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Ans: to the que: No-1

Given that,

$m(\text{mass}) = 50\ kg$ $r = \frac{d}{2} = \frac{0.14}{2} = 0.07\ m$

$F(\text{force}) = 9.84\ N$ $S = 2.5\ m$

we know,

the law of rotation,

$\tau = \alpha I = Fr \ldots (i)$

and, $I = \frac{1}{2} m r^2 \ldots (ii)$ [I is the moment of cylinder]

From (i) and (ii),

$$\alpha = \frac{Fr}{\frac{1}{2} m r^2} = \frac{2F}{mr} = \frac{2 \times 9.84}{50 \times 0.07}\ rad/s$$

$$= 5.62\ rad.s^{-1}$$

Angular distance,

$$\theta = \frac{S}{r} = \frac{2.5}{0.07}\ rad. = 35.714\ rad.$$

we know that,

$\omega^2 = \omega_0^2 + 2\alpha\theta$ [ω_0 = Initial angular velocity = 0 $rads^{-1}$]

$\Rightarrow \omega = \sqrt{2\alpha\theta}$

$= \sqrt{2 \times 5.62 \times 35.714}$

$= 20.04\ rads^{-1}$

∴ The speed of the road,

$V = \omega r = 20.04 \times 0.07 = 1.4\ ms^{-1}$

Ans: to the que: NO-2

We know,

Mass of Earth, $M = 6 \times 10^{24}$ kg

Gravitational const. $G = 6.673 \times 10^{-11}$ $Nm^2 Kg^{-2}$

radius of Earth, $R = 6.4 \times 10^6$ m

$\therefore$ escape velocity, $V_e = \sqrt{\frac{2GM}{R}}$

$$= \sqrt{\frac{2 \times 6.673 \times 10^{-11} \times 6 \times 10^{24}}{6.4 \times 10^6}} \ ms^{-1}$$

$$= 11185.64 \ ms^{-1}$$

$$= 11.185 \ kms^{-1}$$

So, the minimum initial speed is 11.185 kms^{-1}

Ans: to the que: NO - 3

Given that,

Velocity of the source, $V_s = 90 km/h$

$= 25 ms^{-1}$

Velocity of the sound, $V = 350 ms^{-1}$

Approaching frequency, $f_a' = \frac{V}{V - V_s} f \ldots (i)$

Passing frequency, $f_p' = \frac{V}{V + V_s} f \ldots (ii)$

(i) - (ii)

$$f_a' - f_p' = f \frac{V}{V - V_s} - f \frac{V}{V + V_s}$$

$$\Rightarrow f_a' - f_p' = f \left(\frac{V}{V - V_s} - \frac{V}{V + V_s} \right)$$

$$\Rightarrow 400 = f \times \left(\frac{350}{350 - 25} - \frac{350}{350 + 25} \right)$$

$$\Rightarrow 400 = f \times \frac{28}{195}$$

$$\Rightarrow f = 2785.71 Hz$$

$\therefore f = 2785.71 Hz$

$\therefore$ Frequency of the whistle is 2785.71 Hz

Ans: to the que. No. -4 (a)

~~4a~~

Fourier series is an infinite series representation of periodic function in terms of trigonometric function sine and cosine.

Formula of fourier series -

$$f(x) = a_0 + \sum_{n=1}^{\infty} a_n \cos\left(\frac{n\pi x}{l}\right) + \sum_{n=1}^{\infty} b_n \sin\left(\frac{n\pi x}{l}\right) \quad [-l<x<l]$$

where,

$$a_0 = \frac{1}{2l}\int_{-l}^{l} f(x)dx$$

$$a_n = \frac{1}{l}\int_{-l}^{l} f(x)\cos\left(\frac{n\pi x}{l}\right)dx$$

$$b_n = \frac{1}{l}\int_{-l}^{l} f(x)\sin\left(\frac{n\pi x}{l}\right)dx$$

when f(x) is a odd function:

we know,

$$f(-x) = -f(x)$$

in that case,

$$\int_{-l}^{l} f(x)dx = 0$$

when f(x) is a even function -

we know,

$$f(x) = f(-x)$$

in that case -

$$\int_{-l}^{l} f(x)dx = 2\int_{0}^{l} f(x)dx$$

Then

$$a_0 = \frac{1}{2l}\int_{-l}^{l} f(x)\,dx$$

$$\Rightarrow a_0 = 0$$

$$a_n = \frac{1}{l}\int_{-l}^{l} f(x)\cos\left(\frac{n\pi x}{l}\right)dx$$

$$\Rightarrow a_n = 0$$

$$b_n = \frac{1}{l}\int_{-l}^{l} f(x)\sin\left(\frac{n\pi x}{l}\right)dx$$

$$\cancel{b_n = \frac{2}{l}\int_{0}^{l} f(x)\sin(}$$

$$b_n = 0$$

Then,

$$a_0 = \frac{1}{2l}\int_{-l}^{l} f(x)\,dx$$

$$\Rightarrow a_0 = \frac{1}{l}\int_{0}^{l} f(x)\,dx$$

again,

$$a_n = \frac{1}{l}\int_{-l}^{l} f(x)\cos\left(\frac{n\pi x}{l}\right)dx$$

$$\Rightarrow a_n = \frac{2}{l}\int_{-l}^{l} f(x)\cos\left(\frac{n\pi x}{l}\right)dx$$

$$b_n = \frac{1}{l}\int_{-l}^{l} f(x)\sin\left(\frac{n\pi x}{l}\right)dx$$

$$\Rightarrow b_n = \frac{2}{l}\int_{0}^{l} f(x)\sin\left(\frac{n\pi x}{l}\right)dx$$

So, the Fourier series will be, when $f(x)$ is odd

$$f(x) = \sum_{n=1}^{\infty} b_n \sin\left(\frac{n\pi x}{l}\right)$$

when $f(x)$ is even,

$$f(x) = a_0 + \sum_{n=1}^{\infty} a_n \cos\left(\frac{n\pi x}{l}\right)$$

Ans. to the que: No - 5(b)

Given that,

mean free path, $\tau = 0.8 \times 10^{5}$ cm

$n = 2.7 \times 10^{19}$ molecules/cm^3

we know,

$$\tau = \frac{1}{\sqrt{2}\,\pi n d^2}$$

$$d^2 = \frac{1}{\sqrt{2}\pi n \tau} = \frac{1}{\sqrt{2} \times 3.1415 \times 2.7 \times 10^{19} \times 0.8 \times 10^5}$$

$$= 1.042 \times 10^{-25}\ cm^2$$

$$\therefore d = 3.23 \times 10^{-13}\ cm.$$

Ans: to the que: NO - 4(b)

Difference between simple harmonic motion and damped is showed below -

Simple harmonic Motion	Damped Harmonic Motion
(i) It's an ideal oscillating system.	(i) It's ~~an~~ not an ideal oscillating system.
(ii) Simple harmonic motion is a special type of periodic motion where the restoring force on the moving object is directly propotional to the objects displacement and acts towards the object equilibrium position.	(ii) The period and frequency are nearly same as for simple harmonic motion. But when the mass is displaced from its equilibrium position there will be restoring force due to the spring and in addition the damping force - ~~b~~ due to the fluid
(iii) Amplitude always remains the same as there is no frictional force acting.	(iii) Amplitude steadily reduces because there's frictional force acting on the system.

(iv) Formula : $F = -kx$ $\Rightarrow \frac{d^2x}{dt^2} + \frac{k}{m}x = 0$	(v) Formula : $F = -kx - bv$ $\Rightarrow \frac{d^2x}{dt^2} + \frac{b}{m}\frac{dx}{dt} + \frac{k}{m}x = 0$

Ans: to the que: No - 5(a)

We know,

the differential form of the first law of thermo-dynamics is:

$$dQ + dW = dU$$

Here, $dW = -PdV$

$$dU = nC_v dT$$

$$\therefore dQ = PdV + nC_v dT$$

$$\Rightarrow dQ = \frac{nRT}{V} dV + nC_v dT$$

Now, let integrate each term of this equation between an arbitrary initial state i and an arbitrary final state of f.

$$\int_{T_i}^{T_f} \frac{dQ}{T} = nR \int_{V_i}^{V_f} \frac{dV}{V} + nC_v \int \frac{dT}{T}$$

$$\Rightarrow S_f - S_i = nR(\ln V_f - \ln V_i) + nC_v(\ln T_f - \ln T_i)$$

$$\Rightarrow \Delta S = nR \ln \frac{V_f}{V_i} + nC_v \ln \frac{T_f}{T_i}$$

As we didn't specify a path in carrying out the integration

So, the above result must hold for all (reversible) paths. Thus the change in entropy between the initial and final states of an ideal gas depends only on properties of the initial state (T_i and V_i) and of the final state (T_f and V_f). It's totally independent of the process by which the ideal gas moves from its initial to its final state. Thus entrophy is indeed a state property, characteristic of the particular state of a system and not dependent on how the system arrived at that state.