CONSTRUCTION OPERATIONS AND METHODS

LIFTING AND RIGGING

→ A crane is designed to lift a load by using ropes or chains. The load must be properly attached using a rigging system.

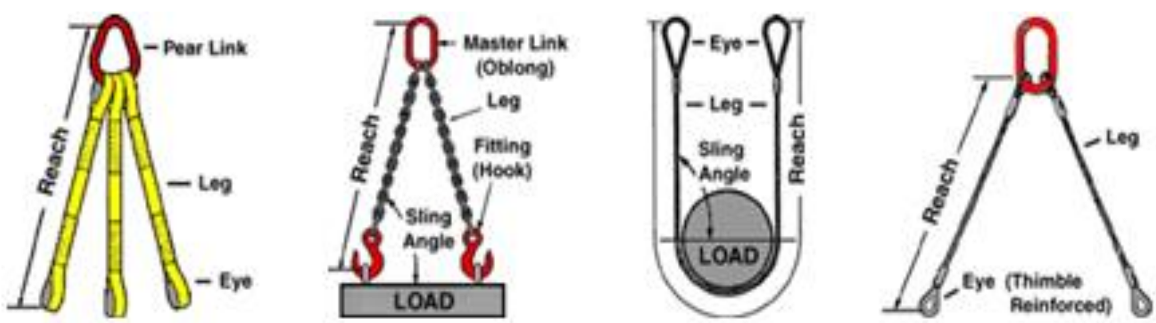
→ There will definitely be a couple questions on the PE exam about lifting and rigging so make sure to do multiple practice questions.

→ For further detailed information download the **Hoisting and Rigging Fundamentals, BEST RIGGING PRACTICES IN LIFTING OPERATIONS,** http://www.learncivilengineering.com/free-engineering-manuals/free-construction-engineering-manuals/

→Below are the things you need to know about Lifting and Rigging;

1. Basic Terms and Equipment used.
2. Basic Rig Planning
3. Weight of all objects being lifted
4. How to Determine the Center of Gravity of the objects being lifted
5. How to figure out the stresses on the rigging system.
6. Basic safety information for lifts

BASIC TERMS AND EQUIPMENT



<u>Sling</u> – an assembly which connects the load to the lifting equipment
<u>Eye</u> – a fabricated loop, normally at the end of a sling, used as an attachment or choke point.
<u>Leg</u> – the extending portion of a sling used in a basket hitch or one extension of a sling with multiple parts
<u>Reach</u> – the working length of a lifting sling when pulled taut. It is measure from the load bearing point at one end of the sling, to the load bearing point at the opposite end.(exeption: wire rope sling)
<u>Hitch</u> – the way the sling is fastened to or around a load.
<u>Headroom</u> – clearance above the load to allow for an unobstructed lift.
<u>Sling Angle</u> – the horizontal angle between a sling (or sling leg) and the load, when pulled taut.
<u>Working Load limit (Rated Capacity)</u> – the maximum static load permitted by the manufacturer.

BASIC PLANNING

→No matter what kind of sling you choose, there are certain common elements you will need to consider to plan a safe and effective lift:

1. Weight of the Load – You will need to know or estimate accurately the weight of the load to ensure a safe lift.

2. Type of hitch and number of slings or legs – Consider the solad's size and shape, load control (balance, slippage), attachment points, and any fittings that will be needed to connect the sling to the lifting device or the load. Loads should be lifted from a point directly over the center of gravity.(CG)

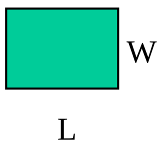
3. Reach and angle of the sling – Available headroom, any obstructions, and type of hitch are important factors in this determination. The angle at which a sling is used significantly effects its capacity. Use the longest reach possible for completing the lift, this will provide the largest angle possible for minimum stress on the sling.

4. Protect the load and sling from damage – Select the best sling material for the load and environment. Use softeners such as shims, padding or sling protectors to prevent damage at corners or projections. Inspect slings before each use.

5. Protect Personnel – Plan to position and utilize personnel safely during rigging and lifting. Use a line to stabilize or maneuver the load during the lift.

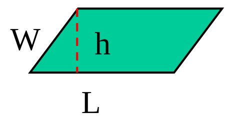
→ First a quick refresher on calculation Area and Volume for a couple shape;

Rectangle



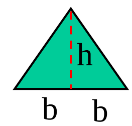
A=LxW

Parallelogram



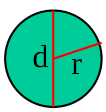
A=hxW

Triangle



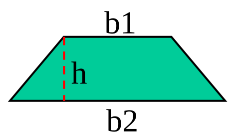
A=1/2 bxh

Circle



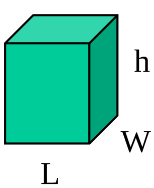
A= πr^2

Trapezoid



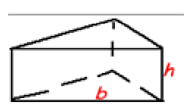
A=((b1+b2)/2) x h

Box



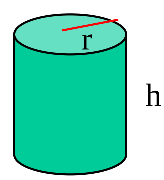
V=LxWxh

Prisms



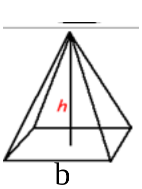
V=bxh

Cylinder



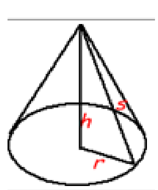
V= πr^2 x h

Pyramid



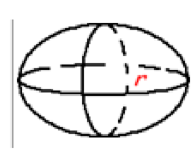
V=1/3 bxh

Cones



V=1/3 πr^2 x h

Sphere



V=4/3 πr^3

DETERMINE CENTER OF GRAVITY

→ Step 1: Divide the object into shapes you can easily find the Area/Volume and Center of Gravity (CG). Setup a reference location.

→ Step 2: Find the Area/Volume and CG for every object

→Step 3: Add up all Area/Volume

→Step 4: Solve for the CG distance using the following equation.

Ax = A1x1 + A2x2 + …

where

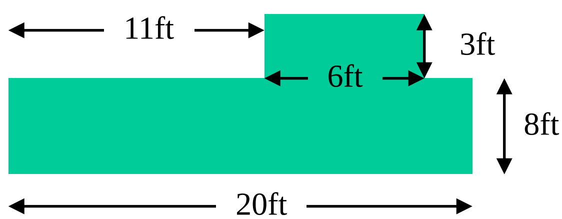
A= Total Area = A1 + A2 +…

x = distance to the CoG in the x direction

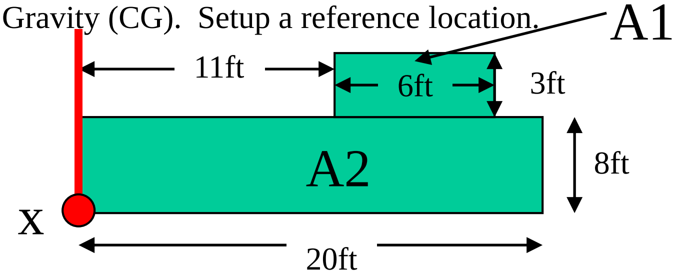
A1 and A2 = Area/Volume or Mass of object 1 and 2

x1 and x2 = distance to the CoG for respective objects 1 and 2

→ Quick Example: Find the Center of Gravity for the below object



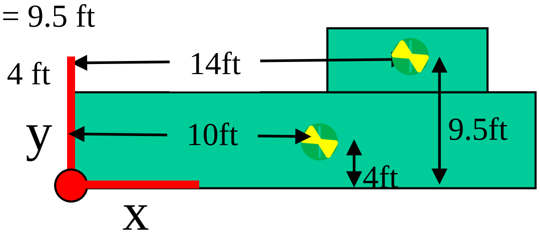
→ Step 1: Divide the object into shapes you can easily find the Area/Volume and Center of Gravity (CG). Setup a reference location.



→ Step 2: Find the Area/Volume and CG for every object

- A1 = 6ft x 3 ft = 18ft^2 , x = 14ft, y = 9.5 ft

- A2 = 20ft x 8ft = 160ft^2 , x = 10ft , 4 ft



DETERMINE CENTER OF GRAVITY

→Step 3: Add up all Area/Volume

$$A = A1 + A2 = 18ft^2 + 160ft^2 = 178\ ft^2$$

→Step 4: Solve for the CG distance using the following equation.

$$Ax = A1x1 + A2x2$$

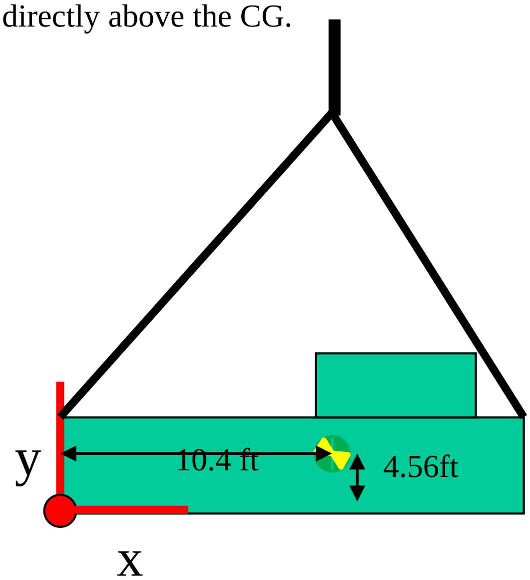
$$178\ ft^2\ (x) = 18ft^2\ (14ft) + 160ft^2\ (10ft) = 252 + 1600 / 178 = 10.4\ ft$$

→Also you need to solve it in the y direction too, using the same formula

$$Ay = A1y1 + A2y2$$

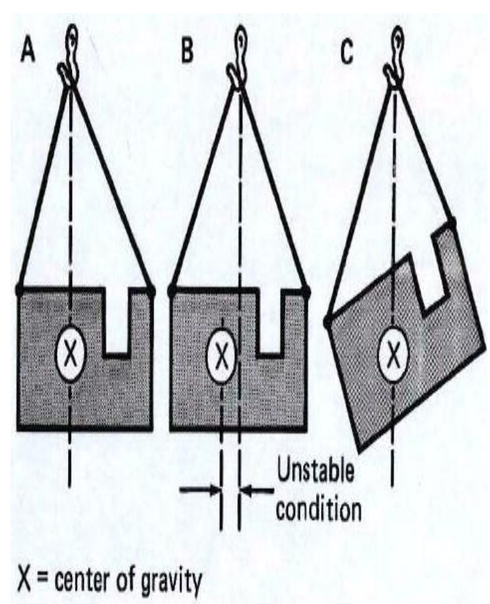
$$178\ ft^2\ (y) = 18ft^2\ (9.5ft) + 160ft^2\ (4ft) = 171 + 640 / 178 = 4.56\ ft$$

→ So below is the CG of the object, when lifting the system make sure the hook is directly above the CG.



→ Before Lifting any load check for hazards

- If not directly below the hook the load is unstable
- If the sling is free to slide across the hook the center of gravity will shift directly below the hook
- If two slings are used one will assume the greater share of the load



→There are three types of rigging systems that PE Exam might ask you to calculate the stress on the slings or factor of safety on the sling. The problems are pretty easy once you understand a few concepts. The different type are Rigging with different number legs attached to the load, Sling hitches(vertical, choker and basket hitches), and Spreader Beam riggings

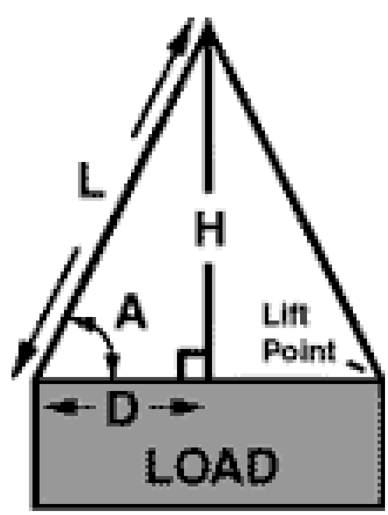
1. Standard Rigging with different number of legs attached.

→ First we will talk about two slings

→ **Trick of the Trade #1: Determine the Sling Angle**

H / L = Sling Angle Factor

Sling Angle (A)	Sling Angle Factor	Sling Angle (A)	Sling Angle Factor
90°	1.000	55°	0.819
85°	0.996	50°	0.766
80°	0.985	45°	0.707
75°	0.966	40°	0.643
70°	0.940	35°	0.574
65°	0.906	30°	0.500
60°	0.866		



→Standard Rigging with different number of legs attached.

Trick of the Trade #2: Determine the Load on Each Leg of a Sling with Equal Legs

Load Angle Factor = L / H

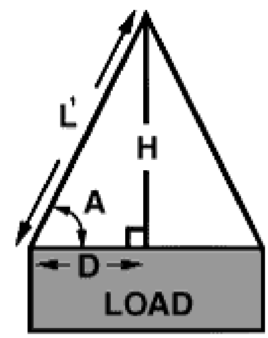
Sling Angle (A)	Load Angle Factor	Sling Angle (A)	Load Angle Factor
90°	1.000	55°	1.221
85°	1.004	50°	1.305
80°	1.015	45°	1.414
75°	1.035	40°	1.555
70°	1.064	35°	1.742
65°	1.104	30°	2.000
60°	1.155		

Load On Each Leg of a Sling (L^1) =

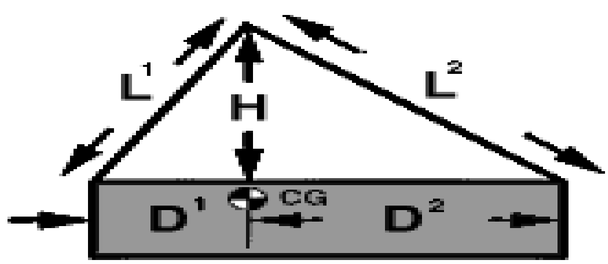
$$\frac{\text{Load (lbs.) x Load Angle Factor}}{\text{Number of Legs*}}$$

or

L^1 = (Load/sin A)/number of Legs



Trick of the Trade #3: Determine the Load on Each Leg of a Sling with UNEqual Legs



$$\text{Load on Leg } L^1 = \frac{\text{Load (lbs) x } D^2 \text{ x } L^1}{H \text{ x } (D^1 + D^2)}$$

$$\text{Load on Leg } L^2 = \frac{\text{Load (lbs) x } D^1 \text{ x } L^2}{H \text{ x } (D^1 + D^2)}$$

→Standard Rigging with different number of legs attached.

Trick of the Trade #4: Formula for adjusting the Working Load Limit of a sling or sling leg used at an angle.

Vertical Hitch Working Load Limit x Number of Legs x Sling Angle Factor = WLL at specified angle

The Working Load Limit for the sample sling above, in a 60° basket hitch would be calculated as follows:

500 lbs. (Vertical WLL) x **2** (num. of legs) x **.866** (sling angle factor from table) = **866 lbs.**

Determining Reach

To calculate the reach for <u>equal</u> legs needed to rig at a 45° or 60° angle.

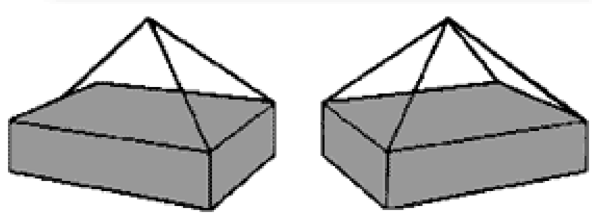
Reach at 60 degrees: L = 2 x D

Reach at 45 degrees: L = 1.4 x D

On Multi-Leg Slings:
Reach = L

Slings in a Basket Hitch:
Reach = 2 L + the distance around the load
(from lift point to lift point.)

Three & Four Legs



Triple leg slings have 50% more capacity than double legs only if the center of gravity is in the center of the connection point and the legs are adjusted to share the load equally.

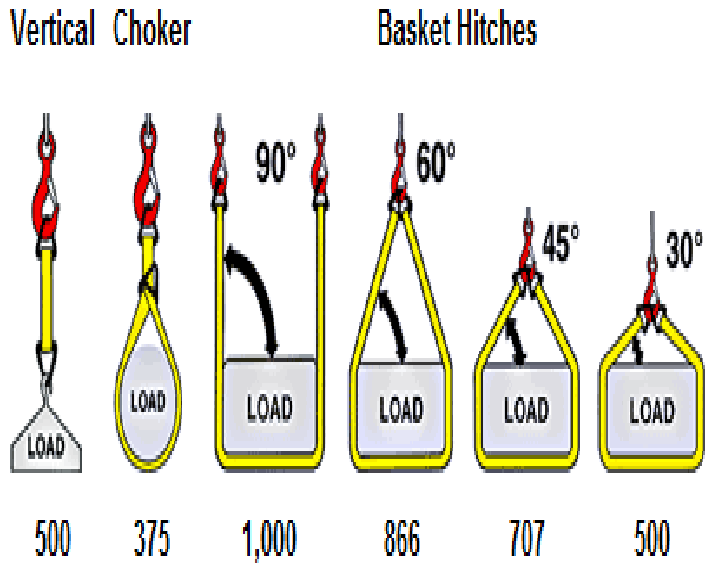
Rigging a **Quad** leg sling so that all legs share the load equally is very difficult. Therefore, when adjusting the working load limit of four leg chain slings, the number of legs in the calculation must be 3 <u>not</u> 4. Many riggers follow this model for quad leg slings of any material, relying on the fourth leg for stability only.

→Basic Sling Hitches

This illustration shows the basic sling hitches.

It also shows capacities for a single sample sling, rigged with each hitch.

The sample sling's Working Load Limit in a vertical hitch is 500 lbs.



Sling Angle	Sling Angle Factor
90°	1.000
85°	0.996
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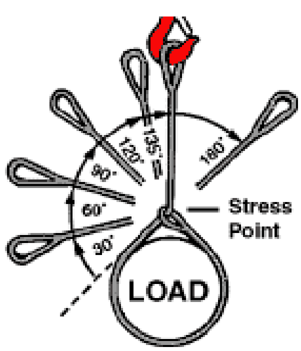
75°	0.966
70°	0.940
65°	0.906
60°	0.866
55°	0.819
50°	0.766
45°	0.707
40°	0.643
35°	0.574

Choker Hitch

Choke Angle - When lifting or turning a load rigged with a choker hitch, the angle at which a sling is turned back on itself can reduce it's capacity below what is listed for its choker hitch, if the angle is too severe. When a load is allowed to hang free, the natural choke angle is about 135°.

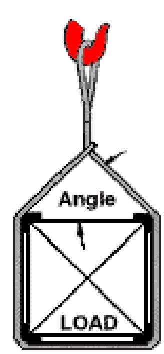
Choke Angle	Choke Factor
120° +	1.00
90°-120°	0.87
60°- 89°	0.74
30°- 59°	0.62
0°- 29°	0.49



If the angle is less than 120°, you must adjust its Choker Hitch Working Load Limit by the appropriate choke factor from this table.

Choker Hitch WLL x Choke Factor = Adjusted WLL

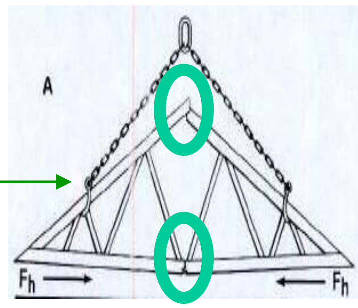
Choker Hitch Rated Capacity - A choker hitch will have 75% of the capacity of a single leg vertical hitch only if the corners are softened and the horizontal angle is greater than 30°.



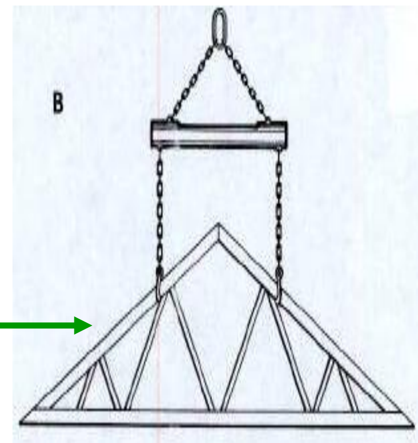
Use blocks to prevent angles less than 30°.

→Spreader Beam: A below-the-hook lifting device that utilizes two or more hooks (attaching devices) located along a beam and the spreader beam attaches to the hoist by means of a bail. The spreader beam is used to handle long or wide load and serves to "spread" the load over more than one lifting point. Often used in conjunction with slings.

→ Horizontal forces act on the load causing damage by compression or buckling



→Horizontal forces are absorbed by using a spreader beam making the sling legs between beam and load vertical



Note: a common misconception of spreader beams is that they equalize the loading along the beam. They do not! Spreaders only eliminate horizontal forces from affecting the load being hoisted.