#420153

Topic: Introduction to Thermodynamics

Explain why

(a) Two bodies at different temperatures T_1 and T_2 if brought in thermal contact do not necessarily settle to the mean temperature $(T_1 + T_2)/2$

(b) The coolant in a chemical or a nuclear plant (i.e. the liquid used to prevent the different parts of a plant from getting too hot) should have high specific heat

(c) Air pressure in a car tyre increases during driving

(d) The climate of a harbour town is more temperate than that of a town in a desert at the same latitude

Solution

(a)

Law of conservation of Energy says that the energy is transferred from one body to another and from one format to another.

If we consider ideal conditions for heat transfer, when two bodies of temperature T_1 and T_2 come in thermal contact, heat transfer takes place from body of higher temperature to body of lower temperature.

The quantity thermal energy is the function of mass and temperature. Hence, the mean temperature of the bodies in contact will be given by the weighted average not normal average.

$\therefore T_{avg} = \frac{m_1T_1+m_2T_2}{m_1+m_2}$

Hence only when $m_1 = m_2$, then $T_{avg} = \frac{T_1+T_2}{2}$

(b)

A coolant is required to have high heat capacity so that its temperature does not change much during heat transfer. Due to this, the coolant is able to hold more heat and allow quicker temperature drop in the hot body.

(c)

As the car moves, temperature of the gas inside the tyre increases.

$PV = nRT$

Since volume is almost constant, air pressure increases.

(d)

Water has a very high value of specific heat capacity. Due to this, the temperature of the water bodies do not change easily. Hence, climate near a harbour town is moderate.

Sand has a very low value of specific heat capacity. Due to this, the temperature of the sand changes rapidly. Hence, climate of a desert is extreme.

#420169

Topic: Adiabatic Processes

A cylinder with a movable piston contains 3 moles of hydrogen at standard temperature and pressure. The walls of the cylinder are made of a heat insulator, and the piston is insulated by having a pile of sand on it. By what factor does the pressure of the gas increase if the gas is compressed to half its original volume?

Solution

The cylinder is completely insulated from its surroundings. As a result, no heat is exchanged between the system (cylinder) and its surroundings. Thus, the process is adiabatic

Initial pressure inside the cylinder $= P_1$

Final pressure inside the cylinder $= P_2$

Initial volume inside the cylinder $= V_1$

Final volume inside the cylinder $= V_2$

Ratio of specific heats, $\gamma = \dfrac{C_P}{C_V} = 1.4$

For an adiabatic process, we have:

$P_1V_1^{\gamma} = P_2V_2^{\gamma}$

The final volume is compressed to half of its initial volume.

$\therefore V_2 = V_1/2$

$P_1V_1^{\gamma} = P_2(V_1/2)^{\gamma}$

$P_2/P_1 = V_1^{\gamma}/(V_1/2)^{\gamma}$

$= 2^{1.4} = 2.639$

Hence, the pressure increases by a factor of 2.639.

#420183

Topic: Adiabatic Processes

In changing the state of a gas adiabatically from an equilibrium state A to another equilibrium state B, an amount of work equal to 22.3 J is done on the system. If the gas is taken from state A to B via a process in which the net heat absorbed by the system is 9.35 cal, how much is the net work done by the system in the latter case? (Take 1 cal $=4$ J)

Solution

The work done (W) on the system while the gas changes from state A to state B is 22.3 J.

This is an adiabatic process. Hence, change in heat is zero.

$\therefore \triangle Q=0$

$\triangle W=-22.3\,J$ (Since the work is done on the system)

From the first law of thermodynamics, we have:

$\triangle Q=\triangle U+\triangle W$

Where,

$\triangle U=$ Change in the internal energy of the gas

$\therefore \triangle U=\triangle Q-\triangle W=-(-22.3\,J)$

$\triangle U=+22.3\,J$

When the gas goes from state A to state B via a process, the net heat absorbed by the system is:

$\triangle Q=9.35\,cal=9.35\times 4.19=39.1765\,J$

Heat absorbed, $\triangle Q=\triangle U+\triangle W$

$\therefore W=\triangle Q-\triangle U$

$=39.1765–22.3$

$=16.8765J$

Therefore, 16.88 J of work is done by the system.

#420199

Topic: First Law of Thermodynamics

Two cylinders A and B of equal capacity are connected to each other via a stopcock. A contains a gas at standard temperature and pressure. B is completely evacuated. The entire system is thermally insulated. The stopcock is now opened. Answer the following :

(a) What is the final pressure of the gas in A and B ?

(b) What is the change in internal energy of the gas?

(c) What is the change in the temperature of the gas?

(d) Do the intermediate states of the system (before settling to the final equilibrium state) lie on its P-V-T surface ?

Solution

(a) When the stopcock is suddenly opened, the volume available to the gas at 1 atmospheric pressure will become two times. Therefore, pressure will decrease to one-half, i.e., 0.5 atmosphere.

(b) There will be no change in the internal energy of the gas as no work is done on/by the gas.

(c) Since no work is being done by the gas during the expansion of the gas, the temperature of the gas will not change at all.

(d) No, because the process called free expansion is rapid and cannot be controlled. the intermediate states are non-equilibrium states and do not satisfy the gas equation. In due course, the gas does return to an equilibrium state.

#420204

Topic: Second Law of Thermodynamics

A steam engine delivers 5.4×10^{8} J of work per minute and services 3.6×10^{9} J of heat per minute from its boiler. What is the efficiency of the engine? How much heat is wasted per minute?

Solution

The efficiency is given by

$$\eta=\frac{\text{Work done}}{\text{Energy}}$$

$$\eta=\frac{5.4\times 10^{8}}{3.6\times 10^{9}}=0.15=15\%$$

Energy wasted $=3.6\times 10^{9}-5.4\times 10^{8}=3.06\times 10^{9}J$

#420210

Topic: First Law of Thermodynamics

An electric heater supplies heat to a system at a rate of 100W. If system performs work at a rate of 75 joules per second. At what rate is the internal energy increasing?

Solution

By law of conservation of energy,

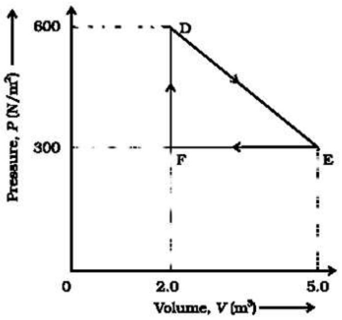
Total energy= Work done + Internal Energy

$100 = 75 + U$=25 J/s

Hence, Internal energy is increasing at the rate of $25\ W$

#420218

Topic: Isobaric, Isochoric, Isothermal Processes



A thermodynamic system is taken from an original state to an intermediate state by the linear process shown in the figure.

Its volume is then reduced to the original value from E to F by an isobaric process. Calculate the total work done by the gas from D to E to F.

Solution

Total work done by the gas from D to E to F = Area of $\triangle DEF$

Area of $\triangle DEF = (1/2) DE \times EF$

Where,

DF = Change in pressure

$= 600 N/m^2 - 300 N/m^2$

$= 300 N/m^2$

FE = Change in volume

$= 5.0 m^3 - 2.0 m^3$

$= 3.0 m^3$

Area of $\triangle DEF = (1/2) \times 300 \times 3 = 450 J$

Therefore, the total work done by the gas from D to E to F is $450 J$.

#420221

Topic: Second Law of Thermodynamics

A refrigerator is to maintain eatables kept inside at $9^o C$. If room temperature is $36^o C$, calculate the coefficient of performance.

Solution

Temperature inside the refrigerator, $T_1 = 9^o C = 282 K$

Room temperature, $T_2 = 36^o C = 309 K$

Coefficient of performance $= T_1 / (T_2 - T_1)$

$= 282/(309 - 282)$

$= 10.44$

Therefore, the coefficient of performance of the given refrigerator is 10.44.