$
5	**(a) temperature**	—
6	**(b) 6.75**	$\beta = T_2/(T_1 - T_2)$
7	**(a) 1,200 J**	the area enclosed: $\Delta p \times \Delta V$
8	**(c) A is true, but R is false.**	A is true: in a cycle $\Delta U = 0$, so $Q = W = 1000$ J. R is false.
9	**0 J**	$\Delta U = Q - W$
10	**9,214.13 J**	$W = nRT \ln(V_2/V_1) = 4 \times 8.31 \times 400 \times 1 \times 0.693$
11	**10.77%; 538.46 J; 4,461.54 J**	$\eta = 1 - T_2/T_1$; $W = \eta Q_1$; $Q_2 = Q_1 - W$
12	**8,500 J removed; 10,200 J given out**	$Q_2 = \beta W$; $Q_1 = Q_2 + W$
13	**Q = ΔU = 4,986 J; W = 0**	$C_v = (3/2)R$; isochoric, so no work
14	**W = 1,869.75 J; ΔU = 4,674.38 J; Q = 6,544.13 J**	$W = nR\Delta T$; $\Delta U = nC_v\Delta T$; $Q = nC_p\Delta T$
15	**−4,750 J; its temperature rises**	$W = (p_1V_1 - p_2V_2)/(\gamma - 1)$
16	**W = 1,500 J; Q = 1,500 J; ΔU = 0**	area of the rectangle; in a cycle $\Delta U = 0$
17	**(a) 65.85%; 9,878.05 J; 5,121.95 J. (b) 328 K**	$\eta = 1 - T_2/T_1$
18	**(a) 5,817 J; (b) 8,725.5 J; (c) 14,542.5 J; (d) 2/5**	$W = nR\Delta T$; $\Delta U = nC_v\Delta T$; $Q = nC_p\Delta T$
19	**(a) 28; (b) 571.43 J; (c) 16,571.43 J**	$\beta = T_2/(T_1 - T_2)$; $W = Q_2/\beta$; $Q_1 = Q_2 + W$
20	**Net work 150 J (the area of the triangle; positive because the cycle is clockwise); net heat absorbed 150 J; ΔU = 0**	area = ½ × base × height