Class 11 Physics · Chapter 11: Thermodynamics

Answer key and marking scheme · 20 marks · about 40 minutes · based on NCERT

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1. A gas gives out 150 J of heat to its surroundings while its internal energy rises by 250 J. The work done on the gas by the piston is [1]

(a) 100 J (b) −400 J
(c) 400 J (d) −100 J

Answer: (c) $\Delta Q = -150$ J (heat removed) and $\Delta U = +250$ J. The work done by the gas is $\Delta W = \Delta Q - \Delta U = -150 - 250 = -400$ J, so 400 J of work is done on the gas. −400 J is the work done by the gas, not on it; 100 J and −100 J drop the sign of the heat.

2. Which one of the following quantities, for a given mass of gas, depends only on the state of the gas and not on how the gas reached that state? [1]

(a) its internal energy (b) the heat given to it
(c) the work done on it (d) the heat it gives out in returning to its initial state

Answer: (a) Internal energy is a state variable. Heat and work are modes of energy transfer whose values depend on the path; the heat given out on the way back depends on the return path chosen.

3. A gas is taken from state i to state f along path 1, absorbing 80 J of heat and doing 50 J of work. It is then brought back from f to i along a different path, on which 30 J of work is done on the gas. The heat absorbed by the gas on the return path is [1]

(a) −60 J (b) 60 J
(c) 0 J (d) −30 J

Answer: (a) $\Delta U(i \to f) = 80 - 50 = 30$ J, so $\Delta U(f \to i) = -30$ J whatever the path. On the return, $\Delta W = -30$ J, so $\Delta Q = \Delta U + \Delta W = -30 - 30 = -60$ J: the gas gives out 60 J. Over the whole cycle $\Delta U = 0$ and net heat $80 - 60 = 20$ J equals net work $50 - 30 = 20$ J, as it must.

4. A quantity of heat raises the temperature of a 0.50 kg block of aluminium by 20 K. The same quantity of heat is given to a 0.50 kg block of copper. Using the specific heats 900 J kg^{-1} K^{-1} for aluminium and 386.4 J kg^{-1} K^{-1} for copper, the rise in temperature of the copper block is about [1]

(a) 8.6 K (b) 46.6 K
(c) 20 K (d) 23.3 K

Answer: (b) $\Delta Q = ms\Delta T$ is the same for both blocks of equal mass, so $\Delta T \propto 1/s$: $\Delta T(Cu) = 20 \times 900/386.4 \approx 46.6$ K. 8.6 K inverts the ratio; 20 K ignores the difference in specific heat.

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5. Three bodies P, Q and R are tested in pairs. P is found to be in thermal equilibrium with R, and Q is also found to be in thermal equilibrium with R. P and Q are now placed in contact through a conducting wall. Then [1]

(a) heat flows from P to Q until their temperatures become equal

(b) heat flows from Q to P until their temperatures become equal

(c) no net heat flows between P and Q, since they are already in thermal equilibrium

(d) whether heat flows depends on the masses of P and Q

Answer: (c) By the Zeroth Law, two systems each in thermal equilibrium with a third are in thermal equilibrium with each other: $T_P = T_R$ and $T_Q = T_R$ give $T_P = T_Q$, so nothing changes when P and Q touch. Masses do not enter the condition for equilibrium.

6. Why must a quasi-static process be, in principle, infinitely slow? Name one condition a real process must satisfy to approximate it. [2]

A sudden change (for example lifting a weight off the piston) makes the piston accelerate and the gas passes through non-equilibrium states with no well-defined pressure or temperature. For every stage to be an equilibrium state, the external pressure and temperature may differ from the gas's only by infinitesimal amounts, so each tiny step must be allowed to equalise: the process is infinitely slow. A real process approximates it if it is slow enough, with no accelerated motion of the piston and no large temperature gradient.

- finite sudden changes give non-equilibrium states; steps must be infinitesimal, so infinitely slow (1)
- one condition: slow, no accelerated piston, or no large temperature gradient (1)

7. State the two main causes of irreversibility in natural processes, giving one example of each from everyday life. [2]

(i) The process takes the system through non-equilibrium states, for example air rushing out of a punctured balloon, or a cracker exploding. (ii) Friction, viscosity and other dissipative effects, for example a cyclist braking to a stop, the kinetic energy appearing as heat in the brake pads.

- non-equilibrium states, with an example (1)
- dissipative effects (friction, viscosity), with an example (1)

8. The molar specific heat of an ideal gas at constant pressure is 29.1 J mol^{-1} K^{-1}. Find its molar specific heat at constant volume and the ratio γ. (R = 8.3 J mol^{-1} K^{-1}) [2]

$C_v = C_p - R = 29.1 - 8.3 = 20.8$ J mol^{-1} K^{-1}. $\gamma = C_p/C_v = 29.1/20.8 \approx 1.40$.

- $C_v = C_p - R = 20.8$ J mol^{-1} K^{-1} (1)
- $\gamma = 29.1/20.8 \approx 1.40$ (1)

9. State the Zeroth Law of thermodynamics. Explain how it leads to the idea of temperature, and how a thermometer makes use of it. [3]

Zeroth Law: two systems in thermal equilibrium with a third system separately are in thermal equilibrium with each other. It implies that there is a quantity having the same value for all systems in thermal equilibrium with one another; this quantity is temperature, $T_A = T_C$ and $T_B = T_C$ giving $T_A = T_B$. A thermometer is the third system C: when it is in equilibrium with body A its reading equals T_A, and if it gives the same reading in body B, the law guarantees that A and B are in thermal equilibrium, without bringing them into contact.

- statement of the Zeroth Law (1)
- a quantity equal for systems in equilibrium: temperature (1)
- thermometer as the third system (1)

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10. State the Kelvin-Planck and the Clausius statements of the Second Law. A ship's engineer proposes to run the ship's engines by drawing heat from the sea water alone and converting it into work. Which statement forbids this, and why does the First Law not? [3]

Kelvin-Planck: no process is possible whose sole result is the absorption of heat from a reservoir and the complete conversion of the heat into work. Clausius: no process is possible whose sole result is the transfer of heat from a colder object to a hotter object. The proposal uses a single reservoir (the sea) and converts its heat wholly into work, which the Kelvin-Planck statement forbids. Energy would be conserved, so the First Law alone would allow it; the Second Law restricts processes that conservation permits.

- Kelvin-Planck statement (1)
- Clausius statement (1)
- Kelvin-Planck forbids it; energy conserved so First Law silent (1)

11. A gas is taken round the cycle A → B → C → A. In A → B (constant volume) it absorbs 600 J of heat. In B → C (constant pressure) it absorbs 1000 J and does 400 J of work. In C → A it gives out 1350 J of heat. The change in internal energy in C → A is −1200 J. Find (a) the change in internal energy in A → B and in B → C, (b) the work done in C → A, and (c) the net work done by the gas in the cycle. [3]

(a) A → B: no work, $\Delta U = 600$ J. B → C: $\Delta U = 1000 - 400 = 600$ J. (These with −1200 J in C → A add to zero, as they must in a cycle.) (b) C → A: $\Delta W = \Delta Q - \Delta U = -1350 - (-1200) = -150$ J, i.e. 150 J of work is done on the gas. (c) Net work = 0 + 400 − 150 = 250 J, equal to the net heat 600 + 1000 − 1350 = 250 J.

- $\Delta U_{AB} = 600$ J and $\Delta U_{BC} = 600$ J (1)
- $W_{CA} = -150$ J (1)
- net work 250 J, equal to net heat (1)

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