MTR Rope Skill Summary

1. Good rope habits

Long-term storage: keep dry, store away from sunlight, solvents, rodents, and unwanted users
Short-term handling:
- avoid stepping on the rope or loading it over sharp rock edges
- use the butterfly coil for rapid coiling and easy carrying
- avoid spaghetti: stack the rope after uncoiling it

Lifespan: retire whenever
- you find severely abraded sheath or mushy-feeling core
- the rope has experienced severe shock loading or questionable use (towing, construction).

General habit: wear a harness and a helmet whenever you're using a rope.

2. Knots (see http://www.animatedknots.com/)

6 knots that every patroller should know:

Figure 8 (on a bight and rewoven)	making a fixed loop
Double fisherman's knot	joining two ends of cord or rope
Water knot	joining two ends of webbing
Clove hitch	tying a rope to a carabiner
Münter hitch	rope-on-carabiner friction
Improved prusik knot	cord-on-rope friction

General habits:
- Dress all knots before loading them
- Leave at least 3-inch tails on any rescue knot
- Avoid the "nylon saw" (rubbing rope on rope or rope on webbing)

Extra credit:

Butterfly knot	making a fixed loop in the middle of a rope
Hasty harness	improvising a harness from webbing
Wrap-3-pull-2 tie-in	tying into a fixed anchor point
Autoblock	backing up a rappel
EDK ("Euro-death knot")	joining 2 ropes for a rappel

3. Hardware

Carabiners:
- When life depends on it, use a locker.
- Load 'biners along their spines. Don't cross-load. Never load the gate.

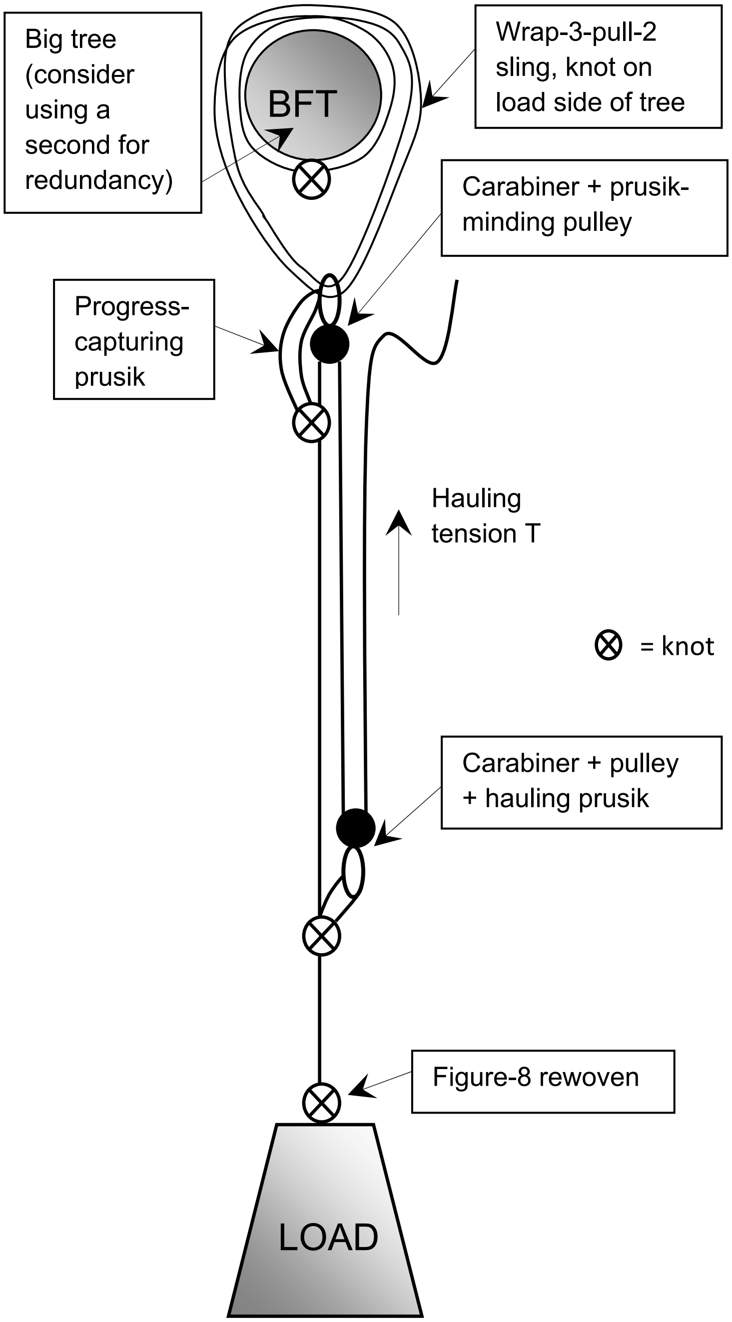
Belay devices:
- Tubular belay devices (ATCs, Reversos, etc.) are more versatile than figure-8 devices
- Use a pear-shaped (HMS) locker with any belay device
- Back up all rappels with an autoblock

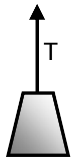
General habits:
- Avoid metal-on-metal (exceptions: belay device or rappel rack on a locking carabiner)
- Re-check all lockers before loading any system

4. Anchors (see http://www.uoregon.edu/~opp/climbing/topics/anchors.html)

Make all anchors SERENE: Solid, Equalized, REdundant, No Extension
Use a cordelette (for rescue work, 20-30 ft of 8 mm cord, tied into a loop using a double fisherman's knot)
Keep angles less than 60° to avoid amplifying forces
Build anchors that have a master point and a shelf

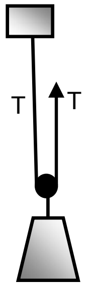
Raising System Cheat Sheet





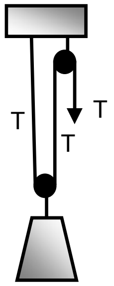
1/1 theoretical mechanical advantage (TMA)*

Hauling tension = T



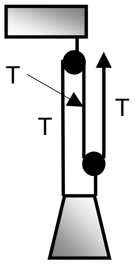
"C-rig": 2/1 TMA

(2T on load, T on anchor)



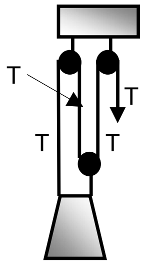
2/1 TMA with change of hauling direction

(2T on load, 3T on anchor)



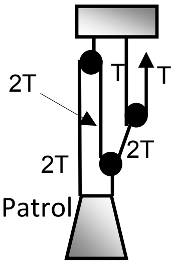
"Z-rig": 3/1 TMA

(3T on load, 2T on anchor



3/1 TMA with change of direction

(3T on load, 4T on anchor)



C×Z or "pig rig": 6/1 TMA

(6T on load, 5T on anchor)

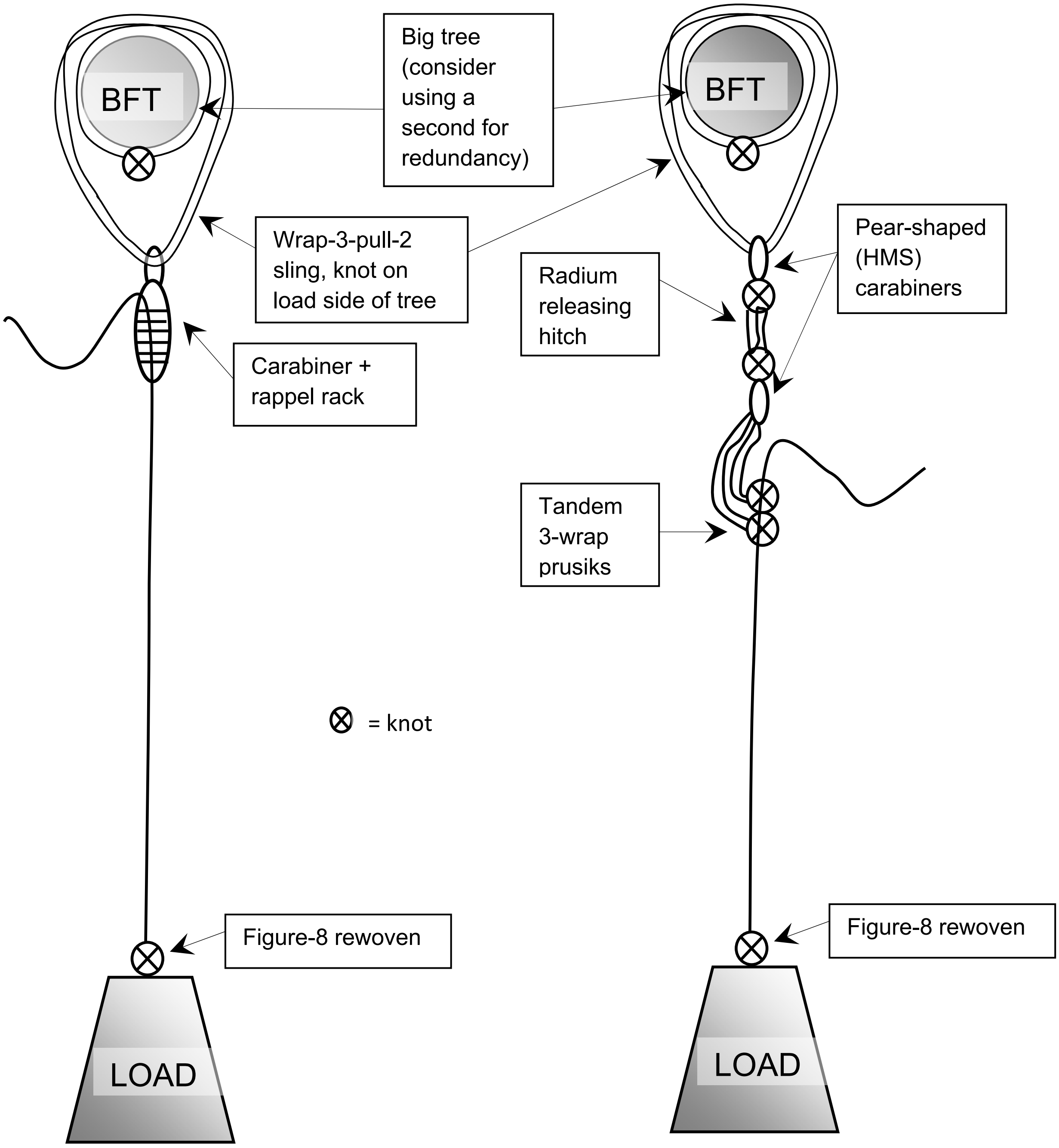
*To compute theoretical mechanical advantage, count the number of times the hauling tension T pulls on the load. *Theoretical* mechanical advantage doesn't take into account friction, which reduces the efficiency of the mechanical system.

A rescue pulley is about 95% efficient. A carabiner used in place of a pulley is about 65% efficient.

Extra credit: In the Z-rig shown above, suppose you have plenty of carabiners but only 1 pulley. Where would you put it?

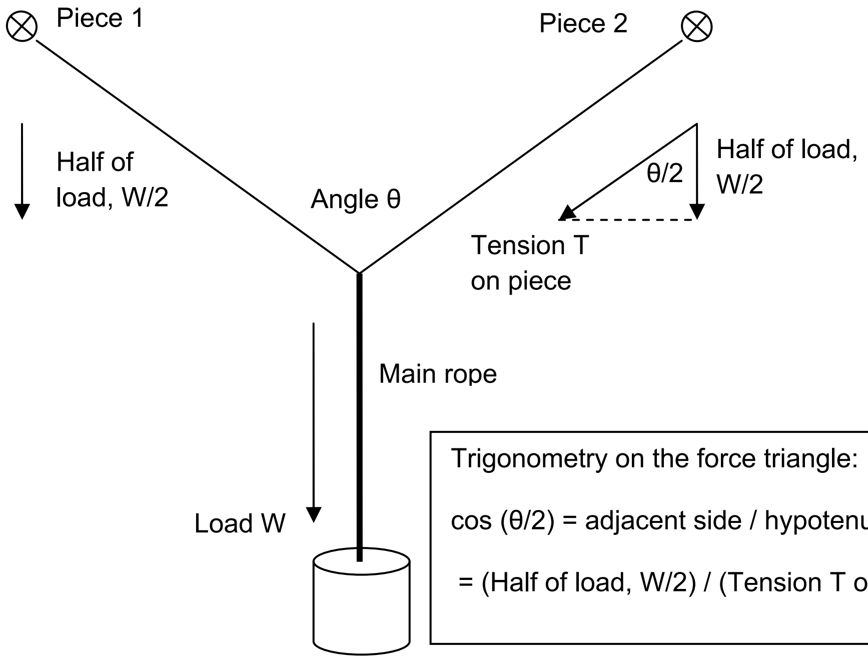
Lowering System Cheat Sheet

Belay System Cheat Sheet



Anchors and Angles

When you place more than one piece in an anchor, you have to be careful not to attach the pieces to the main rope using a large-angle system. To see why, you have to relate the total tension on each anchor to the vertical load that it bears. In an equalized, symmetric system, the *vertical* load on each piece will be half the total load. But the resulting tension on the piece isn't easy to calculate in your head. It involves some trigonometry, which some climbers can resurrect from those school days when they weren't daydreaming about crystals and cracks. Here's the diagram:



Trigonometry on the force triangle:

cos (θ/2) = adjacent side / hypotenuse

= (Half of load, W/2) / (Tension T on piece)

It's useful to write the relationship between the load and the tension on one of the pieces in the form

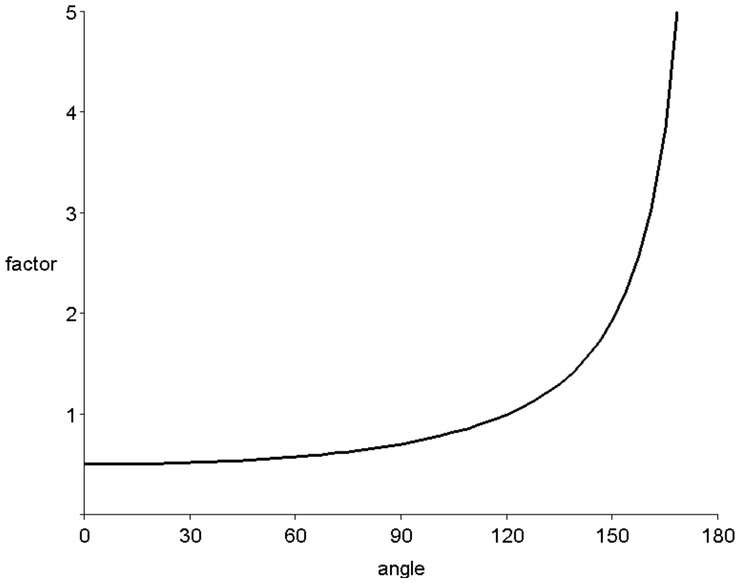
Tension T on piece = Load factor × Load W.

The diagram shows that the tension on a piece is T = (W/2) / cos (θ/2). So the load factor is 1 / [2 cos (θ/2)], where θ is the angle between the slings connecting the pieces. The ideal load factor is ½, meaning that the tension on each piece is 50% of the load. The ideal case occurs when the angle is θ = 0° (so cos (θ/2) = 1). The closest you can get, in practice, is to place one piece directly behind the other and to make sure that the pieces are loaded equally. Whenever the angle is greater than 0°, the load factor is greater than ½, which means you're placing more than the ideal amount of tension on the pieces.

When the angle is small, this undesirable effect is pretty small. But when the angle is large, the tension on the pieces can be huge, defying many people's intuition and making for unacceptably weak systems. To be more specific, the table below gives load factors corresponding to several angles. Notice what happens when the angle is greater than 120°.

Angle θ between pieces	Load factor 1 / [2 cos (θ/2)]	Approximate percentage of load held by each piece
0°	0.5000	50%
15°	0.5043	50%
30°	0.5176	52%
45°	0.5412	54%
60°	0.5774	58%
90°	0.7071	71%
120°	1.0000	100%
150°	1.9319	193%
165°	3.8306	383%
175°	11.4628	1,146%
180°	∞	See remarks below

A more visual way to see what's going on is to graph the load factor against the angle. This graph, shown below, indicates that the load factor hovers around its ideal value, ½, when the angle is small. However, the load factor grows extremely rapidly as the angle approaches 180°. One climber's informal description — namely that the load factor is "exponential" — actually understates the case. In theory it's worse: it blows up.



This blow-up, corresponding in theory to infinite tension on the pieces when the connection to the load is perfectly horizontal, doesn't occur in real-world systems. Any nonzero load will cause a real system to have an angle slightly less than 180°. Because of this effect, you don't have to worry about infinite tension on your pieces. But you *do* have to worry about dangerously large tension.

In summary, the table and graph drive home three important points:

1. When the angle between the pieces is less than 60°, the load-multiplying effect is small.
2. Angles approaching 120° effectively negate one of the key benefits of equalized systems, namely their ability to share the load among several pieces.
3. An angle greater than 120° is just plain dangerous.