Elasticity, Thermal Expansion, Calorimetry , Heat Transfer

1. Two identical rods made of two different metals A and B with thermal conductivities K_A and K_B respectively are joined end to end. The free end of A is kept at a temperature T_1 while the free end of B is kept at a temperature T_2 ($< T_1$). Therefore, in the steady state **[NSEP-2017]**

(A) the temperature of the junction will be determined only by K_A and K_B

(B) if the lengths of the rods are doubled the rate of heat flow will be halved.

(C) if the temperature at the two free ends are interchanged the junction temperature will change

(D) the composite rod has an equivalent thermal conductivity of $\frac{2K_AK_B}{K_A + K_B}$

2. A small pond of depth 0.5 m deep is exposed to a cold winter with outside temperature of 263 K. Thermal conductivity of ice is $K = 2.2\ W\ m^{-1}\ K^{-1}$, latent heat $L = 3.4 \times 10^5\ Jkg^{-1}$ and density $\rho = 0.9 \times 10^3\ kgm^{-3}$. Take the temperature of the pond to be 273 K. The time taken for the whole pond to freeze is about. **[NSEP-2017]**

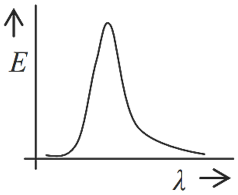
(A) 20 days (B) 25 days (C) 30 days (D) 35 days

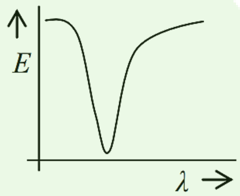
3. Under standard conditions of temperature and pressure a piece of ice melts completely on heating it. Obviously, the increase in internal energy of the system (ice and water) is: **[NSEP-2018]**

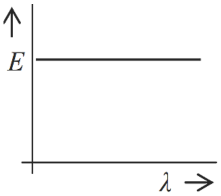
(A) equal to the heat given. (B) more than the heat given.

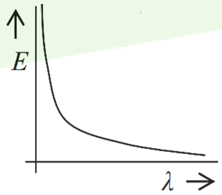
(C) less than the heat given. (D) zero.

4. Which of the following curves represents spectral distribution of energy of black body radiation? **[NSEP-2018]**

(A) 

(B) 

(C) 

(D) 

5. A sphere and a cube having equal surface area are made of the same material. The two are heated to the same temperature and kept in identical surroundings. The ratio of their initial rates of cooling is: **[NSEP-2018]**

(A) 1 : 1 (B) $\sqrt{\frac{\pi}{2}} : 1$ (C) $\sqrt{\frac{\pi}{3}} : 1$ (D) $\sqrt{\frac{\pi}{6}} : 1$

6. The Sun having radius R and surface temperature T, emits radiation as a perfect emitter. The distance of the earth from the sun is r and the radius of the earth is R_e. The total radiant power incident on the earth is: **[NSEP-2018]**

(A) $\frac{R_e^2R^2\sigma T^4}{4\pi r^2}$ (B) $\frac{R_e^2R^2\sigma T^4}{r^2}$ (C) $\frac{4\pi R_e^2R^2\sigma T^4}{r^2}$ (D) $\frac{\pi R_e^2R^2\sigma T^4}{r^2}$

7. A steel cooking pan has copper coating at its bottom. The thickness of copper coating is half the thickness of steel bottom. The conductivity of copper is three times that of steel. If the temperature of blue flame is 119°C and that of the interior of the cooking pan is 91°C, then the temperature at the interface between the steel bottom and the copper coating in the steady state is: **[NSEP-2018]**

(A) 98°C (B) 103°C (C) 115°C (D) 108°C

8. Consider the following physical expressions **[NSEP-2019]**

(I) ρv^2 (ρ: density, v: velocity)

(II) $\frac{Y\Delta L}{L}$ (Y: Young's modulus, L: length)

(III) $\frac{\sigma^2}{\varepsilon_0}$ (σ: surface density of charge)

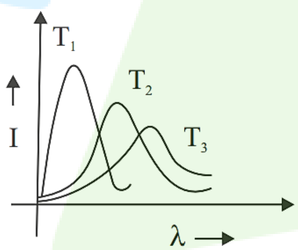
(iv) $h\rho rg$ (h: rise of a liquid in a capillary tube of radius r)

The expressions having same dimensional formula are

(A) I and II only (B) II and III only

(C) II, III and IV only (D) I, II and III only

9. Plots of intensity (I) of radiation emitted by a black body versus wavelength (λ) at three different temperatures T_1, T_2 and T_3 respectively are shown in figure. Choose the correct statement. **[NSEP-2019]**



(A) $T_1 > T_2 > T_3$ necessarily (B) $T_3 > T_2 > T_1$ necessarily

(C) $T_2 = (T_1 + T_3)/2$ necessarily (D) $T_2^2 > T_2 > T_3$ necessarily

10. Consider a composite slab consisting of two different materials having equal thickness and equal area of cross-section. The thermal conductivities are K and 2K respectively. The equivalent thermal conductivity of the composite slab is: **[NSEP-2019]**

(A) $\frac{2K}{3}$ (B) $\sqrt{2}$ K (C) 3K (D) $\frac{4K}{3}$

11. The temperature of an isolated black body falls from T_1 to T_2 in time t. Then, t = C x where x is **[NSEP-2019]**

(A) $\left(\frac{1}{T_2}-\frac{1}{T_1}\right)$ (B) $\left(\frac{1}{T_2^2}-\frac{1}{T_1^2}\right)$ (C) $\left(\frac{1}{T_2^3}-\frac{1}{T_1^3}\right)$ (D) $\left(\frac{1}{T_2^4}-\frac{1}{T_1^4}\right)$

12. Heat is absorbed or evolved when current flows in a conductor having a temperature gradient. This phenomenon is known as **[NSEP-2019]**

(A) Joule effect (B) Peltier effect

(C) Seeback effect (D) Thomson effect

13. Three containers A, B and C are filled with water at different temperature. When 1 litre of water from A is mixed with 2 litre of water from B, the resulting temperature of mixture is $52^\circ C$. When 1 litre of water from B is mixed with 2 litre of water from C, the resulting temperature of mixture is $40^\circ C$. Similarly when 1 litre of water from C is mixed with 2 litre of water from A, the resulting temperature of mixture is $34^\circ C$. Temperature of mixture when one litre of water from each container is mixed (neglect the water equivalent of container) is **[NSEP-2020]**

(A) $40^\circ C$ (B) $42^\circ C$ (C) $38^\circ C$ (D) $45^\circ C$

14. What amount of heat will be generated in a coil of resistance R(ohm) due to a total charge Q (coulomb) passing through it if the current in the coil decreases down to zero halving its value every Δt second? **[NSEP-2020]**

(A) $\frac{1}{2}\frac{Q^2R}{\Delta t}$ (B) $\frac{Q^2R}{\Delta t}\ln 2$ (C) $\frac{1}{2}\frac{Q^2R}{\Delta t}\ln 2$ (D) $\frac{1}{4}\frac{Q^2R}{\Delta t}$

15. Consider the process of the melting of a spherical ball of ice originally at 0° Assuming that the heat is being absorbed uniformly through the surface and the rate of absorption is proportional to the instantaneous surface area. Which of the following is true for the radius (r) of the ice ball at any instant of time? Assume that the initial radius of the ice ball at $t = 0$ is $r = R_0$ and that the shape of the ball always remains spherical during melting. Also assume that L and ρ are respectively the latent heat and density of ice at 0° **[NSEP-2021]**

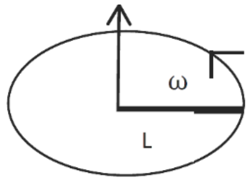
(A) radius decreases exponentially with time as $r = R_0 e^{-\frac{kt}{\rho L}}$. Here k is constant

(B) radius decreases exponentially with time as $r = R_0 e^{-\frac{k\rho t}{2L}}$

(C) radius of the ice ball decreases with time linearly with a slope $-\frac{k}{\rho L}$

(D) radius of the ice ball decreases with time linearly with a slope $-\frac{k\rho}{2L}$

16. A thin uniform metallic rod of length L and radius R rotates with an angular velocity ω in a horizontal plane about a vertical axis passing through one of its ends. The density and the Young's modulus of the material of the rod are ρ and Y respectively. The elongation in its length is **[NSEP-2021]**



(A) $\frac{\rho\omega^2L^3}{6Y}$ (B) $\frac{\rho\omega^2L^3}{3Y}$ (C) $\frac{\rho\omega^2RL^2}{2Y}$ (D) $\frac{\rho\omega^2L^3}{2Y}$

17. A certain rod of uniform area of cross section $A\left(A = 1.0\text{cm}^2\right)$ with its length $= 2\text{m}$ is thermally insulated on its lateral surface. The thermal conductivity (K) of the material of the rod varies with temperature T as $K = \frac{\alpha}{T}$ where α is a constant. The two ends of the rod are maintained at temperature of $T_1 = 90^\circ$ and $T_2 = 10^\circ$... The correct option(s) is /are **[NSEP-2021]**

(A) The temperature at 50cm from the colder end is 17.32° -

(B) The temperature at 50cm from the hotter end is 51.96° -

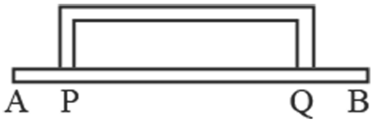
(C) The rate of heat flow per unit area of cross section of the rod is 1.1α in SI units.

(D) The temperature gradient is numerically higher near the hot end compare to that near the cold end.

18. Solar constant for Earth is 2.0 cal per cm² per minute. [1cal = 4.2 J]. Angular diameter of the Sun (as seen from the Earth) is $\frac{1^\circ}{2}$ (= half a degree). Treating Sun as a black body, its surface temperature is estimated to be nearly **[NSEP-2022]**

(A) 6000 K (B) 5800 K (C) 6200 K (D) 5500 K

19. End A of a uniform thin rod of length 2L is in boiling water (100ºC and end B is in melting ice (0ºC). P and Q are two points at distance $\frac{L}{2}$ from A and B respectively. A similar bent rod of length $\frac{3L}{2}$ of same material and equal cross section is joined to rod AB between points P and Q as shown in figure. Then **[NSEP-2022]**



(A) Temperature at P will increase and that at Q will decrease

(B) Rate of flow of heat will increase by 25%

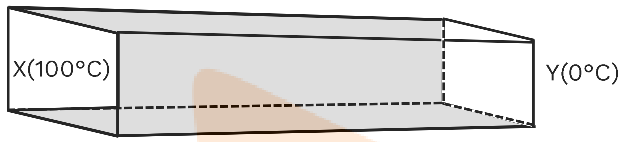
(C) Rate of flow of heat will decrease by 20%

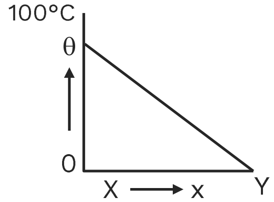
(D) Rate of heat flow will increase by 37.5T

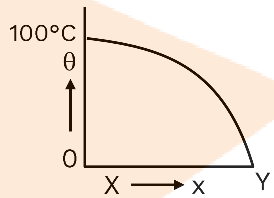
20. A uniform rod of the material of Young's modulus Y is pushed over a smooth horizontal surface by a constant horizontal force F. The area of cross-section of the rod is A. The compressional strain in the rod is **[NSEP-2022]**

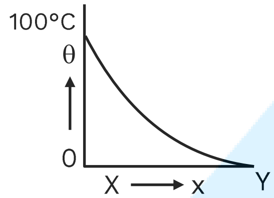
(A) $\frac{F}{AY}$ (B) $\frac{F}{2AY}$ (C) $\frac{3F}{2AY}$ (D) $\frac{2F}{AY}$

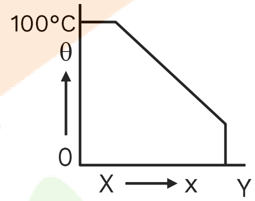
21. The figure shows a lagged bar XY of non-uniform cross section. One end X of the bar is maintained at $100^\circ C$ and the other end Y at $0^\circ C$. The variation of temperature along its length from X to Y in steady state is best represented by the curve. **[NSEP-2023]**



(A) 

(B) 

(C) 

(D) 

22. Assuming the Sun to be a spherical body (radius R_S) of surface temperature T, the total radiation power received by Earth (radius R_E) at a distance r from Sun is **[NSEP-2023]**

(A) $\frac{\sigma\pi R_E^2 R_s^2 T^4}{r^2}$ (B) $\frac{\sigma 4\pi R_E^2 R_S^2 T^4}{r^2}$ (C) $\frac{\sigma\pi R_E^2 R_S^2 T^4}{4r^2}$ (D) $\frac{\sigma R_E^2 R_s^2 T^4}{4\pi r^2}$

KTG And Thermodynamics

1. If a system is made to undergo a change from an initial state to a final state by adiabatic process only, then **[NSEP-2017]**

(A) the work done is different for different paths connecting the two states

(B) there is no work done since there is no transfer of heat

(C) the internal energy of the system will change

(D) the work done is the same for all adiabatic paths.

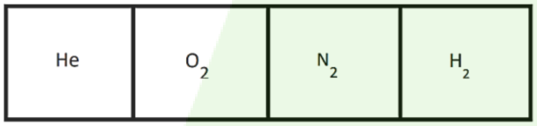
2. Two moles of hydrogen are mixed with n moles of helium. The root mean square speed of gas molecules in the mixture is $\sqrt{2}$ times the speed of sound in the mixture. Then n is. **[NSEP-2017]**

(A) 3 (B) 2 (C) 1.5 (D) 2.5

3. The molar specific heat of an ideal gas in a certain thermodynamic process is $\frac{\alpha}{T}$ where α is a constant. If the adiabatic exponent is $\gamma = \frac{c_p}{c_v}$, the work done in heating the gas from T_0 to nT_0 is. **[NSEP-2018]**

(A) $\frac{1}{\alpha}\ell nn$ (B) $\alpha\ell nn - \frac{(n-1)}{(\gamma-1)}RT_0$ (C) $\alpha\ell nn - (\gamma-1)RT_0$ (D) $\frac{(n-1)}{(\gamma-1)}RT_0$

4. A horizontal insulated cylinder of volume V is divided into four identical compartments by stationary semi-permeable thin partitions as shown. The four compartments from left are initially filled with 28 g helium, 160 g oxygen, 28 g nitrogen and 20 g hydrogen respectively. The left partition lets through hydrogen, nitrogen and helium while the right partition lets through hydrogen only. The middle partition lets through hydrogen and nitrogen both. The temperature T inside the entire cylinder is maintained constant. After the system is set in equilibrium, **[NSEP-2018]**



(A) pressure of helium is $\frac{14RT}{V}$ (B) pressure of oxygen is $\frac{20RT}{V}$

(C) pressure of nitrogen is $\frac{4RT}{3V}$ (D) pressure of hydrogen is $\frac{10RT}{V}$

5. The average translational kinetic energy of oxygen (M = 32) molecules at a certain temperature is 0.048 eV. The translational kinetic energy of nitrogen (M = 28) molecules at the same temperature is (consider the two gases to be ideal) **[NSEP-2019]**

(A) 0.0015 eV (B) 0.042 eV (C) 0.048 eV (D) 0.768 eV

6. If the average mass of a smoke particle in an Indian kitchen 3×10^{-17} kg, the rms speed of the smoke particles at 27°C is approximately **[NSEP-2019]**

(A) 2 cm/sec (B) 2 m/sec (C) 2 km/sec (D) none of these

7. In a real gas **[NSEP-2019]**

(A) the force of attraction between the molecules depends upon intermolecular distance.

(B) internal energy depends only upon temperature.

(C) internal energy is a function of both temperature and volume.

(D) internal energy is a function of both temperature and pressure.

8. One mole of a gas with $\gamma = \frac{5}{3}$ is mixed with two moles of another non-interacting gas with $\gamma = \frac{7}{5}$

The ratio of specific heats $\gamma = \frac{C_P}{C_V}$ of mixture is approximately **[NSEP-2020]**

(A) 1.50 (B) 1.46 (C) 1.49 (D) 1.53

9. An ideal gas is expanding such that PT^3 = constant. The coefficient of volume expansion of the gas is **[NSEP-2020]**

(A) $\frac{1}{T}$ (B) $\frac{2}{T}$ (C) $\frac{3}{T}$ (D) $\frac{4}{T}$

10. An ideal monatomic gas is confined within a cylinder by a spring loaded piston of cross-sectional area $4 \times 10^{-3}\,m^2$. Initially the gas is at $400K$ and occupies a volume $2 \times 10^{-3}\,m^3$ and the spring is in its relaxed position. The gas is heated by an electric heater for some time. During this time the gas expands and the piston moves out by a distance $0.1m$. The spring connected to the rigid wall is massless and frictionless. The force constant of the spring is $2000 Nm^{-1}$ and atmospheric pressure is $10^5 Nm^{-2}$ then **[NSEP-2020]**

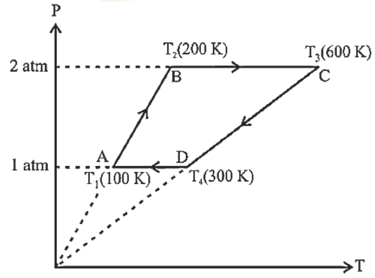
(A) The final temperature of the gas is $720K$.

(B) The work done by gas in expanding is $50J$

(C) The heat supplied by heater is $190J$

(D) The heat supplied by heater is $290J$

11. The work done by the three moles of an ideal gas in the cyclic process ABCD shown in the diagram is approximately. Given that **[NSEP-2021]**



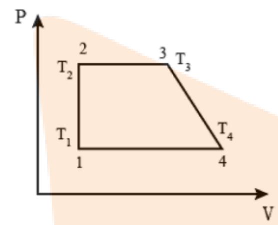
$T_1 = 100$ K, $T_2 = 200$ K and $T_3 = 600$ K, $T_4 = 300$ K

(A) 7.5 kJ (B) 5.0 kJ (C) 2.5 kJ (D) Zero

12. The molar specific heat capacity of a certain gas is expressed as $C = C_V + \alpha\frac{P}{T}$. The equation of state for the process can be written as (α and Aare constant) **[NSEP-2021]**

(A) $PV = RT$ (B) $V = \alpha T^2$ (C) $V^2 = \alpha \ln T$ (D) $T = Ae^{\frac{V}{\alpha}}$

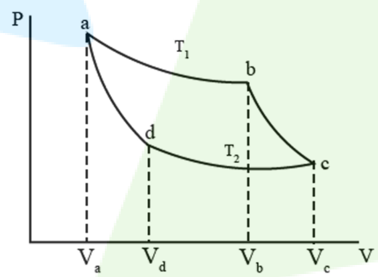
13. A cyclic process 1-2-3-4-1 consisting of two isobars 2 – 3 and 4 – 1, an isochor 1 – 2 and a process 3 – 4 represented by straight line on a P – V diagram, as shown in figure, involves n moles of an ideal gas. The gas temperatures at states 1,2,3 & 4 are T_1, T_2, T_3 and T_4 respectively. Also points 3 and 4 lie on the same isotherm. The work done by gas during the cycle is **[NSEP-2022]**



(A) $\frac{1}{2}nR(T_2 - T_1)\left(\frac{T_2}{T_1} + \frac{T_3}{T_4} - 2\right)$ (B) $\frac{1}{2}nR(T_3 - T_2)\left(\frac{T_3}{T_2} + \frac{T_4}{T_1} - 2\right)$

(C) $\frac{1}{2}nR(T_2 - T_1)\left(\frac{T_3}{T_1} + \frac{T_3}{T_2} - 2\right)$ (D) Zero

14. Two identical Carnot (cycles) engines oprate between maximum and minimum temperatures T_1 and T_2 volume limits, V_a, V_b, V_c, & V_d as shown in figure. Given that $\frac{V_c}{V_a} = e^3$ and $\frac{T_1}{T_2} = e$ (e is the base of natural logarithm). Engine 1 operates on mono atomic gas while engine 2 on diatomic gas. Choose correct alternatives **[NSEP-2022]**



(A) Ratio of volumes $\frac{V_{b,1}}{V_{b,2}} = e$

(B) Ratio of work done per cycle of the two is $\frac{W_1}{W_2}$ =3

(C) Ratio of work done per cycle for the two is $\frac{W_1}{W_2} = 1$

(D) Ratio of efficiencies (η) of two engines $\frac{\eta_1}{\eta_2} = 1$

15. Two Carnot heat engines are connected in series such that the sink of the first engine is heat source of the second. Efficiency of the engines are η_1 and η_2 respectively. Net efficiency η of the combination is given by **[NSEP-2023]**

(A) $\eta = \eta_1 + \eta_2$ (B) $\eta = \frac{\eta_1\eta_2}{\eta_1 + \eta_2}$ (C) $\eta = \eta_1 + \eta_2(1-\eta_1)$ (D) $\eta = \eta_1 - \eta_2(1-\eta_1)$

16. An ideal gas (n moles) is initially at pressure P and temperature T. It is cooled isochorically to a pressure $\frac{P}{4}$. The gas is then expanded at a constant pressure so as to attain back its initial temperature T. Work done by gas during the entire process is **[NSEP-2023]**

(A) $\frac{5}{4}$nRT (B) $\frac{3}{4}$nRT (C) $\frac{1}{4}$nRT (D) Zero

17. Two moles of nitrogen in a container, of negligible thermal capacity, are initially at 17°C. The gas is compressed adiabatically from an initial volume of 120 liter to 80 liter. The correct option(s) is/are **[NSEP-2023]**

(A) Initial pressure of the gas is nearly 40.2kPa

(B) Final temperature of the gas is nearly 68°C

(C) Work done by the gas is 2.12 kJ

(D) The internal energy of the gas increases by 2.12 kJ