PHYSICS

BOOKS - HC VERMA PHYSICS (HINGLISH)

SPECIFIC HEAT CAPACITIES OF GASES

Examples

1. $0.32g$ of exygen is kept in a rigid container and is heated. Find the amount of heat needed to raise the temperature from $25^{0}C \rightarrow 35^{0}C$. The molar heat capacity of oxygen at constant volume is $20JK^{-1}mol^{-1}$.

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2. A tank of volume $0.2m^{3}$ contains helium gas at a temperature of $300K$ and pressure $1.0 \times 10^{5}Nm^{-2}$. Find the amount of heat required to raise the temperature to $400K$. The molar heat capacity of helium at constant volume is $3.0 cal K^{-1} mol^{-1}$. Neglact any expansion in the volume of tank.

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3. The molar heat capacity of a gas at constant volume is found to be $5 cal mol^{-1} K^{-1}$. Find the ratio $\gamma = \frac{C_p}{C_v}$ for the gas. The gas constant `R=2 cal mol^(-1) K^(-1).

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4. Dry air at $15^0 C$ and 10 atm is suddenly released at atmospheric pressure. Find the final temperature of the air $\left[\frac{C_p}{C_v} = 1.41\right]$.

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5. Calculate the internal energy of $1g$ of oxygen STP.

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Worked Out Examples

1. Calculate the value of mechanical equivalent of heat from the following data. Specific heat capcity of air at constant volume = $170 cal kg^{-1} K^{-1}, \gamma = \frac{C_p}{C_v} = 1.4$ and the density of air at STP is $1.29 kg m^{-3}$. Gas constant $R = 8.3 J K^{-1} mol^{-1}$.

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2. An ideal gas has a molar heat capacity at constant pressure of $Cp = 2.5R$. The gas is kept in a closed vessel of volume $0.0083 m^3$, at a temperature of $300K$ and a pressure of 1.6 xx 10^(6) Nm^(-2). An amount 2.49 xx 10^(4) J of heat energy is supplied to the gas. calculate the final temperature and pressure of the gas.

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3. A sample of ideal gas $(\gamma = 1.4)$ is heated at constant pressure. If $140J$ of heat is supplied to gas, find ΔU and W`.

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4. An experiment is performed to measure the molar heat capacity of a gas at constant pressure using Regnault's method. The gas is initially contained in a cubical reservoir of size $40cm \times 40cm \times 40cm \times at600kPaat27^0C$. A part of the gas is brought out, heated to 100^0C and is passed through a calorimeter at constant pressure. The water equivalent of the calorimeter and its contents increases from $20^0C \rightarrow 30^0C$ during the experiment and the pressure in the reservoir decresases to $525kPa$. Specific heat capacity of water =`4200 J kg^(-1) K^(1). Calculate the molar heat capacity Cp from these data.

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5. A quantity of air is kept in a container having walls which are slightly conducting. The initial temperature and volume are 27^0C (equal to the temperature of the surrounding) and $800cm^3$ respectively. Find the rise in the temperature if the gas is compressed to `200 cm^(3) (a) in a short time (b) in a long time . Take gamma= 1.4.

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6. A sample of gas $(\gamma = 1.5)$ is taken through an adiabatic process in which the volume is compressed from $1600cm^3 \rightarrow 400cm^3$. If the initial pressure is $150kPa$, (a) what is the final pressure and (b) how much work is done by the gas in the process?

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7. Two moles of helium gas (gamma = 5 / 3) are initially at 27^@C and occupy a volume of 20 literes. The gas is first expanded at constant pressure until the volume is doubled. Then it undergoes an adiabatic change until the temperature returns to its initial value. (a) Sketch the process in a p_V diagram. (b) What is the final volume and pressure of the gas ? (c) What is the work done by the gas?

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8. An ideal gas enclosed in a cylindrical container supports a freely moving piston of mass M. The piston and the cylinder have equal cross-sectional area A. When the piston is in equilibrium, the volume of the gas is V_0 and its pressure is P_0. The piston is slightly displaced from the equilibrium position and released. Assuming that the system is completely isolated from its surrounding, the piston executes a simple harmonic motion with frequency

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9. Two vessels of volume (V_1) and (V_2) contain the same ideal gas. The pressures in the vessels are (P_1) and (P_2) and the temperatures are (T_1) and (T_2) respectively . The two vessels are now connected to each other through a narrow tube. Assuming thar no heat is exchanged between the surrounding and the vessels, find the common pressure and temperature attained after the connection.

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10. 4 mol of an ideal gas having $(\gamma = 1.67)$ are mixed with 2 mol of another ideal gas having $(\gamma = 1.4)$. $F \in dthe \equiv a \leq ntvalueof$gamma ` for the mixture.

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11. A diatomic gas $(\gamma = 1.4)$ does 200 J of work when it is expanded isobarically. Find the heat given to the gas in the process.

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12. Calculate the ratio $\left(\frac{C_p}{C_v}\right)$ of oxygen from the following data . Speed of sound in oxygen$\left(=32gmol^{-1}\right)$ and the gas constant $\left(R=8.3JK^{-1}mol^{-1}\right)$.

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Short Answer

1. Does a gas have just two specific heat capacities or more than two ? Is the number of specific heat capacicties of a gas countable?

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2. Can we define specific heat capacity at constant temperature?

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3. Can we define specific heat capacity at constant for an adiabatic process?

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4. Does a solid also have two kinds of molar heat capacities C_p and C_v? If yes , do we have $C_p > C_v$? Is $C_pC_v = R$?

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5. In a real gas the internal energy depends on temperature and also on volume. The energy increases when the gas expands isothermally. Looking into the derivation of $(C_p - C_v = R_1)$ find whether $(C_p - C_v)$ will be more than R, less than R, or equal to R for a real gas.

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6. Can a process on an ideal gas be both adiabatic and isothermal. ?

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7. Show that the slope of $p-V$ diagram is greater for an adiabatic process as compared to an isothermal process.

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8. Is a slow process always isotheramal ? Is a quick process always adiabatic?

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9. Can two states of an ideal gas be connected by an isothermal process as well as an adiabatic process?

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10. The ratio $\left(\frac{C_p}{C_v}\right)$ for a gas is 1.29 . What is the degree of freedom of the molecules of this gas?

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Objective 1

1. Work done by a sample of an ideal gas in a process A is double the work done in another process B. The temperature rises through the same amount in the two processes. If `(C_A and C_B) be the molar heat capacities for the two processes,

A. $C_A = C_B$

B. $C_A < C_B$

C. $C_A > C_B$

D. C_A and C_B cannot be defined.

Answer: C

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2. For a solid with a small expansion coefficient,

A. $C_P - C_V = R$

B. $C_p = C_v$

C. C_p is slightly greater than C_v

D. C_p is slightly less than C_v

Answer: C

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3. The value of $(C_p - C_v)$ is $1.00R$ for a gas sample in state A and is 1.08 R in state B. Let (p_A, p_B)denote the pressures and $(T_A \text{ and } T_B)$ denote the temperatures of the states A and B respectively . Most likely

A. $p_A < p_B$ and $T_A > T_B$

B. $p_A > p_B$ and $T_A < T_B$

C. $p_A = p_B$ and $T_A < T_B$

D. $p_A > p_B$ and $T_A = T_B$

Answer: A

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4. Let (C_v) and (C_p) denote the molar heat capacities of an ideal gas at constant volume and constant pressure respectively . Which of the following is a universal constant?

A. $\frac{C_p}{C_v}$

B. C_pC_v

C. $C_p - C_v$

D. $C_p + C_v$

Answer: C

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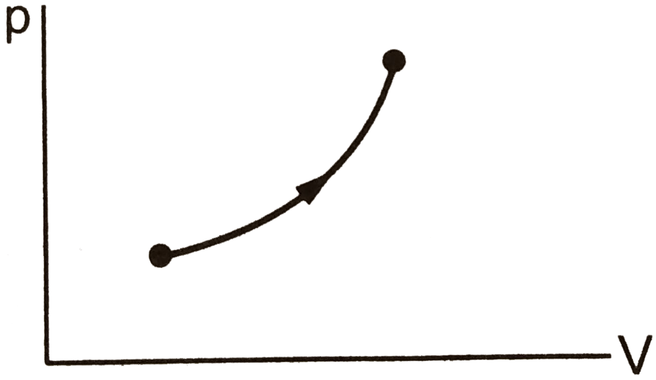
5. 70 calories of heat is required to raise the temperature of 2 mole of an ideal gas at constant pressure from 30^@C to 35^@C . The amount of heat required to raise the temperature of the same gas through the same range at constant volume is



A. 30 calories

B. 50 calories

C. 70 calories

D. 90 calories

Answer: B

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6. Figure shows a process on a gas in which pressure and volume both change. The molar heat capacity for this process is C.

A. $C = 0$

B. $C = C_v$

C. $C > C_v$

D. $C < C_v$

Answer: C

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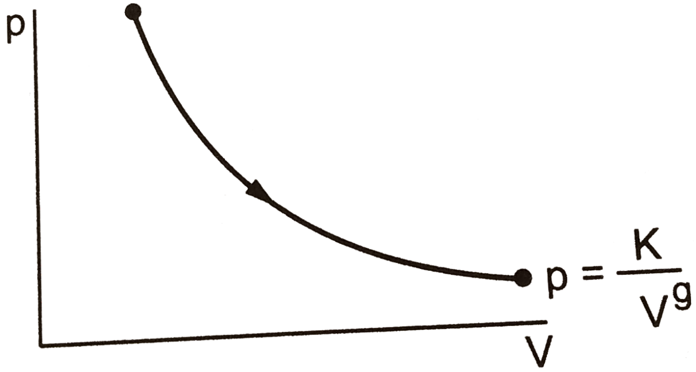
7. The molar heat capacity for the process shown in figure is



A. $C = C_p$

B. $C = C_v$

C. $C > C_v$

D. $C = 0$

Answer: D

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8. In a isothermal process on an ideal gas, the pressure increases by 0.5%

. The volume decreases by about.

A. 0.0025

B. 0.005

C. 0.007

D. 0.01

Answer: B

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9. In an adiabatic process on a gas with $(\gamma = 1.4)$ th pressure is increased by 0.5% . The volume decreases by about

A. $0.36\ \%$

B. $0.5\ \%$

C. $0.7\ \%$

D. $1\ \%$

Answer: A

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10. Two samples A and B are initaially kept in the same state. The sample A is expanded through an adiabatic process and the sample B through an isothermal process. The final volumes of the samples are the same . The final pressures in A and B are p_A and P_B respectively.

A. $P_A > P_B$

B. $P_A = P_B$

C. $P_A < P_B$

D. The relation between P_A and P_B cannot be deduced.

Answer: C

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11. Let T_a and T_b be the final temperatures of the samples A and B respectively in the previous question.

A. $T_a < T_b$

B. $T_a = T_b$

C. $T_a > T_b$

D. The relation between T_a and T_b cannot be deduced.

Answer: A

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12. Let (ΔW_a) and (ΔW_b) be the work done by the system A and B respectively in the previous question.

A. $\Delta W_a > \Delta W_b$

B. $\Delta W_a = \Delta W_b$

C. $\Delta W_a < \Delta W_b$

D. The relation between ΔW_a and ΔW_b cannot be deduced.

Answer: C

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13. The molar heat capacity of oxygen gas at STP is nearly $2.5R$. As the temperature is increased, it gradually increase and approaches $3.5R$. The most appropriate reason for this behaviour is that at high temperatures

A. oyxgen does not behave as an ideal gas

B. oxygen molecules dissociate in atoms

C. the molecules collide more frequently

D. molecular vibrations gradually become effective.

Answer: A

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Objective 2

1. A gas kept in a container of finite conductivity is suddenly compressed . The process

A. must be very nearly adiabatic

B. must be very nearly isothermal

C. may be very nearly adiabatic

D. may be very nearly isothermal

Answer: C::D

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2. Let Q and W denote the amount of heat given to an ideal gas the work done by it in an isothermal process.

A. $Q = 0$

B. $W = 0$

C. $Q \neq W$

D. $Q = W$

Answer: D

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3. Let Q and W denote the amount of heat given to an ideal gas the work done by it in an adiabatic process.

A. $Q = 0$

B. $W = 0$

C. $Q = W$

D. $Q \neq W$

Answer: A::D

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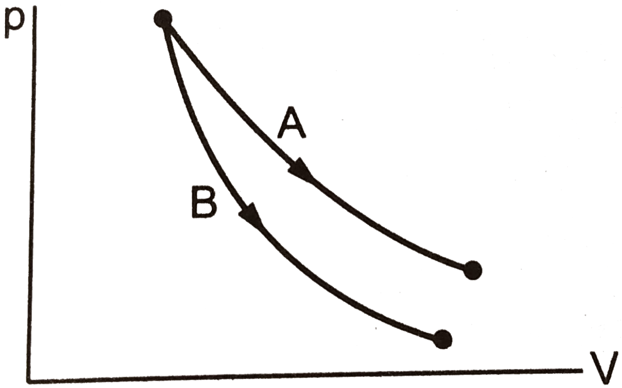
4. Consider the processes A and B shown in Figure (27- Q3) It is possible that (fig.)



A. both the processes are isothermal

B. both the processes are adiabatic

C. A is isothermal and B is adiabatic.

D. A is adiabatic and B is isothermal.

Answer: C

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5. Three identical adiabatic containers A, B and C Contain helium, neon and oxygen respectively at equal pressure. The gases are pushed to half their origianl volumes.

A. The final temperatures in the three containers will be the same

B. The final pressures in the three containers will be the same

C. The pressures of helium and neon will be the same but that of oxygen will be different

D. The temperatures of helium and neon will be the same but that of oxygen will be different

Answer: C::D

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6. A rigid container of negligible heat capacity contains one mole of an ideal gas. The temperatures of the gas increases by $1^{\circ}C$ if 3.0 cal of heat is added to it. The gas may be

A. helium

B. argon

C. oxygen

D. carbon dioxide

Answer: A::B

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7. Four cylinders contain equal number of moles of argon, hydrogen, nitrogen and carbon dioxide at the same temperature. The energy is minimum in

A. argon

B. hydrogen

C. nitrogen

D. carbon dioxide

Answer: A

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Exercises

1. A vessel containing one of mole of a monatomic ideal gas $(mo \le c\underline{a}rweight = 20gmol\hat{}(1))$ is moving on a floor at a speed of $50ms^{-1}$ The vessel is stopped suddenly. Assuming that the mechanical energy lost has gone into the internal energy of the gas , find the rise in its temperature .

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2. $5g$ of a gas is contained in a rigid container and is heated from $15^{\circ}C \rightarrow 25^{\circ}C$. Specific heat capacity of the gas at constant volume is

$0.172calg^{-1}$ ^ $\circ C^{-1}$ and the mechanical equivalent of heat is 4.2 J cal .

Calculate the change in the internal energy of the gas.

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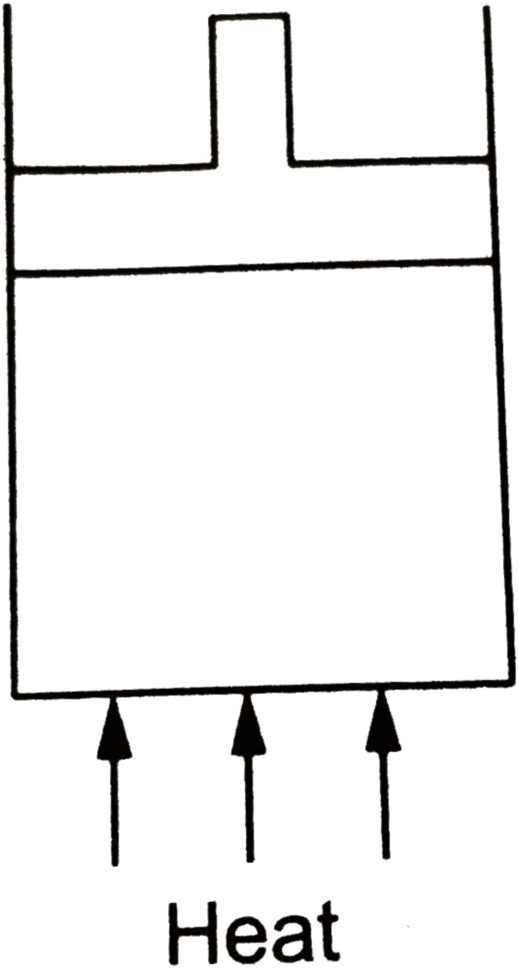
3. Figure shows a cylindrical container containing oxyegn $(\gamma = 1.4)$ and closed by a 50 kg frictionless piston. The area of cross section is $100cm(2)$, atmospheric pressure is $100kPa$+E2 and g is 10 m s^(-2)`. The cylinder is slowly heated for some time. Find the amount of heat supplied to gas if the piston moves out through a distsnce of 20 cm.



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4. The specific heat capacities of hydrogen at constant volume and at constant pressure are $2.4calg^{-1}\hat{}\circ C^{-1}$ and $3.4calg^{-1}\hat{}\circ C$ respectively. The molecular weight of hydrogen is $2gmol^{-1}$ and the gas constant $R = 8.3 \times 10^7 erg^{\circ}Cmol^{-1}$. Calculate the value of J.

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5. The ratio of the molar heat capacities of an ideal gas is $\left(\frac{C_p}{C_v}\frac{7}{6}\right)$. Calculate the change in internal energy of 1.0mole of the gas when its temperature is raised by $50k(a)$ keeping the pressure constant , (b) keeping the volume constant and (c) adiabatically.

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6. A sample of air weighing $1.18g$ occupies $1.0 \times 10^3 cm^3$ when kept at $300K$ and 1.0×10^5 pa. When $2.0cal$ of heat is added to it constant volume, its temperature increases by $1^{\circ}C$. Calculate the amount if heat needed to increases the temperature of air by $1^{\circ}C$ at constant pressure if the mechanical equivalent of heat si 4.2×10^{-1} . Assume that air behaves as an ideal gas.

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7. An ideal gas expands from $100cm^3 \rightarrow 200cm^3$ at a constant pressure of 2.0×10^5 when $50J$ of heat is supplied to it. Calculate (a) the change in internal energy of the gas , (b) the number of moles in the gas if the initial temperature is 300K , (C) the molar heat capacity C_P at constant pressure and (d) the molar heat capacity C_v at constant volume

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8. An amount of heat is added to a monatomic ideal gas in a process in which the gas performs work $\frac{Q}{2}$ on its surrounding. Find the molar heat capacity for the process.

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9. An ideal gas is taken through a process in which the pressure and the volume are changed according to the equation $p = kv$. Show that the molar heat capacity of the gas for the process is given by $\left(C = C_v + \frac{R}{2}\right.$

.

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10. An ideal gas $\left(\frac{C_p}{C_v} = \gamma\right)$ is taken through a process in which the pressure and volume vary as $(p = aV^b$. Find the value of b for which the specific heat capacity in the process is zero.

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11. Two ideal gases have same value of $\left(\frac{C_p}{C_v} = \gamma\right)$. What will be the value of this ratio for a mixture of the two gases in the ratio $(1:2)$?

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12. A mixture contains 1 mole of helium $(c_p = 2.5R, C_v 1.5R.)$ and 1mole of hydrogen $(C_p = 3.5R, C_v = 2.5R,)$. Calculate the values of C_p, C_v and γ for the mixture.

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13. Half mole of an ideal gas $\left(\gamma = \frac{5}{3}\right) istakenthroughthecyc \le abcdaasshown \in figure. Take$(R = 25/3 JK^(-1) mol^(-1))

$. (a)F \in dthetemperatureofthegas \in thestaesa, b, c$ and $d. (b)F \in dthe$

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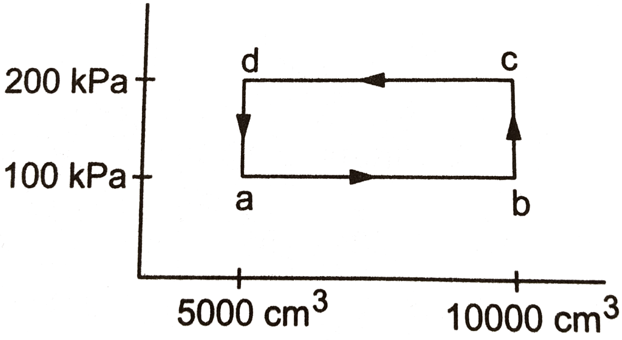

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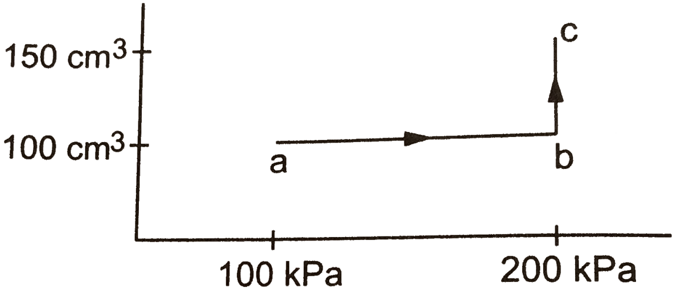
14. An ideal gas $(\gamma = 1.67)$ is taken through the process abc shown in figure . The temperature at the point a is $300k$. Calculate (a) the temperature at b and c, (b) the work done in the process, (c) the amount of heat supplied in the path ab and in the path bc and (d) the change in the internal energy of the gas in the process.



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15. In Joly's differential steam calorimeter, $3g$ of an ideal gas is ccontained in a rigid closed sphere at $20^{\circ} C$. The sphere is heated by steam at $100^{\circ} C$ and it is found that an extra $0.095g$ of steam has condensed into water as the temperature of the gas becomes constant. Calculate the specific heat capacity of the gas in $(Jg^{-1}K^{-1}$. The latent heat of vaporization of $water = 540calg^{-1}$.

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16. The volume of an ideal gas $(\gamma 1.5)$ is changed adiabatically from 4.00 liters to 3.00 liters . Find the ratio of (a) the final pressure to the initial pressure and (b) the final temperature to the initial temperature.

A.

B.

C.

D.

Answer:

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17. An ideal gas at pressure2.5×10^5 pa and temperture $300k$ occupies 100. It is adiabatically compressed to half its original volume. Calculate (a) the final pressure, (b) the final temperature and (c) the work done by the gas in the peocess. Take $(\gamma = 1.5)$.

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18. Air $(\gamma = 1.4)$ is pumped at 20atm pressure in a motor tyre at $20^{\circ} C$. If the tyre suddenly bursts, what would be the temperature of the air coming out of the tyre. Neglect any mixing with the atmoshpheric air.

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19. A gas is enclosed in a cylindrical can fitted with a piston. The walls of the can and the piston are adiabatic. The initial pressure , volume and temperture of the gas are $100 kpa, 400 cm^3$ and $300 k$ respectively. The ratio of the specific heat capacities of the gas is $\left(\frac{C_p}{C_v} = 1.5\right)$ Find the pressure and the temperature of the gas if it is (a) suddenly compressed (b) slowly compressed to 100 cm^(3).

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20. The initial pressure and volume of a given mass of a gas $\left(\frac{C_p}{C_v}=\gamma\right)$ are

(p_0) and $(V_0). Thegascanexchan \geq heatwithsurround \in g. (a)Itisslowl$

(V_0 / 2) and $thensuddenlycompressed \rightarrow$ (V_0 /4)

$. F \in dthef \in alpressure. (b)Ifthegasissuddenlyc \pm pressedomthevolu$

(V_0 to V_0 / 2) and $thenslowlycompressed \rightarrow$ (V_0 / 4)`, What will be the final pressure?.

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21. Conider a given sample of an ideal gas $\left(\frac{C_p}{C_v}=\gamma\right)$ having initial pressure (p_0) and $volume(V_0)$. (a) The gas is isothermally taken to a pressure $\left(\frac{P_0}{2}\right)$ and from there adiabatically ta a pressure $\left(\frac{p_0}{2}\right)$ and $omthereisothermally \rightarrow apressure$(p_0 / 4)` . find the volume.

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22. A given sample of an ideal gas $(\gamma = 1.5)$ is compressed adiabatically from a volume of $150cm^3$ to $50cm^3$. The initial pressure and the initial temperature are $150kpa$ and $300K$. Find (a) the number of moles of the gas in the sample, (b) the molar heat capacity at constant volume, (c) the final pressure and temperature, (d) the work done by the gas in the process and (e) the change in internal energy of the gas .

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23. Three samples A, B and C of the same gas $(\gamma = 1.5)$ have equal volumes and temperatures. The volume of each sample is doubled, the process being isothermal for A, adiabtic for B and isobaric for C. If the final pressures are equal for the three samples, Find the ratio of the initial pressures.

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24. Two samples A and B of the same gas have equal volumes and pressures . The gas is sample A is expanded isothermally to double its volume and the the gas in B is expanded adibatically to double its volume . If the work done by the gas is the same for the two cases, show that gamma satisfies the equation $(1 - 2^{1-\gamma} = (\gamma - 1)1n2$.

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25. 1 liter of an ideal gas $(\gamma = 1.5)$ at $300k$ is suddenly compressed to half its original volume. (a) Find the ratio of the final pressure to the initial pressure. (b) If the original pressure is $100kpa$, find the work done by the gas in the process. (c) What is the change in internal energy? (d) What is the final temperature? (e) the gas is now colled to $300k$ keeping its pressure constant. Calculate the work done during the process . (f) The gas is now expanded iasothermally to achive its original volume of 1 liters. Calculate the work done by the gas .(g) Calculate the total work done in the cycle.

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26. Figure shows a cylindridcal tube with a adibatic walls and fitted with an adiabatic separtor. The separator can be slid into the tube by an external mechanism. An ideal gas$(\gamma = 1.5)$ is injected in the two sides at equal pressures and temperatures . The separator remains in equilibrium at the middel. It is now slid to a position where it divides the tube in the ratio 1:3 Find the ratio of the tempertures in the two parts of the vessel.

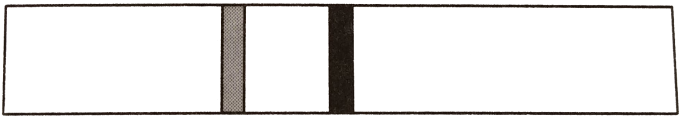

Figure 27-E4

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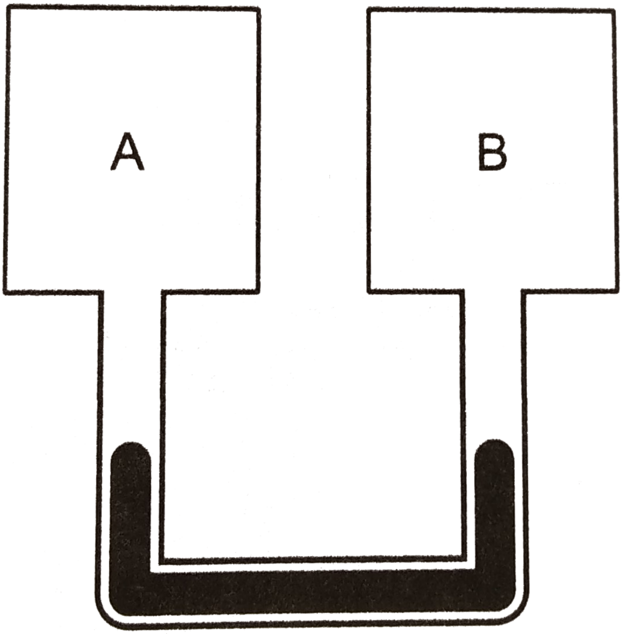
27. Figure shows two rigid vessels A and B, each of volume $200cm^3$ containg an ideal gas $\left(C_v = 12.5JK^{-1}mol^{-1}\right)$. The vessels are connected to a manometer tube containing mercury. The pressure in both the vessels is 75 cm mercury and the temperature is 300k. (a) $(5-0J)$ of heat is supplied to the gas in the vessels.(b) $(10J)$ to the gas in the vessels B. Assuming no appreciable transfer of heat from A to B calculate the dufference in the heights of mercury in the two sides of the manometer. Gas constant $\left(R = 8.3JK^{-1}mol^{-1}\right)$



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28. Figure shows two vessels with adiabatic walls, one containing 0.1 g of helium $\left(\gamma = 1.67, M = 4gmol^{-1}\right)$ and the other containing some amount of hydrogen $\left(\gamma = 1.4, M = 2gmol^{-1}\right)$. Initially , the temperatures of the two gases are equal. The gases electrically heated for some time during which equal amounts of heat are given to the gases. It is found that the temperatures rise through the same amount in the two vessels. Calculate the mass of hydrogen.

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29. Two vessels A and B of equal volume (V_0) are connected by a narrow tube which can be closed by a value. The vessels are fitted with piston which can be moved to change the volumes. Initially, the valve is open and the vessels contain an ideal gas $\left(\frac{C_p}{C_v}=\gamma\right)$ at atomspheric pressures (P_0) and atmoshpeheric temperature (T_0). The walls of the vessels A are diathermic and those of B are adiabatic. The value is now closed and the pistons are slowly pulled out to increase the volumes of the of the vessels to dobuled the original value.(a) Find the temperatures and pressures in the two vessels. (b) The value is now opened for sufficeint time so that the gases acquire a common tempertures and pressures . Find the new values of the temperatuere and the pressures.

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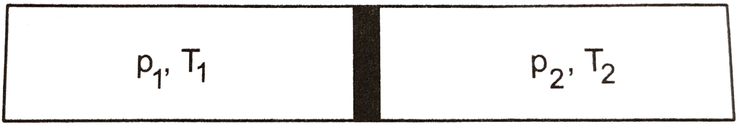
30. Figure shows an adiabatic cylindrical tube of volume (V_0) divided in two parts by a frictionless adibatic separator . Initially, the separator is kept in the middle, an ideal gas at pressure (p_1) and the temperatures (T_1) is injected into the left part and the another ideal gas at pressures (P_2) and temperature (T_2) is injected into the right part. $\left(\frac{C_p}{C_v}=\gamma\right)$ is the same for both the gases. The separator is slid slowly and is released at a position where it can stay in equilibrium. Find (a) the volumes of the parts, (b) the heat given to the gas in the left part and (c) the final common pressure of the gases.



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31. An adibatic cylindrical tube of cross-sectional area $1cm^2$ is closed at one end fitted with a piston at the other end. The tube contains $0.03g$ of an ideal gas . At 1 atm pressure and at the temperture of the surrounding, the length of the gas column. The pressure of the gas falls to $0.355atm$. Find th speed of sound in the gas at atmospheric temperture.

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32. The speed of sound in hydrogen at $0^\circ c$ is $1280ms^{-1}$. The density of hydrogen at STP is $0.089kgm^{-3}$. Calculate the molar heat capacities $(C_p \text{ and } C_v)$ of hydrogen.

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33. $4.0gofheliumou\pi es22400cm^3$ at STP. The specific heat capacity of helium at constant pressure is $\left(5.0calK^{-1}mol^{-1}\right)$. Calculate the speed of sound in helium at STP.

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34. An ideal gas having density $1.7 \times 10^{-3} gcm^{-3} atapreesure$ 1.5 xx

10^(5)

$paisafil \leq dKundttube. Whenthegasisreso \cap atedata\mathfrak{e}quencyof3.0kHz,$

(C_p and C_v)` of the gas.

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35. Standing waves of frequency $5.0kHz$ are produced in a tube filled with oxygen at $300k$. The separation between the consecutive nodes is $3.3cm$. Calculate the specific heat capacities $(C_p \text{ and } C_v)$ of the gas.

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