SALT LAKE COUNTY
SHERIFF'S OFFICE

SEARCH *RESCUE*

Rescue Physics

- Force Units and Strength of Components
- Strength of Anchors
- Basic Statics
- The T-Method and Haul System Forces
- Vectors

  Highlines, Anchors, Direction Changes, Rope Loads and Slopes

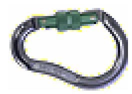
- Friction

This presentation can be downloaded at
http://www.xmission.com/~tmoyer/testing
Many images in this presentation were generated with RescueRigger (rescuerigger.com)

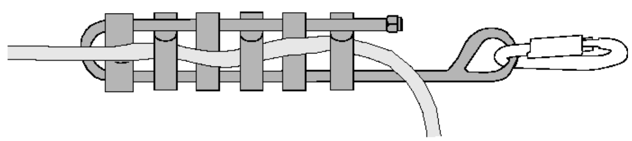
Strength of Components

Webbing: 4,000 lb per strand - knot

Tree: Bombproof?



Carabiners: 23 kN = 5,200 lb



Brake Bar Rack: 44 kN = 10,000 lb

Pulleys: 36 kN = 8,100 lb

Litter end-to-end: 18 kN = 4,100 lb

Rope: 29 kN = 6,500 lb new (~4,500 lb with knot)

Safety Factors and Forces

- Anchors should be able to hold rescue loads with “sufficient” safety factor
  - Rescue load = 1000 lb
- “Sufficient” safety factor
  - NFPA says 15:1
  - Some people say 10:1
  - Some people say 4:1
- Know the forces, know the equipment

What is the safety factor used in the design of this airplane?

Force Units

1 Newton (=.22 lb = 3.6 oz)

1 kiloNewton
(=1000 N = 225 lb)

1 Carabiner equals

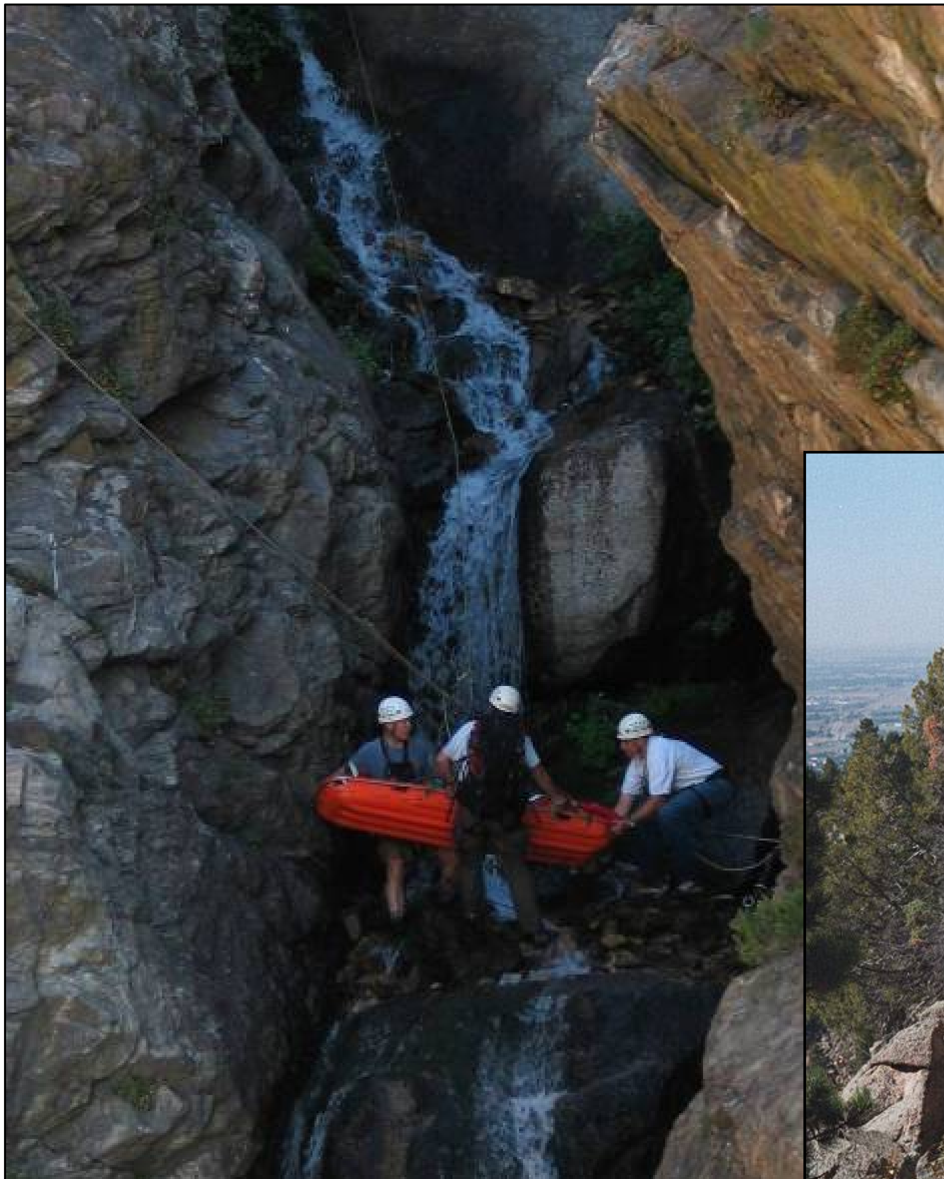
1.5 Subarus: 15 kN each = 3,400 lb

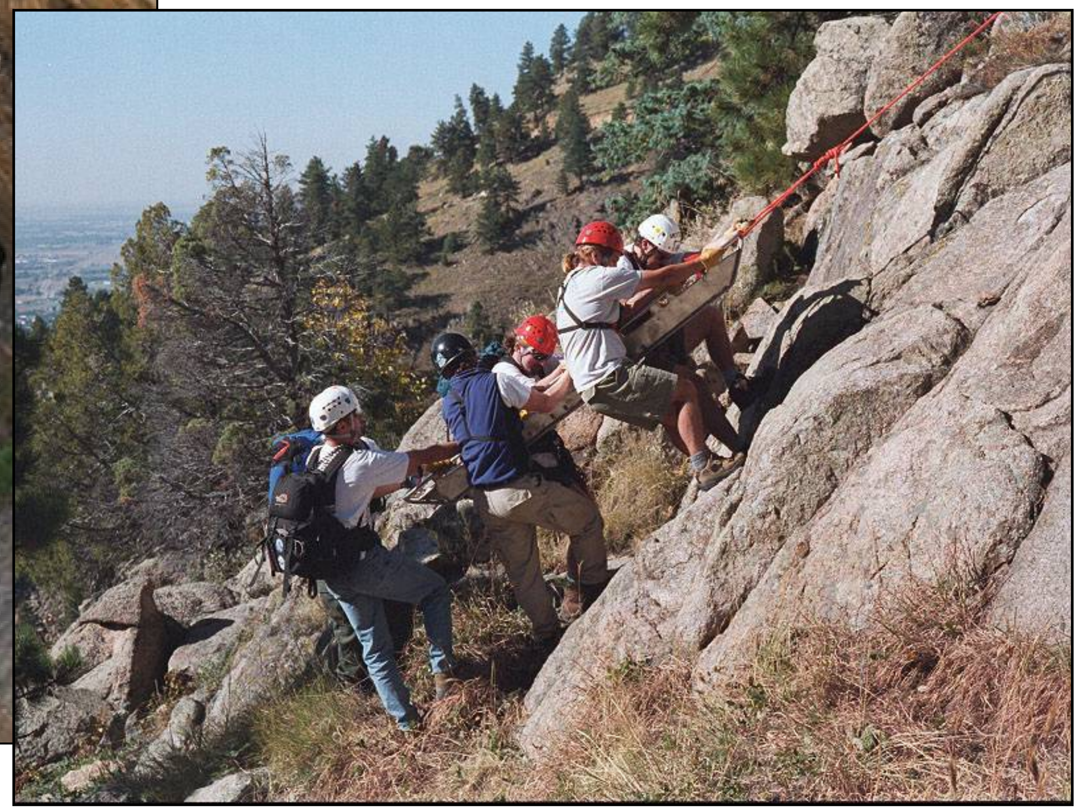
23 Dans:
23 kN = 5,200 lb

90% of a Hummer: 26 kN each = 5,800 lb

Rescue Loads

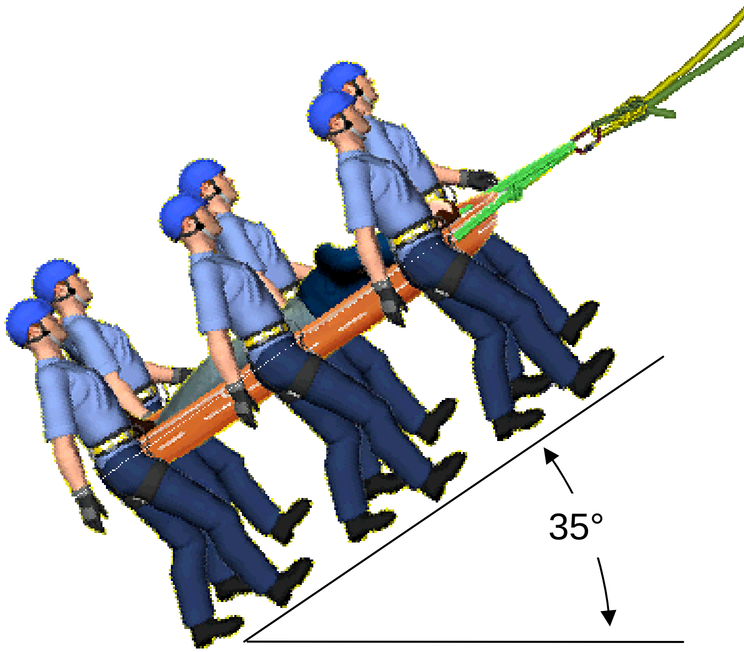
Which Situation has higher load?



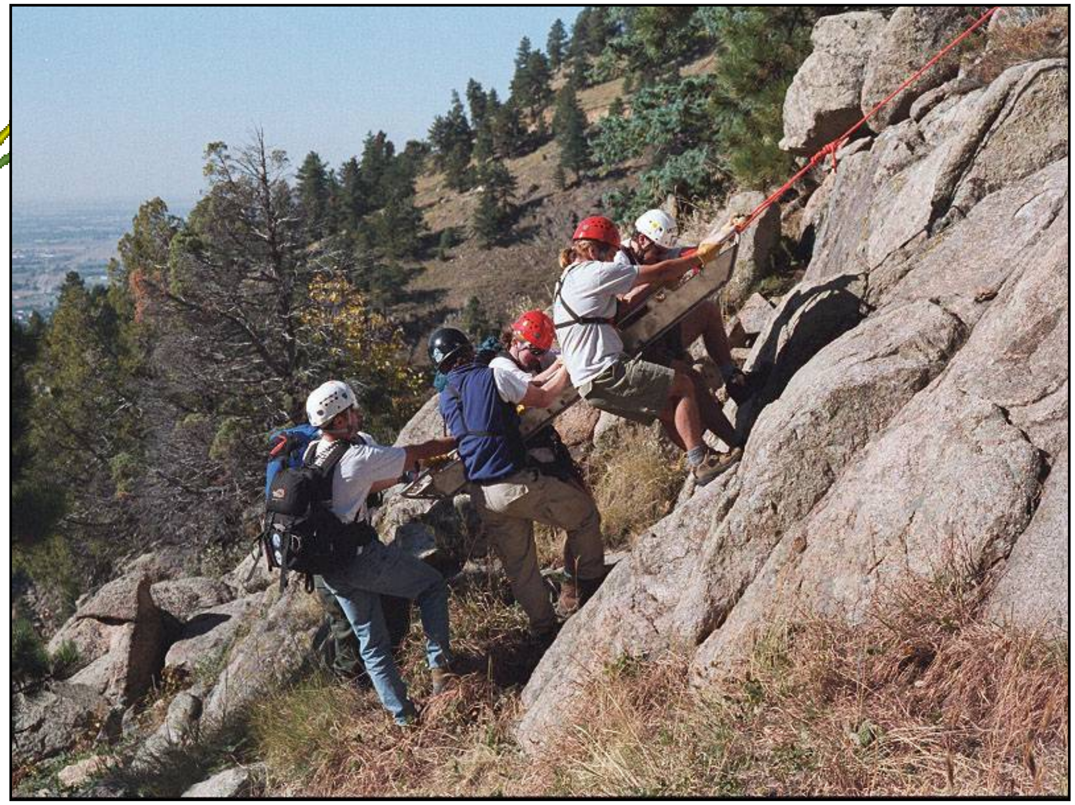


Rescue Loads

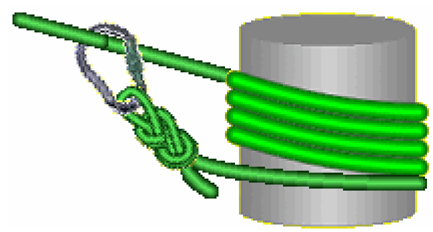
1000 lb load



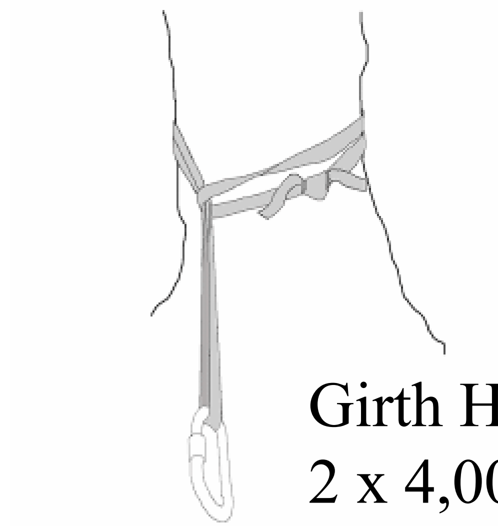
Which Situation has higher load?



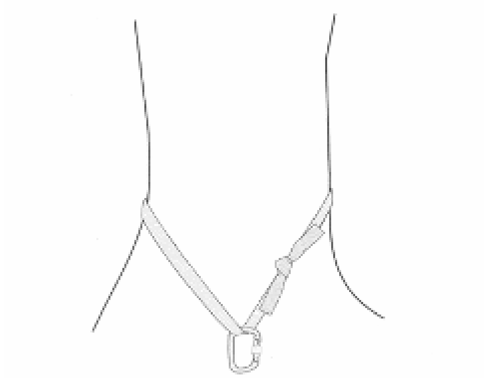
Strength of Anchors



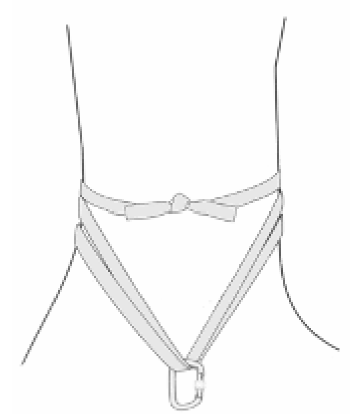
No Knot:
Rope strength (**6,500 lb**)



Girth Hitch:
2 x 4,000 lb ≈ **8,000 lb**

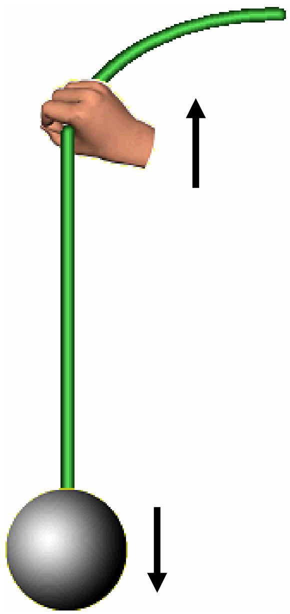


Tied:
2 x 4000 lb x 2/3 ≈ **5,300 lb**

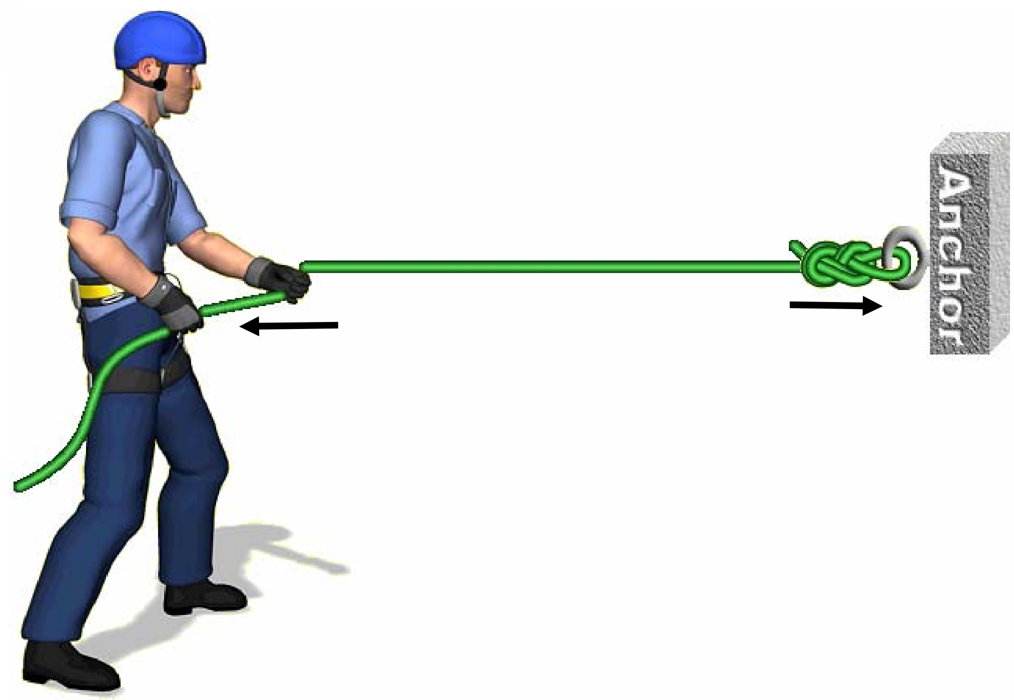


Wrap 3 Pull 2:
4 x 4000 lb ≈ **16,000 lb**

Statics

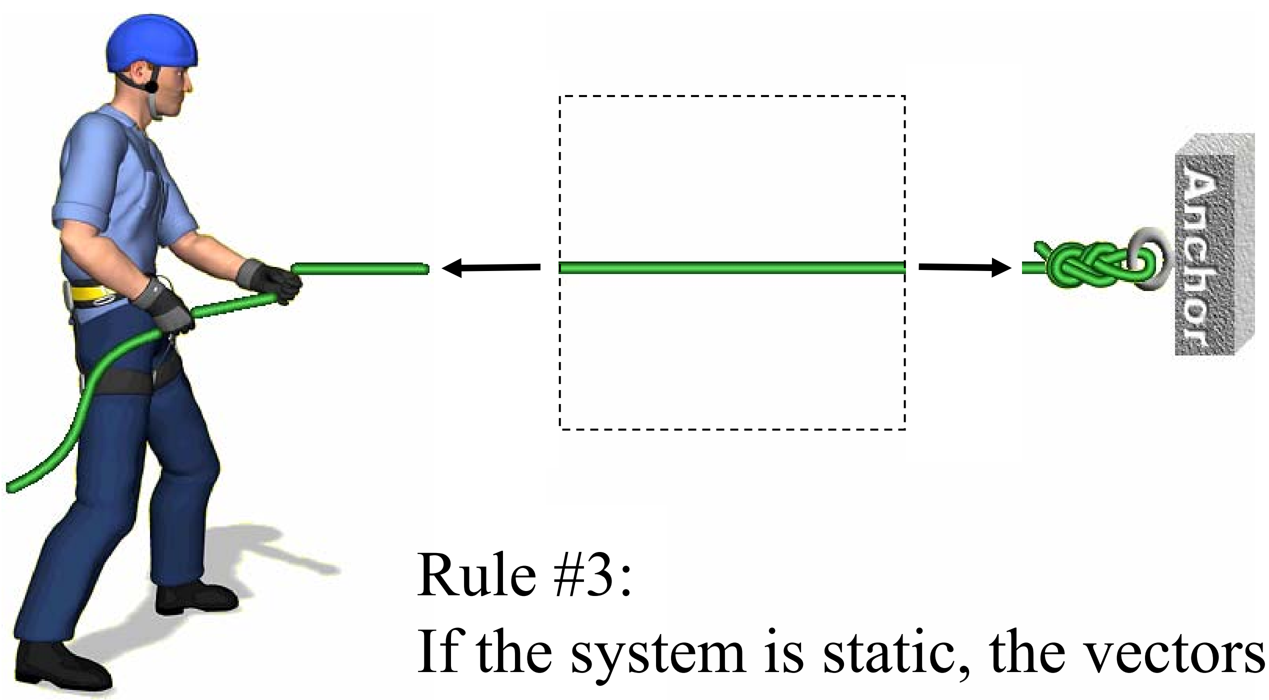


Rule #1: Every action has an equal and opposite reaction.



Statics

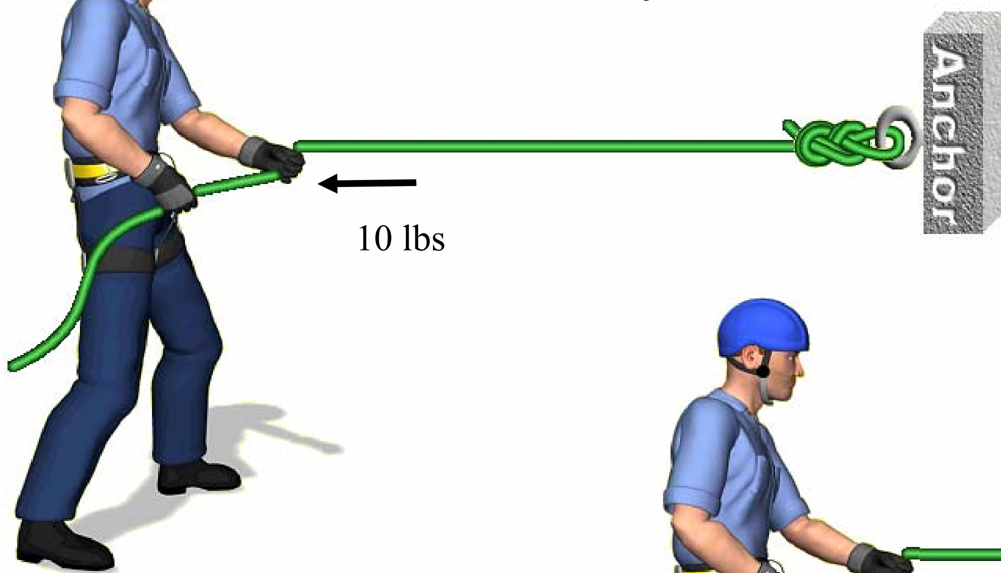
Rule #2:
Draw a box around any piece of the system.
Replace anything you cut with force vectors.

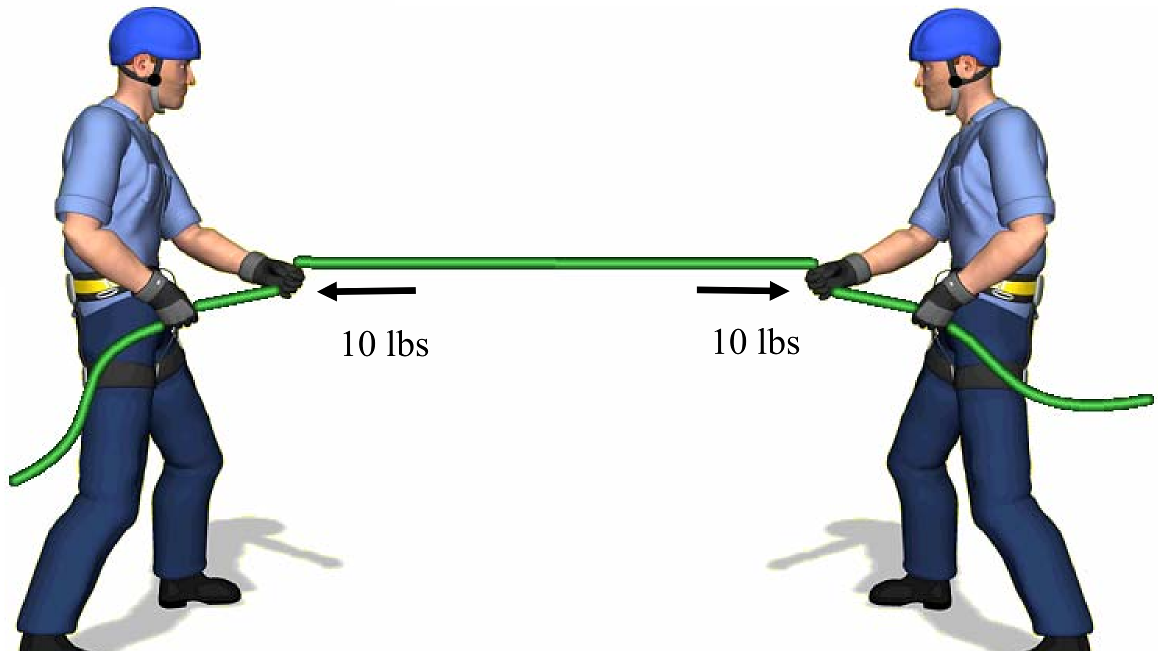


Rule #3:
If the system is static, the vectors have to add to zero.

Statics

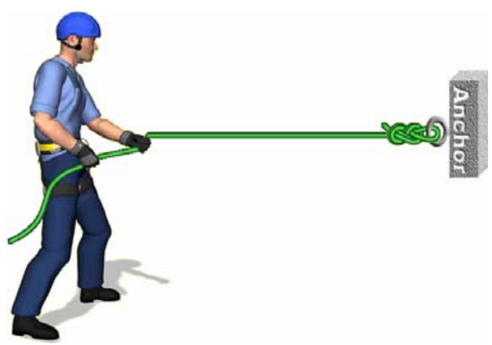
Does this system...

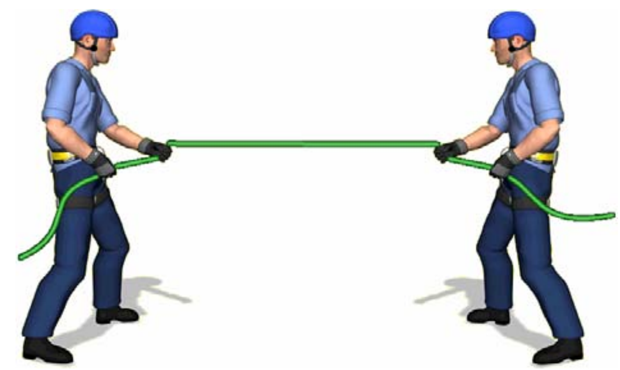


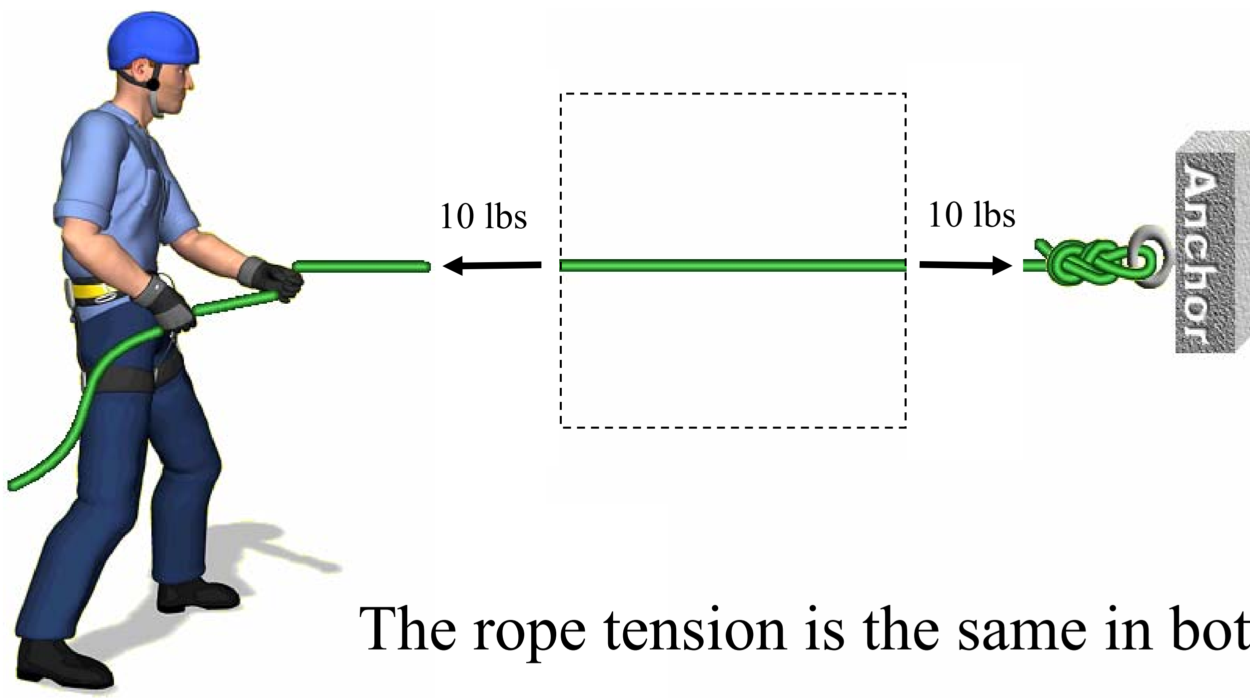


differ from this one?

Statics

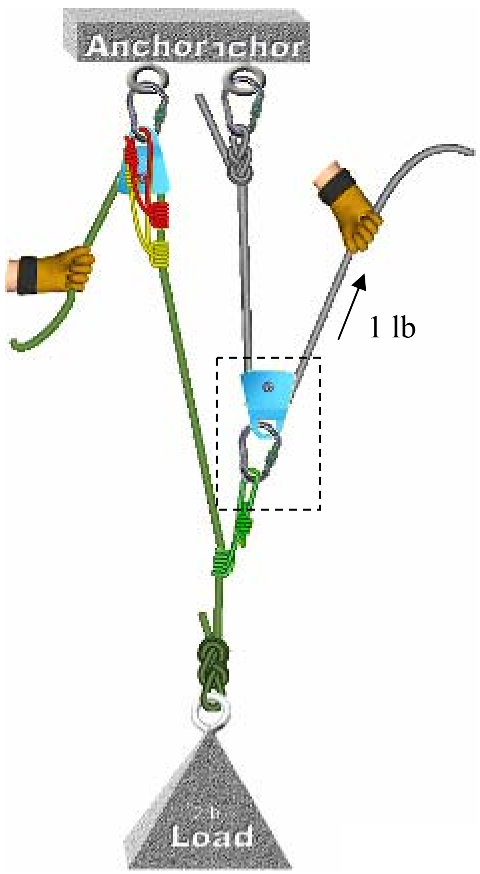


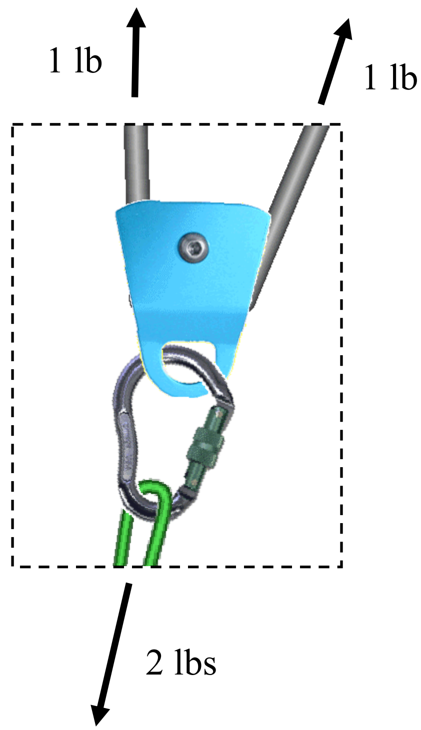




The rope tension is the same in both systems

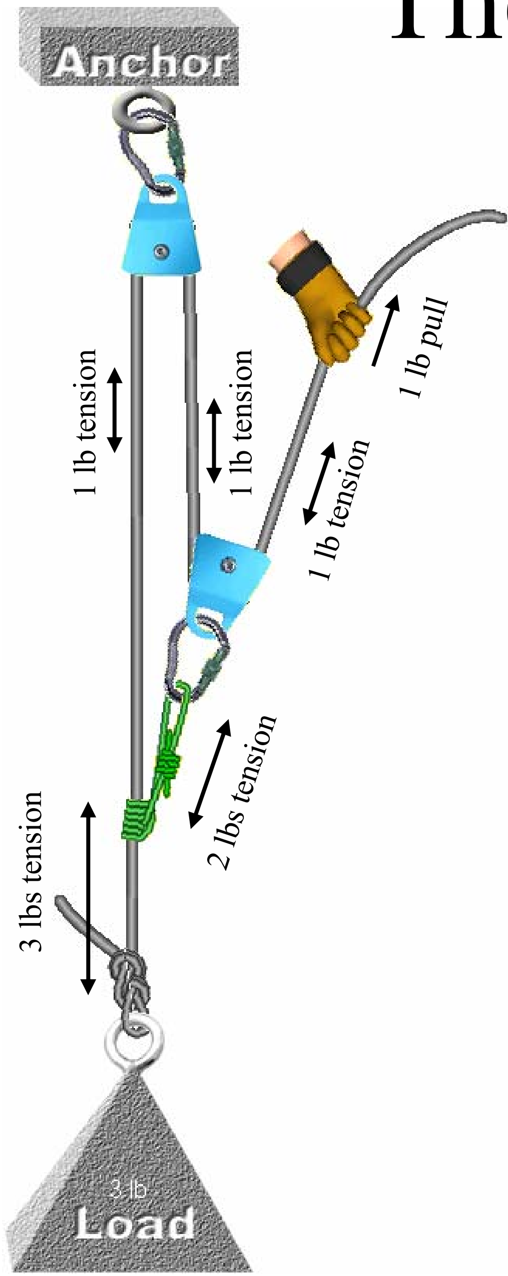
The T-Method





Any box you draw has to be balanced.
2 pounds in = 2 pounds out.

The T-Method

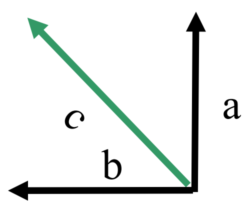


Start at the haul rope with 1 lb pull.

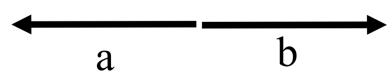
Trace the rope through the system and find the tension at each point.

Vectors

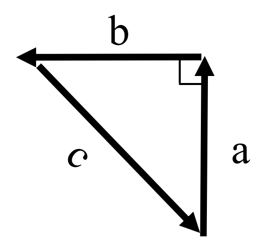
Vectors have a magnitude and a direction.
Vectors are added graphically.
Arrow lengths represent the magnitude of the forces.
Force arrows can be moved around as needed.



a + b = c

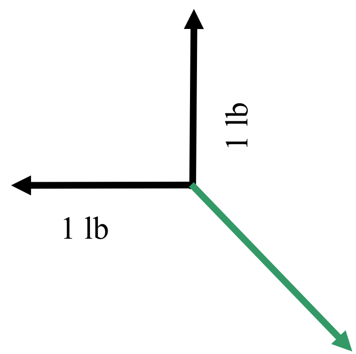


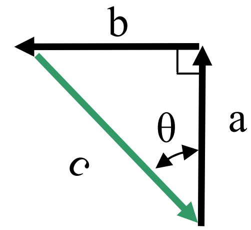
a + b = 0
static



a + b + c = 0
static

Vectors





Pythagorean theorem:

$c^2 = a^2 + b^2$

$c^2 = 1 + 1$

$c \approx 1.4$

Useful Trigonometry:

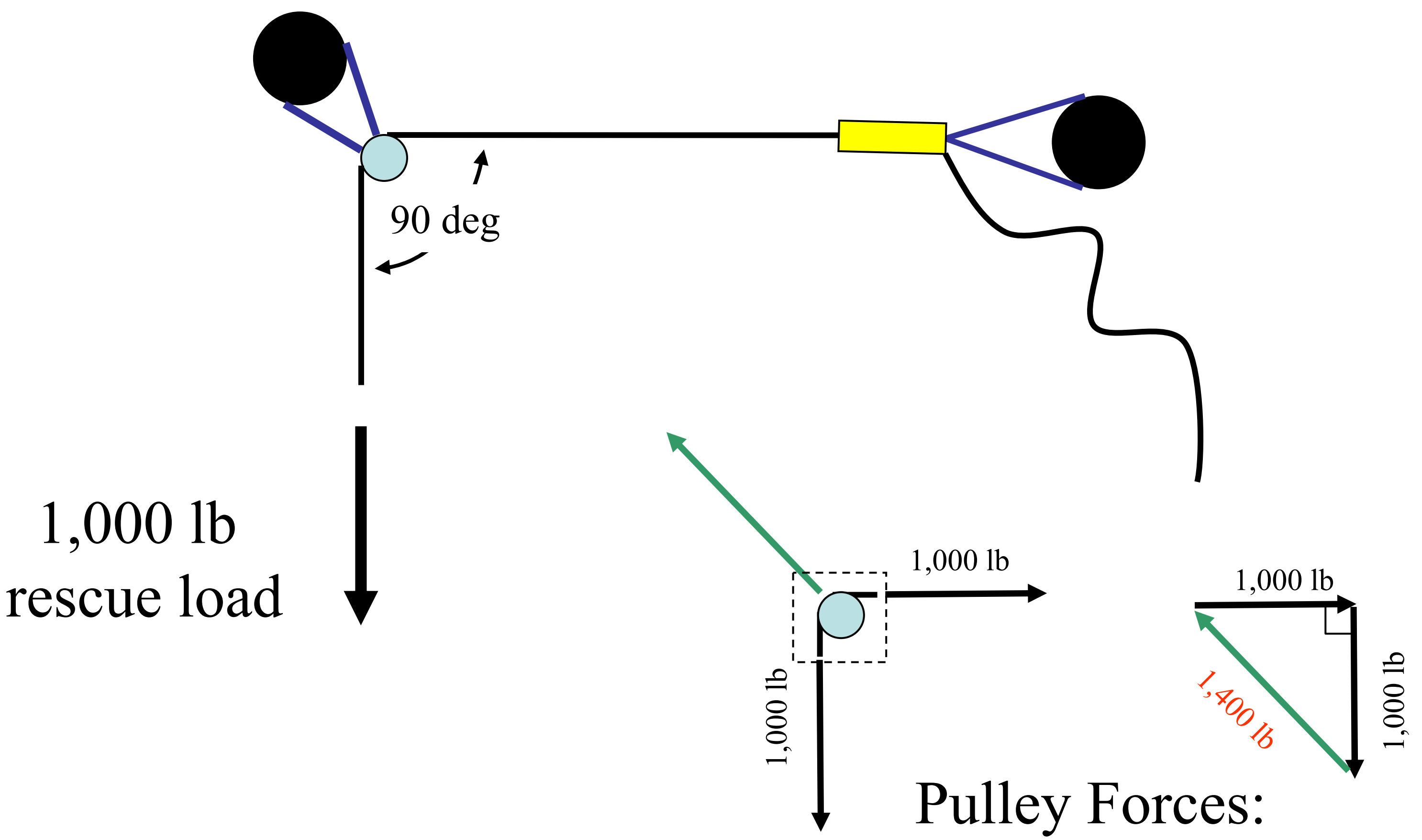
$\text{Sin } \theta = b / c$

$\text{Cos } \theta = a / c$

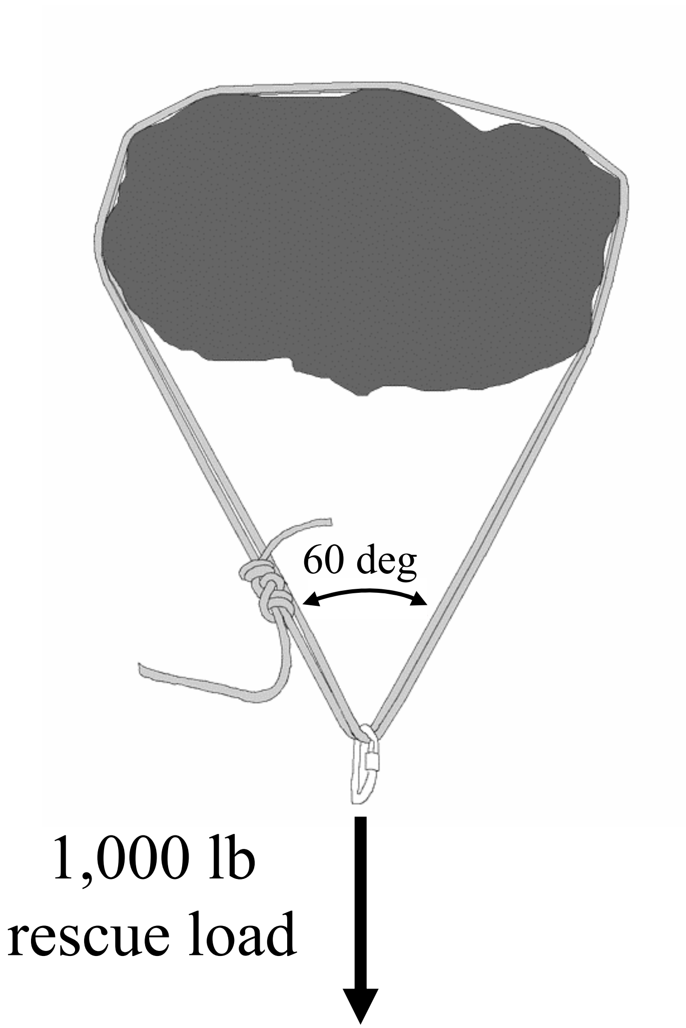
$\text{Tan } \theta = b / a$

Direction Change Forces

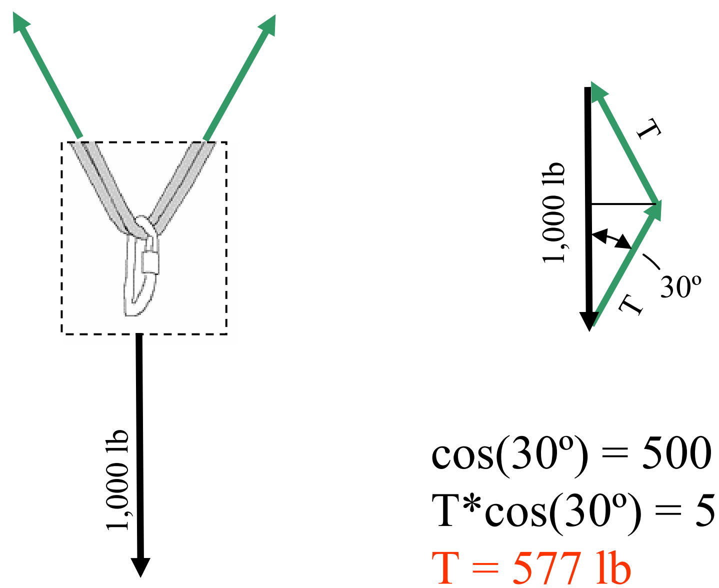
Which tree is supporting the largest force?



Internal Anchor Forces



Carabiner Forces:

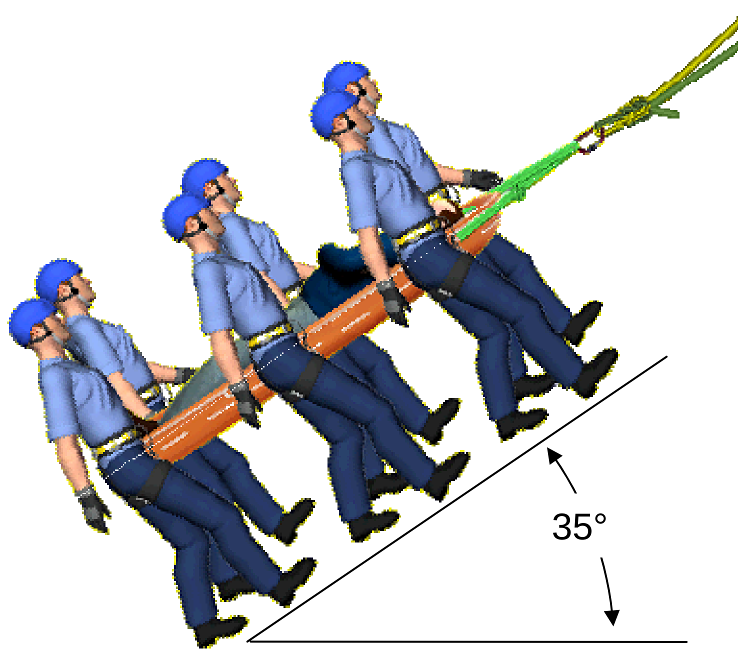


$\cos(30^\circ) = 500 \text{ lb} / T$

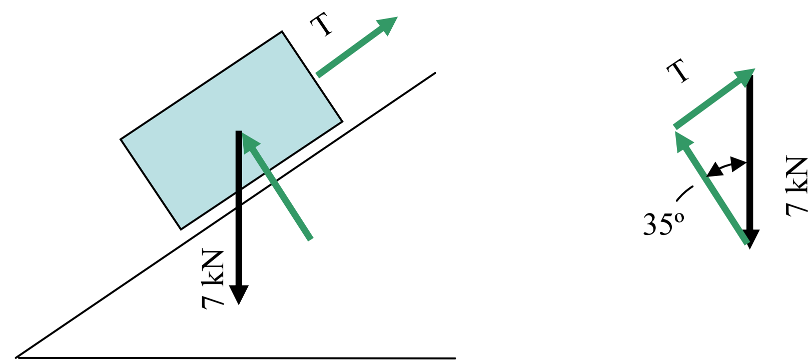
$T*\cos(30^\circ) = 500 \text{ lb}$

$T = 577 \text{ lb}$

Litter Team Forces



Litter Team Forces:

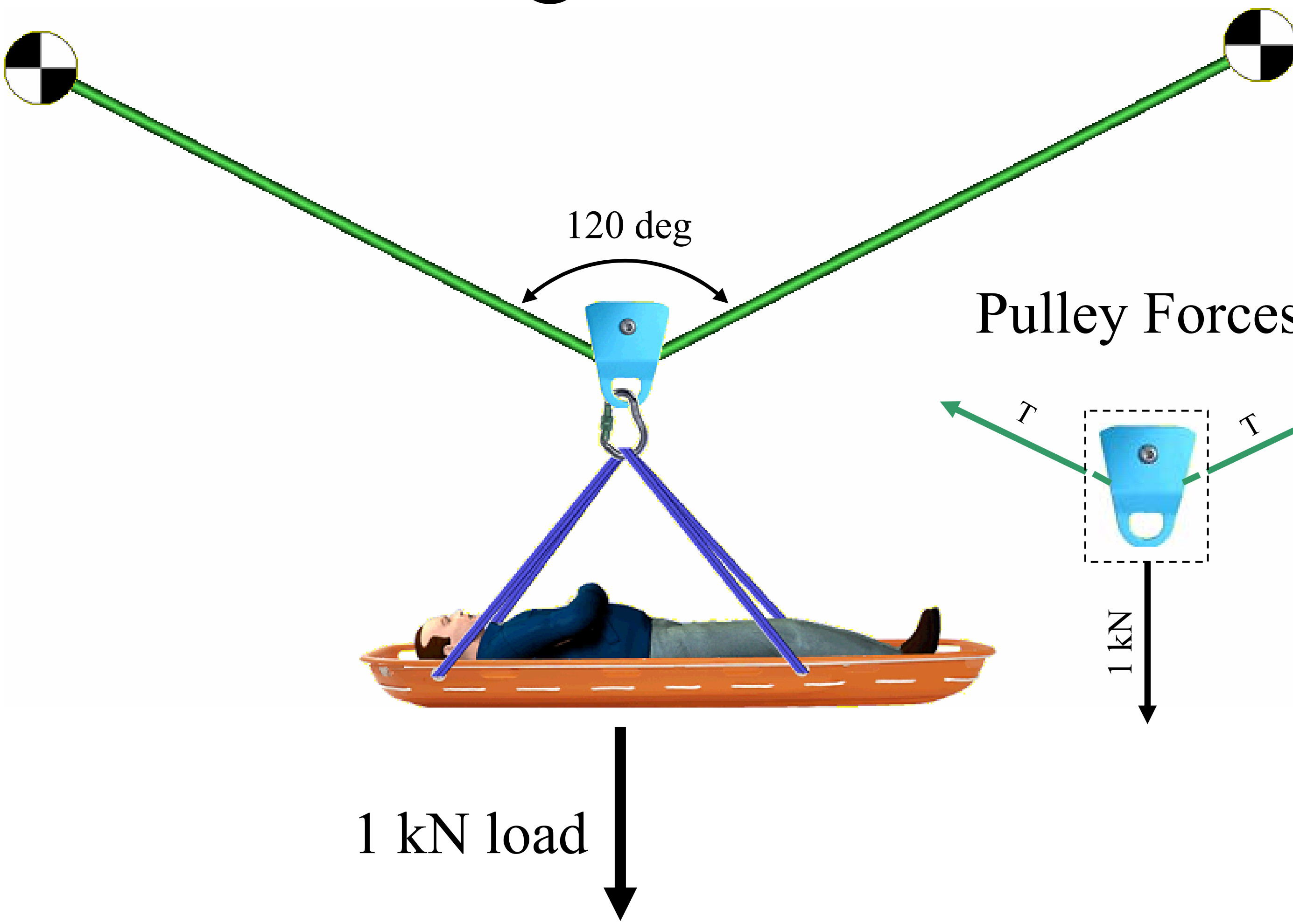


sin(35º) = T / 7 kN

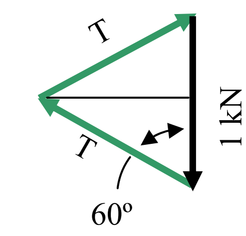
T = 7 kN*sin(35º)

T = 4.0 kN = 900 lb

Highline Forces



Pulley Forces:

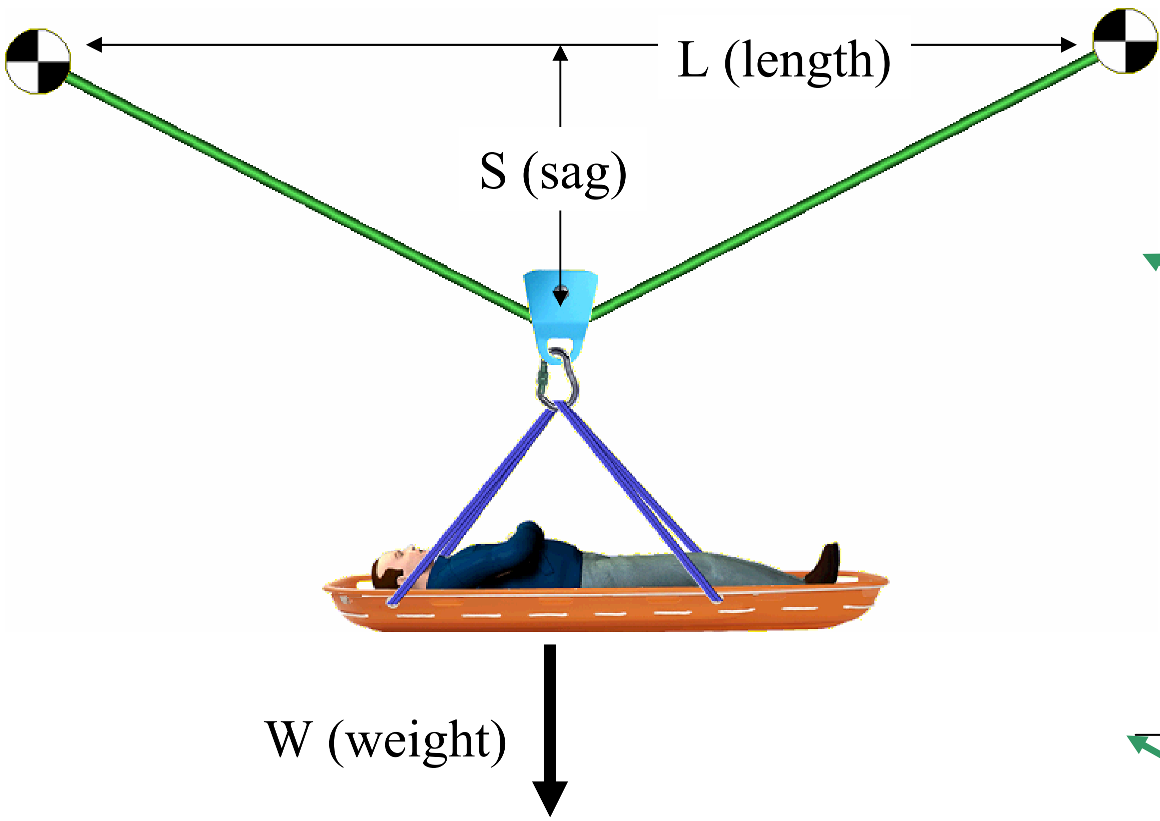


$\cos(60^\circ) = 500\text{N} / T$

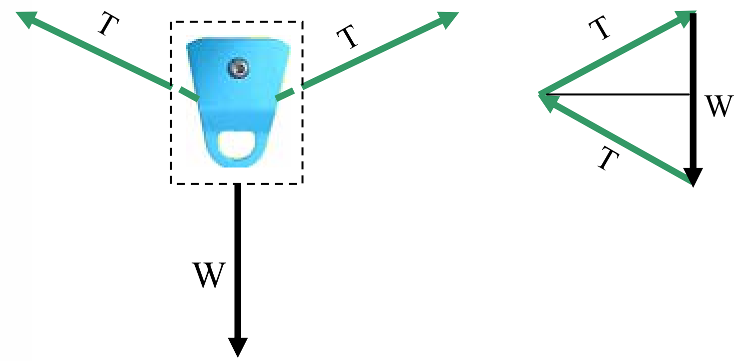
$T^*\cos(60^\circ) = 500\text{N}$

$T = 1\text{ kN}$

More Highline Forces



Pulley Forces:



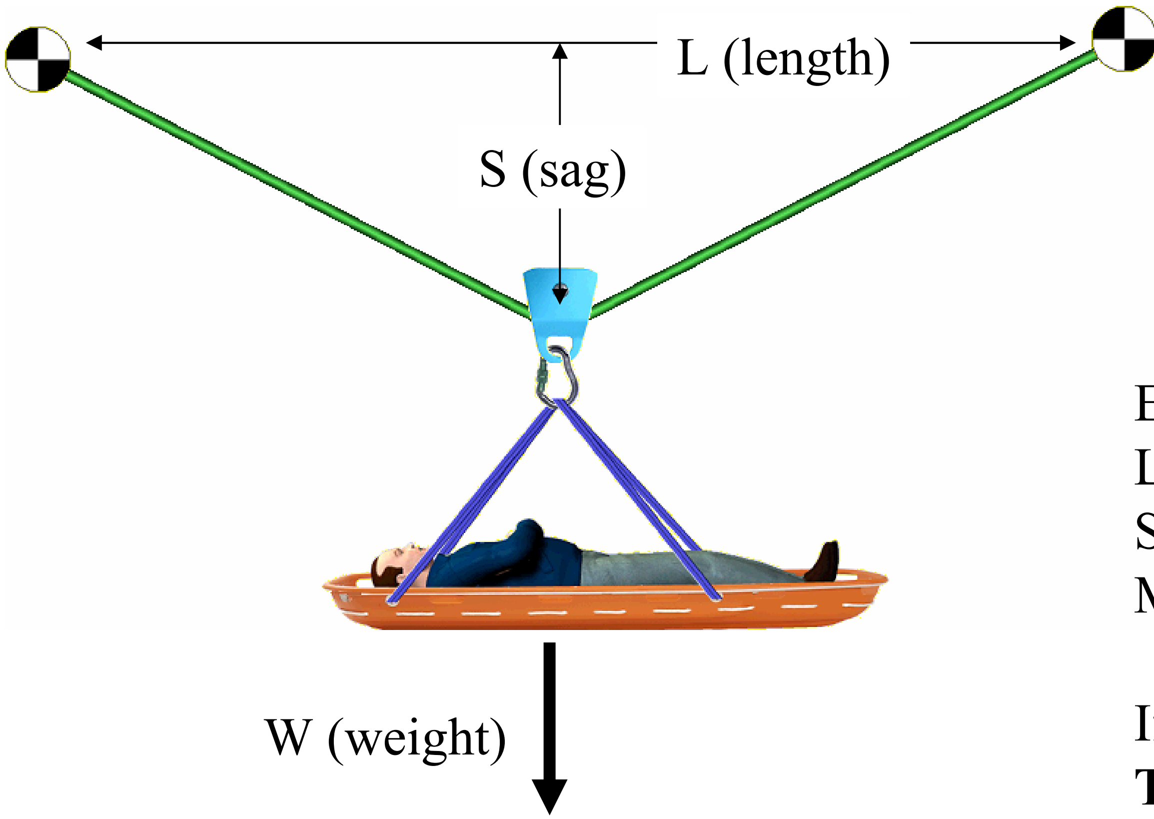
Similar Triangles:

$T / (W/2) \approx (L/2) / S$

$T \approx (W/2) * (L/2) / S$

$\mathbf{T \approx W * (L / 4S)}$

More Highline Forces



T ≈ W * (L / 4S)

Example:
L = 200 ft
S = 10 ft
Multiplier = 200 / (4 * 10) = 5

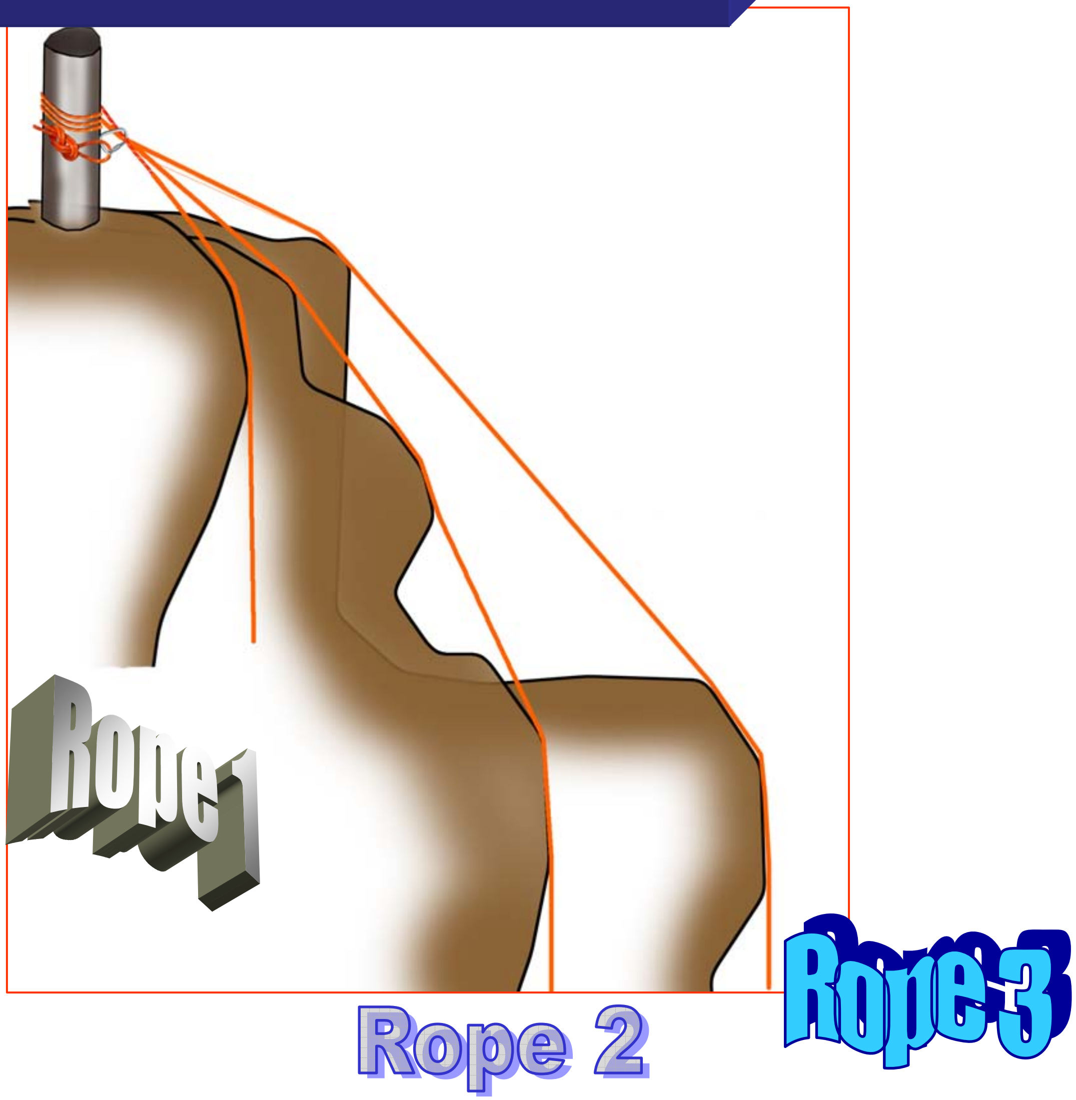
If W = 200 lbs, then
T = 5 x 200 lbs = 1000 lbs

Active Highline Forces

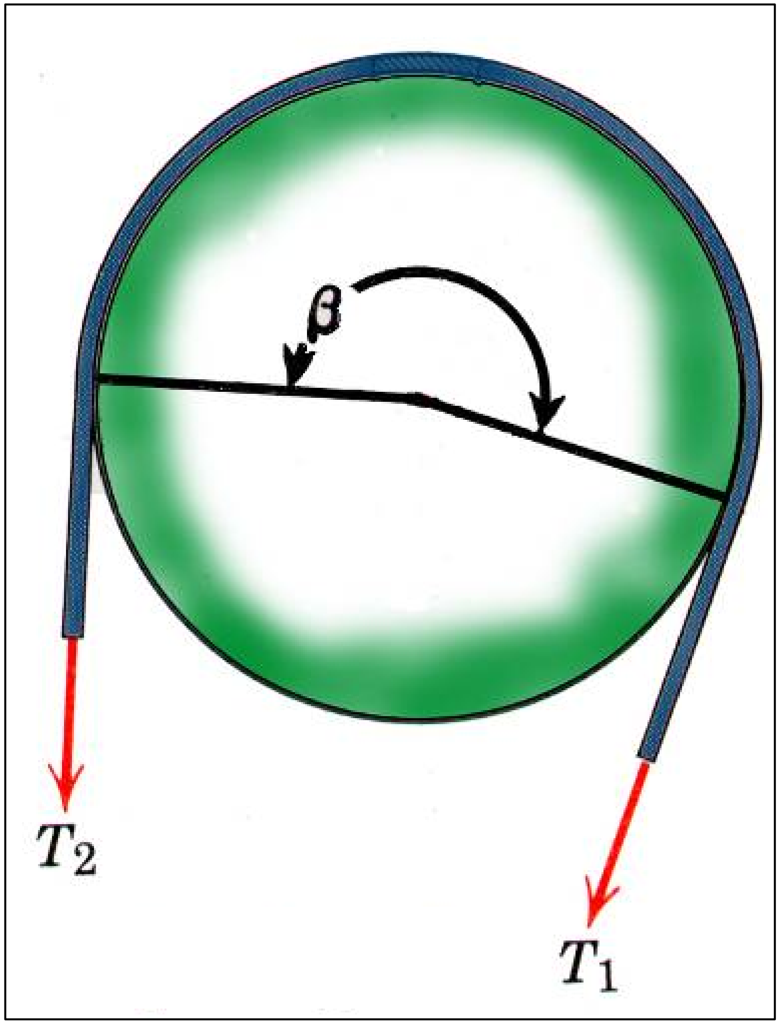
Highline Tension ≈ 50 lbs x (number of haulers) x MA
As shown here, T ≈ 50 x 3 x 3 = 450 lbs

Some teams talk about a “rule of 12”
Haulers x MA must be less than 12.
This is equivalent to a 600 lb working load limit.

Which rope has more friction?

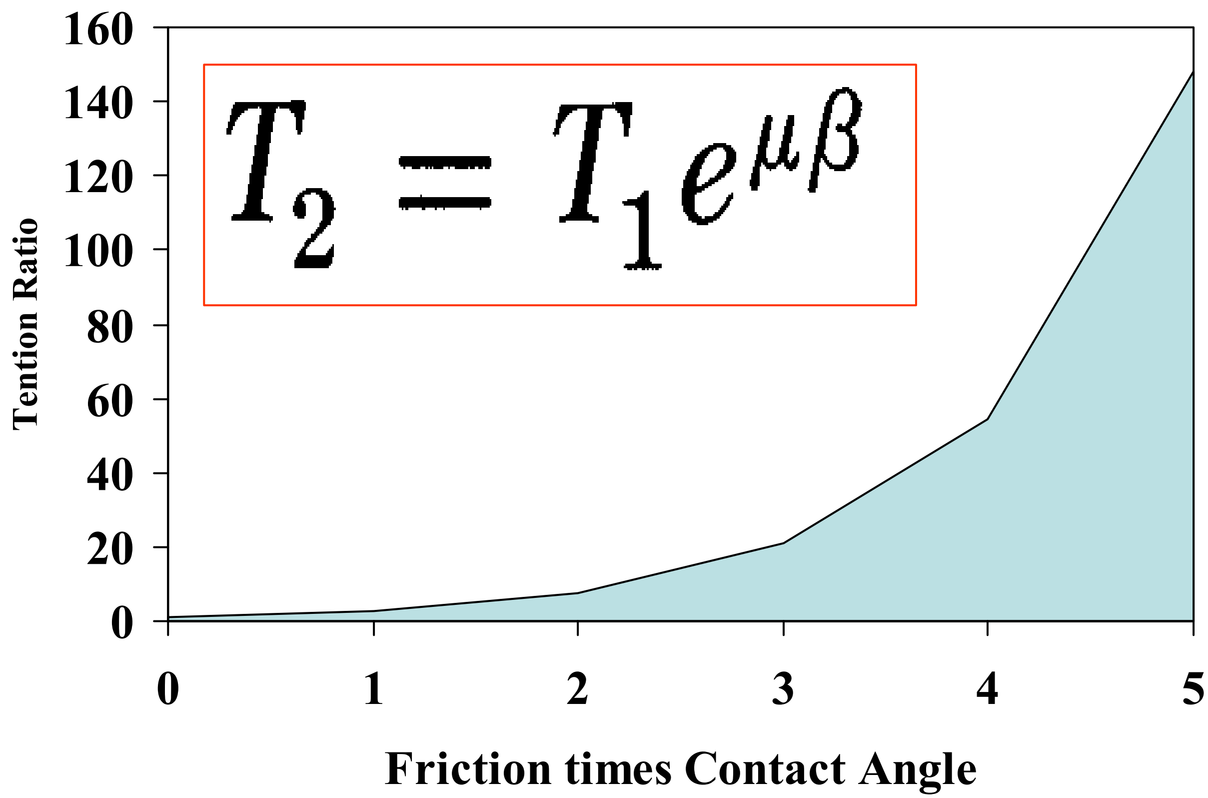


Friction from a Belt



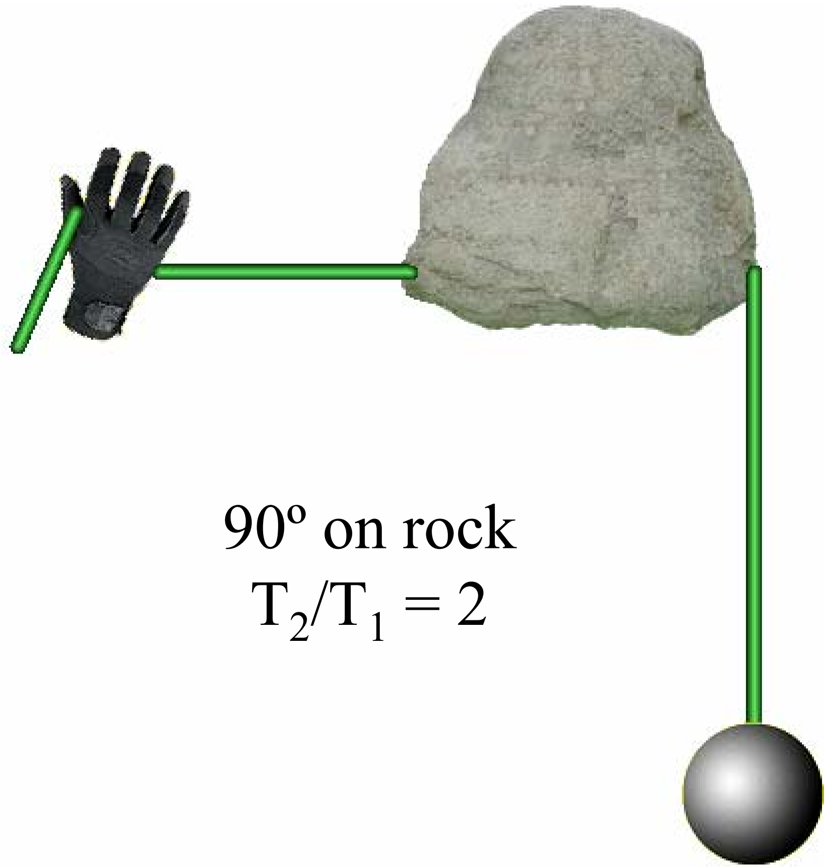
$$T_2 = T_1 e^{\mu\beta}$$

Exponential Function of Friction and Contact Angle



Useful Friction Approximations

180º on carabiner
$T_2/T_1 = 2$

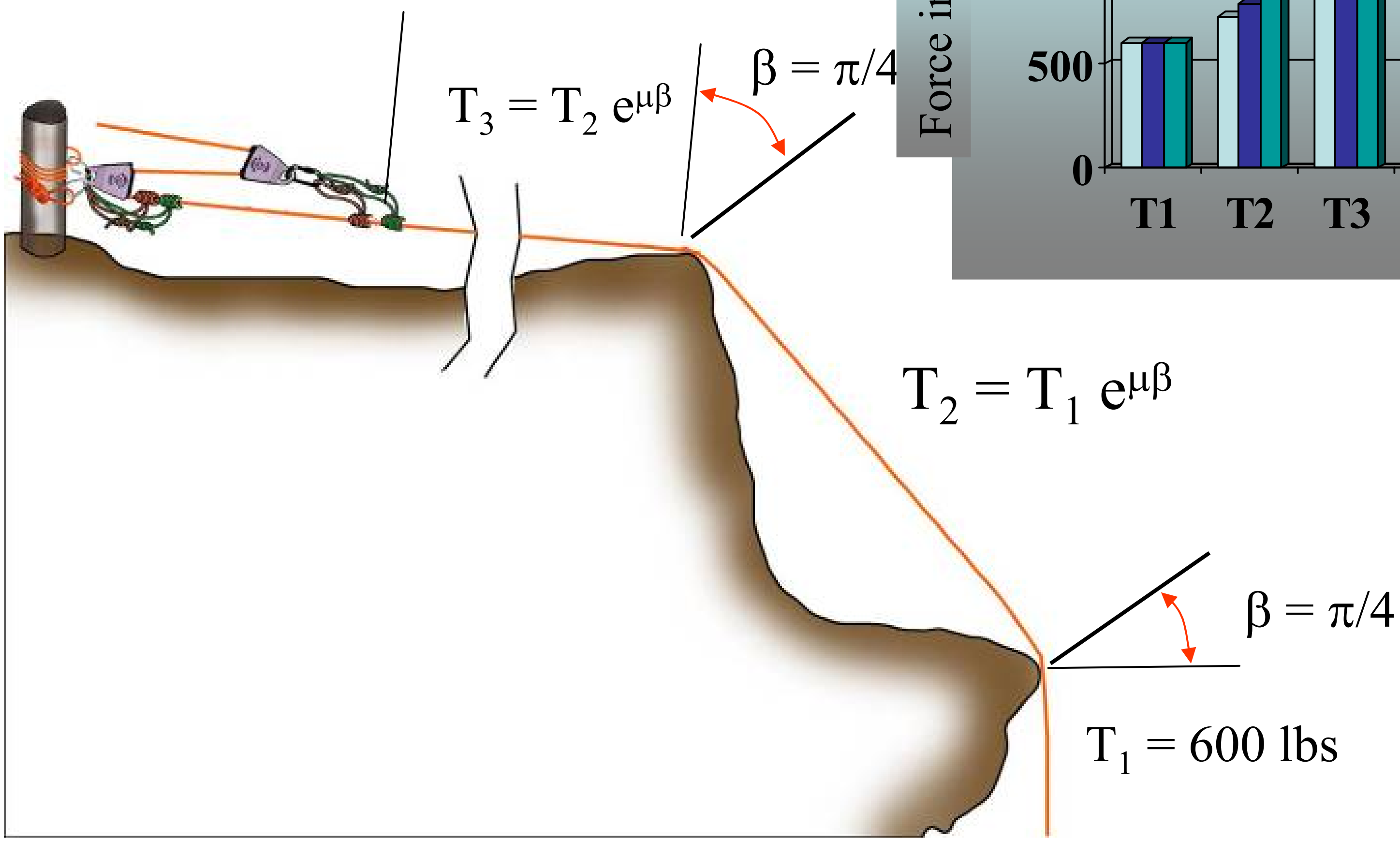


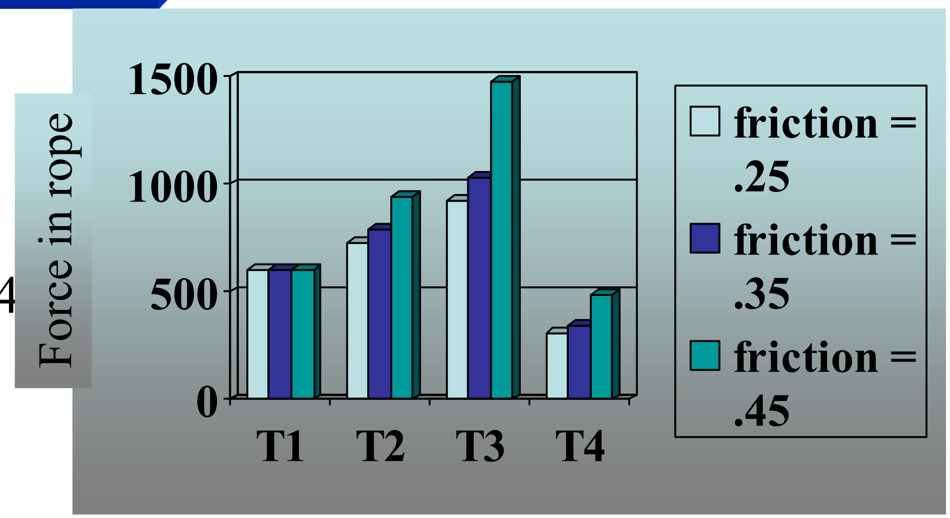
90º on rock
$T_2/T_1 = 2$

Tension increases if hauling. Tension decreases if lowering.

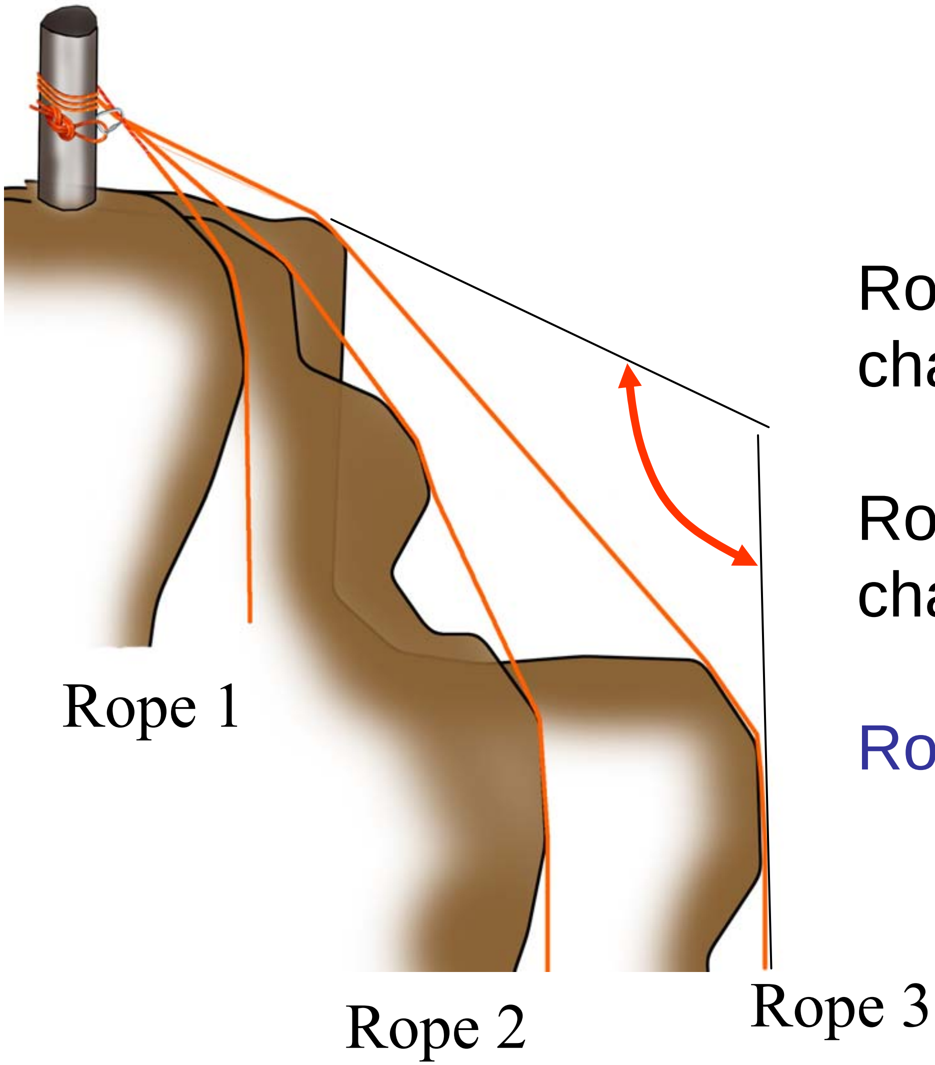
What is T_2/T_1 for a 180º change on rock?   For 360º?

Friction Example





Which rope has more friction?



Rope 3 has the greatest change in angle

Rope 1 has the smallest change in angle

Rope 3 has the most friction