Chapter 1

Introducing Physics

1.0 Introduction

Physics deals with physical characteristics and physical behavior of “things”, that we find around ourselves, not only on the earth but in the whole universe.

1-1 The Purpose of Physics

The study of physics aims to explain the past, present and the future of “things”, related to their physical appearances and behavior.

To study physics, we need a set of laws, called the Laws of Physics. These laws have been developed by thinkers, philosophers and scientists, over a period of many centuries. To understand, learn and use these laws, we need to know the basic concepts of physics.

We shall now define “things” and describe their most basic properties.

1-2 Things

Things are of two types

(i) Material: material things have matter or *mass*. Living beings, mountains, stars, books, cookies, water, dust particles, air and electrons are some everyday examples. We can see material things if they are of a reasonable size. If a thing is very large (ocean, desert, forest etc.), we may see only a part of it. On the other hand, if it is very small (dust particle, air molecule, electron etc.), we may see it through a microscope or we may not see it at all. Masses of material things are measured in *kilograms* and we write *kg* for it. Matter lives for ever.

(ii) Non-material (but not *immaterial*): Non-material things have no material (or matter or mass). We call them *waves*. Waves carry energy and live only as long as they are in motion. We measure their energies in *joules* and write *J* for it. Light and sound waves are some familiar examples. We cannot see either of them! Nature has, however, endowed us with special body parts for them: *eyes* for sensing light waves and *ears* for sensing sound waves.

Presently we shall study “material” things with their “masses” expressed in kg.

1-3 Fundamental Characteristics of Material Things

Material things have three fundamental characteristics. These characteristics are very basic and we must introduce them as the basis for the material things to be called material things. In other words, we would define an entity as a material thing, *only* if it has all three of these basic characteristics.

1-4 ***(A) Fundamental Characteristic #1***

Material things "attract" one another

All material things (no matter how big or how small) have an insurmountable urge to *attract* or *pull* one another. The urge to pull gives rise to a force, called the *gravitational* force. Gravitational force is very weak. This is why we do not see material things getting closer to one another and colliding. The magnitude of the force grows with the mass of the object. In case of earth (a very large mass) the force is readily visible. Whenever a material thing is dropped or thrown, it always lands on the ground (the earth). Again, as the earth revolves around the sun, we are told that sun pulls the earth. Similarly the earth pulls the moon and causes it to revolve around the earth.

Gravitational force is purely a consequence of the amount of matter (mass) that a material thing possesses. The larger the quantity of mass possessed, the greater will be the force that it will exert on other material thing (separation of the two remaining the same). The mass of a material thing, therefore, is called its *gravitational mass*.

The *urge* to pull is an inherent characteristic of *all* material things. It can never be shielded, masked, disabled or switched off. It can, however, be *neutralized* or *balanced out* under special circumstances. We state:

Every material thing "attracts" every other material thing, as a consequence of the "Gravitational Mass", that each owns

1-5 ***(B) Fundamental Characteristic #2***

Material things have "inertia"

All material things (no matter how big or how small) exhibit an insurmountable *dislike* for being pushed around. Thus when a material thing is at rest, it will tend to remain that way and will be very unwilling to be moved. This characteristic of material things is known as *inertia*.

If you want to reposition a table, *you* have to make an appropriate effort. Why should you make an effort? The answer lies in the "unwillingness" on the part of the table to get moved. It simply doesn't want to be disturbed. This attitude of the table forces us to be forceful in order to enforce our wish; so we apply a force large enough to surpass its unwillingness.

Forget the table! You may think that you are applying a force because the table is on the floor and there is friction between the table and the floor. Consider a chandelier suspended from the ceiling. If you want to deflect it from rest, you will still have to flex your muscles because the chandelier, like the table, doesn't want to be pushed around.

Forget the chandelier! Deflecting it may not be a practical proposition. Consider a *charm* that you have suspended in your car from the rear view mirror. When you move your car from rest, the charm doesn't move. It continues to stay in its place (at rest) with the result that it gets swung backward (as far as the string allows) and then gets dragged along. The charm, quite like the chandelier and the table, did not want to be disturbed!

The property *inertia* is purely a consequence of the quantity of matter (mass), that material things possess. The larger the mass the material thing possesses the greater is its inertia, and vice versa. We find that bulky things such as a bowling ball or a motor car, require us to make a large effort to move them; while tiny things such as a tennis ball or a marble get moved with tiny efforts. The mass of a material thing, therefore, is used as a measure of its inertia and is called its *inertial mass*. We state:

Every material thing has "Inertia" as a consequence of the "Inertial Mass" that it possesses.

1-6 What if the Object is Not at Rest?

If a material thing is not at rest and is, (for example) moving in a straight line, then its *unwillingness* to being disturbed increases (gets aggravated or enhanced, shall we say?) If we try to disturb its motion (try to stop it, for example), we shall have to make enhanced effort. This *aggravated inertia* is called *momentum*, and depends on how fast the object is moving. Being motion-dependent, momentum is not measured in *kg.* We shall learn more about it later.

1-7 Equivalence of the Gravitational Mass and the Inertial Mass

Please be advised that the gravitational and the inertial masses are two entirely and totally and completely unrelated properties of material things. One comes from the property of *pulling one another*. The other, on the other hand, stems from their *unwillingness to being pushed around.* It is, therefore, very surprising to find that the magnitude of the gravitational mass of a material thing is numerically equal to the magnitude of its inertial mass, *as determined by us*. Einstein tells us that our inability to distinguish between the two masses is a direct consequence of the non-existence of an *absolute reference frame* in our universe. Now that the two masses have identical magnitudes, we have taken the liberty of using the same unit (*kg*) for both of them. Many textbooks do not bother to tell you that there are these two distinct properties of matter, giving rise to two distinct types of *mass*. This is kind of sad.

In anticipation of what you will read later, we would like to tell you that the *weight* of an object is due to its *gravitational* mass while the *acceleration* that the object acquires (for whatever reason), is due to its *inertial* mass.

1-8 (C) Fundamental Characteristic #3

Material things have "elasticity"

All material things (no matter how hard or how soft) get stressed out (develop strain) when subjected to stresses and recover when stresses are removed. If stresses are unbearable, breakdown occurs. The property is called *elasticity.* Some material things are more sensitive to stresses than others. We exploit this property gainfully to make devices, such as springs, rubber bands, trampoline, bungee cords, drums and the like.

1-9 Elasticity as a "Non-Mass" Property

The property Elasticity of material things does not depend on the amount of matter (or mass) that they have.Elasticity will, therefore, be characterized as a *non-mass* property of material things. Elasticity is also observed to remain unaffected by variations in the gravitational and/or the inertial mass of things. When analyzing elastic devices, such as springs, rubber bands, bungee cords, stretched strings or trampolines, we should never ask, "Sir, how much matter do you own?" Or, "Sir, what is the worth of your *material* holdings?" However, in view of the fact that we are so grossly infatuated with everything having some *material* holdings, that we do not feel comfortable without a mention of the *mass* of the object. So the books have to keep telling us in so many words that the object (device) is massless. Or that *ignore the mass of (say) the bungee cord*. Rest assured, in this book you will not find a mention of mass for elastic objects, directly or indirectly. We expect you to memorize these facts and then be responsible for them because you are not a school student any more.

1-10 The Gravitational Mass, the Inertial Mass, and the Non-Mass

In anticipation of what you will read later, we would like to tell you that the *Gravitational Potential Energy* of a material thing is due to its *gravitational* mass, its *Kinetic Energy* is due to its *inertial* mass, and its *Elastic Potential Energy* is due to its *non-mass*.

There are only three basic properties of material things in Mechanics and only three (corresponding) energies in Mechanics. A perfect one-to-one correspondence!

Amazing! Isn't it?

1-11 Classification of Material Things

Material things are classified as:
(1) solids (2) liquids (3) gases.

Presently we shall study "Solid Material Things" and call them "Objects"

1-12 Classification of Solid Objects

(1) An object by itself: a "Unibody System" or a "Discrete Object" or a "Rigid Body"
(2) Groups of objects: "Many Body Systems" or "Families of Objects"

When an object is an individual object, i.e. it is all by itself and has no constituent or member parts, then it is called a *unibody* or a *rigid body.* The word rigid tends to tell us that the level of elasticity of the object is minimum. Under normal usage, it will not undergo a (recoverable) change of shape. Stones, marbles, bricks, mountains, bones, tables, dust particles, or electrons are some examples. For simplicity we refer to *rigid bodies* simply as *objects* or *particles*. **Most objects belong to this category.**

Sometime objects are bundled together like a family. We may treat them as *aggregates* of rigid bodies. In an aggregate, each participating rigid body is able to function independently and individually. The aggregate, however, maintains an overall status of being *one* object (like a family). A good example is a motor car or a human body. Pebbles in a can, boat and passengers, solar system, pancake in a saucepan, billiard balls on a pool table, a bag of sand, or flowers in a vase are some other examples. Such aggregates of objects are called *many body* systems or *systems of objects* or *systems of particles* or simply *objects* or *particles* or *systems*. **Most objects belong to this category.**

How come "most objects" belong to both categories?

Well, if in a *many body system* the movement of the participating rigid bodies be irrelevant to whatever we are studying or the participating rigid bodies stop moving independently (go on strike, for example, or freeze as if they have seen a ghost), then we will have to treat them as *particles*. Quite often we treat a whole motor car (with a whole lot of internally moving parts) as a particle. The movement of the independent parts of the car, in this case, is irrelevant. Or consider the moon. In the absence of air or water, its many different constituent parts have no motion relative to each other. They behave exactly as if they are frozen! The moon may very well be called a rigid body.

How come objects of both types are called "objects"?

Laziness, I suppose! We may not like to keep saying or writing *many body systems* or *systems of objects* and may just say (or write) *objects*. Whenever a distinction becomes unavoidable, or a lack of distinction will cause confusion, we shall immediately use the correct terminology.

1-13 Objects Have "Centers of Mass"

If you have not, so far in your life, tried balancing an umbrella on the palm of your hand (to impress your friends), you may do so now.

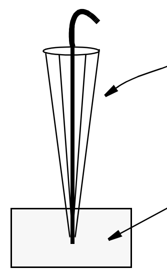

Fig (1) Balancing an Umbrella on the Palm of Your hand

All rigid bodies possess a unique and well defined geometrical point, called the *center of mass.* It is understood that, for all scientific purposes, the entire mass of the object is concentrated at the *center of mass* of that object and that the rest of the body has no mass. The center of mass of an object is usually somewhere in the body of the rigid body, even though it is not necessary. The center of mass of an umbrella is for sure in the body of the umbrella but that of a cup of coffee is not in the body of the cup.

The concept of the *center of mass* is of great importance and manifests itself in the following ways:

(1) It renders all scientific considerations and operations independent of the shape and size of the object. All objects are represented, very simply, just by their centers of mass (a geometrical point).

(2) The earth exerts its force of pull *only* on the center of mass of the object. It is this characteristic of the earth's pull that allows us to balance umbrellas on the palms of our hands.

(3) It is the center of mass of an object that follows the trajectory of motion, the trajectory of motion having been carved by the law that has generated that motion.

(4) All forces effectively act at the center of mass of the object.

(5) The energy that an object possesses, resides at the center of mass of that object.

(6) If an object is set into free spinning motion, the center of mass of the object *must* lie on the axis of rotation.

(7) and more

1-13 What about "Systems of Objects"?

A *many body system* or a *system of objects* cannot always be balanced at the same point. When the member parts are in one configuration you may balance it at some point. If, however, the configuration of the member parts changes, it will be balanced at a different point. This shows that the position of the center of mass of a *system of objects* is not unique and depends on how the member parts are positioned relative to one another.

1-00 Summary

A summary of the above is presented in the form of a *stabile*, shown below.

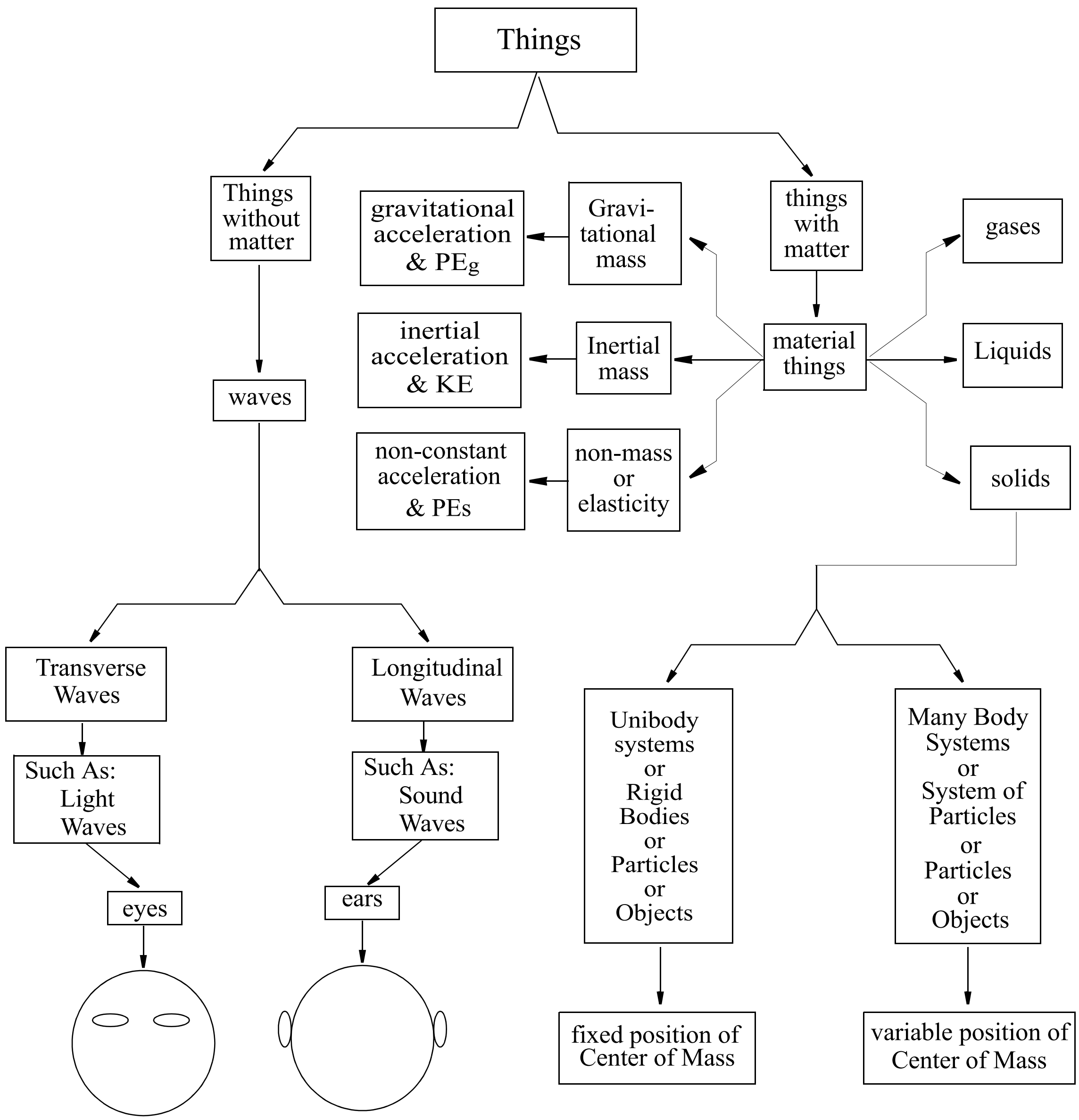

Fig (2) A Stabile of Things