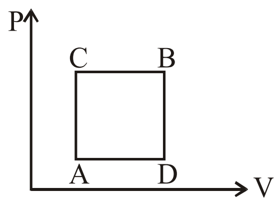
HEAT & THERMODYNAMICS

1. A 15 g mass of nitrogen gas is enclosed in a vessel at a temperature 27°C. Amount of heat transferred to the gas, so that rms velocity of molecules is doubled, is about :
[Take R = 8.3 J/ K mole]
(1) 10 kJ
(2) 0.9 kJ
(3) 6 kJ
(4) 14 kJ

2. Two Carrnot engines A and B are operated in series. The first one, A, receives heat at T_1(= 600 K) and rejects to a reservoir at temperature T_2. The second engine B receives heat rejected by the first engine and, in turn, rejects to a heat reservoir at T_3(= 400 K). Calculate the temperature T_2 if the work outputs of the two engines are equal :
(1) 400 K (2) 600 K
(3) 500 K (4) 300 K

3. A gas can be taken from A to B via two different processes ACB and ADB. When path ACB is used 60 J of heat flows into the system and 30 J of work is done by the system. If path ADB is used work done by the system is 10 J. The heat Flow into the system in path ADB is:

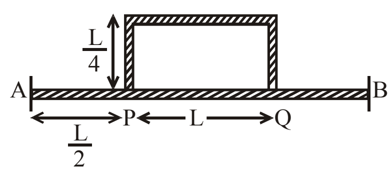


(1) 80 J (2) 20 J
(3) 100 J (4) 40 J

4. A mixture of 2 moles of helium gas (atomic mass = 4 u), and 1 mole of argon gas (atomic mass = 40 u) is kept at 300 K in a container. The ratio of their rms speeds $\left[\frac{V_{rms}(\text{helium})}{V_{rms}((\text{argon})}\right]$, is close to:
(1) 2.24 (2) 0.45
(3) 0.32 (4) 3.16

5. A rod, of length L at room temperature and uniform area of cross section A, is made of a metal having coefficient of linear expansion α/°C. It is observed that an external compressive force F, is applied on each of its ends, prevents any change in the length of the rod, when its temperature rises by ΔT K. Young's modulus, Y, for this metal is :
(1) $\frac{F}{2A\alpha\Delta T}$
(2) $\frac{F}{A\alpha(\Delta T-273)}$
(3) $\frac{F}{A\alpha\Delta T}$
(4) $\frac{2F}{A\alpha\Delta T}$

6. Temperature difference of 120°C is maintained between two ends of a uniform rod AB of length 2L. Another bent rod PQ, of same cross-section as AB and length $\frac{3L}{2}$, is connected across AB (See figure). In steady state, temperature difference between P and Q will be close to :



(1) 60°C (2) 75°C (3) 35°C (4) 45°C

7. An unknown metal of mass 192 g heated to a temperature of 100ºC was immersed into a brass calorimeter of mass 128 g containing 240 g of water a temperature of 8.4ºC Calculate the specific heat of the unknown metal if water temperature stabilizes at 21.5ºC (Specific heat of brass is 394 J kg^{-1} K^{-1})

(1) 1232 J kg^{-1} K^{-1}

(2) 458 J kg^{-1} K^{-1}

(3) 654 J kg^{-1} K^{-1}

(4) 916 J kg^{-1} K^{-1}

8. Half mole of an ideal monoatomic gas is heated at constant pressure of 1atm from 20 ºC to 90ºC. Work done by gas is close to : (Gas constant R = 8.31 J /mol.K)

(1) 73 J (2) 291 J

(3) 581 J (4) 146 J

9. Two kg of a monoatomic gas is at a pressure of 4×10^4 N/m^2 . The density of the gas is 8 kg /m^3. What is the order of energy of the gas due to its thermal motion ?

(1) 10^3 J (2) 10^5 J

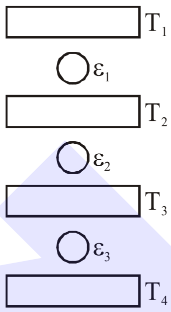
(3) 10^6 J (4) 10^4 J

10. A heat source at $T = 10^3$ K is connected to another heat reservoir at $T = 10^2$ K by a copper slab which is 1 m thick. Given that the thermal conductivity of copper is 0.1 WK^{-1} m^{-1}, the energy flux through it in the steady state is :

(1) 90 Wm^{-2} (2) 200 Wm^{-2}

(3) 65 Wm^{-2} (4) 120 Wm^{-2}

11. Three Carnot engines operate in series between a heat source at a temperature T_1 and a heat sink at temperature T_4 (see figure). There are two other reservoirs at temperature T_2, and T_3, as shown, with $T_2 > T_2 > T_3 > T_4$. The three engines are equally efficient if:



(1) $T_2 = \left(T_1^2 T_4\right)^{1/3}; T_3 = \left(T_1 T_4^2\right)^{1/3}$

(2) $T_2 = \left(T_1 T_4^2\right)^{1/3}; T_3 = \left(T_1^2 T_4\right)^{1/3}$

(3) $T_2 = \left(T_1^3 T_4\right)^{1/4}; T_3 = \left(T_1 T_4^3\right)^{1/4}$

(4) $T_2 = (T_1 T_4)^{1/2}; T_3 = (T_1^2 T_4)^{1/3}$

12. Two rods A and B of identical dimensions are at temperature 30°C. If A is heated upto 180°C and B upto T°C, then the new lengths are the same. If the ratio of the coefficients of linear expansion of A and B is 4 : 3, then the value of T is :-

(1) 270°C (2) 230°C

(3) 250°C (4) 200°C

13. When 100 g of a liquid A at 100°C is added to 50 g of a liquid B at temperature 75°C, the temperature of the mixture becomes 90°C. The temperature of the mixture, if 100 g of liquid A at 100°C is added to 50 g of liquid B at 50°C, will be :-

(1) 80°C (2) 60°C

(3) 70°C (4) 85°C

14. A thermometer graduated according to a linear scale reads a value x_0 when in contact with boiling water, and $x_0/3$ when in contact with ice.

What is the temperature of an object in 0 °C, if this thermometer in the contact with the object reads $x_0/2$?

(1) 35 (2) 25
(3) 60 (4) 40

15. In a process, temperature and volume of one mole of an ideal monoatomic gas are varied according to the relation VT = K, where K is a constant. In this process the temperature of the gas is incresed by ΔT. The amount of heat absorbed by gas is (R is gas constant) :

(1) $\frac{1}{2}R\Delta T$ (2) $\frac{3}{2}R\Delta T$
(3) $\frac{1}{2}KR\Delta T$ (4) $\frac{2K}{3}\Delta T$

16. A metal ball of mass 0.1 kg is heated upto 500°C and dropped into a vessel of heat capacity 800 JK^{-1} and containing 0.5 kg water. The initial temperature of water and vessel is 30°C. What is the approximate percentage increment in the temperature of the water ? [Specific Heat Capacities of water and metal are, respectively, 4200 $Jkg^{-1}K^{-1}$ and 400 $JKg^{-1}K^{-1}$]

(1) 30% (2) 20%
(3) 25% (4) 15%

17. A rigid diatomic ideal gas undergoes an adiabatic process at room temperature. The relation between temperature and volume of this process is TV^x = constant, then x is :

(1) $\frac{5}{3}$ (2) $\frac{2}{5}$ (3) $\frac{2}{3}$ (4) $\frac{3}{5}$

18. The gas mixture constists of 3 moles of oxygen and 5 moles of argon at temperature T. Considering only translational and rotational modes, the total inernal energy of the system is:

(1) 12 RT (2) 20 RT
(3) 15 RT (4) 4 RT

19. Ice at –20° C os added tp 50 g of water at 40°C. When the temperature of the mixture reaches 0°C, it is found that 20 g of ice is still unmelted. The amount of ice added to the water was close to

(Specific heat of water = 4.2 J/g/°C)
Specific heat of Ice = 2.1 J/g/°C
Heat of fusion of water at 0°C = 334 J/g)

(1) 50 g (2) 40 g
(3) 60 g (4) 100 g

20. A vertical closed cylinder is separated into two parts by a frictionless piston of mass m and of negligible thickness. The piston is free to move along the length of the cylinder. The length of the cylinder above the piston is ℓ_1, and that below the piston is ℓ_2 , such that $\ell_1 > \ell_2$. Each part of the cylinder contains n moles of an ideal gas at equal temperature T. If the piston is stationary, its mass, m, will be given by :

(R is universal gas constant and g is the acceleration due to gravity)

(1) $\frac{nRT}{g}\left[\frac{1}{\ell_2}+\frac{1}{\ell_1}\right]$ (2) $\frac{nRT}{g}\left[\frac{\ell_1-\ell_2}{\ell_1\ell_2}\right]$
(3) $\frac{RT}{g}\left[\frac{2\ell_1+\ell_2}{\ell_1\ell_2}\right]$ (4) $\frac{RT}{ng}\left[\frac{\ell_1-3\ell_2}{\ell_1\ell_2}\right]$

21. An ideal gas is enclosed in a cylinder at pressure of 2 atm and temperature, 300 K. The mean time between two successive collisions is 6×10^{-8} s. If the pressure is doubled and temperature is increased to 500 K, the mean time between two successive collisions will be close to:

(1) 4×10^{-8}s (2) 3×10^{-6}s

(3) 2×10^{-7}s (4) 0.5×10^{-8}s

22. A cylinder of radius R is surrounded by a cylindrical shell of inner radius R and outer radius 2R. The thermal conductivity of the material of the inner cylinder is K_1 and that of the outer cylinder is K_2. Assuming no loss of heat, the effective thermal conductivity of the system for heat flowing along the length of the cylinder is:

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

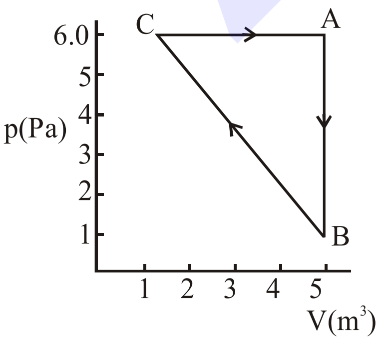
(3) $\frac{2K_1+3K_2}{5}$ (4) $\frac{K_1+3K_2}{4}$

23. An ideal gas occupies a volume of $2m^3$ at a pressure of 3×10^6 Pa. The energy of the gas is:

(1) 3×10^2 (2) 10^8 J

(3) 6×10^4 J (4) 9×10^6 J

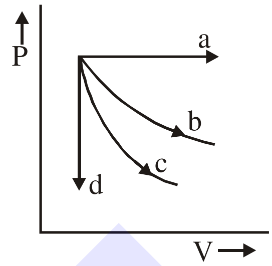
24. For the given cyclic process CAB as shown for a gas, the work done is :



(1) 1 J (2) 5 J

(3) 10 J (4) 30 J

25. 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 :-



(1) d a c b (2) a d c b

(3) a d b c (4) d a b c

26. The temperature, at which the root mean square velocity of hydrogen molecules equals their escape velocity from the earth, is closest to :

[Boltzmann Constant $k_B = 1.38 \times 10^{-23}$ J/K

Avogadro Number $N_A = 6.02 \times 10^{26}$ /kg

Radius of Earth : 6.4×10^6 m

Gravitational acceleration on Earth = $10 ms^{-2}$]

(1) 650 K (2) 3×10^5 K

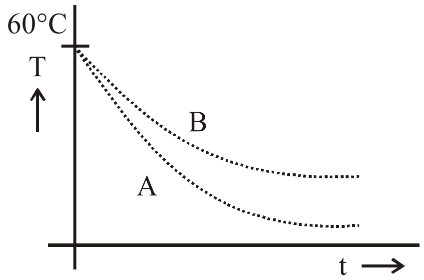
(3) 10^4 K (4) 800 K

27. A boy's catapult is made of rubber cord which is 42 cm long, with 6 mm diameter of cross-section and of negligible mass. The boy keeps a stone weighing 0.02kg on it and stretches the cord by 20 cm by applying a constant force. When released, the stone flies off with a velocity of 20 ms^{-1}. Neglect the change in the area of cross-section of the cord while stretched. The Young's modulus of rubber is closest to:

(1) 10^4 Nm^{-2} (2) 10^8 Nm^{-2}

(3) 10^6 Nm^{-2} (4) 10^3 Nm^{-2}

28. Two identical breakers A and B contain equal volumes of two different liquids at 60°C each and left to cool down. Liquid in A has density of 8×10^2 kg/m^3 and specific heat of 2000 J kg^{-1} K^{-1} while liquid in B has density of 10^3 kg m^{-3} and specific heat of 4000 J kg^{-1} K^{-1}. Which of the following best describes their temperature versus time graph schematically? (assume the emissivity of both the beakers to be the same)

(1)


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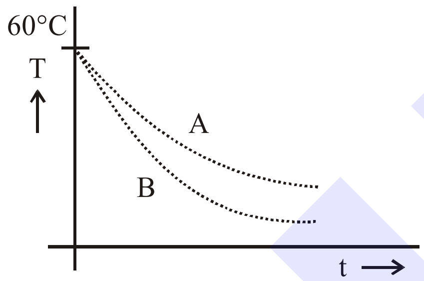

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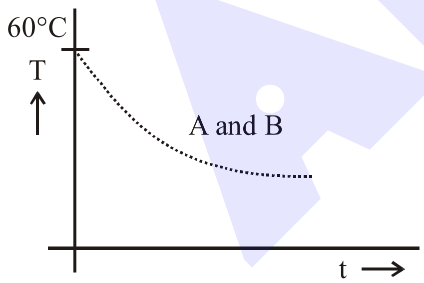
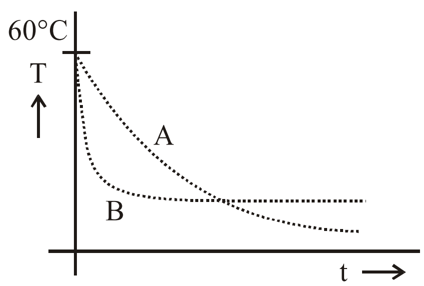


(4)


29. A steel wire having a radius of 2.0 mm, carrying a load of 4 kg, is hanging from a ceiling. Given that g = 3.1 π ms^{-2}, what will be the tensile stress that would be developed in the wire ?

(1) 4.8×10^6 Nm^{-2}

(2) 5.2×10^6 Nm^{-2}

(3) 6.2×10^6 Nm^{-2}

(4) 3.1×10^6 Nm^{-2}

30. A thermally insulated vessel contains 150g of water at 0°C. Then the air from the vessel is pumped out adiabatically. A fraction of water turns into ice and the rest evaporates at 0°C itself. The mass of evaporated water will be closest to :

(Latent heat of vaporization of water = 2.10×10^6 J kg^{-1} and Latent heat of Fusion of water = 3.36×10^5 J kg^{-1})

(1) 130 g (2) 35 g

(3) 20 g (4) 150 g

31. If 10^{22} gas molecules each of mass 10^{-26} kg collide with a surface (perpendicular to it) elastically per second over an area 1 m^2 with a speed 10^4 m/s, the pressure exerted by the gas molecules will be of the order of :

(1) 10^8 N/m^2 (2) 10^4 N/m^2

(3) 10^3 N/m^2 (4) 10^{16} N/m^2

32. A massless spring (k = 800 N/m), attached with a mass (500 g) is completely immersed in 1 kg of water. The spring is stretched by 2 cm and released so that it starts vibrating. What would be the order of magnitude of the change in the temperature of water when the vibrations stop completely ? (Assume that the water container and spring receive negligible heat and specific heat of mass = 400 J/kg K, specific heat of water = 4184 J/kg K)

(1) 10^{-3}K (2) 10^{-4} K

(3) 10^{-1} K (4) 10^{-5}K

33. The specific heats, C_P and C_V of a gas of diatomic molecules, A, are given (in units of J mol^{-1} K^{-1}) by 29 and 22, respectively. Another gas of diatomic molecules, B, has the corresponding values 30 and 21. If they are treated as ideal gases, then :-

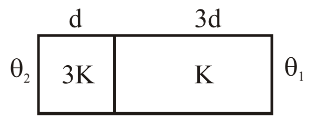
(1) A has one vibrational mode and B has two

(2) Both A and B have a vibrational mode each

(3) A is rigid but B has a vibrational mode

(4) A has a vibrational mode but B has none

34. Two materials having coefficients of thermal conductivity '3K' and 'K' and thickness 'd' and '3d', respectively, are joined to form a slab as shown in the figure. The temperatures of the outer surfaces are 'θ_2' and 'θ_1' respectively, ($\theta_2 > \theta_1$). The temperature at the interface is :-



(1) $\frac{\theta_2 + \theta_1}{2}$ (2) $\frac{\theta_1}{10} + \frac{9\theta_2}{10}$

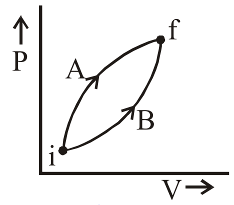
(3) $\frac{\theta_1}{3} + \frac{2\theta_2}{3}$ (4) $\frac{\theta_1}{6} + \frac{5\theta_2}{6}$

35. An HCl molecule has rotational, translational and vibrational motions. If the rms velocity of HCl molecules in its gaseous phase is $\overline{v}$, m is its mass and k_B is Boltzmann constant, then its temperature will be :

(1) $\frac{m\overline{v}^2}{6k_B}$ (2) $\frac{m\overline{v}^2}{5k_B}$

(3) $\frac{m\overline{v}^2}{3k_B}$ (4) $\frac{m\overline{v}^2}{7k_B}$

36. Following figure shows two processes A and B for a gas. If ΔQ_A and ΔQ_B are the amount of heat absorbed by the system in two cases, and ΔU_A and ΔU_B are changes in internal energies, respectively, then :



(1) $\Delta Q_A = \Delta Q_B$; $\Delta U_A = \Delta U_B$

(2) $\Delta Q_A > \Delta Q_B$; $\Delta U_A = \Delta U_B$

(3) $\Delta Q_A > \Delta Q_B$; $\Delta U_A > \Delta U_B$

(4) $\Delta Q_A < \Delta Q_B$; $\Delta U_A < \Delta U_B$

37. For a given gas at 1 atm pressure, rms speed of the molecule is 200 m/s at 127°C. At 2 atm pressure and at 227°C, the rms speed of the molecules will be :

(1) 80 m/s (2) $100\sqrt{5}$ m/s

(3) $80\sqrt{5}$ m/s (4) 100 m/s

38. The elastic limit of brass is 379 MPa. What should be the minimum diameter of a brass rod if it is to support a 400 N load without exceeding its elastic limit ?

(1) 1.16 mm (2) 0.90 mm

(3) 1.36 mm (4) 1.00 mm

39. When heat Q is supplied to a diatomic gas of rigid molecules, at constant volume its temperature increases by ΔT. The heat required to produce the same change in temperature, at a constant pressure is :

(1) $\frac{7}{5}Q$ (2) $\frac{3}{2}Q$ (3) $\frac{5}{3}Q$ (4) $\frac{2}{3}Q$

40. In an experiment, bras and steel wires of length 1m each with areas of cross section 1 mm^2 are used. teh wires are connected in series and one end of the combined wire is connected to a rigid support and other end is subjected to elongation. The stress required to produce a net elongation of 0.2 mm is :

(Given, the Young's Modulus for steel and brass are respectively, 120×10^9 N/m^2 and 60×10^9 N/m^2)

(1) 0.2×10^6 N/m^2 (2) 4.0×10^6 N/m^2

(3) 1.8×10^6 N/m^2 (4) 1.2×10^6 N/m^2

41. One mole of an ideal gas passes through a process where pressure and volume obey the relation $P = P_o\left[1-\frac{1}{2}\left(\frac{V_0}{V}\right)^2\right]$. Here P_o and V_o are constants. Calculate the change in the temperature of the gas if its volume changes from V_o to $2V_o$.

(1) $\frac{1}{2}\frac{P_oV_o}{R}$ (2) $\frac{3}{4}\frac{P_oV_o}{R}$

(3) $\frac{5}{4}\frac{P_oV_o}{R}$ (4) $\frac{1}{4}\frac{P_oV_o}{R}$

42. A cylinder with fixed capacity of 67.2 lit contains helium gas at STP. The amount of heat needed to raise the temperature of the gas by 20°C is : [Given that R = 8.31 J mol^{-1} K^{-1}]

(1) 748 J (2) 374 J

(3) 350 J (4) 700 J

43. A 25×10^{-3} m^3 volume cylinder is filled with 1 mol of O_2 gas at room temperature (300K). The molecular diameter of O_2, and its root mean square speed, are found to be 0.3 nm, and 200 m/s, respectively. What is the average collision rate (per second) for an O_2 molecule ?

(1) $\sim 10^{11}$ (2) $\sim 10^{13}$

(3) $\sim 10^{10}$ (4) $\sim 10^{12}$

44. n moles of an ideal gas with constant volume heat capcity C_V undergo an isobaric expansion by certain volume. The ratio of the work done in the process, to the heat supplied is :

(1) $\frac{4nR}{C_V - nR}$ (2) $\frac{nR}{C_V - nR}$

(3) $\frac{nR}{C_V + nR}$ (4) $\frac{4nR}{C_V + nR}$

45. One kg of water, at 20ºC, is heated in an electric kettle whose heating element has a mean (temperature averaged) resistance of 20 Ω. The rms voltage in the mains is 200 V. Ignoring heat loss from the kettle, time taken for water to evaporate fully, is close to :

[Specific heat of water = 4200 J/kg ºC), Latent heat of water = 2260 kJ/kg]

(1) 3 minutes

(2) 22 minutes

(3) 10 minutes

(4) 16 minutes

46. The number density of molecules of a gas depends on their distance r from the origin as, $n(r) = n_0 e^{-\alpha r^4}$. Then the total number of molecules is proportional to :

(1) $n_0\alpha^{1/4}$ (2) $n_0\alpha^{-3}$

(3) $n_0\alpha^{-3/4}$ (4) $\sqrt{n_0}\,\alpha^{1/2}$

47. A Carnot engine has an efficiency of 1/6. When the temperature of the sink is reduced by 62ºC, its efficiency is doubled. The temperatures of the source and the sink are, respectively

(1) 124ºC, 62ºC

(2) 37ºC, 99ºC

(3) 62ºC, 124ºC

(4) 99ºC, 37ºC

48. 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 ?

(1) 35 J (2) 40 J

(3) 25 J (4) 30 J

49. 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) equals to :

(1) $F/(3\pi r^2 YT)$ (2) $3F/(\pi r^2 YT)$

(3) $6F/(\pi r^2 YT)$ (4) $9F/(\pi r^2 YT)$

50. When M_1 gram of ice at –10ºC (specific heat = 0.5 cal g^{-1}ºC^{-1}) is added to M_2 gram of water at 50ºC, finally no ice is left and the water is at 0ºC. The value of latent heat of ice, in cal g^{-1} is:

(1) $\frac{5M_1}{M_2} - 50$ (2) $\frac{50M_2}{M_1}$

(3) $\frac{50M_2}{M_1} - 5$ (4) $\frac{5M_2}{M_1} - 5$

51. Two moles of helium gas is mixed with three moles of hydrogen molecules (taken to be rigid). What is the molar specific heat of mixture at constant volume ? (R = 8.3 J/mol K)

(1) 21.6 J/mol K (2) 19.7 J/mol K

(3) 17.4 J/mol K (4) 15.7 J/mol K

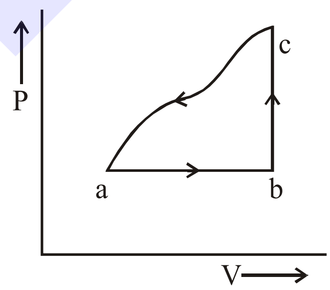
52. At 40ºC, a brass wire of 1 mm radius is hung from the ceiling. A small mass, M is hung from the free end of the wire. When the wire is cooled down from 40ºC to 20ºC it regains its original length of 0.2 m. The value of M is close to :

(Coefficient of linear expansion and Young's modulus of brass are 10^{-5}/ºC and 10^{11} N/m^2, respectively; g = 10 ms^{-2})

(1) 1.5 kg (2) 9 kg

(3) 0.9 kg (4) 0.5 kg

53. A sample of an ideal gas is taken through the cyclic process abca as shown in the figure. The change in the internal energy of the gas along the path ca is –180J. The gas absorbs 250 J of heat along the path ab and 60 J along the path bc. The work done by the gas along the path abc is :



(1) 100 J (2) 120 J

(3) 140 J (4) 130 J

SOLUTION

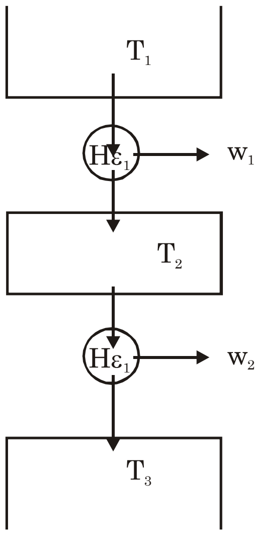
1. Ans. (1)

$Q = nC_V\Delta T$ as gas in closed vessel

$$Q = \frac{15}{28}\times\frac{5\times R}{2}\times(4T-T)$$

$Q = 10000$ J = 10 kJ

2. Ans. (3)



$w_1 = w_2$

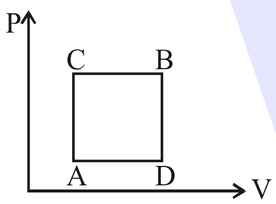
$\Delta u_1 = \Delta u_2$

$T_3 - T_2 = T_2 - T_1$

$2T_2 = T_1 + T_3$

$T_2 = 500$ K

3. Ans. (4)



$\Delta Q_{ACB} = \Delta W_{ACB} + \Delta U_{ACB}$

$\Rightarrow$ 60 J = 30 J + ΔU_{ACB}

$\Rightarrow \Delta U_{ACB} = 30$ J

$\Rightarrow \Delta U_{ADB} = \Delta U_{ACB} = 30$ J

$\Delta Q_{ACD} = \Delta U_{ACB} + \Delta W_{ADB}$

= 10 J + 30 J = 40 J

4. Ans. (4)

$$\frac{V_{rms}(He)}{V_{rms}(Ar)} = \sqrt{\frac{M_{Ar}}{M_{He}}} = \sqrt{\frac{40}{4}} = 3.16$$

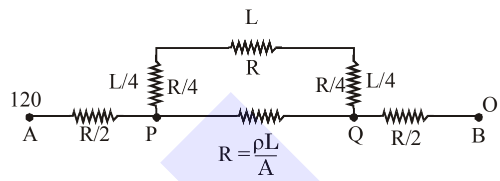
5. Ans. (3)

Young's modulus $y = \dfrac{\text{Stress}}{\text{Strain}}$

$$= \frac{F/A}{(\Delta\ell/\ell)}$$

$$= \frac{F}{A(\alpha\Delta T)}$$

6. Ans. (4)



$$\frac{\Delta T}{R_{eq.}} = I = \frac{(120)5}{8R} = \frac{120\times5}{8R}$$

$$\Delta T_{PQ} = \frac{120\times5}{8R}\times\frac{3}{5}R = \frac{360}{8} = 45°C$$

7. Ans. (4)

192 × S × (100 – 21.5)

= 128 × 394 × (21.5 – 8.4)

+ 240 × 4200 × (21.5 – 8.4)

$\Rightarrow$ S = 916

8. Ans. (2)

$$WD = P\Delta V = nR\Delta T = \frac{1}{2}\times 8.31\times 70$$

9. Ans. (4)

Thermal energy of N molecule

$$= N\left(\frac{3}{2}kT\right)$$

$$= \frac{N}{N_A}\frac{3}{2}RT$$

$$= \frac{3}{2}(nRT)$$

$$= \frac{3}{2}PV$$

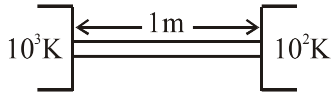
$$= \frac{3}{2}P\left(\frac{m}{8}\right)$$

$$= \frac{3}{2}\times4\times10^4\times\frac{2}{8}$$

$= 1.5\times10^4$

order will 10^4

10. Ans. (1)



$$\left(\frac{dQ}{dt}\right) = \frac{kA\Delta T}{\ell}$$

$$\Rightarrow \frac{1}{A}\left(\frac{dQ}{dt}\right) = \frac{(0.1)(900)}{1} = 90\,W/m^2$$

11. Ans. (1)

$$t_1 = 1 - \frac{T_2}{T_1} = 1 - \frac{T_2}{T_2} = 1 - \frac{T_4}{T_3}$$

$$\Rightarrow \frac{T_2}{T_1} = \frac{T_3}{T_4} = \frac{T_4}{T_3}$$

$$\Rightarrow T_2 = \sqrt{T_1T_3} = \sqrt{T_1\sqrt{T_2T_4}}$$

$$T_3 = \sqrt{T_2T_4}$$

$$T_2^{3/4} = \sqrt{T_1^{1/2}T_4^{1/4}}$$

$$T_2 = T_1^{2/3}T_4^{1/3}$$

12. Ans. (2)

$$\Delta\ell_1 = \Delta\ell_2$$

$$\ell\alpha_1\Delta T_1 = \ell\alpha_2\Delta T_2$$

$$\frac{\alpha_1}{\alpha_2} = \frac{\Delta T_1}{\Delta T_2}$$

$$\frac{4}{3} = \frac{T-30}{180-30}$$

$$\boxed{T = 230^\circ C}$$

13. Ans. (1)

$$100 \times S_A \times [100 - 90] = 50 \times S_B \times (90 - 75)$$

$$2S_A = 1.5\,S_B$$

$$S_A = \frac{3}{4}S_B$$

Now, $100 \times S_A \times [100 - T] = 50 \times S_B(T - 50)$

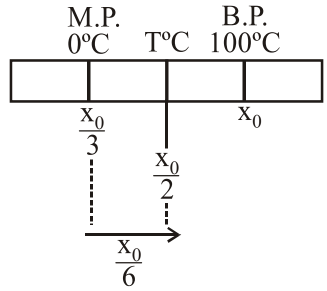
$$2 \times \left(\frac{3}{4}\right)\ (100 - T) = (T - 50)$$

$$300 - 3T = 2T - 100$$

$$400 = 5T$$

$$T = 80$$

14. Ans. (2)



$$\Rightarrow T^\circ C = \frac{x_0}{6}\ \&\ \left(x_0 - \frac{x_0}{3}\right) = (100 - 0^\circ C)$$

$$x_0 = \frac{300}{2}$$

$$\Rightarrow T^\circ C = \frac{150}{6} = 25^\circ C$$

15. Ans. (1)

$VT = K$

$$\Rightarrow V\left(\frac{PV}{nR}\right) = k \Rightarrow PV^2 = K$$

$$\because\ C = \frac{R}{1-x} + C_V\ \text{(For polytropic process)}$$

$$C = \frac{R}{1-2} + \frac{3R}{2} = \frac{R}{2}$$

$$\therefore\ \Delta Q = nC\,\Delta T$$

$$= \frac{R}{2} \times \Delta T$$

16. Ans. (2)

$$0.1 \times 400 \times (500 - T) = 0.5 \times 4200 \times (T - 30) + 800\,(T - 30)$$

$$\Rightarrow 40(500 - T) = (T - 30)\,(2100 + 800)$$

$$\Rightarrow 20000 - 40T = 2900\,T - 30 \times 2900$$

$$\Rightarrow 20000 + 30 \times 2900 = T(2940)$$

$T = 30.4°C$

$$\frac{\Delta T}{T} \times 100 = \frac{6.4}{30} \times 100$$

$$\simeq 20\%$$

17. Ans. (2)

For adiabatic process : $TV^{\gamma-1}$ = constant

For diatomic process : $\gamma - 1 = \frac{7}{5} - 1$

$$\therefore x = \frac{2}{5}$$

18. Ans. (3)

$$U = \frac{f_1}{2}n_1RT + \frac{f_2}{2}n_2RT$$

$$= \frac{5}{2}(3RT) + \frac{3}{2}\times 5RT$$

U = 15RT

19. Ans. (2)

Let amount of ice is m gm.

According to principal of calorimeter

heat taken by ice = heat given by water

$\therefore$ 20 × 2.1 × m + (m – 20) × 334

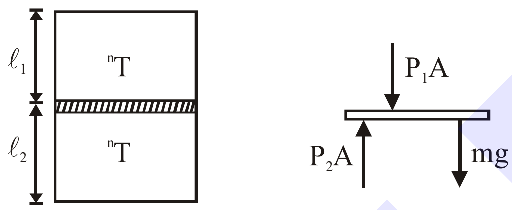
= 50 × 4.2 × 40

376 m = 8400 + 6680

m = 40.1

$\therefore$ correct answer is (2)

20. Ans. (2)



$P_2A = P_1A + mg$

$$\frac{nRT.A}{A\ell_2} = \frac{nRT.A}{A\ell_1} + mg$$

$$nRT\left(\frac{1}{\ell_2} - \frac{1}{\ell_1}\right) = mg$$

$$m = \frac{nRT}{g}\left(\frac{\ell_1 - \ell_2}{\ell_1.\ell_2}\right)$$

21. Ans. (1)

$$t \propto \frac{\text{Volume}}{\text{velocity}}$$

$$\text{volume} \propto \frac{T}{P}$$

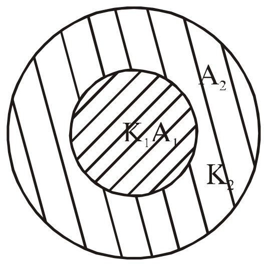
$$\therefore\ t \propto \frac{\sqrt{T}}{P}$$

$$\frac{t_1}{6\times 10^{-8}} = \frac{\sqrt{500}}{2P} \times \frac{P}{\sqrt{300}}$$

$t_1 = 3.8 \times 10^{-8}$

$\approx 4 \times 10^{-8}$

22. Ans. (4)



$$K_{eq} = \frac{K_1A_1 + K_2A_2}{A_1 + A_2}$$

$$= \frac{K_1(\pi R^2) + K_2(3\pi R^2)}{4\pi R^2} = \frac{K_1 + 3K_2}{4}$$

23. Ans. (4)

$$\text{Energy} = \frac{1}{2}nRT = \frac{f}{2}PV$$

$$= \frac{f}{2}(3\times 10^6)(2)$$

$= f \times 3 \times 10^6$

Considering gas is monoatomic i.e. f = 3

E. = 9×10^6 J

Option-(4)

24. Ans. (3)

Since P–V indicator diagram is given, so work done by gas is area under the cyclic diagram.

$$\therefore\ \Delta W = \text{Work done by gas} = \frac{1}{2}\times 4\times 5\text{ J}$$

= 10 J

25. Ans. (4)

Sol. isochoric $\rightarrow$ Process d

isobaric $\rightarrow$ Process a

Adiabatic slope will be more than isothermal so

Isothermal $\rightarrow$ Process b

Adiabatic $\rightarrow$ Process c

order $\rightarrow$ d a b c

26. Ans. (3)

Sol. $v_{rms} = \sqrt{\frac{3RT}{m}}$ $\qquad v_{escape} = \sqrt{2gR_e}$

$v_{rms} = v_{escape}$

$\frac{3RT}{m} = 2gR_e$

$\frac{3 \times 1.38 \times 10^{-23} \times 6.02 \times 10^{26}}{2} \times T$

$= 2 \times 10 \times 6.4 \times 10^6$

$T = \frac{4 \times 10 \times 6.4 \times 10^6}{3 \times 1.38 \times 6.02 \times 10^3} = 10 \times 10^3 = 10^4 k$

Note : Question gives avogadro Number N_A = 6.02 × 10^{26} /kg but we take N_A = 6.02 × 10^{26}/kmol.

27. Ans. (3)

Sol. Energy of catapult $= \frac{1}{2} \times \left(\frac{\Delta \ell}{\ell}\right)^2 \times Y \times A \times \ell$

= Kinetic energy of the ball $= \frac{1}{2} mv^2$

therefore,

$\frac{1}{2} \times \left(\frac{20}{42}\right)^2 \times Y \times \pi \times 3^2 \times 10^{-6} \times 42 \times 10^{-2} = \frac{1}{2} \times 2 \times 10^{-2} \times (20)^2$

$Y \simeq 3 \times 10^6 \ Nm^{-2}$

28. Ans. (1)

Sol. $-ms\frac{dT}{dt} = e\sigma A\left(T^4 - T_0^4\right)$

$-\frac{dT}{dt} = \frac{e\sigma A}{ms}\left(T^4 - T_0^4\right)$

$-\frac{dT}{dt} = \frac{4e\sigma A T_0^3}{ms}(\Delta T)$

$T = T_0 + (T_i - T_0)e^{-kt}$

where $k = \frac{4e\sigma A T_0^3}{ms}$

$k = \frac{4e\sigma A T_0^3}{\rho vs}$

$\left|\frac{dT}{dt}\right| \propto k$

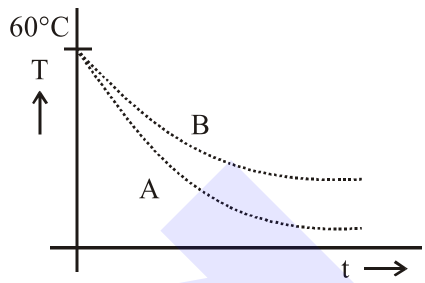
$\therefore \left|\frac{dT}{dt}\right| \propto \frac{1}{\rho s}$

$\rho_A s_A = 2000 \times 8 \times 10^2 = 16 \times 10^5$

$\rho_B s_B = 4000 \times 10^3 = 4 \times 10^6$

$\rho_A s_A < \rho_B s_B$

$\left|\frac{dT}{dt}\right|_A > \left|\frac{dT}{dt}\right|_B$



29. Ans. (4)

Sol. Tensile stresss in wire will be

$= \frac{\text{Tensile force}}{\text{Cross section Area}}$

$= \frac{mg}{\pi R^2} = \frac{4 \times 3.1\pi}{\pi \times 4 \times 10^{-6}} Nm^{-2} = 3.1 \times 10^6 \ Nm^{-2}$

30. Ans. (3)

Sol. Suppose 'm' gram of water evaporates then, heat required

$\Delta Q_{req} = mL_v$

Mass that converts into ice = (150 – m)

So, heat released in this process

$\Delta Q_{rel} = (150 - m) L_f$

Now,

$\Delta Q_{rel} = \Delta Q_{req}$

$(150 - m) L_f = mL_V$

$m(L_f + L_v) = 150 L_f$

$m = \frac{150 L_f}{L_f + L_v}$

m = 20g

31. Allen Ans. is BONUS

Final Ans. by NTA (3)

Sol. Note :

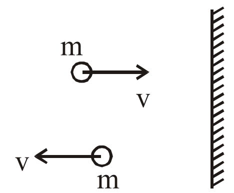
Pressure is defined as normal force per unit area.

Force is calculated as change in momentum/ time

By this answer is 2N/m²

None of the option matches so this question must be Bonus

Detailed solution is as following.



Magnitude of change in momentum per collision = 2mv

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{N(2mv)}{1}$$

$$= \frac{10^{22} \times 2 \times 10^{-26} \times 10^{4}}{1}$$

$= 2N/m^2$

32. Ans. (4)

Sol. By law of conservation of energy

$$\frac{1}{2}kx^2 = (m_1s_1 + m_2s_2)\,\Delta T$$

$$\Delta T = \frac{16 \times 10^{-2}}{4384} = 3.65 \times 10^{-5}.$$

33. Ans. (4)

Sol. For A

$R = C_p - C_v = 7$

$$C_v = \frac{fR}{2} = 22 \Rightarrow f = \frac{44}{7} = 6.3$$

$f \simeq 6$ → 5 (Rotation + Translational), 1 (Vibration)

For B

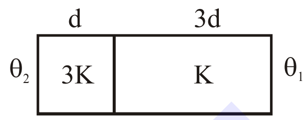
$R = C_p - C_v = 9$

$$C_v = \frac{fR}{2} = 21 \Rightarrow f = \frac{42}{9}$$

$f \simeq 5$ → 5 (Rotation + Translational), 0 (Vibration)

34. Ans. (2)

Sol.



Let the temperature of interface be "θ"

$i_1 = i_2$ {Steady state conduction}

$$\frac{3KA(\theta_2 - \theta)}{d} = \frac{KA(\theta - \theta_1)}{3d}$$

$$\theta = \frac{9\theta_2}{10} + \frac{\theta_1}{10}$$

35. Ans. (3)

Sol. According to equipartion energy theorem

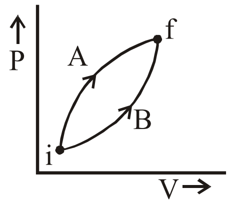
$$\frac{1}{2}m\left(v_{rms}^2\right) = 3 \times \frac{1}{2}K_bT$$

$$T = \frac{m\bar{v}_{rms}^2}{3k}$$

∴ correct option should be (3)

36. Ans. (2)

Sol.



Initial and final states for both the processes are same.

$\therefore \Delta U_A = \Delta U_B$

Work done during process A is greater than in process B.

By First Law of thermodynamics

$\Delta Q = \Delta U + W$

$\Rightarrow \Delta Q_A > \Delta Q_B$

Option (2)

37. Ans. (2)

Sol. $V_{rms} = \sqrt{\frac{3RT}{M_w}} \Rightarrow v_{rms} \propto \sqrt{T}$

Now, $\frac{v}{200} = \sqrt{\frac{500}{400}} \Rightarrow \frac{v}{200} = \frac{\sqrt{5}}{2}$

$\Rightarrow v = 100\sqrt{5}$ m/s

Option (2)

38. Ans. (1)

Sol. $\frac{F}{A} = \text{stress}$

$\frac{400 \times 4}{\pi d^2} = 379 \times 10^6$

$d^2 = \frac{1600}{\pi \times 379 \times 10^6} = 1.34 \times 10^{-6}$

$d = \sqrt{1.34} \times 10^{-3} = 1.15 \times 10^{-3}$ m

39. Ans. (1)

Sol. $Q = nC_v \Delta T$

$Q' = nC_p \Delta T$

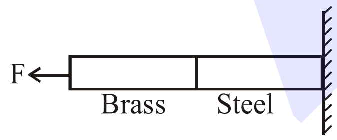
$\therefore \frac{Q'}{Q} = \frac{C_p}{C_v}$

For diatomic gas : $\frac{C_p}{C_v} = \gamma = \frac{7}{5}$

$Q' = \frac{7}{5}Q$

40. Allen Answer is BONUS
Final Ans. by NTA (2)

Sol.



$k_1 = \frac{y_1 A_1}{\ell_1} = \frac{120 \times 10^9 \times A}{1}$

$k_2 = \frac{y_2 A_2}{\ell_2} = \frac{60 \times 10^9 \times A}{1}$

$k_{eq} = \frac{k_1 k_2}{k_1 \times k_2} = \frac{120 \times 60}{180} \times 10^9 \times A$

$k_{eq} = 40 \times 10^9 \times A$

$F = k_{eq}(x)$

$F = (40 \times 10^9)A \cdot (0.2 \times 10^{-3})$

$\frac{F}{A} = 8 \times 10^6 \text{ N/m}^2$

No option is matching. Hence question must be bonus.

41. Ans. (3)

Sol. $P = P_0\left[1 - \frac{1}{2}\left(\frac{V_0}{V}\right)^2\right]$

Pressure at $V_0 = P_0\left(1 - \frac{1}{2}\right) = \frac{P_0}{2}$

Pressure at $2V_0 = P_0\left(1 - \frac{1}{2} \times \frac{1}{4}\right) = \frac{7}{8}P_0$

Temperature at $V_0 = \frac{\frac{P_0}{2}V_0}{nR} = \frac{P_0V_0}{2nR}$

Temperature at $2V_0 = \frac{\left(\frac{7}{8}P_0\right)(2V_0)}{nR} = \frac{\frac{7}{4}P_0V_0}{nR}$

Change in temperature $= \left(\frac{7}{4} - \frac{1}{2}\right)\frac{P_0V_0}{nR}$

$= \frac{5}{4}\frac{P_0V_0}{nR} = \frac{5P_0V_0}{4R}$

42. Ans. (1)

Sol. $\Delta Q = nC_V \Delta T = n\frac{3}{2}R\Delta T$

$= \left(\frac{67.2}{22.4}\right)\left(\frac{3}{2} \times 8.31\right)(20)$

≈ 748 J

43. Allen Ans. (3)
Final Ans. by NTA (4)

Sol. $\nu = \frac{V_{av}}{\lambda}$

$\lambda = \frac{RT}{\sqrt{2}\pi\sigma^2 N_A P}$

$\sigma = 2 \times .3 \times 10^{-9}$

$P = \frac{RT}{V}$

$\Rightarrow \lambda = \frac{V}{\sqrt{2}\pi\sigma^2 N_A}$

$V_{av} = \sqrt{\frac{8}{3\pi}} \times V_{rms}$

$\therefore \; \nu = \frac{200 \times \sqrt{2}\pi \times \sigma^2 N_A}{25 \times 10^{-3}} \times \sqrt{\frac{8}{3\pi}}$

$= 17.68 \times 10^8$/sec.

$= .1768 \times 10^{10}$/sec. $\sim 10^{10}$

This answer does not match with JEE-Answer key

44. Ans. (3)

Sol. $w = nR\Delta T$

$\Delta H = (C_v + nR)\,\Delta T$

$\frac{w}{\Delta H} = \frac{nR}{C_v + nR}$

45. Ans. (2)

Sol. $Q = P \times t$

$Q = mc\Delta T + mL$

$P = \frac{V_{rms}^2}{R}$

$4200 \times 80 + 2260 \times 10^3 = \frac{(200)^2}{20} \times t$

$t = 1298$ sec

$t \simeq 22$ min

46. Ans. (3)

Sol. Given number density of molecules of gas as a function of r is

$n(r) = n_0 e^{-\alpha r^4}$

$\therefore$ Total number of molecule $= \int_0^\infty n(r)\,dV$

$= \int_0^\infty n_0 e^{-\alpha r^4} 4\pi r^2\,dr$

$\therefore$ Number of molecules is proportional to $n_0 \alpha^{-3/4}$

47. Official Ans. by NTA (2)
Final Ans. by NTA (4)

Sol. Efficiency of Carnot engine $= 1 - \frac{T_{sink}}{T_{source}}$

Given,

$\frac{1}{6} = 1 - \frac{T_{sink}}{T_{source}} \Rightarrow \frac{T_{sink}}{T_{source}} = \frac{5}{6}$ .....(1)

Also,

$\frac{2}{6} = 1 - \frac{T_{sink} - 62}{T_{source}} \Rightarrow \frac{62}{T_{source}} = \frac{1}{6}$ .....(2)

$\therefore \; T_{source} = 372\text{ K} = 99^\circ C$

Also, $T_{sink} = \frac{5}{6} \times 372 = 310\text{ K} = 37^\circ C$

(**Note :-** Temperature of source is more than temperature of sink)

48. Ans. (1)

Sol. For a diatomic gas, $C_p = \frac{7}{2}R$

Since gas undergoes isobaric process

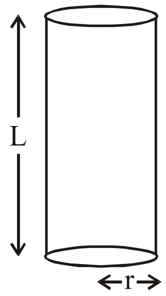
$\Rightarrow \; \Delta Q = nC_P\Delta T$

Also, $\Delta W = nR\Delta T = 10J(\text{given})$

$\therefore \; \Delta Q = n\frac{7}{2}R\Delta T = \frac{7}{2}(nR\Delta T) = 35\text{ J}$

49. Ans. (2)

Sol.



$\because$ Length of cylinder remains unchanged

so $\left(\frac{F}{A}\right)_{Compressive} = \left(\frac{F}{A}\right)_{Thermal}$

$\frac{F}{\pi r^2} = Y\alpha T$

(α is linear coefficient of expansion)

$\therefore\ \alpha = \frac{F}{YT\pi r^2}$

$\therefore$ The coefficient of volume expansion $\gamma = 3\alpha$

$\therefore\ \gamma = 3\frac{F}{YT\pi r^2}$

50. Ans. (3)

Sol. Heat lost = Heat gain

$\Rightarrow M_2 \times 1 \times 50 = M_1 \times 0.5 \times 10 + M_1.L_f$

$\Rightarrow L_f = \frac{50M_2 - 5M_1}{M_1}$

$= \frac{50M_2}{M_1} - 5$

51. Ans. (3)

Sol. $f_{mix} = \frac{n_1f_1 + n_2f_2}{n_1 + n_2} = \frac{2\times3+3\times5}{5} = \frac{21}{5}$

$C_V = \frac{fR}{2} = \frac{21}{5}\times\frac{R}{2} = 17.4\,J/mol\,K$

52. Ans. (2)

Sol. $Mg = \left(\frac{Ay}{\ell}\right)\Delta\ell$

$\frac{\Delta\ell}{\ell} = \alpha\Delta T$

$Mg = (Ay)\alpha\Delta T = 2\pi$

It is closest to 9.

53. Ans. (4)

Sol.

	ΔE	ΔW	ΔQ
ab			250
bc		0	60
ca	–180		

	ΔE	ΔW	ΔQ
ab	120	130	250
bc	60	0	60
ca	–180		