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Ministry of Education
General Directorate of Curricula

PHYSICS 4

Scientific Secondary

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المديرية العامة للمناهج
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Introduction

Dear students

This book forms a pillar of the pillars of the developed system of physics and that works on achieving scientific and practical goals which keep up the scientific evolution in information and communication technology. this book also achieves connection between the Facts and the concepts that the student study and his daily community.

This book aims to the following topics;

- Clarify the relationship between science and technology in science field and its effect on development and its connection between practical life.
- Gives the students methodology of scientific thinking and moving them from the basic way of learning to a way full of fun and motivation.
- Trying to train the students for discovering through developing of the observing and analyzing skills.
- Gives the students life skills and applicable scientific capabilities.
- Develop the concept of modern ways in maintaining the environmental equilibrium practically and globally.

This book contains nine chapters they are:

- Chapter 1: Basic parameters in physics.
- Chapter 2: Mechanical properties of material.
- Chapter 3: Static fluids.
- Chapter 4: Thermal properties of material.
- Chapter 5: Light.
- Chapter 6: Reflection and refraction of light.
- Chapter 7: Mirrors.
- Chapter 8: Thin lenses.
- Chapter 9: Electrostatic.

And each chapter contains new concepts such as: did you know, question, remember, think, in addition to a wide collection of different activitys and trainings questions so the students know much of that chapter's aims were achieved.

We ask Allah to grant us benefit through this book, and we ask him that the basis of our work be full of love to our country. We also would like to thank mister Prof. Dr.Mohammed Salah Mahdi and the educational specialist Mr. Mohammed Hamd Al-Ajaili for their scientific review to the book we also thank the teacher Saeed Maggied Al-Obeidi and the teacher Rafid Yahya.

The Authors

Contents

1.1 Measurements

Generally all the sciences and specially physics depends on measurement. Physical concepts such as mass, distance, time, speed, force, pressure, area, and temperature are physical quantities determined by mentioning it's numerical value and measurement unit to know them using measurement in experiments was a basic factor for improving physics science and develop it rapidly.

Despite the importance of human senses as a sign of measurement but they are limited in range, trueness and accuracy. Our sense of time formed from our realization of the past, and what we are now. Noting our bodies provided with natural scale for timing which pulse of the heart that is almost regular and lasting throughout life.

A day is the time of the complete earth revolution around its axis, and a year is the time of its complete revolution around the sun and the sequence of day and night and the sequence of the seasons considered as natural scale for timing. So our sense of time is a result of our realization for material and movement around us.

In your previous study, you have known for dimensions and masses of some of the components of this universe to understand the greatness of the creator in the creation of this universe and what it contains from very large objects and very small particles.

1.2 International System of Units

The international system of unit (SI) is an abbreviation of French phrase (system international units) and it's a continuing to the traditional metric system and contains seven base units as shown in table (1).

Table (1) (SI) International System of Units

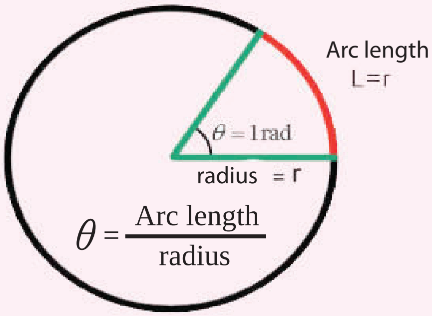
	Quantity	Unit	Symbol
1	Length	Meter	m
2	Mass	Kilogram	kg
3	Time	Second	s
4	Electrical Current	Ampere	A
5	Amount of substance	mole	mol
6	Temperature	Kelvin	K
7	Luminous intensity	Candela (Candle)	cd

(SI) unit is more suitable for the practical life than any other system. This system is considered to be decimal so that the units are connected to each other with a simple decimal points that make the calculations which include any number of them simple calculations and do not require any effort. And each quantity in this system has only one measurement unit. The parts and their multiples can be obtained by placing a prefix preceding the name of this unit the multiples of the units used are in steps of (10^3) and their parts are in steps of (10^{-3}) see the prefixes table number (3), and there is supplementary units as shown in table (2).

Table (2) Supplementary Units

Quantity	Unit	symbol
plane angle	radian	rad
solid angle	steradian	sr

Radian angle: Its a central angle whose arc length equal to the radius of the circle, radian is used to describe circular motion, which is equal to ($2\pi\ rad$).



$$2\pi\ rad = \frac{2\pi r}{r}$$

$$1\ rad = \frac{360^\circ}{2\pi} = 57.3^\circ$$

Solid angle: it is a central solid angle that opposite a part of a spherical surface with an area equal to square radius of thats ball, it is measured in units (Sr).

$$\frac{4\pi r^2}{r^2} = 4\pi\ \text{Sr}$$

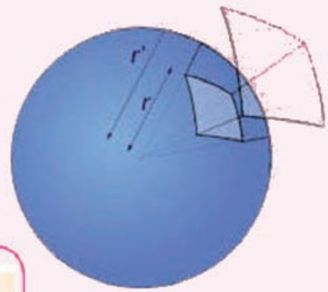


Table (3) Some parts and multiples of System International Units (SI) Prefixes

		Symbol	prefix
	10^{12}	T	tera
	10^{9}	G	giga
$1Mm=10^6m$	10^{6}	M	Mega
$1km=10^3m$	10^{3}	k	kilo
	10^{-2}	c	centi *
$1mA=1\times10^{-3}A$	10^{-3}	m	milli
$1\mu C=1\times10^{-6}C$	10^{-6}	μ	micro
$ns=10^{-9}\ s$	10^{-9}	n	nano
$1PC=1\times10^{-12}C$	10^{-12}	P	pico
$1fm=1\times10^{-15}m$	10^{-15}	f	femto

* Not included in international system of units

1.3 Measurement Errors

Most of the sciences depend on the accurate experiment to achieve their theories, so it is necessary to find accurate ways to deal with measurements and the conclusion facts from it and reduce experimental errors. The accuracy of the physical measurements depends on the accuracy of the measuring instruments used the skill and experience of the experimenter and the working conditions of the experiment. So inaccuracy in the measurements is due to many errors, such as:

1. Errors from Measuring instruments and tools:

There are errors resulting from the inaccuracy gradients of the device due to poor device making or incorrect calibration, some of them change gradually due to the circumstances surrounding of the device or with the age of the device. Also, the error of the device or measuring tool depends on the accuracy of its micro reading. For example, the micro reading of a metric ruler is (1mm) while the micro reading of a micrometer is (0.01 mm). Therefore, the error in measuring the dimensions of a small object in the ruler is very large compared to the error using the micrometer. Repeating observations and measurements by devices with the above specifications does not help to reduce the error.

When mentioned result of any measured quantity the error range must be stated. Example when measuring the length by a measuring device with an accuracy of (0.1mm) the object length was (1.32cm) the probability of error on both sides of the measuring device may reach (0.2 mm) so the real length may be (1.32 cm $\pm$0.02).

2. Personal errors

They are mistakes made by a person because of his lack of reading skills or when transferring information depends on his knowledge of the devices and the correct usage of them. In addition to some mistakes those are out of the control of the person because of the circumstances surrounding him. These random errors are the only ones that can be processed and corrected by repeated measurements. And can be easily treated in statistical ways and the simplest is to find their Arithmetic mean since it is the best guess for the true value.

Dear student remember that a simple mistake in measurement (measuring a location on a map with a ruler for example) might leads to big mistake in the real distance.

1.4 Graphs

Graphs are considered one of the favorite ways to get the arithmetic mean for a number of readings. To illustrate the relation between two experimentally variables prefer plot graphic chart. And graph can be used in many cases to conclude the mathematical relation connect these two variables, In addition to determining the constants values from the graph.

Dear student, you learned from mathematics how to plot a graphical line you also learned the graph shape from the mathematical equation that connect between two variables.

To Plot a Graph requires the following:

1. Determining the origin point in a proper location on the graph paper (0,0).
2. Drawing the two perpendicular axes from the origin point so the horizontal axis represent the (x-axis) and the vertical axis represent the (y-axis) see figure (1.1).
3. Selecting proper scale drawing for each axis alone or for two of them together according to readings that have been collected for purpose benefit from graph paper that you have.
4. Its better to use even numbers for the scales drawing.

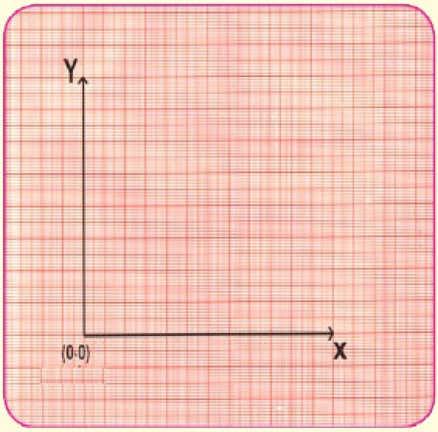


Figure (1.1)

Application in how to plot graphical line from practical experiments

A car moves with the constant speed and passes the distances mentioned in the table with the times, find the car speed in km/h graphically.

Distance (d)	km	20	40	60	80	100
Time (t)	h	0.25	0.5	0.75	1	1.25

To plot the graphical line for the given readings in above we follow these steps

1. We Determine the origin point (0,0) on the graph paper, and from it we plot two perpendicular lines represent (x,y) axes.
2. Scale drawing is determined for the two axes.
   a. The (y) axis represent the distance (d) and each square of it represent (20 km).

b. The (X) axis represent the time (t) and each square from it represent (0.1 h).

3. We locate each point on the graph paper by knowing its coordinates (x,y), as in figure (1.2).

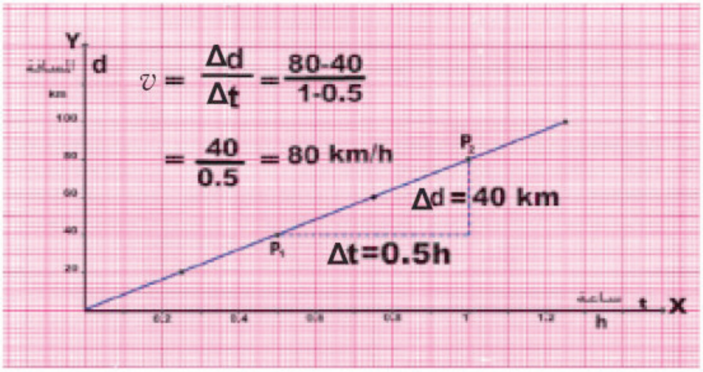


Figure (1.2)

4. We plot a graphical line that pass throw these points, so we get a straight line that passes through the origin, since the equation that connect distance (d) with time (t) is similar to the equation of the straight line that represent it in the following equation:

$$m = \frac{\Delta y}{\Delta x}$$

Such that (m) represent the slope of the straight line and it can be obtained by taking two points on the straight line, for example (p_1, p_2), as in figure (1.2).
In this example the slope of the straight line represent the speed of the car (υ) and can be calculated from the following relation.

$$\upsilon = \frac{d_2 - d_1}{t_2 - t_1} = m$$

$$\upsilon = \frac{80 - 40}{1 - 0.5} = \frac{40}{0.5} = 80 \text{ km/h}$$

1.5 Direct proportion and inverse proportion for physical quantities

Direct proportion

Quantity (a) is said to be directly proportional with quantity (b), if two quantities dependent on each other such that if (b) changes then (a) change with the same ratio.

$$\frac{a_1}{b_1} = \frac{a_2}{b_2} = \frac{a_3}{b_3} = \dots\dots\dots = \frac{a}{b} = constant$$

Then if we represent the change by (α) we can put this change by mathematical way:

$$a \propto b \quad \Leftrightarrow \quad a = k\,b$$

Where (k) is a constant that represent the proportion constant.
This is called direct proportion

Example 1

A train moves with a constant speed (υ), and the distance (d) that the train travels is direct proportion with the time (t) the train takes to travel that distance, then if the traveled distance in two hour is (160km) what is the time needed for the train to travel a (400km) distance.

Solution

The distance changes with time.

$$d \propto t \quad d = kt$$

Where k represent the proportion constant and here it's the trains constant speed.

The relation shows that the distance the train travels is equal to the multiplication of the time with the quantity constant.
(The quantity constant in this example is the trains speed).

$$160\text{km} = k \times 2\text{h}$$

$$k = \frac{160\text{km}}{2\text{h}} = 80\text{km/h}$$

To find the time needed to travel (400km) we apply the relation:

$$d = k\,t$$

$$400 = 80\,t$$

$$t = \frac{400}{80} = 5\text{h}$$

The time needed for the train to travel a (400km) distance.

Or another way to solve:

$$\frac{d_1}{t_1} = \frac{d_2}{t_2}$$

$$\frac{160}{2} = \frac{400}{t_2}$$

$$t_2 = \frac{2 \times 400}{160}$$

$$t_2 = 5\text{h}$$

Sometimes the physical quantity depends on more than one variable as clarified in the following example:

Example - 2

The volume (V) of a standing cylinder changes with respect to the square of its base radius (r^2) while the height (h) is constant, and its volume changes with respect to the height while the radius is constant. If the base radius was (14 cm) and the height was (10 cm) the cylinder volume become (6160cm^3). find the cylinders height when the cylinder volume is (3080cm^3) and base radius is (7 cm).

Solution

$V \alpha r^2$ With constant height (h)

$V \alpha h$ With constant radius (r)

$$V \alpha r^2 h \Longleftrightarrow V k r^2 h$$

Where (k) represent the proportion constant

K is found by substitution

$$6160cm^3 = k \times 14cm \times 14cm \times 10cm$$

$$\therefore k = \frac{6160}{14 \times 14 \times 10} = \frac{22}{7} = \pi$$

So k is the constant ratio (π) and that means

Cylinder volume = base area × height

$$V = \pi r^2 h$$

$$3080\,cm^3 = \frac{22}{7} \times (7cm^2) \times h$$

$h = 20cm$ Cylinder height.

Inverse Proportion

Quantity (a) is said to be inversely proportional with quantity (b). when it directly changes with the inverse of quantity (b).
And it can be written in mathematical formula :

$$a \ \alpha \ \frac{1}{b} \iff a = k \frac{1}{b}$$

Where k represents the proportion constant
And to clarify that we derive the equation of the ideal gas through the following example

Example

Found practically the volume (V) of a certain mass of gas is directly proportional with the absolute temperature (T) when the pressure (p) is constant and this is charle's law.
$V \propto T$ (at constant pressure).
And the volume (V) of a certain mass of gas is inversely proportional with the applied pressure (P) on it while the temperature (T) is kept constant and this is Boyl's law.

$V \propto 1/P$ at (constant temperature)
And when the temperature and pressure change then the volume changes with the following relation.

$$V \propto T/P \iff V = KT/P$$

$$pV = kT = nRT \Rightarrow \boxed{pV = nRT}$$

$R = 8.314 \ J.mol^{-1}.k^{-1}$
Where k is the proportion constant that is equal to (nR) where (R) is the general gas constant and n is moles number

Remember

- The following relation ($y = 2x$):y changes with (x) direct linear proportion change and the straight graphical line pass through the origin
- The following relation ($y = 2x+a$):y changes with (x) direct linear proportion change and the straight graphical line doesn't pass through the origin when ($a \neq 0$).

Questions of chapter one

Q1. Choose the correct answer for the followings:

1. Radian is the centered angle that faces an arc with length of :

a. Circle radius b. Circle diameter c. Half circumference d. Circumference

2. Circumference faces:

a. π from the radius angle b. 2π from the radius angle

c. 3π from the radius angle d. One radius angle

3. Surface area of sphere faces:

a. πSr b. $2\pi Sr$ c. $3\pi Sr$ d. $4\pi Sr$

4. One of the following physical quantities is measured by ampere

a. Electrical voltage difference c. Electrical current

b. Resistance d. Electrical power

5. Square millimeter equals to:

a. 10^{-2} m^2 b. 10^{-6} m^2 c. 10^{-4} m^2 d. 10^{-3} m^2

6. If x is directly proportional with (y) and (x = 8) when (y = 15), then what is (x) equals when (y = 10).

a. 7/3 b. 2 c. 16/3 d. 3

7. If (x) is inversely proportional with (y) and (x = 7) when (y = 3), then what is (x) equals when (y = 7/3).

a. 7 b. 9 c. 10/3 d. 6

8. The radius angle that equals to (1) rad faces an angle that equals to:

a. 57.3° b. 360°/π c. 90°/π d. 1°.

9. The value of number (5) that is raised to the power of zero (5^0) equals to :

a. 5 b. Zero c.1 d. Infinity

10. If the mathematical relation that connects the variables (x,y) is (y=2x + 5) then (y) changes:

a. Linearly directly with x and passes through the origin point.

b. Inversely with (x).

c. . Linearly directly with x and doesn't pass through the origin point.

d. Not linearly with (x).

11. If the mathematical relation that connects the variables (x,y) is (y = mx) then (y) changes:

a. Linearly directly with x and doesn't pass through the origin point.

b. Inversely with (x).

c. Not linearly with (x).

d. Linearly directly with (x) and passes through the origin point.

INTRODUCTION

The mechanical properties of the material depend on its behaver when external forces act on it. And it's known that material have three states which are solid, liquid, and gas, according to the molecular force and kinetic energy of the molecules and the distance between them. There is also another state that is called plasma.

Gases don't keep their shape and volume constant as external forces act on them, while liquid materials keep their volume constant but don't keep their shape. And external forces act on solid material causes deformation in them means that their shape changes and this deformation depends on several factors include:

1. Magnitude of external force act on the object .
2. Dimensions of the material.
3. The material that it's made of.

Studying the mechanical properties of materials is very important due to its effective role in technological improvement, so new industrial materials which don't exist in nature are been made such as synthetic fiber that is special about affording high stress despite to its light weight. So it opened wide prospects for industrial and construction applications like:

1. Industrial applications: such as the manufacture of compressed gas cans, tires and transport structures especially Aircraft structures and wings as well as various construction industries and sports equipment.

2. Space applications: such as the manufacture of many parts of rockets, space vehicles and fuel tanks.

2.1 Elasticity Concept and Hook s Law

If you pull a rubber rope by force from both ends, it resists the extension but its length is stretched due to the force. When it's left it goes back to its original length. If a steel wire is suspended from one end and a weight is attached to the other end it slightly expands after a period of time and when the weight is gone, the wire returns to its original length.

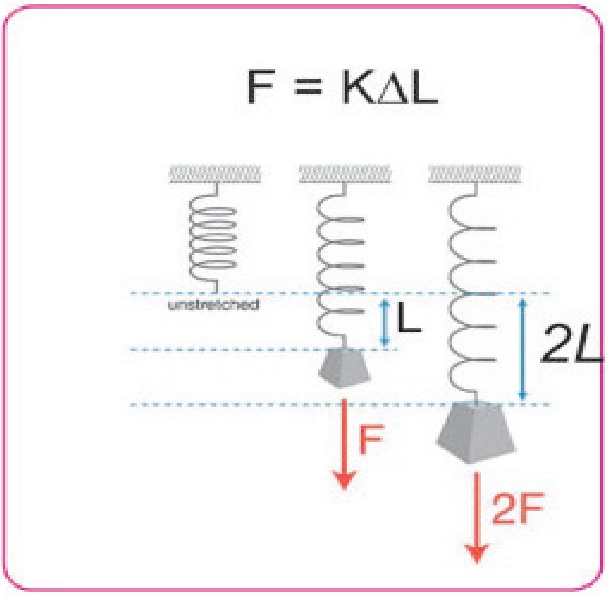


Figure (2.1)

The explanation of that is: The wire that any weight is attached resists external force that affects it strongly and this force comes from the molecular attraction forces between the molecules of the material itself that appear as a result of the change in the shape or length of the object and these molecular forces are trying to restore the object to its original state after disappearance of the effective forces, see figure (2.1).

If gas or liquid is compressed then they resist the change in their volume (liquid resists more) then if the pressure is removed they come back to their original volume.

The scientist Robert Hook found the relation between the external force that acts on a wire and the amount of change that occurs on its length (Hook's law).

To understand the concept of this relation we perform the following activity:

Activity: Elasticity Concept

Activity Tools: spring, equal weights each one equal to 0.1N, iron hanger, graduated ruler, paper.

Steps:

* Arrange the tools as in figure (2.2).

* Attach the spring vertically with the iron hanger and make a sign on its last ring on a paper behind the spring.

* Attach a weight of (0.1N) and record the increase in the spring length.

* Attach another weight so the total weight become 0.2N. Notice that increase in length of the spring is double of the previous increase.
See figure (2.3).

* Repeat the procedure using many weights in sequentially.

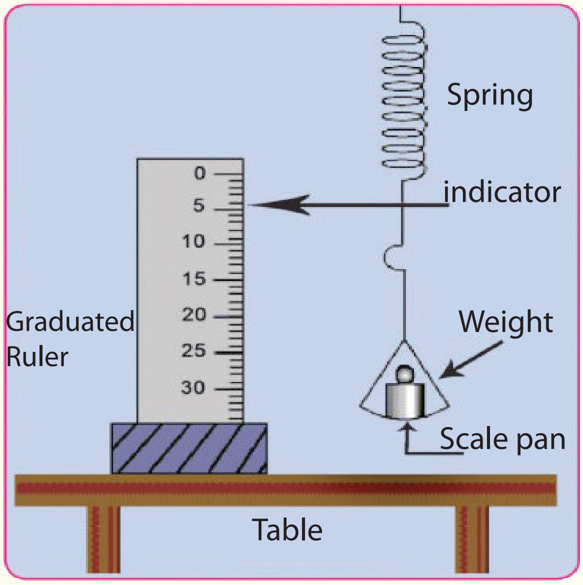


Figure (2.2)

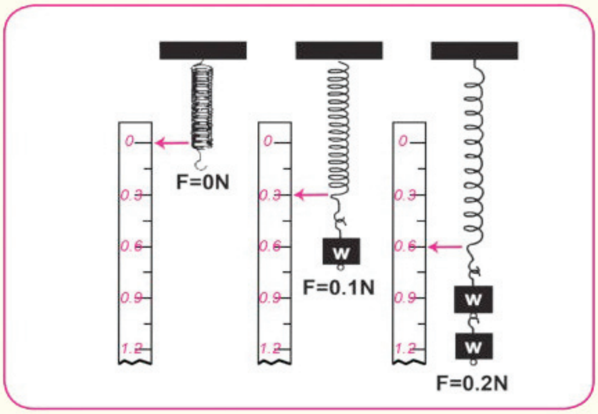


Figure (2.3)

We record the readings that we get as shown in table (1).

Table (1)

Force F (N)	The increase in the length $\Delta L \times 10^{-2}$m
0	0
0.1	0.3
0.2	0.6
0.3	0.9
0.4	1.2

* We plot the graphical relation between the amount of weights and the increase in the spring length (the stretching) on a graph paper (assuming the spring mass is neglected).

* We get a graphical linear relation between the weights and the stretching as in figure (2.4).

We conclude from this figure. The increase in the spring length is directly proportional with the tensile force within the limits of elasticity.

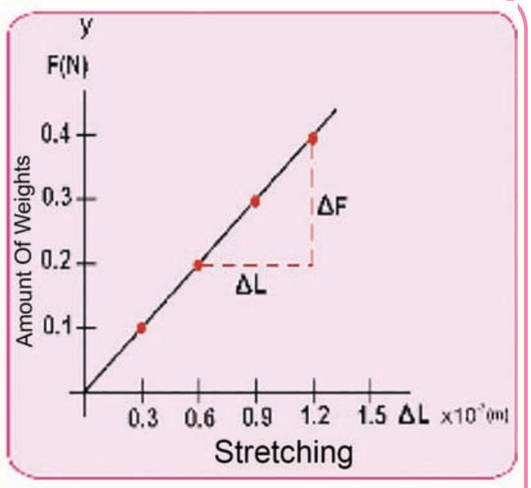


Figure (2.4)

Means that:

Tensile force = Elasticity constant for spring × Change in the stretching

$$F = k \, \Delta L$$

Where:

F: Tensile force that caused stretching of the spring.

ΔL: Amount of the stretching.

k: Spring Elasticity Constant, and its value represents by the slope of the straight line and its measured in (N/m) and its value is constant and doesn't change only by changing the spring shape or the material it's made of, and we see in this activity that the spring return to it's original shape immediately as the force is gone.

By this we can say that: elasticity is the resistance that an object shows to the force that changes It's shape or volume or length and returns back to previous condition after the effectual is gone.

The elastic object is characterized:

* Returns to it's previous shape or volume or length after the effective force is gone

* The deformation that happens linearly proportional with the causing force in the limits of elasticity.

Elasticity limit:

Elasticity limit: is the limit that if the effective force exceeds the object doesn't return as before after that force is gone, therefore it's said that a (permanent deformation happened) to this object.

2.2 Stress and Strain

Stress: is a magnitude of perpendicular force affecting on the unit area of the object.

If a force acted on an object making deformation in it (change in shape or volume or both) then it's said the object faced to stress and it measured by N/m^2.

Stresses differe in the materials in which the force effect on object, and in the following some types of stress:

1. Longitudinal Stress:

Is the stress that causes deformation in the length of the object like the spring that was mentioned in the previous activity and this stress has two type:

a. Tensile stress: is the stress that causes a deformation in the length of the object when two perpendicular tension force act on facing planes causing as a result an increase in the length (stretching), see figure (2.5).

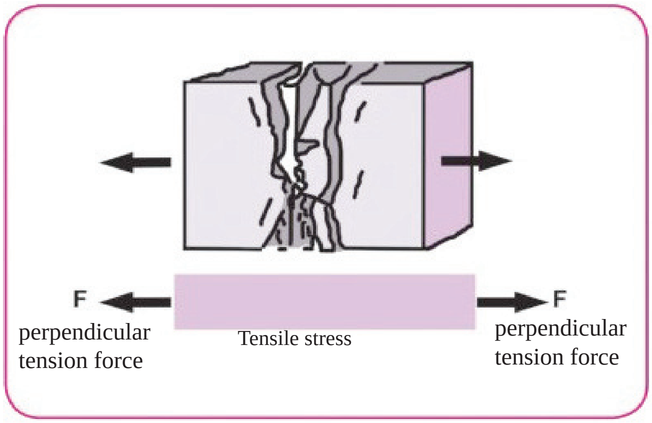


Figure (2.5)

b. Compressive stress: when two forces act on an object in perpendicular way inwardly causing a press (decrease in length), see figure (2.6).

The longitudinal stress can be defined by the following mathematical relation:

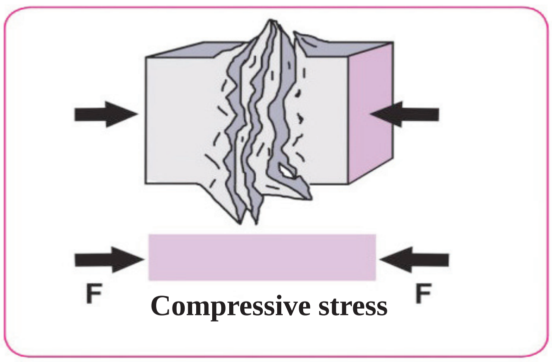


Figure (2.6)

$$\text{Longitudinal stress} = \frac{\text{Perpendicular component of effective force on a surface}}{\text{Area of the surface that the force effective on it}}$$

2. Shear stress:

If you put your hand on a book that is on a rough table and you push it with a tangential force to its surface we see a deformation in the shape of the book, see figure (2.7) Shear stress can be defined by the following mathematical relation:

$$\text{Shear stress} = \frac{\text{Tangential force component for the surface}}{\text{Surface area that the force effective on it}}$$

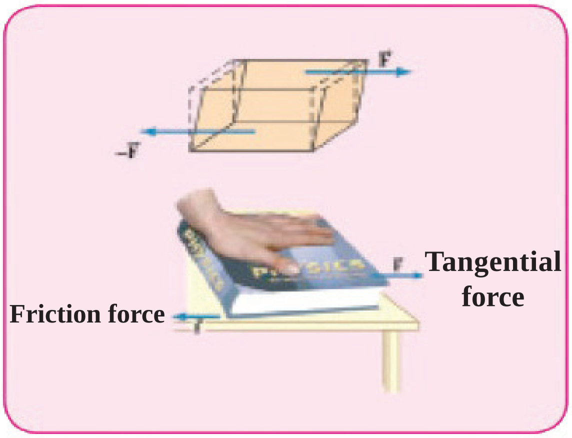


Figure (2.7)

Strain

Strain is defined as the measurement of the amount of material deformation (change in shape or volume) because of the stress that it exposed to.

Strain types depend on the stress type that was exposed, and the strains type are:

1. Longitudinal strain:

When the object stretches or compresses it's shape changes without a change in the volume, see figure (2.8).

The original length L_0 changes to ΔL
Hence the longitudinal strain is known as:

$$\text{Longitudinal strain relativity} = \frac{\text{Change in length}}{\text{Original length}}$$

$$= \frac{\Delta L}{L_0}$$

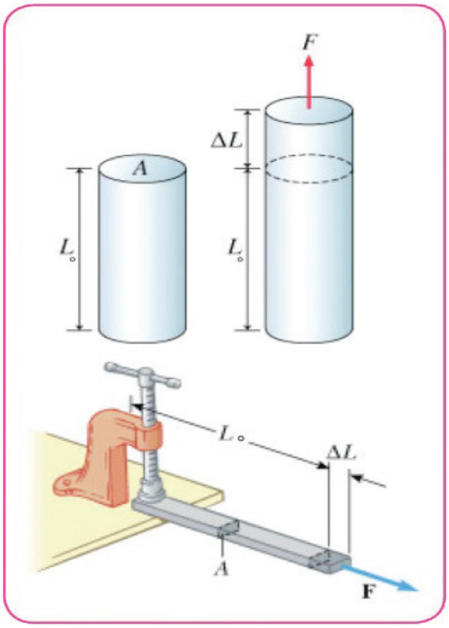


Figure (2.8)

2. Shear strain

The reaction of the object when exposed to shear stress is given as lateral displacement, see figure (2.9). so the object's shape deform but it's volume doesn't. And shear strain is measured the amount of angle (θ) in which the two surface of the opposite vertical object affecting them force (F) deviates.

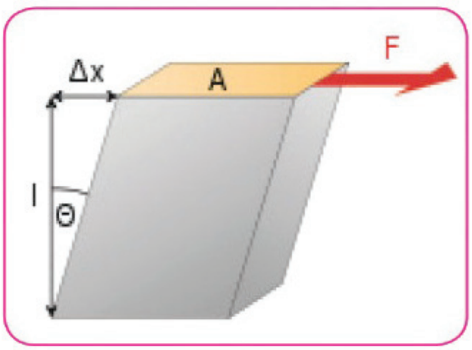


Figure (2.9)

3. Volume strain

Results from exposing the whole object to press so its volume decreases with keeping its shape constant, see figure (2.10).

$$\text{Volume strain relativity} = \frac{\text{Change in volume}}{\text{Original volume}}$$

$$= \frac{\Delta V}{V_0}$$

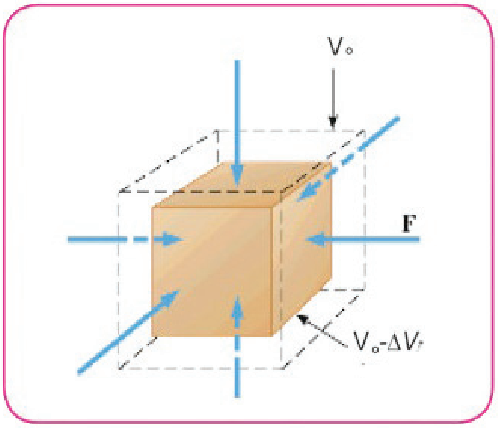


Figure (2.10)

2.3 Young Modulus

The ratio between stress and relativity strain is called young modulus or elasticity modulus and is given by the following relation:

$$\text{Young Modulus} = \frac{\text{Stress}}{\text{Relativity strain}}$$

$$Y = \frac{(F/A)}{(\Delta L/L_0)}$$

Where :

F: is force acting on object.

A: cross sectional area.

L_0: original length.

ΔL: amount of the increase in length.

And young modulus (Y) is measured by:

N/m^2 and the ratio (stress/ strain) is a special property for solid materials and table (2) shows young modulus values for different materials.

Table (2) Young modulus values for different materials

Material	Young Modulus (N/m^2)
Aluminum	70×10^9
Lead	16×10^9
Copper	120×10^9
Diamond	1200×10^9
Gold	79×10^9
Tungsten	360×10^9
Steel	200×10^9
Concrete	$(25\text{-}30)\times10^9$
Glass	65×10^9

Example:

A steel wire having a length of (4m) and a cross section area of ($0.05\ cm^2$), what is the amount of the increase in it's length if it's pulled by a force of (500N)? Young modulus for steel is ($200 \times 10^9\ N/m^2$).

Solution

$$\text{Young Modulus} = \frac{\text{Stress}}{\text{(Relativity strain)}}$$

$$Y = \frac{F/A}{\Delta L/L_0}$$

$$Y = \frac{F.L_0}{A.\Delta L}$$

$$\Delta L = \frac{F.L_0}{Y.A}$$

$$\Delta L = \frac{500 \times 4}{200 \times 10^9 \times 0.05 \times 10^{-4}}$$

$\Delta L = 2 \times 10^{-3} m = 2mm$ Amount of the increase on length.

Question:

A group of students performed an experiment to determine young modulus for a wire of a certain material and the got the results shown in table (3), the wire length is (2m) and it's cross section area is ($1.25 \times 10^{-6} m^2$) then find?

1. Graphical relation between the force and the wire's stretching.
2. The young modulus of the wire material graphically from the slope of the line.

Table (3)

ΔL stretching mm	Tension force (F) $\times$ 100N
0	0
2.8	1
6.2	2
8.7	3
12.1	4
15	5

2.4 Some mechanical properties for solid materials

There are many mechanical properties that should be taken in consideration when testing solid materials for work application like metallic parts of machines or constructional material and housewares and others.

And here some of these properties:

1. Ductility:

The property of material which has ability for elongating, compressive, rolling, drawing or hammering. like copper.

2. Brittleness:

The property of material that shows inability of resisting suddenly stress it shall be broken and doesn't reach permanent deformation state.

Hence definition of brittle materials: they are materials that directly break after exceeding the elasticity limits like glass, iron and concrete.

3. Stiffness:

The property of material to resist the deformation that happens on shape or volume due to external force, and requires high stress to generate the strain itself, also is has high young modulus such as steel that have a young modules of (2×10^{11} N/m^2).

4. Toughness:

The property of material to resist cutting force, means that:

$$\text{Toughness} = \frac{\text{Cutting force}}{\text{Area}}$$

It's unit is: (N/m^2)

5. Hardness:

The property of material to scratch other materials or it's resistance to scratching.

Hardness of the material is measured by comparing it with the hardness of other ten materials that are arranged in the following table from (1to10) where each material in the table scratches the material that have less hardness than it and scratches the material that is in higher arrangement from it.

Table to measure hardness ascendingly.

1.talc 2.Gypsum 3.calcite 4.fluoride 5.apatite 6.feldspar (silicate aluminum) 7.quartz 8.topaz 9.ruby 10.diamond.

6. Failure:

The property of material to loose it's resistance under external stress

Think: What are the mechanical properties that rubber and diamond have?

ELASTIC AND PLASTIC DEFORMATION

Many materials (excepts steel) has ductility property and the undergo permanent deformation after exceeding the elasticity limit such as copper, when a (150N) is applied on copper wire which has section area of (1 mm^2), elasticity limit is reached and the wire doesn't break unless the force is doubled, figure (2.11) shows graph of stress of an iron rod and the linear line of the graph represents Hook's law (linear response) in which an elastic deformation occurs and when the elastic limit is exceeded the shape flattens and that means any increase in the tension force causes a proportional increase in the length that is bigger compared to the increase in length before reaching elastic limit (non-linear response) thus when the tension force increase a continuous increase in it's length occurs and that's called plastic deformation. Noting that the rod become the longest under the greatest force that it can withstand and when the force is exceeded the breakdown results , and this is clear on the heights point of the curve, see figure (2.11).

Elastic deformation:

The temporary increase in length or shape of the object within the elasticity limit with respect to Hooke's law, thus when the effective force is gone the object returns to it's original situation.

Plastic deformation:

The permanent increase in length or shape of the object out of the elasticity limit without applying Hook's law thus when the effective force is gone the object doesn't return to it's original situation.

Do you know ?

1. The beginning of the breaking shows on the material surface at the places that have low toughness and that have cracks in it since the have failure in their crystal structure.

2. The brittle material resistance increases by compressing for example at (10km) depth in the Lithosphere the rocks breaking possibility decreases and their possibility of being deformation increases.

3. To prevent glass break (or to break crack) two glass plates is taken those are separated by Polyvinyl butyral layer that work as a crack growing absorber.

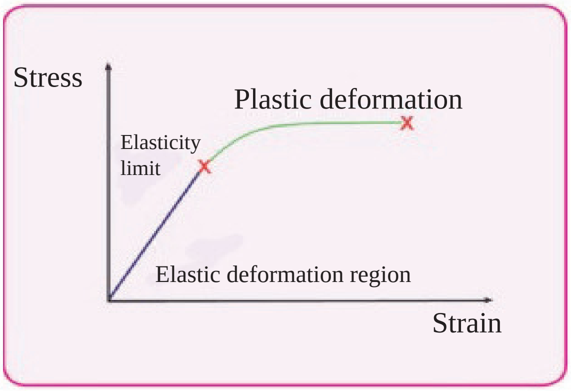


Figure (2.11)

Questions of chapter Two

Q1. Choose the correct answer for the following :

1. The property of the material that makes the spring returns to its original length after being pulled a little and left is

a. Brittleness b. Ductility c. Stiffness d. Elasticity

2. The steels elasticity is greater then rubbers elasticity because

a. Steel needs tension or large compressive force
b. Rubber needs tension or large compressive force
c. Young modulus of steel is small
d. Young modulus of steel is large

3. Hook’s law is applied to solid material in limit:

a. Toughness b. Failure c. Elasticity d. Shear stress

4. The materials that’s length can’t be increased unless by high stress and in their elasticity limit are called :

a. Brittle b. Have high elasticity c. Not elastic d. Can be hammered

5. When a force acts on an object then the longitudinal stress in it is equal to:

a. Relative change in its dimensions b. Perpendicular force acting on an unit area
c. Young modulus d. Elasticity limits

6. Shear stress on an object effects it’s:

a. Length b. Width c. Volume d. Shape

7. The stress that acts on a vertically wire attached on the load doesn’t depend on:

a. Length of the wire b. Diameter of the wire
c. Mass of the load d. Gravitational acceleration

8. Consider two identical wires (x and y). the length of wire x is half of the length of wire y and the diameter of wire x is twice of the diameter of wire y, if the magnitude of elongations of both wires are same, then the force applied on wire x is:

a. Half the force applied on Y. b. Twice the force applied on Y.
c. Four times the force applied on Y. d. Eight times the force applied on Y.

9. The increase in the length or shape of an object out of the elasticity limit is called:

a. Temporary deformation. b. Permanent deformation.
c. Directly proportional to force. d. Proportional to force.

10. When two pull forces that are equal in magnitude and opposite in direction acts on an object in parallel direction to each other the its said that the object is under effect of:

a. Tensile stress b. Compressive stress c. Strain d. Shear stress

Q2. If the force required to cut a certain wire is F then what is the amount of force required to cut

a. Two identical wire tied together.
b. Two same wire, the second one have twice the diameter of the first one, and which one is toughness?
c. Two same wire, the second one have twice the length of the first one,

Answer: a. 2F b. 4F c. F

Q3. What are the factors that determine the amount and type of deformation that occurs in the solid material?

Q4. What is meant by the elasticity constant of the spring? What is the unit which we use to measure it? and on what does its magnitude depends on?

Q5. What is the type of the relativity strain that is defined by:

a. Ratio of change in length to original length.
b. Ratio of change in volume to original volume.
c. Amount of angle that two facing surface of the object which deviates by two force that parallel to them.

Problems

Q1: A tensile stress effect of (20×10^6 N/m^2) on a metal wire having cross sectional area of (1.5mm^2). What is the force acting on it?

Ans: F = 30N

Q2: What is the amount of length that occurs on (2m) long steel wire with diameter of (1mm) if a mass of (8 kg) is attached to it's end (g = 10m/s^2)? Young modulus for a steel is (200×10^9N/m^2).

Ans: $\Delta L = 0.001$ m

Q3: A wire with cross sectional radius of (0.5mm) and length of (120cm) hanging vertically. What is the perpendicular force that needs to be applied to its end so that its length become (121.2 cm) (young modulus of the material is (1.4×10^{10} N/m^2).

Ans: F = 109.9N

Q4: Two identical wires the length of one of them is (125 cm) and the other is (375 cm) if the first wire was cut by a force of (489N), what is the force required to cut the second wire?

Ans: F = 489N

Q5: A rod with length of (0.4m) was pressed an its length shortened by (0.05m) what is it's relativity strain?

Ans: 0.125

**Q6: A bronze wire with length of (2.5m) and a cross sectional area of (1×10^{-3} cm^2) pulled and elongated (1mm) by attaching an object of (0.4 kg), calculate young modulus for the metal.
Consider the gravitational acceleration is (10N/kg).**

Ans: $Y = 10^{11}$ N/m^2

Chapter 3: Static Fluids

We will try to study the mechanical properties of fluids in their steady state (means balanced state) and it should to be clear when the fluid is steady state the particles that the fluid is formed are always in random continuous movement state.

3.1 Fluid

Fluid is the material that have weak cohesive force and can’t keep a certain shape for the material thus the particles move and take the shape of the container that its placed in. And this definition fits liquids and gases .and its easy in response to the external forces that tries to change its shape.

Fluid have essential role in our life, since we breathe it, swim in it and it circulates in our bodies in the veins and arteries and it controls our weather and the ships float on it and planes fly in it and submarines dive in it, see figure (3.1).

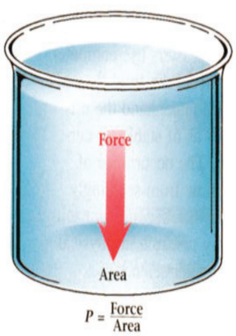
Figure (3.1)

Do you know?

Mercury is the metal that found in liquid state under the room temperature and considered as fluid.

3.2 Fluid Pressure

You studied before that the pressure of the fluid (liquid or gas) is the amount of perpendicular force that acts on unit area and we can represent that mathematically as:



$$\text{Pressure} = \frac{\text{Perpendicular force}}{\text{Area}}$$

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$P = \frac{F}{A}$$

Where (P) is the pressure and (F) is the perpendicular acting force on the area (A) and the units of pressure is N/m^2 this unit is called (Pascal), so if a perpendicular force of (1N) applied to an area of ($1m^2$) then the resulting pressure equals to (1Pa) and this is Pascal’s definition.

And to measure the amount of pressure at any point inside the liquid, we assume the area (A) on a depth (h) from the liquid surface, as in figure (3.2). Then the force that acts perpendicular on area (A) is the weight of the liquid column that's height is (h) and cross section area is (A), and if we consider the liquid is incompressible then its density (ρ) stay constant.

That's the weight of the column of liquid represents the perpendicular force that acts on the area.

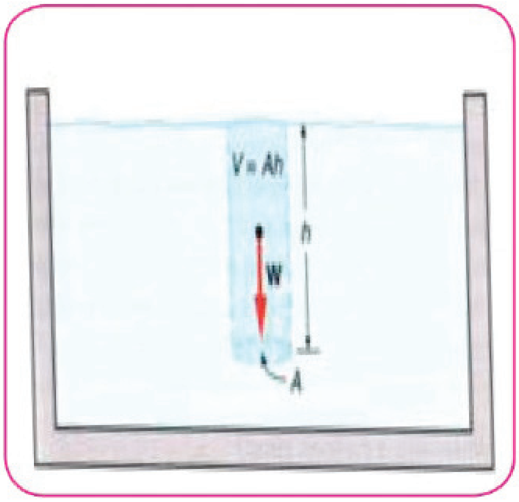


Figure (3.2)

$$F = \rho g h A$$

Where (g) is the gravity and the pressure of the liquid on a height (h) is:

$$P_h = \frac{F}{A} = \frac{\rho g h A}{A}$$

Liquid Pressure = liquid density × gravity × depth

$$P_h = \rho g h$$

If there was a pressure on the liquid surface like atmospheric pressure (P_0) that any liquid in an open container faces, see figure (3.3) then the atmospheric pressure should be added to the liquid pressure in order to get the total pressure (P) in any point in the liquid means that:

Total pressure = atmospheric pressure + liquid pressure

$$P = P_0 + P_h$$

$$P = P_0 + \rho g h$$

REMEMBER

Liquid have two properties these are inability to be compressed and sliding of its molecules on each other easily that let it apply force on the walls of the container that its in and also a force upward. That's the pressure of the liquid doesn't only affects downward but it affects in all directions.

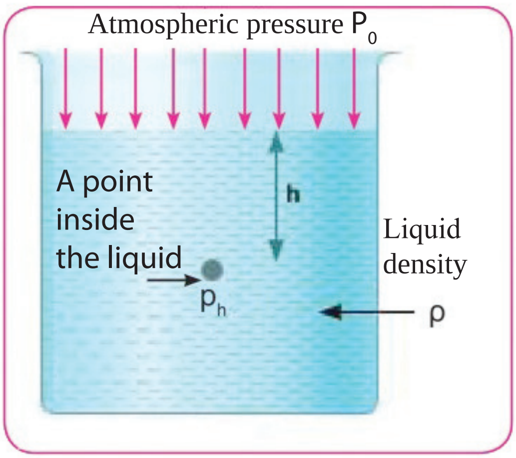


Figure (3.3)

This pressure produces a force of amount (Pa) and this force is same in all direction at depth (h) from the liquid surface as this force acts downward there is a force equal in magnitude to it acts upward, see figure (3.4).

Figure (3.4)

Example

Calculate the pressure in N/m^2 unit generated on a diver in a depth of (20m) below the water surface noting water density is ($1000\ kg/m^3$).

Solution

Pressure = liquid density × gravity × depth

$P = \rho g h$

$P = (1000\ kg/m^3) \times (9.8\ m/s^2) \times (20\ m)$

$P = 196000\ N/m^2$

3.3 Measuring Atmospheric Pressure

We already know the atmospheric has pressure, and it's the weight of the air column that is applied perpendicular on a unit area of the surface, and it's measured by barometer which is a device designed by the scientist Torricelli, see figure (3.5) which is a graduated glass tube of one meter long opened from one end is filled totally with mercury and its opened end is placed in a container filled with mercury, you note the mercury in the tube stable on a certain height higher than its level in the container leaving an empty space in the top tube.

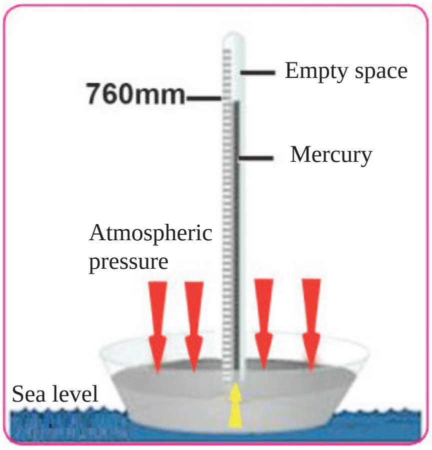


Figure (3.5)

One of results obtained by Torricelli the atmospheric pressure balances with the pressure of the mercury column in the points those are on the one horizontal level which is the mercury surface in the external container, the height of the mercury column is equal to (76 cm) at sea level and with tempreture zero degree Celsius. And column length changes by changing the height of the experiment place that is performed from sea level.

Example

What is the length of the water column that is needed to equalize the atmospheric pressure where the mercury column equals to (76cm) noting that the water density is ($1000 kg/m^3$) and the mercury density is ($13600 kg/m^3$).

Solution

Water column pressure = mercury column pressure

Where

water = w

Mercury = m

$\rho_m g h_m = \rho_w g h_w$

$13600 \times 9.8 \times 0.76 = 1000 \times 9.8 \times h_w$

$h_w = 13.6 \times 0.76 = 10.33$ m height of water column

3.4 Pascal s Principle

Maybe you noticed that when the enclosed fluid is exposed to external pressure that pressure moves equally to all the fluid particles and the containers wall and this is called Pascal's principle, see figure (3.6) and it is important principles in fluid mechanics.

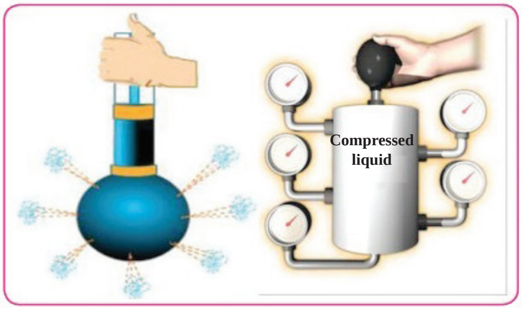


Figure 3.6

And this fact plays an important role in the work principle of many devices that work by hydraulic pressure such as car brakes, press machines, hammers and hydraulic lifts. And figure (3.7) clarify how the hydraulic lift works (oil is used since it has very low compressibility), its composed of two presses and two cylinders with different section areas and connected to each other by an oil filled tube, when a force of magnitude (F_1) affects the small press that have an area of (A_1) then the pressure of the small press is $P_1 = \frac{F_1}{A_1}$ and this pressure is transferred equally to all the parts of the enclosed liquid means (P_1) = (P_2) and from that:

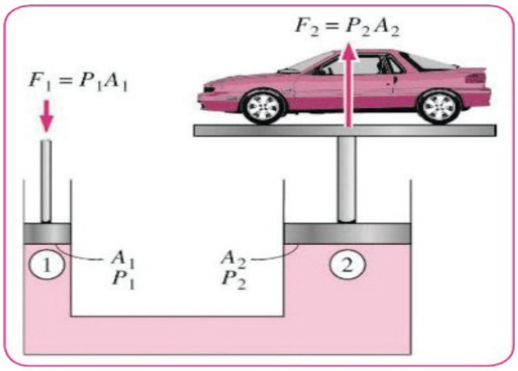


Figure (3.7)

Do you know ?

The simplest application of physics in medicine is blood pressure device which is a mercury manometer with some additions where the doctor wraps the band around the patient's hand, see the figure a above and he pushes the air inside the band with a hand pump and using the stethoscope where the air pressure reaches the blood pressure then the heart beat can't be heard. that time the doctor opens the valve so the air escapes from the band and he start to hear the heart beats and he record the systolic pressure which is about 120mm Hg and when the beats disappears he records the diastolic pressure which is about 80 mm Hg for (normal person).

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

And from this relation it's seen that;

$$F2 = \frac{A_2}{A_1} F1$$

And this means that the amount of the force is controlled by the ratio of the presses areas $\frac{A_2}{A_1}$ so as this ratio increases the lifting force in the big press increases.

Do you know?

That the liquid used in the presses, hammers and hydraulic lifts shouldn't freezes and get very viscid in low temperatures and it also shouldn't evaporate and shouldn't be poisons or inflammable.

Example

Calculate the force required to lift a car with (3000kg) mass (see the figure bellow) using the hydraulic lift that is used in car washing garages knowing that the sectional area of the small cylinder is ($15cm^2$) and the sectional area of the big cylinder is ($2000cm^2$)? Consider $g = 10\ m/s^2$.

Solution

$F_2 = mg = 3000 \times 10 = 30000$ N

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$F_2 = F_1 \times \frac{A_2}{A_1}$$

$$30000\ N = \frac{F_1 \times 2000\ cm^2}{15\ cm^2}$$

$F_1 = 225$ N the force applied to the small press.

3.5 Archimedes' Principle

We usually see in our life that some objects floats in the liquids like boat on water surface and some flow in air such as balloon in the air. And this clearly shows to exist upward force that the fluid applies to the floating object or submerged in it called (buoyant force). the first who discovered this phenomenon is the Greek scientist Archimedes, and he made his famous principle that is:

Archimedes Principle:

If an object is partially or totally immersed in a fluid it loses from weight equal to weight of the displaced fluid. To know buoyant force and how does that force form? Lets assume that a solid cubic object is fully immersed in a fluid having density (ρ) and attached to a spring balance, see figure (3.8). Since the object is fully immersed in the fluid. Then the weight of the displaced liquid (that represents the buoyant force) is equal to the volume of the immersed object (hA) multiplied by the weight density of the liquid (ρ g).

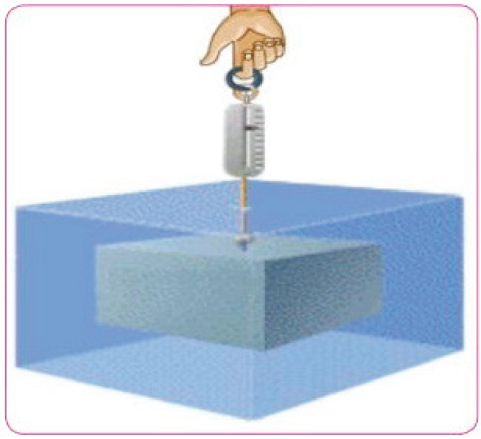


Figure (3.8)

Buoyant force = volume of immersed object × weight density of the liquid

$$F_B = \rho g h A$$

Where:

h: height of the object

A: object's base area

g: gravity = 9.8 m/s^2

F_B: buoyant force

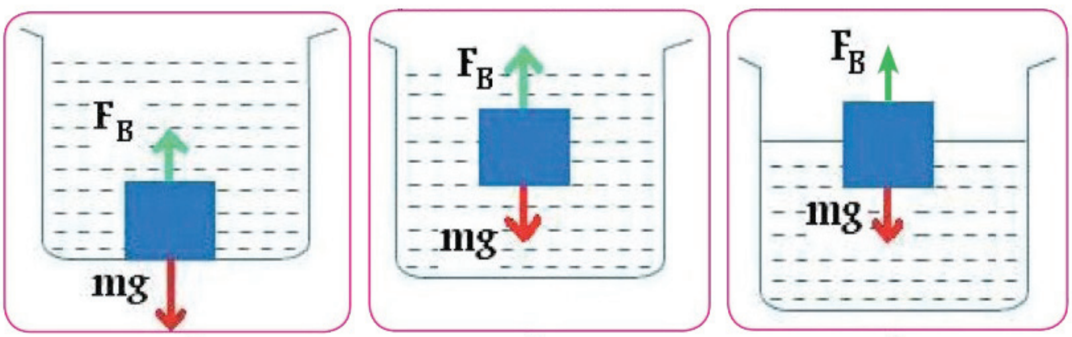
The above equation represents Archimedes' principle, where the right part represents the buoyant force and the left part represents the weight of the displaced fluid means that:

The buoyant force on an object which immersed in fluid = Displaced fluid weight

So we can say that any object when immersed in a fluid affect on it by two forces and they are :

1. Weight (mg) that is perpendicular in downward direction
2. Buoyant force F_B (displaced fluid weight) that is perpendicular in upward direction.

From figures (3-9)(a-b-c) representing an object placed in different liquids



a	b	c
The density of the object is greater than the density of the liquid, the object sinks to the bottom. (F_B < mg)	density object = density liquid the object is hanged inside the liquid and in an equilibrium state. (F_B = mg)	The density of the object is less than the density of the liquid. (F_B > mg)

Figure (3.9)

From that it's clear that Archimedes' principle for fully or partially immersed objects can be derived as:

a. For fully immersed objects, see figure (3.10 - a).

Buoyant force for liquid = weight of displaced liquid.

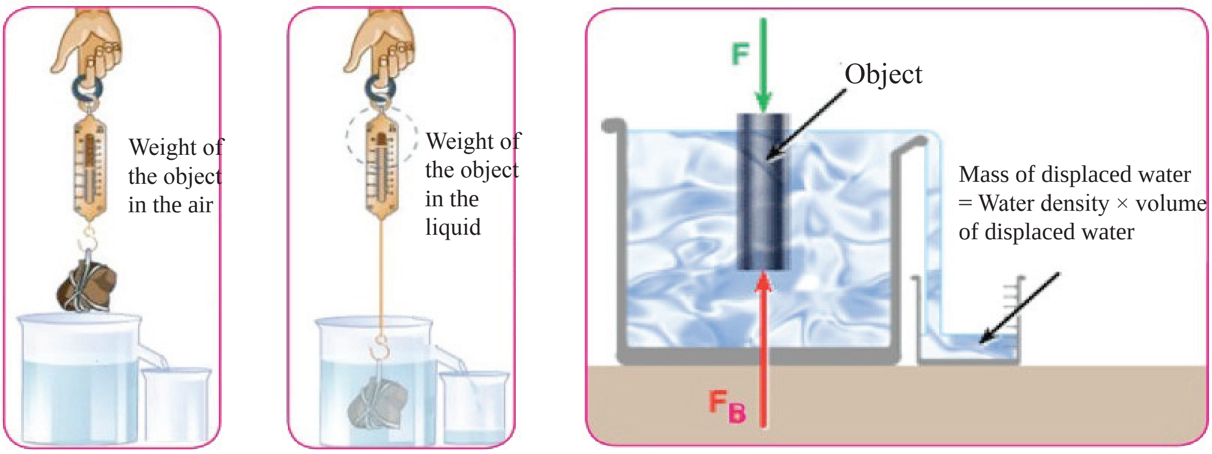
Weight object in air - weight object in liquid = weight of displaced liquid.

Weight object in air - weight object in liquid = volume of displaced liquid $\times$ weight density of liquid

$$\text{Weight of displaced liquid} = \text{Weight}_{\text{in air}} - \text{Weight}_{\text{in liquid}}$$

$$\text{Weight}_{\text{in air}} - \text{Weight}_{\text{in liquid}} = \text{Volume (V)} \times \text{density} (\rho) \times g$$

$$= V \rho g$$



(A) Figure (3.10) **(B)**

b . for partially immersed objects (floating objects) ,see figure (3. 10 - b)

The weight of floating object in the liquid = zero

The weight of floating object in the air – zero = weight of the displaced liquid

Weight of the floating object (W_{body}) = the volume of immersed part (V)×weigh density of the liquid(ρ_w)

ρ_w is weight unit volume:

$$\rho_w = \frac{W}{V}$$

$$W_{body} = V \times \rho_m \times g$$

Noting that:

Weight density of the object × Volume of the object = Weight density of water × Volume of the immersed part

Example 1

An object weights (5N) in air and weights (4.55N) when fully immersed in water, find the object's volume? Considering the water density as:
(1000 kg/m^3) and that gravity equals to (g =10 N/kg).

Solution

$W_{\text{in air}} - W_{\text{in water}}$ = volume (V) × density (ρ) × g

$5 - 4.55 = V \times 1000 \times 10$

$0.45 = 10000V$

$V = 0.45 \times 10^{-4}\ m^3$ the volume of the object

Remember:

* If the density of the fluid is greater than the density of the object then the object float on the fluid surface.
* If the density of the object is greater than the density of the fluid then the object totally immerses in the fluid.
* If the density of the fluid equals to the density of the object then the object will be hanged in an equilibrium state inside the fluid.

Example 2

A wooden cube have aside length of (10 cm) and weight density of (7840N/m^3) floats on water, what is the length of the immersed part in water ?

Solution

We assume that the length of the immersed part of the cube = (h)

Weight of the floating object = weight of the displaced liquid

Weight of the floating object = volume of the immersed part × Weight density of the liquid

$W_{body} = V \times (\rho_m \times g)$

Weight density of the object × volume of the object = weight density of water × volume of the immersed part

$(\rho V)_{body} = (\rho V)_{water}$

Weight density of water = mass density × gravity

$(9.8\ N/kg) \times (1000\ kg/m^3) = 9800\ N/m^3$

$7840 \times (0.1)^3 = h \times (0.1)^2 \times 9800$

$h = 784/9800$

$h = 0.08m$ length of immersed part

3.6 Surface Tension

The internal molecules that form the liquid are affected by equal attraction forces in all directions. The molecules on the surface of the liquid are subjected to resultant force that draw them downwards (inside the fluid). This makes the liquid surface behave like a thin flexible membrane in a continuous state of tension and reduces the surface area to as less as possible, see figure (3.11).

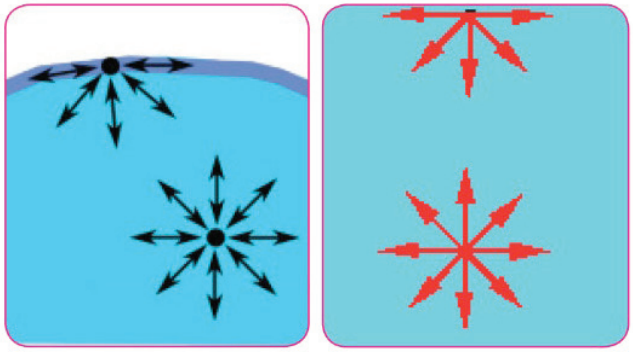


Figure (3.11)

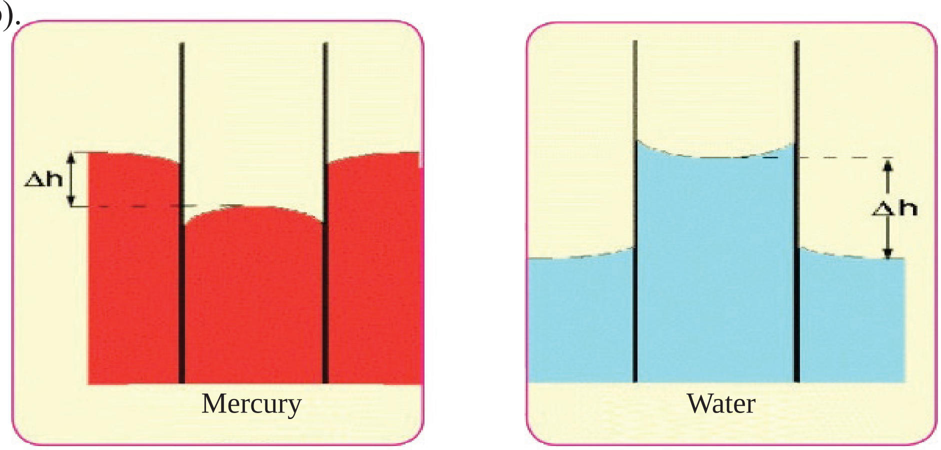
Surface tension causes some physical phenomena, for example floating of the needle over the surface of the water and the moving of insects on the surface of the liquid, and the spherical shape that the water droplets form, see figure (3.12).

Figure (3.12)

3.7 Capillary Property

One of the common things that is related to the surface tension is the phenomenon of the dropping and the rising of the liquid in the narrow (capillary) glass tubes which is called capillary property.

Hence when a two-ends opened capillary glass tube is perpendicular immersed in water, see figure (3.13a) the water inside the tube arise to a level that's higher than its level outside the tube. But in mercury the opposite happens its level drops inside the tubes compared to its level outside the tube, see figure (3.13b).



(b) Figure (3.13) (a)

And the water rising inside the capillary tube is due to the domination of the adhesive forces of the water with the glass to the cohesive forces of the water particles with each other, see figure (3.14), but for mercury the cohesive forces between its particles is greater than their adhesive forces with the glass.

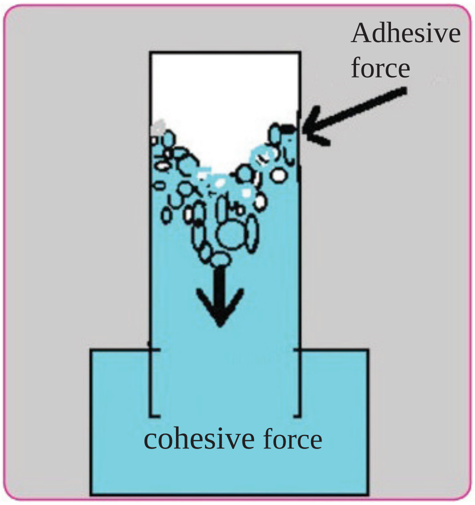


Figure (3.14)

Remember

* The cohesive force is the attraction force between the particles of the material itself meaning particles from same type (mercury).

* The adhesive forces is the attraction force between different particles, and its amount varies depending on the materials such as water adhesion to the glass.

The capillary property has very big importance:

1. Rising of the underground water inside the soil pores and its prove is the appearance of the salt on the soil surface.
2. Rising of the water through the plant roots and stems.
3. Filtration of the blood in the humans kidney.
4. The rising of the petrol used in the petrol heater's filament.

3.8 Mechanical Properties for Dynamic Fluids

Dynamic fluid has great importance in our daily life, like what happens for the movement of airplanes or submarines in the fluids or the flowing of the blood in the veins and arteries or the flowing of water in pipes .and fluids are characterized their ability to flow when a force acts in it even if its small. And in order to describe the flowing of a certain fluid in a certain time the fluid's density, pressure and flowing speeds should be known, and to simplify the study of the fluids we will assume the ideal fluid which is characterized by the following:

Properties of ideal fluid

1. Incompressible: means can’t be presses so its density remains constant during flowing
2. regular flowing: means that the speed of the fluid flow in a certain point remain constant in amount and direction with time
3. not viscos: viscosity is considered a measure to the internal friction in the fluid at flowing therefore we assume viscosity of the fluid is zero
4. not spiral or rotational: its flowing is not Turbulent, means flowing lines don’t overlap so no spirals form in it

3.9 Continuity Equation in Fluids

While we use water hoses in watering, extinguishing fire and washing cars we notice that as long as the exit path get smaller we get a big flowing speed, and that means that water’s flowing speed increases as its exit path gets small.

Figure (3.15) shows an ideal fluid of density (ρ) flows through a horizontal pipe of irregular cross sectional area.

Where its big cross section area is (A_1) and its small cross section area is (A_2) and in the smooth flow situation the continuity equation is established, which states that:

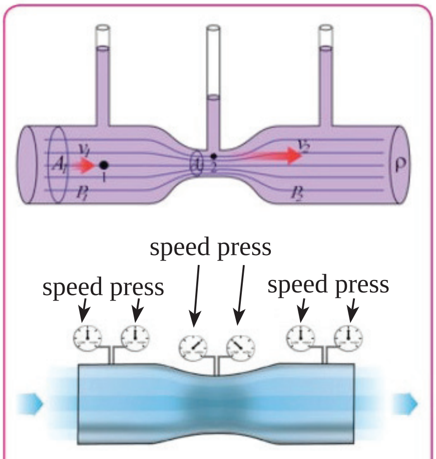


Figure (3.15)

The average flow of the fluid amount in any section inside the pipe stays constant

And the flowing continuity equation can be expressed by the following:

Big section area (A_1) × flowing speed (υ_1) = Small section area (A_2) × flowing speed (υ_2)

$$A_1\upsilon_1 = A_2\upsilon_2$$

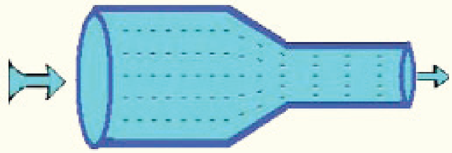
Where

υ_1 is the fluid speed in section (A_1).

υ_2 is the fluid speed in section (A_2).

This relation is true along the horizontal tube, and it shows the speed of flow in ant point is inversely proportional with the sectional area at that point, means the speed increases as the pipe get smaller.

Example



The water flows in a horizontal pipe with two sections the diameter of the big section is (2.5cm) with a speed of (2m/s) to its small section that's radius is (1.5cm), what is the water flowing speed in the narrow pipe?

Solution

$$A_1 \upsilon_1 = A_2 \upsilon_2$$

$$A_1 = \pi r_1^2 \qquad A_2 = \pi r_2^2$$

$$A_1 = \frac{22}{7} \times (r_1)^2 = \frac{22}{7} \times (2.5)^2$$

$$A1 = \frac{22}{7} \times (r_2)^2 = \frac{22}{7} \times (1.5)^2$$

$$\upsilon_2 = \upsilon_1 \times \frac{A1}{A2}$$

$$\upsilon_2 = 2 \times 100 \times \frac{(22/7) \times (2.5)^2}{(22/7) \times (1.5)^2}$$

$$\upsilon_2 \approx 555\text{cm/s}$$

$= 5.55$m/s the speed of water flow in the narrow tube.

3.10 Bernoulli's Equation

The scientist Bernoulli's discovered in 1738 that the fluid pressure changes by changing its speed, and when he derived the equation that known by his name, he assumed that the fluid is non viscose and incompressible and flows in smoothly flowing as shown in figure (3.16) and to get the mathematical relation that connect between the pressure (P), the height (h) from a certain horizontal level and the fluid's ideal speed (υ). a assume that a fluid is in a tube with irregular sectional area, and its parts height differs from a certain level.

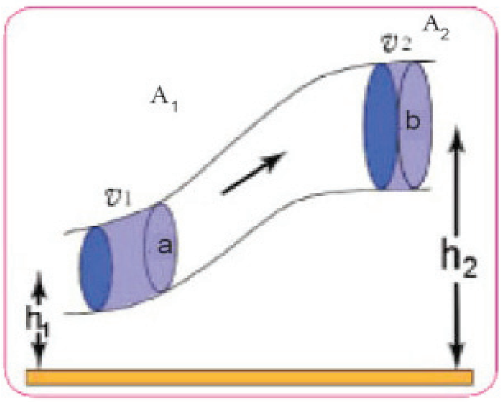


Figure (3.16)

So if the fluid pressure in point (a) was (P_1) and the sectional area was (A_1) and the fluid speed was (υ_1)

And the fluid pressure in point (b) is (P_2) and the sectional area is (A_2) and the fluid speed is (υ_2). And the height of the center of section (A_1) from a certain horizontal level is (h_1), and the height of the center of section (A_2) from the same level is (h_2) .

So Bernoulli's equation can be written as following:

The sum of all pressures and kinetic energy per unit volume and the potential energy per unit volume equal to a constant amount in all the points along the path of the ideal fluid.

$$P_1 + \frac{1}{2}\rho \upsilon_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho \upsilon_2^2 + \rho g h_2$$

Noting that ρ is the fluid density and its constant since the fluid is incompressible

$$P + \frac{1}{2}\rho \upsilon^2 + \rho g h = \text{constant}$$

3.11 Application of equation and Bernoulli's Principle

a. Venturi scale

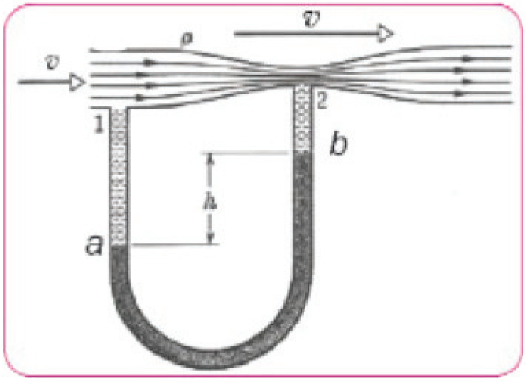
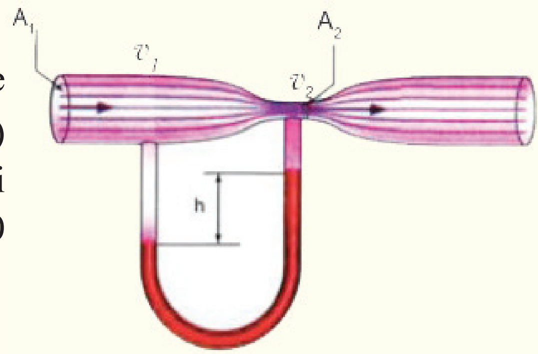


Figure 3.17

Venturi pipe is one of the most famous practical applications for Bernoulli's equation which can be used to measure the speed of a fluid having density (ρ), flowing through a horizontal pipe changing in cross sectional area. And the pressure difference between the two points (a,b) is measured using mercury manometer, see figure (3.17). The fluid speed can be measures by measuring the pressure difference (P_1-P_2) between the two sections of the pipe that's due to the height difference (h) in the liquid level that's used in the manometer, then it will be:

$$P_1 - P_2 = \rho g h$$

Example



Venture tube diagram

The figure shows venturi scale, if the height difference between the two pipes of the manometer is (0.075m) calculate the pressure difference between the two venturi scale's sections noting that the (ρ) of mercury is (13600 kg/m^3).

Solution

$P_1 - P_2 = \rho\, g h$

$= (13600\ kg/m^3) \times (9.8\ N/kg) \times (0.075\ m)$

$P_1 - P_2 = 9.996 \times 10^3\ N/m^2$ pressure difference between two Venturi scale's sections

b. Atomizer

All atomizers work according to Bernoulli's principle, when blowing air into the horizontal tube which shown in figure (3.18) produces an air flow in front of the vertical pipe's aperture that's bottom is immersed in the liquid resulting pressure drop (P_1) inside the pipe. But the atmospheric pressure (P_0) that is applied on the liquid's surface is greater ($P_0>P_1$) thus the liquid in the vertical pipe arises. And when the liquid reaches the aperture it mixes with the air flow in that's flowing in the horizontal pipe which lead to divides the liquid into very small drops (dribbles) and atomizer is used in many applications like car painting atomizers, Insecticide atomizers, perfume cans and carburetor in cars.

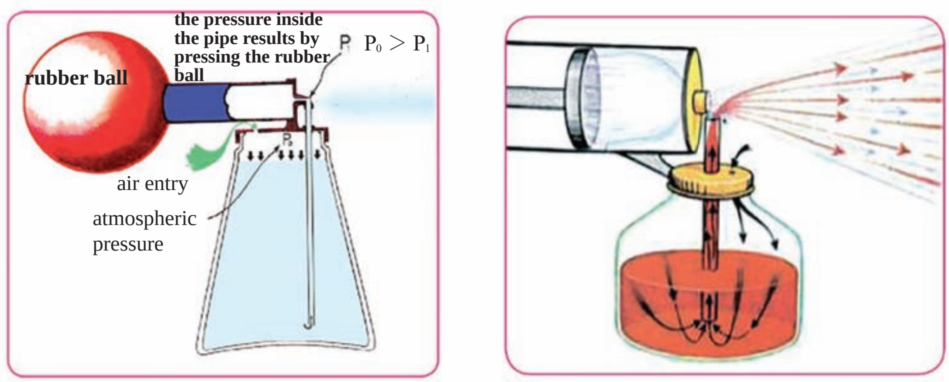


Figure (3.18)

c. Airplane lift force

The smooth shape for the airplane wings when moving forward leads to the flow of air stream in two different method on the two surfaces of airplane wings making the air moves faster on the upper surface than the lower surface of the wings.

For this reason the pressure on the lower surface is greater than the pressure on the upper surface which leads to generating pressure difference between the two surfaces of the airplane's wing and creating a force in the vertical direction called lifting force, which helps to lift the airplane, see figure (3.19).

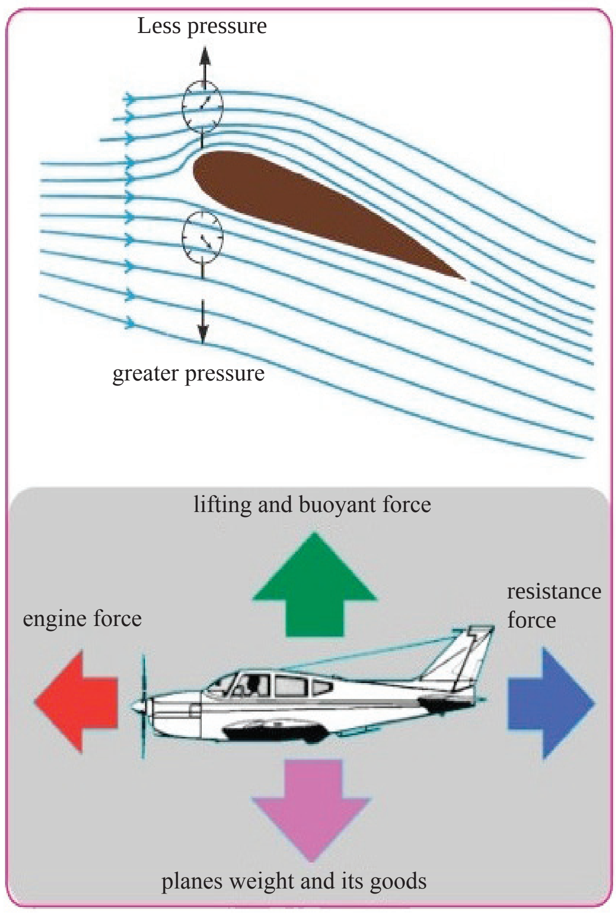


Figure (3.19)

Viscosity

Viscosity in fluids faces the friction between the surfaces of solid objects. Viscosity in fluids comes out during its flow. Materials that flows easily like water have low viscosity and material those don't flow easily like honey, molasses and concentrated juice have high viscosity figure (3.20a).

And from figure (3.20b) we see that the speed of the balls fall inside the engines oils of different viscosity decreases as its viscosity increase.

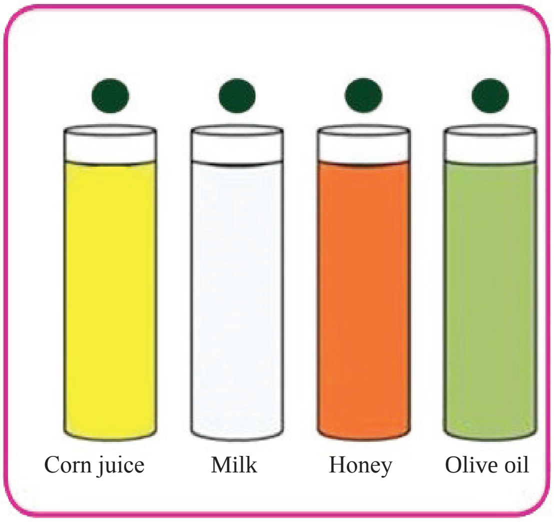


Figure (3.20a)
Shows fluids with different viscosities

Viscosity is the friction force between the layers of the fluid itself and between the layers of the fluid and the walls of the tube that contains them, and it was found experimentally that fluid viscosity depends on:

1. Fluid type.
2. Its temperature.

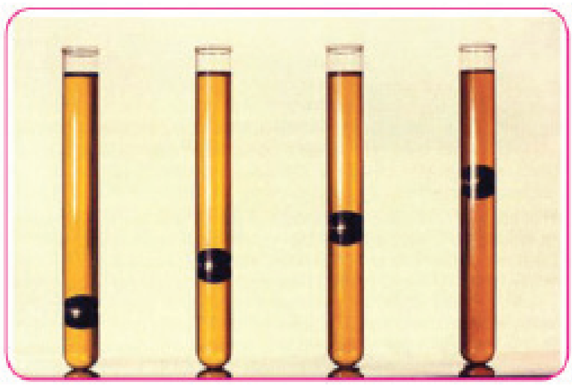


Figure (3.20b)
Shows fluids with different viscosities

Fluid's temperature increases their viscosity decreases, sine as temperature of the fluid increase its particles kinetic energy increases which lead to weaken the attraction force between them and decreases their resistance to the movement of the fluid particles and thus viscosity decreases, but in gases rising temperature increase the probability of the collision of its particles with each other which means increase in the resistance of particles to their movement thus viscosity increases.

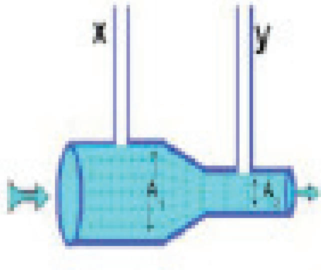
Think

What is the type of engine oil that you advise the driver to use in summer and in winter, and why?

Questions of chapter three

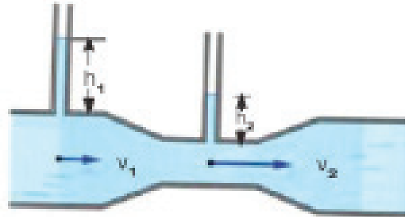
Q1. Choose the true answer for the following :

1. The following figure shows a fluid of neglected viscosity that flows regularly in tube with changing cross section area, then:



a. The liquid pressure in section (A_1) is less than the liquid pressure in section (A_2).
b. The height of the liquid in tube y equals to the height of the liquid in tube (X).
c. The flowing average of the liquid in section (A_1) is greater than its flowing average in section (A_2).
d. The height of the liquid in tube (X) is greater than the height of the liquid in tube (Y).

2. A horizontal tube where a liquid flows, its diameter decreased from (10 to 5cm), then which one of the followings is true:



a. Fluid's speed and pressure increases.
b. Fluid's speed and pressure decreases.
c. Fluid's speed increases and its pressure decreases.
d. Fluid's speed decreases and its pressure increases.

3. The pressure applied to an enclosed fluid moves in all direction and without decreases according to:

a. Archimedes principle b. Pascal principle
c. Bernoulli effects d. Continuity flowing equation

4. The weight loss of the object immersed in a liquid depends on:

a. Mass of the object b. Weight of the object c. Shape of the object d, volume of the object

5. Bernoulli principle is bases on:

a. Energy conservation law b. Archimedes principle
c. Pascal principle d. Capillary tubes

6. Gases and liquids are called fluid since the have flowing property because of:

a. The high internal friction between its particles b. Big distance between particles
c. Big particles force d. The low internal friction between its particles

7. Fluids have force that lifted up the immersed objects in it which called:

a. Buoyant force b. Gravitational force c. Frictional force d. Compressing force

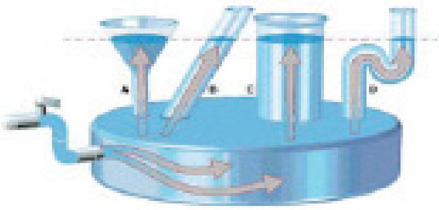
8. One of the following applications doesn't depend on Bernoulli's effect:

a. Sailing boat b. Airplane c. Hydraulic press d. Atomizer

9. a swimming pool of (100m) length and (20m) width and the water height in it is (5m), then the pressure on the pool base is:

a. 98×10^2 N/m^2 b. 95×10^6 N/m^2 c. 49×10^6 N/m^2 d. 49×10^3 N/m^2

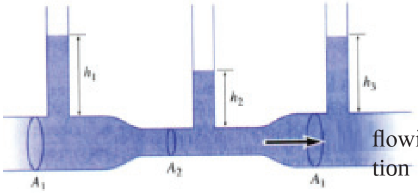
10. When the liquid flows from a side tap into a closed container like in the given shown figure, we note that the liquid rises in all the different containers by the same amount, this can be explained by:



a. Archimedes' principle b. Pascal's principle c. Atmospheric pressure d. Liquid pressure

11. From the given shape which of the following relation is true:

a. $h_1 = h_3$
b. $h_1 < h_3$
c. $h_1 > h_3$
d. $h_2 > h_1$



12. If an object of weight mg is immersed inside a liquid and still hanged in an equilibrium state then the buoyant force (F_B) is:

a. $F_B > mg$ b. $F_B = mg$ c. $F_B < mg$ d. $F_B = 2$ mg

13. to describe the regular flowing of a fluid at any time, we need to know:

a. Its density, weight and pressure b. Only its density and flowing speed
c. Its density, volume and pressure d. Its pressure, density and flowing speed

14. If an object is immersed in a liquid and this object's density is greater then the liquids density, then the object:

a. Floats on the liquid's surface
b. Fully immersed in the liquid
c. Still hanged in the liquid and in an equilibrium state
d. Still partially immersed in the liquid.

Q2. Give reason for the following

1. A razor can be placed on a steady water surface without immersed.

2. Swimming shirt sticks to the swimmer body when he comes out of the water but doesn't stick when he is inside the water.

3.when pressing the internal surface of a tent with a finger while its raining water flows from that point ?

4. a wet towel absorbs water from the skin faster than dry towel?

5. The concavity of the liquid surfaces that touches the walls of the capillary tubes?

6. The flying of building's roofs that made up of aluminum sheets during hurricane?

7. The barefooted swimmer feels pain in the rough beach and his pain decreases as he goes deeper in the water?

PROBLEMS

Q1. An rectangular fish growing pool of (20m) length, (12m) width and the water height in it is (5m) calculate:

a. Pressure on the pools base?

b. The force acting on the base?

Ans: a. 49000 N/m^2 b. $F = 1176\times10^4$ N

Q2. If the mercury barometer reading is (75cm), then what is the amount of the atmospheric pressure in Pascal?

Ans: P = 99960 Pa atmospheric pressure

Q3. In a hydraulic press has big press area is (50) times as much the small one, if the force applied on the big press is (6000N), then calculate the force applied on the small press?

Ans: F_1=120N

Q4. A person is about to flow while totally immersed in water if the body weight is (600N), calculate its volume? Considering the gravity is (10 m/s^2)?

Ans : V=0.06 m^3

Q5. The weight of a solid object in air is (20N) and in water is (15N) calculate the objects volume ?

Ans : $V = 5\times10^{-4}$ m^3

Q6. The water flows through the big section of a tube with a speed of (1.2m/s) and when reaches the small section its speed becomes (6m/s) . calculate the ratio between the two sections diameter?

Ans : $\sqrt{5}$

4.1 Quantity of Heat and Specific Heat

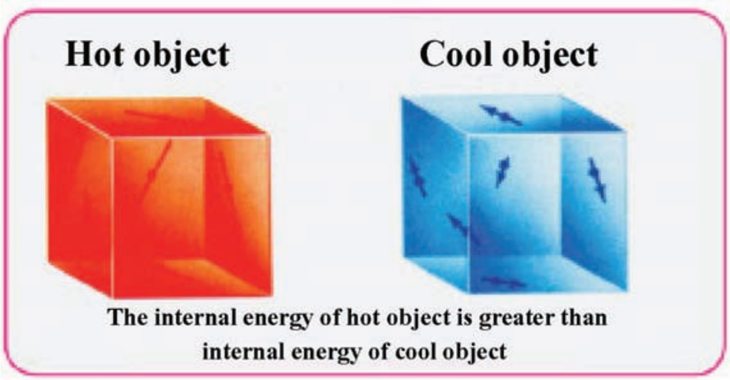


Figure (4.1)

You studied before that matter is composed particles and these particles have kinetic and potential energy and the sum of the kinetic and the potential energy of the particle is called the internal energy of it, thus when we heat objects their average internal energy increase when their temperature increase. Thus the quantity of heat that the matter needs to raise its temperature by a certain amount depend on that change amount, so it increases when amount increases and decreases when it decreases, see figure (4.1), thus heat quantity is directly proportional to the change in the matter's temperature.

And if we take different amounts of a certain material, and tried to raise their temperature to the same degree, then we need different quantity of heat proportion to the masses of these materials. And since the matter's mass depends on the number of the particles that its made of, and the heat quantity that increase the internal energy for these particles also depends on the matter's mass, means that heat quantity is proportional to the matter's mass.

And if we take equal masses from two different materials and tried to raise their temperature to the same degree, we see need different amount of heat despite of their equal masses and amount of temperature change, and that's due to the difference of the type of materials.

Thus if we give the same amount of heat to two equal mass from two different material, its not necessary their temperature raise by the same amount, for example if we take an aluminum container contains amount of water so the water and the aluminum mass is equal and put it on a heat source, after a while we see that the container became hot so it can't be touched but the water inside it still tepid , meaning that the amount of heat that the container gained made a increase in its temperature greater than the increase that the same amount of heat made in the water temperature despite their equal masses.

From that we conclude that the quantity of heat needed to heat an object depends on:

1.mass of the object   2. The change in its temperature   3. The type of the material its made of

And so we can calculate the quantity of heat (Q) needed to raise the temperature of an object with mass (m) from a certain temperature (T_1) to a temperature (T_2) by the following relation.

Heat quantity = Mass of the object × Specific heat of the material × Change in temperature

$$Q = mC_p \triangle T = mC_p(T_2 - T_1)$$

Where (C_p) is the specific heat of the material measured under a constant pressure (P) and defined: the quantity of heat required to raise the temperature of (1kg) from material one degree Celsius and its unit is (Joule/kg.°C).

Its important to mention that the sign of (ΔT) and (Q) is positive when the material gains heat energy from the surrounding so its temperature increases and the sign is negative when the material losses heat energy to the surrounding so its temperature decreases.

Do you know?

That heat quantity is measured by calorie unit and one calorie equals to (4.2J).

$\boxed{\textbf{1cal = 4.2J}}$

4.2 Heat Capacity

Specific heat was related to the temperature raising of one kg from material one Celsius degree, but we called the amount of heat required to raise the temperature one degree Celsius and its unit is (Joule/kg.°C): (the Heat capacity of that object), and it can be calculated by the following relation:

Heat Quantity = Mass of the Object × Specific Heat × Change in Temperature

Heat Quantity = Heat Capacity × Change in Temperature

Means that :

Heat Capacity = Mass of the Object × Specific Heat

$$C = mC_p$$

Where (C) is the heat capacity for the material, and heat capacity for a certain mass of the material is defined as:

The amount of heat required to raise the temperature of the whole mass from material one degree Celsius and its unit is (Joule/°C).

Table (1) clarify the specific heat for different materials:

Table (1)

Material	Specific heat (Joule/kg.°C)	Material	Specific heat (Joule/kg.°C)
Pure water at 15 °C	4186	Glass	837
Ice at 0 °C	2093	Steel	500
Water vapor at 100 °C	2010	Iron	448
Wood	1750	Copper	387
Aluminum	900	Silver	234

Remember:

Specific heat depends only on the type of material and the heat capacity changes with object mass and the specific heat for its material.

Example 1

What is the amount of heat energy required to raise the temperature of (3kg) aluminum from (15°C) to (25°C) noting that the specific heat of aluminum is (900 J/kg.°C).

Solution:

Mass of aluminum = 3 kg

Initial temperature (before heating) for the aluminum $T_1 = 15$ °C.

Final temperature (after heating) for the aluminum $T_2 = 25$ °C.

Specific heat of aluminum $Cp = 900$ (J/kg.°C).

And according to the equation:

$Q = m\,C_p\,(T_2 - T_1)$.

$Q = 3\text{kg} \times 900\ \text{J/kg.°C} \times (25-15)\text{°C}$.

$Q = 27000$ J amount of heat energy.

From you observation to table (1) you find that the specific heat for water is greater than all other material used in our daily life. And this can help us to explain many natural phenomenon. And its also useful in many daily application as:

1.Its Effect to the weather (land and sea breeze), shown in figure (4.2).

2. Its use in car engine cooling.

3. Cooling of the machines in the factories using water.

Figure (4.2)

Example 2

What is the heat capacity for a piece of iron of (4kg) mass and its specific heat is (448 J/kg.°C)?

Solution:

Heat capacity = mass × specific heat

$C = m\,C_P$

$C = 4kg \times 448\ J/kg.°C = 1792\ J/°C$ the heat capacity

Do you know ?

Heat energy is measured by joule unit that's if a matchstick burns it will produces about (2000J)

Question

If you have three different metal pieces and where given the same heat quantity so their temperature increased as shown in the following figure then which one of them have the greater heat capacity, explain your answer?

$\Delta T = 5°C$ $\Delta T = 9°C$ $\Delta T = 3°C$

4.3 Thermal Equilibrium

It's known the heat is a type of energy and energy can't be created or destroyed, then heat also can't be created or destroyed but transferred from one object to another. And assuming that the two objects are thermally isolated from the medium that surrounds them (mean there is no any exchange with the surrounding medium), see figure (4.3) then we say the two objects are in thermal equilibrium state also when mixing two liquids together heat moves from the hot object to the cold one and the heat flow continues until the temperature of the two liquids become equal and results in a thermal equilibrium in the isolated system.

Heat Lost = Heat Gained

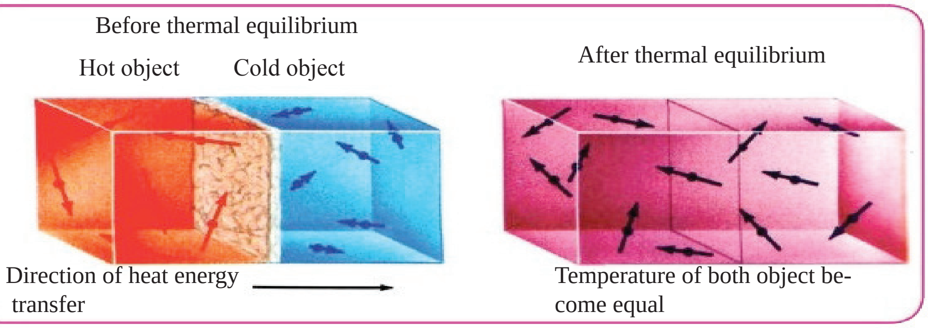


Figure (4.3)

And it's important to mention measuring the specific heat for a certain object is done by using the calorimetry as a water container that is thermally insulated, see figure (4.4), its composed of a thin container made up of a good heat conducting metal like copper and its surrounded by another container from the same metal and is separated by a heat insulating material like sawdust or fibers to thermally insulate the inner container and its contents from its surrounding medium and it has a cover, with two aperture first to enter the thermometer and second to enter the stirrer to mix the material together.

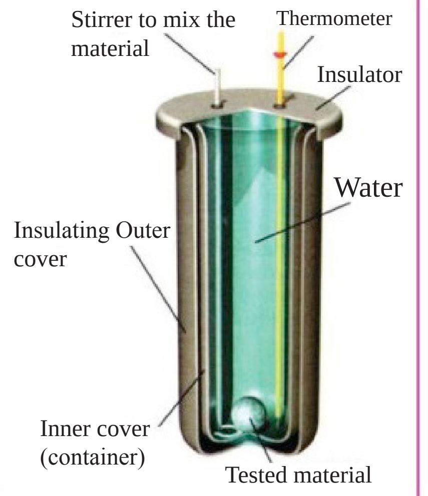


Figure (4.4)

Example 1

An aluminum cube of (0.5) kg at (100°C) was placed in a container filled with (1kg) of water at (20 °C), (suppose that there is no lose for the heat energy to the surrounding), calculate the final temperature for the (aluminum and water) when thermal equilibrium is reached (means the temperature of the aluminum and water equalize).

(Noting that the specific heat for water is (4200 J/kg.°C) and specific heat of aluminum is (900 J/kg.°C)

Solution

Suppose the final temperature for them = T_f °C.

So the aluminum temperature decreases by $(100 - T_f)$ °C.

And the water temperature increases by $(T_f - 20)$ °C.

We apply the following equation:

The amount of heat energy that the aluminum loses = the amount of heat energy that the water gains

Water = W, Aluminum = A

$m_w \times C_{pw} (T_f - 20)_w = m_A \times C_{pA} (100 - T_f)_A$

$1 \times 4200 (T_f - 20) = 0.5 \times 900 \times (100 - T_f)$.

$4200 T_f - 84000 = 45000 - 450 T_f$

$T_f = 129000 / 4650$

$T_f = 27.7$ °C the final temperature for both of them.

Example 2

Calculate the heat capacity for a copper calorimeter contains (100g) of water at a temperature (10°C) add another amount of water its mass of (100g) at a temperature (80°C) and the mixtures final temperature became (38°C)?

Solution

We assume that the heat capacity for the calorimeter is C

Quantity of gained heat

Quantity of heat the cold water gained = mass × specific heat of water × change in temperature

$Q_1 = m\,C_p\,(T_f - T_1)$

$= 0.1 \times 4200 \times (38-10)$

$= 11760$ J Amount of heat the water gained

Quantity of heat the calorimeter gained = heat capacity of the calorimeter × change in temperature

$Q_2 = C\,(T_f - T_1)$

$Q_2 = C(38-10)$

$= 28$ C

Quantity of lost heat

Quantity of heat the hot water lost = mass × specific heat × change in temperature

$Q_3 = m\,C_p \times (T_f - T_1)$

$= 0.1 \times 4200 \times (38-80)$

$= -17640$J

During thermal equilibrium

Quantity of gained heat$(Q_2 + Q_1)$ = Quantity of lost heat (Q_3)

Quantity of heat that the water and the calorimeter gained = quantity of heat that the hot water lost

$Q_3 = Q_1 + Q_2$

$17640 = 11760 + 28C$

$C = 5880/28$

C = 210 J/°C heat capacity of the calorimeter

4.4 Heat Effect on Materials

Materials expand by heat:

When the temperature of the solid, liquid or gas material is increases the average kinetic energy of the particles increases so the gaps between them increase then it gets in expansion but this expansion is different depending on the state of the material, so gases expansion is more than liquids and liquids expansion is more than solids if the gained heat was equal for the three states.

a. Expansion of solids

Expansion means increase in the dimensions of the material, thus there is:

* Longitudinal expansion means increase in the length of the stem (expansion in one dimension).
* Surface expansion means increase in the surface area (expansion in two-dimensions).
* Volumetric expansion means expansion in objects volume (expansion in three-dimensions).

Longitudinal expansion:

Let assume that the original length of the object is (L) and by increasing the temperature by (ΔT) amount occurs increase in the length by (ΔL) amount, the experiments have proved that the change in the length is directly proportional with the change in temperatures and original length and type of material, see figure (4.5). thus the equation of the length change can be written as the following:

Figure (4.5)

Length change = Longitudinal expansion factor × Original length × Amount of temperature change

$$\Delta L = \alpha L \Delta T$$

Where ΔL= new length – original length

α = longitudinal expansion factor and given by the following relation:

$$\alpha = \frac{1}{L} \times \frac{\Delta L}{\Delta T}$$

And thus the longitudinal expansion factor (α) can be defined as:

The amount of increase in the unit lengths of the material when heated one degree Celsius is measured by($\frac{1}{°C}$)unit and it differs according to the material, see table (2).

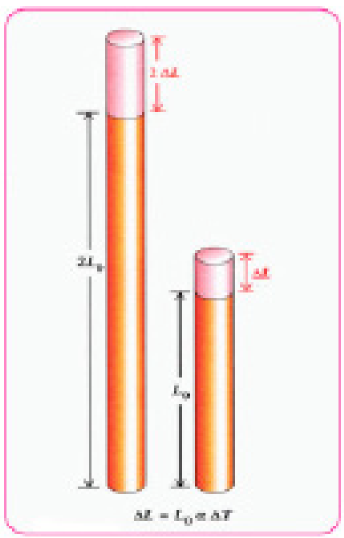


Figure (4.6)

Table (2) longitudinal expansion factor for some materials:

Table (2)

Material	Longitudinal expansion factor (α) (1/°C)
Aluminum	24×10^{-6}
Copper	17×10^{-6}
Steel	$\backsimeq 12\times10^{-6}$
Glass	9×10^{-6}
Lead	29×10^{-6}
Cement	12×10^{-6}

Surficial expansion:

The area of any surface increases when its temperature raises. On this based the surface area (A) increases by (ΔA) due to temperature increase by (ΔT) amount, see figure (4.7) so:

Change in area = surficial expansion factor × Original Area × Amount of temperature change

$$\Delta A = \gamma \; A \, \Delta T$$

Where

ΔA = new area – original area.

The symbol (γ) represents the surficial expansion factor and it's given by:

$$\gamma = \frac{1}{A} \times \frac{\Delta A}{\Delta T}$$

Thus we can defined the surficial expansion factor (γ) which is called Gama as:

The amount of increase in the area unit from object when temperature rises one degree Celsius and is measured by (1/°C) unit.

And to be clear:

Surface expansion factor γ = twice the longitudinal expansion factor

$$\gamma = 2\alpha$$

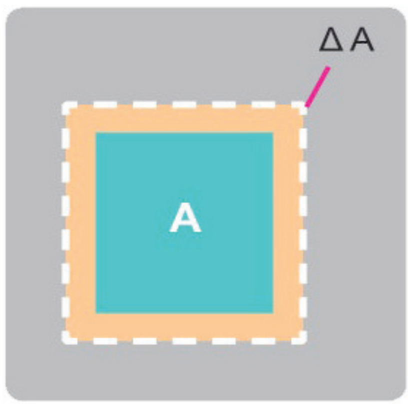


Figure (4.7)

Volumetric expansions:

The change in the volume of the matter as the temperature changes and it's described by volumetric expansion factor of matter (β), see figure (4.8). Thus the volume of the matter (V) increases by (ΔV) amount due to temperature increase by (ΔT) amount, and so:

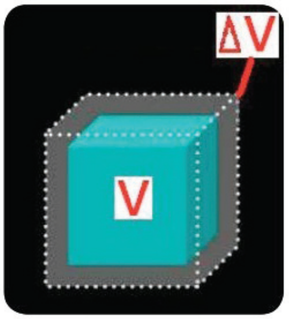


Figure (4.8)

Change in Volume = Volumetric Expansion Factor × Original Volume × Amount of temperature change

$$\Delta V = \beta V \Delta T$$

Where: $\Delta V = V_2 - V_1$

Change in volume (ΔV) = new volume – original volume.

And symbol β is called the volumetric expansion factor and given by the following relation:

$$\beta = \frac{1}{V} \times \frac{\Delta V}{\Delta T}$$

Thus we can define the volumetric expansion factor (β) is amount of increase in the volume unit of the material when temperature rises one degree Celsius and is measured by (1/°C) unit.

And to be clear:

Volumetric Expansion Factor (β) = three times the Longitudinal Expansion Factor (α)

$$\beta = 3\alpha$$

Applications on solid material expansion by heat:-

The phenomenon of the expansion materials as the temperature increase and the contraction of them as the temperature decreases had been used in many practical applications like the automatic thermostat in electrical devices like fridge, freezer, flat irons and fire alarm device, Where a bimetallic strip band is used to control the opening and the closing of the electric circuit, see figure (4.9).

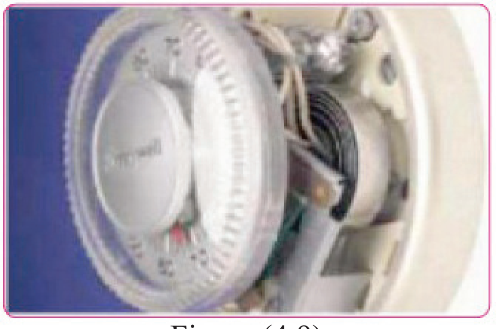


Figure (4.9)

The metal of high expansion factor bends around the metal of lower expansion factor when temperature increases leads to open the electric circuit and when the temperature decreases it returns straight to close the circuit and open it again, see figure (4.10).

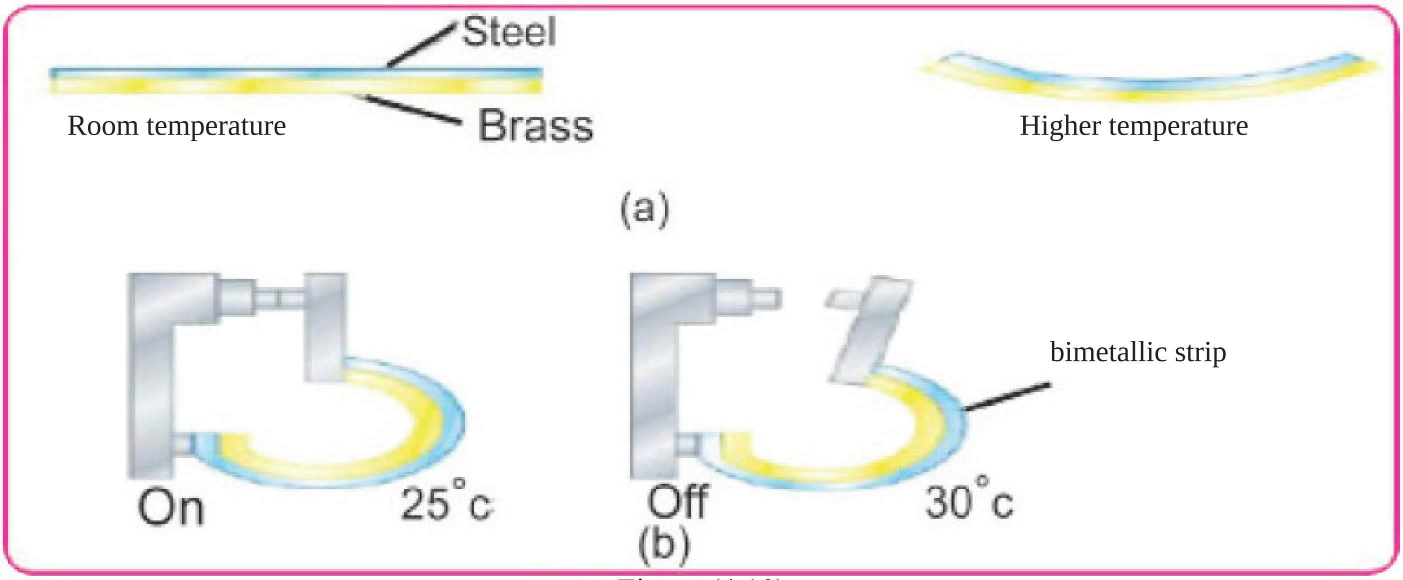


Figure (4.10)


Figure (4.11)

Some of the important application for the difference solid material expansion phenomenon.

- The usage of two different materials have equal thermal expansion factor and taking the advantage of this in the electric lamp industry. The lamp's glass have equal thermal expansion factor to the wire used so when the wire that holds the lamp filament and that's other end is immersed in the lamp's glass expands the glass also expands by the same amount in order to prevent the lamp's base from breaking, see figure (4.11).
- Also materials thermal expansion was taken into account in the construction design to avoid the dangers , and that's by putting proper spaces or separators in bridges and leaving spaces between railway bars, see figure (4.12).


Figure (4.12)

b. Thermal expansion of liquids

The solid material expands by increasing temperature , liquids also expands by it and to know about the liquid expansion we perform the following activity:

Activity: **Extent the fluids by heat**

Tools: glass beaker, big container, two-end opened narrow glass tube, a rubber cub that's the tube passes through, colored water, thermal source.

Steps :

1. We fill three quarters of the container with water and then heat it by the thermal source.
2. We fill the beaker with the colored water and close it by cub as in figure (4.13a) and make a sign at the water surface in the tube.
3. Put the beaker in the container and observe what happen to the water height in the tube.

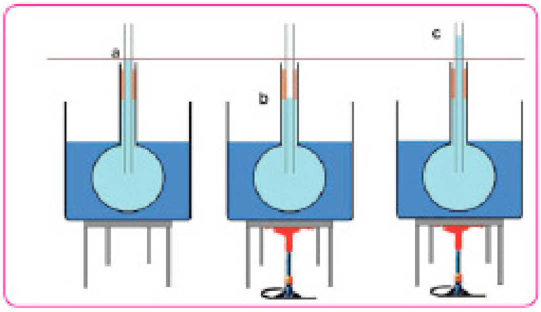


Figure (4.13)
Heating starts the level of the water decreases a little in the tube.

When heating starts the level of the water drops a little in the tube because the class expands at first and increases in the volume, so the water level drops to replace (figure 4.13.b), the vacuum resulting from the increase in the volume of the beaker. When the heat reaches the water through the beaker's glass it expands and raises in the tube due to its volume increase (figure 4.13c) but the volumetric expansion of liquids is greater than the volumetric expansion of solid materials under the same temperature change, as a result of the containers expansion that contain the liquid then the expansion that we see and measure is less than the real expansion and its called apparent expansion.

And so we can define :

Apparent Volumetric expansion factor (β_v) for the liquid in a container: is the ratio of the apparent volume increase for each Celsius degree.

Apparent Volumetric expansion factor (β_r) for the liquid in a container: is the ration of the real volume increase for each Celsius degree (β_r).

Its important to know the following:

Real expansion factor for the liquid (β_r)> apparent expansion factor (β_v).

And also:

Real expansion factor for the liquid (β_r) = apparent expansion factor (β_v) + Volumetric expansion factor for the container

$$\beta_r = \beta_v + 3\alpha$$

Where (α) is the longitudinal expansion factor for the container.

Do you know ?

That the Pyrex glass withstand fast changes in temperature without breaking and that's because it's longitudinal expansion factor is smaller compared to normal glass.

Table (3) shows volumetric expansion factor for some liquids.

Table (3)

Material	Volumetric expansion factor (β) 10^{-4}/°C
Alcohol	1.12
Gasoline	9.6
Glycerin	4.85
Mercury	1.85

Think

When placing a mercurial thermometer in a hot liquid then it drops a little at first then rises, explain that?

Example

The gasoline tank of the car of (60) litter volume was fully filled with gasoline when the temperature was (25°C), then the car was left under the sun light many hours till the tank temperature became (45°C), calculate the volume of the gasoline that's expected to spill from the tank (neglect the gasoline expansion)?

Solution

From table (3) we find that the volumetric expansion factor for gasoline is:

$\beta = 9.6 \times 10^{-4}\ 1/°C$

$\Delta T = T_2 - T_1$

$\Delta T = 45 - 25 = 20\ °C$

$\beta = \frac{1}{V} \times \frac{\Delta V}{\Delta T}$ volumetric expansion factor for gasoline.

$\therefore \Delta V = V\ \beta\ \Delta T$

$\Delta V = 60 \times 9.6 \times 10^{-4} \times 20$

$\Delta V = 1.152$ Litter the volume of the spilled gasoline.

C. Gases expansion

The gases expansion is greater then the liquids expansion and greater the solid materials due to less molecular force between their molecules . and gases are characterized by having equal volumetric expansion factor at constant pressure, and it has been proven that the expansion of the container that contain the gas is very small compared to the expansion of the gas itself so container's expansion can be neglected thus the apparent expansion of gases is considered as real expansion.

REMEMBER

That β for any gas equals to $\frac{1}{273}(\frac{1}{°C})$ under constant pressure.

4.5 State Change of Matter

Latent heat of fusion

Each pure material has its own melting point. The different kinds of materials requires different quantity from heat to melt equal masses. And the quantity of heat required to convert a masses unit from solid to liquid at the same temperature (for example melting point for ice is 0°C) and under constant pressure is called latent heat of fusion and measured by (J/kg) units.

The quantity of heat required to melt a certain mass of a material at its melting point can be calculated by following relation, see figure (4.14):

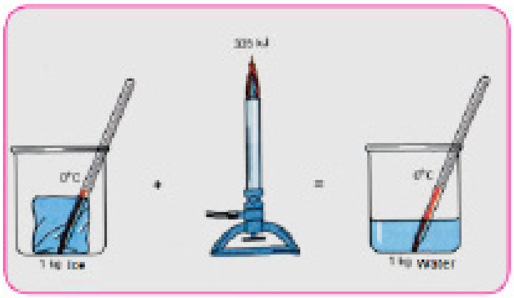


Figure (4.14)

Quantity of heat required to melt the material = mass × latent heat of fusion

$$Q = m \times L_f$$

Where :

m represents mass of the object

L_f represents latent heat of fusion.

And table (4) shows melting point for some material and also their latent heat of fusion.

Table (4)

Material	Melting point °C	Latent heat of fusion kJ/kg
Ice	0	335
Aluminum	658.7	321
Copper	1083	175
Iron	1535	96

Example 1

Calculate the quantity of heat required to convert an ice piece of (25g) at (0°C) to water under the same temperature.

Solution

Amount of heat = mass × latent heat of fusion.

$Q = m\, L_f$

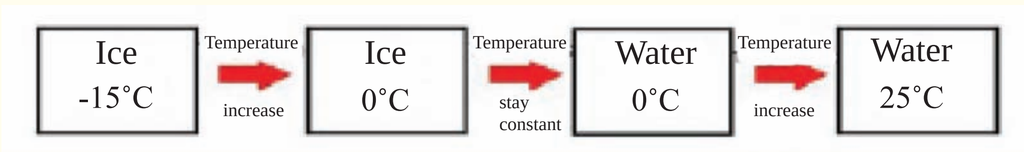
$Q = (25/1000) \times 335$

$Q = 8.375$ kJ   the quantity of heat required

Example 2

Calculate the quantity of heat required to convert (2 kg) of ice at (-15 °C) to water at (25 °C) noting that specific heat of water is (4200 J/kg.°C) and the latent heat of fusion for ice at (0 °C) is (335 kJ/kg) and specific heat of ice is (2093 J/kg.°C).

Solution



To raise the ice temperature from (-15 to 0 °C) we need to supply it with a heat quantity equals to:

Quantity of heat = mass × specific heat of ice × temperature difference

$Q_1 = m\, C_{ice}\, \Delta T$

$= 2 \times 2093 \times [0-(-15)]$

$= 2 \times 2093 \times 15$

$= 30 \times 2093$

$Q_1 = 62790$ Joule

To convert ice to water at (0 °C) we need to supply it with a heat quantity equals to:

Quantity of heat = mass × latent heat of fusion of ice

$Q_2 = m\, L_f$

$= 2 \times 335$ kJ/kg

$Q_2 = 670000$ Joule

To raise the water temperature from (0 to 25 °C) we supply it with a heat quantity equals to:

Quantity of heat = mass × specific heat of water × temperature difference

$Q_3 = m\,C_{water} \times \Delta T$

$= 2 \times 4200 \times (25\text{-}0)$

$= 50 \times 4200$

$Q_3 = 210000$ Joule

To calculate the heat quantities that were supplied to the ice till it became water equal (25 °C):

$Q_{total} = Q_1 + Q_2 + Q_3$

$= 62790 + 670000 + 210000$

$Q_{total} = 942790$ Joule total heat quantity

Latent heat of vaporization

You have studied before the vaporization occurs on the liquids surface and at any temperature, as long as the liquid particles near the surface gain enough kinetic energy that makes them overcome the force between them, so they will vaporize and become free to move outside the liquid surface in form vapor, see figure (4.15a) but in boiling situation the liquid particles all of it (not only these on the surface) gain kinetic energy that let them overcome the forces between them, an raise as a vapor, see figure (4.15b).

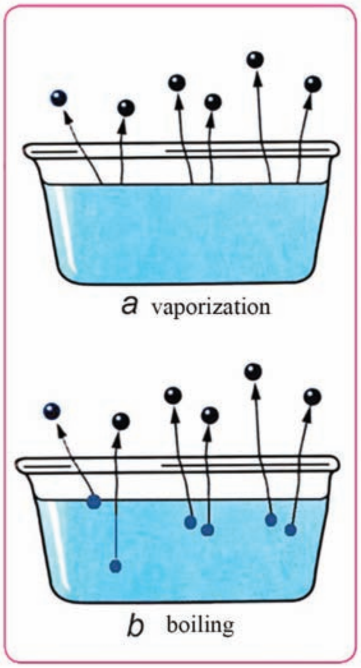


Figure (4.15)

The temperature which matter start converting from liquid state to gas state is known by boiling temperature, which is a physical property of matter, where each pure matter has specific boiling temperature at a specific atmospheric pressure.

The heat quantity required to convert a masses unit of the material from liquid to gas state at the boiling point is called latent heat of vaporization, see figure (4.16).

Each pure matter has its specific boiling point, and we can calculate the heat quantity required to convert a mass of any liquid to gas state without changing its temperature by the following relation:

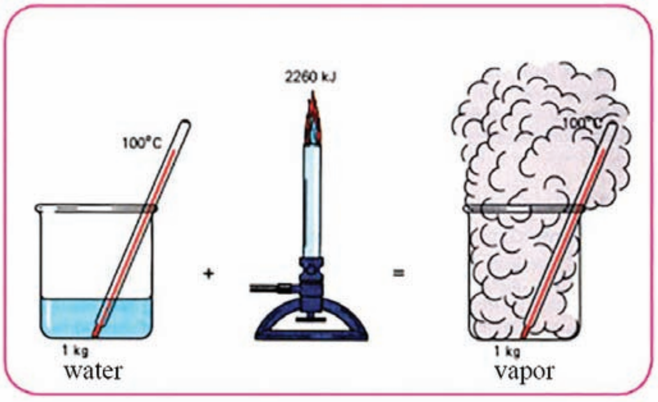


Figure (4.16)

Heat quantity required to convert an amount of liquid to vapor under the same temperature = mass × latent heat of vaporization

$$Q = mL_v$$

Where :

m represents mass of the object

L_v represent the latent heat of vaporization and measured by kJ/kg.

Table (5) represent boiling point of some material and their latent heat of vaporization.

Table (5)

Material	Boiling point °C	Latent heat of vaporization kJ/kg
Pure water	100	2260
Mercury	357	284
Copper	2300	4820
Iron	3000	6290
Silver	2100	2360

Example

Calculate the quantity of heat required to convert (3kg) of water at (20°C) to vapor at (110°C) noting that the specific heat of water is (4200 J/kg) and the latent heat of vaporization of water is (2260 kJ/kg) and the specific heat of water vapor is (2010 J/kg°C) ?

Solution

Total heat quantity = Quantity of heat required to heat the water from (20 to 100°C) + quantity of heat required to convert water to vapor at 100°C + quantity of heat required to raise the water vapor temperature from (100 to 110°C).

$$Q_{total} = Q_1 + Q_2 + Q_3$$

$$= mc\,(T_2\text{-}T_1) + mL_v + mc\,(T_3\text{-}T_2)$$

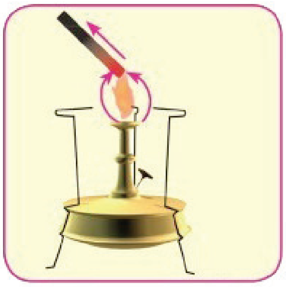
$$= 3 \times 4200 \times (100\text{-}20) + 3 \times 2260 \times 10^3 + 3 \times 2010 \times (110\text{-}100)$$

$$= 1008000 + 6780000 + 60300$$

Q_{total} = 7848300 J total heat quantity

4.6 Methods of Heat Transfers

Radiation



Conduction

Convection

Figure (4.17)

It was mentioned in previous classes that heat transfers from one object to another by three ways

1. Conduction
2. Convection
3. Radiation

Thermal conduction

You have studied that heat transfers in solid material by conduction method, and the time average of the transferred thermal energy differs from one material to another depending on the internal structure of the material and metals are considered good thermal conduction materials and that is because of their free electrons and close atoms while heat transfers very weekly in poor thermal conduction materials like wood, rubber, plastic and others, see figure (4.18).

Figure (4.18)

Thermal conductivity

The heat energy amount that is transferred through the an object by conduction method depends on a property called thermal conductivity of matter, so if we take a flowing state of thermal energy through a metallic rod of L (m) length and A (m^2) cross-section area which is thermally insulated from the surrounding (coverd by a thermally insulating material from the surrounding) and place on of rod sides on flame, see figure (4.19) and the other side is placed in a container of ice crushed at (0°C) and its required to keep the temperature differences constant and continuous during the heating process.

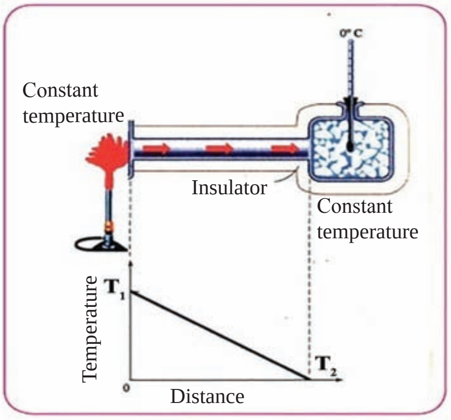


Figure (4.19)

The amount of change in conductor's temperature at each meter of its length when the heat transfers perpendicular on its cross sectional area is called thermal gradient.

$$\text{Thermal gradient} = \frac{\text{temprature difference}}{\text{Length of object}}$$

$$\text{Thermal gradient} = \frac{\Delta T}{L}$$

And from this we find that as long as the thermal gradient increases the amount of thermal energy flow increases, and the time average for the transfer of thermal energy can be expressed by the following relation, see figure (4.20):

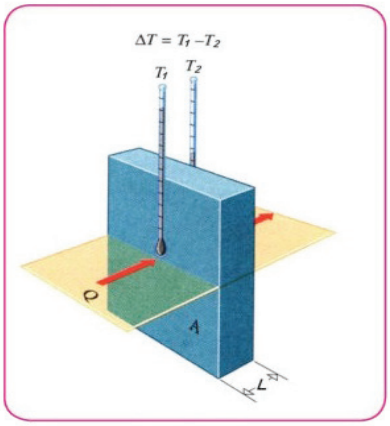


Figure (4.20)

$$\text{The time average for the transfer of thermal energy} = \text{thermal conduction coefficient} \times \text{cross sectional area} \times \text{thermal gradient}$$

$$H = k\,A\,\frac{\Delta T}{L}$$

Where:

H: represents the time average for the transfer of thermal energy by conduction method and measured by Watt

A: cross section area measured by (m^2).

ΔT : temperature differences measured by (°C).

L: length of the rod (or its thickness) measured by (m).

k: thermal conduction coefficient measured by (watt/m.°C).

It is worth to be mentioned that different solid materials have different thermal conduction coefficients and table (6) shows some of these materials.

Table (6) approximate thermal conduction coefficient of some solid materials.

Table (6)

Materials	**Thermal conduction coefficient (k) Watt/(m .°C)**
Aluminum	210
Glass	0.8
Iron	79
Silver	406
Red copper	385
Yellow copper	109
Steel	46
Gold	293
Mercury	8.7
Bricks	0.63
Wood	0.15
Air	0.025
Cement	0.3
Water	0.61

Question

Why does firefighters use helmet made of yellow copper rather than helmet made of red copper?

Example 1

An iron rod of (50cm) length and sectional area of ($1cm^2$), its one side was placed on flame at (200°C) and the other end was placed in crushed ice at (0°C), if the rod was covered by insulating material and if the thermal conduction coefficient of iron is (79 Watt/m.°C) then calculate:

1. Thermal gradient
2. The time average for the transfer of thermal energy.

Solution

1. Thermal gradient $= \dfrac{\Delta T}{L}$

Thermal gradient $= (200-0)/50 \times 10^{-2} = 4 \times 10^{2}$ °C/m.

2 The time average for the transfer of thermal energy = The thermal conduction coefficient × sectional area × thermal gradient

$$H = k\,A\,\frac{\Delta T}{L}$$

$H = 79 \times (1 \times 10^{-4}) \times (200-0)/50 \times 10^{-2}$

$= 3.16$ watt

Example 2

Room has a glass window with one-layer, if the length of the window (2.2m), width (1.2m) and thickness 5mm, assuming the temperature of the window surface inside the room (22°C) and the temperature outside it (3°C), calculate the time average to transfer thermal energy from room, note the thermal conduction coefficient of glass (0.8w/m.°C)?

Solution

The time average for the transfer of thermal energy = The thermal conduction coefficient × Cross sectional area × Thermal gradient

$$H = kA\frac{\Delta T}{L}$$

$$= kA(T_1 - T_2)/L$$

$$= 0.8 \times (2.2 \times 1.2) \times (22 - 3)/0.005$$

$$H = 8026 \text{ Watt}$$

Thermal conduction applications include :

1. Using metals to make Kitchen-ware.
2. Using insulating material for handles in Kitchen-ware.
3. Thermal insulation in house constructions using insulating materials like air, glass and polystyrene, the engineers are using thermal insulating system for a wall composed of two layers having different thickness (L_1, L_2) and thermal conduction coefficient of (k_1, k_2) and surface temperature of (T_1, T_2), see figure (4.21), when this system reaches to thermal stability state then the temperature at any point in the wall and the average of heat transfer energy will not change with time means the average of heat transfer that transmission from the first layer is same that transmission from the second layer.

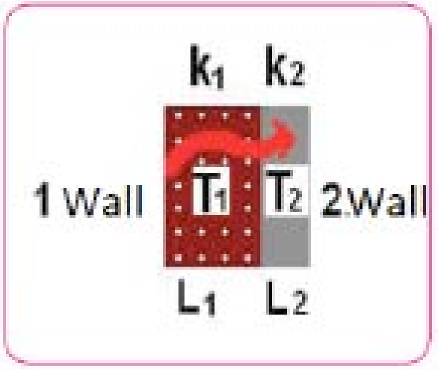


Figure (4.21)

One of the other application on thermal insulation is the thermos can which is made of an interior layer of plastic and an exterior layer of polystyrene, and according to this system the temperature of the liquid in it is kept by reducing thermal leakage to the outside.

Question

If an ice cube was placed in an aluminum box and another identical cube was placed in a wood box, then which one of the cubes melts first at room temperature?

Do you know ?

Engineers took the expression of thermal resistance for an insulating layer and it's calculated according to the following equation:

$$\text{Thermal resistance} = \frac{\text{Layer thickness}}{\text{Thermal conduction Coefficient of the layer}}$$

Transfer of heat by convection

We knew in the thermal conduction method that the thermal energy flows through the material without the transfer of the material's particles themselves.

While we find in thermal convection method that the material's particles themselves move and transfer from one place to another, and thermal convection occurs only in fluid and doesn't occur in solids, and its common to us that placing the heater in one of the room sides results in heating all the room after time and this phenomenon results from the transfer of heat by convection, see figure (4.22).

Figure (4.22)

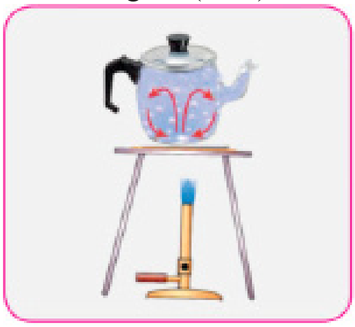


Figure (4.23)

And convectional streams also occur in liquids, when you put a metallic pot filled contains water on a heat source, see figure (4.23) then the water that is near the heat source warms up more than the water in the other places thus it expands and its density decreases compared to the density of the surrounding water as a result it raises carrying thermal energy with it by method called thermal convection and another water with less temperature comes to its place, heat is transferred in gases by the same way.

Types of convection

1. Free convection

In this type the convectional current generate by effect of gravity, see figure (4.24), cold air have greater density so it comes down because the upthrust force is less than its weight, while hot air's density is less so it goes up carrying the thermal energy with it because the upthrust force is greater than its weight in this case.

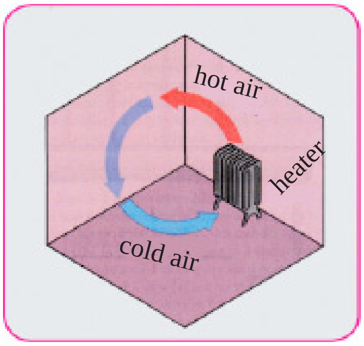


Figure (4.24)

2. Forced convection

In this type the fluid is motivated to circulate by installing a pump or a fan in the fluid's way that creates a pressure difference which forces the particles to move, hence in some central heating processes the hot air is pushed into the halls using fan or the hot water is pumped into radiators that's placed on the ground, see figure (4.25).

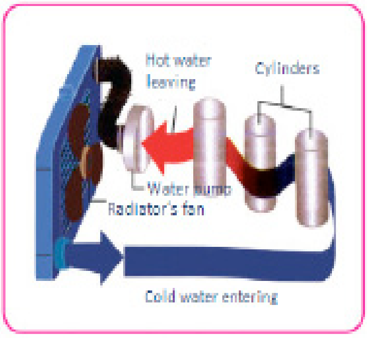


Figure (4.25)
Cooling in car engine

THINK

Which one of the methods is used in the car engine's cooling, explain that?

Heat transfer by radiation

You have studied before that the sun's heat transfers and reaches to the earth and warms it and we know that there is a huge gap between the sun and the earth that doesn't allow heat to be transferred whether by conduction or by convection method since there is no material medium that transfers the heat, the method that heat is transferred from the sun is called radiation. Heat is transferred by radiation in form of electromagnetic waves in the speed of light and its wavelengths differ depending on the radiating object's temperature, and it ranges between violet rays and infrared rays. And all the objects radiate energy in the form of electromagnetic waves even the ice cube and our bodies. And the amount of radiation energy emitted from the objects **depends on:**

1. The nature of the surface that emits radiation energy that's as long as the surface's area increases the amount of emitted energy increases. also its color, since black surface radiates energy with an average that is very greater then the average emitted by a fair colored object.
2. Temperature: the objects radiates energy in the form of electromagnetic waves that can be seen if the temperature of the objects was high while the radiations are invisible when the object's temperature is low.

And its worth to mention that material those are good heat radiation are also good heat absorbers and the amount of absorbed heat energy differs by the following changes:

1. Type of the material
2. Color of the material
3. How smooth it is

Where smooth and fair colored objects absorb radiation energy less than rough and dark colored objects do

Figure (4.26)

Application on heat transfer by convection and radiation methods:

1. Plastic (glass) houses $\longrightarrow$ radiation, see figure (4.26).
2. Solar heater $\longrightarrow$ radiation (see figure 4.27).
3. Central heating $\longrightarrow$ convection + radiation
4. Night photographing by infrared rays $\longrightarrow$ radiation.

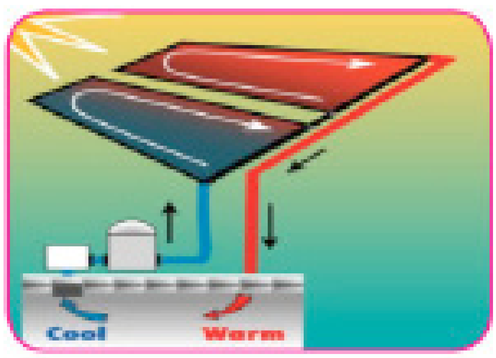


Figure (4.27)

4.7 Thermal Pollution

Human in our century is making many activities that result together in the temperature increase of the land and atmosphere and water which leads to a dysfunction in the environmental structure and this phenomenon is named thermal pollution

Thermal pollution sources:

Thermal pollution is considered an industrial problem in spite of the civil waste also cause a limited change in the temperature of receiving water for this waste, the most important thermal pollution sources are:

1. Electrical energy generating sources:

These stations are constructed near waters sources (like rivers or seas), see figure (4.28). And that's because of the huge amount of waters that these stations need for cooling purpose. And the waters those enter to the station for cooling process gain high thermal energy that causes a big raise in the leaving waters temperature and these waters are discharged into the same water source that were taken from resulting in pollution to the waters of the water source. and also the nuclear energy stations:

Figure (4.28)

Where some of the heat is released into the atmosphere through chimneys and due to the high generating efficiency and for environmental concerns and in fear of escaping to the atmosphere that becomes difficult, so the bigger amount of the thermal energy that results from the nuclear stations is discharged into the water sources close to it, see figure (4.29).

2. Petroleum industry and refineries

Petroleum refineries use huge quantities of waters for cooling and in different industrial processes. And these hot waters that results from theses processes are discharged into the water sources (like rivers or seas) and this causes a big damage for micro aquatic organisms that are in the waters, and the waters that come out of the refineries contain oils and fats which leads to the pollution of the water sources by oil.

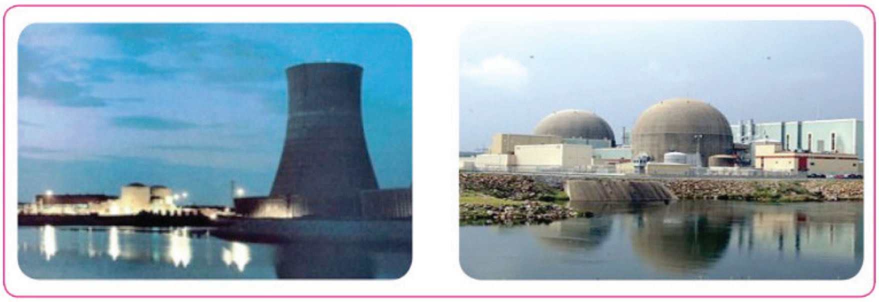


Figure (4.29)

Questions of Chapter four

Q1. Choose correct answer for the following questions.

1. When water converse from one state to another then its temperature:

a. Increases by one Celsius degree.
b. Always changes.
c. Decreases by one Celsius degree then stay constant until all the water amount is converted.
d. Stay constant until all the water amount is converted.

2. When the first object of (T_1) temperature contacts with the second object of (T_2) temperature both are thermally insulated from the surrounding medium, so if ($T_1>T_2$) then the heat energy transfer between them continues until:

a. The second object's temperature become less than the first object.
b. The first object's temperature become less than the second object.
c. Both of them reaches the same temperature (T) where ($T_2<T<T_1$).
d. The temperature of the first object become zero.

3. If The time average of the transfer of thermal energy from the window's glass to the room was (H), then if the area and the thickness of the glass were decreased to half then the time average of the transfer of thermal energy becomes:

a. 4H b. 2H c. H d. H/2

4. Heat Transfer in gases occurs by:

a. Radiation only.
b. Convection only.
c. Radiation and convection only.
d. Radiation, conduction and convection.

5. When Vapor condenses and becomes liquid:

a. Its temperature increases.
b. Its temperature decreases.
c. Absorbs heat.
d. Emits heat.

6. Heat transfer is space is done by:

a. Radiation only.
b. Convection only.
c. Radiation and convection only.
d. Radiation, conduction and convection.

7. When the mass and the temperature is constant then the heat quantity of the object depends on:

a. Volume of the object.
b. Shape of the object.
c. Type of the material of the object.
d. All of the above.

8. When matter convers from liquid state to gaseous state at the boiling point then it should be supplied by a heat quantity equals to:

a. Multiplication result of the mass × latent heat of vaporization × temperature.
b. Multiplication result of the mass × temperature difference.
c. Quantity of latent heat of vaporization.
d. Multiplication result of the mass × latent heat of vaporization.

Q2 Answer the following questions:

1. Three rods of copper, steel and aluminum have equal length at (0°C) which one of them will be longer at (250°C).
2. Steel rods are added to reinforced cement to strength it, why the stell is considered suitable to strengthen the cement?
3. Why its advised not to open the radiators cover until the engine cools down, explain that ?
4. The pipes in the solar heater are painted with black paint, why?
5. The water in the aluminum cup freezes before the water in the glass cup when placed in the fridge ?
6. When you touch two pieces one is iron and the other is wood at (0°C) you feel like the iron is colder. Why?
7. Hot water is poured out on the glass containers cover that contain specific food in order to open it easily?

PROBLEMS

1. A piece of gold of 100g mass and at (25°C) and its specific heat is (129 J/kg.°C) calculate:

a. Thermal capacity of the piece
b. Temperature of the gold piece if it is supplied by heat quantity of 516 joule

Ans: a. c =12.9 Joule/°C, b. T_2 = 65°C

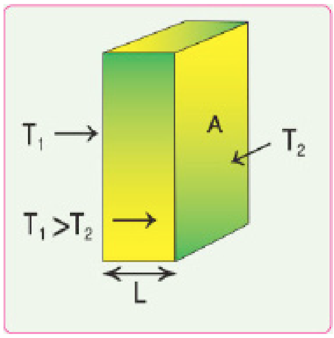
2. What is the quantity of heat that a (160g) mass of water vapor lost at (100°C) when the water became (20°C)?

Ans: Q_{total} = - 415360 Joule

3. A container of (50 J/°C) thermal capacity contains (0.5kg) of water at (10°C), an amount of (1 kg) hot water at (80°C) was added to the water in the container, what is the final temperature of the mixture?

Ans: T_f = 56.3°C

4. **A wall of bricks with ($10m^2$) area and (15cm) thick, calculate the time average for transfer thermal energy if it's two sides temperature are (T_1= 20°C), (T_2= 10°C), see the near by figure, noting that thermal conduction coefficient of bricks is (0.63 watt/m.°C).**



Ans: H = 420 watt

5. **When heating three quantity of water of masses (m_1= 0.5kg), (m_2= 0.1kg), (m_3= 1kg) by same heaters for three minute which one of the masses temperature raise more, and why?**

6. **(0.5 kg) of water and the same amount of oil were heated for the same time, which on of the objects gets warm faster? And why?**

7. **What is the quantity of heat that a (200g) of water gains when temperature increase from (20 to 80°C)?**

Ans : Q = 50400 Joule

8. **What is the quantity of heat that a (500g) of copper looses when its temperature decreases from (75 to 25°C)?**

Ans : Q= -9675 Joule

9. **What is the final temperature for a (300g) of water with initial temperature of (20°C) when gains (37800 Joule) of heat quantity?**

Ans: T = 50°C

10. **A (0.5kg) of water at (20°C) was placed in the ice cubes tray and then entered to the upper freezing part of the fridge, what is the amount of energy that need to be removed from the water to convert it into ice cubes at (-5°C)?**

Ans: Q_{total} = -214732.5 Joule

Chapter 5: The Light

5.1 Light nature and its propagation

The light that falls on objects and being reflected from them and that reaches to the eye allows us to see them. The objects that emit light are called luminous objects like the lighted candle and the sun, and the objects that reflect light are called by the illuminated objects like the moon, see figure (5.1). But the light does not limit to this. For example, the bodies that sun light falls on them are heated. This means the light has energy that transfers it from the sun to the earth through the free space, and its known that energy transfers either by waves or particles, and according to this the nature of light was explained by two theories: they are the particulate theory and the wave theory.

Luminous object Illuminated object

Figure (5.1)

According to the particulate theory, the light is a flux of very small particles called by Newton (corpuscles) diffused in a medium and he explained using it the phenomena of reflection, refraction and the spread of light in straight lines in the homogeneous medium (but his explanation of the phenomenon of refraction was wrong), see figure (5.2).

While the scientist Huygens who was contemporary of Newton assumed the wave theory and he explained using it the Phenomena of reflection, refraction, interference and diffraction in light. And each of these two theories had both supporters and objectors. The particulate theory prevailed for more than a century because Newton had a prestigious scientific position. Although that neither of these two theories alone could not explain all optical phenomena fully explained.

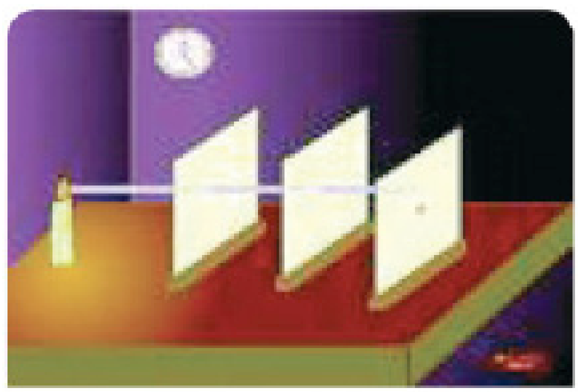


Figure (5.2)

And at the end of the 19th century, Clark Maxwell put electromagnetic theory, it showed that each light ray is an electromagnetic wave.

And by that he reinforces the role of the wave theory again and by looking to figure (5.3) we find that the frequency of the electromagnetic spectrum includes frequencies of visible light waves whose wavelengths range from approximately (400nm) and it is the violet color to approximately (700nm) and it is the red color.

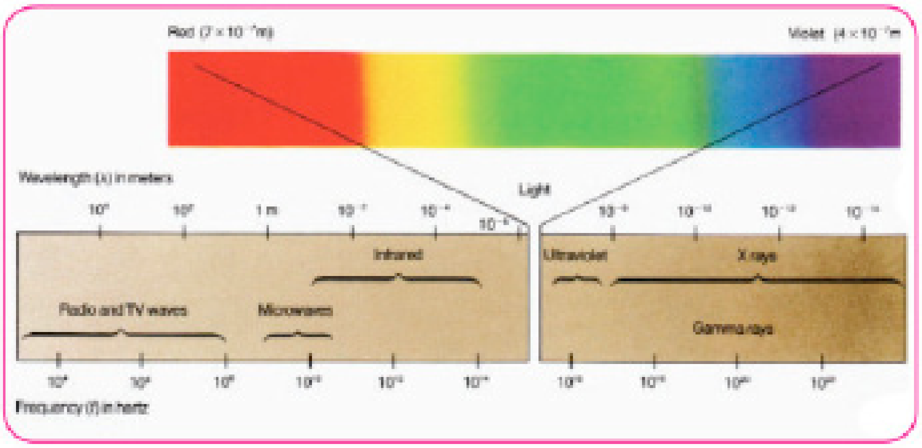


Figure (5.3)

The frequency of the visible light can be found using its wavelength (λ) and the speed of light in space according to the following relation:

$$\text{Frequency} = \frac{\text{speed of light in vacuum}}{\text{Wavelength}}$$

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

Where:

c: speed of light in vacuum (3×10^{8}) m/s.

λ: wavelength.

f: frequency.

And it is worth mentioning that there are other phenomena that the electromagnetic theory has failed to explain such as the phenomenon of blackbody radiation and photoelectric phenomenon, which was later explained by the scientist Max Planck (assuming that the light does not radiate from the source in the form of waves but in the form of specific packages of energy those are indivisible called (Photons), and light quantum energy (photon) is directly proportional to the frequency of its radiation.

Do you know?

That light year is the distance that The light travel it in the vacuum at speed of (3×10^{8}) m/s in (365) days Which is estimated about (10^{13} km).

$$\text{Photon Energy} = \text{Planck constant} \times \text{frequency of radiation}$$

$$E = h.f$$

Where:

E : energy of the photon

f : frequency

h: Planck's constant equals (6.63×10^{-34} J.s)

Example 1

Calculate the frequency of the violet light that have wavelength of (400nm), noting that the speed of light in the vacuum is ($c = 3 \times 10^{8}$ m/s)?

Solution

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

$$f = \frac{3 \times 10^{8}}{400 \times 10^{-9}}$$

$f = 7.5 \times 10^{14}$ Hz frequency of the violet light.

Example 2

What is the energy of the green light radiation photon whose wavelength is (555nm)?

Solution

Energy of the photon = Planck's constant × frequency

$E = h.\ f$

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

$$E = \frac{hc}{\lambda}$$

$\lambda = 555 \text{ nm} = 555 \times 10^{-9}$ m

$$E = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{555 \times 10^{-9}}$$

$E = 3.58 \times 10^{-19}$ J energy of the green light radiation photon.

5.2 Point Light Source

The light waves are transmitted in the homogeneous medium in straight lines and in the direction of light propagation. If these waves encounter a barrier with a circular opening of diameter (d) that is much larger than the wavelength of light ($d>>\lambda$), the wave passes through this opening and continues to move in a straight line, see figure (5.4a). But If the diameter of the barrier's opening is approximately as much as the wavelength of this light ($\lambda= d$) then it will be diffused from the opening in all directions see figure (5.4b). But If the diameter of the barrier's opening is much smaller than the wavelength of the light ($d<<\lambda$) then this opening is considered as a point source of light, see figure (5.4c).

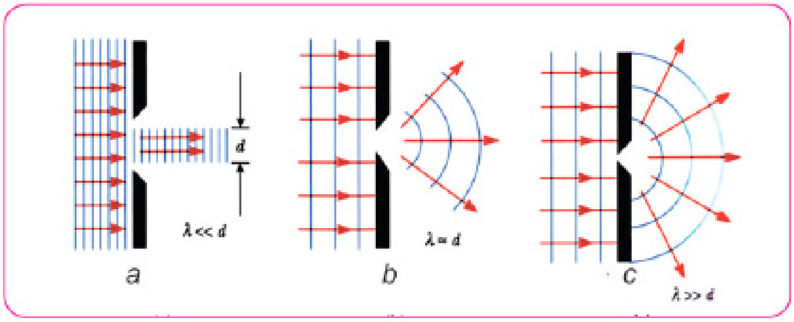


Figure (5.4)

5.3 Huygen's principle

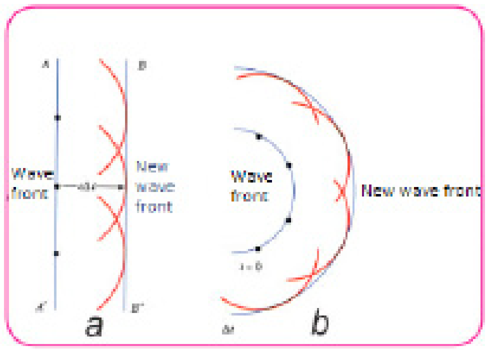


Figure (5.5)

Huygen's principle states that (Each point of the wave front points is considered a point source to generate secondary spherical waves called wavelets) Which spread away from the source through the medium at a certain waves velocity in that medium. After some time, the new position of the wave front is the tangential surface of the wavelets. Consider a plane wave moving through the free space, see figure (5.5a) at time ($t = 0$). The wave front is represented by (AA') plane. According to Huygen's virtual principle any point on the wave front is considered as a point source. And by the same way figure (5.5b) shows a virtual construction of Huygen's principle for spherical wave.


Figure (5.6)

Figure (5.6) shows the Huygen's principle, plane waves coming from a far towards the shore passing through openings in the barrier wall in the form of circular waves with two dimensions diffused outward towards the beach.

5.4 Luminous Intensity

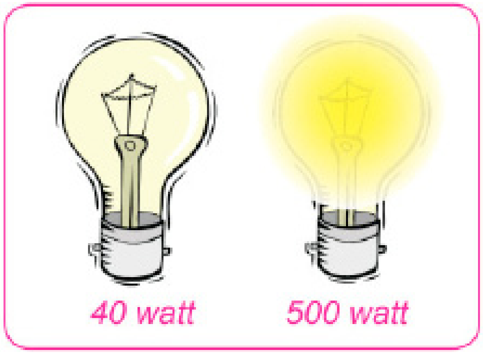


Figure (5.7)

We have noticed previously the difference of light sources in their light production, The sun lights up more than the light of the lamp on a particular surface and the lamp lights more than the light of the candle for the same conditions.

If we take two identical lamps of the same type, the power of one of them is (500) watt and the other is (40) watt, the first lamp lights more than the second lamp, see figure (5.7) This difference is due to the difference in the luminous intensity, means the difference in the average time of emitted energy from each of the light sources and on this basis we can say that: the luminous intensity of the first lamp is more than the luminous intensity of the second lamp and the luminous intensity for a light source is known as the amount of light energy (visible) emitted from a light source per unit time.

To evaluate the effect of light rays to the eye, a physical quantity called luminous flux is used and its known as: The part of the radiation flux that generates a light sensation in the eye so it is a measure to luminous intensity of the source. (l)

And it's expressed by the following mathematical relation

Luminous flux = 4π × Luminous intensity of the source

$$\phi = 4\pi 1$$

Where:

l = illumination intensity of the point source measured by Candela (cd) and the luminous flux (Φ) is measured by lumen (Lm) which is known by incident flux on a ($1m^2$) unit area of a spherical surface that's radius is one meter and a point light source of one Candela (cd) is placed in its center, see figure (5.8).

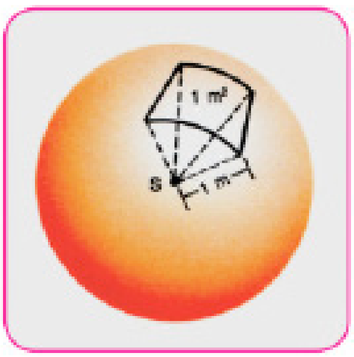


Figure (5.8)

Do you know?

That an electric light lamb of (100W) has illumination power of (139) cd and gives a luminous flux of (1750) Lm when it's operating.

5.5 ILLuminance (E)

It is difficult to see objects around us in a dark room, but when there is a burning candle its light allows us to see the objects around us, and this is explained by the spread of a luminous flux from the light source (the candle) where some of the incident flux on those objects is reflected to the eye then we can see these objects. Whenever the incident luminous flux on the visible objects is larger our vision of these objects is clearer, it means that the amount of illuminance (E) distinguishes different vision of the objects caused by the incident luminous flux on them and we call it Illuminance.

So when the incident luminous flux on a surface is regular then the amount of illuminance is measured by the incident luminous flux perpendicular on the unit area of this surface, means:

$$\text{Illuminance} = \frac{\text{Luminous flux}}{\text{Area}}$$

$$E = \frac{\phi}{A}$$

Where

E = illuminance and measured by lumen/m^2 and it's called: (Lux).

Lux = Lm/m^2.

A = area measured by m^2.

ϕ = luminous flux measured by (Lm)

Illuminance (E) is measured by the photometer device and the Luxmeter, see figure (5.9).

Figure (5.9)

5.6 Inverse Square Law

There are two ways to increase the illuminance on a surface using a point source of Luminous intensity is known and they are:

1. Increase the incident luminous flux (ϕ) on the lighted surface.
2. Decrease the distance between the point light source and the lighted surface.

According to this illuminance (E) is direct proportional with luminous flux of the source and inverse proportional with square of the distance between the point light source and the lighted surface that faces the light source according to the following relation:

$$E = \frac{\phi}{4\pi r^2}$$

Φ = incident luminous flux that's perpendicular to the area.

r = distance between the point light source and the lighted surface.

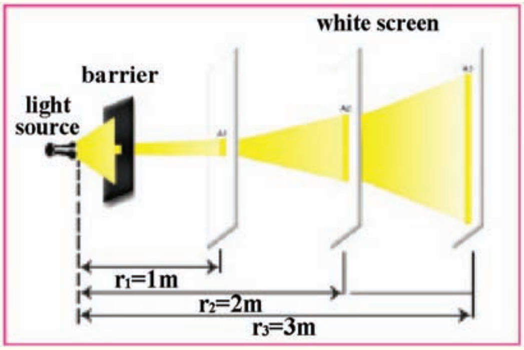
And the above equation satisfies only in the case of the perpendicular incidence of light that production from a point light source.

Activity

Illuminance for a point light source is inversely proportional to the square of the distance between the source and the lighted surface.

Activity tools:

Light source, barrier having square shaped opening, white screen.



Steps:

* We attach the barrier in front of the light source and make the screen at a distance of (1m) (r_1= 1m) from the source, then a lighted surface will appear on the screen and its area is (A_1) square shaped.

* We make the screen at a distance of (2m) (r_2 = 2m) from the source a lighted surface square shaped surface appears with (A_2) area that's four times greater than (A_1), which means that the illuminance on the screen decreased to $\frac{1}{4}$ what it was firstly.

* We make the screen at a distance of 3m (r_3 = 3m) from the source. We will get a lighted surface square shaped with (A_3) area on it, that's nine times greater than (A_1), which means that the illuminance on the screen decreased to $\frac{1}{9}$ what it was firstly.

Conclusion: Since the incident luminous flux (ϕ) on the surface stay constant in the three cases and;

$$\phi = \text{constant}$$

$$E = \frac{\phi}{4\pi r^2}$$

$$E \alpha \frac{1}{r^2}$$

$$E_1 = \frac{\phi}{4\pi r_1^2} \text{ and } E_2 = \frac{\phi}{4\pi r_2^2}$$

The illuminance on the lighted plane is inversely proportional to the square of its distance from the point light source, means:

$$\frac{E_1}{E_2} = \frac{r_2^2}{r_1^2}$$

Example 1

A white screen is placed at a perpendicular level to the direction of the incidence of a rays of light from a point source having a luminous intensity of (5cd), calculate the amount illuminance on the screen if it is (5m) away from the source.

Solution

$$\text{Illuminance} = \frac{\text{Luminous intensity}}{\text{Square of the distance from the source}}$$

in perpendicular incidence case: $E = \frac{\phi}{4\pi r^2}$

$$E \alpha \frac{1}{r^2} \quad , \quad I = \frac{\phi}{4\pi}$$

$$E = \frac{I}{r^2}, \quad E = \frac{5}{25} \text{Lm/m}^2, \quad E = 0.2\text{Lux}$$

Example 2

A lamp having a luminous intensity of (32cd), and its distance of (0.6m) from a screen and there is another lamp on the other side of the screen its distance of (1.2m) from it then if the illuminance was equal on both side of the screen, what is the luminous intensity of the second lamb?

Solution:

$\because E_1 = E_2$

$$\frac{l_1}{r_1^2} = \frac{l_1}{r_2^2} \quad , \quad \frac{l_2}{l_1} = \frac{r_2^2}{r_1^2}$$

$$\frac{l_1}{32} = \frac{(1.2)^2}{(0.6)^2}$$

$$l_2 = \frac{32 \times 1.44}{0.36}$$

$l_2 = 128$ cd luminous intensity of the second lamb.

Questions of chapter five

Q1. Choose the correct answer for the following questions.

1. Light produces a point source spread in the vacuum in:

a. One direction b. Two direction
c. All directions d. All of the above

2. To double the illuminance directly on a horizontal table surface where the lighted lamb is placed exactly above it on 1m height from its center, by making the lamb at Height

a.0.75m b. 0.707m
c. 0.5m d. 0.25m

3. The luminous intensity is measured by:

a. Candle b. lux
c. Watt d. Lumen

4. Illuminance is measured by:

a. Joule b. Lumen
c. Lux d. Watt

5. As long as the distance of the surface that's lighted by a point source increases the illuminance on the surface:

a. Decreases b. Increases
c. Not effected d. All of the above

6. A point light source is placed in the center of a spherical surface, if the radius of curvature for this plane increased then the incident luminous flux from the source:

a. Decreases b. Increases
c. Doesn't change d. All of the above

PROBLEM

Q1. Two lamps the luminous intensity of the first one is nine times that of the second one and the distance between them is (1m), where a photometer should be placed between the two sources to become the illuminance to be equal on both sides of the photometer ?

Answer: X = 0.75m

Q2. A lamp with luminous intensity of (12cd) was placed (1.2m) distance from a photometer and on the other side of it another lamp was placed at (1.32m) distance, the illuminance was equal on both sides of the photometer, calculate the luminous intensity of the second lamp.

Answer: $I_2 = 14.52$ cd

Q3. A lighted lamp in a perpendicular incidence on a book's page creating a luminous flux of (100πLm) how far the book from the lamp? if its illuminance was (4Lux).

Answer: r = 2.5m

Q4. In a moonlighted night where the moon was full in it, the illuminance was (0.6 Lux) find the luminous intensity of the moon in that night, noting that the distance between the moon and the earth is (3.84×10^8 m).

Answer: $I = 8.84 \times 10^{16}$ cd

Q5. A light photon having a radiation wavelength of (600nm), what is the amount of energy noting that Planck's constant is ($h=6.63 \times 10^{-34}$ J.s)?

Answer: $E= 3.315 \times 10^{-19}$ J

6.1 Introduction to reflection and refraction of light

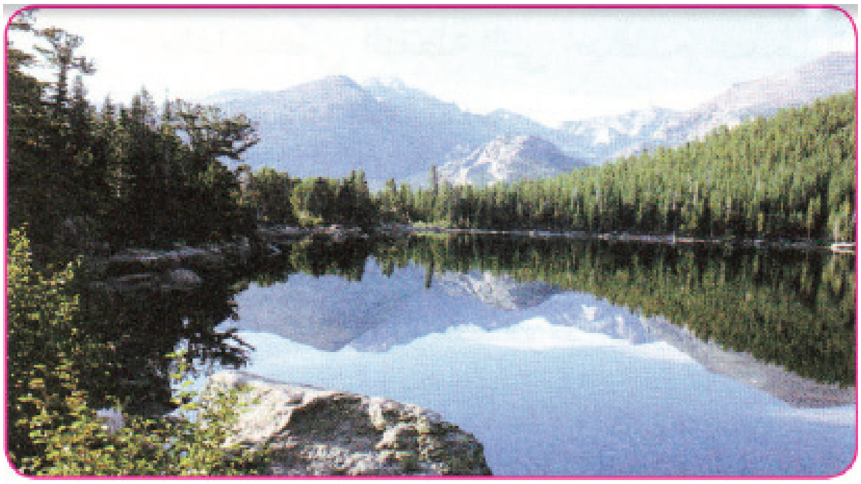


Figure (6.1)

If we asked the following question: Why an image of the group of mountains and trees is made up in the water as in figure (6.1)? Your answer will be that the image is the result of the reflection phenomenon light. So what is the meaning of reflection of light? And what happens when the light falls on a transparent surface for example?

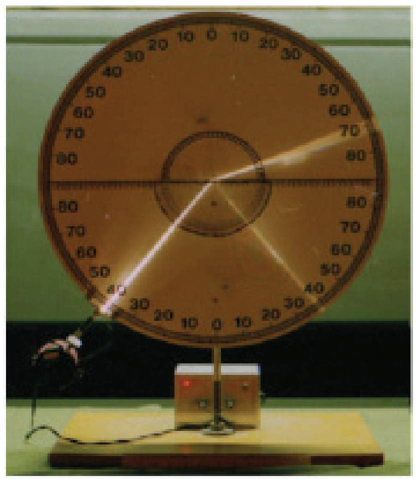


Figure (6.2)

The reflection of light is the phenomenon of the rebound of the incident light on a surface that separates between two medium to the medium that came from it. If the light falls on a surface part of it is reflected and another part is passed through the transparent objects and the remaining is absorbed by that surface, see figure (6.2).

We explained briefly phenomenon of reflection light, is this always the behavior of light when it falls on a surface separator between two different transparent mediums?

A question that needs to be answered and we also need to answer on two following questions:

Why the fish seems in a basin with water at a depth less than its real depth? And why the pen seems broken when placed in a glass filled with water?

See figure (6.3), the reason of that is the light refraction phenomenon, so what is the meaning of refraction of light?

The refraction of light is a change of the direction of the light ray when moving between two transparent medium different in optical density if it fall in an oblique way on the separating surface between two medium, what we mean by optical density?

Figure (6.3)

Optical density is an property of the transparent medium that the speed of the light passing through the medium depends on.

As long as the optical density of the transparent medium increases the speed of light in it decreases and vice versa.

For example the speed of light in glass (lets assume it υ_2) is less than the speed of it in air (lets assume it υ_1) and that's because the optical density of glass is greater than the optical density of air, see figure (6.4).

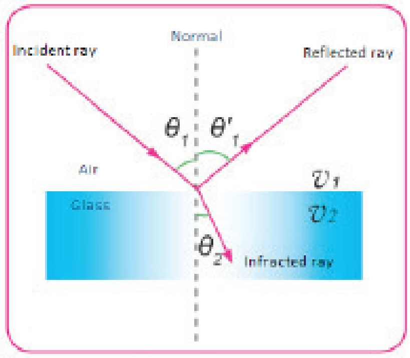


Figure (6.4)

6.2 Reflection of Light and the Laws of Reflection

In the previous paragraph we talked about the phenomenon of light reflection, see figure (6.5), so what the laws that control it? And how we can prove them practically?

To clarify the idea of light reflection practically we do the following activity:

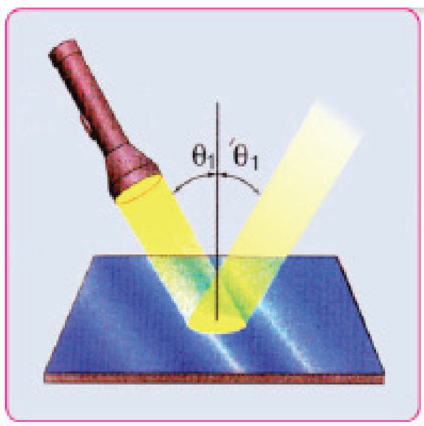


Figure (6.5)

Activity 1: Special Concepts of light reflection

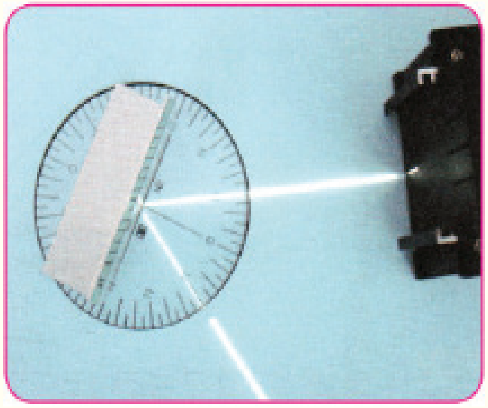


Figure (6.6)

Activity Tools: Light source with parallel light beam (Or laser source), plane mirror, piece of Polystyrene material to install the mirror on it, paper (or transparent panel) Placed (or painted) on it a protractor.

Steps:

* We arrange the activity tools as in figure (6.6).
* We send a thin beam of light from a light source (or a laser source) in an oblique form towards the perpendicular plane mirror on the paper, we will see the reflection of light from the surface of the mirror from a point called incidence point.
* We Draw a column from the incidence point of the incident ray on the reflective surface

Can you now conclude the relationship between the incident ray, the reflected ray, and the column normal to the reflective surface?

* We determine the incidence angle (θ_1) (Which is the angle between the incident ray and the column normal) and reflection angle (θ'_1) (which is the angle between the reflected ray and the normal) and then we measure the two values of the incident angle and reflected angle for this condition.

Table (1)

Incidence angle θ_1	25°	30°	35°	40°
Reflected angle θ'_1	25°	30°	35°	40°

* We change the incident angle many times and determine the value of the reflected angle correspond in all cases and we write the results in table (1).

Conclusion: from your results that you obtained from this activity you must have reached that the reflection of light is the phenomenon of the bounding of the incident light on a surface that separates between two medium to the medium that it came from. Also you have surely reached to the two laws of reflection.

First law of reflection	Second law of reflection
The incident ray, reflected ray, column drawn from the incidence point (normal) are all lie in one plane.	Incidence angle equals to the reflected angle.

6.3 Refraction of Light and the Laws of Refraction

It has become clear to you that the process of refraction of light means change of direction of the light ray when travels between two transparent medium those are different in the optical density when it falls in an oblique way on one of the two surfaces and the reason for this is the change of the speed of light from the first transparent medium to the second transparent medium, see figure (6.7).


Figure (6.7)

How is the path of the refracted ray inside the refracting medium? When a light ray that have fallen obliquely from a transparent medium that is less optical density such as air to another medium of higher optical density such as glass, so is transmits into the other medium and refract getting close to the normal of the surface that separate between two mediums as in figure (6.8) means the incidence angle (θ_1) is greater than the refraction angle (θ_2). And when a light ray that have fallen obliquely from a transparent medium that have high optical density to another medium of lower optical density, so is transmits into the other transparent medium and refract getting away from the normal as in figure (6.9) means the incidence angle (θ_1) is smaller than the refraction angle (θ_2).
To clarify the idea of refraction practically we perform the following activity:

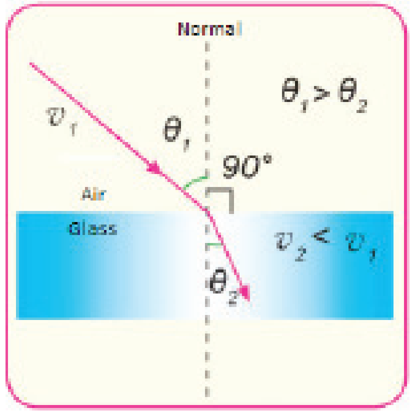


Figure (6.8)

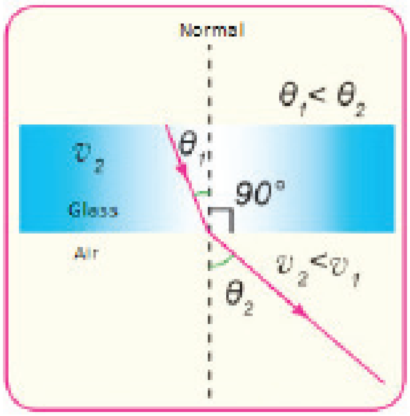


Figure (6.9)

Activity 2 Special concept about refraction of light

Activity tools:

Transparent container (plastic or glass filled with water), light source of a particular wavelength, chalk dust, protractors, paper.

Steps:

* Arrange the activity tools as in figure (6.10), notice that it is Preferred that the workplace has a dark background.

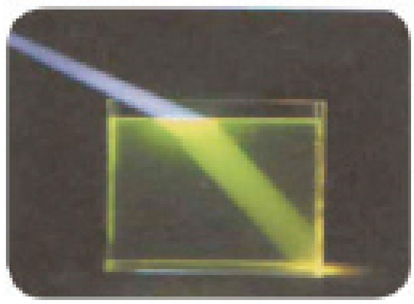


Figure (6.10)

* Direct light ray to be perpendicular to the separating surface between two transparent medium (water and air in this activity), what do notice? You will notice that the light is transmitted perpendicular on the separating surface between the two mediums without bending or (refracted), means the light ray is not refracted.

* Direct the light but this time in an oblique way (not perpendicular) on the separating surface, when you look at it in a perpendicular way from one sides then you will notice the transmitted light (mean refracted ray) is not on the straightness of the incident light like in the perpendicular incidence case but it deviate from its path (means refracted), see figures (6.10), (6.11).

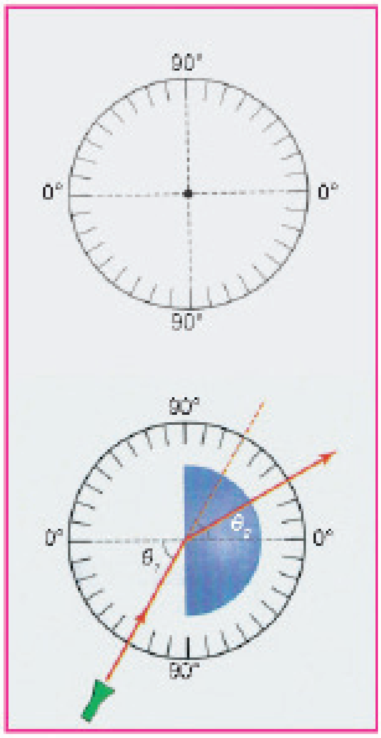


Figure (6.11)

* On the paper determine the separating surface between two mediums, and the incident ray and refracted ray as well as the normal on the separating surface from the incidence point now you must have noticed that the incident ray, and refracted ray and the normal are all lie in one plane perpendicular on the separating surface.

* By using the protractors find the value of the angle between the incident ray and the normal, which called the incidence angle (θ_1), Also find the value of the angle between the refracted ray and the normal which called the refraction angle (θ_2). did you find them equal? Actually you will notice they are not equal.

* Change the incidence angle many times you will notice a change in the refraction angle that is correspond to it in each case, then find the sine of the incidence angle and the sine of the refracted angle in each case (you can arrange the results in a table) then you will find that the ratio between the sine of the incidence angle ($\sin \theta_1$) and the sine of the reflected angle ($\sin \theta_2$), is constant in all cases. From the previous activity you knew some of the concepts that's related to the light refraction phenomenon that you have studied before and that states:

The first law of refraction

The incident ray, refracted ray, and the normal or (normal line) drawn from the incidence point on the separating surface are all lie in one plane perpendicular on the surface separating between two transparent medium.

The second law of refraction

The ratio of the sine of the incidence angle to the sine of the reflected angle is equal to constant value.

6.4 Index of Refraction and Snell's Law

We previously noticed that the ratio of sin incident angle for the incident ray in first transparent medium to sine refraction angle for the second transparent medium is a fixed ratio of these two mediums. This ratio is called index of refraction from the first transparent medium to the second transparent medium or the relative index of refraction between two transparent mediums and its given according to the following relation:

$$ {}_1n_2 = \frac{\sin\theta_1}{\sin\theta_2} \quad .... (6 - 1)$$

Where:

$\sin\theta_1$: is sine incidence angle for incident ray in the first transparent medium.

$\sin\theta_2$: is sine refraction angle for refracted ray in the second transparent medium.

${}_1n_2$: The relative index of refraction between the two transparent mediums or index of refraction from first transparent medium to second transparent medium.

The relative index of refraction between two transparent mediums also equals to the ratio of light speed in the first transparent medium (υ_1) to light speed in second transparent medium (υ_2) means:

$$ {}_1n_2 = \frac{\upsilon_1}{\upsilon_2} \quad .... (6 - 2)$$

From the two equations (6.1), (6.2) we can write:

$$ \frac{\upsilon_1}{\upsilon_2} = \frac{\sin\theta_1}{\sin\theta_2} \quad .... (6 - 3)$$

Using (Huygens's principle) that you have seen before we get:

$$ \frac{\sin\theta_1}{\sin\theta_2} = \frac{\lambda_1}{\lambda_2} \quad .... (6 - 4)$$

Where

λ_1: wavelength of light in the first transparent medium (or the first transparent material).

λ_2: wavelength of light in the second transparent medium (or the second transparent material).

From the two equations (6.3), (6.4) we can get:

$$\frac{\upsilon_1}{\upsilon_2} = \frac{\lambda_1}{\lambda_2} \quad \text{..................} (6 - 5)$$

When the first transparent medium is vacuum then, (υ_1 = c) in equation (6.2) where (c) represents the speed of light in vacuum is equal (3×10^8 m/s), in this case the refraction index is called absolute index of refraction (n), given by the following relation:

$$\text{Absolute index of refraction of the medium (or the transparent material)} = \frac{\text{Light speed in vacuum}}{\text{Light speed in the transparent medium (or transparent material)}}$$

$$n = \frac{c}{\upsilon} \quad \text{...........} (6 - 6)$$

Where (υ) represents light speed in material transparent medium means, the absolute index of refraction transparent material equals to ratio of light speed in the vacuum to light speed in transparent material, and it is worth to mention that light speed in any material (or medium) is always less than light speed in vacuum.

REMEMBER

Each incidence angle has a specific refraction angle of its own between two medium of different optical density.

Example 1

It was found that the light speed in a transparent medium equals to (1.56×10^8 m/s), find the absolute index of refraction of this medium, if you know that the light speed in the vacuum is equal to (3×10^8 m/s)?

Solution

We have the relation

$$\text{Absolute index of refraction of the medium} = \frac{\text{Light speed in vacuum}}{\text{Light speed in the transparent medium}}$$

$$n = \frac{c}{v} = \frac{3 \times 10^8}{1.56 \times 10^8} = \frac{3}{1.56}$$

n = 1.92 absolute index of refraction.

REMEMBER:

The absolute index of refraction of the vacuum equals to one (n=1).

Table (2) show the values of the absolute index of refraction of some material (solid, liquid, gas) for the sodium light that's wavelength is about (589 nm) at (20°C).

Material	Absolute index of refraction	Material	Absolute index of refraction	Material	Absolute index of refraction
1. Gases*		2. Liquids **		3.solids **	
Air	1.00029	Water	1.33	Polystyrene	1.49
Water vapor	1.00025	Acetone	1.36	Window glass	1.52
Carbon dioxide	1.00045	Carbon-tetrachloride	1.46	Sodium chloride	1.54
		Glycerin	1.47	Zircon	1.92
				Diamond	2.42

You have been learned to the absolute index of refraction of a transparent material or a transparent medium as well as the relative index of refraction between two transparent mediums, is there a relationship between the relative index of refraction for two transparent mediums and the absolute index of refraction of them? And what is that relationship?

From equation (6.6) we can write the absolute index of refraction for first transparent medium:

$$n_1 = \frac{c}{\upsilon_1} \ldots\ldots\ldots (6 - 7)$$

Also the absolute index of refraction for the second transparent medium equal:

$$n_2 = \frac{c}{\upsilon_2} \ldots\ldots\ldots (6 - 8)$$

By dividing equation (6.8) in equation (6.7) we get:

$$\frac{n_2}{n_1} = \frac{\upsilon_1}{\upsilon_2} \ldots\ldots\ldots (6 - 9)$$

From equation (6.7)

$$\frac{n_2}{n_1} = \frac{\lambda_1}{\lambda_2} \ldots\ldots\ldots (6 - 10)$$

Also from the equation (6.2) and (6.9) we can write:

$${}_1n_2 = \frac{n_2}{n_1} \ldots\ldots\ldots (6 - 11)$$

Means that the relative index of refraction from first transparent medium to second transparent medium is equal to ratio between absolute index of refraction for second transparent medium to the absolute index of refraction of first transparent medium. And after our conclusion of previous relationship, equation (6.11) now we can reach to one of important laws on optical physics: (Snell's law), how can we reach it?

Using equations (6.1) and (6.11) we can write:

$$\frac{n_2}{n_1} = \frac{\sin\theta_1}{\sin\theta_2} \ldots\ldots\ldots (6 - 12)$$

Means that:

Absolute index of refraction of first transparent medium × Sine of the angle of incidence in it = Absolute index of refraction of second transparent medium × Sine of the angle of refraction in it

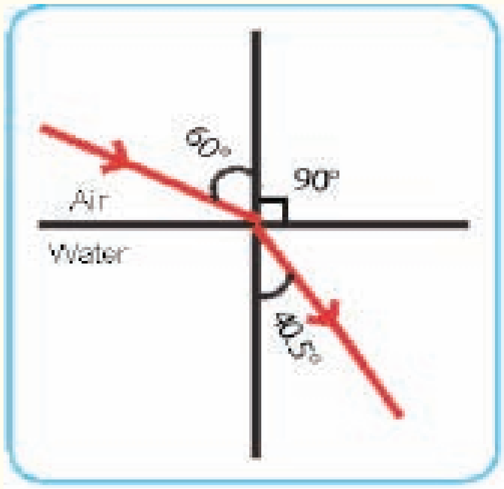
$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \ldots\ldots\ldots (6 - 13)\ (\text{Snell's law})$$

* At (1 atm) pressure and (0 °C).

** Rounded for two digit after the comma.

Example 2

A light ray fell from air on the water surface in an incidence angle of (60°) and its refraction angle in water was (40.5°), find the absolute index of refraction of water? (Noting that sin 40.5°= 0.649, sin 60° = 0.866).



Solution (From Snell's law)

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$1 \times \sin 60° = n_2 \times \sin 40.5°$

$1 \times 0.866 = n_2 \times 0.649$

$n_2 = \dfrac{0.866}{0.649} = 1.33$ the absolute index of refraction of water.

6.5 Critical Angle and the total Internal Reflection

If a light beam fell from a transparent medium that's absolute index of refraction (n_1) is big (has more optical density) such as glass, to another transparent medium that's absolute index of refraction (n_2) is smaller (has less optical density) such as air, then the refracted ray gets away from the normal drawn on the separating plane from the incidence point, and as long as the incidence angle at

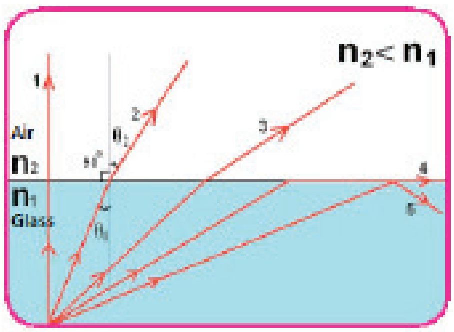


Figure (6.12)

the first transparent medium (the glass) increases the refraction angle at the second transparent medium (the air) also increases according to Snell's law, see figure (6.12) and when the refraction angle become (90°) in the second transparent medium then the incidence angle in the first transparent medium is called critical angle, so what do we mean by critical angle?

Critical angle: the angle of incidence at which the refracted light makes an angle of (90°) with the normal. And critical angle always occurs in transparent medium of greater index of refraction than absolute index of refraction for other transparent medium, at separate surface for them, see figure (6.12) (6.13), so what will happen if incidence angle increased so it become greater than the critical angle?

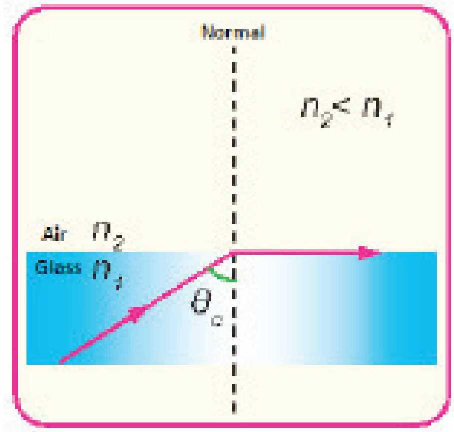


Figure (6.13)

If the light falls at an incidence angle greater than the critical angle inside the transparent medium (of greater absolute index of refraction) then the light ray does not transmit any part to the air from it (means not broken) but all of it reflect a total internal reflection from the surface separating between two transparent medium, rebounding to the medium of higher optical density that it came from and according to reflection law, this phenomenon is called the total internal reflection phenomenon.

Figure (6.14)

REMEMBER

Total internal reflection phenomenon doesn't occur only if the two following conditions satisfied:

1. When the light moves from a transparent medium to another transparent medium that have less optical density.

2. When the incidence angle in the transparent medium of higher optical density is greater then the critical angle of it.

By applying Snell's law between the transparent medium of higher optical density and that have absolute index of refraction of (n_1) where the critical angle occurred in it (θ_c) and the other transparent medium of lower optical density that have absolute index of refraction of (n_2) and when ($\theta_1 = \theta_c$) and ($\theta_2 = 90°$) then we find that (where sin 90° = 1).

$$\sin\theta_c = \frac{n_2}{n_1} \quad ....(6 - 14)$$

And in the case that the air is the transparent medium of lower optical density means $n_2 = 1$ and using equation (6.14) then we get:

$$n = \frac{1}{\sin\theta_c} \quad ....(6 - 15)$$

Means that the absolute index of refraction for a transparent medium or (transparent material) equal to the inverted of the sine of the critical angle to that transparent medium or (transparent material).

Figure (6.15)

It is worth mentioning that diamonds owes much of its beauty to the total internal reflection phenomenon, where the brilliance and shininess of the diamond is due to its critical angle (about 24.4°) that is considered one of the smallest critical angles relatively so its absolute index of refraction (about. 2.42) is relatively the greatest absolute index of refraction, the light falling on the diamond passes into it will suffer many internal reflections to comes out to the observer eyes giving the diamond that brilliance, see figure (6.15).

Example 3

If you knew that the critical angle of a light transmitted from a transparent medium to air is (41.1°), then what is absolute index of refraction to this material?
Noting that (sin 41.1° = 0.657).

Solution

We have the relation:

$$n = \frac{1}{\sin\theta c}$$

$$n = \frac{1}{\sin 41.1^\circ}$$

$$= \frac{1}{0.657}$$

$$= 1.52$$

There are other natural phenomena that can be explained by the phenomenon of total internal reflection we mention an example them, mirage phenomenon which you have known previously, also there are many applications in optical devices for the phenomenon of total internal reflection, mention one of them the reflecting prism. Which is a glass prism of angles (45°- 90°- 45°) and its used to change the path of light beam by (90° or 180°), see figure (6.16).

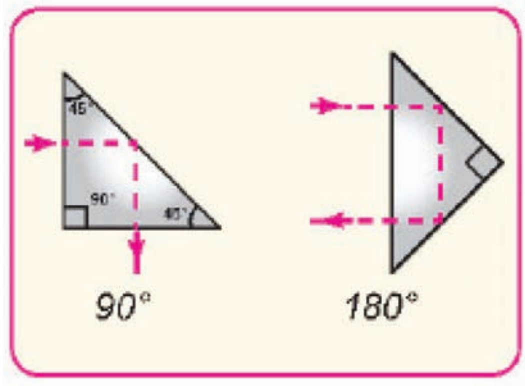


Figure (6.16)

Reflecting prism is used in many optical applications such as the binoculars of two prism, see figure (6.17) and the periscope that is usually used in submarines to see the objects over the water surface, see figure (6.18). Also preferred use the reflecting prism in optical devices rather than using the plane mirror because its more reflector for light that's because light in the prism reflects a total internal reflection by an approximate percentage to (100%), but in mirror absorption accurs of the light incident on it by certain percentage make their reflection less than reflecting prism (ideal mirror usually reflects about 90%) thus the image looks sharp and clear detailed and brighter when using the reflecting prism.

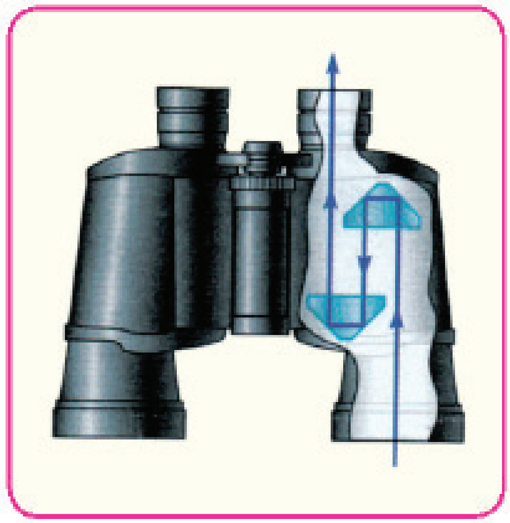


Figure (6.17)

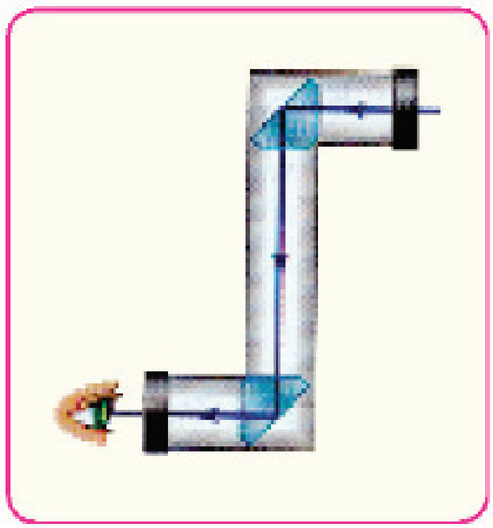


Figure (6.18)

And another important application of the total internal reflection phenomenon is the (fiber optics) we will explain it in the coming section, because its very important.

6.6 Fiber-Optics

Have you ever wondered dear student that light can be transferred from a place to another through a fine fiber? Actually that is possible where there is fibers used for this purpose called fiber optics, so what is fiber optics and where it can be used?

Figure (6.19)

Optical fibers are fine glass or plastic fibers used to transfer light from one place to another according to the phenomenon of total internal reflection, see figure (6.19), where almost the light doesn't lose any energy except very small quantity (For example, the optical beam can move a very long distance, several kilometers in some cases, Before a significant amount of light is lost) if light ray falls on one end of the optic fiber in such a way that its angle of incidence on its inner cover is greater than the critical angle of its material itself it will be reflected a total internal reflection and the ray remain Inside the optic fiber and get out of the other end even if the optic fiber is curved, see figure (6.20), and small part of the object's image is transferred to the other end of the optic fiber, see figure (6.21), and the optical fiber has a refraction index slightly less than the core of the optic fiber and this prevents the escape of light from optical fiber.

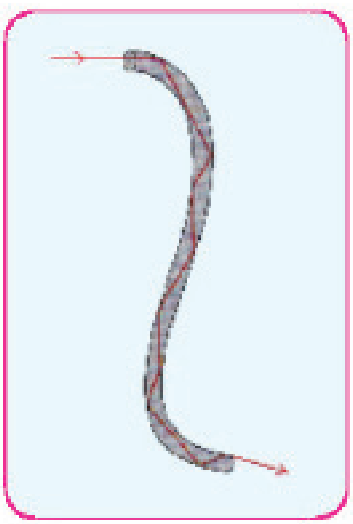


Figure (6.20)

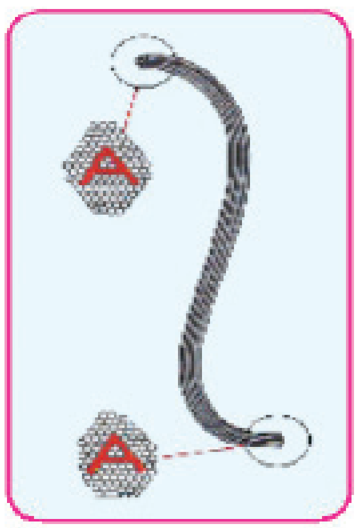


Figure (6.21)

6.6 Fiber-Optics Applications

1. Used in medicine, in endoscopy, means looking inside the part that need to be examined in the body, such as gastroscopy stomach and kidneys using a device called (Endoscope), see figure (6.22) lately the uses of the endoscope have increased in addition to use for diagnosis, it can be linked to some other devices so that the doctor can take a sample of the patient's tissue, or cauterization of blood vessels or even perform a surgical operation. Also another type that is similar to endoscope was used in the diagnosis and the treatment of some arthritic diseases and it is called arthroscope which is used in knee surgery, see figure (6.23).

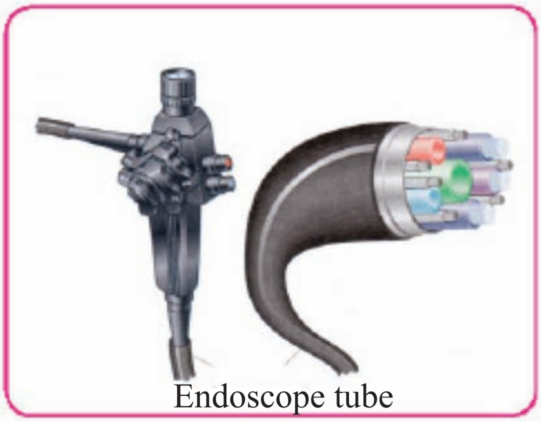


Figure (6.22)

Figure (6.23)

2. Used in controlling internal materials in machines and electronic devices and also in controlling nuclear reactors.

3. It is also used to transmit optical and audio information across the oceans and continents while they are loaded on laser ray. Optical fibers are characterized by that they can carry more phone calls compared with electrical wires, for example modern electronic methods allow to carry (32) phone call at the same time by using a pair of copper wires, while more than a million phone call can be carried them by one optical fiber, see figure (6.24).

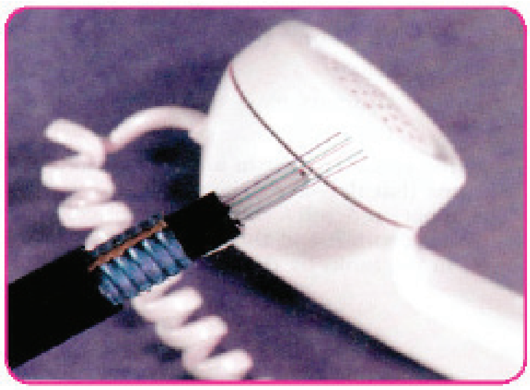


Figure (6.24)

Questions of chapter six

Q1. Choose the correct answer for the following questions.

1. Which of the following statements expresses one of the reflection laws:

a. An incidence angle equals to twice the reflection angle.

b. An incidence angle equals to half the reflection angle.

c. An incidence angle equals to the reflection angle.

d. An incidence angle equals to the square root of the reflection angle.

2. The speed of light in glass is :

a. Less then the speed of light in vacuum b. Greater then the speed of light in vacuum

c. Equals to the speed of light in vacuum d. All of the above

3. The ratio between the sine of the incidence angle of the incident ray in the first transparent medium and the sine of the refraction angle in the second transparent medium is a constant ratio for these two mediums and its called:

a. Energy of the light ray.

b. Momentum of light ray.

c. Relative refraction coefficient between the two transparent mediums.

d. Frequency of the light ray.

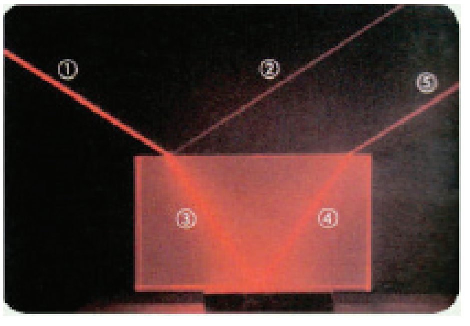
4. The unit of the absolute index of refraction for a transparent medium is :

a. m b. 1/m

c.m^2 d. has no units

Q2. Answer the following equation:

1. What's the reason for brilliance of diamonds?
2. Which one is more efficient in light reflection, reflecting prism or plane mirror? and why?
3. What are two laws of refraction? And what are two laws of reflection?
4. State the mathematical equation for Snell's law explaining the physical meaning for each symbol?
5. what do you mean by critical angle? And what is the relation to absolute index of refraction for a transparent medium ?
6. what is meant by saying that (the absolute index of refraction of water is 1.33)?
7. When the ray (1) is the incident ray in the figure, then what are the reflected rays and refracted rays from the other four red rays?



Problems

1. If you knew that the absolute index of refraction of diamond is (2.42) and light speed in the vacuum is (3×10^8 m/s) find the light speed in the diamond?

Answer: $\upsilon = 1.24\times10^8$ m/s

2. If you knew that the light speed in a transparent material is (c/1.52) where (c) is the light speed in vacuum, then what is the absolute index of refraction?

Answer: n = 1.52

3. If the absolute index of refraction of water is (4/3) and the absolute index of refraction for a certain type of glass is (3/2), find the value if the critical angle between these two mediums.

Noting that (sin 62.75° = 0.889)

Answer: $\theta_0 = (62.75°)$

4. A light fall from air on water surface at an incidence angle of (30°), apart of it was reflected and another part was refracted, so if you knew that the absolute index of refraction for water is (4/3) find:

a. Reflection angle

b. Refraction angle

(Noting that sin 30° = 0.5, sin 22.02° = 0.375)

Answer: a. $\theta_1 = 30°$

b. $\theta_2 = 22.02°$

5. If the speed of light in ice was (c/1.31) where c is the speed of light in vacuum, find the critical angle for light transferred from ice to air.

(Noting that sin 49.73° = 0.763)

Answer: $\theta_c = 49.73°$

6. Light falls from air on a transparent medium of (1.5) absolute index of refraction and at an angle of (30°), find:

a. Refraction angle

b. Wavelength of the light ray in the transparent medium if its wave length in the air was (600nm)

(Knowing that sin 30° = 0.5 , sin 19.45° = 0.333)

Answer: a. : $\theta_1 = 19.45°$

b. : $\lambda_2 = 400$ nm

Introduction

In your previous study, you knew that light is reflected from different objects when it falls on them, and that its reflection is regular when it falls on smooth surfaces, as mirrors, so what are the types of mirrors? What characterizes each mirror? Mirrors are classified according to the geometrical shape of their reflective surfaces. The images formed by mirror different by the type of the mirror. In this chapter we will learn the plane and spherical mirrors.

7.1 Plane Mirror

The plane mirror is a flat smooth surface, the light is reflected from it a regular reflection, and the making a good mirror is not easy since the mirror surface should have high degree of smoothness and its absorption of light should be very small and this is available in metals, the plane mirror that is used in our daily life is made from a good polished glass plate one of its faces is painted with compounds of silver or aluminum and it is considered the reflective surface. And the efficiency of mirror depends on the type of the glass or metal used and the degree of polishing, see figure (7.1).

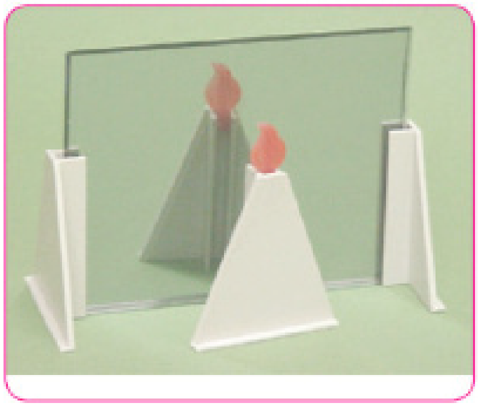


Figure (7.1)

7.2 Images Formed by a Plane Mirrors

Stand in front of the plane mirror and notice your image in it? Where is it? What shape is it? What size is it? Notice the movement of the image when you get close to the mirror or move away from it? Also move your right hand? See figure (7.2) you will see your image erect and not inverted and without magnification or minimization. Means the same size and the distance of the image from the mirror equal to your distance from it, the image formed by rays appear to come from image object behind the mirror. And the image is imaginary (virtual) and not real, which means cannot be projected onto a screen, it gets close if we get close to the mirror and gets far as we move away from the mirror.

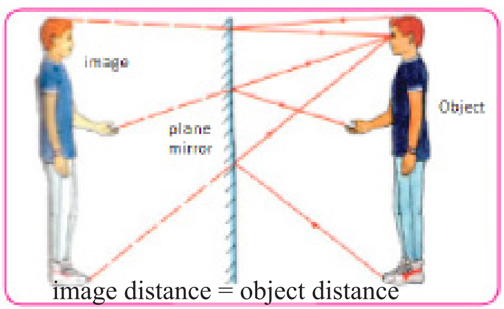


Figure (7.2)

If you move your right hand you sees that the left hand of the image is moving means its reversed, see figure (7.3).

Figure (7.3)

Also if you put a writing in front of the plane mirror you'll find that the writing in the image is reversed for this reason the word an ambulance is written in a reverse (ƎƆИA⅃UᙠMA) on the front of ambulance cars to let the driver of the car in front of it can read the reversed writing correctly from the driving mirror and give way to it, see figure (7.4).

Figure (7.4)

The image location of the image in the plane mirror can be found using the ray diagram. And the law that determines how the images are formed in mirror is the reflection's law, see figure (7.5) shows a point light source at the shape of (o) point and a distance (u) in front of plane mirror, the rays fall from the source at a certain angle with the normal of the mirror and it's the incidence angle and then it reflects from the surface of the mirror at an angle equal to the incidence angle called the reflection angle.

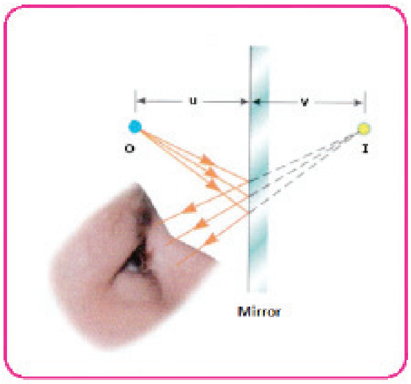
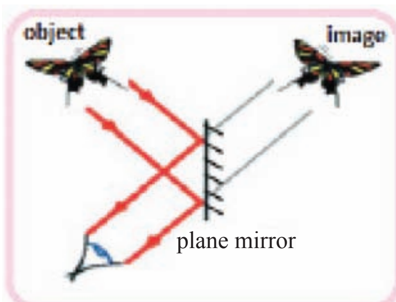


Figure (7.5)

The reflected rays continue to be scattered but it appear as emitted from point (I) behind the mirror and point (I) is called the image of the source at point (o) and the point source image location can be determined from extension of reflected rays intersection on from the surface of the mirror in the point (I).

THINK

What are the characteristics of butterfly image (see the figure beside) when it is in front of the plane mirror? What is the distance between the image of head's butterfly and mirror, if the distance between its head and the surface if the mirror equal (50cm).



7.3 Multiplicity of Image in Angled Mirrors

In the barbers, you will find two plane opposite mirrors, one is in front of you and the other is behind you. When you sit on the barber's chair you see infinite number of images of your body where you see front images followed back images, thus you see the back of your head. Is there a relationship between the number of images formed in the two mirrors and the angle that they make with each other? This activity may help you to answer this question.

Activity 1:

The number of images formed for an object in two mirrors at an angle between them.

Activity tools: Two plane mirrors, lighted candle, protractor.

Steps:

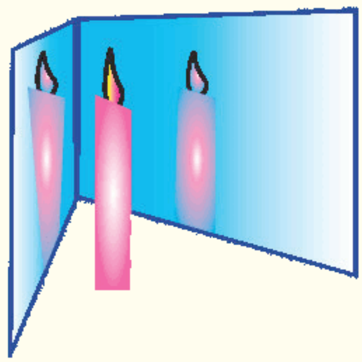


Figure (7.6) the number of images depends upon angle between mirrors

- Place the two mirrors on a horizontal surface where reflective surfaces are angled, see figure (7.6).
- Put a lighted candle between them.
- Look at the mirrors, How many images do you see for the candle?
- Mesure the angle between the two mirrors for different measurements. (30°, 60°, 90°).
- Note the number of images formed and record your notes.

We conclude from this activity that the number of images formed by the lighted candle changes by changing the angle between the two mirror according to the following equation:

$$\text{Number of formed images} = \frac{360°}{\text{Angle between the two mirrors}} -1$$

Where

n = number of images

θ = angle between the two mirrors.

$$n = \left(\frac{360°}{\theta}\right) - 1$$

Example

An object was places between two plane mirrors the angle between them is (24^0). What is the number of formed images for the object?

Solution

$$\text{Number of formed images} = \frac{360°}{\text{Angle between the two mirrors}} - 1$$

$$n = \frac{360°}{\theta} - 1$$

$$n = \frac{360°}{24°} - 1$$

$n = 15 - 1$

$= 14$ number of images.

7.4 Spherical Mirrors

Have you seen the image of your face in a metal spoon, from its Internal or external surface? What do you notice? The internal or external surface of the metal spoon works like a reflecting surface that's not flat, see figure (7.7).

Figure (7.7)

Spherical mirrors: is a mirror which has the shape of piece cut of a spherical surface in another meaning reflecting surface is part of a sphere.

There are two types of spherical mirrors, concave mirror and convex mirror, see figure (7.8).

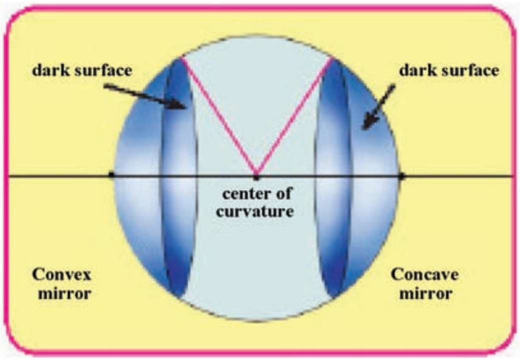


Figure (7.8)

Spherical mirror with inner face as the reflecting surface is known as concave mirror. Spherical mirror with outer face as the reflecting surface is known as convex.

To know how images form in these two types of spherical mirror we have to know some concepts related to them, see figure (7.9) and (7.10).

1. Center of curvature (c): is a center of sphere which the mirror was cut from it.

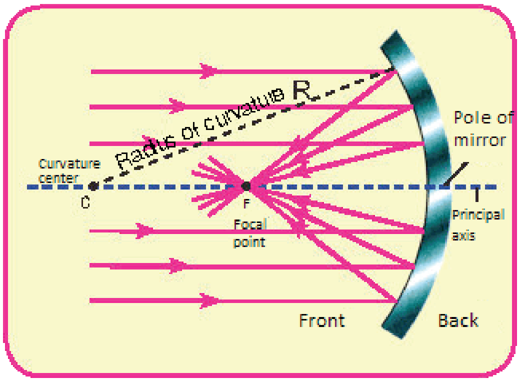


Figure (7.9)

2. Pole of the mirror (v): is a point that in surface center of spherical mirror.

3. Principal axis of the mirror: is the line passing through the center of curvature of the mirror and its pole.

4. Radius of curvature of the mirror (R): the radius of the sphere that's the mirror's surface was cut from it.

5. Focus point (F): the point that is on the principal axis of the mirror and that is resulted from the intersection of the reflected rays on the mirror's surface (or their extensions) and incident in a parallel way to the principal axis, see figure (7.10).

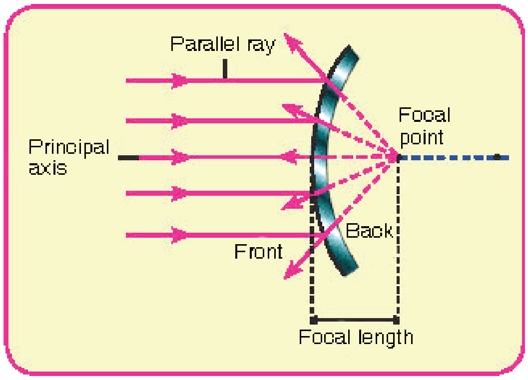


Figure (7.10)

6. Focal length (f): is the distance between the mirror's pole and its focal point, and the focal length for mirror curvature equals to (f= ½ R).

To determine the drawing of the images formed from the spherical mirror.

We take into account that:

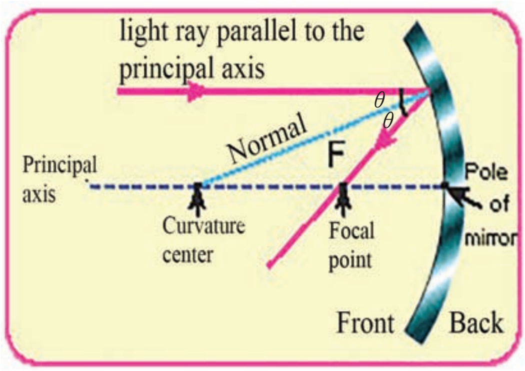


Figure (7.11)

1. The light ray that is parallel to the principal axis of the concave mirror reflects passing through its real focal point, see figure (7.11) while the light ray that is parallel to the principal axis of the convex mirror reflects where its extensions passing through its virtual focal point, see figure (7.10).

2. The light ray (or it's extensions) that passes through focal point of the mirror reflects in a parallel way to its principal axis, see figure (7.12).

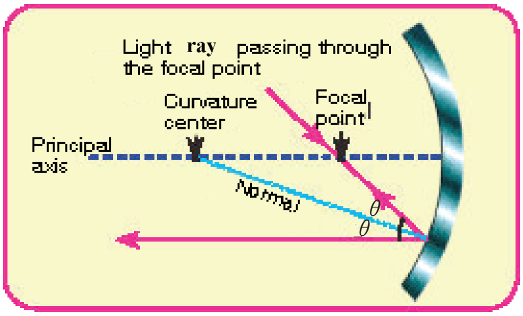


Figure (7.12)

3. The ray that passes through the center of curvature concave mirror bounce back to itself after reflection, and the ray that goes toward the center of curvature of convex mirror also reflected back to itself, see figure (7.13)

Activity 2 Formation of images in concave mirrors.

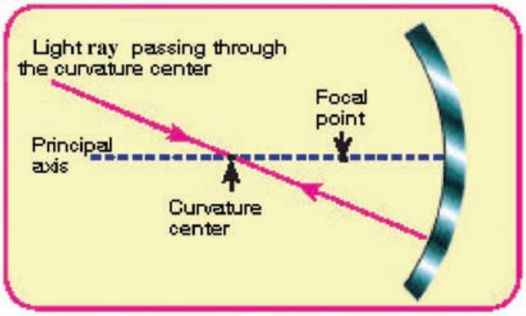


Figure (7.13)

Activity tools: concave mirror, mirror stand, candle, white carton piece (screen).

Steps:

• Put the mirror on its stand and light the candle then put it at a certain distance from the mirror

• Move the screen in front of the mirror until a clear image of the flame is formed behind the candle. What are the characteristic of the formed image? Is it bigger than the flame of the candle or smaller? Is it erect or inverted? Is the image distance from the mirror is bigger than the candle distance from it or smaller?

• Repeat the previous steps several times and each time change the distance between the candle and the mirror.

Figure (7.14)

We conclude from this activity the radiation emitted from the candle's flame can be collected at the screen, as we have observed the object and the image are located in one side according to the concave mirror like this type of image that results from the collection of the reflected rays on a screen is called a real image while the image produced by the extensions of the reflected rays is called the virtual image.

THINK

Does the characteristics of the image formed by plane mirror and the image formed by concave mirror differ?

7.5 Characteristics of Image formed in Concave Mirror

1. If the object is located at a distance from the mirror is greater than twice of its focal length (2f) then the object's image form between focus and the center of curvature its real, inverted and minimized, see figure (7.15).

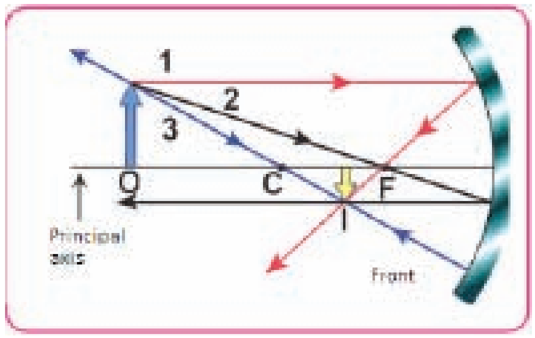


Figure (7.15)

2. If the object is located in the curvature center (means at a distance twice of focal length) then the image of the object is real inverted and is in the center of curvature and have the same length of the object at the same place, see figure (7.16).

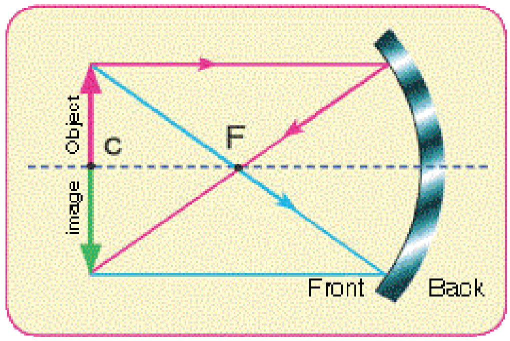


Figure (7.16)

3. If the object is located between the focus and the center of curvature then the formed image is behind the center of curvature and its real, inverted and magnified, see figure (7.17).

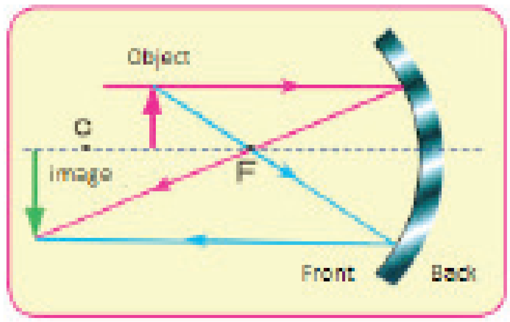


Figure (7.17)

4. If the object is located at a distance equal to the focal length of the mirror then the rays reflect in parallel way, see figure (7.18).

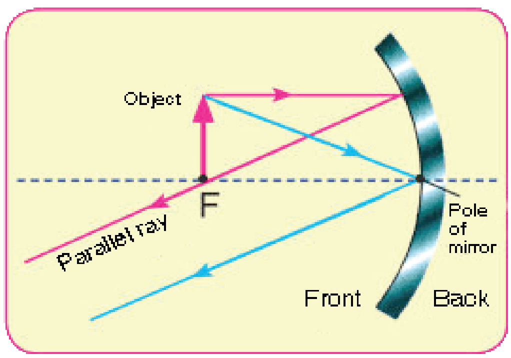


Figure (7.18)

THINK

What is the characteristic of an image formed on concave mirror for an object that is an infinity distance?

5. If the object is located in a distance from the mirror that's less than the focal length of the mirror then the image of the object is virtual, erect, magnified and placed behind the mirror, see figure (7.19).

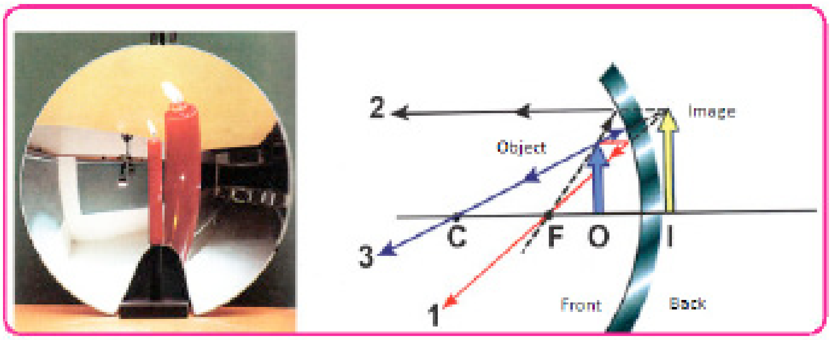


Figure (7.19)

7.6 Characteristics of Image formed in Convex Mirror

If we fall a light ray from a bright object in parallel to the principal axis it will reflect where its extension will pass through the focus and if we fall another ray from the head of object going towards the focus, it will be reflected parallel to the principal axis, see figure (7.20). The convex mirror diverges light rays which falls on it therefore called a diverging mirror. Does this mean that the image formed by the convex mirror is virtual or real? To answer this question we conduct this activity:

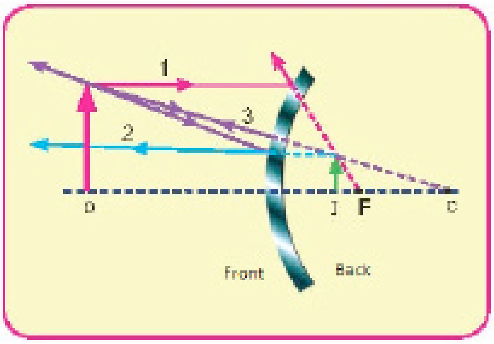


Figure (7.20)

Activity 3: Image formed in convex mirror

Activity tools: convex mirror, mirror stand, candle, and screen.

Steps:

• Hold the mirror in your hand and look at its reflective surface what do you See? What is the characteristics of the image that you see? Is it erect or inverted or magnified or minimized?

• Move the mirror close to you then move it away from you and note the formed image, see figure (7.21) (record your notes).

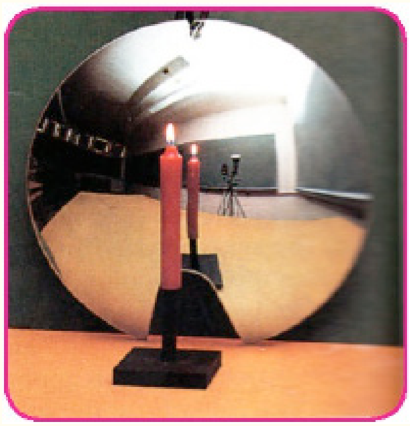


Figure (7.21)

• Place the mirror on the stand then light the candle and place it in front of the mirror and opposite its reflecting surface.

• Try to be make an image of the candle at the screen. Do you succeed in that?
• Look in the mirror. What do you notice? Is the image of the candle you see real or virtual? Where is it located? What are its characteristics?
So we can say that whatever the distance of the object from the mirror was, the characteristics of the image are virtual, erect, and minimized.

Spherical Aberration:

To get a clear and not distorted image of the object in Spherical mirror, then each light beams emitted from the object points must be reflected on the mirror's surface collection in a one point formed an image corresponding to the point that it was emitted from it, and this is impossible in reality because the formation of many images of the bright point and on different distances from the mirror, this is called spherical aberration is not collecting the reflected radiation from the surface of a spherical mirror in one point.

The radiation parallel and near to the principal axis pass or its extensions after reflection in focus. While parallel rays that fall on the surface of the spherical mirror and those are far from the pole their extension pass after the reflection at the nearest point to the mirror's pole from its focus, see figure (7.22).

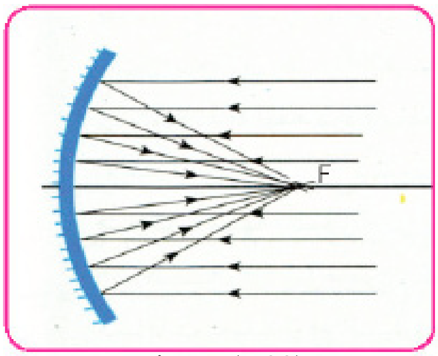


Figure (7.22)

To avoid the spherical aberration, the concave mirror is made as parabola with a point- focus and it's preferred to use spherical mirrors of small face, see figure (7.23) as in light reflectors and reflective astronomical telescopes.

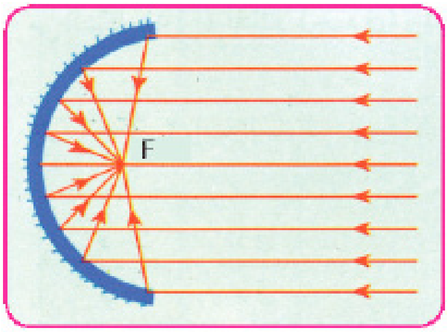


Figure (7.23)

7.7 General Equation of Spherical Mirrors

After you knew how the images form in the spherical mirrors (concave and convex), you must have noticed that the location of the image changes by changing the location of the object. From this we can conclude a mathematical relationship that connects the object's distance with the distance of the image from the mirror and by this we can conclude the characteristics of the formed image for the object.

This mathematical relationship is called the general law of mirror, see figure (7.24) and its:

$$\frac{1}{\text{focal length of the mirror}} = \frac{1}{\text{distance of the object from the mirror}} + \frac{1}{\text{distance of the image from the mirror}}$$

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

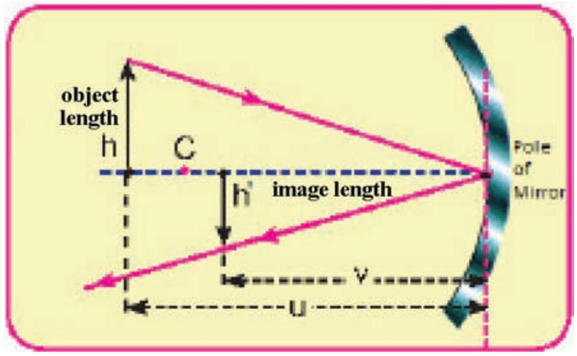


Figure (7.24)

Where

f: focal length of the mirror.

u: distance of the object from the mirror's pole.

v: distance of the image from the mirror's pole.

And when applying the general law of mirrors we have to take these cases into account:

1. The distance of the object (u) positive if the object is real in front of the mirror and negative if the object is virtual behind the mirror, (in a system of a spherical mirror and a lens).
2. The distance of the image (V) is positive if the image is real and negative if the image is virtual.
3. The focal length (f) is positive if the mirror is concave and negative if the mirror is convex.

7.8 Magnification Law in Mirrors

The ratio between the lengths of the image formed in the spherical mirror to the length of the object is called magnification (M) and it's equal to the ratio of the image distance to the object distance from the mirror.

$$\text{Magnification} = \frac{\text{image height } (h')}{\text{object height } (h)} = -\frac{\text{image distance from the mirror } (u)}{\text{objects distans from the mirror } (v)}$$

$$M = \frac{h'}{h} = -\frac{v}{u}$$

Where:

M: magnification.

h: height of the object.

h′: height of the image.

When applying magnification law the following should be noted:

1. Length of the image is positive for erect image (upward) and is negative for inverted image (downward).
2. Length of the object is positive for erect object (upward) and the object is negative for inverted object (downward).
3. Magnification sign is negative when the image is real and inverted to the object.
4. Magnification sign is positive when the image is virtual and erect to the object.

Also magnification shows us the magnifying and minimizing range of the image:

a. If the magnification M>1 then the image is magnified to the object.

b. If the magnification M<1 then the image is minimized to the object.

c. If the magnification M=1 then the image is equal to the object.

d. The magnification sign is positive for image is erect (upward) and its negative for inverted real image (downward).

Example 1

A concave mirror having a focal length of (20cm) find the location of the formed image and its characteristics and the amount of magnification for an object placed at a distance (30cm) in front of the mirror.

Solution

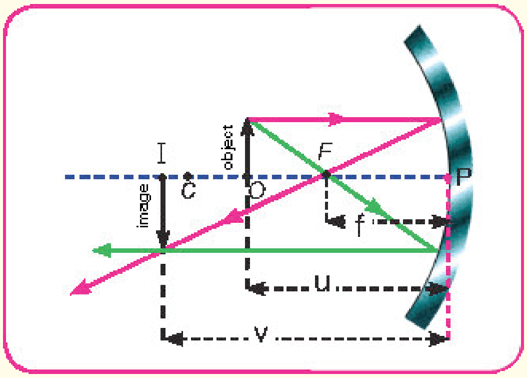
$$\frac{1}{\text{focal length of the mirror}} = \frac{1}{\text{distance of the object from the mirror}} + \frac{1}{\text{distance of the image from the mirror}}$$

Since its concave mirror then the sign of (f) is positive.

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

$$\frac{1}{20} = \frac{1}{30} + \frac{1}{v}$$

$$\frac{1}{v} = \frac{3-2}{60} = \frac{1}{60} \Rightarrow v = 60$$ cm the real image is inverted and at a distance greater then the center of curvature.



$$M = -\frac{v}{u}$$

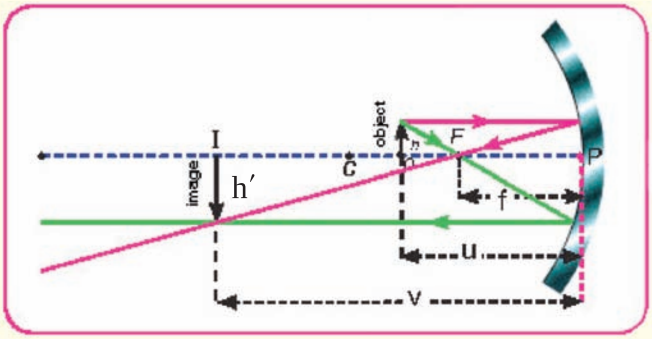
$$M = -\frac{60}{30} = -2$$

Since M= 2 means the image is magnified two times.

Example 2

A concave mirror having a focal length of (15cm) where should an object be placed in front of the mirror to form an image for it:

1. Real and three times magnified
2. Virtual and three times magnified



Solution

$$M = -\frac{v}{u} = \frac{h'}{h}$$

1. Since the image is 3 times magnified then,

$$-\frac{v}{u} = \frac{3}{1}$$

$$v = -3u$$

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

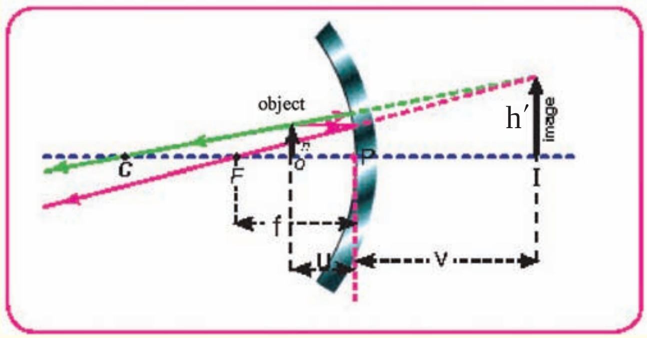
$$\frac{1}{15} = \frac{1}{u} + \frac{1}{3u}$$

$$\frac{1}{15} = \frac{3+1}{3u}$$

u = 20 cm distance from the object to the mirror.

V= 20×3 = 60 cm distance from the image to the mirror.

2. Since the image is virtual then the sign of its length is positive



$$-\frac{v}{u} = \frac{3}{1}$$

$$v = -3u$$

And by applying general law of mirrors:

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

$$\frac{1}{15} = \frac{1}{u} + \frac{1}{-3u}$$

$$\frac{1}{15} = \frac{+3-1}{3u}$$

$$\frac{1}{5} = \frac{2}{u}$$

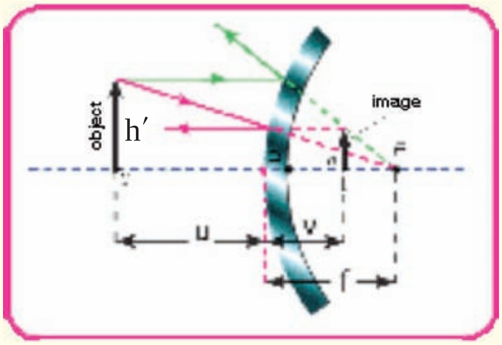
u = 10cm distance of the object from the mirror.

v = -3 × 10 = - 30 cm the virtual image erect and magnified.

Example 3

A convex mirror has a radius curvature of (8cm), an object placed in front of the mirror of (6cm)from its pole, find the distance of the formed image? And the magnification power?

Solution



$$\text{Focal length} = \frac{\text{Radius of curvature of the mirror}}{2}$$

$$f = \frac{1}{2} R$$

$$f = \frac{1}{2} \times 8$$

f= 4 cm

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

$$-\frac{1}{4} = \frac{1}{6} + \frac{1}{v}$$

Since the mirror is convex then the focal length will be negative.

$$\frac{1}{v} = -\frac{1}{4} - \frac{1}{6}$$

$$\frac{1}{v} = \frac{-3-2}{12}$$

$$\frac{1}{v} = \frac{-5}{12}$$

$$v = -\frac{12}{5}$$

v = -2.4 cm

$$M = -\frac{v}{u}$$

$$M = -\frac{-2.4}{6}$$

M = + 0.4 magnification. Positive sign means that the image is virtual.

7.9 Application on Mirrors

Mirrors of different types (plane and spherical) have Several benefits in our lives:

Figure (7.25)

1. Applications of plane mirror:

It has many uses where it exists everywhere in the house to decorate the houses and lounges as well for personal use in bedrooms and in bathroom and others, see figure (7.25) the mirror at home.

Figure (7.26)

2. Use the angled mirrors to get multiple images and invest this phenomenon in embellishment and shops, see figure (7.26).

3. And in front mirror of the driver to see behind the driver when driving the car, see figure (7.27). The driving plane mirror in front of driver and sometimes it is called the driver's third eye.

Figure (7.27)

2. Applications of concave mirror

1. To magnify the images, dentists use the concave mirror which gives a larger image of the patient's teeth to help them see the details clearly, see figure (7.28).

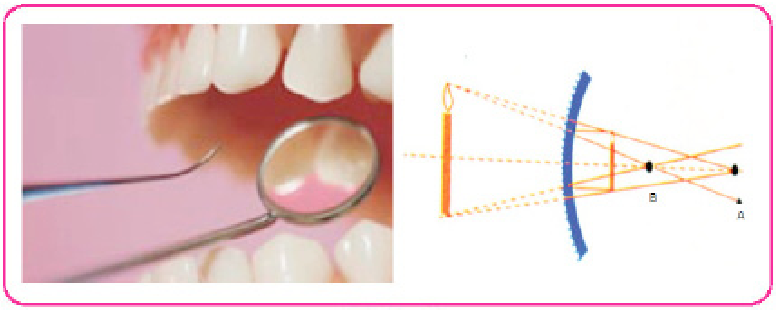


Figure (7.28)

2. Used in car headlights

Where the light source is placed in the focus of parabola and the light rays fall on its surface and reflect from it in parallel so it lights for far distances in front of the car, see figure (7.29).

Figure (7.29)

3. Collect solar energy and use concave mirror to focus sunlight in its focal point and use the energy for heating and cooking this is called the solar cooker, see figure (7.30).

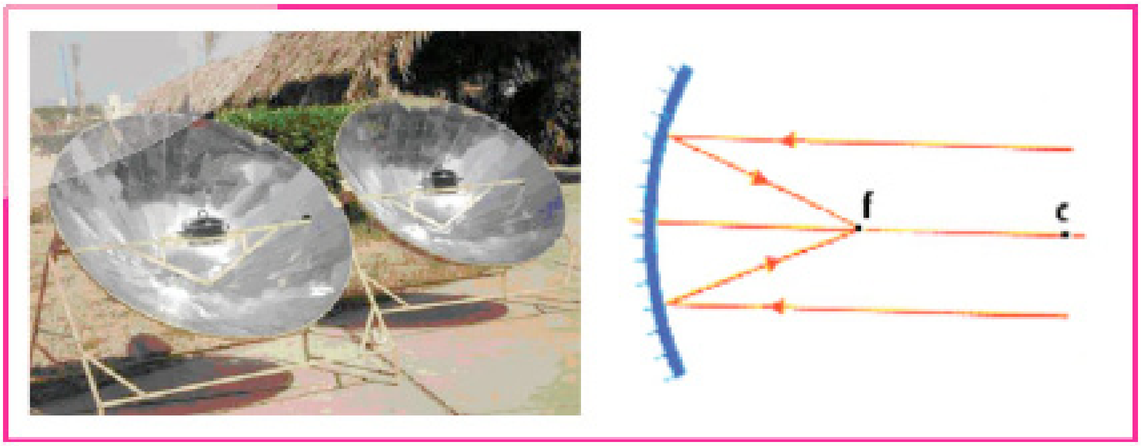


Figure (7.30)

3. Application of convex mirror

Convex mirror is called driving mirror its found on both sides of the driver to give miniature and erect images and it gives a wide field of vision on both sides, see figure (7.31).

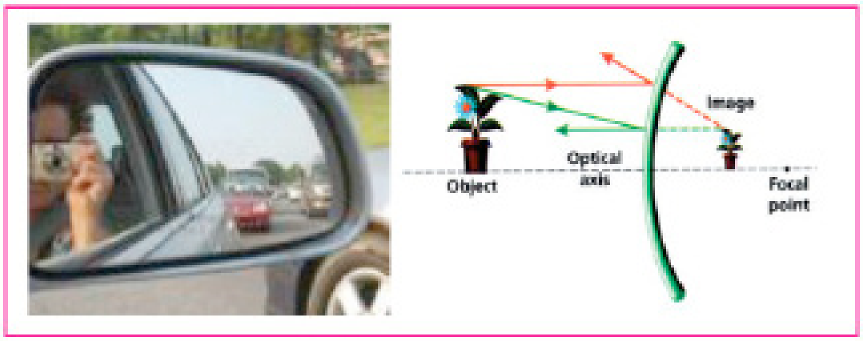


Figure (7.31)

Do you know?

That satellites those we put on our homes work the same work of a big mirror that reflects the broadcast waves and focus it on the receiver unit (LNB)

And it's used in shopping center to observe the customers during their shopping, see figure (7.32).

Figure (7.32)

Questions of chapter seven

Q1. Choose the correct answer for the following questions.

1. Virtual image:

a. Is erect with to the object. b. Its inverted with to the object.

c. It can be projected on a screen. d. It's in front of the mirror.

2. The concave mirror shows an erect image of the object when it is distance from it

a. Is less than the focal length (f) of it b. Is equal to the focal length of it

c. Twice the focal length d. Very far from the mirror

3. Number of images formed in faced parallel mirrors:

a. 30. b. 180. c. Infinity. d. 0.

4. The principal axis for a spherical mirror is the straight line than passes:

a. Through the center of curvature of the mirror and another point.

b. Through the center of curvature of the mirror and its pole.

c. Through the focal point of the mirror and any point on its surface.

d. Tangential to the mirror.

5. If you look in the mirror and your image was magnifying then the mirror is:

a. Concave. b. Convex. c. Plane. d. All of the above.

6. The radius of curvature of spherical mirror is:

a. Half of the focal length. b. Twice of the focal length.

c. Three times of the focal length. d . $\frac{1}{3}$ of the focal length.

7. The characteristics of the image formed in the convex mirror:

a. Real, erect and miniature.

b. Virtual, erect and miniature.

c. Real, magnifying and inverted.

d. Virtual, inverted and magnifying.

8. A spherical mirror of 15 cm focal length then its radius of curvature is :

a. 15 cm. b. 7.5 cm. c. 60 cm. d. 30 cm.

9. A ruler having a length of 10 cm was placed perpendicular in front of a concave mirror that's focal length is (+ 50cm) and at a distance of 100 cm from the pole of the mirror then the length of the formed image is:

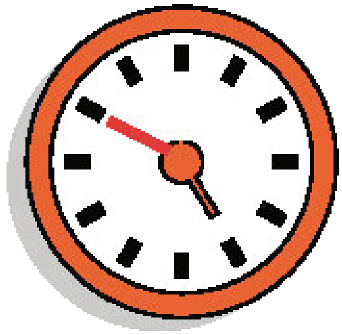
a. 3cm erect b. 10 cm erect c. 3 cm inverted d. 10 cm inverted

Answer the following question:

Q1. Someone is suggesting to place a concave mirror on both sides of the car instead of convex mirror? Do you see that his suggestion is true? And why?

Q2. Ahmed stood in front of a plane mirror wearing a sports shirt with a number (81) written on it. What do you read the image of number (81)?

Q3. The next shape represents a clock image placed in front of a plane mirror what time the clock is referring to?



Q4. Why no image form for an object placed in the focal point of a concave mirror?

Q5. What is real and virtual focus?

Q6. Distinguish between convex mirror and concave mirror in terms of the reflective surface and the characteristics of images formed in each of them?

Q7. Show by drawing the image's location of an object that's at a distance greater than the radius of curvature of :

a. concave mirror. b. convex mirror.

Problems

Q1. An erect image formed by using a concave mirror having a curvature radius of (36 cm) , if the magnification power was = 3 . Calculate the location of the object with respect to the mirror.

Answer: u = 12 cm

Q2. Two plane mirrors the angle between them is 120 °. Calculate the number of images formed in the mirrors.

Answer: n = 2

Q3. An object was placed an object 4cm away from a mirror and an virtual and three times magnified image formed for it. What is the kind of the mirror and what is the focal length of it?

Answer: f = +6 cm concave mirror.

Q4. An object was placed in front of a concave mirror that's focal length is (12cm), then a real four times magnified image formed for it. Find the distance of the object from the mirror and also its image distance from it (consider the object is perpendicular on the principal axis of the mirror).

Answer: u = 15cm
v = 60 cm

Q5. An object of 4 cm long was placed in front of a convex mirror that's radius of curvature is (20cm), if the object was (40cm) away from the mirror. Then find the type of the formed image and its length and clarify your answer by drawing.

Answer h\` = 0.8 cm virtual erect miniature image.

8.1 Thin Lenses

You learned from your previous study that lenses are transparent material with two spherical surfaces or a spherical surface and a plane one, it is usually made of glass (or transparent elastomer materials) in visible light applications, and it's made of quartz for ultraviolet (UV) applications and of germanium for (far-infrared) applications.

In this chapter our study will be limited about thin lenses, whose thickness is small compared to its focal length.

Lenses have two types:

1. Convex lenses: or called (Converging lens) and it is center is thicker than its edge, used to converge the incident rays on it after its passes from the lens when the refraction coefficient of the lens material is greater than the refraction coefficient of the medium it's found in it, and exist on several types, as in figure (8.1).

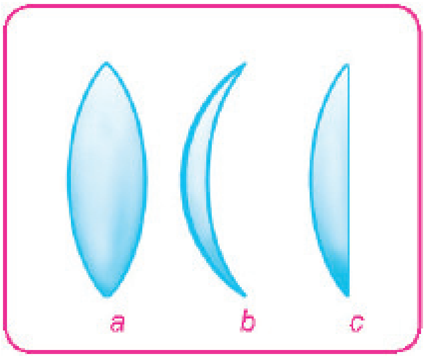


Figure (8.1)

a. Biconvex.
b. Convex - Concave.
c. Plano - convex.

2. Concave lens : called (diverging lens): its center is less thick than its edge, used to diverge the incident light rays that passed from the lens, and exist on several types, as in figure (8.2):

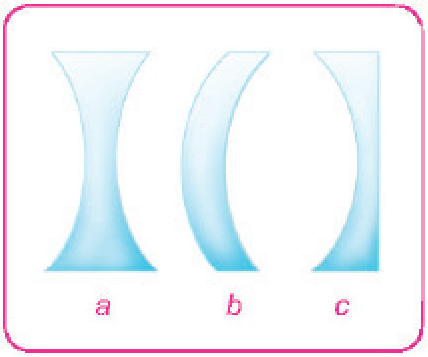
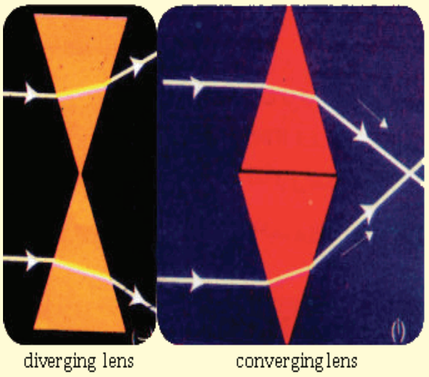


Figure (8.2)

a. Double-concave.
b. Convex Concave.
c. Plane - concave.

REMEMBER

A convex lens (Converging lens) is like two prisms placed base to base located at the optical center, diverging lens is like two prisms placed head to head located at the optical center.



8.2 Some Basic Concepts in Lenses

In your previous study, you learned some common terms in lenses that we will talk about them again due to their importance in determining the locations of the images formed by the lenses and some of them are:

1. Optical Center:

Is a point at the center of the lens if a light ray passes through it transmit straightly without deviation because the two sides of the lens at the optical center are approximately parallel? See figure (8.3), mean the passed ray diverges slightly from its original path which can be neglected because the lens is thin.

2. Principal Axis:

A straight line passes through optical center of the lens and its two focuses, see figure (8.3).

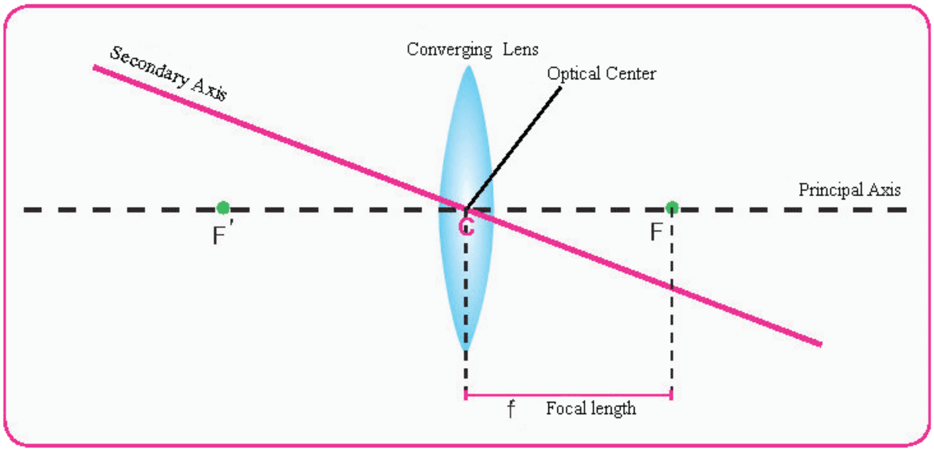


Figure (8.3)

3. Focus:

Is the point placed on the principal axis of the lens, that any ray emitted from it or going toward it travels after refraction parallel to the principal axis, see figure (8.4).

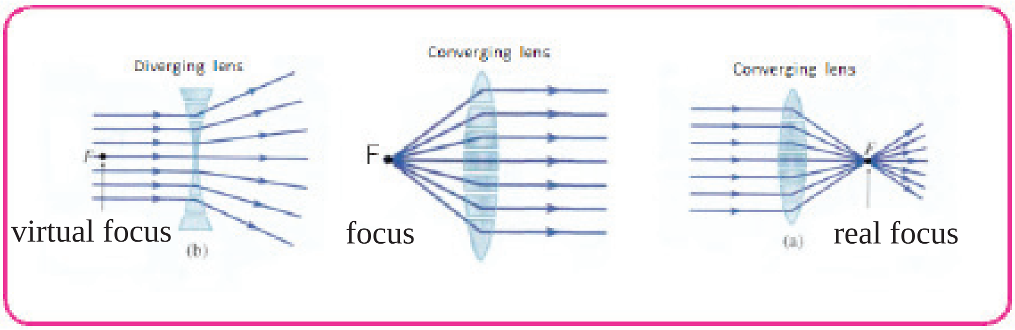


Figure (8.4)

4. Focal Length

The distance between the focus and the optical center for the lens, see figure (8.3).

5. Secondary Axis:

The straight line that passes through the optical center for the lens is called the secondary axis, see figure (8.5).

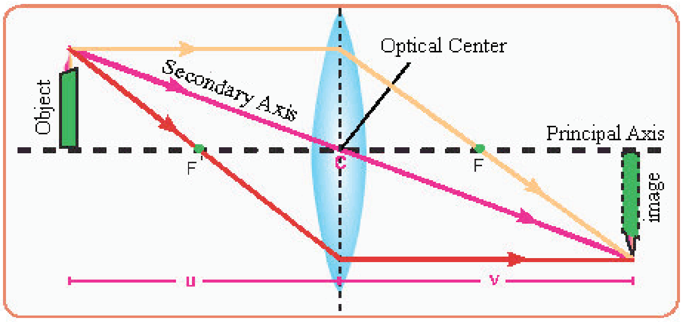


Figure (8.5)

When you know the focal length of a thin lens, you can draw a simple diagram to an object placed at a certain distance from the lens (larger or smaller or equal to the focal length), that we conclude from it all the information required for the image in terms of it (erect or inverted, magnified or minimized, real or virtual) the bright object whose image is need to determined can be represented by an arrow that's perpendicular on the principal axis for the lens, its head represents the head of the object, emitted from any point of its point (arrow head example) unlimited light rays directed to all directions and a few of them passes through the lens so to determine the image of an object we can take three path of light ray emitted from the object, two of them are sufficient to locate the image and the third to make sure about the location of the image, and they are:

1. Ray (1) a ray of light emitted from the arrow's head (the object) parallel to the principal axis after refraction passes through the focus (F`) on other side of the lens, see figure (8.6).

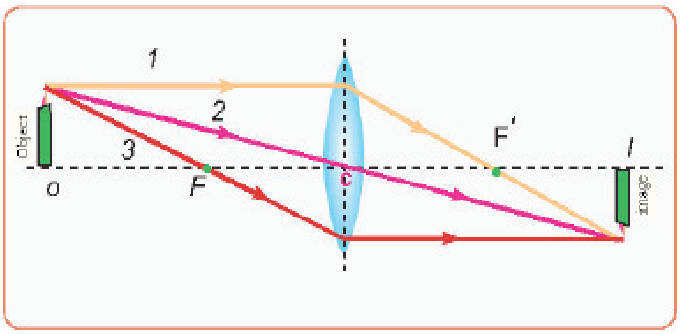


Figure (8.6)

2. Ray (3) a ray of light passing through the focus (F) after refraction goes parallel to its principal axis.
3. Ray (2) a ray of light passing through the optical center goes without any deviation.

Where

F is the primary focus.

F` is the secondary focus.

To draw the image of an object when is placed at twice of the focal length away we draw two ray (1),(2) coming out from the head's object as in figure (8.7), the light ray (1) is parallel to the principal axis of the lens goes out of it and refracted passing through the focal (F`) and the other ray (2) that passes through the optical center of the lens, it goes away straight.

The intersection point of rays (1) and (2) those passed from the lens represent the image of the head of the object and it's easy to determine its characteristics:

1. Inverted
2. Minimized (the image is smaller than the object).
3. Real

Because it formed from the intersection of the same rays in the other side of the lens and it can be projected on a screen.

4. Located between the focus and twice the focal length of the lens.

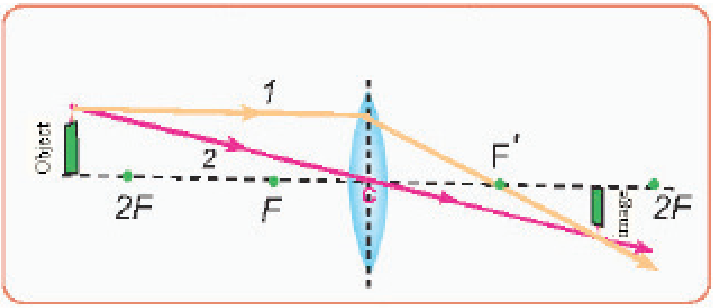


Figure (8.7)

8.3 The images formed for an object through a converging Lens

a. When the object is placed between the focus of the lens and twice its focal length, see figure (8.8).

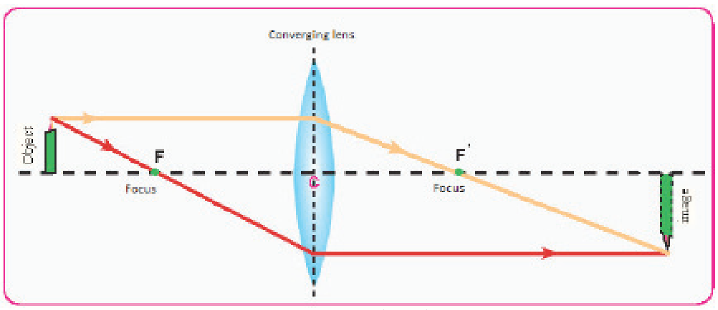


Figure (8.8)

1. Properties of the formed image

1. Real.
2. Inverted.
3. Located on the other side of the lens.
4. Magnified.

b. When the object is placed between the focus (F) and the optical center of the converging lens, see figure (8.9).

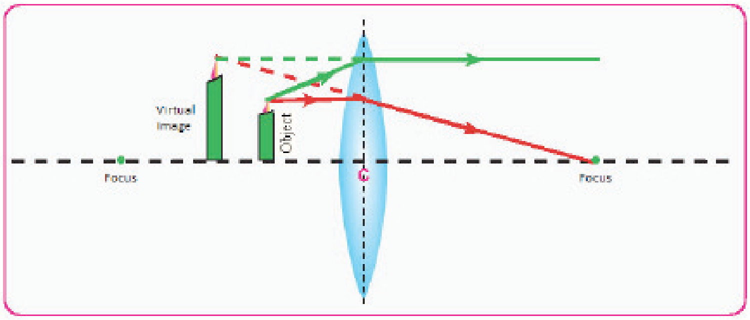


Figure (8.9)

Properties of the formed image

1. Virtual.
2. Erect.
3. Greater than the object and on the same side of the object and behind it.

THINK

What are the properties of an image formed by a converging lens for a certain object that's at a distance?

1. At infinity.
2. Farther than its focal length.
3. Between the focus and twice the focal length.
4. In the focus.

8.4 The Images formed for an Object through a Diverging Lens

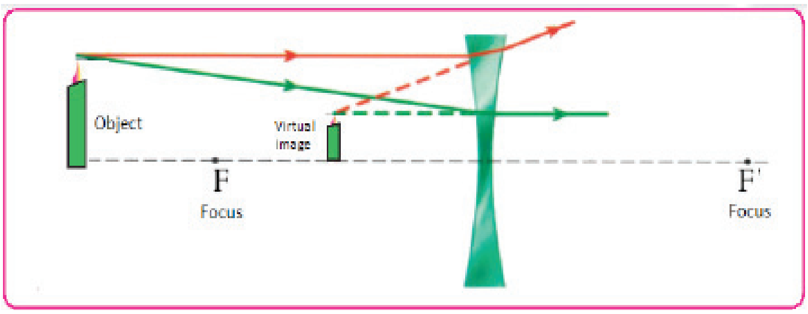


Figure (8.10)

The properties of the image formed by diverging lens (concave), see figure (8.10) no matter where the object was locate for this type of lenses is:

1. Virtual .
2. Erect.
3. Smaller than the object.
4. In the same side of the object and in front of the lens.

Activity: Determining the focal length for a converging lens in an approximate and quick way.

Tools: converging lens, screen.

1. Outside the laboratory

By directing the lens to the sun disk and projecting its image on a screen (wall or paper), with changing the location of the lens until we get the clearest image on the screen to a very bright point and it represents the focus location of the lens considering that the rays coming from the sun are parallel to their principal axis, so the distance between the lens and the focus represents approximately the focal length of the lens.

2. Inside the laboratory

By directing the lens to a far object like a tree or an electric pole through the laboratory's window and projecting its image on a screen or paper, change the distance of the lens from the screen until you get the clearest image of the far object. Hence the distance between the lens and the screen represents approximately the focal length of the lens, considering that the tree, or the electric pole is a far object. So the rays that come from it be parallel to the principal axis of the lens so they converges after passing through the lens in the focus of the lens.

8.5 Law of lenses and magnification

When placing an object in front of a converging lens in a perpendicular on its principal axis and at a distance (u) From its optical center, a real minimized and inverted image will appear that's located at a distance (v) from its optical center and on the other side of the lens, see figure (8.11) the relationship that connects the object distance (u) from the lens and the image distance (v) from the lens and the focal length of the lens (f).

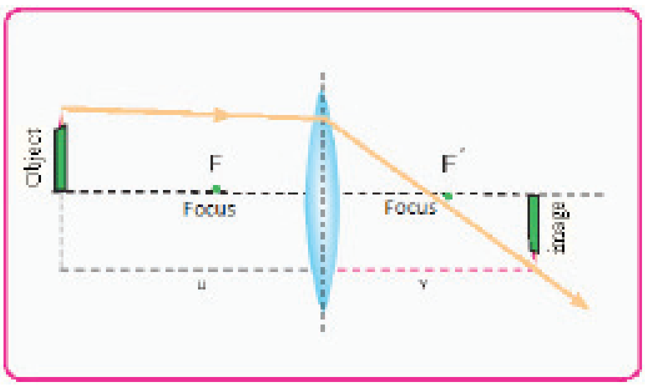


Figure (8.11)

$$\frac{1}{\text{Focal length (f)}} = \frac{1}{\text{object distance from the lens (u)}} + \frac{1}{\text{image distance from the lens (v)}}$$

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

And it's worth to mention that this law is a general law for lenses and mirrors while the magnification law (M) for lenses is given by:

$$\text{Magnification} = \frac{\text{length of the image } (h')}{\text{length of the object (h)}} = -\frac{\text{image distance from the lens (v)}}{\text{object distance from the lens (u)}}$$

$$M = \frac{h'}{h} = -\frac{v}{u}$$

The general law of lenses is applied whether the lens is convex or concave with regard to the sign of each quantity when the light incident on the lens moves from left to right as follows:

1. The object's distance (u) is positive if the object was real located on the left of the lens takes negative sign if the object was located on the right of lens.
2. The image's distance (v) is positive if the image was real and located on the right of the lens and takes negative sign if the image was virtual located on left of lens.
3. The focal length (f) is positive for converging lens (convex lens) and negative sign for diverging lens (concave lens).
4. The length of the erect object (upward) have positive sign and the length of the inverted object (downward). have negative sign.
5. The length of the erect image (upward) have positive sign and the length of the inverted image (downward), have negative sign.

And for the magnification (M) sign:

1. **Positive:** the image is virtual and erect according to the object.
2. **Negative**: the image is real and inverted according to the object.

The value of magnification tells us the following:

a. If M>1 then the image is magnified according to the object.

b. If M <1 then the image is minimized according to the object.

c. If M=1 then the image is equal to the object.

The ratio between two areas of image and the object equals to the ratio between the square of distance from the optical center of lens.

Means:

$$\frac{\text{Area of the image}}{\text{Area of the object}} = \frac{(\text{image distance from the lens})^2}{(\text{object distance from the lens})^2}$$

$$\frac{A'}{A} = \frac{v^2}{u^2}$$

THINK

What is the meaning of magnification: M=1 and M=2 and M = - 0.5

Example 1

A converging lens of (10 cm) focal length, formed images for objects that are away from it in the distances:

u=30cm.

u=10cm.

u=5cm.

From on of the sides of the lens. Find the image distance, magnification and its properties in each case.

Solution

By applying the thin lenses equation:

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

a. When the object is at 30 cm away from the lens.

$$\frac{1}{10} = \frac{1}{30} + \frac{1}{v}$$

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

$\Rightarrow$ **v = + 15 cm** distance of the image from the lens.

The positive sign for the image distance means that the image is located in the second side on the right of the lens and its real.

$$M = -\frac{v}{u}$$

$$M = -\frac{15}{30} = -0.5$$

The negative sign for magnification means that the image is inverted and its minimized because the magnification is less than one.

b. When the distance (u) of the object equals to the focal length of the lens (10 cm), means the object is located in the focus of the lens so the image is located in infinity.

c. When the object is (5 cm) away from the lens, and by applying the thin lenses equation.

$$\frac{1}{10} = \frac{1}{5} + \frac{1}{v}$$

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

V= -10 cm sign of the image distance is negative means the image is virtual.

$$M = -\frac{v}{u} = -\frac{-10}{5} = +2$$

The positive sign for magnification means the image is erect and number (2) means the image is magnified.

Example 2

An object was placed (12 cm) away in front of a diverging lens (6 cm) focal length. What are the properties of the formed image?

Solution

The focal length for diverging lens = - 6 cm and by applying the lenses law.

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

Since the lens is diverging then the sign of (f) is negative

$$\frac{1}{-6} = \frac{1}{12} + \frac{1}{v} \Rightarrow \frac{1}{v} = -\frac{1}{6} - \frac{1}{12} = -\frac{1}{4}$$

v = - 4 cm the negative sign of (v) means that the image is virtual (in the same of the object side) and in front of it?

$$M = -\frac{v}{u} = -\frac{-4}{12} = \frac{1}{3}$$

The positive magnification means the image is erect and virtual and its length equals to $\frac{1}{3}$ of the objects length.

Combination of Thin Lenses

Many optical devices contain two or more thin lenses. The figure (8.12a) shows a system consisting of two Convex lenses, an object placed in front of the first lens (u_1), so where will the final image form after the refraction of light in the two lenses? First of all we deal with the first lens as a single lens and the second lens as doesn't exist, after determining the location of the image formed by the first lens, see figure (8.12b) we consider it an object for the second lens then find the location of the final image, see figure (8.12c). by observing the figure (8.12) the system can be treated by the following relationship:

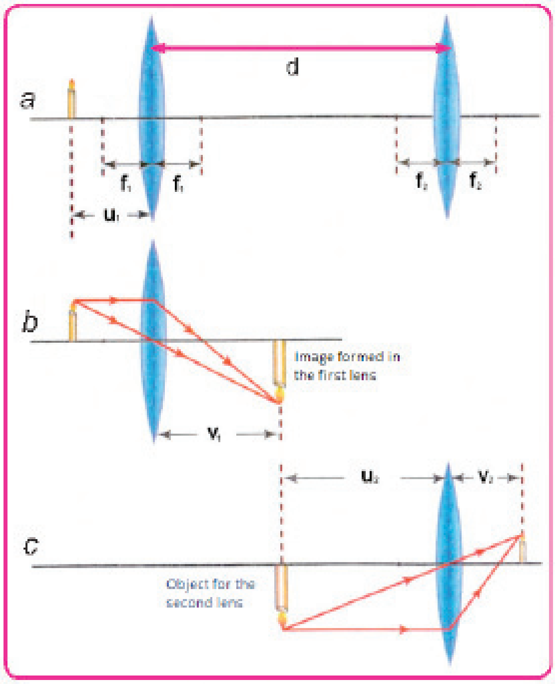


Figure (8.12)

Total Magnification M = Magnification of the first lens (M_1) × Magnification of the second length (M_2)

$$M_{Total} = M_1 \times M_2$$

Its found that the focal length (f) of the system in this case depends on the two focal lengths of its lenses (f_1, f_2) as the following relation:

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$$

Where:

d represents the distance between the two optical centers of the two lenses while the special case that's when the two lenses are placed in contact each other (d = zero).

So the relation that connects the focal length for the system that's composed of two lenses are placed in contact each other with the focal lengths of its lenses (f_1), (f_2) is given by the following relation:

$$\frac{1}{\text{The focal length of the system } (f)} = \frac{1}{\text{The focal length of the first lens } (f_1)} + \frac{1}{\text{The focal length of the second lens } (f_2)}$$

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

8.6 Lens Power

Optometrists and ophthalmologists use diopter unit to measure the power of the eye lens. Which is the inverse of the focal length of the lens measured by meters:

$$\text{Lens power} = \frac{1}{\text{Focal length of the lens (f) in meter}}$$

$$\text{Lens power (P)} = \frac{1}{\text{f (meter)}}$$

So the converging lens of (20 cm) focal length have a lens power is:

$$P = \frac{1}{f} = \frac{1}{0.2} = +5\,D$$

While the diverging lens of (25 cm) focal length have a lens power is:

$$P = \frac{1}{f} = \frac{1}{-0.25} = -4\,D$$

By applying the general law of lenses and by knowing the radii of the lenses R_1, R_2, and the index of refraction of its material (n) we can find the lens power by the equation that the lens makers use:

$$\text{Lens power (P)} = \{\text{index of refraction} - 1\}\left\{\frac{1}{\text{Radius of the first lens}} - \frac{1}{\text{Radius of the second lens}}\right\}$$

$$P = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Example 3

A system consists of two convex lenses the focal lengths of the first one is (10cm) and the second one is (5cm), the distance between them is (40cm). An object was placed (15cm) to the left of the first lens find the location the final formed image and its magnification?

Solution

$$\frac{1}{f_1} = \frac{1}{u_1} + \frac{1}{v_1} \Rightarrow \frac{1}{10} = \frac{1}{15} + \frac{1}{v_1} \Rightarrow v_1 = 30\text{cm}$$

$$\text{Magnification of the first lens} = -\frac{\text{Distance of the image from the first lens}}{\text{Distance of the object from the second lens}}$$

$$M_1 = -\frac{v_1}{u_1} \Rightarrow M_1 = -\frac{30}{15} = -2$$

$u_2 = 40 - 30 = 10$ cm [Since the image formed in the first lens is real and formed in front of (left) of the second lens therefore it's considered a real object for the second lens and is located on a distance (u_2).]

$$\frac{1}{f_2} = \frac{1}{u_2} + \frac{1}{v_2} \Rightarrow \frac{1}{5} = \frac{1}{u_2} + \frac{1}{v_2} \Rightarrow v_2 = 10\text{cm}$$

$$M_2 = -\frac{v_2}{u_2} \Rightarrow M_2 = -\frac{10}{10} = -1$$

$M_2 = -v_2/u_2$

$M_2 = -10 / 10 = -1$

$M = M_1 \times M_2$ [where the total magnification M = first lens magnification × second lens magnification]

$M = (-2) \times (-1) = +2$ the positive sign means image is erect.

8.7 Spherical Aberration

A common defect in lenses is that the optical beam that incident on one side of the lens in parallel way to its principal axis does not converge at one point.

Incidence rays that fall In a parallel way to the principal axis and far from it refract converging at a point closer to the lens (focus) from same type of ray that is close to the principal axis, see figure (8.13).

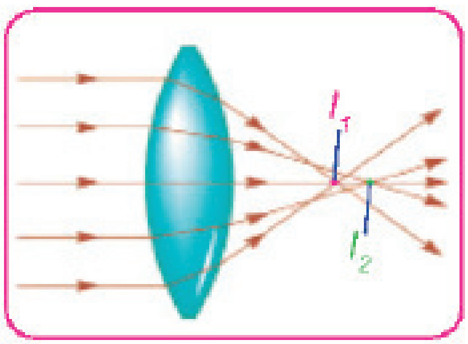


Figure (8.13)

So the rays passing through the points near to the center of the lens from further images from the lens (I_2) than the images formed from the rays that pass through points near to the edge of the lens (I_1) so the images formed by this kind of lenses don't have defined parameters and details. And this defect in lenses is called spherical aberration which is one of the lenses defects that results from the not converging of the light rays incident in a parallel way to the principal axis and that refract from the lens at one focus.

Spherical aberration can be decreased by using a barrier that's placed in front of the lens's edge to prevent the rays far from the principal axis to pass through the lens, also a convex-Plano lens can be used for the same purpose that's the convex-Plano lenses were used as objective lens in telescope and eyeglasses.

8.8 Chromatic Aberration

You learned from your previous study that when white light incidence on the face of the prismatic glass it analysis into a set of colors due to difference of the refraction coefficient of Prism material with the different wavelengths of the White light components, where violet will pass suffering the largest deviation towards the prism base due to its short wavelength while the red color faces less deviation due to Its long wavelength. And the rest of the colors their wavelengths range between these two colors of visible light, see figure (8.14).

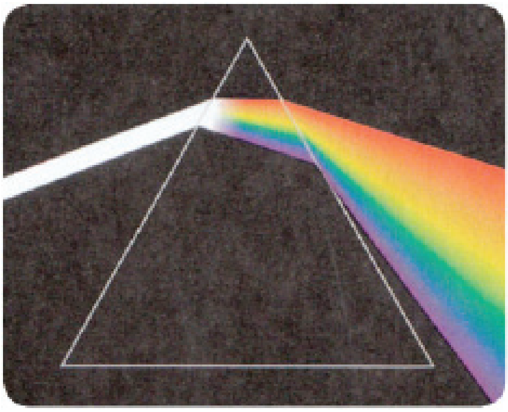


Figure (8.14)

Since the converging lens can be considered as of a number of prisms whose bases are towards the center of the lens, the light rays that pass through a converging lens refract through the lens and with different angles according to different wavelengths and when passing through the lens notice that the violet color intersection the principal axis of the lens at a point closer to the lens than the rest of the colors, see figure (8.15), while the red color intersection the principal axis at a point farther from the lens than the rest of the colors, this difference in the color positions on the principle axis is called chromatic aberration.

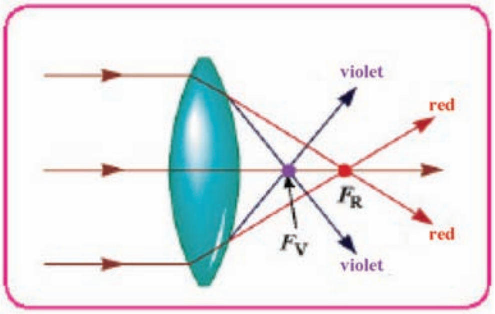


Figure (8.15)

Chromatic aberration can be gone by installing an achromatic converging lens made of crown glass having a focal length (f_1) (of large positive power) and adhesive on a diverging two-face concaved lens or concave – plano that's focal length is (f_2) and made of flint glass (of small negative power) and the total shape of the attached lens is a (convex – concave) or (convex – plano lens), see figure (8.16) and the dispersion that results from one of them cancels the other when passing out of the lens and the colors converge in one point approximately and to calculate the focal length for this installed lens (f) we apply the following relation:

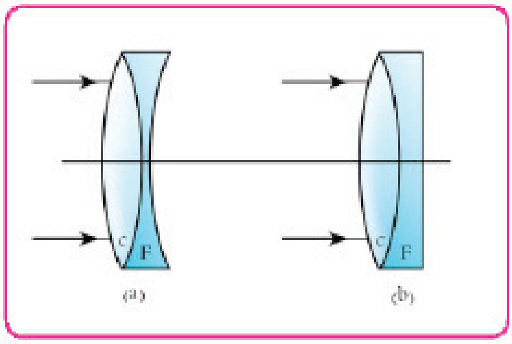


Figure (8.16)

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

8.9 Application on Lenses

1. To treat defects of vision

Dear student, in your previous study, you learned that the eye is an important optical device to receive the light that is emitted from lighted objects around us so we can see these objects. The healthy eye sees bright and lighted objects clearly if they were at a distance farther than twice the focal length of the eye lens as a result a real inverted image forms in the retina and smaller than the object. If the eye fails to see close or far objects, so it have a defects of vision that can be treated using medical glasses.

a. Myopia (nearsightedness)

The inability of the eye to see far objects clearly (their images form in front of the retina) and it's treated by using diverging lenses, see figure (8.17)

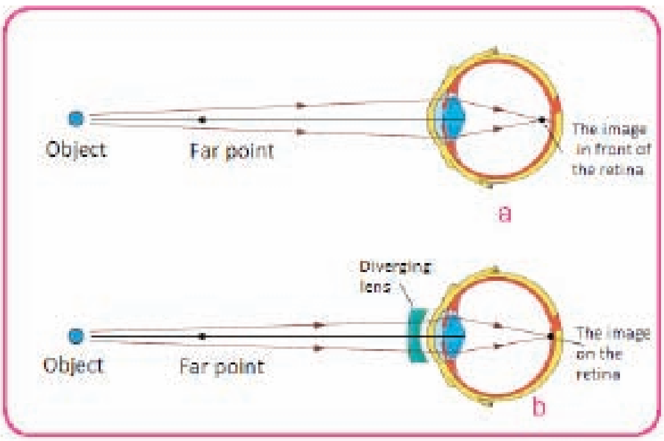


Figure (8.17)

b. Hyperopia (far sightedness)

The inability of the eye to see close objects clearly (their images form behind the retina) and its treated using converging lenses, see figure (8.18).

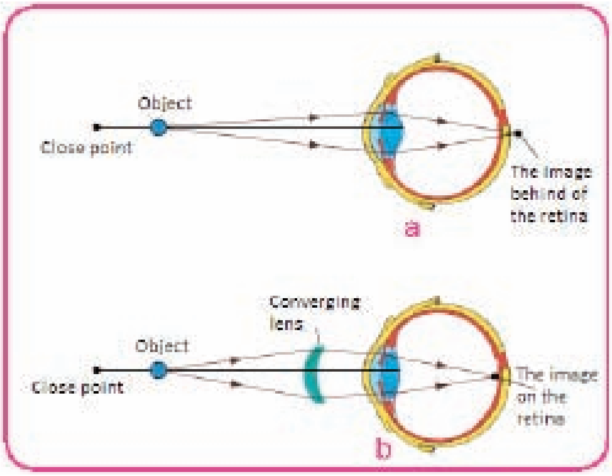


Figure (8.18)

c. Astigmatism

The images formed for the point objects in the defected eye by this defect are not points like in the case of the healthy eye, but lines on the retina, see figure (8.19). The cause of this defect is the Irregularity curvature of the cornea or the lens of the eye or both of them in different directions. The Curvature might be larger in the horizontal section than It is in the vertical section, since the group of horizontal and vertical lines don’t converge in the focus synchronal.

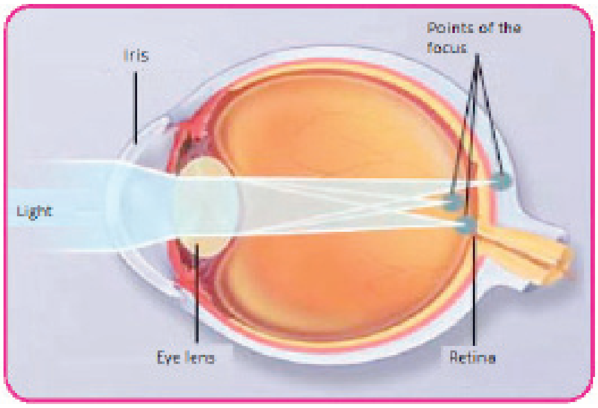


Figure (8.19)

This defect can be detected by looking at a set of black lines the healthy eye sees all lines in the same clearness (same black level), while the defected eye with astigmatism will see a change in the clearness of these lines.

And this defect is treated by using cylindrical lenses which is a section of a cylinder that’s other face is flat, see figure (8.20).


Figure (8.20)

2. In photographic devices:

The camera is a small box having a converging lens or group of lenses in front of it work as a converging lens and in its back from the inside a light sensitive film (which represents the retina) is placed, see figure (8.21). And the camera has an aperture in front of the lens (diaphragm) that's capacity can be controlled and allow for different amounts of the light to enter the machine and the distance between the lens and the film can be controlled to form a real inverted and clear image on the film as long as the object at a distance greater than twice the focal length of the lens of the machine and the image is always minimized, and to get magnified image of small insects for example, we get the lens closer so that the location of the insect is between the focus of the lens and twice the focal length of the lens.

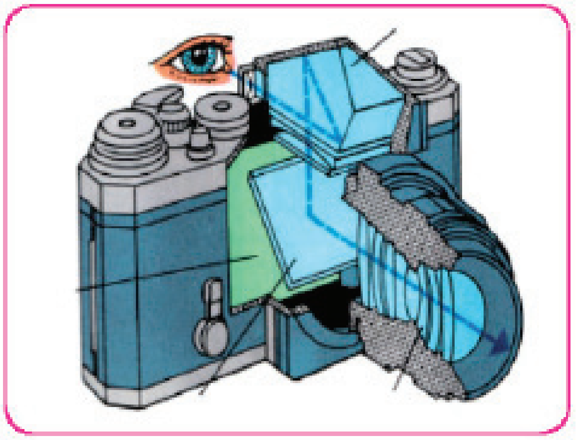


Figure (8.21)

3. Optical instruments

They are of two types:

A. Objects magnifying instruments

Used to form magnified image of the object and includes:

1. Simple magnifier:

A converging lens of short focal length used to form virtual erect and magnified images for the small objects and that is done by placing it within the focal length of the lens, see figure (8.22).

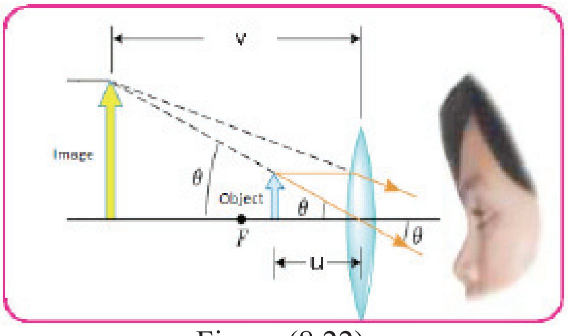


Figure (8.22)

2. Compound microscope:

Compound microscope is used to see micro objects that can't be seen by the naked eye such as bacteria and or small strips of plant leaf and stems tissues. It consists of two lenses, an objective lens with a short focal length, the small object that need to be examined (magnification) is placed at a distance slightly greater than its focal length to get a real, magnified, inverted image. And from another lenses that is seen through called the eyepiece and has a proper focal length longer then the focal length of the objective so the location of the image formed by the objective lens within its focal length to get a magnified, virtual, erect image of the first image formed by the objective lens, see figure (8.23). These two lenses can be moved individually up and down using a pivot. We use a concave mirror to concentrate the light on the object need to be magnified, see figure (8.24). And these devices have been developed by increase their magnification by adding many objective lenses to the device and any of them can be selected .and also the ability of connecting it to digital camera to view its images on a screen.

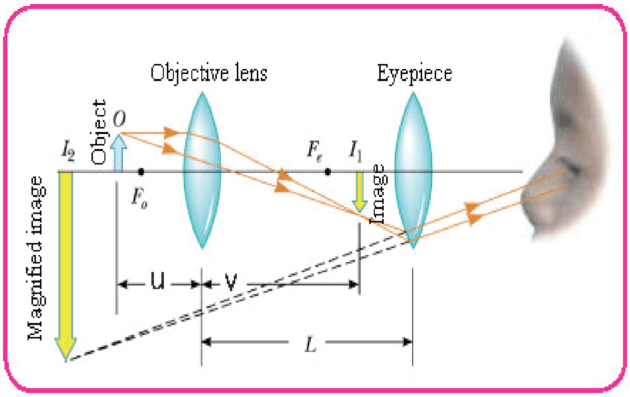


Figure (8.23)

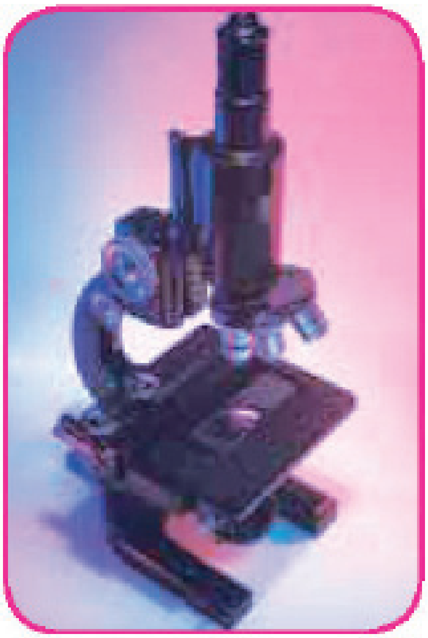


Figure (8.24)

In addition to that there are different projecting devices (that allow to show the image on far screen) like:

a. Image transparent projector

b. Epidiascope: which is used to show an image that is on a book's page or any other image to magnify it on a screen or a wall and make its details clear for the Attendees.

c. Over head projector

d. Moving image (Carton) projection device (the cinema machine).

The image of these devices is always inverted magnified and real, and the object is placed between the focus and twice the focal length.

There are projecting devices that connect with the laptops to show what is on their screens for the attendees and it's called data show and it's based on the same idea.

B. Telescope

Used to see far objects and military surveillance and in race tracks for horses. In addition to monitoring the movements of celestial bodies and it have many types:

a. Refracting telescope

This telescope has two sets of converging lenses, a wide surfaced objective lens with long focal length that allows for the largest amount of light that's emitted from the monitored object to enter the telescope, and a small spaced eyepiece with short focal length. The final image formed of these objects in the device is magnified virtual and erect to the image formed in the objective. It is used to monitor the planets and is called the astronomical telescope, see figure (8.25).

Figure (8.25)

b. Galileo telescope

This telescope is different from the astronomical telescope that the image it forms is erect with respect to the original object and of shorter length.

c. Reflecting telescope:

Is one of the biggest telescopes in the word where a concave mirror is used instead of objective lens to converge the light, so the intensity of the reflected light of the surface of the mirror is greater than the intensity of the light passing through the lens, see figure (8.26).

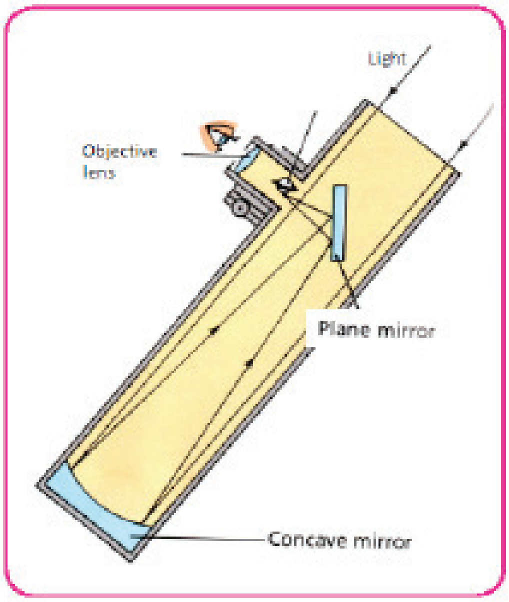


Figure (8.26)

Questions of chapter eight

Q1. Select the correct answer for the following questions.

1. The focal length for a thin lens doesn't depend on:

   a. Diffraction coefficient of the lens's material.

   b. Diffraction coefficient of the medium surrounding the lens.

   c. Two radius of curvature of the lens.

   d. Diameter of the lens.

2. To get a inverted, real image and magnified than object using a converging lens, the object should be placed at a distance from lens

   a. Greater then twice the focal length of the lens.

   b. Between the focus and twice the focal length of the lens.

   c. Less than the focal length of the lens.

   d. Equals twice the focal length of the lens.

3. To get an erect virtual magnified image of the object using a converging lens the object should be placed at a distance from lens

   a. Equals to the focal length of the lens.

   b. Equals twice the focal length of the lens.

   c. Less than the focal length of the lens.

   d. Greater then twice the focal length of the lens.

4. To get an erect virtual magnified image we should use :

   a. Diverging lens (two side concaved).

   b. Diverging lens (concave – plane).

   c. Converging lens and the object is placed within its focal length.

   d. Converging lens and the object is placed at a distance greater than its focal length.

5. To get a virtual minimized image to the object a diverging lens should be used and the object should be placed at a distance :

   a. Less than its focal length.

   b. At any distance from the lens.

   c. Greater than its focal length.

   d. Equal to twice of its focal length.

6. An object is placed at infinity distance from a converging lens an image formed for it and was:

   a. Real   b. Virtual   c. Erect   d. Greater then the object

7. A converging lens of 15 cm focal length (f) the distance of the image formed for an object on this lens depends on :

a. Distance of the object from the lens.
b. Height of the object.
c. Weather the object is erect or reversed.
d. All of the above.

8. A diverging lens of (10cm) focal length, an object was placed (40cm) away from it then the location of the image of that object will be at a distance of :

a. +16 cm b. – 10 cm c. +20 cm d. – 8 cm

9. An object was placed (40cm) away from a converging lens that's focal length is (20cm) so an image formed at a distance of :

a. 30cm b. 20cm c. 15 cm d. 40 cm

10. If the magnification of a converging lens is (-3) then the properties of the image is:

a. Virtual, erect and having a length that's three times the object's length.
b. Virtual, inverted and having a length that's three times the object's length.
c. Real, inverted and having a length that's three times the object's length.
d. Real, inverted and having a length that's one third the object's length.

11. An object was placed 80 cm away on the left side of a diverging lens , a virtual minimized and erect image formed for it and at 16 cm away from the lens and on the left side also , then the power of the lens equals:

a. -5D b. -4D c. -2D d. -1.25D

Answer the following question:
Q1. Give reason for the following.

a. The focal length for a lens differs depending on the color of the light that fells on it ?
b. The change in the focal length of the converging lens when moved from the air to the water ?
c. Light rays those pass through the optical center of the thin lenses goes out from the lens at the same direction ?

Q2. What is the reason for chromatic aberration in lenses ? and how is it treated ?

Q3. What is the reason of spherical aberration in lenses ? and how is it treated?

PROBLEMS

1. An object was placed in front of a diverging lens that's focal length is (12cm) an image formed for it that's length is one third the length of the object, what is the distance of the object from the lens, and what is the distance of its image?

Answer: u = 24 cm   v = -8 cm

2. A magnifying lens (converging lens) of (15cm) focal length, on what distance from it an object should be placed to get an erect and three times magnified image ?

Answer: u =10 cm

3. A model used slides to get an image on a barrier that's is (6 m) away, if the height of the image was (1.5m) and the height of the slide was (5cm), what is the focal length of the projectors lens ?

Answer: f = 19.4 cm

4. A pencil that's length is 10 cm was placed at (70cm) away from the left of a lens that's focal length is (+50 cm), find the properties of the formed image:

Answer: h = - 25 cm length of the image
(Real, magnified, inverted
according to the object).

9.1 Electric Charge

We have already studied the subject of electrostatic charge and it's charging methods we observed that, there are two types of electric charges (positive and negative charges). So when getting close a charged and isolated object by an electric charge from another object charged with electrical and insulated a reciprocal electrical force between the two objects is created, this force is a repulsion in the case of similar charges and it's an attraction in the case of different charges.

Electrical charges are characterized by:

1. Unlike charges attract each other while like charges repel each other.
2. The electric charge is conserved.
3. The smallest amount for the electric charge is the electron charge, any charged object will be the multiples of the electron charge. When an objects is charged, it's charge is a multiple of one electron charge (e) unit, this is means the charge is quantized, that charge equals integer number for electron charge.

And the total electric charge is given by the following relation:

Total electric charge (Q) = positive integer number (n)× electron charge (e)

$$Q = ne$$

Where

n : represents a positive integer number (n =1,2,3,4 …)

e : electron charge and it's equal to (1.6×10^{-19} C).

Do You know ?

It has been found lately that there is six types of particles inside the nucleus called quarks three of them have a charge equals to + 2/3 of the proton's charge and the other three have a charge equals to – 1/3 of the proton's charge.

9.2 Coulomb's Law

The scientist Charles Coulomb was able to formulate an empirical law that describe the electron force of attraction and repulsion between two charged objects using a torsion balance of his own design: it contains two charged balls, see figure (9.1). And that the attraction or repulsion causes a twisting in a bar suspended from its middle by a thin fiber and amount of angle in which the bar spins show amount of the electrical force, whether it is attraction or repulsion.

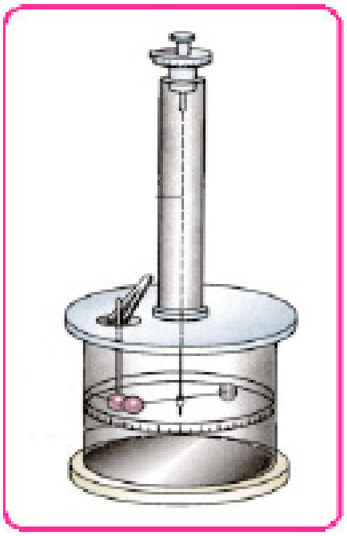


Figure (9.1)

And coulomb experiment clarified the electric force (F) that's mutual between two static electric points charges is direct proportional to the multiplication of the two charges and inverse proportional to the square of the distance between them.

So if the two electric point charges are (q_1) and (q_2) and the distance between them is (r), see figure (9.2) then the mutual electric force between them is given by the following relation:

$$\text{Electric force (F)} = \text{Proportional constan (K)} \times \frac{\text{charge } (q_1) \times \text{charge } (q_2)}{\text{square of the distance between them } (r^2)}$$

$$F = K \quad q_1 q_2 / r^2$$

Coulomb's law: The electric force between two point charge is direct proportional to the amount of the charges and inversely proportional to square of the distance between them

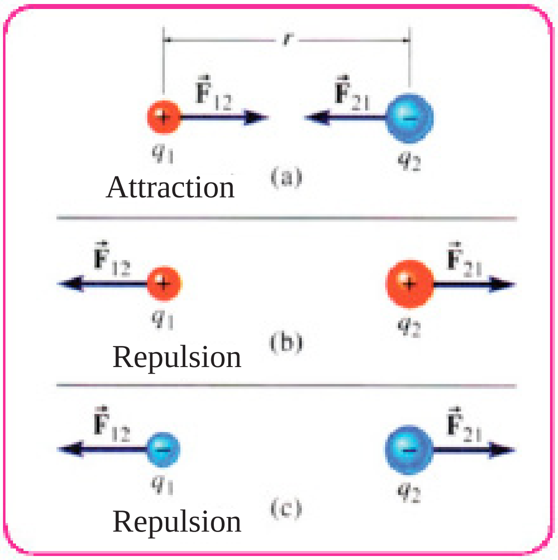


Figure (9.2)

If (q_1, q_2) was measured by coulomb and (r) measured by meter then the amount of the constant (k) depends on the type of the medium the two charges are placed in and measured by Nm^2/C^2.

And for vacuum its amount is:

$$k = (9 \times 10^9 \ Nm^2/C^2)$$

And K can be written by the following relation:

$$k = (1/4\pi\epsilon_0)$$

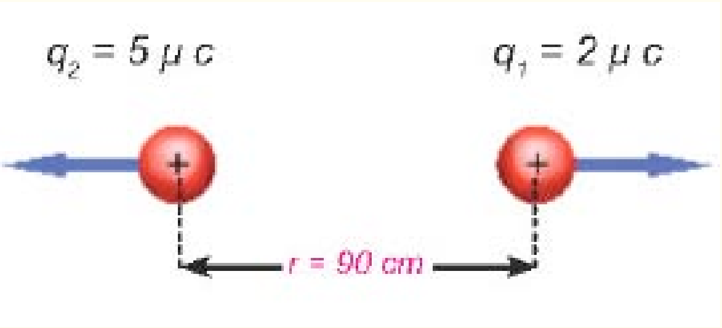
Where (ϵ_0) (the Greek letter epsilon) represents the air or free space permittivity and its value is ($8.85\times10^{-12}\ C^2/Nm^2$).

If the medium was an insulating material that's permittivity (ϵ) is different from the air's permittivity then the mutual electric force between the two charges will be smaller.

Example 1

A point charge (+2 µC) was placed at (90cm) from another positive point charge of (+5 µC) calculate the mutual force between the two point charges identifying the type of the force and the reason?

Solution



By applying coulombs law

$F = q_1q_2/r^2$

$F = \{9\times10^9.N\ .m^2/C^2\times(+2\times10^{-6}\ C)\times(+5\times10^{-6}\ C)\}/(0.9m)^2$

$= 1/9\ N$

Since the force between the charges is mutual and according to newton's 3rd law:

$\vec{F}_{12} = -\vec{F}_{21}$

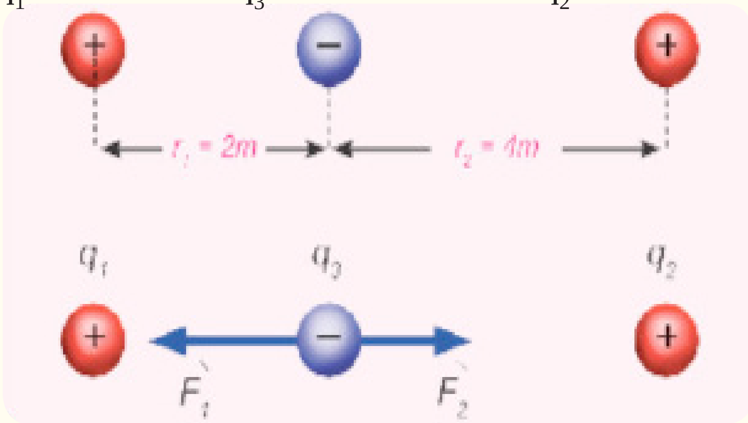
Then $\vec{F}_{12}$ is in an opposite direction of ($\vec{F}_{21}$).

So the force between the two point charges is a repulsion force because they have the same charge which is positive charge.

Example 2

In the following figure there is (three point) charges placed on the same line. Calculate the amount of the resultant force that affects the negative charge.

q_1=+4X10^{-6} C q_3= -5 X 10^{-6} C q_2=+6X 10^{-6} C



Solution

By observing the figure above we find that the negative charge is attracted toward (q_1) by ($\bar{F}_1$) force and the negative charge is attracted to (q_2) by ($\bar{F}_2$) force, and we calculate these two forces by applying coulomb's law:

$F = K\, q_1 q_2 / r^2$

$F_1 = \{ 9\times10^9\times(+4\times10^{-6})\times(-5\times10^{-6})\}/(2)^2$

$= -0.0450$ N An attraction force to the left

$F_2 = \{ 9\times10^9\times(+6\times10^{-6})\times(-5\times10^{-6})\}/(4)^2$

$= -0.0169$ N An attraction force to the right

Since these two forces are in an opposite direction so the resultant force (F_R) is:

$F_R = F_1 - F_2$

$= -0.0450 - (-0.0169)$

$= -0.0450 + 0.0169$

$F_R = -\ 0.0281$ N

The resultant force is toward left side and in the direction of the bigger force (F_1).

9.3 Electric Conductivity

Materials are divided according to their ability to conduct electricity into insulators, conductors and semi-conductors.

Insulating material in which the electrons are closely connected to the nuclei of their atoms and cannot move freely within the material. If we bring a charged object near an insulating material, no charge will be induced on it.

Examples of insulating materials rubber, glass, mica, dry silk, distilled water and others. The conducting materials are completely different. If we bring a charged object near a conducting material, the valence electrons present in the outer part of the conductor's atoms (Electrons that are weakly attached to the nuclei of their atoms) will be affected by the charge of the charged object that is close to it.

So it will affect the electrons and move them inside the conducting material transferring the electric through it means it allow electric charges to pass through it immediately and metals are considered that conduct electricity and the best one is silver, followed by copper and aluminum.

While semi-conductors are those materials that have intermediate properties between conductors and insulators in terms of their ability to conduct electric and the most common is the silicon (Si) and germanium (Ge) and these two materials have a special importance in technology since they are used in the manufacture of transistors, crystalline diodes and solar cells.

9.4 Distribution of Electrical charges on conductor surfaces

In order to know the distribution of charges on the surfaces of conductors we perform the following Activity:

Activity: Distribution of electrical charges on conductors surfaces.

Tools: a metal net on two insulating holders, small piece of paper, and a source for static electric charges.

Steps:

• Attach one end of each paper to the network and keep the other end free, this is performed from both sides.

• Charge the metal net with a specific charge, so the free end of the papers gets far from the net by repulsion form both sides, see figure (9.3a)

• Bend the metal net so its surface is curved as in figure (9.3b) we notice the repulsion of the papers those are on the outer surface of the net and the papers on the interior surface remain without repulsion.

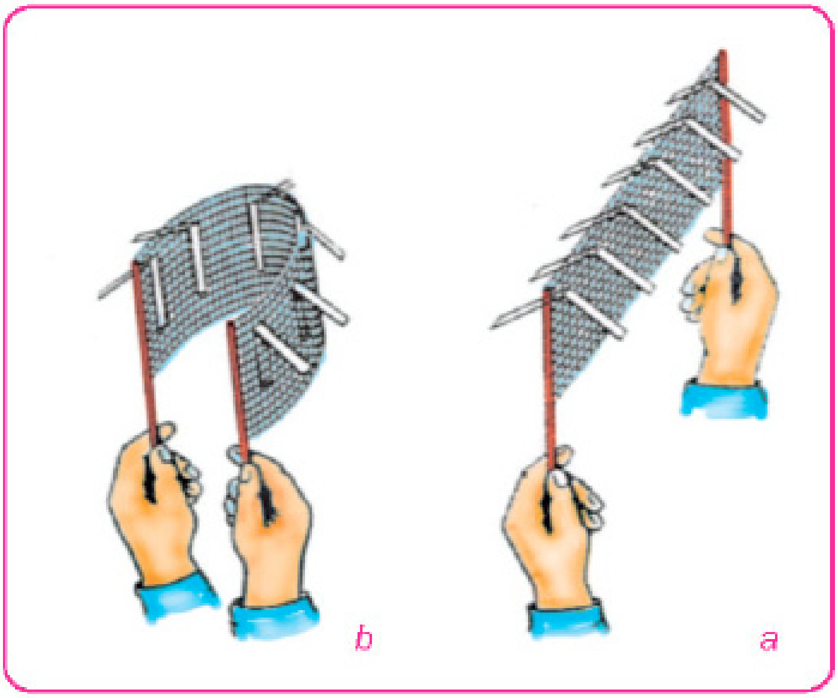


Figure (9.3)

We conclude from this activity that electric charges stay on the outer surfaces of the isolated charged conductors due to the repulsion of these charges when placed inside the conductors object because they are of the same type, see figure (9.4).

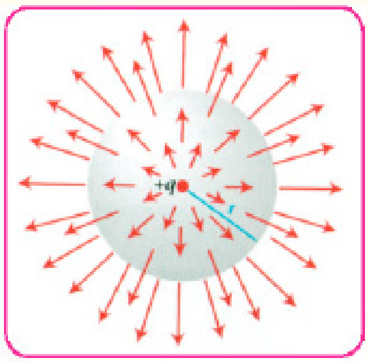


Figure (9.4)

Electric charge density.

The amount of electric charge per unit area of the isolated charged conductor's surface. The charge density on the metal spherical surface is calculated as follows:

$$\text{Charge density} = \frac{\text{The amount of charge on the conductor surface}}{\text{Surface area of the conductor}}$$

$$\text{Charge density } (\sigma) = \frac{\text{charge } (q)}{\text{area } (A)}$$

$$\sigma = \frac{q}{A}$$

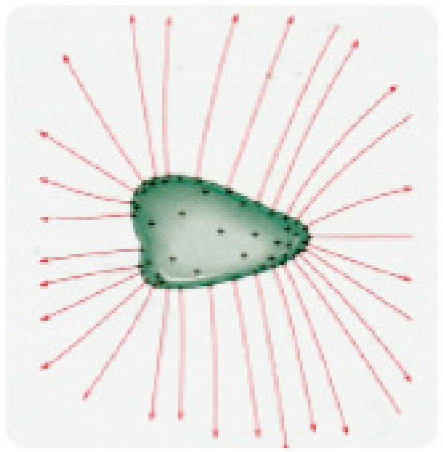
σ = is the charge density (a Latin letter called sigma) measured by $(\frac{C}{m^2})$

q = Amount of charge measured by coulomb.

A= surface area for spherical charged isolated conductor and measured by (m^2).

REMEMBER

Electrical charges are concentrated on sharp headers from the charges and isolated conductors surface with greater charge density.



9.5 The Electric Field

You have previously studied that the electric field of an electric charge is the space around the electric charge where the effect of an electric force shows on a positive test charge placed at any point in the field, see figure (9.5).

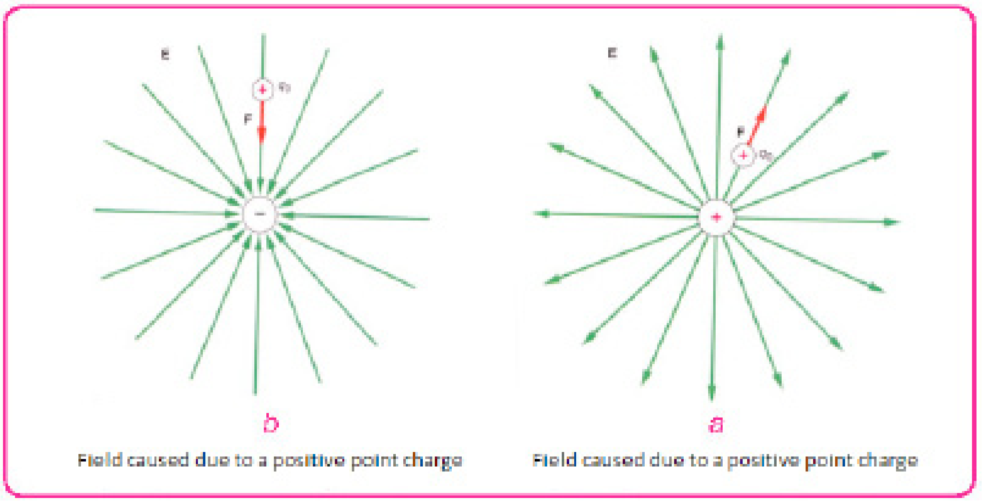


Figure (9.5)

The electric field is a vector quantity and its direction is towards the resultant of the electric force. That affects in the test charge. It is positive when it's made by a positive charge and the field is negative if it's made by a negative charge. The electric field is represented by lines called electric force lines or the electric field lines. The electric field line can be define as: the path taken by a free positive test charge when placed in the field.

Electric field lines are characterized by:

1. Its generated from the positive charge and perpendicularly over the charged surface and its directed towards the negative charge perpendicularly over the charged surface by the negative charge, see figure (9.6).

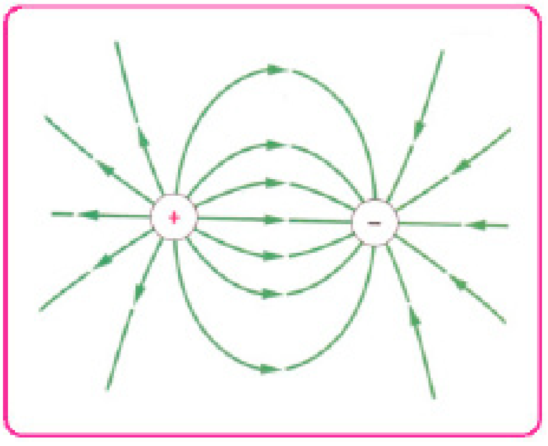
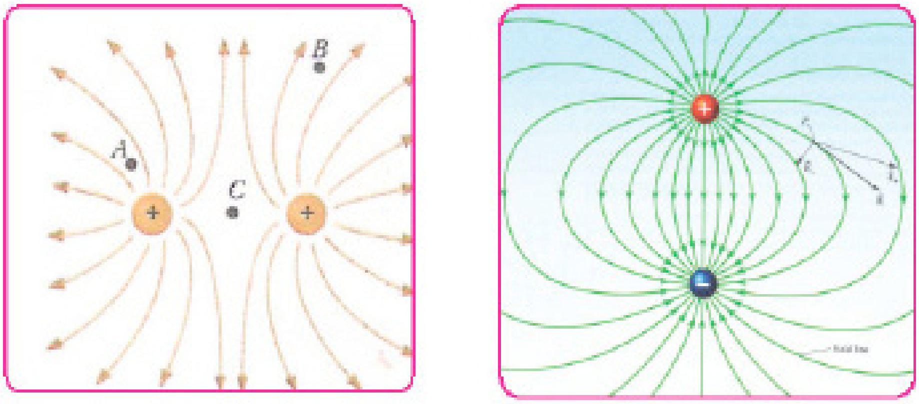


Figure (9.6)

2. The tangential of the force line at any point represents the direction of the electric field at that point, see figure (9.7).



b. electric field for two same charges

a. electric field for two different charges

Figure (9.7)

3. Electric field lines don't intersect with each other but they repel and tension to take the shortest possible length, see figure (9.8).

The electric field quantity at any point can be define as: the amount of electric force that the field affects on a charge placed at that point divided by that charge quantity.

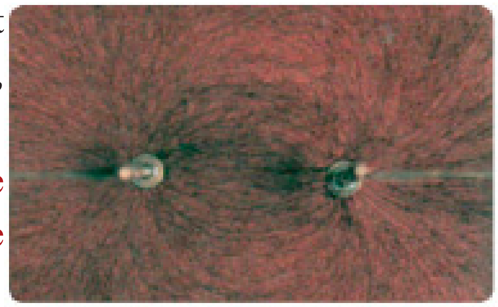


Figure (9.8)

$$\text{Electric field} = \frac{\text{electric force}}{\text{charge affected by the field}}$$

$$E = \frac{F}{q'}$$

Where

E = is the electric field measured by: $\frac{Newton}{Coloumb}$

F = affecting force measured by newton

q` = charge that's affected by the field, measured by coulomb and have (μC) and (PC) parts.

When the electric field is generated by a point charge, then the affecting force F on the test charge (q`) is given by the following relation:

Coulomb's law

$$F = K \frac{q \times q'}{r^2}$$

And since the electric field: $E = \frac{F}{q'}$

$$\therefore \quad E = \frac{K\,q}{r^2}$$

Where

E: is the electric field generated by the point charge at a distance (r) from it.

q: the point charge which caused the electric field.

r: the distance between the point and the point charge.

k: a constant that's equal: ($9 \times 10^9\ Nm^2/c^2$).

Homogeneous and non-homogeneous electric field:

Homogeneous electric field: is the field that has constant amount and direction at every point of its points and the electric force lines in it are parallel and of constant density and homogeneous, electric field can be made by charging two wide parallel plates with two equal and opposite charges and the electric field lines in the area between the two plates and the distances between them is equal.

(Neglecting effect of bending edges) and that means the field have same amount and same direction at all points, see figure (9.9)

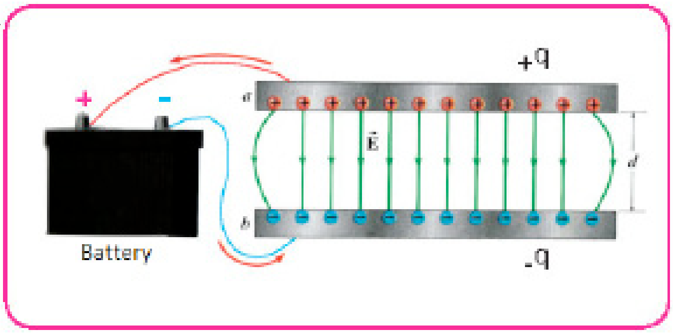


Figure (9.9)

Non-homogeneous electric field:

Is the field that's amount change from a point to another. Like the field generated from a point charge or around a charged spherical conductor, see figure (9.10). where the field decreases as we get far from it due to decrease in the density of electric force lines.

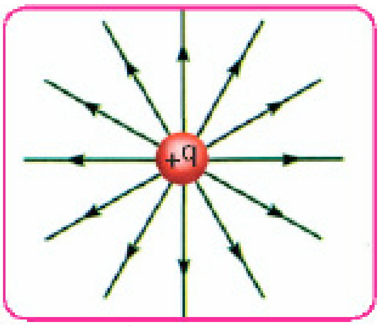
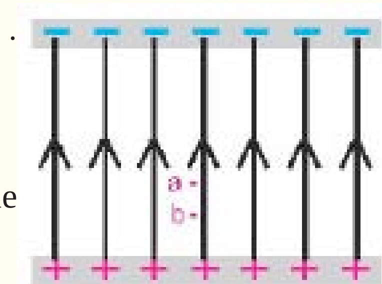


Figure (9.10)

Example 1

Two identical parallel plates are charged with two charges of same amount and different type. A charge of (2×10^{-6} C) at point (a), see figure on the right, between the plates and it was affected by an electrical force of (6×10^{-4} N) in the direction of the field lines .



1. What is the type of the point charge?
2. Calculate the amount of the electric field at point (a).
3. If the charge was moved to point (b) what is the amount of the affecting force on it?

Solution

1. Since the electric force is in the direction of the field then the point charge is positive.
2. Electric field = $\dfrac{\text{Electric force}}{\text{Charge affected by the field}} \Rightarrow E = \dfrac{F}{q`}$

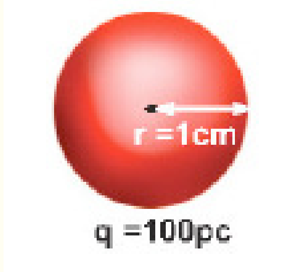
$$E = \frac{6 \times 10^{-4}}{2 \times 10^{-6}} = 3 \times 10^{2} \frac{\text{Newton}}{\text{Coulomb}}$$

3. When the charge is moved to point (b) it will be affected by the same amount of force ($F = 6 \times 10^{-4}$ N) in the direction of the field (E) because the electric field between the plates is homogeneous.

Example 2

A charged spherical conductor of (100pC) charge and (1cm) radius calculate:

1. The electric field at a point that's (50cm) from its center.
2. The electric field on its surface.
3. The electric field at a point inside the sphere.



Solution

$1PC = 1\times10^{-12}C$

$100PC = 100\times10^{-12}C$

$= 10^{-10}\ C$

Since the electric field is non-homogeneous we use the following relation:

1.

$E = K\ q/r^2$

$= 9 \times 10^9\ Nm^2/C^2 \times (10^{-10})/(50\times10^{-2}\ m)^2$

$= 3.6\ N/C$

2.

On the surface of the sphere $r = 1cm = 0.01m$

$E = K\ q/r^2$

$= 9 \times 10^9\ Nm^2/C^2 \times (10^{-10})/(1\times10^{-2}\ m)^2$

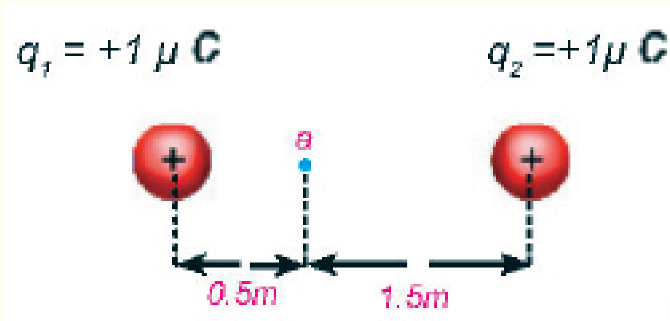
$= 9000\ N/C$

3. The electric field inside the conducting sphere equals to zero since there is no charges, hence all charges are on the external surface of the sphere :

$E = 0$

Example 3

The following figure shows two point charges of ($1\mu C$) and the distance between them is (2m), calculate the amount of the electric field at a point on the line connecting the two charges that's at (0.5m) from the first charge and (1.5m) from the second charge.



Solution

Since its required to find the electric field at point (a) so we assume a positive test charge at point (a). And then we calculate the amount of the electric fields created by these point charges. Where the test charge will be affected by repulsion force with (q_1) and repulsion force with (q_2)?

$E = K\ q/r^2$

$E_1 = 9 \times 10^9 \times (1\times10^{-6})/(0.5)^2$

$E_1 = 36 \times 10^3$ N/C electric field generated by charge (q_1)

$E_2 = 9 \times 10^9 \times (1\times10^{-6})/(1.5)^2$

$E_2 = 4 \times 10^3$ N/C electric field generated by charge (q_2)

Since the direction of (E_1) is opposite to the direction of (E_2) then the resultant electric field (E_R) is in the direction of the greater electric field.

E_R (the resultant electric field) = $E_1 - E_2 = 36 \times 10^3 - 4 \times 10^3$

$E_R = 32 \times 10^3$ N/C

9.6 The Electric Flux

The electric field in a particular area depends on the density of the electric force lines passing by that area, so it increases as the density increase and therefore the density of the electric force lines is a measure of the electric field. The number of electric force lines that intersect the surface perpendicularly is called the electric flux and is symbolized by the Greek symbol (Φ). By looking at figure (9.11). Find that the amount of electric flux increases by increasing the number of the electric force lines penetrating the surface (A) perpendicularly, as well as by increasing the area of the penetrated surface.

And from that we can conclude the relation between the electric flux and the electric field as:

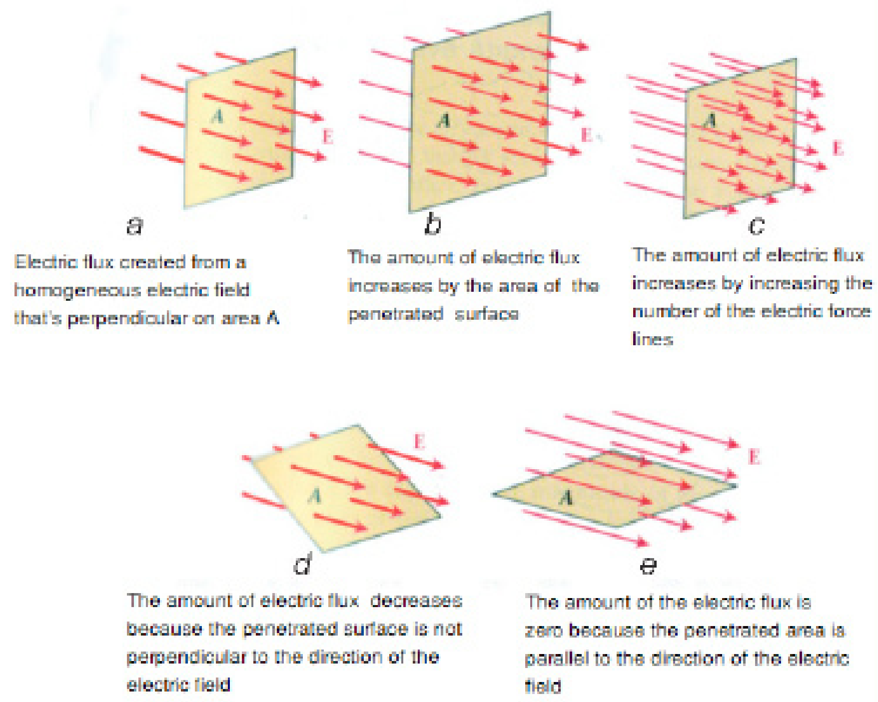


Figure (9.11)

Electric flux (Φ) = Perpendicular electric field ($E_{\perp}$) × Area of the penetrated suface

$$\Phi = E_{\perp} A$$

Example 1

Calculate the electric flux through a charged and isolated spherical conductor that's radius is one meter and there is a (1μC) charge on its surface.

Solution

$E = K\, q/r^2$

$= 9 \times 10^9 \times (1\times10^{-6})/(1)^2$

$E = 9 \times 10^3$ N/C amount of electric field at a point on the sphere's surface

Electric flux (Φ) = Perpendicular electric field $E_\perp$ × Area of the penetrated surface

$\Phi = E_\perp A$

$\Phi = E_\perp \times 4\pi r^2$

$= 9 \times 10^3 \times 4 \times 3.14 \times 1^2$

$\Phi = 1.13 \times 10^5$ N.m²/C amount of electric flux

Example 2

An electric charge of ($+2\times10^{-6}$ C) was placed in a homogeneous electric field that shows a force of (8×10^{-2} N) what's the amount of the electric field?

Solution

$$E = \frac{F}{q`}$$

$$E = \frac{8\times10^{-2}\text{ N}}{2\times10^{-6}\text{ C}}$$

$E = 4\times10^4$ N/C the amount of the electric field.

9.7 Electric Potential

If we assume that there is a positive to electric charge (q) at a distance (r_A) from a positive test charge (q`). Then the positive test charge (q`) will be affected by the electric field of the charge (q) according to coulomb's law by moving away from (q) as in figure (9.12), and this charge has certain potential electric energy. If the test charge (q`) moves close to the charge (q) with a distance (r_B) note figure (9.13) and at an opposite direction of the electric field. This will require a work to overcome the repulsion force, So the work also converts to electric potential energy.

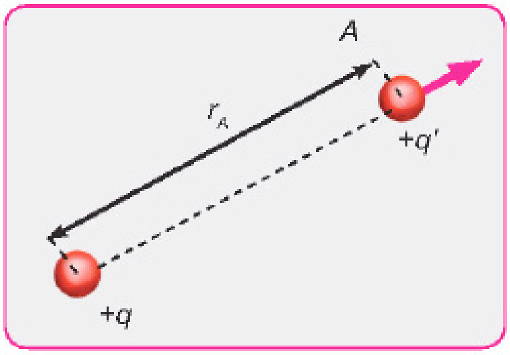


Figure (9.12)

That time the amount of the potential energy at point (B) will be greater than the amount of the potential energy at point (A) by the amount of work done, and according to that the electric potential can be defined as the electric potential energy to the charge unit at a point inside the electric field , its scalar quantity that means:

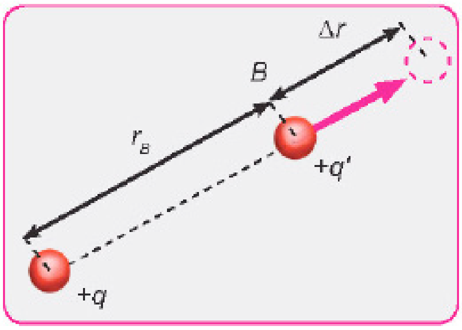


Figure (9.13)

$$\text{Electric potential } V = \frac{\text{Electric potential energy (work w)}}{\text{Affected charge (q)}}$$

$$V \text{ (volt)} = \frac{w \text{ (joule)}}{q \text{ (coloumb)}}$$

And to calculate the electric potential at a distance (r) from the center of a charged and isolated conducting sphere we apply the following relation:

$$V = k \frac{q}{r}$$

Where

K: constant equals to ($9 \times 10^9\ Nm^2/C^2$). (for air).

The electric potential is measured by volts (V). The potential is positive if it's generated from a positive charge and negative if it's generated from negative charge.

9.8 Potential Difference

The potential difference between the potential of two points (A), (B) inside the electric field, see figure (9.14) is the difference in the electric potential energy to the charge unit between these two points . It is the amount of work required to move the positive electric charge from one of the point to the other divided by the amount of that charge.

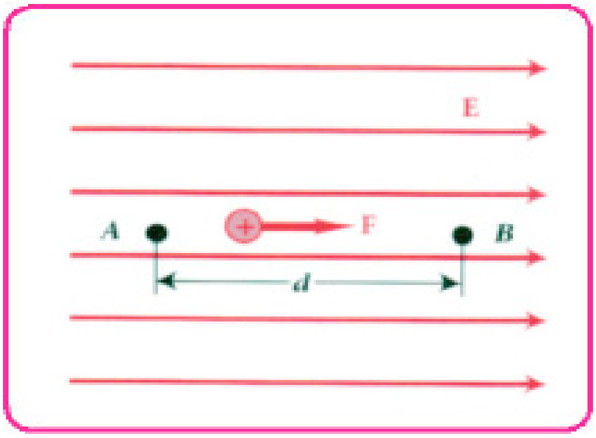


Figure (9.14)

Electric potential difference = Work at B - Work at A

$$V_{AB} = V_B - V_A = \frac{W_{AB}}{q}$$

And from it:

Work = potential difference × moved charge

$$W_{AB} = q\,V_{AB}$$

<u>The relation between the electric field and the potential gradient.</u>

We have find that:

$$\text{Potential difference} = \frac{\text{Work}}{\text{Moved charge}}$$

$$V_{AB} = \frac{W_{AB}}{q}$$

When substituting W_{AB} by what equals to it in the homogeneous electric field

Work (W_{AB}) = Force (F) × Displacement (X)

$$W_{AB} = F\,x$$

From it we get:

$$V_{AB} = \frac{F\,x}{q}$$

$$\frac{V_{AB}}{x} = \frac{F}{q}$$

Electric field (E) equal $\frac{F}{q`}$

The amount of $\frac{V_{AB}}{x}$ is called the potential gradient and measured by $\frac{\text{Volt}}{\text{meter}}$

Means:

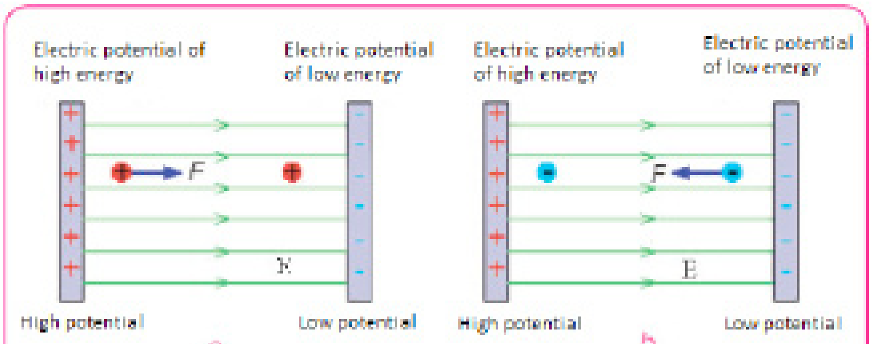
Electric field = potential gradient

$$E = \frac{V_{AB}}{x}$$

REMEMBER

* The affecting electric force on a positive electric charge point on the direction that potential energy of the low potential see figure (a).

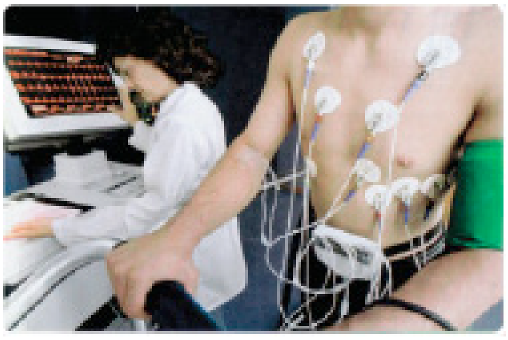
* The electric field is always in the direction of low potential, see figure (a,b).



a b

Do you know ?

The stress test used to examine heart patients is performed by calculating the relationship between potential differences between two metal poles as a function of time. This test shows if the heart is functioning normally or not.



9.9 Equipotential Surface

Equipotential surface is the surface that's surface point have the same amount of electric potential means the potential difference between any two points of its points equals to zero.
Most important properties of equipotential surfaces:

1. Don't intersect with each other, see figure (9.15).
2. Electric force lines are perpendicular on the equipotential surfaces.
3. Equipotential surfaces get close to each other at the areas of high electric field (E) so the density of the electric force lines also increase and for that reason the equipotential surfaces get close to each other near the sharp ends of the charged and isolated objects.

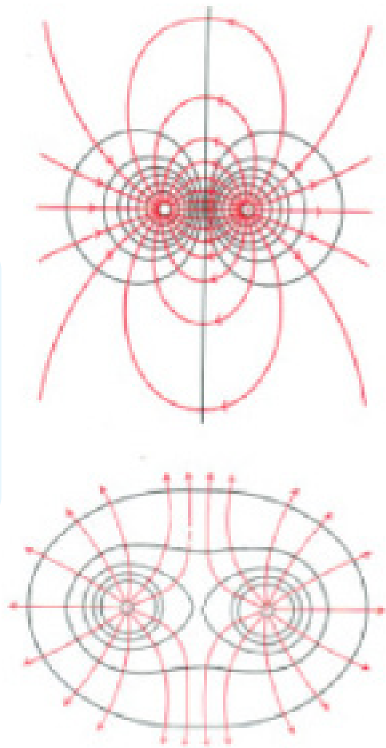


Figure (9.15)

Figure (9.16) shows equipotential surfaces (drawn as dashed lines) and the electric force lines drawn as continuous lines for two shapes of different electric field. When the field is generated from a point charge as in (a) the equipotential surfaces are spherical and united center. While is the case of homogeneous field (like that between the two parallel plates) as in figure (b) then the equipotential surfaces are parallel.

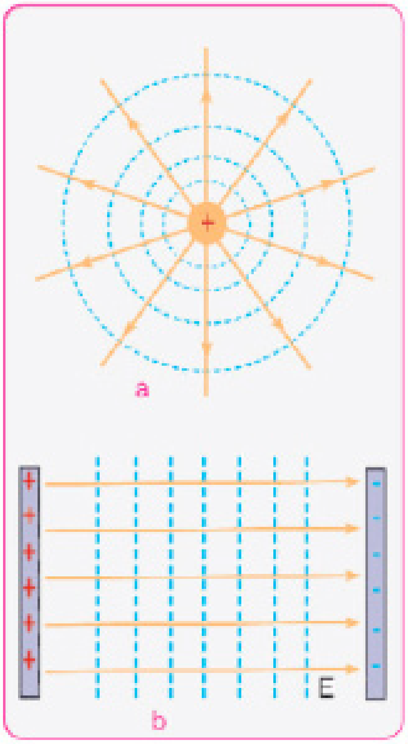


Figure (9.15)

Example 1

A metallic isolated sphere that's radius is (5cm) and a (20 μC) charge is placed on it, find the electric potential at the point:

1. On its surface
2. At (15 cm) from its surface

$q = (20\ \mu C) = (20\times10^{-6} C)$

Solution

1.

$V = k\ q/r$

$V_1 = \{9\times10^9 \times 20\times10^{-6}\} / 0.05$

$V_1 = 36\times10^5$ volt the potential of its all points

2.

$V_2 = \{9\times10^9 \times 20\times10^{-6}\} / (0.05+0.15)$

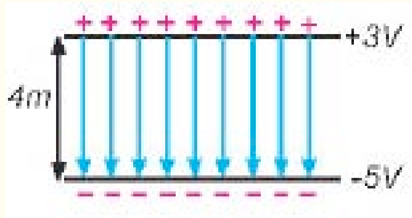
$V_2 = 9\times10^5$ volt the potential at (15 cm) from its surface.

Example 2

The following figure shows two parallel plates of equipotential surfaces, the potential of one of them is (– 5V) and the potential of the other is (+3V) and the distance between them is (4m). calculate the electric field between them.

Solution

Since the electric field between the two plates is homogeneous then the field lines will be parallel and perpendicular to both surfaces so:



Electric field (E) $= \dfrac{\text{Potential difference}}{\text{Distance}}$

Means:

Electric field = potential gradient

$$E = \frac{\Delta V}{x} = \frac{V_2 - V_1}{x} = \frac{3-(-5)}{4} = \frac{8}{4}$$

E = 2 V/m amount of electric field

Example 3

The point (A) is (30cm) away from a sphere's center that's radius is (1cm) and its charged by (2×10^{-9} C) and point (B) is at a distance (90cm) from the center of the same sphere, calculate the work needed to move a charge of (1μC) from point (B) to (A).

Solution

Electric field (E) $= \dfrac{\text{Constant} \times \text{work}}{\text{Distance}}$

$V = k\ q/r$

Where (q) represent the field generated charge.

$V_A = 9\times10^9 \times 2\times10^{-9}/0.3 = 60$ volt Potential at point A

$V_B = 9\times10^9 \times 2\times10^{-9}/0.9 = 20$ volt Potential at point B

Potential at point B – potential at point A = potential difference between (A,B).

$V_{AB} = V_A - V_B = 60 - 20 = 40$ volt

Work = potential difference × charge

$W_{AB} = q\ V_{AB}$

$W_{AB} = 1\times10^{-6} \times 40 = 40\times10^{-6}$ Joule

The earth electric potential

The electric potential of earth is zero, and this doesn’t mean the earth doesn’t contain electric charges but due to its very large surfaces that doesn’t allow any charge that’s taken from it or given to it to change its potential since its considered a very big storage of positive and negative charges.

Conductors those are charged by positive charges and away from electrical effect have positive potential, if the reach the earth negative charges will move to it from the earth and equalize it thus its potential become zero like the earths potential but if the conductor was negatively charged then when connected to the earth then negative charges will move from the conductor to the earth and its potential will become zero like the earth’s potential the rule of geared heads in the discharging of electrical charge.

Charge density is inversely proportional to the radius of the conductor thus the density of the charges will be greater at the geared heads, so electricity is discharged from it to the atmosphere through the free ions that are always found in the air due to the high electric field that causes the ionization of the air surrounding this geared head, see figure (9.17) that attracts the equalized or differently charged air particles, thus the charges equalize then a charge that is same to the geared head charge is gained and repels with it. And by that the electrical charge is being discharged from it to the atmosphere.

Figure (9.17)

Atmospheric electricity:

There are many visible electrical phenomena appear in different areas on earth including the polar aurora, whirlwinds, lightning and thunder. In our study we will consider some of these phenomena, such as lightning and thunder in the rainy weather, see figure (9.18).

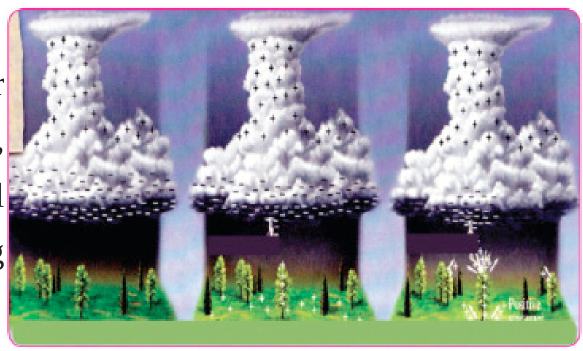


Figure (9.18)

In particular, when the clouds become electrified and their charge is positive in the upper layers and negative in the lower layers of the cloud, If a discharge occur (in the form of close strikes) between the different parts of the same cloud, or between two different clouds then its called (lightning) which is no longer than (1/1000) of a second and it occur at a rate of (100) flash per second approximately. And at a power of (4×10^9) kilowatts and the length of the spark may reach several kilometers and at a diameter of (15cm -10cm) which leads to the ionization of the air and suddenly heat it to (30000°C) which gives a glowing light.

This sudden increase in temperature leads also to the sudden expansion of air generating a sound that's echo is repeated between the clouds and called thunder.

Lightning stroke

If an electrical discharging occur between a charged cloud and any other object that have different charge with it on the earth then its called lightning stroke that's average occurrence time is $\frac{1}{4}$ second, see figure (9.19).

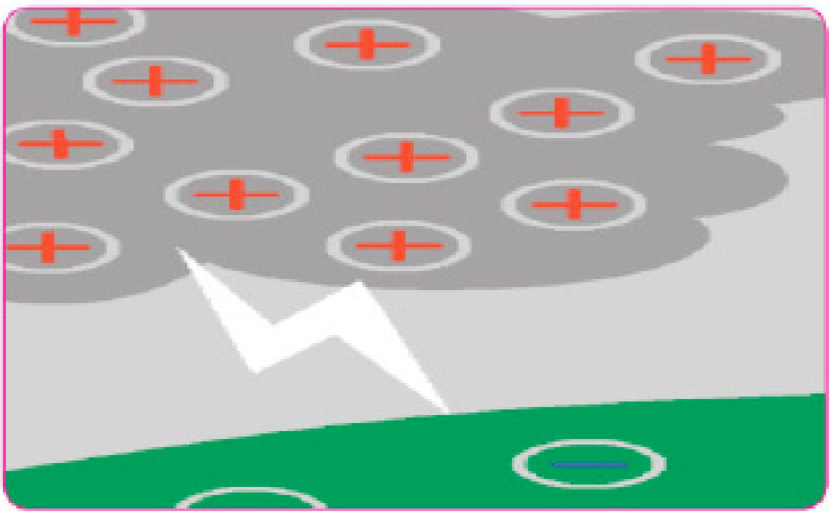


Figure (9.19)

Lightning arrester

Figure (9.20)

Used to protect the facilities and houses from atmospheric electric discharge. It works to discharge the electrical charge towards the earth slowly and its work depends on the action of the tooth it is composed of a conductor that's one end is attached to a moist ground and other end rises above a surface of the building and its sharp. So If the atmosphere is charged with negative charges then positive charges are generated on the surface of the earth and transferred to the sharp head of the lightning arrester.

Then goes away from it resulting in a step-by-step discharging due to the potential difference between the earth and the atmosphere surrounding the sharp head and thus decreases the danger of external discharging, see figure (9.20).

Do you know ?

It appear to the naked eye that only one lightning discharge occur but the truth is that many successive and fast strokes occur at the same path in the air.

Applications of Static Electric

1. Electrostatic filters

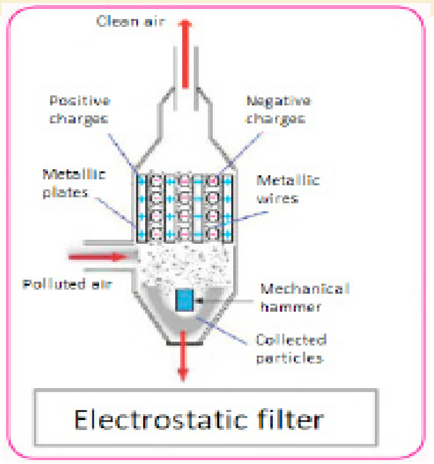


Figure (9.21)

Many factories release gases that contain small particles in the form of a cloud of smoke that lead to the environment pollution. And electrostatic filters were used in filtering the environment from that. Figure (9.21) shows the work of the electrostatic filter. The filter contains thin metallic wires charged with negative charge and work on charging the smoke particles with negative charge when the polluted gases pass through the filter then the smoke particle will be attracted by positive charged metallic plates then using a mechanical hammer these plates will be shaken to collect the particles down.

2. Photocopier machine

Photocopier machine is considered one of the important application of the static electric, figure (9.22) shows the main steps that occur inside the photocopier machine.

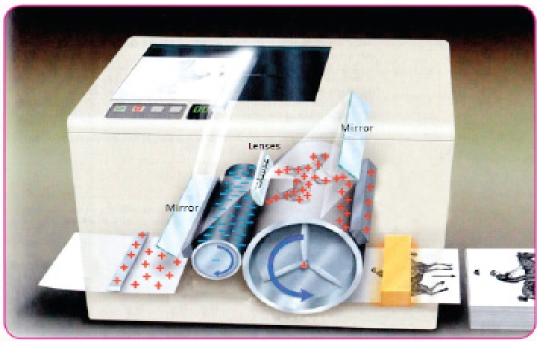


Figure (9.22)

Questions of chapter nine

Q1. Choose the correct answer for the following questions.

1. The electric charge density for a charged isolated conductor that have sharp heads is:

a. The greater on its sharp heads.

b. The smaller on its sharp heads.

c. Equal in all points.

d. All of the above.

2. In the case of homogeneous electric field:

a. The field amount is changing in all of its points.

b. The field amount and direction constant in all of its points.

c. The field direction is constant in all of its points.

d. The field amount and direction are changing in all of its points.

3. The electric potential of points located between two parallel plates those are charged by equal but different charge is:

a. Always positive   b. Always negative

c. Positive or negative   d. Maybe positive , negative or zero

4. If you place a free electric charge in an electric field than it will move:

a. In the direction of the field always.

b. Inverse the direction of the field always.

c. In the direction of the field if it was positive and inverse to it if it was negative.

d. Perpendicular to the field.

5. The potential of a point of an isolated charged conducting sphere is one volt, the potential of its center is:

a. One volt   b. Zero

c. Less than one and greater than zero volt   d. Greater than zero volt

Q2. Put the right sign for the correct statement and wrong sign for the false statement and correct the false statement without changing the under lined part:

1. The electrical attraction or repulsion force between two charged objects is greater than the gravitational force attraction between their masses.
2. The electron attracts the nucleus's proton in the atom with a force smaller than the force that the proton attracts the electron .
3. All the point of charged conducting sphere have the same potential.
4. Semi-conductor are always good electric conductors.
5. Coulomb's law applies for electric charges those are equal only.
6. Coulomb's law applies for electric charges of large volume.
7. The electric charge is distributed on a conducting surface in homogeneous way.
8. The surface of charged isolated conduction sphere is an equipotential surface.
9. Electric force lines are parallel in the homogeneous electric field.
10. The earth can be charged by a positive electric charge.
11. Electric force lines cannot intersect.
12. If a certain electric charge was placed in a homogeneous electric field then the electric force that act on it will be constant in magnitude and direction.

Q3. Can two electric force lines intersect? And why?

Q4. How do you explain the equal potential for all the points of the isolated charged conductor?

Q5. Give a reason for the absence of electric field inside a charged isolated metallic ball?

Q6. If the potential of a certain point is zero then is it necessary that the electric field is also zero?

Q7. Which one is bigger, the potential of a point inside a charged metallic ball or the potential of a point at its surface, and why?

Q8. What is lightning stroke? And what is lightning arrester? And how does it work to protect buildings and facilities?

Q9. What's lightning and how does it happen?

Q10. Why we see the lightning before hearing the sound of the thunder that result from it.

Q11. The electric field inside a charged isolated hallow metallic ball equals to zero, does that mean the potential inside the ball is also zero?

Problems

Q1. What is the magnitude of the repulsion force between two equal point charges, the magnitude of each one of them is (1μC) and they are (10 cm) away from each other?

Answer: $F = 0.9N$

Q2. The two point charges (+3 μC) (+27 μC)were placed on a straight line separated by one meter distance, then where should the third point charge be placed until the resultant force on it due to the two charges is zero.

Answer: X = 25 cm distance of the point charge (q_3) from the point charge (q_1)

Q3. If the potential difference between two points (B,A) is (60V) then what is the work needed to move

a. A proton (q=+ e) from (A) to (B)

b. A electron (q= -e) from (A) to (B)

Answer: a. $W_{AB}=(-9.6\times10^{-18}\ J)$

b. $W_{AB}=(+9.6\times10^{-18}\ J)$

Q4. Two parallel surfaces of equipotential surfaces, the potential at point (a) equal to (10V) and the potential of point (b) equal to (-2V) and the distance between them is (4mm) calculate the electric field between the two points?

Answer: $E = 3000N/C$

Q5. Point (A) is (0.5m) away from the center of a charged ball that's charge is (1×10^{-3} μC) and the point (B) is (0.9m) away from the center of the same ball, calculate the required work to move a (2 μC) charge from point (B) to (A) ?

Answer: $W = 16\times10^{-6}\ J$

The positive work equals to the energy transferred to the charged object.

Q6. A charge of (6 μC) was placed at (1.2 m) away from another charge of (5 μC) in vacuum, calculate the required work to move the second charge to be at (0.9m) from the first charge?

Answer: $W = +0.075\ J$

The positive work equals to the energy transferred to the charge.

Scientific terminology مصطلحات علمية

Chapter One	**الفصل الأول**
Measurement	القياس
International system of units	النظام الدولي للوحدات
SI Units	وحدات النظام الدولي
Supplementary Units	الوحدات التكميلية للنظام الدولي
Length	طول
Mass	كتلة
Time	زمن
Electrical current	تيار كهربائي
Amount of substance	كمية المادة
Temperature	درجة الحرارة
Luminous Intensity	شدة الإنارة -الإضاءة
Plane angle	الزاوية المستوية
Solid angle	الزاوية المجسمة
Prefixes	البادئات
Measurement errors	أخطاء القياس
Graphs	الرسوم البيانية
Slope	الميل
Variation	التغير
Direct Proportion	التناسب الطردي
Inverse Proportion	التناسب العكسي
Proportional Constant	ثابت التناسب
Absolute temperature	درجة الحرارة المطلقة
Chapter Two	**الفصل الثاني**
Elasticity and Hooks Law	المرونة وقانون هوك
Stress	الإجهاد
Mechanical Properties of Matters	الخواص الميكانيكية للمواد
Limit of Elasticity	حد المرونة
Toughness	المتانة
Tensile stress	إجهاد الشد
Compressive stress	إجهاد الكبس
Shearing stress	إجهاد القص
Modulus of Elasticity	معامل المرونة
Elastic Deformation	التشوه المرن
Plastic Deformation	التشوه البلاستيكي (اللدن)
Longitudinal strain	المطاوعة الطولية

Shear strain	مطاوعة القص
Volume strain	مطاوعة الحجم
Brittleness	الهشاشة
Failure	العجز (الفشل)
Hardness	الصلادة
Chapter Three	**الفصل الثالث**
Static fluids	الموائع الساكنة
Fluid	المائع
Archimedes's principle	مبدأ ارخميدس
Surface tension	الشد السطحي
Capillary property	الخاصية الشعرية
Continuity equation	معادلة الاستمرارية
Bernoulli's equation	معادلة برنولي
Application of Bernoulli's equation	تطبيقات معادلة برنولي
Atomizer	المرذاذ
Lift force	قوة الرفع
Viscosity	اللزوجة
Chapter Four	**الفصل الرابع**
Quantity of heat	كمية الحرارة
Specific heat	الحرارة النوعية
Heat capacity	السعة الحرارية
Thermal equilibrium	الاتزان الحراري
Latent heat	الحرارة الكامنة
Thermal expansion	التمدد الحراري
Phase change	تغير حالة المادة
Latent heat of fusion	الحرارة الكامنة للانصهار
Latent heat of vaporization	الحرارة الكامنة للتبخر
Methods of heat transfer	طرائق انتقال الحرارة
Thermal conduction	انتقال الحرارة بالتوصيل
Thermal conductivity	التوصيلية الحرارية
Transfer of heat convection	الحمل الحراري
Thermal radiation	انتقال الحرارة بالإشعاع
Thermal gradient	الانحدار الحراري
Free convection	الحمل الحراري الحر
Forced convection	الحمل الحراري الاضطراري
Thermal pollution	التلوث الحراري
Sources of thermal pollution	مصادر التلوث الحراري

Chapter Five	**الفصل الخامس**
Optics	البصريات
Sources of light	مصادر الضوء
Propagation of light	انتشار الضوء
Velocity of light	سرعة الضوء
Luminous object	الجسم المضيء
Illuminated object	الجسم المستضيء
Huygen's principle	مبدأ هايجنز
Wavefront	جبهة الموجة
Wave length	طول الموجة
Frequency	تردد
Visible spectrum	الطيف المرئي
Luminous flux	السيل الضوئي
Luminous Intensity	قوة الإضاءة
illuminance	شدة الاستضاءة
Chapter Six	**الفصل السادس**
Critical angle	الزاوية الحرجة
Fiber-optics	الألياف البصرية
Index of retraction	معامل الانكسار
Optical density	الكثافة الضوئية
Reflection	انعكاس
Reflecting prism	الموشور العاكس
Refraction	انكسار
Sine of the angle	جيب الزاوية
Snell’s law	قانون سنيل
Total internal reflection	الانعكاس الكلي الداخلي
Transparent medium	وسط شفاف
Vacuum	فراغ
Incident ray	شعاع ساقط
Reflected ray	شعاع منعكس
Refracted ray	شعاع منكسر
Air	هواء
Glass	زجاج
Chapter Seven	**الفصل السابع**
Types of Mirrors	أنواع المرايا
Plane mirrors	المرايا المستوية
Spherical Mirrors	المرايا الكروية

Concave Mirror	مرآة مقعرة
Convex Mirror	مرآة محدبة
Real focus	البؤرة الحقيقية
Virtual focus	البؤرة التقديرية
Images Formed by a plane Mirror	الصور المتكونة بالمرايا المستوية
Image Formed by spherical Mirror	الصور المتكونة بالمرايا الكروية
Chapter Eight	**الفصل الثامن**
Thin lens	عدسة رقيقة
Convex lens	عدسة محدبة
Converging lens	عدسة لامة
Focus	البؤرة
Focal Length	البعد البؤري
Optical center	المركز البصري
Principle axis	المحور الأساس
Radius of curvature	نصف قطر التكور
Lens formula	معادلة العدسة
Real object	الجسم الحقيقي
Lateral magnification	التكبير العرضي
Power of lens	قدرة العدسة
Combination of thin lenses	نظام من مجموعة عدسات رقيقة
Chromatic aberration	زيغ لوني
Spherical aberration	زيغ كروي
Aperture	فتحة
Achromatic Lens	عدسة لا لونية
Chapter nine	**الفصل التاسع**
Electric charge	الشحنة الكهربائية
Coulomb’s law	قانون كولوم
Electricity and matter	الكهربائية والمادة
Electric conduction	التوصيل الكهربائي
Electric field	المجال الكهربائي
Electric lines of forces	خطوط القوة الكهربائية
Electric field intensity	مقدار المجال الكهربائي
Flux and Electric Flux density	الفيض وكثافة الفيض الكهربائي
Electric potential	الجهد الكهربائي
Electric potential for two charge	الجهد الكهربائي لشحنتين
Electric potential difference	فرق الجهد الكهربائي
Equipotential surfaces	سطوح تساوي الجهد

ارشادات بيئية

* بيئة نظيفة تعني حياة افضل.

* عندما تكون للبيئة اولوية .... البيئة تدوم.

* الماء شريان الحياة ... فحافظ عليه من التلوث.

* حماية البيئة مسؤولية الجميع .... فلنعمل لحمايتها.

* بالتشجير تصبح بيئتك ابهى.

* لنعمل من اجل بيئة افضل ووطن اجمل.

* ان اقتلعت شجرة او نبتة مضطراً فازرع غيرها.

* حافظ على بيئتك لتتنعم بحياة افضل.

* بيئة الانسان مرآة لوعيه.

* لنعمل معاً .... من اجل عراق خال من التلوث.

* يداً بيد من أجل وطن اجمل.

* بيئتك حياتك .... فساهم من أجل جعلها مشرقة.

* البيئة السليمة تبدأ بك.

* من اجل الحياة على الارض .... انقذوا أنهارها.

* معاً لترشيد استهلاك الطاقة، فلنكن يداً بيد نحو بيئة مستدامة.

* إطفيء الانوار عند عدم الحاجة لها .... معاً لترشيد استهلاك الكهرباء.