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Vectors - forces and static equilibrium

The topic of vectors remains a fundamental concept in the introductory physics curriculum. Static equilibrium and the forces involved are one of the areas that best illustrates the use of vectors and their meaning.

Realistic examples of static equilibrium are very graphic, thus, easy to understand; four basic examples that cover most cases are presented. Three of these occur realistically in the vertical plane. Simply imagine rotating the vertical plane 90° to the horizontal plane and solve. Best of all, the apparatus required for all four is simple; much of it you may already have on hand.

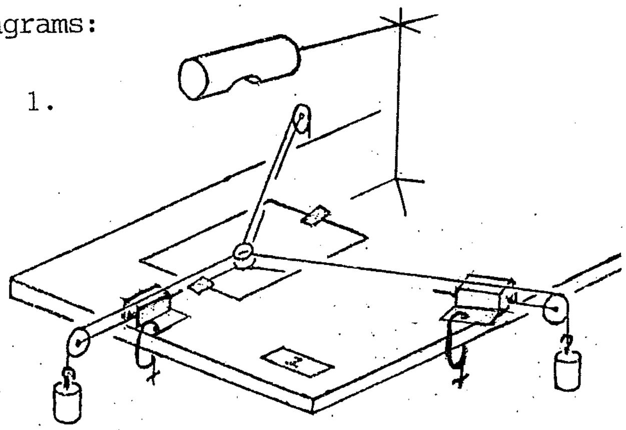
How you choose to present this topic is your decision, as a class lesson (homework?) exercise or a laboratory exercise. Its solution by the parallelogram method or by the use of trigonometry is also an open choice depending on the academic level of the class.

All four examples can be set up on the ends of the standard, two-person, 24" x 54" science room table. Or if space and apparatus are limited, each example can be set up and solved one at a time. As diagram (1.) shows, shadow projection may be used to determine the direction of each force vector. The one apparatus difficulty is the pulley holder. You may have to make an inexpensive holder out of wood that utilizes the common C-clamp. Directions for its construction follow.

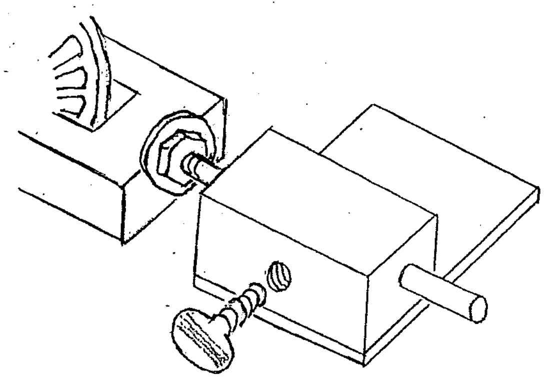
Materials: near-frictionless pulleys (PASCO?), ripple tank lights with stands (rods, clamps, bases), gram hooked masses, coarse nylon thread, very small snap rings or paper clips, pulley rods, wooden holders, C-clamps, masking tape, 8½" x 11" paper, 30 cm ruler

Diagrams:

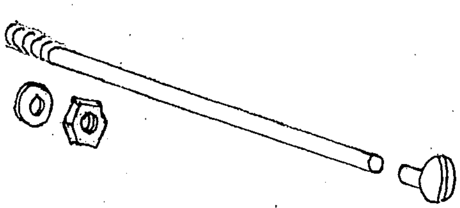
1.



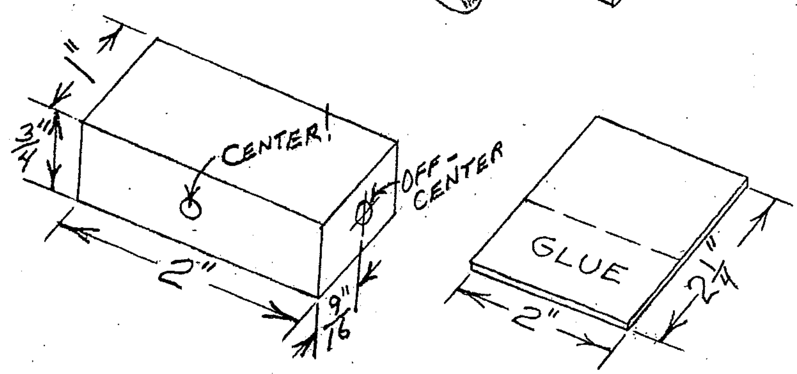
2.



3.



4.



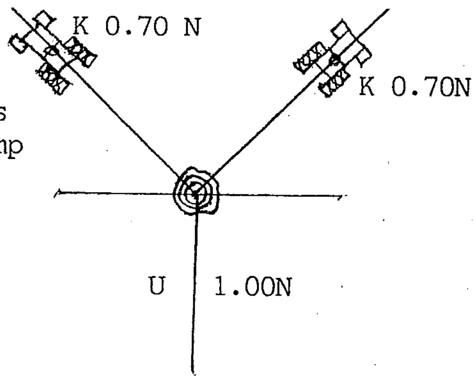
Construction: To make the pulley rods (3.), choose ¼" x 5" long machine or stove bolts and cut off the heads. (The pulleys have the standard ¼" x 20 threads like the bolts.) Add the ¼" washers and hex nuts to tighten the assemblies. See 2. and 4..

To make the wooden holders, cut a 3/4" pine stick, 1" wide, and 6¼" long. Then cut the stick into three 2" long pieces. With a ¼" bit, drill a hole, slightly off-center, the length of the wood block for the steel rod. With a 7/32" or 15/64" bit (test!), drill a hole, on center, into the side of the wood block to hold the ¼" x 3/4" thumb screw; drill down to meet the previous rod hole. "Press thread" the thumb screw into the pine. If the process is too tight, use a ¼" x 20 tap part way in to start the threading; you do want some tightness, however.

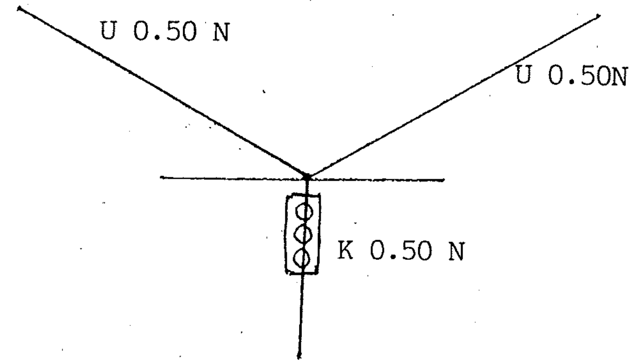
Using 1/8" masonite, cut out 2" x 2¼" pieces for the bases, and glue (Elmer's?) the wood blocks to them.

The four examples (problems):

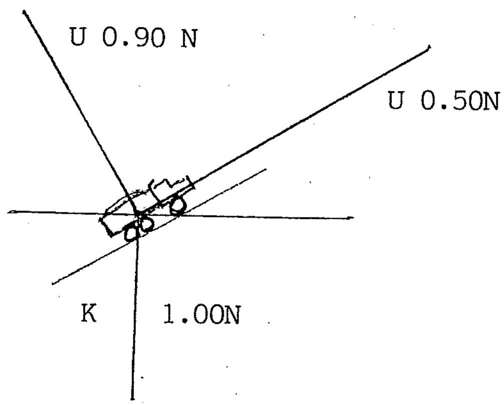
A. tractors & a stump



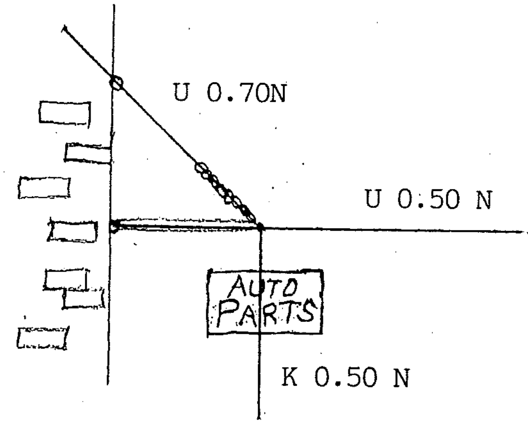
B. suspension, a stoplight



C. inclined plane, a gravel truck



D. sign on side of building



The weights (masses) used in the diagrams are suggestions only. Keep things on the "light" side to reduce the friction in the pulleys. K stands for "known", U for "unknown" in each problem. Cover the U's with very small pieces of masking tape that can be removed easily and replaced.

Procedure: Set up each example as shown in the diagrams with the light source directly above the equilibrium point so the shadows are not distorted. Before taping down the paper, "bounce" the equilibrium point to test the alignment. Make sure the pulley rods are just below and parallel to the threads. Center the paper under the equilibrium point and tape it down. With a ruler, trace the shadows of the threads. Record the newton values of the K weights (tensions in the threads), letting 1.00 N = 100 gm. Circulate among the four set-ups collecting data.

In solving for the "unknown" (U) value(s), a suggested scale is 1 cm = 0.10 N. Having solved the U value(s), go back and carefully lift the masking tape on the U weight(s) to see how close you came; replace the tape.