Similitude And Approximations In Engineering,
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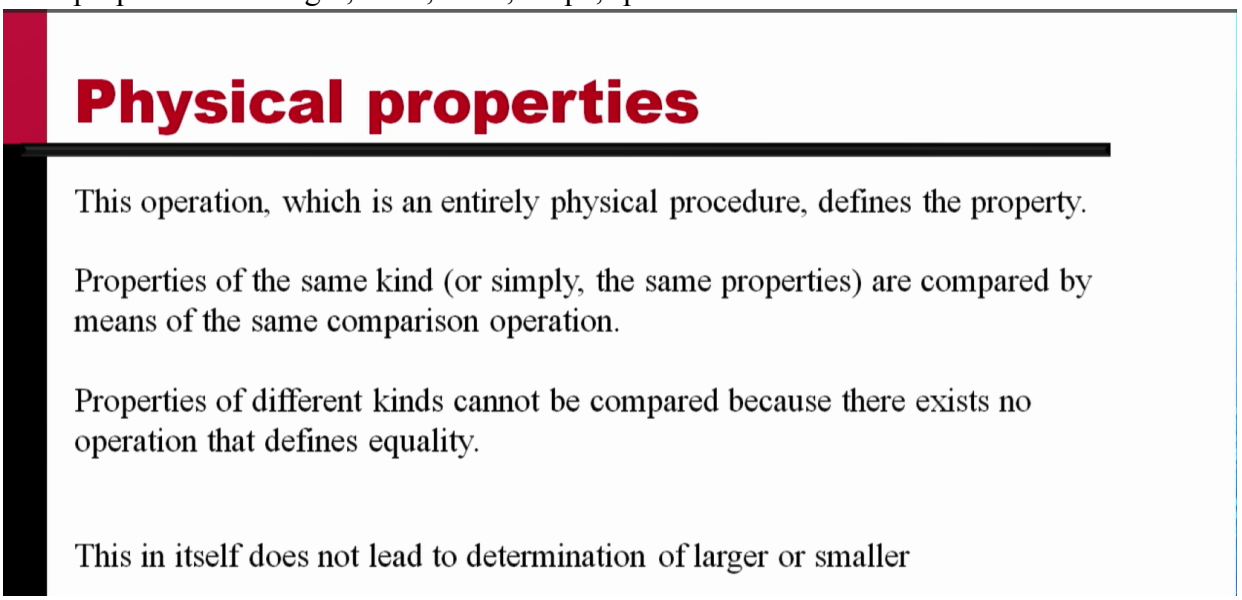
Week - 01
Lecture – 02

Welcome back. In this video, we will learn about the nature of physical quantities. We will start from the very beginning. Einstein said that pure logical thinking cannot yield us any knowledge of the empirical world. All knowledge starts from experience and ends in it. Propositions arrived at by pure logical means are completely empty as regards reality. So, all science emanates from experience.

Science begins with observation and precise description of things and events. Description in absolute term is impossible. We can do no more than compare one thing with another to catch the resemblance of things so to say. When we hear the word a tree, the human mind has evolved to an extent that picture of tree is formed in a mind.

But it is very difficult to describe what the tree is. All these are trees. There is no simple description of a tree. Is this a tree? So, if we want to do physics, we have to start by breaking the descriptive process down into simpler terms. An object or event is described in terms of basic properties like length, mass, color, shape, speed and time.



None of these physical properties can be defined in absolute terms but only by reference to something else. That is by comparison. The references may be made more precise but in essence description is simply a noting of the similarities between one thing and a set of others that are known to us. We can do no more than compare one thing with another. A physical property first arises as a concept based on experience and is formalized by defining a comparison operation for determining whether two samples of it are equal, that is A is equal to B or unequal, that is A different from B.

This operation which is an entirely physical procedure defines the property. Property of the same kind, that is the same property are compared by means of some comparison operation. Properties of different kind cannot be compared because there exists no operations that define

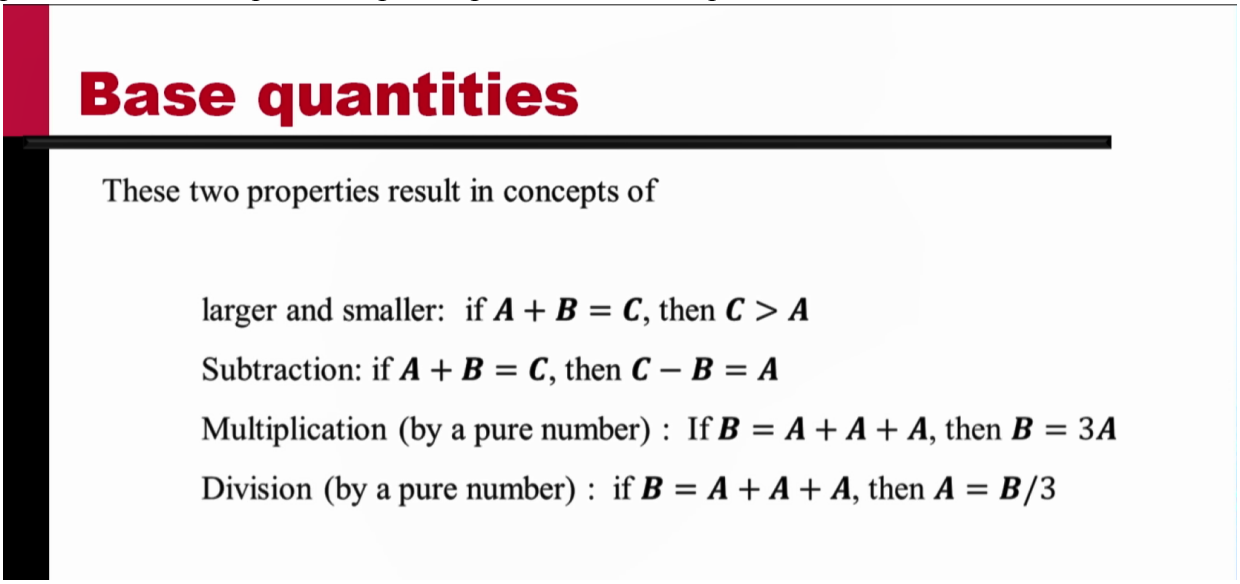
equality of those quantities of different kinds. This in itself does not lead to determination of larger or smaller. Mere description does not make science.

Science requires establishing the laws connecting these physical properties. This requires a mathematical framework and only those properties that are amenable to mathematical operations are involved in science. Such properties are termed as physical quantities. They are magnitudes that may be equal or unequal. Physical quantities are those properties which allow not only the comparison operation that is A is equal to B or A not equal to B but also a concept of greater or smaller.

The concept of greater or smaller is introduced through an addition operation C is equal to A plus B. If C is obtained by adding something to A, then C is greater than A. A physical property first arises as a concept based on experience and is formalized by defining comparison operation determining whether two samples are equal or unequal. In addition we have a concept of greater or smaller. Colour and shape though physical properties are not physical quantities because there is no concept of greater or smaller.

They are physical properties because we can talk of equal color is same shape, unequal colors or unequal shape but we cannot say which color is greater or which shape is greater. Physical quantities allow two types base quantities and derived quantities. The base quantities which are defined entirely in physical terms form a complete set of building blocks for an open ended system of derived quantities that may be introduced as necessary for description. The base and the derived quantities together provide a rational basis for describing and analyzing the physical world in quantitative terms. Physics as any other science requires a description of physical world in quantitative terms on which we can do mathematical operations.

So to revise, a base quantity is defined by specifying two physical operations: a comparison operation, and an addition operation that defines what is meant by some C is equal to A plus B of two sample of properties. The two properties of equality and greater and smaller results in the concept of larger and smaller. If A plus B is equal to C then C is greater than A. Subtraction A plus B is equal to C then you take away B from C you get A subtraction. Multiplication by pure number B is equal to A plus A plus A then B is equal to 3 A.

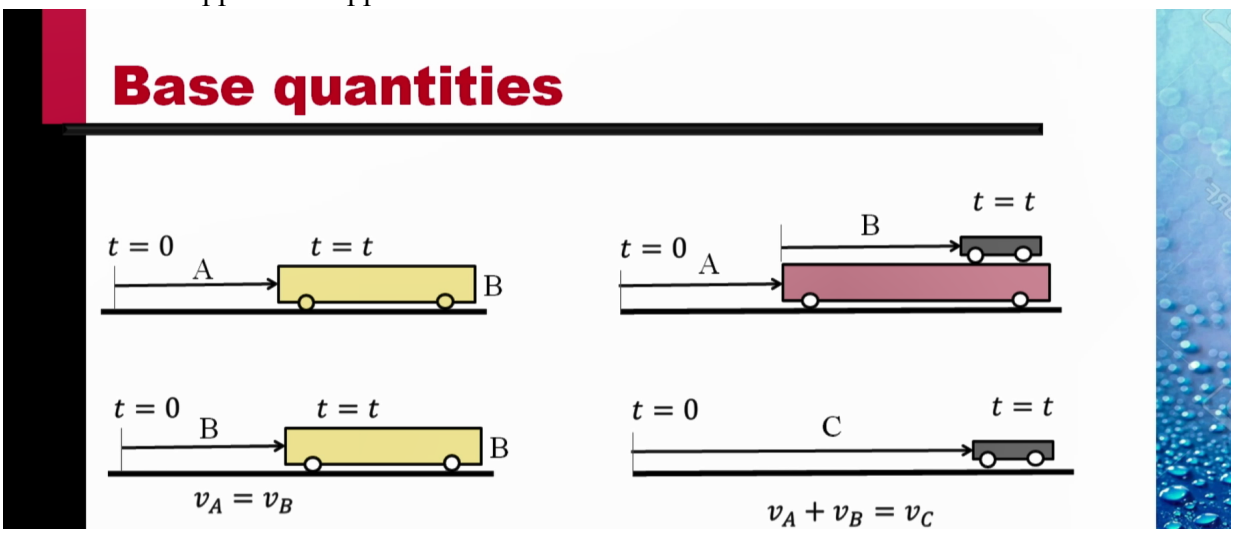


Division by a pure number if B is A plus A plus A then A is B by 3. These are all possible on base quantities. Base quantity is thus a physical quantity for which comparison addition

subtraction multiplication and division by pure numbers are defined. The comparison and addition operation are physical but they require to have certain properties that mimic those of the corresponding mathematical operation for pure numbers. The comparison operation must obey the identity law: if A is equal to B and B is equal to C, then A must be equal to C.

And the addition operation must be commutative: A plus B must be B plus A. Associative: A plus B plus C is the same as A plus B plus C and unique, if A plus B is equal to C then there exist no finite D such that A plus B plus D is also equal to C. The D must be 0 in this case. So, from the given reference of Sonnen's book, I introduce the base quantities. Length: the length A and B are equal and A is less than C because you need to add B to A to get C.

It is physically possible to conceive both operation comparison as a addition operation to establish the length can be treated as a base quantity. Mass: using a physical balance the mass A is equal to mass B and mass A plus mass B is equal to mass C. So, mass can also be treated as a base quantity. Is force a base quantity? I can see this. Consider this small car with two force A and B applied in opposition.



If the car does not have any acceleration A then the force A must be the force B. So, a comparison of forces are possible. If the two forces are applied in opposition and no acceleration results then these forces must be equal. Similarly, we can define for force an addition operation A and B on one side and C on the other and still no acceleration. So, F A plus F B must be equal to F C.

So, force can be treated as a base quantity. This may go against the grain of what we learned in high school. In high school force was almost always treated as a derived quantity rather than a base quantity. But since we can conceive of this operation of comparison, we are within our rights to treat force as a base quantity. If there are any complications that result we learn to handle them.

Similarly, if we learn to handle them. Similarly, the area can be treated as a base quantity. Two areas the gray and the pink they are equal. They do not need to be of the same shape, but they definitely these two areas are equal. So, this area meets the condition of having equality operation.

Similarly, the pink A and the gray B gives you the total area C which is pink plus gray and you know that the pink area is smaller than the overall area. So, the comparison operation of greater than smaller is also possible. So, area can be treated as a base quantity. If we so wish, it may be

convenient to us to treat this as a derived quantity. So, we will see what gives us benefit in our operations and we will treat these quantities as base quantities or derived quantities.

Some of these quantities there is nothing inherent in them to make them base or derived. Even speed. In time t this car travels a distance a, the second car also travel the distance b. Clearly the velocity of a is equal to velocity of b. How can we conceive a addition operation velocities? Consider this picture.

The pink car is moving on ground and a gray car is moving on top of the pink car. With respect to the pink car, the gray car has a velocity b, the pink car itself has a velocity a. We look at the gray car in the second operation, clearly v a plus v b is equal to v c. So, v c the velocity the net velocity of the gray car is more than the velocity of the pink car taken alone. You are well aware that in your high school you treated velocity as a derived quantity.

But again we can treat this as a base quantity if it is convenient for us. Now let us talk about units. Two operations that are given to us are the velocity of the car. Now let us talk about units. Two operations that define a base quantity make it possible to express any such quantities as a multiple of a standard sample of its own kind that is to measure it in terms of a unit.

The unit is a standard sample that may be chosen arbitrarily such that the length A when compared to a unit, the lower case a. The length A is built up of two units of a and then three-tenths of a. So that the length of the unit is equal to the length of a can be written as 2.3 a, a is the unit. Unit is arbitrary and this number 2.

Three is also arbitrary, depends upon a. Of course, you know that the units have been standardized. Some of the old definition of units are based on physical samples kept in a museum in Paris. Length is compared to a rod which is kept in a museum and it is called a meter. So all lengths are measured in comparison with meters. Of course, the present day accuracy required has made us change into a number of wavelengths of a specific specified light.

As I said units could be arbitrary. So, the a based the quantity A can be written as numeral A, capital A times unit a, or also if we change unit lower case a to a prime then the number A prime would be different. A capital A small a is equal to A prime a prime. And this gives a divided by a prime is a prime by a. If I change the size of the unit by a factor n, then the number measure of the physical quantity changes by the reciprocal of n. If the size of the base quantity unit is changed by a factor n then the quantities numerical value changes by a factor of n raised to power minus 1 that is 1 over n.

The ratio of the numerical values any two quantities of the same kind is independent of the base unit size. So, if I measure the distance between two points or between two sets of points in any units in kilometers or miles or yards or feet the ratio would be independent of the base unit size. Thank you. .