Summary

Heat and Thermodynamics

Heat Transfer:

- Introduction:

The transfer of heat from one body to the other takes place through three routes.
(i) Conduction
(ii) Convection
(iii) Radiation

- **Conduction:**

The process of transmission of heat energy in which heat is transferred from one particle of the medium to the other, but each particle of the medium stays at its own position is called conduction. Rate of flow of heat is given by

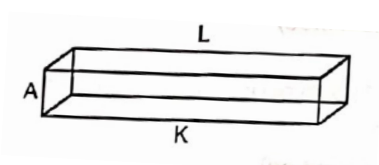
$$\boxed{\frac{dQ}{dt} = -KA\frac{dT}{dx}}$$

- **Steady state:**

If the temperature of a cross-section at any position x in the above slab remains constant with time (remember it does vary with position x), the slab is said to be in steady state.

- **Conduction:**

thermal resistance R is given as



$$R = \frac{L}{KA}$$

in terms of R, the amount of heat flowing though a slab in steady-state (in time t)

$$\frac{Q}{t} = \frac{(T_H - T_L)}{R} \Rightarrow i_T = \frac{T_H - T_L}{R}$$

- **Slabs in series and Parallel:**

(1) Slabs in series (in steady state)

If two or more than two slabs are joined in series and are allowed to attain steady state, then equivalent thermal resistance is given by

$$R = R_1 + R_2 + R_3 + ...$$

$$\frac{\ell_{eq}}{K_{eq}} = \frac{\ell_1}{K_1} + \frac{\ell_2}{K_2} + ...$$

(2) Slabs in parallel:

If two or more than two rods are joined in parallel, the equivalent thermal resistance is given by

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$$

$$K_{eq}A_{eq} = K_1A_1 + K_2A_2 + ...$$

- **Convection:**

It is the process in which medium Is required and heat transfer occurs by actual movement of medium. For example, heat transfer by air,

- **Radiation:**

The process of the transfer of heat from one place to another place without heating the intervening medium is called radiation,

- **Prevost theory of exchange:**

According to this theory, all bodies radiate thermal radiation at all temperatures. The amount of thermal radiation radiated per unit time depends on the nature of the emitting surface, its area and its temperature,

- **Perfectly black body:**

A perfectly black body is one which absorbs all heat radiations of whatever wavelength, incident on the it. It neither reflects nor transmits any of the incident radiation and therefore appears black whatever be the colour of the incident radiation,

- **Absorption, reflection and emission of radiations:**

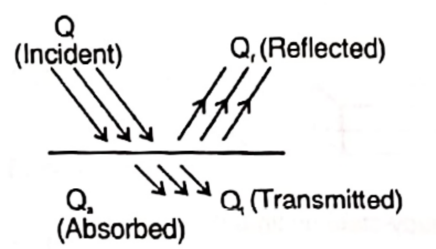
$$Q = Q_r + Q_t + Q_a$$

$$1 = \frac{Q_r}{Q} + \frac{Q_t}{Q} + \frac{Q_a}{Q}$$

$$1 = r + t + a$$

where r= reflecting power,

a= absorptive power



and t= transmission power.

(i) r=0, t=0, a=1, perfect black body

(ii) r=1, t=0, a=0, perfect reflector

(iii) r=0, t=1, a=0, perfect transmitter

As all the radiations incident on a black body are absorbed, a = 1 for a black body.

Spectral Emissive power (EI):

$$\frac{dE}{d\lambda} = E_\lambda \quad \Rightarrow E = \int_0^\infty E_\lambda d\lambda$$

Emissivity:

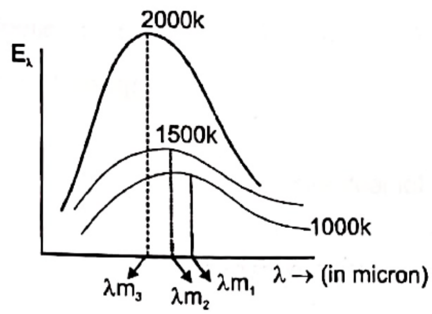
$$e = \frac{\text{Emissive powerof a body at temperatue T}}{\text{Emissive power of a black body at same temperature T}} = \frac{E}{E_0}$$

- **Kirchoff's Law:**

The ratio of the emissive power to the absorptive power for the radiation of a given wavelength is same for all substances at the same temperature and is equal to the emissive power of a perfectly black body for the same wavelength and temperature.

$$\frac{E(\text{body})}{a(\text{body})} = E(\text{black body})$$

- **Nature of thermal radiations: (Wien's displacement law)**



$\lambda_m \propto \frac{1}{T}$ or $\lambda_m T = b$

This is called Wien's displacement law.
Here b = 0.282 cm-K, is the Wien's constant.

- **Stefan-Boltzmann's law :**

$u = \sigma A T^4$ (for perfectly black body)

Where σ is Stefan's constant = 5.67 x 10^{-8} W/m^2k^4

$u = \sigma A T^4$ (for a body which is not a perfectly black body)

where e = emissivity (which is equal to absorptive power) which lies between 0 to 1

$$\Delta u = u - u_0 = e\sigma A\left(T^4 - T_0^4\right)$$

- **Newton's law of cooling:**

For small temperature difference between a body and its surrounding,

$\frac{d\theta}{dt} \propto (\theta - \theta_0)$ Where θ and θ_0 are temperature corresponding to object and surroundings.

$$\frac{d\theta}{dt} = -k(\theta - \theta_0)$$

$$\theta_f = \theta + (\theta_i - \theta_0)e^{-kt}$$

Calorimetry and Thermal Expansion

- Total heat given by hot objects = Total heat received by cold objects.
- Specific heat (s)

$\Delta Q = ms\,\Delta\theta$

when temperature changes but phase does not change.

- $\Delta Q = mL$

When phase changes but temperature does not change.

- Linear expansion

$L = L_0\left(1+\alpha\Delta\theta\right)$

- Thermal stress

$F / A = Y\alpha\Delta\theta$

- Measured value = calibrated value $\left(1+\alpha\Delta\theta\right)$

$\alpha = \alpha_{\text{object}} - \alpha_{\text{scale}}$

- Area expansion

$A = A_0\left(1+\beta\Delta\theta\right)$

- Volume expansion

$V = V_0\left(1+\gamma\Delta\theta\right)$

- Relation between α, β and γ for isotropic solid

$\frac{\alpha}{1} = \frac{\beta}{2} = \frac{\gamma}{3}$

- Volume overflow

$\Delta V = V_0\left(\gamma_L - \gamma_C\right)\Delta T$

- Haight of liquid in container

$h = h_0\left\{1+\left(\gamma_L - 2\alpha_S\right)\Delta T\right\}$

- General formula for the conversion of temperature from one scale to another:

$$\frac{\text{Temp on one Scale}(S_1)\text{-Lower fixed point}(S_1)}{\text{Upper fixed point }(S_1)\text{-Lower fixed point }(S_1)} = \frac{\text{Temp. on other scale}(S_2)\text{-Lower fixed point }(S_2)}{\text{Upper fixed point }(S_2)\text{-Lower fixed point }\left(S_2\right)}$$

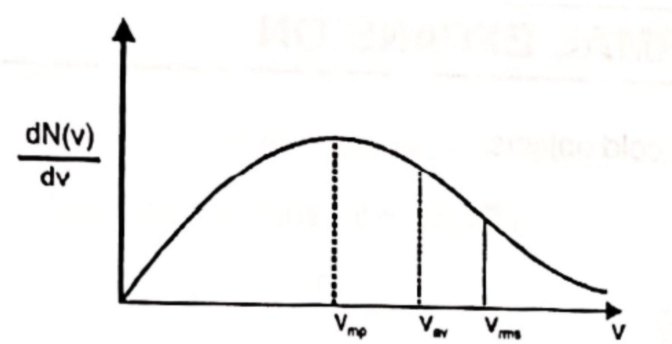
Kinetic Theory of Gases

- **Total translational K.E. of gas:**

$$= \frac{1}{2} M < V^2 > = \frac{3}{2} PV = \frac{3}{2} nRT$$

$$< V^2 > = \frac{3P}{\rho} V_{rms} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3RT}{M_{mol}}} = \sqrt{\frac{3KT}{m}}$$

- **Maxwell's distribution law:**



$V_{rms} > V_{Av} > V_{mp}$

- **Important Points:**

$$V_{rms} \propto \sqrt{T},\ \vec{V} = \sqrt{\frac{8KT}{\pi m}} = 1.59\sqrt{\frac{KT}{m}} \quad V_{rms} = 1.73\sqrt{\frac{KT}{m}}$$

- **Most Probable speed:**

$$V_{mp} = \sqrt{\frac{2KT}{m}} = 1.41\sqrt{\frac{KT}{m}} \qquad \therefore V_{rms} > \overline{V} > V_{mp}$$

- **Degree of freedom**:

Mono atomic f =3
Diatomic f = 5
Polyatomic f = 6

- **Maxwell's law of equipartition of energy:**

Total K.E. of the molecule = $= \frac{1}{2} f\ KT$

For an ideal gas:

Internal energy $U = \frac{f}{2} nRT$

Thermodynamics

- **Work done in isothermal process:** $W = \left[2.303\,nRT\log_{10}\frac{V_f}{V_i}\right]$
- **Internal energy in isothermal Process:** $\Delta U = 0$
- **Work done in isochoric process:** $dW = 0$
- **Change in internal energy in isochoric process:** $\Delta U = n\frac{f}{2}R\Delta T = \Delta Q\left(\text{heat given}\right)$
- **Isobaric process:**

Work done $\Delta W = nR\left(T_f - T_i\right)$

Change in internal energy $\Delta U = nCv\Delta T$

heat given $\Delta Q = \Delta U + W$

- **Molar heat capacity of an ideal gas in terms of R:**

$C_v = \frac{f}{2}R \qquad C_p = \left(\frac{f}{2}+1\right)R$

(i) for mono atomic gas: $\frac{C_P}{C_V} = 1.67$

(ii) for diatomic gas: $\frac{C_P}{C_V} = 1.4$

(iii) for triatomic gas: $\frac{C_P}{C_V} = 1.33$

- **In general**: $\gamma = \frac{C_P}{C_V} = \left[1+\frac{2}{f}\right]$

Mayer's equation $\Rightarrow C_p - C_v = R$ for an ideal gas only

- **Adiabatic process:** Work done $W = \frac{nR\left(T_i - T_f\right)}{\gamma - 1}$
- **In cyclic process:** $\Delta U = 0 \quad \Delta Q = W$
- **In a mixture of non-reacting gases f:**

$\text{Mol.wt.} = \frac{n_1M_1 + n_2M_2}{n_1 + n_2}$

$C_v = \frac{n_1C_{V_1} + n_2C_{V_2}}{n_1 + n_2}, C_v = \frac{n_1C_{p_1} + n_2C_{p_2}}{n_1 + n_2}$

$\gamma = \frac{C_{p(mix)}}{C_{v(mix)}} = \frac{n_1C_{p_1} + n_2C_{p_2} + \ldots}{n_1C_{v_1} + n_2C_{v_2} + \ldots}$

Practical Questions

1. One mole of an ideal monatomic gas is compressed isothermally in a rigid vessel to double its pressure at room temperature, 27^0C. The done on the gas will be : (2018)

(a) 300 R

(b) 300 R *In*2

(c) 300 *In*6

(d) 300R *In*7

2. A Carnot engine works as a refrigerator between 250K and 300K. It receives 500 cal heat from the reservoir at the lower temperature. The amount of work done in each cycle to operate the refrigerator is (2018)

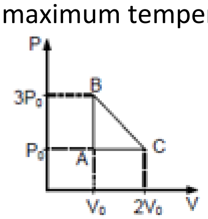
(a) 772 J

(b) 420 J

(c) 2100 J

(d) 2520 J

3. One mole of an ideal monatomic gas is taken along the path ABCA as shown in the PV diagram. The maximum temperature attained by the gas along the path BC is given by : (2018)



(a) $\frac{25}{4}\frac{P_0V_0}{R}$

(b) $\frac{5}{8}\frac{P_0V_0}{R}$

(c) $\frac{25}{8}\frac{P_0V_0}{R}$

(d) $\frac{25}{16}\frac{P_0V_0}{R}$

4. C_P and C_V are specific heats at constant pressure and constant volume, respectively. It is observed that $C_P - C_V = a$ for hydrogen gas $C_P - C_V = b$ for nitrogen gas. The correct relation between a and b is (2017)

(a) a = b

(b) a = 14b

(c) a = 28b

(d) $a = \frac{1}{14}b$

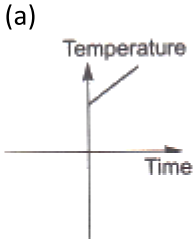
5. A copper ball of mass 100 g is at a temperature T. It is dropped in a copper calorimeter of mass 100 g, filled with 170 g of water at room temperature. Subsequently, the temperature of the system is found

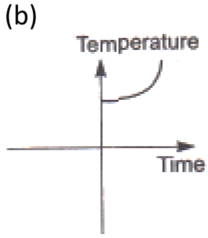
to be 75^0 C. T is (Given, room temperature = 30^0 C, specific heat of copper = 0.1 cal/g^0 C) (2017)

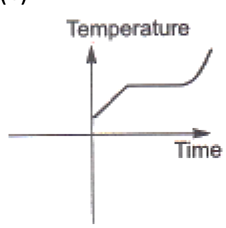
(a) 885^0 C
(b) 125^0 C
(c) 825^0 C
(d) 800^0 C

6. Calorie is defined as the amount of heat required to raise temperature of 1 g of water by 1^{0}C and it is defined under which of the following conditions? (2005)
(a) From 14.5^{0}C to 15.5^{0}C at 760 mm of Hg
(b) From 98.5^{0}C to 99.5^{0}C at 760 mm of Hg
(c) From 13.5^{0}C to 14.5^{0}C at 76 mm of Hg
(d) From 3.5^{0}C to 4.5^{0}C at 76 mm of Hg

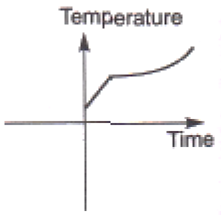
7. Water of volume 2 L ins container is heated with a coil of 1 kW at 27^{0}C. The lid of the container is open and energy dissipates at rate of 160 J/s. In how much time temperature will rise from 27^{0}C to 77^{0}C? [Specific heat of water is 4.2 kJ/kg]
(a) 8 min 20 s
(b) 6 min 2 s
(c) 7 min
(d) 14 min

8. Liquid oxygen at 50 K is heated to 300 K at constant pea of I atm. The rate of heating is constant. Which following graphs represent the variation of temperature time? (2004)
(a)


(b)


(c)


(d)

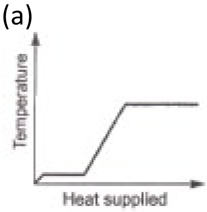


9. 2 kg of ice at - 20^{0}C is mixed with 5 kg of water at 20^{0}C in an insulating vessel having a negligible heat capacity. Calculate the final mass of water remaining in the container. It is given that the specific heats of water and ice are 1 kcal/kg/^{0}C and 0.5 kcal/kg/^{0}C while the latent heat of fusion of ice is 80 kcal/kg (2003)

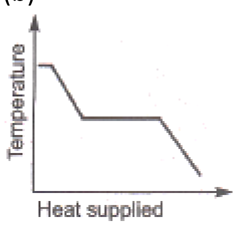
(a) 7 kg
(b) 6 kg
(c) 4 kg
(d) 2 kg

10. A block steam phenomena a of ice at - 10^{0}C is slowly at 100^{0}C. Which of the following qualitatively? a heated and converted to curves represents the (2000)

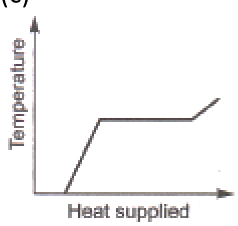
(a)



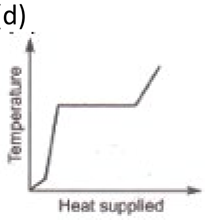
(b)



(c)



(d)



11. Steam at 100^0C is passed into 1.1 kg of water contained in a Calorimeter of water equivalent 0.02 kg at 15^0C till the temperature of the calorimeter and its contents rises to 80^0C. The mass of the steam condensed in kg is (1986)

(a) 0.130
(b) 0.065
(c) 0.260
(d) 0.135

12. 70 cal of heat are required to raise the temperature of 2 moles of an ideal diatomic gas at constant pressure from 30^0C to 35^0C. The amount of heat required (in caloric) to raise the temperature of the same gas through the same range (30°C to 35°C) at constant volume is (1988)

(a) 30
(b) 50
(c) 70
(d) 90

13. An external pressure p is applied on a cube at 0^0C so that it is equally compressed from all sides. K is the bulk modulus of the material of the cube and α 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 (2017)

(a) $\frac{p}{\alpha K}$
(b) $\frac{3\alpha}{pK}$
(c) $3pK\alpha$
(d) $\frac{p}{3\alpha K}$

14. A pendulum clock loses 12 s a day if the temperature is 40^0C and gains 4 s a day if the temperature is 20^0C. The temperature at which the clock will show correct time, and the coefficient of linear expansion a of the metal of the pendulum shaft arc, respectively. (2016)

(a) 25^0C, $\alpha = 1.85 \times 10^{-5}$ /^{0} C
(b) 60^0C, $\alpha = 1.85 \times 10^{-4}$ /^{0} C
(c) 30^0C, $\alpha = 1.85 \times 10^{-3}$ /^{0} C
(d) 55^0C, $\alpha = 1.85 \times 10^{-2}$ /^{0} C

15. Two rods, one of aluminium and the other made of steel, having initial length l_1 and l_2 are connected together to form a single rod of length $l_1 + l_2$. The coefficients of linear expansion for aluminium and steel are α_a and α_s, respectively. If the length of each rod increases by the same amount when their temperature are raised by t^0C, then find the ratio $\frac{l_1}{l_1 + l_2}$ (2003)

(a) $\frac{\alpha_s}{\alpha_a}$

(b) $\frac{\alpha_a}{\alpha_s}$

(c) $\frac{\alpha_s}{(\alpha_a+\alpha_s)}$

(d) $\frac{\alpha_a}{(\alpha_a+\alpha_s)}$

16. Parallel lays of light of intensity I = 912 Wm^{-2} are incident 4111 II spherical black body kept in surroundings of temperature 300 K. Take Stefan constant $\sigma = 5.7 \times 10^{-8} Wm^{-2}K^{-4}$ and assume that the energy, exchange with the surroundings is only through radiation. The final steady state temperature of the black body is close to (2014)

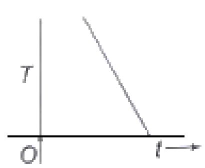
(a) 330 K
(b) 660 K
(c) 990 K
(d) 1550

17. Three rods of copper, brass and steel are welded together to form a Y-shaped structure. Area of cross-section of each rod is 4 cm^2. End of copper rod Is maintained at 100^0 C whereas ends of brass and steel are kept at 0^0 C. Lengths of the copper, brass and steel rods are 46, 13 and 12 cm respectively. The rods are thermally insulated from surroundings except ar ends. Thermal conductivities of copper. brass and steel are 0.92, 0.26 and 0.12 in CGS units. respectively. Rate of heat flow through copper rod is (2014)

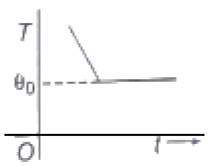
(a) 1.2 cal/s
(b) 2.4 cal/s
(c) 4.8 cal/s
(d) 6.0 cal/s

18. If a piece of metal is heated to temperature θ and then allowed to cool in a room which is at temperature θ_0. graph between the temperature T of the metal and time t will be closed to

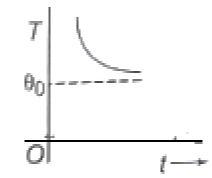
(a)



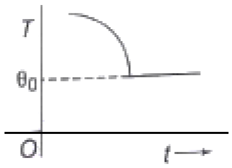
(b)



(c)



(d)



19. Three very large plates of same area arc kept parallel and close to each Whet 'I hey are considered as ideal black surfaces and have very high thermal 4:mains:fishy. The first and third plates arc maintained al temperatures 2T and 3T respectively. The temperature of the middle (i.e. second) plate under steady state condition is (2012)

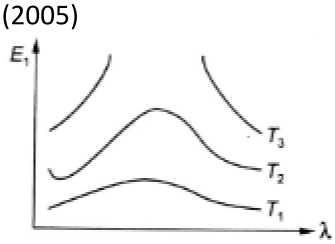
(a) $\left(\frac{65}{2}\right)^{\frac{1}{4}} T$

(b) $\left(\frac{97}{4}\right)^{\frac{1}{4}} T$

(c) $\left(\frac{97}{2}\right)^{\frac{1}{4}} T$

(d) $(97)^{\frac{1}{4}} T$

20. Variation of radiant energy emitted by sun, filament of tungsten lamp and welding arc as a function of its wavelength is shown in figure. Which of the following option is the correct match?
(2005)



(a) Sun-T_1, tungsten filament-T_2, welding arc-T_3
(b) Sun-T_1, tungsten filament-T_1, welding arc-T_7
(c) Sun-T_3, tungsten filament-T_2, welding arc-T_1
(d) Sun-T_1, tungsten filament-T_3, welding arc-T_2

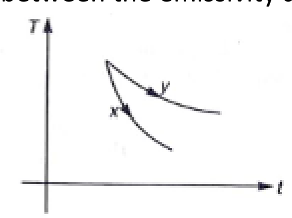
21. In which of the following process, convection does not take place primarily? (2005)
(a) Sea and land breeze
(b) Boiling of water

(c) Warming of glass of bulb due to filament
(d) Heating air around a furnace

22. Three discs, A, B and C having radii 2 m, 4 m and 6 m respectively are coated with carbon black on their outer surfaces. The wavelengths corresponding to maximum intensity are 300 nm, 400 nm and 500 nm, respectively. The power radiated by them are Q_A, Q_B and Q_C respectively (2004)
(a) Q_A is maximum
(b) Q_B is maximum
(c) Q_C is maximum
(d) $Q_A = Q_B = Q_C$

23. Two identical conducting rods are first connected independently to two vessels, one containing water at 100^0C and the other containing ice at 0^0C. In the second case, the rods are joined end to end and connected to the same vessels. Let q_1 and q_2 gram per second be the rate of melting of ice in the two cases respectively. The ratio $\frac{q_1}{q_2}$ is (2004)
(a) $\frac{1}{2}$
(b) $\frac{2}{1}$
(c) $\frac{4}{1}$
(d) $\frac{1}{4}$

24. The graph, shown in the diagram, represents the variation of temperature (T) of the bodies, x and y having same surface area, with time (t) due to the emission of radiation. Find the correct relation between the emissivity and absorptivity power of the two bodies (2003)

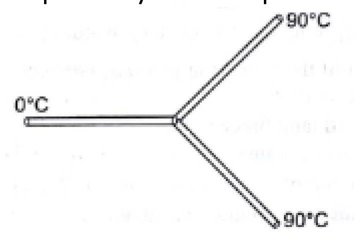


(a) $E_x > E_y$ and $a_x < a_y$
(b) $E_x < E_y$ and $a_x > a_y$
(c) $E_x > E_y$ and $a_x > a_y$
(d) $E_x < E_y$ and $a_x < a_y$

25. An ideal black body at room temperature is thrown into a furnace. It is observed that (2002)
(a) initially it is the darkest body and at later times the brightest
(b) it is the darkest body at all times
(c) it cannot be distinguished at all times

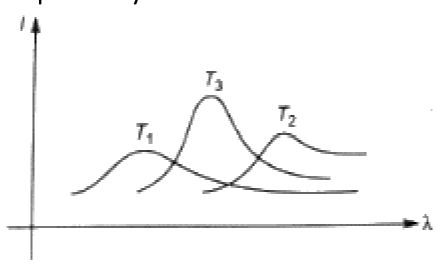
(d) initially it is the darkest body and at later times it cannot be distinguished

26. Three rods made of the same material and having the same cross-section have been joined as shown in the figure. Each rod is of the same length. The left and right ends arc kept at 0^0C and 90^0C respectively. The temperature of junction of the three rods will be (2001)



(a) 45^0C
(b) 60^0C
(c) 30^0C
(d) 20^0C

27. The plots of intensity versus wavelength for three black bodies at temperatures T_1, T_2 and T_3 respectively are as shown. Their temperatures are such that (2000)



(a) $T_1 > T_2 > T_3$
(b) $T_1 > T_3 > T_2$
(c) $T_2 > T_3 > T_1$
(d) $T_3 > T_2 > T_1$

28. A black body is at a temperature of 2880 K. The energy of radiation emitted by this body with wavelength between 499 nm and 500 nm is U_1, between 999 nm and 1000 nm is U_2 and between 1499 nm and 1500 nm is U_3. The Wien constant, $b = 2.88 \times 10^6$ nm-K. Then, (1998)
(a) $U_1 = 0$
(b) $U_3 = 0$
(c) $U_1 > U_2$
(d) $U_2 > U_1$

29. A spherical black body with a radius of 12 cm radiates 450 W power at 500 K. If the radius were halved and the temperature doubled, the power radiated in watt would be (1997)
(a) 225
(b) 450
(c) 900
(d) 1800

30. The intensity of radiation emitted by the sun has it maximum value at a wavelength of 510 nm and that emitted by the north star has the maximum value at 350 nm. If these stars behave like black bodies, then the ratio of the surface temperature of the sun and the north star is (1997)

(a) 1.46

(b) 0.69

(c) 1.21

(d) 0.83

31. Two metallic spheres S_1 and S_2 are made of the same material and have got identical surface finish. The mass of S_1 is thrice that of S_2. Both the spheres are heated to the same high temperature and placed in the same room having lower temperature but are thermally insulated from each other. The ratio of the initial rate of cooling of S_1 to that of S_2 is (1995)

(a) $\frac{1}{3}$

(b) $\frac{1}{\sqrt{3}}$

(c) $\frac{\sqrt{3}}{1}$

(d) $\left(\frac{1}{3}\right)^{1/3}$

32. Three rods of identical cross-sectional area and made from the same metal from the sides of an isosceles mangle ABC, right angled at B. The points A and B are maintained at temperatures T and $(\sqrt{2})$ T respectively. In the steady state, the temperature of the point C is T_c. Assuming that only heat conduction takes place, T_c/T is (1995)

(a) $\frac{1}{2(\sqrt{2}-1)}$

(b) $\frac{3}{\sqrt{2}+1}$

(c) $\frac{1}{\sqrt{3}(\sqrt{2}-1)}$

(d) $\frac{1}{(\sqrt{2}+1)}$

33. A cylinder of radius R made of a material of thermal conductivity K_1 is surrounded by a cylindrical shell of inner radius R and outer radius 2R made of a material of thermal conductivity K_2. The two ends of the combined system are maintained at two different temperatures. There is no loss of heat across the cylindrical surface and the system is in steady state. The effective thermal conductivity of the system (1988)

(a) $K_1 + K_2$

(b) $K_1K_2/(K_1+K_2)$

(c) $(K_1+3K_2)/4$

(d) $(3K_1+K_2)/4$

34. The temperature of an open room of volume 30 m^3 increases from 17^0C to 27^0C due to the sunshine. The atmospheric pressure in the room remains 1×10^5 Pa. If n_i and n_f are the number of molecules in the room before and after heating, then of $n_f - n_i$ of will be (2017)

(a) 1.38×10^{23}
(b) 2.5×10^{25}
(c) -2.5×10^{25}
(d) -1.61×10^{23}

35. An ideal gas undergoes a quasi static, reversible process in which its molar heat capacity C remains constant. If during this process the relation of pressure p and volume V is given by $_pV^n$ = constant, then n is given by (Here, C_P and C_V are molar specific heat at constant pressure and constant volume, respectively) (2016)

(a) $n = \frac{C_P}{C_V}$

(b) $n = \frac{C - C_P}{C - C_V}$

(c) $n = \frac{C_P - C}{C - C_V}$

(d) $n = \frac{C - C_V}{C - C_P}$

36. A mixture of 2 moles of helium gas (atomic mass = 4 amu and 1 mole of argon gas (atomic mass = 40 amu) is kept at 300 K in a container. The ratio of the rms speeds $\left(\frac{v_{rms}(\text{helium})}{v_{rms}(\text{argon})}\right)$ is (2012)

(a) 0.32
(b) 0.45
(c) 2.24
(d) 3.16

37. A real gas behaves like an ideal gas if its (2010)
(a) pressure and temperature are both high
(b) pressure and temperature are both low
(c) pressure is high and temperature is low
(d) pressure is low and temperature is high

38. A gas mixture consists of 2 moles of oxygen and 4 moles of argon at temperature T. Neglecting all vibrational modes, the total internal energy of the system is (1999)

(a) 4 RT
(b) 15 RT
(c) 9 RT
(d) 11 RT

39. Two identical containers A and B with frictionless pistons contain the same ideal gas at the same temperature and the same volume V. The mass of the gas in A is m_A and that in B is m_B. The gas in each cylinder is now allowed to expand isothermally to the same final volume 2V. The changes in the pressure in A and B are found to be Δp and 1.5 Δp respectively. Then (1998)
(a) 4 m_A = 9 m_B
(b) 2 m_A = 3 m_B
(c) 3 m_A = 2 m_B
(d) 9 m_A = 4 m_B

40. A vessel contains a mixture of one mole of oxygen and moles of nitrogen at 300 K. The ratio of the average rotational kinetic energy per O_2 molecule to per N_2 molecule is (1998)
(a) 1 : 1
(b) 1 : 2
(c) 2 : 1
(d) depends on the moment of inertia of the two molecules

41. A vessel contains 1 mole of O_2 gas (molar mass 32) at a temperature T. The pressure of the gas is p. An identical vessel containing one mole of the gas (molar mass 4) at a temperature 2T has a pressure of (1997)
(a) p/8
(b) p
(c) 2p
(d) 8p

42. The avenge translational kinetic energy of O_2 (molar mass 32) molecules at a particular temperature is 0.048 eV. The translational kinetic energy of N_2 (molar mass 28) molecules in eV at the same temperature is (1997)
(a) 0.0015
(b) 0.003
(c) 0.048
(d) 0.768

43. The avenge translational energy and the rms 300 speed of are molecules in a sample of oxygen gas at 300 K are 6.21×10^{-21} J and 484 m/s respectively. The corresponding values at 600 K are nearly (assuming ideal gas behaviour) (1997)
(a) 12.42×10^{-21} J, 968 m/s
(b) 8.78×10^{-21} J, 684 m/s

(c) 6.21×10^{-21} J, 968 m/s
(d) 12.42×10^{-21} J, 684 m/s

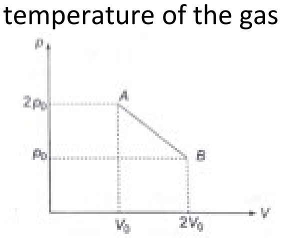
44. The temperature of an ideal gas is increased from 120 K to 480 K. If at 120 K the root mean square velocity of the gas molecules is v, at 480 K it becomes (1996)
(a) 4 v
(b) 2 v
(c) v/2
(d) v/4

45. Three closed vessels A, B and C at the same temperature T and contain gases which obey the Maxwellian distribution of velocities. Vessel A contains only O_2, B only N_2 and C a mixture of equal quantities of O_2 and N_2. If the average speed of the O_2 molecules in vessel A is v_1, that of the N_2 molecules in vessel B is v_2, the average speed of the O_2 molecules in vessel C is (1992)
(a) $(v_1 + v_2)/2$
(b) v_1
(c) $(v_1 v_2)^{1/2}$
(d) $\sqrt{3kT/M}$ where, M is the mass of an oxygen molecule.

46. If one mole of a monoatomic gas (γ = 5/ 3) is mixed with one mole of a diatomic gas (γ = 7/ 5), the value of γ for the mixture is (1988)
(a) 1.40
(b) 1.50
(c) 1.53
(d) 3.07

47. At room temperature, the rms speed of the molecules of a certain diatomic gas is found to be 1930 m/s. The gas is
(a) H_2
(b) F_2
(c) O_2
(d) Cl_2

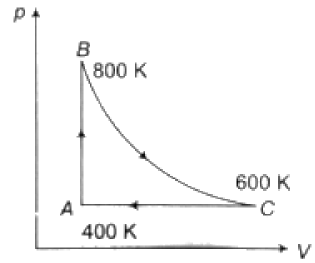
48. n moles of an ideal gas undergoes a process A and B as shown in the figure. The maximum temperature of the gas during the process will be (2016)



(a) $\frac{9}{4}\frac{p_0 v_0}{nR}$
(b) $\frac{3}{2}\frac{p_0 v_0}{nR}$
(c) $\frac{9}{2}\frac{p_0 v_0}{nR}$

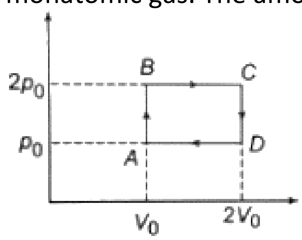
(d) $\frac{9p_0v_0}{nR}$

49. One mole of diatomic ideal gas undergoes a cyclic process ABC as shown in figure. The process BC is adiabatic. The temperatures at A, B and C are 400 K, 800 K and 600 K. respectively. Choose the correct statement. (2014)



(a) The change in internal energy in whole cyclic process is 250 R
(b) The change in internal energy in the process CA is 700 R
(c) The change in internal energy in the process AB is -350 R
(d) The change in internal energy in the process BC is -500 R

50. The shown p-V diagram represents the thermodynamic cycle of an engine, operating with an ideal monatomic gas. The amount of heat, extracted from the source in a single cycle is (2013)



(a) p_0v_0

(b) $\left(\frac{13}{2}\right)p_0v_0$

(c) $\left(\frac{11}{2}\right)p_0v_0$

(d) $4p_0v_0$

51. 5.6 L of helium gas at STP is adiabatically compressed to 0.7 L. Taking the initial temperature to be T1, the work done in the process is (2011)

(a) $\frac{9}{8}RT_1$

(b) $\frac{3}{2}RT_1$

(c) $\frac{15}{8}RT_1$

(d) $\frac{9}{2}RT_1$

52. An ideal gas expands isothermally from a volume V_1 to V_2 and then compressed to original volume V_1 adiabatically. Initial pressure is p_1 and final pressure is p_3. The total work done is W. Then,
(2004)

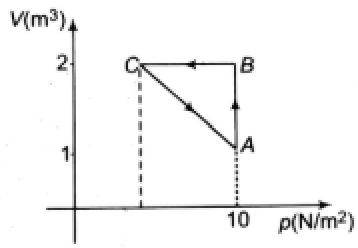
(a) $p_3 > p_1, W > 0$

(b) $p_3 < p_1, W > 0$

(c) $p_3 > p_1, W < 0$

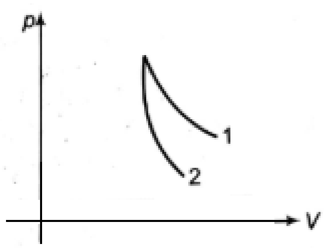
(d) $p_3 = p_1, W > 0$

53. An ideal gas is taken through the cycle $A \to B \to C \to A$, as shown in the figure. If the net heat supplied to the gas in the cycle is 5 J, the work done by the gas in the process $C \to A$ is (2002)



(a) -5 J
(b) -10 J
(c) -15 J
(d) -20 J

54. p-V plots for two gases during adiabatic processes are shown in the figure. Plots 1 and 2 should correspond respectively to (2001)



(a) He and O
(b) O_2 and He
(c) He and Ar
(d) O_2 and N_2

55. Starting with the same initial conditions, an ideal gas expands from volume V_1 to V_2 in three different ways, the work done by the gas is W_1 if the process is purely isothermal, W_2 if purely isobaric and W_3 if purely adiabatic, then (2000)

(a) $W_2 > W_1 > W_3$

(b) $W_2 > W_3 > W_1$

(c) $W_1 > W_2 > W_3$

(d) $W_1 > W_3 > W_2$

56. A monoatomic ideal gas, initially at temperature T_1, is enclosed in a cylinder fined with a frictionless piston. The gas is allowed to expand adiabatically to a temperature T_2 by releasing the piston suddenly. If L_1 and L_2 are the lengths of the gas column before and after expansion respectively, then T_1/T_2 is given by (2000)

(a) $(L_1 / L_2)^{2/3}$

(b) (L_1 / L_2)

(c) L_2 / L_1

(d) $(L_2 / L_1)^{2/3}$

57. Two cylinders A and B fitted with pistons contain equal amounts of an ideal diatomic gas at 300 K. The piston of A is free to move, while that of 8 is held fixed. The same amount of heat is given to the gas in each cylinder. If the rise in temperature of the gas in A is 30 K. then the rise in temperature of the gas in B is (1998)

(a) 30 K
(b) 18 K
(c) 50 K
(d) 42 K

58. When an ideal diatomic gas is heated at constant pressure the fraction of the heat energy supplied which increases the internal energy of the gas is (1990)

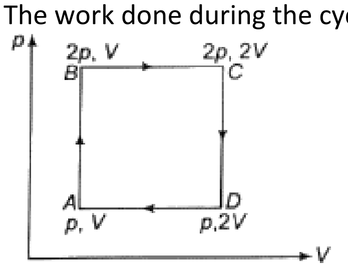
(a) $\frac{2}{5}$

(b) $\frac{3}{5}$

(c) $\frac{3}{7}$

(d) $\frac{5}{7}$

59. An ideal monoatomic gas is taken round the cycle ABCDA as shown in the p-V diagram (see figure). The work done during the cycle is (1983)



(a) PV
(b) 2 PV
(c) 1/2 PV
(d) zero

60. Consider a spherical shell of radius R at temperature T. The black body radiation inside it can be considered as an ideal gas of photons with internal energy per unit volume $u = \frac{U}{V} \propto T^4$ and pressure $p = \frac{1}{3}\left(\frac{U}{V}\right)$. If the shell now undergoes an adiabatic expression, the relation between T and R is (2015)

(a) $T \propto e^{-R}$

(b) $T \propto \frac{1}{R}$

(c) $T \propto e^{-3R}$

(d) $T \propto \frac{1}{R^3}$

61. Consider an ideal gas confined in an isolated closed chamber. As the gas undergoes an adiabatic expansion, the average time of collision between molecules increases as V^q, where V is the volume of the gas. The value of q is $\left(\gamma = \frac{C_P}{C_V}\right)$ (2015)

(a) $\frac{3\gamma+5}{6}$

(b) $\frac{\gamma+1}{2}$

(c) $\frac{3\gamma-5}{6}$

(d) $\frac{\gamma-1}{2}$

62. A solid body of constant heat capacity 1 J/^{0}C is being heated by keeping it in contact with reservoirs in two ways

(i) Sequentially keeping in contact with 2 reservoirs such that each reservoir supplies same amount of heat.

(ii) Sequentially keeping in contact with 8 reservoirs such that each reservoir supplies same amount of heal.

In both the cases. body is brought from initial temperature 100^{0}C to final temperature 200^{0}C. Entropy change of the body in the two cases respectively, is (2015)

(a) *In* 2, *In* 2

(b) *In* 2, 2 *In* 2

(c) 2*In* 2, 8 *In* 2

(d) *In* 2, 4 *In* 2

63. An ideal gas enclosed in a vertical 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 (2013)

(a) $\frac{1}{2\pi}\frac{A_\gamma p_0}{V_0 M}$

(b) $\frac{1}{2\pi}\frac{V_0 M p_0}{A^2\gamma}$

(c) $\frac{1}{2\pi}\sqrt{\frac{A^2\gamma p_0}{MV_0}}$

(d) $\frac{1}{2\pi}\sqrt{\frac{MV_0}{A_\gamma p_0}}$

64. Two moles of ideal helium gas are in a rubber balloon at 30^0C. The balloon is fully expandable and can be assumed to require no energy in its expansion. The temperature of the gas in the balloon is slowly changed to 35^0C. The amount of heat required in raising the temperature is nearly (take R = 8.31 J/mol-K) (2012)

(a) 62 J
(b) 104 J
(c) 124 J
(d) 208 J

65. An ideal gas is expanding such that pT^2 = constant. The coefficient of volume expansion of the gas is (2008)

(a) $\frac{1}{T}$

(b) $\frac{2}{T}$

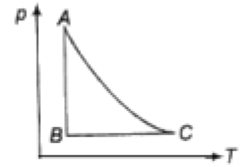
(c) $\frac{3}{T}$

(d) $\frac{4}{T}$

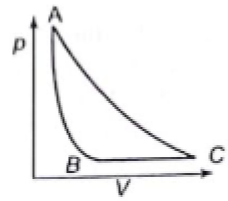
66. In a thermodynamics process, pressure of a fixed mass of gas is changed in such a manner that the gas releases 20 J of heat and 8 J of work is done on the gas. If internal energy of the gas was 30 J, then the final internal energy will be

(a) 42 J
(b) 18 J
(c) 12 J
(d) 60 J

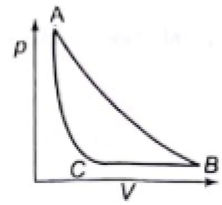
67. The p-T diagram for an ideal gas is shown in the figure, where AC is an adiabatic process, find the corresponding p-V diagram (2003)



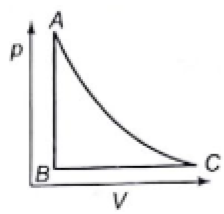
(a)



(b)



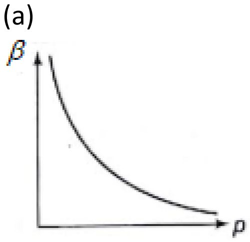
(c)



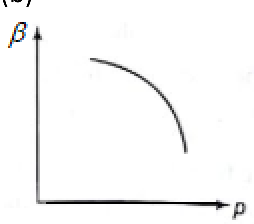
(d) None of the above

68. Which of the following graphs correctly represent the variation of $\beta = -\dfrac{dV/dp}{V}$ with p for an ideal gas at constant temperature ? (2002)

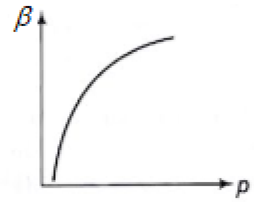
(a)



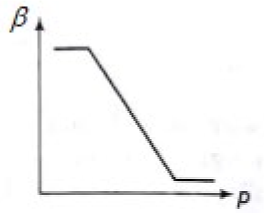
(b)



(c)

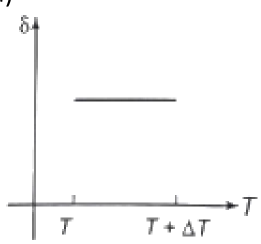


(d)

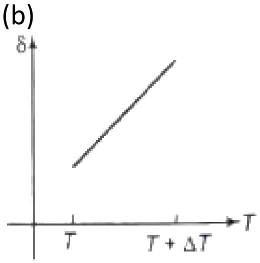


69. In a given process of an ideal gas, dW = 0 and dQ < 0. Then for the gas (2001)
(a) the temperature will decrease
(b) the volume will increase
(c) the pressure will remain constant
(d) the temperature will increase

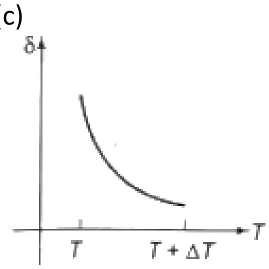
70. An ideal gas is initially at temperature T and volume V. Its volume is increased by ΔV due to an increase in temperature ΔT, pressure remaining constant. The quantity δ = ΔV/VΔT varies with temperature as (2000)
(a)



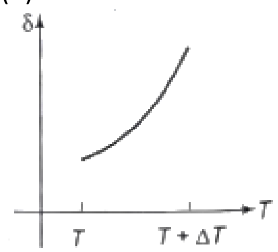
(b)



(c)



(d)



71. The ratio of the slopes of p-V graphs of adiabatic and isothermal

(a) $\frac{\gamma-1}{\gamma}$

(b) $\gamma-1$

(c) $\gamma/1$

(d) γ

72. An ideal gas at a pressure 1 atm and temperature of 27°C is compressed adiabatically until its pressure becomes 8 times the initial pressure. Then, the final temperature is $\left(\gamma=\frac{3}{2}\right)$

(a) 627^0 C

(b) 527^0 C

(c) 427^0 C

(d) 327^0 C

73. A cylinder with a movable piston contains 3 moles of hydrogen at standard temperature and pressure. The walls of the cylinder are made of 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?

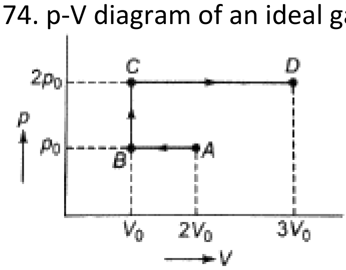
(a) 1.40

(b) 1.60

(c) 2.64

(d) 1.94

74. p-V diagram of an ideal gas is as shown in figure. Work done by the gas in the process ABCD is



(a) $4PV_0$

(b) $2P_0V$

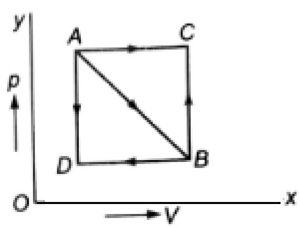
(c) $3P_0V_0$

(d) P_0V_0

75. If for hydrogen C_P - C_V = m and for the nitrogen C_P - C_V = n, where C_P, C_V refer to specific heats per unit mass respectively at constant pressure an constant volume, the relation between m and n is
(a) m = 14 n
(b) n = 7 n
(c) m = 7 n
(d) n = 14 n

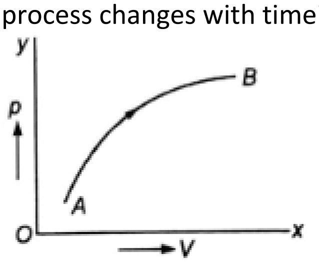
76. If an average person jogs, hse produces 14.5×10^3 cal/min. This is removed by the evaporation of sweat. The amount of sweat evaporated per minute (assuming 1 kg requires 580×10^3 cal for evaporation) is
(a) 0.25 kg
(b) 2.25 kg
(c) 0.05 kg
(d) 0.20 kg

77. An ideal gas is taken from state A to state B following three different paths as shown in p-V diagram. Which one of the following is true?



(a) Work done is maximum along AB
(b) Work done is minimum along AB
(c) Work done along ACB = work done along ADB
(d) Work done along ADB is minimum

78. Figure shows a thermodynamic process on one mole of a gas. How does the work done in the process changes with time?



(a) decreases continuously
(b) increases continuously
(c) remains constant
(d) first increases and then decreases

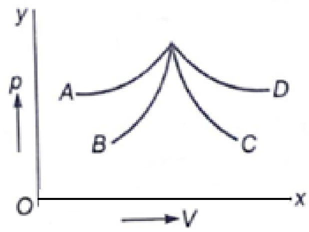
79. During an adiabatic process, the pressure p of a fixed mass of an ideal gas changes by Δp and its volume V changes by ΔV. If $\gamma = C_P / C_V$, then $\Delta V/V$ is given by
(a) $-\frac{\Delta p}{p}$

(b) $-\gamma \frac{\Delta p}{p}$

(c) $-\frac{\Delta p}{\gamma p}$

(d) $\frac{\Delta p}{\gamma^2 p}$

80. Figure shows four p-V diagrams. Which of these curves represent isothermal and adiabatic process?



(a) D and C
(b) A and C
(c) A and B
(d) B and D

ANSWERS

1. (b) 2. (b) 3. (c) 4. (b) 5. (a) 6. (a) 7. (a) 8. (c) 9. (b) 10. (a) 11. (a) 12. (b) 13. (d) 14. (a) 15. (c) 16. (a) 17. (c) 18. (c) 19. (c) 20. (c) 21. (c) 22. (b) 23. (c) 24. (c) 25. (a) 26. (b) 27. (b) 28. (d) 29. (d) 30. (b) 31. (d) 32. (b) 33. (c) 34. (c) 35. (b) 36. (d) 37. (d) 38. (d) 39. (c) 40. (a) 41. (c) 42. (c) 43. (d) 44. (b) 45. (b) 46. (b) 47. (a) 48. (a) 49. (d) 50. (b) 51. (a) 52. (c) 53. (a) 54. (b) 55. (a) 56. (d) 57. (d) 58. (d) 59. (a) 60. (b) 61. (b) 62. (a) 63. (c) 64. (d) 65. (c) 66. (b) 67. (d) 68. (a) 69. (a) 70. (c) 71. (d) 72. (d) 73. (c) 74. (c) 75. (a) 76. (a) 77. (d) 78. (b) 79. (c) 80. (a)

"Detail solutions are mentioned in the content library"