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PHYSICS

Class 10th (KPK)

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SIMPLE HARMONIC MOTION AND WAVES

COMPREHENSIVE QUESTIONS

Q1. What is simple harmonic motion? What are the conditions for an object to oscillate with SHM?

Ans: <u>Simple Harmonic Motion:</u>

Simple harmonic motion is the type of vibratory motion in which the acceleration is directly proportional to the displacement from the equilibrium position and is always directed towards the equilibrium position.

Explanations:

If "a" is the acceleration of the body and "*x*" represents the displacement of the body from its mean position.

<u>Conditions of SHM:</u>

The characteristic of SHM are as follows:

i. In SHM a body oscillates about a mean position 0.

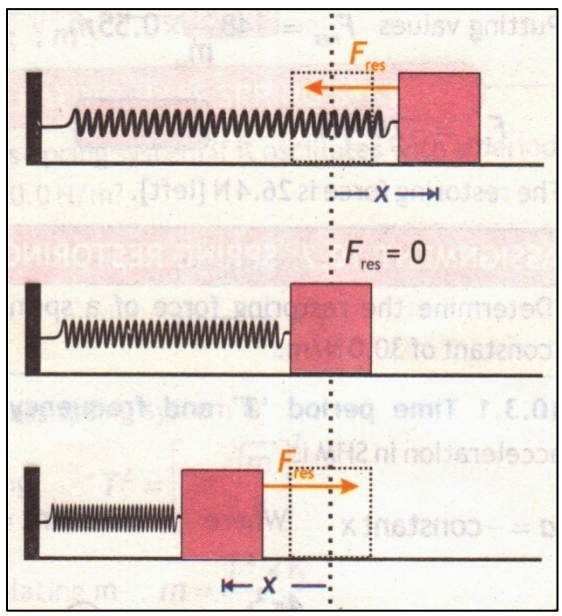
ii. A restoring force is always directed towards the mean position 0. The acceleration produced by it is also directed towards the mean position.

iii. Its acceleration is directly proportional to its displacement from the mean position. i.e. $a \propto -x$

Q2. Show that the mass spring system executes SHM.

Ans: <u>Mass Spring System</u>

Consider a block of mass m attached to one end of elastic string, which can move freely on a frictionless horizontal surface as show in figure



<u>Explanation</u>:

When the block is displaced the elastic restoring force pulls the block towards equilibrium position. For an ideal spring that obeys Hook's law the elastic restoring force F_{res} is directly proportional to the displacement x from equilibrium position.

$$F_{res} \propto -x$$

Since F and x always have opposite directions therefore we have a negative sign in equation. Each spring is different, and so is the force required to deform it.

The stiffness of the spring, or a spring constant, is represented by the letter k. the equation for Hook's law is

$F_{res} = -kx$ ----------------1

Thus motion of mass attach to spring is SHM. Restoring force produces acceleration in the body, given by Newton's second law of motion as

$F_{res} = ma$ --------------2

Comparing equation 1 and 2, we get

$$ma = -kx$$

$$a = -\frac{k}{m}x \ \ldots\ldots\ldots (A)$$

As spring constant k and mass m does not change during oscillation of mass attached to spring therefore they are regarded as constants.

$$a \propto -x$$

If the restoring force obeys Hook's law precisely, the oscillatory motion of mass attached to spring is simple harmonic.

Time period "T" of mass spring system:

Since acceleration SHM is

$a = -constant\ x$ Where $constant = \frac{4\pi^2}{T^2}$

Therefore

$$a = -\frac{4\pi^2}{T^2}x \ldots\ldots\ldots (3)$$

Form equation (A), we have

$$a = -\frac{k}{m}x \ \ldots\ldots\ldots (4)$$

Comparing equation (3) and (4), we get

$$-\frac{k}{m}x = -\frac{4\pi^2}{T^2}x$$

Or

$$\frac{k}{m} = \frac{4\pi^2}{T^2}$$

Rearranging

$$T^2 = 4\pi^2\frac{m}{k}$$

Taking square root on both sides, we have

$$\sqrt{T^2} = \sqrt{4\pi^2}\sqrt{\frac{m}{k}}$$

Time period "T" is the time, its takes for the mass spring system to complete one vibration, and it's given by the following equation

$$T = 2\pi\sqrt{\frac{m}{k}}$$

Where" m" is the mass in kg and "k" is the spring constant in N/m of mass spring system. It is worth nothing that time period does not depend upon amplitude of oscillation.

Frequency "f" of mass spring system:

Since frequency is the reciprocal of time period therefore the frequency of mass spring system is given as

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

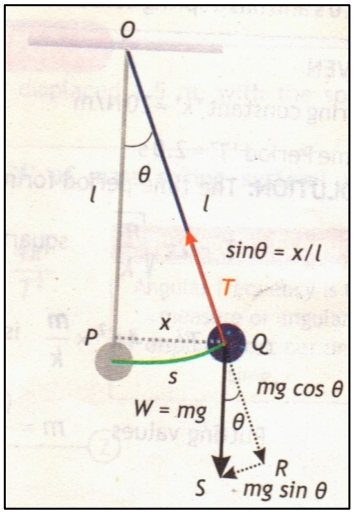
Q3. What is simple pendulum? Diagrammatically show the forces acting on simple pendulum. Also show that simple pendulum executes SHM.

Ans:

Simple Pendulum:

A simple pendulum is an idealized model consisting of a point mass suspended by a weightless, in-extendable string supported from a fixed frictionless support

Explanation:



A simple pendulum is driven by the force of gravity due to a weight of suspended mass "m" (W=mg). A real pendulum approximates a simple pendulum if

- The bob is small compared with the length ℓ
- Mass of the string is much less than the bob's mass
- The cord or string remain straight and does not stretch

Pull the pendulum bob aside and let it go, the pendulum then swings back and forth. Neglecting air drag and friction at the pendulum's pivot, these oscillations are periodic. We shall show that, provide the angle is small; the motion is that of a simple harmonic oscillator. As show in figure for ΔQRS we resolve the weight (W=mg) in two components "mg sinθ" and "mg cosθ".

The component "mg cosθ" is balanced by the tension "T" in the string. The restoring forces only provided by component "mg sinθ". Therefore

$F_{res} = -mg\sin\theta$ ----------- (1)

Also only for small angles the arc length "s" is nearly the same length as displacement "x". Therefore, from ΔOPQ

$\sin\theta = \frac{x}{\ell}$-------------(2)

Putting eq (2) in eq (1)

$F_{res} = -mg\frac{x}{\ell}$------------(3)

Since mass "m", acceleration due to gravity "g" and length "ℓ" are constant for simple pendulum oscillating with small angle, therefore

$F_{res} \propto -x$

Which is the condition for simple harmonic motion. Thus motion of simple pendulum can be approximated as is simple harmonic motion.

Also by Newton's second law of motion

$F_{res} = ma$ ---------(4)

Comparing eq (3) and eq (4)

$$ma = -mg\frac{x}{\ell}$$

Or

$a = -g\frac{x}{\ell}$-----------------(A)

Since "g" and "ℓ" are constants for oscillating simple pendulum, therefore

$a \propto -x$

Hence, when released the mass will move towards the equilibrium position, will cross over it due to inertia and will execute simple harmonic motion.

<u>Time period "T" of simple pendulum:</u>

The acceleration and displacement of simple pendulum are related by its time period "T" by the following equation:

$a = -\frac{4\pi^2}{T^2}x$ ----------------- (5)

Form equation (A), we have

$a = -\frac{g}{\ell}x$--------------------(6)

Comparing equation (5) and (6), we get

$$-\frac{g}{\ell}x = -\frac{4\pi^2}{T^2}x$$

Or

$$\frac{g}{\ell} = \frac{4\pi^2}{T^2}$$

Rearranging

$$T^2 = 4\pi^2\frac{\ell}{g}$$

Taking square root on both sides, we have

$$\sqrt{T^2} = \sqrt{4\pi^2}\sqrt{\frac{\ell}{g}}$$

Hence,

$T = 2\pi\sqrt{\frac{\ell}{g}}$-------------(B)

Above equation shows that the time period "T" of simple pendulum depends directly on the length "ℓ" of the pendulum and inversely on gravitational acceleration". The period of the pendulum does not depend on the mass of the pendulum bob. The period of the pendulum does not depend on its amplitude.

<u>Frequency "f" of simple pendulum</u>:

Since the frequency is the reciprocal of time period therefore the frequency of the simple pendulum is given as:

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{\ell}}$$

Q4. What is wave motion? How waves can be categorized?

Ans: **<u>Waves Motion:</u>** The transmission of energy in a medium due to the oscillatory motion of the particles of the medium about their mean positions is called the wave motion.

OR

A mechanism by which energy transferred from one place to another is known as wave motion.

OR

It is the energy transfer by propagation of periodic disturbance called wave motion.

<u>Types of waves:</u>

There are two main kinds of waves.

i. Mechanical waves
ii. Electromagnetic waves

i. <u>Mechanical waves</u>

The waves produced by the oscillation of material particles called mechanical waves.

For example:

Water waves, sound waves, seismic waves etc. These waves can exist only within a material medium.

ii. <u>Electromagnetic waves</u>

The waves that propagate by oscillation of electric and magnetic fields are called electromagnetic waves, they don't require material medium for their propagation. The wave is a combination of traveling electric and magnetic fields. The fields vary in value and are directed at right angles to each other and to the direction of travel of the wave.

For example:

The common examples of electromagnetic waves are visible and ultraviolet light, radio waves, microwaves, x-rays etc.

Waves can also be classified as transverse and longitudinal in terms of directions of disturbance or displacement in the medium and that of the propagation of waves.

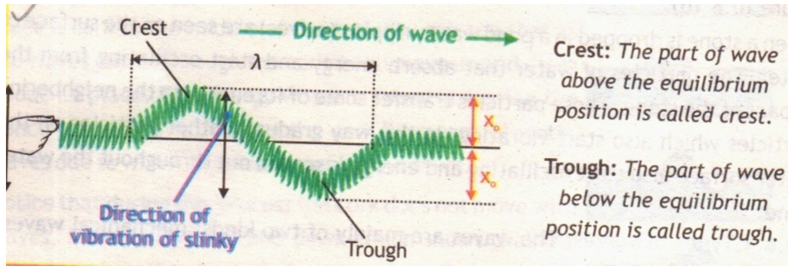
a. Transverse waves:

A transverse wave is one in which the disturbance occurs perpendicular to the direction of motion of wave.

Explanation:

The transverse waves consist of crests and troughs which are produced one after the other in a certain order. The crest represents the part of the wave above the equilibrium position while the trough represents the part of the wave below the equilibrium position.

Production of transverse waves in slinky:



Transverse wave can be generated using a slinky (a long loosely coiled spring). If one end of the slinky is jerked up and down, and upward pulse is sent travelling towards the right. If the end is then jerked down and up, a down word pulse is generated and also moves to the right.

If the end is continually moved up and down in simple harmonic motion, and entire wave is produce.

Examples:

Radio waves, light waves and micro waves are transverse waves.

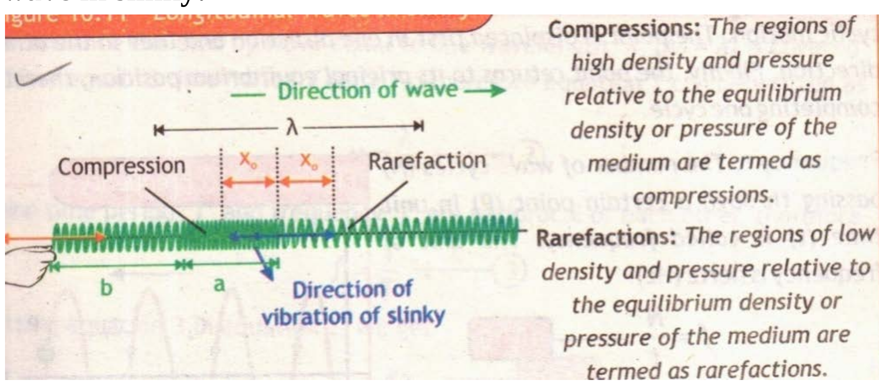
b. **Longitudinal wave:**

A longitudinal wave is one in which the disturbance occur parallel to the line of travel of the wave.

Explanation:

The longitudinal wave consists of compression and rarefactions which are produced one after the other in a certain order. Compression represents the regions of high density and pressure relative to the equilibrium density or pressure of the medium. The rarefaction represents the regions of low density and pressure relative to the equilibrium density or pressure of the medium.

Production of Longitudinal wave in slinky:



A longitudinal wave can also be generated with a slinky. When one end of the slinky is pushed forward and backward along its length two regions are formed.

The region where the parts of slinky are compressed together (called compression) is seen moving towards the right. The region where the part of slinky are stretched apart (called rarefaction) is also seen moving towards the right.

Examples:

A sound wave is a longitudinal wave.

Q5. How waves transport energy without carrying the material medium? Also describe the connection between oscillatory motion and waves.

Ans: A wave is a disturbance that moves outward from its point of origin, transferring energy by means of vibrations with little or no transport of medium.

Or

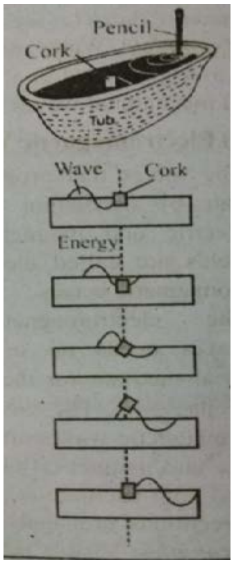
A wave is a disturbance which carries energy from one place to another without carrying the material medium

There are two common features to all waves:

1. A wave is a traveling disturbance.
2. A wave carries energy from place to place.

This can be explaining with the help of following example:

Example:



Take a tub full of water, move a pencil up and down at one edge of the tub. Waves are produced on the water surface which moves away from the point of impact of the pencil. The particles of water begin to oscillate about their mean position. The disturbance spread out in the form of waves on the surface of water.

For example, if we placed a cork in the middle of the tub. As the waves passes through the cork it will move up and down about its place. The energy which is spent in moving the pencil up and down reaches the cork by means of water waves due to which it is also move up and down.

During this process the cork does not move with waves, it only move up and down which shows that particles of matter does not move forward with waves instead they oscillate about their mean position.

This shows that during propagation of waves, the particle of the medium does not change its position permanently and perform oscillatory motion only.

Q6. Prove the relation between wave speed, wavelength and frequency of wave.

Ans: We know that the speed is given as

$$v = \frac{s}{t} \quad --------(1)$$

In case of wave distance cover by a wave in one time period ”T” is equal to wave length “λ". so we put s= λ and t=T in equation(1) so we get

$$v = \frac{\lambda}{T}$$

$$v = \frac{1}{T} \times \lambda ------(2)$$

We know that

$$f = \frac{1}{T} ----- (3)$$

Putting eq (3) in eq (2) we get

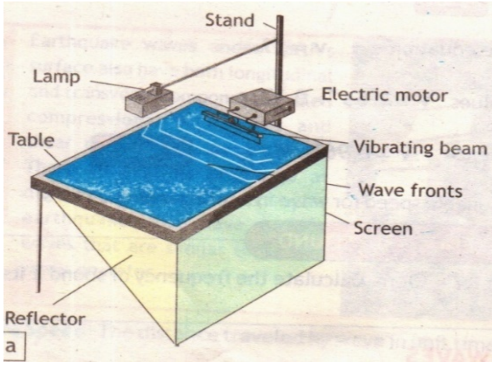
$$v = f\lambda ----- (4)$$

Eq (4) represents the relation between wave speed, frequency and wavelength of a wave.

Q7. Using ripple tank explain reflection, refraction and diffraction of waves.

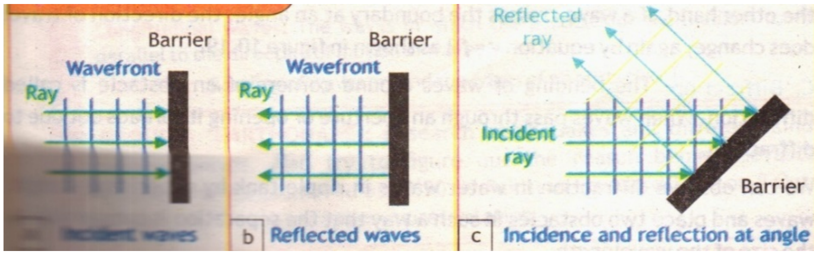
Ans: Ripple Tank:

Ripple tank is an experimental setup to study the two dimensional features or characteristics of wave mechanics such as reflection, refraction and diffraction.



Reflection:

Reflection is the change in direction of a wave-front at an interface between two different media or rigged barriers so that the wave-front returns into the medium from which is originated.



When wave runs into a straight barrier they are reflected along their original path. However, if a wave hits a straight barrier obliquely, the wave-front is reflected at an angle to the barrier.

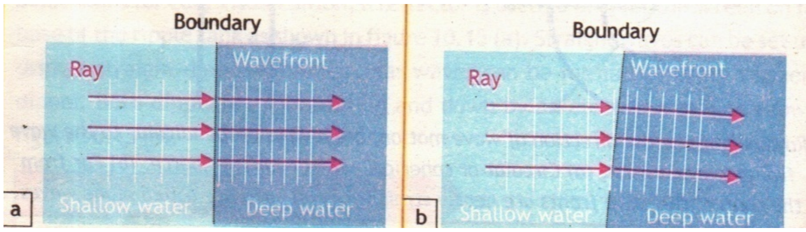
In ripple tank reflection can be demonstrated by placing an upright barrier in tray and the reflection of water can be seen.

Refraction:

When wave travel from one medium into another, their speed changes this phenomenon is called refraction.

We can observe refraction occurring in a ripple tank if we placed a thick sheet of plastic in the tray. When the waves travel from shallow to deep water, we can observe that its wavelength, hence its speed, changes. If the wave crosses the boundary between the two depths straight on, no change in the direction occur. On the other hand, if a wave crosses a boundary at an angle, the direction of travel does change, again by equation.

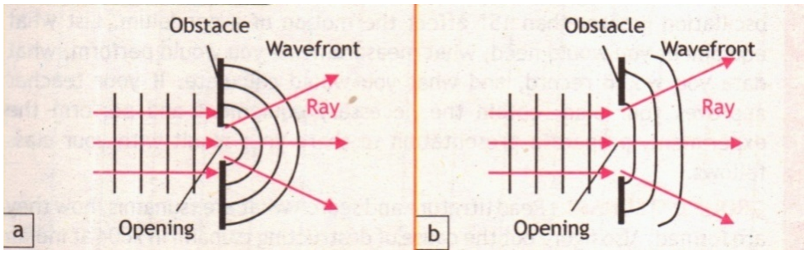
$$v = f\lambda$$



Diffraction:

The bending of wave around of corners of an obstacle is called diffraction. When waves pass through an aperture or opening its spreads out due to diffraction.

We can observe diffraction in water wave in ripple tank by generating the straight waves and place two obstacles in such a way that the separation is comparable to the size of wavelength.



After passing through the opening, waves spread out in every direction and turn into circular waves. This effect is greatest when the size of the opening is less than or equal to the size of the wavelength of generated waves. It must be noted that wavelength (or speed) of the wave is not affected by diffraction.

If the separation is large between obstacles to the wavelength, it can be seen that central part of the wave is not affected, only part of the wave at the edges diffract.

CONCEPTUAL QUESTIONS

Q1. Is every oscillatory motion simple harmonic? Give example.

Ans: No, it is not necessary for every oscillatory motion to be simple harmonic motion. Since all restoring forces are not proportional to the displacement. While for SHM the following two conditions must be satisfied.

a) The acceleration of the vibrating body is directly proportional to the displacement and is directed towards the mean position.
b) The resorting force is proportional to the displacement and is directed towards the mean position.

Example:

Motion of simple pendulum and spring mass system are both oscillatory and simple harmonic motion.

Whereas, the Earth revolving around the Sun, a bouncing ball are examples of oscillatory motion but not simple harmonic motion.

Q2. For a particle with simple harmonic motion, at what point of the motion does the velocity attain maximum magnitude? Minimum magnitude?

Ans: For a particle executing SHM its total energy at any instant of time is constant. That is the sum of kinetic and potential energy remains the same at every point.

When the particle is at mean position, the K.E is maximum so at this position the velocity of the particle will be maximum.

At extreme position the particle come to rest and due to restoring force it moves backward. Therefore, at extreme position it K.E is zero. So, at this position the velocity of the particle will be minimum or zero.

Q3. Is the restoring force on a mass attached to spring in simple harmonic motion ever zero? If so, where?

Ans: Yes, the restoring force in SHM become zero at the mean position. According to Hook's law, we have

F=-kx---------(1)

In equation (1) 'x' represents the displacement of vibrating body from mean position.

Now at the mean position, we have

x=0

so, equation (1) becomes

F=-k(0)

F=0 ------ (2)

Equation (2) shows that the restoring force is zero at mean position.

Q4. If we shorten the string of the pendulum to half its original length, what is the effect on its time period and frequency?

Ans: i) we know that the time period of simple pendulum is given by

$$T = 2\pi\sqrt{\frac{\ell}{g}} \quad \text{------------- (1)}$$

Put $\ell = \frac{\ell}{2}$ in eq (1), as length of string decreased to half, so we get

$$T' = 2\pi\sqrt{\frac{\ell/2}{g}}$$

$$T' = 2\pi\sqrt{\frac{\ell}{2g}}$$

$$T' = 2\pi\,\frac{1}{\sqrt{2}}\sqrt{\frac{\ell}{g}}$$

$$T' = \frac{1}{\sqrt{2}}\left(2\pi\sqrt{\frac{\ell}{g}}\right)$$

$$T' = \frac{1}{\sqrt{2}}\text{T}$$

$$T' = \frac{T}{\sqrt{2}} \quad \text{------- (2)}$$

Equation (2) shows that the time period will decreased by the factor $\frac{1}{\sqrt{2}}$ when the length of the string becomes half.

ii) The frequency of the simple pendulum is given by formula

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{\ell}} \quad \text{------------- (3)}$$

Put $\ell = \frac{\ell}{2}$ in eq (3), as length of string decreased to half, so we get

$$f' = \frac{1}{2\pi}\sqrt{\frac{g}{\ell/2}}$$

$$f' = \frac{1}{2\pi}\sqrt{\frac{2g}{\ell}}$$

$$f' = \frac{1}{2\pi}\sqrt{2}\sqrt{\frac{g}{\ell}}$$

$$f' = \sqrt{2}\left(\frac{1}{2\pi}\sqrt{\frac{g}{\ell}}\right)$$

$$f' = \sqrt{2}f \quad \text{------ (4)}$$

Equation (4) shows that the frequency will increase by the factor $\sqrt{2}$ when the length of the string becomes half.

Q5. A thin rope hangs from dark high tower so that its upper end is not visible. How can the length of the rope be determined?

Ans: To determine the length of rope we attach a stone to its lower end of rope, so that the arrangement becomes like a simple pendulum.

Now time period of simple pendulum is

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

Squaring both sides

$$(T)^2 = \left(2\pi\sqrt{\frac{\ell}{g}}\right)^2$$

$$\Rightarrow T^2 = 4\pi^2\frac{\ell}{g}$$

$$\Rightarrow gT^2 = 4\pi^2\ell$$

$$\Rightarrow \ell = \frac{gT^2}{4\pi^2} \quad \text{------ (1)}$$

Now set pendulum into vibration and note the time period of pendulum for one vibration which gives the time period. Put values of "g", "T" and "π" in eq(1) the length of rope can be calculated.

Q6. Suppose you stand on a swing instead of sitting on it. Will your frequency of oscillation increase or decrease?

Ans: The swing may be considered as a simple pendulum. As we know that

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{\ell}} --- (1)$$

Where ℓ =length of the pendulum, which is equal to the distance from the point of suspension to the center of mass of the person on the swing.

Earlier, when a person is sitting on the swing, the Centre of mass was far from the point of suspension.

As person stand up on the swing the length between the centre of mass of a person and the point of suspension decreases.

It is clear from equation (1), that frequency of oscillation is inversely proportional to the square root of length of the pendulum. So frequency of oscillation increases as length decreases when the person stands up instead of sitting.

Q7. Explain the difference between the speed of transverse wave traveling along a cord and the speed of a tiny colored part of the cord?

Ans: Transverse waves are those in which particles of the medium vibrate at right angle to the direction of propagation of wave motion.

Consider a cord having a colored tiny part. It's one end is fixed and the other end is in our hand. If we move our hand up and down transverse waves are produced moving in forward direction. As these are transverse waves, so each part of the string moves up and down i.e. vibrating up and down, while the transverse waves move in the forward direction. Thus, transverse waves move in the forward direction while the colored tiny part of the string moves up and down executing SHM.

Q8. Why waves refract at the boundary of shallow and deep water?

Ans: Refraction of waves involves a change in the direction of waves as they pass from one medium to another. In refraction, both speed and wavelength of waves change. The speed of a wave depends upon the properties of a medium through which it travels. The speed of waves is not same in shallow and deep water. Wave travel faster in deep water as compared to shallow water. Refraction occurs as the speed of the wave changes.

Thus, if water waves are passing from deep water into shallow water, they slow down. The speed of wave is proportional to the wavelength. So when waves are transmitted from deep water into shallow water, its speed and wavelength decreases and wave change its direction i.e. refracted.

Q9. What is the effect on diffraction if the opening is made small?

Ans: Diffraction is the bending of waves around corners of an obstacle. The amount of bending of a wave depends upon the relative size of the wavelength of the wave and size of the opening.

If the opening is much larger than the wavelength, then very less bending occurs which is un-noticeable. However, the separation is comparable to the size of the wavelength, and then a considerable bending occurs and can be seen easily with naked eye. Thus, the wave bends more and more if the opening is made small.

ASSIGNMENTS

10.1 When an object oscillates with a frequency of 0.5 Hz, what is its time period?

Given data:

Frequency=f=0.5 Hz

Required:

Time period=T=?

Solution:

Using formula

$T=\frac{1}{f}$

$=\frac{1}{0.5}$

$=\frac{10}{5}$

T=2 sec

10.2 Determine the restoring force of a spring displaced 1.5 m, with the spring constant of 30.0 N/m.

Given data:

Displaced=x= 1.5 m

Spring constant =k= 30.0 N/m

Required:

Restoring force= F_{res}=?

Solution:

We know that

F_{res}= -kx

= -(30.0)(1.5)

F_{res} = -45 N

10.3 A body of mass 0.2 kg is attached to a spring placed on a frictionless horizontal surface. The spring constant of spring is 4 N/m. Find the time period of oscillating mass spring system.

Given data:

Mass =m= 0.2 kg

Spring constant =k= 4 N/m

Required:

Time period=T=?

Solution:

We know that

$$T = 2\pi\sqrt{\frac{m}{k}}$$

Putting values

$$T = 2(3.14)\sqrt{\frac{0.2}{4}}$$

$$= 2(3.14)\sqrt{0.05}$$

$$= 6.28 \times 0.223$$

T = 1.4 sec

10.4 At what angle must a pendulum be displaced to create a restoring force of 4.00 N on a bob with a mass of 500.0g?

Given data:

Restoring force=F_{res}= 4.00N

Mass=m=500.0 g =0.5 kg

Required:

Angle=θ =?

Solution:

By using formula

F_{res}=mg $sin\theta$

$$\frac{F_{res}}{mg} = sin\theta$$

$$=> sin\theta = \frac{F_{res}}{mg}$$

$$\theta = \sin^{-1}\frac{F_{res}}{mg}$$

$$\theta = \sin^{-1}\frac{4.00}{(0.5)(9.8)}$$

$$\theta = \sin^{-1}\frac{4.00}{4.9}$$

$$\theta = \sin^{-1} 0.816$$

$$\theta = 54.6^{o}$$

10.5 What is the gravitational field strength at the top of the Mount Everest at an altitude of 8954.0m, if a pendulum with a length of 1.00m has a period of 2.01 sec?

Given data:

Length=ℓ=1.00m

Time period=T=2.01 sec

Required:

Gravitational field strength=g=?

Solution:

We know that

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

$$T^2 = \left(2\pi\sqrt{\frac{\ell}{g}}\right)^2$$

$$T^2 = 4\pi^2\frac{\ell}{g}$$

$$gT^2 = 4\pi^2\ell$$

$$g = \frac{4\pi^2\ell}{T^2}$$

$$g = \frac{4(3.14)^2 \times (1.00)}{(2.01)^2}$$

$$g = \frac{4 \times 9.8596 \times 1.00}{4.0401}$$

$$g = \frac{39.4384}{4.0401}$$

$g=9.761\ m/s^2$

10.6 A sound wave of wavelength $1.7x10^{-2}$ m. Calculate the frequency of sound if its velocity is 343.4 m/s?

Given data:

Wavelength= λ =$1.7x10^{-2}$ m

Speed of sound= v =343.4m/s

Required:

Frequency = f=?

Solution:

As we know that v=fλ

f=$\frac{v}{\lambda}$ → (1)

Putting values in equation (1) we get,

$f = \frac{343.4}{1.7\ x\ 10^{-2}}$

f = $202.0x10^2$Hz

f = $2.20x10^4$Hz

This is the required frequency of the wave.

NUMERICAL QUESTIONS

1. **A mass hang from a spring vibrates 15 times in 12sec. calculate (a) the frequency and (b) the period of the vibration.**

Given data:

No. of vibrations=N=15

Time for 15 vibrations=t=12sec

Required:

(a) Frequency=f=?

(b) Time period=t=?

Solution:

a. Frequency =f=$\frac{N}{t}$

Putting the values in eq, we get

f=$\frac{15}{12}$

f=1.25Hz

b. We know that

T=$\frac{1}{f}$

Putting values

=$\frac{1}{1.25}$

T=0.8 sec

2. **A spring requires a force of 100.0N to compress it to a displacement of 4cm.what is its spring constant?**

Given data:

Force=F=100.0N

Displacement=x=4cm=4/100m=0.04m

Required:

Spring constant=k=?

Solution:

We know

F=kx

$k = \frac{F}{x}$

$= \frac{100}{0.04}$

=2500N/m

k=2.5×10^3N/m

3. **A second pendulum is a pendulum with period of 2.0 sec. How long must a second pendulum be on earth (g=9.8m/s^2) and moon (where g=1.62 m/s^2)? What is the frequency of second pendulum at earth and on moon?**

Given data:

Time period=T=2.0sec

Gravity on earth=g_e=9.8m/s^2

Gravity on earth=g_m=1.62m/s^2

Required:

i. Length of pendulum on earth=ℓ_e=?

ii. Length of pendulum on moon=ℓ_m=?

iii. Frequency of pendulum on earth=f_e=?

iv. Frequency of pendulum on moon=f_m=?

Solution:

i. We know that

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

$$T^2 = \left(2\pi\sqrt{\frac{\ell}{g}}\right)^2$$

$$T^2 = 4\pi^2\frac{\ell}{g}$$

$$T^2 g = 4\pi^2\ell$$

$$\frac{T^2 g}{4\pi^2} = \ell$$

$$=> l = \frac{T^2 g}{4\pi^2}$$

<u>On earth</u>

$=> \ell_e = \frac{T^2 g_e}{4\pi^2}$ ---------- (1)

Putting values in eq (1) we get

$$\ell_e = \frac{(2.0)^2 \times (9.8)}{4(3.14)^2}$$

$$\ell_e = \frac{4 \times (9.8)}{4 \times 9.8596}$$

$$\ell_e = \frac{9.8}{9.8596}$$

$$\boxed{\ell_e = 0.99\text{m}}$$

ii. For moon, we replaced"ℓ_e" by"ℓ_m" and "g_e" by "g_m" in eq (1) ,we get

$$\ell_m = \frac{T^2 g_m}{4\pi^2}$$

Putting values

$$\ell_m = \frac{(2.0)^2 \times (1.62)}{4(3.14)^2}$$

$$\ell_m = \frac{4 \times (1.62)}{4 \times 9.8596}$$

$$\ell_m = \frac{1.62}{9.8596}$$

$$\ell_m = 0.164m$$

$$\boxed{\ell_m = 0.16m}$$

iii. The frequency of pendulum is given by

$$f = \frac{1}{T}$$

Frequency on Earth

$$f_e = \frac{1}{T}$$

Putting values

$$f_e = \frac{1}{2.0}$$

$$\boxed{f_e = 0.5Hz}$$

iv. Frequency on Moon

$$f_m = \frac{1}{T}$$

Putting values

$$f_m = \frac{1}{2.0}$$

$$\boxed{f_m = 0.5Hz}$$

4. Calculate the period and frequency of a propeller on a plane if it completes 250 cycles in 5.0 sec.

Given data:

No. of cycles=N=250

Time for 250 cycles=t=5.0sec

Required:

i. Time period=T=?

ii. Frequency=f=?

Solution:

i. We know that

$$T = \frac{t}{N}$$

Putting values

$$T = \frac{5.0}{250}$$

$T = 0.02\ sec$

ii. We know that

$$f = \frac{1}{T}$$

Putting values

$$f = \frac{1}{0.02}$$

$$f = 50Hz$$

5. Water waves with wavelength 2.8m, produced in a ripple tank, travel with a speed of 3.80m/s. What is the frequency of the straight vibrator that produced them?

Given data:

Wave length $=\lambda = 2.8m$

Speed of waves$= v = 3.80m/s$

Required:

Frequency=f=?

Solution:

We know that

$v = f\lambda$

$$f = \frac{v}{\lambda}$$

Putting values

$$f = \frac{3.80}{2.8}$$

$$f = 1.357Hz$$

$$f = 1.4Hz$$

6. The distance between successive crests in a series of water waves is 4.0m and the crests travels 9.0m in 4.5 sec. What is the frequency of the waves?

Given data:

Distance=s=9.0m

Wavelength$= \lambda = 4.0m$

Required:

Frequency=f=?

Solution:

We know that

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

Putting values

$$v = \frac{9.0}{4.5}$$

$$v = 2m/s \quad ------i)$$

As we know that

$v = f\lambda$

$f = \frac{v}{\lambda}$

Putting values

$f = \frac{2}{4.0}$

$f = 0.5Hz$

7. A station broadcasts an AM radio wave whose frequency is 1230×10^{3}Hz (1230kHz on the dial) and an FM radio waves whose frequency is 91.9×10^{6}Hz (91.9 MHz on the dial). Find the distance between adjacent crests in each wave.

Given data:

Frequency of AM radio=f_{AM}=1230×10^{3}Hz

Frequency of FM radio=f_{FM}=91.9×10^{6}Hz

Speed of radio waves= $v = c$ =3×10^{8}m/s

Required:

i. Wavelength of AM radio waves= λ_{AM}=?

ii. Wavelength of FM radio waves= λ_{FM}=?

Solution:

i. We know that

$v = f\lambda$

⇨ $c = f_{AM}\lambda_{AM}$

⇨ $\lambda_{AM} = \frac{c}{f_{AM}}$ -------1)

Putting values in eq (1), we get

$$\lambda_{AM} = \frac{3 \times 10^8}{1230 \times 10^3}$$

$$\lambda_{AM} = 2.44 \times 10^2 m$$

$\lambda_{AM} = 244.0m$

ii. For FM waves, eq (1) can be written as

$\lambda_{FM} = \frac{c}{f_{FM}}$ -------2)

Putting values in eq (2), we get

$$\lambda_{FM} = \frac{3 \times 10^8}{91.9 \times 10^6}$$

$$\lambda_{FM} = 0.0326 \times 10^2 m$$

$$\lambda_{FM} = 3.26m$$