Pulleys

A little force goes a long way, but there's no free lunch!

A pulley is a simple machine that allows you to lift a large weight using a small force. But the advantage gained in force is paid back in distance. And then there's friction. When all is said and done, a pulley can enable you to do a job you might not be able to do without it, but you will actually do more mechanical work by using the pulley than you would if you could do the job without it. If there were no friction, you could actually break even on the work...but unfortunately there are no "frictionless" pulleys.

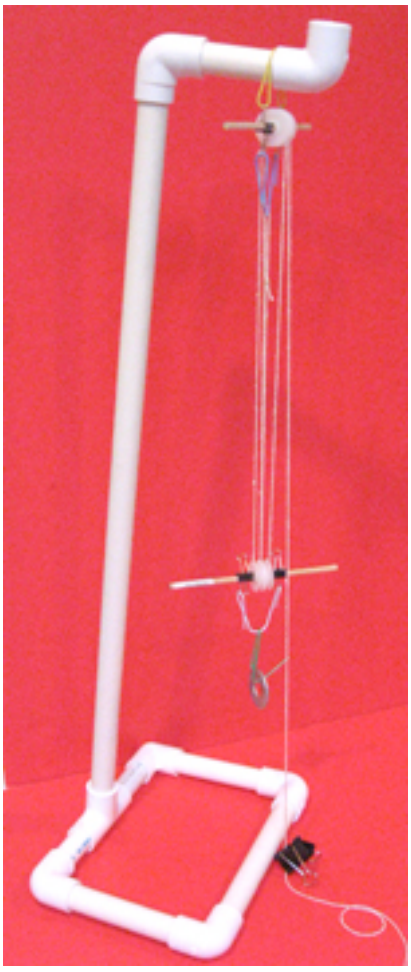
Option 1: Screen Door Replacement Pulleys

Materials

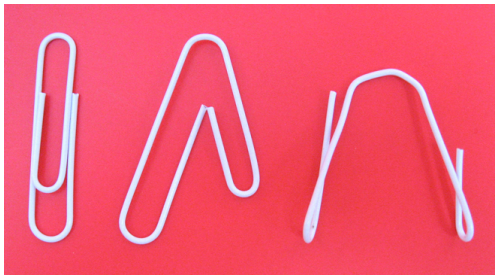
stand -- any kind of stand can be used to hang the pulley system -- build one from PVC as shown, or use an available ring stand set-up
pulleys (4**)** -- these are commonly available replacements for sliding screen doors, available at Home Depot, hardware stores, etc. -- the ones shown were about $1.40/pack of 2 at this writing
other items -- **jumbo paper clips** (at least 3 -- more if you want to use them for weights); **lengths of 3/16 in dowels** (2); **mini-binder clips** (1/2 in) (4); **medium binder clip** (1 1/4 in) (1); **steel washers** (3/8 in are handy, but any size can be used); **string** (at least 3 meters)

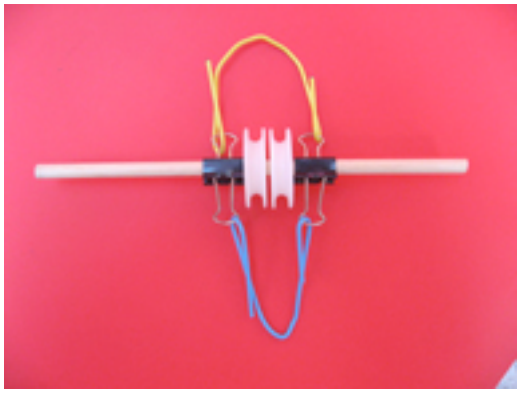
Assembly

Assemble the pulley system shown in the photos below. Especially if you haven't worked with pulleys before, you will likely find that it's much easier to do this with two people.



If you haven't had experience with pulleys, you may be surprised at how much string is necessary. Cut yourself a LONG piece of string to start with -- a conservative length might be to stretch your arms straight out sideways and use three lengths of string that stretch from hand to hand. This should give you something over 3 meters of string. You can always cut extra string off if the string is too long, but you can't really tie strings together if it's too short, since knots won't go through the pulley system very well.





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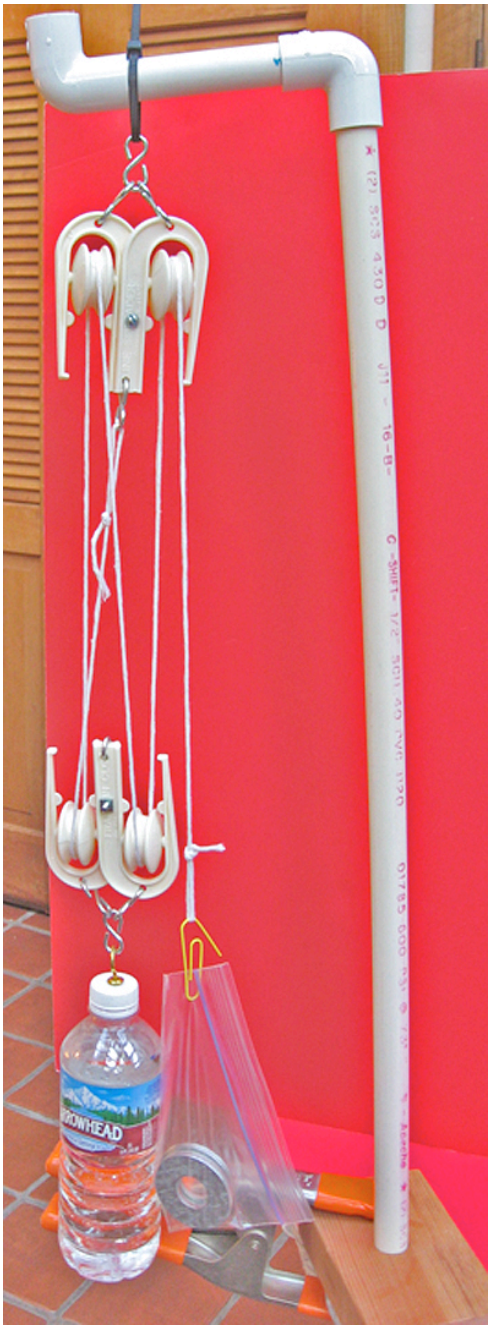
Option 2: Clothesline Spreader Pulleys



Materials
stand -- any kind of stand can be used to hang the pulley system -- build one as shown, or use an available ring stand set-up

2 clothesline spreaders (see NOTE on page 4) cut and fastened together to make two double pulleys, as shown in the photo

other items -- **6 S hooks** (also called 8 hooks); **string** (at least 3 meters); **cable tie**; **500 mL water bottle** with **brass cup hook** screwed into cap; **water**; **paper clip**; **plastic bag; steel washers**; **balance**

Assembly
Assemble the pulley system shown in the photo. Especially if you haven't worked with pulleys before, you will likely find that it's much easier to do this with two people.

If you haven't had experience with pulleys, you may be surprised at how much string is necessary. Cut yourself a LONG piece of string to start with -- a conservative length might be to stretch your arms straight out sideways and use three lengths of string that stretch from hand to hand. This should give you something over 3 meters of string. You can always cut extra string off if the string is too long, but you can't really tie strings together if it's too short, since knots won't go through the pulley system very well.

To Do and Notice
The "loose" end of the string in the photos is being held down in Option 1 by a large binder clip and in Option 2 by the bag of washers. In both cases, these weights prevent the string from unwinding back through the pulleys. **HOLD** this string and remove the binder clip or the bag of washers **(DON'T EVER LET GO OF THE STRING ONCE THERE IS NOTHING ELSE HOLDING IT!!)**. Pull down on the string to lift whatever weight is hanging from the bottom pulley assembly, and then let up on the string to let the weight move down. Repeat this a few times and try to observe what's going on. NOTE: You can cut some string off if it's way too long, but leave enough to tie a loop on the end if necessary (ask about this in the workshop before cutting if you're in doubt).

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Pulley Vocabulary

Force
Distance
Work
Effort
Resistance
Input
Output
Efficiency
Ideal Mechanical Advantage (IMA)
Actual Mechanical Advantage (AMA)

Equations: For your reference if you want them.

$W_{input} = F_e d_e$ $W_{output} = F_r d_r$ $\%\text{Efficiency} = \frac{W_{out}}{W_{in}} \times 100$

$IMA = \frac{d_e}{d_r}$ $AMA = \frac{F_r}{F_e}$ $\%\text{ Efficiency} = \frac{AMA}{IMA} \times 100$

Questions: We'll discuss some of these together.

1. What do you notice about the distance you pull compared to the distance the weight goes up? Could you measure these distances?

2. Can you tell anything about the difference between the force you are pulling with compared to the weight of the object being lifted? How could you get quantitative information about this?

3. Does a pulley system give you a force advantage or a distance advantage?

4. How many strings are supporting the load?

5. How can you quickly tell the IMA of a pulley system by inspection?

6. (a) Which ONE of the following quantities -- F_r, d_r, F_e, d_e -- is affected by friction?
   (b) For the answer in part (a), does friction make the quantity larger or smaller?

7. (a) If there were no friction in a pulley system, how would W_{out} compare to W_{in}?
   (b) Which one is always larger in real pulley systems with friction?

8. (a) If there were no friction in a pulley system, how would IMA compare to AMA?
   (b) Which one is always larger in real pulley systems with friction?

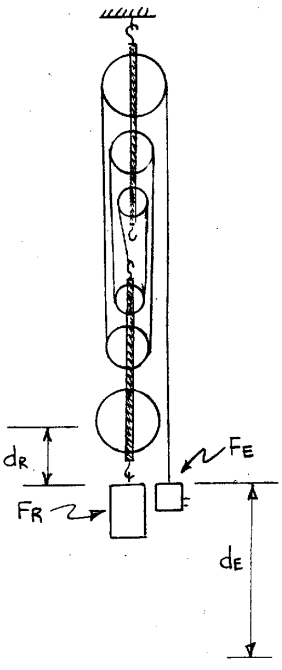
9. If output work in a pulley system is always less than input work, why are pulleys used?

10. Can you think of an application of a simple machine where you actually want a distance advantage rather than a force advantage?

11. The IMA of the pulley system shown in the drawing is
    a. 3 b. 4 c. 5 d. 6

12. If the pulley system shown in the drawing is used to lift a 1000 g (10 N) load, F_e must be
    a. less than 2 N b. equal to 2 N c. greater than 2 N

13. In the pulley shown in the drawing, if 30 cm of string are pulled through your hands, the load will be raised by
    a. 3 cm b. 6 cm ` c. 9 cm d. 12 cm e. 15 cm



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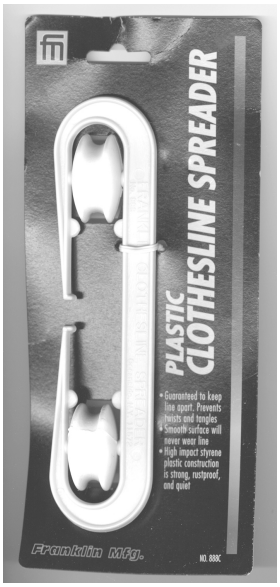
Going Further

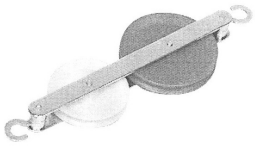
Collect data which will enable you to find the % Efficiency of the pulley system. One way to do this is to use enough weight for the effort force so that when you push down gently on the effort weights, they continue to move downward at constant speed as the resistance weights are lifted. Under this condition, the effort force is lifting the resistance force and also exactly balancing the friction force. See equations listed above for two equivalent ways to determine the % Efficiency. The method employing input work and output work is probably a more fundamental way to be thinking about Efficiency, but either method will work.

NOTE ON PULLEY SOURCES: The pulley system shown in Option 1 above was improvised from sliding screen door replacement pulleys shown in the photo below. Cost at this writing was approximately $1.40 for a pack of two wheels. The pulley system shown in Option 2 above was improvised from clothesline spreaders obtained at True Value hardware. Cost in May 2008 was $2.29. Compared to commercial versions from scientific supply sources, the virtue of these materials virtue is cost, and deep, wide grooves rather than shallow narrow ones often found in pulleys from science supply companies. But any usable pulleys which are available may be used. An example of an economy student pulley available from a commercial science vendor is the Frey Scientific pulley shown below.



Economy Double Tandem Pulley

Economy Double Tandem Pulley



Brightly colored, plastic, student pulleys with aluminum yokes and top and bottom hooks. Non-tandem pulleys have 50 mm wheels.

Item #: 1625939015
Catalog: 2009 FREY ELEMENTARY
Catalog Page #: 79

Your Price: $2.50

Quantity: Add to Cart

Minimum Quantity: 1
Package Size: 1
Unit of Measure: EA

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