PULLEYS

Name: ……………………………………………………………………………………………

Date: ……………..

School: ………………………………………………………………………………………………… Class: …………………

Before the experiments

QUESTIONS BEFORE THE EXPERIMENTS

Answer the following questions:

I. What is the tension of a rope? Is it a force? What is its direction? ….

II. Can tension pull and push an object?

III. What is a pulley ?

IV. Where we find pulleys?

Pulleys are all around us. Give examples of where you might see pulleys working.

V. Explain what is the advantage of using a pulley in the examples at the point IV?

VI. A one wheel pulley allows the direction of a force to be changed.
Why do the modulus force required and work done remain the same?

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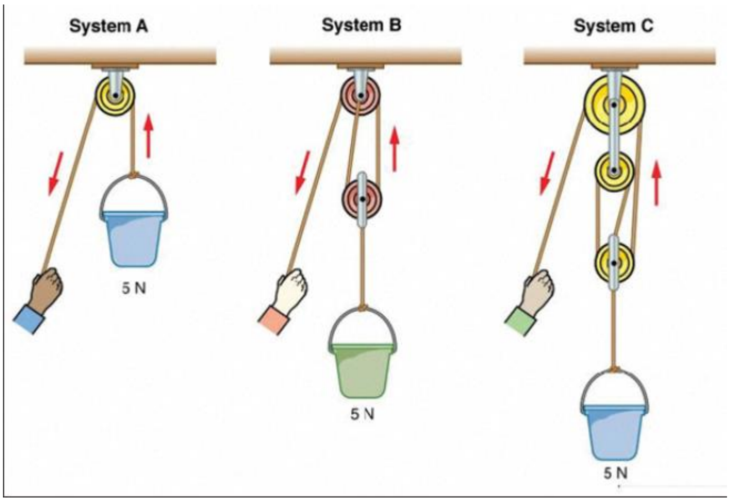
VII. In the figure below, which system needs the least force to lift the load?



b) In which system do you move the load over the greatest distance?

Experiment 1

TITLE: THE TENSION ON A ROPE OR A STRING

FOR THE TEACHER

The experiment and the questions are intended to make it clear that, with certainty, the tension exerted on a block by a vertical wire has a vertical component, and that it's not possible to exert a horizontal force and move the block horizontally by a vertical wire, but we need to tilt the strand.

Students should conclude that the tension on a strand has always the same direction as the wire, and that it is not possible to point the tension in the opposite direction: if you lower your hand, the wire bends and you cannot exert a downward force on the mass. Tension can only pull on an object and not push it. This is because the wire is flexible and not a rigid rod.

By doubling the wire the tension can be distributed on them.

Things get complicated if the body is suspended by two wires that form an angle with the vertical.

An elastic is a particular rope that stretches. When the elastic is at maximum tension it behaves like a rope.

The experiment, the discussion on the results obtained and the answers to the questions are intended to lead to the definition of the *ideal rope*.

An ideal rope:

- ✓ is perfectly flexible: the tension cannot have components perpendicular to the rope itself and it cannot push
- ✓ is inextensible: its length does not vary, regardless of its tension
- ✓ its mass is zero

For ideal ropes, the tensions on either ends have the same magnitude but opposite direction. It is necessary to help students in thinking that the rope used in the experiment has much less mass than that of the block, that it is flexible and inextensible and that can be approximately considered an ideal rope.

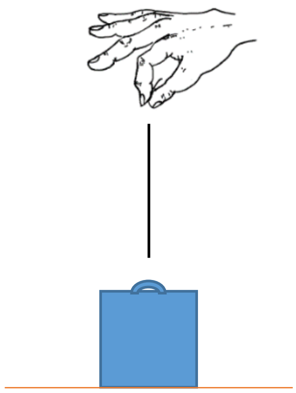
LAB SHEET

In physics, tension is the force exerted by a rope, string, cable, or similar object on one or more objects. Anything pulled, hung, supported, or swung from a rope, string, cable, etc. is subject to the force of tension.

But *what is* the tension of a rope? Let's experience the characteristics of this force.

Tools and materials: mass holders with hook and masses (or block with hook), thin wires, dynamometers of different sensitivity and capacity, elastic bands.

Attach one end of the wire to the hook of the mass holder, hold the other end and keep the wire vertical



A) Don't lift the block, and/or the mass-holder from the table, and:

1) Show the direction of the tension exerted on the block by the rope.

2) Draw the force diagram on the mass holder

3) Can you vary the magnitude of the tension? What happens if you lower your hand?

4) Can you push the mass holder downwards?

5) Can you move the weight holder / block horizontally if you keep the wire vertical?

6) How can you move the block horizontally?

7) What can you conclude about the direction of the tension?

B) Repeat experiment A) using a rubber band. Highlight the differences.

C) Lift the mass holder and keep it suspended and still

1) What is the direction of the force (tension) exerted on the block?

2) Draw the force diagram on the mass holder

3) Draw the force diagram on the wire

4) Measure the magnitude of this force with a dynamometer of appropriate capacity

D) Repeat experiment C) using a rubber band. Highlight the differences.

E) Now attach two ropes to the mass holder hook, lift the mass holder and keep it suspended.

1) What is the direction of the forces (tensions) exerted by each of the two wires on the block?

2) Draw the force diagram on the mass-holder/block in this case

3) What can you conclude on the direction and magnitude of the tension on each of the two wires?

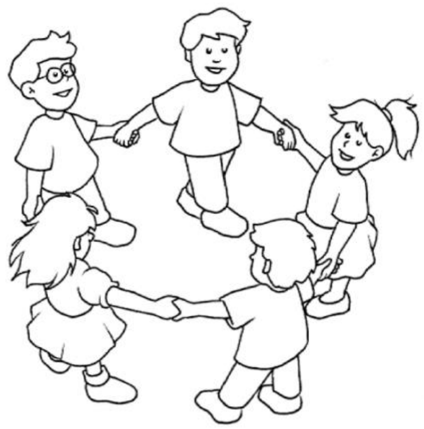
4) Check your previous statement by placing two dynamometers in the middle of the two sections of the wire.

5) Now, asking for help, or using both hands, keep the block raised with the two ropes forming an angle with the vertical. Has the tension of each rope increased or decreased compared to the previous case? Explain

6) Use the two dynamometers to check your answer. Place both ropes in such a way that they form an angle of 60 °with the vertical. What do the two dynamometers indicate? Explain

7) Imagine cutting the wire that holds the block. Tension is the force that holds the two ends of the wire together.

It is a bit like a ring-around-the-rosey:



Why can a rope break when prompted by a too intense force?

8) Check your answers to the questions I and II.

FIX CONCEPTS AND REFLECTIONS

1) Indicate plausible values for the order of magnitude of the tension of the indicated ropes to situations shown in the figure. Can the indicated ropes be considered *ideal*?

(0,1 N)

(10 N)

(1000-10000 N)

(100 N)

1000-10000 N

2) We can safely hang ourselves on a clothesline when it is vertical, but we break the rope if we try to make it support our weight when it is stretched horizontally, why?

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Experiment 2

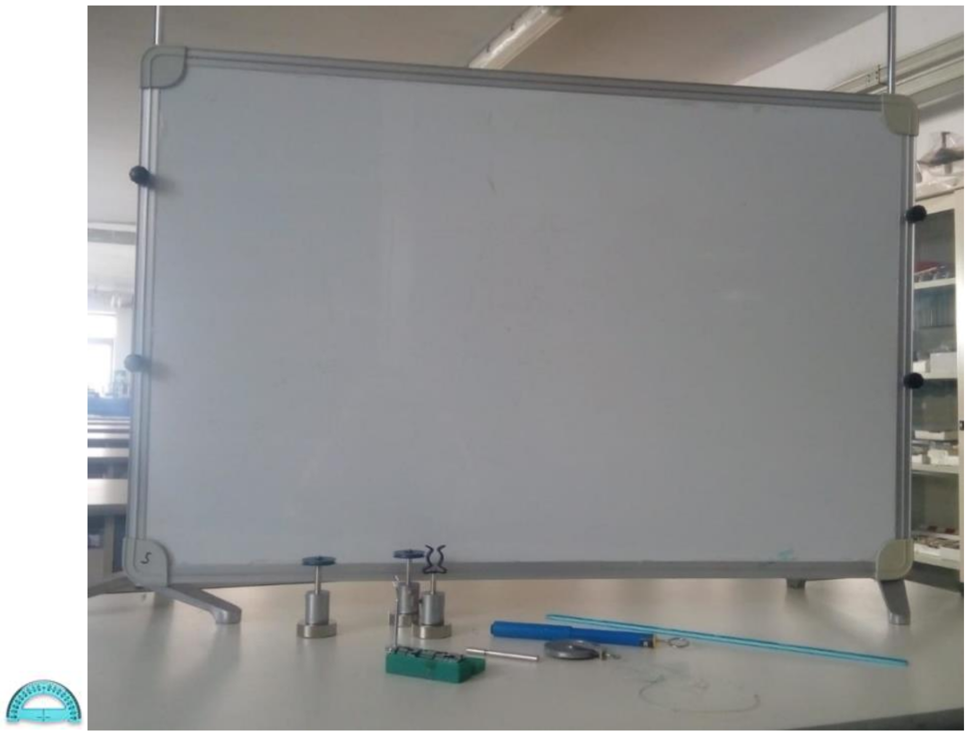
The Fixed Pulley

FOR THE TEACHER

The experiment and the questions are intended to clarify: what fixed pulleys are; that a single fixed pulley changes only the direction of the force (you pull down and the weight goes up.); and that a pulley can create an advantage to the user simply by changing the direction of the effort force even if it doesn't change the intensity of the force.

LAB SHEET

Equipment



The equipment used for the experiment: magnetic board, fixed pulley, magnetic supports, cord, dynamometer clamp, precision dynamometer (range 1,20 N sensitivity 0,01N) or dynamometer resettable according to the setup, full scale suitable for the weight of the masses, ruler (50 cm, 1mm), thin ropes, protractor, 20 g mass series.

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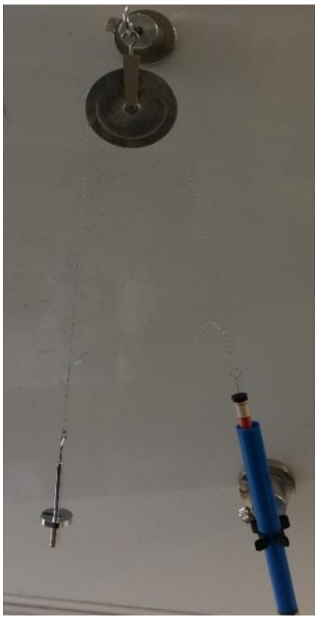
Procedure:

- ✓ Look at the pulley and describe it. Locate the pulley bracket and throat.
- ✓ Mount the device as shown in the figure and measures the force indicated by the dynamometer for different masses of the load.
  Remember to reset the dynamometer every time



- ✓ Repeat the measurements by varying the inclination of the rope where the dynamometer is attached. Use the protractor to measure the angle that the dynamometer forms with the vertical.
- ✓ Fill in the table below:

Table 1

M (g) Mass of the load	S_L (cm) Load displacement	S_D (cm) Dynamometer displacement

- ✓ Raise the load and measure how much the load is raised and how low the dynamometer is. Fill in the table below:

Table 2

M (g) Mass of the load	P (N) Load weight	F (N) Force measured by the dynamometer	?? Angle that the dynamometer forms with the vertical

1) Check that within the experimental errors the force F measured by the dynamometer is equal to the weight of the load. Check that this is true even if you change the direction of the cord in the branch where it is applied F. (Table 1)

2) Verify that the mechanical advantage of a fixed pulley is 1 (Mechanical advantage =Load/Input Force (F))

3) A student asserts that a fixed pulley is a first type lever in which the arm of power is equal to that of resistance. Do you agree? Explain your answer

4) What is the tension of the rope on the side where the dynamometer is applied? Indicate magnitude and direction of the rope tension.

5) What is the tension of the rope on the side where the load is applied? Indicate magnitude and direction of the rope tension.

6) Draw the load free-body diagram

7) Check, within the experimental errors, that the displacement of the dynamometer is equal to the displacement of the load. (Table 2) Check that this is true even if you change the direction of the cord in the branch where it is applied F.

8) Check, within the experimental errors that the work done by the force F is equal to the work of the load weight force

9) Check your answers to the questions before the experiments V an VI. Which are your conclusions?

Experiment 3

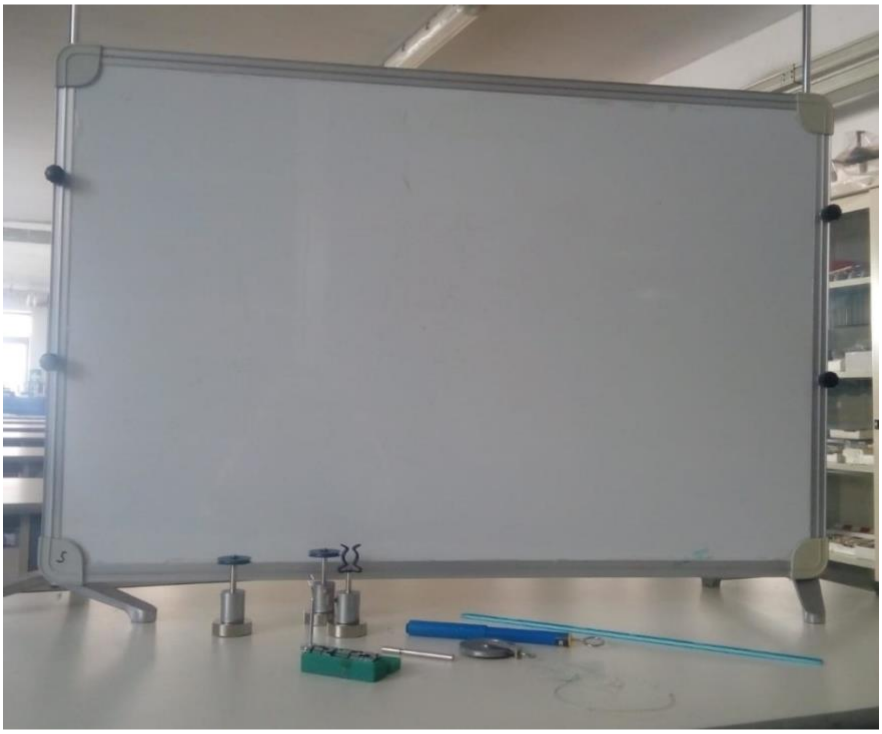
The Mobile Pulley

FOR THE TEACHER

In this experiment the students will understand the working of a mobile pulley, that even the pulley has a weight and we need to take it into account, what is an ideal pulley, that by mobile pulleys we can reduce the effort, that there are similarities between levers and pulleys and if we use combination of fixed and mobile pulleys we can have a mechanical advantage.

LAB SHEET

Equipment



The equipment used for the experiment: magnetic board, fixed and mobile pulleys, cord, dynamometer clamp, precision dynamometer (range 1,20 N sensitivity 0,01N) or dynamometer resettable according to the setup, full scale suitable for the weight of the masses, ruler (50 cm, 1mm), thin ropes, 20 g mass series

Procedure:

- ✓ Take note of the weight of the mobile pulley ($P_c = m_c g$) and of its error (consider negligible the error on g= 9,81 m/s^2) : Pc =_______±_______.
- ✓ Mount the device as shown in the figure below
- ✓ Add to the wire attached to the pulley a weight ***P***, that will be our load force, measure *P=m g*
- ✓ Measure F on the dynamometer when the system is balanced. F will be our input force to support the load.

- ✓ Add to the hook hanging on the mobile pulley some different weights ***P***, then search for the appropriate force **F** to obtain the balance of the system. Measure P=*mg* of each one and measure F on the dynamometer.
- ✓ Complete the following table:

Table 1

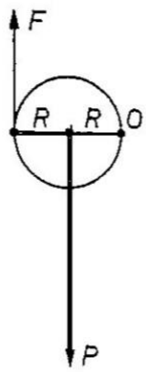
P (N)	ΔP (N)	F (N)	ΔF (N)	$P + P_c$ (N)	$\Delta (P + P_c)$ (N)

Observe and compare the values of F and of $P + P_c$. You can also use a graph by reporting abscissa $P + P_c$ and ordinate F.

1) Write the relation between F and $P + P_c$, did you expect this result?

(Within the experimental errors, students should find F = (P + Pc) / 2)

2) Now observe the figure below:



Recognize the arms of a lever inside the mobile pulley and complete the following sentences:

The fulcrum (center of rotation) is the point __________;

The lever arm of the load is ________;

The lever arm of the input force is _____.

Now we can analyze the torque balance condition: $F \cdot 2R = (P + P_c) \cdot R$

3) Draw the mobile pulley and the load's free-body diagram and discuss the theoretical torque balance condition relationship with the experimental results

4) The Mechanical Advantage of a mobile pulley is:

   load force/input force = _____________

5) Move the mobile pulley and its load P upwards. Measure how much the the center of the movable pulley is raised and how much you need to lower the dynamometer so that the wire is always tight and the system in balance.
   Check, within the experimental errors, that the displacement of the dynamometer is two times the displacement of the movable pulley . Explains this result

6) Has the F value indicated by the dynamometer changed?

7) Calculate the work done by the force F, supposed constant during this movement, and the work of the weight force of the mobile pulley and its load. What do you observe?

8) Move W down and measure the displacement. How high is P raised? Justify your observation

9) Check your answer to the question before the experiments VII . Which is your conclusions?

Experiment 4

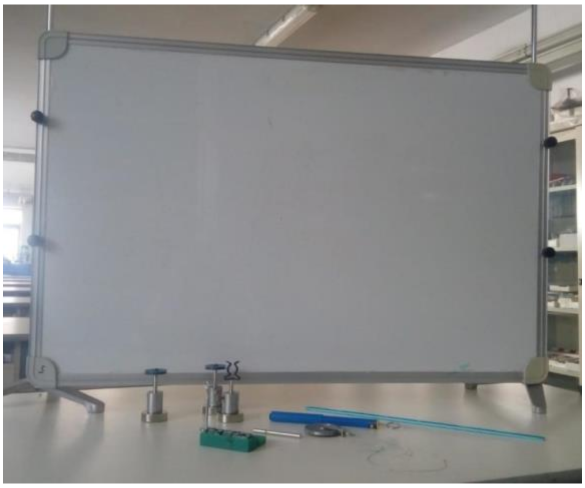
Mix of two movable pulleys and a fixed one

FOR THE TEACHER

The experiment and the questions are intended to clarify and verify that this layout of pulleys creates a greater advantage than the previous one, because it further reduces the intensity of the applied force, but at the expense of a greater displacement. What clearly emerges from this experiment is that the work done by the weight of the load P equals the work of the input force F.

LAB SHEET

Equipment



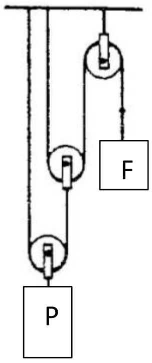


Fig. 1

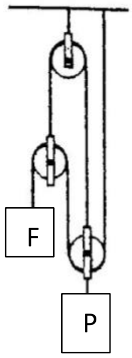


Fig. 2

Equipment used for the experiment:

magnetic board, 3 magnetic brackets, 3 rods with hook, two movable pulleys, a fixed pulley, precision dynamometer (range 1,20 N sensitivity 0,01N) or dynamometer resettable according to the setup, full scale suitable for the weight of the masses, ruler (50 cm, 1mm), thin ropes, 20 g mass series.

Procedure:

- ✓ Look at the pulley systems in figure 1 and 2 and describe them.
- ✓ Mount the device as shown in the figure 1, apply a load (masses of the equipment) to the movable pulley
- ✓

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- ✓ Take note of the weight of the mobile pulley ($P_c = m_c g$) and of its error (consider negligible the error on g= 9,81 m/s^2) : Pc =________±________.
- ✓ Measure the force F indicated by the dynamometer when the system is balanced, for different loads, varying the number of the hanging masses. Include the weight of the lowest pulley in the total load weight so that P_{tot} is the weight of the hanging masses and the pulley.
  F will be our input force to support the total load.
  Remember to reset the dynamometer every time.
  Fill in the table below:

Table 1

P_{tot} (N)	ΔP (N)	F (N)	ΔF (N)

- ✓ Mount the device as shown in the figure 2, and again apply a load (masses of the equipment) to the movable pulley.
- ✓ Repeat the measurements for the systems shown in figure 2 using the same method.

Fill in the Table 2 with new datas:

Table 2

P_{tot} (N)	ΔP (N)	F (N)	ΔF (N)

Now, raise the load as indicated in experiment 3, and measure how much the (center of mass of the) load has been lifted up and how much the (center of mass of the) dynamometer has been lowered down.

Fill in the table below for the layout in figure 1:

Table 3

M (g) Mass of the load	S_L (cm) Load displacement	S_D (cm) Dynamometer displacement

Fill in the table below for the layout in figure 2:

Table 4

M (g) Mass of the load	S_L (cm) Load displacement	S_D (cm) Dynamometer displacement

1) Check, within the experimental errors, that in both cases the relation between the force F (supposed constant during this movement), measured by the dynamometer and the weight P_{tot} of the load is $F= P_{tot} /4$. Check that this is true even if you change the direction of the rope in the branch where F is applied.

2) Verify that the mechanical advantage of the system is 4 in both cases (Mechanical advantage =Load/input force (F))

3) What is the tension of the rope on the side where the dynamometer is applied? Analyze both case 1 and 2.

4) Draw the free-body diagram of the load both case 1 and 2.

5) Check, within the experimental errors, the relation between the displacement of the dynamometer and the displacement of the load. (Table 3 and 4). Verify that there is a strong connection with the relation between the force F measured by the dynamometer and the weight P of the load. Check that this is true even if you change the direction of the cord in the branch where F is applied.

6) Check inside the experimental errors that the work done by the force F is equal to the work done by the load weight force.

7) Do you think that the ceiling is holding the weight of the load?

8) What is the role of the first pulley on the top of figure 1? [redirect the input force]

9) Check your answers to questions V an VI before the experiments. Which are your conclusions?

Experiment 5

Pulleys in series

FOR THE TEACHER

The experiment and the questions are intended to clarify and verify that the system of pulleys in series can create a great advantage for the user as it changes the intensity of the applied force, but at the expense of a greater displacement.

LAB SHEET

Equipment

Equipment used for the experiment:

magnetic board, magnetic bracket, a rod with hook, two double and triple pulleys in series, cord, precision dynamometer (range 1,20 N sensitivity 0,01N) or dynamometer resettable according to the setup, full scale suitable for the weight of the masses, ruler (50 cm, 1mm), thin ropes, 20 g mass series.

Procedure:

- ✓ Look at the pulley system and describe it.
- ✓ Mount the device as shown in the figure, apply a load to the pulley system (masses of the equipment).

✓ Measure the force indicated by the dynamometer for different layouts of the total load, including the mass of the pulley system in the load. (Follow the instructions of experiment 4).
Remember to reset the dynamometer every time.
Fill in the table 1A below:

Table 1A

M (g) Mass of the load	P_{tot} (N) Total Load weight	F (N) Force measured by the dynamometer

Now raise the load and measure how much the load has been lifted up and how much the dynamometer has been lowed down.

Fill in the table below:

Table 2A

M (g) Mass of the load	S_L (cm) Load displacement	S_D (cm) Dynamometer displacement

10) Check, within the experimental errors, that the relation between the force F (supposed constant) measured by the dynamometer and the weight P_{tot} of the load is F= P_{tot} /4. Check that this is true even if you change the direction of the rope in the branch where F is applied. (Table 1)

11) Verify that the mechanical advantage of pulleys in series is 4

12) Which is the tension of the rope on the side where the dynamometer is applied?
Draw free-body diagram of the load.

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13) Check, within the experimental errors, the relation between the displacement of the dynamometer and the displacement of the load. (Table 2). Verify that there is a strong connection with the relation between the force F measured by the dynamometer and the weight P of the load. Check that this is true even if you change the direction of the cord in the branch where F is applied.

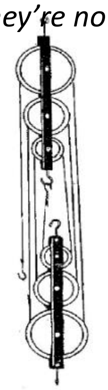
14) Check, within the experimental errors, that the work done by the force F is equal to the work of the load weight force.

15) Do you think that the ceiling is holding the weight of the load?

16) What is the utility of the first pulley on the top? [redirect the input force]

17) Check your answers to questions V an VI before the experiments. Which are your conclusions?

[the input force less by increasing the input displacement; mechanical advantage=number of supporting loops (not strings, because they're not separate strings)]



18) What do you expect the answers to be if instead of having two pulleys in series you have three as in the picture below?