# THE PRISONER

by

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This is an exciting force vector demonstration, which is guaranteed to create some pandemonium in your classroom! It can be done just as a visual demonstration, or as the introduction to a stimulating and challenging problem to get everyone in the class working. Your better grade-12 students can pursue the solution to a considerable length.

Set up the apparatus as shown in the diagram. The basic idea is to mount a low-friction pulley wheel (such as the PASCO smart pulley) about 40 cm above the edge of a table. It should be rigidly mounted, so as not to flex. Three pieces of wood as shown, with the vertical piece drilled to accept the rod of the pulley, work well and allow for a C-clamp to hold it down. Arrange a push button or knife switch near the base of the pulley. Wire a loud bell to ring if the switch is closed. A plastic box or wooden slab that allows for a variable mass load is then pulled toward the pulley with a doubled thread. By looping the thread through a hole or screw eye, you can avoid a knot which would significantly reduce the tensile strength of the thread.

the setup to your class, and diagram the forces and their components. Pull the load up to the switch and ring the bell. A good loud ringing bell always helps for an effective demonstration! Now slap a $5 bill on the table and announce that you'll give it to the student who can repeat the demonstration, making the bell ring. Your "ace in the hole" is that you get to substitute the thread for the string! To pull on the thread, you will need to wind it around a pencil, or supply a glove. As the force required to move the load increases, the tension in the thread and the classroom increases dramatically. The student doing the pulling knows from experience when the breaking limit of the thread is near, and will become more and more desperately careful to try and win the prize. I am always amazed at how everyone in the class seems to hold their breath, or even gather around the table to cheer on their friend. I have had students repeatedly come within a millimetre of the switch when the thread broke! The snapping thread brings down a chorus of hoots and hollers as students yell "let me try!"
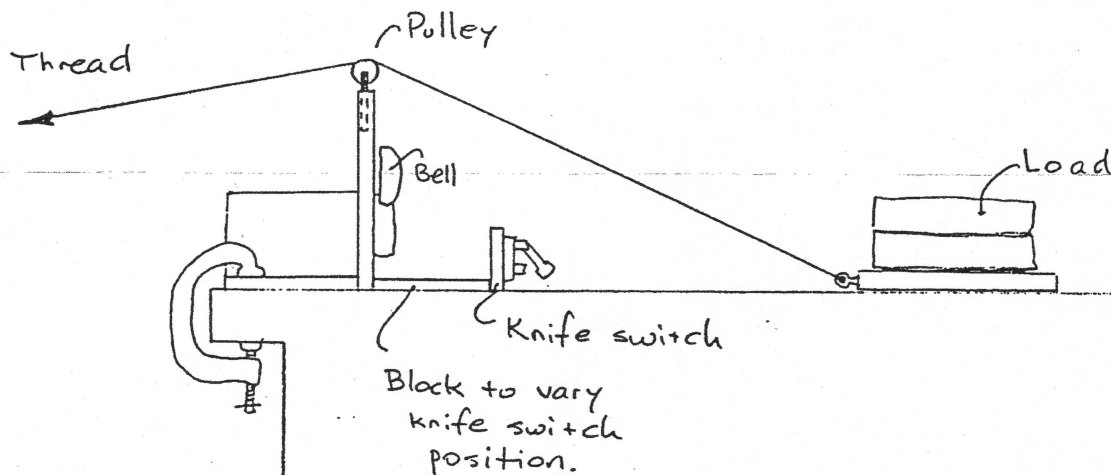
With some testing before class, you can arrange things pretty easily so that the string always breaks before it rings the bell. (Except for Murphy's Law!) You can modify the load to increase or decrease friction, or move the switch in or out from the base to change the angle necessary to reach it. Using a strong cord, display

The analysis of the force vectors shows that, when the load is far away (about a metre or more to start), the applied force is nearly the same as its horizontal component, due to the small angle. As the box approaches the switch, the applied force acts at a greater angle, so it must increase considerably in order to

apply the same horizontal component to keep the box sliding against friction. Of course, as the vertical component also increases, it reduces friction, and makes things even more interesting.

With a load of two bricks (3 to 5 kg), the thread should break when it is about 10 cm out from the base of the pulley. As the load gets closer to the switch, and more likely to break, students invariably slow down the motion of the box for fear of "overdoing it". If the dimensions are set up to bring the box within millimetres at the breaking point, a good student may realize that this is the most crucial time <u>not</u> to stop, as

"The Prisoner"

Your wealthy friend has been chained to the wall of a dungeon, without food, for many days. You cannot get into the room, and the only way to save him is to pull on the rope and drag the 100 kg box with the food and keys on it so they can reach him. Your friend can reach out only 1 m, and the top of the box is 1 m above the floor, and 7 m away from the wall where
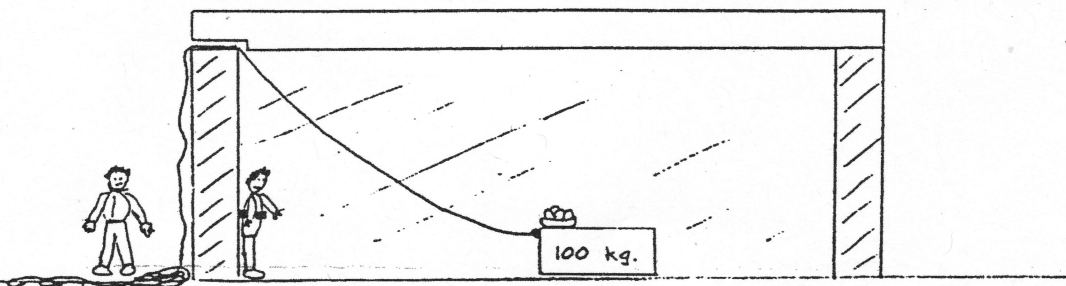
static friction is greater than kinetic friction, and could easily mean the difference between success and failure.

The demonstration can be set in the form of a test or extra credit problem in an interesting "Indiana Jones" format, as below. As the problem has several ways of arriving at a solution, it lends itself to a thorough discussion and analysis. I have prepared detailed notes that I use as student handouts, covering the solution explanations, that I would be glad to send to anyone requesting them.

he is chained. The rope goes through a hole in the wall 5 m above the floor. The coefficient of friction between the box and the floor is 0.55. The rope is old and rotten, and will break if you pull on it with more than 500 N of force. Can you save your friend? Prove your conclusion in detail, using short explanations as you work. If you can save your friend, you will be rewarded with one million dollars! If you cannot save him, how close does the box get before the rope breaks?

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