Q1: The given diagram shows four processes i.e., isochoric, isobaric, isothermal and adiabatic. The correct assignment of the processes, in the same order, is given by


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(a) dacb
(b) dabc
(c) adbc

## Solution

In an isochoric process, volume remains constant while in the isobaric process, pressure remains the same. The slope of an isothermal process is given as ( $-\mathrm{P} / \mathrm{V}$ ) while for an adiabatic process, the slope of the $\mathrm{P}-\mathrm{V}$ curve is $(-\gamma \mathrm{P} / \mathrm{V})$, where $\gamma>1$. The adiabatic curve is steeper than the isothermal curve.

Answer: (b) d a b c
Q2: The ratio of work done by an ideal monoatomic gas to the heat supplied to it in an isobaric process is
(a) $2 / 5$
(b) $3 / 2$
(c) $3 / 5$
(d) $2 / 3$

Solution

For an ideal gas in an isobaric process,
Heat supplied, $\mathrm{Q}=\mathrm{nCp} \Delta \mathrm{T}$
Work done, $\mathrm{W}=\mathrm{P} \Delta \mathrm{V}=\mathrm{nR} \Delta \mathrm{T}$
Required Ratio $=W / \mathrm{Q}$
Required Ratio $=(n R \Delta T) /(n C p \Delta T)$
$\mathrm{R} / \mathrm{Cp}=\mathrm{R} /(\gamma \mathrm{R} / \gamma-1)$ [since $\gamma=5 / 3$, for a monoatomic gas]
$=2 / 5$
Answer: (a) 2/5
Q3: The work of 146 kJ is performed in order to compress one-kilo mole of gas adiabatically and in this process the temperature of the gas increases by $7^{\circ} \mathrm{C}$. The gas is $\left(\mathrm{R}=8.3 \mathrm{~J} \mathrm{~mol}^{-1} \mathrm{~K}^{-1}\right)$
(a) monoatomic
(b) diatomic
(c) triatomic
(d) a mixture of monoatomic and diatomic

Solution
Increase in temperature, $\Delta \mathrm{T}=\mathrm{T}_{2}-\mathrm{T}_{1}=7 \mathrm{~K}$
(Since it is change in temperature so its value will be same in Kelvin and degree celsius)
Work done on the system, $\mathrm{W}=146 \mathrm{KJ}=146 \times 1000 \mathrm{~J}$
Number of moles of gas, $\mathrm{n}=1000$
Work done in an adiabatic process, $\mathrm{W}=\mathrm{nR}(\mathrm{T} 2-\mathrm{T} 1) / \gamma-1$
put the values,
$146000=1000 \times 8.3 \times 7 /(\gamma-1)$
$\gamma-1=0.39$
$\gamma \approx 1.4$
Hence the gas is diatomic
Answer: (b) diatomic
Q4: Two moles of an ideal monatomic gas occupies a volume V at $27^{\circ} \mathrm{C}$. The gas expands adiabatically to a
volume 2 V . Calculate (i) the final temperature of the gas and (ii) change in its internal energy.
(a) (i) 198 K (ii) 2.7 kJ
(b) (i) 195 K (ii) 2.7 kJ
(c) (i) 189 K (ii) 2.7 kJ
(d) (i) 195 K (ii) 2.7 kJ

## Solution

For an adiabatic process, $\mathrm{PV}^{\gamma}=$ constant
(nRT/V)V $\gamma=$ constant or $\mathrm{TV}^{\gamma-1}=$ constant
$\mathrm{T}_{1} \mathrm{~V}_{1}^{\gamma-1}=\mathrm{T}_{2} \mathrm{~V}_{2}^{\gamma-1}$
$\mathrm{T}_{2}=\mathrm{T}_{1}\left[\mathrm{~V}_{1} / \mathrm{V}_{2}\right] \gamma-1$
Here, $\mathrm{T}_{1}=27^{\circ} \mathrm{C}=300 \mathrm{~K}, \mathrm{~V}_{1}=\mathrm{V}, \mathrm{V}_{2}=2 \mathrm{~V}, \gamma=5 / 3$
$\mathrm{T}_{2}=300(\mathrm{~V} / 2 \mathrm{~V})(5 / 3-1)=300(1 / 2) 2 / 3=189 \mathrm{~K}$
Change in internal energy, $\Delta \mathrm{U}=\mathrm{nCV} \Delta \mathrm{T}$
$\Delta \mathrm{U}=\mathrm{n}[(\mathrm{f} / 2) \mathrm{R}](\mathrm{T} 2-\mathrm{T} 1)=2 \times(3 / 2) \times(25 / 3)(189-300)$
$\Delta \mathrm{U}=-2.7 \mathrm{~kJ}$
Answer: (c) (i) 189 K (ii) 2.7 kJ
Q5: A wooden wheel of radius R is made of two semicircular parts (see figure). The two parts are held together by a ring made of a metal strip of cross-sectional area $S$ and Length $L$. $L$ is slightly less than $2 \pi R$. To fit the ring on the wheel, it is heated so that its temperature rises by $\Delta \mathrm{T}$ and it just steps over the wheel. As it cools down to the surrounding temperature, it presses the semicircular parts together. If the coefficient of linear expansion of the metal is $\alpha$, and it's Young's modulus is Y , the force that one part of the wheel applies on the other part is

(a) $2 \mathrm{SY} \alpha \Delta \mathrm{T}$
(b) $2 \pi S Y \alpha \Delta T$
(c) $\mathrm{SY} \alpha \Delta \mathrm{T}$
(d) $\pi S Y \alpha \Delta T$

Solution
Radius $=\mathrm{R}$
Cross -sectional area $=\mathrm{S}$
Length $=$ L
$\mathrm{Y}=$ Young's modulus
$\alpha=$ coefficient of thermal expansion
$\mathrm{Y}=$ Stress $/$ Strain $=\mathrm{FL} / \mathrm{A} \Delta \mathrm{L}$ - (1)
Strain, $\Delta \mathrm{L} / \mathrm{L}=\alpha \Delta \mathrm{T}$

Putting the values in equa (1)
$Y=F / S \alpha \Delta T$
$F=S Y \alpha \Delta T$
Answer: (c) $\mathrm{SY} \alpha \Delta \mathrm{T}$
Q6: The pressure that has to be applied to the ends of a steel wire of length 10 cm to keep its length constant when its temperature is raised by 1000 C is
(For steel Young's modulus is $2 \times 10^{11} \mathrm{Nm}^{-2}$ and coefficient of thermal expansion is $1.1 \times 10^{-5} \mathrm{~K}^{-1}$ )
(a) $2.2 \times 10^{7} \mathrm{~Pa}$
(b) $2.2 \times 10^{6} \mathrm{~Pa}$
(c) $2.2 \times 10^{8} \mathrm{~Pa}$
(d) $2.2 \times 10^{9} \mathrm{~Pa}$

Solution
Given, $\Delta \mathrm{T}=100^{\circ} \mathrm{C}, \mathrm{Y}=2 \times 10^{11} \mathrm{~N} \mathrm{~m}^{-2}$
$\alpha=1.1 \times 10^{-5} \mathrm{~K}^{-1}$
Young's modulus, $\mathrm{Y}=$ stress/strain $=(\mathrm{F} / \mathrm{A}) /(\Delta \mathrm{L} / \mathrm{L})$
Therefore, $\mathrm{Y}=\mathrm{P} /(\Delta \mathrm{L} / \mathrm{L})$
$\mathrm{Y}=\mathrm{P} / \alpha \Delta \mathrm{T}[$ since $\Delta \mathrm{L}=\mathrm{L} \alpha \Delta \mathrm{T}]$
Thermal stress in a rod is the pressure due to the thermal strain.
Required pressure $\mathrm{P}=\mathrm{Y} \alpha \Delta \mathrm{T}=2 \times 10^{11} \times 1.1 \times 10^{-5} \times 100=2.2 \times 10^{8} \mathrm{~Pa}$
Answer: (c) $2.2 \times 10^{8} \mathrm{~Pa}$
Q7: Two wires are made of the same material and have the same volume. However, wire 1 has cross-sectional area $A$ and wire 2 has cross-sectional area 3A. If the length of wire 1 increases by $\Delta x$ on applying force $F$, how much force is needed to stretch wire 2 by the same amount?
(a) 6 F
(b) 9 F
(c) F
(d) 4 F

## Solution

For the same material, Young's modulus is the same and it is given that the volume is the same and the area of the cross-section for the wire 11 is A and that of 12 is 3 A .
$\mathrm{V}=\mathrm{V}_{1}=\mathrm{V}_{2}$
$\mathrm{V}=\mathrm{A} \times 1_{1}=3 \mathrm{~A} \times 1_{2}$
$1_{2}=1_{1} / 3$
$\mathrm{Y}=(\mathrm{F} / \mathrm{A}) /(\Delta \mathrm{l} / \mathrm{l}) \Rightarrow \mathrm{F}_{1}=\mathrm{YA}\left(\Delta \mathrm{l}_{1} / \mathrm{l}_{1}\right)$
$\mathrm{F}_{2}=\mathrm{Y} 3 \mathrm{~A}\left(\Delta \mathrm{l}_{2} / \mathrm{l}_{2}\right)$
Given $\Delta \mathrm{l}_{1}=\Delta \mathrm{l}_{2}=\Delta \mathrm{x}$ (for the same extension)
$\mathrm{F}_{2}=\mathrm{Y} 3 \mathrm{~A}\left(\Delta \mathrm{x} / 1_{1} / 3\right)=9\left(\mathrm{YA} \Delta \mathrm{x} / 1_{1}\right)=9 \mathrm{~F}_{1}$ or 9 F
Answer: (d) 9F
Q8: A uniform cylindrical rod of length $L$ and radius $r$, is made from a material whose Young's modulus of elasticity equals Y . When this rod is heated by temperature T and simultaneously subjected to a net longitudinal compressional force F , its length remains unchanged. The coefficient of volume expansion, of the material of the rod, is (nearly) equal to
(a) $9 \mathrm{~F} /\left(\pi \mathrm{r}{ }^{2} \mathrm{YT}\right)$
(b) $\mathrm{F} /\left(3 \pi \mathrm{r}^{2} Y \mathrm{Y}\right)$
(c) $6 \mathrm{~F} /\left(\pi \mathrm{r}^{2} \mathrm{YT}\right)$
(d) $3 \mathrm{~F} /\left(\pi \mathrm{r}^{2} \mathrm{YT}\right)$

Solution
Given, Length $=$ L
Longitudinal force $=F$
Radius $=r$
Young's modulus $=\mathrm{Y}$
Temperature $=\mathrm{T}$
Since length remains same
$($ Stress $)$ Compressive $=($ Stress $)$ Thermal
$\mathrm{F} / \mathrm{A}=\mathrm{Y} \alpha \mathrm{T} \Rightarrow \mathrm{F} / \pi \mathrm{r}^{2}=\mathrm{Y} \alpha \mathrm{T}$ (where $\alpha=$ coeficient of linear expansion)
$\alpha=\mathrm{F} / \pi \mathrm{r} 2 \mathrm{YT}$
Coefficient of volume expansion, $\gamma=3 \alpha$
$\gamma=3 \mathrm{~F} / \pi \mathrm{r}^{2} \mathrm{YT}[$
Answer: (d) $3 \mathrm{~F} / \pi \mathrm{r}^{2} \mathrm{YT}$
Q 9: During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its absolute temperature. The ratio $\mathrm{C}_{\mathrm{P}} / \mathrm{C}_{\mathrm{V}}$ for the gas is
(a) $4 / 3$
(b) 2
(c) $5 / 3$
(d) $3 / 2$

Solution
In an adiabatic process, $\mathrm{T} \gamma=($ constant $) \mathrm{P} \gamma-1$
$\mathrm{T} \gamma / \gamma-1=($ constant $) \mathrm{P}$
Given $\mathrm{T}_{3}=($ constant $) \mathrm{P}$
$\gamma / \gamma-1=3 \Rightarrow 3 \gamma-3=\gamma \Rightarrow \gamma=3 / 2$
Answer: (d) 3/2
Q10: An external pressure P is applied on a cube at $0^{\circ} \mathrm{C}$ so that it is equally compressed from all sides. K is the bulk modulus of the material of the cube and is its coefficient of linear expansion. Suppose we want to bring the cube to its original size by heating. The temperature should be raised by
(a) $3 / \mathrm{PaK}$
(b) $\mathrm{P} / 3 \alpha \mathrm{~K}$
(c) $3 \alpha / \mathrm{PK}$
(d) $3 \mathrm{PK} \alpha$

## Solution

The bulk modulus of the gas is given by $\mathrm{K}=-\mathrm{P} /(\Delta \mathrm{V} / \mathrm{V} 0)$
(Here negative sign indicates the decrease in volume with pressure)
$\Delta \mathrm{V} / \mathrm{V}_{0}=\mathrm{P} / \mathrm{K}$ [in magnitude $] \ldots .$. (1)
Also, $\mathrm{V}=\mathrm{V}_{0}(1+\gamma \Delta \mathrm{T})$ or $\Delta \mathrm{V} / \mathrm{V}_{0}=\gamma \Delta \mathrm{T} \ldots \ldots$ (2)
Comparing eq. (1) and (2), we get $\mathrm{P} / \mathrm{K}=\gamma \Delta \mathrm{T}$
$\Delta \mathrm{T}=\mathrm{P} / 3 \alpha \mathrm{~K}($ since $\gamma=3 \alpha)$
Answer: (b) P/3aK

Q11: Steel wire of length ' $L$ ' at $40^{\circ} \mathrm{C}$ is suspended from the ceiling and then a mass " $m$ " is hung from its free end. The wire is cooled down from $40^{\circ} \mathrm{C}$ to $30^{\circ} \mathrm{C}$ to regain its original length "L". The coefficient of linear thermal expansion of the steel is $10^{-5} /{ }^{\circ} \mathrm{C}$, Young's modulus of steel is $10^{11} \mathrm{~N} / \mathrm{m}^{2}$ and radius of the wire is 1 mm . Assume that $\mathrm{L} \gg$ diameter of the wire. Then the value of " m " in kg is nearly

Solution
$\mathrm{E}=(\mathrm{F} / \mathrm{A}) /(\Delta \mathrm{L} / \mathrm{L})$
$=(\mathrm{F} \times \mathrm{L}) /(\mathrm{A} \times \Delta \mathrm{L})$
$\Rightarrow(\Delta \mathrm{L} / \mathrm{L})=\mathrm{F} / \mathrm{AE}$

Since, $(\Delta L / L)=\alpha \Delta t$
$\alpha \Delta t=F / A E$
$\alpha \Delta t=m g / A E$
$\mathrm{m}=[(\alpha \Delta \mathrm{t}) / \mathrm{g}] \mathrm{AE}$
$\mathrm{m}=3.14 \simeq 3$

Answer: 3

Q12: A diatomic gas with rigid molecules does 10 J of work when expanded at constant pressure. What would be the heat energy absorbed by the gas, in this process?
(a) 25 J
(b) 35 J
(c) 30 J
(d) 40 J

Solution
The value of Cp for a diatomic gas is
$\mathrm{Cp}=(7 / 2) \mathrm{R}-(1)$
It is given that work done during expansion at constant pressure is $\mathrm{dW}=10 \mathrm{~J}=\mathrm{nR} \Delta \mathrm{T}$
Since the gas undergoes an isobaric process
$\Rightarrow \Delta \mathrm{Q}=\mathrm{n}(7 / 2) \mathrm{R} \Delta \mathrm{T}=7 / 2(\mathrm{nR} \Delta \mathrm{T})=(7 / 2)(10)=35 \mathrm{~J}$
Answer:(b) 35 J

