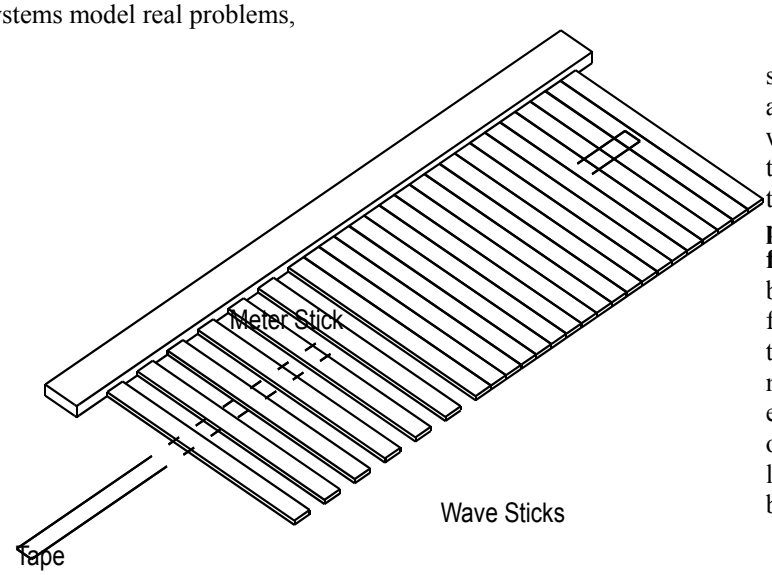
20500 Wave Sticks

Purpose:

To investigate the properties of waves in a way that will allow direct student participation in the preparation of the apparatus. While the usual parameters of frequency, wavelength, amplitude, and phase are as demonstrable as with a traditional torsional wave apparatus, the novel suspension requires student involvement with the notions of impedance, propagation velocity, reflection, refraction, interface between wave media, and the effect of impedance matching. The behavior of pulses, wave trains, reflectors, refractors, damping, standing waves, transmission lines, terminators, and transformers can now be demonstrated in slow motion by simply hanging the assemblies vertically in the classroom. The relative ease with which systems can be crafted provides an opportunity to involve a whole class in productive activity. The product of each team makes a distinctive contribution to the understanding of the whole group. Since these concepts can be explored independently of language, the materials have served the organized play needs of elementary students as well as the more complex requirements of the advanced student through at least senior high school level.

Discussion:

Early in their study of wave behavior, students should have the opportunity to handle things that vibrate, and manipulate systems that show vivid wave behavior. This kit further requires the participation of each student in assembling the final apparatus. Since at least five separate systems of sticks and string will have to be assembled in order to investigate the properties described in the purpose, there is an excellent opportunity for meaningful collaboration. No one system can show it all. Some systems model real problems, others show familiar solutions to these problems. There does not need to be any mention of dimensions in either metric or English units. The typical system should hang from the ceiling (or from the arm of a student standing on a desk top). The spacing of sticks should be by "stick-widths" for ease and convenience of assembly. The first system to be investigated should be the one supplied. This system should be subjected to much discussion before construction is begun on the others. Among other benefits, this will allow the student teams to think about how theirs might perform in comparison to the "standard" as they are building it. The whole basis for evaluation of the wave behavior is essentially one of comparison between systems. There is no intrinsic need for absolute values, although computer interfacing buffs will find many opportunities to take real data. The spacing of the sticks and the spacing of the two pieces of string will determine the way in which the system transmits waves. They are easily explored by varying one while holding the other constant.



Assembly:

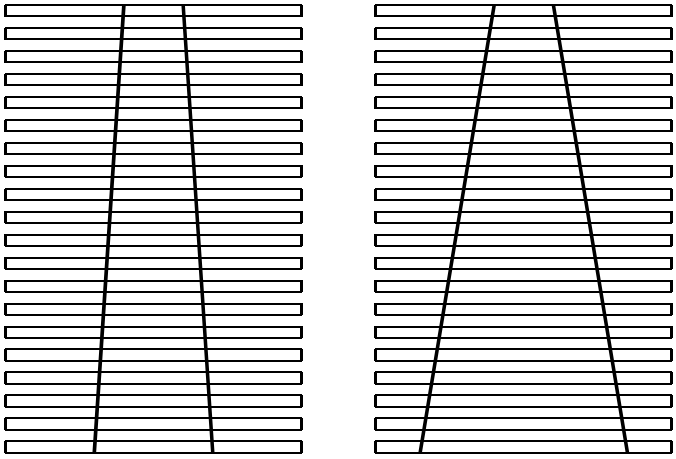
Assembly will require continuous bench space at least as long as the finished devices, about 6 feet. Alternatively, a wide board or plank set between student desks or on saw horses might be necessary, or perhaps the models can be assembled on the floor. Look at the unit already assembled for guidance.

Begin by laying a strip of tape, sticky side up, along the entire length of the work bench. Tape each end of this length down to the bench top. **Place and tape a second piece of tape parallel to the first one**. Make the space between these tapes different from the spacing of the unit that was supplied. Position a meterstick or other straight edge parallel to these lengths of tape and one half the stick length from the midpoint between the two tapes.

Using the straight edge (meterstick) as a guide, place one end of a stick against the straight edge and lay it across the tapes. Lightly press the stick onto each tape. Lay the next stick down along side the first and continue this procedure until all of the sticks in one packet have been used. Now, go back to the beginning end of the wave model and remove every other stick by lifting it from the tapes. When you remove sticks, make sure you do not disturb the neighboring sticks!

With the remaining sticks that have been removed from the model, continue placing them side by side at the "growing" end of the model. Repeat the removal and adding steps until all of the sticks are used. When all of the sticks are in place, stretch a second piece of tape over the entire length of the model (sticky side down) and position it directly over each of the tapes that lie under the sticks. When each tape is properly aligned press it onto the sticks. Make sure that tape sticks to tape between the sticks.

Transformers



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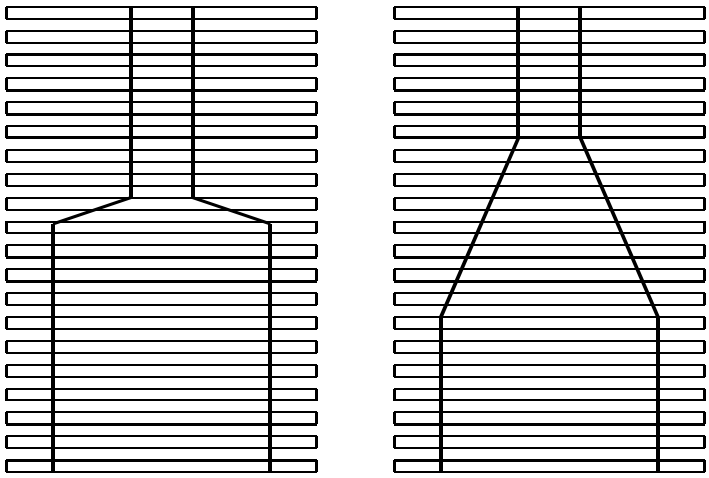
When the model is finished, it can be hung from the ceiling, an overhead pipe, or suspended from a student's outstretched arm. Another student might pull the bottom of the suspended model. This tends to make the pulses a little sharper and easier to see. Try using different amounts of force to see how this affects the wave's speed. Early exploration should include anchoring the top so that an arriving pulse tries vainly to shake the whole building, and another with the top two stings brought together at the attachment so that the topmost stick is free to swing. Pulses and continuous wave trains of different frequencies should be initiated at the bottom and also at the top. The whole system can then be inverted so that the bottom stick becomes the topmost, and the investigation repeated. Other models can be constructed by varying the distance between tapes as shown in the remaining figures.

The vertical lines represent the position of the tapes. This sets the stage for investigating each of the other systems. Pulses will travel at different rates of speed on the different systems. Reflection will occur when the medium changes abruptly, as at the very top or bottom. Partial reflection and some refraction will occur at an abrupt change in medium where there is less of a difference in rates of propagation (less of a difference in impedances). The polarity of the reflected and refracted pulses at different interfaces is an interesting and very obvious property . Composite systems [F] and [G], are

Composites



composed of two different media both without and with a matching transformer, so that very little reflection should be noticed at the interface of [G] compared with [F]. The behavior of this latter system can be compared with the transformer in the antenna connection to the TV set or again in the matching transformers used in connecting speakers to a sound system. In all of these cases the desire is to cut down on reflection losses for some incoming signal.

Extensions:

Depending on the amount ot time and the extent of student talent available, other composite systems (with and without transformers) and other simple and composite systems having different stick and tape spacings might be investigated. The best use of the finished apparatus after it has served its classroom need might be to donate it to some lower grade level teacher. It is rather easy to safely store the unit by rolling it in paper or toweling. Simply spread one system on top of the material and roll it up with the apparatus inside. By labeling the wrapper on the outside, the apparatus can be shared or, the teacher caught with too little time to repeat the whole activity can still include parts of it as a quick demonstration another time.

Time Allocation:

To prepare this product for an initial experimental trial should take less than ten minutes. Actual experiments will vary with needs of students and the method of instruction, but each of the separate undertakings described is easily concluded within one class period.

Feedback:

If you have a question, a comment, or a suggestion that would improve this product, you may call our toll free number.