

## Make lifting easy with a rope and the principles of “mechanics”

(Accomplishing heavy tasks without machinery is often a challenge in rural areas. Hence this series by Don Fallick. This is the second part; the first appeared in Issue No. 8, the March/April 1991 issue.)

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Some of humanity's earliest mechanical contrivances involved ways of using rope to lift or pull heavy objects. Anyone who's ever hauled water buckets out of a well hand-overhand has probably said something like, "There's got to be a better way to do this!" Well, there is. In fact, there are several.

### The Pulley

Pulley wheels have been in use so long that their origin is lost in the mists of antiquity. We do know that they were used by all the ancient civilizations of Asia and the Middle East. Some archaeologists now believe they may also have been in use in the Americas in pre-Columbian times, though wheeled vehicles apparently were not.

In its crude form, such as a rope thrown over a tree limb, the pulley is a very simple device, used only to change the direction of pull. Pulleys of this sort were probably used by cave-dwelling hunters. Anyone who has ever tried to lift even a small carcass for cleaning and skinning can appreciate the usefulness of such a simple pulley.

In mechanical terms, a pulley changes the direction of pull from up to down, increasing our effective strength by adding the force of gravity to the force of our muscles.

A simple system like this has three limiting factors: the friction of the tree branch, the breaking strength of the rope, and the weight of the person. If

we substitute a pulley wheel for the tree limb, we can greatly reduce the friction, and also reduce the chance of the limb breaking. Breaking the rope is another matter. A rope is rated by its ultimate load—the maximum, steady weight it'll hold without breaking, and also by its working load,

which allows for some stretching, tugging, and bending.

In purchasing rope, **always** go by the working load, then allow a **generous** safety margin, say 50% or more. Remember, ratings only apply to **new** rope.

Your weight is also a limiting factor. If you are trying to lift a 500 lb. auto engine, and you weigh 180 lbs., you can pull as hard as you like, even climb the rope, and the engine won't budge, because the total downward force on your side of the pulley is less than the total downward force (the weight) on the engine side.

One way to increase your effective strength is to add weight to your side of the pulley. A convenient way to add weight to a rope is to tie cement

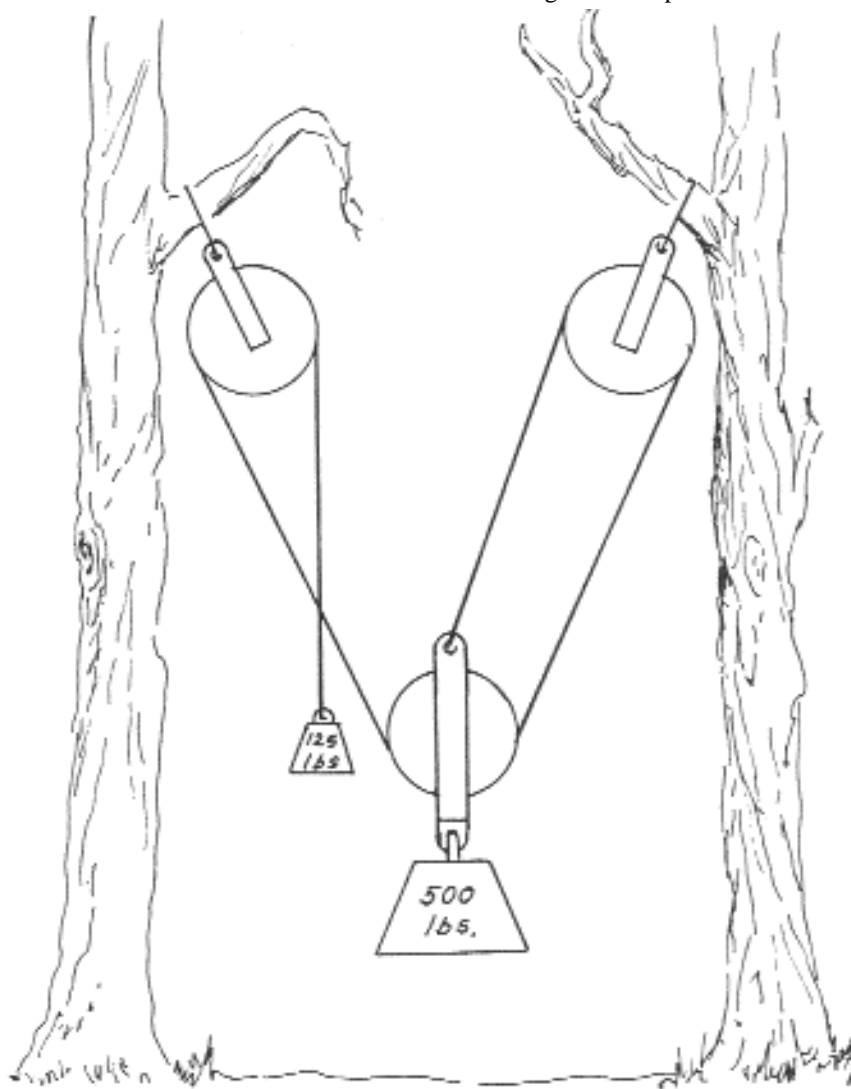


Figure 1. The pulley.

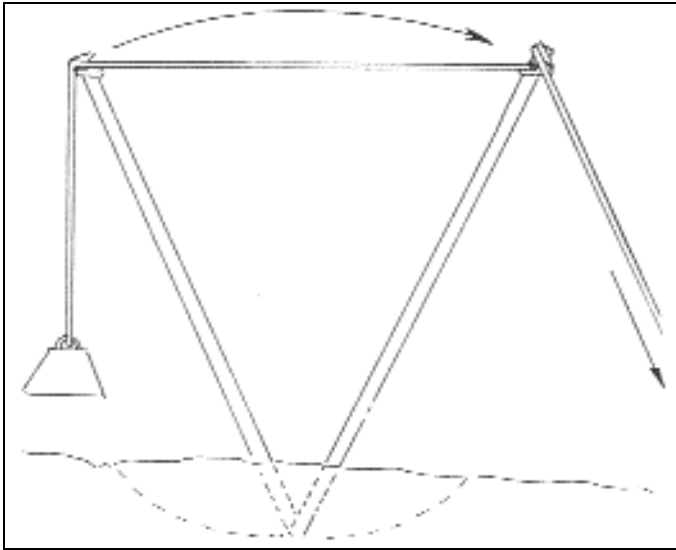


Figure 2. The gantry.

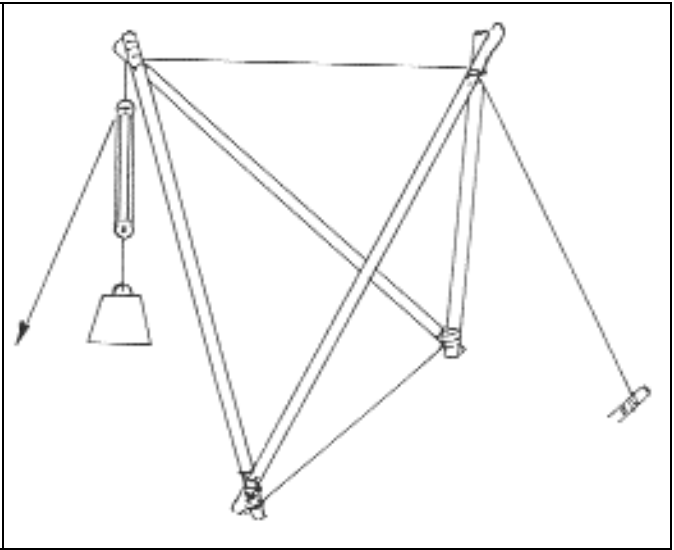


Figure 3. Gantry with pulley.

blocks to it. They weigh about 40 lbs. each, so if you tie 10 blocks to your side of the pulley rope, you can lift the engine with a 100-lb. pull. I have used this method. I have also used buckets of water, lumps of metal, and pieces of dead machinery for counterweights. Once I used my pickup truck as a counterweight. More about this later.

### Block and tackle

You may not always have a heavy counterweight to help you. Well, if you have two pulleys, you can improvise a block & tackle. So far, we've been discussing only systems in which the pulley is at the top. What happens if we attach one end of the rope to the tree limb at the top and hang the weight from the middle of the rope by the pulley? Of course, we'll now have to exert force in an upward direction. But because the weight, hanging from the pulley, is free to slide, it only rises one foot for every two feet that we lift our end of the rope. So the force we must exert is equal to only 1/2 the weight. If we add another pulley at the top, and reverse the direction of pull, we'll have a downward-pull system that doubles our effective strength. In fact, it doubles ANY force exerted on

it including the weight of inanimate objects, so three cement blocks would exert as much force as if they weighed 80 lbs. each, or 320 lbs. total. To figure

out what's required for the lift, we can add all the forces on our side of the pulley (our weight plus the blocks) and multiply by our mechanical advantage factor, which is 2, since we can lift twice the weight with the same force.

**3 blocks at 40 lbs. each = 120 lbs.**  
**us—average man weighs + 180 lbs**  
**300 lbs.**  
**x 2 (advantage factor)**  
**TOTAL FORCE: 600 lbs.**

This is much more than the 500 lb. weight of the engine we want to lift. Actually, we only need to exert 130 lbs. to lift the engine. But we can do even better than this if we have three pulleys. If we tie one end of the rope to the frame of the bottom pulley, and thread the other end through one of the top pulleys, then through the bottom pulley, then through the other top pulley, we can re-double our mechanical advantage.

We will have to pull four feet on our rope to lift the engine one foot, but will only have to pull 1/4 as hard! So a pull of 125 pounds could lift a 500 lb. engine without counter weights (see Figure 1). Of course, you don't have to do the math to use the pulleys.

This principle was understood long before Roman times. No one knows who first got the idea of combining several pulley wheels into one block of wood or metal, and, using two such blocks, strung together with tackle

(ropes) for hoisting, but they have been used this way, all over the world, for millennia. I recently saw such a block and tackle hoist, with a 16:1 advantage factor in the automotive section of a large supermarket. It was rated at 1500 lbs. lifting capacity, and sold for \$15, surely a terrific bargain.

### The gantry

When you need to lift something heavy, you may not always have a place to hang a pulley or a block and tackle. What you really need is some kind of instant crane.

One of the simplest such devices, and one of the most ancient, is the gantry (see Figure 2). In its simplest form, this is a pair of poles, fastened together at one end to form a V. A rope between the top ends keeps the V from spreading. The bottom of the V is placed in a trench, to keep it from falling over sideways.

The weight to be lifted is suspended from one arm of the V by a rope, while the other arm is pulled down by some source of power or weight. When you pull down on one arm of the gantry, the whole thing pivots and pulls up the other arm. In effect, a gantry is a kind of lever with a kink in the middle. Like any other lever, we can make the pulling arm longer than the lifting arm, reducing the effort needed for the lift.

Gantries can be made out of quite flimsy materials. I have used 15-foot 2x4s, with 8-foot pieces nailed to their centers for stiffening, to lift quite heavy weights. The weight of the load is carried in tension by the rope connecting the ends of the gantry arms. The poles carry the load only in compression as long as you keep them from actually bending. Wood is strongest in compression. That's why the weight of a house can be carried by the vertical 2x4s in the walls.

Gantries have been used in construction for 4000 years or more, so I don't understand why nobody thought of turning one upside-down and making a roof truss, but truss construction was unknown before 400 AD, and didn't become common until the Middle Ages.

If you're going to do a lot of lifting, you may wish to make a more permanent gantry, by substituting upside-down V's for the poles. This type of gantry is much more stable, and eliminates the need for a trench. The legs can be kept from spreading with rope or another pole. A final refinement is to add a pulley or block and tackle to the end of the lifting arm (see Figure 3), so you can lift or lower your load vertically, without horizontal movement. This makes it into a true crane.

## The capstan

Another ancient device for increasing the power of a rope is the capstan (see Figure 4). This consists of a log, or drum, which can be rotated, winding up the rope. Since the crank wasn't invented until the 14th Century or so, the ancients just drilled holes through the end of the drum and inserted spokes, like the spokes of a wheel, minus the rim. Nobody is really sure whether the spoked wheel inspired the capstan, or the other way around.

Capstans can be very powerful. Each spoke can have a separate man or beast pulling on it, and the spokes act like levers, increasing the users' effective pull on the rope. A modern refinement is to add a ratchet to the drum, so it will turn in only one direction, and another ratchet, attached to a lever, in place of the spokes. Such a

device is called a "come-along" and is available where auto parts are sold.

Comealongs are rated by the weight they can lift straight up, without damage. Repeated abuse will eventually render them useless. When they break, they usually jam, making it real hard to remove the come-along. That's why I don't buy used comealongs. Since weight on the ratchet makes it impossible to release, it's a good idea to have two come-alongs, anyway. I can't recommend using a come-along as a hoist, since there's no way to gently lower the load after you've lifted it.

There are lots of heavy pulling jobs around the homestead that don't involve lifting. Unsticking a stuck vehicle is probably the most common. A come-along will do this just fine, as long as there's a tree or something to anchor the come-along to.

Even if there are no trees, you can still use a come-along if you can make your own anchor. A wooden fence post will work, if set two or three feet deep, and angled against the direction of pull. Tie the come-along as low on the post as possible. If the soil is soft or the vehicle is heavy or badly stuck, the post may tear out anyway. To prevent this, set a "safety" post 5-10 feet behind the anchor post, and tie the top of the anchor post to the bottom of the safety post.

If it still tears out, use two comealongs, each with its own anchor post and safety post. If you hook both come-alongs to the vehicle, the posts will probably still tear out, because it's almost impossible to get both rigs to transfer equal loads to their posts simultaneously. The total pull rests briefly on each anchor alone, tearing it out of the ground.

A better way is to use a single tree, a device used for hitching horses to a wagon. It's simply a three-foot-long post with an eyebolt or hook in each end, and another through the middle, facing the opposite way. The middle hook is fastened to the vehicle, and the ends to the come-alongs (or horses). Because it's not fastened rigidly to the load, but is free to swing, the single tree keeps the pull on both

comealongs, equal. Thus the stress on each anchor is halved.

Another good use for a come-along is removing tree stumps. The key to this trick is to make the stump as tall as possible. In fact, it's best if you can pull the tree down whole. The weight of the tree helps a lot in levering the stump up out of the ground.

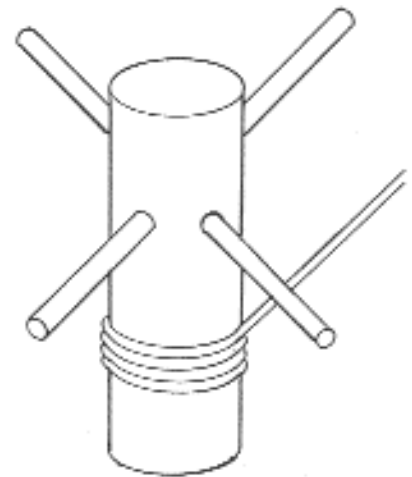


Figure 4. The capstan.

If you can't leave the tree whole, at least leave a good, long lever—six or eight feet of trunk is not too long. Securely fasten a rope as high on the tree trunk as you can. Then dig around the surface roots near the tree and chop through them with a mattock or an old axe.

The dirt on the roots will quickly dull an axe, so you'll have to spend a lot of time resharpening it. A "dull" axe that bounces off wood can still be plenty sharp enough to take a bite out of your leg, so it pays to keep the blade sharp. Never pull a tree toward yourself.

Always use a pulley tied to another tree, and pull at right angles to the direction of fall. I have seen people pull trees toward themselves, when they thought they had plenty of room.

One of the hardest judgements to make is the actual height of a standing tree. And catching a couple of tons of wood in your lap can spoil your whole day. Rig your come-along to a chain, tied to your end of the rope, and wear

the same hardhat and protective gear you'd use cutting timber. And when the tree starts to fall, GET OUTA THERE PRONTO! Felled timber has the cut to guide its fall. A tree wrenched out of the ground by its roots has nothing to guide it but gravity, and its irregularly shaped root stubs may make it twist and turn. Don't depend on the rope to pull it straight down. Once the tree starts to fall, the rope is slack. Of course the tree will probably be pretty close to the ground before the roots let go, depending on the weight of the tree, the soundness of the remaining roots, etc. So it's not likely to fall far out of the path you've chosen for it, But I wouldn't bet my life on it.

### **Improvise**

Just when you need a hoist, pulley, or a come-along most, you probably don't have one, right? Wait a minute. Maybe you do...if you've got a rope and a bumper jack. The ratchet of a bumper jack is quite strong. Strong enough to lift one end of a truck weighing a couple of tons right off the ground.

The trick is rigging it to pull instead of lift. The vertical part of most bumper jacks is a hollow, triangular tube. Thread your pulling rope

through this tube, from the top down, and out the bottom end. Then tie the end to something that won't slip back into the tube, like a large bolt. Tie the other end to whatever you want to pull. You'll need another piece of rope long enough to fasten to your "anchor" plus about six feet. This allows enough room for the jack to operate, plus two or three feet for making a loop in the end.

If you know how to tie a bowline knot, it's a good one to use for making the loop. If you don't know how to tie one, try this instead: double the end of the rope and tie an ordinary "overhand" knot in it—the kind of knot you tie when you start to tie your shoelaces, or make the first half of a square knot. This will leave a loop in the end that won't slip down, though you may not be able to untie it after pulling it tight with the jack. Slip the loop over the hook on the jack and you've got a home-made come-along.

Depending on the geometry of your particular jack, the tube may tend to wander around a lot as you tighten the rope. Tying it to the anchor line with a short piece of twine will help a lot.

One of the best features of this "jury rig!" is that you can use it for safe lifting, since the jack is designed for lowering, as well as lifting. Just be sure to pad any sharp places on the jack that

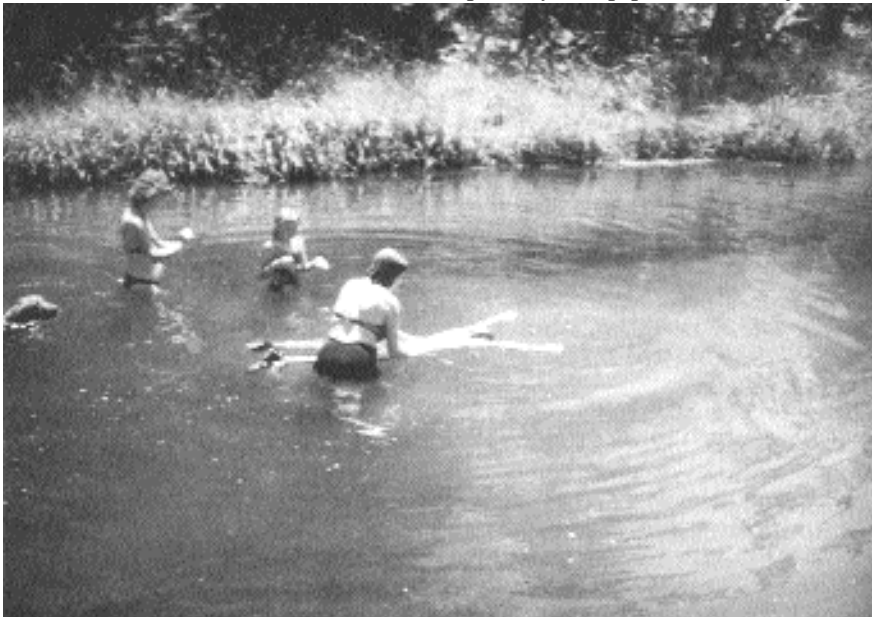
could cut the rope. The hooks of some bumper jacks can be quite sharp.

### **Pickup truck**

One of my favorite devices for increasing the power of a pulley is a good pickup truck. Not only can a truck pull like crazy, sometimes you can use the truck's weight to advantage, too

Once I was cutting logs for firewood on the "back" side of a ridge. The "back" side was real steep and the traction minimal. I knew I'd never be able to drive up it with a loaded truck. After several tries, I did get most of the up the "front" of the ridge, where I parked. I chained the logs together in a big bundle, and ran a rope over the crest of the ridge to the truck on the other side.

I was worried that my rope would fray on the rocky ridgeline, so I put log rollers under it. Instant pulley! As the truck ran down, the logs rose effortlessly up the steep ridge to the top. From there it was easy to drag them downhill to a place where I could load them on the truck. Now I use this technique often, harvesting firewood in locations that would be "impossible", without a long rope and the principles of Mechanics. Δ



*A family outing at a remote swimming hole.*

*Here comes the orator! with his flood of words and his drop of reason.*

Benjamin Franklin, October 1735

*The powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved to the States respectively, or to the people.*

The tenth amendment to the Constitution of the United States