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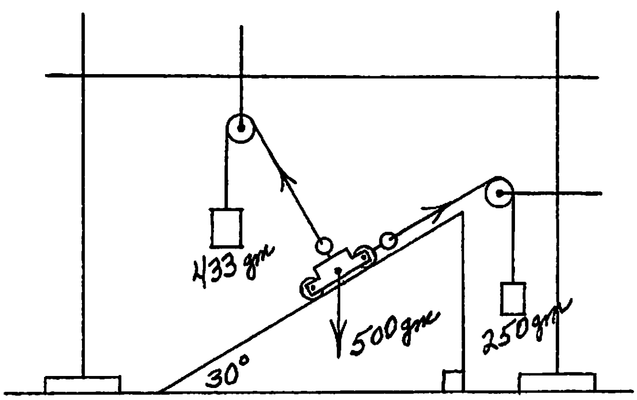
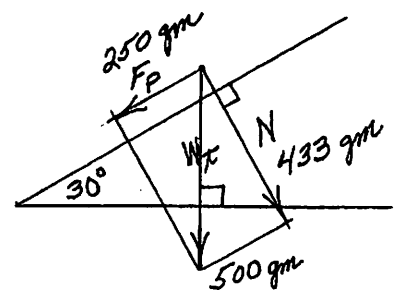
Vectors - forces associated with the inclined plane <u>or</u> resolving a vector into its components.

As long as vectors are taught in introductory physics this demonstration is essential, and it never ceases to amaze. It does require much first-time preparation; after that, little effort is needed. Without this demo, students must accept the force vector diagrams involved on blind faith. With this demo, the truth, the real proof, is provided. For real life examples, think of the San Francisco cable cars or the gondolas on a ski lift. The diagram illustrates my set-up and masses used; you may alter as you see fit. I chose a "Hall's carriage" as my vehicle; a small toy truck to hold masses would work as well. In either case, the vehicle will need to have holes drilled in it to attach connectors. I used two eyebolts in the "carriage". Heavy, black nylon thread with paper clips tied on each end makes fine "cables" with "hooks" to attach to the eyebolts. I use Ohaus hooked masses as "weights" (forces). For the "3 gms", I used paper clips taped together (and labeled), measured on a triple beam balance (tbb). The carriage's mass was measured on a tbb also, and brought up to 500 gms by adding masses and finally, paper clips.

I made a rigid, inclined plane and chose a 30°-60°-90° triangle because of the easy trig functions (.500 and .866). I used 1/8" masonite (tempered) and 3/4" pine boards. I chose a size for the classroom, not a large lecture hall, and a size to limit material and storage space required. You may wish to change the angles and the dimensions.

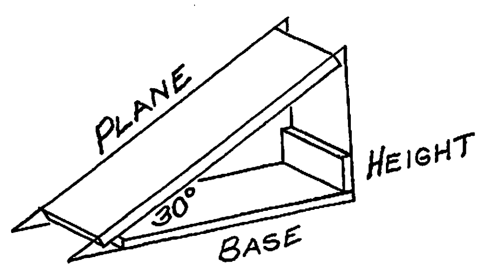
Diagram:





Materials: two bases, two 1.3 x 60 cm rods, one 1.3 x 100 cm rod, four right angle clamps, two very low friction pulleys (PASCO?)

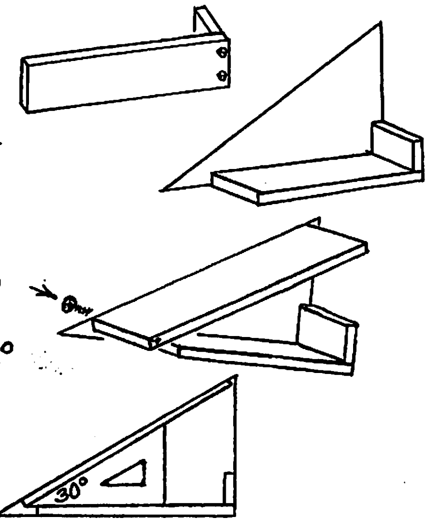
Plan for the rigid, inclined plane:



Suggested dimensions: 1/8" masonite sides: base - ~17 11/16 in., height - 10¼ in., plane (hypotenuse) - 20½ in.

3/4" pine pieces (width - 4¼ in. or width of your vehicle): base - 14 in., height - 2 in., plane - 18 in.

Assembly of plane: (a) Butt and screw (#6 x 1 5/8" dry wall?) together the base and height pieces.



(b) With one masonite side standing up on a flat surface, attach the base and height pieces to it, fully with #6 x 5/8" PH screws. (Clamps will help.)

(c) Attach the inclined plane (hypotenuse) to the masonite side with one screw near the bottom (so it can pivot) as close to 30° as possible.

(d) Standing up, insert and jam tight a precision, 30°- 60° - 90° draftman's triangle between the base and inclined plane. When perfectly aligned, clamp the plane and masonite side together and insert the final screws.

(e) Finish by attaching the second masonite side to the three boards to complete the rigid, triangular "box". Gaps between the ends of the boards are expected; the "box" is still very strong. Round off (sand) the sharp corners a little so they "wear" better over time.

Presentation: (a) Have the 30° plane and pulleys in place. Measure the mass (500 gm) of the vehicle (W_t) on the tbb. With this info, have the students calculate the downhill "force" (250 gm) or F_p component and thus, the uphill "force" needed to balance it and to reach equilibrium. Place the vehicle on the plane, stretch the "parallel" thread over the pulley, and hang on the necessary masses. Move the vehicle up and down the plane. Does it always stay put?

(b) Have the students calculate the normal (N) component or perpendicular "force" (433 gm) to the plane, the supporting "force" that the plane exerts on the vehicle. Stretch the N thread over the pulley and hang on the necessary masses. Equilibrium in all directions should have been achieved with the wheels of the vehicle hardly touching the plane.

(c) With a dramatic flourish, remove the plane! The vehicle should remain in position, unchanged.

(d) Now distort the vehicle's position with your finger, applying an additional outside force; the angles must change because the other forces (masses) are unchanged. Use "new" components to explain.

(e) Remove your finger, and the vehicle returns to its original equilibrium position. Prove it by returning the plane to its original position. Neat! A lot about vectors has been demonstrated and proven.

Storage: Except for the pulleys and hooked masses that I use for other demos, I store all of the pieces together in the triangular "box" with these notes and a list of the needed, hooked masses. The two threads with paper clips should be wound around two separate "spools" that are labeled F_p and N so they won't get tangled. This demo everafter should be easy!