Chapter 2

Concepts (I)

2-00 What Concepts?

Of the many concepts that we want you to know, five are presented in this chapter. In what follows, the word *object* will refer to both: objects and systems-of-objects.

(A) Spaces & Dimensions I

(B) Spaces & Dimensions II

(C) Spaces & Dimensions, General

(D) Observing objects

(E) Objects and their neighbors

2-A-i Spaces & Dimensions I:

The First Set of Three Dimensions : The Coordinate System

All objects in our universe, have one or more of the following:

(i) length, (ii) width or breadth, and (iii) thickness or height.

These are called *dimensions*. Objects may be one-dimensional (a cord, for example), two-dimensional (such as a sheet of paper), or three-dimensional (such as a book). One-dimensional (1-D) objects have *length* and they may be represented by a *line.* Two-dimensional (2-D) objects have *surfaces.* A surface is formed by a *closed line* and is said to have an *area.* Three-dimensional (3-D) objects have *volumes.* A volume is formed by a *closed surface*.

We need a work-place where to *set up* the objects so that we may study them. Such a work-place is called a *reference frame*. To accommodate the three dimensions of the object, the reference frame is fitted with three so-called *coordinate axes*. One such reference frame is *Cartesian* or the *rectangular* reference frame in which the coordinate axes are known as x, y and z-axes. The three axes meet at one point, called the *origin* of the reference frame. The diagram below shows such a reference frame;

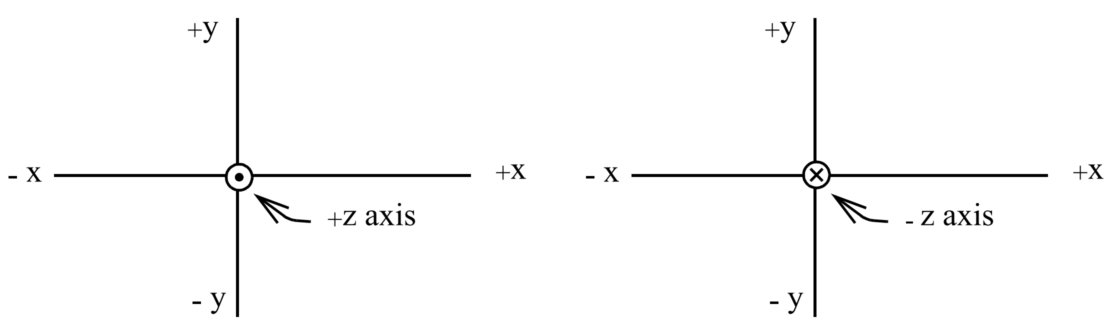

Fig (1) A 3 Dimensional Cartesian Reference Frame

As one cannot really draw a three-dimensional diagram on a two-dimensional sheet of paper (or chalk-board), a *protocol* has been adopted. Enclose a dot in a small circle and place the combination at the center (the origin). This will represent a line vertically upward on the surface of the sheet or the $+z$ coordinate axis. A small "x" placed in the small circle, will represent a $-z$ axis. This arrangement eliminates drawing awkward-looking, half-hearted attempts to draw all three (mutually perpendicular) lines on a two-dimensional surface. However, if a system is just two-dimensional but involves z-axis, we may draw the reference frame on the surface of the sheet of paper and then place the sheet in an upright position.

A reference frame is used mainly for:

(i) measuring the geometrical shapes and sizes of objects,

(ii) specifying and/or measuring positions of objects in space,

(iii) measuring heights,

(iv) following the movement of an object from one place to another or from one moment in time to another,

(v) representing and processing vectors,

and for

(vi) plotting graphs.

An object has specific *magnitudes* along these coordinate axes. Given these magnitudes, it is possible to *configure* or to *recreate* the object. Objects differ from one another in shapes and sizes because they have different specific magnitudes along the three coordinate axes. It should be clearly understood that it is not the coordinate axes that cause the objects to be different from one another. It is the *magnitudes* along those axes that make them different from one another.

In general we associate the dimension *length* with the x-axis, the dimension *width* with the y-axis, and the dimension *thickness* (or height) with the z-axis. It is also customary to associate x-axis with the *east-west* direction, or with our *right and left* sides. Similarly y-axis is associated with the *north-south* direction or our *front and back*. We associate z-axis with the *up and down* direction. For diagrams in a book or on a sheet of paper in students' notebooks, z-axis will be *coming out of the page* or *going into* it.

Table 1: The Cartesian Reference Frame

Coordinate Axis	Geometry	Geography	Physics	You & Me
x-axis	length	east - west	x-mode	right - left
y-axis	width	north - south	y-mode	front - back top of page / bottom of page
z-axis	thickness or height	up - down (vertically)	z-mode	up - down (vertically); or out of page / into the page

2-A-ii *Other Coordinate Systems*

The Cartesian coordinate system, even though most general, is not the only coordinate system. There are many others which are frequently used in physics for specific purposes.

We shall mention two of them here. One is the *spherical polar* coordinate system, with coordinate axes r, θ, and ϕ. It is used for analyzing circular and spherical objects. The other is the *cylindrical polar* coordinate system, with axes r, θ, and z is suitable for dealing with cylindrical objects. These coordinate systems are extensively used in calculus-based introductory level physics textbooks. Again, for the study of rotational motion, the *radial*, *tangential* and *axial* coordinates form a natural reference frame.

2-A-iii Coordinates are Mutually Perpendicular

An important, essential, and basic characteristic of all coordinates (irrespective of the system to which they belong) is that they are all mutually perpendicular. In the Cartesian reference frame, x-axis is simultaneously perpendicular to the y- and z-axes; y-axis is simultaneously perpendicular to x- and z-axes; and z-axis is simultaneously perpendicular to x- and y-axes. It should be noted that, geometrically speaking, only three lines can all be *simultaneously mutually* perpendicular. This is a fundamental characteristic (or limitation, shall we say?) of our universe. It is for this reason that the world around us (and the universe) is three-dimensional and we say that we live in a 3-D world. Cinema and television screens sometimes present 3-D pictures for the viewers, using special techniques. No one ever tries to make a four (or more) dimensional movie.

2-A-iv "Perpendicularity" in Physics

In mathematics, perpendicularity means ***to be at 90°***. In physics, however, it means *to be independent*. Thus what we really want to tell you is that the three coordinate axes (and hence the three dimensions) are ***independent*** of each other.

The length, width or thickness (or height) of an object are three *independent* geometrical characteristics of that object. There is no equation in physics or formula in mathematics that interrelates them. It is for this reason that knowing the length of an object we cannot calculate or predict its width or its thickness (or both). We cannot, for example, calculate the number of pages (thickness) of a book from a knowledge of its length or its width (or both). This is why our school textbooks did not carry problems such as: "A rectangular block is 5 cm long. Calculate its volume." or, "A table is 2 ft. high. Calculate the surface area of the table-top".

2-A-v Defining "Perpendicularity" or "Independence"

We define *perpendicularity* or *independence* as follows:

A set of entities A, B, C.... are said to be (i) *independent of one another, or (ii) perpendicular to one another, or (iii) at 90° to one another, or (iv) at right angles to one another, or (v) orthogonal,*

if

knowing one of them, does not lead us to the knowledge of any of the others in the set, in any way, shape or form, using any rational technique whatsoever

2-A-vi Importance of Being "Perpendicular" or "Independent"

Being *perpendicular* or *independent* is *very* important indeed.

The independence of dimensions makes them sovereigns in their own territories. One dimension or one coordinate axis has no authority over the other two; it cannot influence them or dictate to them. There is no communication amongst them.Thus *perpendicularity* or *independence* boils down to our inability to determine one geometrical characteristic of an object from a knowledge of its other geometrical characteristic(s). In other words, perpendicularity imparts freedom to the dimensions and prevents them from being influenced by other dimensions. The three dimensions of an object, therefore, are also known as three *degrees of freedom*. An object is *free* to have any length for itself without being *constrained* by its width and/or by its thickness. Likewise an object can have any width (or height) without being constrained by its length or thickness.

As a consequence of this independence, we shall, in this textbook, treat each dimension as an independent kingdom *or* domain*, and call it a* mode*. Thus the three degrees of freedom will be referred to as the* x-mode*, the* y-mode *and the* z-mode*. Our objects and systems of objects will be said to be* active *in these modes. A particular object may live or be active only in one* mode *at one time, or it may live or be active in two* modes *at the same time, or in all three of them simultaneously.*

2-A-vii An Example

When a marble rolls on the surface of the table, it has horizontal motion and, as such, it is active in the x-mode. If it falls off the table, then it also acquires a vertical (z-mode) motion. The marble is now simultaneously living in x- and z-modes.

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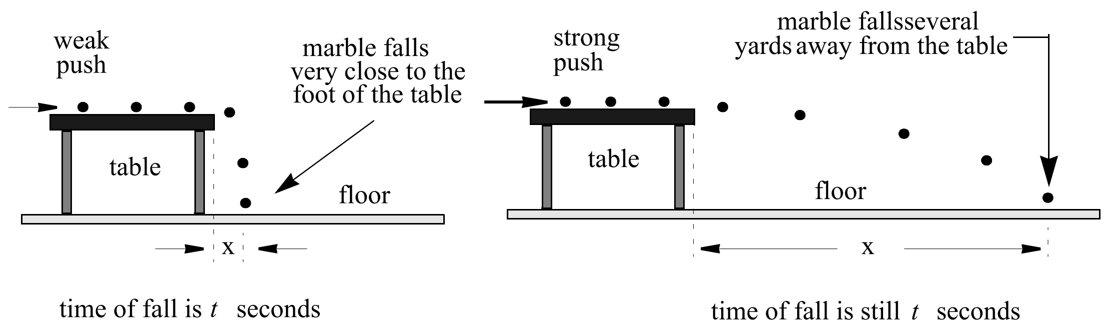


Fig (2) Marble Rolls Off a Table with Different Speeds: Time of Travel Does Not Change!

The time of fall is a parameter of the z-mode. It depends on the height of the table. If the marble takes t seconds to fall, then it will always fall in t seconds, provided that the height of the table doesn't change. It will not depend on the speed of the marble in the x-mode. No matter how large or how small the x-mode motion be, the marble will hit the floor in exactly t seconds! If the x-mode motion is small, the marble will hit the floor close to the foot of the table. If, on the other hand, the x-mode motion is large, the marble will land farther away from the foot of the table. A small x-mode motion cannot make t any smaller and a large x-mode motion cannot make t any larger. The horizontal distance on the floor, as measured from the foot of the table, is of course, an x-mode entity and will certainly depend on the x-mode speed of the marble on the table.

2-A-viii An Interesting Observation

We noticed that when the marble was rolling on the table, it was active in x-mode only; but when it was falling downward, it was active simultaneously in x- and z-modes. Stated differently, we may say that when on the table, only the x-mode of the marble was active and the other two modes (the y- and the z-modes) were inactive. When the marble fell, the x- and z-modes were active but the y-mode was still inactive. This is an intriguing example of the independence of axes. The marble, or for that matter any other object, can be *active (in motion)* in one mode and be simultaneously completely *inactive (at rest)* in the other two modes. Or, it can be in motion in two modes (at the same time) and still be completely at rest in the third mode!

Again, please note that, in the above example, the z-mode motion (acquired later by the marble) could not affect, change or modify the x-mode motion. The x-mode motion continued unabated till such time that the marble hit the floor and was eventually stopped by the floor (but not by the z-mode motion).

2-A-ix Did you ever think that you could be running and not running at the same time?

In fact you are always running and not running in the same breath! Please be informed that when you run in a straight line on level ground, you are running in the x-mode but you are simultaneously completely at rest in your y- and z-modes! If, however, you are running along a level *curved* path, you are running in x- and y-modes and are still simultaneously completely at rest in the z-mode! Only if you were to run uphill (or downhill) along a *curved* path, you will be running in all three modes.

Alternatively we may say that we have three degrees of freedom of running. It is possible to run in such a way that only one degree of freedom is activated and is working like mad while the other two are fast asleep!

This information may not change your habit or trait or style of running but the concept is of great importance when it comes to understanding physics.

2-A-x Another Example

Consider *transmission lines* that carry electricity from one town to another. Heavy overhead cables are supported on pylons. All pylons are vertical. The cables, however, sag very noticeably and have the appearance of *bags* under the eyes of an elderly person. This cannot be cured. We can *never* pull the cables hard enough to straighten them. The cables sag because the weight force (acting on them) pulls them downward, in the z-mode. The force of pull, on the other hand, is applied horizontally (in x-mode). As the two are independent, we cannot pull the cables **up** by pulling them **sideways**! The same is true of a clothes-line that holds freshly laundered clothes.

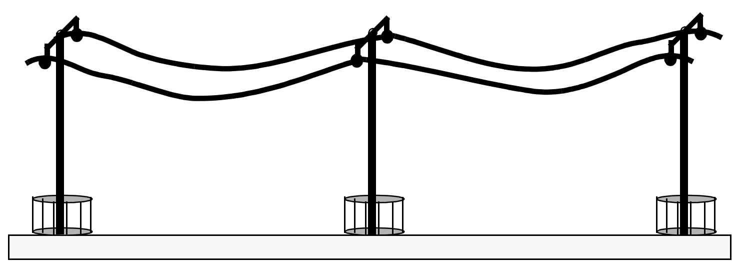


Fig (3) Transmission Lines; The "Saggy" Looks That Cannot be Cured!

2-A-xi The Euclidean Space

Dimensions cannot be lurking like ghosts, in *nowhere* land. They need to be housed somewhere. This *somewhere* is called a *space.* The need for such a space was first realized by the famous Greek thinker Euclid. The space assigned to the Cartesian coordinate system is, therefore, named the *Euclidean space*. We say that the Euclidean space is a three dimensional space and is *spanned* by the Cartesian coordinates.

2-B-i Spaces & Dimensions II: The Second Set of Three Dimensions in Mechanics

Having familiarized ourselves with the basics, we now enquire about the nature of physics we shall be investigating (for our objects) in the Euclidean space. Physics begins with Mechanics that introduces us to the first set of laws of Nature. After a long (very long indeed) period of development, maturity was reached in 1687 when Isaac Newton introduced his *Laws of Motion* to the mankind. Mechanics is the fundamental branch of physics and serves as the foundation for all other branches.

As we think about the associated basic physical characteristics of material objects in Mechanics, we recognize *inertia* or *mass* as the foremost basic characteristic. We write M for it. The representation of the object in a reference frame leads us to recognize the geometrical dimensionality of the object as another associated basic characteristic. We pick up length to represent its dimensionality and write L for it. To study the past, present and future of objects, we need to consider *time*. We, therefore, pick up *time* as a third basic characteristic. We write T for it. These are the *only* three characteristics of objects in Mechanics.

Obviously these characteristics are, in the sense defined above, quite **independent** of each other. Knowing the *mass* of the object (for example), it will be impossible to determine the object's geometrical shape and size. Similarly *time* is not affected or constrained by the geometry of the object or by its mass. As such these three characteristics may, adequately be named **dimensions**.

These *are* indeed called *dimensions*. L, M, and T are, therefore, our second set of three dimensions.

2B-ii We Need to Talk

In the last section, the parameter *time* came-in out of nowhere. It is such a familiar, everyday concept that we did not think that it would need to be *introduced* formally. So we won't. This link between the *past* the *present* and the *future,* is measured in units of *seconds.* Other related units, often used, are: hours, months, years etc.

2-B-iii The System of Units

The question is: how do the dimensions L, M, and T help us in dealing with an object in Mechanics? Well, they do so by giving us a *system of units*. Several unit systems are used by the scientific community at large. Of note is the *FPS* system (the British Engineering System) that we use in the USA. Distances and lengths are expressed in feet (represented by *F*) even if they are in inches or miles; mass is expressed in pounds (represented by *P*) even if it is in ounces or tons; and time is measured in seconds (represented by *S*) even if it is in days or years. Chemists prefer the *cgs* system where the distances and lengths are expressed in centimeters (represented by *c*), mass in grams (represented by *g*) and time in seconds (represented by *s*). We, the Physicists, use the *MKS* system, where all distances are measured in meters (represented by *M)*, and all masses (gravitational or inertial) are measured in kilograms, (represented by *K)*. Everyone seems to agree on seconds (represented by *S*) as being the basic unit of time. The *MKS* system is also known as the *metric* system or the *SI* system of units. The letters *SI* stand for *International System (of units)* as written and read in the French language.

In addition to being measures for mass, length and time, these dimensions are used for balancing equations and for identifying the nature of physical entities. Thus when it comes to changing a *proportionality* to an *equality*, we seek a *suitable* constant, called the *constant of proportionality.* A *suitable* constant is one that causes the dimensions to become identical on the two sides of the equation. We say that the equation has been balanced, or has become *homogeneous*. In fact the sole purpose of the *constant of proportionality* is to *balance* the equation. If a proportionality, established by observations, per chance *happens* to be balanced, no constant is then introduced in the equation.

In this book, we shall use the *MKS* system of units. (except as needed, in accordance with the unwritten rule: ***exceptions excepted***.)

2-C-i Spaces & Dimensions, General

Having talked exhaustively about the 3-D Cartesian coordinate systems and the 3-D MKS-units system for Mechanics, we want to tell you that there is more to spaces and dimensions than what has been said above. Here we go!

2-C-ii Dimensions In Other Branches of Physics

Objects have other basic characteristics in other branches of physics that would be *independent* of those described for Mechanics. For example, for studies in Electricity, electrical effects on material objects are described in terms of *electrical current*. Electrical current (represented by I; measured in *amperes*: A), is introduced as an *independent* characteristic of objects. Combined with the three dimensions in Mechanics, we now have a four-dimensional system comprising of L, M, T, and A. A table lamp may be cited as a glowing example. For the study of systems in Thermodynamics, we shall have to bring in *temperature* as yet another applicable dimension. Temperature is measured on the *Kelvin* scale denoted by K. Again combined with the three dimensions in Mechanics, we have a four-dimensional system which now comprises L, M, T, and K. Think of a hot cross bun as an appetizing example. If an electrical system happens to be in the territory of thermodynamics (or vice versa), then we shall have a five-dimensional system comprising of L, M, T, A, and K; where all five of them are simultaneously mutually perpendicular. to one another. Making coffee using an electric percolator, is a perky example.

The total number of dimensions for all branches in physics is seven. These are presented in the table below:.

Table 2: The Magnificent Seven

	Dimension	Represented by	name	Unit
1	Mass	M	kilogram	kg
2	Length	L	meter	m
3	Time	T	second	s or sec
4	Electrical Current	I	current	A
5	Temperature	T	kelvin	K
6	Luminous Intensity	I	candela	cd
7	Amount of Substance	n	mole	mol

2-C-iii Other Spaces in Physics

Euclidean space is not the only space around. For his relativistic systems, Einstein used Minkowski's space; a 4-D space that incorporates *time* as the fourth dimension. For the study of the kinetics of gases, we use Phase space which combines together the three degrees of freedom of motion and the three degrees of freedom of momentum of gas molecules, a 6-D space altogether. For the quantum mechanical systems, Schroedinger used Hilbert space, a multi-dimensional space, which combines together the dimensions of particles and the dimensions of waves.

2-C-iv Coordinate System for Non-material things

The need to use a system of coordinates is not limited to material things only. A coordinate system is equally badly needed for non-material things, i.e. waves. We would like to tell you that waves, such as sound waves, cannot be identified by just three coordinates. Waves may easily have a score or more active coordinates (dimensions). These coordinates are the *fundamental* wave and the accompanying *overtones* or *harmonics*. Harmonics are waves with frequencies that are integer-multiples of the frequency of the fundamental wave. If a wave is adequately identified by a *score* (twenty) of harmonics, then the total number of coordinates, needed to describe it, will be twenty. What's more, all these twenty coordinates will be deemed to be simultaneously mutually perpendicular. The mathematical concept of perpendicularity (i.e. being at 90° to one another) becomes totally meaningless here. Mathematicians try to hide this apparent impossibility in the eyes of commoners, by using the fancy word *orthogonal* for *perpendicular*. Any standard dictionary will tell you that orthogonal means nothing else but perpendicular. The interpretation of *perpendicularity* as being *independent*, however, remains fully meaningful. Not only that twenty or thirty things can be independent of each other, even a thousand (and more) aspects also can *all* be independent of each other!

Just as material things differ from one another by having different *magnitudes* along a common set of coordinate axes, waves differ from one another by having different *amplitudes* along a common set of harmonics. This is why identical musical notes played on piano and violin sound so different to our ears. Mind you they both have identical fundamental frequencies and identical overtones (harmonics).

2-C-v Dimensionality - beyond, beyond

The concept of dimensions and spaces extends well beyond the realm of science and mathematics. Citing examples from our everyday lives, we have a three-dimensional *personal identification* space (spanned by: the name, date of birth and the social security number), a maximum of seven-dimensional *address* space (spanned by: name, house number, apartment number, street, city, state, and zip code+four), a ten-dimensional *long distance telephone* space and so on. Again, for a topic in *humanities*, when you discover a new aspect of something, you are said to have added a new *dimension* to it.

It turns out that our concept of dimensions as being a geometrical entity, limited to a set of three mutually perpendicular straight lines, is a very damaging concept indeed; and the sooner we get out of it, the better it is for our scientific health and happiness.

An aggregate of dimensions is an aggregate of independent aspects (coordinate axes) for gathering information in a particular environment (space). Informations having been collected and *linearly superposed* in regard to these aspects, the object stands completely defined in that environment. A material object has only three mutually perpendicular dimensions, true; but at the same time a wave has a score or more **active** dimensions that are *all* simultaneously mutually perpendicular! The concept of a three-dimensional world, therefore, fails miserably when it comes to pianos and violins.

2-C-vi A Pair of Analogies

The coordinates of the *personal identification space* and the *address space* are all mutually perpendicular as per the definition given in section 2-A-v. Given the name of a person, it is impossible to calculate or predict his (or her) date of birth, or social security number. Same is true of the coordinates of the *address space*. Given (for example) the information for the *apartment number* coordinate axis, it is impossible to calculate or predict information for any of the other six coordinate axes. Suppose we want to identify Mr. MechDonald, in the personal identification space and in the address space, we shall do the following.

It should be noted that for different persons, the coordinate-axes will be the same but the entries for these axes will all be different.

Table 3: "Personal Identification" and "Address" Spaces

"3-D" Personal Identification Space		"7-D" Address Space	
coordinate axes	information	coordinate axes	information
Name	Mr. MechDonald	Name	Mr. MechDonald
Date of Birth	01 - 23 - 45	House or Building #	12
Social Security Number	567 - 89 - 1011	Apartment Number	34
		Street Name	56th Avenue, NE
		City	San Quanto
		State	Quantifornia
		Zip Code + Four	78910 - 1112

2-D-i Observing an Object:

To observe an object or to monitor it, we need to hire an agent; called the *Observer*.

2-D-ii One Object, One Observer

An *observer* is a person or an agent (human or otherwise) who observes a characteristic of an object or of a system-of-objects. The observer *monitors* the system, makes *measurements* and collects *data*. For example, the observer may record that at zero hour the suspect under surveillance was at position *A* and was moving in a direction 30° North of East at 50.00 m.p.h. (miles per hour).

Following are four important rules regarding *observers* and *observations*:

(1) Every observer *requires* a reference frame (to do what he is got to do). In the above example, the observer used the Cartesian reference frame in the Euclidean space.

(2) Reference frames belong to the observer, and not to the object(s) under surveillance. An observer owns an unlimited number of reference frames of each kind.

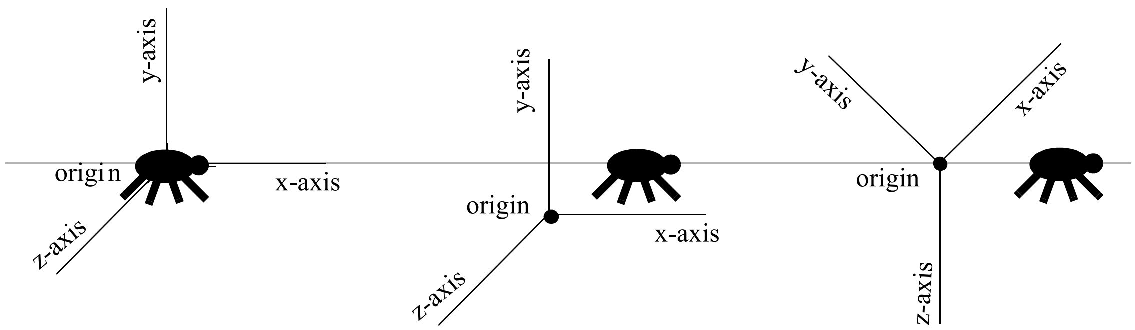
(3) The observer has the *full authority* of placing a reference frame in any position or in any orientation with respect to the object under study. The observer may decide to position the origin of his reference frame at the object itself or at some distance away from it in any direction. Similarly, the observer may decide to let the x-axis of his reference frame

align with the direction of motion of the object or let the y-axis do that. The observer may also decide to rotate his reference frame in such a way that the direction of motion of the object makes an angle of 47° (as an example) with respect to the x-axis of his reference frame! Some choices are shown in Fig (3).

A clever observer, however, will select the position and the orientation of his reference frame in such a way that the observations can be expressed in the simplest possible manner. A clever choice minimizes algebra and hence maximizes efficiency.

(4) The reference frame used by an observer is deemed to be a part of the observer, sort of glued to him. As such, the reference frame is always at rest with respect to the observer, or the observer is at rest with respect to his reference frame. We state that:

An observer is always at rest in his own reference frame.



(a) placing the CM of object at the origin (b) Displacing the reference frame (c) rotating the reference frame

Fig (4) An observer owns the reference frame and can position it anywhere.

2-D-iii One Object, Two Observers: Need For A Neutral Reference Frame

Different observers, in general, will collect different data from their observations of the same object or event. This is because they may be in different positions with respect to the object. If not, we may treat them all as just *one* observer. We would, in this case, tend to retain just one observer and fire the rest of them.

Consider two observers sitting side by side on a sidewalk and observing cars passing by. Obviously, their observations will be identical (even though they may use different reference frames); and as such the two will have to be treated as just one observer. If, however, the two sit on opposite sides of the road, then a car going to the right for one of them will be going to the left for the other! By sitting opposite one another, their observations have turned out to be opposite! More complicated differences in observations would result if the two were sitting on perpendicular sidewalks or on sidewalks that are at some angle $\angle\theta$ with respect to one another. To achieve coherence in observations, one would need a third reference frame. Such a reference frame is called a *neutral* reference frame. In the above example we may consider the *ground* as a *neutral* reference frame and let the geographical east-west and north-south be its x- and y- coordinate axes. The observations of each observer can then be described relative to this neutral reference frame thereby producing coherent results.

2-D-iv Two Observers, Observing One Another

The purpose of the above example was to show you, in a simple manner, that observations of different observers are different. Now we discuss the case of a pair of observers who observe one another. Consider a car. Let Sheila, the driver of the car be one observer.

For the second observer we choose Tequila, sitting on the pavement (a bystander, so to speak). The two observers observe one another using Cartesian reference frames in which each is at rest. In her reference frame, the person sitting on the pavement (Tequila) observes that the car is travelling east at 30 mph. The driver of the car Sheila, on the other hand, using her own reference frame, finds that the bystander is moving west at 30 mph. We find that the two observations are opposite of one another! This is typical of the observations made by observers who observe one another. We may call the two persons as the *observer inside* and the *observer outside*. When observing each other, the observations of the *observer inside* will always be opposite to that of the *observer outside* (and vice versa). Who is *observer inside* and who is *observer outside*, depends on which one you want to be. In the reference frame of the person sitting on the pavement (Tequila) in which she is at rest, she is the *observer inside* and the observer inside the car (Sheila) is the *observer outside.* In the reference frame of Sheila, in which she is at rest, she is the *observer inside* and the person sitting on the pavement (Tequila, the bystander, even though she is not standing) is the *observer outside*. This is a very important concept and should be given due attention. It has been purposely made somewhat entangled so that you may spend some time to un-entangle it in order to understand it fully.

A little thinking, however, will put us at ease with this entanglement, and we may not even have to un-entangle it. When two objects move relatively to one another, then it is really not important who moves and who doesn't. Only the relative motion is important.

In the reference frame of the person inside the car, it will be *perfectly legitimate* for Sheila to say that the bystander, Tequila is travelling west at 30 mph, even though the person in the car *knows* very well that the other person, Tequila, is sitting on the pavement and is *really not moving*!

An interesting example is that of the relative motion of the Sun and earth. As the earth rotates around its axis, nights and days are formed. We tend to think that the Sun is revolving around the earth, which is obviously ridiculously untrue. (Somehow it doesn't feel as ridiculous as saying that the bystander is moving west at 30 mph!) In the reference frame of the earth, however, it is perfectly legitimate for us to say that the Sun *is* revolving around the earth. Remember the earth is at rest in its own reference frame (rule #4). We actually *see* the sun going round and round and we use the words, *sunrise*, *sunset*, and the statements: *the sun rises from east*, *the sun sets in the west*, *the sun reaches the equinox* etc., etc. on a regular basis, in our everyday life.

The same will also be true of several other observations. Take the case of a chandelier hanging from the ceiling. In its reference frame (the *observer inside*), the chandelier feels that it is being stopped from falling by the chain. Hence it experiences a force of pull in the upward direction which is expressed as the tension force in the chain, directed *upward*. The ceiling, on the other hand, and the people around (the *observers outside*) feel that the chain (quite obviously) is being pulled downward by the weight of the chandelier. The tension force is, therefore, directed *downward*. The two observations are opposite of each other. Chandelier pulls the chain for *observers outside* and the chain pulls the chandelier for the *observer inside*.

Or take the case of a car going round a bend. An observer outside the car finds that the car is somehow being pushed toward the center of curvature of the bend and that's why it does not skid off the road. For an observer inside the car, however, the feeling is exactly opposite. The observer experiences a *real* push away from the center of curvature. If an observer were to be sitting on the passenger's seat and the car were taking a left turn, the observer would feel that the door is stopping him from being thrown out. This shows that, in the reference frame of the observer (the *observer inside*), the same force is directed radially outward.

It is easy to imagine what would happen if there was no door. The observer will simply be thrown radially outward, in the observer's reference frame, (the *observer inside*). For *observers outside*, however, the motion of the observer will be tangential to the arc of rotation. We make use of this fact in *centrifuge* machines. To separate particulates from viscous liquids in which they are suspended, we place the whole thing in a centrifuge machine and rotate it as fast as we can. The particulates (*observers inside*) experience a force *away* from the axis (*radially outward*) and as the rotation continues, they settle at the ***bottom*** of the test tube, *and not* at its sides (near the bottom). They are also not sucked-up toward the top of the test tube by the centripetal force! These particulates are, all the time, inside the rotating object and hence (to get to the bottom of the tube) they must have been keeping travelling radially away from the center, all the time! But this is what we expected from the *observers inside* perspective!

2-D-v *The Relative Motion of Two Moving Objects*

As another variation of the theme of observation, consider the motion of ships and airplanes. It is general knowledge that speeds of objects travelling in water are always determined relative to still water and not relative to the shore. Similarly, speeds of objects travelling in air are always determined relative to still air (called *air-speed*) and not relative to the ground. If water (ships) and air (airplanes) are also moving then we get two moving objects. To analyze their motion, we use the *ground* as a third member of the system. Three parameters are involved in such cases. For a ship (as an example), the parameters will be: (i) the speed of the ship relative to water, (ii) the speed of water relative to the shore, and (iii) the speed of the ship relative to the shore. An observer on the shore may determine the speed of the ship but this will be the speed of the object relative to the shore and will *not* be the actual speed of the ship with which it travelled in water. We will learn later that the speed determined by the observer is a *combination* of sorts of the speed of ship relative to water and the speed of the water relative to the shore.

Perhaps it will be news to you that a boat that crosses a river, directly across along its width, traverses a distance significantly greater than the width of the river. Suppose you wished to cross a 600 m wide river by going directly across and your boat needs half a liter of gasoline for every 100 m, and hence you put only 3 liters of gasoline in the empty tank, you will never make the it to the other end and will have to call for help. The time of flight of airplanes flying from A to B is never equal to the time of flight from B to A, even if they maintain identical air-speeds each way.

2-D-vi *Observers And Higher Physics. Need For An Absolute Reference Frame*

For more advanced situations in higher physics, a neutral frame may not be neutral for all concerned observers. One, then, looks for an *absolute* reference frame to replace the neutral reference frame. This is kind of funny because such a reference frame simply does not exist. We state that:

There is no such thing as an absolute reference frame.

2-E-i Objects and Their Neighbors

Everyone has neighbors. Objects (and systems of objects) are no exceptions. The neighbors of objects are other objects. Presence of neighbors, causes objects to be affected by them. The neighbors, in turn, get affected by the object(s) to whom they are neighbors. We say that objects and their neighbors *interact* with one another.

There is no limit as to the number of neighbors an object may have. Often times the neighbors are in physical contact with the object (touching) but this is not necessary. For a stone on the ground, ground is the neighbor. For the stone thrown in air, air is a neighbor. As the stone is constantly being pulled by the earth, the earth is also a neighbor. Please note that as the stone travels through air, it is not in physical contact with the earth but earth is still a neighbor. For flowers in a vase, the table, the carpet, and the floor may all be treated as neighbors. For a set of billiard balls on a pool table, the pool table will be a neighbor. In a mechanics laboratory, a glider on an air track will have the cushion of air as a neighbor. Air track itself, and other gliders and accessories of the track will all be its neighbors.

2-E-ii Interaction with Neighbors: Very Important

How important a neighbor is, depends on the magnitude of interaction between the object and the neighbor. When we walk we interact with the neighbor, the ground. This is an important interaction. It is because of this interaction that we are able to walk. When vehicles such as cars, boats or airplanes travel, they interact with the road, the water or the air. The interaction is essential for the vehicles to be able to move, and is, therefore, very important. Again, if you pull a crate on the floor, the crate interacts with the floor. This interaction is also important but it is an unwelcome interaction. In the presence of this interaction, we have to work harder.

2-E-iii Interaction with neighbors: Quite Unimportant

Sometime the interaction between an object and its neighbor is minimal. Consider a ball thrown in air. As the ball moves through air, it interacts with air. This interaction is small and even though not negligible, one may ignore its effect on the motion of the ball. We say that the interaction is unimportant. In the case of a glider on an air track (in a mechanics lab), the glider glides on a cushion of air. The interaction with air, here, is really minimal and we say that the interaction is quite unimportant. In one type of a train the wheels of its cars are magnetically levitated to reduce the interaction between the wheels and the rails. The interaction becomes quite unimportant. Again, in case of a wheel-and-axle system, there is a significant interaction between the wheel and its neighbor, the axle. We use *ball bearings* to minimize this interaction and make it quite unimportant

2-E-iv The Unneighbors

When the interaction of an object with its neighbor is minimal and has no worthwhile effect on the object, we say that the object does not interact with the neighbor. We may also say that the object does not *communicate* with the neighbor. In such cases the neighbor is deemed to be so unimportant that we may not even acknowledge its presence. The neighbor then becomes an *unneighbor*. You will come across statements such as, “ignore air resistance”. Here we declare *air* to be an un-neighbor. In many problems you will be instructed to ignore friction. This amounts to refusing to acknowledge the presence of the solid surface upon which the given object is moving.

Funny! Isn’t it?

This is not the only funny situation. Consider the following:

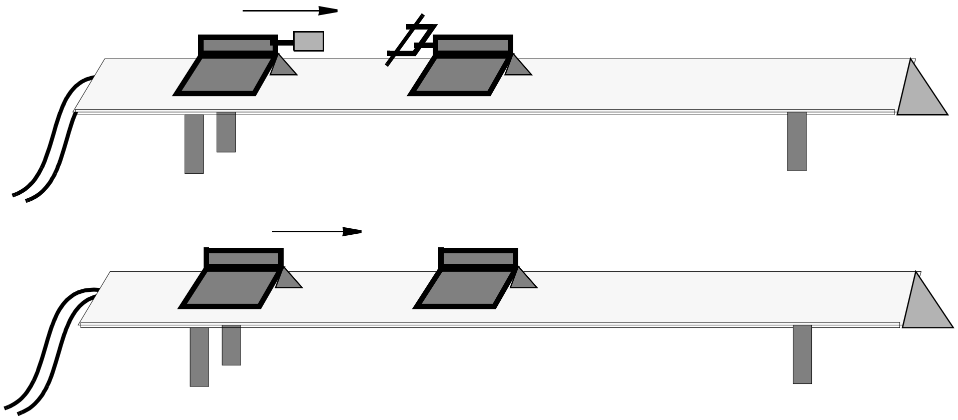


Fig (5) The System of "Stretched Rubber Bumper and Flag" is an Un-Neighbor

In a mechanics lab when two gliders are made to collide, they always attach a stretched-rubber bumper to one of the gliders and a flag to the other. Then they ask you to ignore the bumper and the flag, altogether and think of the collision as if the gliders collided directly. The stretched-rubber bumper and the flag that are neighbors of the gliders now become total un-neighbors.

Equally *funny* is the situation where we ask you to treat a given pulley as *massless* and *frictionless*. Anything that is massless cannot be seen by our eyes. Hence here, we are essentially, saying to you, "*do not even see it*!"

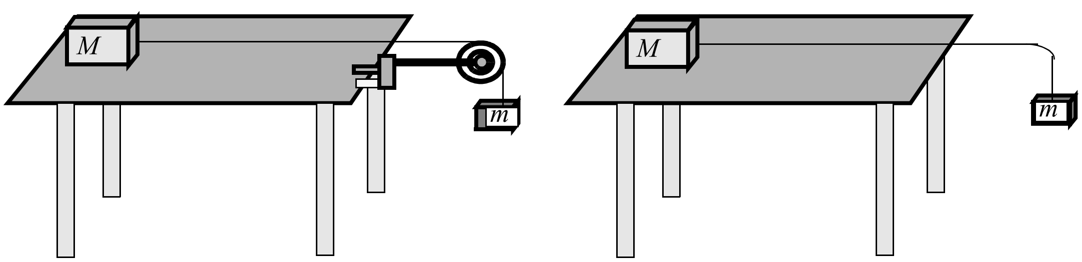


Fig (6) "Do not even see it!"

2-E-v Isolated Systems

When an object or a system-of-objects does not communicate with its neighbors, it is said to be an *isolated system*. Certain techniques in physics (such as energy conservation) are applicable to isolated systems only.