What is a fall factor?

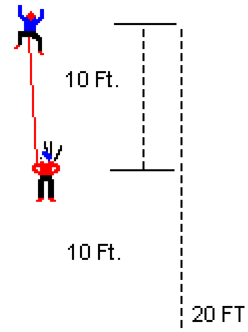
The fall factor is a derived number used to evaluate the shock loads generated on the climber, belayer and anchors that occur when a climber falls. The higher the fall factor, the greater the forces placed on the components of the system. The math is simple:

Fall factor = length of fall / length of rope

Why is it confusing?

The maximum fall factor generated in climbing situations is **2**. A quick look at the math is just a little misleading. A climber can't fall farther than the length of the rope, right? So the length of the fall can't be more than the length of the rope, right? 1/1 = maximum fall factor of **1**, right? Not, quite.

Actually, it IS possible for a climber to fall farther than the length of the rope. In a worst case situation, the climber can fall TWICE the length of the rope out. The diagram gives the classic example. Two climbers are hundreds of feet up a cliff face. The lead climber leaves the belay and climbs 10 feet above his anchored belayer. When he falls, he falls not only the 10 feet he climbed above his belayer, but continues to fall another 10 feet until the rope comes taught. Though he climbed only 10 feet, he falls 20 feet.



Fall Factor = 2

Fall factor = length of fall / length of rope

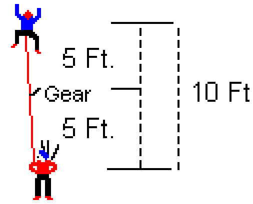
Fall factor = 20 feet of fall / 10 feet of rope

Fall factor = 2

Reducing the fall factor

Big fall factors are bad! They indicate tremendous forces in the system which may lead to failure of one of the components. Remember, the climber and belayer are both components and will absorb some of the forces. In the situation diagrammed above, if the anchor fails, both climber and belayer plummet to the ground. Learn to recognize situations with high fall forces especially if your anchors or gear placements are less than ideal.

The simplest way to reduce the fall factor is to reduce the distance of the fall by placing gear. If the lead climber is able to place a piece of gear once he has climbed 5 feet, then falls once he has climbed 10 feet above the belayer, he will fall only 10 feet (hello belayer) instead of 20 feet. The fall factor is now 1.



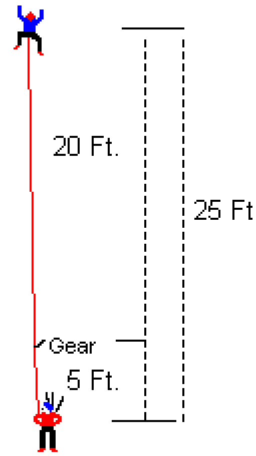
Fall Factor = 1

Fall factor = length of fall / length of rope

Fall factor = 10 feet of fall / 10 feet of rope

Fall factor = 1

By placing a single piece of gear, most of the forces are now removed from the critical belay anchor securing the climbers to the cliff.



Fall factor = 1.6

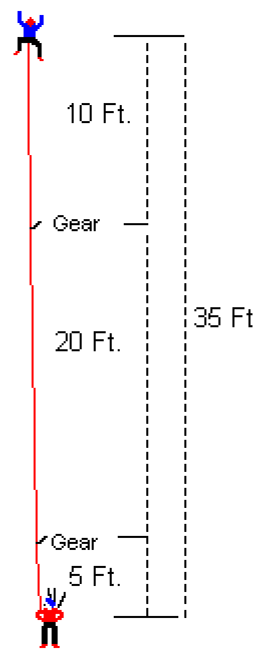
Placing that single piece of gear has a surprisingly big effect on reducing the forces in the system. Even if the lead climber continues 20 feet above the piece of gear placed 5 feet from the belayer, then falls, the forces are reduced. Of course, the climber is going to take a 40 foot fall. Let's hope he doesn't hit the belayer on the way down!

Fall factor = length of fall / length of rope

Fall factor = 40 feet of fall / 25 feet of rope

Fall factor = 1.6

We're lucky enough in this instance that the climber was able to place one bomber solid piece of gear to catch him. It took a tremendous amount of force, enough to rip out many of your smaller pieces of protection or even break the rock it was placed in.



Fall factor = 0.57

Assuming our climber was lucky enough to get a second solid piece of gear in 25 feet above his belayer, we can look at how a 20 foot fall now affects the system. Our lead climber continues above the second piece of protection for another 10 feet, then has the misfortune of peeling off the rock. He falls 20 feet - the 10 feet he was above the last anchor plus the 10 feet of slack in the rope once he falls to the level of the last piece of protection. In this instance the fall factor is 0.57.

Fall factor = length of fall / length of rope

Fall factor = 20 feet of fall / 35 feet of rope

Fall factor = 0.57

The good news for the belayer is the climber is not going to fall onto him. He is also going to experience less force from the fall. The top piece of protection still takes a tremendous amount of force.

It is clear now that the amount of rope out has a great effect on the fall factor (and the forces on the components of the system). In our first example, the climber took a 20 foot fall resulting in a factor 2. In this case our climber took a 20 foot fall resulting in a factor of 0.57. Even when the climber took a 40 foot fall, because he had placed gear, the fall factor was reduced to 1.6. This is so because of the increased length of the rope in use. It is the reason climbers use specifically designed dynamic climbing ropes.

Rule: Place gear frequently in the early part of the climb when there is only a short amount of rope out.

Another technique for reducing the forces in a fall is to incorporate a dynamic belay. Rather than belaying directly off an anchor, incorporate the belayers body weight in the system so there is some movement when the forces come to bear. Allowing a small amount of rope slippage through the belay device is a practiced art that also cushions the shock.

Dynamic Ropes and Fall Factors

The shock load resulting from a fall in a climbing system is the result of three factors; the energy absorbing (stretch) characteristics of the rope, the fall factor, and the weight of the falling climber. The amount of stretch designed into in dynamic climbing ropes varies from about 6 - 10 percent. The climbing industry (U.I.A.A.) has set standards of the amount of force a climbing rope must absorb.

According to the International Mountaineering and Climbing Federation (**U**nion **I**nternationale Des **A**ssociations Des **A**lpinism) a dynamic climbing rope must be designed to absorb enough energy so that the maximum force on an 80 kg. (180 lb.) climber in a factor 2 fall is not more than 12 kn. (2698 lb.) All of the other components in the climbing system (climbing gear) are designed to function with these levels of force. It is the design of dynamic climbing ropes which limit the force the climber experiences.

Knowing this we can draw several conclusions:

Do not use static ropes for climbing. Static ropes stretch very little at all (0.5 to 1.5 percent or less). Forces generated in a climbing system can quickly exceed factor 2 if a static rope is used, causing grave (deadly) injuries to the climber and generating forces in the system which exceed the strength of the gear used. (a fall of as little as 4 feet on a static rope can create enough shock load to cause injury, death, or failure of climbing gear). A static rope may be used (cautiously) in a top rope system or a gym where falls are measured only in inches, but not in the system used for lead climbing.

The more rope out in the system, the more gradually the energy can be absorbed. For example, if a rope with 10 percent stretch is 10 feet long, it will have 1 foot of stretch to absorb the energy of a fall. However, if 100 feet of rope are in play, the shock will be absorbed by stretching 10 feet. Surprisingly high forces can be generated in our first example where the climber was just leaving the belay with just a small amount of rope in use. We see in later examples that the fall factor reduces dramatically as the amount of rope in use increases.

Particularly burly climbers need to make allowances. The system is designed for an 80 kg. (180 lb.) climber. If you weight considerably more than this, or are carrying a heavy pack, you will need to take the additional forces generated into account. Place more gear, and place it closer together. Build your anchors stronger or double them up whenever possible.

Additional Comments

Our first example of a factor 2 fall should raise some concerns. Anchor failure in this situation is mostly likely fatal to both the climber and belayer. It is good practice to set up a second anchor in addition to the main anchor when belaying a leader who is climbing above. At minimum, run the rope through one bomber piece of protection separate from the main anchor before the lead climber departs. The leader should also try to place a good piece of gear as soon as possible above the belayer.

In our example, there was a good chance the lead climber would fall onto the belayer. This situation should be avoided whenever possible. You can build the main anchor to one side of the route (good practice), or the climber can try to stay to one side of the belayer until enough gear has been placed to protect him from a fall. The climber must think not only of protecting himself, but also protecting his belayer while he climbs above him.