Introduction to Mechanical Vibration
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Lecture-21
Transducers and Vibration Pickup

Welcome to the lecture on Vibration Measuring Instruments, so far we have studied the forced vibrations and free vibration. So, we see that any structure that is subjected to some force, it response to that force, so the response can be in terms of displacement, velocity, acceleration. Also there is some frequency contained in that response.

So, in case of free vibration usually the structure vibrates with its measured frequency or if it is damped structure with some damped natural frequency that is called omega t that is equal to omega n root one - zeta square where zeta is the damping factor. When there is a forced vibration, so the structures have two responses, I mean the total response is sum of two responses, that is, transient response and steady state response.

So the transient response die out due to damping effect of damping in the initial few, initial sometime how about the steady state response that remains till the force is applied, so if there is some harmonic force, as we discussed several cases in which the structure or the system is subjected to harmonic force like f zero sin omega T. So usually the response of the structure comes to like X = X sin Omega t - Phi where, so the response contains some amplitude of the sin curve and there is some phase lag respect to that force.

Moreover, when we differentiate x =, so if we differentiate the x = X sin omega t - Phi. So we can get x dot okay that is omega x and cos omega t - phi or x double dot that is - omega square x sin omega t - phi.

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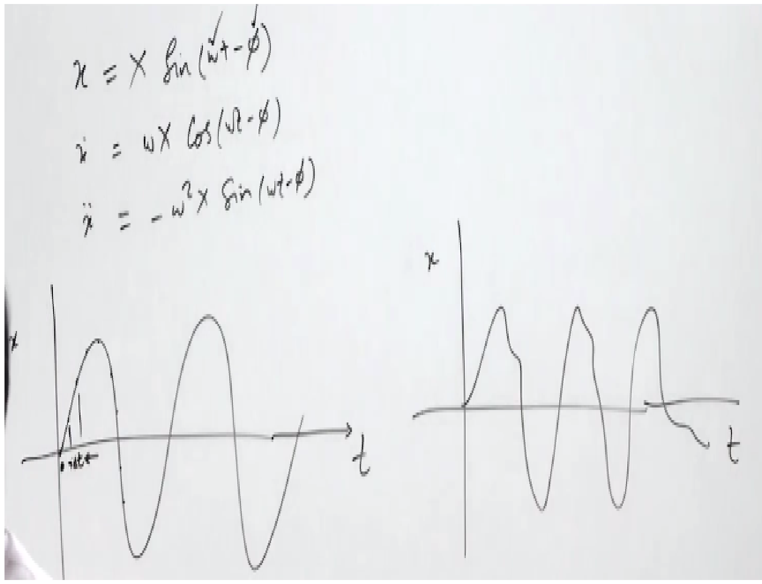

So all these three terms, they are displacement, velocity and acceleration so they are the response properties of the structure, moreover there is omega, frequency and the phase. So now, the question is, how we will measure these vibration responses when our structure is vibrating and we want to know with the measurement with some experimental system that what is the vibration response? What is the displacement response?

What is velocity response? What is the acceleration response? Then, what is the frequency contained? So all these parameters if we want to know we have to measure and so we have to use some instruments and because we have already dealt with some fundamentals of vibration and theory of vibrations. We know that, if we are going to measure the vibration, using those instruments, those instruments must be designed, based on the theory of vibration.

Then only they can measure the vibrations, so here basically, the theory that we have already studied that we will use to discuss the design of the vibration measuring instruments. So in this first lecture of this vibration measurement, we will discuss today the transducers and the vibration pickups the basics of this measurement.

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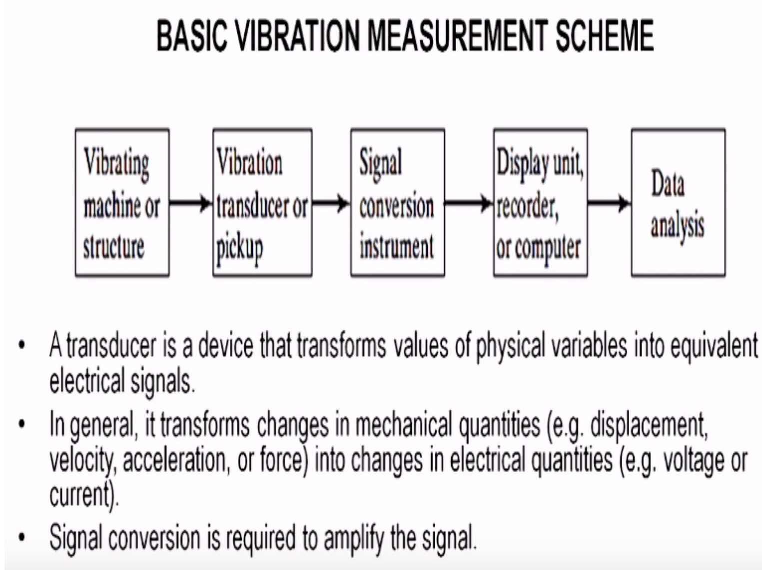

So let us see here, so what could be a basic scheme of the vibration measurement. So here we start with some structure machine, that is vibrating so we have some structure that is vibrating there is some physical structure that exists and that is vibrating it has some oscillatory motions and we have to measure; so we are to use some instrument so we call it transducer, vibration transducer or vibration pickup; so they are the instruments so what is a transducer?

Transducer converts a signal into electrical signal. So it converts a physical quantity into an equivalent electrical signal like more specifically, it converts a change in the physical quantity. So if there is some change and it converts the change into electrical quantity, so if there is some displacement, velocity, acceleration or a force, so there is some change corresponding it will show the change in the electrical signals.

And so there is some relation between this physical quantity and the electrical quantity and with that relation, we can know that from the measurement of the electrical signal, we can know, what is the change in the physical parameter or physical quantity. So, here we have vibration transducer and they give us some electrical signal; so when we get the electrical signal we have to apply some amplifier or signal conversion instrument.

So why do we need the signal conversion instrument because the electrical signal, the change in the electrical signal is very small and so it is not very strong with respect to noise or some other vibrations. So basically noise, that is why we have to amplify these signals using this amplifier. So we use this signal conversion instrument that amplifies that signal. Now, that signal we have to see on that display or on the computer screen.

So we can, for example. If we have this signal that we are measuring so suppose we are measuring x and versus time, so this is a signal that we will obtain here and here time is 0, so here we have for different so here there is some delta t, the time step, so at each time step, we will get the value of that quantity, the physical quantity that is displacement here x and we can see this signal on the screen.

Now, when we have signal, we have, what we will do with the signal, because this signal is not giving us enough information for example, this signal is simple but it could be also some signal like in this. So from this kind of signal I mean how we will understand that what does it mean. So we need to do some data analysis. We have to do the analysis of this signal and from the analysis of this signal, so there are several analysis like we can do the Fast Fourier transform.

So we can know the frequency contained and amplitude of that frequencies that corresponding to those frequencies, we can know the amplitude of that signal. So this data analysis will give us the characteristics of the vibration behavior or vibration response and that is what we want from the measurement. So from this process of this measurement, we can know, by using the instrument we can know finally the vibration, characteristic or vibration response of a physical body.

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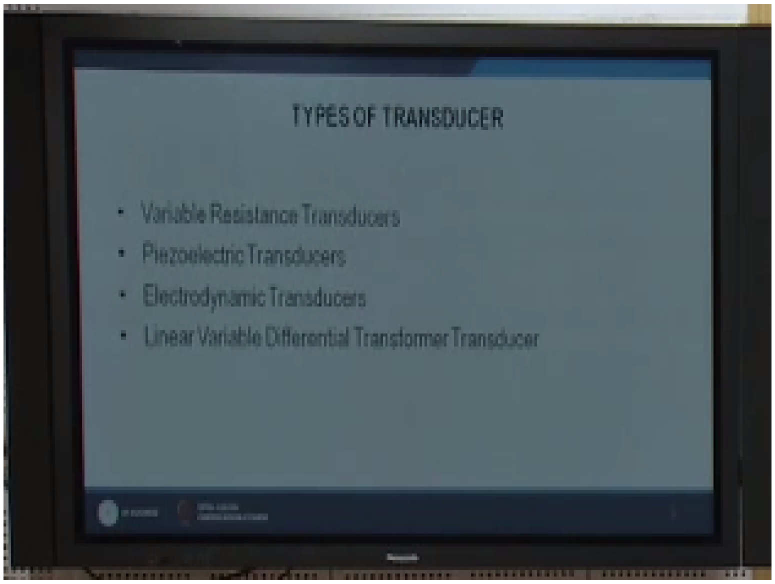

So first let us discuss some general different types of transducers. So transducers, as I said that they transform the physical variable into some equivalent electrical signal. So it means there should be some relation that the electrical signal is related to some mechanical or mechanical aspects. For example, there is variable resistant transducers.

So variable resistance transducers mean that those transducers utilizes the characteristics of resistance change and link it with the vibration measurement. For example, you know that the resistance of the wire depends on the length. So the resistance is proportional to the length of the wire. So if the length is increased, the resistance will increase and if the length is decreased, the resistance will decrease.

So this relation can be used as resistance transducers. Similarly, there are piezoelectric materials and piezoelectric materials when some force is applied they develop some charge on their surface and that charge can be converted into the voltage and that voltage can be measured. So these characteristic of the material, so force, application of force is some physical or mechanical quantity of some vibration characteristic.

And we are converting into the corresponding electrical voltage. Then, electro dynamic transducers, these transducers, they use the characteristic of these inductor that is - because the voltage in an inductor is proportional to the rate of change of the current and so they use the principle of electro magnetism and they can with some rate of change we can relate to the velocity.

Because velocity is also the rate of change of displacement and we can relate it to find the change in the voltage of that inductor. Then, there is a linear variable differential transformer transducer so this is also based on the principle of the coil and the inductor voltage. So we will discuss in further details in this aspect.

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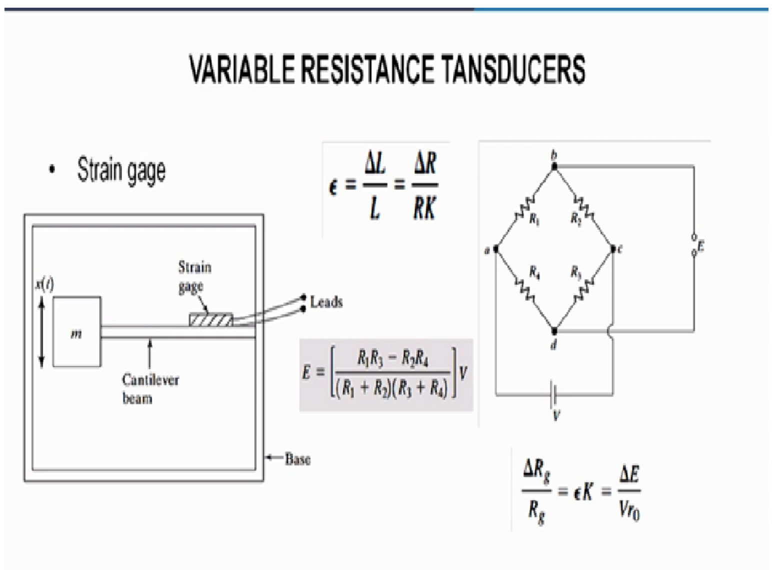

So here we have the variable resistance transducers, so we can see that the strain, strain is change in length.

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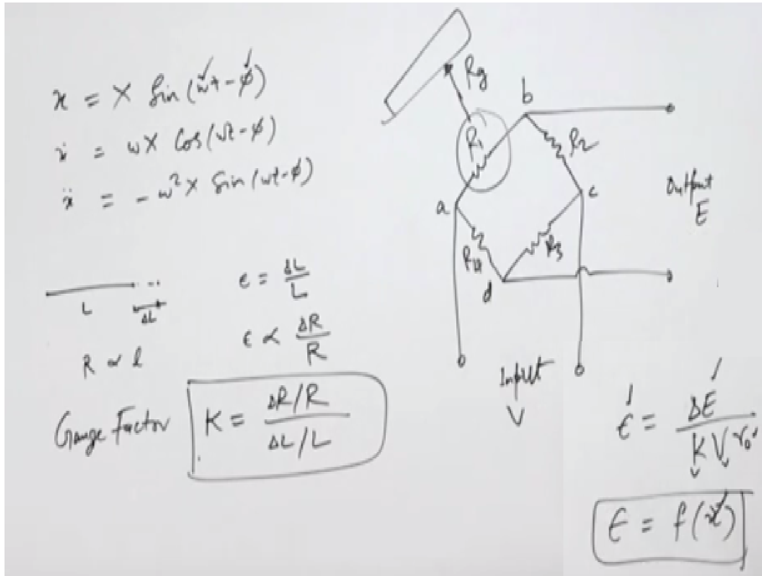

So if I have some wire and its initial length is l and it is extended as delta L. So the strain is delta L by l. and we know that the resistance is proportional to the length of the wire. So the strain is proportional to delta R by R. Then this proportionality needs some constant term that will depend on the wire and its relation with the strain and resistance. So here we say epsilon, we say K, so here K is known as the gauge factor.

And there are the transducers known as strain gauges that uses this characteristic and the gauge factor is constant for that strain gauge or for that wire and we can use the strain gauges to measure the strains in some mechanical systems. So these transducers are based on the resistance. Now, this strain gauge can be if we can see that figure when there is some strain gauge attached to some cantilever beam and there is some mass.

And so this mass is vibrating and we want to capture the vibration of this mass and we have attached this strain gauge here on this cantilever beam. Now the strain at that location of the strain gauge will be depending on the displacement x because if it is more displaced from its equilibrium position and more strain will be there and so by measuring the strain and by relating the strain to that x, we can measure x.

Now here there are some circuits because there are electrical strain gauges and so they follow some circuits and this particular circuit we call Wheatstone bridge. So here is the Wheatstone bridge. So here is input voltage and here is output voltage. So this is called Wheatstone bridge and we can see the relation that = R1 R3 - R1 R4 by R1 + R2 and R3 + R4.

So when this bridge is first balanced and when it is balanced, there is no any current and so the output E is 0. When we use this bridge, so let us say R1, this strain gauge we apply to measure on some vibration measurement we attach some cantilever and so we say this is Rg because R gauge so this is the main strain gauge that is attached to the structure others are not attached. So when this is attached and our bridge is disbalance, there is no any voltage E, so E is 0.

However, when there will be some change, some vibration, there will be change in the resistance of the strain gauge R1 or Rg and so the Wheatstone bridge will be unbalanced. So there will be some current and then some voltage E. So E will be non-zero and we can measure E and we can – by measurement of E, we can convert it to measure the strain E. And the strain can be related to x.

So here we can see this final formula epsilon equal to, – so we can measure epsilon = k delta E by K V R0. So here we know the because gauge factor – gauge factor is given for strain gauge, R0 is some constant that depend on the resistances R1, R2, R3, and R4. And Delta E is the change in the output voltage that we measure, we know this and so we can know the strain and this strain we can relate with x and so we can measure x.

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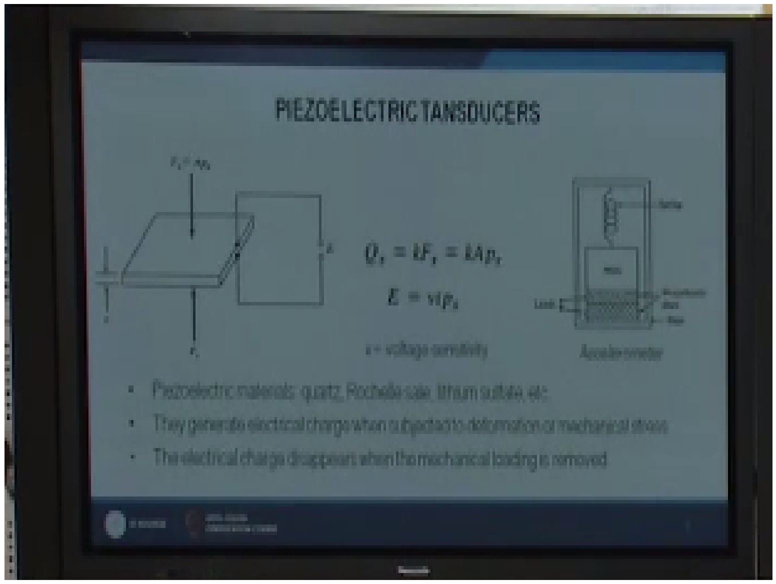

Now, there are another type of transducer known as piezoelectric transducers. So when there are certain materials on this earth, when they are subjected to some pressure, there is some charge developed on the surface of the materials and they are known as piezoelectric materials. So here we can see there is some plate of piezoelectric material with thickness t and there is some force applied on the surface in the x direction.

So it is perpendicular to the surface and if we connect the two surfaces, we can know the what is the voltage developed on the surface due to the application of that force and by measurement of that voltage, we can know that what is the force or displacement force applied on the surface. So here q is the charge on the surface that is equal to K into F. K is some constant of the piezoelectric material and F is the force.

And force is area into pressure, so we can write K A P X and this E = V T P X this formula. So voltage sensitivity. So general piezoelectric materials, they are quartz, (()) (23:06), or lithium sulphate. However, when we unload the material, so again the material is in its initial stage and so it is discharged. So based on the piezoelectric material there are some transducers, some vibration pickup they are met, so one example is the accelerometer.

Piezoelectric accelerometer, they are very frequently used in the measurement of the vibration responses and so here you can see there is some spring and mass system and there are some descopepiezoelectric materials and they are between the mass and the base. And so when there is some vibrations of the mass, they major the difference between the mass and the base because base is attached to the surface which is vibrating.

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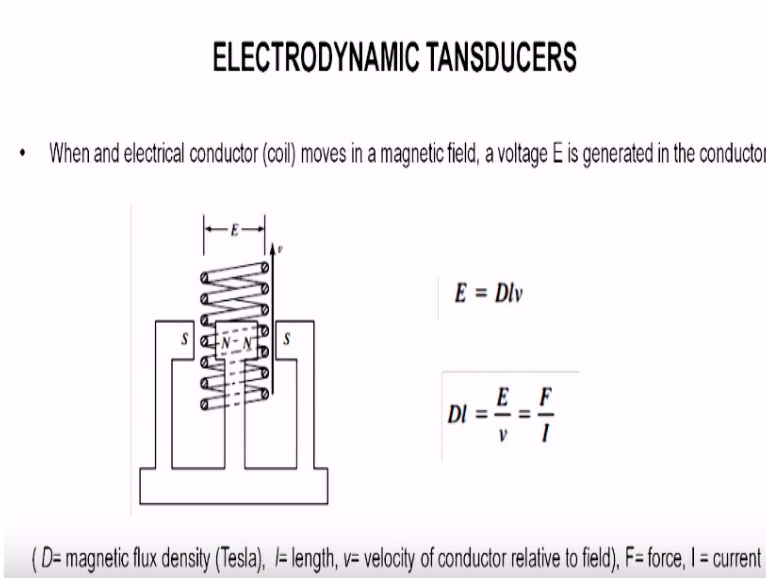

So here are some electro dynamic transducers, so we know that when some electrical conductor moves in a magnetic field, there is some voltage generated in the conductor. And so these principle is used here to design or to make this kind of transducers. And the voltage developed is Dlv, where D is the magnetic flux density, l is the length of the conductor and v is the relative velocity.

So here this transducer is working I mean based on the relative velocity, so we, these type of transducers can be used in for velocity pickups. Moreover, this magnetic field can be produced by two ways either we provide some permanent magnet or we use the electro magnet means we have coils and we pass some current and so there will some magnetic flux created in that coil.

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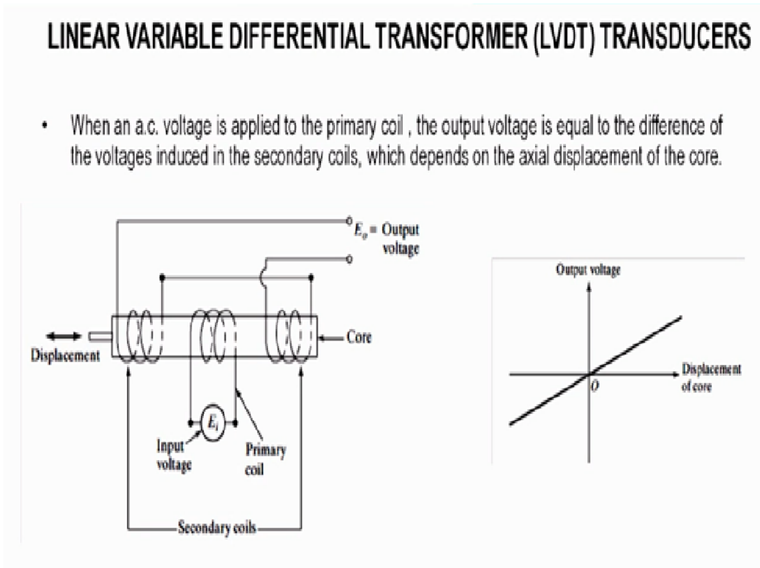

There is another type of transducer that is LVDT, so Linear Variable Differential Transformer Transducers. So in this kind of transducers, as you can see, there are – this is the primary coil and there are two secondary coils. So this primary coil is given some input voltage, ac voltage Ei and there is some magnetic core, some material magnetic material core and here are the output is taken from the difference between the two secondary coils.

This magnetic core is such that if it is in the middle of the two secondary coils. There is the cancellation of the voltage, because equal voltage and opposite voltage in both the secondary coils, so they cancel, so they produce the zero voltage. However, when there is the movement of the core, because the core is connected to the displacement measuring some instrument so if it is displaced, so it moves, so it is out from one end of the secondary coil and it is more inserted into the other end of the secondary coil.

So this system also – So there is some magnetic coupling from this system measures the voltage away from zero when there is some displacement of the magnetic core. However, there is also the directional measurement because the coil at the magnetic core can be moved to one direction, so it enters in one coil more. If it is in opposite direction, it enters more into the another coil. So it also measures the direction and so measures the vibration in the with respect to equilibrium point.

Now here this is the linear voltage displacement response of this system for small movement of this core. So we can see here zero and it is more linear in the both side the positive and negative displacement side.

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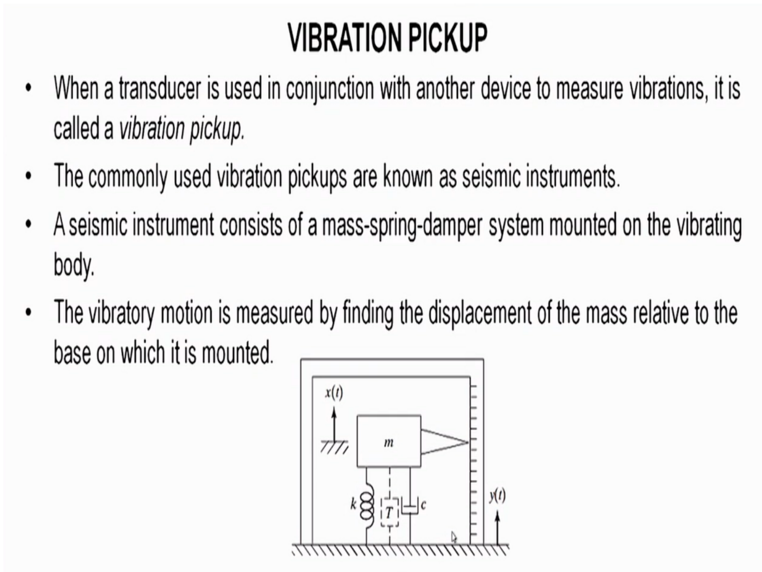

Now vibration pickups, so vibration pickups are used, so they are using conjunction with transducers and they are also called seismic instruments. They contain usually mass-spring and damper system. So when this is the mass-spring-damper system, and this system is attached to the vibrating body and here we can put some transducer like piezoelectric transducer and so we can know the relative displacement between the base and this mass and that relative can be measured from this transducer.

And we can with the help of the theory of vibration, we can relate this relative displacement to the base displacement and we can measure the vibration of the structure.

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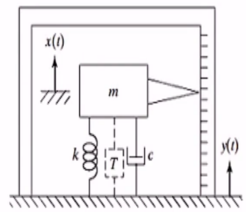
VIBRATION PICKUPS

- An instrument that measures the displacement of a vibrating body - *vibrometer* or a *seismometer* .
- An instrument that measures the acceleration of a vibrating body – accelerometer
- An instrument that measures the velocity of a vibrating body- A velometer or velocity pickup



So these vibration pickups can be of different types, it could be, so their name differs based on what they are going to measure. If they measure displacement, they are called vibrometer or seismometer, if they measure velocity, they are called velometer or velocity pickups. However, if they are used to measure the acceleration responses, they are known as accelerometers. So I stop here and thank you for this lecture and see you in the next lecture.