HEAT AND THERMODYNAMICS

SYNOPSIS

GAS LAWS:

Charle’s law:

$V \alpha T$ at constant pressure

$V_1/T_1 = V_2/T_2$

Boyle’s Law:

$V \alpha 1/p$ at constant temperature

$V_1P_1 = V_2P_2$

Gay Lussac’s law :

$P \alpha T$ at constant volume

$P_1/T_1 = P_2/T_2$

Volume coefficient of a gas :

$\alpha = V\text{-}V_o/V_o t$ the ratio between rate of change in volume of a gas to volume at 0^0C

Pressure coefficient of a gas :

$\beta = P\text{-}P_0/P_0 t$ The ratio between rate of change in pressure of a gas to pressure at 0^0C

Perfect gas equation: $PV = nRT$ where n is the number of moles and R is universal gas constant

Conversion formula for one scale of temperature to another.

C-0/100 =F-32/180 =K-273/100

Isothermal change: The process in which the temperature of the system is remains constant

du=0 increase in the internal energy is zero

Adiabatic change: The process in which neither heat is added to or removed from the system

dQ=0 under adiabatic change

PV^{v} = constant where v =Cp/Cv and TV^{v-1} =constant

Isochoric change: The process in which the volume of a gas is remains constant.

dw=0 work done on the or by the gas is zero

Isobaric change: The process in which the pressure of the gas is remains constant

Here dQ =du +dw

Sign conventions :

Heat supplied to the system dQ= +ve

Heat removed from the system dQ= -ve

Work done by the system dW =+ve

Work done on the system dW =-ve

Van der Waal's equation: for real gas

$(P+a/V^2)(V-b) = RT$ where a and b are constants

Specific heat capacity of substance:

If dQ is the heat supplied to or removed from the system to increase its temperature or decrease by $d\theta$ then **$dQ = mc\,(d\theta)$**

where m is the mass of a substance and c is the specific heat of a substance

For molar specific heats of gases we can write

$C=1/n\ (dQ/d\theta)$ where n is the number of moles

And $n=m/M$ where M is the molecular mass and m is the mass of a gas

therefore **$C= M/m\ (dQ/d\theta)$ J/mole-K**

Mayer's equation: $C_P - C_V = R$ where R is the universal gas constant its value equals to 8.31 J/mole-K

The ratio of specific heat capacities in terms of degrees of freedom.

$V = 1+2/n$ where n is the number of degrees of freedom n=3 for mono atomic gas n=5 for diatomic and n=6 for tri and polyatomic molecules

Law of equipartition of energy:

Energy associated with for n degrees of freedom per molecule is given by **n/2 kT** where k is the Boltzmann's constant and T is the temperature

For one mole of a gas, Energy = **n/2 kT N = n/2 RT where R=kN** Here N is the Avagadro’s number

Principle of calorimetry:

Heat lost by the hot body =sum of heat gained by cold bodies

Thermal conductivity:

At steady state , the rate of heat transfers from one face of the slab to another face is given by

dQ/dt = H =KA dT/L where A is the area and L is the length of the slab and K is the thermal conductivity

dQ/dt = KA dT/L implies dQ/dt = dT/(L /KA)

= dT/R where (R= L /KA) called thermal resistance

Newton's law of cooling: If the body temperature is decreases from θ_1 to θ_2 and surrounding temperature is θ_o then according to Newton's law of cooling

$$\theta_1 - \theta_2 /t = K \{(\theta_1 + \theta_2 /2) - \theta_o \}$$

Kirchhoff's Law: for given temperature and for given wavelength for any surface the ratio between emissive power to absorptive power is always constant and is equal to emissive power of perfectly black body

$e_\lambda / a_\lambda = E_\lambda$ emissive power of perfectly black body

Wien's displacement law: λ_{max} T=constant

where λ_{max} is the wavelength at maximum intensity and T is the temperature

I law of thermodynamics

$$dQ=dU+dW$$

Equivalent molar mass :when n_1 moles of a gas with molar mass M_1 are mixed with n_2 moles of a gas with molar mass M_2, then equivalent molar mass of a mixture is

$$M_{mix} = n_1M_1+n_2M_2/n_1+n_2$$

$$(C_V)mix = n_1 (C_{V1}) +n_2 (C_{V2}) /n_1+n_2$$

$$(C_p)mix = n_1 (C_{p1}) +n_2 (C_{p2}) /n_1+n_2$$

$(v)_{mix} = n_1+n_2 / v-1 = n_1/v_1-1 + n_2/v_2-1$

Where v is the specific heat capacity of mixture

Efficiency of Carnot's heat engine :

$\eta = 1 - T_2/T_1$ where T_2 is the sink temperature and T_1 is source temperature

As $Q_2/Q_1 = T_2/T_1$ $\quad \eta = 1 - Q_2/Q_1$

Performance of refrigerator $\beta = Q_2$ /work

$= Q_2 / Q_1 - Q_2$

MCQ

1) S.I Unit of Thermal conductivity is

1) J/m-K
2) J/s- m^2K
3) J/mK
4) J/s-mK

Ans :-4

WKT $Q = \frac{KA(Q_1 - Q_2)t}{l}$

$K = \frac{Ql}{A(Q_1 - Q_2)t} \quad \frac{Jm^1}{m^2Ks} = \frac{J}{msK}$

$= \frac{J}{s-mK}$

2. On heating one end of the rod, the temperature of whole rod will be uniform, when

1) $K = 1$

2) $K = 0$

3) $K = 100$

4) $K = \infty$

Ans :- 4

wkt $\frac{dQ}{dt}$ = KA $\frac{d\theta}{dx}$,

$$\frac{d\theta}{dx} = temp.\,gradiant$$

K = $\frac{\frac{dQ}{dt}}{\frac{Ad\theta}{dx}}$ $/ \, here \; given \frac{d\theta}{dx} = 0$

hence K =∞

3) A cycle tyre bursts suddenly. This represents an

1) Isothermal process

2) Isobaric process

3) Isochoric process

4) Adiabatic process

Ans: 4

The process is very fast so that the gas fails to gain or lose heat, hence it is an adiabatic process

4) The number of molecules per unit volume of a gas is given by

1) P/KT
2) KT/P
3) P/RT
4) RT/P

Ans :- 1

WKT PV = nRT V=1 unit

P = nRT but $R = k_B N_A$

$P = (KN_A)\, nT$ nN_A = No of molecules per unit volume

therefore $(N_A n) = P/KT$

5) A perfect gas at 27^0C is heated at constant pressure so as to double its volume, the increase in temp. of the gas will be

1) 600^0C

2) 327^0C

3) 54^0C

4) 300^0C

Ans :- 4

$\frac{V}{T} = cont.$ at constant pressure

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ $V_2 = 2V_1,$

$\frac{V_1}{V_2} = \frac{T_1}{T_2}$ $\frac{V_1}{2V_1} = \frac{T_1}{T_2} \rightarrow \frac{T_1}{T_2} = \frac{1}{2} \rightarrow T_2 = 2T_1$

where $T_1 = 27+273=300K$

$T_2 = 2X300=600K = 327^0C$

Increase in temperature $= 327-27=300^0C$

6) The mean kinetic energy of one mole of gas per degree of freedom is

1) ½ kT

2) 3/2 kT

3) 3/2 RT

4) ½ RT

Ans :- 4

WKT Energy / mole = n/2(RT)

n = no of degree of freedom

Here n =1 (per degree of freedom)

Therefore Energy / mole = ½ RT

7) If the density of gas at NTP is 1.3 kg/m^3 & velocity of sound in it 330 m/s. The number of degrees of freedom of gas molecule is

1) 2

2) 3

3) 6

4) 5

Ans :- 4

We know that

$$V = \sqrt{\frac{\gamma p}{\rho}}$$

$$\gamma = \frac{V^2 \rho}{p} = \frac{1.3X(330)^2}{1.01X10^5} = 1.4$$

$\& \ \gamma = 1 + \frac{2}{n}$ **1.4 -1 = 2/n**

0.4 = 2/n n= 2/0.4 = 20/4 =5

n=5

8) A beaker is completely filled with water at 4^0C It will Overflow if

1) Heated above 4^0C

2) Cooled below 4^0C

3)Both heated & cooled above and below 4^0C resp.

4) None of above

Ans :- 3

H_2O has maximum density at 4^0C so if the H_2O is heated above 4^0C or cooled below 4^0C density is decreases i.e volume increases . In other words it expands, so it overflows in both cases

9) Ideal gas & real gas have major difference of

1) Phase transition
2) Temperature
3) Pressure
4) None of the above

Ans . 3

10) 10 mole of an ideal monoatomic gas at 10^0C is mixed with 20 moles of another monoatomic gas at 20^0C, then the temperature of the mixture is

1) **15.5^0C**
2) **15^0C**
3) **16^0C**
4) **16.6^0C**

Ans :- 4

Temp. of mixture is

$$T = \frac{n_1 t_1 + n_2 t2}{n_1 + n_2}$$

$$T = \frac{10X10+20X20}{10+20} = 16.6^{0}C$$

11) If at the same temperature and pressure the densities of two diatomic gases are d_1 & d_2 respectively. the ratio of mean Kinetic energy per molecule of gases will be.

1) **1: 1**
2) **$d_1 : d_2$**
3) **$\sqrt{d_1} : \sqrt{d_2}$**
4) **$\sqrt{d_2} : \sqrt{d_1}$**

ANS: 1

The kinetic energy per molecule per *degree of freedom is ½ kT .If temperature is same then the energy is remains same*

12) The molar heat capacity in a process of a diatomic gas " if does work of Q/4 when a heat Q is supplied to it is

1) (2/5) R

2) (5/2) R

3) (10/3) R

4) (6/7) R

Ans. 3 WKT the molar heat capacity

C= $\frac{dQ}{QT}$ here n= 1 for one mole

because (dQ = C(dT)n)

But dQ = du + dw.

du = dQ – dw = Q – $\frac{Q}{4}$ = $\frac{3Q}{4}$

but du = C_v dT =(5/2) R dT for diatomic n=5

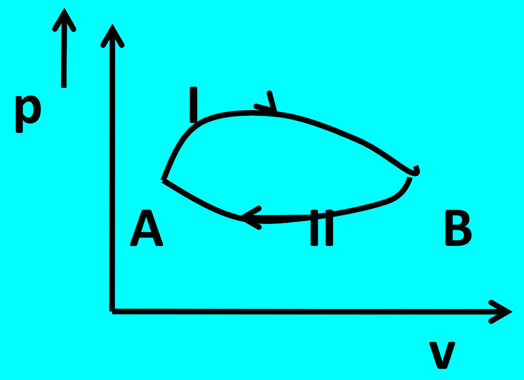
dT= $\frac{du}{\left(\frac{5}{2}\right)R}$ AND

C = $\frac{dQ}{dT} = \frac{Q}{du/\left(\frac{5}{2}\right)R} = \frac{Q}{\frac{\left(\frac{3Q}{4}\right)}{\left(\frac{5}{2}\right)R}} = \frac{\frac{5}{2}RQ}{\frac{3Q}{4}}$

$= 10R/3$

13) A certain amount of an ideal gas is taken from State A to state B one time by process I& and another time by the process II if the amount of heat absorbed by the gas are Q_1 & Q_2 respectively then,

1) $Q_1=Q_2$
2) $Q_1<Q_2$
3) $Q_1>Q_2$
4) Data insufficient



Ans :- 3

Work in one case is more that the second case

because the area under the I curve is more than the second curve

but du is same in both the cases

$$du = dQ - dw$$

$$Q_1 - dw \quad \text{and}$$

$$du = Q_2 - dw \quad / \quad Q_1 > Q_2$$

14) An ideal gas mixture is filled inside a balloon expands according to the relation $pv^{2/3}$ =constant .The temperature inside the balloon is

1) Increasing
2) Decreases
3) Constant
4) Cannot be defined

Ans :- 1

$PV^{2/3}$ = constant (PV = RT , P = RT/V)

$(RT/V)\,V^{2/3}$ = constant or

$RTV^{-1/3}$ = constant or

$T \propto V^{1/3}$

with increase in the volume the temperature is also increases

15) The temperature gradient in a rod of 0.5m long is 80 ^{0}C/m . If the temperature of hotter end of the rod is 30^{0}C. then the temperature of the cooler end is

1) 40^{0}C

2) -10^{0}C

3) 10^{0}C

4) 0^{0}C

Ans :- 2

$\frac{d\theta}{dx} = 80^0C\ /m$ l = 0.5 m

i.e $\frac{\theta 1 - \theta 2}{l} = 80$ → $\frac{30 - \theta_2}{0.5} = 80$

$30 - \theta_2 = 0.5 \times 80$

$= 40$

$\theta_2 = -10\ ^0C$

16) By keeping the door of an refrigerator open in a room, then the room is

1) Get heated

2) Get cooled

3) Unchanged

4) None of these

Ans :- 1

we know that the working of the refrigerator is to extract heat from the chamber and transfer it to surrounding by doing work on it. Therefore when door of refrigerator is kept open room is get warmed.

17) In thermodynamic process the presence of a fixed mass of gas is changed in such a manner that the gas release 20 J of heat and 8 J of work done on the gas. If the initial internal energy of the gas was 30 J. The final internal energy will be

1) **2 J**
2) **42J**
3) **18J**
4) **58J**

Ans: 3

Energy gained = 8 J

energy released =20 J

Net loss of energy = 20-8 =12 J

Therefore final internal energy = 30-12 =18 J

18) The one mole of a monatomic gas is mixed with one mole of diatomic ideal gas. The molar specific heat of the mixture at constant volume is

1) R
2) 2R
3) 4R
4) None of these

Ans :- 2

$$(Cv)mix = \frac{n_1(C_{V_1}) + n_2(C_{V_2})}{n_1 + n_2}$$

For monoatomic (C_{V1}) $= \frac{3}{2}$ R. $n_1 = 1$

For diatomic (C_{V2})= $\frac{5}{2}$ R . $n_2 = 1$

$$(C_v)_{mix} = \frac{1X\frac{3}{2}R + 1X\frac{5}{2}R}{1+1} = 2R$$

19) A body takes 4 min to cool from 100^0C to 70^0C if the room temperature is 15^0C. The time taken to cool from 70^0C to 40^0C will be

1) 7 min
2) 6 min
3) 5 min
4) 2 min

Ans :- 1

$$\frac{100-70}{4} = K\left(\frac{100+70}{2} - 15\right)$$

$$\frac{30}{4} = K\,(85-15)$$

$$\frac{15}{2} = K(70)$$ and

$$\frac{70-40}{t} = K\left(\frac{70+40}{2} - 15\right)$$

$$\frac{30}{t} = \frac{15}{140}(55-15)$$

$$\frac{30}{t} = \frac{15}{140}(40) = \frac{15X4}{14}$$

$$t = \frac{14X30}{15X4} = \frac{28}{4} min$$

= 7 min

20) A slab consists of two parallel layer of two different materials of same thickness having thermal conductivities K_1 & K_2.the equivalent conductivity of the combination is

1) K_1+K_2

2) $\frac{K_1+K_2}{2}$

3) $\frac{2K_1K_2}{K_1+K_2}$

4) $\frac{K_1+K_2}{2K_1K_2}$

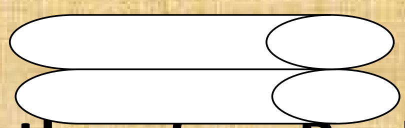
ANS. 2 **R = thermal resistance**

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{2KA}{L} = \frac{K1\ A}{L} + \frac{K2A}{L}$$ **implies** $K = K_1 + K_2/2$

{BUT $\frac{dQ}{dt} = KA\,\frac{d\theta}{L}$ **or** $\frac{dQ}{dt} = \frac{d\theta}{L/KA} = \frac{d\theta}{R}$

where $R = \frac{L}{KA}$ **Thermal resistance }**



when in parallel the area doubles therefore R =L/2KA

21) The layers of atmosphere are heated through

1) convection

2) conduction

3) Radiation

4) None of these

Ans.1 convection

22) Mud houses are cooled in summer and warmer in winter because

1) Mud is superconductor of heat

2) Mud is good conductor of heat

3) mud is bad conductor of heat

4) None of the above

Ans :- 3

Mud is bad conductor of heat, So it prevents the flow of heat between surrounding and inside.

23) Two spherical black bodies of radii $r_1$and r_2 and with surface temperatures$T_1$and T_2 resp. radiate the same power, then r_1/r_2 must be equal to

1) $\left(\frac{T_1}{T_2}\right)^2$

2) $\left(\frac{T_2}{T_1}\right)^2$

3) $\left(\frac{T_1}{T_2}\right)^4$

4) $\left(\frac{T_2}{T_1}\right)^4$

Ans :- 2

WKT according to Stefan's law the rate of emission of radiation by perfectly black body per unit area is directly proportional to fourth power of its absolute temperature .

Power radiated $P \propto AT^4$

$P \propto 4\pi r^2 \ T^4$

given power emitted is same $P_1 = P_2$

$$4\pi r_1^2 T_2^4 = 4\pi r_2^2 T_2^4 \rightarrow \frac{r_1}{r_2} = \frac{T_2^2}{T_1^2}$$

24) “Good Emitter are good absorber” is a statement concluded from

1) Newton's law of cooling

2) Stefan’s law of radiation

3) Prevost’ s theory

4) Kirchhoff’s law

Ans. 4

25) The temperature of a radiating body is increases by 30% ,then the increase in the amount of radiation emitted will be approximately

1) 185 %

2) 285%

3) 325%

4) 245%

Ans :- 1 WKT $E \propto T^4$ – 1)

$E_1 \propto (1.3\ T)^4$ --- 2)

(30%.increase)

$E_1 - E = (1.3)^4\ T^4 - T^4 = (2.85-1)\ T^4 = 1.85\ T^4$

ie increase in radiation is 185 %

26) If a body cools down from 80 ^{0}C to 60^{0}C in 10 min when the temperature of surrounding is 30^{0}C then the temperature of the body after next 10 min will be

1) 50^0 C
2) 48^0 C
3) 30^0 C
4) none of these

Ans :- 2 WKT $\frac{\theta 1-\theta_2}{t}$ = K ($\frac{\theta_1+\theta_2}{2}$ - θ_0)

implies $\frac{8o-6o}{10}$ = K $(70 - 30)$

2 = K 40

1 = K(20) – (1)

$\frac{60-\theta}{10}$ = K $\left(\frac{60+\theta}{2} - 30\right)$ $-$ (2)

$\frac{60-\theta}{10}$ = $\frac{1}{20}$ ($\frac{60+\theta}{2} - 30)$ from (1)

$$120 - 2\,\theta = \frac{60 + \theta - 60}{2}$$

240- 4 θ =θ

240 = 5θ / $\theta = \frac{240}{5} = 48\,degree$

27) If γ is the ratio of specific heats and R is the universal gas constant then the molar specific heats at constant volume C_v is given by

1) $\left(\frac{\gamma-1}{\gamma}\right)$ R

2) γR

3) $\frac{\sqrt{R}}{\gamma-1}$

4) $\frac{R}{\gamma-1}$

Ans :- 4

WKT $C_P - C_V = R$ **divide by** C_v **we get**

$\boldsymbol{C_p - 1 = \frac{R}{CV}}$ **but** $\boldsymbol{\frac{cp}{cv} =}$ ν

ν $\boldsymbol{- 1 = \frac{R}{C_v},}$ $\boldsymbol{C_v = \frac{R}{\nu - 1}}$

28) A gas mixture consists of 2 moles of 0_2 and 4 moles of Ar. At temperature T. Neglecting all vibrational modes, the total internal energy of the system is

1) 4RT

2) 15RT

3) 9RT

4) 11RT

Ans :- 4

per mole energy associated is $\frac{n}{2}RT$

$where$

$n = 5\, no.\, of\ degrees\ of\ freedom\ \ for\ diatomic$

$n = 3$ for mono atomic

therefore

U =2(5/2 RT) + 4 (3/2RT) =11RT

29) On which of the following scales of temperature . The temperature is never negative

1) Celsius

2) Fahrenheit

3) Reaumur

4) Kelvin

Ans 4

30) **Two mono atomic gases at absolute temperatures 300 K & 350 K respectively,the ratio of average KE of their molecules is**

1) 7:6
2) 6:7
3) 36:49
4) 49:36

Ans :- 2

wkt {1/2mv^2 = $\frac{3}{2}$KT }For mono atomic

Le K .E ∝ T

$$\frac{KE_1}{KE_2} = \frac{T_1}{T_2} = \frac{300}{350} = \frac{6}{7}$$

31) A thermodynamic system is changed from state (P_1,V_1) to ($P_2$$V_2$) by two different process . The quantity which will remain same will be

1) ΔQ

2) ΔW

3) $\Delta Q + \Delta W$

4) $\Delta Q - \Delta W$

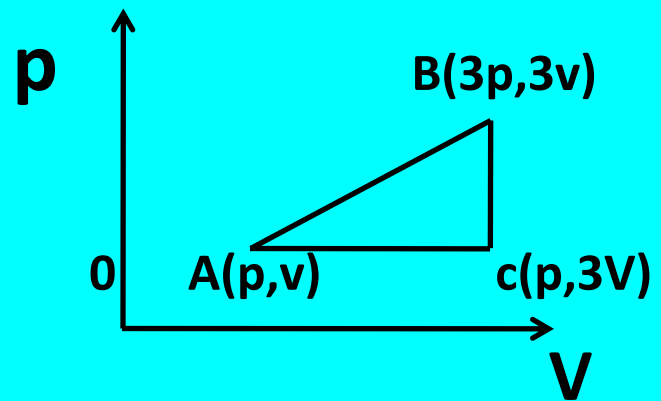
ANS. 4

we know that $\Delta Q = \Delta U + \Delta W$

$\Delta U = \Delta Q - \Delta W$ which is constant

Because T is constant

32) An Ideal gas is taken around ABCD as shown in the fig. P - V diagram, the work done during the cycle is



1)2pv

2)Pv

3)pv/2

4)zero

Ans. 1

we know that , the work done during the any thermodynamic process can be calculated by the area under the p-v diagram

Therefore work done = Area of the triangle ABC

$$= \frac{1}{2}(AC)(BC)$$

$$= \frac{1}{2}(3V-V)(3p-p)$$

$$= \frac{1}{2}(2v)(2p)$$

$$= 2pv$$

33) The work done in which of the following process is zero?

1) **Isothermal process**
2) **Adiabatic process**
3) **Isobaric process**
4) **Isochoric process**

Ans. 4

Volume is constant in case of isochoric process

Hence piston in the cylinder is not moving ,

therefore work done is equal to zero

34) A Carnot's engine is made to work between 200^0C and 0^0C first and then between 0^0 and -200^0C . The ratio of efficiencies η_2 / η_1 of the engine in the two cases is

1)1:1.5

2)1:1

3)1:2

4) 1.73:1

ANS: 4

In first case T_2 =0+273 =273, T_1 =200+273

In the second case T_2 =-200+273 =73, T_1 =0+273=273

WKT efficiency of the engine $\eta_1 = 1 - T_2/T_1$

$= 1-273/473$

$= 200/473$

efficiency of the engine $\eta_2 = 1 - T_2/T_1$

$=1-73/273$

$=200/273$

therefore we get η_2/η_1 =1.73:1

35) In an Isochoric process If $t_1 = 27^0C$ and $t_2 = 127^0C$ then p_1/p_2 will be equal to

1) 9/59
2) 2/3
3) 3/4
4) None of these

ANS. 3

In Isochoric process volume is constant

i.e $p \alpha T$ means $p_1/p_2 = T_1/T_2 = 300/400$

$= 3/4$

($T_1 = 27+273 = 300K$ $T_2 = 127+273 = 400$)

36) When an ideal gas is compressed isothermally then its pressure increases because

1)Its potential energy increases

2)Its K.E increases and molecules move apart

3)Its number of collisions per unit area with walls of containers increases

4) Molecules energy increases

Ans. 3

we know that , in the container the pressure of the gas is due to collisions of molecules with walls of the container.

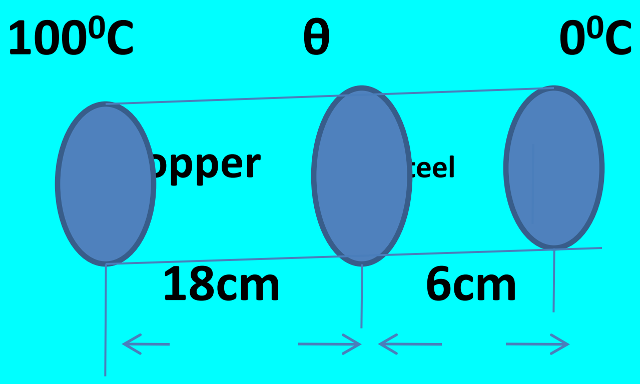
37) The coefficient of thermal conductivity of copper is 9 times that of steel in the composite cylindrical bar shown in the fig. What will be the temperature at the junction of copper and steel?

1) 67^0C

2) 75^0C

3) 33^0C

4) 25^0C



Ans. 2

We know that at steady state the rate of flow of heat in both the cases is same

Therefore $Q_1 = Q_2$ If θ is the temperature of the interface(between copper and steel)

then $K_c(\theta_1 - \theta)A / d_1 = K_s(\theta - \theta_2)A / d_2$ given Kc=9Ks

$9K_s(100 - \theta)/18 = K_s(\theta - 0)A / 6$ on simplification we get $\theta = 75^0C$

38) An ideal monoatomic gas is compressed (No heat being added or removed in the process) so that its volume is halved. The ratio of the new pressure to the original pressure is

1) $(2)^{3/5}$
2) $2^{4/3}$
3) $2^{3/4}$
4) $2^{5/3}$

Ans.4

Under adiabatic change $\Delta Q = 0$

And pv^{v} = constant

$p_1 v_1^{v} = p_2 v_2^{v}$ **for monoatomic gas $v = 5/3$**

$p_2 / p_1 = (v_1 / v_2)^{v}$ **but $v_2 = v_1/2$ we get**

$p_2 / p_1 = 2^{5/3}$

39) For which combinations of temperatures the efficiency of Carnot's engine is highest?

1) 80 K,60 K

2)100 K,80 K

3)60 K,40 K

4)40 K,20 K

Ans. 4

Efficiency of Carnot's engine is

$$\eta = 1 - T_2/T_1$$

The efficiency is more if the ratio T_2/T_1 is less hence by inspection for the combination of temperatures 40K and 20K, the ratio T_2/T_1 is less and efficiency is high.

40)The temperature of the sink of Carnot's engine is 27^0C and its efficiency is 25%. The temperature of source is

1) 227^0C

2) 27^0C

3) 327^0C

4) 127^0C

Ans.4

Efficiency of Carnot's engine is $\eta = 1 - T_2/T_1$

$$T_2/T_1 = 1-\eta = 1-0.25 = 0.75$$

$$T_1 = T_2/0.75 = 300/0.75 = 400K = 127^0C$$

Thank you

All the Best…..