1. For echo to be heard $\frac{2d}{v} > \frac{1}{10}$ $\therefore$ $d > \frac{v}{20}$.

2. $dU = 0$ as $dT = 0$

3. Since $dU = 0$ and $dV = 0$, no work is done. So $dQ = 0$.

4. Due to less escape velocity of atoms or molecules from its surface.

5. Velocity v_1 is more than v_2 from continuity equation on both P.E. and K.E. increase since work is done by pressure at entry.

6. Water since it has less strain for a given force.

7.

$T \propto P^a d^b E^c$

$\Rightarrow$ $[T] = [ML^{-1}T^{-2}]^a\ [ML^{-3}]^b\ [ML^2T^{-2}]^c$

Equating powers of

$M\ :\ 0 = a + b + c$

$L\ :\ 0 = -a - 3b + 2c$

$T\ :\ 1 = -2a - 2c$

Solve the three equations to get,

$$t = \frac{Kd^{\frac{1}{2}}\ E^{\frac{1}{3}}}{P^{\frac{5}{6}}}.$$

i.e., $a = \frac{-5}{6}$, $b = \frac{1}{2}$, $c = \frac{1}{3}$

OR

$v \propto T^a m^b l^c$ $\Rightarrow$ $v = kT^a m^b l^c$

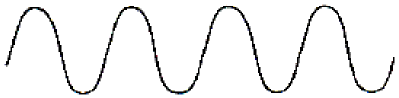
$[LT^{-1}] = k[MLT^{-2}]^a\ [M^b L^c]$

solving, we get $v = \sqrt{\frac{Tl}{m}}$.

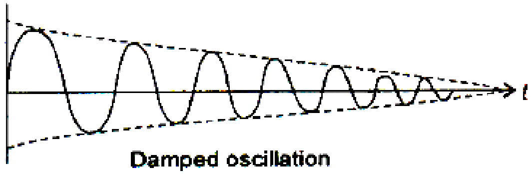
8.

2. **Damped Oscillation.** If the amplitude gets reduced continuously with time and the oscillation dies out in due course, it is called damped oscillation. Damping force is proportional to velocity.

When damping force acts on the oscillating system, then



Undamped oscillation



Damped oscillation

$$\frac{md^2x}{dt^2} = -Kx - Dv$$

or $$\frac{md^2x}{dt^2} + Kx + \frac{Ddx}{dt} = 0.$$

The solution is given by,

$$x = x_m\, e^{-\frac{Dt}{2m}} \cos(\omega' t + \phi)$$

where $\omega' \rightarrow$ angular frequency of the damped oscillation.

$$\omega' = \sqrt{\frac{K}{m} - \frac{D^2}{4m^2}}$$

It is not strictly periodic.

9.

$$T_{20} = 2\pi\sqrt{\frac{l_{20}}{g}} = \frac{2\pi}{\sqrt{g}}\sqrt{l_0(1+20\alpha)}$$

$$T_{40} = 2\pi\sqrt{\frac{l_{40}}{g}} = \frac{2\pi}{\sqrt{g}}\sqrt{l_0(1+40\alpha)}$$

$$\frac{T_{40}}{T_{20}} = \left(\frac{1+40\alpha}{1+20\alpha}\right)^{1/2} = (1+20\alpha)(1-10\alpha)$$

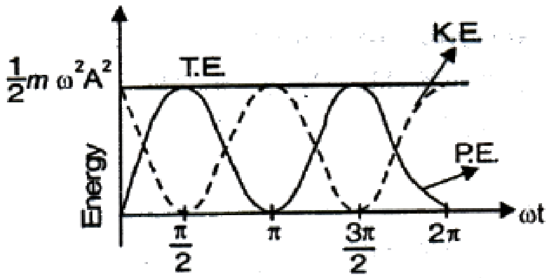
Find T_{40} in terms of T_{20} using $\alpha = \frac{\gamma}{3}$ $= 1.2 \times 10^{-6}/°C$ and multiply by 86400 for a day.

10.

$v = \sqrt{\frac{r\rho}{\rho}}$ instead of $\sqrt{\frac{P}{\rho}}$ as according to Laplace, as sound passes through a medium $dT \neq 0$ but exchange of energy $dQ = 0$ making an adiabatic process.

11.

$x = A\sin(\omega t)$.



$$\therefore\ P.E. = \frac{1}{2}m\omega^2x^2 = \frac{1}{2}m\omega^2 A^2 \sin^2(\omega t)$$

$$\text{K.E.} = \frac{1}{2} mv^2$$

$$= \frac{1}{2} m\left[\frac{d}{dt}(x)\right]^2$$

$$= \frac{1}{2} m\omega^2 A^2 \cos^2 \omega t.$$

$$\text{T.E.} = \frac{1}{2} m\omega^2 A^2.$$

OR

As shown total energy is independent of time or position and is a constant.

12.

If initial point is $x = 0$, and $x = \frac{A}{2}$ at any time 't' then using, $x = A \sin \omega t$, we have

$$\frac{A}{2} = A \sin(\omega t) \Rightarrow \omega t = \frac{\pi}{6} \text{ or } t = \frac{T}{12} \text{ sec.}$$

$\therefore$ Time taken to travel from $-\frac{A}{2}$ to $+\frac{A}{2}$ will be $2t = \frac{T}{6}$ sec.

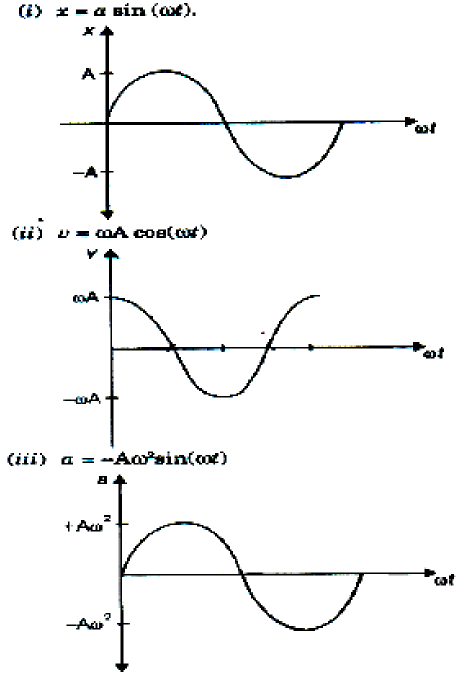
OR

Graphical Representation of S.H.M.

(i) $x = a \sin(\omega t)$.

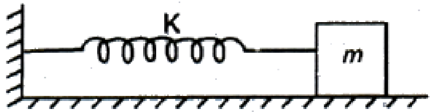
(ii) $v = \omega A \cos(\omega t)$

(iii) $a = -A\omega^2 \sin(\omega t)$



13.

The mass when displaced will stretch or compress the spring. If x is the displacement, the restoring force will be $F = -Kx$. This makes the mass to oscillate.



$$\therefore \quad ma = -Kx,\ a = \frac{-K}{m}x$$

We know, $$T = 2\pi\sqrt{\frac{\text{Displacement}}{\text{Acceleration}}},$$

$$T = 2\pi\sqrt{\frac{m}{K}}.$$

14.

We know that, stress = Y × strain

$$= Y \times \frac{\Delta l}{l}.$$

Due to heating rod tends to expand and so apply stress on the walls. So $\Delta l = l\,\alpha\,\Delta t$ where α is the coefficient of linear expansion and Δt is variation in temperature. So thermal stress

$$= Y \times \frac{l\alpha\Delta t}{l} = Y\alpha\Delta t$$

15.

Comparing the given equation with $x = A\cos(\omega t + \phi)\ m$. We have, A = 6 m,

$\omega = 100$ rad/sec, $\phi = \frac{\pi}{4}$.

(i) Amplitude = 6 m

(ii) Frequency $= \frac{\omega}{2\pi} = \frac{50}{\pi}$ Hz.

(iii) Maximum velocity $= \omega A = 600$ m/sec.

(iv) Max. K.E. $= \frac{1}{2} m\omega^2 A^2 = 18 \times 10^4$ J.

16.

Since, initial velocity is zero, $v' = \sqrt{7gR}$.

According to Bernoulli's theorem, for an incompressible, non-viscous liquid having streamlined flow, the sum of pressure head, velocity head and gravitational head is a constant., *i.e.*, $\frac{P}{\rho g} + \frac{v^2}{2g} + h$ = constant.

Consider an incompressible non-viscous liquid entering the cross-section A_1 at A with a velocity v_1 and coming out at a height h_2 at B with velocity v_2.

The P.E. and K.E. increases since h_2 and v_2 are more than h_1 and v_1 respectively. This is done by the pressure doing work on the liquid. If P_1 and P_2 are the pressure at A and B, for a small displacement at A and B,

The work done on the liquid A

$= (P_1 A_1)\Delta x_1 = P_1 A_1 v_1 \Delta t$

The work done by the liquid at B

$= -(P_2 A_2)\Delta x_2 = -P_2 A_2 v_2 \Delta t$

(Considering a small time Δt so that area may be same)

Net work done by pressure $= (P_1 - P_2) Av\,\Delta t$

since $A_1 v_1 = A_2 v_2$

From conservation of energy,

$(P_1 - P_2) Av\,\Delta t$ = change in(P.E. + K.E.)

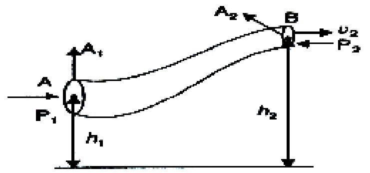
$(P_1 - P_2) Av\,\Delta t =$

$Av\rho\Delta t g(h_2 - h_1) + \frac{1}{2} Av\Delta t\rho(v_2^2 - v_1^2)$

$\therefore \quad P_1 - P_2 = \rho g(h_2 - h_1) + \frac{\rho}{2}(v_2^2 - v_1^2)$

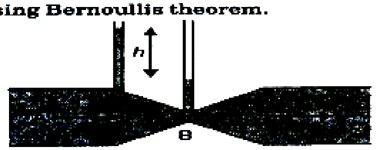
(*i.e.*) $\quad P_1 + \rho g h_1 + \frac{\rho}{2}v_1^2 = P_2 + \rho g h_2 + \frac{\rho}{2}v_2^2$

$\therefore \quad \frac{P}{\rho g} + h + \frac{v^2}{2g}$ = constant.



OR

Venturimeter is a device used to find the velocity of flow of liquid in a tube. It works on the continuity equation for the streamlined flow and the relation for velocity can be found using Bernoullis theorem.



Since cross-sectional area at B is less, velocity will be more and pressure will be less. The difference in pressure is $P_1 - P_2 = h\rho g$.

Applying Bernoulli's theorem,

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} = \frac{P_2}{\rho g} + \frac{v_2^2}{2g}$$

$$\Rightarrow \quad \frac{P_1 - P_2}{\rho g} = \frac{v_2^2 - v_1^2}{2g}$$

$\therefore \quad v_2^2 - v_1^2 = 2gh$

$\because$ For streamlined flow, $a_1 v_1 = a_2 v_2$

$$v_2^2 - \frac{a_2^2 v_2^2}{a_1^2} = 2gh$$

$$\Rightarrow \quad v_2^2 = 2gh\left(\frac{1}{1 - \left(a_2^2/a_1^2\right)}\right)$$

$$\Rightarrow \quad v_2 = a_1\sqrt{\frac{2gh}{a_1^2 - a_2^2}}$$

By placing it in a tube of cross-sectional area '*a*', the velocity *v* can be found.

17.

First Law of Thermodynamics. It is based on the conservation of energy. The total heat energy change in any system is the sum of the internal energy change and the work done, *i.e.*, $dQ = dU + dW$

where $dU \rightarrow$ internal energy change and $dW = PdV$ is the work done by/on the system, dU is a state function and depends on dT. ($dU = nC_v dT$). dW depends on the path followed and so is different in various processes.

Relation between C_p and C_v. Suppose one mole of a gas is heated so that its temperature rises by dT.

Heat supplied $= 1 \times C_v \times dT = C_v dT$ ...(*i*)

Since the volume is constant, the gas will not perform external work in accordance with the first law of thermodynamics and the heat supplied will be just equal to the increase in the internal energy of the gas.

$\therefore\ dU = C_v dT$ ...(*ii*)

Let the gas be heated at constant pressure to again increase its temperature by dT, and dQ be the amount of heat supplied, therefore,

$dQ = 1 \times C_p \times dT = C_p dT$ ...(*iii*)

The heat supplied at a constant pressure increases the temperature by dT hence increases its internal energy by dV as well as enables the gas to perform work dW.

$dW = PdV$ ...(*iv*)

From the first law of thermodynamics, we have

$dQ = dU + dW$

Substituting the values, we get,

$C_p dT = C_v dT + PdV$

But $PV = RT$ (For one mole of the gas)

or $PdV = RdT$ $\therefore$ $C_p dT = C_v dT + RdT$

or $C_p - C_v = R$ ...(*v*)

This is the relation between two principal specific heats of the gas when C_p, C_v and R are measured in the units of either heat or of work.

$C_p > C_v$ because a part of it goes on increasing the volume of the gas and the remaining

OR

(i) Isothermal process	Adiabatic process
1. $dT = 0$	1. $dQ = 0$
2. Generally a slow process	2. Generally a fast process
3. Carried out in a conducting cylinder	3. Carried out in a closed cylinder

(*ii*) For an adiabatic process of thermodynamics $dQ = 0$.

Since $dU = n\, C_v\, dT$ irrespective of the process, from Ist law we get $dW = -dU$ $= -n\, C_v\, dT$

So work done $= W = -n\, C_v (T_f - T_i) = -\dfrac{C_v}{R}(P_f V_f - P_i V_i)$

18.

(*i*) Consider a lengthy column of a dense liquid like glycerine. As the ball or spherical ball is dropped in it, the forces experienced are,

(*a*) weight $= mg = \frac{4}{3}\pi r^3 \rho g$

where ρ-density of ball

(*b*) upthrust $= U = \frac{4}{3}\pi r^3 \rho_l g$

where ρ_l – density of liquid

(*c*) viscous force $F_v = 6\pi\eta\rho v$

where v – terminal velocity.

When terminal velocity is attained, acceleration should be zero and the net force should be zero.

$\therefore\ mg - U - F_v = 0$

$$\frac{4}{3}\pi r^3 \rho g - \frac{4}{3}\pi r^3 \rho_l g - 6\pi\eta r v = 0$$

$$\therefore\ v = \frac{\frac{4}{3}\pi r^3 g(\rho - \rho_l)}{6\pi\eta r} = \frac{2}{9}\frac{r^2 g(\rho - \rho_l)}{\eta}$$

(*ii*) $8 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$

$\therefore\ 2r = R$

Since $v \propto r^2$, new terminal velocity will be 4 times the old terminal velocity.

OR

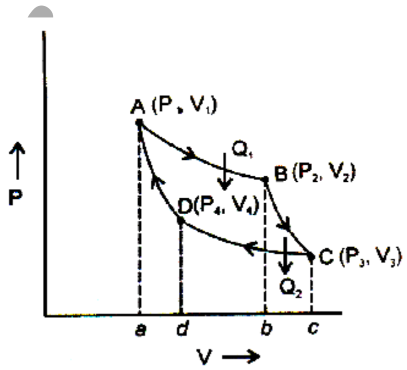
Four Stages

AB → Isothermal expansion

BC → Adiabatic expansion

CD → Isothermal compression

DA → Adiabatic compression.



Refrigerator : It works in the reverse Carnot's cycle. Heat is absorbed from sink at low temperature T_2 and given to the source at higher temperature T_1 with the help of an external agency doing work on the system. ($W = Q_1 - Q_2$). The compressor in the refrigerator uses electrical energy and does work on the system. The coefficient of performance is defined as the heat energy absorbed from low temperature sink Q_2 to the amount of work done

$W = Q_1 - Q_2$

(*i.e.,*) $\text{COP} = \dfrac{Q_2}{Q_1 - Q_2} = \dfrac{T_2}{T_1 - T_2}$