PHY-1111: Physics

Chapter- 1 (Mechanics)

by

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❖ What is meant by Fundamentals of Physics?

The research carried out in the Fundamental Physics theme is focused on discovering the nature of space and time and the proprieties of matter in the universe at the deepest level.

❖ What is the difference between Physics and Fundamentals of Physics?

According to the scientist descriptions, "Physics" is suitable for engineers and science majors and "Fundamentals of Physics" is for engineers. So, the last one is aimed at a more applied approach to the material. Hence, which one is "better" depends entirely on what you wish to get out of it.

Mechanics:

Branch of physical sciences concerned with the state of rest or motion of bodies subjected to forces.

Mechanics

- **What are the basic concepts of mechanics?**

Mechanics may be divided into three branches: statics, which deals with forces acting on and in a body at rest; kinematics, which describes the possible motions of a body or system of bodies; and kinetics, which attempts to explain or predict the motion that will occur in a given situation.

Mechanics

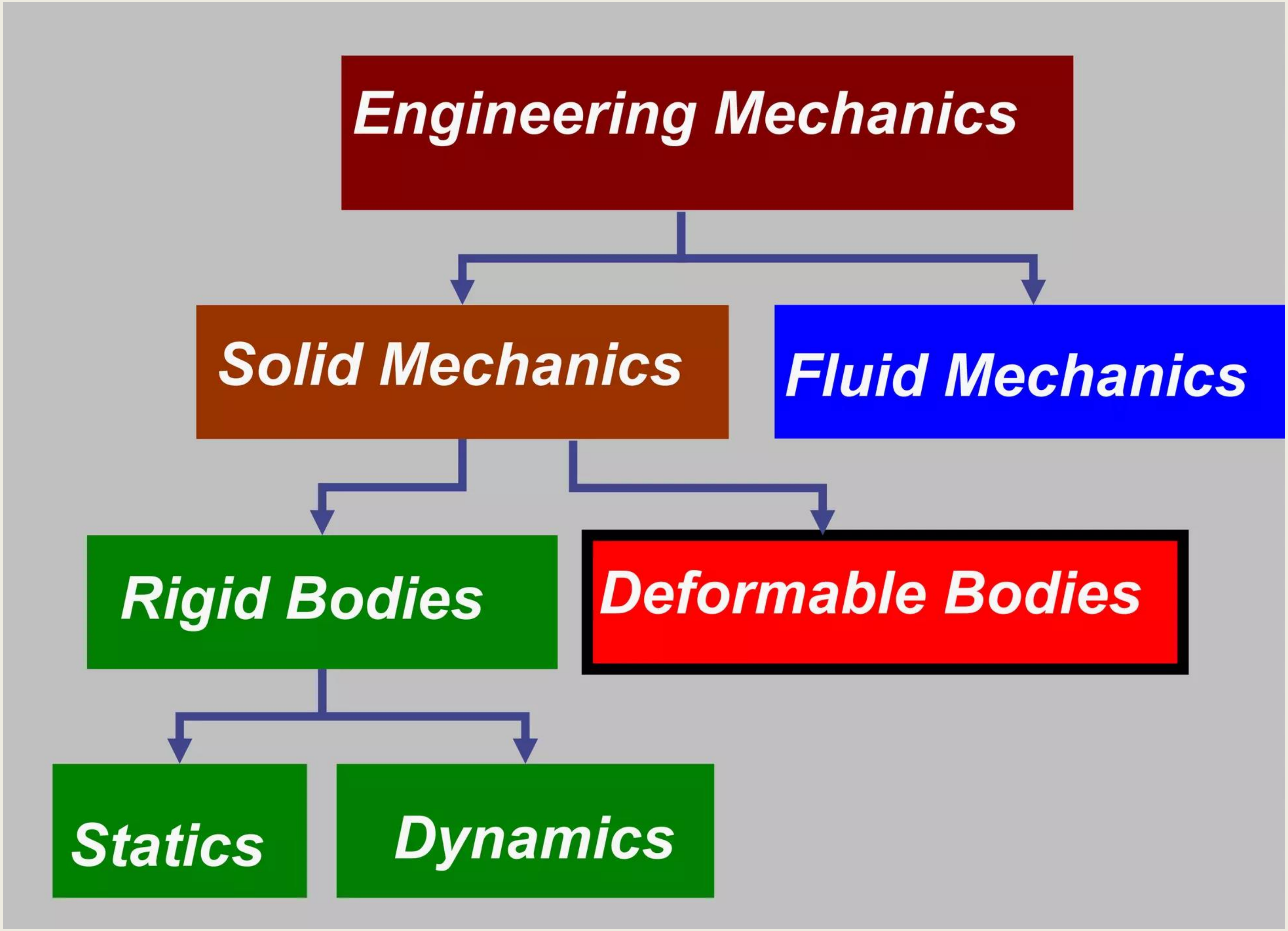
Objectives

1. To provide an introduction to the basic quantities and idealizations of mechanics.
2. To give a statement of Newton's laws of Motion and Gravitation.
3. To review the principles for applying the SI system of units.
4. To examine the standard procedures for performing numerical calculations.
5. To present a general guide for problem solving.

Following are the seven fundamental quantities: Length (meter), Mass (kilogram), Time (second), Electric current (ampere), Thermodynamic temperature (kelvin), Amount of substance (mole), Luminous intensity (candela).

Idealization in Mechanics: The mathematical description of a real engineering problem can become. simplify the application of the theory.

Mechanics


Engineering Mechanics
Solid Mechanics
Fluid Mechanics
Rigid Bodies
Deformable Bodies
Statics
Dynamics

Motion in One Dimension

Kinematics:

Describes motion while ignoring the external agents that might have caused or modified the motion.

- Consider motion in one dimension
- Along a straight line
- Motion represents a continual change in an object's position.

Types of Motion

- Translational

An example is a car traveling on a highway.

- Rotational

An example is the Earth's spin on its axis.

- Vibrational

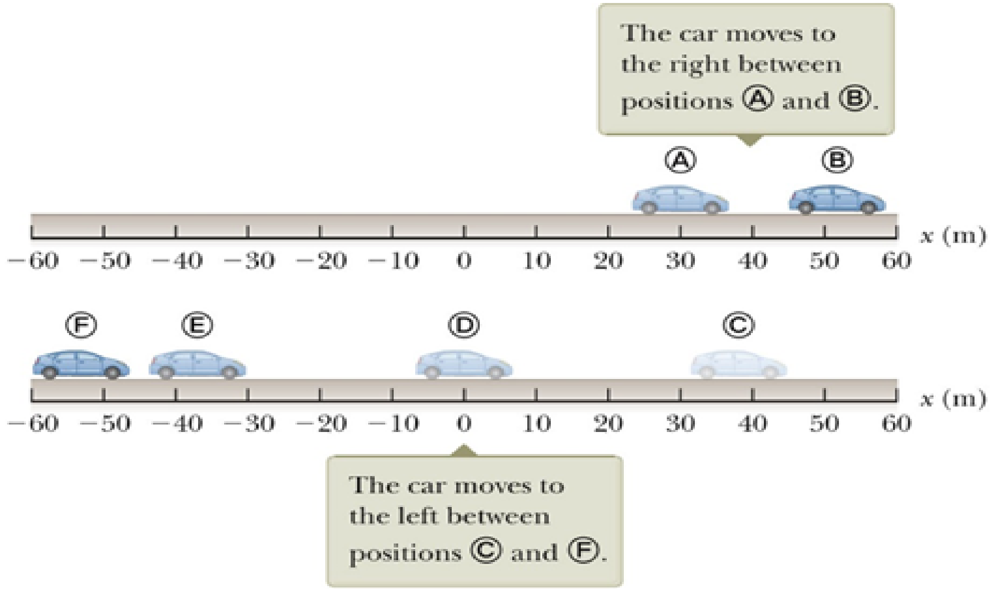
An example is the back-and-forth movement of a pendulum.

Position

The object's position is its location with respect to a chosen reference point.

- Consider the point to be the origin of a coordinate system.

Only interested in the car's translational motion, so model as a particle



Displacement:

Displacement is defined as the change in position during some time interval.

Represented as Δx

$$\Delta x \equiv x_f - x_i$$

SI units are meters (m)

- Δx can be positive or negative
- Different than distance
- Distance is the length of a path followed by a particle.

Distance vs. Displacement – An Example

Assume a player moves from one end of the court to the other and back.

Distance is twice the length of the court

- Distance is always positive

Displacement is zero

- $\Delta x = x_f - x_i = 0$ since $x_f = x_i$

Mechanics

Kinematic Equations:

- The kinematic equations can be used with any particle under uniform acceleration.
- The kinematic equations may be used to solve any problem involving one-dimensional motion with a constant acceleration.
- You may need to use two of the equations to solve one problem.
- Many times there is more than one way to solve a problem.

Kinematic Equations, 1

For constant a_x,

$$v_{xf} = v_{xi} + a_x t$$

Can determine an object's velocity at any time *t* when we know its initial velocity and its acceleration

Kinematic Equations, 2

For constant acceleration,

$$v_{x,avg} = \frac{v_{xi} + v_{xf}}{2}$$

The average velocity can be expressed as the arithmetic mean of the initial and final velocities.

- This applies only in situations where the acceleration is constant.

Kinematic Equations, 3

For constant acceleration,

$$x_f = x_i + v_{x,avg}\, t = x_i + \frac{1}{2}\left(v_{xi} + v_{fx}\right)t$$

This gives you the position of the particle in terms of time and velocities.

Doesn't give you the acceleration

Kinematic Equations, 4

For constant acceleration,

$$x_f = x_i + v_{xi}t + \frac{1}{2}a_x t^2$$

Gives final position in terms of velocity and acceleration

Doesn't tell you about final velocity

Kinematic Equations, 5

For constant *a*,

$$v_{xf}^2 = v_{xi}^2 + 2a_x(x_f - x_i)$$

Gives final velocity in terms of acceleration and displacement

Does not give any information about the time

Mechanics

When a = 0

When the acceleration is zero,

- $v_{xf} = v_{xi} = v_x$
- $x_f = x_i + v_x t$

The constant acceleration model reduces to the constant velocity model.

Freely Falling Objects

- Freely falling object is any object moving freely under the influence of gravity alone.
- It does not depend upon the initial motion of the object.
  - Dropped – released from rest
  - Thrown downward
  - Thrown upward

Mechanics

What is two-dimensional motion?

Two-dimensional (2D) motion means motion that takes place in two different directions (or coordinates) at the same time. The simplest motion would be an object moving linearly in one dimension. An example of linear movement would be a car moving along a straight road or a ball thrown straight up from the ground.

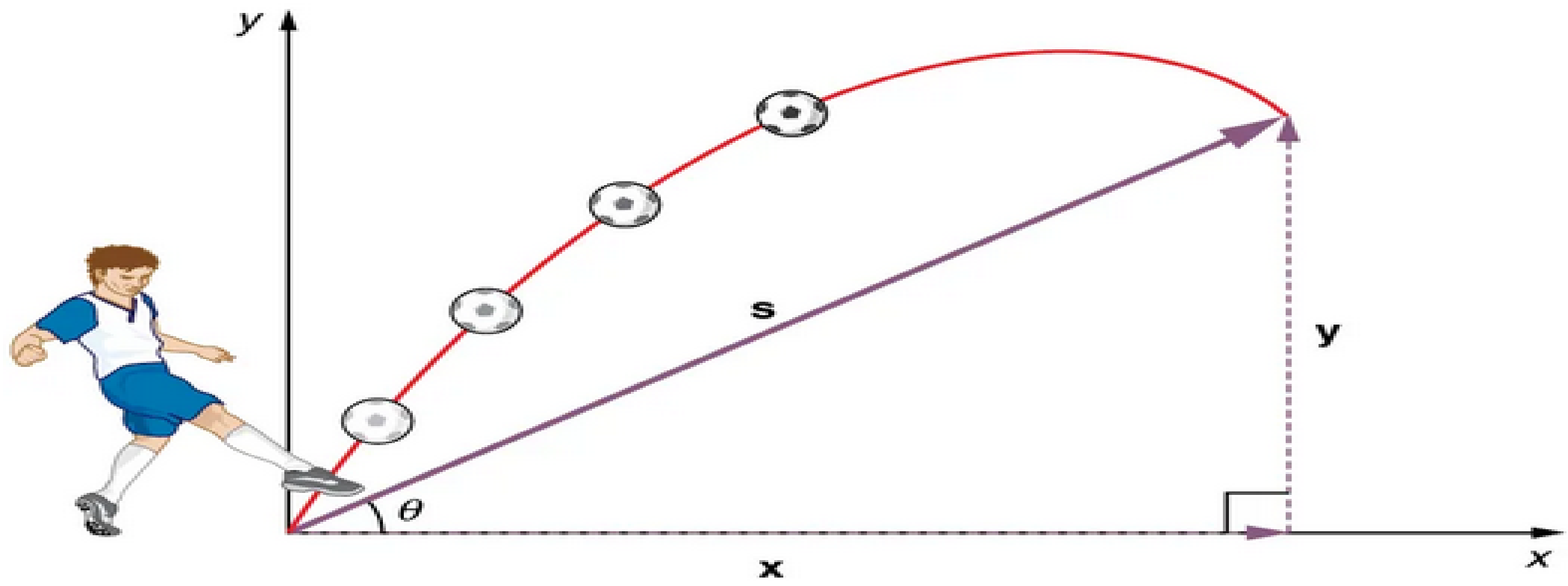


Figure 3.34 The total displacement **s** of a soccer ball at a point along its path. The vector **s** has components **x** and **y** along the horizontal and vertical axes. Its magnitude is s, and it makes an angle θ with the horizontal.

Mechanics

What are the components of two-dimensional motion?

Two dimensional motion can be described using the two separate components. The two separate motions are in horizontal and vertical directions respectively. Projectile motion is two-dimensional because it has a horizontal component and a vertical component.

What is the formula for two-dimensional motion?

Few Examples of Two – Dimensional Projectiles

Quantity	**Value**
Time of maximum height	$t_m = v_o \sin\theta_o / g$
Time of flight	$2t_m = 2(v_o \sin\theta_o / g)$
Maximum height of projectile	$h_m = (v_o \sin\theta_o)^2 / 2g$
Horizontal range of projectile	$R = v_o^2 \sin 2\theta_o / g$

Equation of Motions in Two Dimensions

The three equations of motion in two dimensions x and y are given as:

$$v_x = u_{x0} + a_x t$$

$$\Delta x = u_{x0} t + \frac{1}{2} a_x t^2$$

$$v_x^2 - u_{x0}^2 = 2 a_x \Delta x$$

Similarly, the equations can be written in y directions.

$$v_y = u_{y0} + a_y t$$

$$\Delta y = u_{y0} t + \frac{1}{2} a_y t^2$$

$$v_y^2 - u_{y0}^2 = 2 a_y \Delta y$$

Solved Examples for Two-Dimensional Motion

Example 1: A particle is moving with an initial velocity (2i + 4j) $\frac{m}{s}$ and has constant acceleration of (10i + 2j) $\frac{m}{s^2}$. Calculate the final velocity and displacement after 6 seconds.

Solution: The above problem can be solved by dividing velocity and acceleration into one dimension. Thus, along the x-axis, we have initial velocity as 2 $\frac{m}{s}$, acceleration as $10\frac{m}{s^2}$. Using the first equation of motion, we have v=u+at. Substituting the values above in this, we get

$$v = 2 + 10 \times 6$$
$$v = 62ms^{-1}$$

Now, using the second equation of motion, we have $s = ut + \frac{1}{2}at^2$. Substituting the above values we get,

$$s = 2 \times 6 + \frac{1}{2}(10) \times 6^2$$
$$s = 12 + 180$$
$$s = 192 \text{ m}$$

Now, we will calculate the same along the y-direction. We get the value of velocity as

$$v = 4 + 2 \times 6$$
$$v = 16 \text{ ms}^{-1}$$

Similarly, the displacement will be

$$s = 4 \times 6 + \frac{1}{2} \times 2 \times 6^2$$
$$s = 24 + 36$$
$$s = 60 \text{ m}$$

Thus, final velocity = $v = v_x \hat{i} + v_y \hat{j} = 62\hat{i} + 16\hat{j}$

or

$$v = \sqrt{62^2 + 16^2}$$
$$= v = 64ms^{-1}$$

The final displacement is

$$s = s_x \hat{i} + s_y \hat{j}$$
$$s = 192\hat{i} + 60\hat{j}$$

or

$$s = \sqrt{192^2 + 60^2}$$
$$s = 201.15 \text{ m}$$

Hence, the final velocity and displacement after 6 seconds are $62\hat{i} + 16\hat{j}$ and 201.15 m.

Example 2: An object is moving in a plane with a velocity $v = 4t\hat{i} + 6t^3\hat{j}$. Find the acceleration of the object between time intervals (0,2).

Solution: Acceleration is denoted as $a = \frac{v}{t}$

At 0 time interval, velocity will be zero, whereas at t=2 seconds, velocity will be

$$v = 4 \times 2\hat{i} + 6 \times 2^3\hat{j}$$

$$v = 8\hat{i} + 48\hat{j}$$

Therefore, acceleration will be

$$\Rightarrow \frac{8\hat{i} + 48\hat{j}}{2}$$

$$\Rightarrow 4\hat{i} + 24\hat{j}$$

Hence, the acceleration of the object between time intervals (0,2) is $4\hat{i} + 24\hat{j}$.

❖ **Difference between one, two and three dimensional motion:**

One dimensional motion is motion along a straight line. The line used for this motion is often the familiar x-axis, or x number line. The object may move forward or backward along this line: Forward is usually considered positive movement, and this movement is usually considered to be to the right. Remember that the study of one-dimensional motion is the study of movement in one direction, like a car moving from point “A” to point “B.”

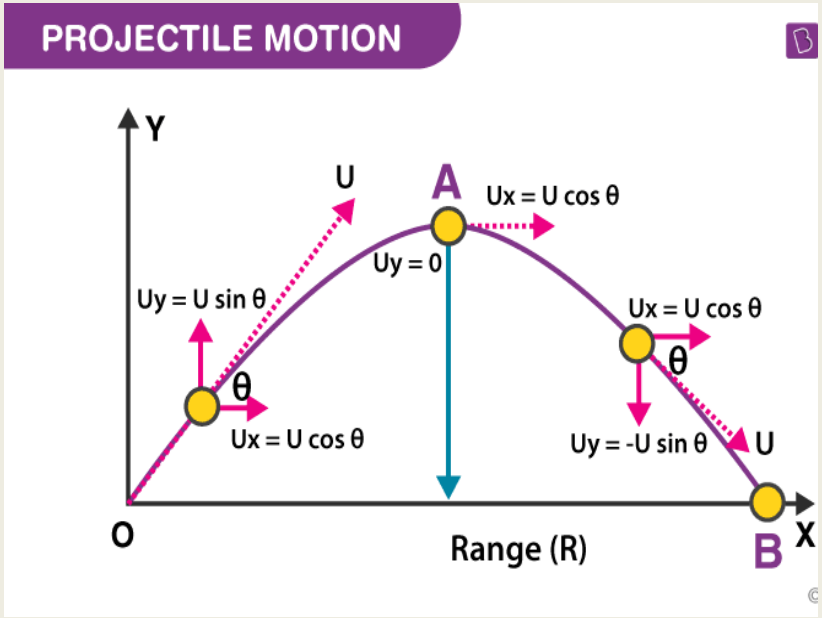
Whereas,

In two-dimensional motion, the path the object follows lies in a plane. Two-dimensional motion is the study of movement in two directions, including the study of motion along a curved path, such as projectile and circular motion. Examples are projectile motion where the path is a parabola, or planetary motion where it is an ellipse.

Whereas,
Three-dimensional motion would be a case where the path is more complex and is not confined to a single plane.

Projectile motion:

Projectile motion is the motion of an object thrown or projected into the air, subject to only the acceleration of gravity. The object is called a projectile, and its path is called its trajectory.

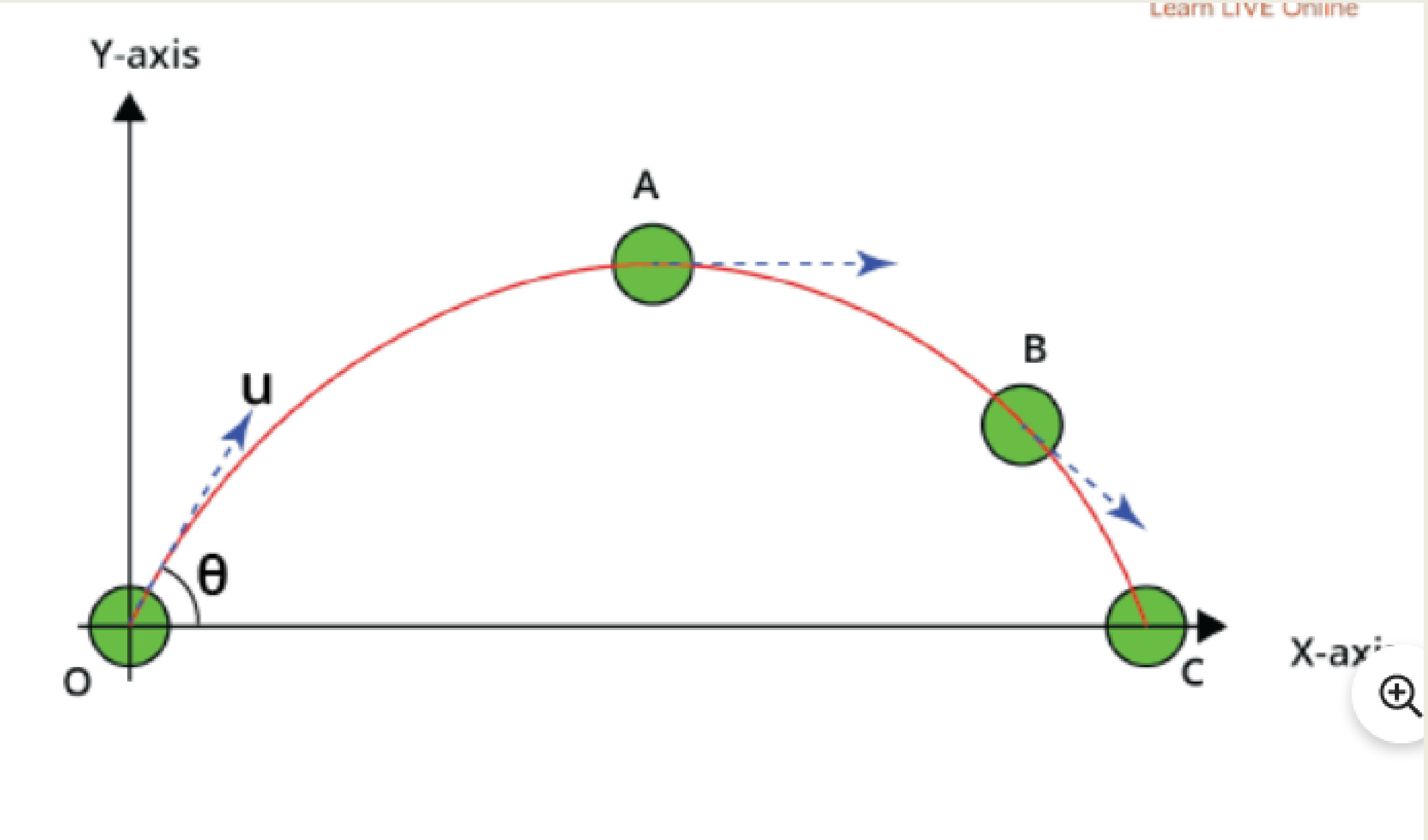


What are the 3 main concepts of projectile motion?

The key components that we need to remember in order to solve projectile motion problems are: Initial launch angle, θ Initial velocity, u. Time of flight, T.

Projectile Motion

The motion of an object in a curved path with constant acceleration is known as projectile motion. The motion in this case is along the x-axis and the y-axis.



Projectile Motion

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The acceleration component along the x-axis is 0, whereas in the vertical direction it is -g. However, the component of velocity along the x-axis is $u\cos(\theta)$ and $u\sin(\theta)$, respectively.

The equation of a projectile or the trajectory formula as it is known is given as

$$y = x\tan\theta - \frac{gx^2}{2u^2\cos^2\theta}$$

Here, x and y are the horizontal and vertical components, respectively, and u is the initial velocity and g is the acceleration due to gravity. There are other important equations related to the projectile motion which include the time of flight (T), maximum height (H), and the horizontal range of the projectile (R). These equations are

$$T = \frac{2u\sin\theta}{g}$$

$$H = \frac{u^2\sin^2\theta}{2g}$$

$$R = \frac{u^2\sin 2\theta}{g}$$

Here, u is the initial velocity, g is the acceleration due to gravity, and θ at which the projectile was thrown with respect to the horizontal.

These are the equations of motion of the projectile.

What Is Frictional Force?

> Frictional force is the force generated by two surfaces that contact and slide against each other.

A few factors affecting the frictional force:

- These forces are mainly affected by the surface texture and the amount of force impelling them together.
- The angle and position of the object affect the amount of frictional force.
- If an object is placed flat against an object, then the frictional force will be equal to the object's weight.
- If an object is pushed against the surface, then the frictional force will be increased and becomes more than the weight of the object.

Dry Friction

Dry friction describes the reaction between two solid bodies in contact when they are in motion (kinetic friction) and when they are not (static friction). Both static and kinetic friction is proportional to the normal force exerted between the solid bodies. The interaction of different substances is modelled with different coefficients of friction. By this, we mean that certain substances have a higher resistance to movement than others for the same normal force between them. Each of these values are experimentally determined.

Fluid Friction

Fluid Friction is the force that obstructs the flow of fluid. It is a situation where the fluid provides resistance between the two surfaces. If both surfaces offer high resistance, then it is known as high viscous and, generally, we call them greasy.

Examples of Fluid Friction

1. To avoid creaking sounds from doors, we lubricate the door hinges, which leads to the smooth functioning of door hinges.
2. When you drop the ball in a full bucket of water, water splashes out of the bucket, and this is all because of the buoyancy of fluid.

Mechanics

Work:

Work is the energy transferred to or from an object via the application of force along a displacement. In its simplest form, for a constant force aligned with the direction of motion, the work equals the product of the force strength and the distance traveled. A force is said to do positive work if when applied it has a component in the direction of the displacement of the point of application. A force does negative work if it has a component opposite to the direction of the displacement at the point of application of the force.[1]

For example, when a ball is held above the ground and then dropped, the work done by the gravitational force on the ball as it falls is positive, and is equal to the weight of the ball (a force) multiplied by the distance to the ground (a displacement). If the ball is thrown upwards, the work done by the gravitational force is negative, and is equal to the weight multiplied by the displacement in the upwards direction.

$$W = Fs$$

W = work

F = force

s = Displacement

Mechanics

Energy:

In physics, energy is the quantitative property that is transferred to a body or to a physical system, recognizable in the performance of work and in the form of heat and light. Energy is a conserved quantity—the law of conservation of energy states that energy can be converted in form, but not created or destroyed.

Momentum:

Momentum is the product of the mass and velocity of an object. It is a vector quantity, possessing a magnitude and a direction. If m is an object's mass and v is its velocity, then the object's momentum p is: mv

Mechanics

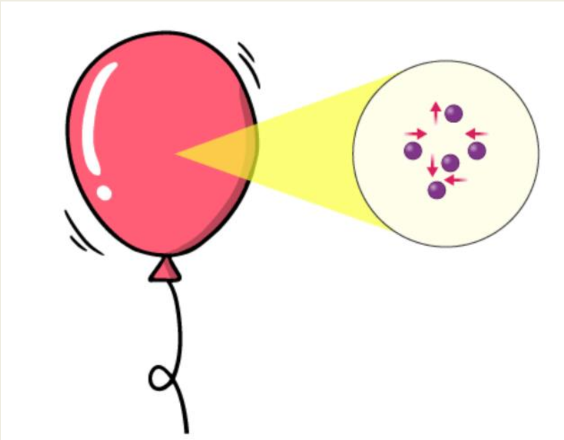
What Is Conservation Of Momentum?

Conservation of momentum is a major law of physics which states that the momentum of a system is constant if no external forces are acting on the system. It is embodied in Newton's First Law or The Law of Inertia.

Example of Conservation of Momentum

Consider this example of a balloon, the particles of gas move rapidly colliding with each other and the walls of the balloon, even though the particles themselves move faster and slower when they lose or gain momentum when they collide, the total momentum of the system remains the same.

Hence, the balloon doesn't change in size, if we add external energy by heating it, the balloon should expand because it increases the velocity of the particles and this increases their momentum, in turn, increasing the force exerted by them on the walls of the balloon.



Application of Law of Conservation of Momentum

Having said so the energy of a system is always conserved, one of the best applications of the law of conservation of momentum would be in space travel, there is no medium in space to exert a force on, then how do rockets travel?

Well, they eject matter at a very high speed, so in an isolated system, the momentum should remain constant therefore, the rocket will move in the opposite direction with the same momentum as that of the exhaust.

Work-energy theorem:

The work-energy theorem explains the idea that the net work - the total work done by all the forces combined - done on an object is equal to the change in the kinetic energy of the object. After the net force is removed (no more work is being done) the object's total energy is altered as a result of the work that was done.

According to the theorem,

$$W_{net} = \Delta K = K_f - K_i$$

- W is the total work done
- ΔK is the change in kinetic energy
- K_f is the final kinetic energy
- K_i is the initial kinetic energy

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Electricity

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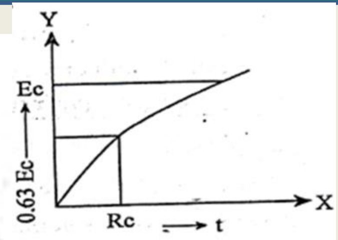
Electricity



$$\Rightarrow q = Ec\left(1 - e^{-t/Rc}\right)$$

This is the equ^n for charging a capacitor. The fig-1 shows that charg grows exponentially with time.

Now current in the circuit,

$$i = \frac{dq}{dt}$$

$$\Rightarrow i = \frac{d}{dt}\left\{Ec\left(1 - e^{-t/Rc}\right)\right\}$$

$$\Rightarrow i = Ec.\frac{e^{-t/Rc}}{Rc}$$

$$\Rightarrow i = \frac{E}{R}.e^{-t/Rc}.$$

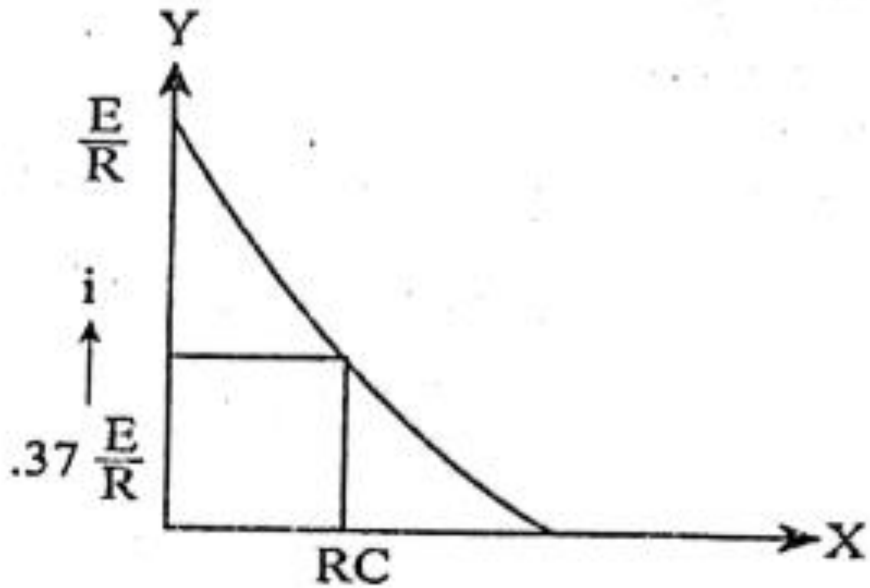


Fig-33

This is the equ^n for current in the R-C circuit. The current decreases exponentially with time as shown in graph.

*11 ~~Show that, capacitance of~~ for two capacitors of ~~are~~ equal capacitance, prove that the equivalent capacitance of the capacitors when in parallel is four times greater than when in series connections.

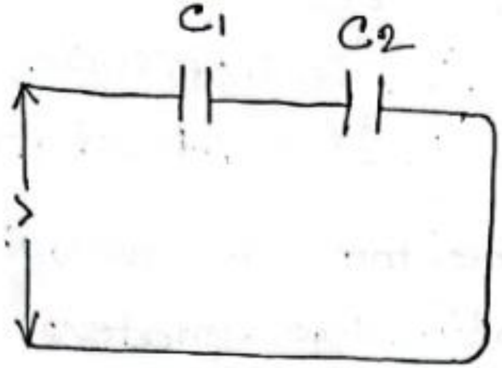


Fig1. Capacitors in series

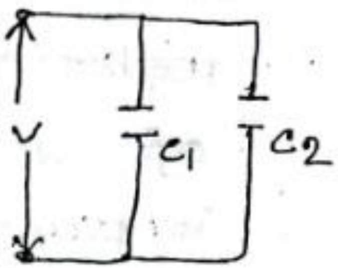


Fig2 capacitor in parallel

We consider two capacitor with equal capacitance c_1 and c_2 connected in series (infig:1) and paralled connections in Fig 2.

We can write the equivalent capacitance for series combination is

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} \longleftarrow (i)$$

When two capacitance is equal. i.e. $C_1 = C_2$ then we can write from eqn (i)

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\Rightarrow \frac{1}{C_S} = \frac{1+1}{C_1}$$

$$\Rightarrow C_1 = 2C_S \longleftarrow (ii)$$

Electricity

Again we can write the equivalent capacitance for parallel combination:

$$C_p = C_1 + C_2 \quad \text{—— (iii)}$$

When two capacitance is equal. i.e. $C_1 = C_2$ then can write eqn (iii)

$$C_p = C_1 + C_1 = 2C_1$$

$$\therefore C_p = 2C_1$$

$$= 2 \times 2C_s \quad [\text{From eq}^n\ 2)$$

$$= 4C_s.$$

So, we can write capacitance of two capacitors are equal to the equivalent capacitance of the capacitors when in parallel is four times greater than when in series connection.

A negative point charge of 10^{-6} coul is situated in air at the origin of a rectangular coordinate system. A second negative point charge of 10^{-4} coul is situated on the positive x-axis at a distance of 50 cm from the origin. What is the force on the second charge?

Soln. : from columb force are have,

$$\vec{F} = \frac{1}{4\pi 6o}\frac{z_1 q_2}{r^2}\hat{\gamma}$$

$$= \frac{9\times10^9\times(-10^{-6})\times(-10^{-4})}{(0.5)^2}$$

$$= 3.6\,\hat{\imath}N$$

$$\frac{1}{4\pi\varepsilon o} = 9\times10^9 NM^2 coul$$

$$z_1 = -10^{-6}C$$

$$z_2 = -10^{-4}Col$$

$$\pi = 50cm = 0.5m$$

This there is a force of 3.6 Newton in the positive x-direction on the second charge.

Calculate the force of repulsion between two protons in a nucleus of iron, assuming a separation of $4\times10^{-15}m$

Soln. From columb law we have,

$$F = \frac{1}{4\pi\varepsilon o}\frac{q_1 q_2}{r^2}$$

$$= 9\times10^9\times\frac{(1.6\times10^{-19})^2}{(4\times10^{15})^2}$$

$$= 14\text{ N}$$

$$q_1 = q_2 = q = 1.6\times10^{-19}C$$

$$\text{r} = 4\times10^{-15}\text{m}$$

Electricity

Prob: What is the magnitude of the electric field strength $\vec{E}$ such that an electron, placed in the field, would experience an electrical force equal to its weight?

Soln. : We have,

$$\vec{E} = \frac{\vec{F}}{q_0} = \frac{mg}{e}$$

$$= \frac{9.1\times10^{-31}\times9.8}{1.6\times10^{-19}}$$

$$= 5.6 \times 10^{-11} N/C$$

$m = 9.1 \times 10^{-31} kg$

$g = 9.8\ ms^{-2}$

$e = 1.6 \times 10^{-19} c$

Thank you

for your kind attention

Electricity

Electricity

Q: Dipole in an electric field or Derive expression for torque and potential energy when an electric dipole is placed in a uniform external electric

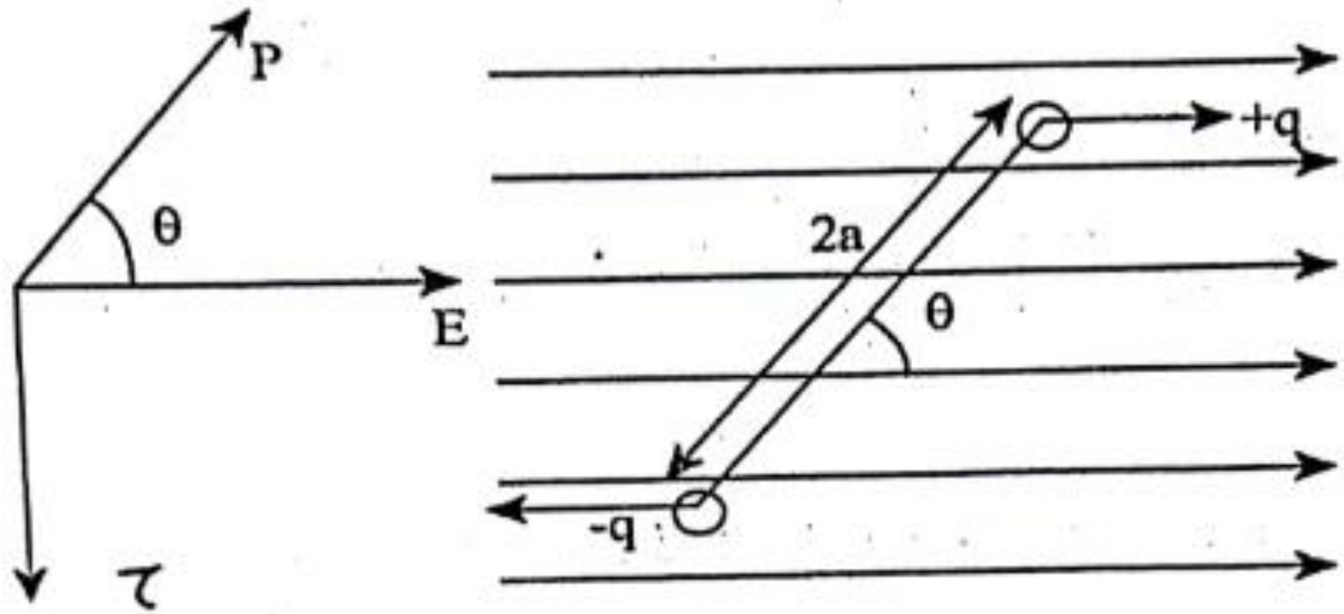


Fig- 5

Figure shows an electric dipole formed by placing two charges +q and –q a fixed distance 2a apart. The arrangement is placed in a uniform external electric field E, its dipole moment P making an angle θ with this field. The two equal and opposite forces F and – F making a couple and the moment of the couple or torque is given by-

$$\tau = \text{Force} \times \text{perpendicular distance}$$
$$= F \times 2a \sin\theta$$
$$= qE \times 2a \sin\theta$$
$$= 2qa \times E\sin\theta$$
$$= P\,E\sin\theta$$

Work must be done by an external agent to charge the orientation of an electric dipole. This work is stored as potential energy in the system. We choose 90° as the initial orientation.

$$U = W = \int dw$$

Electricity

$$= \int_{90}^{\theta} \tau . d\theta = \int PE \sin\theta . d\theta$$

$$= PE\left[-\cos\theta\right]_{90}^{\theta}$$

$$= PE(-Cos\theta - Cos 90)$$

$$= -PE\ Cos\theta.$$

In vector form $\vec{U} = -\vec{P}.\vec{E}$