Chapter 10: Principles of Rigging

Chapter Overview

An understanding of engineering principles is not required in order to become a good rescue rigger. However, a basic understanding of engineering principles and forces as they apply to rope rescue systems is beneficial. Being able to differentiate between key, closely related concepts (e.g., weight and mass) and apply that knowledge to rope rescue is also key.

With this information, a rescuer can build an effective rope rescue system and make adjustments as need to ensure the safety of everyone involved as well as the integrity of the equipment. Various systems and equipment have been developed to address the specific forces and principles at work in rope rescue activities. Familiarity with these systems will help rescuers to make informed decisions when selecting equipment for a particular operation or environment.

Objectives and Resources

**Knowledge Objectives**

After studying this chapter, you should be able to:

 Understand the principles of rigging. (NFPA 1006: 5.2.5, 5.2.7, pp. 185–191)

 Explain the relationship of angles to forces. (NFPA 1006: 5.2.6, pp. 186–187)

 Describe the purpose and types of edge protection. (NFPA 1006: 5.2.8, pp. 188–191)

 Describe how to calculate expected loads in a rope rescue system. (NFPA 1006: 5.2.5, 5.2.6, 5.2.22, 5.2.23, pp. 191–192)

 Describe the factors that influence the integrity of a rope rescue system. (NFPA 1006: 5.2.6, pp .192–194)

 Describe how static loads differ from dynamic loads. (NFPA 1006: 5.2.6, p. 192)

 Understand when a belay is appropriate, and why. (NFPA 1006: 5.2.9, pp. 192–193)

 Describe the purpose of dual-tensioned systems. (pp. 192–193)

 Understand the methods for reducing force to system components. (NFPA 1006: 5.2.17, p. 194)

**Skill Objectives**

After studying this chapter, you should be able to:

 Identify rope rescue system priorities based on anticipated forces. (NFPA 1006: 5.2.9, p. 194)

Support Materials

 Dry-erase board and markers or chalkboard and chalk

 LCD projector, slide projector, overhead projector, and projection screen

 PowerPoint presentation or slides

 **Navigate for Students**

 **Advantage**

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Reading and Preparation

Review all instructional materials, including *Rope Rescue: Principles and Practice,* Fifth Edition, Chapter 10, and all related presentation support materials.

Chapter Presentation Overview

Pre-lecture

I. You Are the Rescuer

Small-Group Activity/Discussion

Purpose

The purpose of this activity is to introduce students to concepts surrounding the understanding and management of water rescue incidents.

Instructor Directions

1. Direct students to read the “You Are the Rescuer” scenario found at the beginning of Chapter 10 (p. 184).

2. You may assign students to a partner or a group. Direct them to review the discussion questions at the end of the scenario and prepare a response to each question. Facilitate a class dialogue centered on the discussion questions.

3. You may also assign this as an activity and ask students to turn in their comments on a separate sheet of paper.

Lecture

I. Introduction

A. Review the learning objectives

B. Building good rescue systems requires an underlying ability to analyze the physical properties of equipment and the manner in which it is used together, and the influence that motion, energy, and other factors will have on forces during the operation of the system.

C. While the principles we will discuss here are commonly used and understood in engineering, one need not be an engineer to be a good rescue rigger.

D. Rope systems used to effect a rescue are usually called a rope rescue system; whether fixed or moving, it should be rigged a sufficient distance back from the edge so that the rescuer has a safe zone in which to operate.

E. Slow is smooth; smooth is fast.

1. This mantra from military marksmanship emphasizes that rushing in a reckless manner is much riskier than slow, careful, and deliberate actions.

2. Organization, discipline, and training are all crucial the success of rope rescue operations.

II. Principles

**A. Force**

1. Force is the push or pull an object experiences as a result of its interaction with another object or external influence. Intuitively:

a. Force is relative to an interaction between two objects or between an object and an external influence such as gravity.

b. Force can only exist in relationship; it exists only as a result of an interaction. As soon as the interaction stops, the force also stops.

2. Mass and weight

a. Mass is the amount of material in an object, while weight is the effect of gravity attracting two masses. The confusion between mass and weight provides a strong reason to use metric units rather than imperial units when calculating forces.

b. Although mass and weight are not the same thing, we can somewhat use them interchangeably for objects near the Earth’s surface.

3. Gravity

a. Mass is independent of gravity, which, in and of itself, technically not a force but a phenomenon that pulls physical objects toward one another. It is only when an object (say, a rescuer) is pulled toward the earth by this phenomenon that the concept of force becomes relevant.

b. Gravity pulls an object toward the Earth at a constant rate. The force exerted on an object is a result of the attractive force between the Earth and that object.

c. The resulting force for objects near the Earth’s surface can be calculated using the equation: gravity force (or weight) = 9.8 newtons (N) / kilogram (kg) \* mass of an object (kg).

d. Although it is an invisible influence, the predictability of gravity makes it a concept that we can use to our advantage. With gravity pulling objects toward the Earth at a constant rate, we can know that a rescue load dangling from the end of a rope will create predictable tension in the system unless some other force acts upon it to change it.

4. Other influences on our systems may come through direct contact – for example, a tensioned rope used to pull a load, or friction between objects.

a. These are more variable influences and more difficult to predict, but no less important to the analysis of force on rescue systems.

b. The magnitude and direction of the applied force will determine if, how much, and where the rescue load moves.

i. When we use a tensioned rope to pull a load upward, the constant force of gravity is pulling the load toward the center of the Earth.

ii. The load moves against the force of gravity in the direction exerted by the countering force of the rope. As we pull harder on the rope (with greater magnitude), the load will move faster.

5. Weight versus mass: units of measure

a. Precise measurements require a distinction between weight and mass.

i. Pounds and kilograms are measurements of weight.

b. An accurate measurement of force is expressed in newtons.

i. A newton (N) is the unit of force required to accelerate a mass of 1 kilogram 1 meter per second.

ii. The impact loads on rope and the breaking strength of equipment are usually expressed in kilonewtons (kN); in the English system, this is expressed in pounds/force (lbf).

c. Major organizations that set standards for high-angle rescue use the International System of Units (SI). Equivalents are as follows:

i. 1 newton = 0.225 lbf

ii. 1 kN (1000 newtons) = 225 lbf

6. Tip: International System of Units (SI)

a. This text was written in the United States, where the English system of measurement (e.g., pounds, quarts) is commonly used.

b. To make the information more accessible to readers outside the United States, equivalent measurements in the International System of Units (SI) have been included.

i. In some cases, the SI units are approximate conversions from the English system.

**B. Vector**

1. Vector collectively refers to direction and magnitude of a given force.

a. Direction is a familiar term, and magnitude is a term that refers to how strong the influence is; it is measured as a result of the angle of the force with respect to a directional reference and the amount of force.

b. With this in mind, the force vector of a system pulling on a floor-mounted anchor might be measured as a result of its direction of pull relative to the floor and the magnitude of the pull. Together, the direction and magnitude of a given force are referred to as a vector.

2. Every force has magnitude and direction, so a vector is associated with every force.

a. This is an important principle, because some rescuers tend toward using the term only in complex rigging, such as with high directional.

b. By grasping and using the concept of vectors in everyday rigging, the principle becomes clearer even as rigging becomes more complex.

3. For every rope rescue system, rescuers should always ask themselves, “What vectors (i.e., force magnitude and direction) are acting on the system at any given time?”

a. By addressing this question directly, rescuers can rig systems to intentionally incorporate forces that influence, mitigate, or even counteract other forces, to ultimately achieve our rescue goals.

b. For example, a load may be transported across a chasm by attaching it to a horizontally rigged rope, known as a highline.

i. In this system, the vector induced by gravity is countered by vectors induced by the rope on the two anchors opposite one another.

ii. For the system to be ultimately useful, however, we must induce yet another force vector, in the form of a haul line to pull the load across the highline.

**C. Resultant**

1. The term resultant has come into vogue in rescue circles to describe the concept of multiple vectors that occur as a result of, or as a part of, complex rigging.

a. In truth, there is a resultant any time that multiple vectors interact with one another, even if it is in a straight line.

b. Just as every force has direction and magnitude (i.e., every force is a vector) so also every combination of vectors has a resultant.

2. In a straight-line system, the net force exerted on an object is the result of adding all the force vectors acting upon it.

a. The sum of all the forces (vectors) is called the resultant.

**D. Angles in rescue systems**

1. Angle is the measure of the difference in direction between two lines as measured at the intersection of the two line segments.

2. In rope rescue, we are most concerned with the point(s) at which two vectors meet; this occurs where a rope is terminated, such as in anchors, or bent, such as around a pulley.

a. Although an angle is not, itself, a force, angles do change the direction in which a force is being exerted – which, in turn, creates a new vector.

b. Wherever two vectors interact, a new resultant vector is created.

c. Rescuers must be capable of analyzing the direction and magnitude of forces as they change and evolve during use of a rope rescue system.

d. Properly managed, angles can be an asset in a rope rescue system as they are used to redirect the path of a rescue load, create mechanical advantage, distribute loads in an anchor system, etc.

3. When two vectors interact at an angle to one another, the direction and magnitude of each of those vectors will change.

a. Also, simply by acting upon one another, these two vectors will create a new vector of some magnitude acting in some direction.

4. Consider a lowering system where the rope path follows a straight line from anchor to load. Should this straight-line path prove inconvenient or hazardous, it may become necessary to offset the direction of travel by inserting a pulley at some point part way down the line.

a. The rope above the pulley, between it and the anchor, will have one vector; the rope below the pulley, between it and the load, will have a second vector; and the pull created by these two vectors upon the pulley itself will result in yet another vector.

b. Each vector affects the other vector(s) in the same system, causing the direction and magnitude of the original vectors to change.

**E. Tension**

1. Tension is the stress in a system or system component due to transmitted forces that pull in equal and opposite directions.

a. Tension is created in the rope or other system components by the forces at each end as they act in opposition to one another.

b. The magnitude of tension is equal to the mass of the object multiplied by gravitational force, plus or minus any acceleration forces that are also acting on the object.

2. When an object is supported (at rest) by a rope, the tension in the rope is equal to the weight of the object. Likewise, in an anchored system, tension is applied equally and opposite longitudinally along the rope.

a. For this reason, parts of a system such as rope, webbing, and other similar equipment are sometimes referred to as tension members.

b. Tension may be applied in multiple directions by different systems at the same time.

3. Compression is a type of transmitted force, in this case referring to the inward or pushing forces that something exerts on another object or structure; the opposite of tension.

4. Compression, like tension, is the result of opposing forces.

a. While it may not seem at face value that we deal with many compressive forces in rescue, the fact is that compression does play a part in rescue systems.

5. Compression may be found in a rope rescue system where a tripod anchorage is supported by the ground, or where an edge roller is pressed into an edge by a rope under tension.

**F. Friction**

1. Friction is an object’s resistance to movement.

2. Friction is calculated by a mathematical formula that takes into account the force that is resisting the motion and the force that is pressing the objects together.

a. The amount of force that it takes to overcome an object at rest and initiate movement determines the static coefficient of friction.

b. The resistance to continued motion while the object is moving determines the dynamic (kinetic) coefficient of friction.

c. In a rescue system, these values will depend upon the characteristics of the contact surfaces (material, roughness, moisture) and how firmly the rope is pressed against the surface (i.e., weight.) If there is a lot of friction, the load will be harder to drag and more susceptible to damage.

d. A rope rescuer may not need to calculate the coefficient of friction, but should understand the concepts and recognize the effects that friction may have on rigging systems.

3. In rope rescue operations, friction occurs between the rescue load and all of the surfaces with which it comes in contact, between the rope and everything it touches, and between the rescuers and the surfaces with which they come into contact.

a. In such cases, there is a combination of forces at play: friction, compression, and tension.

4. When planned for, the addition of friction to a system can contribute positively to an operation. When not planned for, friction can make the work more difficult or even create hazards and jeopardize the operation.

a. Generally speaking, friction works for us when lowering a load and works against us when raising a load. As a rule of thumb, friction can be assumed to amplify the effects of a load by a factor of about 2.5.

**G. Edge protection**

1. Rope should be protected any time it goes over potentially damaging edge.

a. Every person and every team that plans to use rope should carry equipment for preventing edge abrasion.

2. Among the simplest and least expensive means of protecting rope from abrasion; they work best for fixed ropes, such as rappel lines.

3. Heavy-duty canvas pads

a. Natural fiber canvas (e.g., such as cotton); preferred where there is a chance that the pad may be used with moving rope because synthetic fibers are prone to melting due to heat generated by frictional forces

b. Twice folded squares of heavy-duty cotton canvas; the squares are stitched around the edge to prevent fraying, and then cross-stitched. Gromets might be added.

4. Sections of discarded fire hose

a. In the past, most fire hoses were made of a cotton jacket over a rubber core.

b. By slitting the fire hose lengthwise, a secure pad could be devised where the rubber interior could be laid directly against the surface to be covered, with limited slip, and the rope could be run over the cotton jacket side.

c. Synthetic fibers such as nylon and polyester have replaced cotton as the material of choice for fire hose jackets. Even synthetic fire hose makes a decent rope sleeve for stationary rope.

5. Rope sleeve

a. To make a firehose rope sleeve, follow these steps:

i. Split the hose down the center.

ii. To prevent the rope from slipping out, secure the edges of the hose with a closure such as snaps or Velcro.

iii. Set a hole or grommet in each end of the fire hose so that it can be anchored to prevent it from slipping down the rope.

iv. This type of protector is also available commercially, often made of ballistic cloth or other fabric, or even metal.

v. A rope sleeve is designed to wrap completely around the rope, and as such is primarily intended for use with stationary ropes.

vi. Those made of fabric are typically designed to be secured in place with a hook-and-loop or other closure, and may also have grommets and a small cord to anchor the sleeve to the host line.

vii. This type of protection is especially useful where a rope comes into contact with an abrasive or potentially damaging structure midline.

6. Plastic edge pad

a. Plastic edge protectors are not as flexible as fabric, but they do tend to conform at least somewhat to the protected surface, and also provide more durable protection.

b. Most plastic edge protectors may be used with either stationary or moving ropes.

c. Some plastic edge protectors are designed to be modular.

7. Aluminum edge guard

a. These are an excellent choice for either stationary or moving ropes and are available in various designs to either conform to a variable surface, or to effectively protect a 90-degree edge.

b. Most have moving rollers along the rope path (although some are fixed).

c. All edge guards must be affixed in place to prevent them from moving or from being dropped during a rescue.

8. Metallic edge rollers

a. Efficient and effective means of reducing the friction of rope over an edge.

b. Disadvantages

i. Some edge rollers may tip over if they are not anchored carefully.

ii. They usually are more expensive than soft protection.

c. Single-unit rollers

i. Two rollers are set into a frame.

ii. Two or more of these units usually are needed to provide adequate edge protection; they generally must be stabilized by anchoring them with their attachment points.

iii. When they are stabilized, these units perform well on irregular surfaces, such as cliffs and other natural conformations.

iv. One particularly versatile edge roller design is composed of three linked units consisting of hard aluminum side plates with two roller bars each.

(i) It can be linked together with the furnished screw links at sharp edges or separated for long, gradual breakovers.

d. Roof roller

i. Specifically designed to excel in protecting a sharp edge, and consists of a unit of two rollers set in a 90-degree frame

ii. They work best on buildings and other structures where 90-degree angles are present.

e. Roll module

i. Has rollers on the sides as well as the bottom, so that if the module tips over, it still offers protection

ii. The four modules are linked with screw links and can conform to a variety of surfaces.

f. Commercial, purpose-built rope protection devices are now the choice of many professionals.

i. While either edge pads or rollers may be used for protecting nonmoving ropes, for systems where ropes are being dragged over an edge, rollers are the better choice.

9. If no premade edge pad is available, other materials may be pressed into service to protect the rope from abrasion. Some examples of improvised rope pads are as follows:

a. Packs

b. Turnout coats

c. Clothing

d. Blankets

e. Carpet squares (wool or natural fiber)

10. Artificial high directionals are another type of device that can help protect ropes from edge abrasion.

III. Fall Line

**A. Fall line can be described as the path a ball would follow when rolling down an incline.**

1. It is influenced by factors such as gravity, friction, and obstacles, and it plays an important role in what directional forces are imparted on the rope rescue system.

**B. Successful rope rescue rigging takes into account the expected fall line when rigging anchors and planning the load path, as the direction of pull is such an important part of vectors influencing the system (as discussed earlier in this chapter).**

**C. Putting it together**

1. The principles addressed in this chapter are foundational to analyzing and evaluating rope rescue systems.

2. An operations-level rope rescuer should be capable of using and applying these principles to analyze rescue systems at a glance, at least for obvious errors and concerns.

IV. Safety Factors

**A. It is imperative that rope rescuers can identify the weakest point in a rope rescue system and analyze it against the maximum anticipated load at that point.**

**B. The rope rescuer must be able to scrutinize force multipliers both within and on the system and adapt rigging methods accordingly – whether by using a different knot, changing direction of pull, using different equipment, etc.**

1. Load ratio is a term used to express the difference between the strength of something and the anticipated load that is expected to be placed on it.

2. System safety factor is the ratio between the breaking strength of the weakest point of a rope rescue system as compared with the maximum anticipated load at that point.

a. A system safety factor may be calculated using the formula, S / L, where S = Strength of the weakest point in the system and L = Maximum anticipated load.

**C. The load ratio that represents the system safety factor may be different from the load ratio that represents a component safety factor. Consider the following example:**

1. The strength of an NFPA 1983 G–rated rope must be at least 40 kN (8992 lbf). The difference between this and the commonly accepted rescue load of 600 lbf (2.66 kN) is a factor of about 15:1 (15 \* 600 = 9000 lbf [2.66 = 40.03 kN]). We would refer to this as a component safety factor.

2. However, when we tie a figure-eight knot in the rope, it can reduce the strength of the rope by as much as 30 percent, bringing the 9000-lbf (40.03 kN) rope strength down to around 6300 lbf (2.66 kN). If this is determined to be the weakest point in the system, the static system safety factor as measured against that 600-pound (272 kg) load would be more like 10.5:1.

3. Ideally, your safety factor should take into consideration the highest potential force on the system at that point, not just the weight of the load.

4. During operation of the rope rescue system, the forces exerted can be significantly higher than the weight of the load, particularly in the event of a failure.

**D. The safety factor should be a prime consideration when constructing a rope rescue system. In order to ensure the safety factor, the rope rescue system should be constructed to absorb a force greater than anticipated.**

V. Rope Systems

**A. Rope rescue system is a rope system used to affect a rescue.**

**B. Fixed rope rescue system**

1. In this system, the ropes do not move (or are stationary); ropes are anchored in place and rescuers use the ropes for ascending or descending.

2. A fixed rope rescue system should be anchored in place, with the anchor a sufficient distance back from the edge so that the rescuer has a safe zone in which to access the rope for rigging and derigging their descending or ascending system.

3. Only one user at a time should access a fixed rope system, but these types of systems can be an excellent choice for providing rescuers access to and from a rescue site.

**C. Rope techniques**

1. Single rope technique (SRT) – all attachments are made on a single rope.

2. Dual rope systems – access equipment is used on one rope and backup/safety equipment is attached to another.

3. Both types of systems are viable, appropriate systems, and should be selected with consideration given to the level of training and skills of personnel, system goals/performance, as well as probability of equipment failure.

**D. Moving rope systems**

1. Moving rope systems are dynamic systems in which rope is used to lower or raise a load.

2. This is the type of system most often used to effect a rescue, as subjects are generally unable to ascend/descend fixed rope as previously described.

3. When using a moving rope system, a second system is usually employed as a belay. Sometimes a moving rope system is used as a belay for a person who is moving along the ground or on a fixed rope system.

**E. Dual-tensioned rope systems (DTRS)**

1. A foundational concept of any rope rescue system is that the failure of any one point does not result in catastrophic failure. In other words, the system should be redundant.

2. There are several ways a system can be made redundant.

a. Backup belay system

b. Two separate lowering lines, each sharing a portion of the load but at the same time each backing up the other

**F. Two-tensioned rescue system (TTRS)**

1. Technique in which two virtually identical systems are employed and simultaneously weighted, has become especially prevalent in recent years due to the advent of autolocking braking devices that may be used for either lowering or backup.

a. Some TTRS rescue systems use two ropes running through one braking device, such as a brake tube or braking/belay device.

b. Other systems use two brakes, each controlling a rope attached to the rescue load.

i. In such cases, the two-brake systems are designed so that each lowering device backs up the other. In essence, each braking device belays for the other one.

2. Advantages

a. Do not require special equipment solely for the belay

b. The roles of brake person and belayer require the same skills and can be interchanged easily.

c. Usually do not accidentally engage and hang up

d. Do not require load-releasing hitches

e. Provide a soft catch

f. Predictable in the way they will perform

3. Disadvantages

a. Operation of the two lines must be well coordinated.

b. With certain devices, there may also be difficulty with changing direction suddenly from lowering to hauling.

4. The TTRS may be operated using any descent device that is also capable of being used as a belay.

5. In general, considerations for evaluating a multifunction device include the following:

a. Load range/maximum rated load

b. Ease of use

c. Smooth transition during initial release of heavy load

d. Ease of transition from lower to raise (and vice versa)

e. Whether additional friction is required for heavy loads

f. Effective function as a progress capture

VI. Optimizing Force

**A. The ongoing analytical assessment of force is a necessary part of every rescue system.**

**B. By understanding that force is a vector that has both direction and magnitude, and by understanding external influences such as friction, angles, fall line, and multiple vectors acting upon one another, the rescuer is better prepared to determine which of these should best be adjusted to achieve the desired result within the parameters of appropriate safety factors.**

VII. Summary

 **Rescuers should have a firm grasp on the concepts of forces and how they relate to one another in a rope system before trying to execute a rope rescue.**

 **Vector refers collectively to the direction and magnitude of a given force. Together, the direction and magnitude of a given force are referred to as a vector.**

 **Every force has magnitude and direction, so a vector is associated with every force.**

 **Just as every force has direction and magnitude (i.e., every force is a vector) so also every combination of vectors has a resultant.**

 **An angle is the measure of the difference in direction between two lines as measured at the intersection of the two line segments. In rope rescue, we are most concerned with the point(s) at which two vectors meet.**

 **Tension is created in the rope or other system components by the forces at each end as they act in opposition to one another. The magnitude of tension is equal to the mass of the object multiplied by gravitational force, plus or minus any acceleration forces that are also acting on the object.**

 **Friction is an object’s resistance to movement. For example, when a rope is dragged over the edge of a rocky cliff, there will be frictional force on the rope where it comes into contact with the rock, in a direction opposite the motion.**

 **The fall line can be described as the path a ball would follow when rolling down an incline.**

 **It is imperative that rope rescuers can identify the weakest point in a rope rescue system and analyze it against the maximum anticipated load at that point. The rope rescuer must be able to scrutinize force multipliers both within and on the system and adapt rigging methods accordingly, whether by using a different knot, changing direction of pull, using different equipment, etc.**

 **Some rescuers use single rope technique (SRT), where all attachments are made on a single rope.**

 **Others use dual rope systems, where access equipment is used on one rope and backup/safety equipment is attached to another.**

  **Both types of systems are viable, appropriate systems, and should be selected with consideration given to the level of training and skills of personnel, system goals/performance, as well as probability of equipment failure.**

Post-lecture

I. After-Action Review

Individual/Small-Group Activity/Discussion

On Scene

This activity is designed to help the student understanding how to approach a fire investigation. This activity incorporates both critical thinking and the application of basic trench rescue knowledge.

Purpose

To allow students an opportunity to develop responses to critical thinking questions.

Instructor Directions

1. Direct students to read the “On Scene” questions located in the After-Action Review section at the end of Chapter 10 (p. 195).

2. Direct students to read and individually answer the discussion questions. Allow approximately 10 minutes for this part of the activity. Facilitate a class review and discussion of the answers, allowing students to correct responses as needed.

3. You may also assign these as individual activities and ask students to turn in their comments on a separate piece of paper.

Answers

1. In a rope rescue lowering system with a long, sloping edge at the top, what effect will the edge have on the system?

The greater the amount of surface area in contact between rope and edge, the greater the amount of friction that would be imparted on the system. Therefore, the amount of force/load on the brake would be less than the weight of the load.

2. If the system described in #1 is converted to a raise, what effect will the edge have on the system?

The greater the amount of surface area in contact between rope and edge, the greater the amount of friction that would be imparted on the system. Therefore, the amount of force required to raise the load would be greater than the weight of the load.

3. What principles of physics should be considered when creating a rescue system?

Mass, force, weight, gravity, motion, and work

4. What considerations should be factored in to a decision of whether to use a fixed or moving system for access to a rescue subject?

- Whether it is best to lower/raise the load from above, or let the load control its own progress

- Best protection for the subject

- Number of resources/personnel available

- Level of training of available personnel

**5.** What are the advantages and disadvantages of a TTRS?

Advantages - Do not require special equipment solely for the belay; roles of brake person and belayer require the same skills/are interchangeable; usually do not accidentally engage and hang up; do not require load-releasing hitches; lower impact forces in the event that one fails; highly predictable.

Disadvantages - Operation of both lines must be well coordinated; redundancy may be limited, especially if operated by one brakeman; challenges associated with managing two devices simultaneously; may pose challenges with changing direction suddenly from lowering to hauling.

II. Lesson Review

Discussion

Note: Facilitate the review of this lesson’s major topics using the review questions as direct questions or slides. Answers are found throughout this lesson plan.

1. Explain the differences between mass and weight. (Lecture II A)

2. Define vector. (Lecture II B)

3. Identify different types of pads that can be used as edge protection. (Lecture II G)

4. Identify the key principles related to rope systems. (Lecture II A–G)

5. What factors influence a fall line? (Lecture III A)

6. Define *load ratio.* (Lecture IV B)

7. Identify the types of rope rescue systems. (Lecture V B–F)

8. What methods can be used to make a system redundant in a DTRS system? (Lecture V E)

9. Describe a TTRS. (Lecture V F)

10. What are the advantages of TTRS rescue systems? (Lecture V F)

III. Assignments

Lecture

A. Advise students to review materials for a quiz (determine the date/time).

B. Direct students to read the next chapter in *Rope Rescue: Principles and Practice,* Fifth Edition, as listed in your syllabus (or reading assignment sheet) to prepare for the next class session.