INSTRUCTOR GUIDE

TOPIC: MECHANICAL ADVANTAGE SYSTEMS

LEVEL OF INSTRUCTION:

TIME REQUIRED: THREE HOURS

MATERIALS: ROPE, WEBBING, HARNESSES, CARABINERS, FIGURE EIGHTS, ASCENDERS, PULLEYS, PRUSSIC CORDS, SLINGS, PICKETS, SLEDGE HAMMER

REFERENCES: RESCUE TECHNICIAN, MARYLAND FIRE AND RESCUE INSTITUTE, MOSBY

==========

PREPARATION:

MOTIVATION:

There may be occasions when a fire department is called upon to perform a rescue involving a heavy load or removal of a victim from above or below ground. Mechanical advantage systems increase the lifting capability of on-scene personnel.

OBJECTIVE (SPO):

The student will demonstrate a basic understanding of the use of rope and rope accessories to construct mechanical advantage systems through participation in class discussions and practical activities.

OVERVIEW:

<u>Mechanical Advantage Systems</u>

* Rope Software and Hardware
* Anchor Points and Use
* Constructing Mechanical Advantage Systems
* Practical Activity

MECHANICAL ADVANTAGE SYSTEMS

SPO	The student will demonstrate a basic understanding of the use of rope and rope accessories to construct mechanical advantage systems through participation in class discussions and practical activities.
EO 1-1	Demonstrate an understanding of software and hardware used with rope in rescue.
EO 1-2	Demonstrate an understanding of anchoring points and the various means of securing to them.
EO 1-3	Demonstrate an understanding of mechanical advantage systems such as the Z-rig and the piggyback Z-rig.
EO 1-4	Demonstrate using anchor points and constructing a mechanical advantage system.

Before beginning the material in this drill, it may be worthwhile to review basic knots and rope terminology so that the skills can be performed.

I. ROPE SOFTWARE AND HARDWARE (1-1)

A. Webbing

1. Flat or tubular
2. Used in place of or with rope
3. Ends connected together using a water knot (overhaul knot reweave) to form a loop
4. Strength

    a. 1-inch - 4,500 lbs. tensile strength
    b. 2-inch - 6,000 lbs. tensile strength

B. Harnesses

1. Constructed of sewn webbing
2. Worn by rescuers during certain rescues
3. Types

    a. NFPA/ANSI Class I - seat-style for emergency escape
    b. NFPA Class II/ANSI Class IV - seat-style for rescue
    c. NFPA/ANSI Class III - full body
    d. ANSI Class IV - sit

NOTE: Only full body harnesses should be used when there is any likelihood that the rescuer will be turned upside down.

C. Carabiners

1. Constructed of steel or aluminum
2. Used for connecting rope or webbing to objects or other pieces of rope or webbing
3. Types

    . Steel - 6,700 lbs. tensile strength
    . Aluminum - 5,500 lbs. tensile strength

D. Figure Eights

1. Constructed of aluminum
2. Used for descent control or equipment collection (attaching several carabiners)
3. 20,000 lbs. tensile strength

E. Ascenders

1. Constructed of aluminum
2. Used for descent control or as part of a mechanical advantage system
3. 2,500 lbs. tensile strength

NOTE: Caution students that most manufacturers do not allow ascenders to be used in systems with loads over 1,000 lbs.

F. Pulleys

1. Constructed of aluminum
2. Used as part of a mechanical advantage system or to change direction of pull
3. May be single pulley or multiple pulleys

G. Prussic cords

1. Formed using 7/16-inch kernmantle rope
2. End connected together using double fisherman knot
3. Used in place of ascenders to control descent or as part of a mechanical advantage system
4. Attached to a rope by wrapping one loop inside the other two or three times while keeping the knot to the side
5. Loops may be of varied lengths

H. Slings

1. Formed from nylon webbing with end generally sewn to form eyes
2. Used to secure rope to anchor point or object being moved

II. ANCHOR POINTS AND USE (1-2)

A. Selection of Anchor Points

1. Fixed objects such as large rocks or trees or similar sturdy objects
2. Building components such as structure supports or heavy equipment mountings
3. Apparatus (sturdy components) such as steamer connections, chassis, or tow hooks
4. Picket systems

. One-inch steel
. Four-inch hardwood or five-inch softwood
. Five feet long
. Three pickets are driven into the ground in a straight line in line with

load to be moved
- Pickets should be spaced at least three feet apart
- Pickets should be driven in approximately two-thirds of their length and at a 90-degree angle of the load
- Holdfast is formed by wrapping rope approximately 50 feet long between the top of the first picket and the bottom of the second picket with four to six wraps (finish off each end of the rope with a clove hitch)
- Wrapping is repeated between the second picket and third picket using a separate piece of rope
- Short object such as a piece of wood is inserted in the middle of the rope between the first and second pickets, three or four twists are made to tighten the rope, and the object is secured in the ground
- Picket tightening process is repeated between the second and third pickets
- Bottom portion of the first picket should be used as the anchor point
- Three-picket system will support about 4,000 pounds depending on the firmness of the soil

B. Anchoring to Objects

1. Single point
    a. Tying a knot or placing a sling or piece of webbing around a single object
    b. One method is to wrap the sling or piece of webbing formed in a loop around the anchor and connecting the two bights using a carabiner
    c. Second method is to wrap the piece of webbing around the anchor three times, connect the two ends together using a water knot, and pull two of the wraps and connect a carabiner to them (wrap three, pull two)
    d. Tensionless consists of wrapping a rope around an anchor point several times, placing a figure eight on a bight in the working end, attaching a carabiner to the knot, and placing the other end of the carabiner over the standing part of the rope
2. Multiple points
    a. Tying a sling or piece of webbing around multiple objects either in line or adjacent to one another
    b. Using three picket or trees in line with the second and third pickets or trees backing up the first
    c. Using pickets or trees adjacent to one another where a sling or piece of webbing formed in a loop can be placed around each object, a piece of webbing can be made into a loop and connected to the bights of the slings or webbing around the objects using carabiners, and a carabiner can be placed in the middle to the middle piece of webbing (this allows load sharing since the carabiner will slide in the direction of the load

NOTE: Instructor should review each method of anchoring using illustrations, demonstrations, or both.

III. CONSTRUCTING MECHANICAL ADVANTAGE SYSTEMS (1-3)

A. Constructing a Z-Rig

0. Lay the rope out in the shape of a "Z"
0. Determine which end of the rope will be attached to the load and which end will be used for hauling (pulling)
0. Place a pulley at each of the two bights in the rope
0. Attach an ascender or prussic cord to the rope near the load
0. Pull the pulley in the second bight to the ascender or prussic cord and connect the pulley to the ascender or prussic cord using a carabiner
0. Secure the pulley at the first bight to the anchor point using a carabiner to attach to the sling or webbing used at the anchor point
0. Attach an ascender or prussic cord between the first ascender or prussic cord and the first pulley but close to the pulley (this ascender or prussic cord serves as the brake for the system) NOTE: If ascenders are being used, make sure they facing the load as denoted by the arrow on the side
0. Connect the ascender or prussic cord to the sling or prussic cord at the anchor point using a carabiner (may require a longer prussic cord or a piece of webbing)
0. Stretch out the rope to make sure that nothing is twisted and the system is laid out properly
0. Make sure all carabiners are locked before applying any load
0. Additional pulleys and ascenders or prussic cords can be added to increase mechanical advantage (the system as outlined above produces a 3:1 mechanical advantage based on two pulleys and pulling (hauling) in the direction that the load is moving)
0. As the load is moved inward, the pulleys will be drawn closer together which requires setting the brake and moving the pulleys outward so that additional space is available on the rope to move the load
0. Load being moved outward should have the pulleys placed as close together as possible since they will be moved outward as the load moved; the brake may need to be set to move the pulleys closer

B. Constructing a Piggy-Back Z-rig

NOTE: A piggy-back system is used to apply mechanical advantage to a rope that is being used for hauling or lifting

1. Place a sling or piece of webbing around a secondary anchor point
2. Attach an ascender or prussic cord to the original hauling/lifting rope
3. Connect the ascender or prussic cord to the sling or piece of webbing using a carabiner (this will hold the original hauling/lifting line in place as well as a brake when the system needs to be adjusted)
4. Lay the rope out in the shape of a "Z"

5. Determine which end of the rope will be attached to the load and which end will be used for hauling (pulling)
6. Place a pulley at each of the two bights in the rope
7. Attach an ascender or prussic cord to the rope near where it is to be attached to the hauling/lifting rope
8. Pull the pulley in the second bight to the ascender or prussic cord and connect the pulley using a carabiner
9. Secure the pulley at the first bight to the sling or piece of webbing used at the anchor point using a carabiner
10. Attach an ascender or prussic cord between the first ascender or prussic cord and the first pulley but close to the pulley (this ascender or prussic cord serves as the brake for the system) NOTE: If ascenders are being used, make sure they facing the load as denoted by the arrow on the side
11. Connect the ascender or prussic cord to the sling or piece of webbing at the anchor point using a carabiner (may require a longer prussic cord or a piece of webbing)
12. Form a figure eight on a bight on the rope that is to be attached to the original rope
13. Attach the ascender or prussic cord to the original hauling/lifting rope
14. Connect the figure eight on a bight to the ascender or prussic cord on the original rope using a carabiner
15. Stretch out the rope to make sure that nothing is twisted and the system is laid out properly
16. Make sure that all carabiners are locked before applying any load
17. Additional pulleys and ascenders or prussic cords can be added to increase mechanical advantage (the system as outlined above produces a 3:1 mechanical advantage based on two pulleys and pulling (hauling) in the direction that the load is moving)
18. As the load is moved inward, the pulleys will be drawn closer together which requires setting the brake and moving the pulleys outward so that additional space is available on the rope to move the load
19. Load being moved outward should have the pulleys placed as close together as possible since they will be moved outward as the load moved; the brake may need to be set to move the pulleys closer

IV. PRACTICAL ACTIVITY (1-4)

A. Set up three practical skills stations with an evaluator at each station to observe skills proficiency. Divide the class evenly into three groups. The anchor points for Stations 2 and 3 should already be in place.

B. Station 1 - Knots and Anchoring to Objects

0 Have each student tie the following knots with safety knot

- Water knot
- Bowline
- Clove hitch
- Figure eight family - Figure eight on a bight, Figure eight reweave, and Figure eight bend

0 Have each student demonstrate the following methods of anchoring to an object

a. Single point with rope and webbing
b. Tensionless with rope
c. Multiple points

0 Have the students construct a three-picket system

NOTE: The knot tying and anchoring can be done in conjunction with one another.

C. Station 2 - Constructing a Z-Rig Mechanical Advantage System

1. Have the students construct a Z-rig system
2. Have the students use the Z-rig system to move an object inward and outward
3. Have the students add another pulley and see if less effort is required to move the object

D. Station 3 - Constructing a Piggy-Back Mechanical Advantage System

1. Have the students construct a piggy-back system
2. Have the students use the piggy-back system to move an object inward and outward
3. Have the students add another pulley and see if less effort is required to move the object

NOTE: All students are expected to perform all the practical skills to the satisfaction of the evaluators. Assistance should be provided when required.

REVIEW:

Mechanical Advantage Systems

* Rope Software and Hardware
* Anchor Points and Use
* Constructing Mechanical Advantage Systems
* Practical Activity

REMOTIVATION: Knowing how to quickly and efficiently construct a mechanical advantage system will result in less physical effort required as well as speed up the work process.

ASSIGNMENT:

==========

EVALUATION:

All students are expected to perform all the practical skills to the satisfaction of the evaluators. Assistance should be provided when required.