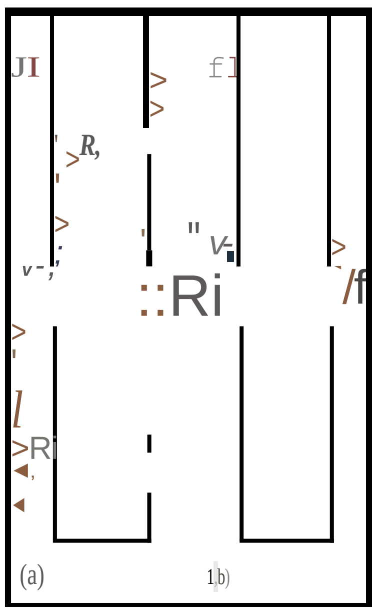
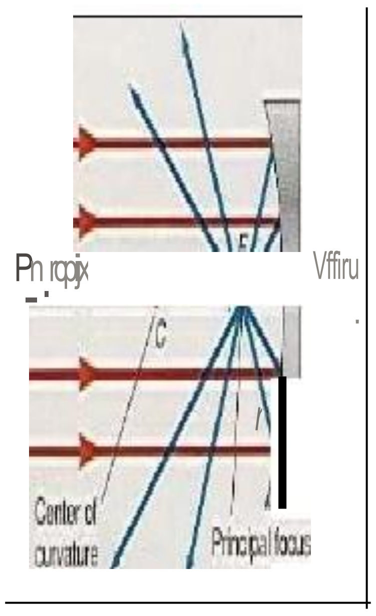
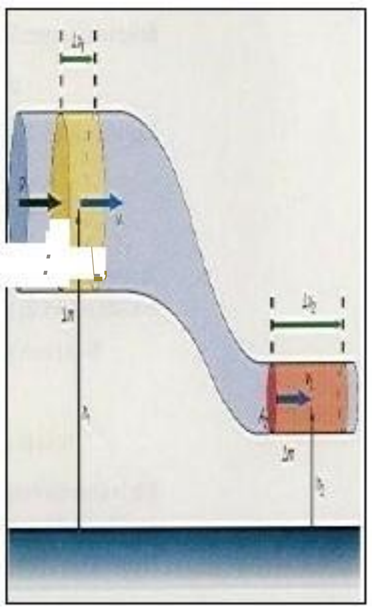
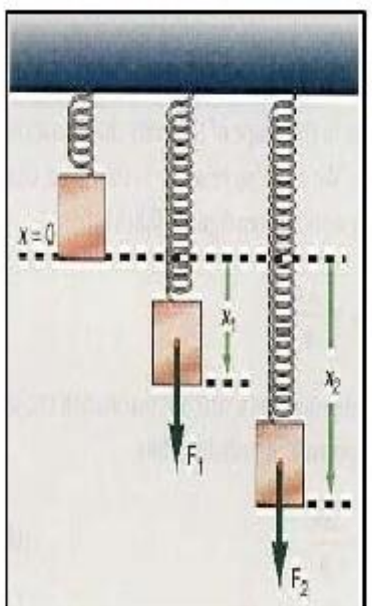
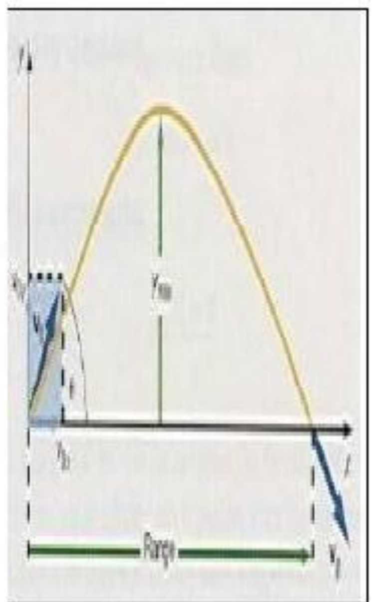
University of Mosul/ Dept of physics
Science College

Lectures of General Physics Lecture =1=

Motion

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Lecture (1) - Motion

Part (Ia) - Kinematics	Part (Ib) - Dynamics
1.1 Kinematics - The Study of Motion	**1.8** Newton's Laws of Motion Newton's first law of
1.2 A Body Moving at Constant Velocity	**1.9** Friction
1.3 A Body Moving at Constant Acceleration	
1.4 The Instantaneous Velocity Instantaneous Acceleration ! a Moving Body	
1.5 The Kinematic Equations	
1.6 The Freely Falling Body	
1.7 Projectile Motion	

((Kinematics)) - LECTURE l

1.1 Kinematics -The Study of Motion

l(inematics *is defined as that branch of mechanics that studies the motion of a body without regard to the cause of that motion.*

The ***average velocity*** *of the body is defined as the displacement of the moving body divided by the time it takes for that displacement*.

That is:

$$v_{avg} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t} \ldots(1-1)$$

We should make a distinction between the average velocity of a body and the average speed of a body.

The average speed of a *body is the distance that a body moves per unit time.*

The average velocity of a body is the displacement of a body per unit time.

Because the displacement of a body specifies the distance an object moves *in a specified direction,* its velocity is also in that direction.

The speed is just the distance traveled divided by the time and does not specify a direction for the motion.

1.2 A Body Moving at Constant Velocity

Whenever a body moves in such a way that it always travels equal distances in equal times, that body is said to be moving with a constant velocity.

The SI unit for velocity is (**mis).**

The units **(cm/s)** and **(km/hr)** are also used.

Note that on a graph of the displacement *(x)* of a moving body versus time ***(t)*** as shown in figure (**1.1**), the slope ***ll.xlll.t*** always represents a velocity.

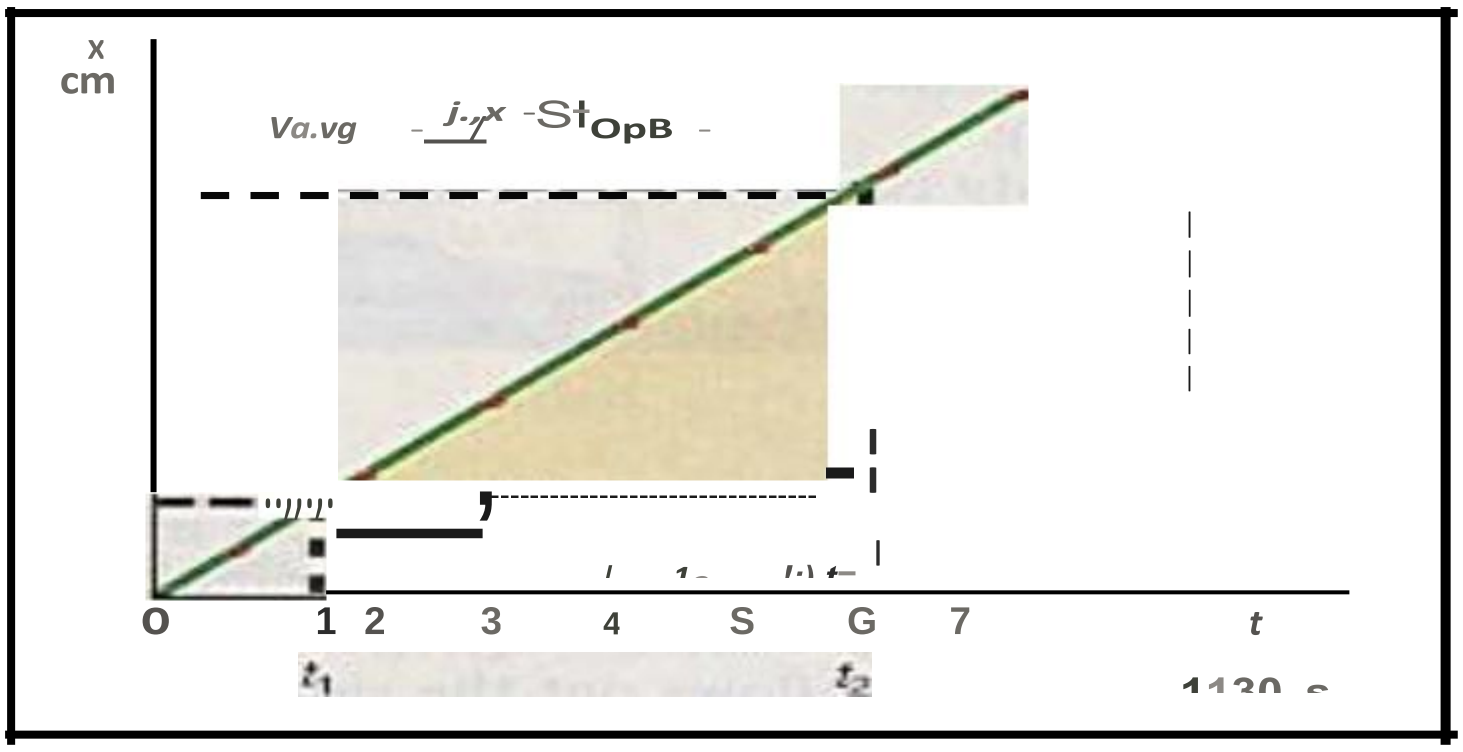

Figure (1.1): Graph of displacement versus time for constant velocity.

If the slope is positive, the velocity is positive and the direction of the moving body is toward the right.

If the slope is negative, the velocity is negative and the direction of the moving body is toward the left.

Lecture 2

A Body Moving at Constant Acceleration

The change of velocity with time is defined as the ***acceleration*** *of the moving body, and the average acceleration is written as:*

$$a_{avg} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t} \quad ...(1-2)$$

If we plot the velocity ***(v)*** against the time ***(t),*** we obtain the graph in figure (**1.2**).

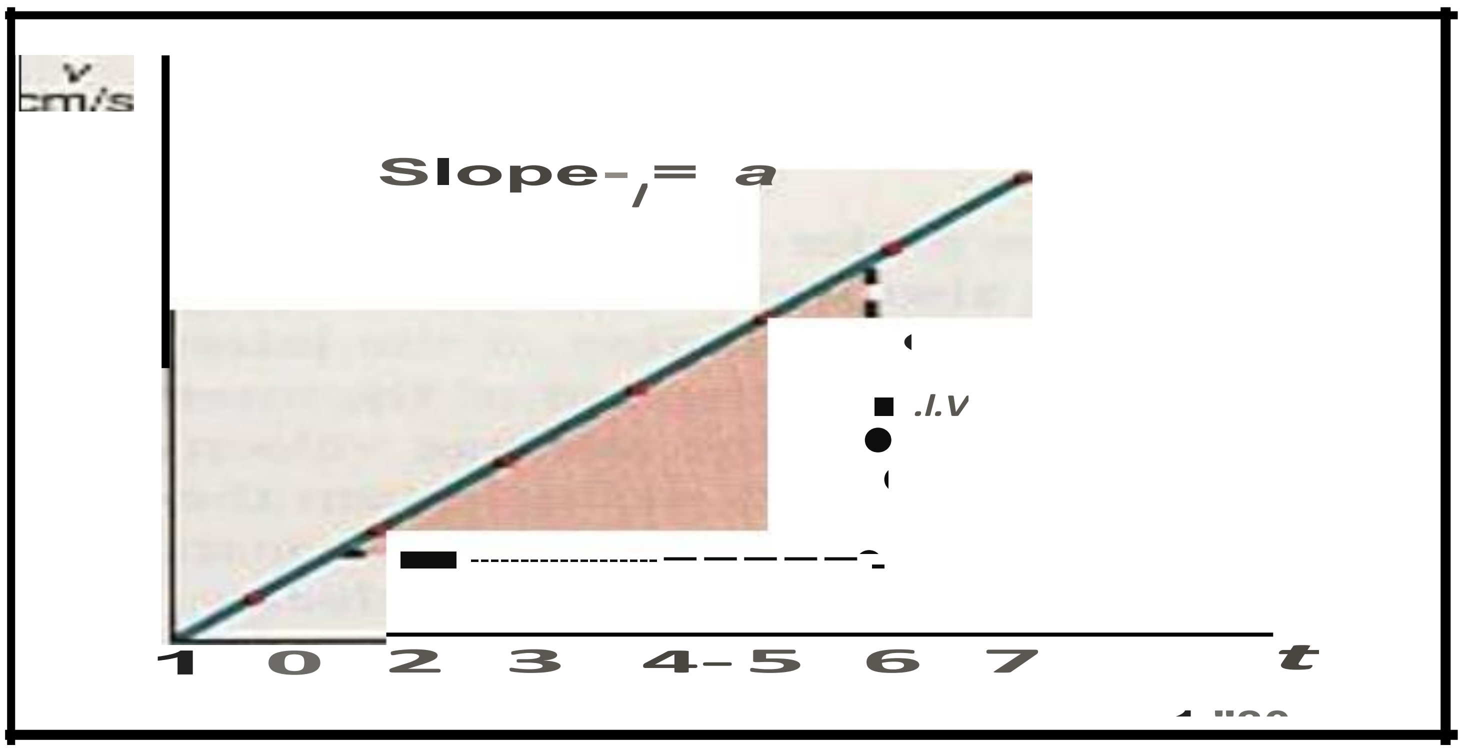

Figure (1.2): Graph of (v) versus (t) for constant acceleration.

Since acceleration is a change in velocity per unit time, the units for acceleration are velocity divided by the time.

In SI units, the acceleration is **(m/s^2)** or **(cm/s^2)** .

1.3 The Instantaneous Velocity and Instantaneous Acceleration of a Moving Body

Instantaneous velocity *is defined as the limit of* ***(ax/at)*** *as* ***(at)*** *gets smaller and smaller, eventually approaching zero.*

We write this concept mathematically as:

$$\boxed{v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt} \text{...(1-3)}}$$

Note that this is the same as the definition of the derivative of (x) with respect to ***(t)*** .

In that case the instantaneous acceleration is defined as the limit of **(av/at) as (at)** gets smaller and smaller, eventually approaching zero.

We write this concept mathematically as:

$$\boxed{a = \dot{\ldots}(1\text{-}4) \frac{v}{t} = - \frac{dv}{d} \text{funill o -}}$$

Note that this is the same as the definition of the derivative of *(v)* with respect to ***(t)***

1.4 The Kinematic Equations

The **first** of the very important kinematic equations, namely,

$$v = v_o + at \quad ...(1\text{-}5)$$

*Equation **(1.5)** says that the velocity **(v)** of the moving object can be found at any instant of time **(t)** once the acceleration (**a)** and the initial velocity (vo) of the moving body are known.*

Equation **(1.6),** the **second** of the kinematic equations, represents the displacement *(x)* of the moving body at any instant of time ***(t).***

$$x = v_o t + \tfrac{1}{2} a t^2 \quad ...(1\text{-}6)$$

*the **third** kinematic equation,*

$$v^2 = v_o^2 + 2a.x \quad ...(1\text{-}7)$$

*which is used to determine the velocity **(v)** of the moving body at any displacement **(x).***

Lecture 4

The Freely Falling Body

A freely falling body is defined as a body that is moving freely under the influence of gravity, where it is assumed that the effect of air resistance is negligible.

From experiments in the laboratory we know that the

value of ***(g)*** near the surface of the earth is constant and is given by : ***(g*** = **9.80 m/s² = 980 cm/s²)**

Any body that falls with the acceleration due to gravity,
(g), *is called a freely falling body.*

Since the first case we consider is a body that is dropped, we will set the initial velocity *(vo)* equal to zero in the kinematic equations.

Also the acceleration of the moving body is now the acceleration due to gravity, therefore we write the acceleration as :

$$a = -g \quad \ldots (1\text{-}8)$$

Therefore, the kinematic equations for a body dropped from rest (vo = **O)** near the surface of the earth are;

$$v = -gt \quad \ldots (1\text{-}9)$$

$$y = -\frac{1}{2} g t^2 \quad \ldots (1\text{-}10)$$

$$v^2 = -2gy \quad \ldots (1\text{-}11)$$

Equation **(1.9)** gives its velocity at any time , equation **(1.10)** gives the height or location of the freely falling body at any time, and equation **(1.11)** gives the velocity of the freely falling body at any height *(y)* .(falling body that is dropped from rest)

The Language of Physics

((Kinematics)) - LECTURE 2

IKinematicsl

The branch of mechanics that describes the motion of a body without regard to the cause of that motion.

IAverage velocit

The average rate at which the displacement vector changes with time.

Since a displacement is a vector, the velocity is also a vector.

IAverage speedl

The distance that a body moves per unit time.

Speed is a scalar quantity.

!Constant velocity!

A body moving 1n one direction in such a way that it always travels equal distances in equal times .

IAccelerationl

The rate at which the velocity of a moving body changes with time.

OCnstantaneous velocit

The velocity at a particular instant of time.

It is defined as the limit of the ratio of the change in the displacement of the body to the change in time, as the time interval approaches zero.

The magnitude of the instantaneous velocity is the instantaneous speed of the moving body .

!Kinematic equations of linear motionl

A set of equations that gives the displacement and velocity of the moving body at any instant of time, and the velocity of the moving body at any displacement, if the acceleration of the body is a constant .

!Freely falling bodyl

Any body that is moving under the influence of gravity only.

Hence, any body that is dropped or thrown on the surface of the earth is a freely falling body .

Kcceleration due to gravity!

If air friction is ignored, all objects that are dropped near the surface of the earth, are accelerated toward the center of the earth with an acceleration of **(9.80 m/s²)** .

!Projectile motionl

The motion of a body thrown or fired with an initial velocity v_o in a gravitational field .

Lecture 5

Summary of Important Equations

((Kinematics)) - LECTURE la

Average velocity	Vavi1r= li ,"C= X2 - X:t aa ,g = fiv = u - flt ll t. t2 - ti t1
Average Acceleration Instantaneous velocity	=!u!.iu- n;..._ .:'.lX dX = - aIHIl t dt
Instantaneous Acceleration	a=lim-=- dn dt At....o tit
Velocity at any time for constant acceleration	u=vo+at
Velocity at any time for free falling body from rest	v=-gt
Displacement at any time for constant acceleration	x = vot + ...1.. at2 2
Displacement at any time for free falling body from rest	y =__________l_gt2 2:
Velocity at any displacement for constant acceleration	I.fl,= 1,,w+ 2ax
Velocity at any displacement for free falling body from rest	u2 =-:2gy
For Projectile Motion x-displacement	x = Uoxt
For Projectile Motion y-displacement	y = VQyt- _l_gt2 2
For Projectile Motion x-component of velocity	Vx : U0x
For Projectile Motion y-component of velocity	Uy= VQy-gt
The time to rise to the top of the trajectory	trr = U(h, g
Total time that of flight	lt = 2vov = 2;ti. g
The range of the projectile	R = vo2 s:iun 20 g
The maximum height of the projectile	Ymax= VOJ:2 2g

((Dynamics)) - LECTURE 5

1.8 Newton's Laws of Motion

Dynamics *is defined as that* branch of mechanics concerned with the forces that change or produce the motions of bodies .

The foundation of dynamics is Newton's laws of motion.

Newton's First Law of Motion

Can be stated as: *A body at rest, will remain at rest and a body in motion at a constant velocity will continue in motion at that constant velocity, unless acted on by some unbalanced external force.*

The resistance of a body to a change in its motion is called ***inertia,*** *and Newton's first law is also called the law of inertia.*

Newton's Second Law of Motion

the acceleration of a body is directly proportional to the applied force and inversely proportional to the mass of the moving body.

The unit of force in SI units, thus defined, 1s
1 newton= 1 kg.m/s² :

$$F = ma \quad \ldots(1\text{-}20)$$

Equation ***(1.20)*** *is the mathematical statement of Newton's second law of motion.*

If the gravitational force pulling an object down toward the earth is called the weight of the body, and its magnitude is ***w,*** and Newton's second law becomes:

$$w = mg \quad \ldots(1\text{-}21)$$

Equation **(1.21)** thus gives us a relationship between the mass of a body ***(m)*** and the weight of a body ***(w).***

Newton's Third Law of Motion

Newton stated his third law in the succinct form, "Every action has an equal but opposite reaction."

Let us express **Newton's third law of motion** in the form, *if there are two bodies, **A** and **B,** and if body **A** exerts a force on body **B,** then body **B** will exert an equal but opposite force on body **A.***

The first thing to observe in Newton's third law is that twobodies are under consideration, body ***A*** and body ***B.***

As an example of the third law, consider the case of a person leaning against the wall, as shown in figure **(1.4).**

The person is body ***A,*** the wall is body ***B.***

The person is exerting a force on the wall, and Newton's third law states that the wall is exerting an equal but opposite force on the person.

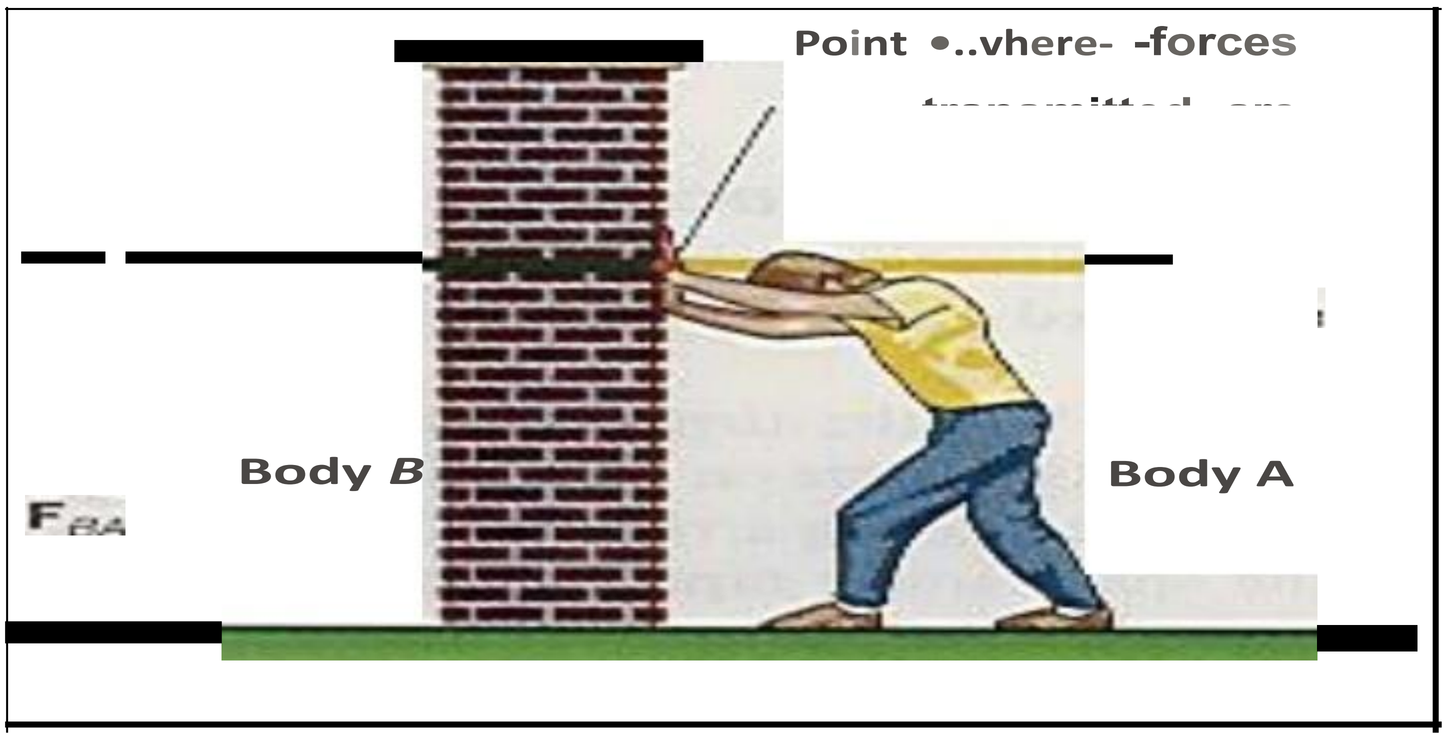

Figure (1.4) : **Forces involved when you lean against a wall.**

Lecture 6

1.9 Friction

Whenever we try to slide one body over another body there is a force that opposes that motion.

This opposing force is called the force of ***friction.***

For example, if this book is placed on the desk and a force 1s exerted on the book toward the right, there is a force of friction acting on the book toward the left opposing the applied force, as shown in figure **(1.5).**

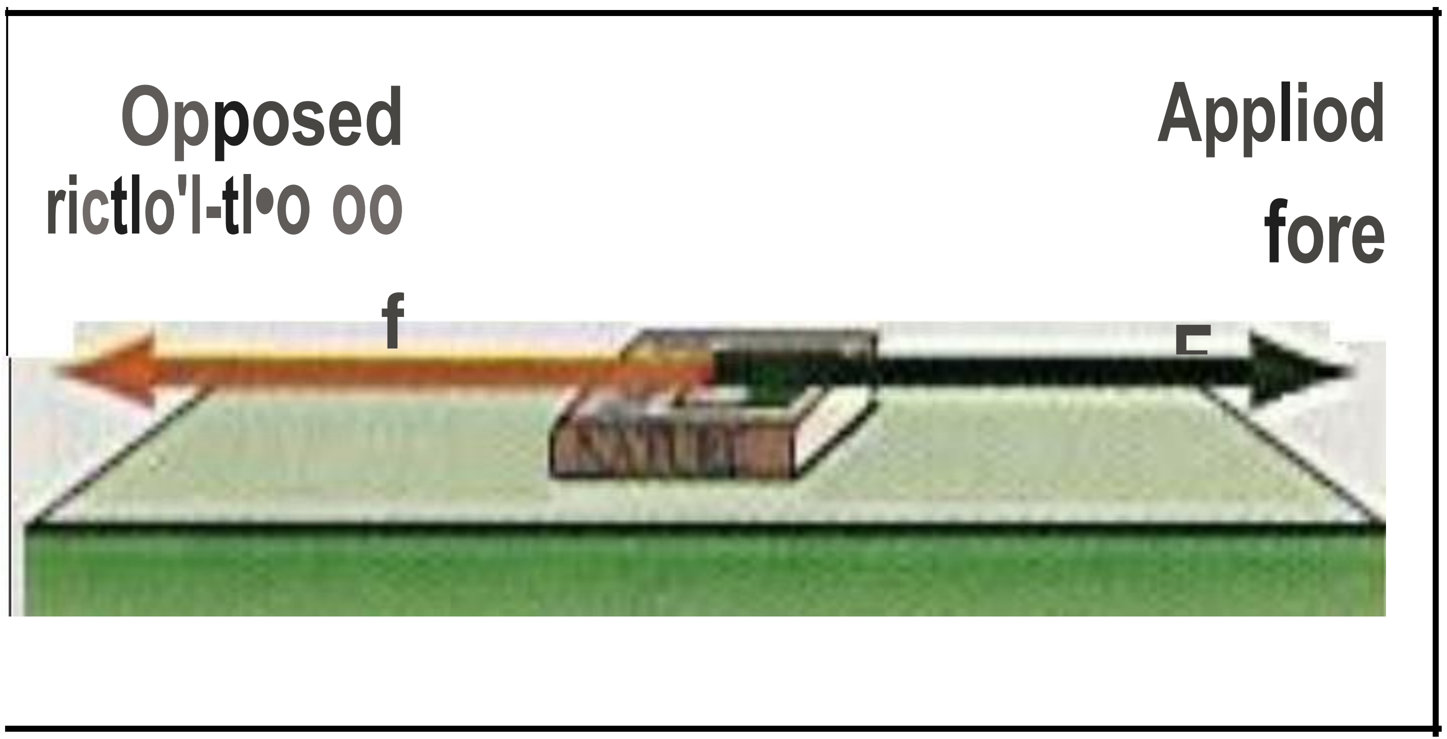

Figure (1.5) : The force of friction.

1.9.1 Force of Static Friction

When the object just begins to move, it has been found experimentally that the frictional force is :

$$\boxed{fs = \mu_s F_N \ldots (1-22)}$$

and is called the force of static friction.

The quantity *(μs)* is called the coefficient of static friction.

1.9.2 Force of l(inetic Friction

For a moving object the frictional force is found experimentally as :

$$\boxed{f_k = \mu_k F_N \ldots (1-23)}$$

and is called the force of kinetic friction.

The quantity *(μk)* is called the coefficient of kinetic friction and is also given for various materials in table **(1.1).**

Table : (1-1)

Approxi1nate C-oefficients of Static and Kinetic Friction for Various lviaberia in Contact

'F=la,teria1s in Conia.et	s	lk
(.¾lass 011 glas.s	0.95	0.40
Steel on steel (lub1t•icate,d)	0.15	0.09
Wood on \Vood	0..50	0.13n
Wood on st.one	0.50	0.40
R.ubher tiit'.•e on dry con,c:n:·et.e	1.00	0.70
R.ubber tir,e on vvet conct:ete	0.70	0.50
L,eath.er 0.11 \Wood	0..50	0.40
T1eflon on steel	0.04	0.04
Copper on steel	0.53	0.36

Lecture 6

The Language of Physics

((Dynamics)) - LECTURE 6

OC?ynamicsl

That branch of mechanics concerned with the forces that change or produce the motions of bodies.

The foundation of dynamics is Newton's laws of motion.

IForcel

The simplest definition of a force is a push or a pull that acts on a body.

Force can also be defined in a more general way by Newton's second law, that is, a force is that which causes a mass ***(m)*** to have an acceleration ***(a).***

!Newton's first law of motionl

A body at rest will remain at rest, and a body in motion at a constant velocity will continue in motion at that constant velocity, unless acted on by some unbalanced external force.

This is sometimes referred to as the law of inertia .

!Newton's second law of motionl

If an unbalanced external force ***(F)*** acts on a body of mass ***(m),*** it will give that body an acceleration ***(a).***

The acceleration is directly proportional to the applied force and inversely proportional to the mass of the body.

Once the acceleration is determined by Newton's second law, the position and velocity of the body can be determined by the kinematic equations.

!Newton's third law of motionl

If there are two bodies, ***A*** and ***B,*** and if body ***A*** exerts a force on body ***B,*** then body ***B*** exerts an equal but opposite force on body ***A*** .

IFrictionl

The resistance offered to the relative motion of two bodies in contact.

Whenever we try to slide one body over another body, the force that opposes the motion is called the force of friction.

!Force of static friction!

The force that opposes a body at rest from being put into motion.

!Force of kinetic friction!

The force that opposes a body in motion from continuing that motion.

The force of kinetic friction is always less than the force of static friction .

Summary of Important Equations ((Dynamics)) -

LECTURE 6

Newton's second law	$F = ma$
The weight of a body	$w = mg$
Force of static friction	fs = JtsF,V
Force of kinetic friction	{k =i.R''''.i

Lecture (7) - Optics	
Part (4a) - Reflection	**Part (4b) - Refraction**
4.1 Light as an Electromagnetic Wave	4.7 Refraction
4.2 The Law of Reflection	**4.8** The Law of Refraction
4.3 The Plane Mirror	**4.9** Total Internal Reflection
4.4 The Concave Spherical Mirror	**4.10** Thin Lenses
4.5 The Convex Spherical Mirror	**4.11** The Lens Equation
4.6 The Mirror Equation and Magnification	

((Reflection and Mirrors)) - LECTURE 7

4.1 Light as an Electromagnetic Wave

light is an electromagnetic wave; a transverse wave that travels through empty space at the speed of **3.00 x 10^8 mis** or **186,000 miles/s.**

The relation between the wavelength ***(.l),*** frequency **(v),** and speed ***(c)*** of the light is given by the fundamental equation of wave propagation as:

1/4.V = C... (4-1)1

Notice that we are now using the Greek lower case letter ***v*** **(nu)** to represent frequency.

This usage is customary in physics, especially when dealing with electromagnetic radiation in modern physics.

The wavelength of visible light varies from about **(3.8 x 10^{-7} m)** for violet light to the longer wavelength of red light at **(7.2 x 10^{-7} m).**

Since the wavelength of light is so small, we commonly use the nanometer **(nm),** where

1 nm= 10^{-9} m

In these units visible light varies from about **(380.0 nm)**
to about **(720.0 nm).**

A great deal of research went into **optics, the study of light,** before its electromagnetic character was known.

4.2 The Laws of Reflection

The ***first law of reflection*** *and it says that the angle of incidence (* ***i)*** *is equal to the angle of reflection* ***(r).***

The ***second law of reflection*** *was implied in the derivation and it says that the incident ray, the normal, and the reflected ray all lie in the same plane.*

4.3 The Plane Mirror

In general, to describe an ***optical image*** *three words are necessary: its* ***nature*** *(real or virtual), its* ***orientation*** *(erect, inverted, perverted), and its* ***size*** *(enlarged, true, or reduced).*

Recall that when you look into a mirror your image is reversed.

That is, if you hold up your right hand in front of the mirror, your image appears as though the left hand was held up.

This inversion of left-right symmetry is called *perversion.*

Thus, a ***plane mirror*** *produces a virtual, perverted, true image.*

Lecture 8

4.4 The Concave Spherical Mirror

*A **spherical mirror** is a reflecting surface, whose radius of curvature is the radius of the sphere from which the mirror is formed,* figure **(4.1).**

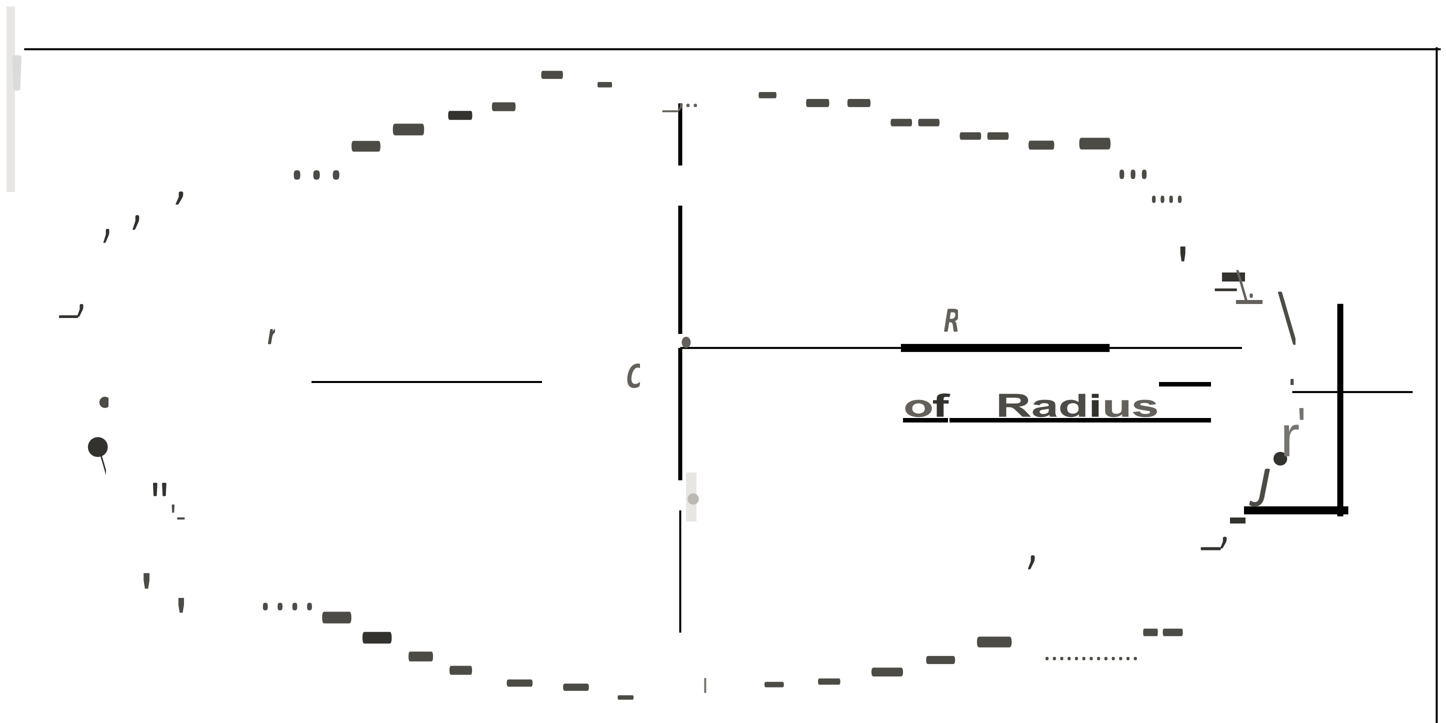

Figure (4.1): A concave spherical mirror.

Here ***(C)*** is the center of curvature of the mirror and ***(R)*** is its radius of curvature.

The line going through the center of the mirror, the *vertex* 1n figure **(4.2),** is called the *principal axis,* or *optical axis,* of the mirror.

Light rays that are parallel and close to the principal axis of the concave mirror converge to a point called the principal focus ***(F)*** *of the mirror as shown in figure* ***(4.2)*** .

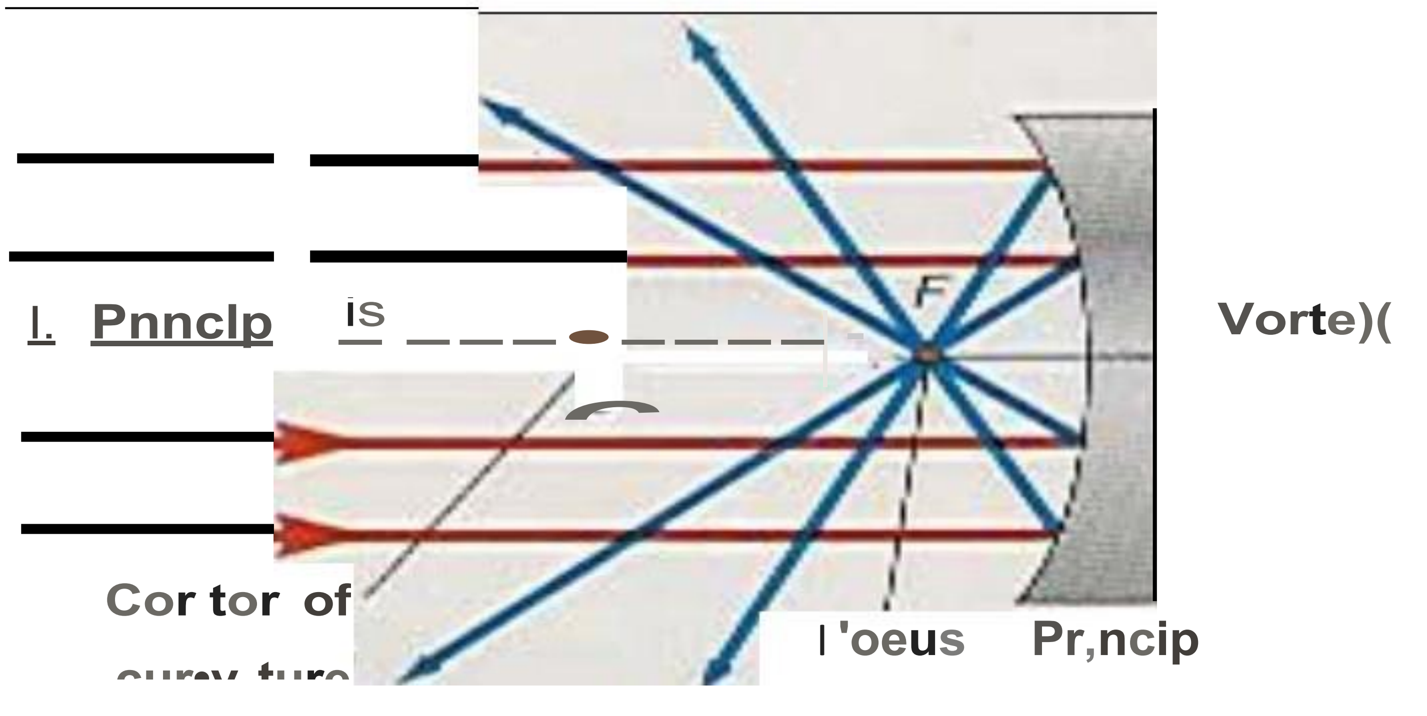

Figure (4.2): Parallel light converges to the principal focus of a concave spherical mirror.

Consider a single ray ***AB*** parallel to the principal axis, as shown in figure **(4.3).**

The normal ***N*** to the reflecting surface at point ***B*** , the incoming ray **AB,** therefore, makes an angle of incidence *(i)* with the normal.

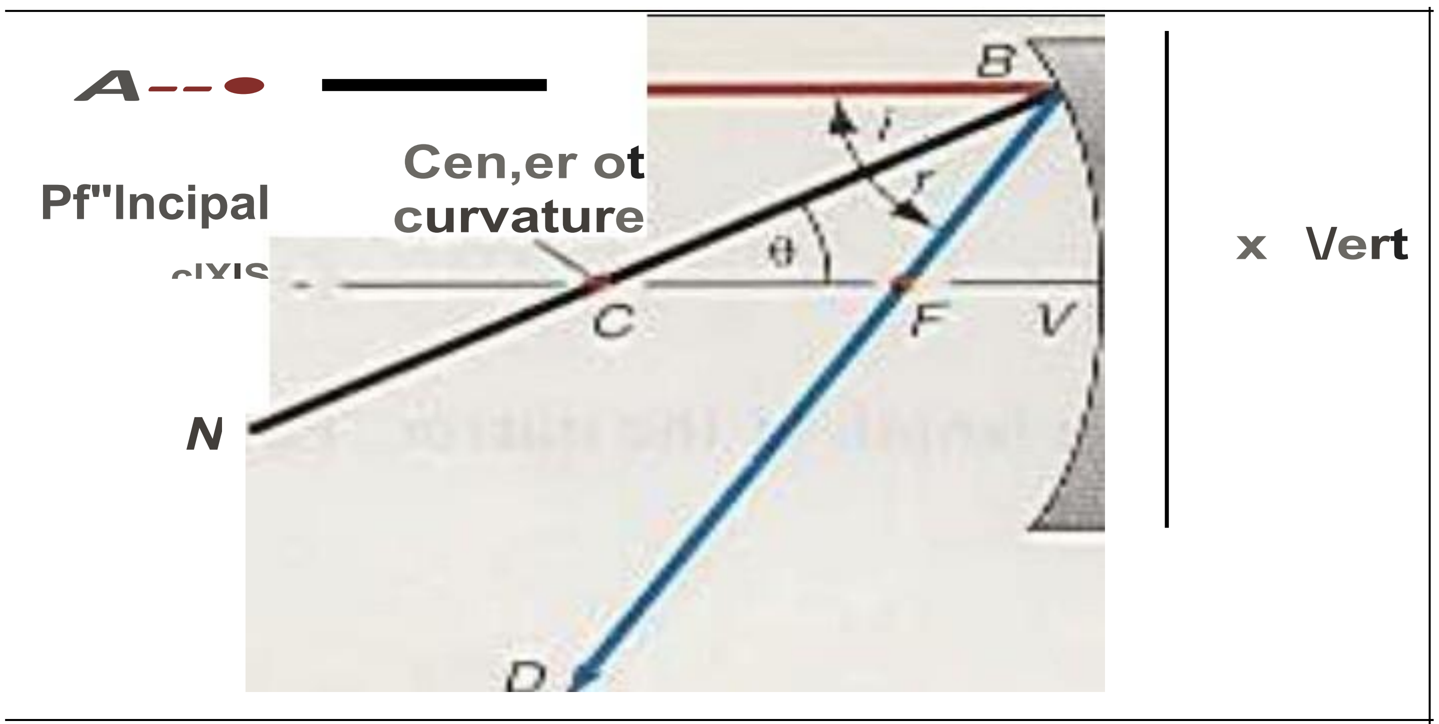

Figure (4.3): Center of curvature and principal focus of a concave spherical mirror.

By the law of reflection, the angle of reflection **(r)** is equal to this angle of incidence **(i)** and the reflected ray is shown as **BD.**

The distance ***VF*** from the vertex of the mirror to the principal focus ***(F)*** is called the focal length ***(f)*** of the mirror.

Using this notation,

$$\boxed{f = \frac{R}{2} \ldots (4-2)}$$

That is, *the* ***focal length of a concave spherical mirror*** *is equal to one-half the radius of curvature of the*

.

mirror.

Lecture 9

4.5 The Convex Spherical Mirror

A convex spherical mirror is a reflecting surface formed from a portion of the outside of a sphere, as shown in figure **(4.4).**

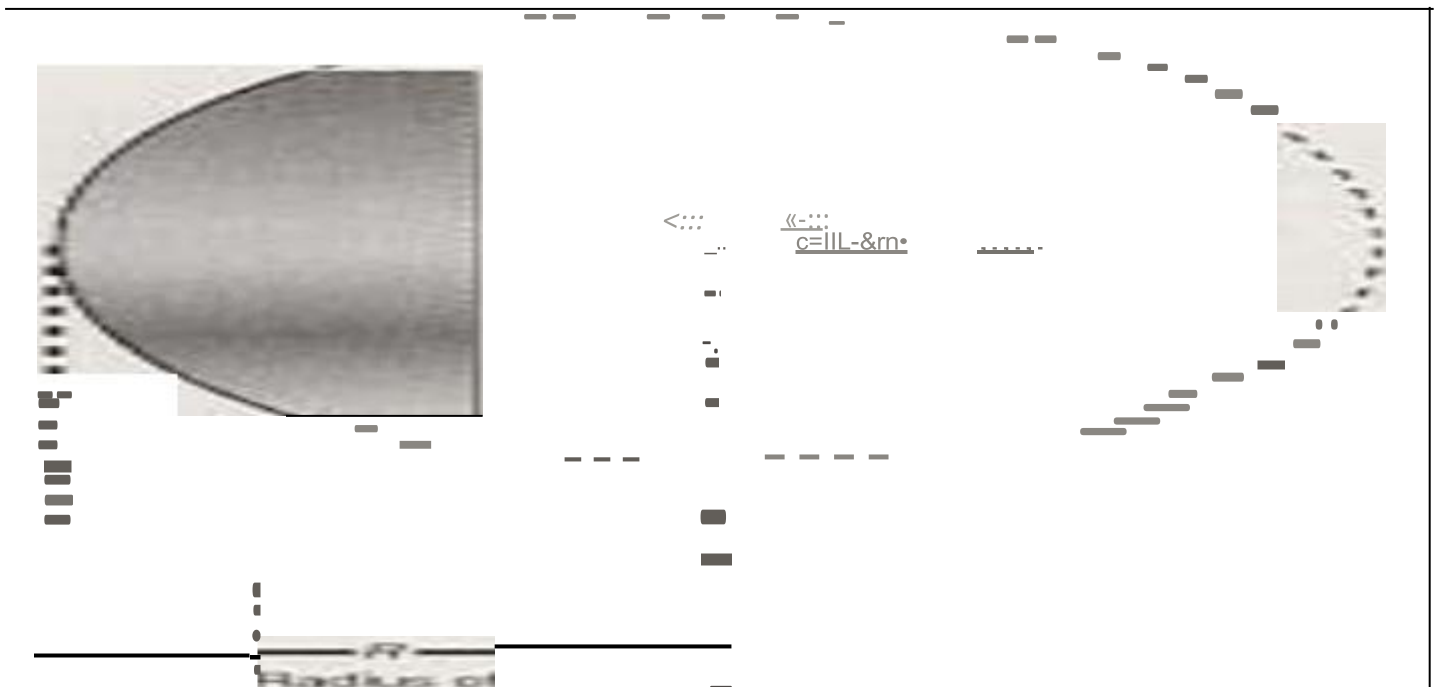

Figure (4.4) : A convex spherical mirror.

An incident ray, parallel to the principal axis of a convex spherical mirror, is shown in figure **(4.5).**

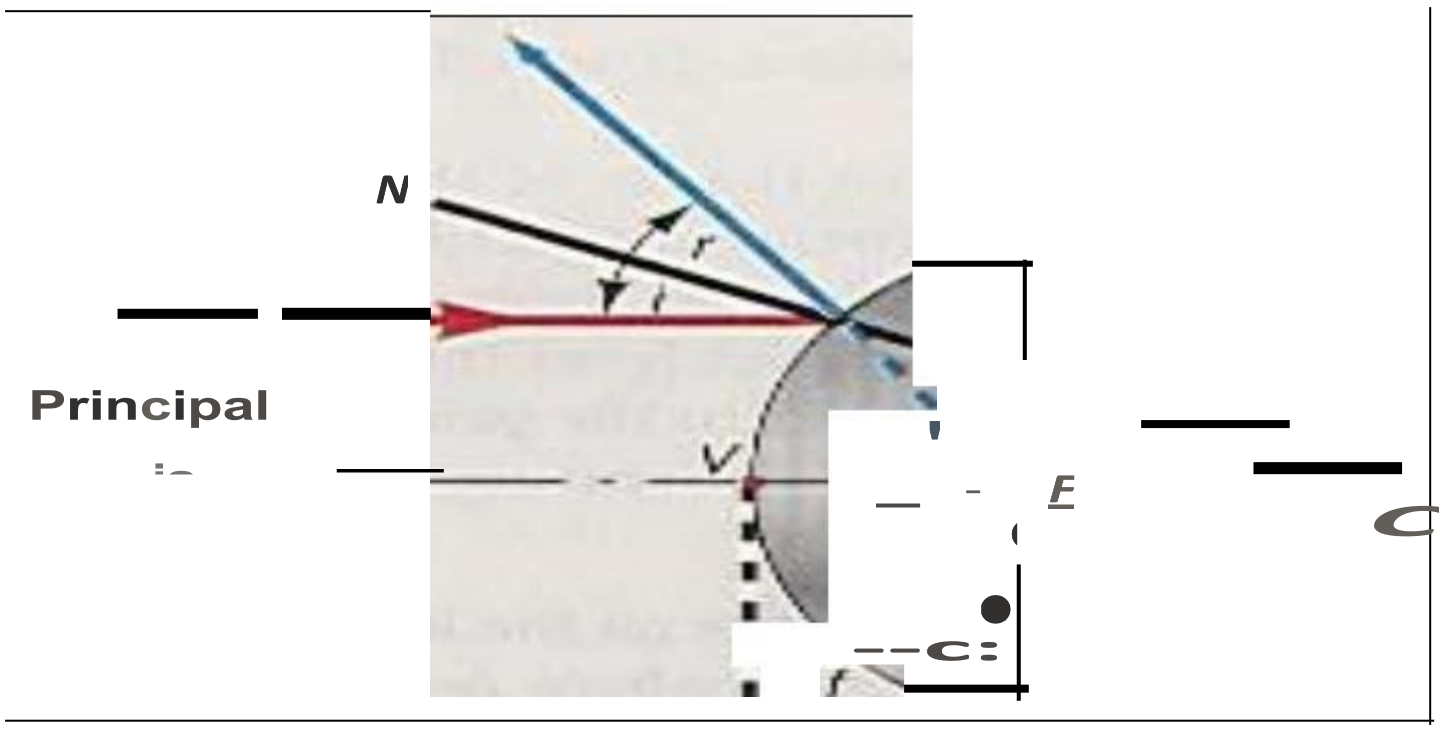

Figure (4.5) : A parallel ray of light diverges away from the principal axis for a convex spherical mirror.

The incident ray makes an angle ***(i)*** with the normal to the surface.

The normal 1s the extension of the radius of curvature from the center of curvature ***(C).***

By the law of reflection, the reflected ray makes an angle ***(r)*** with the normal and the angle ***(r)*** is equal to angle ***(i).***

The reflected ray is thus seen to diverge away from the principal axis.

Hence, for a convex spherical mirror, all rays parallel to the principal axis are reflected such that they diverge away from the principal axis.

(Recall that for a **concave spherical mirror,** parallel rays converged to the principal axis.)

If the reflected ray is dashed backward, it intersects the principal axis at the point ***(F).***

All rays parallel to the principal axis intersect at this same point, which is called the *principal focus* of the convex spherical mirror.

Thus, rays that are parallel to the principal axis appear to diverge from the principal focus ***(F).***

The distance from ***(V)*** , the vertex of the mirror, to ***(F)*** is called the */ocal length (**f)*** of the mirror.

The radius of curvature of the convex spherical mirror is considered to be negative because the center of curvature is on the other side of the mirror.

(Recall that for the **concave spherical mirror,** the center of curvature was on the same side as the reflecting surface and the radius of curvature was positive.)

Since the radius of curvature is negative for the convex spherical mirror, the focal length ***(f),*** which is equal to one-half the radius of curvature, is also negative.

Lecture (10)

4.6 The Mirror Equation and Magnification

*Equation **(4.3)** is called the mirror equation, and it shows the relation between the focal length **(f)** of the mirror, the object distance **(p)** , and the* <u>*image distance (**q**)*</u> .

17=¼+ --(4.3)1

Another important relationship in an optical system can be obtained by *defining the linear **magnification** **(M)** of the mirror as the ratio of the size of the image **(hi)** to the size of the object **(ho)**.*

That is,

$$\boxed{M = \frac{h_i}{h_o} \ldots (4-4)}$$

Thus, the magnification tells how much larger the image is than the object.

We can rewrite this equation as:

$$\boxed{M = \frac{h_i}{h_o} = -\frac{q}{p} \ldots (4-5)}$$

When we know the magnification ***(M),*** wefind the height of the image **(hi)** from <u>equation **(4.6)** as:</u>

$h_i = Mh_0 \ldots (4-6)$

The Language of Physics

((Reflection and Mirrors)) - LECTURE 10

IOpticsl

The study of light .

!Geometrical opticsl

The analysis of an optical system in terms of light rays that travel in straight lines.

frhe law of reflection!

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

The incident ray, the normal, and the reflected ray all lie in the same plane .

IReal imagel

An image formed by rays converging to a point.

!virtual imagel

An image formed by rays diverging from a point.

!Spherical mirrorl

A reflecting surface whose radius of curvature is the radius of the sphere from which the mirror is formed.

lplane mirrorl

Is a mirror with a radius of curvature that is infinite .

!Focal lengtij

The point where all rays parallel and close to the principal axis converge.

The focal length of a concave spherical mirror is equal to one-half of its radius of curvature .

Magnification!

The ratio of the size of an image to the size of its object.

Lecture 11

Summary of Important Equations

((Reflection and Mirrors)) - LECTURE 11

The wavelength, frequency, and speed of light	'J...v =c
Law of **reflection**	i=.r
Focal length of a spherical mirror	*f=R/2*
Mirror equation	1/f = 1/p + 1/q
Magnification	M=.lJi..=-.JL }l., p
Height of image	hi= *Mli.o*

Table (4.1) : A summary of the sign conventions for spherical mirrors.

Table : { **4-1**)		
Sign Conve.ntio,ns fo,:r S:ph,e1·ical l\{[i.r1 0:rs		
Q·uantit l	Positive	N,egati,r,e
Convex Dll"l I'Ol,; Concav,e .1 nl · rro1·	*R* a:nd.f	*R* an.df
R,eal 1n1,ag1e Vi1. tual 1m,ag1e	,*q*	*q*
Eir.ect 111a.ge 1	*M*	
In1,r1erted 11n,age		*M*
Real object Virtual object	*p*	*p*

Problems

((Reflection and Mirrors)) - LECTURE 4a

!Problem 4.1al

Finding the image* for *a concave sR herical mirror.

An object **(5 cm)** high is placed **(30 cm)** in front of a concave spherical mirror of **(10 cm)** focal length.

Where is the image located? Determine the magnification and size of the image?

Answer : q = **15 cm , M =- 0.500 , hi = -2.50 cm**

!Problem 4.2al

M.n object is]! laced within the R rinciR al locus

An object, **(5 cm)** high, is placed **(7 cm)** in front of a concave spherical mirror of **(10 cm)** focal length.

Find the location of its image and its final size.

Answer: q **=- 23.3 cm, hi= 16.7 cm**

!Problem 4.3al

Winding the image [or a convex s herical mirron

An object **(5 cm)** high is placed **(30 cm)** in front of a convex spherical mirror of **(-10 cm)** focal length.

Where is the image located? Determine the magnification and size of the image?

Answer: q = **-7.52 cm, M =+ 0.251, hi= 1.26 cm**

Lecture 12

4.7 Refraction

If the reflecting surface is a boundary between two different transparent mediums, such as air and glass, some of the incident light is also transmitted into the glass, as shown in figure **(4.6)** .

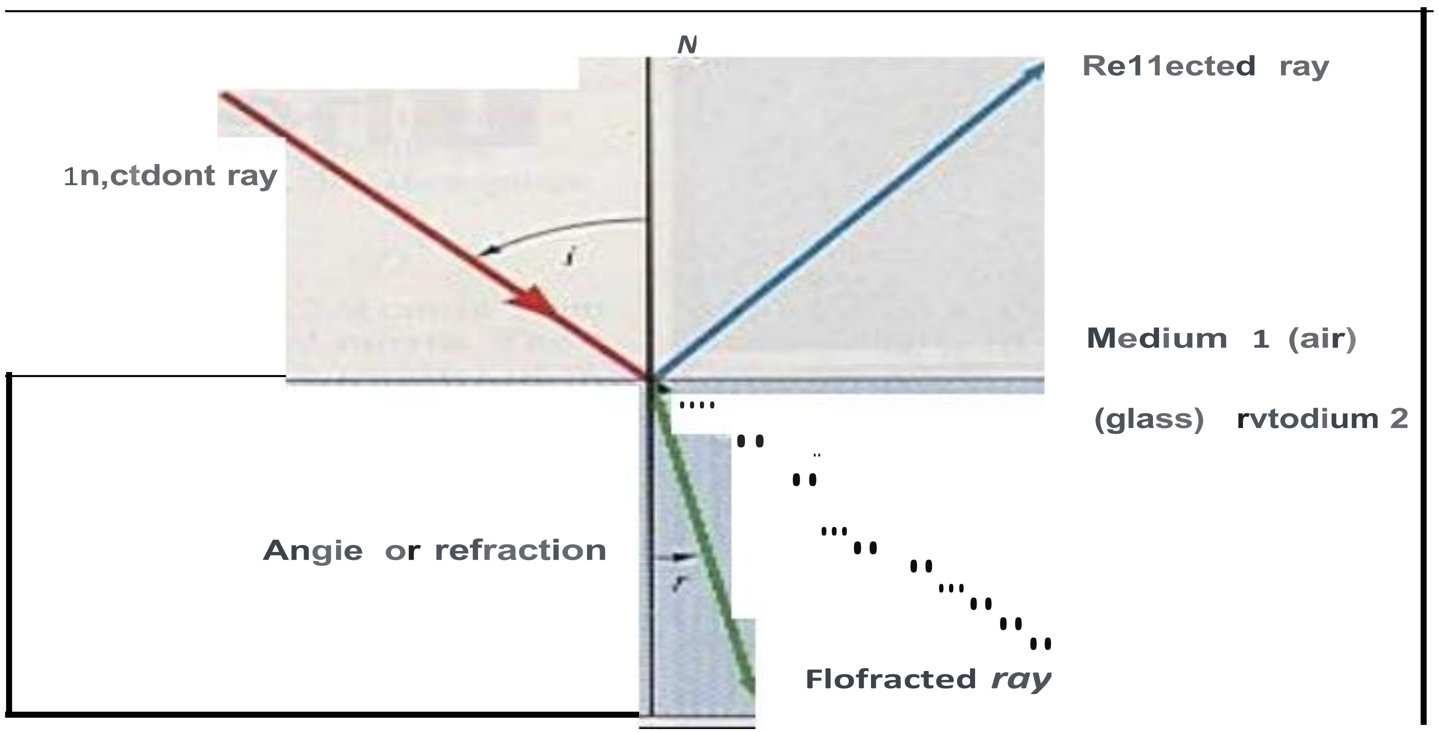

Figure (4.6) : Reflection and refraction of light.

However, it is observed experimentally that this transmitted ray of light is bent as it enters the second medium.

The bending of light as it passes from one medium into another is called ***refraction.***

Refraction of light occurs because light travels at different speeds in different mediums.

4.8 The Law of Refraction

If medium **(1)** is a vacuum, then **(v1= c)** , and the index of refraction of the medium with respect to a vacuum is:

$$n = \frac{c}{v} ...(4-7)$$

Since the speed (v) in any medium is always less than **(c),** the index of refraction, **(n =c/v)** , is always greater than **(1),** except for in a vacuum where it is equal to **(1).**

Indices of refraction for various substances are given in table **(4.2).**

Table : f 4-2 l

Index of Refractionfor variousMruterials $0.$= 589'.2 nm,the Dline ofsodiium)

Substance	n
Afr	1.00029
Benzene	1.5
lliam.ond	2.42
Glass, cro\iirn	1.62
Glass flint	1.67-1.72
Glass, fusedtjuartz	1.46
Glycerine	1.47
[ce	1.31
Ptexig[a.ss	1.49
Quart.zcrystal	1.54
\\Tater	1.33

Notice that the index of refraction of air is so close to the value **(1),** the index of refraction of a vacuum, that in many practical situations, air is used in place of a vacuum.

$$n_1.Sin(i) = n_2.Sin(r)...(4-8)$$

*Equation **(4.8)** is the form of the law of refraction **(Snell's Law)** that we will use in what follows.*

4.9 Total Internal Reflection

As shown in figure **(4.7),** when an incident ray falls on a boundary of a transparent material, part of the ray is reflected back into the first medium, while part of the ray is refracted through the second medium.

If the incident ray is in the dense medium, then the refracted ray is bent away from the normal, as shown in figure **(4.7(a))** .

If the angle of incidence is increased, the angle of refraction is also increased, as shown in figure **(4.7(b)).**

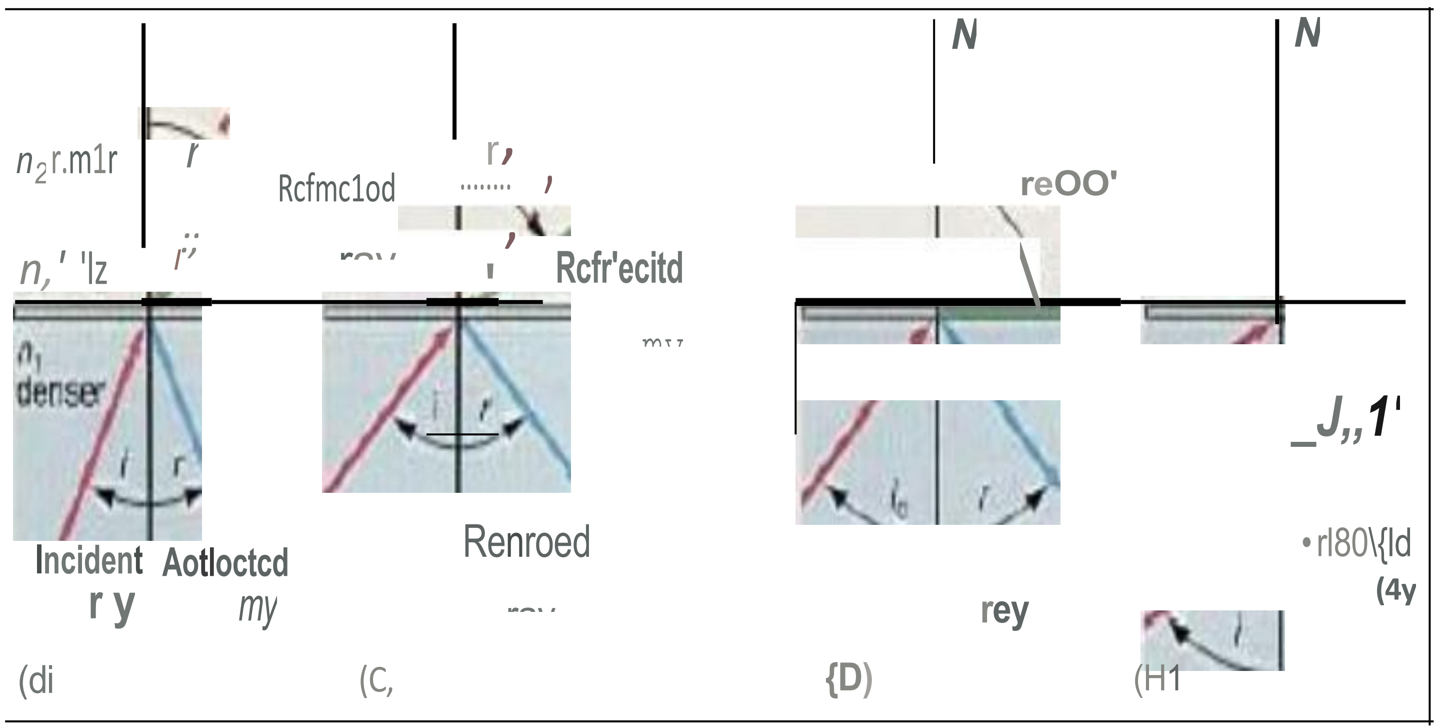

Figure (4.7) **: Total internal reflection.**

If the angle of incidence is increased still further, the point is reached where the angle of refraction becomes **(90°),** as shown in figure **(4.7(c)).**

*The angle of incidence that causes the refracted ray to bend through **(90°)** is called **the critical angle of incidence.***

When the incident angle becomes greater than the critical angle, no refraction occurs.

That is, no light enters the second medium at all; all the light is reflected.

*This condition is called **total internal reflection,** because refraction has been eliminated entirely.*

We obtain the condition for total internal reflection by finding the critical angle of incidence that allows the angle of refraction to be **(90°).**

This is done by applying **Snell's law** of refraction:

$$n_1 \sin i_c = n_2 \sin 90^0$$

Or

$$\boxed{Sin(ic) = \frac{n^1}{n,} .Sin(90°) = \frac{n^1}{n,} \quad ...(4\text{-}9)}$$

Equation **(4.9)** gives the condition for total internal reflection.

Total internal reflection can only occur when light travels from a denser medium to a rarer medium, because it is only then that the refracted ray is bent away from the normal.

For a light ray going 1n the opposite direction, the refracted ray bends toward the normal and the angle of refraction could never become **(90°).**

Lecture (13)

4.10 Thin Lenses

*An optical **lens** is a piece of transparent material, such as glass or plastic.*

Because of its shape, however, light passing through it either converges or diverges to its principal axes.

A *double convex lens,* because the shape of its surfaces are convex.

All rays parallel and close to the principal axis converge to the principal

focus, as seen in figure **(4.8).**

Such a lens is called a **converging lens.**

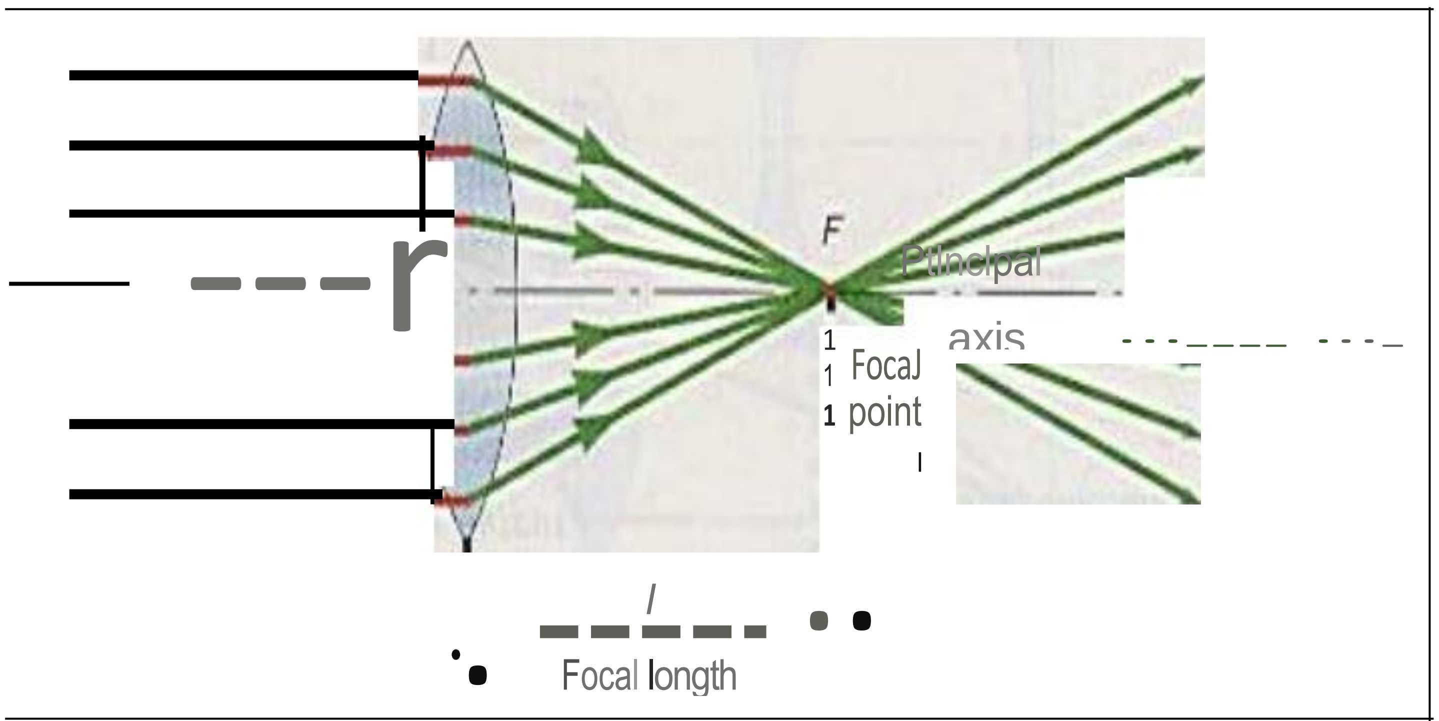

Figure (4.8): A converging lens.

Figure **(4.9)** shows some examples of converging lenses.

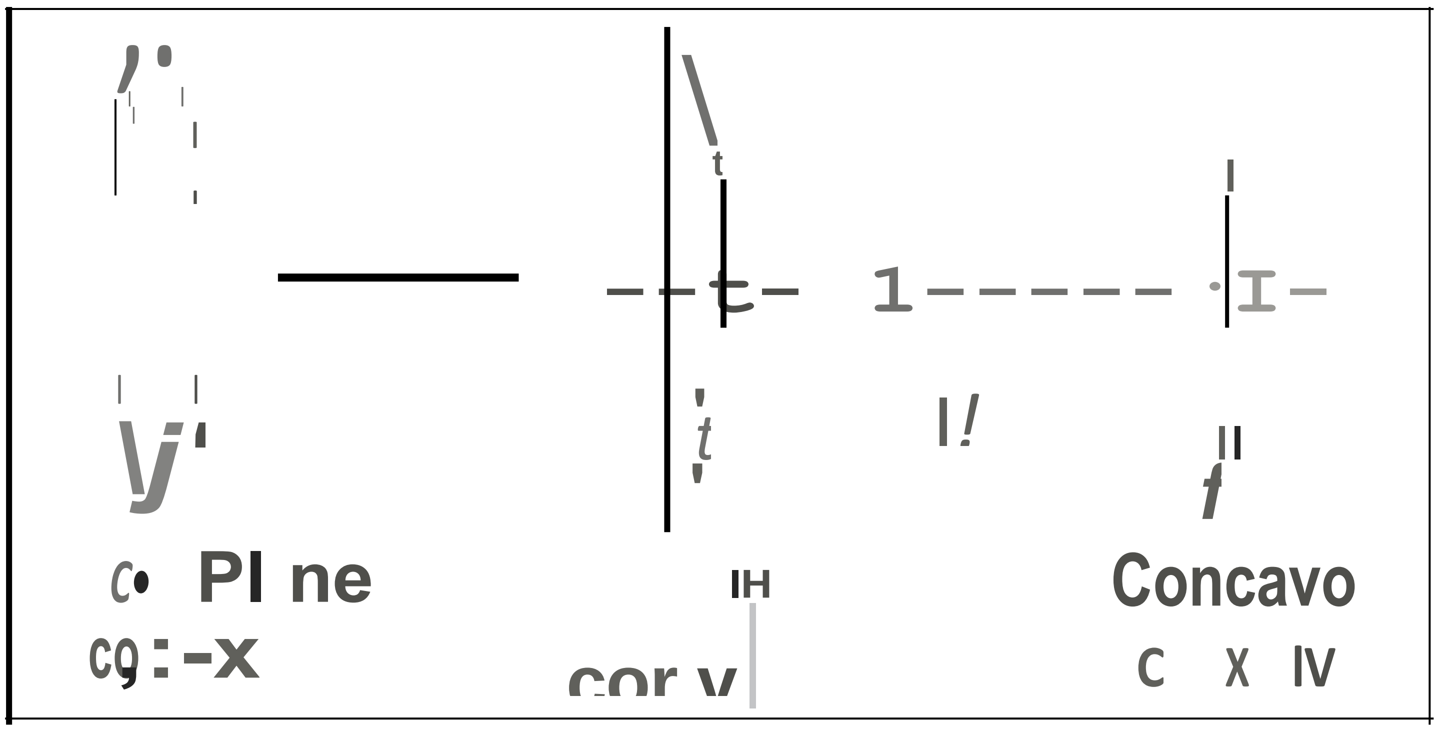

Figure (4.9): Examples of converging lenses.

An easy way to identify such a lens is to note that a converging lens is always thicker at the center of the lens than it is at the rim.

A diverging lens is a lens that takes a bundle of parallel light rays and diverges them away from the principal axes, as shown in figure **(4.10).**

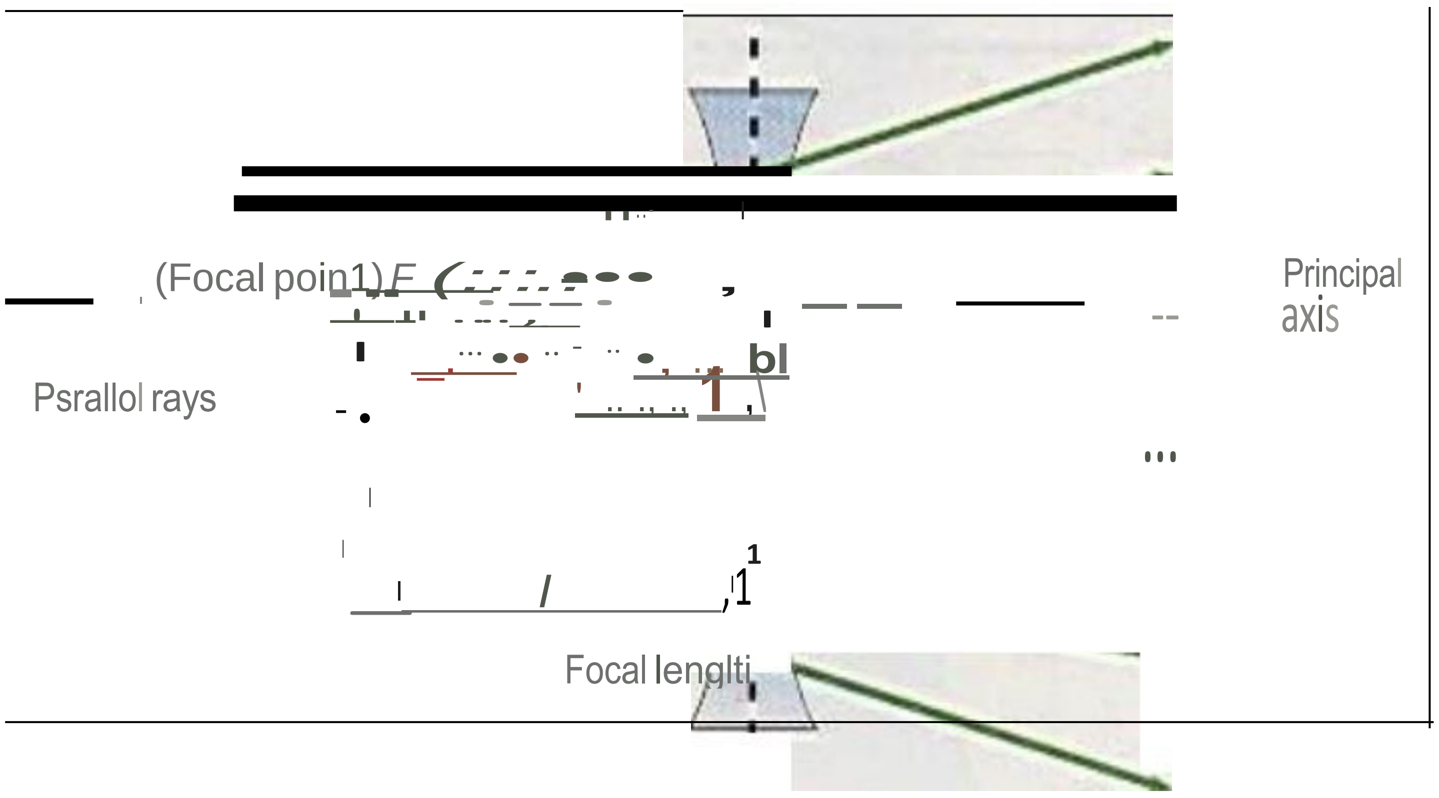

Figure (4.10) : A diverging lens.

Some examples of diverging lenses are shown 1n figure **(4.11).**

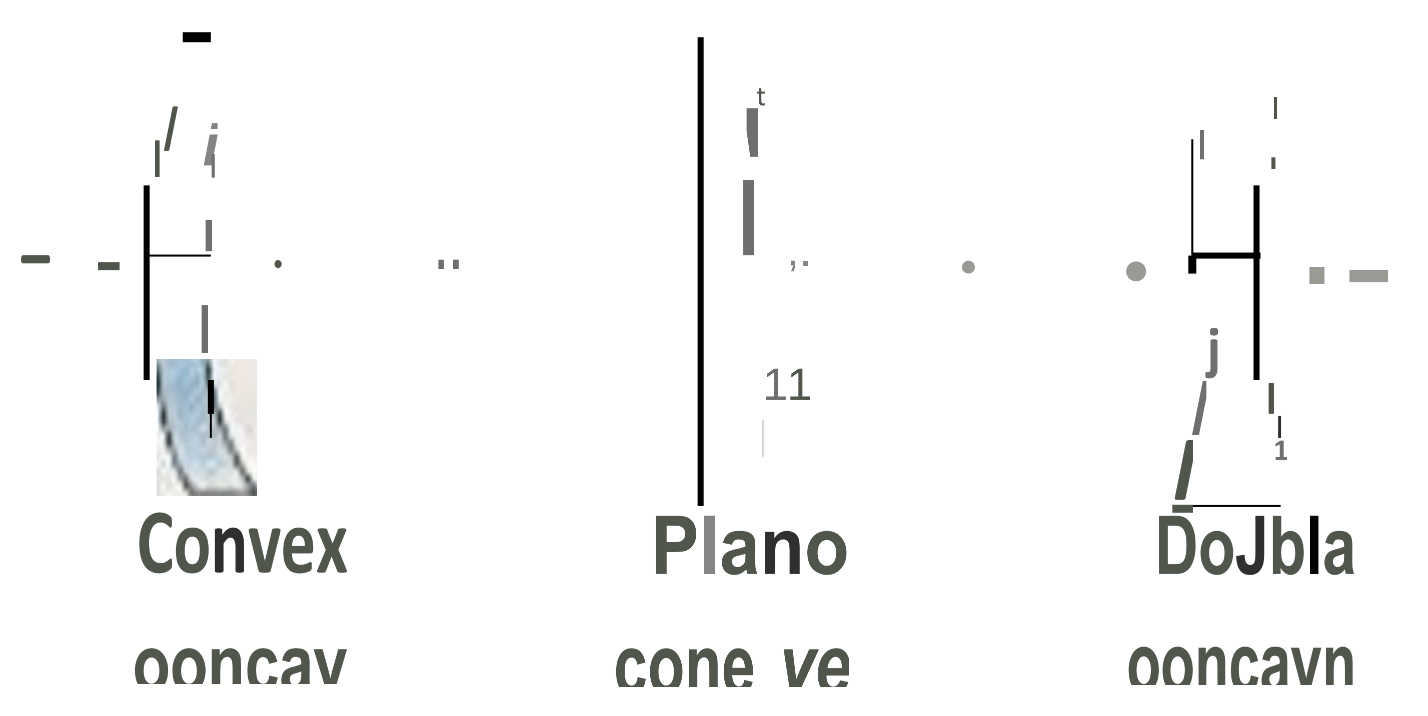

***Figure (4.11)* : Examples of diverging lenses.**

One characteristic of all diverging lenses is that they are thinner at the center of the lens than they are at the rim.

Lecture 14

4.11 The Lens Equation

A mathematical relation between the object distance ***(p),***

theimage distance ***(q)*** , and the focal length ***(f)*** ,

$$\boxed{\frac{1}{f}=\frac{1}{q}+\frac{1}{p}...(4\text{-}10)}$$

Equation (**4.11) is *the lens equation*** *and gives the relation between the object distance* ***(p),*** *the image distance* ***(q),*** *andthe focal length* ***(f)*** *of the lens.*

Notice that it is the same formula as the mirror equation.

The linear magnification ***(M)*** *of a lens system is defined as the ratio of the height of the image to the height of the object,* that is,

$M=$ height of i111age $=$ *ll;*
iheigibt of object ho

height of object *(ho)*

We can also write this as:

$$\boxed{M=\frac{hi}{h_{\circ}}=-\frac{q}{p}...(4-11)}$$

The magnification tells how much larger the image is than the object.

The Language of Physics

((Refraction and Lenses)) - LECTURE 14

IRefractionl

The bending of light as it travels from one medium into another.

It occurs because of the difference in the speed of light in the different mediums.

Whenever a ray of light goes from a rarer medium to a denser medium the refracted ray is always bent toward the normal.

Whenever a ray of light goes from a denser medium to a rarer medium, the refracted ray is bent away from the normal.

ILaw ofrefractionj

The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant.

The constant is called the relative index of refraction and it is equal to the ratio of the speed of light in the first medium to the speed of light in the second medium.

Because of the changing speed of light, the wavelength of light changes as the light passes into the second medium.

frhe critical angle of incidence!

The angle of incidence that causes the refracted ray to bend through **(90°).**

When the incident angle exceeds the critical angle no refraction occurs.

In that case, it is called total internal reflection because **all** the light that strikes the interface is reflected .

Lens

A piece of transparent material, such as glass or plastic, that causes light passing through it to either converge or diverge depending on the shape of the material.

frhin lensl

A lens whose thickness is negligible compared to the distance to the principal focus and to any object or image distance.

!Converging lensl

A lens that causes light, parallel to its principal axis, to converge to the principal axis.

Converging lenses have positive focal lengths .

!Diverging lensl

A lens that causes light, parallel to its principal axis to diverge away from the principal axis.

Diverging lenses have negative focal lengths .

frhe lens equation!

An equation that relates the image distance, the object distance, and the focal length of a lens. It has the same form as the mirror equation.

Summary of Important Equations

((Refraction and Lenses)) - LECTURE 15

The law of refraction	$n_1 \sin i = n_2 \sin r$
The index of refraction	$n = \frac{c}{v}$
Speed of a wave in terms of wavelength and frequency	$v = \lambda \nu$
Critical angle	$\sin i_c = \frac{n_2}{n_1}$
Lens equation	$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$
Magnification	$M = \frac{h'}{h} = -\frac{q}{p}$
Height of image	$h' = Mh$

Problems

((Refraction and Lenses)) - LECTURE 15

[Problem 4.lbl

(]'he refraction of ligh

A ray of light of **(500 nm)** wavelength in air, impinges on a piece of crown glass at an angle of incidence of **(35°).** Find the angle of refraction? Take (n_{glass} = **1.52)**

Answer : **r** = **22.2°**

[Problem 4.2bl

'Critical angle [or a glass-air interlace

What is the critical angle for a ray of light that goes from glass to air? Take (n_{glass} = **1.50)**

Answer : ic = **41.8°**

Critical angle lor a water-air interlace

What is the critical angle between water and air? The index of refraction for water is **(n_w = 1.33).**

Answer : ic = **48.8°**

[Problem 4.3b| |A converging lens

An object **(5 cm)** high is placed **(35 cm)** in front of a converging lens of **(10 cm)** focal length.

( ) Where is the image located? **Answer: q = 14 cm**

(b) What is the magnification? **Answer : M = -0.400**

(c) What is the size of the image? **Answer: hi= - 2 cm**

[Problem 4.4b|

!A diverging lens

An object **(5 cm)** high is placed **(35 cm)** in front of a diverging lens of **(-10 cm)** focal length.

( ) Where is the image located? **Answer: q = -7. 78 cm**

(b) What is the magnification? **Answer: M = + 0.222**

(c) What is the size of the image? **Answer: hi= 1.11 cm**