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Lecture-Demonstration

Velocity Amplifier Using Stacked Disks

Abstract

Stacked balls have traditionally been used to demonstrate velocity amplification resulting from energy transmission from one ball to the next. I have found that this demonstration can be done using disks. Disks are aligned simply by a slotted guide. The demonstration can be repeated quickly.

Support required: None

Approximate size: 3 feet wide, 1 foot deep, 5 feet high

Electric Power needed: No

Will I be present to set apparatus up: Yes

Velocity Amplifier Using Stacked Disks

Introduction

Velocity amplification is a process by which the velocity of an object increases when it absorbs energy. I have found that velocity amplification can be demonstrated by dropping a set of disks. The demonstration is traditionally done using a set of balls.[1,2,3,4] When I have seen the demo done with balls, there has been an extraordinary amount of time and effort put into retrieving the balls and keeping them together. In the disk method described in this paper, all the disks stay in a slotted channel with the exception of a low-mass disk that gets sent towards the ceiling. The demonstration can be repeated quickly.

Theory

Velocities of objects can change as the result of a collision. The change of velocity comes from a net force being applied to the object (m delta-v=F delta-t). When two objects collide, each feels a force. The forces are equal in magnitude and are oppositely directed. If the same force is applied to two objects, the object with a smaller mass experiences the greatest change of velocity. Suppose objects are stacked one on top of the other. Let the mass of the objects be progressively smaller from the bottom of the stack to the top. When this set of objects is dropped the object on top rebounds with a great change of velocity. An analysis of velocity changes when balls are dropped has been published.[1,2,3,4]

Demonstration

The apparatus is shown in Figure 1. The channels are vertical. The transparent slotted channel faces the

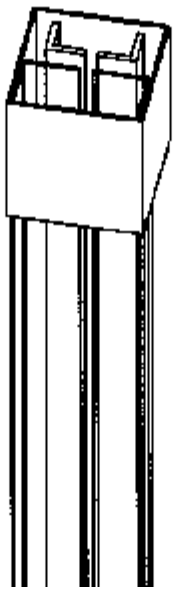
audience. The transparent slotted channel can be pulled away from the aluminum slotted channel, leaving room between them to insert disks. The nail portion of a disk goes into the vertical slots of the channels. The disks are sandwiched between the transparent slotted channel and the aluminum slotted channel, one end of the nail goes through the slot of one channel and the other end goes through the slot of the other channel. Try three disks of like material. Unlatch the cabinet hinge at the base of the apparatus. Pry the plastic channel and the aluminum channel apart. Place the largest diameter disk in the slotted channel. While holding the large disk in place against the aluminum channel put the smallest diameter disk on top of the large disk. Let the transparent channel sandwich the disks in place. Let the aluminum support of the plastic channel move into place around the guide pin. Close the cabinet hinge. The two disks should now be able to move freely up and down. With a finger on the nail, lift the large disk and then let it drop. Repeat, dropping the two disk combination from ever increasing heights. Notice the small disk can gain enough energy to exit the channels into the air. Colored marking clips can be clipped at various heights on the transparent channel. Find a drop height where the small disk comes close to leaving the channels but cannot. Mark the height with a clip. Now insert the medium diameter disk between the other disks. Raise the three disk combination to the marked height. When this combination drops, the small disk gets sent out of the channel into the air. This shows that the velocity of the smallest disk can change dramatically with a stack of many disks.

References

- 1. William G. Harter, Am. J. Phys. 39, 656 (1971).
- 2. James D. Kerwin, Am. J. Phys. 40, 1152 (1972).
- 3. J.S. Huebner and T.L. Smith, Phys. Teach. 30, 46 (1992).
- 4. Walter Roy Mellen, Phys. Teach. 33, 56 (1995).

Conclusion

A velocity amplifier can be made using plastic disks. Because most of the disks stay aligned in the channel, the demonstration can be repeated many times in a short period of time. The short reset time and being able to open the device to insert other disks, makes it easy to compare the drops of different numbers of and sizes of disks. The smallest disk that flies into the air can be made large enough to be seen and large enough to be found afterwards.



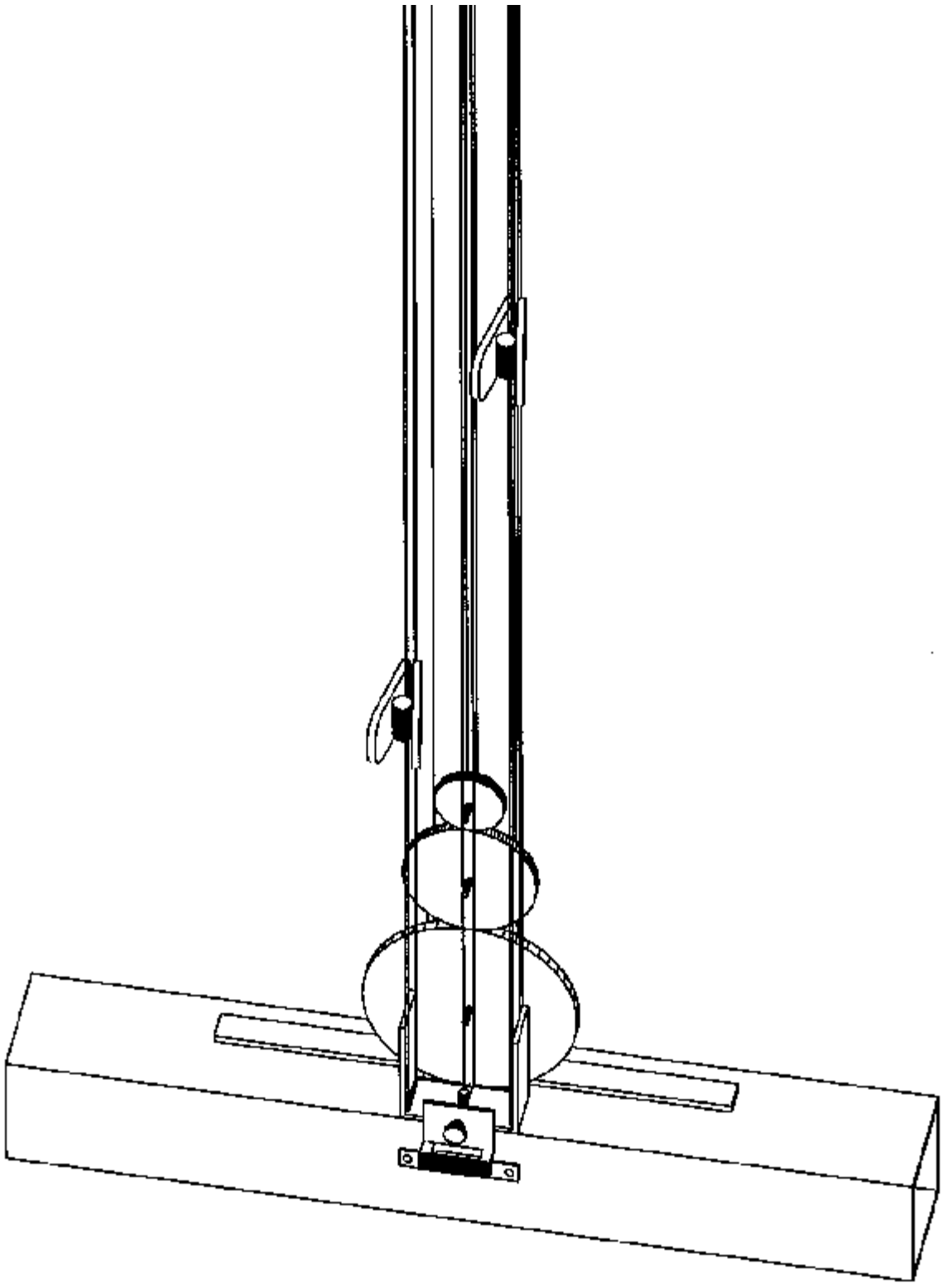
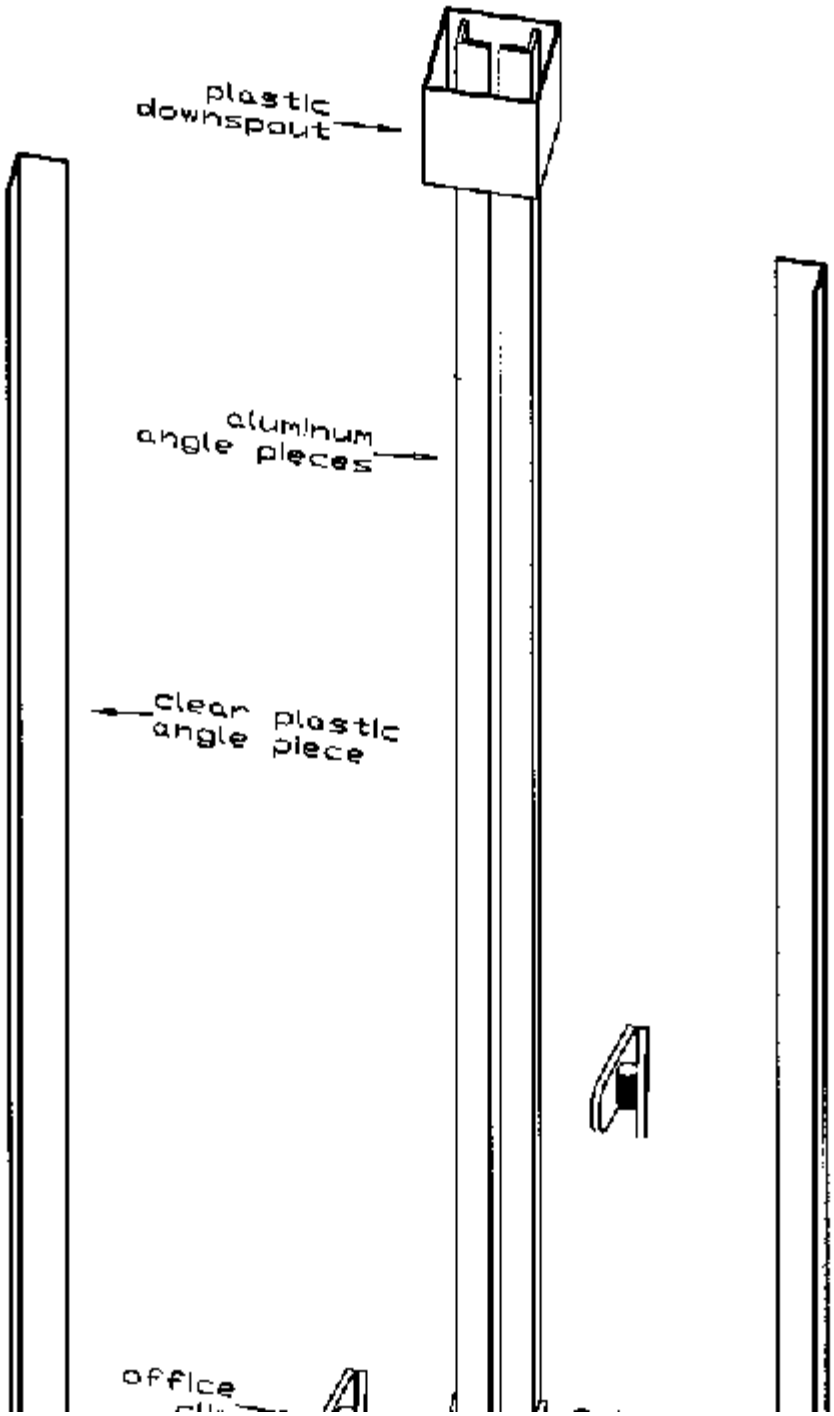


Fig. 1. Three disks aligned by slotted channels

APPARATUS CONSTRUCTION

The assembled apparatus is shown in Figure 1. See Figure 2. for an exploded view of the parts. The actual dimensions of each piece are given in the materials list. The "base" is square aluminum pipe. Two "galvanized angle brackets" support two "aluminum angle pieces". One modified piece of aluminum

pipe supports the ?clear plastic angle pieces?. This support is called the ?aluminum U?. A ?U? is made from a piece of square aluminum pipe. One side of the pipe is cut off leaving a ?U? shaped piece. A slot is cut in the base of the ?aluminum U?. This slot serves to guide the clear plastic channel assembly into place after changing the disks. A spring-loaded ?cabinet hinge? is used at the base to keep the clear plastic channel assembly in place. The hinge has a knob installed in one of the center holes normally used for a screw. The aluminum angle pieces and the plastic angle pieces are held in place at the top of the apparatus by a small section of ?plastic downspout? material. The disks, shown in Figure 1., are made of Sintra (expanded PVC) plastic. A nail is driven through a one sixteenth inch diameter hole in the center of each disk. The nail extends an equal distance on each side of the disks. Plastic ?office clips? are attached to the clear plastic angle. One is to mark how far the disks were raised before they were dropped. Another clip is used to mark how high a disk went after the bounce.



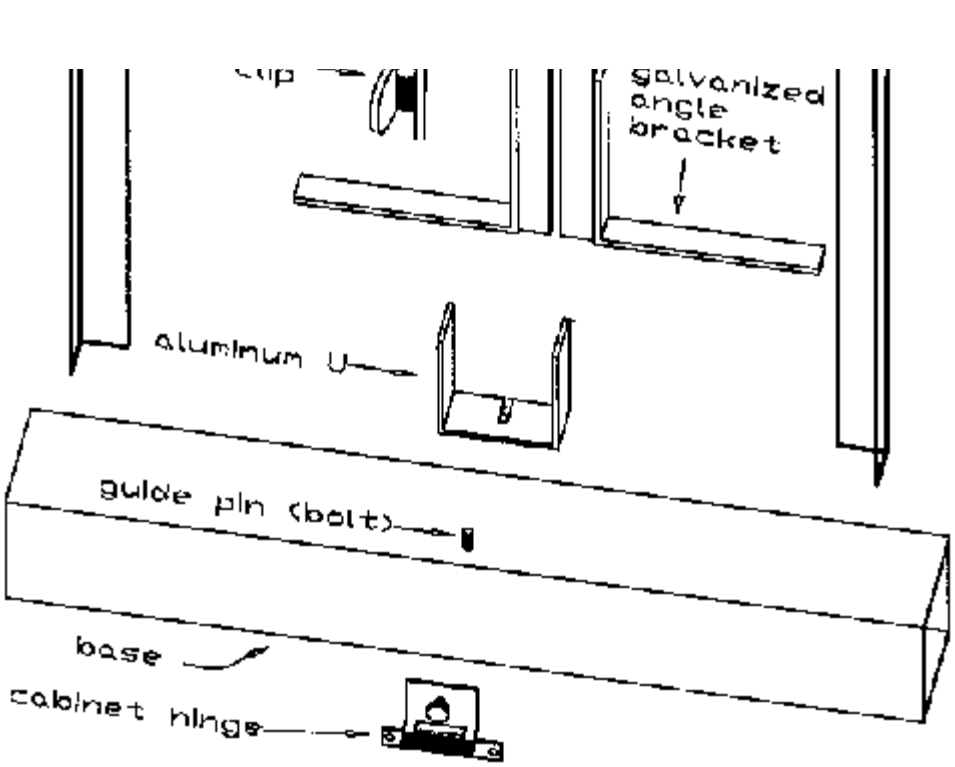


Fig. 2. Explodeo view.

Materials List

?base**?**: 1 square aluminum pipe (3 inches square, 21 inches long, 1/8 inch wall thickness) Source: Affiliated Metals **?** Salt Lake City, Utah Cost: $18.27 ($207.60 per 20 feet)

?aluminum angle pieces**?**: 2 aluminum angle (3/4 inch each side,4 feet long, 1/8 inch thick) Source: hardware store Cost:2@$7.02 2@$7.02 ea =$14.04

?galvanized angle brackets**?**: 2 galvanized angle bracket (3-3/4 inches x 3-3/4 inches, ¾ inches wide, 1/8 inch thick) Source: hardware store Cost: 2@$0.99 2@$0.99 ea=$1.98

?clear plastic angle pieces**?**: 2 plastic corner saver (1-1/8inch each side, 4 feet long, 1/16 inch thick) Source: hardware store Cost: 2@$4.86 2@$4.86 ea=$9.72

?aluminum U**?**: 1 square aluminum pipe (3 inches square, 1-1/2 inches long, 1/8 inch wall thickness) Source: Affiliated Metals **?** Salt Lake City, Utah Cost: $1.31 ($207.60 per 20 feet)

?plastic downspout**?**: 1 plastic vinyl downspout (2-1/2 inches square, 10 feet long, 1/16 inch wall thickness) Source: hardware store Cost: $0.15 ($5.40 per 10 feet)

?Sintra (expanded PVC) disks**?**: 3 disks (5 inch dia., 3.125 inch dia., and 1.625 inch dia.) 0.5 sq. ft. Sintra expanded PVC (4 feet x 8 feet sheet, 6mm thick) Source: Regional Supply Co.- Salt Lake City, Ut. Cost: $0.68 (0.5 sq. ft. at $1.36/sq. ft.) ($43.32 per 4 feet x 8 feet sheet)

?office clips**?**: 2 office spring clip(1-1/2 inch x 2-1/4 inch, plastic) Source: office supply store Cost: 2@$0.50 2@$0.50 ea=$1.00

cabinet hinge and knob: 1 cabinet door hinge(1-3/4 inch x 2-3/4 inch)($1.99 for 2 hinges) 1 knob(1/2 inch x ½ inch dia.)($1.47) Source: hardware store Cost: $2.00

Cost of items listed above (excluding need to buy in quantity): $50.37

Other: Bolts Nuts 3 Nails (1-1/4 inch long , size 3d , finishing nails) Taxes Cost: ? (15.00)

Total Approximate Cost: $65.0**0**