Phy

MONDAY, 24th MARCH, 20..

MATHEMATICAL REPRESENTATION OF WAVE.

The general equation for the representation of wave is

$$y = A \sin\left(\frac{2\pi x}{\lambda}\right) \quad \text{--- } 1$$

where y = vertical component

A – Amplitude

λ – wavelength

x – horizontal component

$$y = A \sin \frac{2\pi}{\lambda}(vt - x) \quad \text{--- } 2$$

where v – velocity

t – period

Examples.

1.) The equation of a wave is $y = 0.05 \sin[\pi(0.5x - 200t)]$ where x and y are in metres and t is in sec. What is the velocity of the wave?

solution.

Using the 2nd formula

$$y = A \sin\left(2\pi ft - \frac{2\pi x}{\lambda}\right) \quad \text{--- } (3)$$

$$y = A \sin \frac{2\pi vt}{\lambda} - \frac{2\pi x}{\lambda}$$

Given $y = 0.05 \sin[\pi(0.5x - 200t)]$.

Comparing equation 3.

$$\frac{2\pi x}{\lambda} = 0.5\pi x$$

$$\frac{2\pi x}{\pi x} = \frac{0.5\lambda \pi x}{\pi x}$$

$$\frac{2}{0.5} = \frac{0.5\lambda}{0.5}$$

$$\lambda = 2 \div \tfrac{1}{2}$$

$$= 2 \times 2 = 4\,m$$

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comparing $\frac{2\pi Ft}{\pi t} = \frac{200\pi t}{\pi t}$

$\frac{2F}{2} = \frac{200}{2}$

$F = 100\,Hz$

∴ Velocity = $F\lambda$

$= 100 \times 4$

$= 400\,m/s$

2. The equation of a transverse wave travelling on a string is given by $y = 5\sin(2.0x - 100t)$ where x and y are in (m) and t is in secs. compute:

(i) Amplitude

(ii) Frequency

(iii) Period

(iv) Wavelength of the wave.

Solution

i) A = 5 cm converting it to m

$\frac{5}{100}$

$= 0.05\,m$

ii) comparing $\frac{2\pi Ft}{t} = \frac{100t}{t}$

$\frac{2\pi f}{2\pi} = \frac{100}{2\pi}$

$f = \frac{50}{\pi}$

$f = \frac{50}{3.142}$

$f = 15.9134$

$f = 15.9$

$\simeq 16\,Hz$

iii) Period $T = \frac{1}{F}$

$= \frac{1}{16}$

$\frac{2\pi}{\lambda}x = 2.0x$

$2\pi ft = 100t$

$T = 0.0625$

$t = 0.0625$ secs

(iv) Comparing $\frac{2\pi x}{\lambda} = \frac{2.0x}{1}$

$\frac{2\pi x}{x} = \frac{2.0\lambda x}{x}$

$\frac{2\pi}{2.0} = \frac{2.0\lambda}{2.0}$

$\lambda = \frac{2 \times 3.142}{2.0}$

$\lambda = \frac{6.284}{2.0}$

$\lambda = 3.142\,m$

3) The equation of a travelling wave is given by $y = 0.025 \sin[\pi(2000t - 0.4x)]$ where x and y are in metres (m) and t in secs. Determine

i) Amplitude

ii) Frequency

iii) Period

iv) Velocity

v) Wavelength of the wave.

solution

$y = 0.025 \sin[\pi(2000t - 0.4x)]$ where x and y are in (m) & t in secs.

i) Amplitude $= 0.025\,m$

ii) Frequency → comparing $\frac{2F\pi t}{\pi t} = \frac{2000\pi t}{\pi t}$

$\frac{2F}{2} = \frac{2000}{2}$

$F = 1000\,Hz$

iii) Period $T = 1/F$

$= \frac{1}{1000} = 0.001$ secs

4

(iv) Velocity = $F\lambda$

v) Wavelength of the wave = comparing $\frac{2\pi x}{\lambda} \times \frac{0.4\pi}{1}$

$$\frac{2\pi x}{\pi x} = \frac{0.4\lambda\pi x}{\pi x}$$

$$\frac{2}{0.4} = \frac{0.4\lambda}{0.4}$$

$$\lambda = \frac{2}{0.4}$$

$$\lambda = 5m$$

(iv) Velocity = $F\lambda$

$= 1000 \times 5$

$= 5000 m/s$

4. The equation of a wave is $y = 0.025 \sin[\pi(1.5x - 250t)]$ where x and y are in cm and t in min what is the velocity of the wavelength.

solution.

$$y = 0.025 \sin[\pi(1.5x - 250t)]$$

Using the 3rd formula $y = A \sin \frac{2F\pi t}{} - \frac{2\pi x}{\lambda}$

Given $y = 0.025 \sin[\pi(1.5x - 250t)]$

comparing equation 3

$$\frac{2\pi x}{\lambda} = \frac{1.5\pi x}{1}$$

$$\frac{2\pi x}{\pi x} = \frac{1.5\pi x\lambda}{\pi x}$$

$$\frac{2}{1.5} = \frac{1.5\lambda}{1.5}$$

$$\lambda = \frac{2}{1.5}$$

$$\lambda = 2 \div 3/2$$

$$\lambda = 2 \times 2/3 = 4/3 = 1.3333m$$

converting m to cm.

1m = 100cm

1.3333m = xcm

xcm = 100 x 1.3333

= 133.33

∴ The velocity of the wavelength is 133.33cm.

SOUND WAVE

Vibrating system produces sound i.e any objects that vibrates produces sound.

Sound is a form of motion which is conveyed through an elastic medium from a vibrating body to a listener. Sound waves can be detected by human ear unlike the electromagnetic waves.

* Sound wave is generally a mechanical wave which originate from vibrations of particles in liquid, Solid and Gas. An object that is vibrating and producing sound has energy because it is capable of producing ~~sound to~~ a force that does work.

Sound is therefore a form of energy just like heat, light, electricity etc. The human ear can detect longitudinal wave of frequencies ranging from about 20 - 20,000 Hertz as sound.

The range is called AUDIBLE RANGE. It is possible to have higher frequencies in Solid, a longitudinal wave with frequency greater than 20,000 Hz is called * ULTRASONIC WAVE while a longitudinal wave with frequency less than 20Hz is called *INFRASONIC WAVE. Both Ultrasonic and Infrasonic waves are not detectable by human ear.

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TRANSMISSION OF SOUND WAVE

Sound can travel through Solid, Liquid and Gas. Sound is caused by vibration of particles in medium. If there are no particle in the medium then sound cannot pass through that medium. Thus, sound cannot pass through a vacuum because no atoms or molecule is present.

Sound require a medium such as air, water, wood etc to pass from one place to another. Sound waves reaches the human ear through the air and can also travels through solid and Liquid. However, sound vibrations hardly pass from one medium to another if the media are of different densities.

SPEED OF SOUND IN SOLIDS, LIQUID AND GAS.

Several phenomena in nature indicates that sound has a definite velocity or speed as it travels from one part to another in a medium. Example when a piece of wood is cut by striking it with axe, the sound of the strokes are heard some little length of time after the striking action.

If the firing of a gun is watched about 100m away, the gun shot is heard some seconds after the flash of the discharge is seen.

The velocity of sound varies according to the medium through which it is passing. It is faster in solids and liquids than in Air (Gas) and faster in solid than liquids or gases (due to different molecular structures and density of the media).

In a solid of density ρ, a sound source subject the medium to varies stress with resulting strain. The velocity of sound V is therefore partly governed by the modulus of the Elasticity E of the medium. i.e $E = \frac{\text{stress}}{\text{strain}}$

Change of force per unit area ... equation (4)
= fractional extension by original dimension.

for a given solid medium, the velocity, V is given by

$$V = \sqrt{\frac{E}{\rho}} \quad \text{equation (5.)}$$

For a liquid, Elasticity E is replaced by a Bulk modulus K, where K is given as $K = \frac{\Delta P}{-\Delta V/V}$ =

pressure change in the liquid. equation (6.)
fractional velocity decrease by original velocity

In gas or Air, E is replaced by the Adiabatic Bulk modulus of a gas (No heat can be added or allowed to leave the system). The Adiabatic Bulk modulus of a gas is γP, where γ is the ratio of molar heat energy capacity at constant pressure C_p and constant volume C_v, i.e. $\gamma = \frac{C_P}{C_V}$ equation (7) and P is the pressure of the gas. Thus for a gas the velocity

$$V = \sqrt{\frac{\gamma P}{\rho}} \quad \text{equation (8.)}$$

EFFECTS OF PRESSURE & TEMPERATURE ON THE VELOCITY OF SOUND IN A GAS

Let us assume that one mole of a gas has a mass M and volume V, then one molecular density is $\rho = \frac{M}{V}$ equation 9.
from ( ) the velocity of sound V_1 is $V_1 = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma PV}{M}}$ — (10)

From Gas law for one mole
$PV = RT$ where equation (11)
R is the Molar gas constant
T is absolute temperature
Hence, from 11 equation 10 can be written as $V = \sqrt{\frac{\gamma RT}{M}}$ (12)

The quantities γ, M, R are constant for a gas and so equation 12 above shows that the velocity of sound in a gas system

is proportional to the square root of its absolute temperature
i.e $V_1 = K\sqrt{T}$ equation (13)
where $k = \sqrt{\frac{\gamma R}{M}}$

If at $T = T_0$, $V = V_0$ and at $T = T_1$, $V = V_1$, then from eq 13, we have that

$V_0 = K\sqrt{T_0}$, $V_1 = K\sqrt{T_1}$ and so it implies that

$\frac{V_0}{V_1} = \sqrt{\frac{T_0}{T_1}}$ or $V_0 = V_1\sqrt{\frac{T_0}{T_1}}$

* Examples :-

A source of sound of frequency 750Hz emits waves wavelength 500mm in air at 20°C. What is the velocity of sound in Air at this temperature? What will be the wavelength of the sound from the source in air at 0°C?

Soln

$F = 750Hz$, $\lambda = 500mm$, $T_1 = 20°c$, $T_0 = 0°c$, from $V = F\lambda$
converts 500mm to m = $\frac{500}{1000} = 0.5m$

$V = 750 \times 0.5$
$= 375 m/s$

at 20°c = 375 m/s
Therefore $V_1 = 375 m/s$
$V_0 = ?$

T_0 = Temperature of sound in air.
V_0 = Velocity of

$T_1 = 20 + 273 = 293 k$

$V_0 = 375\sqrt{\frac{273}{293}} = 361.96 ms^{-1} \approx 362 ms^{-1}$

$\lambda_0 = \frac{v}{f} = \frac{361.96}{750} = 0.4826m$

Echoes

An echo is the sound perceive (Heard) after the reflection of sound from a plain hard surface. Echo have applications

1) In finding the distance of a cliff from a ship.
2) In finding the speed of sound in Air
3) It is used in Oil prospecting.
4) Echo sounding device is used in measuring sea depth and to detect sub-marines.

Disadv. ⇒ Echoes can sometimes be a nuisance e.g echo produce multiple reflection in a close room. One way of minimizing such echo is by covering the walls and roofs of the room with a perforated spot sheet. To have no echo at all is also not good because it makes music dead, therefore echo is good to have good music.

Physics Of The Ear As It Relates To Sound.

The ear is one practical mode of reception of sound. Physics of the ear is summarized in the sequence of the mechanical and electrical events in hearing.

Location	Mechanical	Neutral
External ear	Sound waves	Endocochlear
	External Auditory matus	Auditory Receptor
Middle ear	Tymparic membrane	Potential
	Auditory Ossicles	Potential (Cochlear)
	Oval windows	Microphonic
Inner ear	Scalar vestibule	
	Scalar media	
	Scala Tymparic	Firing cochlear
	Round window	Nerve fibres.
		Auditory cortex.

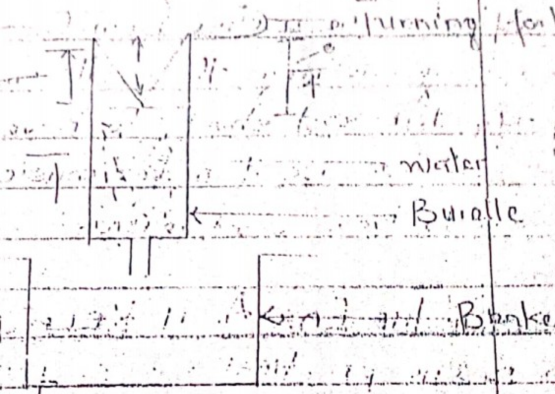
Sequence of Mechanical and Electrical Events in Hearing.

Determination Of Velocity Of Sound In Air.

There are two methods for determining the velocity of sound in Air.

1. Resonance Tube Method.
2. The Echo Method.

1. The Resonance Tube Method And End Correction.



When we hold a sounding turning fork over the open end of a tube filled with water as shown in the fig above, resonance is obtained at some position while the water level is gradually lower. If C is the end correction of the tube and L is the length from the water level to the top of the tube, then

$$L + C = \frac{\lambda}{4} \quad \text{equation (15)}$$

where

$$\lambda = V/F \quad \text{equation (16)}$$

Substitute eqn 16 into equation 15 we have

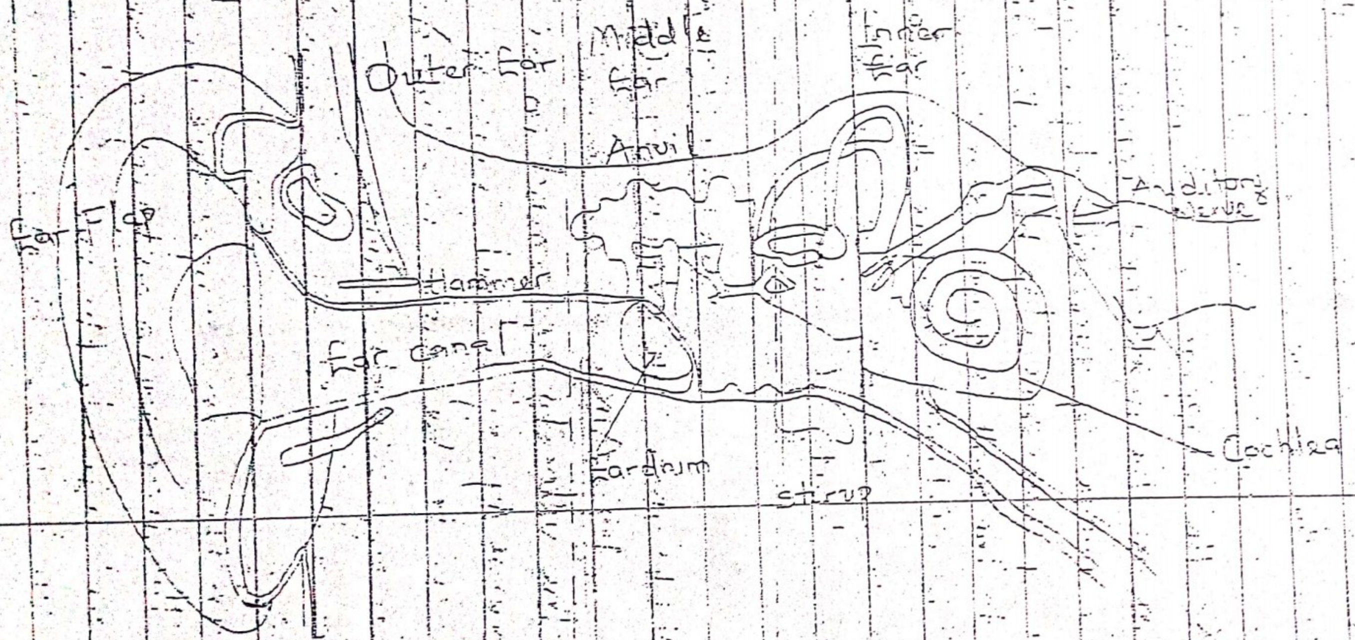
$$L + C = \frac{V}{4F} \quad \text{Equation (17)}$$

If we make V the subject of the formula we have

$$V = 4f(L+c) \quad \text{eqn (18)}$$ This is valid equation for resonance tube for determining the velocity of sound in air.

$$L + C = \lambda/4$$

$$\frac{V/F}{4}$$



THE HUMAN EAR

THE ECHO METHOD.

We can use the echo to determine the velocity of sound in air by directing a sound signal to a wall and measuring the echo time. This can be done by standing infront of a vertical wall clapping the hands and listening to the echo produced. As the clapping is continuously repeated it is possible to arrange the next clap to coincide with the echo. Then the time for a number of successive clap is found. Let the time for a number of successive clap be (t), the distance (x) from the observer to the wall is found. Sound waves takes (t's) to cover twice this distance. Therefore, the velocity of sound wave is given as ; $V = \frac{2x}{t}$ . . . . . . (19) which is referred to as the velocity of sound in air using echo method.

Read again

MONDAY, 7TH APRIL, 2014.

* FACTORS AFFECTING THE VELOCITY OF SOUND IN AIR.

1. Wind affect the velocity of sound in air in such a way that velocity of sound increases when sound and wind travels in the same direction and decrease when travel in opposite direction.
2. HUMIDITY :- The velocity of sound is higher when humidity is high.
3. TEMPERATURE :- Increase in temperature increases the velocity of sound. The increase in velocity of sound is very small in solid and liquid. However, in air and other gases the velocity of sound varies directly with the square root of absolute temperature.

   i.e $V \propto (T)^{1/2}$ or $V \propto \sqrt{T}$

   As speed increases, temperature also increases.
4. The nature of the molecules of the air determines how the velocity of sound is.

TONE OR MUSICAL NOTE:

An audible pleasant sound of regular frequency is referred to as TONE or MUSICAL NOTE. Music is a combination of such sound. Certain combination of notes do however produce an effect of emotional tension or dissonance which can lead to noise. Noise and its relation to music is not easy to define but fairly general agreement may be expected with the definition that it is an unpleasant sound or combination of sound or constantly varying pitch or irregular frequency. The ratio of the frequencies of the note is called the Musical Interval btw them.

Note may be similar to or different from each other in (3) three respect:

i) Pitch, loudness and quality

a) Pitch:- The pitch of a note is its position in the Musical scale and depends on the frequency of vibration of its source. It is analogous to colour in light which depend on the wavelength or frequency of the light wave. A high frequency give rise to a high pitched note while a low frequency produces a low pitched note.

b) LOUDNESS:- This is the magnitude of the sensation produced when a sound reaches the ear. Intensity of a sound is related to a fixed reference tone to define intensity and frequency.

c) QUALITY:- This is the fidelity of reproduction of a sound. The quality is generally stated to be dependent upon relative amplitude and number of the partials the resulting wave form being determined by the super position of the component PARTIALS:- It's a component tone, the frequency of each tone, usually related to the generating tone (fundamentals) by the equation $A = nf$ equation 2.0

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where n is an integer
A, F are frequencies of a tone of the series and of the fundamentals respectively.

5. Tones above fundamental are known as OVERTONE or UPPER PARTIALS.

* HARMONICS :- are partials but since partials may be IN-HARMONICS then the converse may not be true.

A note therefore is called an Octave of another note when the frequency is twice that of the first note i.e (when n = 2).

Examples :- A hunter y m from a cliff fires a gun. The echo is heard after 5 s from the cliff. If the speed of sound in air is 340 m/s, estimate y.

TUESDAY, 22ND APRIL, 2014

DOPPLER EFFECTS IN SOUND

Doppler effect is the change in frequency (Pitch) of a source when there is a relative motion between the source of the observer. It occurs in both sounds and light waves. For example, when a train sound its whistle or an ambulance with a siren just passes an observer a sudden drop in the pitch is heard. On the otherhand, when the train is approaching an observer, the Pitch heightens.

The same effect is noticed if the source is stationary and the observer is moving.

* EXPRESSION FOR APPARENT FREQUENCY ARISING FROM THE EFFECT OF DOPPLER

Case 1 :-

A sound moving towards a stationary observer, it is shown that if V is the velocity of the sound $V(s)$ is the velocity of the source, of the frequency (F) then the apparent frequency FAP is given by:

$V - V_s$

from the equation (21) $V - V_s < V$ therefore the apparent frequency will increase when the sound is moving towards a stationary observer.

Case 2:-

When the source is moving away from a stationary observer. The apparent frequency (Fap) is given as;

$$Fap = \frac{VF}{V + V_s} \quad (22)$$

Note that equation (22) above shows that Fap decreases when the source is moving away from the observer.

Case 4:-

If the observer is moving away from the stationary source, then we have that, $Fap = \frac{V + V_o}{}$ (24) equation (24) above is an indication of F/V decrease in Fap.

Case 3:-

When the source is stationary and an observer is moving towards it with a velocity Vo, then we have

$$Fap = \frac{(V + V_o)}{V/F} = \frac{(V + V_o)}{F/V} \quad (23)$$

from the equation above, sin $V + V_o > V$ then it implies that the apparent frequency (Fap) is increased.

Case 5:-

If both observer and source are moving in the same direction then; $Fap = \frac{(V + V_o)F}{V + V_o}$ (25)

* Exercise 1:- Suppose a stationary siren emits a note of frequency 1401Hz as the train approaches it with 30m/s. What frequency will be received on the train?

solution

~~Using case 3 equation (23) $Fap = \frac{(V+V_o)}{F/V}$~~

~~where $F = 440\,Hz$~~

~~$Fap = \frac{(340+30)\,440}{340}$ $V_o =$~~

Using case 3 equation (23). $Fap = \frac{(V+V_o)}{F/V}$

where $F = 440\,Hz$

$V_o = 30\,m/s$

$V = 340\,m/s$ (constant)

$$Fap = \frac{(340+30)}{440/340}$$

$$= \frac{(340+30)\,440}{340}$$

$$= \frac{(370)\,440}{340}$$

$$= \frac{162800}{340}$$

$$= 478.823$$

$$= 478.8\,Hz$$

2. A motor boat speeding at 15 m/s is moving in the same direction as a group of water wave of frequency 0.17/s and speed 9.3 m/s relative to the water. What is the frequency with which wave crest pound on the motor boat

Solution

Using case 5 equation 25. $Fap = \frac{(V+V_o)F}{V-V_o}$

where $F =$

$V_o = 15\,m/s$

MODE OF VIBRATION OF A WAVE ON A STRETCHED STRING

When a wire stretched between 2 points is plucked at the centre, a transverse wave travelled along the wire and is reflected at the fixed end as shown in the figure above. This give rise to a stationary wave. From the figure, we have that

$l = \frac{\lambda}{2} \Rightarrow \lambda = 2L$ — eqn 26.

But from general wave equation

$F = \frac{V}{\lambda}$ — 27

substitute (27) into (26)

$F = 2L$

$\therefore F = \frac{V}{2L}$ — 28. But also

$V = (T/m)^{1/2}$ — 29

where T is the Tension,

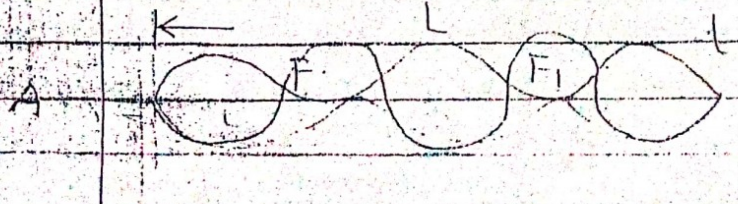
m is mass per unit length.

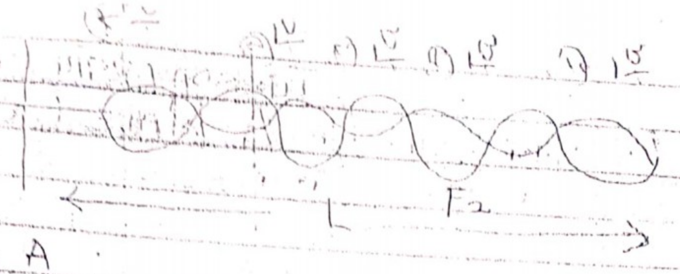
The fundamental frequency F_0 as shown in the figure above is given by the expression

$$F_0 = \frac{1}{2L}\sqrt{T/m} \quad — 30.$$

Equation 30 above is the lowest obtainable frequency from the system.

OVERTONES FOR A STRETCHED STRING.





From A

$$L = \frac{3\lambda}{2} \Rightarrow \lambda = \frac{2L}{3} \quad --- \quad 31$$

$$F_1 = \frac{V}{\lambda_1}$$

$$F_1 = \frac{3}{2L}\sqrt{\frac{T}{m}} = 3F_0 \quad --- \quad 32$$

In B

$$L = \frac{5\lambda_2}{2} \Rightarrow \lambda_2 = \frac{2L}{5} \quad 33$$

$$\lambda_2 = \frac{2L}{5} \quad --- \quad 34$$

$$F_2 = \frac{V}{\lambda_2} = \frac{5}{2L}\sqrt{\frac{T}{m}} = 5F_0$$

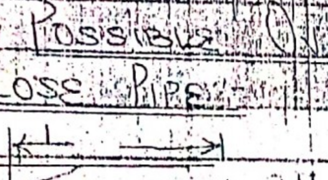
∴ For a stretched string the overtones present are $3F_0, 5F_0, 7F_0, 9F_0$ etc.

* An overtone therefore is a note whose frequency is obtained from a particular system e.g. Pipe, string.

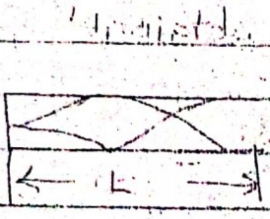
Possible Overtone in a Pipe

Close Pipe

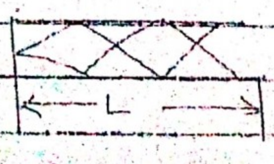
A



B



C



In A,

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

But for a closed pipe

$$L = \frac{\lambda}{4} \quad 36$$

$$\Rightarrow \lambda = 4L \quad 37$$

$$\therefore F_0 = \frac{v}{4L}$$ fundamental frequency (F_0) 38

Subsequently, other harmonics are gotten from

$$F = (2n-1)F_0 \quad 39$$

where

$n = 1, 2, 3, 4 \ldots$

In B,

$n = 2$

$\therefore F_1 = 3F_0$

In C,

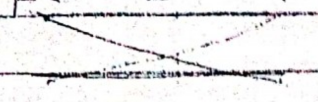
$n = 3$

$F = 5F_0$

Therefore, the above implies that for a closed pipe, only odd harmonics are present i.e. F_0, $3F_0$, $5F_0$, ... $(2n-1)F_0$.

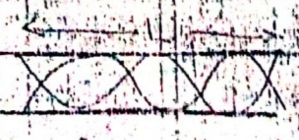
OPEN PIPE.

A) |← L →|



B) |← L →|

C)



In a)

$$L = \frac{\lambda}{2} \Rightarrow \lambda = 2L$$

Hence $F_0 = \frac{V}{2L}$

open pipe combine both subsequently, the harmonics can be gotten from $F = nF_0$ 40

where $n = 1, 2, \ldots$

In b)

$n = 2$ then;

$F_1 = 2F_0$ 41

In c)

$n = 3$

$F_0 = 3F_0$ 42

Open pipe contain both odd and even harmonics i.e equation 40, 41 and 42 above

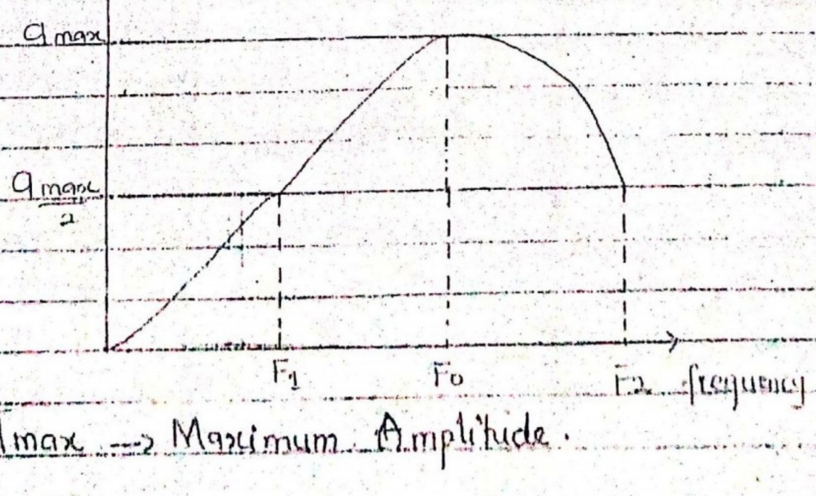
$$e = \frac{F_0}{F_2 - F_1} \quad \ldots\ldots 43$$

FRIDAY, 16TH MAY 2014.

RESONANCE

A vibrating system produces its largest amplitude of vibration when it is set into oscillation at its own natural frequency by the impulse received from an external body which is oscillating with the same frequency. The phenomenon above is referred to as RESONANCE CONDITION

RESONANCE CURVE.



a_{max} --> Maximum Amplitude.

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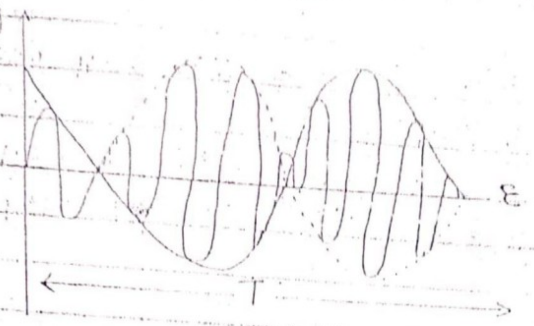
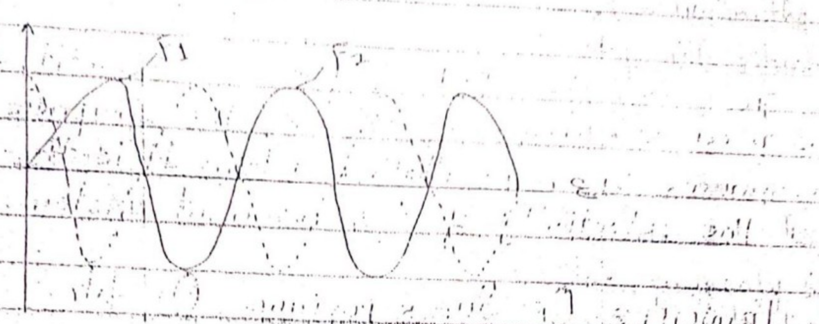
I know right

I got Surprised When i discovered that Sha this Page 21  . . .

BEATS





$y = y_1 + y_2$

Beats are produced when two (2) nodes or trains of nearly the same/equal frequency, F_1 and F_2 (F_1 is always bigger than F_2) but equal amplitude in the same direction and the same velocity are superposed.

BEAT FREQUENCY:- This is the difference between the two (2) frequencies ($F_1 - F_2$). This is the frequency with which the amplitudes pulsates

$$\Delta F = F_1 - F_2 \quad \ldots \quad 48.$$

MEASUREMENT OF FREQUENCY OF A TURNING FORK

This phenomenal can be used to measure the frequency of the unknown turning fork. This is done by measuring the frequency using a solometer produced by the frequency, F_1 (known), F_2 (unknown), $F_1 - F_2$

$$\therefore \Delta F = F_1 - F_2$$

$$F_2 = F_1 - \Delta F \quad \ldots \quad 49$$

In 49 above, given the frequency of the unknown turning fork. The beat frequency (ΔF) is obtained from solometer.

adjusting the length of solometer wire with constant measure until frequency of solometer wire is the same as that of the beat freq.

$$\therefore \Delta F = F_0 = \frac{1}{2L}\sqrt{\frac{T}{m}} \quad \ldots \ldots \quad 50$$

Equation 50 above represent the beat frequency from a solometer wire.

INTERFERENCE

When two (2) or more wave combine together to produce maximum or zero effect. They are according to have interfered constructively or destructively. Interference is however the super-position of different frequencies.

If the resultant intensity is more than what is expected from the intensities of different / each individual wave. It is called constructive Interference while if it is zero / or less, it is called destructive interference.

Examples :

1. Find the fundamental frequency of
   a) a closed pipe
   b) an open pipe which is 300cm long if the velocity of sound in air is 340 m/s.

solution.

a) Closed Pipe. $F_0 = \frac{V}{4L}$ converting cm to m $\frac{300}{100} = 3m$

$F_0 = \frac{340 \, m/s}{4 \times 3}$

$F_0 = \frac{340 \, m/s}{4 \times 3m}$

$F_0 = \frac{340}{12}$

$= 28.333$

$\simeq 28Hz$

b) Open pipe: $F_0 = \frac{V}{2L}$

... = 340 m/s
... = 2 X 3 m
= 340 m/s / 6 m
= 56.6667
... ≈ 56 Hz.

24

MONDAY, 19th MAY, 2014.

LIGHT WAVES

Light is that which enables us to see and is said to originate from an action that is heated. When an atom is heated, an electron of the atom absolutely absorbs the heat energy and moves to a higher energy level. If the excited electron moves back it emits electromagnetic waves in form of light. As the atom continually vibrates, it emits a succession of discontinuous waves of different wavelength as the electrons of the atom oscillate between the energy level.

The nature of the light has always remained complex. One school of thought, through a Dutch physicist, Christian Huygens, believed that light consists of a series of waves characterized by frequency, wavelength, amplitude by a sine function and are somehow sinusoidal (i.e its motion is governed by a sine function). Light as wave explains phenomenon such as diffraction, polarization, and interference. On the other hand, Isaac Newton, postulated that light behaves like a particle. Thus light is ... of particles, called P... as they are emitted and travel as such. The particle or corpuscular theory has also developed to successfully explain phenomenal such as photoelectric effect, Compton scattering of X-rays and some aspect of blackbody radiation.

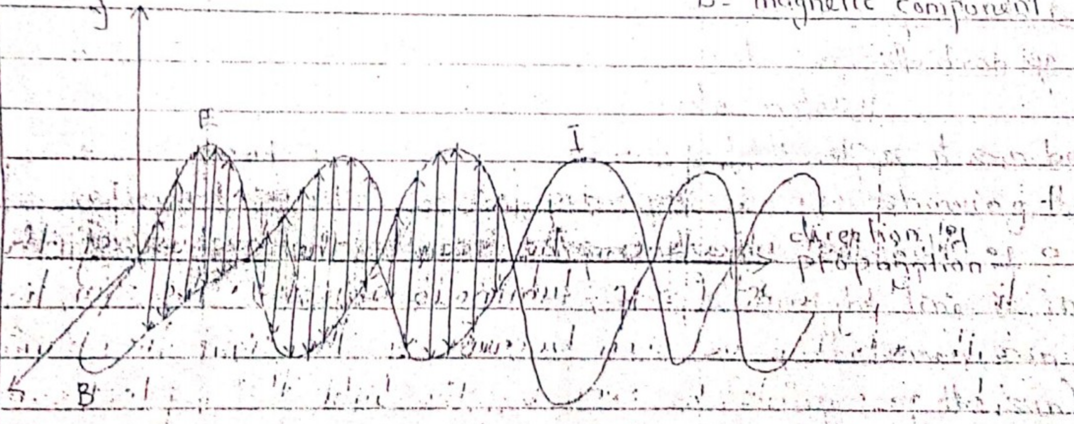
Light therefore exhibits a dual nature as wave and as particle. Light exhibits wave particle duality.

As we look at light as a wave here, we bear in mind

... made up of strings different

that light from the sun which is wavelength and frequency. light of a particular colour from a source is composed of waves of the same wavelength and so in principle, the white light can be seperated into sets of identical wavelengths, each giving a particular colour or characteristics.

We note in passing here that light is electromagnetic in nature. Electromagnetic waves are waves produced by varying electric and magnetic fields. These varying fields, which are mutually perpendicular to one another travels in space in form of radiation. Radio and heat are also examples of electromagnetic waves.



GEOMETRICAL PROPERTIES OF LIGHT.

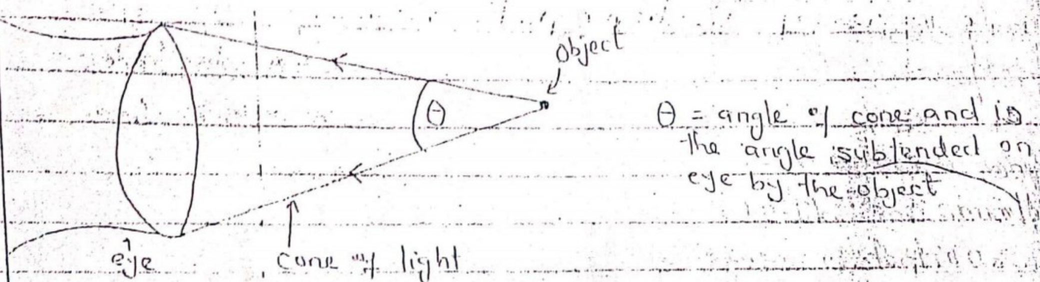
The wavelength of light (visible part of the electromagnetic spectrum) is so small that the ordinary eye cannot see the transverse nature of it. thus an advancing transverse light wave from a source appears as a ray which is the direction which the light energy travels. A collection of light rays is called a beam of light. We note that:

* Light travels in straight line ~~with~~ and therefore it can be represented by a straight line with an arrow showing the direction as ⟶. This is the ray one example of a typical case in which light travels in a straight line is in the eclipse of the sun or moon. Shadows of the moon can be cast on some parts of the earth (eclipse of the sun)

of the moon in the earth's shadow (eclipse of the moon). Both eclipse involve the sun, earth and moon, being aligned in a straight line.

* Light from a point source travels in all directions. As many rays of light as possible from the source can be drawn.

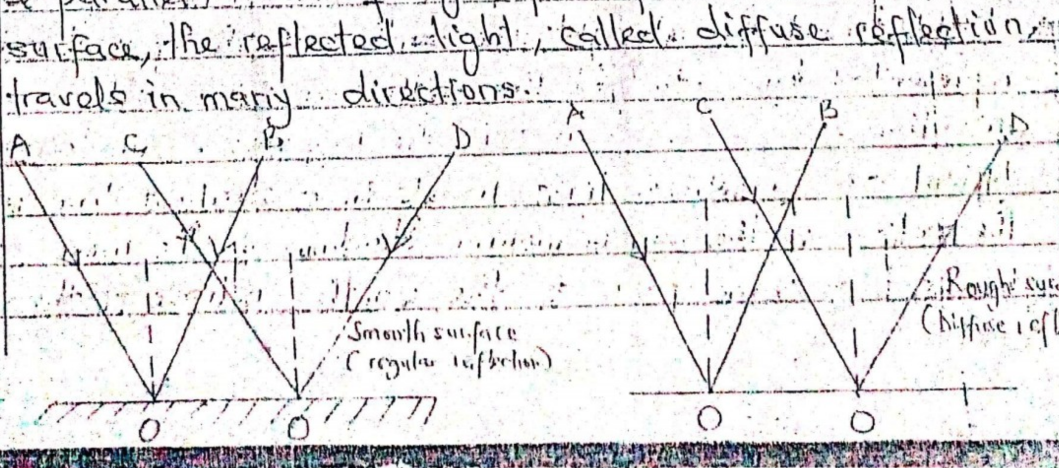
* A beam from a point enters the eye in form of a cone with the object at the apex of the cone. The angle of the cone (solid angle) determines whether the object is far or near.



Note that objects can be seen by the because of the light they emit (self-luminous objects). The sun, lighted bulbs etc can be seen because of the light they emit. Objects can also be seen by the light the reflect when it (light) falls on them.

Reflection of Light at Plane Surface

If a parallel beam of light falls on a very smooth plane mirror, it is reflected as a parallel beam and the reflection is said to be regular. On the other hand, an irregular reflection takes place on a rough surface when a parallel beam of light falls upon it. Unlike the smooth surface, the reflected light, called diffuse reflection, travels in many directions.



incident rays are AO and CO' and the reflected rays are OB and O'D respectively at their point of incidents O and O'. In the case of regular

* Object between C and F :- Image; real inverted, magnified and lies beyond C.
* Object at F : Image ; at infinity, real and very large.
* Object between F and P : Image ; behind mirrors virtual, erect and magnified.

IMAGES FORMED BY CONVEX MIRRORS.

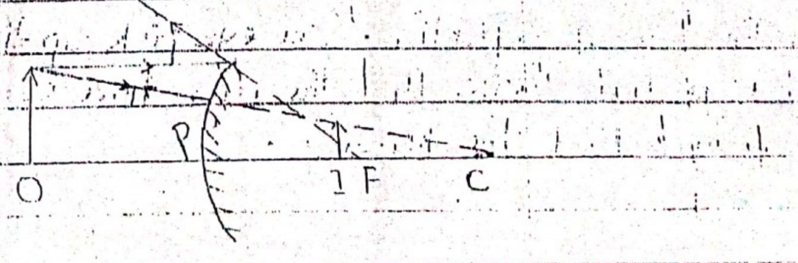
The following points must be considered when constructing the position of image of an object due to a convex (or diverging) mirror.

(i) Rays parallel to the principal axis are reflected as if they have come from the principal focus.

(ii) Rays directed towards the principal focus are reflected parallel to the principal axis.

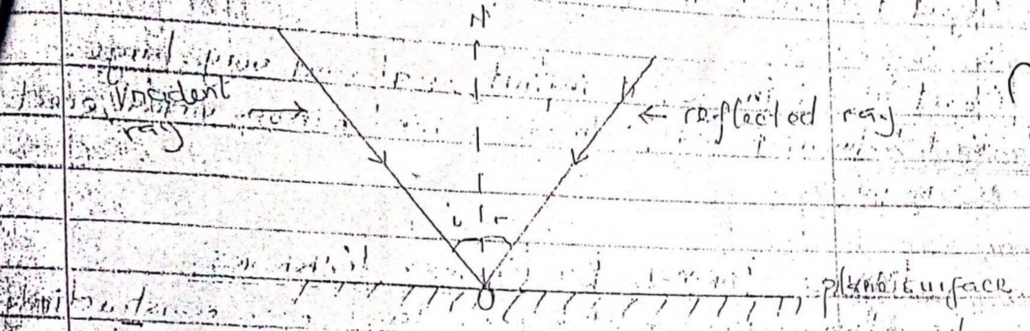
(iii) Rays directed towards the centre of curvature are reflected back along the same path.

By considering an object O in front of a convex mirror whose principal focus F and centre of curvature C are lying to the right of the pole P and D, by applying the above rules we can locate the position of the Image I.



Reflection, OB parallel O'D, just as the incident rays AO and CO' are parallel. This is not the case for the rough surface.

In a regular reflection at plane smooth surfaces, we can draw a line at the point of incidence O to N in the plane of incident [illegible] the reflected rays. this is called "NORMAL" to the surface. Angles of incidence 'i' and reflection 'r' measured with respect to the normal can be indicated.



Two laws, known as the laws of reflection for regular reflection can be stated as:

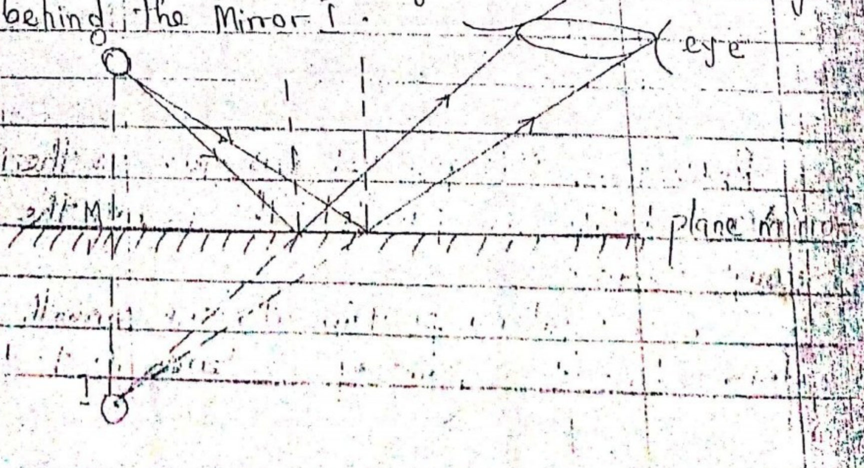
a) The incident ray, the reflected ray and the normal at the point of incidence, will lie in the same plane (i.e. a vertical plane can be imagined in which all these rays and the normal are lying on).

b) Under the condition in (a), the angle of incidence 'i' and the angle of reflection 'r' are equal, i.e. $i = r$.

IMAGE FORMATION BY PLANE REFLECTING SURFACE

We can make use of the two laws of reflection and other properties in the last section to show how we use image of an object from a reflecting surface like the plane mirror.

Consider two(2) rays from an object 'O'. The rays will obey the laws of reflection. Our eye pick up the two(2) reflected rays and thinks that the rays have come in straight lines from behind the Mirror I.



Since I is not the object, we call this point, the image of O. The image I is formed apparent (and not virtual) intersection of rays entering the eye when produced, backwords through the mirror. Thus, the image cannot be formed on a screen. This is a virtual Image.

We can also notice that the cone nature of the beam from the point object O as it enters the eye.

The Geometrical implication of the laws of reflection applied to plane surface as indicated in the above figure shows that:

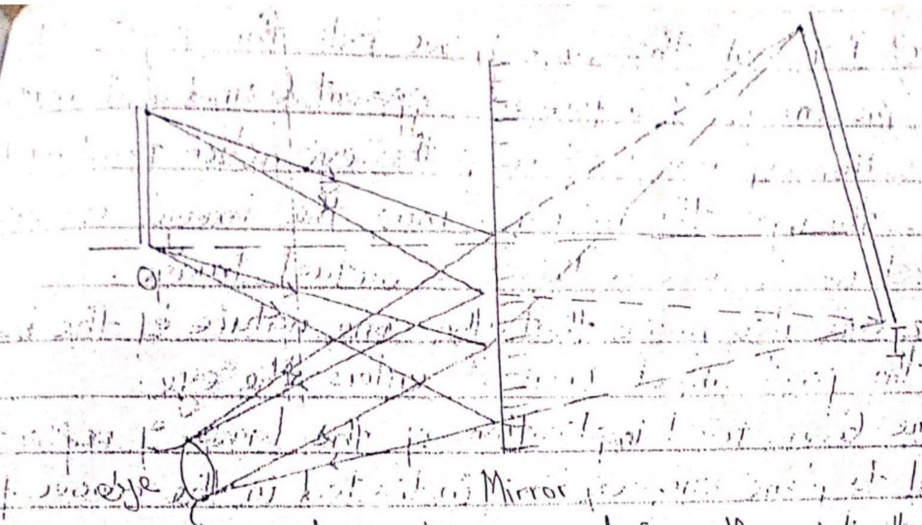
* a) The object's distance from mirror is the same as the Image's distance from the mirror. i.e $OM = IM$.
b) The size of the object is the same as the size of the mirror laterally inverted, and
c) The image cannot be formed on a screen since it is not formed by actual reflection/intersection of rays after reflection.

To draw ray diagram like the one above:

i) Start from the eye and draw rays as if they have come from the extremities (ends) of the image I, knowing that the image has same size as the object O, and is laterally inverted (the image is a 180° lateral rotation of the object).

N/B If you stand before a long vertical plane mirror, you will notice that your right hand is the ~~righ~~ left hand of the image and your left hand is the right hand of the image.

ii) then join the points where the ray meet the reflecting surface to the extremities of the object; and draw the arrows on the rays to indicate direction of energy transport

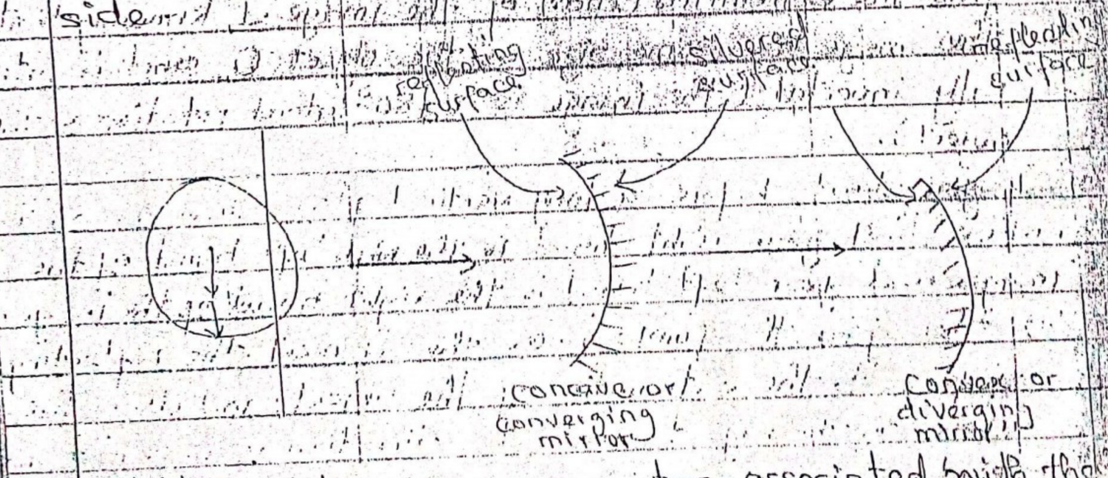


N/B: Image and object measured from the mirror must be the same

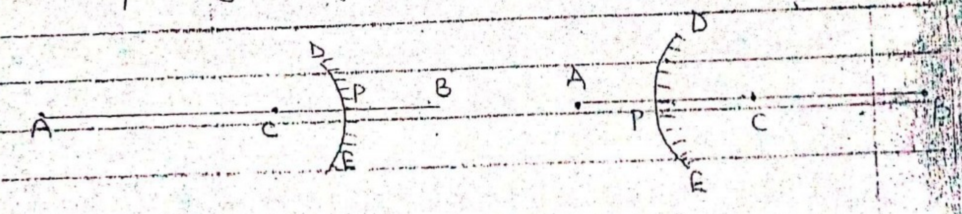
(MI = MO)

REFLECTION OF A LIGHT AT CURVED SURFACES

A curved reflecting surface is usually obtained by cutting a piece of material (i.e. glass) which would form part of a shell of a hollow sphere of radius r. A concave or converging mirror curves inwards with the arch-out surface silvered while the convex or diverging mirror curves outward with the silvered surface on the other side.



We can define some parameters associated with the curved reflecting surfaces.



curved mirror. It is called the PRINCIPAL AXIS.

b The point C on the principal axis is the centre of the sphere to which the curved mirror is a part and thus the distance CP is the radius of the sphere. Thus C is the centre of curvature and CP = r is the radius of curvature.

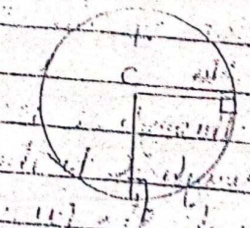
c The point P is called the POLE OF THE CURVED MIRROR and is a point on the principal axis which divides the mirror into two(2).

d DE is called the CURVED MIRROR APERTURE.

IMAGE FORMED BY CONCAVE MIRROR

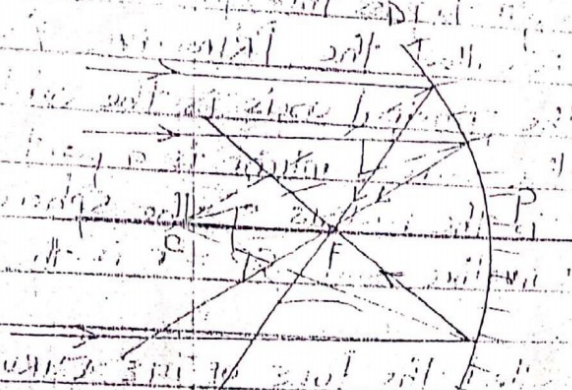
Rays of light falling on the reflecting surface of a concave mirror are reflected in a regular manner similar to the ones for the plane mirror. The laws of reflection thereby apply to the curved mirror.

Bearing in mind that any line from the centre of a circle or sphere drawn to intercept the circumference will fall at an angle of 90°. Thus, such a line is normal to the circumference at any point.



For a concave mirror, a line from C (centre of curvature) to any point on the curved mirror is a NORMAL.

First consider rays that are parallel and close to the principal axis. When these parallel rays fall on the concave mirror they get reflection and all of them pass through a point on the principal axis. This point is known as the PRINCIPAL FOCUS F of the concave mirror. F always lies between C and P.

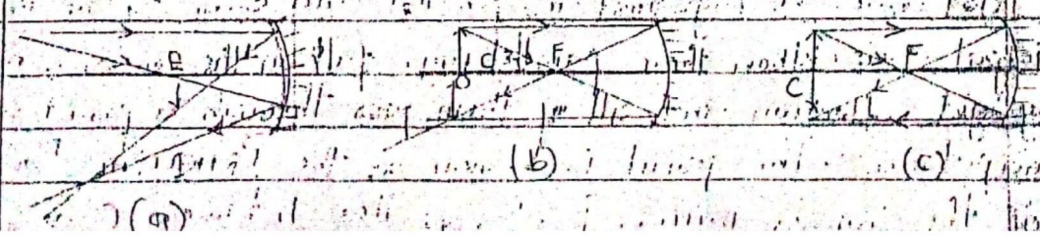


The length FP is denoted by f and is known as the focal length of the concave mirror.

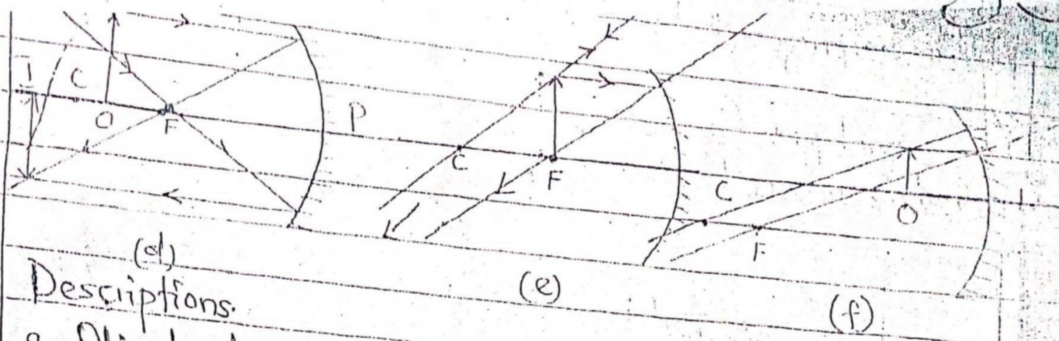
The parallel rays falling on the concave mirror come from a distant (infinite) object. After reflection, the point where the reflected rays intersect each other defines the position of the image. In this case, the image is formed at the principal focus.

We can draw and locate the image positions of objects placed at various distances from the pole of a concave mirror on the principal axis. We also note how the eye can be positioned to see these images if light from them come (appear to come) and enter the eye in a cone-shape manners. At least two rays from the object can be used to define the position of the image for each object distance from the pole. ~~No~~

N/B :- Any ray passing through C is reflected along its path since any line through C to the pole is along the normal. Also rays through the principal focus go parallel after reflection.



(a) (b) (c)



Descriptions.

a Object at infinity :- Image, real, inverted, smaller than Object & at F.

b Object beyond C :- Image, real, inverted, smaller than object & between C and F.

c Object at C :- Image, real, inverted, same size as object and at C.

d Object between C & F :- Image, real, inverted, magnified and lies beyond C.

e Object at F :- Image, at infinity, real and very large.

f Object between F and P :- Image, behind mirror, virtual, erect and magnified.

IMAGES FORMED BY CONVEX MIRROR

The following points must be considered when constructing the position of image of an object due to a convex (diverging) mirror.

(i) Rays parallel to the principal axis are reflected as if they have come from the principal focus.

(ii) Rays directed towards the principal focus are reflected parallel to the principal axis.

(iii) Rays directed towards the centre of curvature are reflected back along the same path.

By ~~thee~~ considering an object O in front of a convex mirror whose principal focus F and centre of curvature C are lying to the right of the pole 'P' and D by applying the above rules, we can locate the position of the Image I.

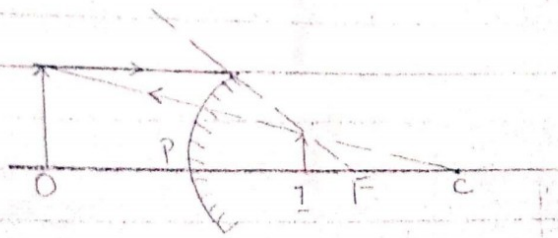
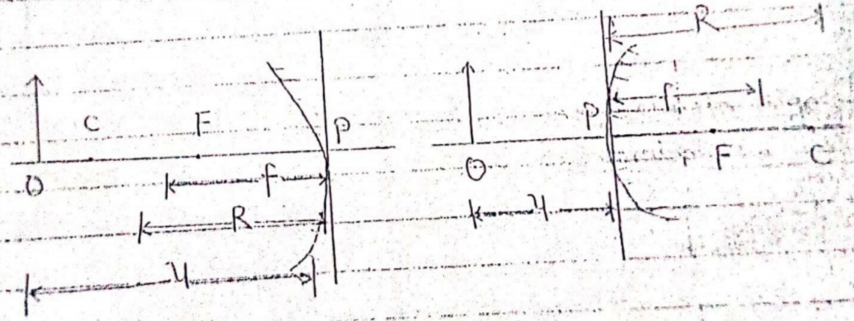


Image formed by a convex mirror is always erect, vi[rtual] and smaller than the object and lies between P and F. [As] O approaches P from the front of the mirror, I approach[es] from behind the mirror.

CURVED MIRROR FORMULA.

Consider the curved mirrors (concave and conv[ex]) which F is the principal focus and C is the centre [of] curvature. O is the object positioned in front of th[e] mirror.



NOTE:

i) All measurement of distances are with interference [to the] centre of the curved mirror, P as the origin.

ii) If the focal length FP = f and the radius of CP is R, then f = ½R or R = 2F.

iii) If u is the object distance measured from P, [v] the image distance, also measured from P, then

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

iv) In order to use the formula above, certain sign[s] must be used. There are two(2) convections:

i) Real is positive

(ii) The Cartesian.

In the cartesian convention, all measurement to the right of P are taken positive (just like x-y graph in plane cartesian co-ordinate system).

* All measurement to the left of P are taken negative. This in case, measurements of f, R and U are all negative for a convex mirror. We shall not be adopting this convention here.

Using the real-is-positive conversion

i) distances of real objects, images and focal lengths are taken positive and

ii) distances of virtual objects, images and focal lengths are taken negative.

(iii) Positive vocal length is defined when parallel rays close to the principal axis actually converge to the principal focus after reflection from the curved mirror. Negative focal length is defined when parallel rays close to the principal ~~focal~~ axis 'appear' to (but not actually) pass through the principal focus after reflection from the curved mirrors.

As we adopt the real-is-positive conversion, we note that the concave mirror has a positive focal length, and a convex mirror has a negative focal length.

v) Lateral magnification, M produced by the curved mirror is defined as

$$m = \frac{\text{height of image}}{\text{height of object}} = \left|\frac{v}{u}\right|$$

when the signs of U and V are ignored.

* Examples 1. A small object 2cm ~~long~~ high stands vertically and 20cm in front of a concave mirror of focal length 15cm. Find the nature, position and size of the image formed.

Solution

where hi = 2cm, U = object distance from mirror = 20cm f = focal length of mirror = 15 cm

Using the formula

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$$

Using the real is positive conversion

u = 20 cm

f = + 15 cm

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$$

$$= \frac{1}{15} - \frac{1}{20}$$

$$= \frac{4-3}{60} = \frac{1}{60}$$

v = +60 cm

Since v is positive (+60 cm), the image is real and 60 cm from the pole of the mirror on the same side as the object.

The magnification M

$$M = \frac{h_2}{h_1} = \frac{v}{u}$$

h_1 = height of object, h_2 = height of image = 2 cm

$$\frac{h_2}{2} = \frac{60}{20} = 3$$

or $h = 6$ cm

Thus, the image is 6 cm tall (or magnified 3 times)

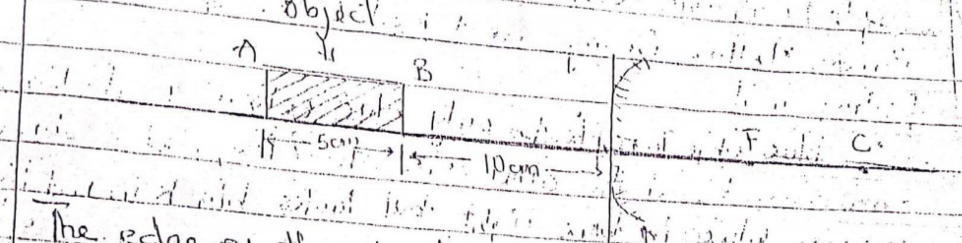
(The above problem can also be solved by scale drawing using the available data: f = 15 cm and R = 30, u = 20 cm and so on. The two rays from the object we can define image portion).

2. An object of length 5 cm lies along the principal axis and in front of a convex mirror which is 10 cm away from the closer edge of the object. If the focal length

image? ... What could be that length?

Solution

Sketching the image,



The edges of the object are A and B. We need to know position of the images of these edges for the length of the image to be known. Let v_1 be the image distance of B and v_2 image distance of A all measured from the mirror. Using the formula

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ and the real-is-positive we have

$u = +ve$, $f = -ve$. We compute v_1 and v_2 for object distances of B ($u_1 = 10cm$) and A ($u_2 = 15cm$) respectively.

$$\frac{1}{v_1} = \frac{1}{f} - \frac{1}{u_1}$$

$$= \frac{1}{10} - \frac{1}{10} = \frac{-1-1}{10} = \frac{-2}{10} = -5cm$$

Also, $\frac{1}{v_2} = \frac{1}{f} - \frac{1}{u_2}$

$$= \frac{-1}{10} - \frac{1}{15} = \frac{-3-2}{30} = \frac{-5}{30}$$

$v_2 = -6cm$

Since the values v_1 and v_2 are negative it means the image formed of AB is virtual. The length of the image is $(v_2) - (v_1) = 6 - 5 = 1$ cm. This is the length of the image. Magnification (lateral) is

$$M = \frac{1cm}{5cm} = 0.2$$

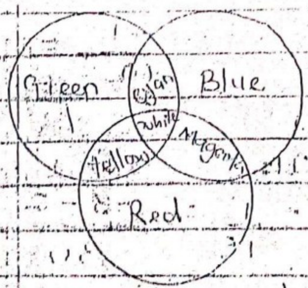
APPLICATIONS OF REFLECTION.

a. **Colours of Objects:-** Colours of object depends on the colours of the light falling on them and also on the colours of objects reflected. Thus, a white object reflect all the several colours: Violet, Indigo, Blue, Green, Yellow, Orange and Red (the visible spectrum) falling on it.

A blue object reflects only blue colour of the light and absorbs all the other six etc. Also, a blue object appears blue in blue light but looks black in red light since no light is reflected, as black is absence of colour.

b. **Mixing Colour light:-** There are three (3) primary colour that are known: Blue, Green & Red. They are primary because none of them can be produced from other colours of light. A mixture of red and green gives yellow, red and blue gives Magenta and blue with green gives Cyan or Peacock blue.

The three primary colours when combined gives white light.



~~Green + blue and~~

Similarly, the secondary colours, yellow, cyan and Magenta combine to give white light.

Complementary colours are any two colours that pr[oduce] a white light. Complementary colours include

i) Red + Cyan
ii) Green + Magenta
iii) Blue + Yellow.

...tion: White light ... study colour absorption and can filters and by so doing, the addition of colours can be allowed to pass through studied.

c) **Mixing of Coloured Pigments**:- Paints and dyes are made from the materials known as PIGMENT. These pigments reflect and absorb certain colours of white light when it falls on them. Most of these pigments reflect more than one colour i.e. to some extent they are impure. When the pigments are mixed, the colour reflected is the one that is reflected by each of the pigments. It is known that blue and yellow paints give green as blue paint reflect indigo, blue, green and yellow paint reflects green, yellow, orange under white light and so a mixture of blue and yellow gives the colour common to them, which is green. Thus, mixing coloured Pigments is a SUBTRACTION PROCESS, while mixing coloured light is an ADDITION PROCESS.

Exercise.

1. A boy stands 3.0m in front of vertical mirror (plane). The mirror is moved 1.5m towards him. What is the distance between the boy and his image?
2. A concave mirror forms a real image three times (3x) the size of the object; If the radius of curvature is 20cm. What is the distance between the image and the object.
3. An object 4cm high is placed vertically on the principal axis of a concave mirror whose radius of curvature is 20cm. If a virtual image 16cm high is obtained, determine the distance of the object from the mirror.
4. An object of height 4cm is placed vertically on the principal axis and 50cm in front of a convex mirror of focal length 25cm, what would be the height of the image formed?

PHOTOELECTRIC EFFECT

The emission of slow moving electron from a metal plate when light of certain wavelengths are incident on it is known as PHOTOELECTRIC EFFECT; the emitted electrons are called PHOTOELECTRON.

* Photoelectric Equation.

Einstein photoelectric equation is given as

$$\frac{1}{2}mv_0^2 = h\nu - w_0$$

where w_0 is the least work required to free a photo electron from the metal and is called the work function of the metal.

ν = frequency of light that illuminates the metal.

$(h\nu - w_0)$ = the energy of the fastest photoelectron

V_m = velocity of the electron

m = mass of electron.

ATOMIC MASS AND ATOMIC NUMBER

In 1911, Rutherford proposed the basic structure of the atom. A neutral atom consists of a very tiny nucleus of diameter 10^{-13} cm, which has a positive charge and contains practically the whole mass of the atom. The nucleus of Hydrogen is the simplest nucleus and is called PROTON a charge of +e, e is the numerical value of an electron charge.

Helium nucleus has + +2e . . . It contains protons. Copper . . . The heaviest element Uranium, has +92e, 92 protons. The no of protons in the nucleus of an atom is called THE ATOMIC NUMBER of the atom, denoted by Z.

It was also discovered that the nucleus has another particles which has the same no as the proton, but different mass and it is neutral. It does not carry any charge. The mass of the hydrogen atom is about 1837 times the mass of electron.

The mass of the proton in unified atomic mass, $m_p = 1.00727662$.

The mass of the proton. $M_n = 1.00866652$

A nucleus is represented by $^{A}_{Z}X_{N}$ i.e.

Z = no of proton.

A = is the Atomic mass and

(A−Z) gives the number of neutrons.

N = No. of Neutrons.

RADIOACTIVITY OR DISINTEGRATION

The heavy element Uranium, Actinum and Thorium are naturally occuring element which disintegrate to form new element. These elements are UNSTABLE so they form new elements. Radioactivity was discovered by Henri Becquerel in 1896 shortly after the discovery of X-rays by Roentgen in 1895. The Soddy and Rutherford rule for defining relative positions in the periodic table of the parent atom and its product states that if an α-particle is emitted by a radio active element, A, say, a new element is produced whose position in the table is two places to the left of A. If a β-particle is emitted from A, a new element is produced whose position in the table is one place to the right of A (check Uranium-radium series of radioactive changes in atomic physics books).

equation :- $^{A}_{Z}X_{N} \rightarrow {}^{A-4}_{Z-2}Y_{N'} + {}^{4}_{+2e}\alpha$ (α-decay)

where X = parent

Y = daughter.

$$ {}^{A}_{Z}X_{N} \longrightarrow {}^{A}_{Z+1}Y_{N} + \beta_{-e} $$

α-PARTICLE :- This is the nucleus of Helium of atomic mass four carrying charge of +2e. If an α-particle is emitted from the nucleus of an element of atomic mass x and atomic no Z, an atom is produced whose atomic mass is $(x-4)$ and whose atomic number is $(Z-2)$. The position of an element is the periodic table is governed by the chemical properties of that element i.e it depend on its atomic no. Thus an α-particle emission moves the element in the table i.e Soddy-Rutherford rule where λ is a constant characteristic of atom called decay constant. If N_0 is the number of atoms at a time $t=0$ and N is the number after time t, then, by integration

$$ \int_{N_0}^{N} \frac{dN}{N} = -\int_{0}^{t} dt $$

$$ \left[\log_e N\right]_{N_0}^{N} = -\lambda t \; \ldots $$

Equation above is the law of statistic and the derived relation is not perfect. It is a subject to error, which depend on the activity.

HALF-LIFE PERIOD

The half-life period, T of a radioactive element is defined as the time taken for half the atom to disintegrate, that is for the activity to diminish to half its value from equatn

$$ \int_{N_0}^{N_0/2} \frac{dN}{N} = -\int_{0}^{t_{1/2}=T} dt \; \ldots $$

In gas or Air, E is replaced by Adiabatic Bulk modulus of a gas (No heat can be added or allowed to leave the system). The adiabatic bulk modulus of a gas is γP, where γ is the ratio of molar heat capacity at constant pressure C_pV and constant Volume C_V. i.e $\gamma = \frac{C_P}{C_V}$ — (7) and P is the pressure of the gas. Thus for a gas the velocity is

$$V = \sqrt{\frac{\gamma P}{\rho}} \quad \text{— (8)}$$

...hen it passes from an up...

TRANSMISSION OF SOUND WAVE [ACCOUSTICS]

Sound can travel through Solid, liquid and Gas. Sound is caused by vibration of particles in a medium. If there are no particles in the medium then sound cannot pass through that medium. Thus, sound cannot pass through a vacuum because no atoms or molecules is present.

Sound requires a medium such as air, water, wood e.t.c to pass from one place to another. Sound waves reaches the human ear through the air and can also travel through solid and liquid. However, sound vibrations hardly pass from one medium to another if the media are ~~from dif~~ of different densities.

SPEED OF SOUND IN SOLIDS, LIQUIDS AND GAS

Several phenomena in nature indicates that sound has a definite velocity or speed as it travels from one point to another in a medium. example, when a piece of wood is cast by striking it with axe, the sound of strokes are heard some little length of time after the strike. If the firing of a gun is watched about 10Cm away, the gun shot is heard some seconds after the flash of the discharge is seen.

The velocity of sound varies according to the medium through which it passes. It is faster in solids and liquids than in air (Gas, and faster in solids than liquids or gases (due to different molecular structures and density of the media).

In Solids of density P, a sound source subjects this medium to various stress with resulting strain. The velocity of sound V is therefore partly governed by the modulus of the Elasticity, E of the medium.

$$\text{i.e.}\quad E = \frac{\text{Stress}}{\text{strain}} \quad — (4)$$

A fractional extension by original dimension for a given solid medium, the velocity V is given by

$$V = \sqrt{\frac{E}{P}} \quad — (5)$$

For a liquid, elasticity E is replaced by Bulk Modulus k, where k is given as

$$k = \frac{\Delta P}{-\Delta V/V} = \frac{\text{Pressure change in liquid}}{\text{Fractional Velocity decrease by original velocity}} \quad — (6)$$

Mathematical Representation of Wave

The general equation for wave is;

$$Y = A\sin\left(\frac{2\pi x}{\lambda}\right) \quad \text{—— (1)}$$

Where; Y = vertical component
A = Amplitude
λ = Wavelength
x = horizontal component.

$$Y = A\sin\frac{2\pi}{\lambda}(vt - x) \quad \text{—— (2)}$$

where; V – Velocity
T – Period

Example

1) The equation of a wave is $y = 0.05\sin[\pi(0.5x - 200t)]$. where x and y are in metres and t is in secs. What is the velocity of the wave

solution

Using the 3rd formula;

$$Y = A\sin\left(2\pi fT - \frac{2\pi x}{\lambda}\right) \quad \text{—— (3)}$$

$Y = A\sin\frac{2\pi vt}{\lambda} - \frac{2\pi x}{\lambda}$ where $f = V/\lambda$

Given; $y = 0.05\sin[\pi(0.5x - 200t)]$

Comparing equation 3

$$\frac{2\pi x}{\lambda} = \frac{0.05\pi x}{1}$$

$$\frac{2\pi x}{\pi x} = \frac{0.05\lambda\pi x}{\pi x}$$

$$\frac{2}{0.5} = \frac{0.05\lambda}{0.05} \quad \therefore \lambda = 4m$$

Comparing $\frac{2\pi fT}{\pi T} = \frac{200\pi T}{\pi T}$

$2f = 200$

$f = 200/2 = 100Hz$

Velocity $= f\lambda$

$= 100 \times 4$

$= 400ms^{-1}$

TYPES OF WAVE

1) Longitudinal Wave.
2) Transverse Wave.

Longitudinal Wave

It is a type of wave in which the particle medium vibrates parallel or in the same direction to the propagation of wave. Example is the sound wave.

Transverse Wave

It is a type of wave in which the particle vibrates perpendicular to the direction of Wave. Example is the light Wave!

Classifications of Wave

1. Electromagnetic Wave.
2. Mechanical Wave.

Electromagnetic Wave	Mechanical Wave
1] It is produced by electric and magnetic forces.	It is produced by varying layers of an object.
2] It is a vector quantity	It is a scalar quantity.
3]. It is transverse	It is longitudinal.
4]. It causes polarization [vibrational character of a wave which travels in a straight line.	It causes no polarization.
5] The intensity of light is measured in candela. (c.d). [intensity- rate of flow ~~often~~ of energy per unit area].	It is measured in decibel (d.b)
6]. Example is the light wave	Example is the sound wave
7] It is very sensitive to the eyes	It is very sensitive to the ears

Progressive Wave

They are moving waves with a velocity of light

Static / Standing wave

When two waves of the same amplitude & wavelength travels in opposite direction and over lap each other, a static wave is produced because the wave profile does not move with a velocity of light.

Mathematical Representation of Wave

2) The equation of a transverse wave travelling on a string is given by $Y = 5\sin(2.0x - 100t)$. where x and y are in (cm) and t is in secs. Compute; (i) Amplitude (iii) Period
(ii) frequency (iv) Wavelength of the wave

Solution

(i) $A = 5cm$

Converting it to metre; $\frac{5}{100} = 0.05m$

ii) frequency -

Comparing $\frac{2\pi f t}{100} = \frac{100t}{100t}$

$\frac{2\pi f t}{t} = \frac{100t}{t}$

$2\pi f = 100$

$f = \frac{100}{2\pi} = \frac{50}{\pi} \approx 15.9134$

$f \simeq 16Hz$

iii) Period $T = \frac{1}{f} = \frac{1}{16}$

$T = 0.0625$

$T = 0.0625secs$

iv) Comparing $\frac{2\pi x}{\lambda}$ $\times \frac{2.0x}{1}$

$\frac{2\pi x}{x} = \frac{2.0\lambda x}{x}$

$\frac{2\pi}{2.0} = \frac{2.0\lambda}{2.0}$

$\lambda = \pi$

$\lambda = 3.142m$

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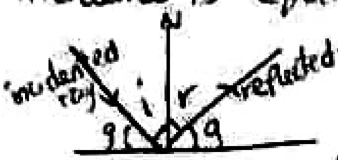
Properties of Wave

A] **Reflection** - Change in the direction of wave within the same medium obeying the laws of reflection.

Law of Reflection

1] The angle of incidence is equal to the angle of reflection.



$i = r$

2] The incident ray, the reflected ray and the normal at the point of incidence all lies on the same plane.

B] **Refraction** - It is the bending of a wave towards the normal when it passes from an optically less dense medium to an optically dense medium and obeys the law of refraction.

Laws of Refraction

1] The ratio of the sine of the angle of incidence to the sine of refraction is constant for a given pair of media. [Also known as SNELL'S LAW OF REFRACTION].

refractive index ${}_a n_g = \frac{\sin i}{\sin r}$ [Note; Change in speed causes refraction]

2] The incident ray, the refractive ray and the normal at the point of incidence all lies on the same plane.

C] **Diffraction** - It is the bending of wave when it passes through an aperture of a sleet. [it depends on the size of the aperture/obstacle]

Uses

1] It is used to be able to see around the corner [in terms of light].

2] It is used to look at molecules using X-ray crystallography.

D] **Interference** - It is the superposition of waves. [overlaps of waves with same amplitude and wavelength travelling in opposite direction].

Types < constructive & destructive interference.

Constructive interference - occurs when the wave amplitudes reinforce each other, building a wave of even greater amplitude.

Destructive interference - occurs when the wave amplitude opposes each other, resulting in waves of reduced amplitude

PHY 103

Waves & Modern Physics

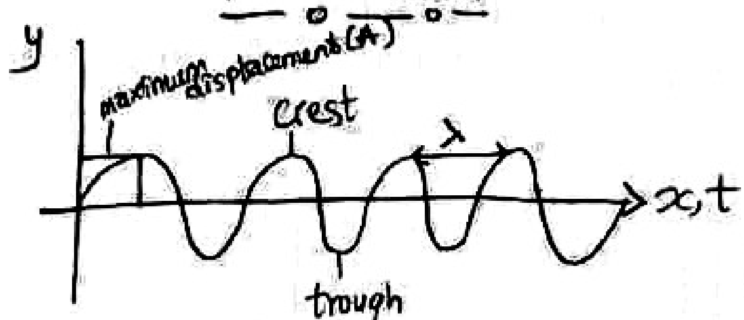
Sound & Optics

Wave

A wave is a periodic disturbance in a medium that cause an elastic displacement transferring energy from one point to another.

Wave motion - propagation of waves

Terms used



1. Wave motion - Propagation of waves.
2. Wavelength - is the distance between two sucessive crest or two sucessive troughs.
3. Amplitude - is the maximum displacement on either side of the oscillation.
4. Sinosoidal Wave - Wave that changes face (from sine to cosine and vice versa) with time at different intervals.
5. Period - It is the time taken for a wave to complete one cycle or oscillation. It is measured in seconds. $T = 1/f$

$$T = \frac{\text{time taken}}{\text{number of cycles}}$$

6. Frequency - It is the number of cycles or oscillations which the wave completes in one second. It is measured in Hertz (Hz) or s^{-1}

$$F = \frac{\text{number of cycles}}{\text{time taken}} \qquad F = \frac{1}{T}$$

7. Wave speed or velocity (v) = $\frac{\text{Wave length}}{\text{Period}} = \frac{\lambda}{T}$ or

$$V = \text{frequency} \times \text{Wavelength}; \quad V = F\lambda$$

EXTENDED OBJECT – these are real objects with length, width and height.

IMAGE

In optics, an image is defined as the collection of focus points of light rays coming from an object

REAL IMAGE

A real image is the collection of focus points actually made by converging rays

A real image can be projected on the screen as it is formed by rays that converge on a real location.

e.g images formed on a projection screen, on the photographic film in camera and on the retina of human eye.

VIRTUAL IMAGE

Virtual image is the collection of focus points made by extensions of diverging rays.

In other words, a virtual image is found by tracing real rays that emerge from an optical device (lens, mirror, or some combination) backward to perceived or apparent origins of ray divergences.

In diagrams of optical systems, virtual rays are conventionally represented by dotted lines; and because the rays never really converge, a virtual image cannot be projected into a screen.

and we say that light is travelling from an optically less dense medium to an optically denser medium. The opposite is implied when ${}_1\mu_2 < 1$ ie light bends away from the normal.

REFRACTION AND WAVELENGTH.

The velocity v of light is related to its frequency ν and wavelength λ by

$$v = \nu\lambda \quad (1)$$

The frequency of light is a function of the light emitted only and it is the same in all media. The velocity and wavelength of light changes as light travels from one medium to another. In fact, the wavelength of light becomes shorter in a optically denser medium.

When light of frequency ν travels from air to a less dense medium, m then

$$v_m = \nu\lambda_m \quad (3)$$

and

$$v_a = \nu\lambda_a \quad (4)$$

for air.

Since the absolute value of refractive index is defined as $\mu = \frac{c}{v}$ (5)

$$\therefore v_m = \frac{c}{\mu_m} \quad (6)$$

$$v_a = c/\mu_a \approx 1 \quad \text{because } \mu_a \approx 1. \quad (7)$$

$$\nu\lambda_m\mu_m = c = \nu\lambda_a \quad (8)$$

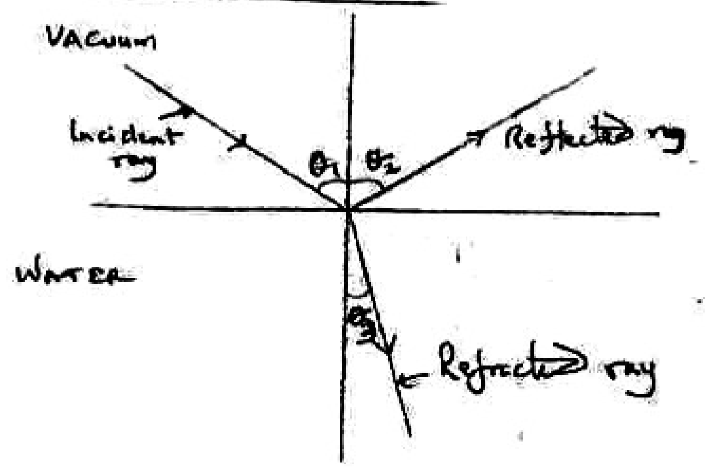
$$\lambda_m = \frac{\lambda_a}{\mu_m} \quad (9)$$

The wavelength of monochromatic light is longer in vacuum (or air); it is shorter in medium of higher index of refraction

Since μ_m ... > 1

(F)

Reflection of Refraction



θ_1 := angle of incidence
θ_2 := angle of reflection
θ_3 := angle of refraction
NOTE: All the angles are formed by the normal and the corresponding ray.

Fig 2

LAWS GOVERNING REFLECTION & REFRACTION

1. The incident ray, the refracted ray and the normal to the surface at the point of incidence all lie in the same plane

2. REFLECTION: the angle of incidence θ_1 is equal to the angle of reflection θ_2

3. REFRACTION. The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant for any two given transparent medium's

$$\frac{\sin\theta_1}{\sin\theta_3} = {}_1\mu_2 = \text{constant} \quad (1)$$

${}_1\mu_2$ is a constant called the 'relative index of refraction for light travelling from medium 1 to medium 2.

For any given medium, the index of refraction is generally expressed relative to vacuum (ie for light travelling from a vacuum into the medium)
The relative index of refraction relates the speeds with which light travels through two media. When ${}_1\mu_2 = 1$, the refracted ray bends toward the normal at the refracting surface

Example

1. Parallel beam eg (a) searchlight, (b) rays from a point on a very distant object like the sun are substantially parallel
2. Divergent beam eg a lamp

parallel beam
Fig 1a

Divergent beam
Fig 1b

3. Convergent beam -
A source of light behind a lens, as in projection lantern provides a convergent beam

convergent beam.
Fig 1c

GEOMETRICAL OPTICS

Geometrical optics is a system of geometrical techniques used in determining the characteristics of the image of an object of known size and position by an optical system.

BASIC PRINCIPLES OF GEOMETRICAL OPTICS

(a) Light travels in a straight line
(b) The straight lines along which light travels are called rays
(c) The position of an object is a combination of distance and direction
(d) The position of an image is the apparent origin of the light rays which enter the observer's eyes.
(e) The change in the relative position of two objects as the eyes moves across the direction of alignment is called PARALLAX. When there is no parallax between the position of the object, the latter are said to be coincident.

POINT OBJECT - a point object have no physical extent

SIGN RULES

These rules are applicable to all situations that is from image formation by a plane mirror or spherical reflecting and refracting surface or by a pair of refracting surfaces forming a lens:

1. SIGN RULE FOR THE OBJECT DISTANCE
   When the object is on the same side of the reflecting or refracting surface as the incoming light, the object distance s is positive; otherwise it is negative.

2. SIGN RULE FOR THE IMAGE DISTANCE
   When the image is on the same side of the reflecting or refracting surface as the outgoing light, the image distance s' is positive; otherwise it is negative.

3. SIGN RULE FOR THE RADIUS OF CURVATURE OF A SPHERICAL SURFACE
   When the centre of curvature C is on the same side as the outgoing light, the radius of curvature is positive; otherwise it is negative.

For a mirror the incoming and outgoing sides are always the same. In fig 3, the object distance s is positive because P is on the same incoming side (the left side) of the reflecting surface. However s' is negative because P' is not on the outgoing side the reflecting surface. The object & image distances are related by

$$s = -s' \text{ (plane mirror)}$$

the image distance and the image magnification

The change of image distance with wavelength is known as CHROMATIC ABERRATION.

The variation of magnification with wavelength is known as CHROMATIC DIFFERENCE OF MAGNIFICATION OR LATERAL COLOUR.

* Chromatic aberration can be corrected/eliminated by combining a strong lens of low-dispersion (crown) glass with a weaker lens made of high dispersion (flint) glass.

ALITER

CHROMATIC ABERRATION

In optics, chromatic aberration also called chromatic distortion and spherochromatism is a failure of a lens to focus all colours to the same point.

It is caused by dispersion - when colours are incorrectly refracted (bent) by the lens, resulting in a mismatch at the focal point where the colours do not combine as they should.

The refractive index of the most transparent materials decrease with increasing wavelength. Since the focal length of a lens depends on the refractive index, this variation in refractive index affects focussing.

Chromatic aberration manifests itself as "fringes" of colour along boundaries that separate dark and bright parts of the image.

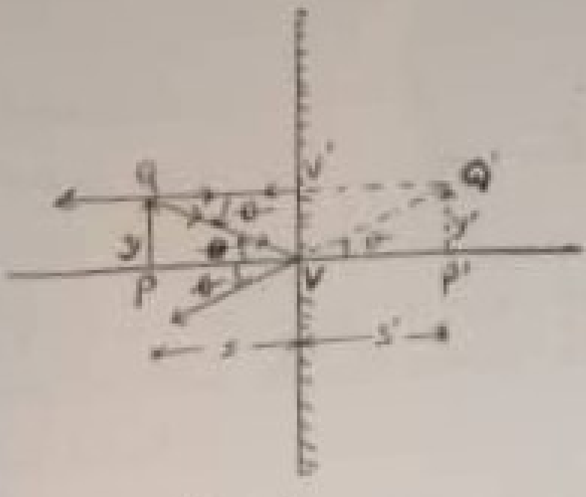


Fig 4

y := height of the object PQ
y' := height of the image P'Q'

The image formed by an extended object PQ is extended image P'Q'; to each point on the object, there corresponds a point on the image. Two of the rays from Q are shown; all the rays from Q appear to diverge from its image point Q' after reflection.
Other points of the object PQ have image points between P' and Q'.

The triangles PQV and P'Q'V are congruent so the object PQ and image P'Q' have the same size and orientation, and

$$y = y' \quad (10)$$

The lateral magnification m is

$$m = \frac{y'}{y} \quad (11)$$

Mirror 1 forms an image P_1' of the object point P, and mirror 2 forms another image P_2', each in the way discussed above. In addition, the image P_1' formed by mirror 1 serves as object for mirror 2 which then forms an image of this object at point P_3'.

The idea that an image formed by one device can act as the object for a second device is of great importance in geometric optics, especially in understanding image formation by combinations of lenses, as in a microscope or refracting telescope.

Absolute refractive Index

This is defined as the ratio of the velocity of light in a vacuum to the velocity of light in the medium

If c = velocity of light in vacuum
v = " " " " the medium

$$\Rightarrow \mu = \frac{c}{v} \quad (5)$$

Remark

1. The value of the absolute index can never be less than 1. This is so because light travels with the fastest speed in vacuum.
2. The lower value of the absolute refractive index indicates a denser medium while a higher value indicate rarer medium.

Some typical values (refractive indices) for yellow light [sodium - wavelength equal to 589nm (10^{-9}m)] are

Medium	Air	Water	Crown glass	Flint glass	Diamond
μ	1.0003	1.3300	1.5170	1.655	2.417

from the table above, diamond is a real medium that is not dense because the component part are not closely compacted together.

3. Refractive index however varies with wavelength. The variation of refractive index with wavelength is source of chromatic aberration in lenses.
4. CHROMATIC ABERRATION — is colour distortion in an image viewed through a glass lens.
Because the refractive index of glass varies with wavelength, every property of a lens that depends on it also varies with wavelength including focal length,

IMAGE FORMATION BY A PLANE MIRROR

To find the precise location of the virtual image P′ that a plane mirror forms of an object at P at a distance s to the left of a plane mirror, we use the following figure. The figure shows two rays diverging from P. s is called the object distance

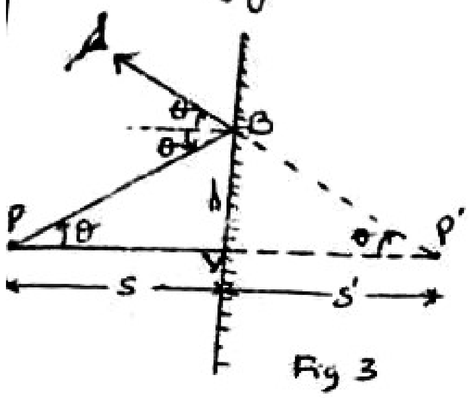


Fig 3

The ray PV is incident normally on the mirror (ie it is ⊥er to the mirror surface) and it returns along its original path. The ray PB makes an angle θ with PV. It strikes the mirror at an angle of incidence θ and is reflected at an equal angle with the normal. When the two rays are extended backwards, they intersect at P′, a distance s′ behind the mirror.

s′ := image distance

Remark

1. The line P and P′ is ⊥ar to the mirror
2. The two triangles PVB and P′VB are congruent, so P and P′ are at equal distances from the mirror and s and s′ have equal magnitudes.
3. The image point P′ is located exactly opposite the object point P as far behind the mirror as the object point is from the front of the mirror
4. The image of an extended object is inverted from left to right (otherwise known as LATERAL INVERSION).

REAL & APPARENT DEPTH

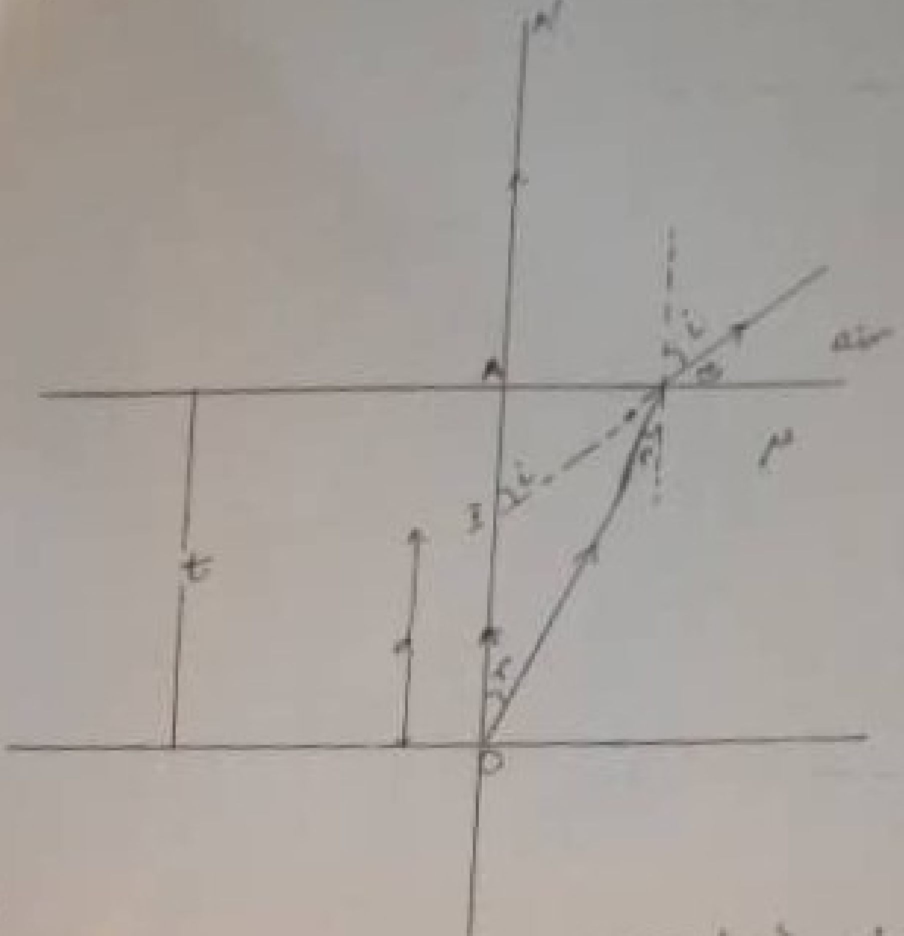


FIG 6

In the figure above, an object is placed at a depth t, in transparent medium of refractive index μ. Light from O at normal incidence to the surface at A is undeviated and pass through to A' while oblique incident ray OB is divergent at B to form an image at I. If light had been travelling into the medium the refractive index

$$\mu = \frac{\sin i}{\sin r} = \frac{AB/IB}{AB/OB} = \frac{OB}{IB}$$

for B very close to A such that the ray OB is almost at normal incidence

$$OB = OA$$
$$IB = IA$$

Answer

(1) For plane mirror, $m = 1$
The reason why your image is the same size as the real you when you look in mirror is m.

(2) In fig 4, the image arrow points in the same direction as the object arrow and the image is said to be "erect"

(3) y and y' have the same sign and m is positive.

(4) The image formed by a plane mirror is always erect, the same magnitude and sign. So y and y' have both the same magnitude and sign.

(5) For an inverted image y and y' have opposite signs and m is negative.

(6) The object in fig 4 has only one dimension.

(7) The reversed image of 3-D object formed by a plane mirror is the same size as the object in all its dimensions. When the transverse dimensions of the object and image are in the same direction, the image is erect. Thus a plane mirror always forms an erect but reversed image.

An important property of all images formed by reflecting or refracting surfaces is that an image formed by one surface or optical device can serve as the object for a second surface or device. (See fig 5)

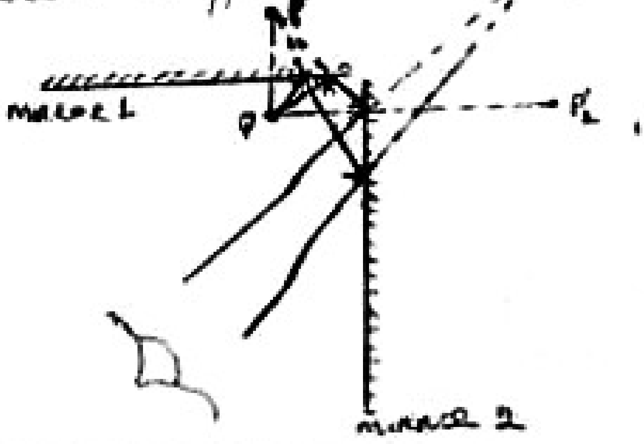


FIG 5