Republic of Iraq
Ministry of Education
General Directorate of Curricula

Physics 5

Scientific Secondary

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Introduction

Dear student

This book forms one of the pillars of the developed curriculum in physics and that works on achieving scientific and practical aims which keep up the scientific evolution in information and communication technology .This book also provides a link between the Facts and the concepts that the student study and his daily community life.

This book aims to the following topics;

- clarify the relationship between science and technology in science field and its effect on development and linking it to practical life.
- gives the student methodology of scientific thinking and moving him from the basic way of learning to a way full of fun and motivation.
- trying to train the student for discovering through developing of the monitoring and analyzing skills.
- gives the student life skills and applicable scientific capabilities.
- develop the concept of modern ways in maintaining the environmental equilibrium practically and globally.

This book contains ten chapters they are:

Chapter 1 : Vectors

Chapter 2 : Linear Motion

Chapter 3 : Laws of Motion

Chapter 4 : Equilibrium and Torque

Chapter 5 : Work, Power, Energy and Momentum

Chapter 6 : Thermodynamic

Chapter 7 : Circular and Rotational Motion

Chapter 8 : Wave and Vibration Motion and Sound

Chapter 9 : Electric Current

Chapter 10 : Magnetism

And each chapter contains new concepts such as : (do you know, remember, question, think) in addition to a big collection of different exercises and trainings questions so the student how much of that chapter's aims were achieved

We ask God to grant us benefit through this book, and we ask him that the basis of our work be full of love to our country and family.

The authors

Contents

Chapter 1: Vectors

1.1 Coordinate systems

In our practical life we need to indicate the location of an object whether it is static or moving, and to determine the location of that object we use what is called "coordinates". There is several types of coordinates that we can apply, as "Rectangular Coordinates" and "polar coordinates".

1.1.a Rectangular coordinates

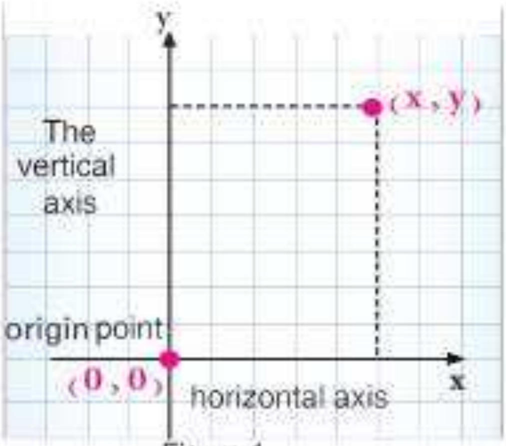


Figure 1

These coordinates contain two axes (vertical axis y and horizontal axis x) which are perpendicular to each other and intersect at (0,0) point that is called (origin point) . The name of the axes is written as (x,y) to indicate the location of any point on the coordinates, to denote the physical quantity and unit of measurement used to measure.
Notice figure (1).

1.1.b Polar coordinates

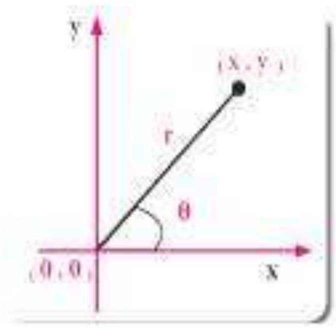


Figure 2

Sometimes the position of a point in a specific plane can be expressed using another axial system, called polar coordinates system, which is determined by distance r and angle θ that is the angle between the distance r and the horizontal axis. So the distance r is the distance between the origin point and (x,y) point in the rectangular coordinates and (θ) is the angle between the straight drawn from the origin point to the specified point and the horizontal axis x ...
Notice figure (2).

1.2 The relation between the rectangular and polar coordinates

The relation between the rectangular coordinates (x,y) and polar coordinates (r,θ) can be noticed in the triangle shown in figure (3).

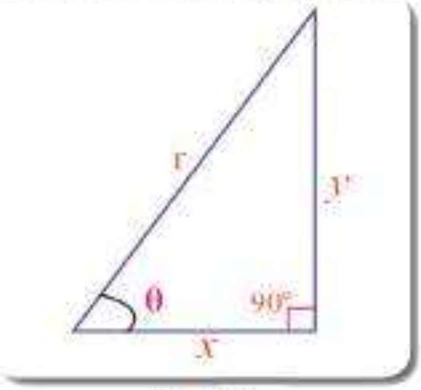


Figure 3

$$\sin\theta = \frac{y}{r}$$

$$\cos\theta = \frac{x}{r}$$

So it is possible to convert the flat polar axis of any point to rectangular axis using the following relation:

$$y = r\sin\theta$$

$$x = r\cos\theta$$

The following mathematical relation can be found: $\tan\theta = \frac{y}{x}$

And by applying Pythagoras theorem on the triangle: $r^2 = x^2 + y^2$

From the previous equation: $r = \sqrt{x^2 + y^2}$

Example 1

If the rectangular axis of a point located in the (x,y) plane is (-3.5,-2.5) as it is shown in figure (4) . Set the polar axis for this point, knowing that tan35.53°=0.714

Solution:

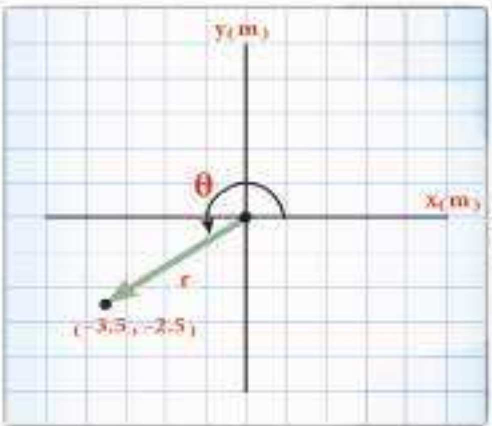


Figure 4

$$r = \sqrt{x^2 + y^2}$$

$$r = \sqrt{(-3.5)^2 + (-2.5)^2}$$

$$r = 4.3m$$

And to indicate the direction of the vector "$\vec{r}$" we use the relation:

$$\tan\theta = \frac{y}{x} = \frac{-2.5m}{-3.5m} = 0.714$$

$$\tan 35.53^\circ = 0.714$$

since θ is located in the third quarter, notice figure (4), then θ=215.53° while the polar axis (r,θ) equal (4.3m , 215.53°)

1.3 Scalar quantities and vector quantities

When you measure the quantity of something, you express the result as a number and unit. For example your height might be 165cm, in this case this quantity has a numerical value only which is (165),and a unit (cm). It is noticed that the quantities as length has an magnitude and a unit and not related with direction similar to other quantities as the volume of a box or the temperature of a object. Quantities that have no direction are called Scalar Quantities, while other quantities are determined by direction. To describe this quantity full description, must determine the direction in addition to the magnitude and unit. For example, we say that the magnitude of vehicle speed is 40 km/h toward the east. Quantities that are described by determining their direction and magnitude are called Vector Quantities which are represented by an arrow above the symbol to indicate that it is a vector quantity.

So the symbol of the force $\vec{F}$ and speed $\vec{\upsilon}$ and acceleration $\vec{a}$.

The vector quantities are graphically represented with an arrow where:

1. The length of the arrow is proportional to the magnitude of the vector quantity using a certain scale.
2. The direction of the arrow indicates the direction of the vector quantity.
3. The origin point which is Vector's effect point represents (starting point).

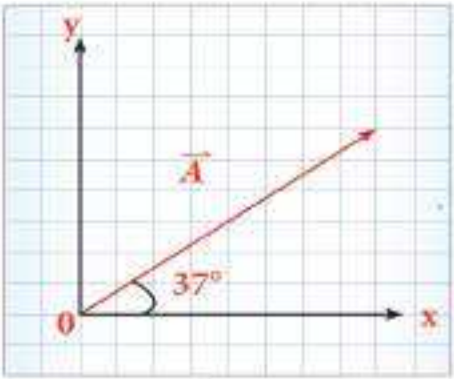


Figure 5

Mathematically, the magnitude of any vector quantity is expressed with the symbol $|\vec{A}|$ or A without an arrow. For example, figure (5) is showing vector $\vec{A}$ that has a quantity of 10 units and an angle of 37° with respect to the x-axis in the positive direction and affect the point (0).

And figure (6) is showing vector $\vec{B}$ that has a quantity of 3 units and an angle of 90° with respect to the x-axis and affect the point (0).

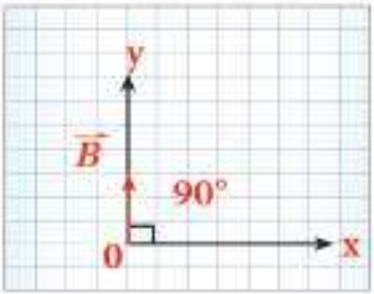


Figure 6

Definition:

The magnitude of the vector quantity $|\vec{A}|$ is a scalar quantity (quantitative quantity) and always positive so it is an absolute value.

Question ?

Classify the following quantities into scalar and vector, expressing those using suitable symbols (distance, force, electric current, acceleration, electric field, time, and electrical charge)).

Example 2

Express the following vector quantities mathematically and graphically:

1. The force $\vec{F}$ has a magnitude of 3N that affect a object in the west direction.
2. The speed $\vec{v}$ of a object has a magnitude of 5m/s making an angle of 37° west north.

Solution:

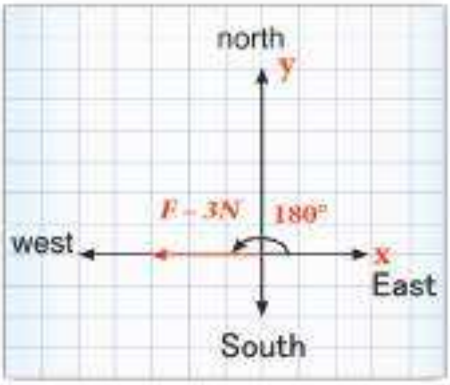


Figure 7

1-We write the magnitude of a force vector as the following: F=3N or $|\vec{F}|$=3N

The direction of the force is west, which is in the direction of the negative x-axis.

So the force vector make an angle θ=180° with the positive x-axis … notice figure (7)

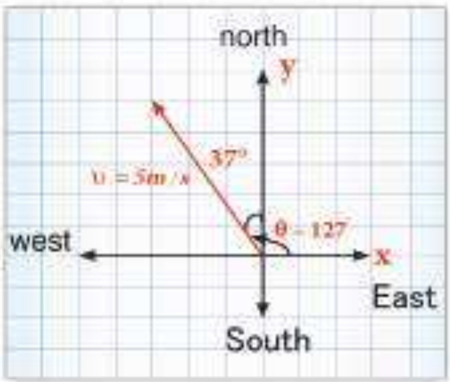


Figure 8

2- The speed magnitude v=5m/s and its direction 37° west north which means: 37° with vertical axis (positive y-axis) so that θ=37°+90°=127° with respect to the positive x-axis … notice figure (8).

1.4 Some properties of Vectors

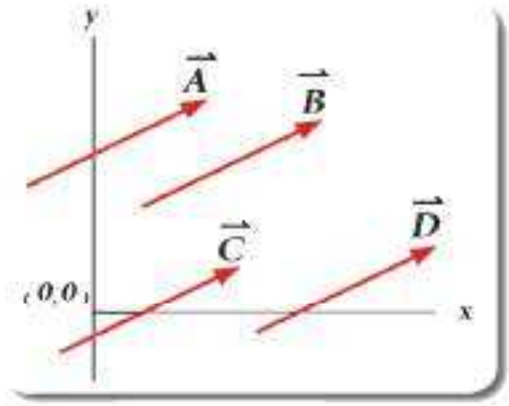


Figure 9

Equality

It is said about two vector that are equal if they have equal magnitudes and same direction regardless of their starting point ... notice figure(9) (Vectors $\vec{A}$, $\vec{B}$, $\vec{C}$, $\vec{D}$) are equal vectors and can be written as:
$\vec{A} = \vec{B} = \vec{C} = \vec{D}$

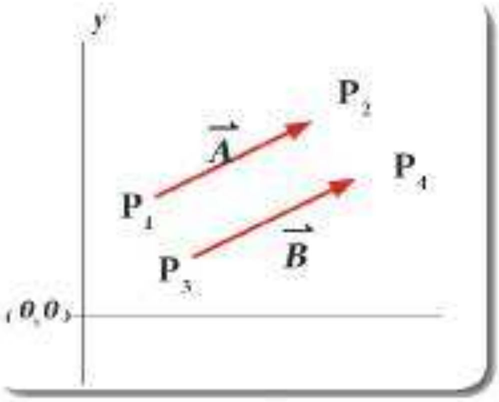


Figure 10

If we examined figure(10) we find that vector $\vec{A}$ has starting point P_1 and ending point P_2, and vector $\vec{B}$ has starting point P_3 and ending point P_4 and we can say that: $\vec{A} = \vec{B}$
Because vector $\vec{A}$ has a magnitude equal to vector ($\vec{B}$) and has same direction.

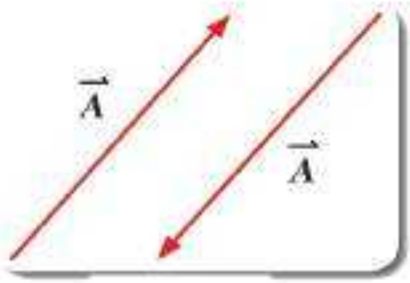


Figure 11

Negative of a Vector

The negative of vector $\vec{A}$ is a vector that has the same magnitude of $\vec{A}$ and an opposite direction of it ... notice figure(11)
The negative of vector $\vec{A}$ is represented as $-\vec{A}$ so that:
The vector and the negative of the same vector have equal magnitudes and opposite directions.

Multiplication of a Vector by a Scalar

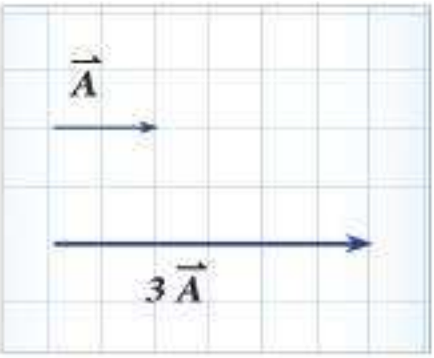


Figure 12

By multiplying a vector by a scalar we get another vector that has a new magnitude but the same direction.
As showing in figure (12) by multiplying the vector $\vec{A}$ by number (3) the magnitude of the vector $|\vec{A}|$ will increase and become $3|\vec{A}|$ and the direction will be kept the same. In physics, there are a lot of examples about multiplying the vectors by scalars such as:
Newton's second law $\vec{F}=m\vec{a}$
The relationship between the electrical force and the electric field $\vec{F}=q\vec{E}$

1.5 Vectors Addition

Since the vector quantity has magnitude and direction, So the vectors addition do not obey to Algebraic addition rule as scalar quantities.

Graphical Method

It is possible to add the vectors graphically according to the following method, notice figure (13a) where both vectors ($\vec{A}$, $\vec{B}$) are located on the same plane which is the plane of the page, and the length of the straight lines of both vectors are directly proportional to the magnitude of each vector and the arrow at the end of the vector is determining the direction of the vector.

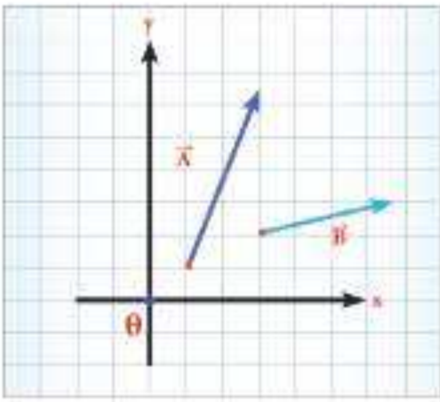


Figure 13a

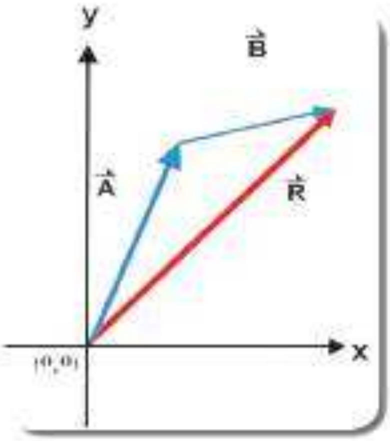


Figure 13b

To add the two vectors ($\vec{A}+\vec{B}$)
Firstly, we draw the first vector $\vec{A}$ then we put the tail of vector $\vec{B}$ on the head of vector $\vec{A}$ then we connect the tail of vector $\vec{A}$ with the head of vector $\vec{B}$ by a straight line notice figure (13b) and this straight line represents the summation vector $\vec{R}$ which is called "Resultant Vector".

$$\vec{R}=\vec{A}+\vec{B}$$

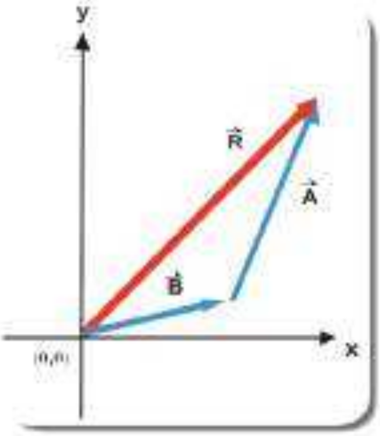


Figure 13c

Figure (13c) is showing another method for adding two vectors ($\vec{A}+\vec{B}$) where we draw the second vector $\vec{B}$ first then we put the tail of the first vector $\vec{A}$ on the head of $\vec{B}$, notice that the resultant vector in this case is the same vector $\vec{R}$, which means:

$$\vec{A}+\vec{B}=\vec{B}+\vec{A}$$

So that vectors' addition is commutative

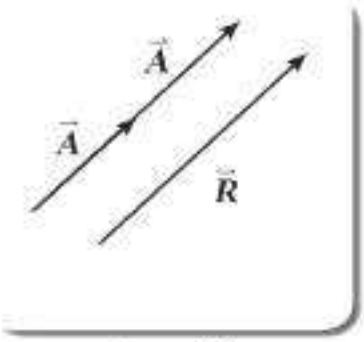


Figure 14

It is worth mentioning that is possible to add vector $\vec{A}$ by itself notice figure (14). Graphically, the resultant vector in this case is:

$$\vec{R}=\vec{A}+\vec{A}=2\vec{A}$$

Here, $\vec{R}$ is the resultant vector, its magnitude is the double of vector's magnitude $\vec{A}$ and has the same direction as vector $\vec{A}$.

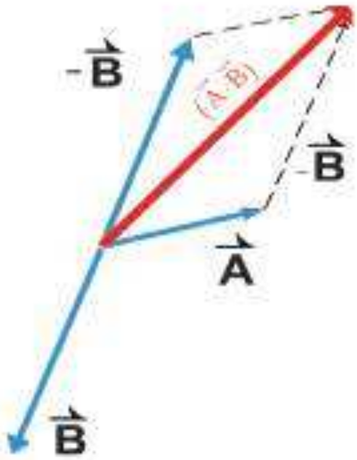


Figure 15

We also can find the subtraction of the two vectors ($\vec{A}$ - $\vec{B}$) as the summation of vectors ($\vec{A}$ and -$\vec{B}$) so that:

$$\vec{A} + (-\vec{B}) = \vec{A} - \vec{B}$$

Figure (15) is showing that:

It is also possible to find the resultant vector for three vectors or more that start from the same affective point. These vectors can be added by putting the tail of the second vector on the head of the first one then putting the tail of the third vector on the head of the second one and so on, then the resultant vector $\vec{R}$ can be drawn as to be the tail of $\vec{R}$ on the tail of the first vector and the head of $\vec{R}$ on the head of the last vector as shown in figures (16a, 16b).

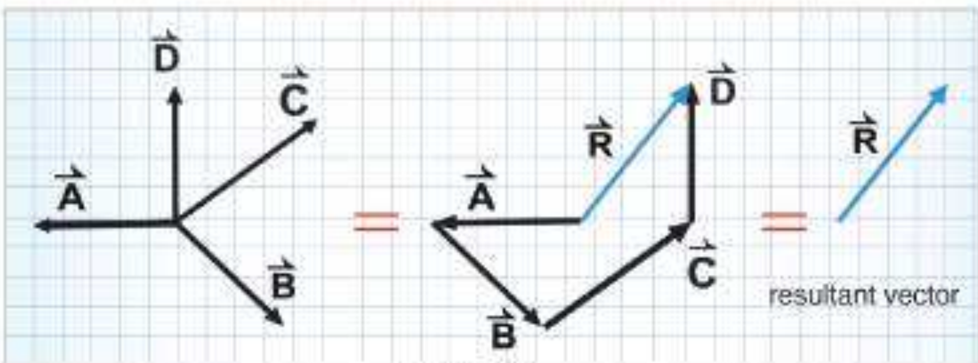


Figure 16a

another case for summation of vectors

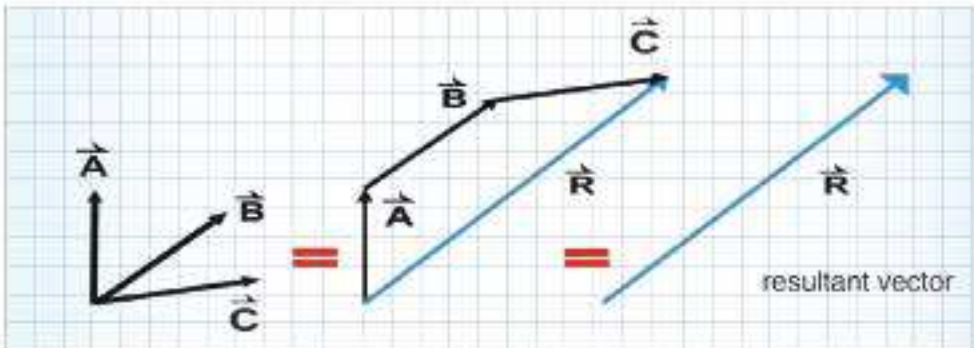


Figure 16b

Vector Analysis

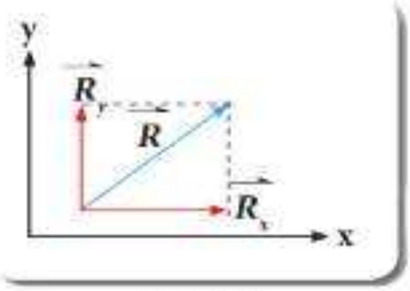


Figure 17

Figure (17) is showing vector $\vec{R}$ that have been analyzed into two components representing two perpendicular vectors, one is parallel to x-axis (called the horizontal component) represented by the vector ($\vec{R}_x$) and one is parallel to y-axis (called the vertical component) represented by the vector ($\vec{R}_y$) and this is called the process of analyzing the vector to its components.

Where (($\vec{R}_x$) ,($\vec{R}_y$)) representing two ribs in a right-angle triangle and the resultant vector $\vec{R}$ representing the hypotenuse in the triangle, notice figure (18), and its magnitude can be calculated by Pythagorean theorem as the following:

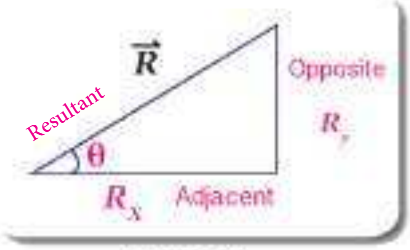


Figure 18

$$R = \sqrt{R_x^2 + R_y^2}$$

While the direction of $\vec{R}$ is determined by angle θ, where:

$$\tan\theta = \frac{R_y}{R_x}$$

So we could find the magnitude and the direction of the resultant vector, and to find the magnitude of its two components (the vertical and the horizontal), we calculate the two components by the following equations:

The magnitude of the horizontal component: $\cos\theta = \frac{R_x}{R} \Rightarrow \boxed{R_x = R\cos\theta}$

The magnitude of the vertical component: $\sin\theta = \frac{R_y}{R} \Rightarrow \boxed{R_y = R\sin\theta}$

Example 3

If the magnitude of vector $\vec{A}$ is 175m and making angle 50° with x-axis

Find the components of vector $\vec{A}$.

Solution:

We represent vector $\vec{A}$ to calculate its components graphically as figure (19)

$A_x = A\cos\theta$ (The horizontal component)

$$A_x = (175m)\times\cos 50°$$

$$A_x = (175m)\times(0.643)$$

$$A_x = 112.53m$$

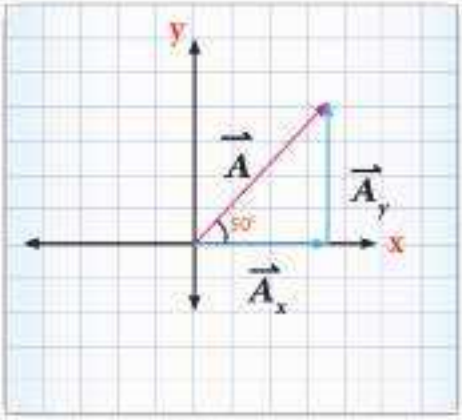


Figure 19

$$A_y = A\sin\theta$$ (The vertical component)

$$A_y = (175m)\times \sin 50^\circ$$

$$A_y = (175m)\times(0.766)$$

$$A_y = 134m$$

Think ?

Which couple of the displacement vectors showing in the table are equal?

vector	magnitude	Direction
$\vec{A}$	100m	North East 30°
$\vec{B}$	100m	South West 30°
$\vec{C}$	100m	SouthEast 30°
$\vec{D}$	100m	East North 60°
$\vec{E}$	100m	West South 60°

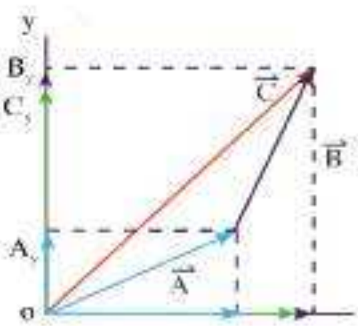


Figure 20

Finding the sum of two vectors or more by perpendicular analyzing method

The process of analyzing the vector into its two components (the horizontal over the x-axis and the vertical over the y-axis) makes the calculation of the addition operation of vectors easier. So it is possible to add two vectors or more as $\vec{A}, \vec{B}, \vec{C}$....etc, and that is by analyzing each vector into its two components the vertical and the horizontal. Firstly notice figure (20), then all the horizontal components of the vectors will be added to make the resultant horizontal component on the x-axis as:

$$\vec{R}_x = \vec{A}_x + \vec{B}_x + \vec{C}_x$$

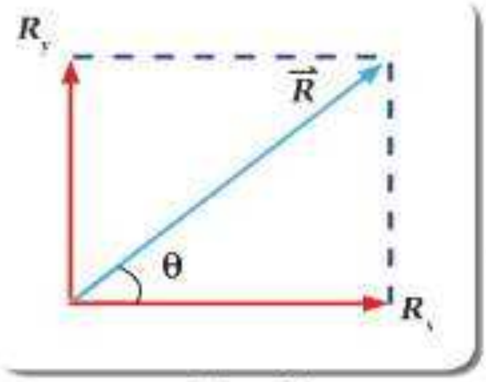


Figure 21

By the same process the vertical components will be added to make the resultant vertical component on the y-axis as:

$$\vec{R}_y = \vec{A}_y + \vec{B}_y + \vec{C}_y$$

This process is explained graphically in figure (21).
Since R_x and R_y are perpendicular to each other so it is possible to calculate the magnitude of the resultant vector using Pythagoras theorem:

$$R^2 = R_x^2 + R_y^2$$

And the angle that the resultant vector make with x-axis can be founded from the following relation:

$$\tan\theta = \frac{R_y}{R_x} \quad \text{or} \quad \left[\theta = \tan^{-1}\frac{R_y}{R_x}\right]$$

The angle of the resultant vector equal inverse tangent the ratio of y component over x component of the resultant vector.

Which means that angle θ: is the angle that its tangent equals: $\frac{R_y}{R_x}$

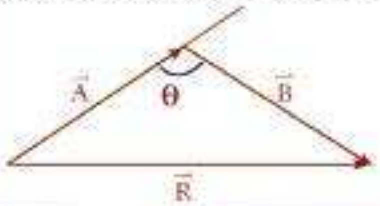
Remember:

To find the magnitude of the resultant vector of two vectors $\vec{A}$,$\vec{B}$ we can apply Pythagoras theorem if the angle between the vectors $\vec{A}$ and $\vec{B}$ is 90° (perpendicular).

However, if the angle between the vectors $\vec{A}$,$\vec{B}$ is not 90° we can use sine or cosine laws as the following:

Cosine law:

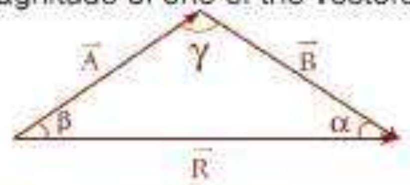
The magnitude of the resultant vector squared equals the summation of the two vectors squared minus the double of the multiplication of the vectors' magnitudes by cosine the angle between them that is opposite of $\vec{R}$.



$$R^2 = A^2 + B^2 - 2AB\cos\theta$$

Sine law:

The magnitude of the resultant vector divided by sine of the opposite angle equals the magnitude of one of the vectors divided by sine of the opposite angle.



$$\frac{R}{\sin\gamma} = \frac{A}{\sin\alpha} = \frac{B}{\sin\beta}$$

Example 4

Vector $\vec{A}$ has a length of 14cm and makes 60° with the positive x-axis, and vector $\vec{B}$ has a length of 20cm and makes 20° with the positive x-axis.
Analyze the vectors $\vec{A}$, $\vec{B}$ into their components then calculate the magnitude and the direction of the resultant vector $\vec{R}$.

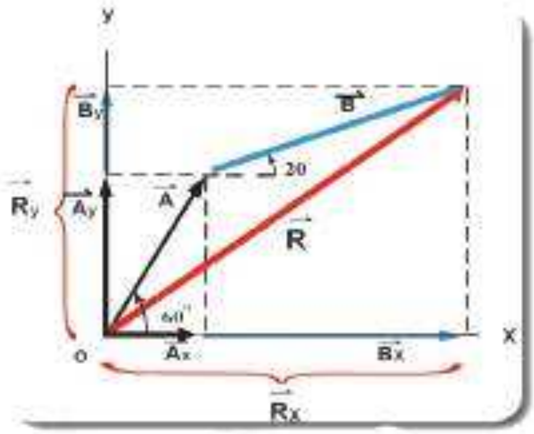


Figure 22

Solution

By noticing figure (22) the magnitudes of the vertical and horizontal components of the vectors are:
The magnitude of the horizontal component;

$$A_x = A\cos\theta$$
$$= 14cm \times \cos60^\circ$$
$$= 14 \times 0.5$$
$$= 7cm$$

The magnitude of the vertical component; $A_y = A\sin\theta$

$$= 14cm \times \sin60^\circ$$
$$= 14 \times 0.866$$
$$= 12.12cm$$

$B_x = B\cos\theta$ The magnitude of the horizontal component

$$= 20cm \times \cos20^\circ$$
$$= 20 \times 0.939$$
$$= 18.79\ cm$$

$B_y = B\sin\theta$ The magnitude of the vertical component

$$= 20cm \times \sin20^\circ$$
$$= 20 \times 0.342$$
$$= 6.84\ cm$$

We calculate the resultant of the vertical components ($\vec{R}_y$)

$$R_y = A_y + B_y$$

$$R_y = 12.12 + 6.84$$

$$= 18.96\text{cm}$$

We calculate the resultant of the horizontal components ($\vec{R}_x$)

$$R_x = A_x + B_x$$

$$= 7 + 18.79$$

$$= 25.79\text{cm}$$

The magnitude of the resultant vector $\vec{R}$ can be founded by Pythagoras theorem:

$$R = \sqrt{R_x^2 + R_y^2}$$

$$R = \sqrt{(25.79)^2 + (18.96)^2}$$

$$R = 32cm$$

And the direction of the resultant vector $\vec{R}$ can be founded with respect to the x-axis from the following relation:

$$\tan\theta = \frac{R_y}{R_x}$$

$$\tan\theta = \frac{18.96}{25.79} = 0.735$$

Theta with respect to the positive x-axis: $\therefore \theta = 36^\circ$

1.6 Multiplication of vectors

Sometimes we need in physics to multiply a vector by a vector and get a scalar quantity as a result, and other times the multiplication of two vectors give us vector as a result. So that we will represent two ways for vectors' multiplication, which are:

1- Scalar product (dot product):

The scalar product is called so, because the result of the product is a scalar quantity, and also called dot product because the sign of the product in it is a dot.

The scalar product (dot product) of the vectors $\vec{A} \cdot \vec{B}$ is known as:

$$\vec{A} \cdot \vec{B} = |\vec{A}||\vec{B}| \cos\theta$$

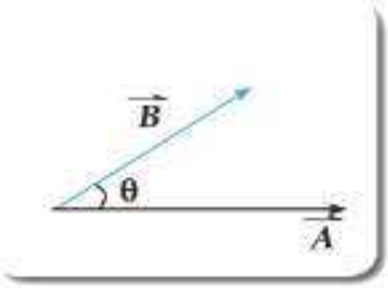


Figure 23

Where θ represents the angle between $\vec{A} \cdot \vec{B}$ as in figure (23) and it ranges between zero and 180°.

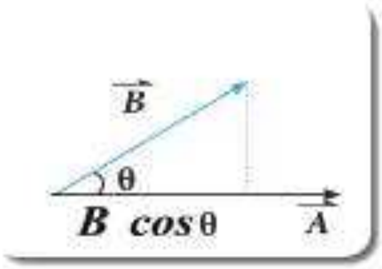


Figure 24

Figure (24) is showing the projection of vector $\vec{B}$ on vector $\vec{A}$ which equals (B cos θ) and this projection is representing the component of vector $\vec{B}$ on the direction of vector $\vec{A}$

2- Vector product (cross product):

This kind of vectors multiplication is called vector product, because the result of vector product is a vector quantity where the result of the multiplication of two vectors is a third vector that is perpendicular to the two vectors plane $\vec{A}, \vec{B}$. Notice figure (25).

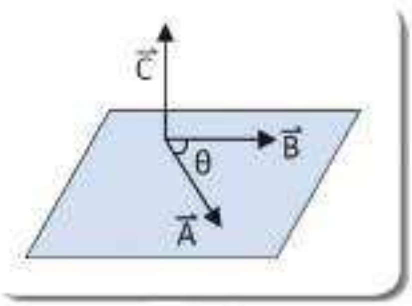


Figure 25

The cross product is mathematically known as:

$$\vec{C} = \vec{A} \times \vec{B}$$

Whereas, the magnitude of the vector $\vec{C}$ is:

$$|\vec{C}| = |\vec{A}||\vec{B}| \sin\theta$$

We apply the right hand rule to determine the direction of the resultant vector of the cross product of $\vec{A}$, $\vec{B}$ vectors: while the fingers of the right hand are rotating from the first vector (assume $\vec{A}$) to the second vector (assume $\vec{B}$) the thumb will show the direction of the resultant vector $\vec{C}$.

Example 5

A force that has a magnitude of 40N in the direction 37° above the horizon affected a object, so it moved the object a displacement of 10m horizontally. Calculate the magnitude of the work that the force do.

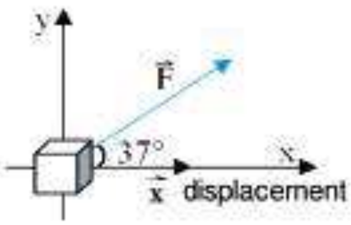


Figure 26

$$W(\text{work}) = \vec{F}(\text{Force}) \cdot \vec{x}(\text{ displacement})$$

$$W = |\vec{F}||\vec{x}|\cos\theta$$

$$W = 40 \times 10 \times \cos 37^\circ$$

$$W = 40 \times 10 \times \frac{4}{5} = 320\text{Joule}$$

Example 6

A force that has a magnitude of 150N affected the lever(ab)in the point (a) which is far from the spindle(b)by 5m, notice figure (27). Find the magnitude and the direction of the resultant vector

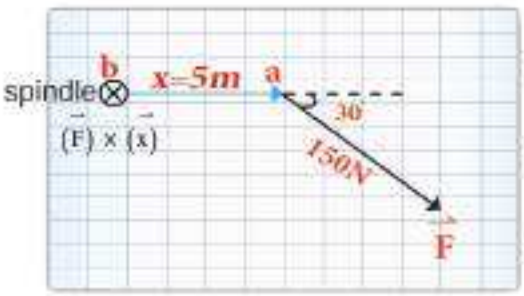


Figure 27

$$|\vec{F} \times \vec{X}| = |\vec{X}||\vec{F}|\sin\theta$$

$$|\vec{F} \times \vec{X}| = 5 \times 150 \sin 30^\circ$$

$$|\vec{F} \times \vec{X}| = 5 \times 150 \times \frac{1}{2}$$

$$|\vec{F} \times \vec{X}| = 375 \text{ N m}$$

Towards the reader this means outside the page ⊙ according to right hand rule.

Remember:

1- $\vec{A} \cdot \vec{A} = |\vec{A}| \, |\vec{A}| \cos 0 = A^2$

2- $|\vec{A} \times \vec{A}| = |\vec{A}| \, |\vec{A}| \sin 0 = 0$

3- $\{\vec{A} \cdot \vec{B} = \vec{B} \cdot \vec{A}\}$ The dot product is commutative

$\{\vec{A} \times \vec{B} = -\vec{B} \times \vec{A}\}$ The cross product is not commutative

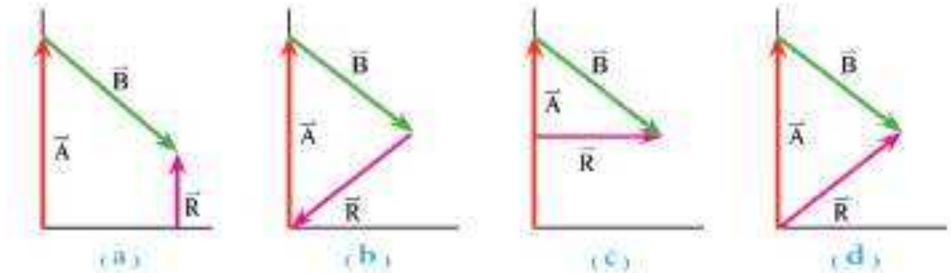
4- if $\vec{A}$ is perpendecular to $\vec{B}$ then $\vec{A} \cdot \vec{B} = 0$

$\cos 90^\circ = 0$, $\sin 90^\circ = 1$, $\cos 0 = 1$, $\sin 0 = 0$

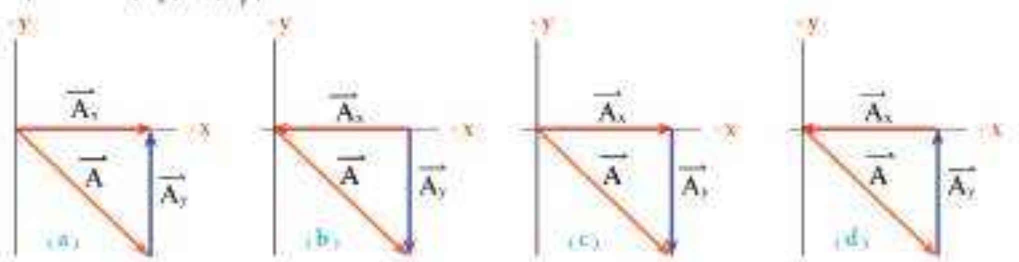
Questions of Chapter 1

Q1- Choose the correct answer for the following:

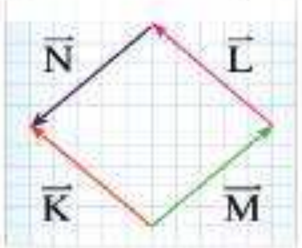
1- The displacement vectors ($\vec{A}$, $\vec{B}$) have been added to get the magnitude of the resultant vector $\vec{R}$. which of the following figures shows the resultant vector in a correct way.



2- A person crossed displacement $\vec{A}$ to the southeast direction. Which of the following figures shows the correct case of the components ($\vec{A}_x$) ,($\vec{A}_y$)



3- Which couples of the vectors ($\vec{K}$, $\vec{L}$, $\vec{M}$,$\vec{N}$) are equal:



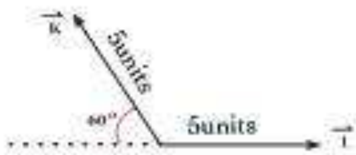
a) $\vec{K}$ and $\vec{L}$

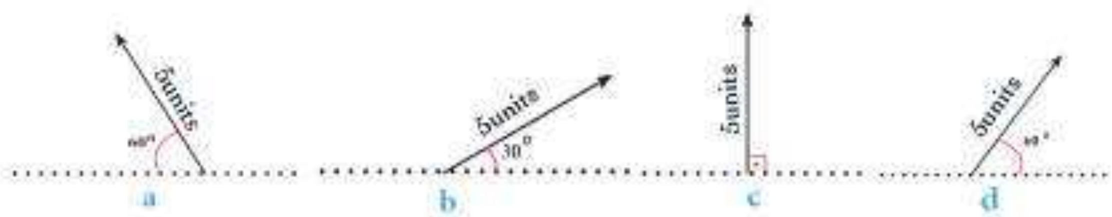
b) $\vec{K}$ and $\vec{M}$

c) $\vec{L}$ and $\vec{M}$

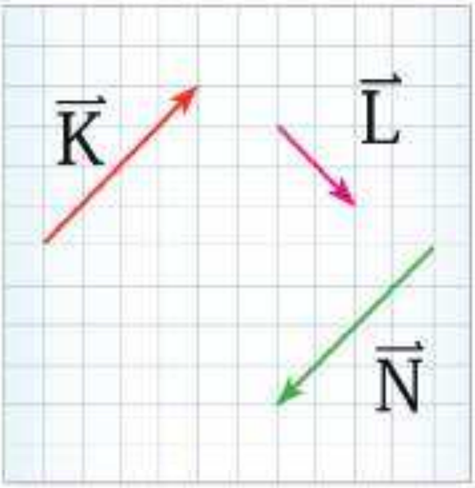
d) $\vec{N}$ and $\vec{L}$

4- In the figure shown the vectors ($\vec{K}$,$\vec{L}$) has equal magnitudes. Which of the following vectors represents the resultant vector?





5- The vectors ($\vec{K}, \vec{L}, \vec{N}$) are as shown in the following figure. Which of the following equations is incorrect?



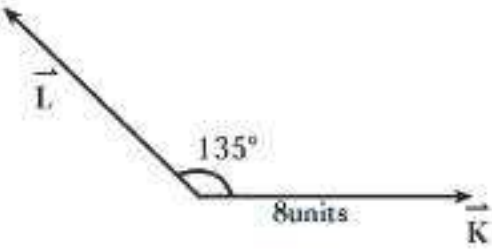
1 .... $\vec{K} = \vec{N}$

2 .... $\vec{K} + \vec{L} + \vec{N} = \vec{L}$

3 .... $\vec{K} + \vec{N} = 0$

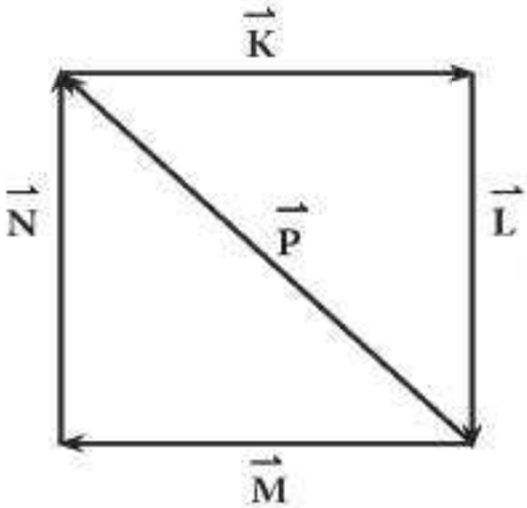
a) Equation 1 .
b) Equation 2 .
c) Equations 2,3 .
d) Equations 1,2,3 .

6- If the resultant vector of the vectors $\vec{K}$, $\vec{L}$ is perpendicular to vector $\vec{K}$ (notice the figure) then the magnitude of vector $\vec{L}$ equals:



a) 8 units
b) $4\sqrt{3}$ units
c) $4\sqrt{2}$ units
d) $8\sqrt{2}$ units

7- Which of the following equations is incorrect for the vectors ($\vec{K}, \vec{L}, \vec{M}, \vec{N}, \vec{P}$) shown in the figure?



1 ...... $\vec{K} + \vec{L} - \vec{M} - \vec{N} = -2\vec{P}$

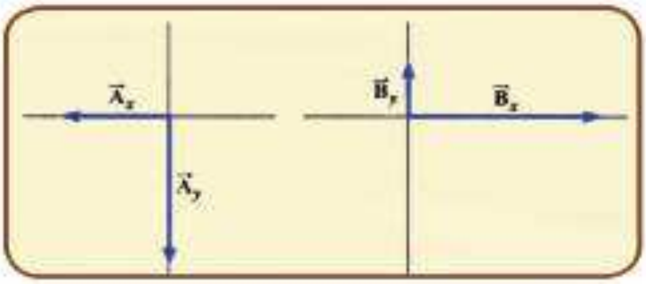
2 .... $\vec{K} + \vec{L} + \vec{M} + \vec{N} = 0$

3 .... $\vec{N} + \vec{M} = \vec{P}$

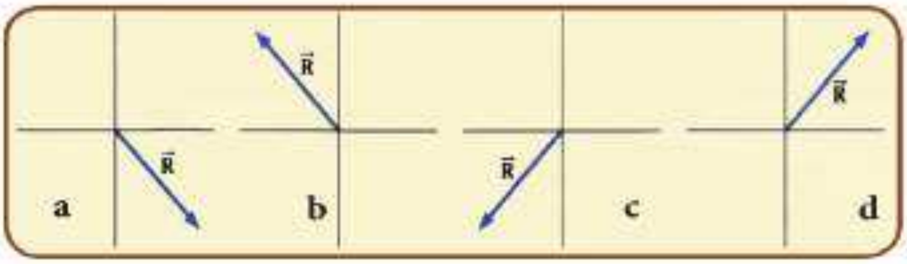
4 ..... $-(\vec{K} + \vec{L}) = -\vec{P}$

a) Equation 1 .
b) Equations 1,2 .
c) Equations 1,2,3 .
d) Equation 4 .

8- The following figure showing the components of the vectors ($\vec{A}$,$\vec{B}$) and the resultant vector is $\vec{R}$.



Which of the figures (a), (b), (c), (d) represents $\vec{A} + \vec{B}$.



Q2- Is it possible for a vector's component to be zero? Even though the magnitude of the vector does not equal zero? Clarify that.

Q3- is it possible for a vector to have a negative magnitude? Clarify that.

Q4- if $\vec{A} + \vec{B} = 0$ what can you say about the vectors?

Q5- under which conditions may a vector has components with equal magnitudes?

Q6- is it possible to add a scalar quantity into a vector quantity? Clarify that.

Q7- if the magnitude of vector $|\vec{A}|$=12m and the magnitude of vector $|\vec{B}|$=9m and the magnitude of the resultant vector $|\vec{R}|$=3m represent that by a graph.

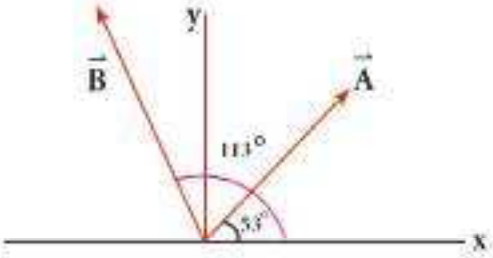
Q8- if the component of vector $\vec{A}$ that is in the direction of vector $\vec{B}$ equal zero what can you say about the vectors ($\vec{A}$, $\vec{B}$)?

Problems of Chapter 1

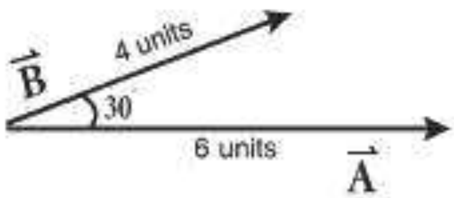
P1- point A is located on the ($\vec{x}$, $\vec{y}$) plane, has coordinates (2, -3)
Write an expression describing the location r_A of the vector ($\vec{A}$) of this point in a vector format and draw a graph shows the direction of that vector.

P2- what is the dot product ($\vec{A}.\vec{B}$) of the vectors ($\vec{A}$, $\vec{B}$) shown in the figure if:

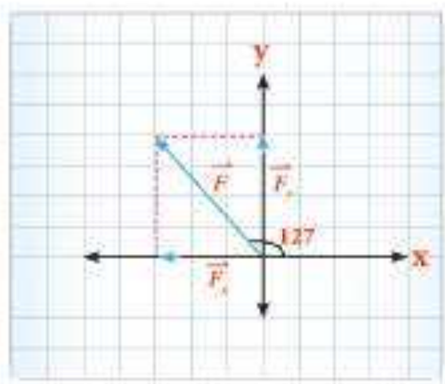
$|\vec{A}|$=4 units,$|\vec{B}|$=5 units



P3- if the magnitude of vector $\vec{A}$ equals (6 units) in the direction of the positive x-axis, and the magnitude of vector $\vec{B}$ equals (4 units) in the direction 30° with the x-axis and located on the ($\vec{x}$, $\vec{y}$) plane. Calculate the magnitude of the cross product of the vectors $\vec{A} \times \vec{B}$.



P4- find the components of the force (25N) that has an angle 127° with x-axis knowing that:
cos 37°=0.8 sin 37°=0.6



Chapter 2: Linear motion

2.1 Motion Description

The Mechanics is one of the branches in physics that studies the motion, it include two main sections are:

1) Kinematics: a science that describes the objects' motion ignoring what causes the motion.

2) Dynamics: a science that concern about the causes of motion such as Force and Energy.

We will study in this chapter basic types of motion, where first we will get to know the concepts of location, displacement, velocity, and acceleration of objects for motion in one dimension then we talk about motion in two dimensions with some applications.

2.2 Frame of Reference

figure (1)

figure (2)

My dear student you studied in previous stages that Motion is the continuous change of the object's location with respect to a constant point. So if a object transferred from a place to another means in moved. And motion has different kinds, for example the car movement on a straight street called transition motion, and the earth rotation around its axis called rotational motion, and the pendulum movement is a vibratory motion. In our life the earth and everything on it as (trees, streets and houses) create frame of reference for us (assuming the earth is constant). Notice figure (1) and it is not possible to take the moving objects with inconstant velocity as frame of reference such as clouds or a moving plane or a moving car. By looking to figure (2) we say that the kids are not in motion because they did not change their places, so they sit on a constant boat. However, by looking to figure (3) we say that the runners are in motion, because they are running next to each other, so they changed their location with respect to any other object that is considered as frame of reference (as the pillar or the lines installed on the road). So To decide on an object, is it constant or moving? Depends on the place changing of the object or not, for a certain point called reference point which is considered a fixed point with respect to frame of reference.

figure (3)

2.3 Position, Displacement and Distance

Assume you met a friend, and you asked him where did he park his car? Then he answered that it is (20m) from the school's gate in east direction. From this sentence you will know that your friend described the position of his car a description shows that the position is a vector quantity, since he determined three phrases which are:

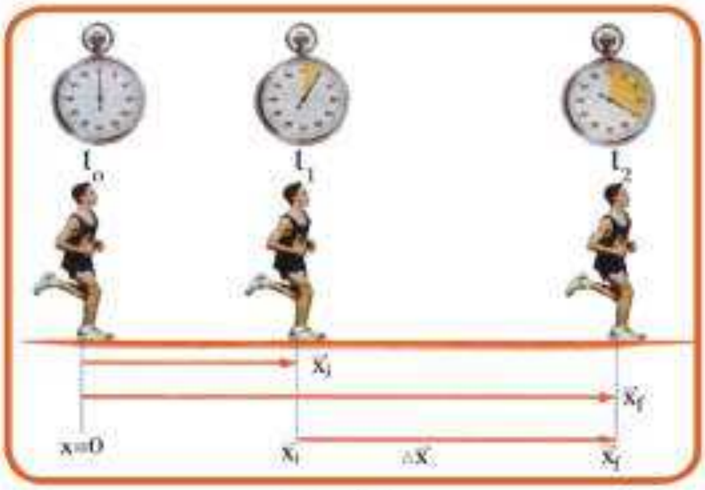


figure (4)

- 20m from the school's gate (it represents a vector quantity).
- In east direction (it represents a vector direction).
- The school's gate (it represents the reference point that your friend chose).

From that we notice:

The position is a vector quantity, has a magnitude and a specific direction with respect to the origin point on one of the three axes of the rectangular coordinates (x,y,z). We say the object is in motion when its position change with respect to a constant reference point. Notice figure (4).

We find that the runner is in motion in a straight line on the x-axis forward the origin point (O) so he changed his position and the vectors of his initial position $\vec{x}_{initial}$ and his final position $\vec{x}_{final}$.

The magnitude of the initial position x_i=+5m and the magnitude of the final position x_f=+12m (the positive sign in front of the position vector magnitude means that the displacement of the object to the right of the x-axis). The change in the position vector called displacement, so that the displacement of the runner is the difference between the final position and the initial position ($\Delta\vec{x}$):

$$\Delta\vec{x} = \vec{x}_f - \vec{x}_i \Rightarrow \Delta x = 12 - 5 = +7m$$

The symbol (Δ) means the change or the difference and it is a Latin letter spelled Delta.
Assume that the runner moved from his initial position x_i=+5m in an opposite direction to the final position x_f=+1m . so the displacement of the runner in this case is:

$$\Delta\vec{x} = \vec{x}_f - \vec{x}_i \Rightarrow \Delta x = 1 - 5 = -4m$$

The negative sign of the displacement means that the object displacement is in the negative direction of the x-axis.
Otherwise, if the runner moved from his initial position x_i=+5m to the position (20m) the returned to the final position x_f=+5 . So the displacement ($\Delta\vec{x}$) of the runner in this case is **zero** :

$$\Delta\vec{x} = \vec{x}_f - \vec{x}_i \Rightarrow \Delta x = 5 - 5 = 0$$

Where the total distance that the runner cut in this case is (30m).
Because in his going he passed (d_1=20-5=15m) and in his return to his initial position he passed a distance of (15m) also so that the total distance (d=15+15=30m).

2.4 Average Velocity

A race car can travel same distance that a small car do , however we notice that their movements are different, so how we can evaluate the motion of a moving object on its path? Let us assume that the motion of the car shown in figure (5) is in a straight line and starts from the origin point (O) at time (t=0).

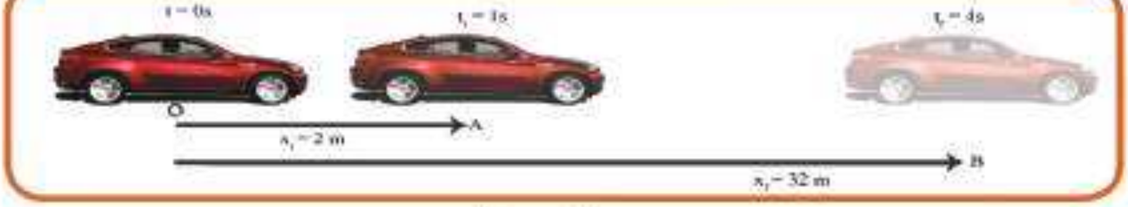


figure (5)

And the direction of the motion of the car is in the positive x-axis. After some time (t_i=1s) the car reach point A that is (2m) far from the origin point so its initial position ($\vec{x}_i$=2m). After time passes (t_f=4s) from starting the motion (from the origin point O) the car reaches point B that is (32m) far from the origin point so its final position ($\vec{x}_f$=32m). The total displacement that the car cut is:

$(\Delta\vec{x}) = (\vec{x}_f) - (\vec{x}_i)$

And the time passed:

$(\Delta t) = (t_f) - (t_i)$

The average velocity can be found from the following equation:

$$|\vec{\upsilon}_{avg}| = \frac{|\vec{x}_f| - |\vec{x}_i|}{t_f - t_i} = \frac{32 - 2}{4 - 1} = \frac{30}{3} = 10 m/s$$

Remember

The sign of the average velocity is the same as the sign of the displacement. So if the displacement sign was in the positive x-axis direction then the average velocity is positive, however if the displacement was in the negative x-axis direction then the average velocity is negative. The average velocity $\vec{\upsilon}$ can be written as:

$$\vec{\upsilon} = \frac{\upsilon_i + \upsilon_f}{2}$$

The graph (displacement-time) as shown in figure (6) shows the changing of the position by time passing. And that the slope of the straight line that connect the two points (A, B) is:

$$\tan\theta = slope = \frac{\Delta\vec{x}}{\Delta t}$$

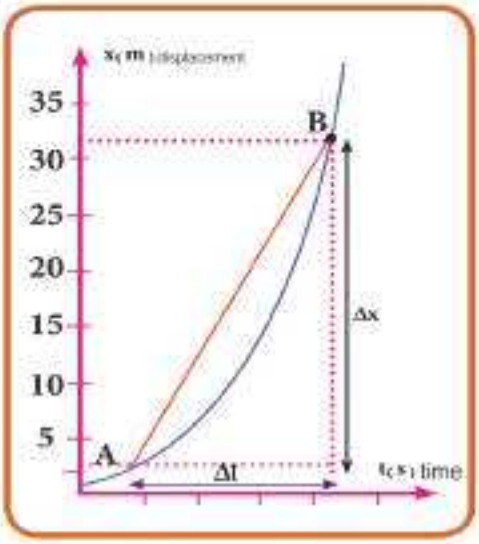


figure (6)

And since the average velocity is; $\overrightarrow{\upsilon}_{avg} = \frac{\Delta \overrightarrow{x}}{\Delta t}$

Then:

The slope of the straight line in the (displacement-time) graph represents the average velocity:

$$\overrightarrow{\upsilon}_{avg} = \text{slope} = \frac{\Delta \overrightarrow{x}}{\Delta t}$$

2.5 Average speed

The ratio of the total distance traveled over the time interval is called (average speed), and it is written as:

$$\text{Average Speed}(\upsilon_{avg}) = \frac{\text{Distance traveled}}{\text{time interval}}$$

Remember:

The distance is a scalar quantity (Numerical quantity) so the average speed is also a scalar quantity.

Let us study now the difference between the average velocity and the average speed by the motion of two trucks (M, K) notice figure (7) the two trucks are moving side by side till they reach point A at the same time and this is the initial position, after that they take different paths to reach point B the final position so truck K takes the straight path (AB) to reach point B, while truck M takes the second path, which is the curved path to reach the same point B. For the same time period (10s) that truck K takes and since the distances traveled by the two trucks are different so the distance that truck K travels through the straight path is (100m) and the distance that truck M travels through the curved path is (130m).

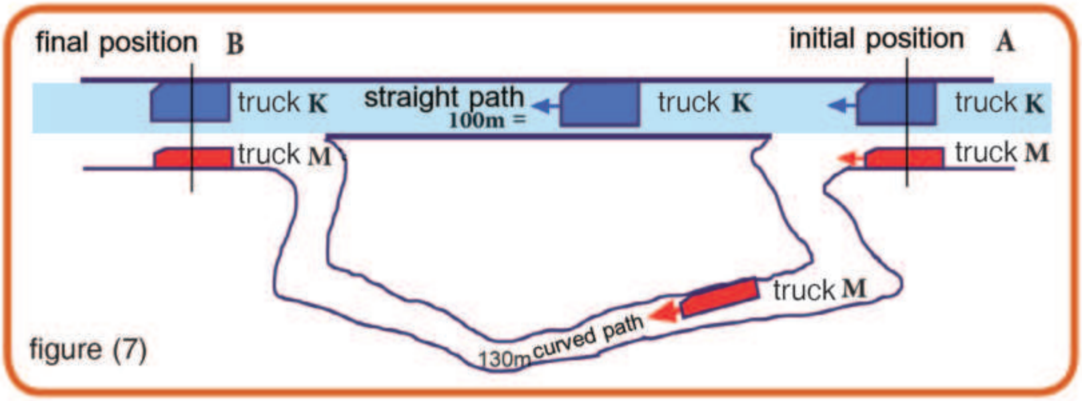


figure (7)

So the average speed for each of them can be calculated from the following relation:
The average speed for truck (K):

$$\underset{\text{truck (K)}}{\text{Average speed}} = \frac{\text{Distance traveled}}{\text{Time interval(s)}} = \frac{100(m)}{10(s)} = 10m/s$$

$$\underset{\text{truck (M)}}{\text{Average speed}} = \frac{\text{Distance traveled}}{\text{Time interval}} = \frac{130(m)}{10(s)} = 13m/s$$

And since the paths of the trucks are different even though they have the same initial and final positions and for equal time intervals then the average velocity of both of them are equal:
The average velocity for truck (K):

$$\underset{\text{truck (K)}}{\text{Average velocity}} |(\vec{\upsilon}_{avg})| = \frac{\text{displacement traveled}}{\text{Time interval}(\Delta t)} = \frac{100(m)}{10(s)} = 10m/s$$

$$\underset{\text{truck (M)}}{\text{Average velocity}} |(\vec{\upsilon}_{avg})| = \frac{\text{displacement traveled}}{\text{Time interval}(\Delta t)} = \frac{100(m)}{10(s)} = 10m/s$$

Remember

If a object traveled through a straight path then its average velocity magnitude equals its average speed so that the speed represents the numerical amount of the velocity in this case.

Example 1

The car in figure (8) started moving from rest at point (A) in the positive x-axis, it reached point C after (80s) then returned back in the opposite direction till it stopped at point (B) through (20s). calculate:

1- The average speed through the first period (80s).
2- The average velocity through the first period (80s).
3- The average speed through the whole period (100s).
4- The average velocity through the whole period (100s).

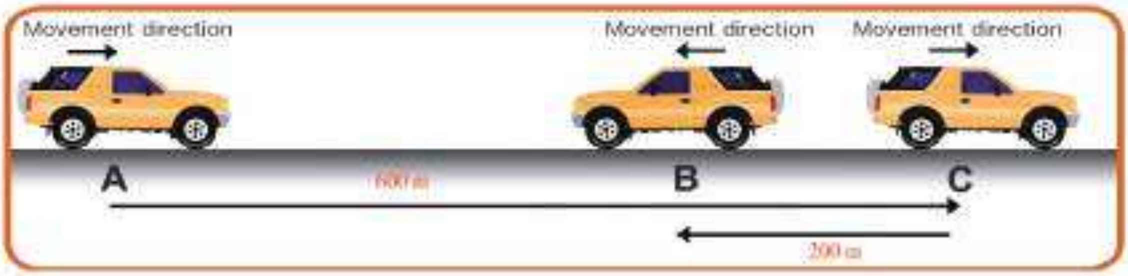


figure (8)

1- When the car moved from point A to point C:

$$\text{Average speed} = \frac{\text{distance traveled}}{\text{time interval}} = \frac{600\,(m)}{80\,(s)} = 7.5\ m/s$$

2- When the car moved from point A to point C:
The distance that car traveled equals the displacement, so the average velocity equals the average speed because it moved in the positive x-axis:

$$\underset{\upsilon_{avg}}{\text{Average velocity}} = \frac{\text{displacement traveled}}{\text{time interval}} = \frac{600(m)}{80(s)} = 7.5 m/s$$

So the speed can express that the magnitude of the scalar quantity of the velocity because the motion in the straight line and in same direction.

3- The average speed when the car moved from A to B:

$$\text{Average speed} = \frac{\text{distance traveled}}{\text{time interval}} = \frac{600+200}{80+20} = 8 m/s$$

4- By taking the total motion of the car from the initial position A to the final position B then its displacement

$(\Delta x)=(x_f)-(x_i)=600-200=400m$

And the time it took to travel is t=80+20=100s

Then its average velocity become:

$$\underset{\upsilon_{avg}}{\text{Average velocity}} = \frac{\text{displacement traveled}}{\text{time interval}} = \frac{400(m)}{100(s)} = 4m/s$$

2.6 Instantaneous velocity and Instantaneous speed

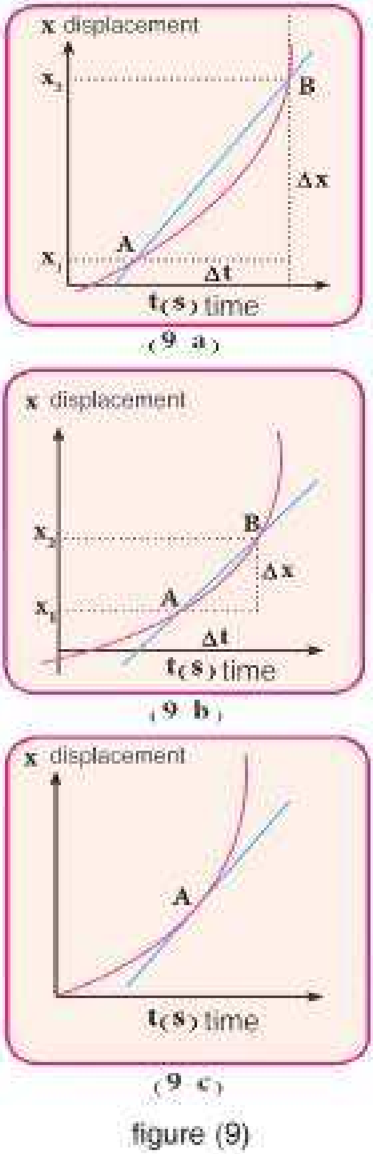


figure (9)

To study the motion in details it needs to know the velocity of the object at any period of time. And the velocity of a object at any instant time is called instantaneous velocity.

Let us go back to the car shown in figure (8) to calculate the average velocity from the (displacement-time) graph. In figure (9-a) from the slope;

$$\vec{\upsilon}_{avg}(m/s) = \text{slope} = \frac{\Delta\vec{x}}{\Delta t}$$

By approach point (B) to point (A) by smaller values of both (Δx ,Δt). Notice the figure (9-b) we will get smaller value for the line slope and also smaller value for average velocity.

By continue approaching position (B) much closer to position (A), so the value of (Δx ,Δt) approach to zero till the straight line become the tangent of the curve at the point (A) notice figure (9-c) and the slope of this line gives the instantaneous velocity of the car at point (A).

Remember

The velocity value of a moving object at any period of time in (displacement-time) curve is the instantaneous velocity at that time.

Do you know ?

The number we read on the board of the car in front of the driver indicates the instantaneous speed of the car and does not indicate the direction of the car. Notice figure (10)

figure (10)

2.7 Motion with constant velocity

figure (11)

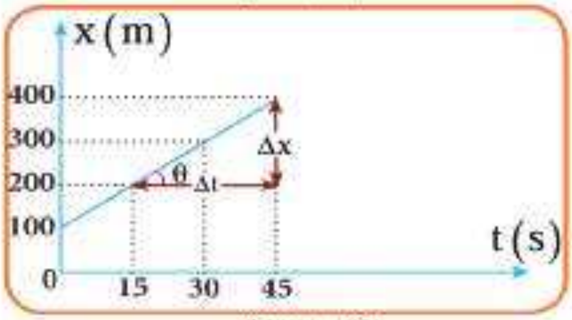


figure (12)

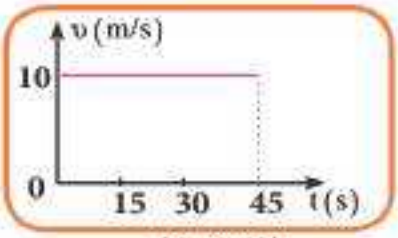


figure (13)

If an object moved in a straight line and travel with an equal displacements through an equal time intervals then it is said that the motion of the object is constant and velocity called (constant velocity).

By noticing figure (11) we find that the car is moving in a straight line, it travels 150m every 15s which means it is moving with a constant velocity 10m/s and when we draw the (displacement- time) graph that is (x-t) in figure (12) we get a straight line and the slope of this straight line equals the average velocity :

$$\vec{\upsilon}_{avg} = \text{slope} = \frac{\Delta\vec{x}}{\Delta t}$$

And if we draw (velocity-time) graph we get a horizontal straight line because the velocity of the car has constant magnitude and direction notice figure (13).

2.8 Acceleration

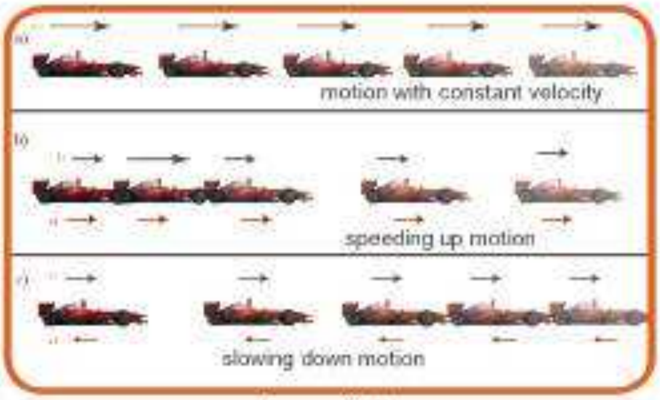


figure (14)


figure (15)

A vehicle, truck or bike can move with a constant velocity and direction through intervals time as shown in figure(14) and it is possible to increase the magnitude of its velocity through certain period of time then its motion will be accelerating and it could slow down in other time then its motion will be slowing down. The acceleration may cause by change in the direction of the velocity with constant speed when the vehicle travels on a horizontal turn (circular path) with constant speed then this acceleration is called the central acceleration and has a symbol (a_c) figure(15). Acceleration: The rate of change of velocity in a given time interval and has a symbol ($\vec{a}$) which is a vector quantity where

$$\vec{a} = \frac{\Delta \vec{\upsilon}}{\Delta t}$$

And when the velocity has a constant magnitude and direction then its acceleration equals zero (a=0).

2.9 Equations of linear motion with reqular a cceleration

a- The derivation of the displacement equation in terms of the initial and final velocity and time:

$$\upsilon_{avg} = \frac{\Delta x}{\Delta t}$$

$$\upsilon_{avg} = \frac{\upsilon_i + \upsilon_f}{2}$$

Since the two equations are equal then:

$$\frac{\Delta x}{\Delta t} = \frac{\upsilon_i + \upsilon_f}{2}$$

By multiplying the two sides of the equation by Δt we get:

$$\Delta x = \left(\frac{\upsilon_i + \upsilon_f}{2}\right) . \Delta t$$

b- The final velocity equation in terms of the initial velocity, acceleration and time:

From acceleration definition:

$$a = \frac{\Delta \upsilon}{\Delta t} = \frac{\upsilon_f - \upsilon_i}{\Delta t}$$

By multiplying both sides of the equation by Δt we get:

$$a\Delta t = \upsilon_f - \upsilon_i$$

$$\upsilon_f = \upsilon_i + a\Delta t$$

c- The displacement equation in terms of the initial velocity, acceleration and time:

We have the displacement equation in terms of the initial and final velocity and time:

$$\Delta x = \left(\frac{\upsilon_i + \upsilon_f}{2}\right)\Delta t$$

By substituting the final velocity from the equation $\upsilon_f = \upsilon_i + a\Delta t$ in the previous equation we get:

$$\Delta x = \left(\frac{\upsilon_i + (\upsilon_i + a\Delta t)}{2}\right)\Delta t$$

$$\Delta x = \left(\frac{2\upsilon_i\Delta t + a(\Delta t)^2}{2}\right)$$

$$\Delta x = \upsilon_i\Delta t + \tfrac{1}{2} a (\Delta t)^2$$

d- The final velocity equation in terms of the acceleration, displacement and initial velocity:

We have the displacement equation in terms of initial velocity, final velocity and time:

$$\{\Delta x = \tfrac{1}{2} (\upsilon_i + \upsilon_f)\ \Delta t\}$$

By multiplying both sides of the equation by (2) we get:

$$2\Delta x = (\upsilon_i + \upsilon_f)\ \Delta t$$

By dividing both sides of the equation by $(\upsilon_i + \upsilon_f)$ we get:

$$2\Delta x / (\upsilon_i + \upsilon_f) = \Delta t$$

We substitute Δt in the equation we get:

$$\upsilon_f = \upsilon_i + a\ \Delta t$$

$$\upsilon_f = \upsilon_i + a \times 2\ \Delta x\ /\ (\upsilon_i + \upsilon_f)$$

$$\upsilon_f - \upsilon_i = a \times 2\ \Delta x\ /\ (\upsilon_i + \upsilon_f)$$

$$\upsilon_f^2 - \upsilon_i^2 = a \times 2\ \Delta x$$

$$\upsilon_f^2 = \upsilon_i^2 + 2\ a\ \Delta x$$

When the object start moving from rest then $(\upsilon_i = 0)$ then the final equation:

$$\upsilon_f = \sqrt{2a\Delta x}$$

Example 2

Calculate the magnitude of the acceleration between two points that are shown in the figure for the car in figure (16) knowing that υ_K=20m/s, υ_L=30 m/s, υ_M=30m/s, υ_N=25m/s during the following periods of time:

1. (t_1=0s) and (t_2=10s)between the points (K,L).
2. (t_2=10s) and (t_3=15s)between the points (L,M).
3. (t_3=15s) and (t_4=20s)between the points (M,N).
4. (t_1=0s) and (t_4=20s)between the points (K,N).

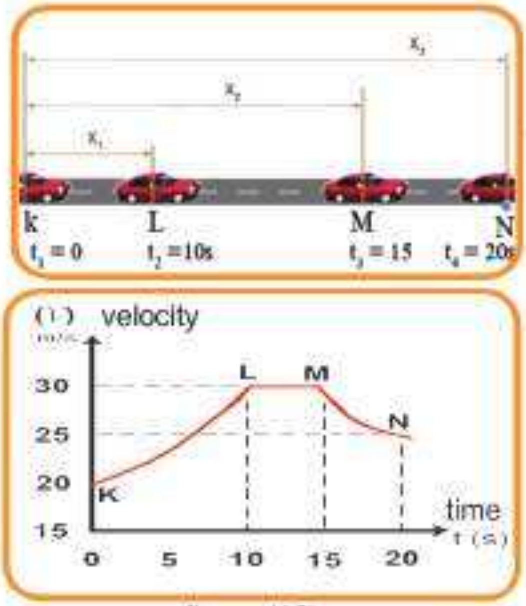


figure (16)

Solution:

Since the slope of the line in the (velocity-time) graph that is (υ-t) in figure (16) equals the acceleration of the object (a) The acceleration between the two points :

(1) $$a_{(KL)} = \frac{\Delta\upsilon}{\Delta t} = \frac{\upsilon_L - \upsilon_K}{t_L - t_K} = \frac{30 - 20}{10 - 0} = 1 m/s^2$$

The acceleration is positive because speeding up

(2) $$a_{(LM)} = \frac{\Delta\upsilon}{\Delta t} = \frac{\upsilon_M - \upsilon_L}{t_M - t_L} = \frac{30 - 30}{15 - 10} = 0 m/s^2$$

The acceleration is ZERO because the velocity is constant

(3) $$a_{(MN)} = \frac{\Delta\upsilon}{\Delta t} = \frac{\upsilon_N - \upsilon_M}{t_N - t_M} = \frac{25 - 30}{20 - 15} = -1 m/s^2$$

The acceleration is negative because it is slowing down

(4) $$a_{(KN)} = \frac{\Delta\upsilon}{\Delta t} = \frac{\upsilon_N - \upsilon_K}{t_N - t_K} = \frac{25 - 20}{20 - 0} = 0.25 m/s^2$$

The acceleration is positive because speeding up

2.10 Acceleration of Gravity

figure (17)

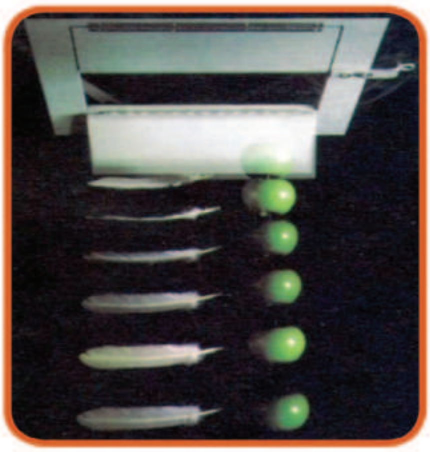


figure (18)

figure (19)

Which of the two balls fall down faster?
(The heavy ball or the light one, the apple or the feather?)
It seems logical that the heavy ball fall down faster than the light on isn't it?
In fact the (BC) scientist Aristotle answered the same.
And after 19 centuries the scientist Galilei made simple experiments. He throw a stone and a bird feather from the top of the leaning tower of pizza notice figure (17) and because of the great influence of air friction on the feather during falling down so the stone reached the feather first.
Then several experiments were done using relatively heavy objects that have equal volumes and different weight and falling down from the same height to the land in the same exact way (constant acceleration) and in the same period of time ignoring their weight. And by the absence of air influence on the falling objects (like the apple and feather experiment) in figure (18) it was found scientifically that the apple and the feather reach the land together with the same speed (with the absence of air resistance).

Free fall:

A lot of experimental scientists repeated the experiment of scientist Galilei following very advanced technical methods. It is a fact that is recognized now that any object falling free fall, it falls down with a constant acceleration. Notice figure (19). It is the acceleration caused the force of the earth's gravitation to the object. Even though the amount of gravity of the earth changes from a place to another near the surface of the earth but it is estimated about
($9.81\ m/s^2$) or ($981\ cm/s^2$) the acceleration due to the gravity (on Earth's surface) has a symbol ($\vec{g}$) and it is supposed to get that magnitude by taking a big attention to decrease the air influence on the falling objects as low as possible.

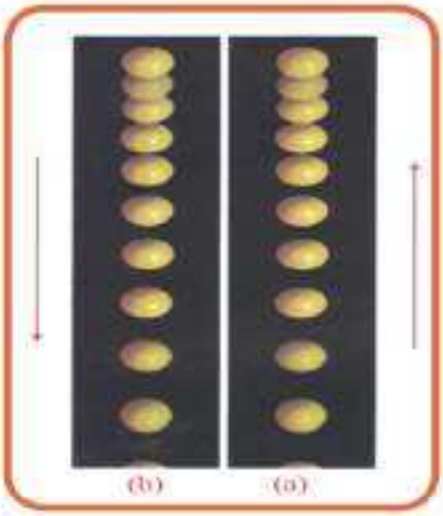


figure (20)

That is why the whole objects that are close to the earth's surface and with the absence of air influence they fall with the same acceleration which is the gravity acceleration, g=-9.8 m/s^2 which is almost (-10 m/s^2) and it always has negative sign because it is directed down, this motion is called free fall. Notice figure (20).

2.11 Equations of the free fall

For the objects falling a free fall and by substituting (υ_i=0) in the linear motion equations we get:

$$\upsilon_f = g t \quad \ldots\ldots\ldots\ldots (1)$$

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

$$\upsilon_f = \sqrt{2gy} \quad \ldots\ldots\ldots\ldots (3)$$

Think ?

- By throwing a ball vertically up then its velocity equals zero at the moment it reaches the highest point in its path. Does that certainly mean that its acceleration equals zero?
- A car travels in a straight line in the direction of (- x-axis) with an acceleration in the direction of (+ x-axis) does that mean the car is slowing down or speeding up?

Example 3

From the roof a building a ball fall down a free fall as shown in figure (21) it reached the earth's surface after a period time (3 s). calculate:

1- The height of the roof of the building.

2- The velocity of the ball at moment it collided with the earth's surface and in which direction?

3- The velocity and the height of the ball over the earth's surface after (1s) from the falling.

Assume that the magnitude of the gravity acceleration ($g = -10\ m/s^2$)

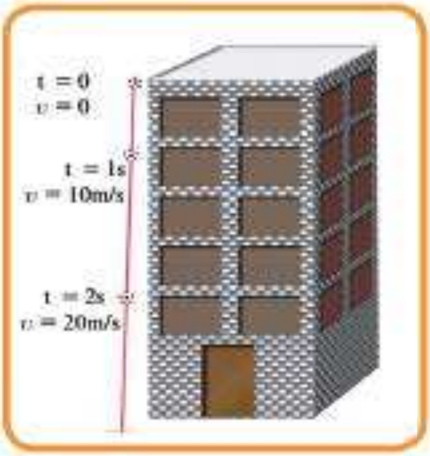


figure (21)

Solution

1- The initial velocity υ_i of the free fall is always equals ZERO. We apply the equation of the displacement, acceleration and time.

$y=1/2\ gt^2$

$y=1/2\ (-10)\times(3)^2=-45\ m$

* The negative sign means the displacement of the ball directed downward then the height of the building's roof over the earth's surface is (h= +45m)

2- To calculate the velocity at the moment it collided the earth's surface. We apply the velocity, acceleration and time equation:

$\upsilon_f = \upsilon_i + g \times t$

$\upsilon_f = 0 + (-10) \times 3 = -30 m/s$

* The negative sign means the velocity of the ball directed downward .

3- To calculate the velocity of the ball after (1s) from its falling we apply the velocity, acceleration and time equation:

$\upsilon_f = \upsilon_i + g\, t$

$\upsilon_f = 0 + (-10) \times 1 = -10 m/s$

* The negative sign means the velocity of the ball is directed downward and to calculate the height of the ball over the earth's surface after (1s), we should calculate the displacement from its falling point:

$y=1/2\ gt^2$

$y=1/2\ (-10)\times(1)^2=-5m$

* Then the height of the ball over the earth's surface (h=45-5=40m)

Example 4

From a point on the earth's surface a small ball was thrown vertically up with a speed (40m/s), figure (22) (ignoring the air influence on the ball). Calculate:

1- The highest height the ball can reach over the earth's surface.

2- The time the ball takes from the moment it is thrown till it reaches its highest height .

3- The velocity and the height over the earth's surface at (t=2s).

4- Its velocity at the moment it collide the earth's surface.

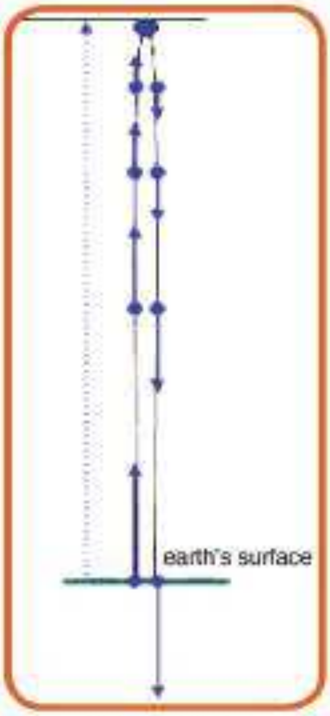


figure (22)

Solution

1- The moment the ball reaches the highest height over the earth's surface its final velocity will be ($\upsilon_f=0$)
Then:

$$\upsilon_f^2=\upsilon_i^2+2\times g\,\Delta y$$

$$0=(40)^2+2\times(-10)\times h$$

The highest height that the ball can reach over the earth's surface h= 80m

2- $\upsilon_f=\upsilon_i+g\times t$

$$0=40+(-10)\times t_1$$

The time that the ball takes to reach its highest height t_1=4s

3- To calculate the velocity after (t = 2s)from the moment it was thrown

$$\upsilon_f=\upsilon_i+g\times t$$

$$\upsilon_f=40+(-10)\times 2=20\ m/s$$

To calculate the height of the ball after (t=2s) from the moment it was thrown

$$\Delta y=\upsilon\times t+\tfrac{1}{2}\,g\times(t)^2$$

$$\Delta y=40\times 2+\tfrac{1}{2}(-10)\times(2)^2$$

y=60m Then the height of the ball h=60m

4- Since the time that the ball takes to reach its highest height t_1=4s
We calculate the time that the ball takes to get down from its highest height to the earth's surface. Where (υ_i=0) we assume that the ball was falling a free fall from that height:

$$\Delta y = \frac{1}{2} g t_2^2$$

$$-80 = \frac{1}{2}(-10) t_2^2$$

$$t_2^2 = \frac{-80}{-5} = 16$$

$$t_2 = 4 \text{ s}$$

Where it is possible to find the velocity of the ball at the moment it collides the ground from the following relation:

$$\upsilon_f = \upsilon_i + gt$$

Where t is the total time that the ball takes to go up and down =8s

$$\upsilon_f = 40 + (-10) \times 8$$

$$\upsilon_f = -40 \text{ m/s}$$

2.12 Motion in two dimensions (Motion in a Plane)

figure (23)

figure (24)

From the well-known examples about the motion of the objects in two dimensions is the motion of a thrown object with an angle in the gravity field like the motion of the water molecules falling from a waterfall and (the motion if the electrical sparks) notice figures (23&24).

The idea of describing the motion of the objects in two dimensions depends on the representation of this motion on the horizontal (x-axis) and the vertical (y-axis) axes, and study the motion of each dimension separated from the other one. Since the vertical and horizontal motions do not effect on each other so we apply the one dimension motion equations on the two axes (x, y), and we call them the horizontal component and the vertical component.

Horizontal motion of a Projectile:

The Horizontal motion of a projectile is the resultant of two kinds of motion. The first kind is a vertical motion where the projectile velocity ((υ_y)) is changeable in magnitude and direction because of the influence of gravity on it and the other kind is the horizontal motion where the projectile velocity ((υ_x)) has a constant magnitude and direction because there is no influence of gravity on it (it is perpendicular to the velocity component ((υ_y)) notice figure (25)) the resultant velocity of these two velocities (υ_f) is given by the equation: $\upsilon_f^2 = \upsilon_x^2 + \upsilon_y^2$

figure (25)

Example 5

The ball k was thrown with a horizontal velocity (40 m/s) from a vertical height h. it collided the ground with a velocity (50 m/s) and from the same height the ball L was thrown vertically downward as shown in figure (26) with initial velocity υ_0.
It collided the ground with a velocity (50 m/s).
Calculate the magnitude of the velocity υ_0 of ball L.

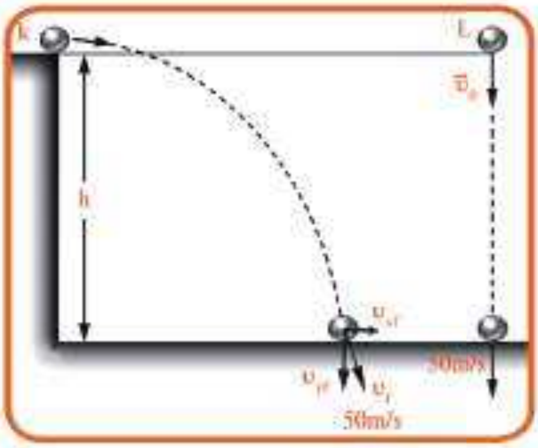


figure (26)

Solution

We draw both of the vertical and horizontal of the final velocity components of ball k (the velocity that collided the ground surface). Since the magnitude of the horizontal component of the Thrown velocity keep constant in its whole path:

$$\upsilon_{xf} = \upsilon_{xi} = 40 m/s$$

$$\upsilon^2_f = \upsilon^2_{xf} + \upsilon^2_{yf}$$

$$(50)^2 = (40)^2 + \upsilon^2_{yf}$$

υ_{yf}=-30 m/s is the vertical component for the final velocity of ball k and the negative sign in front of the velocity magnitude υ_{yf} shows that it is directed down.
To calculate the vertical height h we apply the equation:

$$\upsilon^2_{yf} = \upsilon^2_{yi} + 2 g \Delta y \Longrightarrow (-30)^2 = 0 + 2 \times (-10) \Delta y$$

y=−45m , the negative sign represents that the displacement is directed downward then the height h = 45m, to calculate the initial velocity (v_{yi}) for ball L we apply the equation:

$$v_{yf}^2 = v_{yi}^2 + 2g\Delta y \Longrightarrow (50)^2 = v_{yi}^2 + 2(-10)(-45)$$

$$2500 = v_{yi}^2 + 900$$

$$v_{yi}^2 = 1600$$

$$v_{yi} = -40 m/s$$

The negative sign is taken because the velocity directed downward

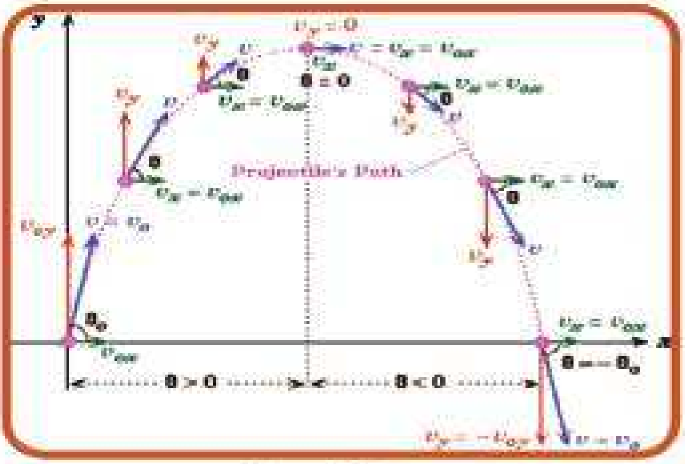


figure (27)

Projectile Launched at an angle:

Each projectile with an angle upper than the horizon takes a shape of parabola as shown in figure (27) its motion then in two dimensions (horizontal and vertical) in other words it moves in a plane and from we find that the projectile has a horizontal motion with constant magnitude and direction because the horizontal component of the initial velocity (v_{xi}) is the same at any point of its path.

$$v_x = v_{ix} = v_i \cos\theta$$

While its vertical motion is a motion with constant acceleration (the acceleration of gravity). So the motion would be slowing down regularly while it is ascending (because the gravity is in the opposite direction to its motion). However, the motion would be increase regularly while it is descending (because the gravity is in the same direction as the projectile motion).

$$\boxed{v_{fy} = v_{iy} - gt}$$

$$v_{fy} = v_i \sin\theta - gt$$

The velocity of the projectile v_f at any time equals the resultant horizontal component v_x and the vertical component v_y

$$\vec{v}_f = \vec{v}_x + \vec{v}_y$$

Since v_x is perpendicular to v_y then the resultant magnitude will be calculated from:

$$v = \sqrt{v_x^2 + v_y^2}$$

The Projectile equations with an angle above the horizon:

a- An equation to calculate the total time of the projectile flight:
We calculate the time that the projectile takes to reach its maximum height (t_{rise}) (we substitute g with a negative sign because it is directed downward)

We apply the equation:

$$\upsilon_{fy} = \upsilon_i \sin\theta - g\, t_{rise}$$

We get:

$$t_{rise} = \frac{\upsilon_{fy}}{g} = \frac{\upsilon_i \sin\theta}{g}$$

When the projectile descends from the top of its path and reach the first plane that it was thrown from, the time it takes descending equal the time it takes ascending from the point it is thrown from to the top of its path. So the total time that the ballistic takes from the moment it is thrown to the moment it reaches the plane that it was thrown from double of the time that it takes to ascend the top of its path. Then the total time equation for the projectile is:

$$t_{total} = \frac{2\upsilon_i \sin\theta}{g}$$

b- An equation to calculate the maximum height (h_{max}) that the projectile can reach:
Since the vertical component of the projectile velocity with an angle above than the horizon equals ZERO in the highest point of its path $\upsilon_{yf} = 0$ we apply the equation:

$$\upsilon^2_{yf} = \upsilon^2_{yi} - 2 g \Delta y$$

$$0 = \upsilon^2_i \sin^2\theta - 2 g h$$

$$2g h = \upsilon^2_i \sin^2\theta$$

$$h_{max} = \frac{\upsilon^2_i \sin^2\theta}{2g}$$

c- An equation to calculate the horizontal range:
The horizontal range is the horizontal displacement that the projectile object travels through the total time and has a symbol (R) and since the horizontal velocity of the projectile has constant magnitude and direction:

$$R = \upsilon_{xi} t$$

$$R = (\upsilon_i \cos\theta_i)\, t$$

$$\Delta y = \upsilon_{iy} t - \frac{1}{2} g t^2$$

$$0 = (\upsilon_i \sin\theta_i)\, t - \frac{1}{2} g t^2 \Rightarrow t = \frac{2\upsilon_i \sin\theta_i}{g}$$

$\because R = (\upsilon_i \cos\theta_i)\, t \qquad \because 2\sin\theta\cos\theta = \sin 2\theta$

$$R = \frac{2\upsilon_i^2}{g}\sin\theta_i\cos\theta_i \Rightarrow \boxed{R = \frac{\upsilon_i^2}{g}\sin 2\theta_i}$$

We conclude from this law that the maximum range of the projectile crosses launch an angle θ_i equals 45° then it will be the maximum horizontal range for the ballistic:

$$\boxed{R_{max} = \frac{\upsilon_i^2}{g}}$$

Example 6

A football player kicked a ball that was on the ground figure (28) its initial velocity was ($\upsilon_{initial}$=20m/s) with an angle (θ=37°) above the horizon. Calculate:

1. The maximum height that the ball reach the ground.
2. The time the ball takes from the moment it is kicked until it reach the top of its path, then the total time from the moment it is kicked until the moment it collides the ground.
3. The ball horizontal range from the moment it is kicked until the moment it collides the ground.
4. Its velocity before it collides the ground and in which direction?
5. The maximum horizontal range for this ballistic?

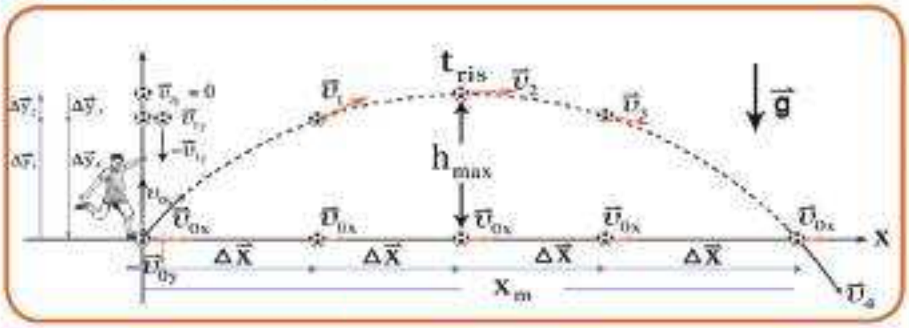
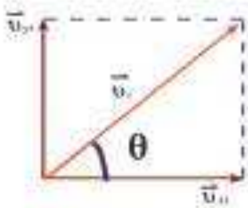


figure (28)

Solution



1- first we calculate the initial horizontal velocity componant of the ball.

$$\upsilon_{xi} = \upsilon_{initial} \times \cos\theta$$

$$\upsilon_{xi} = 20\cos 37^0 = 20 \times 0.8 = 16m/s$$

second we calculate the vertical velocity componant to the ball.

$$\upsilon_{yi} = \upsilon_{initial} \times \sin\theta$$

$$\upsilon_{yi} = 20\sin 37^0 = 20 \times 0.6 = 12m/s$$

Since the velocity of the ball when it reaches the top $\upsilon_{yf} = 0$ we apply the equation:

$$\upsilon_{yf}^2 = \upsilon_{yi}^2 + 2g\Delta y$$

$$0 = (12)^2 + 2(-10)\Delta y$$

$$\Delta y = 144 / 20$$

$$\Delta y = 7.2m$$

Then the highest height the ball reaches over the ground is (h = 7.2 m)

2 – To calculate the total time to the ball to fly it needs first to calculate the time it takes from the moment it is kicked to the moment it reaches the top of its path:

$$\upsilon_{yf} = \upsilon_{yi} + g \times t$$

$$0 = 12 + (-10) \times t_1$$

$$t_1 = 1.2s$$

Then we calculate the time the ball takes to descend from the top of its path until it collides the ground (it falls a free fall from a height h = 7.2 m) since it is directed downward then Δy=-7.2 m

$$\Delta y = ½\, g \times (t)^2$$

$$-7.2 = ½(-10) \times (t_2)^2$$

$$-7.2 = -5 \times (t_2)^2$$

$$t_2 = 1.2\, s$$

The total time = ascending time + descending time

OR

The total time = ascending time x 2

$$2.4\, s = 1.2\, s + 1.2\, s$$

$$t_{total} = 2.4\, s$$

3 – The horizontal range = the horizontal component of the initial velocity $\upsilon_x = \upsilon_i \times \cos\theta$ multiplied by the total time

$$R = \upsilon_x t_{total}$$

$$R = 16 \times 2.4 = 38.4m$$

4 – To calculate the velocity of the ball at the moment it collides the ground υ_f. We need to calculate the components of this velocity and since the horizontal component of the ball velocity is constant in the whole path $\upsilon_x = 16m/s$ so we should calculate the vertical component υ_{yf}

$$\upsilon_{yf} = \upsilon_{yi} + g \times t_2$$

$$\upsilon_{yf} = 0 + (-10) \times 1.2 = -12\, m/s$$

(The negative sign means the direction of the vertical component of the final velocity is downward)

Since the vertical and horizontal components are perpendicular figure (27).

Then : $\upsilon_f^2 = \upsilon_{xf}^2 + \upsilon_{yf}^2$

$$\upsilon_f^2 = (16)^2 + (-12)^2$$

$$\upsilon_f^2 = 256 + 144 \Rightarrow \upsilon_f = 20m/s$$

To indicate the direction of the velocity we apply the trigonometric ratio:

$$\tan\theta = \frac{\upsilon_y}{\upsilon_x} = \frac{-12}{16} = \frac{-3}{4}$$

$$\theta = -37^0$$

(The negative sign means that the angle θ is under the horizon)

5- To calculate the maximum horizontal range for this projectile , its angle should equals 45° over the horizon then we apply the equation:

$$R_{max} = \frac{\upsilon_i^2}{g}$$

$$R_{max} = \frac{(20)^2}{10} = 40m$$

Questions of Chapter 2

Q1/ choose the correct answer from the following states:

1- The motion is an expression returns to the change of the position of the object with respect to:

a) Frame of reference
b) A star
c) Clouds
d) Sun

2- Two objects have similar shape and volume but the weight of one of them the double of the other, the fell together from a tower (ignoring the resistance of air), then:

a) The heavier object will collides the ground first and both will have the same acceleration.
b) Both will reach the ground together but the heavier will have bigger speed.
c) Both will reach the ground together with the same speed and acceleration.
d) Both will reach the ground together but the heavier will have bigger acceleration.

3- The acceleration of the object thrown vertically upward (ignoring the resistance of air):

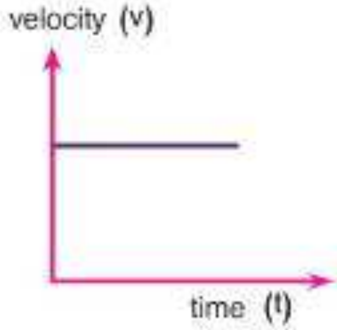
a) Bigger than the acceleration of the object thrown vertically downward.
b) Less than the acceleration of the object thrown vertically downward.
c) Equal the acceleration of the object thrown vertically downward.
d) Bigger that the acceleration of the object fallen free fall downward.

4- Imagine you are riding a bike and moving with constant speed in a straight line, and you have a small ball in your hand, if you threw the bell vertically upward (ignoring the resistance if air), then the ball will fall:

a) In front of you
b) Behind you
c) In your hand
d) Any of the previous probabilities and that depends on the ball speed.

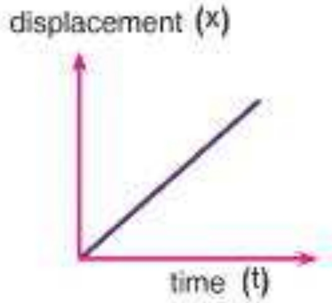
5- In all the following examples the car is in motion, which of them does not have acceleration?

a) The car is moving on a horizontal turn with constant speed (50 km/h).
b) The car is moving on a straight road with constant speed (70 km/h).
c) The velocity of the car is decreasing from (70 km/h) to (30 km/h) through (20s).
d) The car started from rest till it reached (40m/s) after (60s).



6- When you make (velocity-time) graph the straight horizontal line drawn in the graph represents a object motion with :

a) velocity equals ZERO.
b) constant velocity in magnitude and direction.
c) velocity in increase in magnitude regularly.
d) decrease in velocity in magnitude regularly.



7- In the (displacement-time) graph the straight italic line in the object motion if it was:

a) velocity equals ZERO.
b) constant velocity in magnitude and direction.
c) velocity in increase in magnitude regularly.
d) decrease in velocity in magnitude regularly.

8- A motorbike is moving on a straight line with constant slowing down then the (velocity-time) chart for its motion is:

a) A straight line tends to the right up.
b) A straight line tends to the right down.
c) A straight horizontal line.
d) A curved line tends to above and increase by time.

9- A stone was thrown vertically upward and it reached the highest height (y) then it fell a free fall from that height returning to the point it was thrown from, then its average velocity equals:

a- zero

b- $2\frac{y}{t}$

c- $\frac{y}{t}$

d- $\left(\frac{1}{2}\right)\left(\frac{y}{t}\right)$

10- A person is standing on the roof of a building and hold two balls in his hands that have equal mass and volume (red and green) if he throw the red ball with horizontal velocity and left the green ball to fell a free fall from the same height then:

a- The balls reach the ground at the same time but the speed of the red one is bigger than the speed of the green one at the moment they reach the ground.
b- The red ball reaches the ground before the green one with a bigger speed.
c- The green ball reaches the ground before the red one with a bigger speed.
d- The balls reach the ground at the same time with equal speed.

Q2/ in which kind of motion the magnitude of the average velocity equals the magnitude of the instantaneous velocity?

Q3/ what is the magnitude of the velocity and the acceleration of a object thrown upward when it is in the top of its path?

Q4/ if the counter put in front of the driver pointing to 70km/h for a period of time, does that mean that the car is moving with a constant speed? Or constant velocity? Or constant acceleration? Explain that.

Q5/ clarify if the bike in the following examples has a linear acceleration or central or both of them?

a- A bike moving with a constant speed on a straight road.
b A bike moving with a constant speed on a horizontal turn.
c- A bike moving with a constant speed on one side of a straight road then it turns and returns in the opposite direction with a constant speed on the other side of the road.

Problems of Chapter 2

P 1/ a car is moving with a velocity (30m/s) if the driver pressed the brakes of the car will slow down ($6\ m/s^2$) calculate the magnitude:

1) The velocity of the car after (2s) from pressing the brakes.
2) The time the car take to stop moving.
3) The displacement the car travels until is stop moving.

P 2/ a stone fell down a free fall from a bridge, it collided by the water surface after (2s) from the moment it fell. Calculate:

1) The height of the bridge over the water surface.
2) The height of the stone over the water surface after (1s) from the moment it fell.
3) The velocity of the stone at the moment it collides the water.

P 3/ a plane is flying in the sky with a horizontal velocity (150m/s) with a height (2000m) over the earth surface . If a bag fall down calculate:

1) The horizontal dimension of the point where the bag collides the earth surface from the vertical line of the point it fell from the plane.
2) The magnitude and the direction of the velocity when the bag collides the ground.

P 4/ from a point on the earth surface a stone was thrown vertically upward and it reached the top of its path after (3s) from the moment it was thrown. Calculate:

1) The velocity that the stone was thrown by.
2) The highest height the stone reach over the earth surface .
3) The total displacement and the total time through its motion.

Chapter 3: Laws of Motion

3.1 The concept of Force and its kinds

Figure 1

The force is: the effect that change or try to change the motion state of the object or the object's shape, and the behavior of objects depends on the resultant forces influences them, for example when you kick a football by your foot notice figure (1) you can control the speed and direction of the ball and that means the force is a vector quantity exactly like the velocity and the acceleration.

Figure 2

And if you pulled out the lower side of a spring that is fixed from the upper side then the spring will be **expand**. Notice figure (2).
As well as when the horse pulls the sled then the sled will move toward the drag force, notice figure (3).

Figure 3

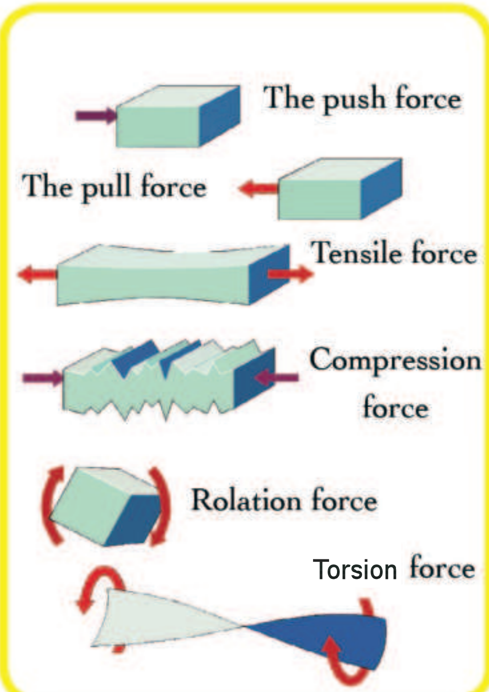


Figure 4

The forces has several kinds and a lot of in-**effects** including push, pull, tensile, clipping, rotation and torsion. Notice figure (4). The unit of Force in the international system for units (SI) is **Newton**

$1N=1\ kg\ m/s^2$

Figure 5

The force can be measured using a spring **scale** notice figure (5) all the forces mentioned effect two objects having direct contact then it is called (contact forces)

In addition to those forces that are known in the nature there is another kind of force where there is no direct contact between the objects.

It is known for physicists the existence of base-forces in the nature which are the gravity force, the electric force, the magnetic force and the nuclear force.

a- The gravity force:

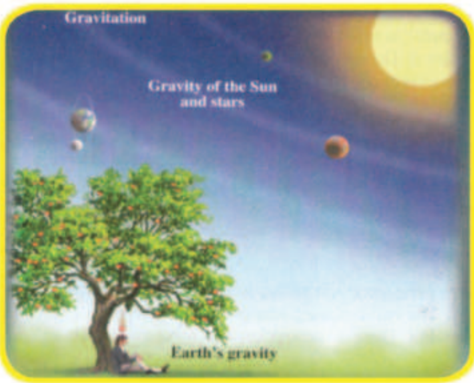


Figure 6

it the reciprocal attraction Force between any two masses in the universe and this force may be so strong for other objects, like the gravity force that the sun influences the earth notice figure (6) which keeps the earth rotating in its orbit around the sun even though the distance between them and the existence of other planets between them, the earth as well imparts the gravity to objects above its surface or close to it surface. (And the attraction force that the planet or the moon imparts to near objects called the object weight).

b- The electric and magnetic forces:

Figure 7

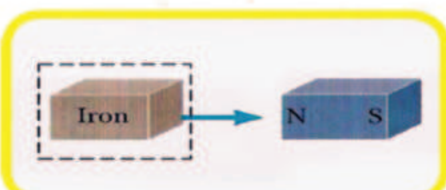


Figure 8

As example , the electrical force between two electrical charges as the attraction of paper pieces to the comb that is combed with wool notice figure (7) and the magnetic force that appears between two magnetic poles or the attraction of an iron piece to the magnet notice figure (8).

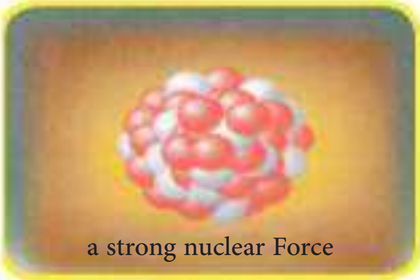


Figure 9a

Figure 9b

c- Nuclear force:

One of the base-forces that exist in nature and it has two types notice figure (9). First type:

First type :

a strong nuclear force: this connect the nucleons with each other notice figure (9a).

Second type: a weak nuclear force: this is responsible about the decay of beta particles that happens inside the nucleus notice figure (9b).

3.2 Inertia and mass

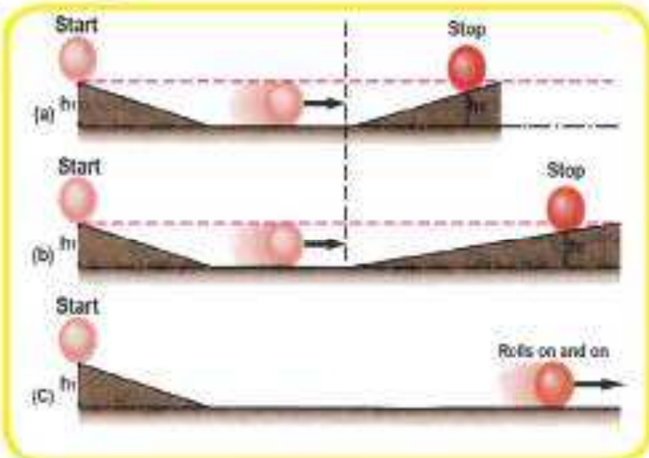


Figure 10

The scientist Galileo made a chain of experiments where he used two sloping planes in front of each other notice figure (10). And left a ball to roll over from the top of the first plane then its velocity increases during descending and reach the maximum in the bottom of the first plane and when the ball ascends the second plane its velocity decreases until it stops in a height close to its first height. Figure (10-a), and when he made the slope of the second plane less than the previous one he found that the ball keep moving and stop after it passes longer distance than the first case figure (10-b). Finally he made the second plane horizontal, he found that the ball keep rolling on the straight horizontal plane without stopping (in the case of no friction) figure (10-c).

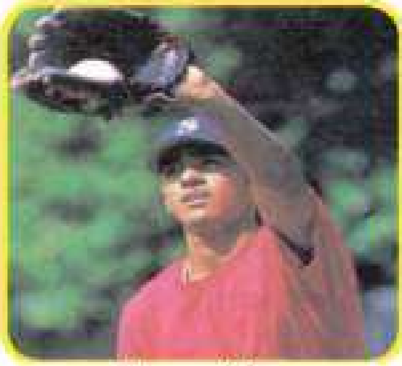


Figure 11

From these views you can define the inertia of an object as: the object property to resist the change in his motion state, so the velocity of the object does not change if the total force that influences it equals ZERO and to understand the relation between the inertia and the mass of an object imagine that you are in a stadium and two balls were thrown to you individually the first was a table tennis ball and the second is baseball, if you tried to catch both of them in your hand what do you think the force that you apply to stop their motion? Notice figure (11), you will find then that the baseball needs bigger force to be stopped than the force that the table tennis ball needs, because the baseball has bigger mass then it resist more for changing its motion state.

We conclude that :

- The Inertia of an object depends on the body mass.

- The inertia is a property that the object has which indicate the amount of resistance that the object shows for any change in its motion state.

3.3 Newton's Laws of Motion

The physical scientist Isaak Newton built his theory about motion through three laws that are known as Newton's Laws of Motion, where he described the forces influence on the objects motion by these laws.

Newton's first law:

This law is called inertia law. And he reached this law depending on Galileo's ideas. The law states that:

An object at rest remains at rest, or if in motion, remains in motion at a constant velocity unless acted on by a net external force.

Figure 12a

If you are sitting in a parked car, what do you feel when the car suddenly move with acceleration toward the front? notice figure (12-a) You will find that your body rushes backward which means your body resisted the change in its motion state so it is trying to remain at rest.

And when the car that is moving in a straight line with constant speed and suddenly stops you find your body rushes forward which means your body resisted the change in its velocity. Notice figure (12 b).

Figure 12b

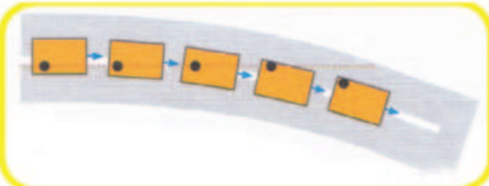


Figure 12c

However, if the car you are sitting in was moving on a horizontal turn with constant speed, you find your body trying to keep his straight motion in the direction of the tangent so it is resisting the change in the direction of the velocity notice figure (12 c).

From the three previous cases we understand that the object at rest remains at rest figure (12 a) and the object in motion with a constant magnitude velocity and moving in a straight line tries to resist the change in the velocity magnitude notice figure (12 b) or resist the change in the velocity direction figure (12 c) that is what Newton's first law states.

Activity / Inertia

Activity tools: pen, smooth metallic ring and opened bottle.

Steps:

- Put the bottle vertically on a horizontal table's surface.
- Put the metallic ring as a vertical plane over the bottle nozzle.
- Put the pen vertically and quietly over the ring figure (13 a).
- Hit the ring by your hand fast and with a horizontal force from the middle figure (13 b).
- You find that the ring stand aside and the pen enter the bottle figure (13 c).

Figure 13

We conclude from the activity:

1- When the ring get influenced by a horizontal force, it moved with acceleration while the pen kept instantaneously static in its place because of the absence of friction.

2- The absence of force influence on the pen makes it keep static and fall in the bottle by the influence of gravity force.

Think ?

1- It is impossible to move a large steamer from static by a small boat influences on it with a force. Notice figure (14).
2- The horse rider rushes forward (when the horse stop suddenly) what is the explanation of that?

Figure 14

Newton's second law:

We understood from Newton's first law, what happens for an object in case obsence the net external forces influence it, an object at rest remains at rest, or if in motion, remains in motion at a constant speed. While Newton's second law answers a question may be asked, what may happen to the object when net external forces influence it?

To answer this question we do the following activity:

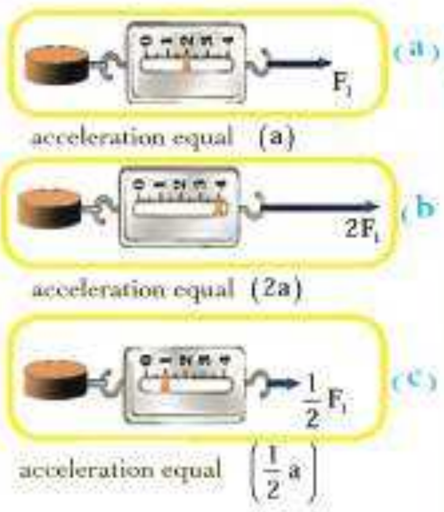


Figure 15

Activity (1)

The relation between the object's acceleration and the magnitude of the force that influences it at constant mass.

Activity tools:
Helical spring, metal disc, Smooth horizontal surface

Steps:
- Fix one side of the spring with the metal disc and hold the other side in your hand.
- Pull the disc with a horizontal force ($\vec{F}_1$) you will find the disc moving on the horizontal surface with an acceleration (a) notice figure (15 a).

- Pull the disc with a bigger horizontal force, let us assume $\Sigma F=(2\vec{F}_1)$ you will find the disc moving on the horizontal surface with bigger acceleration assumed to be (2a) so the acceleration of the object doubles by doubling the total force influencing the object notice figure (15 b).
- Pull the disc with a smaller horizontal force let us assume $\Sigma F=(1/2 \quad F_1)$ you will find the disc moving on the horizontal surface with smaller acceleration assumed to be (1/2 a) notice figure (15 c).

We conclude from the activity:
The acceleration is directly proportional to the net resutlant of forces that influence the object and always directed to its direction, so that $\vec{a} \propto \Sigma \vec{F}$
With constant mass.

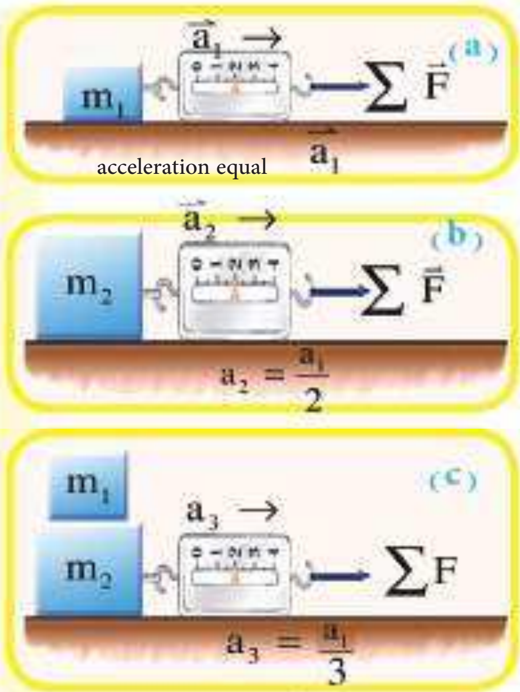


Figure 16

Activity (2)

The relation between the acceleration of the objects and its mass with constant force.

Activity tools:
Spring scale , two cubic of ice, Smooth horizontal surface.

Steps:

- Put the ice cubic (has a mass m_1) on the Smooth horizontal surface.
- Fix one side of the spring with the cubic and hold the other side in your hand.
- Pull the first cubic with a horizontal force $(\Sigma \vec{F}_1)$ you will find the cubic moving on the horizontal surface with an acceleration $\vec{a}_1$ notice figure (16 a).
- Put the second cubic that has a mass m_2 which has the double of the first cubic mass, on the smooth horizontal surface.
- Pull the second cubic that has a mass $(m_2=2m_1)$ with the same horizontal force $(\Sigma \vec{F})$ you will find the cubic moving on the horizontal surface with an acceleration $(\vec{a}_2)$ supposed to be the half of $(\vec{a}_1)$ and $\vec{a}_2=\frac{\vec{a}_1}{2}$ notice figure (16 b).

- Put the first cubic that has a mass(m_1) over the second cubic that has a mass (m_2)notice figure (16c).
- Pull the group with the same horizontal force applied on the first cubic ($\Sigma\vec{F}$) you will find the cubic moving on the horizontal surface with an acceleration (a_3) supposed to be equal to:

$$\vec{a}_3=\vec{a}_1/3$$

We conclude:

The acceleration of the object is inversely proportional to body mass with net effective force kept constant, that is: $a \alpha \frac{1}{m}$

From the two conclusions we find: $\vec{a} \alpha \frac{\sum \vec{F}}{m}$

And when the magnitude of the effective force is $\Sigma\vec{F}$=1N and the object's mass m=1kg then the object will move with acceleration

$$a=1m/s^2.$$

Force = mass x acceleration

Which means $\vec{F}=m\vec{a}$ this is the mathematical expression of Newton's second law.

Weight and mass

Figure 17

It is clear for us that all the objects on the earth are influenced by an attraction force toward the center of the earth, the force that the earth influences on the objects is the gravity force (F_g) and the amount of force that the gravity that influences on the object called the weight of the object (w), which means:

Weight = mass x acceleration of gravity

$$\vec{w} = m\vec{g}$$

According to Newton's second law: $\vec{F}=m\vec{a}$

So $\vec{a}=\vec{g}$ for all the objects that fall free fall (as explained in chapter 2) it falls with the acceleration of gravity $(\vec{g})$ directed to the center of the earth (minus sign is always in front of its magnitude). And the weight of the object changes when its distance from the center of the earth changes according to Newton's general law that states:

Two particles attract each other with forces directly proportional to the product of their masses and invesely proportional the square of the distance between them.

$$\sum \vec{F} \alpha \frac{m_1 \ m_2}{d^2}$$

$$\text{Gravitational force} = \text{Constant} \times \frac{\text{First mass} \times \text{second mass}}{\text{Displacemant square}}$$

$$\sum \vec{F} = G \frac{m_1 \ m_2}{d^2}$$

$\sum \vec{F}$: is the net force the gravity

G : gravitational constant $(6.67 \times 10^{-11} \frac{N.m^2}{(kg^2)})$

m_1:The first mass.
m_2:The second mass.
d is the distance between the masses centers.

Figure 18

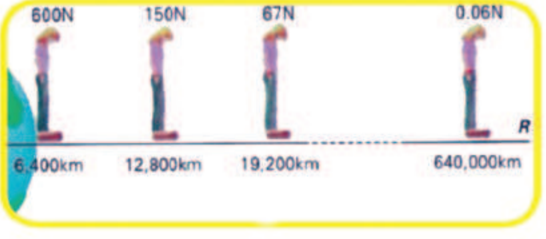


Figure 19

Since the amount of gravity changes by the change of the object distance from the earth center so it increases when the object get close to the center of earth. Notice figure (19).

Think ?

Assume you have a piece of gold has a weight (1N) and you are on the earth's surface and an astronauts also has a piece of gold has a weight (1N) and he is on moon. Does the astronauts and you have the same mass of gold? (Who has bigger gold mass?)

Newton's third law:

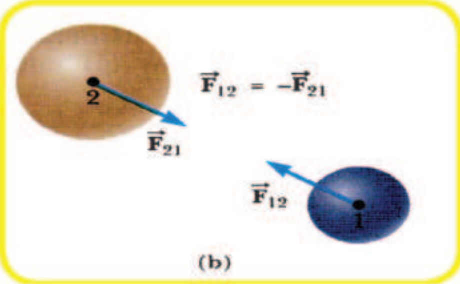


Figure 20

Newton focused on the nature of the forces that influence the objects in his third law, and clarified that forces always couples notice figure (20), if the first object (m_1) influenced the second object with a force ($\vec{F}_{12}$) then the second object (m_2) will influence the first object with a force ($\vec{F}_{21}$) and these two forces has equal magnitude and opposite directions as:

$\vec{F}_{12}=-\vec{F}_{21}$ And they are located on the same act line and influence different two objects.
It is important to mention that the balance does not happen because of these two forces because they influence other two objects not only one object.
The force $\vec{F}_{12}$ is called action force, where the force $\vec{F}_{21}$ is called reaction force.
Notice figure (21), we find that the hammer influences with force $\vec{F}_{12}$ on the nail that is representing the Action , then the reaction of the nail on the hammer $\vec{F}_{21}$.
Newton stated his third law as the following statement:

Figure 21

The action force is equal in magnitude to the reaction force and opposite in direction The have common line of action and acting on two object .

Remember

The two force in anaction reaction are:
* equal in magnitude and opposite in direction.
* acting on two different objects.
* They are a common line of action.

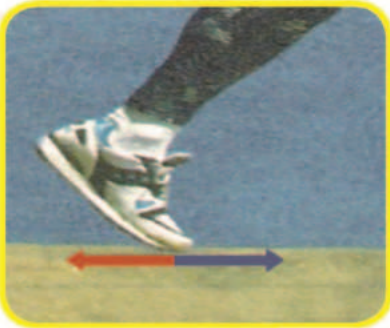


Figure 22

In our daily life there are visions that enable us to understand Newton's third law.

* While walking on ground, the feet of the person push him by a force that has a horizontal component directed backward and at the same time the ground push the person's feet by a force that has a horizontal component directed forward and this component cause the person's motion, notice figure (22).

Figure 23

* In rowing sport, the sitting in the boat push the water backward by paddle (the action force) at the same time the water push the paddle forward (reaction force) so the boat will be pushed forward notice figure (23).

Figure 24

* When the swimmer jump on the jumping board to sink in water, we find that the swimmer push the plate downward (action force) we see the board reverses backwards at the same time so it push the swimmer upward (reaction force) notice figure (24).

Figure 25

* The rocket's rush upward is the result of the reaction force of the gases exits from its back, while the action force is the force that the rocket use to push the gases out of it. Notice figure (25).

Think ?

We all know that the earth attracting the moon, does the moon attract the earth, if yes, which of them has bigger attraction force? Or are they equal? Clarify that.

3.4 Applications about Newton's Laws of motion

We will discuss the relation between the force and the acceleration of an object or group of objects (the group of objects is called a system).
When an object move with constant acceleration ($\vec{a}$) as a result of a constant force ($\vec{F}$) ignoring the condition that the acceleration of the object (or system) equals ZERO, because it means balance case that we will study next chapter, let us study now the base-forces that influences an object or a system.

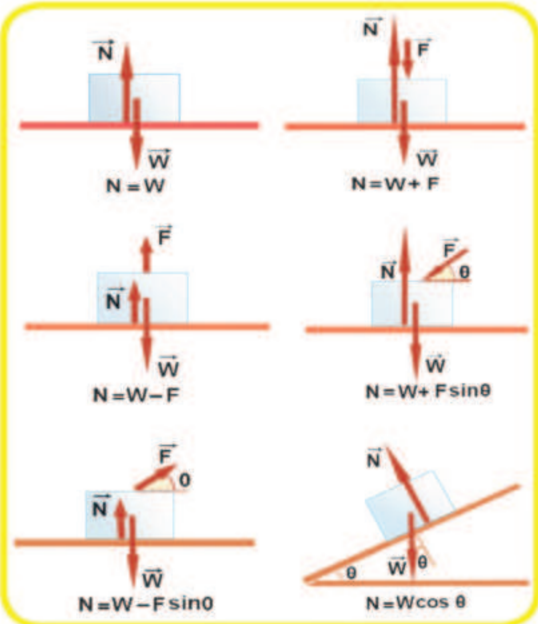


Figure 26

a) Vertical force:

Depending on Newton's third law, when an object was put above a surface then this surface will influence the object with a force, notice figure (26). (In case the object is static or moving on the surface) in the absence of such force, the body will sink into the surface or go down with acceleration notice figure (26). The normal force that the surface influences the object by is called the normal force and has a symbol ($\vec{N}$) and this force $\vec{N}$ is special that:

* It is perpendicular to the surface and directed far from the surface.
* It is the reaction force of the surface on the object and its magnitude is not constant since it equals the magnitude of the net effective force that influences the surface vertically, and in the opposite direction to the net force notice figure (26) it shows some of this vertical forces.

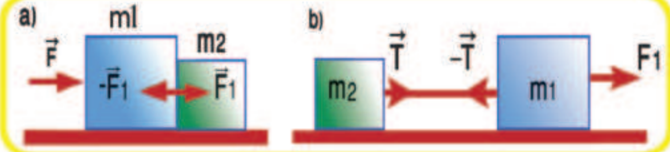


Figure 27

b) Tensile force:

In our daily life when we need to move an object we need to pull it by a thread, rope or a wire and when the object get pulled by a rope then the rope influences the object with a force. Notice figure (27). The force that the rope influences the object with is called tensile force that has a symbol ($\vec{T}$).

In most exercises we assume the rope (or the thread or the wire) has no weight and friction so the tensile force is the same in all the points of the rope.
It is possible to change the direction of the tensile force using pulley and in this case the magnitude does not change assuming the reels has no weight and friction. Notice figure (28).

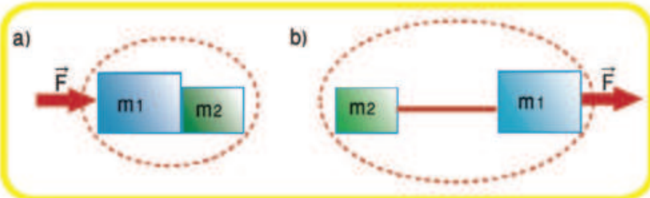


Figure 28

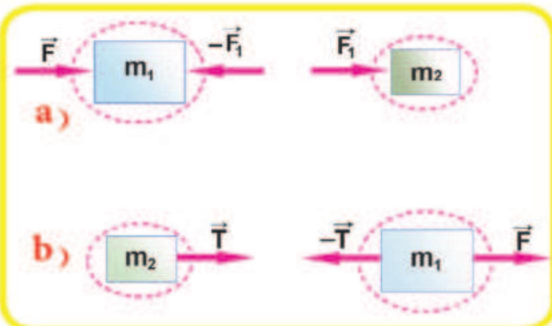


Figure 29

c- Internal and external forces:

When we assume that the system (group of objects) is insulated then the forces influences it is called external forces ($\vec{F}_{ext}$). Notice figure (29) the surface is horizontal and smooth (frictionless) so the friction force does not appear in it then the net vertical force equals ZERO because (N = w)

Then the force $\vec{F}$ is the only external force that influences the system. However, the internal forces are the result of the interaction between the components of the system and it is usually exist as couple force like: ($\vec{F}_1$, $-\vec{F}_1$, $\vec{T}$, $-\vec{T}$) where:

$\vec{F}$ Is the external forces that influences the system.

$\vec{F}_1$ Is the force that mass m_1 influences mass m_2 .

$-\vec{F}_1$ Is the force that mass m_2 influences mass m_1 .

$\vec{T}$ is the tensile force of the rope that influences mass m_2.

$-\vec{T}$ is the tensile force of the rope that influences mass m_1.

By applying Newton's second law on the whole system:

The external forces only are taken into account without depending on the internal forces.

However, when we take the system as parts of its components then the internal forces that were influencing it will be considered as external forces influencing every component in it.

3.5 Free body diagram

While solving an exercise in motion science (dynamic) it is important to:
Analyze the forces influencing the object or the system in a correct way, so the object (static or dynamic) will be insulated from its surrounding, then every force from the forces influencing it will be clarified, and this method is called free body diagram. In the following there are the forms of the forces applied on the objects notice figure (30).

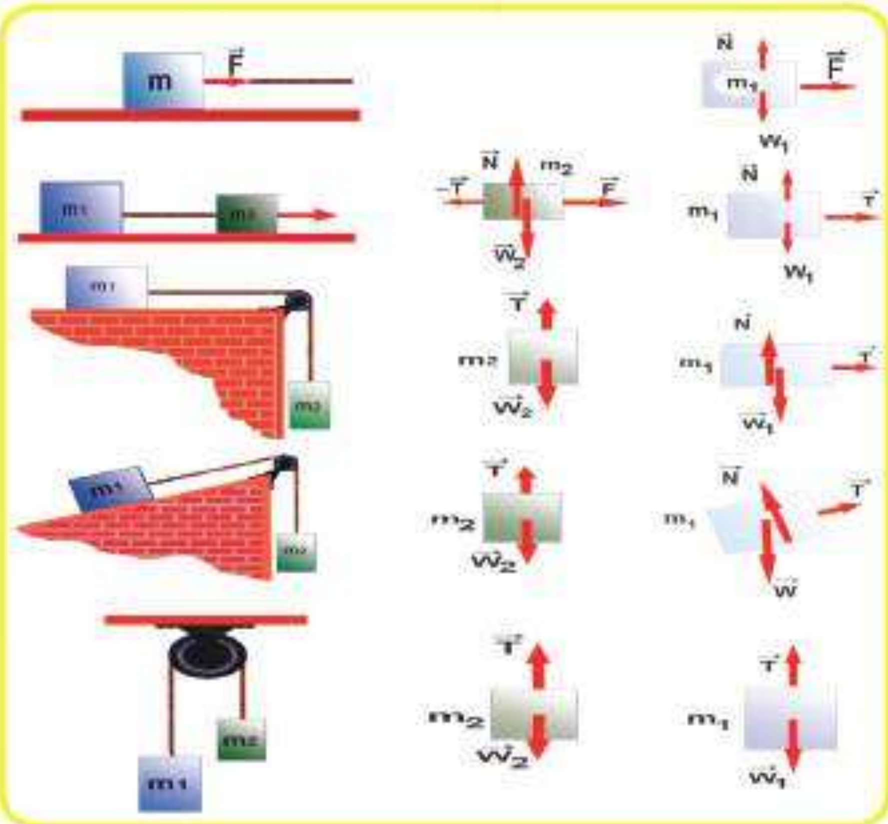


Figure 30

Think ?

In figure (31 a) the horse is pulling a ski on the ice with a horizontal force, causing the acceleration of the ski clarify the forces influencing the ski in figure (31 b). Clarify the forces influencing the horse in figure (31 c).

Figure 31

Example 1

Two objects, one has a mass of (2kg) and the other has a mass of (3kg) hanging vertically with the two sides of a light rope passing over a weightless and frictionless pulley notice figure (32). Calculate the magnitude of the two objects' acceleration and the tensile of the rope assuming ($g = 10\ m/s^2$)

Solution:

Figure (32 a) two objects are connected by a light rope that passes over a frictionless pulley .Figure (32 b) the schematic diagram of the two objects (m_1,m_2) (the tensile force is equal in the two sides of the pulley since the pulley is weightless and frictionless)

The net force influencing the object that is going up (2kg) is:

$T-m_1 g=m_1 a$
$T=2\times10+2\times a$
$T=20+2a$......(1)

While the net force influencing the object that is going down (3kg) is:

$m_2 g-T=m_2 a$
$3g-T=3a$
$T=3g-3a$
$T=30-3a$......(2)

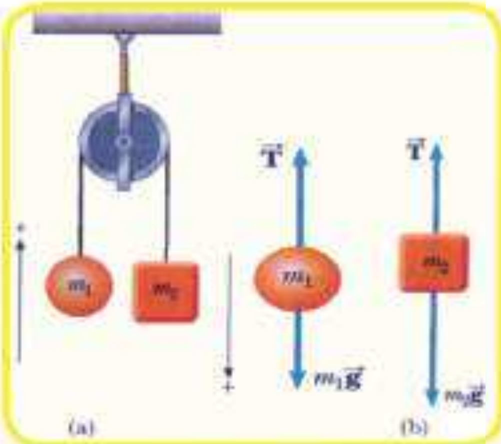


Figure 32

The left side of equation (1) equals the left side of equation (2)

$20+2a=30-3a$
$5a=10$
$a=2\ m/s^2$

The acceleration of both objects
We substitute a in one of the equations let it be equation (1):

$T=20+2\times2$
$T=20+4=24$ N

Question?

In the previous example what would happen if: $m_1= m_2$

3.6 Friction

When an object move on a surface or through a viscous medium like air or water, then there will be resistance to motion as a result of interacting the object with its surrounding this resistance is called friction force. The friction force is so important in our daily life, it allows us to walk or run as well as it is important for the motion of the animals and the vehicles that has wheels and it may be harmful as the friction appears between the wheel and spindle for the bike or the car.

Friction force:

When the net external force influence an object placed on a horizontal coarse surface and tries to move it, and because of the contact between the object's surface and the surface placed on the protrusions between the two surfaces overlap, causing a force inhibiting movement called friction force. Notice figure (33).

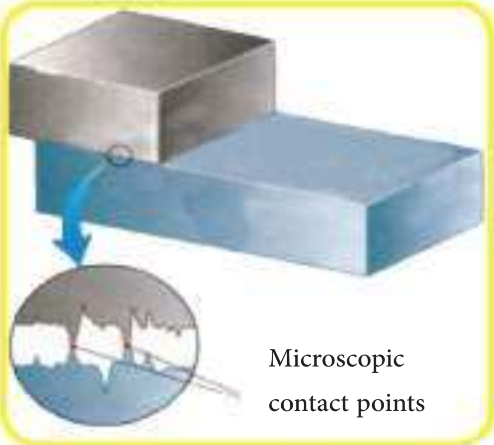


Figure 33

The direction of the influence of the friction force is tangential for both surfaces and always opposite to the motion direction.

And the forces that are pushing between the two surfaces are representing the perpendicular force on the surface that has a symbol ($\vec{N}$) and the experiments results showed that the friction force appears even if the object is static. If a net force influenced an object and could not make it move, then certainly there is friction force that preventing the object from moving.

Since the object is still static we call the friction force in this case (static friction force) and has a symbol f_s.
Its magnitude increases by the increase of the force that influences an object, until it reaches the maximum magnitude where the object is about to move. It is found experimentally that the maximum magnitude of the static friction force (f_s) is proportional to the perpendicular force N, depending on the following relation:

$$\vec{f}_{s(max)} = \mu_s \vec{N}$$

Where μ_s : represents the static friction coefficient.

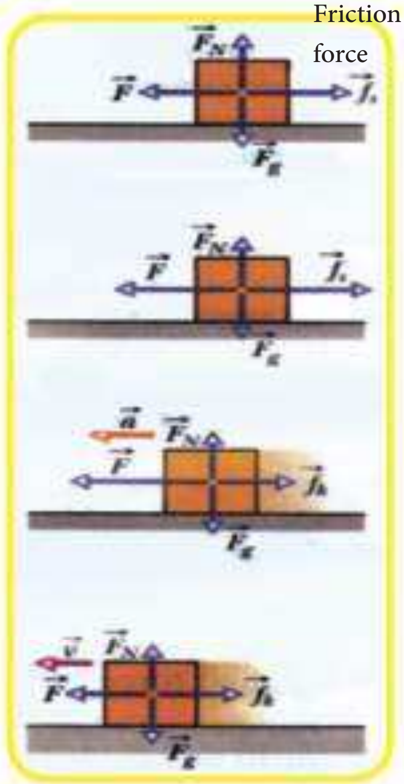


Figure 34

When the force that influencing an object increase to be more than the static friction force, the object starts moving then the friction force decreases so much, then it will be called kinetic frictional force and a symbol (f_k) notice figure (34).

The kinetic frictional force is a constant force within the limits of small velocities, and directly proportional with the vertical force according to the following relation:

$$f_k = \mu_k \vec{N}$$

Where μ_k: represents the coefficient of kinetic friction.
It is worth to mention that the friction coefficient depends on the nature of the two contacting objects and does not depend on the area of the two contacting surfaces.

Example 2

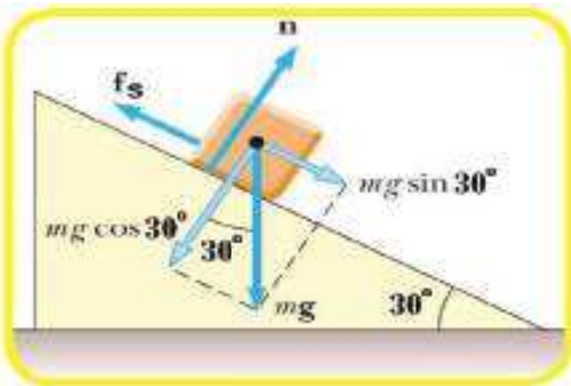
A box of a mass (400kg) was put on a coarse slanted surface, the surface was caught from one of its sides and leaned over the horizon then its tendency increases gradually until the angle of the surface becomes 30° over the horizon, the box was about to slide, calculate:

1- The static friction force when the box is about to move.
2- The acceleration of the box if the kinetic friction coefficient is μ_k=0.1

Solution:

1- The object is about to move:

$$\therefore f_s = m\,g\,\sin 30°$$
$$= 400 \times 10 \times 0.5$$
$$= 2000N$$



2- We apply Newton's second law on the box in this case

$$\therefore \sum \vec{F} = m\vec{a}$$

$$\therefore \ mg\sin\theta - f_k = ma$$

$$mg\sin\theta - \mu_k mg\cos\theta = ma$$

$$400 \times 10 \times 0.5 - \mu_k\,(mg\cos 30^\circ) = 400a$$

$$2000 - 0.1\,(400 \times 10 \times \frac{\sqrt{3}}{2}) = 400a$$

$$2000 - 340 = 400a$$

$$a = \frac{1660}{400}$$

$a = 4.15\ m/s^2$ The acceleration magnitude of the box

Example 3

An object has a mass (150kg) was put on a horizontal surface as shown in figure (a) a pulling force (300N) influenced it that makes an angle 37° over the horizon that made it about to move, calculate:

1- The static friction coefficient between the object and the horizontal surface.

2- The acceleration of the object if the influencing force was doubled if the kinetic friction coefficient (dynamic) is (μ_k=0.1).

Solution:

1- When the body is about to move its static friction force is equivalent to the horizontal component of the force;

$$\sum F_X = 0$$

$$f_s = F_X$$

$$f_s = F\cos\theta$$

$$f_s = 300 \times \frac{4}{5} = 240N$$

$$N = w - F_y$$

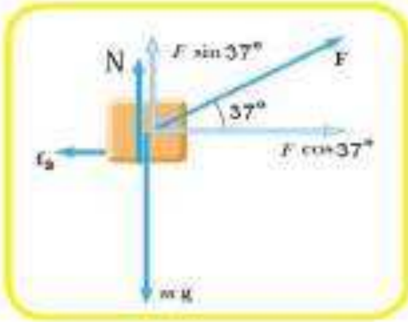
$$= 1500 - 300 \sin\theta$$

$$= 1500 - 300 \times \frac{3}{5}$$

$$= 1500 - 180 = 1320N$$

$$\mu_s = \frac{f_s}{N} = \frac{240}{1320}$$

$$= 0.18$$



2- When the force is doubled F=600N, Then its horizontal component equals

$$F=600N$$

$$F\cos 37° = 600 \times 0.8 = 480N$$

and vertical component equals:

$$F\sin 37° = 600 \times 0.6 = 360N$$

$$\therefore \quad \sum Fy = 0$$

$$N = w - F\sin 37°$$

$$= 1500 - 360 = 1140N$$

we calculate kinetic frictional force

$$f_k = \mu_k N$$

$$= 0.1 \times 1140 = 114N$$

According to Newton's second law:

$$\sum F_x = ma$$

$$F\cos 37° - f_k = ma$$

$$480 - 114 = 150a$$

$$366 = 150a \Rightarrow a = 2.44 m/s^2$$

Questions of The Chapter 3

Q1/ choose the correct statement from the following statements:

1- Net external force influenced an object and caused it moving from static, if the magnitude and the direction of this net force was known and its mass was also known then it is possible to apply Newton's second law to find:

a) The object weight
b) The object speed
c) The object displacement
d) The object acceleration

2- When a horse pull a pulls a vehicle then the force that cause the horse to move forward is:

a) The force that pulls the vehicle
b) The force that vehicle influences the horse.
c) The force that the horse influences the ground.
d) The force that the ground influences the horse.

3- The friction force between two contact surfaces does not depend on:

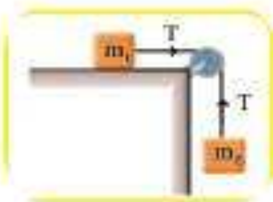
a) The force that is pushing vertically on the contact surfaces
b) The area of the contact surfaces
c) The relative motion between the contact surfaces
d) The existence of oil between the surfaces or the absence of it.

4- If you wanted to walk on an iced ground without sliding it is better to walk with:

a) Big steps
b) Small steps
c) Circler path
d) curved Horizontal path

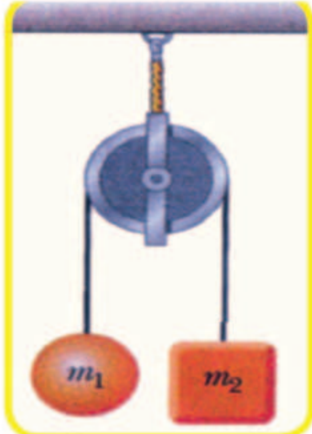
5- Two masses (m_1, m_2) are connected by a weightless wire as shown in the figure and m_1 was moving on a glaze surface while m_2 is suspended vertically with tip of the wire. Then the tensile in the wire (T):

a) $T=0$
b) $T < m_2\ g$
c) $T = m_2\ g$



6- In the next figure the two masses (m_1,m_2) are connected by a weightless rope that passes on a weightless and frictionless reel, if we assumed m_1=m_2 then the system acceleration is:

a)Equals g
b) Bigger than g
c) ZERO
d) Less than g



7- A car of a mass (m) is sliding on a surface covered by frictionless ice and oblique with an angle θ as shown in the figure, then the car acceleration equals:

a) g sinθ
b) sinθ/g
c) 2g sinθ
d) 1/2 g sinθ

8- A horizontal force(40N)is necessary to make a box of iron that has a mass(10kg)about to move over a horizontal wooden floor then the static friction coefficient μ_s will equal:
a) 0.08
b) 0.25
c) 0.4
d) 2.5

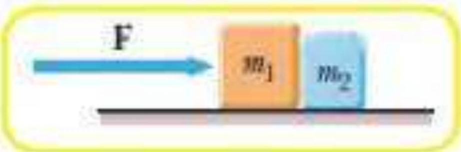
9- The force 10N give an object an acceleration of 2 m/s^2, while the force 40N gives the same object an acceleration equals:
a) 4 m/s^2
b) 8 m/s^2
c) 12 m/s^2
d) 16 m/s^2

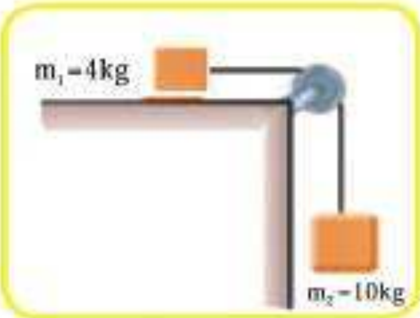
10- An object of a mass (m) is suspended by a rope in the roof of an elevator if the elevator was moving upward with constant velocity then the tensile of the rope:

a- Equals mg
b- Less than mg
c- Bigger than mg
d- Indicated from the velocity magnitude

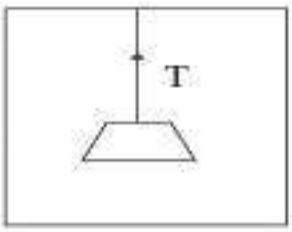
Problems of The Chapter 3

P1/ the following figure shows tow objects (m_1, m_2) that are in tangency position placed on a glaze horizontal surface, the first object mass was (m_1=4kg) and the second object mass (m_2=2kg) if the horizontal force F = 12N was applied it will push mass m_1 as in figure, find the acceleration of the group that is consist of the two objects





P2/ An object of mass 4kg is places on a coarse horizontal surface and connected by a tip of a wire that passes over a glaze weightless reel and in the other tip of the wire an object of mass 10kg is connected vertically as shown in figure. Calculate the friction coefficient between the object m_1 and the horizontal surface when the group move from static with an acceleration of 6 m/s^2



P3/ an object of mass 1kg is suspended by a weightless rope in the roof of an elevator notice the figure, calculate the tensile(T)of the rope when the elevator start moving:

a- Upward with acceleration 2 m/s^2
b- Downward with acceleration 2 m/s^2

P4/ a horizontal force has a constant magnitude (20N) influenced an object that its mass (2kg) that is placed on a glaze horizontal surface, calculate:

a- The speed of the object at the end of the first second of its motion.
b- The displacement that the object traveled through 3s from starting moving.

P5/ in the figure a person is pushing his daughter when she sits on a ski for sliding on ice. Which of the following forces is better for the person so his daughter moves easily on the ice:

a- Push her by influencing with a force F on her shoulders with an angle 30° under the horizon.
b- Pull her with the same force F using a rope that tends 30° over the horizon.

Chapter 4: Equilibrium and Torque

4.1 Concept of equilibrium

We notice around us that some objects are static and other objects are dynamic and their motion may be accelerating or has a constant speed and in a straight line. The rigid body (the rigid body is a system of particles the distance between them remains constant does not change with the influence of external torques and forces). If an external net force influenced the rigid body, will move with acceleration, and that is according to Newton's second law of motion $\vec{a}=\vec{F}/m$, and when the net external force that influences the object equals ZERO ($\sum\vec{F}=0$) then the object will be applied to Newton's first law (continuity law) in this case either the object will be static then it will be said the object is static equilibrium or it will be dynamic with constant speed in straight line then it will be said the object is dynamic equilibrium.

4.2 Transitional equilibrium

To say the object is equilibrium, two conditions must be a vailable , the first condition (condition of transitional equilibrium) that happens when the net external forces that influenc ing the object equals ZERO

$\sum\vec{F}=0$

(The symbol Σ means the sum or the net of any quantity and it is spelled summation) And this means that the net external forces that influences an object at any axis form the horizontal and vertical axes (x, y) equals ZERO that is

$$\sum\vec{F}_x=0$$

$$\sum\vec{F}_y=0$$

Example 1

In figure (1) a ball suspended by the tip of the thread, was pulled aside with a horizontal force (15N). Calculate:

1- The tensile force of the thread

2- The weight of the ball.   Knowing that $\cos 53° = 0.6$, $\sin 53° = 0.8$

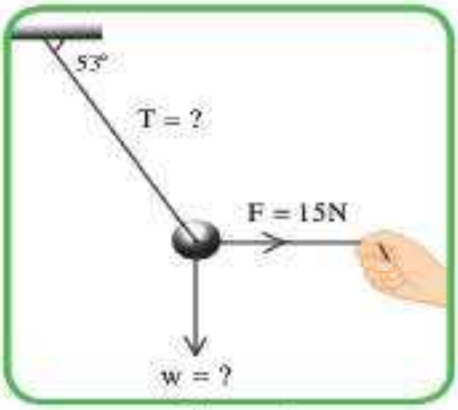


Figure 1

Solution:

1- We draw free body diagram and point the three influencing forces on it notice figure (1) which are:

The weight of body $\vec{w}$

The horizontal influencing force in the body $\vec{F}$

Tensile force of the thread $\vec{T}$

Since the body is in static equilibrium case, we analyze the oblique force $\vec{T}$ to its two components the horizontal and vertical one as in figure (2) then we apply the condition of transitional equilibrium:

$\sum \vec{F} = 0$

Then the net force on the x-axis = ZERO

And the net force on the x-axis is given as:

Figure 2

$$\sum \vec{F}_x = 0$$

$$\vec{F} - \vec{T}_x = 0$$

$$T_x = F$$

$$T \cos 53^0 = 15$$

$$T \times 0.6 = 15$$

$$T = 25 \text{ N}$$

The tensile force of the thread

Also the net force on the y-axis = ZERO

$$\sum \vec{F}_y = 0$$

$$\vec{T}_y - \vec{w} = 0$$

$$T_y = w$$

$$T \sin 53^0 = w$$

$$(25) \times (0.8) = w$$

$$w = 20N \quad \text{Body's weight}$$

4.3 Rotational equilibrium

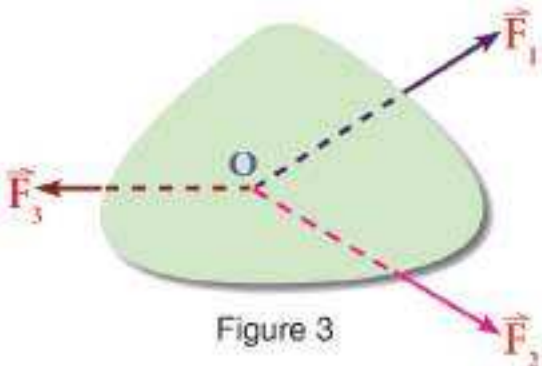


Figure 3

If the body was in transitional equilibrium it is not necessary to be in rotational equilibrium, for this reason the body can keep rotating even though the net external forces that is influencing it equals ZERO.

By noticing figure (3) you will find that there are three forces ($\vec{F}_1$, $\vec{F}_2$, $\vec{F}_3$) influencing a plate and the extensions of these force **converge** at one point (O) in the body. Since the net force equals Zero $\sum \vec{F}=0$

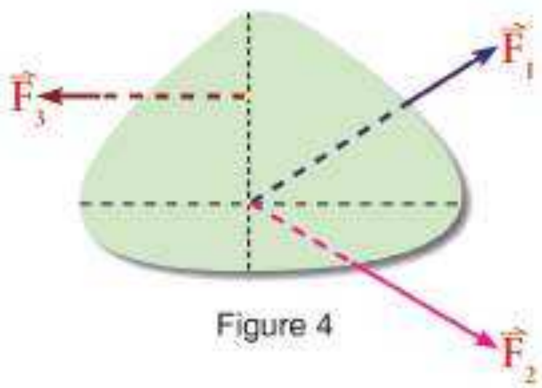


Figure 4

Then the plate is in transitional equilibrium. However, we notice in figure (4) that the three forces that has equal magnitudes do not **converge** at one point in this case, so the plate will rotate and the rotational equilibrium will be approved when the net external torques that influence the object around a certain axis equal zero, which means ($\Sigma \vec{\tau}=0$) where $\vec{\tau}$ is the torque symbol.

From the previous we conclude that any object in static equilibrium case must be in transitional equilibrium and rotational equilibrium at the same time.

4.4 Torque

When we open a book, door or window or when we fix the water pipes notice figure (5) we use a force that has circular influence (rotational effect) and the rotational effect of the force is called torque and has a symbol τ.

Figure 5

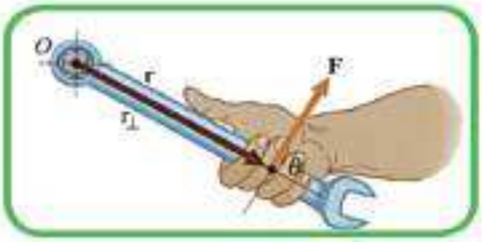


Figure 6

We also find difficulty in rotation a screw by hand, so we use spanner to rotate the screw notice figure (6).

The spanner generates a big rotational effect so it generates bigger torque than that the hand can generates. And the point that the force tries to rotate the object around is called the spindle or (point of rotation).

Activity

To indicate the factors on which the torque of the force is based.

Tools: spanner – screw – spring

Steps:

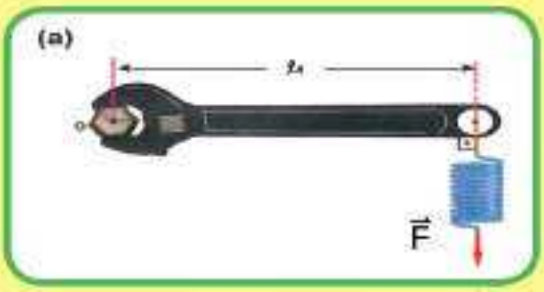


Figure 7a

* Enter the head of the screw in the nozzle of the spanner and using the spring apply a small force $\vec{F}_1$ perpendicular to the arm of the spanner with distance (ℓ_1) from the screw notice figure (7a).

* Try to rotate the screw using the spanner you will find difficulty in rotating.

Figure 7b

* Double the first force to be ($\vec{2F}$) with same distance from the rotation spindle you will find then ease of rotating the screw. Notice figure (7 b).

We conclude from this:

The torque of the force is directly proportional to the force $\vec{\tau} \propto \vec{F}$

*Try to use the same force ($\vec{F}$) using the spring and make the influencing point with distance (ℓ_2) in order to make it nearer to the screw then you will find more difficulty to rotate the screw.
Where $\ell_2 < \ell_1$ notice figure (7 c).

Figure 7c

* Repeat the same procedure several times, and in every time make the influencing point nearer to the screw you will find the amount of difficulty is increasing to rotate the screw.

We conclude from this:

The amount of the torque of the force is directly proportional to the vertical distance from the rotation spindle, $\vec{\tau} \propto \ell$ with constant $\vec{F}$

Figure 7d

* Apply the same force ($\vec{F}$) on the influencing point (ℓ_1) in the tip of the arm as shown in figure (7 d) but this time make the force not perpendicular to the spanner arm (oblique force making angle θ with the spanner arm), then the circular torque can be given as:

$\tau = F \ell \sin\theta$

Try again to rotate the screw, you will find more difficulty in rotating it whenever the angle θ deceases between the force and the spanner arm.

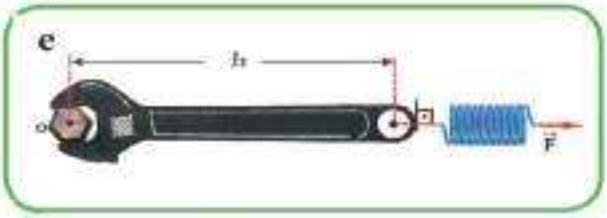


Figure 7e

* Make the force action line in parallel to the spanner arm (in this case the extension of force $\vec{F}$) passes from the rotation center notice figure (7 e). Then there will be no rotational effect of the force.

We conclude from this:

That there will be no torque of the force if the force or its extension passes from the rotational center, because the influence of the force arm become zero in this case.
It was noticed in the previous activity that the torque of the force directly proportional to each of the following:

1- Influencing force magnitude.
2- The vertical distance (ℓ) from the influencing point of the force to the rotation spindle.
3- The angle (θ) between force action line and the line which reach between the rotation point (spindle) and the point force effect.

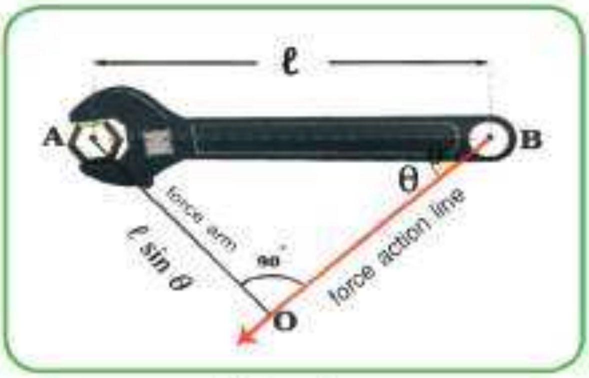


Figure 8

$\tau = F \ell \sin\theta$

To calculate the force arm (torque arm) we draw a straight line connecting between the force action line and the distance perpendicular to it from the rotation spindle then we get right-angled triangle ABO...
Notice figure (8) were the force arm is the rib AO equals ($\ell \sin\theta$)

Then the torque: $\tau = F\ell \sin\theta$

4.5 Torque is a vector

From our study to vectors in chapter 1 we knew that the product of two vectors may be scalar quantity like the dot product $c = \vec{F} \cdot \vec{d}$ or vector quantity like the cross product $\vec{A} = \vec{F} \times \vec{d}$ and since the torque is the result of the cross product of the position vector $\vec{r}$ to the force vector $\vec{F}$ notice figure (9) it is written as the following equation:

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

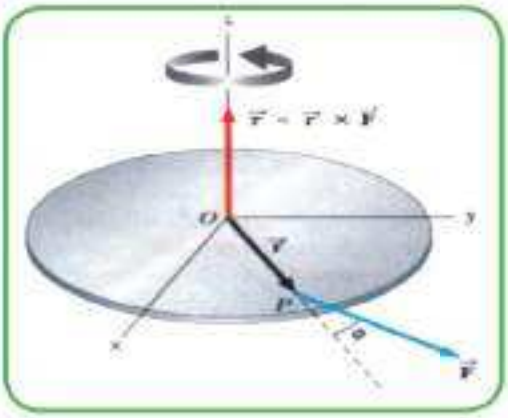


Figure 9

And the direction of the torque is perpendicular to the plane that contain $(\vec{F}, \vec{r})$ as in figure (9) and to indicate the torque direction we apply the right-hand rule notice figure (10).

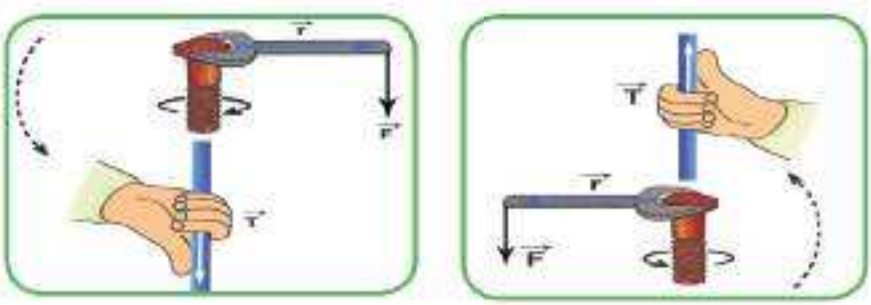


Figure 10

Figure 11

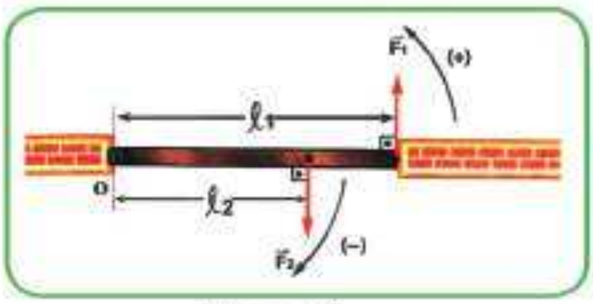


Figure 12

It worth to mention that the torque is always relative to a particular reference point, if a change in the position of that point happened the torque relatively change as in figure (11).

For example the torque of the force $\vec{F}$ is ZERO relative to the rotation point (O) but the torque of that force does not equal zero if point A was taken as the rotation point then:

$\vec{\tau} = (\vec{OA}) \times \vec{F}$

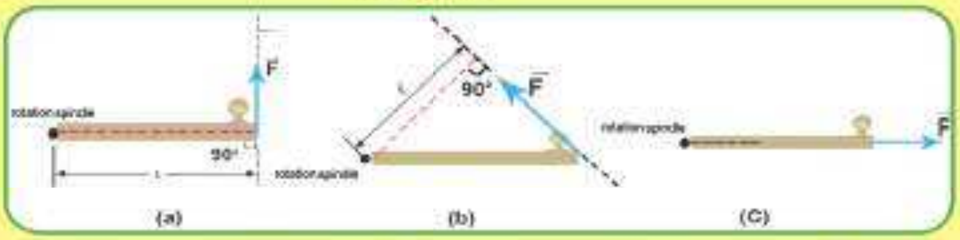
from that we understand that it is not enough to say (the torque of the force $\vec{F}$ but we must say the torque of the force $\vec{F}$ with respect to the point (O) or around the point (O) or any other point.

By noticing figure (12) you will find the force $\vec{F}_1$ is trying to rotate the object around point (O) in counter clockwise direction. However, the force $\vec{F}_2$ is trying to rotate the object around point (O) in clockwise direction. To differentiate between the possibilities we put positive sign for the counter clockwise rotating torques and negative sign for the clockwise rotating torques.

Remember

* The torque resulted from the force influence in rotating the object become the maximum τ_{max} when the force action line is perpendicular to the line connecting between the force influencing point and the rotation spindle notice figure (13a) which is : $\tau_{max} = F_{\perp} \cdot \ell$ and the toque magnitude decreases when the force action line is oblique notice (13b).

Figure 13

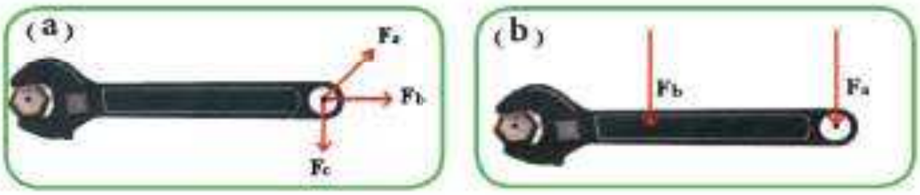


* There will be no torque (τ=0) when the force action line pass through the rotation point or spindle notice figure (13c) which means:

$$\tau = F_{\parallel} \cdot \ell = 0$$

Think ?

The forces shown in figure (a, b) causing less torque for the spanner in rotating the screw even though the forces' magnitudes are equal.



Example 2

If the magnitude of the applied force on the spanner of length (0.2m) equals (20N) figure (14) calculate the resultant torque of this force.

Figure 14

Solution:

We analyze the force $\vec{F}$ to its two components (F_x) the parallel component to the arm, and the other (F_y) is the perpendicular component to the arm and since the horizontal component (F_x) passes through the rotation point or spindle then:

$\tau = F_x \times 0 = 0$: because the torque arm= zero

Figure 15

While the vertical component (F_y) generates a torque tries to rotate the spanner in clockwise direction:

$$\tau = F_y \cdot \ell = (F \sin\theta) \cdot \ell$$

$$\tau = 20 \times 0.6 \times 0.2 = 2.4 \text{ N.m}$$

4.6 Net torque and the rotation direction

When several forces influence one object and tries to rotate it, then the torque of each force is calculated around the same rotation point, so the vector summation of individual torques equals the net torque ($\vec{\tau}_{net}$) notice figure (16) which means:

$$\vec{\tau}_{net} = \vec{\tau}_1 + \vec{\tau}_2 + \vec{\tau}_3 + \ldots.$$

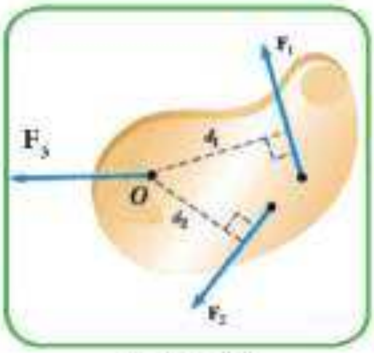


Figure 16

Example 3

A solid rigid cylinder can rotate around the horizontal axis (frictionless) a rope was rolled around its outer perimeter that has radius (R_1) notice figure (17) if a horizontal force (F_1) directed to the right was applied and another rope was rolled around the smaller perimeter that has radius (R_2) and the force (F_2) was applied downward from the tip of the second rope. Calculate: the net torque influencing the cylinder around the Z-axis if: R_1=1m, R_2=0.5m, F_1=5N, F_2=6N

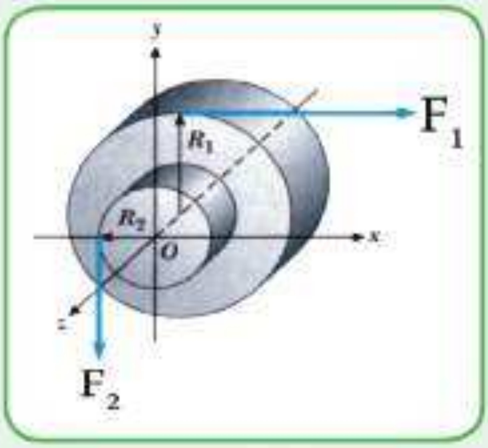


Figure 17

Solution:

The torque of force F_1 that is τ_1 is negative (because it is trying to rotate the cylinder in the clockwise direction ↻) then:

$$\tau_1 = -R_1 F_1 \Rightarrow \tau_1 = -1 \times 5 = -5\text{N. m}$$

While the torque of force F_2 that is τ_2 is positive (because it is trying to rotate the cylinder in the counter clockwise direction (↺)) then:

$$\tau_2 = R_2\ F_2 = 0.5 \times 6 = 3\ N\ .\ m$$

The net torque:

$$\vec{\tau}_{net} = \vec{\tau}_2 + \vec{\tau}_1$$

$$\sum \tau = R_2F_2 - R_1F_1$$

$$= 0.5\times6 - 1\times5$$

$$\sum \tau = -2\ N\ .\ m$$

Since the net torque has negative sign that means the cylinder is rotating in the clockwise direction.

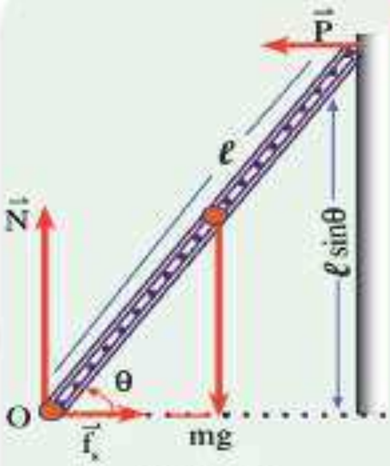


Figure 18

Example 4

A regular ladder has a length of ℓ and a mass (m) based on a glaze vertical wall notice figure (18) and the static friction coefficient between the floor and the ladder was (μ_s=0.4) find the smallest angle θ without the ladder slides.

Solution:

From noticing the figure (18) the ladder is static and based on a glaze vertical wall.

Then it is in equilibrium under the influence of four forces which are:

$\vec{P}$= the reaction of wall on the ladder.

$\vec{N}$= the reaction of floor on the ladder

$\vec{f_s}$= the friction force between the floor and the bottom of the ladder

mg = the weight of the ladder

Since the ladder is in static equilibrium we apply the first condition of equilibrium.

$$\sum F_x = 0 \Rightarrow f_s - P = 0$$

$$\therefore\ p = f_s \text{ and } f_s = \mu_s N$$

$$p=\mu_s N \quad \text{.................}(1)$$

$$\sum \vec{F}_y = 0 \Rightarrow N-mg=0$$

$$mg=N \quad \text{.................}(2)$$

Dividing equation (1) by equation (2):

$$\frac{p}{mg} = \frac{\mu_s N}{N} \Rightarrow \frac{p}{mg} = \mu_s$$

Since the ladder is in rotational equilibrium we apply the second condition of equilibrium and we take the point (O) as a center for torques:

$$\sum \tau = 0 \Rightarrow P\,\ell \sin\theta - mg\left(\frac{\ell}{2}\cos\theta\right) = 0$$

$$\frac{\sin\theta}{\cos\theta} = \frac{mg}{2p}$$

By substituting the value of : $\frac{p}{mg}$

$$\tan\theta = \frac{1}{2\mu_s} \quad , \quad \tan\theta = \frac{1}{2\times 0.4}$$

$$=1.25$$

$\therefore \theta = 51^\circ$ The angle of the ladder with the floor is the smallest angle without the ladder slide.

4.7 Couple

Figure 19

By rotating the steering wheel, the handlebar or the water tap you apply two forces that has equal magnitudes, opposite directions, parallel and do not have mutual action line and these two forces represent what is called couple notice the figure (19), and there are a lot of other applications in our practical life for example when you rotate the key of the door or when you use changing tire key.

And to calculate the couple torque, the torques of forces can be taken around any point between the two forces then their torques will be added because they work to rotate the arm in the same direction, and the simplest way to calculate the couple torque is to multiply one of the forces by the perpendicular distance between them.

By noticing figure (20) we can understand from it how to choose the point that represents the rotation spindle, since its position does not affect the magnitude of the couple torque.

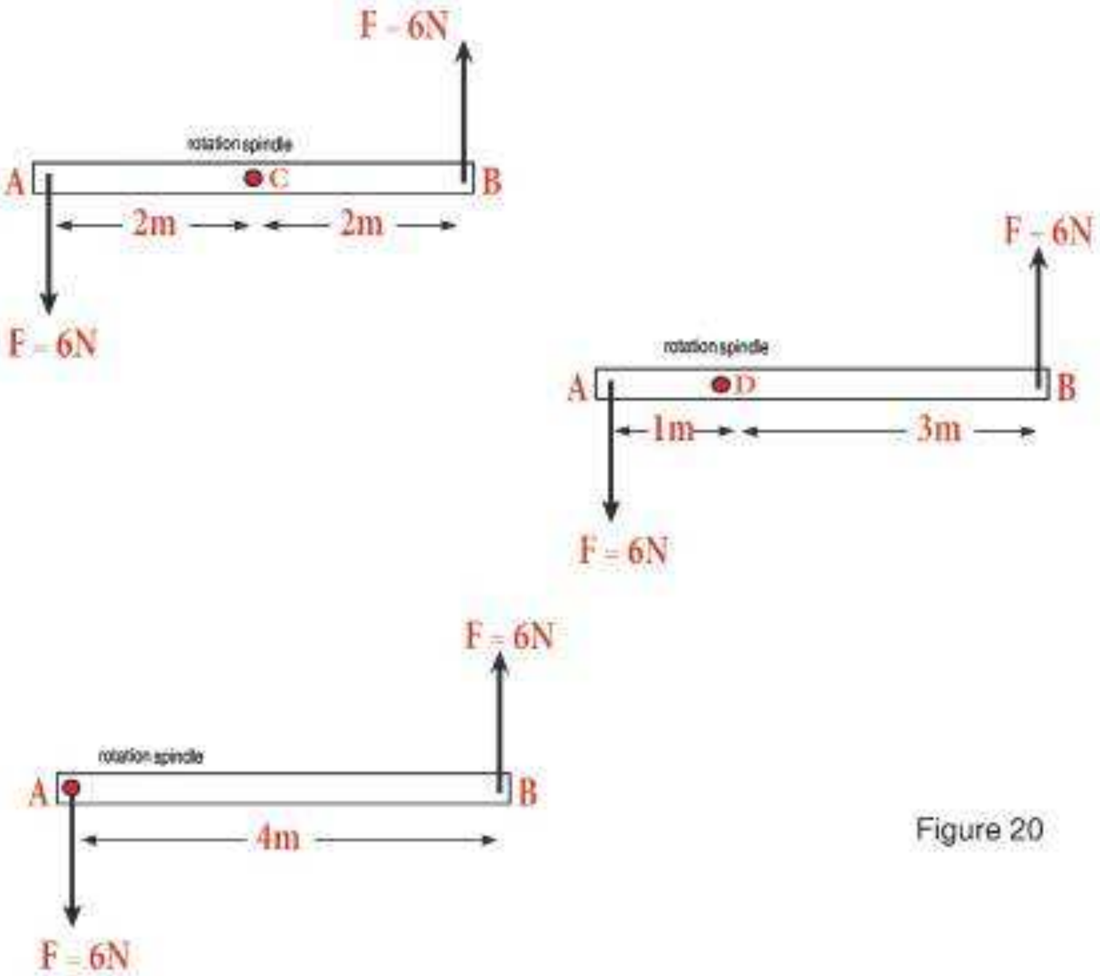


Figure 20

And we can calculate the couple torque of figure (20) as follows:

$$\vec{\tau}_{total} = \vec{\tau}_1 + \vec{\tau}_2$$

The couple torque = one of the forces multiplied by the perpendicular distance between them.

$$\tau_{total} = F(AC + CB) = F(AD + DB) = F \times AB$$

$$\tau_{total} = 6 \times (2 + 2) = 6 \times (1 + 3) = 6 \times 4$$

$$\tau_{total} = 24Nm$$

4.8 Center of mass

Every rigid body has dimensions is a system of particles, its motion described with respect to an important point called the body's center of mass and it is the point that is supposed to be the summation of the body's particles' masses (m) centered in, has a symbol (Cm).

Figure 21

Assume the system of particles contain couple of particles connected together by a light stalk (weightless) and the center of mass is located on the line that is connecting the two particles and it is nearer to the bigger mass, notice figure (21).

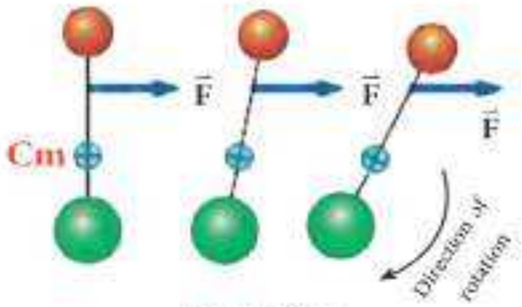


Figure 21a

If the force $\vec{F}$ influenced the stalk on a point nearer the smaller mass, then the system will rotate in clockwise direction by the influence of the torque of that force notice figure (21a).

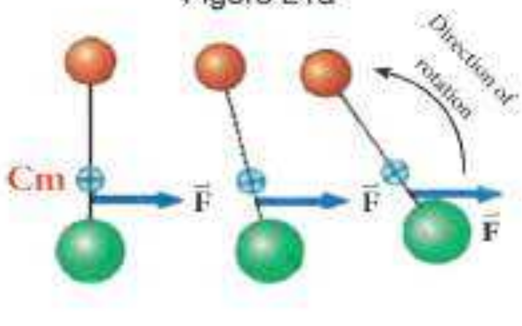


Figure 21b

If the influence of the same force $\vec{F}$ was on a point nearer to the bigger mass then the system will rotate in counter clockwise direction notice figure (21b).

However, if the force $\vec{F}$ influenced on the center of mass of the system, in this case the system will move with acceleration:

$$\vec{a} = \frac{\vec{F}}{m}$$

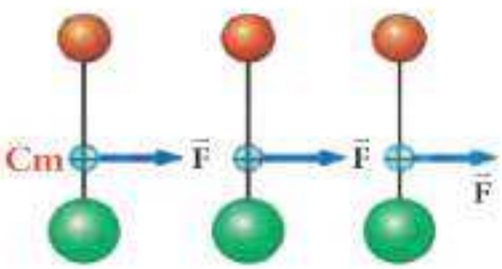


Figure 21c

As shown in figure (21c) and this is similar to the case when the net external force influence an object that its mass (m) is centered in that point and it is the center of mass.

It worth to mention that the center of homogeneous and symmetrical bodies' mass is located on the symmetrical axis and it is the geometric center of the body like (ball, cube or cylinder…) notice figure (22).

If the body was inhomogeneous and unsymmetrical then its center of mass is located on a point nearer to the part that has bigger mass.

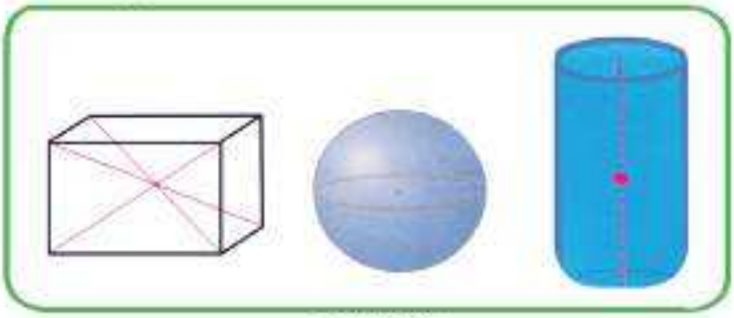


Figure 22

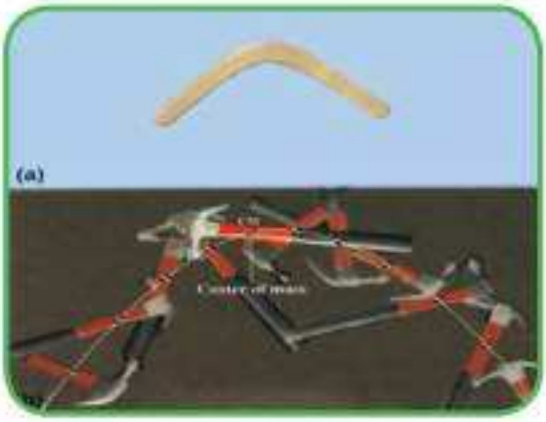


Figure 23

Do you know?

If you throw a hammer in the air, you will notice that the hammer is rotating in its path around a certain point which is its center of mass (Cm) and the path of that point has the shape of parabola and it is the path of the thrown object itself notice figure (23).

4.9 Center of gravity

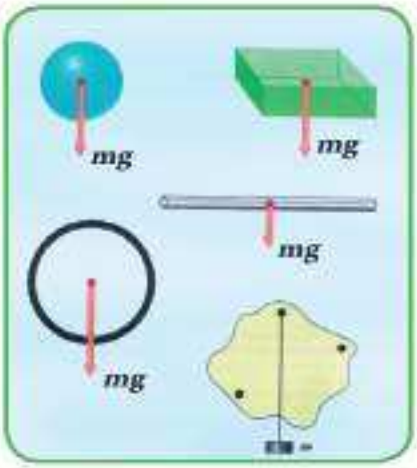


Figure 24

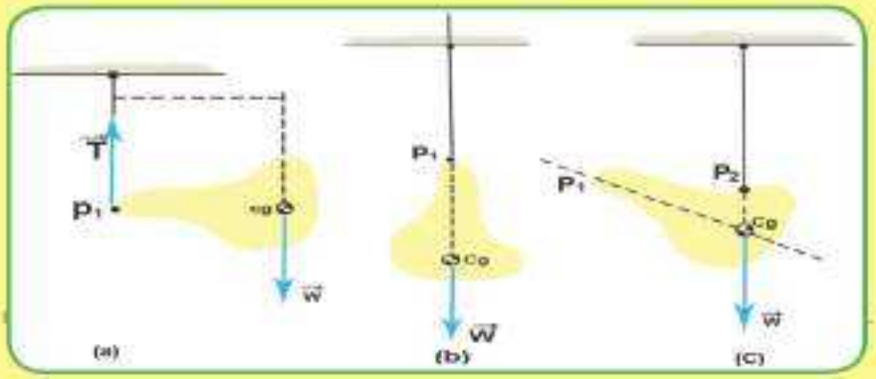
In the most paths of the equilibrium rigid objects, one of the forces influencing the object is the gravity force and it is the weight of the object which is represented by an arrow directed vertically downward (to the center of earth) and to calculate the torque of the gravity force we assume the total weight of particles that the object consists of is collected in one point called the center of gravity and has a symbol (C_G) notice figure (24).

The center of gravity is defined as it is the point that if an object was suspended from it in any position the object will not try to rotate because the net torques influencing the object around that point is equal ZERO and this point is the center of gravity.

The center of gravity of homogeneous and symmetrical bodies is located in its geometric center.

Remember

- The center of gravity is a point in the body which appears that the whole weight of the body is combined in it.
- The center of mass is a point in the body which if the action line of the force influencing the body (or its extension) passes through it, then that force will not cause rotation.



Questions of The Chapter 4

Q1/ choose the correct statement of the following statements:

1- The torque unit:

a- N.m
b- N/m
c- Kg.m
d- Kg/m

2- To have an equilibrium object and the two conditions be approved:

a- $\sum\vec{F}<0$, $\Sigma\vec{\tau}>0$
b- $\sum\vec{F}>1$, $\Sigma\vec{\tau}=0$
c- $\sum\vec{F}=0$, $\Sigma\vec{\tau}=0$
d- $\sum\vec{F}>0$, $\Sigma\vec{\tau}=0$

3- A person pushes a door with a force (10N) influences vertically on a point (80cm) far from the door joints, then the torque of this force in (N·m units) equals:

a- 0.08
b- 8
c- 80
d- 800

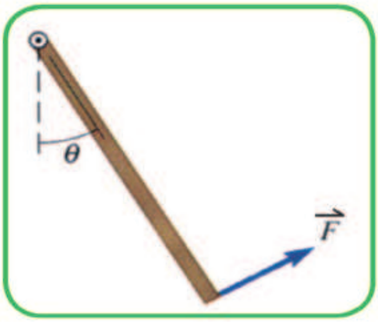
4- A homogenous stalk is settled over a pillar from its middle, if two forces of equal magnitudes and opposite directions influenced it, then the net force equals:

a- $2\vec{F}$ upward
b- $2\vec{F}$ downward
c- $\vec{F}/2$ downward
d- zero

5- In the previous question, as a result of the influence of these two forces then the stalk will:

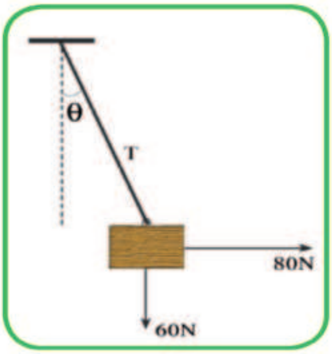
a- Rotate
b- Remains static
c- Moves transiently
d- Moves vibrantly

6- A homogenous lever has a mass (m) notice the figure, is suspended from the top at point (o) and this lever is moving freely like pendulum, if a force $\vec{F}$ influenced the lever vertically from its free side. Then the maximum force of magnitude F makes the lever equilibrium and has an angle with the vertical axis equals:



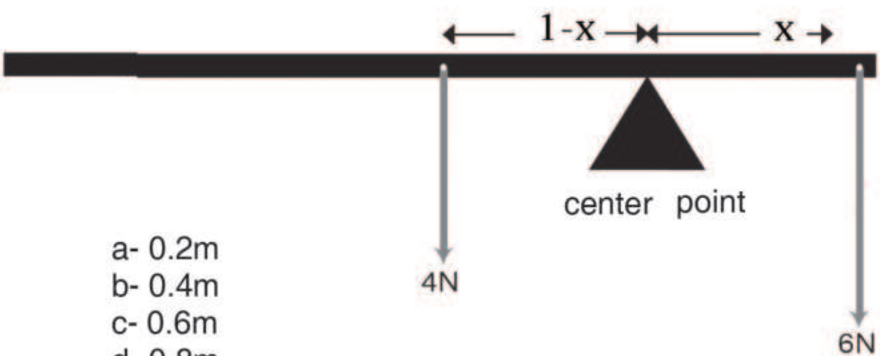
a- 2mg
b- 2mg sinθ
c- 2mg cosθ
d- (mg/2) sinθ

7- A box has a weight (60N) is hanging by a rope in a headrest notice the figure, if a horizontal force (80N) influenced it then the rope will make an angle with the vertical axis, the angle is:



a- 37°
b- 45°
c- 60°
d- 53°

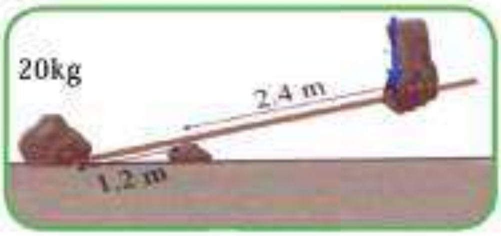
8- A homogenous lever has a weight (4N) and length (2m), an object of (6N) is suspended to one of the lever sides notice the figure, it is horizontally equilibrium at a point centered on it, which is away from the side that the body is suspended to a distance of:



a- 0.2m
b- 0.4m
c- 0.6m
d- 0.8m

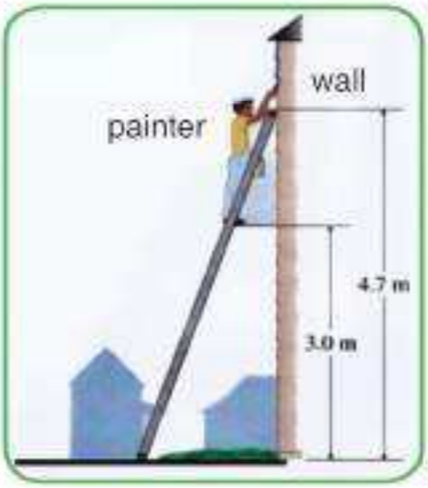
Problems of The Chapter 4

P 1/ what is the amount of force $\vec{F}$ the worker need to influence the lever by to be able to lift the weight that has a mass (20kg) shown in the figure.



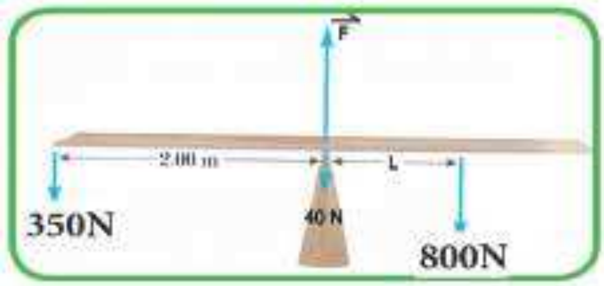
P 2/ A painter is standing on a regular plane that is horizontally equilibrium as shown in the figure below, the plane is suspended from its two sides by two ropes that have tensile forces $\vec{F}_R$ & $\vec{F}_L$ and the mass of the painter is (75kg) and the mass of the plane (20kg). If the distance between the left side of the plane and where the painter is standing is (d=2m) and the total length of the plane is (5m) find:

a- The magnitude of the force $\vec{F}_L$ influencing by the left rope.
b- The magnitude of the force $\vec{F}_R$ influencing by the right rope.



P 3/ A painter is standing on a regular ladder that has a length of (5m) on a height (3m) from the ground, the ladder upper side is based on a vertical wall at a point (4.7m) from the ground. Notice the figure, if the painter weight was (680N) and the ladder weight (120N) assuming there is no friction between the ladder and the wall find the friction force f_s between the ground and the lower side of the ladder.

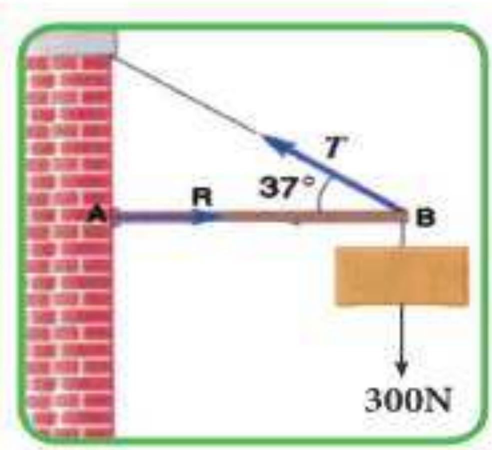
P4/ two kids are sitting on a homogenous plate fixed from the middle by a pillar as shown in the figure. If the plate's weight was (40N) and influenced from the middle, and the weight of the first kid (350N) and the weight of the second kid (800N), find the following:



a- The perpendicular force $F_{\perp}$ the pillar influences the plate by.

b- The distance L that is shown in the figure, to make the plate horizontally equilibrium.

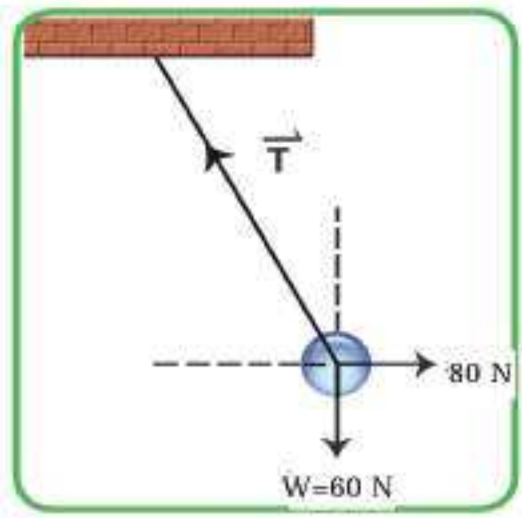
P5/ a horizontal weightless plate has a length of (6m) stands out of a building's wall and the free side of it is connected with the wall by a rope that makes an angle (37°) with the horizon, as shown in the figure a weight of (300N) is suspended from its free side. What is?



a- The tensile T in the rope

b- The reaction of the wall R on the plate

P6/ a horizontal force of (80N) influences an object that has a mass of (6kg) that is suspended by a rope, notice the figure, what is the magnitude and the direction of the tensile force (T) that the rope influences the object by to keep it in static equilibrium case? Assume (g = 10 N/kg)



5.1 The concept of work

All of us use the word work, but how many of us knows what is the exact meaning of it?

The word work in general meaning is said for every mental or muscular effort that the human do. However, in physical definition there must be a force influencing an object and this object travels a displacement in a parallel direction to that force or to one of its components, for example let us assume that the force $\vec{F}$ influenced a box and could move it (from a to b) a displacement of $\vec{x}$ as shown in figure (1) then it spent work on it.

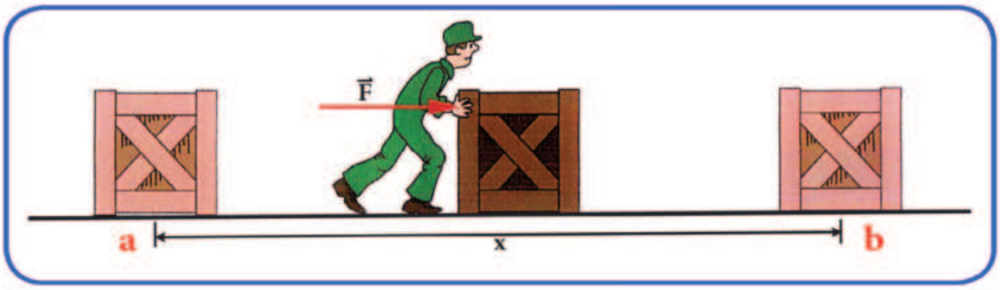


Figure 1

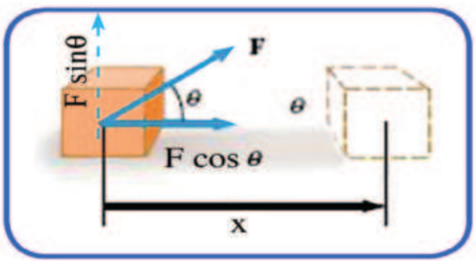


Figure 2

However, if the force influenced the box in a direction making angle θ with the displacement direction $\vec{x}$, we analyze the force vector into two components, as in the figure(2)the horizontal component($F\cos\theta$)and the vertical component($F\sin\theta$), if we were asked which of the components moved the object? Which of them done a work?

To answer this question notice figure (2) where we find that only the force component that is in the direction of the object's displacement did the work. So the work(w)definition becomes as the follow:

$$\text{Work done}(W) = \text{Force}(\vec{F}) \cdot \text{Displacement}(\vec{x})$$

$$W = (F\cos\theta) \cdot x$$

$$W = F.x\cos\theta$$

The work is known mathematically as, the dot product of the force and displacement vectors:

$\vec{F}$: The vector of the constant force that influencing the object.

$\vec{x}$: The displacement vector.

θ: The angle between the two vectors $\vec{F}$, $\vec{x}$.

The unit of the work depends on the units of the force and the displacement, in the international system of unit the force mesured in newton and the displacement in meter so the work unit is(Newton. meter) which is called Joule and the work is a scalar quantity it can be positive, negative or ZERO.

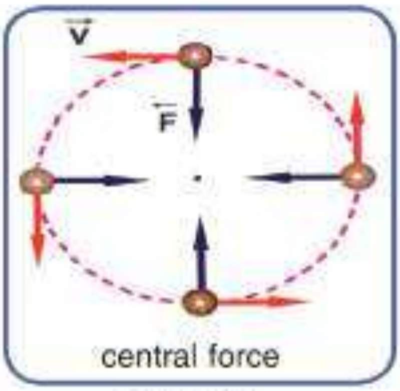


Figure 3

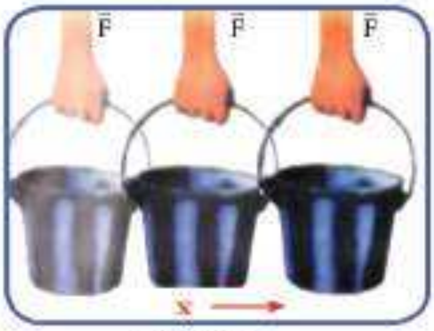


Figure 4

The sign of work depends on the angle θ between the force and displacement vectors and that is because the magnitudes of both $\vec{F}$,$\vec{x}$ are always positive.

One of the examples about the forces that do not do work (work = ZERO),

the central force because it is always **perpendicular** to the displacement, notice figure (3) and (4).

It means that $\vec{F}$ does not do work on the pail because $\vec{F}$ has no component with the displacement direction.

Figure 5

Figure 6

Think ?

1) A person is walking horizontally and carring a box in his hands. what is the amount of the work done by this person? Notice figure (5).

2) what is the amount of the work , does the student do to push a wall? Notice figure (6).

Example 1

Figure 7

A man pulls a vacuum cleaner with a force F=50N making angle 30° with horizon notice figure (7) calculate the work done by the force on the vacuum cleaner while moving it a displacement of 3m in the right direction.

$$\text{Work done (W)} = \text{Force (F)} \times \text{displacement (x)} \times \cos\theta$$

$$W = F\,x\cos\theta$$

$$W = [\,(50N)\,(3m)\,\cos(30^0)\,]$$

$$W = 130 \text{ Joule}$$

Question?

If the force influencing a certain object could not move it, what is the amount of the work done by the force in this case?

Example 2

Figure 8a

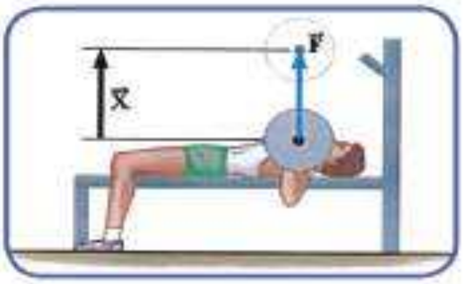


Figure 8b

The figure (8-a) is showing the weightlifter lifting weights of 710N. And in figure (8-b) it shows the weightlifter lifting weights for a displacement of 0.65m upward and in figure (8-c) it shows him lowers them for the same displacement.

If the procedure of lifting and lowering the weights was done with constant velocity find the work done on the weights by the weightlifter in case:

a- He lift the weights.

b- He lower the weights.

Solution:

a- In the case of lifting the weights figure (8-b), the work done by the force $\vec{F}$ can be given from the relation:

$$W = F\ x \cos\theta$$

$$W = (710N)(0.65)\cos 0^0$$

$$\cos 0^0 = 1$$

$$W = 460\ \text{Joule}$$

b- In the case of lowering the weights figure (8-c), the work done by the force $\vec{F}$ can be given from the relation:

$$W = F\ x \cos\theta$$

$$W = (710N)(0.65)\cos 180^0$$

$$\cos 180^0 = -1$$

$$W = -460\ J$$

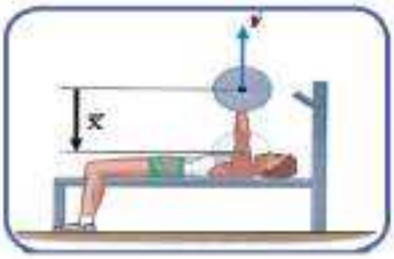


Figure 8c

From this we find that the work is negative in this case because the force vector is opposite to the displacement direction, while the work in the case of lifting the weights is positive because the force vector is in the same direction as the displacement.

5.2 Graphical representation of work

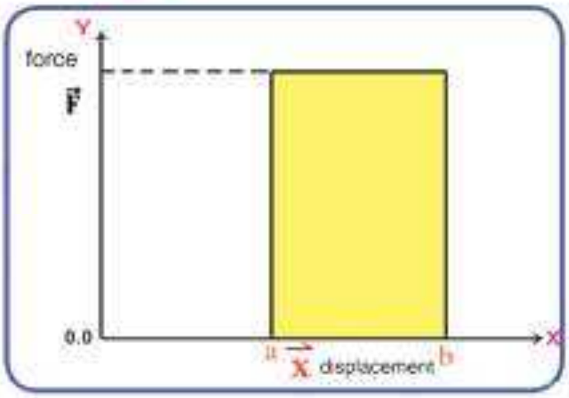


Figure 9

If an object was displaced horizontally by the influence of a constant force, then it is possible to represent the relation between the force and displacement graphically, as in figure (9) where the x-axis represents the horizontal displacement $(\vec{x})$ and the y-axis represents the force where the force $(\vec{F})$ remained constant and didn't change.

The shadowed area = the area of the rectangular that its length is (ab) and its width (OF) that is:
The area under the curve = work

$W = \vec{F} . \vec{x}$

In the previous, we studied the definition of work that a constant force do to an object, what if more than on force influenced the object?

In such a case we analyze each force to its components then we calculate the work of each component alone, then we calculate the total work that represents the work of the net force.

Example 3

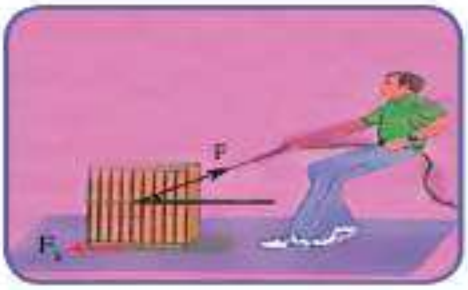


Figure 10a

A person is pulling a box on a horizontal Rough surface with constant velocity by the influence of tensile force $\vec{F}$ that makes angle 37° with the x-axis and move it a displacement of 5m notice figure (10-a). If the sliding friction force f_k between the box and the surface equals 20N. How much is the tensile force $\vec{F}$ and the work done by that force?

Solution:

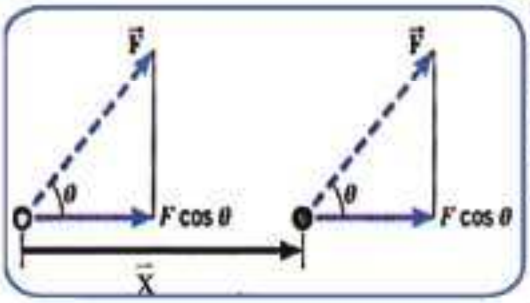


Figure 10b

From figure (10-a) we notice that the friction force f_k equals 20N and the horizontal component of the tensile force equals Fcos37°. And since the box is moving with constant velocity then the net horizontal force influencing it is ZERO ($\Sigma F_x = 0$) (according to Newton's first law) so the work done is ZERO, which means:

Total work = net force x displacement = ZERO, which also means:

Work done by tensile force (W_1) + work done by sliding friction force (W_2) = ZERO

$$W_1 = -W_2$$

the horizontal tensile force ($F\cos\theta$) equal and oppsite sliding friction force f_k

$$F\cos\theta = f_k = 20N$$

$$F\cos 37° = 20N$$

$$F \times 0.8 = 20N$$

$$F = (20 / 0.8) = 25N$$

the work done by the tensile force (F) is W_1

$$W_1 = F\cos 37° \times 5 = 100\ J$$

5.3 Power

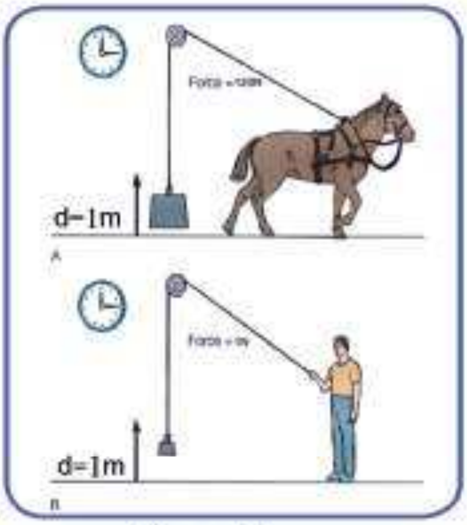


Figure 11

The figure (11) shows a man and a horse lifting two different weights for a displacement of 1m by the same time. Consider the figure (11) and answer the following questions:

1- What is the work done by each of them individually?
2- Did the man and the horse do the same work?
3- Find the division of the work to the time for both of them, what do you notice.

The result of the division of the work done to the time represents the power of each of them, where the power is known as the rate at which work is done

$$\text{Power}_{(\text{Watt})} = \text{Work}_{(\text{Joule})} / \text{Time}_{(s)}$$
$$P = W / t$$

From the equation we notice that the power has a unit of joule/second which is known as Watt.

And one of the common units of power is the horse power

1 horse power (hp) = 746 watt

And there is another relation for power is called the instantaneous power which is the average power when the time duration goes to zero. So if the force that is doing the work is constant (does not change with time), then the instantaneous power P_{inst} can be given from the relation:

$$\text{Instantaneous Power (Pi)} = \frac{\text{work done (w)}}{\text{Time (t)}} = \frac{\vec{F} \cdot \vec{x}}{t}$$

Since $\vec{\upsilon}$=x/t and it is the instantaneous velocity, we get:

$$P_{inst.} = \vec{F} \cdot \vec{\upsilon}_{inst.}$$
$$P_{inst.} = F\upsilon\cos\theta$$

And θ is the angle between the instantaneous velocity vector $\vec{\upsilon}_i$ and the force vector $\vec{F}$.

Example 4

An electrical elevator is loaded with several people, is ascending upward with constant velocity 0.7 m/s if the power that the iron wire that holds the elevator is 20300 watt. Calculate the tensile force in the wire. Notice the figure (12).

Figure 12

Solution:

The influence of the wire on the elevator is by the tensile force directed upward during its ascending, according to that the force and the velocity are in the same direction which means: the angle between them is zero (θ=0) and using the instantaneous power law we get:

$$P_i = F \cdot \upsilon_i \cos\theta$$

$$20300 = (F) \times (0.7) \times (\cos 0^{\circ})$$

Tensile force $F = 20300 / 0.7 = 29000\ N$

5.4 Energy

The body that has the ability to do work has energy. And the energy is measured by the same unit as the work (Joule). There are different kinds of energy and can be converted to each other, such as:

1- Mechanical energy

a - Kinetic energy

b - Potential energy in its two kinds: Gravitational Potential energy and elastic Potential energy

2- Thermal energy

3- Chemical energy

4- Magnetic energy

5- Nuclear energy

6- Electrical energy

7- Optical energy

8- Sound energy

a- Kinetic energy

The moving bodies has the ability to do work, which means it has energy, and the energy that a moving body has called kinetic energy, the examples of it are so much, such as: a ball falling toward the floor, a moving car, the winds, and a person running … etc. But the bodies wary in their kinetic energy.

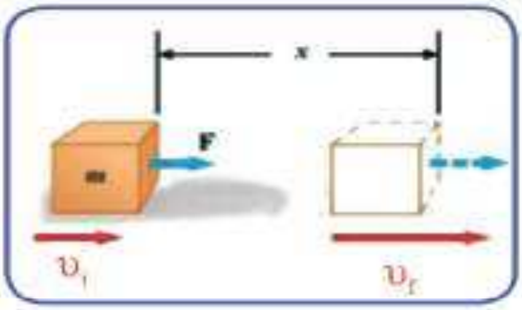


Figure 13

What is meant by work and energy? And what is the relation between them? To answer this, we will find an important relation that connect the work with energy as follows:

If a body of mass (m) walking in a straight horizontal line, was influenced by a net external force $\vec{F}$ so its velocity changed from $\vec{\upsilon}_i$ to the velocity $\vec{\upsilon}_f$ and moved the displacement $\vec{x}$ notice figure (13).

Then the work done on the body is;

$$W = \vec{F} . \vec{x}$$

Acording to newton's second law

$$\vec{F} = m . \vec{a} \qquad W = (ma) x$$

From motion equation with constant acceleration:

$$\upsilon_f^2 = \upsilon_i^2 + 2ax \Rightarrow x = (\upsilon_f^2 - \upsilon_i^2) / 2a$$

$$W = ma (\upsilon_f^2 - \upsilon_i^2) / 2a \qquad W = \vec{F} . \vec{x}$$

$$W = \frac{1}{2} m\upsilon_f^2 - \frac{1}{2} m\upsilon_i^2$$

$$W = \frac{1}{2} m\upsilon_f^2 - \frac{1}{2} m\upsilon_i^2$$

$$\boxed{W = KE_f - KE_i = \Delta KE}$$

And that means, the work which a net external force influencing a body do equals the change of kinetic energy (Δ K E) , with noticing that the net force is positive if it was in the direction of motion and negative if it was opposite to the direction of motion.

So we can say that the body of mass (m) and moves with velocity (υ) has a kinetic energy (KE) that can be given from the relation:

$$\text{Kinetic Energy (KE)} = (1/2)\,\text{mass (m)}\,(\text{velocity } (\upsilon))^2$$

$$KE = (1/2)\, m\upsilon^2$$

And the unit of the kinetic energy (KE) is the same as work (Joule).

Example 5

A car of mass (2000kg) is moving on a horizontal land. The driver pressed the breaks when the car was moving with velocity 20 m/s so is stopped after it cut a distance (100m), as in figure (14). Find the following:

1- The change in kinetic energy.
2- The work done by the friction force to stop the car.
3- The magnitude of the friction force between the wheels and the road assuming it remained constant.

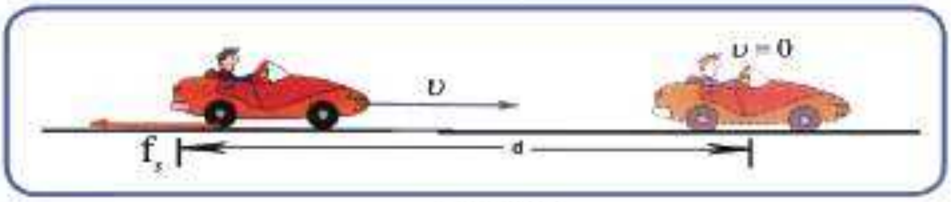


Figure 14

Solution

1- The change in kinetic energy (ΔKE) = the final kinetic energy (KE_f) – the initial kinetic energy (KE_i)

$$\Delta KE = (KE)_f - (KE)_i$$

$$\Delta KE = 1/2\, m\upsilon_f^2 - 1/2\, m\upsilon_i^2$$

$$= (1/2)\, 2000 \times (0)^2 - (1/2)\, 2000\, (20)^2$$

$$= 0 - 1000 \times 400$$

$$\Delta KE = -400\,000\ J$$ Amount of change of kinetic energy

2- work done by the friction force (W) = change of kinetic energy (ΔKE)

$$W = -400\,000\ J$$

3- work done by the friction force ($f_s x \cos\theta$) = change of kinetic energy (ΔKE)

$$\Delta KE = f_s x \cos\theta$$

$$\theta = 180^\circ,\ \cos(180)^\circ = -1$$

$$KE = f_s x \cos 180$$

$$400000 = f_s \times 100 \times (-1)$$

$$f_s = -400000 / -100$$

$$= 4000\ N$$ friction force

b- Potential Energy

In our previous study we noticed some of the objects that can done working as a result of movement, but there are other objects that can do a work because of the amount of stored energy in the object, What is the potential energy (stored)? Potential energy is the amount of stored energy in the object do work at any time that can accomplish a task when I want it to. It is divided as follows:

Potential Energy

- Elastic Potential Energy
- Gravitational Potential Energy

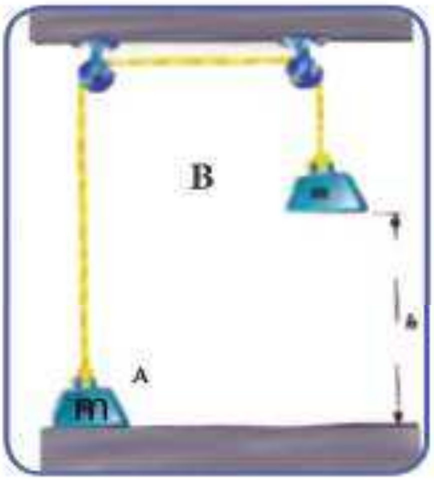


Figure 15

Gravitational Potential energy:

It is the energy gained by the object due to the forces of gravity for example, the system shown in Figure (15) it is represented by two frictionless and weightless rollers that are carrying two objects of equal mass, and suppose that the weight of each is mg, If Body B was pusheda small push down, it would start slowly falling toward the ground at a constant speed and Body A will begin to rise to the top at the same time as body B goes down, so for example if B fall distance h downward then A will rise the same distance h from the ground. How much work done by the rope on A while lifting it from the ground with constant velocity? Since the tensile in the rope equal the weight of A (mg) then the work done by the rope according to work definition:

$$W=mg.h$$

Since body B is pulling body A upward then it is doing work (mg.h), where h is the distance that B fall from, so object A acquires amount of energy equal to the work done on it, That is body A in its new position stores energy.

Because the body gains this energy when it rises up against gravity, the energy stored is called (gravitational potential energy) And it equals the work that has been done on the body against gravity. That is, the gravitational potential energy (GPE) is given by the following:

Gravetational Potential Energy (GPE) =

mass (m) × gravity acceleration (g) × vertical hight (h)

$$GPE = m \times g \times h$$

The unit for (GPE) is joules and it calculated by multiplying the weight of object with vertical hight.

Do you know ?

The water of the waterfalls has the potential energy because of its high position, so when it is falling to its original level it can do work because of weight, so the turbines rotate and generators operate.

Figure 16

Example 6

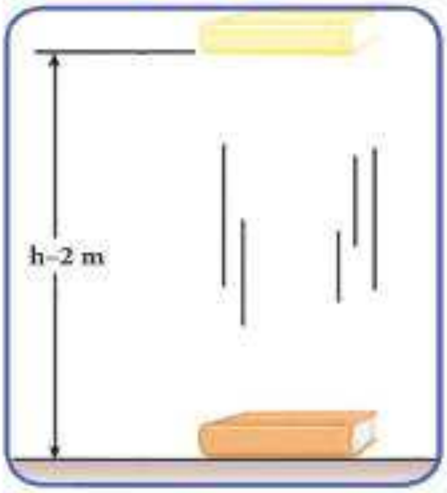


Figure 17

Calculate the change in the gravitational potential energy in the field of gravity of a book that has mass of 3kg, at the Earth's surface and at a height of 2m above the Earth's surface.
Assume that $g = 10\ m/s^2$

Solution:

First, we choose the reference position , which is the Gravitational potential energy equal to zero let it be the earth's surface at(h=0)then we calculate the potential energy in the two referred sites.

Potential energy at ground level (standard level) (GPE_1) is given as:

$$GPE_1 = mgh$$
$$GPE_1 = 3 \times 10 \times 0$$
$$GPE_1 = 0$$

While the potential energy (GPE_2) at 2m height from the standard level is given by:

$$GPE_2 = mgh$$
$$GPE_2 = 3 \times 10 \times 2$$
$$GPE_2 = 60J$$

Then we calculate the change in the potential energy of the body from the horizontal level as follows:

$$\Delta GPE = GPE_2 - GPE_1$$
$$= 60 - 0$$
$$= 60J$$

Question ?

Repeat the previous example solution on the assumption that the reference level at a height of 2m and prove that the question of change in potential energy is equal to the gravitational value itself 60J and thus verify that the change in potential energy does not depend on the choice of the reference level.

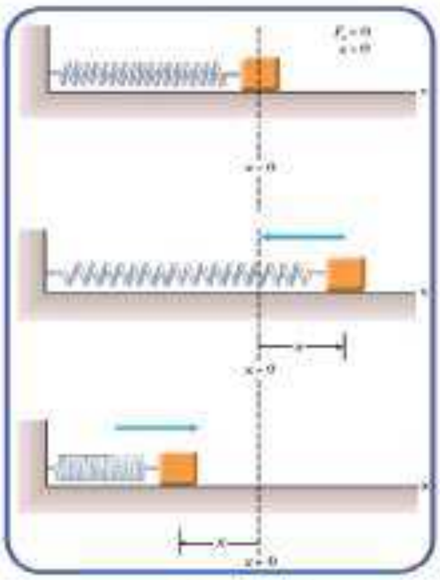


Figure 18

Elastic potential energy

An important example of a work done by variable forces is the work done by the spring force. The figure(18) shows a massless string placed on a glaze horizontal surface (frictionless), and it is fixed from one side by a vertical wall and the other side by a mass (m). When a force influence it, it will be expressed as a displacement (x) in the form of elongation or compression, a force arises from the spring equals the external force and reverses it in direction.

And the Elastic potential energy (EPE) in this case is known as the following:

Elastic potential Energy (EPE) = 1/2 [spring constant (K)] × (change in spring's length)(x^2)
$$EPE = \frac{1}{2}Kx^2$$

That is:

K the string constant and has unit N/m.
X The amount of change in the length of the spring.
The Elastic potential energy unit is Joule.

Example 7:

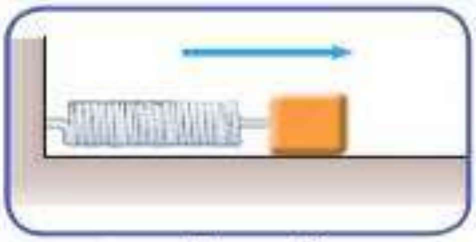


Figure 19

A metallic spring of constant force 200N/m, it is fixed from one side by a vertical wall and the other side by a mass (2kg) placed on a glaze horizontal surface. Notice figure (19) the spring was pushed a displacement of 0.2m, what is the maximum speed that the object can reach when the force is removed?

Solution:

Elastic Potential Energy (EPE) = Kinetic Energy (KE)

$$\Delta EPE = \Delta KE$$

$$\frac{1}{2} Kx^2 = \frac{1}{2} m\upsilon^2$$

$$\frac{1}{2}(200)(0.2)^2 = \frac{1}{2} \times 2 \times \upsilon^2$$

$$\upsilon^2 = 4$$

$$\upsilon = 2m/s$$

5.5 Conservation of mechanical energy

We've found that the objects may possess potential energy or kinetic energy, and you may wonder: Can the body has potential energy and kinetic energy at the same time? Can the potential energy be converted into kinetic energy, or vice versa?
In order to reach the answer, Figure (20) shows the energy that an object has at different points during its descent (by neglecting air resistance and friction) and then answer the following questions:

KE	PE	E=KE+PE
0 J	600 000 J	600 000 J
200 000 J	400 000 J	600 000 J
400 000 J	200 000 J	600 000 J
600 000 J	0 J	600 000 J

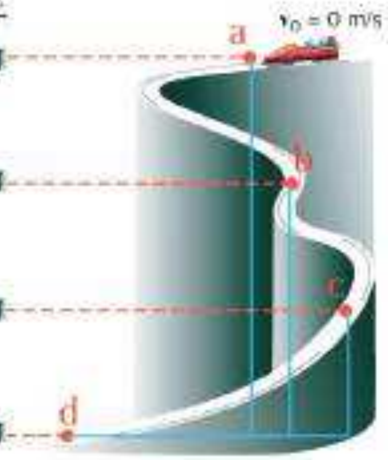


Figure 20

1- At what point will the potential energy be the maximum value? And why?
2- At what point will the kinetic energy be the maximum value? And why?
3- How describes the change in potential energy and kinetic energy during the movement of the body?
4- Find the sum of the potential energy and kinetic energy at each point?
What do you notice? What does the answer represent?

The case shown inFig.20 is an example of conservation of mechanical energy E_{mech} that is the energy can be converted from one form to another, but in any process of energy conversion, what turns from one form of energy is equal to what is produced by other forms, So that the total amount of energy remains constant, that is:

Mechanical Energy (E_{mech}) = Potential Energy (PE) + Kinetic Energy (KE)
$E_{mech} = PE + KE$

The sum of the potential energy and kinetic energy of a conservative system in position is called mechanical energy E_{mech} that means:

Mechanical energy in initial position = Mechanical energy in final position

(KE_i+PE_i) (KE_f+PE_f)

The above equation is called (conservation law of mechanical energy).

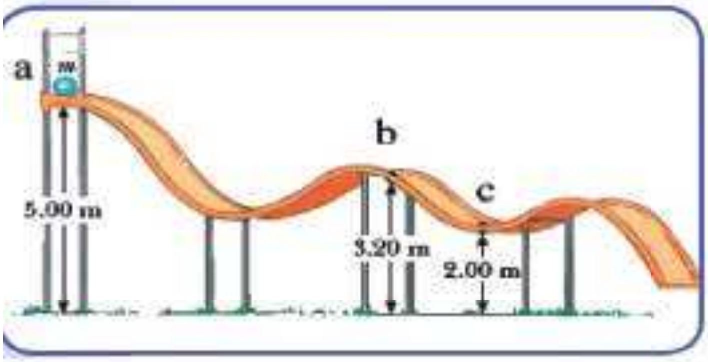


Figure 21

Example 8

A 5kg ball slid from rest from point (a) across a frictionless path as in Figure (21) Calculate the velocity of the ball at the points b, c and note that the gravity acceleration is 10 m/s^2 .

Solution:

Firstly we select reference position where we assume the potential energy in the gravitational field is equal to zero, Let it be the earth's surface. To calculate the velocity of the ball at point b, we apply the mechanical energy conservation law between locations a, b.

Mechanical energy in initial position=Mechanical energy in final position

$$KE_f + PE_f = KE_i + PE_i$$

$$(1/2)\,m\upsilon_b^2 + (m\,g\,h)_b = (1/2)\,m\upsilon_a^2 + (m\,g\,h)_a$$

$$(1/2)\times 5\times \upsilon_b^2 + 5\times 10\times 3.2 = 0 + 5\times 10\times 5$$

$$2.5\upsilon_b^2+160=250 \Rightarrow \upsilon_b^2=36 \quad \Rightarrow \upsilon_b=6\ m/s$$

Ball velocity at the position (b) equal to 6 m/s, while the velocity at the position (point) C will be calculated by the conservation law of energy between two position c,b.

$$KE_c + PE_c = KE_b + PE_b$$

$$(1/2)\,m\upsilon_c^2 + (m\,g\,h)_c = (1/2)\,m\upsilon_b^2 + (m\,g\,h)_b$$

$$(1/2)\times 5\times \upsilon_c^2 + 5\times 10\times 2 = (1/2)\times 5\times (6)^2 + 5\times 10\times 3.2$$

$\upsilon_c = 7.746\ m/s$ Ball velocity at the position (c)

Question ?

Figure (22) shows a ball placed at the top of an inclined surface (by neglecting air resistance and friction) fill the blanks in the shape in the following cases:

1- The free fall of the ball.

2- The movement of the ball on the inclined plane.

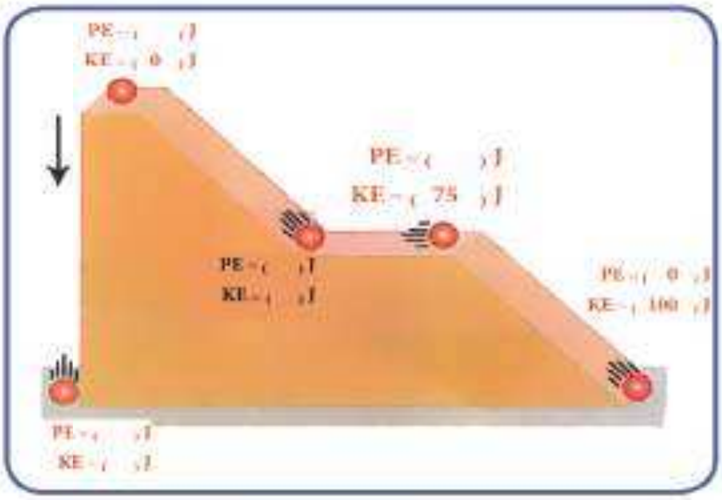


Figure 22

5.6 Work done by non-conservative forces

The presence of non-conservative forces in a gravitational system causes a change in the mechanical energy of the system.

On this basis, the work of non-conservative forces equals the change in the mechanical energy of the system as follows:

Work done by Nonconservative forces $(W)_{nc}$	=	Change in the mechanical energy of the system $(E_f - E_i)$
	$W_{nc} = E_f - E_i$	

Where W_{nc} is the work of non-conservative forces, if the work of non-conservative forces is negative, as in friction and air resistance forces, this causes a decrease in the mechanical energy of the system.

However, if the non-conservative forces do a positive work, as in the case of engines and machines, an increase in the mechanical energy of the system is achieved.

Question ?

A ball of 5kg mass slide from rest at point a on the curved path as shown in figure (23) if it is known that the path is frictionless from part (a) to (b) and coarse from (b) to (c) find the following:

1- The velocity of the ball at the point (b).

2- The friction force exposed to the ball in the part from (b) to (c), if you know that it stopped at point (c) after cutting 10m from the point (b).

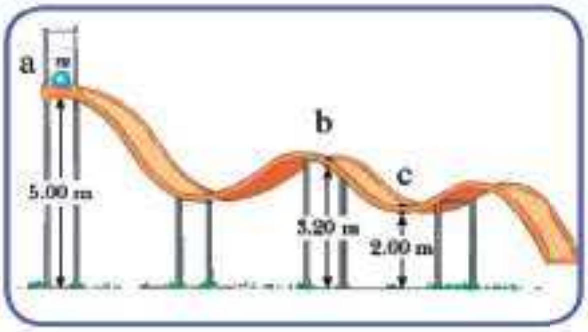


Figure 23

5.7 Conservation law of Energy

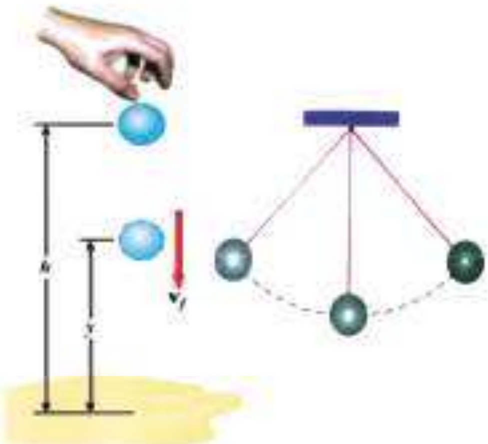


Figure 24

During your study - dear student - you learned that energy has various forms For example, when an object falls towards the ground (a stone for example), the moment it fell to the ground it has kinetic energy notice figure (24) But it is noticeable that the body become static after colliding with ground, in other word, its kinetic energy becomes zero, as well as its potential energy (In case of selection the reference position is ground) Where did the energy go? Also if you hanged a simple pendulum and watched its movement for long enough to note that the height gradually will decrease and eventually it will stop, then where the energy went? On this basis, the transformation of any form of energy is equal to that produced by other forms, in the sense that energy is always reserved. This process is based on one of the most important laws in nature: the

Energy Conservation law, which states:

Energy connot be created or destroyed, but only changed from one form into another meanes that the total energy of the universe remains constant.

5.8 Linear momentum and impulse

The quantity resultant from multiplying the object mass by its velocity is called the linear momentum and it is represented by the following relation:

Linear Momentum (P) = Mass (m) × Velocity ($\vec{\upsilon}$)
$\vec{P} = m\vec{\upsilon}$

Momentum:

Is a vector quantity that is always in the direction of the object's velocity, and Newton **scientist** called it (quantity of motion).

The momentum quantity depends on the mass of the object and its velocity, so if there are two equal masses cars and the velocity of one of them is the double of the other, then it is easy to stop the car of low velocity because of its small momentum but it is so hard to stop the car of the higher velocity because of its high momentum, it worth to mention that the momentum of an object doubles if its mass doubled. The unit of momentum is kg.m/sec

Imagine a moving object of mass m, is influenced by a force F for a period of time so its velocity changed from $\vec{\upsilon}_i$ to $\vec{\upsilon}_f$ as shown in figure (25):

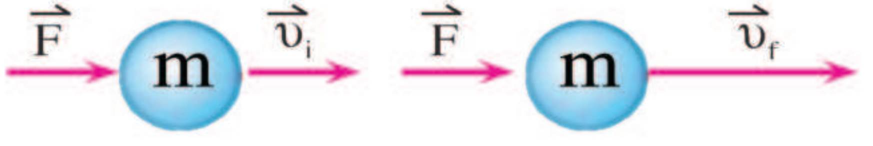


Figure 25

$$\vec{a} = (\vec{\upsilon}_f - \vec{\upsilon}_i)/t$$
$$\vec{F} = m\vec{a}$$
$$\vec{F} = m(\vec{\upsilon}_f - \vec{\upsilon}_i)/t$$
$$\vec{F}t = m\vec{\upsilon}_f - m\vec{\upsilon}_i$$

($\vec{F}$×t) Represents a physical quantity called impulse. And the impulse considered a measure for the force influencing an object multiplied by the time duration that the force influences the object .

It worth to mention that the force $\vec{F}$ is the net forces influencing the object or a system containing several particles, from that we notice that if a force influenced an object for a certain time duration, it leads to change in its momentum.

Example 9

A car of mass (1200kg) calculate:

a- The momentum when it moves with a velocity 20m/s north.

b- The momentum if it stopped moving then it moved with a velocity 40m/s south.

c- The change in the car's momentum in the two previous cases.

Solution

$$\text{Linear Momentum } (\vec{P}) = \text{Mass } (m) \times \text{Velocity } (\upsilon)$$

$$\vec{P} = m\vec{\upsilon}$$

$$a)\ P_i = m\,\upsilon_i = 1200 \times 20 = 24 \times 10^3\ kg.m/s$$

$$b)\ P_f = m\,\upsilon_f = 1200 \times 40 = 48 \times 10^3\ kg.m/s$$

c) change in Momentum P = Final Momentum p_f – intial Momentum P_i

$$\Delta\vec{P} = \vec{P}_f - \vec{P}_i$$

$$\Delta P = 48 \times 10^3 - 24 \times 10^3$$

$$\Delta P = 24 \times 10^3\ kg.m/s$$

Figure 25

Example 10

A car of mass 1200 kg moving with velocity 20m/s collided with a tree and stopped after it crossed a distance of 1.5 m during 0.15s. Find the average force for the tree to stop the car.

Solution

$$\text{impulse } (\vec{F}t) = \text{change in momentum } (\vec{P})$$

$$\vec{F}.t = m\,(\vec{\upsilon}_f - \vec{\upsilon}_i)$$

$\upsilon_i = 20\ m/s$ $\qquad\qquad$ $\upsilon_f = 0\ m/s$

$$F \times 0.15 = 1200\,(0 - 20)$$

$$F = -24000 / 0.15$$

$$F = -16 \times 10^4 N$$

The force $\vec{F}$ is the average force for the tree to stop the car. And the minus sign means that the force is influencing opposite to the motion direction.

Do you know ?

The designers of cars try to reduce the impact of accidents on the passengers and that is by making the time duration for the force to influence the objects exist in the car longer.

The airbag notice figure (26) works to reduce the influence of the force on the bodies during the collision then increasing the time duration needed to prevents the driver and the passengers' bodies' from moving.

Figure 26

5.9 Conservation of Linear Momentum

We knew that the change in a system's momentum equals the impulse that it receives by the net external force multiplied by the time of influencing. So if the net external force equals ZERO, meaning that the system is mechanically isolated we can write the equation of the linear momentum and impulse as follows:

$$\text{impulse } \sum \vec{F}t = \text{change in momentum}(\vec{P})$$

$$\underset{\text{momentum after collide}}{(m'\vec{\upsilon}_f)} \quad \underset{\text{momentum before collide}}{= (m\,\vec{\upsilon}_i)}$$

$$\sum \vec{F}t = m'\vec{\upsilon}_f - m\vec{\upsilon}_i$$

$$\sum \vec{F} = 0$$

$$0 = m'\vec{\upsilon}_f - m\vec{\upsilon}_i$$

$$m'\vec{\upsilon}_f = m\vec{\upsilon}_i$$

m' = mass after collide

m = mass before collide

The above equation is called (conservation of linear Momentum) which states:
If the net force influencing a system equals zero then the total linear momentum of the system remains conserved.

Example 11

A truck of mass $3x10^4$ kg was moving with velocity 10m/s collided with a car of 1200kg moving in the opposite direction with velocity 25m/s. if the cars were stuck together after the collision in which velocity the group will move?

Solution

Assume that the velocity of the group after the collision is $\vec{\upsilon}_{total}$

And the mass of the group is m_1+m_2

total momentum before collusion=total momentum after collusion

track mass (m_1) × track velocity(υ_1) + car mass(m_2) × car velocity(υ_2) = group mass($m_1 + m_2$) × group velocity (υ_{total})

$$m_1 \times \upsilon_1 + m_2 \times \upsilon_2 = (m_1 + m_2) \times \upsilon_{total}$$

$$(3 \times 10^4)\ (10) + (1200)\ (-25) = (30000 + 1200) \times \upsilon_{total}$$

The velocity of the car is negative because it is in the opposite direction of the track.

υ_{total} = (300000 - 30000) / 31200 = 270000 / 31200 = 8.65 m/s

The amount of group velocity after the collision immediately.

Types of Collisions:

There are three types of collisions:

a- Perfectly Elastic Collision:

It is a system that is characterized by that the kinetic energy before the collision is equal to kinetic energy after the collision, that is:

kinetic energy before the collision=kinetic energy after the collision

This type of collision is not accompanied by loss of kinetic energy of the system.

b- Perfectly Inelastic Collision

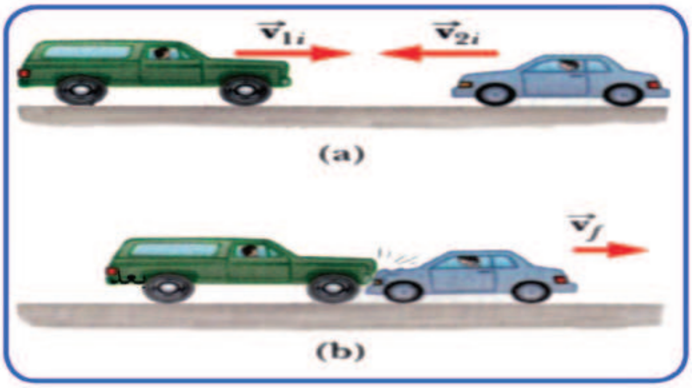


Figure 29

This type of collisions is characterized by the fact that the kinetic energy of the system is not **conserved** as it is accompanied by a significant lack of kinetic energy, it is distinguished that the two opposing objects always fuse after the collision, notice Figure (29).

Figure 30

c- Inelastic Collision

In this type the objects do not combine together, but are kept separate and accompanied by a lack of kinetic energy such as colliding the bowling balls notice figure (30).

Remember:

- The linear momentum of the system is **conserved** no matter what type of collision.
- Collisions are classified according to the change in kinetic energy of the system.

Example 12

If the mass of a train carriage 2.5×10^4 kg is moving with velocity 8m/s as in Figure (31) it hit carriage **at rest** with a mass of 1.5×10^4 kg, and moving together in the same direction with velocity 5m/s. Calculate the change in kinetic energy of the system.

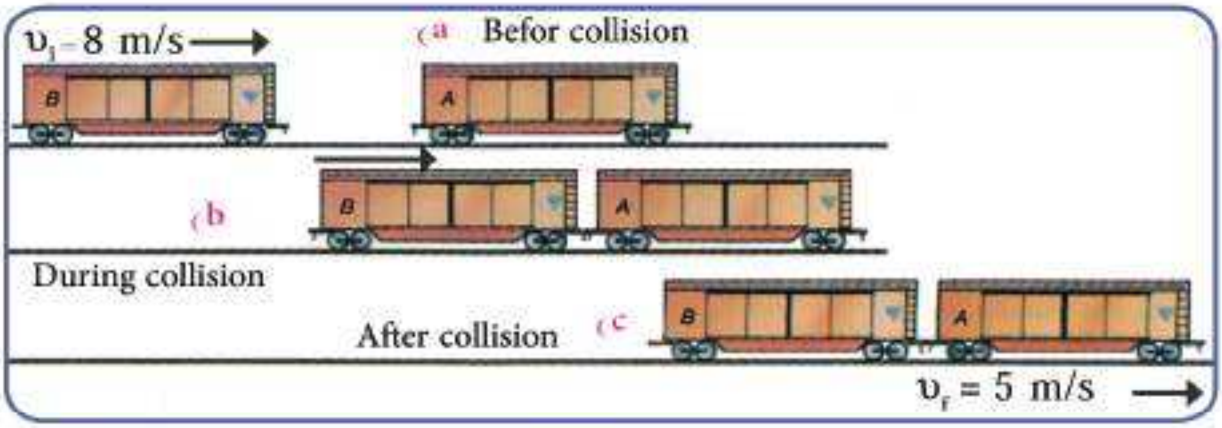


Figure 31

Solution

kinetic energy after collision = KE_f
kinetic energy before collision = KE_i

change in kinetic energy= kinetic energy before collision- kinetic energy before collision

(KE_i) (KE_f) (ΔKE)

$$KE_i = 1/2\, m_1 \upsilon_i^2 + 1/2\, m_2 \times \upsilon_i^2$$

$$KE_i = 1/2 \times 2.5 \times 10^4 \times 8^2 + 0$$

$$KE_i = 80 \times 10^4\ J$$ kinetic energy before collision

$$KE_f = 1/2\,(m_1 + m_2)\,\upsilon^2_{total}$$

υ_{total} = final velosity for combined train.

$$KE_f = 1/2\,(2.5 \times 10^4 + 1.5 \times 10^4)(5)^2$$

$$KE_f = 1/2\,(4 \times 10^4) \times 5^2$$

$$KE_f = 50 \times 10^4\ J$$ kinetic energy after collision

$$\Delta KE = KE_f - KE_i$$

$$= 50 \times 10^4 - 80 \times 10^4$$

$$\Delta KE = -30 \times 10^4\ J$$

conclude that the collision here is inelastic collision.

Questions of Chapter 5

Q1/ choose the correct statement from the following statements:

$$g = 10\ m/s^2$$

1- A boy has a mass of 40kg ascends a stair of a vertical height 5m during 10s then its power is:

a- 20W
b- 200W
c- 0.8W
d- $2x10^4$W

2- According to conservation law of energy :

a- Can be created but not destroyed
b- Can be destroyed but not created
c- Can be created and destroyed
d- Cannot be created or destroyed

3- An object spent a power (1hp) at the instantaneous speed 3 m/s then the maximum force is:

a- 248.7N
b- 2238N
c- 2613N
d- 3600N

4- One of the following units is not for power:

a- Joule-second
b- Watt
c- N.m/s
d- hp

5- To save a vehicle moving with speed υ it needs a force F against friction then the power needed :

a- $F.\upsilon$
b- $\frac{1}{2} F\upsilon^2$
c- F/υ
d- F/υ^2

6- An object of mass 1kg has gravitational potential energy 1J with respect to the ground when it vertical height is :

a- 0.012m
b- 0.1m
c- 9.8m
d- 32m

7- An object of weight 10N falls from rest from the height 2m above the ground surface then its velocity at the moment it collide with the ground is:

a- 400 m/s
b- 20 m/s
c- 10 m/s
d- $\sqrt{40}$ m/s

8- The one that does not change when two or more objects collide is:

a- Linear momentum of each.
b- Kinetic energy of each.
c- Total linear momentum.
d- Total kinetic energy.

9- When two objects collide with equal masses, the change in total momentum

a- Depends on the speed of the two opposing bodies.
b- Depends on the angle in which the two bodies collide.
c- Equals ZERO.
d- Depends on the impulse given to each object.

Problems of the Chapter 5

P1/ The body of mass a 2kg fell from a height of 10m on a sandy ground and settled in. After cutting 3cm vertically into the sand, what is the average force that sand affects the body? On the assumption of neglecting the air effect.

P2/ A car of mass 1250 kg slid till it become static after a distance of 36 m. How much friction between its four sliding tires and the surface of the road if the sliding friction factor 0.7? What is the amount of work done by the friction force on the car?

P3/ Push a shipping box of mass 80kg a distance 3.5 m to the top of a sloping surface (Friction is assumed to be neglected) making an angle 37^0 with respect to the horizon. How much work is done to push the shipping box? Assume that the shipping box is pushed at a constant velocity.

P4/ How much power do you need to push a shopping cart loaded with horizontal force of 50N a horizontal distance of 20m through 5s?

P5/ A friction force of 20N affects a 6kg mass box sliding on a horizontal floor. How much power is required to pull the box on the floor at a constant velocity of 0.6 m/s?

P6/ A tractor can lift its trailer with a constant force of 12000N when its velocity is 2.5 m/s. What is the value of tractor power in watt and horsepower under these conditions?

P7/ While a 90kg football player was running at a velocity of 6m/s, a player from the other side pulled him from the back and stopped after a distance of 1.8m.

a- What is the average force that caused the player to stop?

b- How long has it taken for the player to stop completely?

Chapter 6: Thermodynamic

Thermodynamic (Introduction)

You have previously studied that heat is a kind of energy and that energy transfers from one body to another when there is a difference in the temperature of the two bodies, you also learned that there is another energy that can be transmitted from one body to another when the two bodies are at one temperature, This energy is work. You encounter in your life a lot of transitions where mutual energy exist on the form of heat or work done, there may be mutual energy together.

For example, when you operate the car or home air conditioner or when cooking meals, or the heat generated in the engine of the car due to the interaction between oxygen and gasoline vapor in the engine cylinders and hot gases caused by combustion, which push the pistons generating a mechanical work that can be used to move the car

The study of such transformations, which include heat and work, is an important subject of physics called thermodynamic (thermal movement).

6.1 The System and the surrounding medium

The study of any phenomenon in a branch of physics. Start by isolating a specific area or part of that physical group from surrounding mediums and the part that is isolated is called system, while the surrounding environment includes all objects and elements that are not part of the system. In the previous example, the mixture of gasoline vapor and air in the engine of the vehicle before the combustion is a "system", the surrounding medium includes the cylinder, and the surrounding medium can affect the system in several ways such as mechanical forces and thermal sources and electric fields ... etc. Figure (1) shows corn grains in a container placed on a heat source, which represents a “thermodynamic system”. The thermal dynamic process described here show that the heat has been added to the system, and the system in turn has been performed a work on the outer environment of the container by lifting the lid.

Figure 1

6.2 Heat and work

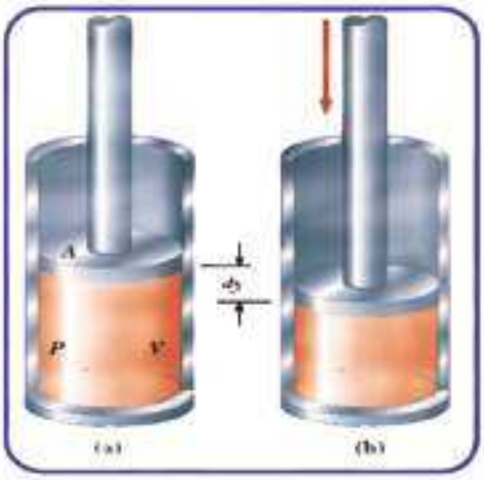


Figure 2

Assume we have a quantity of gas trapped (thermodynamic system), and that system is the result of different thermal processes moving from state to another. Notice figure (2).

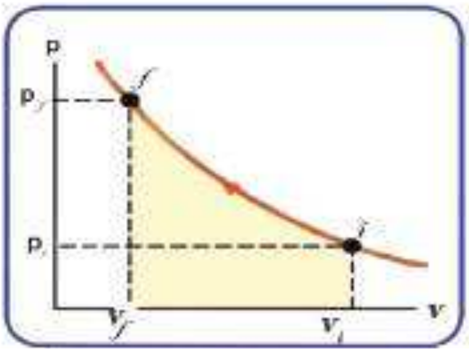


Figure 3

If we draw the graphical relation between the pressure and volume of that system notice figure (3), then the area trapped between the curve and the volume axis equals the work done to make this change.

It worth to mention that the process of transferring a certain system from state to another may happen according to several processes: notice figure (4)

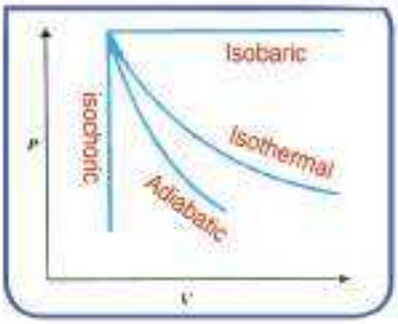


Figure 4

1- Fixed pressure process (Isobaric):
It is the process where the system transfer from a state to another with remaining its pressure constant.

2- Fixed volume process (isochoric):
It is the process where the system transfer from a state to another with remaining its volume constant.

3- Fixed temperature process (Isothermal):
It is the process where the system transfer from a state to another with remaining its temperature constant.

4- The process of no thermal transformation from and to the system (Adiabatic):
It is the process that does not contain thermal transformation from and to the system (without thermal exchange).

6.3 First law of thermodynamics

This law expresses the relationship between work and heat. It is known experimentally, whenever the work turns to heat or the heat turned into work, there is a simple fit between the work and heat, called the constant proportion of thermal mechanical equivalent and it eqauls 4.2 joule/cal where the scientist joule was the first to find this constant. According to energy conservation law, the total energy in any isolated system remains constant, whatever the shifts in the forms of energy.

In the process of turning the work into heat, the energy conservation law is known as the first law of thermodynamics.

If a system absorbs a quantity of heat ΔQ notice Figure (5 a), and the work done by this system is ΔW. During that time, the energy conservation law states that the difference between the amount of heat absorbed by the system and the work performed is equal to the increase in the internal energy of the system.

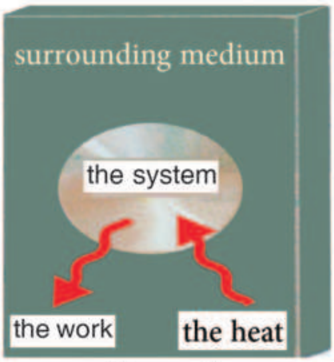
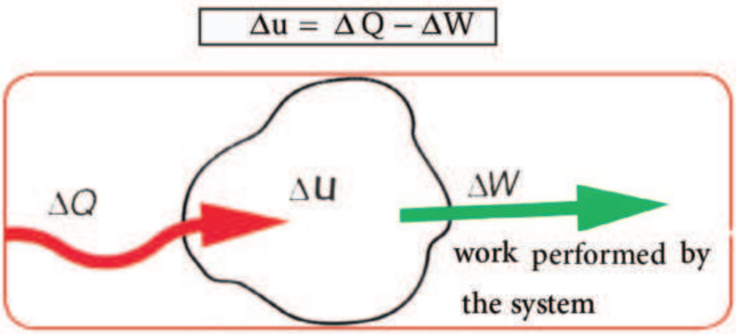


Figure 5a



This law can be written as follows:

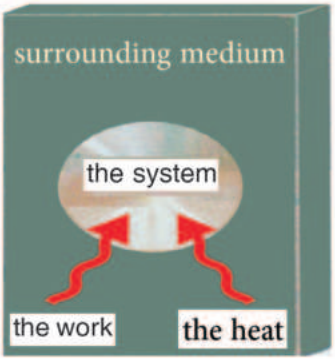
When a work is performed on a system of its surroundings at a different temperature, the transmitted energy is equal to the difference between the change in internal energy and the completed work. This energy is referred to as heat energy and is symbolized by the symbol ΔQ.

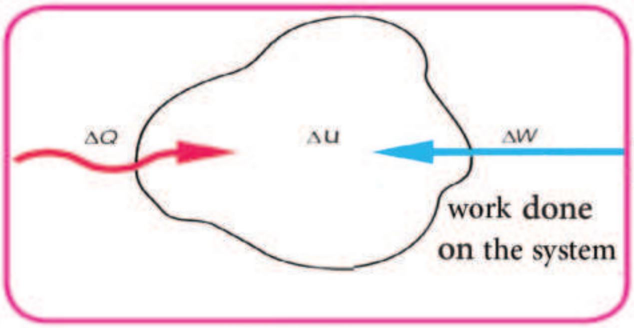
So that:

First law of thermodynamics $\Delta Q=\Delta W+\Delta u$ where Δu Represents the increase in the total energy of the system (the internal energy of the system) which is equal to the sum of the kinetic and the potential energies of the system. While using this law we must remember that:

1- ΔQ Considered positive if heat was added to the system notice figure (5) and considered negative when Heat transfer out of system.

2- ΔW Considered positive When a work is performed by the system on the surrounding medium (Such as the work done when the gas is extended and it is represented by the energy that left the system), And ΔW is considered negative when performing any work on the system by the surroundings and it is represented by the energy that entering the system notice figure (5b).





$$\Delta u = \Delta Q + \Delta W$$

Figure 5b

6.4 Applications of the first law of thermodynamics

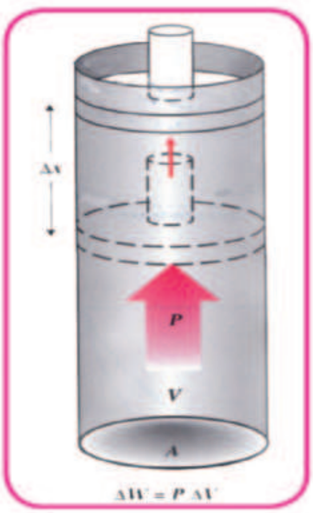


Figure 6

Suppose a thermal system is a confined gas separated from its outer environment by a cylinder equipped with a movable piston. Notice Figure (6). To calculate the work of this system, we do the following:

$$F = P \times A$$

$$W = (\text{force}) \times (\text{displacement})$$

$$W = F\,\Delta x = PA\,\Delta x$$

A Δx Represents the increase in the gas volume and equalΔV, that is:

$$\Delta W = P\,\Delta V$$

the work done by gas.

$$\Delta W = -P\,\Delta V$$

the work done on gas.

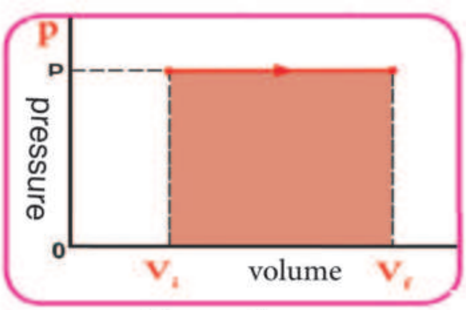


Figure 7a

To calculate the work of the system in the following operations:

1- Work done at constant pressure (Isobaric): notice figure (7 a) in this case
ΔW=PΔV

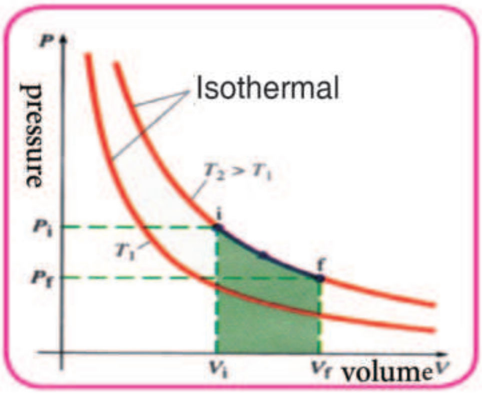


Figure 7b

2-Work done at constant temperature(Isothermal) notice figure (7-b) in this case

$W=P_i V_i \ln (V_f/V_i)$

From Boyle's law: $P_i V_i = P_f V_f$

$W = P_i V_i \ln (P_i/P_f)$

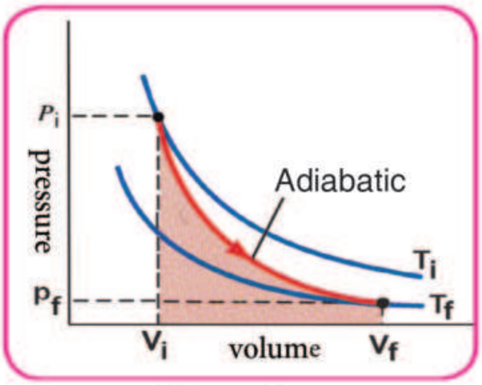


Figure 7c

3- Work done in the Adiabatic process (There is no heat exchange between the gas and the surrounding environment) where the process is done relatively quickly, In this case: $\Delta W=-\Delta U$ notice figure (7 c).

Example 1

If we assume that the volume of the human lungs is increased by 500 cm^3 at one inspiratory process.
Calculate the work done on the lungs during this process, considering that the pressure inside the lungs remains constant and equal to the atmospheric pressure 10^5 N/m^2.

Solution

$\Delta W = P \Delta V$ since work done

$\Delta W = P(V_f - V_i)$ at constant pressure (Isobaric)

$= 10^5 \times 500 \times 10^{-6}$

$\Delta W = 50$ J Work done

Example 2

Air trapped in piston cylinder extended where its volume 0.2 m^3 and its pressure 10^6 N/m^2 and after extending its volume became (0.6 m^3), if its temperature remained constant through this process at (T=300K), calculate the work done knowing that Ln x=2.303 log x .

Solution

Since work is done at constant temperature (Isothermal process) then:

$$\Delta W = P_1 V_1 \ln (V_2 / V_1)$$

$$= 10^6 \times 0.2 \times \ln (0.6 / 0.2)$$

$$= 0.2 \times 10^6 \times 2.303 \log \left(\frac{0.6}{0.2} \right)$$

$$\Delta W = 0.4606 \times 10^6 \log_{10} 3 \Rightarrow W = 0.46062 \times 10^6 \times 0.47$$

$$\Delta W = 2.19722 \times 10^5 J$$

Figure 8a

Figure 8b

Example 3

Figure (8) shows a system with its surrounding in figure (8 a), and the system was provided by 1500 J of heat from the surrounding medium and the work done by the system equal 2200 J. In figure (8 b) the system was provided by 1500 J and the work done on the system by the surrounding medium equals 2200 J. calculate the change in the internal energy of the system (ΔU) in each case.

Solution

In the case of figure (8 a) the internal energy of the system (ΔU) can be given form the relation:

$$\Delta U = \Delta Q - \Delta W$$

And the work done is positive because it was done by the system on the surrounding medium.

$\Delta U = 1500\,J - 2200\,J$

$\Delta U = -700\,J$ the internal energy of the system

In the case of figure (8-b) the internal energy of the system (ΔU) can be given form the relation: $\Delta U = \Delta Q - \Delta W$

the work done ΔW is negative because it was done on the system.

$\therefore \Delta U = (1500\,J) - (-2200\,J)$

$\Delta U = +3700\,J$

Question?

Fill the spaces in the table below with a sign (-, +, 0) for each cas and also for each indicator system

	Situation	System	Thermal Energy ΔQ	Work Done ΔW	Internal Energy ΔU
a	Quick infl-atable bicycle frame	There is air in the pump			
b	Water at room temperature placed on a hot stove	Water is in a pot			
c	Air quickly leaks outside the balloon	Air is inside a balloon			

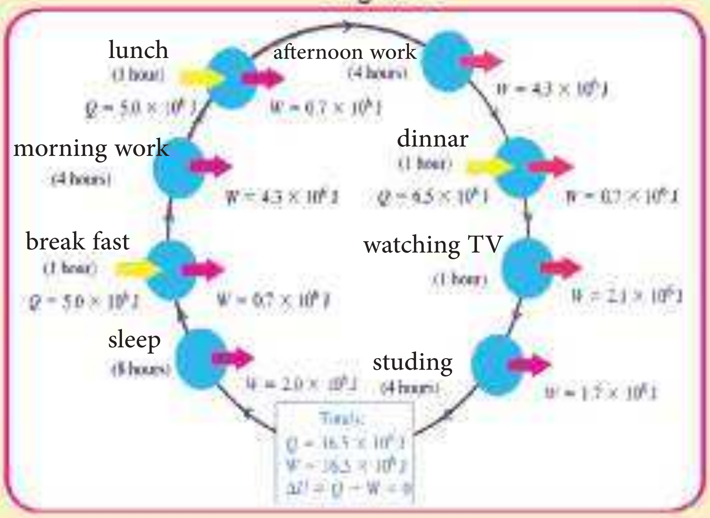
Do you know ?

Every day, your body is a thermodynamic system, where heat ΔQ is added by the food and your body do work through breathing, walking and all other activities.

Notice Figure (9) and at the end of the day, the: $\Delta Q = \Delta W$

Thus, the total internal energy is zero $\Delta U = 0$

Figure 9



6.5 Heat engine

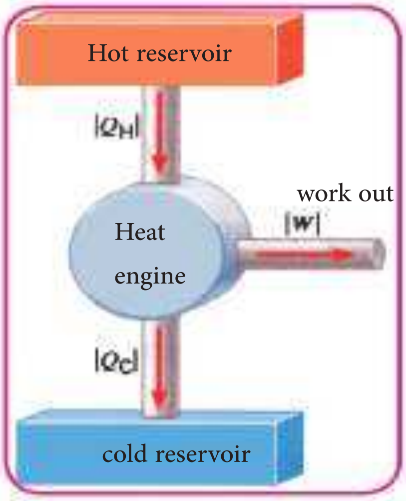


Figure 10

A device that converts part of the thermal energy into a mechanical work as a result of the transfer of heat to this device from a thermal source (thermocouple) with a high temperature (T_H) and transfer the remaining heat to a low temperature thermocouple (T_C) notice figure (10).

The efficiency of the heat engine is given as a percentage in the following relation:

$$\text{Efficiency } (\eta) = \frac{\text{The work done by the engine}}{\text{The Energy supplied to the engine}} \times 100\%$$

$$\eta = (W / Q_H) \times 100\%$$

$$\because \quad W = Q_H - Q_C$$

$$\therefore \quad \eta = \frac{Q_H - Q_C}{Q_H} \times 100\%$$

Example 4

A heat engine that receives 1200 J of heat from a high thermal source (Q_H) at each cycle and performs a work of 400 J in each cycle.

a- Calculate the efficiency of the engine.
b- Calculate the amount of heat exhaled (Q_c) in each cycle.

Solution

a-

$$Q_H = 1200\ J$$
$$W = 400\ J$$
$$\eta = \frac{W}{Q_H} \times 100\%$$
$$\eta = \frac{400\ J}{1200\ J} \times 100\% = 33\%$$

b-

$$W = Q_H - Q_C$$
$$Q_C = Q_H - W$$
$$= 1200\ J - 400\ J$$
$$Q_C = 800\ J$$

6.6 Second law of thermodynamics

You may have noticed that the first law in thermodynamics is a form of energy conservation law but does not specify the direction of energy transfer. For example, if I left a cup of ice cream or a cold bottle of juice for a period of time in hot weather, they will not become colder ... This is normal You might ask yourself why the opposite action does not take place, which they are becoming cooler? This opposite action is not inconsistent with the Energy Conservation Law.

To illustrate the above, the second law of dynamically determines the direction of thermal energy transfer processes (heat) and there are two formulas for this law, and both are equal.

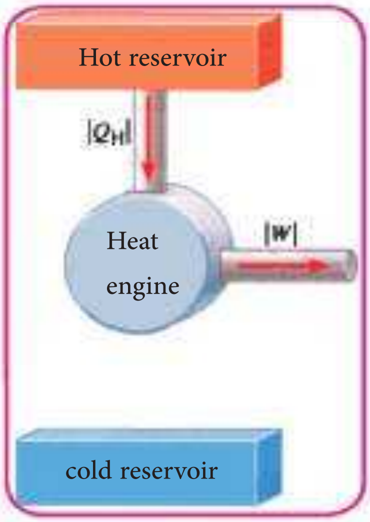


Figure 11

1- Kelvin-Black formula:

It is impossible to build a heat engine that absorbs thermal energy from one thermal reservoir and turns it completely into mechanical work.
Notice Figure (11) that in order for the heat engine to produce a work, two different thermocouples must be in different temperatures.

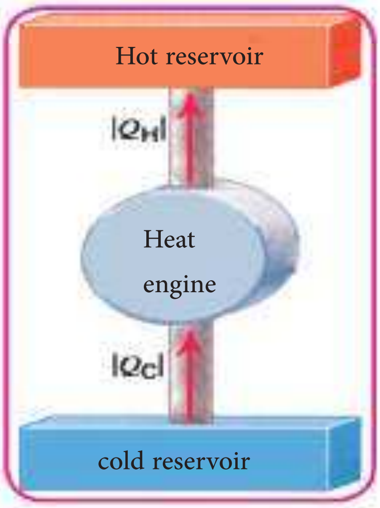


Figure 12

2- Clausius formula:

It is impossible to build a heat engine that absorbs heat from a low-temperature reservoir and moves it to another reservoir with a higher temperature without having to do mechanical work. Notice figure (12).

Questions of the Chapter 6

Q1/ Select the correct phrase for each of the following statements:

1- A heat engine operates using an amount of heat entering it at certain temperature and works to:

a- Convert them all to work.
b- Turning some of them into a work and the remainder is left at a lower temperature.
c- Turning some of them into a work and the remainder is left at the same temperature.
d- Turning some of them into a work and the remainder is left at a higher temperature.

2- The natural direction of heat flow transferred to and from the system is from the thermal tank of the higher temperature (T_H) to the thermal tank of the lower temperature (T_L), without considering the amount of heat contained in each tank. This fact represents:

a- First law of thermodynamics
b- The second law of thermodynamics
c- Energy conservation law
d- linear momentum conservation law

3- The adipatic process in the system is one of the processes in which:

a- The heat does not enter or exit the system.
b- The system does not perform any work on the medium no a work performed on it.
c- System temperature remains constant.
d- System pressure remains constant.

4- A frictionless heat engine can be 100% efficient only when the exit temperature (T_C):

a- Equal to the entry temperature (T_H).
b- Less than the entry temperature (T_H).
c- Equal 0°C
d- Equal 0 K

Problems of the Chapter 6

P1/ A system contains of gas trapped in a piston cylinder Extended, had a volume of 0.02 m^3 and pressure of $5x10^5$ Pa after extending its volume become 0.022 m^3 at the same pressure, Find the work done by the system?

P2/ A n insulated vessel contains gas trapped inside it. If the external work on the gas is equal to 135 J, find the amount of change in the internal energy of the system.

P3/ A heat engine gives 2 x 10^3 J Of heat from the higher temperature reservoir and transfer 1.5 x 10^3 J Of heat to the lower temperature reservoir, find the efficiency of the engine.

P4/ A heat engine that receives a temperature of 3000kJ from a high temperature thermal source and expels 900KJ of heat to a low temperature reservoir.
a- How much work does the engine do?
b- What is the efficiency of the heat engine?

P5/ During the operation of a certain heat engine, the internal energy was reduced by 400j while performing a wok of 250 J. Calculate the net heat ΔQ.

7.1 Circular Motion

When a rigid object (an object that cannot be distorted and modulated by the influence of external forces and torque) is rotated around a fixed axis, then any particle in it is far from the rotation axis for a certain distance, It is said that the motion of this particle is circular Such as the motion of the nozzle of the air frame in the bicycle wheel Notice Figure (1).

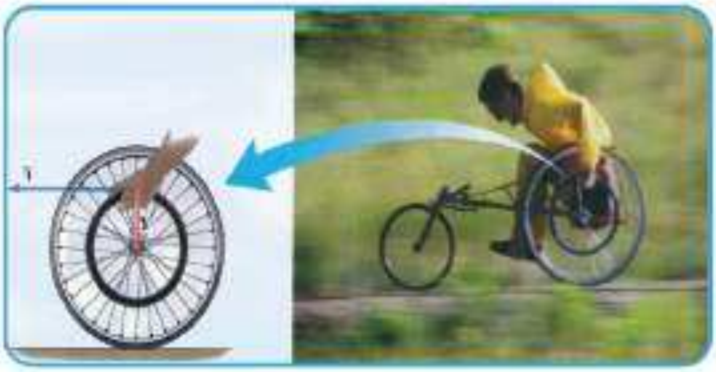


Figure 1

And the movement of the person sitting in the air wheel which rotates vertically. Notice figure (2).

Figure 2

While Figure (3) shows the movement of the plane on a circular path at a horizontal level.

Figure 3

7- 2 Angular displacement and angular velocity

We find it difficult to describe the circular motion by relying only on the linear quantities given in the second chapter of this book, because the direction of movement of the body in a circular motion is continuously changing so the circular motion is described in terms of the particle rotation angle (angular displacement) This means that each point of the rigid body that rotates around a fixed axis (except for points on the axis of rotation) Rotate at the same angles in the same period of time so The three important quantities that passed through in the linear motion [linear displacement $\overrightarrow{\Delta x}$, linear velocity $\overrightarrow{\upsilon}$, and linear acceleration $\overrightarrow{a}$] correspond to

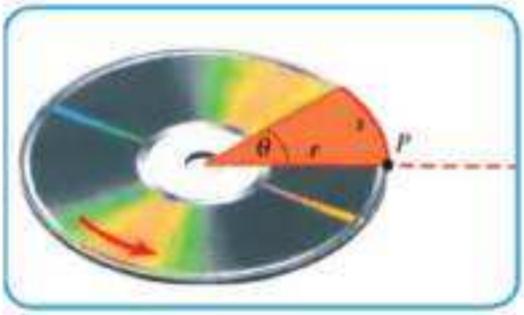


Figure 4

it in angular motion three other quantities [angular displacement $\overrightarrow{\Delta\theta}$, angular velocity $\overrightarrow{\omega}$,and angular acceleration $\overrightarrow{\alpha}$].
The analysis of this movement requires the choice of a reference line notice Figure (4) If we assume that the position of the particle is the point represented by the red line at (t=0) and after a period of time Δt the red line moves to another location, In this period, the red line rotate an angle displacement (θ) with respect to the reference line while the particle cut a distance of (S) on the arc of the circle that is representing the length of the arc. This figure shows that angle(θ)is an angular displacement and that (S) represents the length of the circle arc whose radius (r) then:

angular displacement=arc length/radius

That is:

$$\theta = \frac{S}{r}$$

When the particle rotates a full cycle, the length of the path (S) equals the perimeter of the circle ($2\pi r$) and the angular displacement:

$$\theta = \frac{S}{r} \quad , \quad \theta = \frac{2\pi r}{r} = 2\pi\,(rad)$$

That the angle θ, during a complete cycle is equal to 2π(radian).

7- 3 The relation between the linear and the angular speed

Since the average linear speed is the ratio of the linear distance to the change of time:

$$\upsilon_{avg} = \frac{\Delta S}{\Delta t}$$

$$\Delta S = r\,\Delta\theta$$

$$\upsilon_{avg} = r\left|\frac{\Delta\theta}{\Delta t}\right|$$

Since the average angular speed is the ratio of the angular displacement to the change of time:

$$\omega_{avg} = \left|\frac{\Delta\theta}{\Delta t}\right|$$

$$\upsilon_{avg} = r \times \omega_{avg}$$

$$\boxed{\upsilon = r \times \omega}$$

linear speed of a particle = the particale's distance from the center of rotation × the angular speed of a partical

When a particle rotates a full cycle then its linear speed equals the perimeter of the circle divided by the time of the full cycle (T) that is:

$$\upsilon = \frac{2\pi r}{T}$$

$$r \times \omega = \frac{2\pi r}{T}$$

$$\therefore \omega = \frac{2\pi}{T}$$

And since the frequency f equals (1/time period T) that is:

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

$$\therefore \omega = 2\pi f$$

Remember ?

If the angular velocity ω was is rev/s then it is called rotational frequency (f).

If the angular velocity ω was is rad/s then it is called angular frequency ω

Example 1:

A disc rotates with angular velocity (5400 rpm) calculate:

a- Angular frequency and the time period for one cycle.
b- If the radius of the disc is (28cm) what is the linear speed of the particle located on the perimeter of the disc.

Solution

(rpm): is shorten of "revolution per minute" means (cycle/minute).

a- We convert the angular velocity from (rpm) to (rev/s)

$$\omega = \frac{5400\,revolution}{\text{minute}} \times \frac{1\,\text{minute}}{60\,\text{second}}$$

$$\omega = \frac{5400\,revolution}{60\,\text{second}} = 90\frac{rev}{\text{s}}$$

The rotation frequency (f) is estimated by (Hz) or (rev/s)

And the time period of one cycle (T) is given as:

$$f = \frac{1}{T} \Rightarrow 90 = \frac{1}{T} \Rightarrow T = \frac{1}{90}s$$

b- And to calculate the linear speed of the particle, firstly the angular speed (ω)

$$\omega = 2\pi f$$

$$\omega = 2\pi \times 90$$

$$\omega = 180\pi\, rad/s$$

$$v = \omega r$$

$$v = 180\pi \times 0.28$$

$$v = 180 \times \frac{22}{7} \times 0.28$$

$$v = 180 \times 0.88$$

$$v = 158.4\,\text{m/s}$$

7- 4 The acceleration and Force Central

Figure 5

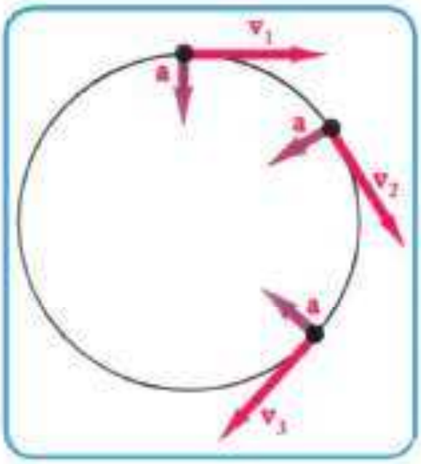


Figure 6a

If a small ball is attached to one end of a non-elongated thread was rotated with a circular path with a steady and horizontal plane (the effect of gravity is ignored in the ball so that the thread is at the circle level) notice figure (5).

We notice that the direction of the instantaneous tangential velocity of the ball is continuously changing during its motion as a result of this change in the tangential velocity with a rate of time, it moves with acceleration that is called central acceleration and has a symbol a_c Thus, the central acceleration is the time-rate of the change in the tangential velocity, which is a fixed amount and is directed towards the center of the circle and perpendicular to the instantaneous tangential velocity vector. Notice figure (6a) then:

$$a_c = \frac{\upsilon^2}{r}$$

Since every moving object has a self-deficient it tries to keep its movement on a straight line. In order for an object to move on a circular path with a constant speed, a net external force must influence perpendicularly on the vector of its instantaneous velocity to change the direction of its tangential velocity, in this case, the tensile force in the thread (T) is the force that changes the direction of the tangential velocity of the ball, keeping it in its circular path and according to the second law of Newton, the central force F_c is given by the relation:

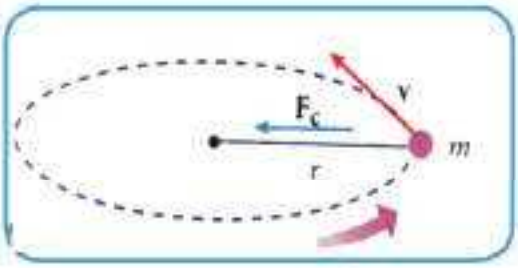


Figure 6b

$$F_c = m a_c$$

$$F_c = \frac{m\upsilon^2}{r} \quad , \quad \upsilon = r\omega$$

$$F_c = m r \omega^2$$

It is worth noting that the central force (F_c) is no different from any force studied previously, such as the static friction force between the tires of the vehicle and the ground of the corner, is the central force necessary to keep the car in its circular path, The force of attraction between the earth and the moon is the central force needed to keep the moon in its circular orbit, The force of electrical attraction between the nucleus and the electron is the central force needed to keep the electron in its circular orbit and others.

Remember:

When an object spends a regular circular motion, the direction of its instantaneous tangential velocity is constantly changing with its fixed speed, so that the object has a central acceleration perpendicular to its instantaneous velocity vector and it has constant magnitude.

•The demise of the central force:

If someone was asked what is meant by the demise of the central force influencing an object moving on a circular path with a fixed speed?

To answer this question ... check the following:

Since the central force (F_c) that is influencing perpendicularly to the instantaneous tangential velocity vector of the body is generating regular circular motion then it works to change the direction of its instantaneous tangential velocity. The demise of the central force means that it stops influencing, So the body will be launched in a straight line towards the tangent of the circular path from that point and with the speed that the body has at that moment, Then the body is applied to the first law of Newton notice figure (7).

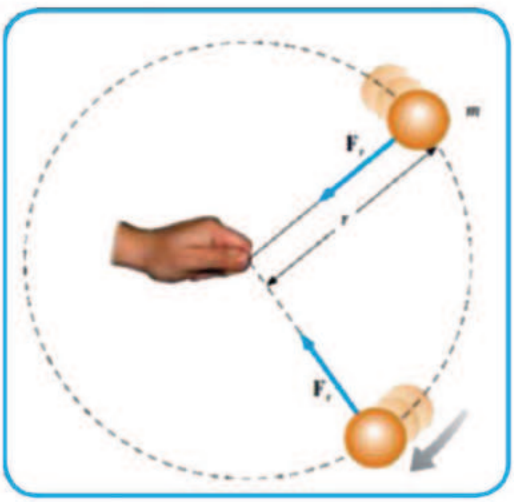


Figure 7a

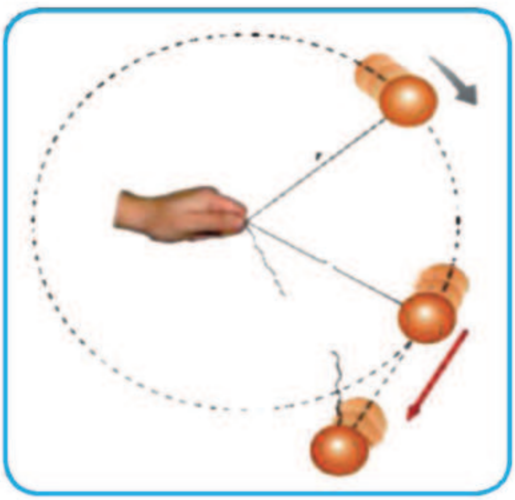


Figure 7b

7- 5 An Irreqular circular motion

In the case where an object moves on a circular path with a variable speed with time, its motion is called an irregular circular motion, in which there is no acceleration vector perpendicular to the instantaneous tangential velocity vector of the object, This means the acceleration of the object(a) does not move towards the center of the circle in this case and then the acceleration vector get analyzed into its two components, one of the components is perpendicular to the instantaneous tangential velocity vector which is called central acceleration (a_c) Which results from a change in the direction of the object's instantaneous tangential velocity and the other component is parallel to instantaneous tangential velocity vector which is called tangential acceleration (a_T) Which results from a change in the object velocity notice figure (8).

Since the vector a_c perpendicular to the vector a_T then their result is calculated by applyingthe Pythagorean Theorem as follows:

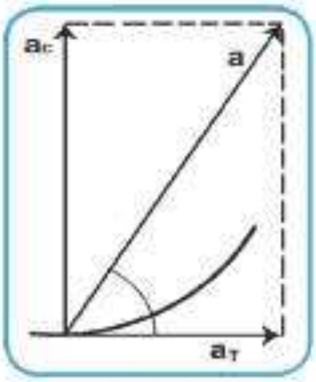


Figure 8

$$a=\sqrt{a_c^2+a_T^2}$$

$$\tan\theta=\frac{a_c}{a_T}$$

$$\theta=\tan^{-1}\left(\frac{a_c}{a_T}\right)$$

7- 6 Movement of vehicles on horizontal turns

When a vehicle moves on a horizontal turn, the central force (F_c) suitable for rotation is the initial friction force (f_s) between its frames and the ground of the turn. Note Figure (9) as follows:

Figure 9

$$f_s = F_c$$

$$f_s = \frac{m\upsilon^2}{r}$$

And that the friction force provided by the road must be no more than (μ_s N), (μ_s is the initial friction coefficient), that is:

$$\boxed{f_s \le \mu_s N}$$

Where (N) is the reaction force of the horizontal turn ground that is perpendicular to the vehicle and equal the weight of the vehicle (N=mg) which means:

$$\frac{m\upsilon^2}{r} \le \mu_s mg$$

$$\frac{\upsilon^2}{r} \le \mu_s g$$

$$a_c \le \mu_s g$$

And this means that the central acceleration (a_c) cannot be more than (μ_s g)Maximum safety speed of the car at the turn of the road without straying from the road:

$$\upsilon = \sqrt{\mu_s g r}$$

Remember:

The mass of the vehicle does not appear in the equation $\upsilon \le \sqrt{\mu_s g r}$ that means the small car, the truck and the bike all can safety move with the same speed at the same turn.

7- 7 Movement of vehicles on oblique turns

Oblique roads arise at the turns (so that the height of the outer edge greater than the height of the inner edge of the road) for central force generation (F_c) that is suitable for rotation. To calculate the angle of the turn slope from the horizon analyze reaction force of the road (N) into two components then the horizontal component of the reaction force (N sinθ) works to change the direction of the instantaneous tangential velocity of the vehicle notice figure (10) which is the suitable central force for rotating and directed into the center of the circle:

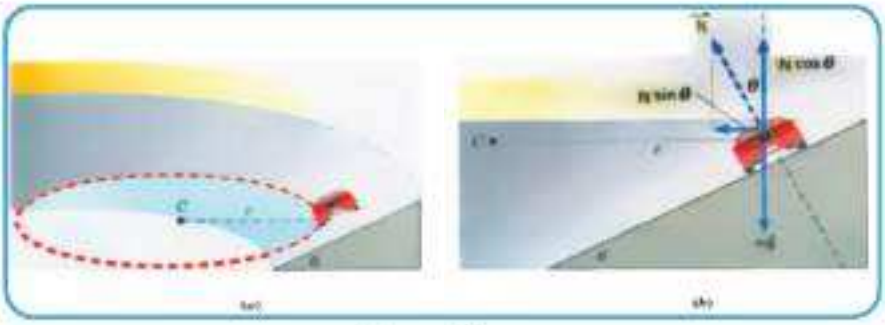


Figure 10

While the vertical component (N cosθ,) equal the weight of the car:

$$N\sin\theta = F_c$$

$$N\cos\theta = w$$

$$\frac{N\sin\theta}{N\cos\theta} = \frac{m\upsilon^2/r}{mg}$$

$$\tan\theta = \frac{\upsilon^2}{rg} \quad \text{or} \quad \theta = \tan^{-1}\frac{\upsilon^2}{rg}$$

7- 8 Real weight and apparent weight

We have shown above that the real weight (w_{real}) of the body is the force of the earth's attraction to its mass (m) and the real weight is measured by the elongation of the spring in the spiral hump. The amount of gravitational field at the earth's surface is: g=9.8 N/kg

$$w_{real} = mg$$

The apparent weight ($w_{apparent}$) of an object is the force that the reference object apply on the object. To clarify that:

Figure 11a

Notice figure (11) It shows a person of mass (m) standing on the scales to measure weight in the elevator. We find that there are only two forces that influence the person. The first force is the Earth's gravitational force (mg) in downward direction (towards the center of the earth) and the other force is ($\vec{N}$), representing the influence of the elevator floor reaction on the body and pointing upward If the elevator is static, ascending or descending vertically at a constant velocity, then the acceleration of the elevator (acceleration of the person) in all three cases is zero (a=0).

By applying the second law of Newton to a constant moving elevator, the net force influencing the person is given as:

$$\sum \vec{F} = m\vec{a}$$
$$\sum \vec{F} = \vec{N} - \vec{w}$$
$$\vec{N} - \vec{w} = m\vec{a}$$

Since the acceleration of the person is zero then

$$\vec{N} - \vec{w} = 0$$
$$\boxed{\vec{W}_{app.} = \vec{W}_{real}}$$

That is:

The apparent weight $\vec{W}_{app}$ (spring reading) = the real weight of the person $\vec{W}_{real}$

- If the elevator is vertically descending by constant acceleration $(\vec{a})$ as in Figure (11 b), the relation of the net force with acceleration is given as follows:

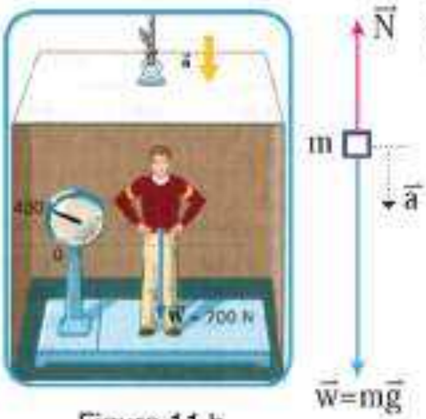


Figure 11 b

$$\sum \vec{F} = m\vec{a}$$
$$\vec{w} - \vec{N} = m\vec{a}$$
$$\boxed{\vec{W}_{app.} = \vec{W}_{real} - m\vec{a}}$$

This means that a person's apparent weight $\vec{W}_{app}$ is less than his actual weight $\vec{W}_{real}$ by the amount (ma).

- If the elevator is vertically ascending by constant acceleration (a) as in Figure (11 c), the relation of the net force with acceleration is given as follows:

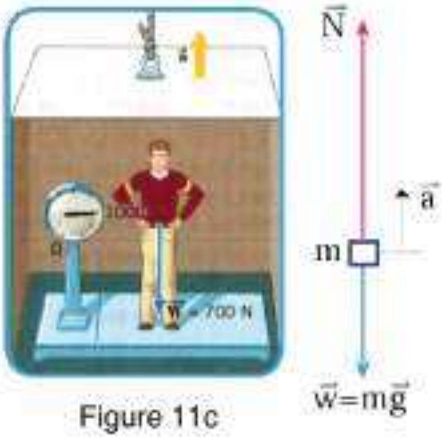


Figure 11c

$$\sum \vec{F} = m\vec{a}$$

$$\vec{N} - \vec{w}_{real} = m\vec{a}$$

$$\vec{W}_{App.} = \vec{W}_{real} + m\vec{a}$$

This means that a person's apparent weight $\vec{W}_{app}$ is higher than his actual weight $\vec{W}_{real}$ by the amount (ma).

- If the elevator fall a free fall (assume the rope was cut) then the acceleration of the elevator equals the gravitational acceleration (a=g) then the net force:


Figure 11d

$$\sum \vec{F} = m\vec{a}$$

$$\sum \vec{F} = m\vec{g}$$

$$\vec{w}_{real} - \vec{N} = m\vec{g}$$

$$\vec{w}_{app.} = \vec{w}_{real} - m\vec{g}$$

$$\vec{w}_{app.} = m\vec{g} - m\vec{g}$$

$$\boxed{\vec{w}_{app} = 0}$$

This relationship shows the apparent weightlessness of the body in the case of free fall.

Example 2:

A person of mass (60kg) on the scales (to measure weight) in the elevator, what is the amount of reading (apparent weight) when the elevator:

a- moves vertically at a constant speed .

b- Vertical descent by $2 m/s^2$ acceleration .

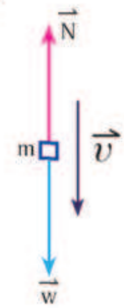
c- Vertical ascent by $2 m/s^2$ acceleration .

Assuming that the ground acceleration of free fall ($g=10 \ m/s^2$)

Figure 12

Solution

By applying the second law of Newton on the y – axis, we plot the free scheme of the body to show the forces that influence it, as in Figure (12).



a – When the elevator moves vertically at a constant velocity in the direction of the y – axis, then the acceleration (a) = zero.

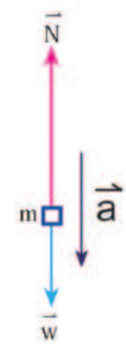
$\Sigma \vec{F} = m\vec{a} = 0$

$N - w = 0 \Rightarrow N - m\vec{g} = 0$

$N = mg = 60 \times 10 = 600N$

Moving with constant velocity downward

b – The elevator descends vertically by accelerating $(2m/s^2)$ then:



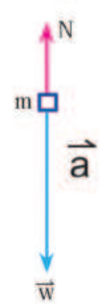
$\Sigma \vec{F} = m\vec{a}$

$W - \vec{N} = m\vec{a} \Rightarrow m\vec{g} - \vec{N} = m\vec{a}$

$60 \times 10 - \vec{N} = 60 \times 2 \Rightarrow N = 600 - 120 = 480N$

That is, the apparent weight of the person is 480Newton, which is less than the real weight.

c – The elevator climbs vertically to acceleration $(2m/s^2)$ then:



$\Sigma \vec{F} = m\vec{a}$

$\vec{N} - m\vec{g} = m\vec{a}$

$N - 60 \times 10 = 60 \times 2$

$N = 720N$

That is, the apparent weight of the 720Newton person is greater than its real weight.

Questions of Chapter 7 (Part1)

Q1/ Choose the correct phrase for each of the following statements:

a- An object that moves on a circular path with a constant speed, its direction of acceleration:

a- In direction of motion.

b- Towards the center of rotation

c- Away from the center of the circle

d- Any of the above depends on the position of the body.

2- A car moving on a circular path on a horizontal road, the central force influencing the car:

a- Inertia

b- Gravity

c- The force of static friction between the vehicle tires and the road.

d- The reaction of the road perpendicular to the car.

3- The central force that keeps the earth in its orbit around the sun is available:

a- Mediated by inertia.

b- By rotating the earth around its axis.

c- Part mediated by clouds gravity.

d- Mediated by the gravity of the sun.

4- An object that moves on a circular path with a constant speed, If the radius of its circular path is doubled, the central force necessary for its keeping it in that path becomes:

a- Quarter of what it was

b- Half of what it was

c- Twice larger than what it was

d- Four times bigger than it was

5- A car of mass (1200kg) and speed of (6m/s) when passing at a circular turn of radius (30m) then the central force working on the car is:

a- 48N

b- 147N

c- 240N

d- 1440N

6- When a person moves from his position at the equator to a location at one of the two poles, the apparent weight of the body:

1- It becomes smaller than the real weight.

2- It becomes bigger than its real weight.

3- Is equal to the real weight.

4- Equals zero.

7- The entertainment train in Theme park is walking on the inner surface of a circle rail with a vertical level. The weight of the person sitting in the train carriage for the moment passing through the lowest point of his path is equal:

a- $W_{app}=W_{real}+F_c$
b- $W_{app}=W_{real}$
c- $W_{app}=F_c-W_{real}$
d- $W_{app}=W_{real}-F_c$

Q2/

1- Write the equation of central force and prove that the unit of measurement is estimated by Newton.
2- Can a body move on a circular path without a central force influencing it? And why?
3- Can the moving body in cicular motion to be in equilibrium state? why?
4- Under any condition, a body can move on a circular path, possessing a central acceleration and no tangential acceleration. Clarify that.
5- What is the reason for the separation of water droplets from wet clothes placed in the drying machine with rotary tub during rotation?

Problems of Chapter 7 (Part1)

P1/ A person installed a fan with a radius of 10m rotates at a vertical level. What is the time period that one full cycle take to make its apparent weight zero in the highest point?

P2/ On the assumption that if the angular velocity of the earth ball increased and the central acceleration of a person standing at the equator become as quick as gravity, what would be the apparent weight of that person?

P3/ Calculate the central acceleration of a body at a point on the surface of the Earth away from the axis of rotation of the Earth 5000km.

P4/ A circular curved road of width 3.75m, sloping on the horizon and has a radius of 120m, designed for the car's running speed 29.698 m/s. Calculate the height of the outer edge of the road from its inner edge.

P5/ A satellite moving with a constant speed in a circular orbit, the radius of its orbit from the center of the earth is 7000km find:

1. Speed of the satellite in its orbit.
2. Time of one cycle at this orbit.

Knowing that the constant of general attraction = 6.67×10^{-11} $(N.m^2)/(kg^2)$

Mass of earth = 5.98×10^{24} kg = M_E

P6/ A car running on a circular curve of a radius 200m with a constant speed 30m/s if the mass of the car is 1000kg.

1. Find the force of friction necessary for the availability of the necessary central force.
2. If the coefficient of static friction is μ_s=0.8 , what is the maximum speed of the car on the circular path with nonslip?

7- 9 Rotational Motion

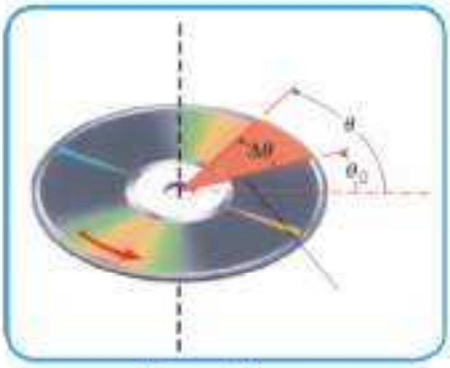


Figure 13

When we deal with a rotating body, the analysis becomes very simplistic on the assumption that the body is rigid. The rotational motion of a rigid body is defined as: the rotation of a rigid object around a particular axis that has passed from it or has passed from one of its points notice figure (13) Which shows the perspective from the top of a disk compact rotated around a fixed axis at point (O) and perpendicular to the disk level.

7- 10 Angular Acceleration

If the instantaneous angular velocity of a particle changes from ω_i to ω_f in a period of time, the particle has an angular acceleration. Angular acceleration (α) is defined as the time-rate of angular velocity change and is given the following relation:

$$\vec{\alpha} = \frac{\Delta\vec{\omega}}{\Delta t} = \frac{\vec{\omega}_f - \vec{\omega}_i}{t_f - t_i}$$

Angular acceleration is measured by rad/s^2 or $rad.s^{-2}$

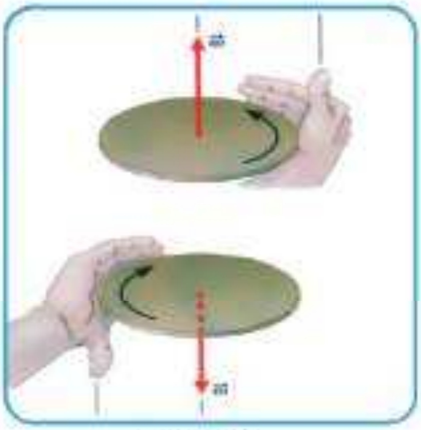


Figure 14

When the rigid body rotates around a fixed axis, each particle of its particles has the same angular displacement around that axis in the same period of time that means it has the same angular velocity and has the same angular acceleration. We apply the right hand rule to set the direction of the angular velocity (the four fingers of the right hand refer to the direction of rotation, the thumb refers to the direction of the angular velocity) notice figure (14).

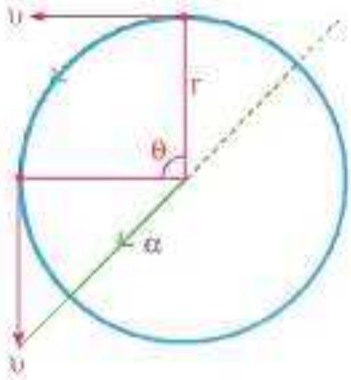


Figure 15

The angular acceleration direction $\overrightarrow{\alpha}$ of a rigid object around its fixed rotational axis is towards the same angular velocity $\overrightarrow{\omega}$, when increasing with time (in the case of acceleration) and in the opposite direction as it decreases with time (in the case of slowdown). Imagine one particle of the rigid object that rotate around its axis with regular angular velocity then it move on a circular path if radius (r) around a fixed rotation axis notice figure (15) and since the particle is moving on a circular path then its tangential velocity vector, has constant magnitude and continuously changing direction with fixed (r).

From that:

$$S = r\theta$$
$$\upsilon = r\omega$$

Thus, the tangential velocity of the particle is equal to the distance between the particle and the axis of rotation multiplied by the angular speed of the rigid body, the relation between the angular velocity of the particle and its tangential acceleration a_t can be found where the acceleration tangential component is:

$$a_t = \frac{\Delta\upsilon}{\Delta t} \Rightarrow a_t = \frac{\Delta(r\omega)}{\Delta t}$$

$$a_t = r\frac{\Delta\omega}{\Delta t}$$

$$\because \quad \alpha = \frac{\Delta\omega}{\Delta t}$$

$$\therefore \quad a_t = r\alpha$$

And that means the tangential component of the transition acceleration (a_T) of the particle that do circular motion equals the distance between the particle from the rotation axis (r) multiplied by the angular acceleration (α).

7-11 The equations of angular motion with the regular angular acceleration

The equations of the angular movement of the rigid body with a regular angular acceleration are expressed in the same mathematical picture of the straight motion of the particle by a linear acceleration. They are given as in the following table:

Linear Motion Equations	Angular Motion Equations
1- $\upsilon_f = \upsilon_i + at$	1- $\omega_f = \omega_i + \alpha t$
2- $\upsilon^2_f = \upsilon^2_i + 2ax$	2- $\omega_f^2 = \omega^2_i + 2\alpha\theta$
3- $x = \upsilon_i t + \frac{1}{2}at^2$	3- $\theta = \omega_i t + \frac{1}{2}\alpha t^2$
4- $x = \frac{\upsilon_i + \upsilon_f}{2} . t$	4- $\theta = \frac{\omega_i + \omega_f}{2} . t$

Example 3 :

A wheel rotates with a regular angular acceleration α=3.5 rad/s² if the angular velocity is 2rad/s at t_{in} =0, what is the angular displacement that the wheel rotate between t=0 and t=2s

1. By radian, and by revolution
2. How much the angular velocity of the wheel at t_f =2 sec

Solution

$$\theta = \omega_i t + \frac{1}{2}\alpha t^2$$

$$\theta = 2 \times 2 + \frac{1}{2} \times 3.5 \times (2)^2$$

$$\theta = 4 + 7$$

$$\theta = 11 \text{ rad}$$

$$\frac{11 \text{ rad}}{2\pi \text{ rad / rev}} = 1.75 \text{ rev}$$

$t = 2s$

$\omega_f = \omega_i + \alpha t$

$\omega_f = 2 + 3.5 \times 2$

$\omega_f = 9 \text{ rad / s}$

7- 12 Moment of inertia (I) and Rotalional energy

You already studied, dear student, in the subject of linear motion, that the objects tend to maintain their motion state and be inertia to change their motion state unless a net external force influence the object and change its state, and this property has been called inertia. We find something similar to this in rotational motion, the rotational wheel shown in figure (16) is inertia to change its rotational motion state only by the influence of net external torques on it ... This indicates the existence of a rotational inertia. Thus, the torque of the inertia of a particle of mass (m) that is located at the distance (r)from the axis of rotation is: $I = mr^2$

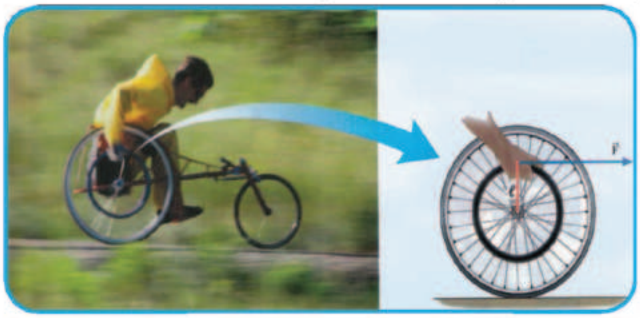


Figure 16

While the inertia torque of a rigid object around a certain axis equals the algebraic summation

of the inertia torques of all its constituent particles around the same axis.

$$I_{body} = I_1 + I_2 + I_3 + \dots$$

And the inertia torque is measured by the unit ($kg.m^2$) in the international system for units (SI), and it worth to mention that the inertia torque (I) is considered a scale for the resistance of the rigid object to change its angular velocity. And the moment of inertia of an object depends on:

1. The mass of the object.
2. The shape of the object.
3. Mass distribution with respect to the axis of rotation.

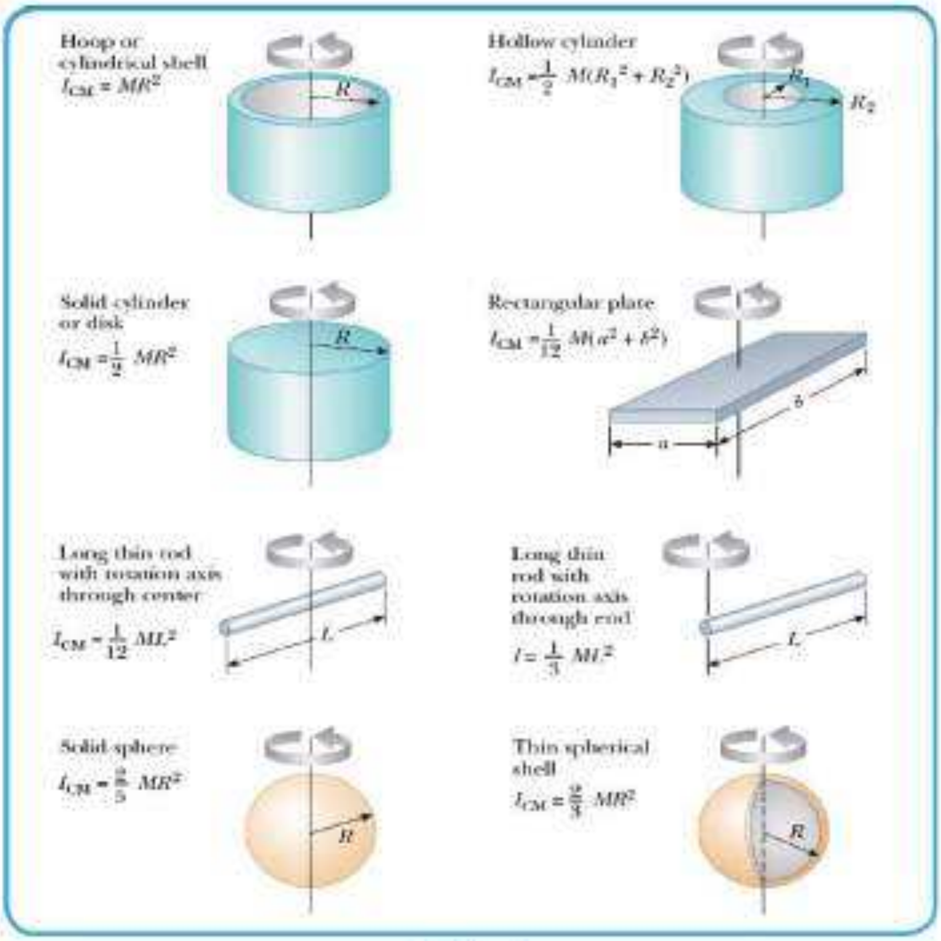


Table 1

table (1) shows the moment of inertia of the various homogeneous rigid bodies of different geometric shapes .

7.13 Complex movement (transitional motion and rotational motion)

Some objects may move two movements at once. One of them is rotational movement and the other is a transitional movement like ball rolling a soft rolling (without sliding) or the motion of the bike tire or the car wheel on a coarse surface then it is transitional and rotational motion on a coarse surface where the total motion of the rigid object equal the summation of two energies which are the linear motion energy and the rotational motion energy.

$$KE_{Total} = KE_{Translational} + KE_{Rotational}$$

$$KE_{Total} = \frac{1}{2} m\upsilon^2 + \frac{1}{2} I\omega^2$$

Example 4:

A solid ball rolled on a coarse horizontal surface a pure rolling with linear speed (1.5m/s) to its center of mass and its radius 0.1m having mass of 0.2kg. Calculate:

1. Moment of inertia around its geometrical axis that is passing from its center.
2. Total kinetic energy knowing that (I)(solid sphere)=2/5 mr²

Solution

$$I_{sphere} = \frac{2}{5} mr^2$$

$$I = \frac{2}{5} \times 0.2 \times (0.1)^2 \quad = 0.0008 kg.m^2$$

$$\upsilon = r\omega \Rightarrow 1.5 = 0.1 \times \omega \Rightarrow \omega = 15 rad/s$$

$$KE_{Total} = KE_T + KE_{Rot} \quad = \frac{1}{2} m\upsilon^2 + \frac{1}{2} I\omega^2$$

$$= \frac{1}{2} \times 0.2 \times (1.5)^2 + \frac{1}{2} \times 0.0008 kg.m^2 \times (15)^2 \quad = 0.315 Joule$$

7-14 Rotational torque of an object and the angular acceleration

We studied the equilibrium of a rigid body when the net external torques influencing it equal zero. Here we ask, what happen to the rigid body if the net external torques influencing it does not equal zero? By comparing the similarity with Newton's second law in the linear transitional motion we must aspect the change that will happen to the angular velocity of the rigid body.

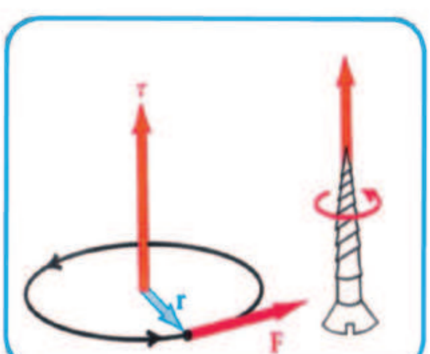


Figure 17

If a net external torques influenced a rotational wheel notice the figure (17). And gain it angular acceleration, this angular acceleration directly proportional to the net torques influencing it and moving towards it, and inversely proportional to the inertia torque of the wheel. So the net external torques influencing a rigid object is directly proportional to its angular acceleration and the constant of this proportion is the inertia torque.

That is: $\sum \vec{\tau} \propto \vec{\alpha}$

$$\sum \vec{\tau} = I\vec{\alpha}$$

This law is applicable on all the rigid objects during their rotation and the rotational torque is measured by (N.m) and it worth to mention that the rotational torque and the angular acceleration are vector quantities in the same direction that is on the rotational axis (according to right hand rule). However, the inertia torque (I) is a scalar quantity.

Example 5:

A solid cylinder of mass 1 kg the radius of its base 0.2m started rotating from static around its long geometrical axis that is passing from the center if the two bases when a tangential force (10N) influenced it. Calculate:

1- The angular velocity after (5s) from starting rotating.

2- How many revolutions.

Solution

1-
$$\vec{\tau} = I\vec{\alpha}$$

$$r \times F = \frac{1}{2} mr^2 \,.\, \alpha$$

$$0.2 \times 10 = \frac{1}{2} \times 1 \times (0.2)^2 \times \alpha$$

$$4 = 0.04\,\alpha$$

$$\alpha = \frac{4}{0.04} = 100\ \text{rad}/\text{s}^2$$

$$\omega_f = \omega_i + \alpha\,\Delta t$$

$$\omega_f = 0 + 100 \times 5$$

$$\omega_f = 500\ \text{rad}/\text{s}$$

2-
$$\theta = \frac{\omega_f + \omega_i}{2} \times \Delta t$$

$$\theta = \frac{500+0}{2} \times 5 = 1250\ \text{rad}$$

$$n_{rev} = (1250\text{rad}) \times \left(\frac{1}{2\pi} \times \frac{\text{rev}}{\text{rad}}\right)$$

$$= \frac{625}{\pi}\text{rev} = 199\text{rev}$$

7-15 Work and Power in rotational motion

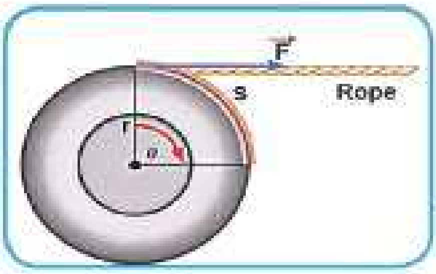


Figure 18

We assume a disc of radius r can rotate around a horizontal axis passing from the center of the bases. A tangential force influenced on the edge ($\vec{F}$) notice the figure (18) after passing a period of time (t) the disc rotated an angle (θ) and the point influenced by the force (a) rotated an arc of distance (s) by that the force did work:

$$\text{Work} = \text{force} \,.\, \text{disatance}$$

$$W = F \,.\, S$$

$$S = r\,\theta$$

$$\therefore W = (\, r \times F \,)\,\theta$$

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

$$\therefore W = \vec{\tau} \,.\, \vec{\theta}$$

The rotational work done equal the multiplication of the rotational torque $\vec{\tau}$ by the angular displacement ($\vec{\theta}$). The work done is measured by (Joule). While the rotational torque is measured by (N.m) and the angular displacement by (rad) "radian" and since the rotational work done (W) that equals the change in the rotational kinetic energy ΔEK_{Rot}

$$W = \Delta KE_{Rot} = KE_{Rot(f)} - KE_{Rot(i)}$$

$$W = \frac{1}{2} I \omega_f^2 - \frac{1}{2} I \omega_i^2$$

$$W = \frac{1}{2} I (\omega_f^2 - \omega_i^2)$$

Since the rotational power (P_{ro}) is the time rate of work done then:

$$P_{ro} = \frac{W_{ro}}{t} \Rightarrow P_{ro} = \frac{\tau\theta}{t}$$

$$\omega = \frac{\theta}{t}$$

$$\bar{\omega}_{1,2} = \frac{\omega_1 + \omega_2}{2} \Rightarrow P_{ro} = \tau \,.\, \bar{\omega}_{1,2}$$

That means the rotational power (P_{ro}) equals the multiplication of rotational torque by the average angular velocity and it is measured by Watt.

Example 6

An electrical motor has power (1.72×10^5 **watt**) rotating with average angular velocity of (500 rev/min) how much is the rotational torque that rotate it?

Solution $\omega = 500 \times \frac{2\pi}{60} = \frac{50\pi}{3}\ \mathbf{rad/s}$

$$P_{rot} = \tau \times \omega_{avg} = \tau \times \frac{50\pi}{3} \Rightarrow \tau = \frac{3 \times 1.72 \times 10^5}{50\pi}$$

$$\tau = 3286\ \text{N.m}$$

7- 16 Angular momentum

The angular momentum (L) of the rigid object around its rotational axis is linear momentum torque around the rotational axis and it is a vector quantity which depends on moment of the inertia (I) and the angular velocity(ω), as the linear momentum depends (P) on its mass (m) and its linear velocity (υ). and the angular momentum is measured by (kg.m^2/s).

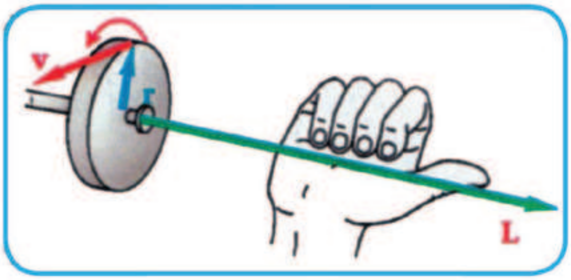


Figure 19

By noticing the figure (19) you find that the angular momentum can be given by:

$$\vec{L} = \vec{r} \times \vec{P}$$

$$\vec{L} = \vec{r}\, m\, \vec{\upsilon}$$

$$\because \vec{\omega} = \frac{\upsilon}{r} \Rightarrow \vec{L} = mr^2 \omega$$

$$\therefore \vec{L} = I . \vec{\omega}$$

7- 17 Conservation of angular momentum law

If the inertia torque of an rigid object changed from (I_1) to (I_2) during its rotating around a fixed axis without an influence of net external torques on the object then its angular velocity will change from ω_1 to ω_2 and that is because its angular momentum (L) remains constant (in the magnitude and direction) during rotation, which means the angular momentum of this object will be conserved during rotating around a fixed axis ant the statement of the conservation of angular momentum law of an object or group of objects:

When a net external torques influencing in a rigid object or a system of rigid particles is zero, then the total angular momentum of the rigid object or rigid particles system remains constant.

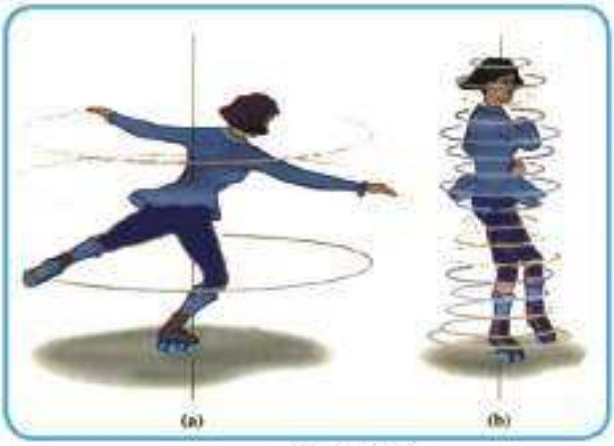


Figure 20

An example for that, an ice skater notice figure (20) increases his angular speed by lowering his arms aside and featuring his feet to each other so the torque inertia around the fixed axis of rotation decreases with the angular momentum remains constant.

final angular momentum=initial angular momentum

$$I_1\omega_1 = I_2\omega_2$$

Practical applications for the conservation of angular momentum (Ballerina, the swimmer spits his body when he jumps from a swimming board (jumping platform), a circus player) and others...

Questions of Chapter 7 (Part2)

Q1/ Choose the correct phrase from the following statements.

1- If a disc rotated around its axis with a regular angular momentum, the amount of one of the following quantities is not zero

a- Angular acceleration of the disc
b- Rotational work of the disc
c- Angular velocity of the disc
d- The net external torques influencing the disc

2- A student stands at the edge of a circular platform that rotates horizontally around a vertical axis passing through its center. If the student approaches the center of the platform slowly (without the effect of external torque), the student's angular momentum

a- Increases
b- Remains constant
c- Decreases
d- Equal the angular momentum of the platform

3- The (Joule.second) is the unit of:

a- Power
b- Rotational torque
c- Rotational acceleration
d- Angular momentum

4- The time rate of the change in angular momentum represents:

a- Rotational torque
b- Rotational work
c- force
d- Angular displacement

5- A train rotating on a circular rail in a horizontal level with constant speed then the thing change in the train wheel is:

a- Angular momentum
b- Moment of Inertia
c- Magnitude of angular velosity
d- Rotational kinetic energy

Q2/ Explain the following:

1- Balance on a moving bike easier than balance on a parked bicycle.
2- A body can have an angular impulse even though the angular impulse in it is zero.
3- The person extends his arms (or holds a horizontal stick) when walking on a tight horizontal rope.

Problems of Chapter 7 (Part2)

P1/ A car started moving from static, the diameter of its wheels was (80cm) and regularly accelerated till it velocity became (20m/s) through (25s) what is:

1- The angular acceleration of each wheel

2- The number of revolutions that each wheel rotate at this time.

P2/ A wheel rotates with a regular angular velocity when an Anti-torque influenced it which caused the wheel to stop after rotating (50rev) through (10s) what is:

1- The initial angular velocity

2- The angular acceleration

P3/ A disc of radius (0.6m) and mass (80kg) rotate with a velocity (3600 rev/min) how much is the torque influencing the disc to stop the rotation through (20s)?

P4/ A wheel of diameter (0.72m) and inertia moment ($4.8kg.m^2$) a tangential force influenced its edge with (10N) where it started from static, what is:

1- The angular acceleration

2- The average of the rotational power resultant from the angular work done through (4s)?

P5/ A disc has inertia moment of ($1kg.m^2$) was rotating with regular angular velocity, a tangential anti-torque influenced the disc, and stopped it from rotating with regular angular acceleration after (4s) where the rotational work done was (200J) how much is the anti-torque influencing the disc?

P6/ A solid ball of mass (0.5kg) and radius (0.2m) rolled from static from the top of a coarse oblique surface of height (7m) what is the total kinetic energy in the bottom of the oblique surface knowing that the inertia torque of the solid ball is $I=2/5\ mr^2$

8.1 Periodic motion

You have seen the motion of the pendulum of the wall clock, the movement of strings in the musical instruments, the movement of the children's swing, the movement of the simple pendulum, and the movement of the weight suspended in the spring notice figure (1).

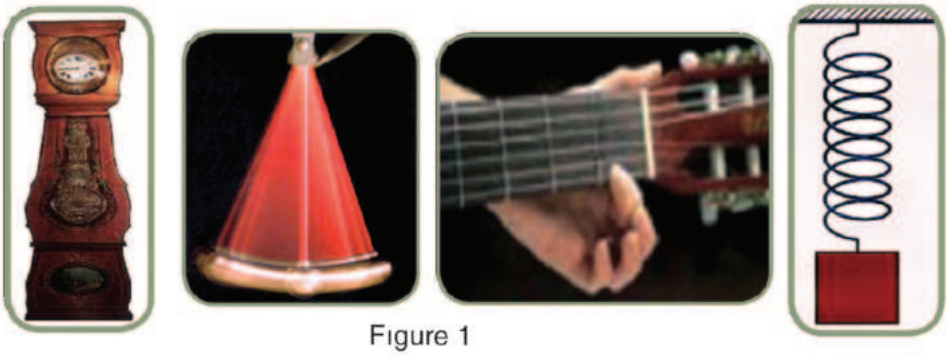


Figure 1

All previous movements repeat themselves over and over again at regular intervals around their positions of stability. Such movement is called periodic motion.

When the body displaced from the position of stability or when it moves away the power of the body to restore the position of stability is called restoring force.

8.2 Vibrational motion

The movement of the body back and forth (in opposite directions) on both sides of its stabilization position is called vibration movement (Figure 2) and its vibration **amplitude** is gradually **damped** due to the presence of energy dissipating forces (like friction forces with the vibrating medium), Vibration motion is a special case of periodic motion and the generation and continuity of vibration motion requires:

- Restoring force
- Continuity
- Source that supply energy

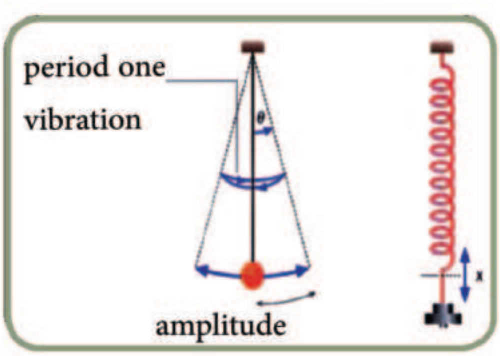


Figure 2

8.3 Simple Harmonic Motion

To identify the simple harmonic motion, is every vibration motion considered a simple harmonic motion?

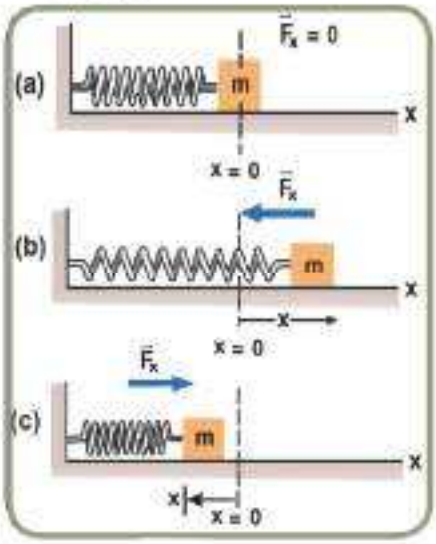


Figure 3

To answer this question we discuss the motion of the object shown in figure (3) that is placed on a frictionless horizontal surface of mass (m) that is tide by one side of a spring and the other side of that spring is fixed to the wall and the mass is in static at the position of stability (x=0). When a pulling force($\vec{F}$) influence the mass(m), it displace it from its position of stability a displacement($\vec{x}$) to the right as in figure (3-b). By this, a work is done on the spring and this work is stored as elastic kinetic energy, as a result the spring that will influence with a force($\vec{F}_x$) it is the elastic force of the spring that tries to return the mass (m) into its position of stability, and this elastic force of the spring equals the magnitude of the force that influence the object and has opposite direction which is called the restoring force.

And when the spring is pushed by the force($\vec{F}$) to the left then the mass will displace a displacement $\vec{x}$ to the left, where an opposite direction and equal magnitude force will appear which is the elastic force of the spring($\vec{F}_{res}$) to the right notice figure (3-c) and the restoring force of the spring is represented by Hooke's Law as follows:

Spring force ($\vec{F}$) = − (spring constant) × displacement

$$\vec{F}_{res} = -k\vec{x}$$

Where:

$\vec{F}_{res}$ = The restoring force measured by (Newton)
k = The spring constant measured by (N/m)
$\vec{x}$ = Displacement measured by (meter)

The magnitude of the restoring force is directly proportional to the displacement and in opposite direction to it (negative sign) and by neglecting the friction force then the mass will move to the right and left with the same range so:

The simple harmonic motion is known as: a vibrational motion on a straight line,which the restoring force and it's the resultant acceleration are directly proportional with the displacement that occurs to the vibrating body from its position of stability and in the opposite direction.

$$\vec{F}_{res} \ \alpha \ -\vec{x}$$

$$\vec{a}_T \ \alpha \ -\vec{x}$$

Activity

Representing the simple harmonic motion graphically

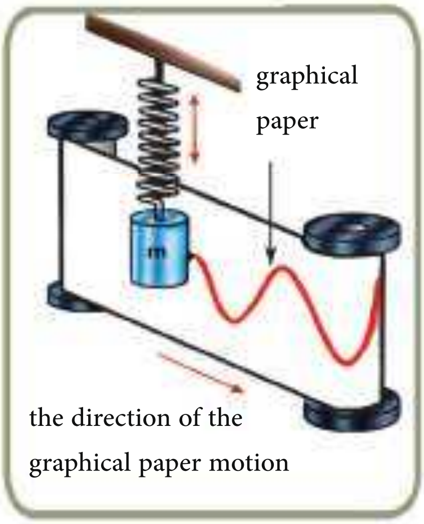


Figure 4

Tools:
An object of mass (m), spring, pen moving on a graphical paper roll that is rolled around a cylinder of vertical axis as shown in figure (4).

Steps:
- We tide the mass with the free side of the spring then we fix the pen by the mass so its top can touch a graphical paper roll. Notice figure (4).
- Pull the mass with a small force downward and leave it move freely a vertical motion then rotate the cylinder so the graphical paper pulls vertically.
- What is the shape that pen will draw?
- The simple harmonic motion representation will appear on the graphical paper that is similar to **sin θ** and **cos θ** curves that you previously studied in math.

And by returning to figure (2) we see that the full wave is the motion of a vibrating body when it passes a certain point on its path twice and in the same direction, while the wave amplitude is the maximum displacement of the vibrating body from its position of stability and the time needed to complete a full wave is called period and has a symbol T

$$\text{Period(T)} = \frac{\text{Time of many Vibration}}{\text{Number of Vibration}}$$

Frequency is known as: the number of vibrations that the object vibrates in one second and it is measured by Hertz (Hz).

8.4 The Relation between Uniform circular motion and simple harmonic motion

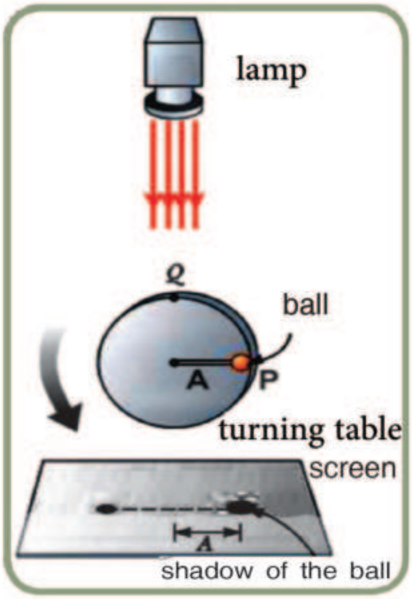


Figure 5

It is possible to observe this relation in the laboratory, by means of a small ball model placed on a regular rotating rotational disk (at a regular angular velocity (ω) so that it casts light on the ball to fall its shadow vertically on a horizontal screen placed under the disc. Notice figure (5).

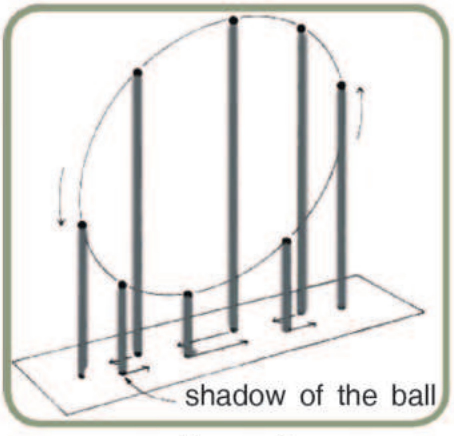


Figure 6

Note that you will see the shadow of the ball on the screen at different locations and that it will take the shape of a sine wave that moves forward and backward with a simple harmonic motion. Notice figure (6).

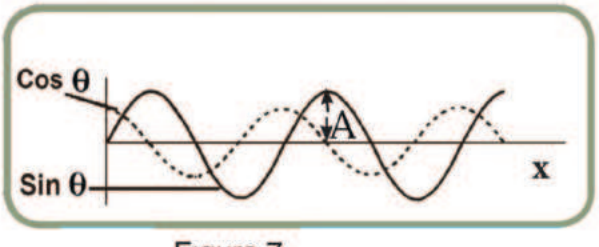


Figure 7

Each periodic movement that can be represented by a sinusoidal curve is a simple harmonic motion. Note Figure (7) as follows:

$$x = A\sin\theta$$

Where:
θ= angular displacement
A= wave amplitude
X= displacement

8.5 Simple pendulum

The simple pendulum contains a ball suspended at the end of a weightless and Non-elongated thread of length (L), and the other end is fixed by a fixed point (o). if the ball was pulled aside and left to vibrate then it swing back and forth around a certain point called the position of stability notice figure (8) and by neglecting the friction forces, and assuming the displacement is small and the angle that the thread make with the vertical is not mare than 5^{o}, then we can consider the motion of the ball as a simple harmonic motion so when the ball move from a to c to b and then return to c then to a it will be completed a full wave.

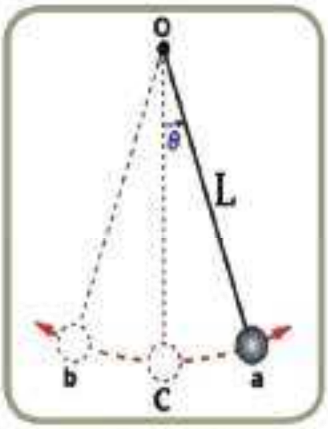


Figure 8

Notice figure (9) then answer the following questions:

- What are the forces influencing the ball at any point in its path?
- What is the influence force causing the acceleration of the ball?

You find that the restoring force F_{res} equals:

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

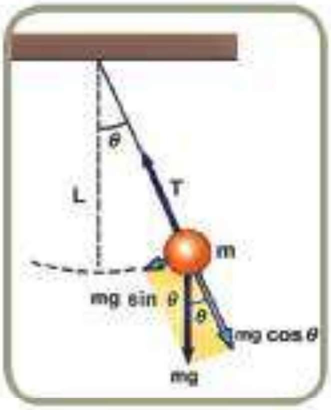


Figure 9

What does the negative sign mean?
Since the restoring force F_{res} of pendulum is similar to moving force of a system (spring , body).

$$\vec{F}_{res} = -k\vec{x}$$

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

Where:

L : the length of the pendulum thread
g : the acceleration of the free fall
T : time period

Example 1:

A pendulum clock has a thread of 1m. Calculate the time period of it if its pendulum was swinging back and forth with a simple harmonic motion, knowing that g = 9.8 m/s²

Solution

$$T = 2\pi\sqrt{\frac{L}{g}} \Rightarrow T = 2\pi\sqrt{\frac{1m}{9.8m/s^2}}$$

$$T = 2s$$

8.6 Damping simple harmonic motion

We know that the pendulum, which moves a simple harmonic movement, its movement continues as long as the energy of the system is conserved. But when an Obstructive force exists as a friction force, such as when a weight is suspended with a spring is immersed in water or high viscosity fluid notice figure (10) this movement does not continue, its vibration gradually damping, This type of vibration is called damping vibration as shown in figure (11).

Figure 10

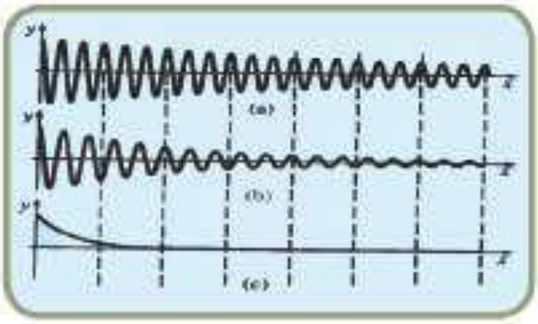


Figure 11

Figure 12

It is clear that in order to vibrate any system for a certain period of time has to be supplied with power continuously to compensate for the energy lost during each pulse and by doing work against the forces of friction, as in the case of pulling a children swing continuously to supply the system with the energy lost at each frequency Figure (12).

Figure 13

Damping vibration also has practical application benefits. In the vehicle's shock absorber system (suspension), the shock absorbers dampen the vibrations caused by the vehicle's passing on road bumps notice Figure (13).

8.7 Wave motion

Figure 14

If you think about what around you will find a lot of wave phenomena that you see every day, such as: Disruption of the surface of static water when a stone is thrown into it and the energy-carrying waves are in the form of concentric circles from the point that the stone fall in to the sides As well as the movement of seismic waves in the Earth's crust energy transporter on the surface of the earth as well as the spread of the sound of the strings of musical instruments vibrating in the air through the vibrations of air molecules. The waves are considered energy transportation methods in all its forms notice figure (14).

Wave motion is a disturbance caused by an energy source. We will begin our study of the waves by discussing what can be understood - the wave generated by a Taut string.

8.8 Pulses in a string

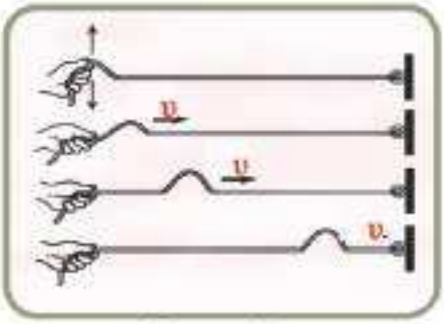


Figure 15

If the end of the string is set tightly and the tip of the other end moved very quickly to the top or bottom a disturbance will be generated which is called a pulse and This pulse moves to all the parts of the string, carrying energy (potential and kinetic) without the passage of the string molecules with it, notice figure (15) the pulse move through the string with velocity (υ) cutting displacement $(\vec{x})$ $[\vec{x}=\vec{\upsilon}.t]$ When the string vibrates, each particle vibrates a simple harmonic motion up and down and the maximum displacement of particles from positions of stability is called amplitude (pulse amplitude) The pulse transmitted through the string with the speed υ called the pulse speed, so the wave generated in the string is a series of pulses.

The speed of the wave in the string depends on the tension of the string (T) and the mass of the length unit of the string (linear mass density) μ.

Where: $$\mu = \frac{m}{L}\ (kg/m)$$

$$\text{Wave speed} = \sqrt{\frac{\textit{Tension}\ \text{in the string}}{\textit{Linear}\ \text{mass density}}}$$

$$\upsilon = \sqrt{\frac{T}{\mu}} \Rightarrow \upsilon = \sqrt{\frac{T}{m/L}}$$

Where:
T : is the tension in the string
μ : is the Linear mass density which is measured by $\frac{kg}{m}$.

The distance between two consecutive peaks or bottoms is equal to the length of a full wave λ and the time of the one cycle (T) of the wave is the time required to vibrate any point in the path of the wave (one vibration) one cycle and the frequency f is:

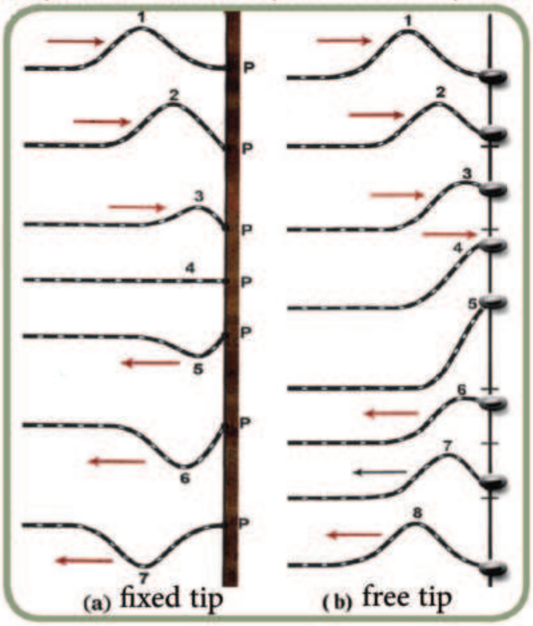


Figure 16

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

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

$$\lambda = \upsilon T$$

It is worth mentioning that the above relations are correct for all waves, as The frequency of the wave is determined by the frequency of the source generating and the wave speed depends on the characteristics of the medium in which it is moving in (such as elasticity and density). When a pulse is generated at the tip of a string and the other end is fixed at a barrier the pulse will move through the string to the right and reach the barrier and influence it with a force upward But the barrier will influence the string by the reaction force that is equal in magnitude and reversed in direction downward and this force will cause the movement of the string downward to drop from its position of stability **then** The pulse is reflected (the **crest** is reflected to be **trough** and the **trough** is reflected to be **crest**) and this is called the coup. Thus, the reflected pulse varies by a phase difference of 180° from the falling pulse. If the tip of the string is free, it moves up and down, then the reflected pulse does not suffer a phase shift (in the same phase) notice figure (16).

Example 2:

A guitar string with a mass of 20g and a length of 60cm what is the amount of tension required in the string to be the wave speed of 30m/s?

Solution

$$\upsilon = \sqrt{\frac{T}{m/L}}$$

$$T = \frac{m\upsilon^2}{L} \Rightarrow = \frac{\frac{20}{1000} \times (30)^2}{\frac{60}{100}} = \frac{0.02 \times 900}{0.6}$$

$$T = 30N$$

8.9 Principle of superposition

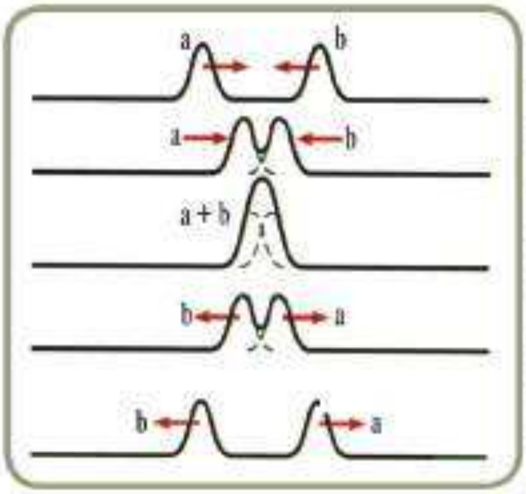


Figure 17

Most of the wave movements that we hear or see or feel in our lives contain a large number of waves, such as the light of the sun which consists of the seven colors of the spectrum, and the sounds we hear that can be spread independently may meet and give a single wave movement this phenomenon is called the Principle of superposition waves, The principle of superposition can be clarified as follows: When two pulses move through a point in a string and at the same time their net displacement at the point of convergence will be equal to the total of the two waves of the resulting pulses each individually in the same string, and The pulses then appear again after the convergence and continue in their original path regardless of the presence of the other pulse notice figure (17).

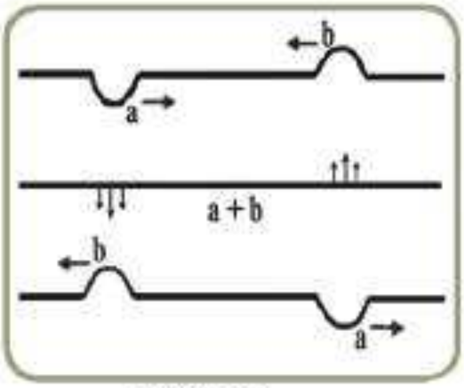


Figure 18

This behavior of the pulses at convergence is called Principle of superposition. When two pulses pass in opposite directions and with the same amplitude (the phase difference is 180 °), according to the principle of the superposition the net displacement at the point of convergence is equal to zero, and then the impulses return to their original path after the point of convergence notice figure (18).

8.10 Periodic waves

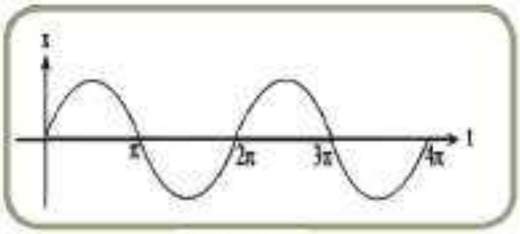


Figure 19

Periodic waves are waves that repeat themselves at regular intervals, and all types of periodic waves have the form of the sinusoidal wave (sine wave-form) so it can be represented by the sine curve or cosine curve like water waves and light waves notice figure (19).

Since the particles of the moving material in the vibrating medium move a simple harmonic movement in a vertical direction to the direction of the wave, which has the shape of the sinusoidal wave. Periodic waves can be described in three quantities: wave speed υ ,wavelength λ, and frequency f. Which are related to each other in the following relation:

$$\text{wave speed} = \text{frequency} \times \text{wave length}$$

$$\upsilon = f\,\lambda$$

Example 9:

A radar sends radio waves at a time of 0.08s and a frequency of 9400MHz if you know that the speed of radio waves is $c = 3 \times 10^8$ m/s find:

a- Wavelength

b- Number of waves

Solution

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8 m/s}{9.4 \times 10^9 Hz}$$

$$\lambda = 3.19 \times 10^{-2} m = 3.19 cm$$

$$n = ft = (9.4 \times 10^9 Hz)(8 \times 10^{-2} s) = 75.2 \times 10^7 \text{ numbers of waves}$$

8.11 Kinds of waves

In your previous study, you knew the types of waves, the waves types are known as:

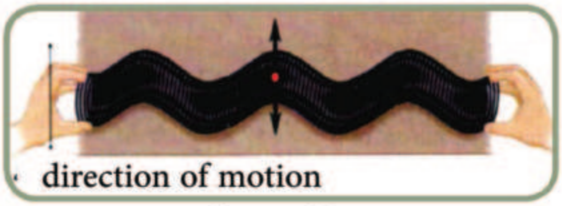


Figure 20

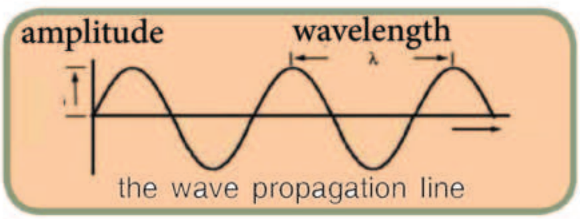


Figure 21

1- Transverse waves:

As in the waves in the one-sided tensile rope and the **spring** where the medium particles vibrate in a perpendicular direction on the wave propagation line, notice figure (20).

The transverse wave can be represented by a cosine, sine curve where the × axis represents the stability positions of the vibrating medium particles and the y axis represents the displacement of the particles from their stability positions notice figure (21).

Transverse mechanical waves can only be applied in flexible mediums whose particles have sufficient coherence forces Such as solid objects and free surfaces of liquids as the vibrating particle can move the adjacent particles perpendicular to the direction of wave propagation. And Transverse waves that do not need a physical medium for transmission are electromagnetic waves.

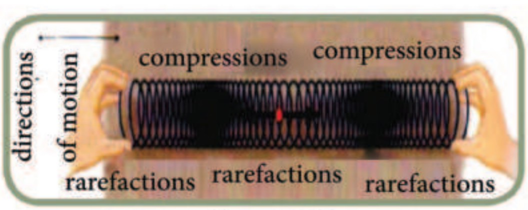


Figure 22

2- Longitudinal waves:

In which the particles of the medium vibrate parallel to the wave propagation line as in Figure (22) as in the oscillator and the sound waves, as the vibration of a **tuning** fork in the air generates a series of periodic compressions and **rarefactions** over time spread through the air.

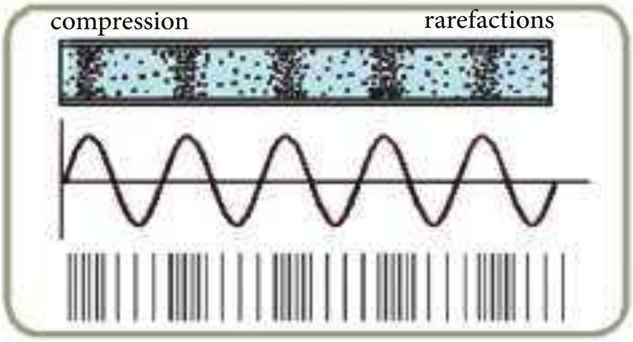


Figure 23

The longitudinal wave can be represented by drawing by close straight lines represents the compressor regions and others occasional represents the rarity regions or it can be represented graphically by sine curve and it is call the compress and rarity curve of the longitudinal notice figure (23).

The speed of the wave represents the distance that the peak of the wave far from the deep or the compress center or extract center from the waving center in one second which depends on:

1- The kind of the wave

2- The nature of the transportation medium for its elasticity and density.

The speed of the longitudinal wave in different mediums depends on the elastic coefficient and the mass density of the medium that is:

$$\upsilon = \sqrt{\frac{\beta}{\rho}}$$

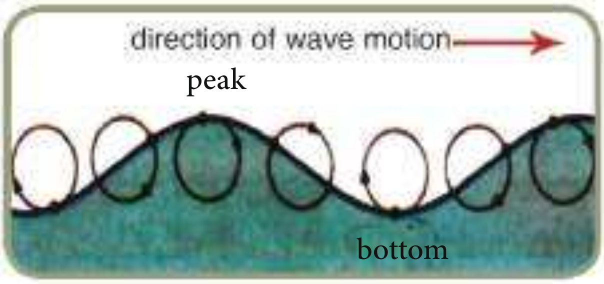


Figure 24

Some wave shows as the water waves by the combine of two kinds of wave's transverse wave and longitudinal wave notice figure (24) when the water waves propagate on the deep water surface the particles exist on the surface moved in circular path. Where the transverse displacements are the change in the vertical change of water particles. And the longitudinal displacement happens when a wave passes on the surface of the water, the water particles move at the peaks in the direction of wave motion while the particles move at the bottom in the opposite direction where the particle that exist on the top will be in the bottom after half a cycle so it motion is the direction of wave motion will vanish because of the existence of the opposite direction motion. And this is applied on all particles affected by the wave so that the waves are on the water surface. As in three-dimension waves that are resultant from earthquakes under the ground contains two kinds of waves (transverse wave and longitudinal wave).

8.12 Sound

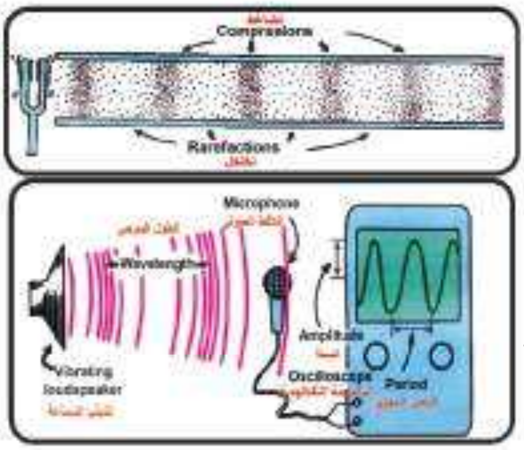


Figure 25

speed of sound in various media v(m/s)	
gases	
1286	hydrogen (0C)
972	helium (0C)
343	air (20C)
331	air (0C)
317	Oxygen (0C)
Liquids at 25C	
1533	Sea water
1493	water
1450	mercury
1324	kerosene
1143	methgl alcohol
926	carbon tetrachloride
solids	
12000	dimond
5640	pyrex glass
5130	iron
5100	aluminum
4700	Brass
3560	copper
1322	Lead
1600	rubber

As we study my dear student in the previous level of your study about the nature of sound is a kind of energy that transfer from a place to another as longitudinal wave in physical mediums that reach the ear so we hear, and to generate the sound there must be a vibrating source in physical medium,that transfer the vibration it may be gas, liquid or solid. the sound wave cannot be transferred through a vacuum notice figure (25) two sources are sending sound waves in the air. The frequency of the sound vibrations that is hearable by humans' ears is between (20-20000Hz) so the sound generated from the vibration of loud speaker (convert the voltage into sound frequency) cause changes in the air pressure, then the air particles vibrate around its position of stability, and since the pressure is irregular then the air particles acquired a force as a result to change in air pressure then the force direction always far from the compress regions and in the direction of rarefaction then the air particles move right and left in the direction of compress and far from rarefaction and the speed of sound depends on the nature of medium that transfer in it, then the speed in solids bigger than the speed in liquids and the speed in liquids bigger than the speed in gases and you can notice in table (1) the different speeds of sound in different mediums.

The speed of the sound in the solid objects depends on the **elasticity** and density of the medium, the sound speed at $0^{\circ}C$ and pressure (1atm) in the aluminum 5100m/s , while the sound speed in the air at the same degree of 331m/s.

On this basis, the sound speed can be formulated with the following relation:

v_s : sound speed

Y : Young's modulus

ρ : density of medium

$$v_s = \sqrt{\frac{Y}{\rho}}$$

Example 4:

If one end of an aluminum roads knocked with a hammer a longitudinal wave propagate through the road. Calculate the sound speed in aluminum road. Note that the Young's modulus of aluminum is equal to $7x\ 10^{10}\ N/m^2$, and the aluminum density is $2.7x10^3\ kg/m^3$

Solution

$$v_s = \sqrt{\frac{Y}{\rho}} = \sqrt{\frac{7x10^{10}\,N/m^2}{2.7x10^3\,kg/m^3}} = 5091\,m/s$$ speed of sound in aluminum

This result is much larger than the amount of the speed of sound in the gas, as shown in the table (1) so that the solids particles are linked more coherent manner and the response to the disturbance is more rapid.

The speed of sound in gases depends on the type of gas and its temperature when temperature increase for one Celsius degree the speed sound in the air increases by 0.6m/s then the speed sound in air at a temperature T:

$$v = 331 + 0.6T$$

The sound speed is increased by increasing the humidity in the atmosphere because the density of the wet air is less than the density of the dry air and the speed of sound in liquids is given in relation to:

$$v_s = \sqrt{\frac{\beta}{\rho}}$$

where β represent liquid elastic coefficient and measured by N/m^2.

Example 5:

Calculate the speed of sound in the water that has elastic coefficient 2.1×10^9 N/m² and density 1×10^3 kg/m³

Solution

$$\upsilon_s = \sqrt{\frac{\beta}{\rho}} = \sqrt{\frac{2.1 \times 10^9 N/m^2}{1 \times 10^3 kg/m^3}} = 1449 m/s$$ the speed of sound in the water

8.13 Interference of wave

You may have sensed that you can clearly hear a person's voice even though his voice intersects with other voices, Have you ever wondered what happens when two or more waves **meet** in the same **medium** ?

What impact will this **meeting** have? These and other questions we can answer, after the following activity:

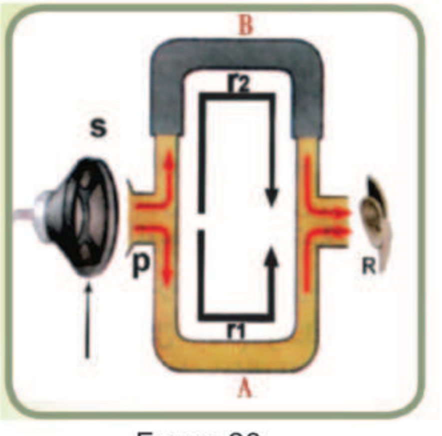


Figure 26

Activity:

Illustrate of interference **phenomenon** in sound

Tools:

The **quincke's** tube is composed of a metal tube A with two branches containing two side openings, P and R, and this tube slides into another tube B uses tube B to change the length of the path (PBR) notice figure (26).

Steps:

- Hit a **tuning fork** or any other sound source at the P hole and a compression will occur.
- Move the tube B so that the PAR-PBR **paths** are equal, i.e the two compression will reach the R hole at the same moment, we hear the sound at the R hole clearly.
- Pull the tube B gradually outwards and increase the length of the path (PBR) from the path PAR and continue to pull the tube, the sound is absent at a certain position and the drag continues to increase the **intensity of sound** again.
- When the length of the two **paths are equal** (PAR) (PBR), the waves arrive from the two **paths** of the hole P and are **same** in the phase will meet the **compression** of the first **path** with the **compression** of the second **path** and also meet the **rarefaction** of the first **path** with the **rarefaction** of the second **path** will strengthen

the sound which it means constructive interference.

- When the length of one of the two tubes is different from the other length, the path difference $(\frac{\lambda}{2})$ will then overlap the compression from the first path with rarefaction frome , the second path, causing an adestructive interference that results in a decrease in sound as the energy of the resulting wave disappears.

We conclude that:

The process of convergence of a set of waves of one type at a time called interference of waves and to obtain a clear and continuous interference pattern must have the same interfering waves the same amplitude and frequency itself.

When the confluence of waves occurs, two types of interference occur:

• Constructive interference:

When the waves overlap, a reinforcement occurs in the resulting wave, called a Constructive interference at interference of the meeting or peak of the wave with another wave peak meeting of the two wave-bottom. Notice Figure 27a.

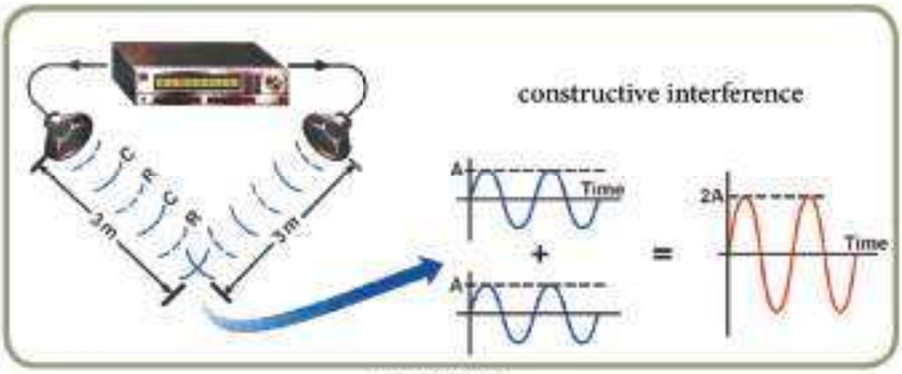


Figure 27-a

• Destructive interference

Where the waves cancel the effect of each other, such as the confluence of the peak of the wave with the bottom of another wave. Note Figure (27b)

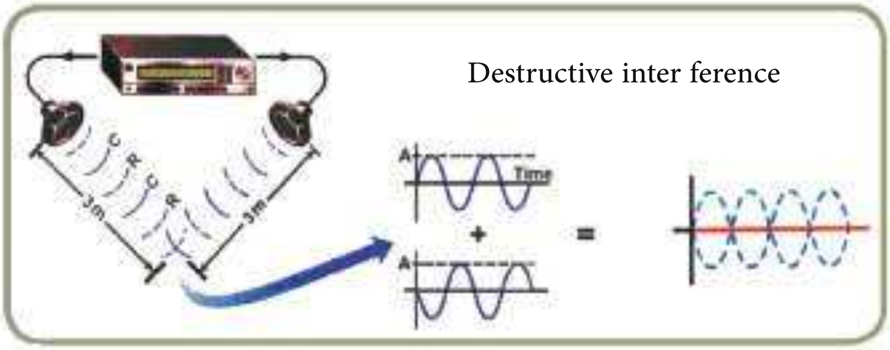


Figure 27b

8.14 Resonance

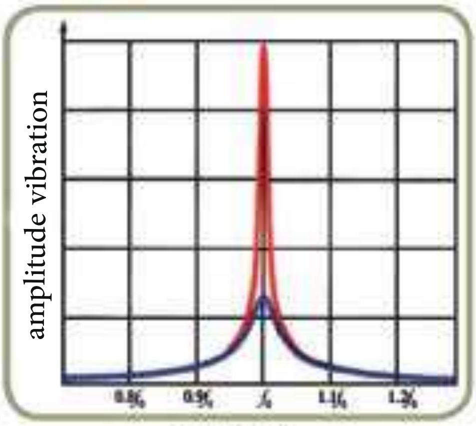


Figure 28

Figure 29

If a periodic external force is affected in a vibrating system and the influence force frequency f is equal to the normal frequency of f_0 that is:

$$f = f_0$$

The relative amplitude of the system vibration is increased. It is then said that the force is in resonance with the system and the frequency in this case is called the resonance frequency and that the system has the maximum energy notice figure (28).

This situation can be observed as it increases vibration swing amplitude when the person standing behind it push it strongly towards the movement at each pulse at the same frequency notice Figure (29).

Think ?

it is not allowed for the soldiers to walk on bridge regularly?

8.15 Beats

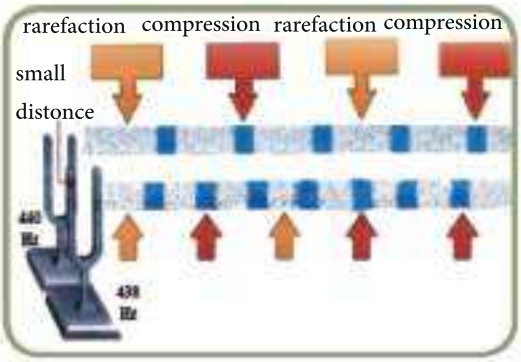


Figure 30

If two tuning forks with slightly different frequencies notice figure (30) then we will hear a voice of varying intensity periodically and this phenomenon is called beats, which is the periodic change in intensity at a point as a result of the interfer of two waves with two slightly different frequencies.

The frequency of beats f_B equal to the difference between the sources frequencies as follows:

$$f_B = f_1 - f_2$$

The phenomenon of beats can be easily recognized if the difference between the interfering waves frequencies is small, not exceeding 10Hz, depending on the ability of the human ear to distinguish it. In general, the human ear cannot distinguish two-tone beats if the frequency difference between them is greater than 7Hz.

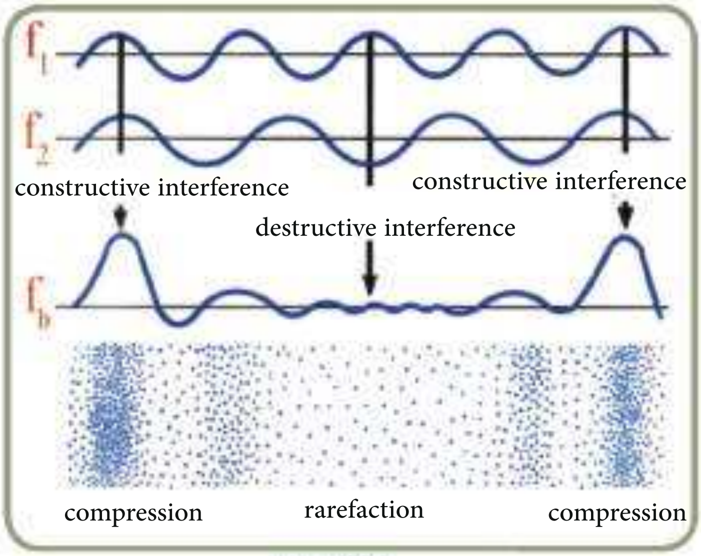


Figure 31

The wave frequency (f) resulting from the waves interference Notice Figure (31) is equal to the average frequency of the waves:

$$f = \frac{f_1 + f_2}{2}$$

Where:

f_1 the first wave frequency

f_2 the second wave frequency

The Beats phenomenon Invested to indicate:

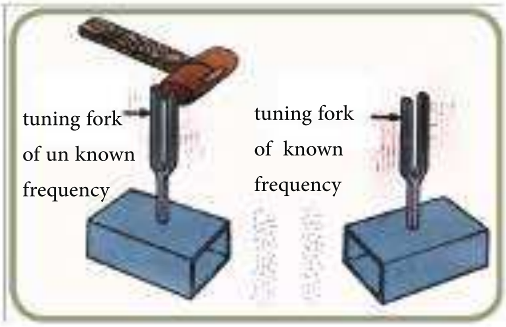
- The frequency of a tendon in a musical instrument.
- Anonymous frequency of tuning fork mediated by other tuning fork.

Example 6

It is intended to set the frequency of a tuning fork near another vibrating one of frequency 446Hz, which was heard from it 7beats/sec. How much is the frequency of the unknown fork?

Solution

$$f_B = f_1 - f_2$$
$$7 = f_1 - 446$$
$$f_1 = 453Hz \quad or$$
$$7 = 446 - f_2$$
$$f_2 = 439Hz$$



To know wich frequency is the correct one, put a load on un known frequency fork (the frequency decreas) if :

1- Beats per second decreas then f_1 is the corrcet frequncy.

2- Beats per second in creas then f_2 is the corrcet frequncy.

Think?

How can you get the phenomenon of beats using two equal frequencies tuning forks?

8.16 Standing waves

You may wonder what is the phenomenon of waves standing? And how do they occur? is it all wave happen?and the most important practical application on it?

These and other questions you can answer after doing the following activity:

Activity

The standing waves in the string

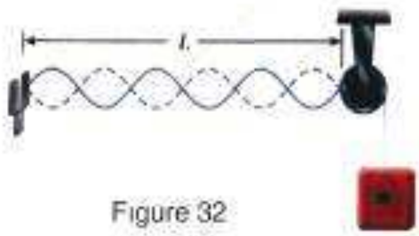


Figure 32

Tools

Tuning fork, string, weight.

Steps

- Fix one end of the string with one of the sub-branches of the tuning fork as in Figure (32).
- Make the other sub-branch of the string passes on the pulley and the weight hanging from it.
- When the tuning fork vibrate, after controlling the length of the string or changing the amount of weight or

both to make the string vibrate with an integer numbers of halves of the wavelength What do you notice? Generated waves will be reflected at the end of the string and bounce in the opposite direction to meet with falling waves composed of standing waves the string is divided into several regions consisting of a nodes and an antinodes . The amplitude of vibration, energy and velocity of the medium particles are absent at the nodes while The amplitude of vibration, energy and velocity of the medium particles increases between each two nodes and the largest amplitude is at mid-distance between each successive nodes Which are called the antinodes and the places of these antinodes and nodes are fixed so these waves are called standing waves or stationary wave. The standing waves are those waves that arise from the interfer of two equal waves in frequency and amplitude that go in opposite directions and have same speed in one limited medium.

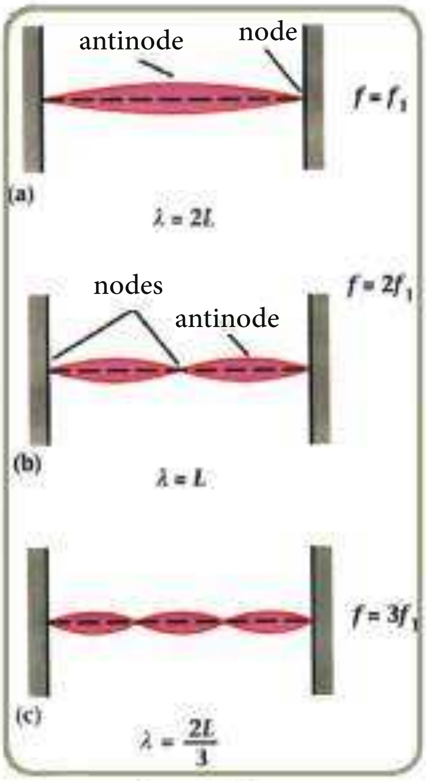


Figure 33

Figure (33) representing standing waves generated in a tight string between two points. To find a relation between the length of the vibrating string and the wavelength of the standing wave notice figure (33).

- How many antinodes are in each case?
- How much is the distance between every two nodes of the wavelength of the standing wave in each case?
- What is the relationship between the wavelength and the length of the string?

Depending on your answer to the above questions, then:

string length (L)=number of antinodes (n)× $\frac{(\lambda)}{2}$

$$L = n \cdot \frac{\lambda}{2}$$

Where n=1, 2, 3 ....

From the relation: $\upsilon = \lambda f$

Frequency is given by the following relation:

$$f = \frac{\upsilon}{\lambda} = n \cdot \frac{\upsilon}{2L}$$

If n=1,

$$f_1 = \frac{\upsilon}{2L}$$

Where f_1 is known as Basic frequency or first harmonic.

If n=1, f_2 is known as second harmonic.

$$f_2 = \frac{\upsilon}{L}$$

And so on...

Example 7

In figure (34) a string of length 42cm in which a standing waves of six antinodes and speed 84 m/s was generated, find the wavelength and the first and second harmonics?

Solution

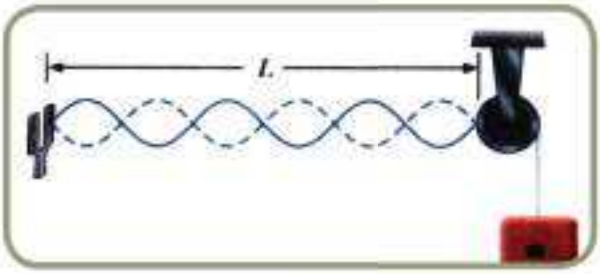


figure (34)

$L = n \cdot \frac{\lambda}{2}$ when (n) is number of antinodes

$0.42 = 6 \times (\frac{\lambda}{2})$

$\lambda = \frac{0.42}{3} = 0.14m$ length of standing wave

we find the first and second harmonics by relation.

$f = n \cdot \frac{\upsilon}{2L}$

$f_1 = \frac{1 \times 84}{2 \times 0.42} = 100Hz$ frequency of first harmonic

$f_2 = \frac{2 \times 84}{2 \times 0.42} = 200Hz$ frequency of secand harmonic

$f_2 = 2f_1$

8.17 Sound characteristics

The voices differ from each other with three basic characteristics:

1) Loudness of the sound.
2) Pitch of the sound
3) tone of the sound.

(1) Loudness

The loudness of the sound is related to the intensity of the sound that has an effect in the ear that gives us a sense of loudness or lowness. Voices around us may be as high as the sound of thunder may be as faint as whispers and sound intensity at a certain point is known as:

((The time average of acoustic energy to unit vertical area of the wave, which is centered at that point)) notice figure (35).

Sound intensity =(Acoustic power)/area

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

P : acoustic power measured by (watt)
A : the area measured by m^2
I : sound intensity measured by $Watt/m^2$

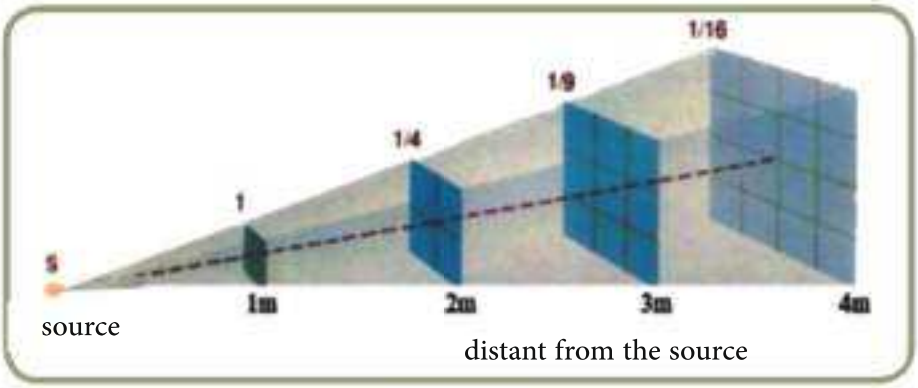


figure 35

The intensity of the sound at the point from the medium depends on:

1) The distance of the point from the source: The sound intensity at a particular point is inversely proportional to the square of the distance between the point and the sound source.

2) Amplitude and frequency of source vibration: the sound intensity is directly proportional to each of the square of amplitude vibration sound source as well as to the square of source frequency.

3) Surface area of the vibrating source : The intensity of the sound increases as the surface area of the vibrating body increases.

4) density of propagation medium: The intensity of the sound increases as the density of the vibrating medium increases.

8.18 Measuring sound levels

you have already studied dear student that the sound frequencies that are sensitive to the human ear well are between 20000Hz - 20Hz, and do not hear the sound if the frequency is less than 20Hz (the frequencies of the infrasonic wave) and greater than 20000Hz (the frequencies of ultrasonic wave).

The relationship between sound intensity and loudness is not a direct relation, but is a logarithmic relationship, as the human ear does not equalize the sounds of different frequencies and equal in intensity.

The human ear senses the intensity of the sound about 10^{-12} Watt/m² till (1 Watt/m²) when the sound frequency is 1000Hz and the intensity 10^{-12} Watt/m² was considered to be the beginning of the hearing and it was called the hearing threshold, and a logarithmic scale was used to calculate the intensity level of the sound that intensity (I) is:

$$L_1(decibel) = 10\left(\log_{10}\frac{I}{I_o}\right)$$

The intensity level L_1 represents the logarithmic relation between the sense of loudness and its intensity at a particular frequency.

Where:

I_o: Represents the hearing threshold of 10^{-12} Watt/m²

L_1: Represents the intensity level that is measured by (dB) decibel

It should be noted that the level of sound intensity at the threshold of hearing is ZERO because:

$$L_O = 10\log\frac{10^{-12}}{10^{-12}} = 10\log_{10}(1) = 10\times 0 = 0$$

And since the greatest intensity that ear can hear is (1 Watt/m²) Then highest level of acoustic intensity at the pain threshold is:

$$L_1 = 10\log\frac{1}{10^{-12}} = 10\log_{10}10^{12} = 120dB$$

Table (2) shows the intensity levels of different sound sources.

Table (2) the intensity levels of different sound sources	
Sound source	intensity level of the sound (dB)
Nearby jet airplane	150
Siren' rock concert	120
Subway, power mower	100
Busy traffic	80
Vacuum cleaner	70
Normal conversation	50
Mosquito buzzing	40
Whisper	30
Rustling leaves	10
Threshold of hearing	0

(2) Pitch of the sound

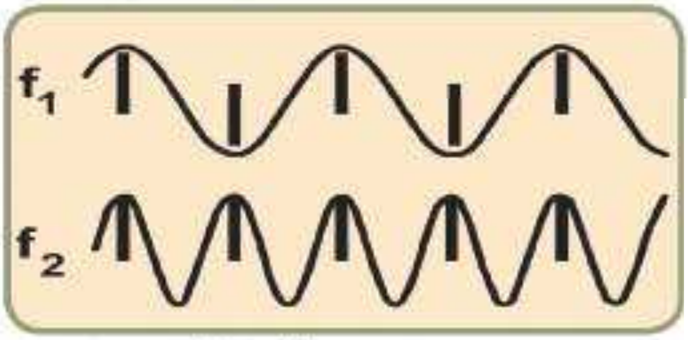


Figure 36

It is a sound property that depends on the frequency of the sound waves that reach the ear, which distinguish between the sharp sounds like the voice of the woman and the thick sounds like the voice of the man? If the frequency of the tone is small, the tone is said to be low- Pitch. If the frequency of the tone is high, the tone is said to be of high Pitch. Notice figure (36).

(3) Tone of the sound

It is this characteristic by which the ear is distinguished between the similar tones in the pitch and intensity of the different musical instruments. For example, a tone of tuning fork of 256Hz can be distinguished from another tone with the same frequency from a piano or violin. Depending on the type of source and the sound generation method, notice figure (37).

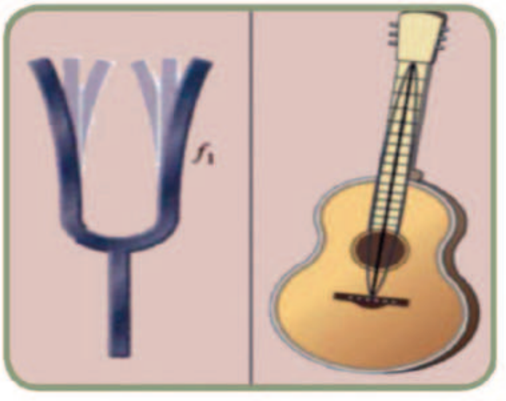


Figure 37

Do you know?

Roofs and walls are furnished according to the purpose of the use of rooms and halls. The ceilings designed for high frequency are usually flat and solid. The rows, libraries and quiet spaces are often soft and covered with sound absorbing material. Notice figure (38).

Figure 38

Example 8:

Two identical instruments were placed on the same dimension of a worker, the intensity of the sound coming from each machine to the worker's position is (2×10^{-7} Watt/m^2). Find the level of **intensity** heard by the worker:

- When one of the instruments is working
- When both of the instruments are working

Solution

a) we calculate the intensity level L_1 at the position of the worker when one of the two machine is warking from the following equation.

$$L_I = 10\log_{10}\frac{I}{I_o}$$

$$L_{I1} = 10\log_{10}\frac{2\times10^{-7}\,watt/m^2}{1\times10^{-12}\,watt/m^2} = 53dB$$

b) The intensity is muttiplies to 4×10^{-7} Watt / m^2 , so the intensity level in this case is:

$$L_{I2} = 10\log_{10}\frac{I}{I_o}$$

$$L_{I2} = 10\log_{10}\frac{4\times10^{-7}\ \text{Watt}/\text{m}^2}{1\times10^{-12}\ \text{Watt}/\text{m}^2} = 56\ \text{dB}$$

that's mean when the intensity mutliply, the intensity level increases by 3dB only.

Think ?

The violinist plays solo and then joined by nine musicians and everyone plays the same intensity as the first musician.

a) When all the musicians play together, how much intensity is the sound of the group?

b) If ten other musicians join, how much more intensity in sound from the one player case?

8.19 Ultrasonic waves

Ultrasonic waves are mechanical waves that propagate at the same speed as sound but have a high frequency of more than 20000H_z and its practical applications:

• Investing in the set dimensions and depths of the sea, as used by the bat in collision avoidance, including blocking their way during the flight, as ultrasonic waves transmitted and reflected when colliding with any obstacle, and the bat receives the reflected waves indicate the existence of obstacles and avoid them, It is also used by humans to calculate the depths of the sea by sending a signal from the ultrasound to the seabed and receive the signal reflected by a special receiver, And by calculating the time of coming and going of the wave and knowing the velocity of ultrasonic waves in the sea water, you can find out how much the depth is.

• Invests in medical and surgical examinations, because each member of the human body, such as tissue, bone and fat vary in their ability to reverse these waves when falling on them, When shedding a package of ultrasonic waves on the part to be examined and receiving the reflected waves on the electronic device connected to a television screen showing the image area to be scanned and It is preferable to use ultrasonic to use X-rays to avoid the harmful effects of X-ray on the body.

• Invest in manufacturing to check the homogeneity of the metal machine and detect defects.

• Invests in the elimination of some bacteria such as diphtheria bacteria and tuberculosis bacteria, as it stopped some viruses and limit their impact.

• Invest in sterilization, purification and refinement: When an ultrasonic passes through a liquid, the particles of the oscillating medium have more velocity and acceleration, and as a result, interruptions in liquid contacts occur continuously. These interruptions are bubbles and when the interruptions fail, a momentary rise in pressure occurs thousands of times as much as atmospheric pressure, thus fragmenting what is present in a liquid of molecules or organisms. Fat and oxide layers are also removed in this way as well as in glass and ceramics.

• It invests in medicine for massage by moving it to the skin, causing its rapid vibration and muscle massage as it is used to break the stones in the kidneys.

Think ?

Why do high frequency (ultrasonic) waves work better than low-frequency waves when determining the location by the echo in the Dolphins?

Notice figure (39).

Figure 39

8.20 Doppler Effect

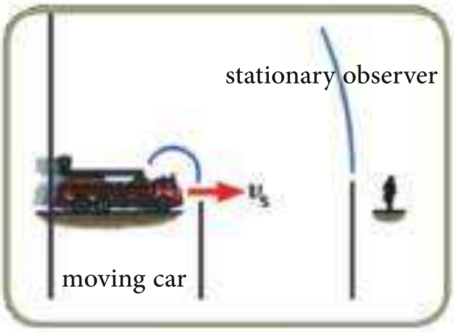


Figure 40

You may have noticed how the sound of a car alarm changes as the car moves away from you. The frequency of the sound you hear when the car approaches you is higher than what you hear when the car moves away from you. The phenomenon of change in the audible frequency from source frequency if the medium or the listener or the source move with respect to each other is called the Doppler Effect.

Doppler Effect is examined if the frequency of the audible wave produced by a sound source changes in the case of a relative movement between the source and the transmitter when the medium is stationary or moving notice figure (40) To illustrate this effect, we assume that the medium is stationary and that the source of the sound and the listener are approaching or moving away from each other. An example of this is the sound of the moving train as the sound of the beep rises when the listener is close and decreases by going far away. You will examine the Doppler Effect as follows:

a- When the sound source moves at a regular velocity towards a static listener.

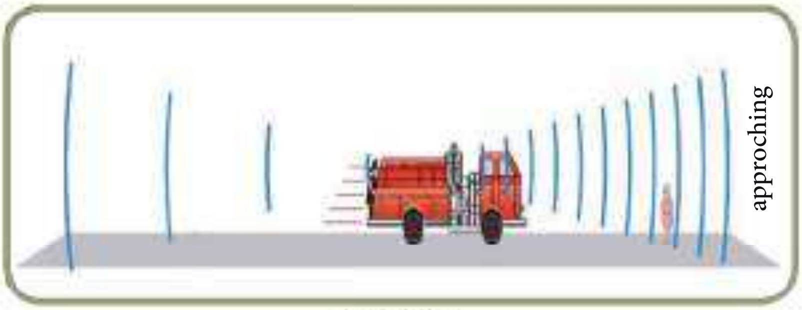


Figure 41

By noticing figure (41) we find that the sound source moves at a regular velocity v_s towards a static listener. The actual frequency of the source(f)and the sound velocity in that medium(v) the frequency of the audible sound is given in the following relation:

$$f' = \left(\frac{v}{v - v_s}\right) f$$

$$f' > f$$

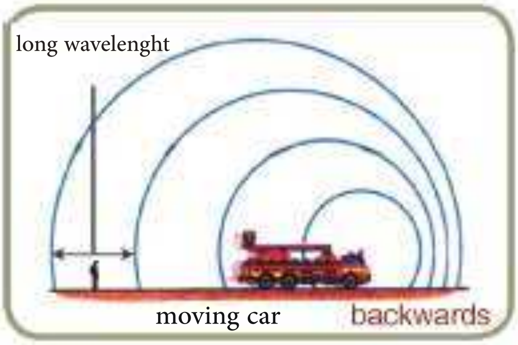


Figure 42

b- When the sound source moves backwards a static listener:

The direction of the source velocity v_s opposite to the sound velocity direction v so we evaluate the source velocity with negative sign ($-v_s$):

$$f' = \left(\frac{v}{v + v_s}\right) f$$

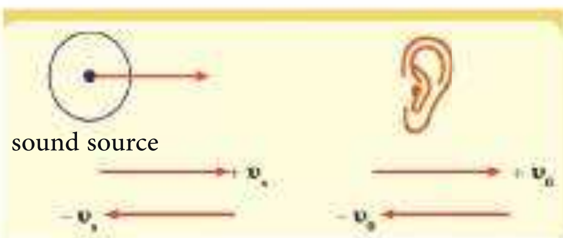
In general:
If the source is moving at velocity v_s and the listener Is moving at velocity v_o atthe same plane, then the general statement can be written as:

$$f' = \left(\frac{v - v_o}{v - v_s}\right) \times f$$

Remember:

If the source was moving at velocity v_s getting close to the listener then we evaluate the source velocity to positive. However, if the source was moving at velocity v_s getting far from the listener then we evaluate the source velocity to negative.

If the listener was moving at velocity v_o getting close to the source then we evaluate the listener velocity to negative. However, if the listener was moving at velocity v_o getting far from the source then we evaluate the listener velocity to positive in the condition to evaluate the velocity sign positive if the direction from the source to the listener and negative if it was in opposite direction. And the velocity of (static source and static listener) is ZERO.



Do you know?

One of the medical applications of Doppler Effect is Doppler flow meter to measure the blood flow notice figure (43).

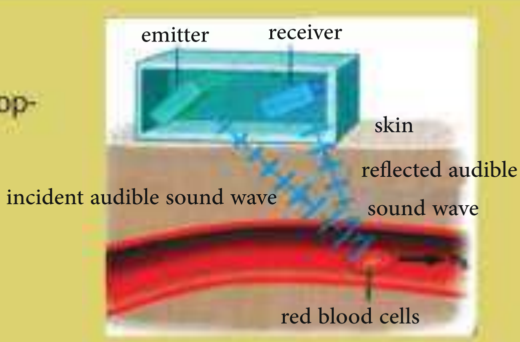


Figure 43

Example 9

A car moves in a straight line with a constant speed (72km/h) relative to a man standing on the pavement and the alarm sound in the car makes a sound of frequency 644Hz and the sound speed in the air then is (342m/s). Calculate the amount of frequency that a man hears and the audible wavelength when the car is moving: a) towards the man. b) away from the man.

Solution:

$$f' = \left(\frac{\upsilon - \upsilon_o}{\upsilon - \upsilon_s}\right) \times f$$

a) since the sound source approaching to the listener then the relocity source with positive sign (with the direction of the sound wave spread).

$$\upsilon_s = \frac{72 \times 1000}{3600} = +\,20\text{m/s}$$

$$f' = \frac{342 - 0}{342 - (+20)} \times 644$$

$$= \frac{342}{322} \times 644$$

$$f' = 684 \text{ Hz}$$

$$\lambda' = \frac{\upsilon}{f'}$$ (we assume audible wavelength λ')

$$\lambda' = \frac{342}{684} = 0.5\text{m}$$

b) since source sound is moving a way from the observer (listener) so the source velocity substitute by negative sign (reverse the direction of propagation of the sound wave) $\upsilon_s = -20 \frac{m}{s}$

$$f' = \left(\frac{\upsilon - \upsilon_o}{\upsilon - \upsilon_s}\right) \times f$$

$$f' = \frac{342 - 0}{342 - (-20)} \times 644 = \frac{342}{362} \times 644$$

$$f' = 608.42 \text{ Hz}$$

$$\lambda' = \frac{\upsilon}{f'} = \frac{342}{608.42} = 0.5621\text{m}$$

Example 10:

A cyclist moves quickly (5m/s) in a straight line relative to a static sound source of frequency (1035Hz) and the sound speed in the air then is (345m/s). Calculate the amount of frequency and the wavelength that the rider hears when he is moving: a) towards the source. B) away from the source.

Solution

$$f' = \left(\frac{\upsilon - \upsilon_o}{\upsilon - \upsilon_s}\right) \times f$$

a) A cyclist moving to wards the source so the observer (listner) velocity υ_o =(-5 m/s) with negative sign (because it is in the opposite direction of the sound wave propagation).

$$f' = \frac{345 - (-5)}{345 - 0} \times 1035$$

$$= \frac{350}{345} \times 1035$$

$$f' = 1050 \text{ Hz}$$

when the source is static the wavelength of sound transmitted by the source does not change.

$$\upsilon = \lambda' f$$

$$\lambda' = \lambda = \frac{\upsilon}{f}$$

$$\lambda' = \frac{345}{1035} = 0.33\text{m}$$

b) since acyclist moving away from the source then the velocity of listener $v_o =$ (+5m/s) positive sign (it's move to words propagation of sound wave).

$$f' = \left(\frac{v - v_o}{v - v_s}\right) \times f$$

$$f' = \frac{345 - (+5)}{345 - 0} \times 1035$$

$$= \frac{340}{345} \times 1035$$

$$f' = 1020 \text{ Hz}$$

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

$$\lambda' = \frac{345}{1035}$$

$$= 0.33\text{m}$$

8.21 Shock waves

Figure 44-a

When an aircraft moves at less than the speed of the sound, the fronts of the waves in front of the plane are close, creating a pressure wave due to the movement of the plane and the observer to the right of the plane measures a frequency higher than the frequency of the source. Notice figure (44a)

Figure 44b

When the speed of the plane increases, the wave fronts in front of the plane converge more and more and the observer registers a higher frequency, When a plane moves at the speed of the sound, the fronts of the wave are crowded in front of the plane and move at the speed of the sound form a barrier of air and in a very high pressure called the sound barrier, notice figure (44b).

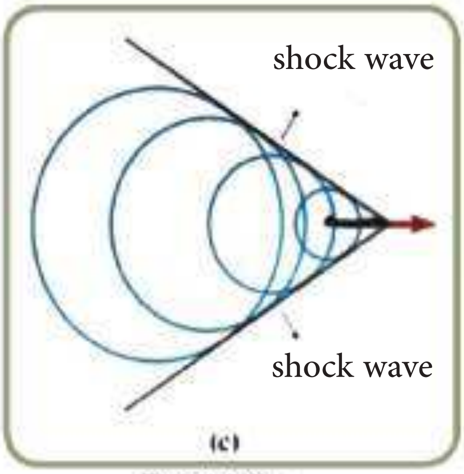


Figure 44c

When the plane moves faster than the sound speed, the wave fronts are crowded one on top of the other, forming a conical surface called shock waves which is A wave of that concentrate energy heavily in the area to be generated which is in the front of the plane and the other at the rear of the plane and you hear a thunderous sound. Notice figure (44c)

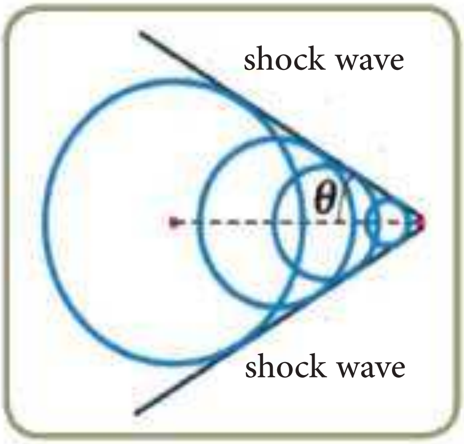


Figure 45

The casing of the fronts is conical. Notice figure (45), and half the angle of its head given in relation:

$$\sin\theta = \frac{\upsilon t}{\upsilon_s t} = \frac{\upsilon}{\upsilon_s}$$

υ_s = Source velocity (plane)

υ = Wave velocity (sound)

The ratio (v_s / v) is called Mach Number and Front conical wave when ($v_s > v$) (ultrasonic velocity) It is known as a shock wave, as in the case of jet movement at an ultrasonic speed, producing shock waves that produce the loud sound that we hear.

Shockwaves carry a large amount of concentrated energy in the center of the cone, which causes significant change in pressure. These shock waves are harmful to hearing and can cause damage to buildings when aircraft fly at supersonic speeds at low altitudes.

Think ?

A plane flying in the air at a constant speed moved from a cool air mass to a hot air mass. Is Mach number increasing, decreasing or remaining constant?

Questions of Chapter 8

Q1/ Choose the correct phrase for each of the following:

1- Which of the following does not affect the periodic time for the simple pendulum vibrate in the air:

a- Thread length.
b- Ball mass.
c- Gravitational acceleration of the simple pendulum site.
d- Ball diameter.

2- A simple pendulum length of 2m and a Gravitational acceleration of 10 m/s^2, the total vibration number within 5min is:

a- 1.76
b- 21.6
c- 106
d- 236

3- Eight waves pass through a certain point each (12s) and the distance between two consecutive peaks is (1.2m) the wave velocity is:

a- 0.667 m/s
b- 0.8 m/s
c- 1.8 m/s
d- 9.6 m/s

4- In which of the following Doppler effect does not occur:

a- The sound source moves toward the observer.
b- An observer moves towards the sound source.
c- An observer and a source stationary to each other.
d- The observer and the source move in opposite directions.

5- A bus passenger passing by a car parked on the side of the road, The driver of the parked car fired the alarm, what is the nature of the sound heard by the bus passenger:

a- The original sound of the alarm goes up.
b- The original sound of the alarm goes down.
c- The sound changes its pitch from a large amount to a small amount.
d- The sound changes its pitch from a small amount to a large amount.

6- The time that a shaky body needs to complete a single shake is:

a- Hertz
b- Periodic time
c- Amplitude
d- Frequency

7- Transverse mechanical waves move only through:

a- Solid bodies
b- Liquids
c- Gases
d- All the previous

8- When you increase the intensity of sound (10) times the level of sound intensity increases to:

a- 100dB
b- 20dB
c- 10dB
d- 2dB

9- The sound start-up in the air is a function for:

a- Wavelength
b- Frequency
c- Temperature
d- Amplitude

Q2/ what feature should be available in an object movement to be a simple harmonic movement?

Q3/ How many times a child swings on a swing through a position of stability during a single cycle time.

Q4/ What happens to periodic time in a simple harmonic pendulum when:

a- Its length double
b- Its mass double
c- Its vibration amplitude double

Q5/ Does the periodic time of the simple harmonic pendulum at sea level differ from the periodic time of the same vibrating on the top of a mountain? And why?

Problems of Chapter 8

P1/ What is the periodic time of a simple pendulum that vibrates harmoniously (12 cycle) through (2 min)?

P2/ A helicopter is about 10m away from a listener it sends its sound regularly in all directions. If the level of its sound intensity is 100dB, the listener can hear so what is:

a- The amount of acoustic power produced by this aircraft.
b- What is the average time of sound energy falling on an ear drum that hears its area ($8x10^{-3}$ m^2).

P3/ Calculate the change in the level of the intensity of the sound emitted from a radio if the sound power of the radio changes from 25×10^{-3} watt to 250×10^{-3} watt

P4/ The acoustic power of the whistle is 3.5π Watt, at which distance the intensity of the sound will be $1.2\times10^{(-3)}$ watt/m^2

P5/ What is the ratio between the two intensities of two sounds for a listener if the difference between the level of their intensities is 40dB.

P6/ A mural clock chimes makes a sound of $4\pi\times10^{-10}$ Watt. Can a normal person hear these chimes if he stands 15m away from them?

P7/ Musical instrument String has mass of 15g and length 50cm and the amount of tensile force 25N calculate the speed of the wave in this string?

P8/ Radar sends radio waves with a wavelength of 2cm and a period of time of 0.1s Calculate:

a- Wave frequency
b- Number of waves sent during this time period. [Knowing that the radio wave speed is 3×10^8 m/s]

P9/ What is thespeed of a sound source if it is moving at conslant speed relative to a girl standing when the girl hears the frequency of the source sound increases by 5% of its real frequency and the sound speed was released in the air then (340m/s).

P10/ a boy is moving at aregular speed (5m/s) approaching from static source, the boy heard the frequency of source with (700Hz), and the speed was in the air (345m/s), calculate the real frequency of source.

Introduction

Most of the devices we use in our lives depend on the presence of electrical power such as radio, lamp, television, refrigerator and computer. In order to operate these electrical devices there must be a source equipped with electric power, examples of these sources: Dry battery, Liquid battery and Generator. It is well known that the free electrons (weak link atoms) are responsible for the formation of electrical currents in metal conductors. But we must remember that currents may also arise from positive and negative ions as they are in electrolytic solutions.

9.1 Electric Current

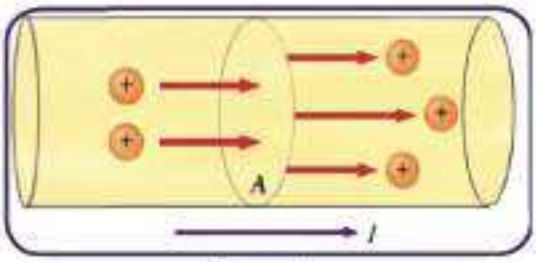


Figure 1

to define the electric current, imagine that the moving electrical charges that cross the surface of a cross section (A) as shown in Figure (1). If (Δq) is the amount of electric charge passing through a conductor section in the time unit (Δt) then:

$$\text{Electric Current} = \frac{\text{Quantity of Charge}}{\text{Time}}$$

$$\boxed{I = \frac{\Delta q}{\Delta t}}$$

electric current measured in units $\frac{\text{coulomb (C)}}{\text{second (s)}}$ this unit defined by ampere

$$1\,\text{ampere} = \frac{1\,\text{coulomb}}{1\,\text{second}}$$

Figure 2

The Electric Current can be defined as the average time of the amount of electrical charge passing through a conductor section.

The direction of the current is directed towards the movement of positive charges and opposite to the direction of the movement of negative charges. Figure (2) represents electric charges moving in two sections of conductors. Note that the current passing through the conductor (a) is greater than the current passing through the conductor (b). As that the direction of the current in figure (a) is to the right and to the left in figure (b). Because of the negative electric charges in a given direction is equal to the movement of an equal amount of positive electrical charges in the opposite direction.

The different electrical charges move in opposite directions in the electric field (E).

The movement of positive charges in the conductor in a certain direction is defined as conventional current, and the movement of the negative charges (electrons) in the metal conductors is in an opposite direction to the conventional current.

Think ?

Figure (3) shows that electrical charges is moving across four sections of conductors if you know that the all charges are equal in magnitude :-

1) Determine the direction of the current in each section.

2) Sort out the four sections according to the amount of current from least to the most.

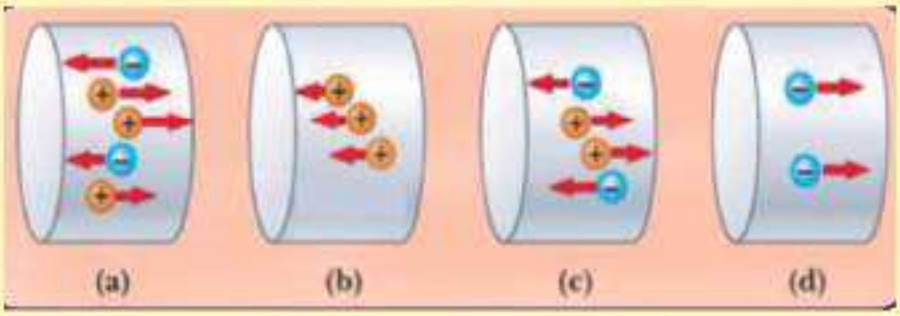


Figure 3

It is important to note that the velocity of the electrical current is the velocity at which the electrical energy travels, which is approaching the speed of light in the vacuum (3×10^8 m/s), while the drift velocity of free charges in the conductors is small. For example, a copper wire of 1mm diameter with an electric current of 1 A, the electrons drift velocity will be(9.4×10^{-5} m/s).

The drift velocity is given by the following relation:

$$\text{Drift velocity of charge } (\upsilon_D) = \frac{\text{Current(I)}}{\text{Cross Section Area(A)} \times \text{Number of Electrons per unit volume(N)} \times \text{Electron charge(e)}}$$

$$\upsilon_D = \frac{I}{ANe}$$

Where:

υ_D represents the drift velocity of electrons which is measured by m/s .
N Represents the number of Electrons per unit volume.
A Represents Cross Sectional Area
e Electron charge .

Example 1

When you press one of the pocket calculator buttons, the calculator battery supplies a current of $300\times 10^{(-6)}$ A in a time of $10^{(-2)}$s.

a- How much flowing charge is required for this time?

b- How many electrons are flowing during this period of time?

Solution

a- $$\text{Electric Current} = \frac{\text{Quantity of Charge}}{\text{Time}}$$

$$I = \frac{\Delta q}{\Delta t}$$

$$\Delta q = I\Delta t$$

$$= (300 \times 10^{-6}\ A) \times (10^{-2}\ s)$$

$$\Delta q = 3 \times 10^{-6}\ C$$

b- $$\text{number of electrons (n)} = \frac{\text{Total charge } (\Delta q)}{\text{electron charge(e)}}$$

$$n = \frac{\Delta q}{e}$$

$$n = \frac{3 \times 10^{-6} C}{1.6 \times 10^{-19} C} = 1.9 \times 10^{13} \text{ electron}$$

Example 2:

A Copper wire with a cross sectional area of 2 mm^2, with $(10\ A)$ current passing through it . Calculate the drift velocity of free electrons in this wire. Note that the number of free electrons per its unit volume (N) equal to 8.5×10^{28} e $/m^3$.

$$\text{Driftvelocity}\ (v_D) = \frac{\text{Current(I)}}{\text{Cross Section Area(A)} \times \text{Number of Electrons per unit volume(N)} \times \text{Electron charge(e)}}$$

Solution

$$v_D = \frac{I}{ANe}$$

$$v_D = \frac{10A}{(2 \times 10^{-6}\ m^2)(8.5 \times 10^{28}\ e/m^3)(1.6 \times 10^{-19}\ C)}$$

$$= 0.37 \times 10^{-3}\ m/s$$

$$= 0.37\ mm/s$$

9.2 Electric Resistance and Ohm's Law

As previously mentioned that the electric current finds a resistance when it is passing through a conductor, caused by collision of free charges with each other and with the atoms of the conductor material . Therefore, the concept of electrical resistance represents the resistance of the conductor to the electrical current , and it is a measure of the impedance that is faced by the electrons while transmission in conductor .you have previously learned the conductor resistance calculation by measuring the voltage difference between the terminals and measuring the current passing through it , notice figure (4) .

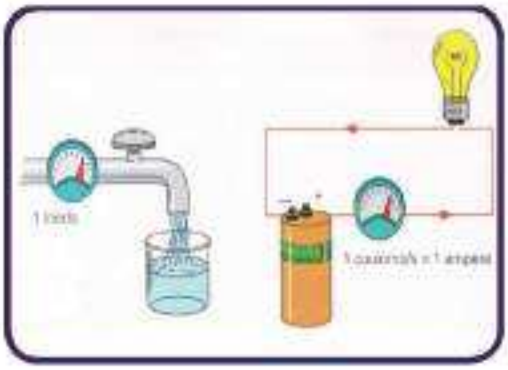


Figure 4

Conductor resistance is known as:

$$\text{Resistance (R)} = \frac{\text{Voltage (V)}}{\text{Current (I)}}$$

$$R = \frac{V}{I} \Rightarrow V = I\,R$$

This formula is known as the ohm's law, which states that :

((The electric current passing through the conductor is directly proportional to the potential difference between the two ends when at a constant Temperature)).

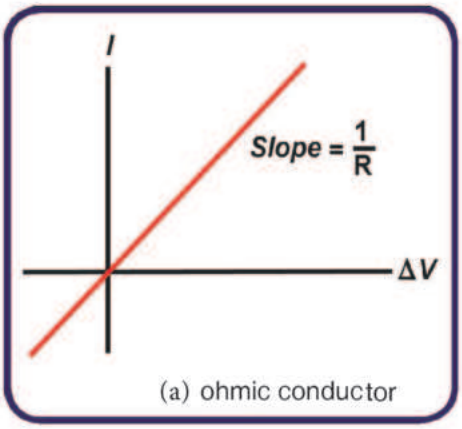


Figure 5a

The resistance is measured by ohm , symbolized by the symbol (Ω) and it is known as "conductive resistance in which a (1A) current passes through when the voltage difference between the terminals is (1V)".

The conductors which ohm's law is applied on it are called ohmic conductors. Notice Figure(5a)

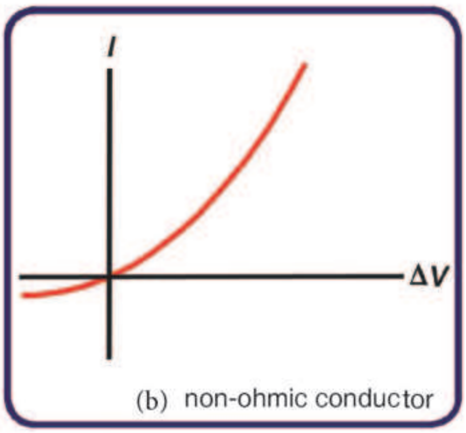


Figure 5b

When the resistance is not constant when the current is increased significantly, the relation between the current and the voltage difference becomes nonlinear. In this case, the conductor is called a non-ohmic conductor. Note figure (5b).

You have studied in previous stages that the resistance of a conductor is directly proportional to the length of the conductor and inversely proportional to its cross sectional area.

with the area of the segment, and expressed it mathematically as follows:

$$\text{Resistance} = \text{constant} \times \frac{\text{Length of the coductor}}{\text{Cross section Area}}$$

This constant depends on the type of conductor material and the temperature it is called Resistivity and symbolizes by the symbol (ρ).

$$\text{Resistance}(R) = \textbf{Resistivity}(\rho) \times \frac{\text{Length (L)}}{\text{Cross section Area}(A)}$$

$$R = \rho \times \frac{L}{A}$$

The unit of Resistivity is (Ω.m)
The Resistivity (ρ) varies depending on the type of material and the temperature.
Table (1) shows the Resistivity of some materials at 20 ° C

	Material	The Resistivity (Ω. m)
conductors	Aluminum	2.8×10^{-8}
	Copper	1.72×10^{-8}
	Gold	2.44×10^{-8}
	Nichrome	100×10^{-8}
	Silver	1.6×10^{-8}
	Tungsten	5.6×10^{-8}
Semiconductors	Silicon	3×10^{3}
Insulators	Glass	10^{10}

The above table shows that the value of resistivity is very low for good conductor materials such as silver and copper, meanwhile their value is very high for insulator materials such as glass. Semiconductor materials has a medium resistance.

The inverse of resistivity (ρ) is called conductivity and has a symbol of (σ).

$$\sigma = \frac{1}{\rho}$$

Do you know?

The resistivity is a characteristic of substances, while resistance is a characteristic of an object, and density is a characteristic of substances while the mass is a characteristic of the object.

The applications of electrical circuits that change their resistance to the change of temperature is the thermostat, notice figure (6)

Figure 6

It is also used in electric fire alarm circuits. It also uses a resistive thermometer to measure the temperature by changing the resistance of a conductor and it is made of platinum.

Example 3

A piece of copper wire is a 4 mm^2 area and 2 m length resistivity of $1.72\times10^{(-8)}$ Ω.m at 20°C, find:

a) the resistance of wire.

b) the voltage difference at the ends of the wire when a current of 10 A is flows through it.

Solution

a) The electric resistance of wire at 20°C

$$R = \rho \times \frac{L}{A} = \frac{(1.72 \times 10^{-8}\Omega.m)(2m)}{(4 \times 10^{-6}m^2)}$$

$$= (8.6 \times 10^{-3}\Omega)$$

b) The voltage difference at the ends of the wire when a current of 10 A is flows through it.

$$\mathbf{V = I\,R}$$
$$\mathbf{= (10A)(8.6 \times 10^{-3}\,\Omega)}$$
$$\mathbf{= 8.6 \times 10^{-2}}$$
$$\mathbf{= 0.086\ Volt}$$

9.3 Temperature Coefficient of Resistivity

The resistivity of the conductors varies almost linearly with temperature changes according to the following relation:

$$\rho = \rho_o \left[1 + \alpha\,(T - T_o) \right]$$

Where ρ_o represents the resistivity in a temperature of $(T_o = 20^\circ C)$ and the constant α is called the temperature coefficient of resistivity which it depends on the type of material.
Whereas

$$\alpha = \frac{1}{\rho_o} \times \frac{\Delta\rho}{\Delta T}$$

$\Delta\rho = \rho - \rho_o$ represents the change in resistivity to temperature change $\Delta T = T - T_o$
the unit of temperature coefficient of resistivity α is $1/(^\circ C)$.
Table (2) shows that the of temperature coefficient of resistivity for some materials in temperature room $(20^\circ C)$.

Tungsten	Silver	Mercury	Lead	Iron	Carbon	Copper	Aluminum	Element
45	38	8.8	43	50	-5	39.3	39	$\times 10^{-4}\,(^\circ C^{-1})$

It is important to note that the resistivity of the conductors increases with increasing of temperature as indicated. But we have to remember that there are substances such as semiconductors and electrolytic solutions that deviate from this rule where their resistance is reduced by increasing the temperature. This means that the temperature coefficient of resistivity is negative for these substances.

Do you know?

The resistivity of the blinking light bulb is increased to more than ten times when the temperature changes from room temperature until the heat is heated to the degree of whiteness.

The change in the conductor resistance can be expressed linearly with the temperature according to the following equation:

$$R = R_o \left[1 + \alpha (T - T_o)\right]$$

Example 4:

The electric cooker has a length of $(1.1 m)$ wire and a cross sectional area of $(3.1 \times 10^{-6} m^2)$ .When the cook is operating, the temperature of the wire rises due to the passage of the electrical current in it . If the material made of the wire has a resistivity of (ρ_o $= 6.8 \times 10^{(-5)}$ (Ω .m)) at a temperature of $(T_o = 320°C)$ and the thermal coefficient of resistance is $\alpha = 2.0 \times 10^{-3} (1/°C)$, calculate the resistant of wire at 420 °C.

Solution

$$\alpha = \frac{1}{\rho_o} \times \frac{\Delta\rho}{\Delta T}$$

$$\alpha = \frac{1}{\rho_o} \times \frac{\rho - \rho_o}{T - T_o}$$

$$2 \times 10^{-3} = \frac{1}{6.8 \times 10^{-5}} \times \frac{\rho - 6.8 \times 10^{-5}}{420 - 320}$$

$$\rho = 8.16 \times 10^{-5} (\Omega \ . \ m)$$

$$R = \frac{\rho L}{A}$$

$$= \frac{8.18 \times 10^{-5} \times 1.1}{3.1 \times 10^{-6}} = \frac{8.976 \times 10^{-5}}{3.1 \times 10^{-6}}$$

$= 29\ \Omega$ *(The resistance of the wire at 420°C)*

9.4 Superconductors

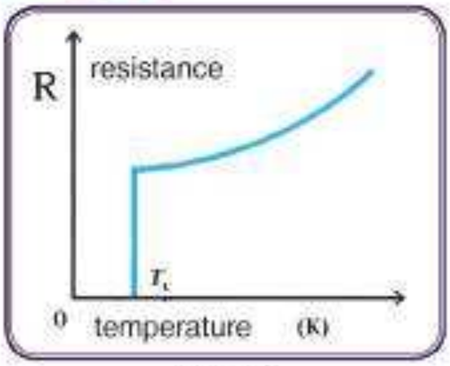


Figure 7

There is a type of metals and compounds whose resistance drops suddenly to zero at a certain temperature called critical temperature. This is called superconductivity. This type of material is called superconducting material. Figure 7 shows the remarkable properties of superconducting materials, If a circuit is created in a closed loop, the current will continue in that circuit for a period of several weeks without an Electromotive Force in the circuit, unlike the currents in the ordinary conductors where it drops to zero just to raise the source of electric power from it.

Figure 8

An important application of superconducting materials is superconducting magnets with a magnetic field of ten times the usual magnets. This type of magnet is used in the magnetic resonance imaging system (MRI), which gives accurate images of the internal organs of the human body, note Figure (8).

9.5 Electromotive Force

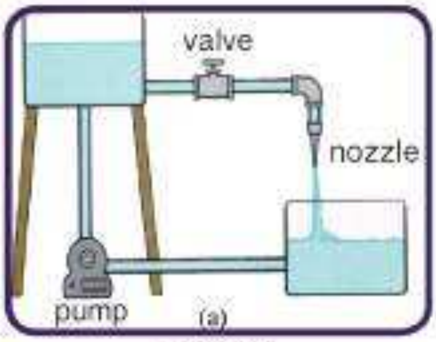


Figure 9a

You have already studied dear student that the free charges (electrons) inside the metal wire moving randomly does not generate from this motion an electric current, to produce an electric current in the wire must to push the electrons to move in a certain direction, and this requires connecting the two ends of the wire source with electrical power and this is similar to the water pump that pumps the water from the bottom tank to the upper tank. Note figure (9a).

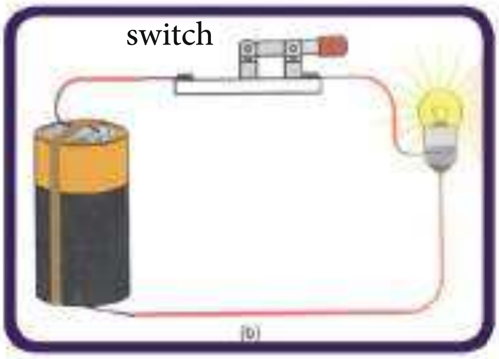


Figure 9b

The source of electric power supply is defined as the source of the Electromotive Force, one of which is the battery. Note figure (9b).

The Electromotive force of a battery is defined as the amount of electrical energy that the battery earns per Coulomb from of the charge moving between its poles. In other words, it represents the work done to the charge unit by the source.

so that ;

$$\text{Electromotive force } (\varepsilon) = \frac{\text{Work (W)}}{\text{Charge (q)}}$$

$$\varepsilon = \frac{W}{q}$$

electromotive force measured in units $\frac{\text{Joule}}{\text{Coulomb}}$ this unit defined by volt

9. 6 Electric Circuit Law

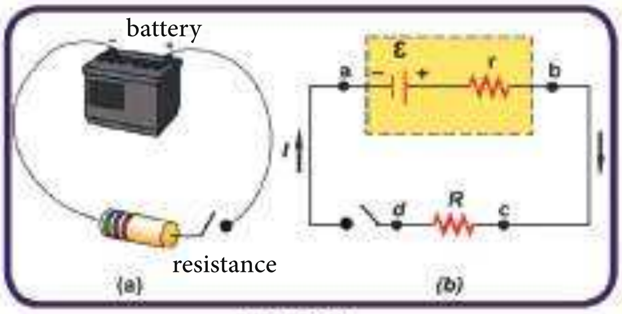


Figure 10

When the two ends of a wire are connected to the source of an electric voltage, a closed path is formed through which an electric current passes. In order to benefit from this current, we put a device or any resistance in this closed path. These four elements constitute: (wire, battery, device, switch) base components of the electric circuit Note Figure (10). When the switch is closed, a closed circuit is formed and an electric current will pass through it , if there is a cut in the wire at any point we say that the circuit is open.

If we assume that the resistivity of the conductive wires is negligible, the voltage at the ends of the battery (The Terminal Voltage of a Battery) is equal to emf. But the battery has an internal impedance r so the voltage of the electrodes is not actually equal to the emf of the battery. A positive charge moving through the battery from (a → b) can be visualized when the charge passes from the negative pole to the positive electrode of the battery. The charge voltage increases by (ε). When the charge passes through the internal resistance r, the voltage decreases by (I r). where (I) represent circuit current It is possible to derive the equation of the closed electric circuit in the law of conservation of energy as follows:

Electromotive force = potential difference between the poles of the battery + current × Internal Resistance

$$\varepsilon = (\Delta V) + (I) \times (r)$$

$$\varepsilon = \Delta V + Ir$$

$$\varepsilon = IR + Ir$$

$$\text{Current} = \frac{\text{Electromotive force}}{\text{Resistance + Internal Resistance}}$$

$$I = \frac{\varepsilon}{R + r}$$

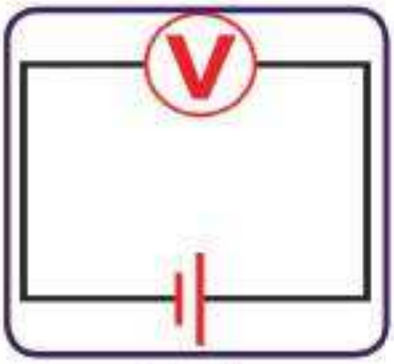


Figure 11

Measuring the electromotive force of a battery.

Connect the voltmeter directly to the poles of the battery. Since the voltmeter resistance is very high, the current that passes through the circuit is very weak and can be ignored. Assuming that the circuit is open so the voltmeter reading represents the emf of the source roughly. Note Figure (11)

9.7 Internal Resistance (r)

So far what has been discussed about voltage sources (batteries or generators) is the effect of their voltage on the circuit, but in fact also it contains a resistance called the internal resistance of battery or the internal resistance of the generator because it exist within the voltage source, and this resistance in the battery is the resistant of the chemical materials, and in the generator is the resistance of wire and the rest of the generator components. Notice figure (12).

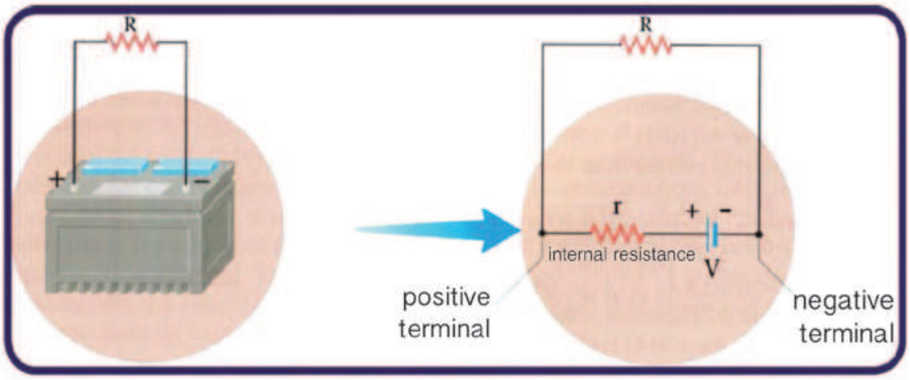


Figure 12

When the voltage source is connected with an external resistor (R), the internal resistance of the source is attached to it in series, and internal resistance is usually very small but its effect can't be ignored in the circuit. Figure (12) shows that when the current is pulled out of a battery, the internal resistance causes the voltage between the poles to drop below the maximum value determined by the electrical impulse of the battery. The actual voltage between the two battery poles is called:

(The Terminal Voltage of a Battery)

Example 5:

Figure (13) shows a car battery with 12V (emf) and internal resistance 0.01 Ω , how much voltage between the poles when the Battery current is :

a) 10A.

b) 100A.

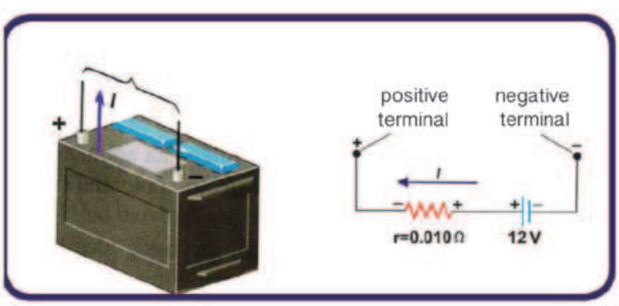


Figure 13

Solution

a) We calculate the voltage drop at the internal resistance (lost voltage at the internal resistance) when current power in 10A: -

$V = I\,r$

$V = 10A \times 0.01\Omega = 0.1V$ **voltage drop**

The voltage difference between the poles of the battery is

$\Delta V = \varepsilon - I\,r$

$\Delta V = 12.0V - 0.10V$

$= 11.9V$

b) We calculate the voltage drop in internal resistance when the current is 100A.

$V = I\,r$

$V = 100A \times 0.01 = 1.0V$

The voltage difference between the poles of the battery is

$V = \varepsilon - I\,r$

$V = 12.0V - 1.0V = 11.0V$

The example above shows how the voltage of the poles of the battery is lower when the current is going out of the battery is high, and this effect can be recognized by the owner of a car when he uses a battery.

Think ?

In the previous example if the car's lights wanted to glow. Which would you prefer? Flare bulbs before you turn on your car engine or after you turn on your car engine and why?

Setting the internal resistance (r) of a battery

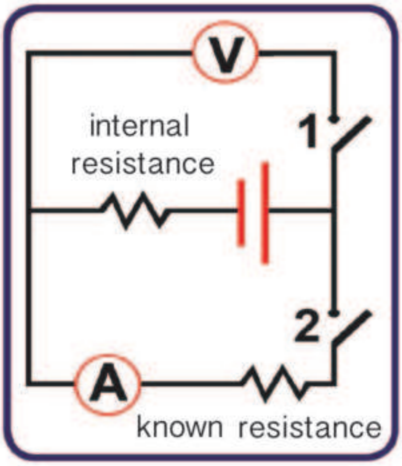


Figure 14

Connect the devices as shown in the circuit at Figure (14)
First, close switch 1 only so that the voltmeter reads the value of the electromotive force as mentioned below.
Second: Close switch 2 also and record the Ammeter readings that represents Current passing through the circuit and then calculate (r) from the following relation:

$$\varepsilon = IR + Ir$$

substituting the value (emf) from the voltmeter reading in the first step. And the value of (I) from the reading of the ammeter at the second step, and if (R) is unknown it can be substituted as (IR) which is the reading of the voltmeter, which represents the difference of voltage across the platform and we do not need to know (R) in this case.
Resistance measurement: There are several ways to measure a resistance including:

1-) Voltmeter and Ammeter method:

This method is not accurate because one of the two devices in any particular link does not give a exact measurement for the resistance to be measured and to minimize the error we follow what comes:

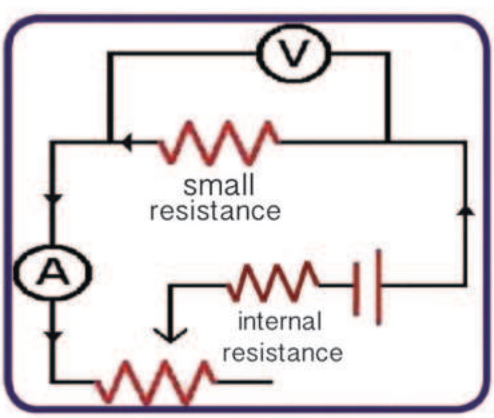


Figure 15

a / If the resistance to be measured is small
Connect the devises as shown in Figure(15),the voltmeter reading is only for the potential difference across that resistance. The ammeter measures the sum of the current of the small resistance and the voltmeter. Since the voltmeter resistance is very high for that resistance, the current is too small so it can be ignored. Considering the ammeter reading is for the current of the resistance and the approximate value of resistance is calculated from the following relation:

Resistance (R)=(Voltmeter reading)/(Ammeter reading)

b/ If the resistance to be measured is large, that connect

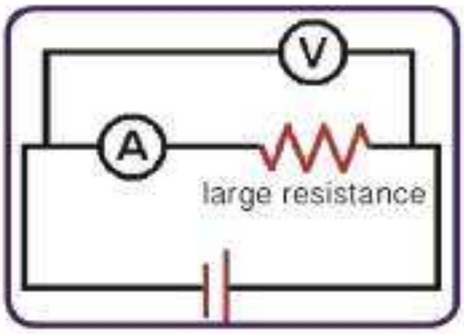


Figure 16

The devices as shown in Figure (16):
The reading of the ammeter represents exactly the current of that resistance only, but the reading of the voltmeter represents the sum of the difference of voltage across both the large resistance and ammeter. Since the resistance of the ammeter is very small, the difference of voltage between the two ends will be very small which can be neglected comparing it with the voltage difference across the resistance .Thus voltmeter reading is can be considered as the difference of voltage across the resistance which is large, the resistance can be calculated by voltmeter reading and current according to the following relation:

$$R = \frac{(V)}{(A)}$$

R=(Voltmeter reading (V))/(Ammeter reading (A))

2-) Wheatstone bridge Method:

This method is accurate and precise to measure the resistance .The circuit consists of (three known variable resistances - unknown resistance - a galvanometer and a power source).We connect the equipment as in Figure 17. We change the value of the known resistances (R_2, R_3, and R_4) until the circuit weighs, so that the galvanometer does not record any current, which means its voltage is equal or the voltage difference is ($V_{db} = 0$) then

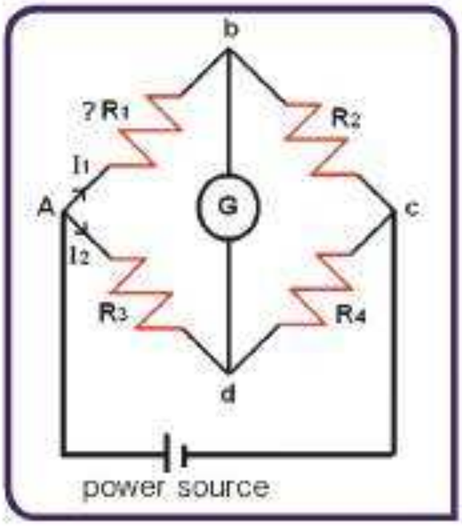


Figure 17

$$V_{Ab} = V_{Ad} \ldots\ldots \Rightarrow I_1 R_1 = I_2 R_3 \ \ldots\ldots (1)$$
$$V_{bc} = V_{dc} \ldots\ldots \Rightarrow I_1 R_2 = I_2 R_4 \ \ldots\ldots (2)$$

dividing the first equation by the second results.

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

Wheatstone bridge Law.

Where R_1 is the unknown resistance .since three resistance known, the fourth (unknown) resistance can be calculated.

$$R_1 = R_2 \times \frac{R_3}{R_4}$$

The unknown resistance R_1 can be calculated according to the above mentioned relation. (R_3, R_4) can be replaced by a homogeneous wire installed on a metric arc. Note Figure (18).
Since (R α L). Therefore, the previous relation becomes the equilibrium case of the circuit as follows:

$$\frac{R_1}{R_2} = \frac{L_1}{L_2}$$

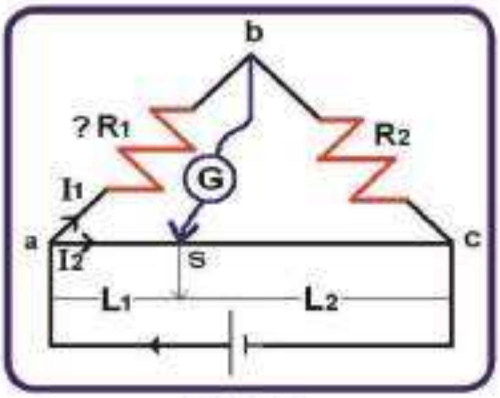


Figure 18

Example 6

Quadrilateral shape (a, b, c, d) ,its four sides resistance are (R , 10 , 2 , 4) respectively . The two points (a c), were connected to the poles of the battery as shown in figure (19). The internal resistance is 1Ω. A galvanometer is connected to (d, b) and it give a zero reading when a current of 0.6 A is passing through R resistance, calculate;

a) The value of resistance R.

b) The current passing through each resistance

c) emf for the battery

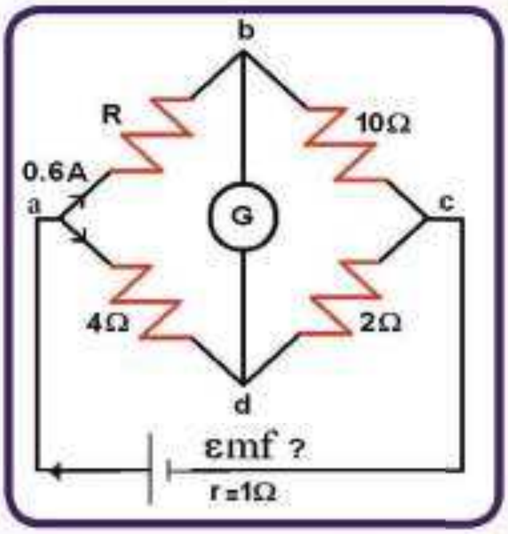


Figure 19

Solution

Since the circuit is balanced (galvanometer is Zero)

a) Calculate the resistance value as equation

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

$$\frac{R_1}{10} = \frac{4}{2} \Rightarrow R_1 = 20\Omega$$

The current passing through each resistance

b) The current passing through the resister (20Ω) is the same as the current through the resistor (10Ω) passing through branch abc

$$V_{ac} = IR$$

$$V_{ac} = (0.6\,\text{A})(20\Omega + 10\Omega) = 18\,\text{V}$$

$$I_{adc} = \frac{V}{R} = \frac{18V}{(4+2)\Omega} = 3A$$ it is the current passing through the two resistances (2Ω, 4Ω)

c) emf for battery

$$I_{Total} = (0.6\,A) + (3\,A) = 3.6\,A$$

$$\frac{1}{R} = \frac{1}{R_{abc}} + \frac{1}{R_{adc}}$$

$$\frac{1}{R} = \frac{1}{(10+20)\Omega} + \frac{1}{(4+2)\Omega} = \frac{1}{5\Omega}$$

$$\therefore R = 5\Omega$$

$$emf = IR + Ir$$

$$emf = (3.6\,A)(5\Omega) + (3.6\,A)(1\Omega) = 21.6\,V$$

9. 8 Electric Power

The main benefits of electrical current that are applied in an electrical circuit are the transfer of energy from the source (battery or generator) to various electrical devices. Figure (20) shows that the positive pole (+) of the battery is connected to the terminal (A) of the electrical device and that the negative pole (-) is bound to the terminal (B) of the device. This means that the battery maintains a constant voltage difference between (A, B) This difference in voltage leads to the movement of charges (Δq) from the high-voltage (A) side to the low-voltage (B) side and decreases its potential energy. This decrease in energy represents (ΔqV) between two sides. (where v is voltage difference)

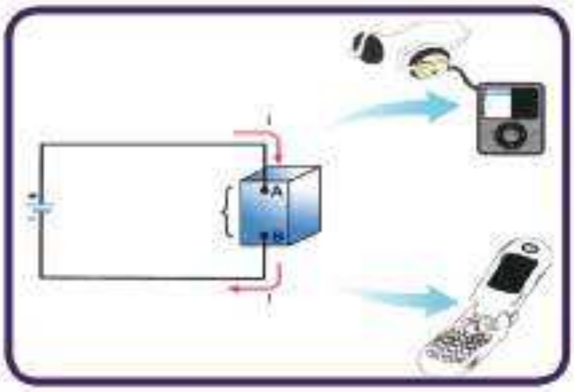


Figure 20

The electrical power of the device is defined as:

The amount of energy consumed (or converted) by the electrical device in the unit of time.

It is expressed mathematically by the following relation:

$$\textbf{power} = \frac{\textbf{potential difference (V)} \times \textbf{quantity of charge}(\Delta q)}{\textbf{time}(\Delta t)}$$

$$P = \frac{V \times \Delta q}{(\Delta t)}$$

$$P = \frac{(\Delta q)}{(\Delta t)} \times V$$

$$P = IV$$

It is measured in joule/second which is known as watt

$$\text{(Ampere) (Volt)} = \left(\frac{\text{Coulomb}}{\text{second}}\right)\left(\frac{\text{Joule}}{\text{Coulomb}}\right) = \left(\frac{\text{Joule}}{\text{second}}\right) = \text{watt}$$

Electrical devices convert electrical energy into one or more forms of energy, and energy can be calculated as:

$$\text{Energy} = \text{power} \times \text{time}$$

$$E = p \times t$$

Power can also be calculated from the following relation:

$$P = IV$$

$$P = I(IR) = I^2R$$

$$P = \left(\frac{V}{R}\right)V = \frac{V^2}{R}$$

Remember:

The maximum amount of power from the source to the load is transferred when the load resistance (R) is equal to the internal resistance of the source (r), then the power consumed in the load is equal to the dissipative power in the battery.

Example 7:

The electromotive force of a battery 12V with an inner resistance of 0.05Ω , the two ends of the battery connected to a load with a resistance of 3Ω notice figure (21). Find:

1) The current passing through the circuit and the voltage difference at the ends of the source.
2) The consumed power by the load, the consumed power at the internal resistance (r) and the consumed power processed by the source .

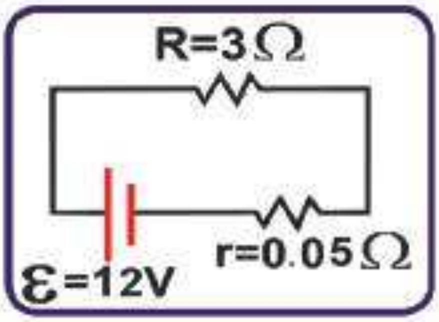


Figure 21

Solution

1) The current passing through the circuit and the voltage difference at the ends of the source

$\varepsilon = IR + Ir$

$I = \frac{\varepsilon}{R+r}$

$I = \frac{12}{3+0.05} = 3.93A$

The voltage difference between the poles of the source = current × external resistance.

$\Delta V = I\,R = 3.93 \times 3 = 11.8\ V$

2) The consumed power by the load, the consumed power at the internal resistance (r) and the consumed power processed by the source.

The consumed power by the load = current square (I^2) × resistance (R)

$P = I^2 R$

$P = (3.93)^2 \times 3 = 46.3W$

The consumed power at the internal resistance = current square × internal resistance

$P = I^2 r$

$P = (3.93)^2 \times 0.05 = 0.772W$

The consumed power processed by the source = the total consumed power by the load and the internal resistance

$\varepsilon I = I^2 R + I^2 r$

$= 46.33 + 0.772 = 47.1W$

The consumed Power processed by the source

$P = \varepsilon I = 12 x 3.93 = 47.1W$

9.9 Series Combination

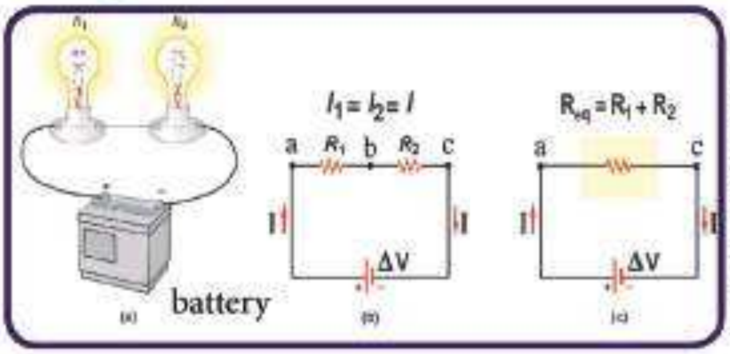


Figure 22

When the end of the first resistance is connected with the beginning of the second resistance as in Figure (22) this connection is called series. The advantage of this connection is that it provides one way to the current and this means that the same current passes through each resistance in the circuit.

Total Current = the current passing through R_1 = the current passing through R_2 .

$$I_{total} = I_1 = I_2$$

Resistances can be simple electrical devices such as light bulbs. When two lamps are connected in series .if a part were broken as a result of damage to either of them, the current in the circuit will be interrupted and the whole circuit will then be open. In the series connection, the voltage processed for the two resistances are divided between the two resistors.

Voltage across a resistance R_1 is V_1 , and Voltage across a resistance R_2 is V_2

total voltage (V_{total}) = voltage across aresistance R_1+ voltage across aresistance R_2

$$V_{total} = V_1 + V_2$$

$$V_1 = I R_1 \ , \ V_2 = I R_2$$

$$V_{total} = V_1 + V_2$$

$$V_{total} = I R_1 + I R_2$$

$$V_{total} = I (R_1 + R_2)$$

$$V_{total} = I R_{eq}$$

$$R_{eq} = R_1 + R_2$$

where R_{eq} means the equivalent resistance.

The properties of series combination:

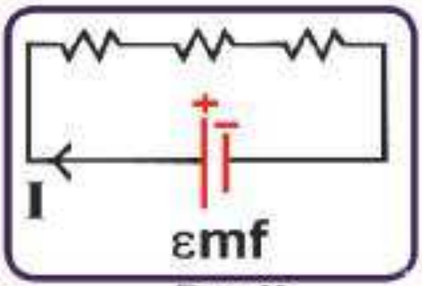


Figure 23

current	$I = I_1 = I_2 = I_3 = \ldots\ldots$
equivalent resistance	$R_{eq} = R_1 + R_2 + R_3 + \ldots\ldots$
voltage difference	$V = V_1 + V_2 + V_3 + \ldots\ldots$

Example 8:

Three resistance 5Ω , 3Ω, 2Ω are connected in series across the battery with potential difference of 20V as shown in Figure (24). Find:

1) The equivalent resistance of the circuit ,
2) The total current.
3) The current passing through each resistance.
4) The voltage difference between the poles of the battery.

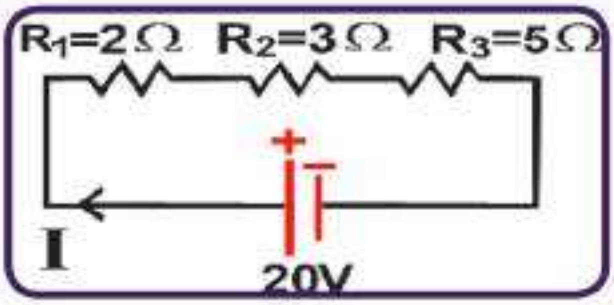


Figure 24

Solution

1) $R_{eq} = R_1 + R_2 + R_3$

$R_{eq} = 2\Omega + 3\Omega + 5\Omega = 10\Omega$

2) $I_{total} = \dfrac{V_{total}}{R_{eq}} = \dfrac{20V}{10\Omega} = 2A$

3) $I_{total} = I_1 = I_2 = I_3 = 2A$

4) $V_1 = I R_1 = (2A)(2\Omega) = 4V$

$V_2 = I R_2 = (2A)(3\Omega) = 6V$

$V_3 = I R_3 = (2A)(5\Omega) = 10V$

to calculate the total voltage difference V_{total} to confirm result

$V_{total} = V_1 + V_2 + V_3$

$V_{total} = 4V + 6V + 10V = 20V$

9.10 Parallel Combination

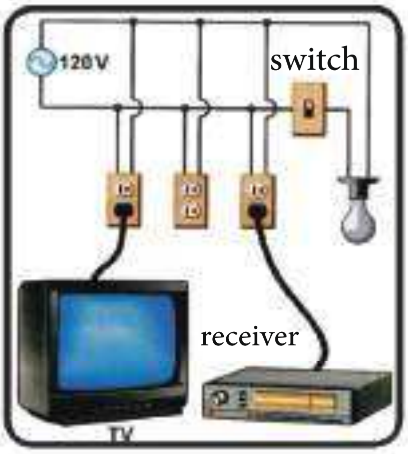


Figure 25

Parallel connection is another way to connect electrical devices. The parallel link is to connect the electrical devices between two joint points in such a way that the voltages are equal to all connected devices in the circuit. Parallel connection is very common. For example, the electrical devices connected to the electrical points in the house are connected to each other in parallel (Figure 25) where the voltage is 220V and is equal to the voltage of each television - stereo - lamp (when the circuit is closed) Unused electricity or other equipment does not affect the operation of the rest of the devices that actually work. Furthermore, if the power is cut off in one of the devices (with an open switch or a broken wire), this does not affect the flow of the current in the rest of the devices.

To calculate the equivalent resistance of two resistances bound together in parallel we must know that the total current:

$$I_{total} = I_1 + I_2$$

since the voltage at both ends of each resistance is equal to the total voltage, then

$$I_{total} = \frac{V}{R_{eq}}$$

$$I_1 = \frac{V}{R_1}$$

$$I_2 = \frac{V}{R_2}$$

$$I_3 = \frac{V}{R_3}$$

$$I_{total} = I_1 + I_2 + I_3$$

$$\frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} \Rightarrow \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

The properties of parallel combination:

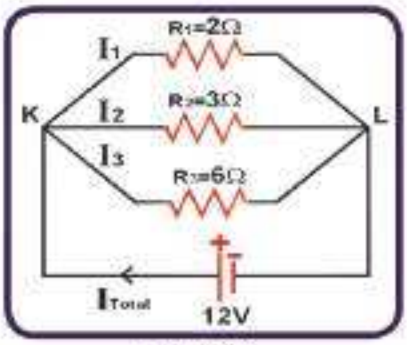


Figure 26

current	$I = I_1 + I_2 + I_3 + \ldots$
equivalent resistance	$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
voltage difference	$V = V_1 = V_2 = V_3 = \ldots$

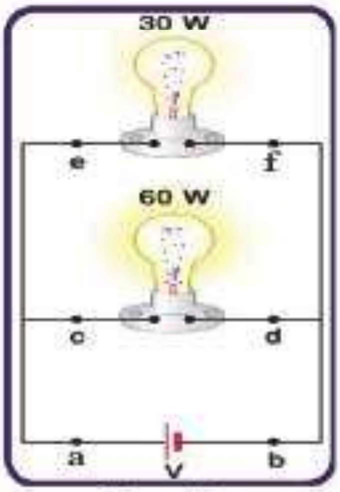


Figure 27

Think?

In Figure (27) two lamps are connected in parallel to each other and their group is connected with the source difference of voltage (V=120V) . The values of the currents in the branches (ef), (cd), (ab) are from the largest to the smallest.

Example 9

Find the equivalent resistance between the two points (x, y) in Figure (28a) the circuit at figure (28b) is equivalent to closing switch circuit in Figure (28a).

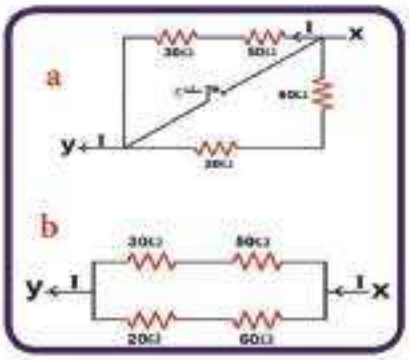


Figure 28

Solution

The 50Ω and 30Ω resistance are connected in series:

$$R_{eq\,s} = 30\Omega + 50\Omega = 80\Omega$$

The 20Ω and 60Ω resistance are connected in series:

$$R_{eq\,s} = 20\Omega + 60\Omega = 80\Omega$$

The 80Ω and 80Ω resistance are connected in parallel:

$$\frac{1}{R_{eq}} = \frac{1}{80\Omega} + \frac{1}{80\Omega} = \frac{2}{80\Omega}$$

$$R_{eq} = 40\Omega$$

After the switch is closed the equivalent resistance = zero because the circuit becomes short circuit with current passing through the wire (x,y) only without passing through any resistance at figure (28).

9. 11 Kirchhoff 's rules

Electrical circuits, which consist of resistors connected in series and parallel, can often be analyzed by dividing them into separate sets of resistances, but this method may not be useful or easy in some circuits where we do not find some resistances connected by using series or parallel methods.to deal with these circuits we use other methods, which is the most important methods, that are the Kirchhoff's rules, which were named after the scientist Kwestan Kirchhoff

1) Junction rule.

The sum of the entering current to any junction point, must be equal to the sum of the leaving current, so that

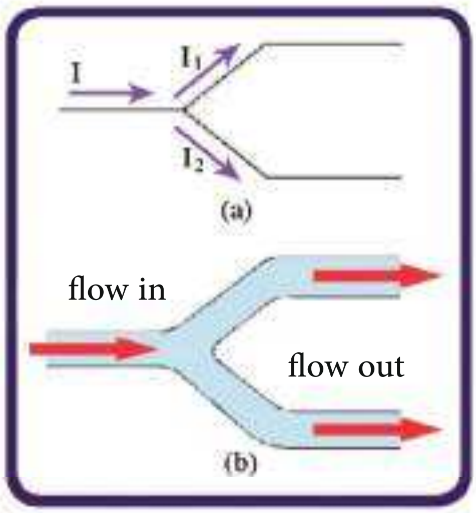


Figure 29

$$\sum I_{in} = \sum I_{out}$$

The first Kirchhoff's rule represents the law of the conservation of electric charge and this indicates that the division of the current or set it apart does not affect its original value note figure (29a, b).

2) Loop rule

The algebraic sum of the voltage across each element around any closed circuit must be zero, so that

$$\sum_{\text{closed loop}} \Delta V = 0$$

The second rule of Kirchhoff can be found in the following relation:

$$\text{Potential drops} = \text{potential rises}$$

$$\sum \Delta V_{drops} = \sum \Delta V_{rises}$$

This represents a special pattern for the expression of conservation of energy law in electrical circuits.

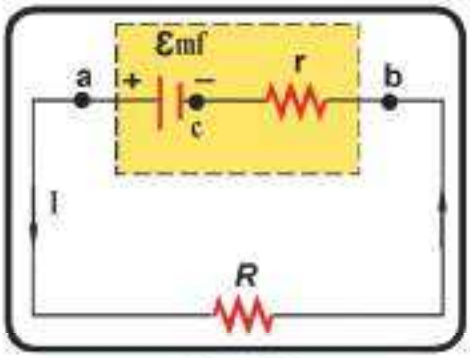


Figure 30

Calculation of the voltage difference in the circuit:

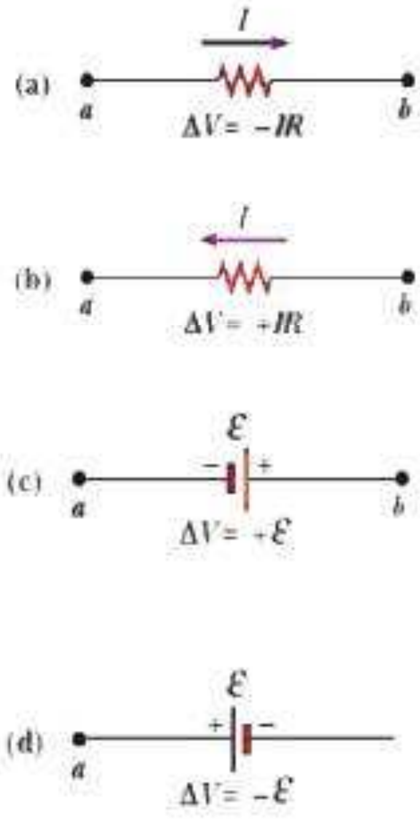
The electric circuit shown in Figure (30) is composed of a source of its electromotive force ε and its internal resistance r is connected with R resistance, while the current of the circuit is in the opposite direction of the clockwise. Calculate the voltage difference (Vab) between the poles of the battery a, b? When we move from point b (V_b) to current through the resistance r to point c (Vc) we see a drop in the voltage (Potential drops) This means that the voltage in b higher than in c because the positive charges flow from high voltage to low voltage. When crossing the electromotive force from point c to point a we find that a voltage increase (potential rise) by amount of **ε**. And this increase in voltage is due to the work performed by the source on the positive charges when it is transferred from the negative pole to the positive pole, which increases the voltage. If we agree to give a positive signal of the rise in voltage and negative of the voltage drop, it becomes very easy to calculate the voltage difference (V_{ab}) by taking the algebraic sum of the changes in voltage through this path so that

$$V_b - Ir + \varepsilon = V_a$$

$$\varepsilon - Ir = V_a - V_b = V_{ab}$$

$$V_{ab} = \varepsilon - Ir$$

Thus, the voltage difference between any two points in an electric circuit can be calculated taking into account the two following bases :



First: a. when current passes toward a resistance Note figure (31a) a potential drops occurs by amount of (IR)

$$V = -IR$$

b. if the current passing in reverse direction Note figure(31b) a potential rise occurs by amount of (IR) .

$$V = +IR$$

Second: a. when passing through electromotive force from its negative pole to its positive pole note figure (31c), a potential rise occur by amount of ε.

$$V = +\varepsilon$$

b. if the passing was reversed from the positive pole into the negative pole note figure(31d) , a potential drops occur by an amount of ε .

$$V = -\varepsilon$$

Figure 31 a, b, c, d

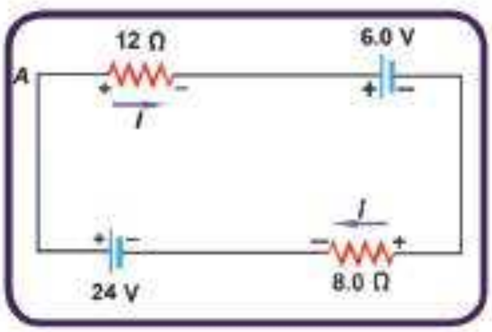


Figure 32

Example 10 :

Figure (32) shows an electrical circuit containing two batteries and resistances, calculate current **I** in the circuit.

Solution

current passes the circuit from high voltage to low voltage , applied the secoud role of kirchhoff, start from point A to words clock wise

Potential drops = potential rises

$$\sum \Delta V_{drops} = \sum \Delta V_{rises}$$

$$I\,(12) + 6 + I\,(8) = 24$$

$$20\,I = 18$$

$$I = 0.9\ A$$

Example 11

For the circuit at figure (33) .Find

a) The current at the circuit.

b) The voltage difference between the points a ,b .

Knowing that: $R = 9\ \Omega$, $r_2 = 2\ \Omega$, $r_1 = 1\ \Omega$, $\varepsilon_2 = 12V$, $\varepsilon_1 = 6V$

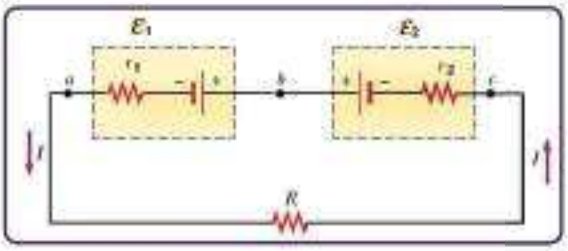


Figure 33

Solution

a) To set the direction of the current in a circuit containing two sources of electromotive forces with two opposite directions, the electromotive force of greater value will determine the direction of the current, and in this question the current will be contrary to clockwise.

Applying second Kirchhoff's rule (loop rule) starting from point(a) in the direction of the current.

Potential drops = potential rises

$$I R + I r_2 + \varepsilon_1 + I r_1 = \varepsilon_2$$

$$I\,(R + r_2 + r_1) = \varepsilon_2 - \varepsilon_1$$

$$I = \frac{\varepsilon_2 - \varepsilon_1}{R + r_2 + r_1}$$

$$I = \frac{12 - 6}{9 + 2 + 1}$$

$$= \frac{6}{12} = \frac{1}{2} A$$

b) to calculate voltage difference between the points a ,b we move from(a)to(b)in opposite direction to the current to obtain

$$V_a + Ir_1 + \varepsilon_1 = V_b$$

$$V_a - V_b = -\varepsilon_1 - I\,r_1$$

$$V_{ab} = -6 - (\frac{1}{2})\ (1)$$

$$V_{ab} = -6.5V$$

Think ?

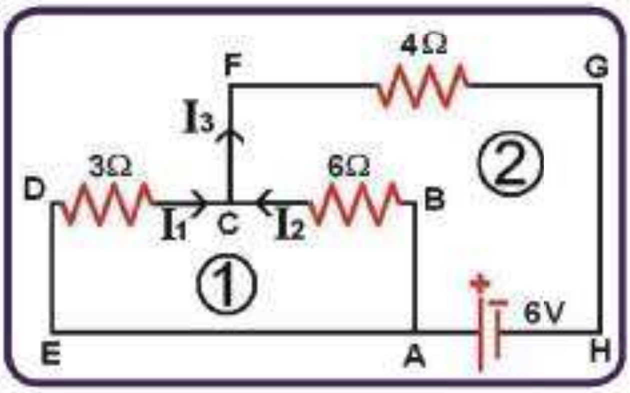
You can use the same method to calculate the voltage difference between the two points c, b You will find the result (11V).

Example 12

In Figure (34) the application of the Kirchhoff's rules find the currents with the three resistances.

Solution

use the branch rule and let it be the point C



$$\sum I_{in} = \sum I_{out}$$

$$I_1 + I_2 = I_3 ...... (1)$$

Figure 34

Applying loop rule, we choose the closed loop 1 (ABCDEA)

Potential drops = potential rises

$$I_2(6) = I_1(3)$$

$$I_2 = \frac{1}{2}I_1 \quad ....(2)$$

Equation 1 and 2 contains three variables, again we apply loop rule choosing loop 2 (ABCFGHA).

Potential drops = potential rises

$$I_2(6) + I_3(4) = 6 \quad ... (3)$$

Substituting $I_{(3)}$ in equation 3 to obtain

$$I_2(6) + (I_1 + I_2)(4) = 6 \quad ....(4)$$

Substituting eqaution (2) into (4)to obtain :

$$\frac{1}{2}I_1(6) + (I_1 + \frac{1}{2}I_1)(4) = 6$$

By simplifying the equation above, it produces

$$I_1 = \frac{2}{3}A$$

$$I_2 = \frac{1}{2}I_1$$

$$I_2 = \frac{1}{3}A$$

$$I_3 = I_1 + I_2$$

$$I_3 = 1A$$

Questions of Chapter 9

Q1) Choose the correct answer:

1- A metal wire with resistance 1Ω, what will be the resistance of a wire made of the same material of the first wire, but twice the length and half of the cross section area?

a- 0.4 Ω
b- 2 Ω
c- 0.2 Ω
d- 4 Ω

2- A copper wire with 10 Ω , what will be its resistance if the wire were cut into halves?

a- 10 Ω
b- 20 Ω
c- 5 Ω
d- 1 Ω

3- An electrical heater with power of (1000w). When operating at (120V), what is the total power consumed by two of these heaters when connected in series to a single voltage source (120V)?

a- 400W
b- 500W
c- 200W
d- 1000W

4 – A battery with electromotive force of (emf)(1V) and its internal resistance(r) what is the amount of external resistance (R) that, if connected through the battery poles, caused voltage differences on both ends of the battery of 1 / 2V?

a- R=1/2r
b- R = 2r
c- R = 4r
d- R = r

5- The unit ($\Omega . A^2$) is used to measure?

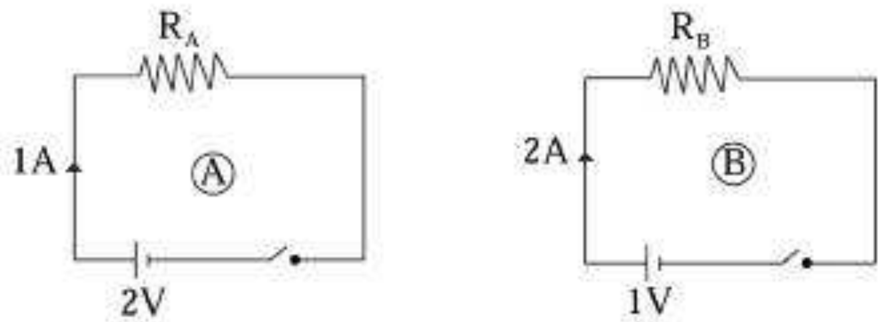
a- current
b- Energy
c- Power
D-voltage

6- A TV works with 120V and a clothes dryer works with 240V according to this information only, which devise will consume more energy?

a- The TV.
b- The clothes dryer.
c- This information is not enough.

7- In circuit (A), the battery is equipped with a double voltage provided by circuit (B), but the current passing through circuit (A) is half the current value of circuit (B), which means that circuit (A) has resistance. . . . . For the Resistance in the circuit (B).

a- double
b- Half
c- Equal
d- four time



8- Two wires made of one material have resistance of 0.1 Ω the length of the second wire is twice the first wire and has a half the radius of the first. What is the resistance of the second wire?

a- 400 Ω
b- 0.2 Ω
c- 0.1 Ω
d- 0.8 Ω

9- Two identical lamps are connected to two similar batteries in two different ways. Method 1: The two lamps are connected in parallel and it is connected via the first battery poles.
Method 2: The two lamps are connected in series and it connected across the second battery poles. The ratio of the power of the battery in the first method to the power processed in the second method is (assuming that the internal resistance is r =0)

a- 1/4
b- 4
c- 1/2
d- 2

Q2) what is the advantage of the galvanometer is Wheatstone bridge when measuring an unknown resistance.

Q3) what is the meaning of Hyperpolarization. Write one application.

Q4) what is the advantage of making the resistance of the electrical motor that is used in the operation of the car, is equal to the internal resistance of the car's battery?

Q5) Why the voltage difference on both ends of the internal resistance is reverse the electromotive force of the source (ε) in sign?

Q6) Why the voltage difference on both ends of the battery (ΔV) located within the electric circuit less than the electromotive force (ε) of the battery?

Q7) Why does the intensity of the car's internal lighting is bright up or down during the operation of the car?

Q8) Connecting the batteries in series leads to an increase in (emf) of the circuit, what are the benefits of connecting them in parallel?

Problems of Chapter 9

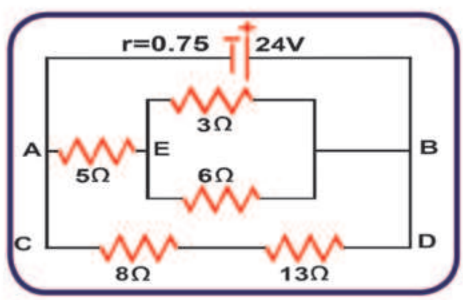
P1- A copper coil for an electric motor with resistance of 50 Ω at $20°C$ and after a period of time, its resistance becomes 60 Ω, what is the its new temperature? Note that the temperature Coefficient of Resistivity of copper is 39.3×10^{-4} $(°C^{-1})$

P2- an electromotive force of a battery 13V and a voltage difference between poles of 12V, when an external load resistance (R) with a power of 24W is equipped, calculate:

a- The resistance (R)
b- The internal resistance (r)

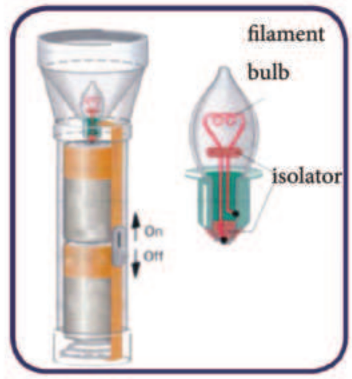
P3- at the next electric net, calculate:

a- The external resistance
b- The total current (current of the battery.)
c- The lost potential (potential drops) in the battery
d- The potential difference through the battery
e- The current passing through each resistance.

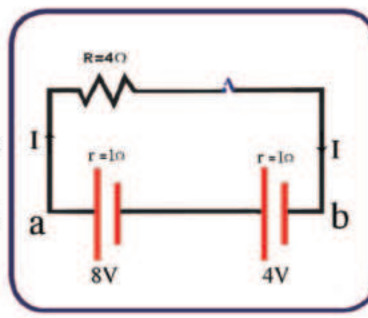


P4- for the next figure, the current passes through a the flashlight with (0.4A) with a voltage of (3.0 V)

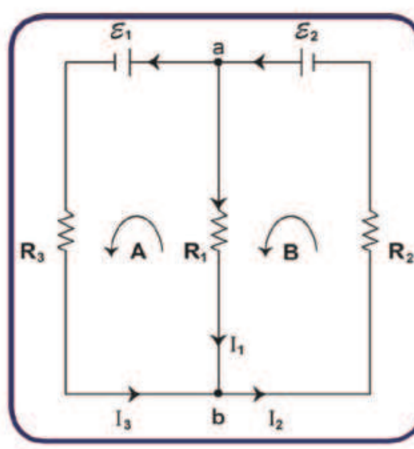
a- Calculate the lamp fuse resistance.
b- The amount of power fitted to the lamp.
c- Power consumption in the lamp during the duration of 5.5minutes of operation.



P5- the next circuit, the resistance R=4 Ω, connected in series with two battery (4V, 8V) if you know that: r_1= 1Ω ,r_2=1Ω, find:
a- The current
b- The potential difference between the points (a, b) when circuit is closed.
c- The potential difference between the points (a, b) when circuit is opened.



P6- the next figure: R_1 = 5Ω, ε_2=1 V , R_2 = 2Ω , R_3 = 4Ω, ε_1 = 3V
a- Calculate the value of the currents passing through the shown net branches.
b- Calculate the potential difference between. (Vab) , (b), (a)



Chapter 10: Magnetism

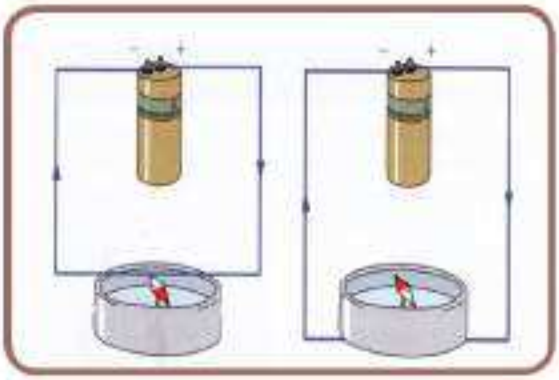


Figure 1

You learned earlier that static electric charges have an electric field that affects other electrical charges with electric force. If the electric charge moves, an electrical current is generated, you got to know its properties. In 1820, the scientist Oersted discovered a very important experiment notice Figure (1) that moving electric chargers had another effect, noting that a magnetic needle (compass) was affected by an electric current in the wire near to it, which led him to wonder:

Does the electric current produce a magnetic field? How to describe this field in terms of magnitude and direction? Is the amount of magnetic field varies depending on the wire shape in which the current applies? These and other questions we will be able to answer after your study of this chapter.

10.1 The Magnetic Field

It is the space that surrounds the magnet from all directions and shows the influence of magnetic force in a moving electrical charge in that space.

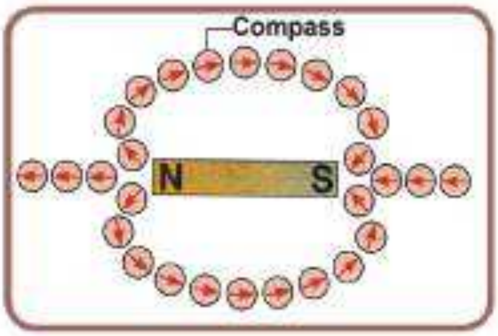


Figure 2

The intensity of the magnetic field at one point is expressed by the density of the magnetic flux at that point and decreases as we move away from it, and has symbol ($\vec{B}$) and The magnetic field has a specific amount and direction at each point in the area surrounded the magnet. The direction of the magnetic field at any point in the vacuum is the direction the compass needle takes at this point, notice figure (2).

10- 2 Magnetic Flux and Magnetic Flux Density

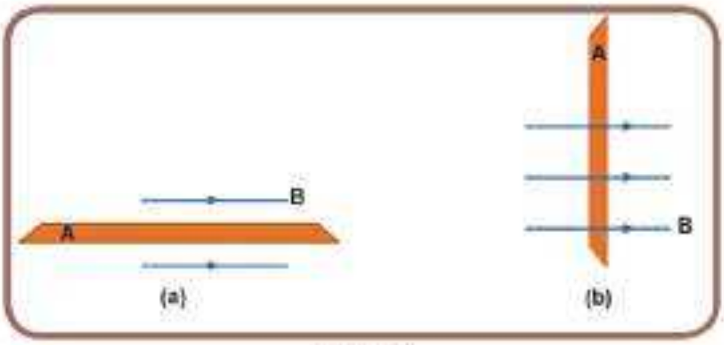


Figure 3

The magnetic field is represented by closed loops that is why there cannot be an individual magnetic pole (north or south) and these closed lines are called magnetic forces lines and the direction of the magnetic field at any point in the field is the same direction as the magnetic forces lines passing through that point where the number of magnetic forces lines that cross the vertical area on the direction of the lines is the magnetic flux density which is a vector quantity in the direction of the magnetic field. While the total lines that the field contains are called the magnetic flux (Φ) in that area, notice figure (3). The unit to measure the magnetic flux (Φ) in the international system (SI) is Weber or Maxwell.

Weber=10^8 Maxwell

And the magnetic flux density $(\vec{B})$ is measured by the number of magnetic lines to the unit, which penetrates the magnetic field vertically, according to the relation:

$$\text{magnetic flux density } (\vec{B}) = \frac{\text{magnetic flux}(\Phi)}{\text{area}(A)}$$

$$(\vec{B}) = \frac{(\Phi)}{(A)}$$

The unit of the magnetic flux density $(\vec{B})$ is (weber/m^2)which is called Tesla (T) while the magnetic flux (Φ) unit is (Tesla).(meter)^2, [(T.m^2)] wich is called Weber (wb), table (1) shows the approximate values of the magnetic flux.

Table (1)

Some approximate amounts of intensity of magnetic fields	
Source of magnetic field	magnetic flux density Tesla
A strong electric magnet generated from a current that is applied to a superconducting material under very low temperatures	30
The magnet used in the medical imaging unit is called (MRI)	2
Magnetic rod .	10^{-2}
The surface of the sun.	10^{-2}
The surface of the earth.	0.5×10^{-4}
Within the human brain (due to the influx of nerves).	10^{-13}

Example 1:

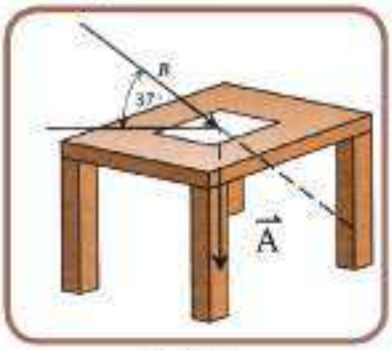


Figure 4

A rectangular Paper has dimensions (21.5cm× 28cm) placed on a horizontal table notice Figure (4). Calculate the amount of magnetic flux (Φ) passing through the paper resulting from the Earth's magnetic field 5.31×10^{-5}T affects in the direction of 37 ° angle horizontally.

Solution

The magnetic field is considered regular on the paper area plane, we choose the vector of the surface area of the paper to be downward, so the angle measurement between $\vec{B}$ and the area vector $\vec{A}$ equals 53°, and by applying the following relation we get the magnetic flux:

$\Phi = BA\cos\theta$

$\Phi = (5.31\times10^{-5})(0.215\times0.280)\cos53^\circ$

$\Phi = 1.92\times10^{-6}\ T.m^2$

10- 3 Earth's Magnetic Field

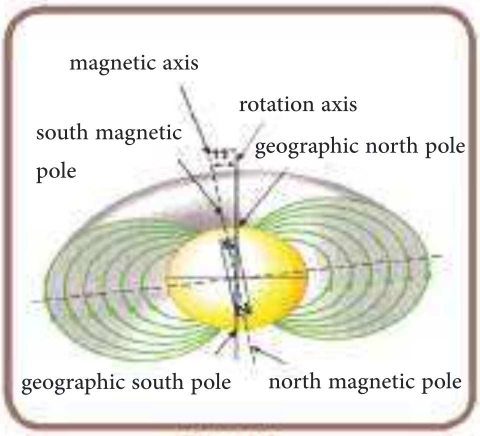


Figure 5

By noticing figure (5) the magnetic field of the Earth is shown to be like a giant magnetic rod buried in the ground and the South magnetic Pole is located near the geographic North Pole and the North magnetic Pole is located near the geographic South Pole. That is, the Earth's magnetic axis deviates slightly from the Earth's geographic axis (about 11°).

Do you know?
Some species of animals such as birds invest the magnetic field of the Earth as its guide in the course of their migration from one place to another.

10.4 The dip angle and the magnetic deviation angle

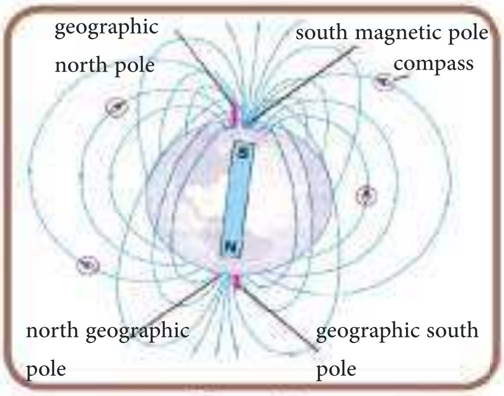


Figure 6

If we make the magnetic axis of the needle horizontal notice figure (6). The needle can rotate freely at a vertical plane and when the needle is placed on one of the magnetic poles (north or south), the needle is stabilized by a vertical position (it makes angle 90 ° with the horizon). When moving the needle to the magnetic equator, this angle will become zero. The angle between the plane of the magnetic needle and the horizontal line is called (dip angle) and it varies between (0° – 90°). If we make the axis of the magnetic needle vertical and the needle can rotate freely horizontally, then it is aligned parallel to the magnetic meridian line. The angle between the magnetic meridian line and the geographic axis is called the angle of the magnetic deviation and its amount in specific areas equals (0 °) or (180 °) the line passing through the point at which the angle of deviation is (0 °) is called (Line of lack of deviation).

10. 5 Magnetic force affecting in moving electric charge particle

When a static test charge (q_o) is placed at a point in a magnetic field area, it is practically found that the magnetic force affecting it is zero. However, if the test charge (q_o) moves with velocity ($\vec{\upsilon}$) through the magnetic field in which the flux density ($\vec{B}$) is perpendicular to it, then it is affected by a force perpendicular to the direction of the velocity ($\vec{\upsilon}$) notice figure (7), The magnetic force ($\vec{F}$) is perpendicular to $\vec{\upsilon}$, $\vec{B}$ plane, that have angle θ between them and it is given the following relation:

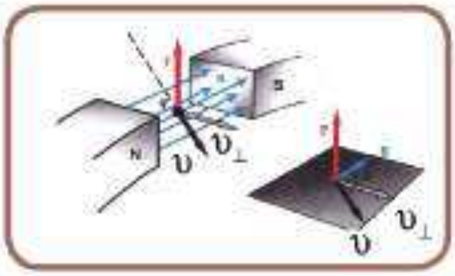


Figure 7

$$\vec{F} = |q_o|\ \vec{\upsilon} \times \vec{B}$$

$$F = |q_o|\ \upsilon \times B \sin\theta$$

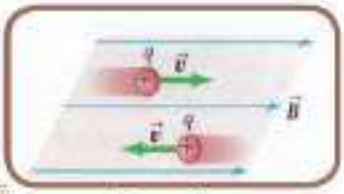


Figure 7a

a charge moving in parallel with the magnetic field $\vec{B}$ the magnetic force = 0

The magnitude of the magnetic force ($\vec{F}$) is proportional to (sinθ) where θ represents the angle between the direction of motion of the charge ($\vec{\upsilon}$) and the field $\vec{B}$. Therefor the magnetic force become the maximum when θ=90°. The direction of the magnetic force $\vec{F}$ can be determined by the right hand rule that states: if you rotate the right hand fingers except the thumb from the direction of the charge velocity ($\vec{\upsilon}$) towards the magnetic flux density $\vec{B}$ at a sharp angle θ then the thumb direction is the magnetic force ($\vec{F}$) direction as shown in figures (7a, b, c).

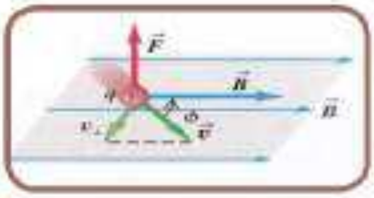


Figure 7b

a charge moving at an angle θ with the magnetic field $\vec{B}$ and the magnetic force $F = q_o\, \upsilon\, B \sin\theta$

It is worth mentioning that if the moving charge is negative, then force $\vec{F}$ will have the same magnitude but in the opposite direction.

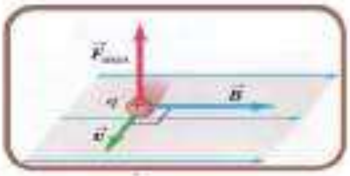


Figure 7c

a charge moving vertically with magnetic field $\vec{B}$ and magnetic force $F_{max} = q_o \upsilon B$

Example 2

Proton (positive electrical charge) moving with velocity 5×10^6 m/s encountered a magnetic field of 0.4T its direction making angle $\theta = 30°$ with proton's velocity vector, knowing that the positive charge of proton is 1.6×10^{-19}C, find:

a- The magnitude and direction of the magnetic force affecting the proton.

b- Acceleration of the proton knowing that it mass 1.67×10^{-27} kg

Solution

a) The magnitude and direction of the magnetic force affecting the proton.

$$F = |q| \upsilon B\sin\theta$$

$$F = (1.6 \times 10^{-19}C)(5 \times 10^{6}m/s)(0.4\,T)(\sin 30°)$$

$$F = 1.6 \times 10^{-13}N$$

The direction of the magnetic force is upward according to the right hand rule.

b) To calculate the Acceleration of the proton we apply Newton's second law:

$$a = \frac{F}{m_p}$$

$$a = \frac{1.6 \times 10^{-13}N}{1.67 \times 10^{-27}kg} = 9.6 \times 10^{13} m/s^2$$

10- 6 The effect of magnetic field on current carrying conductor

The electric current flowing in a wire made from a conducting material of length (L) and cross sectional area (A) passing an electrical current (I), and the wire is put magnetic field

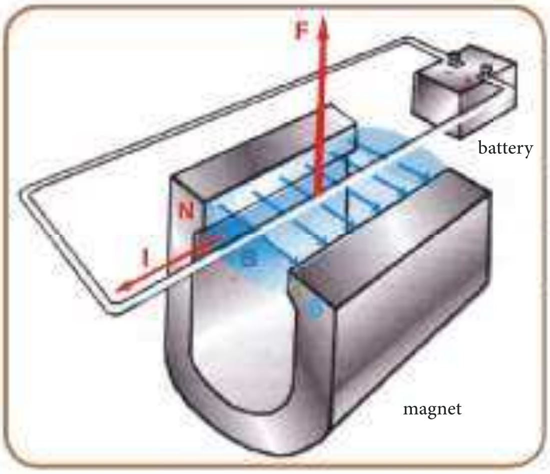


Figure 8

($\vec{B}$), notice figure (8).

The charges move inside the conducting material with velocity called (drift velocity υ_d) when the charge moves through the magnetic field then the force influencing it can be calculated from the relation:

$F = q_o \; \upsilon_d \; B.\sin\theta$

And to find the magnetic force that influence the wire we assume the existence of moving electrical charges in the wire and the number of charges is (NAL) where (N) is the number of charges per volume unit, from that the total magnetic force is given by the relation:

$$F = q_o \, \upsilon_d B(NAL)\sin\theta$$

and the drift velocity

$$\upsilon_d = \frac{I}{NqA}$$

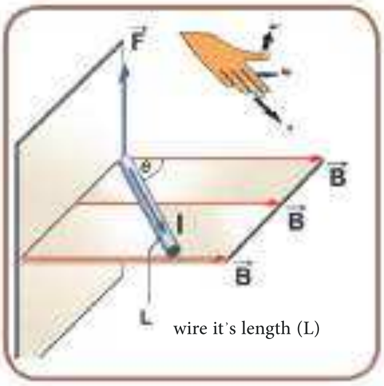


Figure 9

By substituting the drift velocity in the equation we get:

$$F = I\,L\,B\sin\theta$$

And when the force is perpendicular to the velocity then $\theta = 90^o$ and $\sin 90^o = 1$ where the force will have the maximum amount, that:

$$F = I\,L\,B$$

This force vanish when the current direction is parallel to the magnetic field ($\theta = 0^o$) and also we can indicate the direction of the magnetic force by the right hand rule notice figure (9).

Example 3:

A wire of length 0.5m was placed perpendicular to the regular magnetic field, and when an electrical current of (20A) flowed in it a force influenced it (3N) find the magnetic flux density B applied on the wire?

Solution

$$F = I\,L\,B \sin\theta$$

$$\because\ \theta = 90^{\circ} \quad \therefore \sin 90^{\circ} = 1$$

$$\therefore F = I\,L\,B$$

$$B = \frac{F}{I\,L} = \frac{3N}{(20A)(0.5m)} = 0.3\ \frac{N}{A\ .\ m}$$

$$B = 0.3\ \frac{wb}{m^2} = 0.3T$$

10.7 Motion of a charge particle in a uniform magnetic field

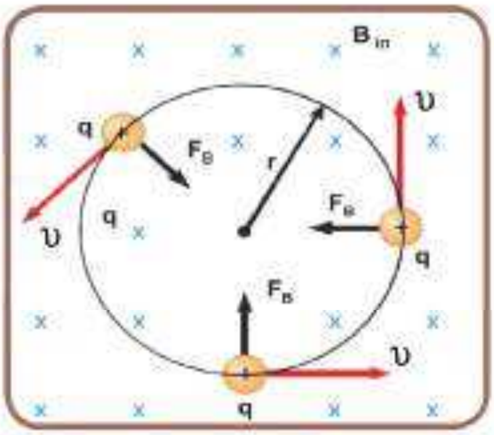


Figure 10

When a particle positively charged (+q) is moving in a regular magnetic field with speed (υ) and in direction perpendicular to the magnetic field. On the assumption that the direction of the magnetic field inside the page ⊗ as in figure(10) The particle moves in a circular path located at a plane perpendicular to the magnetic field (B) and the magnetic force (F_B) that is perpendicular to each of υ, B and its magnitude is constant which equals ($q\upsilon B$) notice figure(10). The direction of rotation is anticlockwise if the charge (q) is positive, and if the charge (q) is negative, then the direction of rotation is clockwise. To find the radius of the circular path (r), we will use the concept of central force (F_C), which is the magnetic force that works to conserve the charge in its circular path as follows:

Centripetal force (F_c) = magnetic force (F_B)

$$F_c = F_{mag}$$

$$\frac{m\upsilon^2}{r} = q\upsilon B$$

$$r = \frac{m\upsilon}{qB}$$

That is, the radius of the circular path (r) is directly proportional to the linear momentum (mv) of the particle and inversely to the amount of the particle charge and the magnetic flux density.

10.8 Magnetic field of long wire flowing current

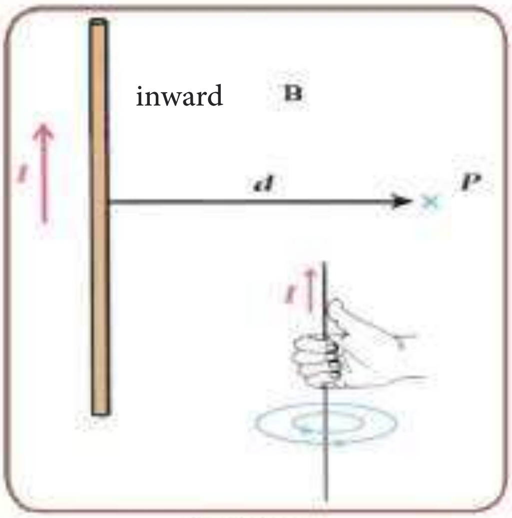


Figure 11

Soon after, Oersted discovered (1820) that the compass needle deviates by the effect of the magnetic field of a conductor carrying a current. Two scientists reached (Payot and Savarat) through multiple experiments on the force exerted by an electrical current flowing in the wire on a magnet placed near the wire. A mathematical expression was obtained that gives the magnetic field at some point in the vacuum near the wire in terms of the electrical current causing this field according to the Payot and Savarat law (Which states that the amount of magnetic flux density (B) generated in the vacuum in the point away a distance (r) from a long wire, passes an electric current (I)). Notice figure (11) it is given by the relation:

$$B = \frac{\mu_o I}{2\pi r}$$

Where μ_o is the a constant called permeability and its value:

$$\mu_o = 4\pi \times 10^{-7} \frac{wb}{A\ .\ m}$$

Example 4

How much is the magnetic flux density 3m away from a straight long wire carries direct current of 15A.

Solution

by apply payot and savarat we get:

$$B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 15}{2\pi \times 3} = 1 \times 10^{-6}\ T$$

$\therefore$ **B = 1 x 10 $^{-6}$ T**

10- 9 Magnetic force between two parallel conductors

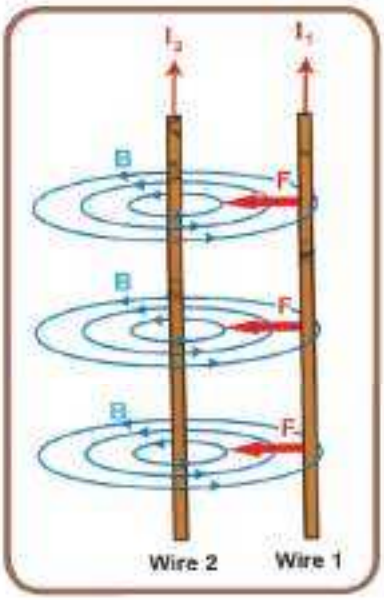


Figure 12

Figure (12) shows two conducting straight long parallel wires separated by distance r, the first wire carries current (I_1) while the second wire carries current (I_2) in the same direction.

The current flows in the second wire (I_2) generated a magnetic field density (B_2) on the first wire. By noticing figure (13) we find that the direction of (B_2) is perpendicular to the first wire, and the magnetic flux density (B_2) can be found from the relation:

$$B_2 = \frac{\mu_0 I_2}{2\pi r}$$

We can find the magnetic force influencing the first wire, by the existence of the magnetic field B_2 that generated current I_2 as follows:

$$F_1 = B_2\ I_1\ L$$

By substituting B_2 in the equation we get:

$$\therefore F = \frac{\mu_o I_2}{2\pi r} I_1 L = \frac{\mu_o I_1 I_2}{2\pi r} L$$

Similarly we can get the same result if we calculated F_2 that is influencing the length (L) of the second wire, that will be directed toward the first wire F_1 and so we find that the magnetic force is the result of two forces between the two wires. It is attraction force when the currents passing in the wires are in the same direction. However, if the directions of currents flowing through the wires are opposite then the resultant force will be repulsion force.

You can check this by yourself. Whether it is attraction or repulsion force, the magnitude of this force per unit length in the wire is:

$$\frac{F}{L} = \frac{\mu_o I_1 I_2}{2\pi r}$$

The idea of attraction between two long parallel wires was used to indicate and identify the unit of the current, according to the international system of units it is (Ampere), so if we substitute the values of both currents in the above equation as (1Amp) and the distance between the two wires (r=1m) and the space permeability $\mu_o = 4\pi \times 10^{-7} \frac{wb}{A.m}$ we get:

$$\frac{F}{L} = \frac{(4\pi \times 10^{-7})(1)(1)}{(2\pi)(1)} = 2 \times 10^{-7} \ N/m$$

Depending on the result found Ampere is identified as:

It is the current that if it passed through two long parallel wires that are separated with distance 1m and placed in space a mutual force per unit length of $2\times10^{(-7)}$ N/m will be resulted.

Think?

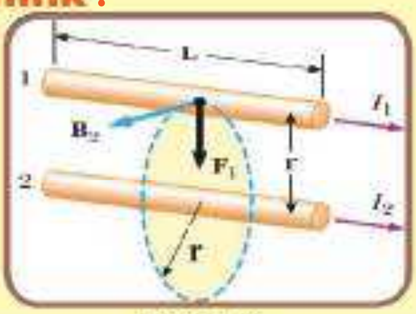


Figure 13

When I_1=2A and I_2=6A in figure (13) which of the following is correct?

a) $F_1 = 3F_2$ b) $F_1 = \frac{F_2}{3}$ C) $F_1 = F_2$

10.10 The magnetic field of a solenoid

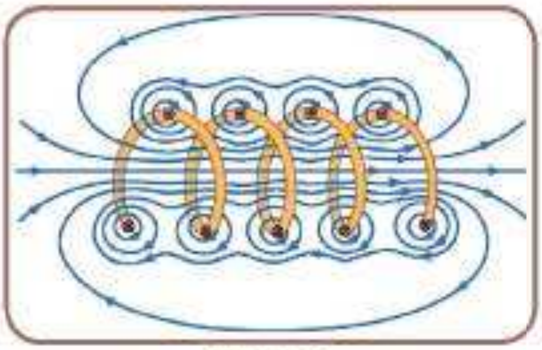


Figure 14

You have already studied that the solenoid is a long wire wrapped in spiral rings, and if an electric current is poured into the coil, it acts as a magnetized rod with two poles, one north (N) (magnetic force lines are leaving the pole) and the other south (S) magnetic force lines are entering the pole completing its cycle inside the coil, taking its closed path inside and outside the coil in the shortest possible way notice figure (14).

The magnetic flux density (B) inside the coil is regular and larger than it is outside. The magnetic flux density (B) can be calculated within a long coil according to the following relation:

$$B = \mu_o \frac{NI}{L}$$

Where N represents number of turns in the coil, I represents the current, L represents the length of the coil, B represents the magnetic flux density inside the coil, and the equation can be written as follows:

$$B = \mu_o \, nI$$

the number of turns per unit length = $n = \dfrac{N}{L}$

It is worth mentioning that the last equation is valid only in the case of points near the axis of the coil (far from the ends) of a too long solenoid, and the field near the ends is smaller than the amount given by the last equation.

Question ?

The movement of light spring rings has a certain amount of freedom. If the spring is suspended in the roof and a large current flows in it, its rings converge or diverge? And why?

Example 5

A cylindrical coil filled with air has 100 turns and length 20cm, carries a current of 4A, what is the magnetic flux density B at the coil axis?

Solution

$$B = \mu_o \frac{NI}{L}$$

$$\mu_o = 4\pi \times 10^{-7} \frac{wb}{A \cdot m}$$

$$\therefore B = 4\pi \times 10^{-7} \frac{100 \times 4}{0.2}$$

$$B = 2.5 \times 10^{-3} \frac{wb}{m^2}$$

$$B = 2.5 \times 10^{-3} \text{ Tesla}$$

10.11 Torque on a current loop

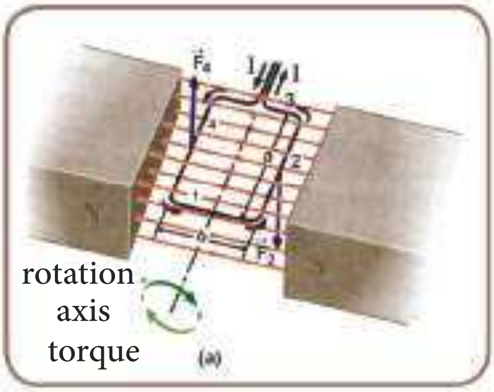


Figure 15

We already clarified, how a magnetic force influence a conductor carrying an electrical current when this conductor is in an external regular magnetic field and in the case of existence of rectangular coil parallel to the regular magnetic field lines (B) flows in it an electrical current (I), by noticing figure (15) we find the regular magnetic flux density B parallel to the sides (1, 3) in the rectangular coil so that the magnetic force does not influence them (the angle between the vector B and current direction = ZERO). While the magnetic forces influencing the sides (2, 4) have equal magnitudes and opposite directions so the coil get influenced by these two parallel forces (F_2,F_4) that are perpendicular to the sides and the magnitude of each:

$$F = I\,L\,B$$

$$F_2 = F_4 = I\,a\,B$$

And the vertical distance between them is equal to the width of the coil that is equal to (b). The coil is then affected by a two-phase torque working on rotations around its axis and the torque (τ) for both forces F_2, F_4 is given as:

Torque (τ)= magnitude of force (F)×lever arm (b)
While the total torque (τ_{total}) on the coil that is resultant from the two forces F_2, F_4 is:

$$\tau_{total} = F_2 \times \left(\frac{b}{2}\right) + F_4 \times \left(\frac{b}{2}\right) = (I\ a\ B) \times \left(\frac{b}{2}\right) + (I\ a\ B) \times \left(\frac{b}{2}\right)$$

$$\tau_{total} = I(a\ b) \times B$$

Where (a, b) represents the length and width of the coil and the result of their multiplication equals the area of the coil: A= ab

$$\therefore \tau_{total} = I\,A\,B$$

If the number of turns of coil is equal to N, so the total torque (τ_{total}) equals:

$$\tau_{total} = B\,I\,A\,N$$

Where (I N A) is called magnetic dipole moment μ, which is a vector quantity and its direction is perpendicular to the area (A) notice figure (16). If the coil plane was oblique to the flux lines then the torque equals:

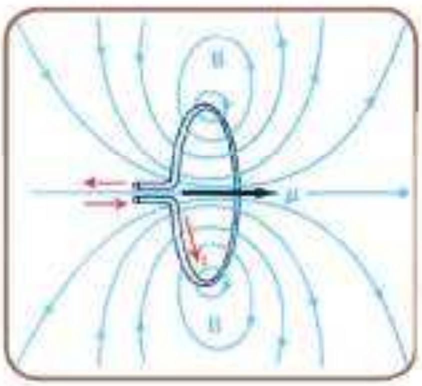


Figure 16

$$\tau = B\,I\,A\,N \sin\theta$$

If the coil plane perpendicular to the magnetic flux lines of the dipole torque = zero because (θ = 0).

Where θ is the angle between the perpendicular to the coil plane and the lines of magnetic flux.

Example 6

A wire coil of area 2.0 x 10^{-4} m^2 and 100 turn, has a current flowing in it (0.045A) the coil was placed in a regular magnetic field that has flux density of (0.15T).

How much is the maximum torque that magnetic field can apply on the coil?

Solution

The maximum torque that magnetic field can apply on the coil is when θ=90°.

$$\sin 90^\circ = 1$$

$$\tau = (N I A)(B \sin\theta)$$

$$\tau = (N I A)(B \sin 90^\circ)$$

$$\tau = 100 \times 0.045 \times 2 \times 10^{-4} \times 0.15 \times 1$$

$$\tau = (9 \times 10^{-4}\ A.m^2)(0.15) \times 1$$

$$\tau = 1.35 \times 10^{-4}\ N.m$$

10.12 Magnetic Hysteric's

If we place a rod of a ferromagnetic material (such as iron) in a coil cavity, it will be magnetized in the case of continuous flow of electric current in the coil, The magnetism acquired by the iron rod is due to the containment of iron on very small magnets, each consisting of a group of dipoles it is called a domain whose torques is aligned towards the external magnetic field. Notice Figure (17).

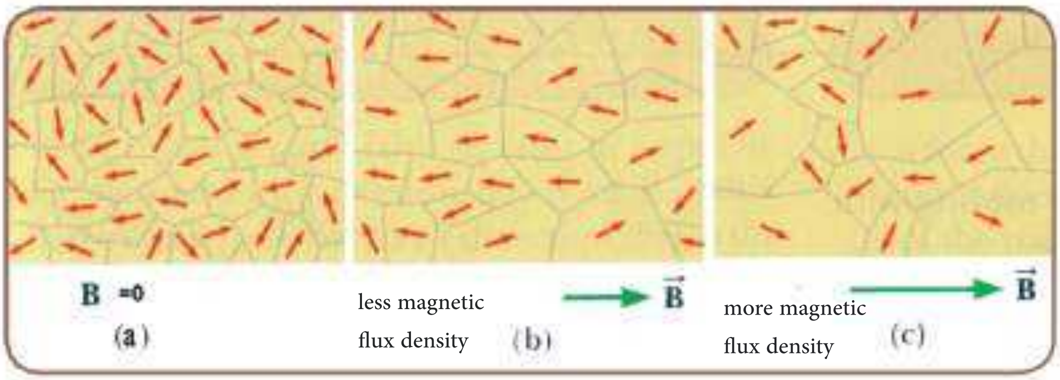


Figure 17

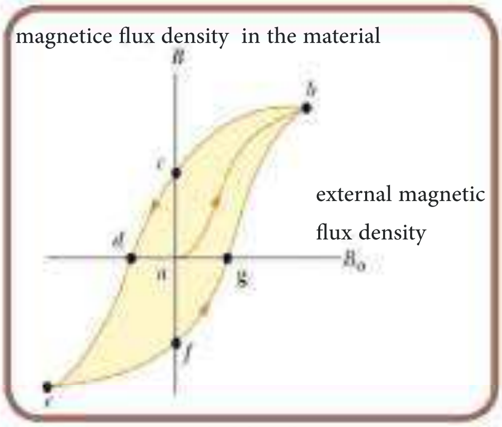


Figure 18

When we draw a graph shows the external magnetic flux density (B_o) that the electrical current generated and the magnetic flux density generated in the material (B) by the influence of the magnetic field (B_o) and for a complete cycle notice the figure (18), we get a closed curve called Magnetic Hysteric's or magnetic hysteresis loop.

At the beginning the iron leg is not magnetized at point (a) then ($B=0$, $B_o=0$) by the increase of the flowing current in the coil the external magnetic flux density (B_o) increases also the magnetic flux density in the material (B) increases till it reach the saturation at state (b) and by decreasing the current to zero it reaches point (c) that ($B_o=0$) but we find that the magnetic field (B) stay in the material and do not vanishes and to remove the magnetism from the material (B), we reverse the current direction then the external magnetic flux density (B_o) reverse as well till it vanishes at point (d) and in case that current continued increasing in the opposite direction then (B_o) increases till it reach point (e) and It is the magnetic saturation state of the material in the opposite direction, then we decrease the current till (f) then we return the current to its original direction and so on till the loop get closed. Knowing that the magnetic hysteresis loop of steel is wide and has big area (the magnetic default in steel is big), while iron has a thin hysteresis loop of a small area. Which means the steel conserve the magnetism obtained for longer time after the magnetic field vanishes, however, the iron acquire the magnetism rapidly and loose it rapidly after the magnetic field vanishes because it does not conserve the magnetism obtained after the magnetic field vanishes.

Remember:

The area of the close curve of the hysteresis loop represents the lost energy value that appears as heat in the core iron.

Questions of Chapter 10

Q1/ Choose the correct phrase for each of the following statements:

1- The magnetic field arises from:

a- Iron atoms

b- Static electric charge.

c- Magnetic Diya Materials.

d- Kinetic electric charge.

2- To draw the magnetic force lines of a particular magnetic field requires knowledge:

a- Magnetic field direction only

b- The magnitude of magnetic field only.

c- The magnitude and direction of the magnetic field together.

d- Source that causes the magnetic field.

3- When drawing the magnetic force lines, the region where the largest amount of field is the area in which they are:

a- The magnetic force lines so close to each other.

b- The magnetic force lines so far from each other.

c- The magnetic force lines only parallel.

d- All the previous cases.

4- A direct electric current flows in one of the power transmission lines to the east. The direction of the magnetic field under the wire is directed towards:

a- North

b- South

c- East

d- West

5- magnetic flux density B at a distance of (r) from a long wire with an electric current that is proportional to:

a- r

b- r^2

c- 1/r

d- $1/r^2$

6- The amount of magnetic flux density inside a coil:

a- ZERO

b- Regular with straight lines.

c- Increases as we move away from the axis.

d- Decreases as we move away from the axis.

7- If an electrical charge moves with velocity $\vec{\upsilon}$ and in a direction perpendicular to the magnetic force lines of a regular magnetic field, this field will change:

a- The amount of charge.

b- Mass of the charged body.

c- Direction of charge velocity.

d- Kinetic energy of the charge.

8- Conductive wire carrying an electric current placed within a regular magnetic field was a current towards the direction of the magnetic field itself, the wire:

a- Will be affected by a magnetic force working on moves it parallel to the magnetic field lines.

b- will be affected by a magnetic force working on moves it perpendicular to the magnetic field lines.

c- will be affected by a dipole moment that is working to rotate it till it stops perpendicular to the magnetic field lines.

d- Does not affect by a force or toque.

Q2/ What is the amount of work done by a regular magnetic field in a moving electrical charge at a velocity of υ in a perpendicular direction to the field lines.

Q3/ Near the North Pole of a magnet from a rubber balloon blown and rolled with wool (negative charge) and hanging with a thread, will the balloon be attracted or repulsion or not affected by magnets? And why?

Q4/ Determine the direction of the magnetic force influencing the charged particle shown in Fig. (19) When entering the regular magnetic field for each of the following cases:

a- Positive charge particle.

b- Negative charge particle.

c- Negative charge particle.

d- Positive charge particle

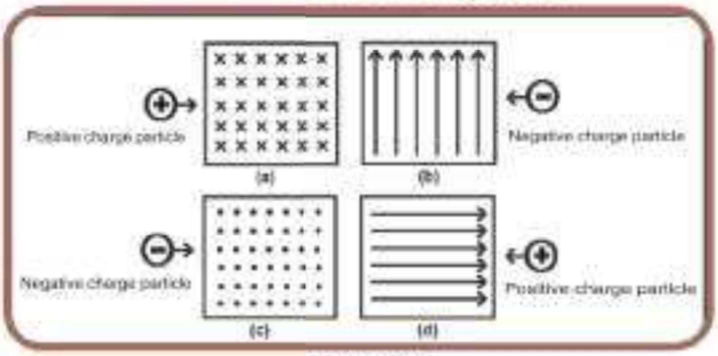


Figure 19

Q5/ can the magnetic field influence in static electric charge and how?

Q6/ a metallic ring has a continuous current flowing in, clarify in which position this ring can be put inside a regular magnetic field so that:

a- The field influence it with the maximum torque

b- The field does not influence it with torque

Q7/ if the same current flows in a wire places in the same magnetic field ($\vec{B}$) in the four cases notice figure (20) arrange the figures in order in terms of the magnetic force magnitude influencing the wire from the bigger to smaller.

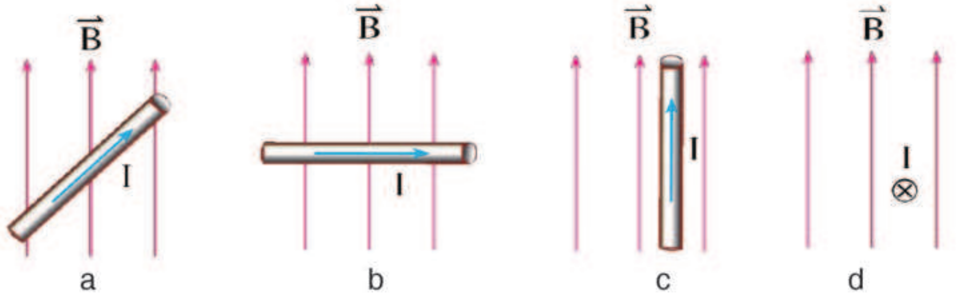


Figure 20

Problems of Chapter 10

P1/ An electron moves in the TV tupe in the screen direction at velocity 8×10^{6} m/s in the x-axis direction. Notice figure (21), the magnetic flux density influencing it (0.025T) in the direction 60° with the x-axis what is the magnitude of:

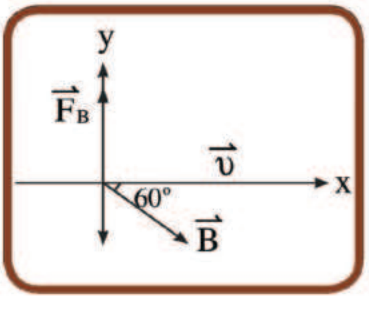


Figure 21

a- The magnetic force influencing the electron

b- The acceleration of the electron

Knowing that:
Electron charge = 1.6×10^{-19} C
Electron mass = 9.11×10^{-31} kg

P2/ A proton moves in acircular path with radius (14cm) inside a regular magnetic field density (0.35T) perpendicular to proton's velocity vector. Calculate the linear velocity of the proton.

P3/ A coil contain (40) turns has a direct current flows in it (2A) is placed in a regular magnetic field its flux density (0.25T) notice figure (22), what is:

a- The rotational torque influencing the coil.

b- The magnetic force influencing in each side and it's which direction?

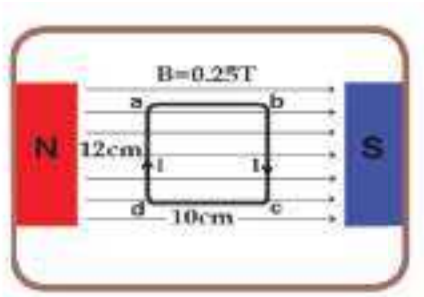


Figure 22

P4/ Two long parallel wires separated by vertical distance 5cm if the current flowing through each of them is 500A in one direction:

a- Calculate the intensity of the magnetic field resultant from each wire at the other wire position.

b- The magnetic force influencing the unit length of both wires.

P5/ A proton moves at a circular orbit of radius (14cm) in a regular magnetic field of density 0.35T perpendicular to proton velocity, find:

a- Linear velocity of proton (m_p=1.67×10 $^{-27}$ kg)

b- If an electron moved vertically on the same magnetic field with the same linear velocity, how much is the radius of its circular path?

P6/ An electron was thrown with velocity 10^6 m/sec in a magnetic field of flux density (5T), and its direction is perpendicular to the paper surface and going far from the reader so if the electron was moving by the paper plane perpendicular to B calculate:

a- The magnetic force influencing it and its direction.

b- The rotational radius, electron mass m_c=9×10 $^{-31}$ kg

P7/ A rectangular coil has dimensions (5cm x 8cm) was placed parallel to the regular magnetic field of flux density (0.15T) if you know that the coil consists of one turn and carries a current (10A) calculate the torque influences by the field on the coil.

P8/ Calculate the magnitude of the magnetic force influencing an electron moving parallel to a long wire separated by distance 10cm with velocity of 5 x 10^4 m/sec knowing that the wire carries a current if 1.5A