Engineering & Physics Review
Part II

Engineering and Physics Part II Review

Outline

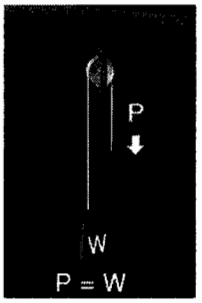
- Pulley & Lift Systems
- Rope & Safe Working Loads
- Wire Rope Breaking Strengths
- Rope Breaking Strengths
- Chains and Safe Working Loads

Pulleys and Lift Systems

•A pulley is an object that is usually round with a smooth groove around its outside edge.

•A pulley transfers a force along a rope without changing its magnitude.

•When engineers work with pulleys, they often assume that the rope through the groove of a pulley moves smoothly and evenly, without catching. They say it moves without friction.

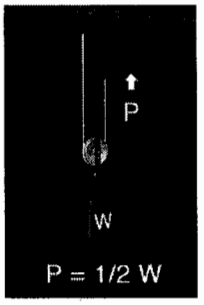


In this pulley, to maintain equilibrium (e.g., no movement), one needs to pull with the same amount of weight as the load being held.

Assume pulleys are frictionless

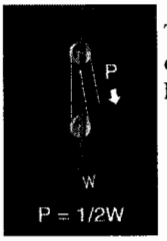
Courtesy of http://www.swe.org/iac/LP/pulley_act.html)

Pulley & Lift Systems

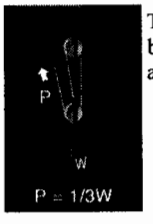


If I pull the rope up, fix the load onto the pulley, the amount of pull (P) that I need will only be 1/2 the weight of the load. Mechanical advantage here is 2.

Rule of Thumb: To determine the mechanical advantage of a pulley, count the number of rope lines connected to the pulley, to include the free line (e.g., the line that you must pull). If the free line is downward, subtract "1" from the mechanical advantage.



This has 3 lines to the pulleys, but it is a downward pull - Mechanical advantage is 2 or P = 1/2 W

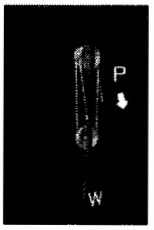


This also has 3 lines to the pulley, but because the pull is up, the mechanical advantage is 3 or P = 1/3 W

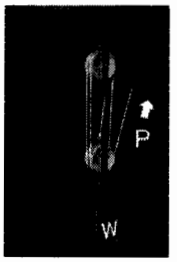
Assume pulleys are frictionless

Courtesy of http://www.swe.org/iac/LP/pulley_act.html)

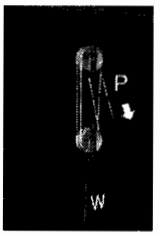
Group Exercise



What is the mechanical advantage?



What is the mechanical advantage?



What is the mechanical advantage?

Assume pulleys are frictionless

Courtesy of http://www.swe.org/iac/LP/pulley_act.html)

Group Exercise

How much pull is required to lift 400 lbs of load?

How much pull is required, in lbs, to lift this 75 lbs load?

Bonus

How much pull, in lbs, is required so that the scale reads only 100 lbs?

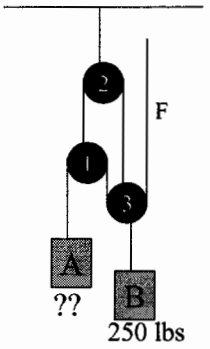
Assume pulleys are frictionless

Courtesy of http://www.swe.org/iac/LP/pulley_act.html)

Pulley and Lift Systems

If Block B is 250 lbs, what must the counterweight of A be in order to maintain balance.

1st Step: Know the pulling force (F) connected to Pulley#3
Therefore, analyze what the pulling force of F is on Pulley#3



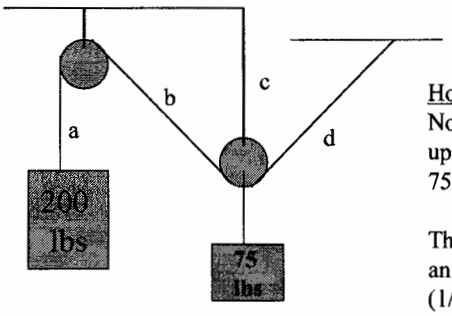
Assume pulleys are frictionless

2nd step: Analyze the number of forces or lines on Pulley#3
There are 4 lines or a mech advantage of 4.

$\frac{1}{4}$ (W) = F = 250(0.25) = 62.5 lbs

Therefore, if pulling force of F upward must be 62.5 lbs, then A must have the same amount of downward force of 62.5 lbs to maintain equilibrium.

Pulley & Lift Systems



How much force is in support c?
Note: Support c is stationary & an upward force to support the weight of 75 lb load and the 2 lines on the pulley.

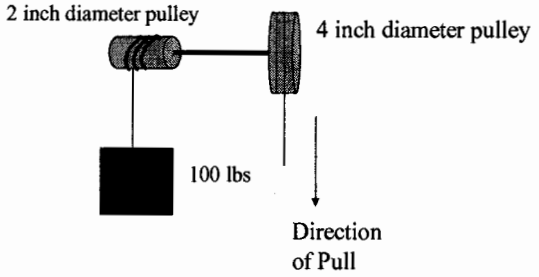
There are 2 lines to the pulley, and an upward force (c):
(1/2)(W) = c= (0.5)(75 lbs) = **37.5 lbs**

How much force is in line b?
There are 2 lines to the pulley holding a 200 lb load. However, line b is a downward pull.
Mechanical advantage = 1 = 2 lines - 1 (due to downward pull)
Therefore, line b is pulling **200 lbs**.

Assume pulleys are frictionless

Pulley & Lift Systems

What happens if you have pulleys with different size diameters?

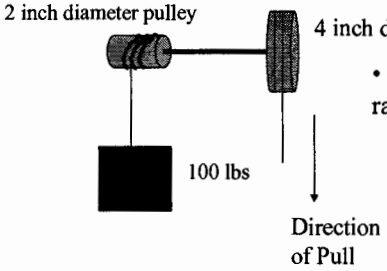


- Diameter of pulley is directly related to the amount of force used.
  - The 2 inch pulley is lifting 100 lbs directly.
  - The 4 inch pulley, however, has a 1 to 2 mechanical advantage over the smaller pulley (2 inch to 4 inch = 1 to 2)

The force to lift a 100 lb object (as shown above) is THEREFORE 100 lbs divided by 2 = 50 lbs. The 4 inch pulley is lifting only **50 lbs**.

Pulley & Lift Systems

Pulleys provide a mechanical advantage to lifting very heavy objects.



- Can solve this problem mathematically rather than intuitively as in last slide

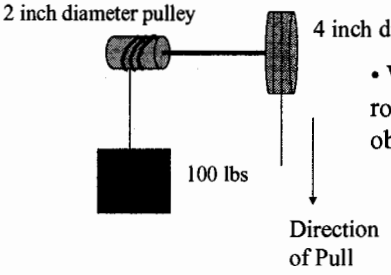
Apply the $F_1D_1 = F_2D_2$ where F_2 is the 4 inch diameter pulley

$(100 \text{ lbs})(2 \text{ inch}) = (F_2)(4 \text{ inch})$

$F_2 = \mathbf{50 \text{ lbs}}$

Pulley & Lift Systems

Pulleys provide a mechanical advantage to lifting very heavy objects.



- What if you needed to know how much rope movement was required to lift the object 5 feet?

Apply the $F_1D_1 = F_2D_2$ where D_2 is the distance that the rope on the 4 inch diameter pulley must move

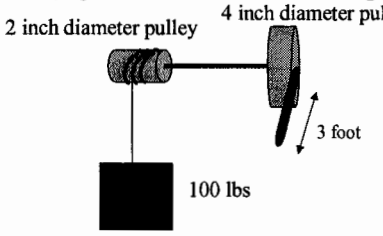
(100 lbs)(5 feet) = (50 lbs)(D_2) *Use 50 lbs solved in previous slide

D_2 = **10 feet**

Therefore, though there is less force required of a large pulley, you need 2 times the distance of rope pull.

Pulley & Lift Systems

Pulleys provide a mechanical advantage to lifting very heavy objects.



- What if you added a handle to the large pulley, how much force is required

Intuitively: The 4 inch pulley now has a diameter of 36 inches. The mechanical advantage is 2 inches to 36 inches (1:18) on the large pulley. Therefore, the new force carried by the large pulley is (1/18) x 100 = 5.6 lbs.

Mathematically: Apply the $F_1D_1 = F_2D_2$ where D_2 is the 36 inches

(100 lbs)(2 inch) = (F_2) (36 inches)

D_2 = **5.6 lbs**

Pulley & Lift Systems

In reality, all pulleys have friction which helps drag the lines connecting it. Therefore, this affects the amount of load that requires a pull.

$$L_L = \frac{\text{Load}}{n}(1 + F_f)^n$$

L_L = Load on the Rope
Load = Weight of the Load
n = Number of Lines (Note the mech advantage)
F_f = Friction Factor due to roller bearings, pulleys, etc.- (%/100)

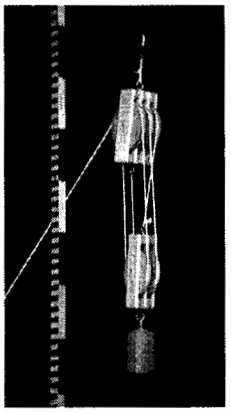
If the load is 400 lbs and the pulleys all exert a 1.4% friction factor, what is the amount of pull required?

$\frac{(400 \text{ lbs})}{5\text{-}1}(1 + 0.014)^4 =$ **105.7 lbs**

Note: Line Load formula is a mathematical formula for all pulley system shown previously (try it!!!)

Note: If there is no friction, then add 0 to 1 and exponent it, which is always 1.

Pulley & Lift Systems



Block and Tackle Systems use the Line Load formula.

This block and tackle needs to lift 75 lbs. This is a 6 line block and tackle system. As shown, what amount of force is needed to lift the load. Assume no friction factor present.

$= \frac{75 \text{ lbs}}{6\text{-}1}(1 + 0)^5 =$ **15 lbs**

Note: Downward Pull – Minus 1 line from Total Lines

Wire Rope and Safe Working Loads

The amount of load that a wire rope can safely lift is dependent upon the number of line on the rope, the frictional forces that the rope works on, and the weight of the load expected.

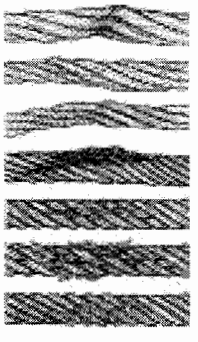
$$L_L = \frac{\text{Load}}{n}(1 + F_f)^n$$

L_L = Load on the Rope
Load = Weight of the Load
n = Number of Lines Making Up the Rope
F_f = Frictional Forces that the rope is on (roller bearings, pulleys, etc..) - (%/100)

- Used to determine if a load exceeds or is within a rope's Safe Working Load.
- SWL defined as the load that can be applied and still obtain the most efficient service and also prolong the life of the rope.
- Rule of Thumb:
  - 1/5th the Manufacturer's Breaking Strength = weight of load is 1/5th the breaking strength of the rope lifting it.
  - For Wire Rope: $\frac{(\text{Diameter of Rope})^2 \times 8}{\text{Diameter in inches}} = \text{SWL (in tons)}$

Wire Rope & Safe Working Loads

If rope is worn out, can take at least 50% or less safety factor off the SWL.

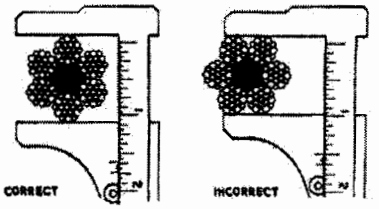


Fiber Rope Breaking Strength

Rule of Thumb, unless specified by the manufacturer:

Breaking Strength (pounds) = (Circumference of Wire Rope)^2 x 8,000

Circumference = (diameter) x 3.14



Note: When measuring the diameter of wire rope (cable), measure as shown above using dial or digital calipers.

Rule of Thumb: Strength of Rope Should be 5 Times the Load Expected to Be Carried.

Fiber Rope Breaking Strength

- Manila rope
  900 lbs. X circumference^2 = breaking strength where Circumference = (3.14) X diameter

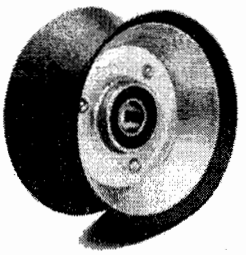
- Synthetic Rope
  Multiply with a material or comparison factor
  (Comparison Factor) x (900 lbs) X (circumference^2) = breaking strength

Line Material	Comparison Factor
Nylon	2.5
Dacron	2.0
Polypropylene	1.4

Rule of Thumb: Breaking Strength of Fiber Rope Should be 5 Times the Load Expected to Be Carried.

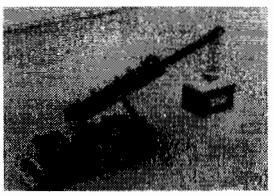
Reasons that Rope or Cable Can Fail when Lifting Objects

- Using the incorrect size, construction, or grade of wire rope
- Dragging rope over obstacles;
- Having improper lubrication;
- Operating over sheaves and drums of inadequate size;
- Overriding or crosswinding on drums;
- Operating over sheaves and drums with improperly fitted grooves or broken flanges;
- Jumping off sheaves;
- Subjecting it to acid fumes;
- Attaching fittings improperly;
- Promoting internal wear by allowing grit to penetrate between the strands; and
- Subjecting it to severe or continuing overload.



Sheave

Rope and Safe Working Loads



Suppose a mobile crane wanted to lift a 320,000 lbs container. The mobile crane uses an 8-part cable that is 1.5 inch in diameter and a pulley that has a frictional coefficient of 3.8%. However, the cable is over 25 years old and looks pretty worn so you give it about a 45% safety factor of the SWL. Can the crane pick up this load safely?

1. Determine your Safe Working Load of the cable.
   - (Diameter of cable)^2 x 8 = SWL (in tons)
   - (1.5 inches)^2 x 8 = 18 tons = 36,000 lbs
   - However, the cable looks worn out.
   - 18 tons x 0.45 = 3.6 tons = 7290 lbs = SWL

2. Determine load weight on line.

$$L_L = \frac{\text{Load}}{n}(1 + F_f)^n$$

$$= \frac{320{,}000 \text{ lbs}}{8}(1 + .038)^8$$

$$= 53{,}906.2 \text{ lbs}$$

3. 53,906.2 lbs > 7290 lbs SWL; **NO**

Rope and Safe Working Loads

In an automotive shop, you inspect this mobile lift device. Inspecting the 1/2 inch diameter cable consisting of 4 parts line, you notice that it is rusted and worn out. The pulley has a 1.5% friction. From your experience, you estimate a the SWL is probably 30% of the SWL. The shop supervisor wants to lift a 1/2 ton engine. Can he do so safely?

1. Determine the Safe Working Load (SWL)
$(0.5)^2 \times 8 = 2$ tons = 4,000 lbs
Rusted and worn, take 30% off of the SWL
4,000 lbs x 0.3 = 1200 lbs

2. Determine the load on the line:

$$L_L = \frac{\text{Load}}{n}(1 + F_f)^n$$

$$= \frac{1000 \text{ lbs}}{4}(1 + .015)^4$$

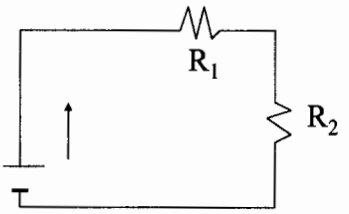
$$= 265.34 \text{ lbs}$$

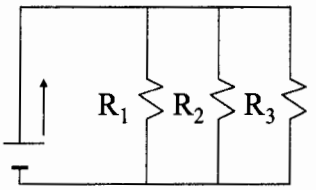
265.34 lbs < 1200 lbs

Electricity

- V=IR
  - Voltage (V); Current (I-amps); Resistance (Ohms)
- P=VI
  - Power (P-watts); Current (I-amps); Voltage

Electricity





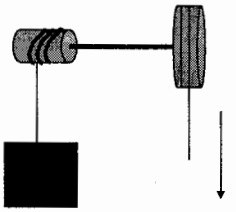
Resistance in Series is Added

$$R_{series} = R_1 + R_2 + ...+ R_N$$

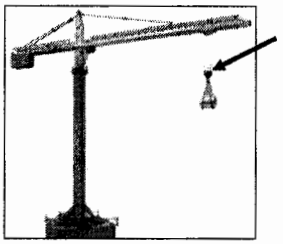
Resistance in Parallel is added fractionally

$$\frac{1}{R_{Parallel}} = \frac{1}{R_1} + \frac{1}{R_2} .....+ \frac{1}{R_N}$$

Group Exercise

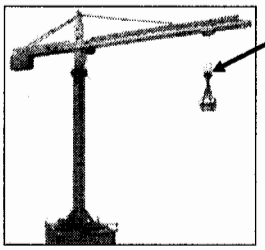


1. The box's weight is 230 lbs. If the diameter of the small pulley is 1 feet and the diameter of the large pulley is 4 feet, how much force is required to pull downward to lift the object?



2. This tower crane uses a 7 line pulley system. If the load weight is 230,000 lbs, what is the actual upward force required to lift the object?

Group Exercises



3. Using the same 7 line pulley, if the reach required for a load pick-up is 145 feet from the mast, and you have a counterweight at 25 feet from the mast, what must the counterweight have to be to pick a load weighing 350,000 lbs?

Group Exercises

4. Suppose a mobile crane wanted to lift a 234,500 lbs container. The mobile crane uses an 5-part cable that is 2.0 inches in diameter and a pulley that has a frictional coefficient of 4.4%. However, the cable is new so no safety factor is applied. Can the crane pick up this load safely?

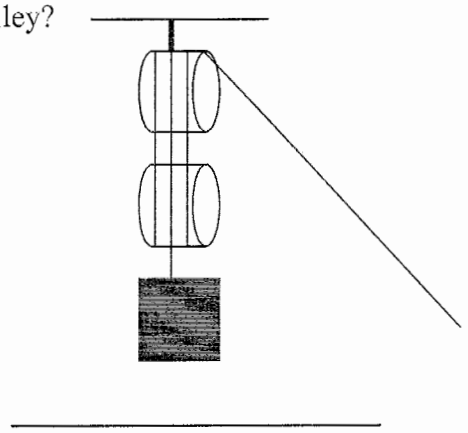
Practical Test
Engineering & Physics
Part II

5 Questions

10 Minutes to Complete

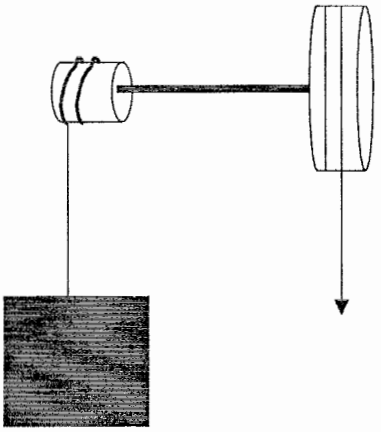
Battle Drills
Engineering & Physics Part II

1. How much downward force is required to lift the object weighing 230 lbs using this pulley?



a. 45 lbs
b. 57.5 lbs
c. 20 lbs
d. 34 lbs

2. How much downward force is required to lift this object weighing 550 lbs using this pulley design where the small pulley has a 6-inch diameter, and the large pulley has a 14 inch diameter?

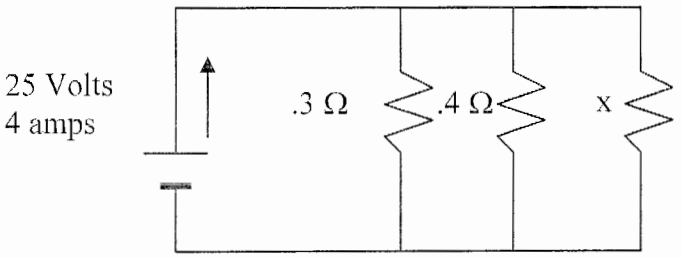


a. 123 lbs
b. 435 lbs
c. 236 lbs
d. 250 lbs

3. Suppose a mobile crane wanted to lift a 235,000 lbs container. The mobile crane uses a 6-part cable that is 2.0 inch in diameter and a pulley that has a frictional coefficient of 3.8%. However, the cable is fairly used so you determine a 25% safety factor of the SWL. Can the crane pick up this load safely?

a. Yes
b. No

4. What is the resistance at x given the following diagram?



a. 1.20 ohms
b. 0.18 ohms
c. 2.3 ohms
d. 5.0 ohms

5. A tower crane uses a 8 line pulley system. If the load weight is 230,000 lbs, what is the actual upward force required?

a. 14,520 lbs
b. 33,283 lbs
c. 28,750 lbs
d. 54,929 lbs