PHYSICS

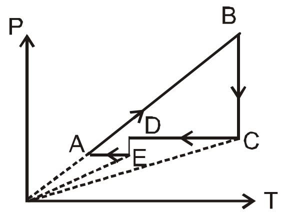
1. According to law of equipartition of energy, energies equally distributed among its degree of freedom, Let translational and rotational degree of freedom be f_1 and f_2.

$\therefore \quad \frac{K_T}{K_R} = \frac{3}{2}$ and $K_T + K_R = U$

Hence the ratio of translational to rotational degrees of freedom is 3:2. Since translational degrees of freedom is 3, the rotational degrees of freedom must be 2.

$\therefore$ Internal energy (U) $= 1 \times (f_1 + f_2) \times \frac{1}{2}RT$

$U = \frac{1 \times 5 \times 8.3 \times 100}{2} = U = 2075$ J

2. 

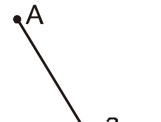
PV = nRT

$\frac{P}{T} \propto \frac{1}{V}$

$\Rightarrow$ Slope of line joining origin to that point $\propto \frac{1}{V}$

as the slope of line OE is greater than the slope of line OC, So, volume at 'E' is less than that at 'C'.
So, ans.is (D).

3. At the initial moment, angular velocity of rod is zero.
Acceleration of end B of rod with respect to end A is shown in figure.
Centripetal acceleration of point B with respect to A is zero ($\because \omega^2\ell = 0$)
So at the initial moment , acceleration of end B with respect to end A is perpendicular to the rod which is equal to $\sqrt{a^2 + b^2}$



$a_{rel} = \ell\alpha$

$\frac{\sqrt{a^2 + b^2}}{\ell} = \alpha$ where α is angular acceleration

4. Before heating let the pressure of gas be P_1 from the equilibrium piston,
$PA = kx_1$

$\therefore \quad x_1 = \frac{PA}{K} = \left(\frac{nRT}{V}\right)\frac{A}{K} = \frac{1 \times 8.3 \times 100 \times 10^{-2}}{0.83 \times 100} = 10^{-1} = 0.1$ m

Since during heating process,
The spring is compressed further by 0.1 m
$\therefore \quad x_2 = 0.2$ m

work done by gas $= \frac{1}{2}.100(0.2^2 - 0.1^2) = \frac{1}{2}.100.(0.1)(0.3) = 1.50 = 1.5$ J

6. Only effective pairs will be body diagonals for this interaction electrostatic potential energy is

$= \frac{4kq^2}{\sqrt{3}\ell}$.

7. Rotational K.E. = Rotational degree of freedom x $\frac{1}{2}$nRT

$= 2 \times \frac{1}{2}nRT \quad = nRT \quad = PV$

$= PA \cdot \frac{V}{A}$ = force on piston (L + x) $\quad = kx\,(L + x)$

8. BC is isochoric. $V_B > V_A$, $V_B = V_C$, $V_D > V_C$

9. Internal energy and volume depend upon states.

10. Work done by gas in going isothermally from state A to B is

$$\Delta W_{AB} = nRT\,\ell n\frac{P_A}{P_B} = nRT\,\ell n2 \qquad ....(1)$$

Work done by gas in going isothermally from state B to C is

$$\Delta W_{BC} = nRT\,\ell n\frac{P_B}{P_C} = nRT\,\ell n\frac{P_0}{2P_C} \qquad ....(2)$$

It is given that $\Delta W_{BC} = 2\,\Delta W_{AB}$

$\therefore \quad \ell n\frac{P_0}{2P_C} = \ell n(2)^2 \qquad \therefore \quad P_c = \frac{P_0}{8}$

11. Current in circuit at any time $t = \left(\frac{B\ell v}{L}t\right)$

So, energy of inductor at time $t = \frac{1}{2}L\left(\frac{B\ell v}{L}t\right)^2$

$t = \frac{x}{v}$

So, $\quad E \propto x^2$

12. The electrostatic force on charge is constant, hence it does not effect the time period of spring + particle system

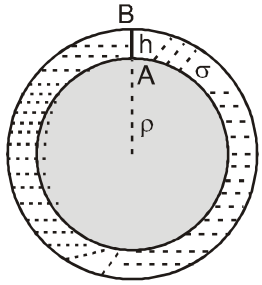
$\therefore \ \omega = \sqrt{\frac{2k}{m}}$

Initially the charge is at rest, i.e., at extreme position.

The equilibrium position, shall be at a distance A towards right, where A (by definition) is amplitude of vibration.

$\therefore 2kA = \frac{\sigma}{\epsilon_0}q \qquad$ or $\qquad A = \frac{\sigma q}{2k\,\epsilon_0}$

13. $g_A = \frac{4}{3}G\pi R\rho$

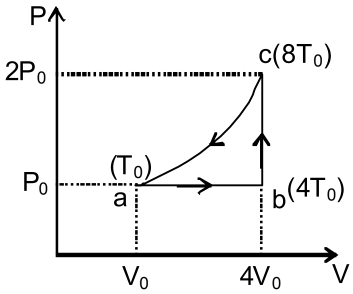


$$g_B = \frac{G\left[\frac{4}{3}\pi\rho R^3 + \left[\frac{4}{3}\pi(R+h)^3 - \frac{4}{3}\pi R^3\right]\sigma\right]}{(R+h)^2}$$

$$= \frac{4}{3}G\pi\rho R\left[1-\frac{2h}{R}\right] + \frac{4}{3}G\pi\left[(R+h)-\left(1-\frac{2h}{R}\right)R\right]\sigma$$

$\Delta g = g_B - g_A = \frac{4}{3}\pi Gh\,[3\sigma - 2\rho].$

14. (a) $U_c - U_a = nC_v dT = (1)\ \frac{3R}{2}(8T_0 - T_0) = \frac{21}{2}RT_0$



(b) $U_b - U_a = nC_v dT$

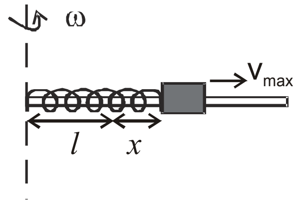
$= (1)\ \frac{3R}{2}\ (4T_0 - T_0) = 4.5RT_0$(wrong)

(c) $W_{c\to a}$ cannot be determined, but

$|W_{c\to a}| > |W_{a\to b}|$

$|W_{c\to a}| > 3P_0V_0$, Hence (C) is wrong

15. Velocity will be maximum at equilibrium position



$\Rightarrow \quad m\omega^2(\ell + x) = Kx$

$\Rightarrow \quad x = \frac{m\omega^2\ell}{K - m\omega^2}$

$$\frac{1}{2}mV_{max}^2 = \int_0^x m\omega^2(\ell + x)dx - \frac{1}{2}Kx^2$$

$\Rightarrow \quad V_{max}^2 = \frac{2m\omega^2\ell x + m\omega^2x^2 - Kx^2}{m}$

$$V_{max}^2 = \frac{\left(m\omega^2\ell + m\omega^2(\ell + x) - Kx\right)x}{m}$$

$\Rightarrow \quad V_{max}^2 = \omega^2\ell = \frac{m\omega^4\ell^2}{m\omega^2 - K}$

$$V_{max} = \sqrt{\frac{m\omega^4\ell^2}{K - m\omega^2}}$$

For maximum extension

$$\int_0^x m\omega^2(\ell + x)dx - \frac{1}{2}Kx_{max}^2 = 0 \quad \Rightarrow \quad x_{max} = \frac{2m\omega^2\ell}{K - m\omega^2}$$

16. from work energy theorem

$v_1 = v_2 = v_3$

$\theta_1 + \theta_2 = 90°$ & $\theta_2 = 45°$

$\Rightarrow \frac{\theta_1 + \theta_3}{2} = \theta_2 \quad \Rightarrow \quad \theta_1, \theta_2$ & θ_3 are in AP AP में है।

$T_1 = \frac{2u\sin\theta_1}{g} \quad \Rightarrow \quad T_2 = \frac{2u\sin 45°}{g} \quad \Rightarrow \quad T_3 = \frac{2u\cos\theta_1}{g}$

$\Rightarrow \frac{T_1^2 + T_3^2}{2} = T_2^2 \quad \Rightarrow \quad T_1^2, T_2^2$ & T_3^2 are in AP

17. From graph in time from t = 0 to t = 3 sec.

acceleration of object of mass m_1 = 10 kg is

$$a = \frac{15 - 0}{3} = 5 \text{ m/s}^2$$

$\therefore$ Force on object of mass m_1 from t = 0 to t = 3 sec. (i)

= 10 × 5 = 50 N

Before and after collision at t = 4 sec, the velocities of blocks are as shown.

m_1=10kg ⟶ u_1=15m/s m_2=25kg ⟶ u_2

Before collision

m_1+m_2=35kg ⟶ v=5m/s

after collision

$\therefore$ initial momentum of system

$= m_1u_1 + m_2u_2 = 150 + 25\,u_2$

final momentum of system

$= (m_1 + m_2)\,v = 35 \times 5 = 175$

From conservationof momentum

$\therefore 150 + 25\,u_2 = 175$

or $u_2 = +\,1$ m/s

$\therefore$ speed of second particle just before collision is 1 m/s and before collision both blocks move in same direction.

18. At constant pressure.

If volume increases, temperature also increases

volume decreases, temperature decreases.

In Isobaric process.

$\Delta Q = \gamma.\Delta U$

$\therefore \Delta Q = \Delta U + \Delta W$

$\therefore \Delta W = \gamma\Delta U - \Delta U = (\gamma - 1)\Delta U$

$\Delta W = (\gamma - 1)\Delta U$

$\therefore \Delta Q = \frac{\gamma}{(\gamma - 1)}.\Delta W$

19. $M = \frac{Q}{2m} \times \frac{2}{3} mR^2.\omega$

$I = \frac{2mR^2}{5}$

$\frac{M}{I} = \frac{5Q.\omega}{6m}$

20. $f_m = \frac{v}{(v - v_s \cos\theta)_{min}} \times f$

$1800 = \frac{v}{(v + v_s \cos\theta)_{max}} \times f$

On solving,

$f_m = 2250$ Hz

$= 2300 - 50$

21. (NBA)i = $c\theta$

$i = \frac{C\theta}{NBA} = \frac{(6 \times 10^{-5})}{10 \times 1 \times \pi \times 10^{-4}} \left(\frac{\pi}{2}\right)$ sss

i = 30 mA

So current corresponding 1 part = $\frac{30}{10}$ = 3 mA.

22. In an adiabatic expansion,

$TV^{\gamma-1}$ = constant

$T_0 V^{\gamma-1} = T\left(\frac{V}{5}\right)^{\gamma-1}$ $\quad\quad \gamma = 1 + \frac{2}{5}$

$\therefore$ $T = (273).(5)^{2/5}$

$< (KE)_{rotational} >$ = kT

$= 1.38 \times 10^{-23} \times 273 \times (5)^{2/5}$

$= 7 \times 10^{-21}$ J (approx).

23. $\gamma = 1 + \frac{2}{f} = 1 + \frac{1}{3}$

$\gamma = \frac{4}{3}$

As we know $\Delta W = \Delta Q - \Delta U$

$\therefore \quad \frac{\Delta W}{\Delta Q} = \frac{\Delta Q - \Delta U}{\Delta Q} = 1 - \frac{C_v}{C_p}$

$\therefore \quad \frac{\Delta W}{\Delta Q} = 1 - \frac{1}{\gamma} = \frac{1}{4}$

$\therefore \quad \Delta Q = 4.\Delta W$

$\Delta Q = 100$ J.

24. Net power given to N_2 gas = 100 – 30 = 70 cal/s
The nitrogen gas expands isobarically.

$\therefore Q = n\,Cp\,\frac{dT}{dt}$ or $70 = 5 \times \frac{7}{2} R \frac{dT}{dt}$

$\therefore \frac{dT}{dt} = 2k/sec$

25. Pressure in the air inside the column of mercury is equal to the weight of mercury over the air divided by the internal cross sectional area of the tube. When the temperature increases, the weight of the upper part of the mercury column does not change. That is why the pressure in the air is also constant. For the isobaric process, the change in volume is proportional to the change in temperature. The same is true for the lengths of the air column.

$$\frac{\ell}{\ell_0} = \frac{T}{T_0} \Rightarrow \ell = \frac{\ell_0 T}{T_0} = 11$$

26. Using 1st law of TD
$Q = W + U\uparrow$

$0 = ((-W_{fan}) + P\Delta v) + n\frac{f}{2}R\Delta T$

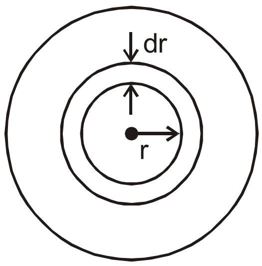
$W_{fan} = n\,R\Delta T + n\frac{f}{2}R\Delta T$

$W_{fan} = n\,C_p\,\Delta T$

$W_{fan} = (1)\left(R + \frac{f}{2}R\right)(500\text{ k})$ (as the gas is expending slowly so p = constant, so $T \propto v$)

$W_{fan} = 14$ kJ

27. Current in the element = $J(2\pi r\ .\ dr)$



Current enclosed by Amperian loop of radius $\frac{a}{2}$

$I = \int_0^{a/2} \frac{J_0 r}{a}\ .\ 2\pi r\ .\ dr = \frac{2\pi J_0}{3a}\left(\frac{a}{2}\right)^3 = \frac{\pi J_0 a^2}{12}$

Applying Ampere's law

$B\ .\ 2\pi\ .\ \frac{a}{2} = \mu_0\ .\ \frac{\pi J_0 a^2}{12} \Rightarrow B = \frac{\mu_0 J_0 a}{12}$

On putting values
$B = 10\ \mu T$

28. From the condition given in the paragraph,
$P \times 2L = nh$, where
P is the momentum,

$P = \frac{nh}{2L}$

29. Kinetic energy $E = \frac{P^2}{2m}$

$E = \frac{n^2h^2}{8mL^2}$

31. The initial force on the piston is PA

$$\because a = \frac{PA}{M}$$

32. Workdone by gas in the adiabatic process

$$= 2PV\left[1-\left(\frac{V}{V+LS}\right)^{1/2}\right]$$

$$\therefore \frac{1}{2}Mv^2 = \Delta W$$

$$\therefore v = \left(\frac{4PV}{M}\left[1-\left(\frac{V}{V+LS}\right)^{1/2}\right]\right)^{1/2}$$

33. $$\frac{T_f}{T} = \left(\frac{V}{V_f}\right)^{\gamma-1} = \sqrt{\frac{V}{V+LS}} = \frac{1}{2}$$

$$\therefore L = \frac{3V}{S}$$

34 to 36.

Let 'F' be the force to be applied on belt to move with same 'v'

$$F = \frac{dp}{dt} = \frac{d(mv)}{dt} = m\frac{dv}{dt} + \frac{dm}{dt}v = \mu v$$

$$\frac{dw}{dt} = \frac{d}{dt}(F\,vdt) = F.v = \mu v^2$$

By work energy theorem

$$\frac{dw_F}{dt} + \frac{dw_{fr}}{dt} = \frac{dK}{dt}.$$

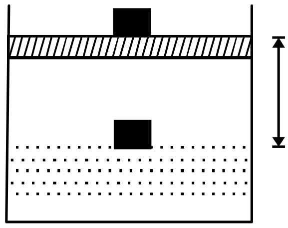
$$K = \frac{mv^2}{2}$$

$$\frac{dK}{dt} = \frac{dm}{dt}.\frac{1}{2}.v^2 = \frac{\mu v^2}{2}$$

$$\Rightarrow \quad \mu v^2 + \frac{dw_{fr}}{dt} = \frac{\mu v^2}{2}$$

$$\frac{dw_{fr}}{dt} = -\frac{\mu v^2}{2}$$

37 to 38. By energy conservation,



$$2mgh = \frac{4}{2}R\Delta T$$

$$\Delta T = \frac{10h}{R} \qquad ....(i)$$

Initially, $\frac{mg}{A}(A.\ell) = RT_1 \qquad ....(ii)$

and finally, $P_{max}A(\ell - h) = RT_2 \qquad ....(iii)$

(iii) – (ii)

$$P_m(1 - h) - 10 = 10\,h \qquad ....(iv)$$

By equation of adiabatic process PV^{γ} = constant

$$\frac{mg}{A}(A\ell)^{\gamma} = P_{max}\{A(\ell - h)\}^{\gamma}$$

$$10 = P_m(1 - h)^{\gamma}$$

Put this P_m in equation (iv)

$$10(1 - h)^{1-\gamma} - 10 = 10h$$

$$(1 - h)^{1-\gamma} - 1 = h$$

$$(1 - h)^{1-\gamma} = (h + 1)$$

$$\frac{1}{\sqrt{1-h}} = (1 + h) \qquad \Rightarrow \qquad \frac{1}{(1-h)} = (1 + h)^2$$

$$h(h^2 + h - 1) = 0$$

$$h = \frac{\sqrt{5}-1}{2}\,m$$

and $\quad P_n = \dfrac{10}{\left(1-\dfrac{\sqrt{5}-1}{2}\right)^{3/2}} = \dfrac{20\sqrt{2}}{(3-\sqrt{5})^{3/2}}$ N/m^2.

39 TO 41

For $\quad P = \frac{4}{5}CT^{3/2}$

We have $\quad PV^3$ = Constant

Thus molar specific heat of gas is

$$C = C_V + \frac{R}{1-3} = C_V - \frac{R}{2} = 2\,R \qquad [\text{as} \quad C_V = \frac{5R}{2}]$$

Heat supplied to gas in temperature increment by ΔT = 300 K in this process is

$$Q = nC\Delta T = n\,(2R)\,(300) = 600\,R$$

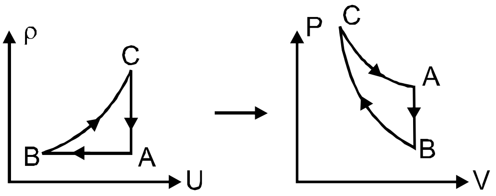
Charge in internal energy of gas in this process is

$$\Delta U = nC_V\Delta T = \frac{5R}{2} \times 300 = 750\text{ R.}$$

Thus work done by the gas is $\qquad \Delta W = Q - \Delta U = -150\,R$.

43. (A) When 0ºC ice converts into 0ºC water volume decreases slightly, so W_{system} = –ve. To melt the ice, some heat has to be given ($Q = mL_f$) which is almost equal to increase in internal energy.

(B)



Since, P–v cycle is clockwise, so W_{net} = +ve

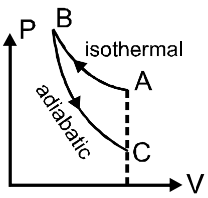
and $(\Delta u)_{cycle} = 0$

(C) By the fan, some work is done on the room air. Done to this, temperature of the gas increases slightly, so internal energy will increase slightly. Mathematically,

$Q = W + \Delta u$

$Q = -ve + \Delta u \Rightarrow \Delta u = +ve.$

(D) P–V diagram for the process is



From the diagram

$W_{A \to B \to C} = -ve$

$(PV)_C < (PV)_A \Rightarrow T_C < T_A$

So, internal energy decrease.

(E) $dQ = -2dU$

$dQ = 2h\frac{5}{2}RdT$

$C = \frac{dQ/dT}{n} = 5R$ ....(i)

$C = C_V + \frac{R}{1-x} = \frac{5}{2}R + \frac{R}{1-x}$ ....(ii)

From equ. (i) & (ii),

get $x = \frac{3}{5}$

So, process equ. is

$PV^{3/5}$ = const.

If $P\downarrow \Rightarrow V\uparrow \Rightarrow W = +ve$

To find relation between T and V, put $P = \frac{nRT}{V}$

$\left(\frac{nRT}{V}\right)(V^{3/5})$ = constant

$T \propto V^{2/5}$

$V\uparrow \Rightarrow T\uparrow \Rightarrow$ internal energy will increase.

44. Root mean square speed of molecules = $\sqrt{\frac{3RT}{M}}$ = $1.732\sqrt{\frac{RT}{M}}$

Most probable speed of molecues = $\sqrt{\frac{2RT}{M}}$ = $1.44\sqrt{\frac{RT}{M}}$

Average velocity of a molecule is zero
Speed of any individual molecule may be anything.

45. $E_n = E_1\frac{z^2}{n^2}\left(\frac{\mu}{m}\right)$

$(\mu = \frac{mM}{m+M})$

$r_n = a_0\left(\frac{n^2}{z}\right)\left(\frac{m}{\mu}\right)$