CBSE Board
Class XI Physics

Time: - 3 **Marks: - 70 Marks**

General Instructions

(a) All questions are compulsory.
(b) There are 29 questions in total. Questions 1 to 8 carry one mark each, questions 9 to 16 carry two marks each, questions 17 to 25 carry three marks each and questions 27 to 29 carry five marks each.
(c) Question 26 is a value based question carrying four marks.
(d) There is no overall choice. However, an internal choice has been provided in one question of two marks, one question of three marks and all three questions of five marks each. You have to attempt only one of the given choices in such questions.
(e) Use of calculator is not permitted.
(f) You may use the following physical constants wherever necessary.

$$e = 1.6\times10^{-19} C$$
$$c = 3\times10^{8} ms^{-1}$$
$$h = 6.6\times10^{-34} JS$$
$$\mu_o = 4\pi\times10^{-7} NA^{-2}$$
$$k_B = 1.38\times10^{23} JK^{-1}$$
$$N_A = 6.023\times10^{23} / mole$$
$$m_n = 1.6\times10^{-27} kg$$

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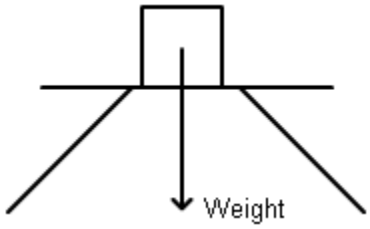
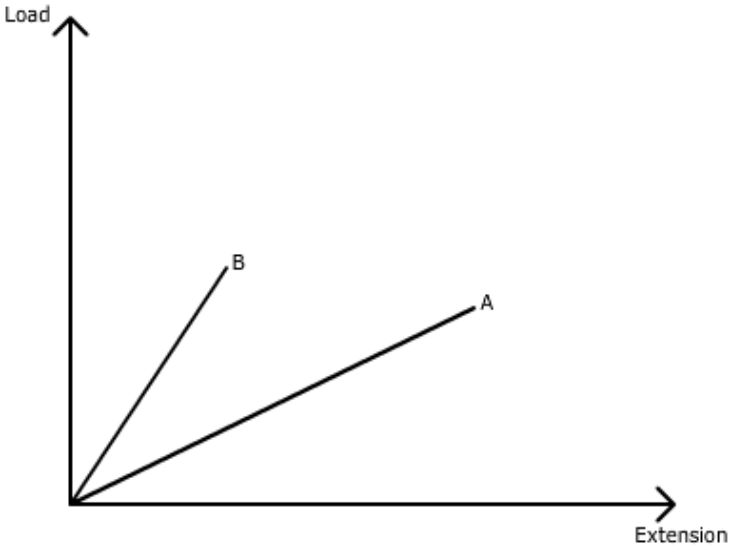
1. Give dimensions of (i) rotational Kinetic energy (ii) strain. (1)

2. If the force shown on the block is action, what is its reaction? (1)



3. Mention two advantages of 'I' shape of iron beams used in building construction. (1)

4. The graph below shows load extension curve for two wires A and B of the same material and of same length. Which one of them is thicker? (1)



5. Give one example each of natural and forced convection. (1)

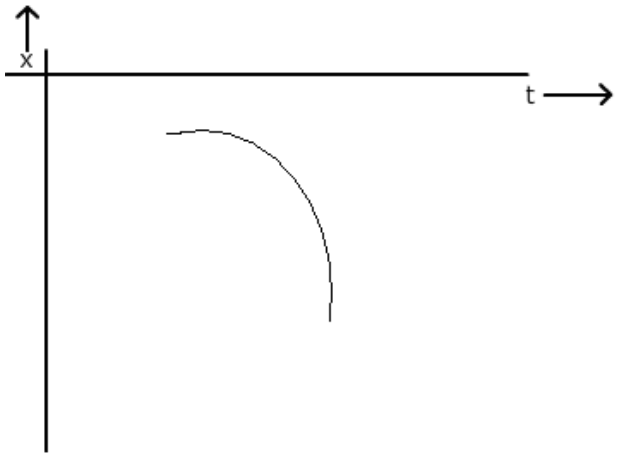
6. Draw cooling curve for hot water. (1)

7. Why is 'invar' used for making the pendulum of a clock? (1)

8. What do you understand by 'natural frequency' of a vibrating system? (1)

9. What is absolute error? The temperature of two bodies measured by a thermometer are $t_1 = 20°C \pm 0.5°C$ and $t_2 = 50°C \pm 0.5°C$. What is the temperature difference and the error therein? (2)

10. From the following graph, find the sign of (i) velocity (ii) acceleration. Give reasons for each answer. (2)



11. What is the maximum height reached by an oblique projectile if its time of flight is T? (2)

12. Explain very briefly, why

(i) A horse cannot pull a cart and run in empty space?

(ii) Passengers are thrown outward when a moving bus takes a sudden turn. (2)

13. What are concurrent forces? Under what conditions will a body remain in equilibrium? (2)

14. Why does a satellite not need any fuel to circle around the earth? Is it possible to put an artificial satellite in an orbit such that it always remains visible directly over New Delhi? (2)

15. A gas mixture consists of molecules of type A, B and C with molecular masses $m_A > m_B > m_C$. Rank the three types according to (a) average kinetic energy (b) rms speed, greatest first. Give justification for each answer. (2)

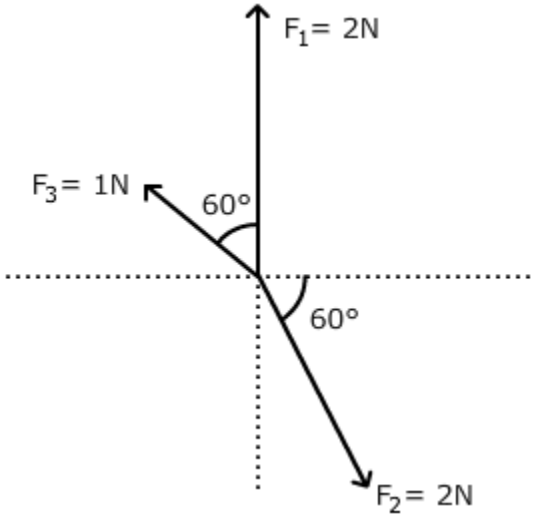
OR

What would be the ratio of initial and final pressures if the masses of all the molecules of a gas are halved and their speeds doubled? What is the kinetic energy per unit volume of a gas if its pressure is 2×10^5 N/m^2. (2)

16. A Carnot's engine takes 2095 J of heat per cycle from source at 400 K and rejects 1676 J to the sink. Calculate the temperature of the sink and efficiency of the engine. (2)

17. The motion of a car along y-axis is given by v(t)= -12t + 12 where velocity v is in m/s and time t in seconds. Find the instantaneous position of the car as a function of time if at t = 0 it was at 5 m. Also find its acceleration at t = 2 second. (3)

18. Find $\vec{F}_1 + \vec{F}_2 - \vec{F}_3$ (3)



19.

(i) Classify the following into conservative and non-conservative spring force, human push, gravitational force, viscous drag.

(ii) Potential energy of a system due to a conservative for F is U. What is the relation between them? (3)

20. Define coefficient of restitution. In an elastic collision of two bodies are the momentum and energy of each body conserved? Why is heavy water chosen in a nuclear reactor to slow down fast moving neutrons? (3)

OR

(a) Find the torque of a force $7\hat{i} + 3\hat{j} - 5\hat{k}$ about the origin. The force acts on a particle whose position vector is $\hat{i} - \hat{j} + \hat{k}$.

(b) How do we find the direction of angular velocity? (3)

21. State perpendicular axis theorem. What is the moment of inertia of a ring of mass 2 kg and radius 0.5m about an axis passing through its centre and perpendicular to its plane? Also find moment of inertia about a parallel axis through its edge. (3)

22. Find the potential energy of a system of four identical particles placed at the vertices of a square of side a. Also obtain the potential at the centre of the square. (3)

23. Define moment of inertia. What is the moment of inertia of a ring about a tangent to the circle of the ring? (3)

24. What is a Carnot's engine? What is its efficiency? (3)

25. Derive a relation for the distance covered in n^{th} second by a uniformly accelerated body. (3)

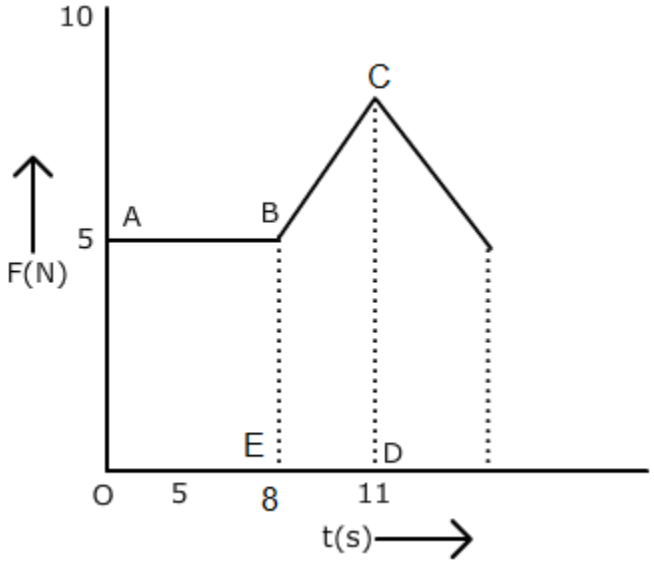
26. Suresh was struggling to understand Kepler's second law of planetary motion. Then his friend Ravi explained to him how the planets move around Sun obeying Kepler's laws of planetary motion.

(a) Comment upon the values of Ravi.

(b) State Kepler's laws of planetary motion. (4)

27.

(a) Force-time graph for a body is given below. What is the velocity of the body at the end of 11 sec? Mass of the body is 7 kg and assumes it to be initially at rest.



(b) When an automobile moving with a speed of 36 km/h reaches an upward inclined road of angle 30°, its engine is switched off. If the coefficient of friction involved is 0.1, use an appropriate free body diagram to find the retardation suffered by the automobile. (5)

OR

Explain the following:

(i) free vibrations
(ii) damped oscillations
(iii) maintained oscillations
(iv) forced oscillation
(v) resonant or sympathetic vibrations. (5)

28. What do you understand by 'laminar flow' and 'streamlined flow'?

Water is flowing with a speed of 2 m/s in a horizontal pipe with cross sectional area 2×10^{-2} m^2 at pressure 4×10^4 Pa. What will be the pressure at a smaller cross section where the area decreases to 0.01 m^2? (5)

OR

Define angle of contact. For what nature of angle of contact will a liquid wet the solid? A liquid drop of diameter 4 mm breaks into 1000 droplets of equal size. Calculate the resultant change in surface energy if the surface tension of the liquid is 0.07 N/m. (5)

29. A displacement wave is represented by $y = 0.25 \times 10^{-3}$ Sin (500t + 0.025 Hz) where y, t and z are in cm, sec and m respectively.

Deduce:

(i) the direction of travel of the wave

(ii) wave frequency

(iii) wavelength

(iv) the wave speed

(v) maximum particle velocity (5)

OR

(a) What is Doppler effect? A whistle is being rotated in a horizontal circle. What will be the effect on the sound frequency for a listener standing (i) outside the circle (ii) at the centre of the circle.

(b) What is the beat frequency when two tuning forks of frequency 200 Hz and 205 Hz are sounded together? Mention one application of beats. (5)

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Class XI Physics
Solution

1.
(i) $[ML^2T^{-2}]$
(ii) Dimensionless

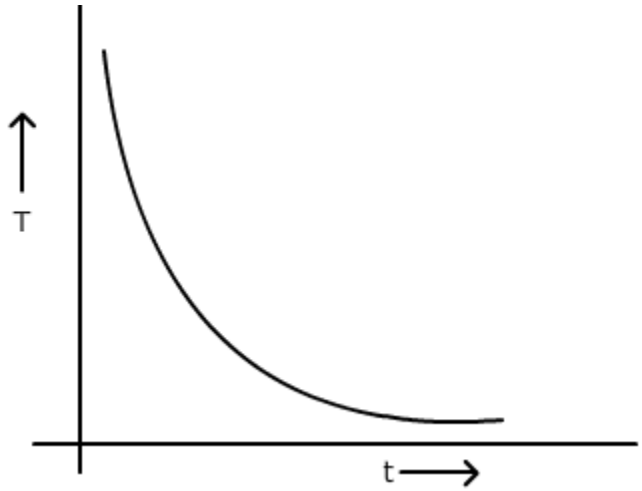
2.
Reaction is the force applied by the block on the Earth.

3.
Two advantages of 'I' shape of iron beams are
(i) minimizes sagging
(ii) minimizes buckling

4.
Wire B.

5.
Natural Convection: Trade winds/Land and sea breeze
Forced Convection: Human circulatory system

6.



7.
Invar is used because of a very small coefficient of linear expansion.

8.
The frequency of free oscillations of a vibrating system.

9.

Absolute error is the magnitude of difference between the value of individual measurement and the true value of the quantity.

$$\Delta t = t_2 - t_1$$
$$= (50 \pm 0.5) - (20 \pm 0.5)$$
$$= 30°C \pm 1°C$$

10.

(i) Velocity is negative as the slope of x-t graph is negative.

(ii) Acceleration is negative. The increasing slope indicates speeding up, and hence the sign of acceleration and velocity are same.

11.

$$T = \frac{2u\sin\theta}{g}$$

$$\Rightarrow u\sin\theta = \frac{gT}{2}$$

Max. Height $H = \frac{u^2 \sin^2\theta}{2g}$

$$= \frac{(u\sin\theta)^2}{2g}$$

$$= \frac{\left(\frac{gT}{2}\right)^2}{2g}$$

$$= \frac{gT^2}{8}$$

12.

(i) A horse cannot pull a cart and run forward in space because no reaction from any surface underneath is available which can make the horse move forward.

(ii) Due to inertia of motion, the upper part of the body continues to move along the tangent to the circular path of the bus and hence passengers are thrown outward when the bus takes a sudden turn.

13.

Concurrent forces are the forces whose lines of action intersect at a common point.

Conditions:

1. $\sum \vec{F} = 0$
2. $\sum \vec{\tau} = 0$

14.

Because the gravitational force between the satellite and the earth provides the necessary centripetal force required to keep it in its orbit.

No, because New Delhi is not on the equatorial plane.

15.

(a) All have same average K.E. as K_{av} depends only on temperature.

(b) C, B and A as $v_{rms} \propto \frac{1}{\sqrt{m}}$

OR

(i) $P = \frac{1}{3}\frac{mn}{V} v_{rms}^2$

$\frac{P_i}{P_f} = \frac{1}{2}$

(ii) $P = \frac{2}{3}E$

$\Rightarrow E = \frac{3}{2}P = 3 \times 10^5 \text{ J/m}^3$

16.

(i) $\frac{Q_1}{Q_2} = \frac{T_1}{T_2}$

$\Rightarrow T_2 = 320 \text{ K}$

(ii) $\eta = 1 - \frac{T_2}{T_1}$

$\Rightarrow \eta = 0.2$

17.

$x(t) = \int v \, dt = \int (-12t + 12) dt$

$= -12\frac{t^2}{2} + 12t + c$

$= -6t^2 + 12t + c$

Since, at t = 0, x(0) = 5, therefore, c = 5

Therefore, $x(t) = -6t^2 + 12t + 5$ m

Also, $a = \frac{dv}{dt}$

$= -12 \text{ m/s}^2$

18.

$$\vec{F}_1 = 2\hat{j}\ N$$

$$\vec{F}_2 = 2\cos 60^0 \hat{i} - 2\sin 60^0 \hat{j}$$

$$= \hat{i} - \sqrt{3}\hat{j}\ N$$

$$\vec{F}_3 = -1\sin 60^0 \hat{i} + 1\cos 60^0 \hat{j}$$

$$= -\frac{\sqrt{3}}{2}\hat{i} + \frac{1}{2}\hat{j}\ N$$

$$\vec{F}_1 + \vec{F}_2 - \vec{F}_3 = 2\hat{j} + (\hat{i} - \sqrt{3}\hat{j}) - \left(-\frac{\sqrt{3}}{2}\hat{i} + \frac{1}{2}\hat{j}\right)$$

$$= \left(1 + \frac{\sqrt{3}}{2}\right)\hat{i} + \left(\frac{3}{2} - \sqrt{3}\right)\hat{j}\ N$$

19.

(i) Conservative: spring force, gravitational force
Non-conservative: Human push, viscous drag

(ii) $F = -\frac{dU}{dr}$

20. Coefficient of restitution: Ratio of relative speed of separation to relative speed of approach.

No, not for each body separately. Total energy and total momentum of the whole isolated system will be conserved.

Heavy water is chosen because collision between fast neutron and near stationary deuterons in heavy water results in maximum exchange of kinetic energy as their masses are comparable.

OR

(a) $\vec{F} = 7\hat{i} + 3\hat{j} - 5\hat{k},\ \vec{r} = \hat{i} - \hat{j} + \hat{k}$

$$\vec{\tau} = \vec{r} \times \vec{F}$$

$$= \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & -1 & 1 \\ 7 & 3 & -5 \end{vmatrix}$$

$$= (5-3)\hat{i} + (5+7)\hat{j} + (3+7)\hat{k}$$

$$\vec{\tau} = 2\hat{i} + 12\hat{j} + 10\hat{k}$$

(b) Curl the fingers of right hand along the direction of rotation, the out stretched thumb points along the direction of angular velocity.

21.

If we define perpendicular axes *X*, *Y*, and *Z* (which meet at origin *O*) so that the body lies in the *XY* plane, and the *Z* axis is perpendicular to the plane of the body and

(i) I_X be the moment of inertia of the body about the *X* axis;

(ii) I_Y be the moment of inertia of the body about the *Y* axis; and

(iii) I_Z be the moment of inertia of the body about the *Z* axis.

The perpendicular axis theorem states that

$I_Z = I_X + I_Y$

$I = MR^2$

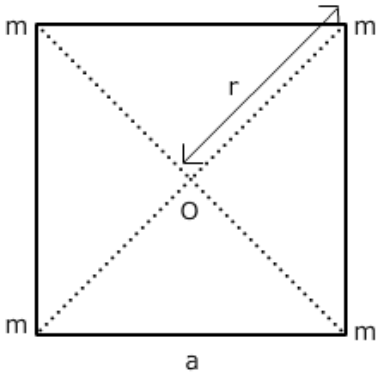
$= 2 \times (.50)^2 = 0.5 \text{ kg m}^2$

$I' = MR^2 + MR^2$

$= 2MR^2 = 2 \times 0.5$

$= 1 \text{kg m}^2$

22.



$$U(r) = -\frac{Gm_1m_2}{r_{12}}$$

Therefore,

$$\text{Total } U = -4\frac{Gm^2}{a} - 2\frac{Gm^2}{a\sqrt{2}}$$

$$= -\frac{2Gm^2}{a}\left(2 + \frac{1}{\sqrt{2}}\right)$$

$$= -5.41\frac{Gm^2}{a}$$

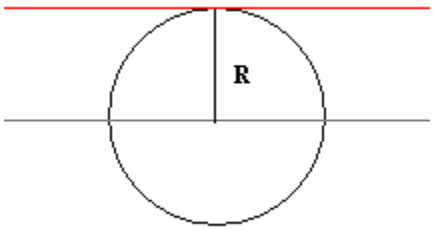
$$\text{Potential } V(r) = -\frac{Gm_1}{r_1}$$

$$\text{Total } V = -4\frac{Gm}{\left(\frac{a\sqrt{2}}{2}\right)} = -4\sqrt{2}\frac{Gm}{a}$$

23.

The moment of inertia of a rigid body about an axis defined by the formula $I = \sum m_i r_i^2$ where r_i is the perpendicular distance of the i^{th} point of the body from the axis.

The moment of inertial about a tangent to the ring in the plane of the ring is the moment of inertia about a diameter parallel to the tangent + Mh^2 where h is the distance between the two parallel axes.



$I = MR^2/2 + MR^2 = 3/2\ MR^2$

24. It is a reversible engine in which all input heat originates from a hot reservoir at temperature T_H and all heat rejected goes into a cold reservoir at T_C, It consists of two isothermal processes and two adiabatic processes.

The efficiency of a Carnot engine is

$$\eta = 1 - \frac{T_C}{T_H}$$

25.

Let S_n and S_{n-1} be the distance covered in n and $(n-1)$ seconds respectively.

$S_n = x(n) - x(0)$

$= v(0)n + \frac{1}{2}an^2 \qquad (\because x(t) - x(0) = v(0)t + \frac{1}{2}at^2)$

and $S_{n-1} = x(n-1) - x(0)$

$= v(0)(n-1) + \frac{1}{2}a(n-1)^2$

But $S = S_n - S_{n-1}$

$= \left[v(0)n + \frac{1}{2}an^2\right] - \left[v(0)(n-1) + \frac{1}{2}a(n-1)^2\right]$

$= v(0)n + \frac{1}{2}an^2 - v(0)n + v(0) - \frac{1}{2}an^2 - \frac{a}{2} + an$

$= v(0) - \frac{a}{2} + an$

or $S = v(0) + \frac{a}{2}(2n-1)$

26.

(a) Ravi shares his knowledge with his friends and has concern towards his friends.

(b)

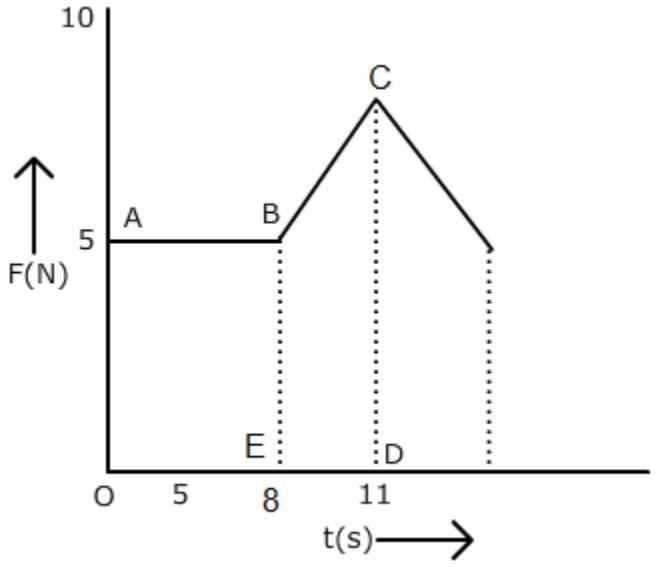
(i) All the planets move around in elliptical orbits with the sun at its focus.

(ii) The line joining the sun and the planet sweeps out equal areas in equal intervals of time.

(iii) The square of the time period of revolution of the planet is directly proportional to the cube of the semi-major axis of the elliptical orbit $T^2 \propto a^3$.

27.

(a)



Impulse = Area under F(t) graph

½ = area OABE + area BCDE

$= 5 \times 8 + \frac{1}{2} \times 3 \times (10 + 5)$

$½ = 40 + \frac{45}{2}$

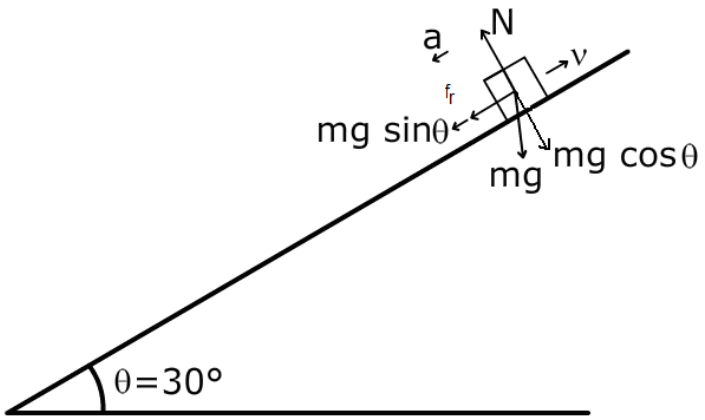
$= 62.5$ kg m/s

$\Delta p = m(\upsilon - u)$ = Impulse

Therefore, $7(\upsilon - 0) = 62.5$

$\upsilon = \frac{62.5}{7} \approx 9$ m/s

(b)



$ma = f_r + mg\sin\theta$

$ma = \mu\, mg\cos\theta + mg\sin\theta$

$a = (\mu\cos\theta + \sin\theta)g = (0.1\cos30° + \sin30°)10$

$= \frac{\sqrt{3}}{2} + 5 = 5.87\ \ m/s^2$

OR

(i) They are the free oscillation of a system purely because of certain specific restoring forces (say gravity of a simple pendulum or the mass attached to the spring). The frequency of such a system is called its natural frequency (n_o) and the corresponding time period as the natural time period of the oscillating system. Since there are no frictional or viscous forces present, the amplitude of oscillations remains constant. These oscillations are also called undamped vibrations.

(ii) The oscillations in which the amplitude decreases progressively with the time are called damped oscillation.

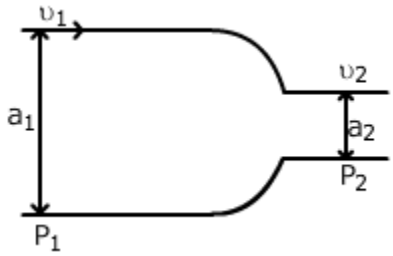
(iii) When we feed energy back to the oscillations at the same rate at which it is dissipated, then the amplitude of such oscillations would remain constant with time. These oscillations are called maintained or sustained oscillations.

(iv) When an external periodic agent of frequency (n) is applied to an oscillator of natural frequency (n_o), the external agent is called the driver and the oscillating body is called the driven. The driven oscillator ultimately settles down to the frequency of the driver. Such oscillations that are forced upon the oscillator by the external periodic agent are known as the forced oscillations.

(v) When the frequency of the driver (n) approaches the frequency of the driven (n_o), then the amplitude of the forced oscillation (and hence power drawn) becomes quite large. The driver and the driven are said to be in resonance. The phenomenon of setting a body into vibration with its natural its natural frequency by another body vibrating with the same frequency is called resonance.

28.

Laminar flow occurs when a fluid flows in parallel layers, with no disruption between the layers.



$$P_1 + \frac{1}{2}\rho v^2_1 = P_2 + \frac{1}{2}\rho v^2_2 \text{ and } a_1 v_1 = a_2 v_2$$

Therefore, $P_2 = P_1 + \frac{1}{2}\rho\left(v_1^2 - v_2^2\right)$

$$= P_1 + \frac{1}{2}\rho\left[v_1^2 - \left(\frac{a_1}{a_2}\right)^2 v_1^2\right]$$

$$= P_1 + \frac{1}{2}\rho v_1^2\left[1 - \left(\frac{a_1}{a_2}\right)^2\right]$$

$$= 4\times10^4 + \frac{1}{2}\times10^3\times4\left[1 - \frac{4\times10^{-4}}{1\times10^{-4}}\right]$$

$$= 4\times10^4 - 0.6\times10^4$$

$$= 3.4\times10^4 \text{ P}_a$$

OR

Definition: The contact angle is the angle at which a liquid/vapor interface meets the solid surface. The contact angle is specific for any given system and is determined by the interactions across the three interfaces.

For acute angle of contact:

$$n \cdot \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3 \Rightarrow r = \frac{R}{n^{\frac{1}{3}}}$$

$$= \frac{4\times10^{-3}}{(1000)^{\frac{1}{3}}} = 4 \times 10^{-4} \text{ m}$$

$$\Delta A = n \cdot 4\pi r^2 - 4\pi R^2$$

$$= 4\pi\frac{R^2}{n^{\frac{2}{3}}} \cdot n - 4\pi R^2 = 4\pi R^2\left(n^{\frac{1}{3}} - 1\right)$$

$$= 4 \times 3.14 \times 16 \times 10^{-16}(10 - 1) = 9 \times 64 \times 3.14 \times 10^{-6} \text{ m}^2$$

Therefore, $\Delta E = \sigma \Delta A$

$$= 0.07 \times 9 \times 64 \times 3.14 \times 10^{-6} \approx 1.23 \times 10^{-2} \text{ J}$$

29.

(i) –z direction

(ii) $f = \frac{w}{2\pi}$

$= \frac{500}{2\pi} = \frac{250}{\pi}$ Hz

(iii) $\lambda = \frac{2\pi}{R}$

$= \frac{2\pi}{0.025} = 80\pi$ m

(iv) $\nu = \frac{\omega}{R}$

$= \frac{500}{0.025} = 2 \times 10^4$ m/s

(v) $\nu_{pmax} = \omega A$

$= 0.25 \times 10^{-3} \times 500 = 0.125$ cm/s

OR

(a) Definition: The Doppler effect is the change in frequency and wavelength of a wave for an observer moving relative to the source of the waves.

(i) For the listener standing outside the circle, the whistle moves towards him as well as away from him. Therefore, the frequency will appear to increase as well as decrease.

(ii) For the listener at the centre, the distance between him and the whistle remains constant. So, there will be no change in frequency.

(b) Beat frequency = 5 Hz
Application of beats is in tuning of musical instruments.