SI Physics - Full Discipline Demo

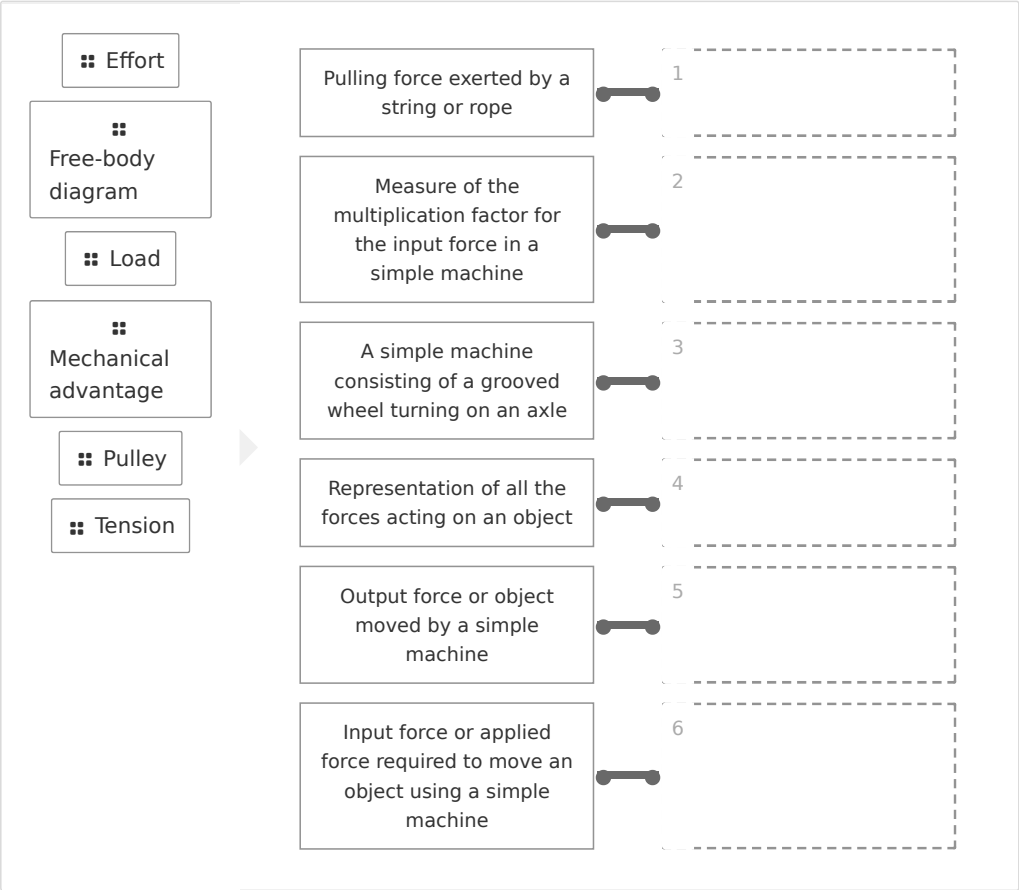
Pulleys

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Physics - Full Discipline Demo
Course	SI Physics - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

Match each term with the best description.



Correct answers:

1 Tension 2 Mechanical advantage 3 Pulley 4 Free-body diagram

5 Load 6 Effort

Identify each statement as true or false.

A pulley system with a mechanical advantage of 2 reduces the amount of energy required to move an object to half the nominal energy.

The efficiency of a simple machine is the ratio of the actual mechanical advantage to the theoretical mechanical advantage.

The reduction in tension in pulley systems is called mechanical advantage.

The theoretical mechanical advantage is always less than the actual mechanical advantage.

The work put into a simple machine must equal the work done by the simple machine.

True	False
1	2

Correct answers:

1

The efficiency of a simple machine is the ratio of the actual mechanical advantage to the theoretical mechanical advantage.

The work put into a simple machine must equal the work done by the simple machine.

The reduction in tension in pulley systems is called mechanical advantage.

2

A pulley system with a mechanical advantage of 2 reduces the amount of energy required to move an object to half the nominal energy.

The theoretical mechanical advantage is always less than the actual mechanical advantage.

Exploration

A combination of fixed and movable pulleys is called a _____ pulley system.

- combo
- compound ✔
- mixed
- None of the above

Multiple pulleys used together in a system can be used to change the _____ of the applied force.

- magnitude
- direction
- direction and magnitude ✔
- None of the above

The tension of a massless string is _____ the pulling force exerted on one end of the string.

- equal to ✔
- greater than
- less than
- All of the above

In a free-body diagram, all the forces acting on an object start with their head on the dot that represents the object.

- True
- False ✔

The net force acting on an object that is not accelerating is _____ .

- positive
- negative
- zero ✔
- None of the above

The applied force in a pulley system is equal to the _____ for a non-accelerating system.

- weight
- tension ✔
- mass
- None of the above

The mechanical advantage is defined as the ratio of _____.

- output force to input force ✔
- input force to output force
- input force to applied force
- None of the above

The output force corresponds to the load.

- True ✔
- False

The theoretical mechanical advantage is equal to the number of _____ supporting the load.

- pulleys
- string segments ✔
- effort forces
- All of the above

Work is defined as the force multiplied by the _____.

- time
- mass
- distance ✔
- None of the above

For a machine with a mechanical advantage greater than one, the distance over which the input force acts is _____ the distance over which the output force acts.

- larger than ✔
- smaller than
- equal to
- None of the above

Exercise 1

Explain the relationship between number of pulleys and mechanical advantage. Use tension and at least two free body diagrams to support your answer. Submit a photo of your free body diagrams in Photo 1.

Mechanical advantage is directly related to the number of pulleys in a system. The tension of the string provides an upward force to support the mass, and introduction of pulleys effectively increases the number of strings supporting the mass. For example, as shown in the attached free body diagrams, one movable pulley (as used in this exercise) effectively has two strings supporting the mass, making the necessary tension of the rope half of the mass's weight, yielding an MA of 2. The compound movable pulley with two pulleys effectively has three strings supporting the mass, making the necessary tension of the rope 1/3 the mass's weight, yielding an MA of 3. Thus, the mechanical advantage for a pulley system with n pulleys can be written as MA=n+1 when a force is applied upward. In short, increasing the number of pulleys increase the mechanical advantage.

Consider a pulley system with a mechanical advantage of 3 connected to a mass moving with a constant velocity. Calculate the mass of the object if the applied force is 15 N. Show your work.

$MA=F_{out}/F_{in}$
3 N=mg/15
3*15 N=mg
45 N=mg
m=45 N/g=45 N/9.81 m/s^2
m=4.6 kg

Compare the efficiencies of single pulley systems and compound pulley systems. Which type of system is more efficient on average and why? Use Data Tables 2 and 3 to explain your answer.

The single pulley system in this exercise is generally more efficient than the compound pulley system as can be seen by comparing any trial with the same number of washers, or by averaging the efficiency of each trial for each system. The single pulley system has an average efficiency of 93.9% across all trials. The compound pulley system has an average efficiency of 91.3% across all trials. This makes sense because the efficiency is reduced as more friction is added to the system and the compound pulley system has two pulleys, or two chances to increase the friction in the system above the ideal frictionless system, while the single pulley system only has one pulley and one chance to increase the friction.

Data Table 1: Washer and Pulley Masses
(SAMPLE ANSWER BELOW)

Mass of 5 Washers (kg)	Average Washer Mass (kg)	Mass of Pulley (kg)
0.035	0.007	0.024

Data Table 2: Single Pulley System
(SAMPLE ANSWER BELOW)

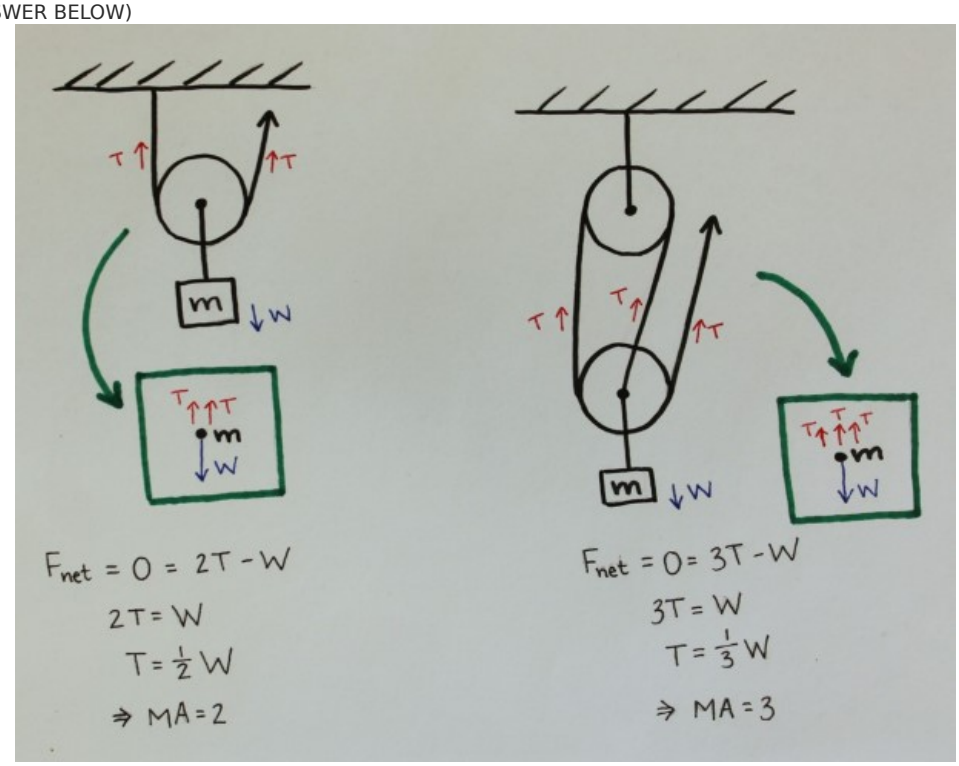
Number of Washers	Mass of Washers and Pulley (kg)	Weight F_{out} (N)	Effort Force $F_{in,actual}$ Actual (N)	Effort Force $F_{in,\ theory}$ Theoretical (N)	Actual Mechanical Advantage MA	Theoretical Mechanical Advantage TMA	Efficiency (%)
1	0.031	0.304	0.16	0.152	1.9	2.00	95
2	0.038	0.373	0.19	0.186	2.0	2.01	100
3	0.045	0.441	0.25	0.221	1.8	2.00	90

4	0.052	0.510	0.27	0.255	1.9	2.00	95
5	0.059	0.579	0.31	0.289	1.9	2.00	95

Data Table 3: Compound Pulley
(SAMPLE ANSWER BELOW)

Number of Washers	Weight F_{out} (N)	Effort Force $F_{in,actual}$ Actual (N)	Effort Force $F_{in,theory}$ Theoretical (N)	Actual Mechanical Advantage MA	Theoretical Mechanical Advantage TMA	Efficiency (%)
1	0.304	0.11	0.101	2.8	3.01	93
2	0.373	0.13	0.124	2.9	3.01	96
3	0.441	0.16	0.147	2.8	3.00	93
4	0.510	0.20	0.170	2.6	3.00	87
5	0.579	0.21	0.193	2.8	3.00	93

Photo 1: Free Body Diagrams for Question 2
(SAMPLE ANSWER BELOW)



Exercise 2

How does addition of pulleys into a system affect the MA? Is it a linear change? Does the direction of applied force matter? Reference Graph 1 in your answer.

The MA increases linearly with increasing number of pulleys, but the direction in which the force is applied factors in. As can be seen in **Graph 1**, the MA has a linear relationship with pulley number: MA=n+1 (n=number of pulleys) for an upward applied force and MA=n for a downward applied force.

How would the mechanical advantage change on a different planet with a different gravitational force? Explain your answer.

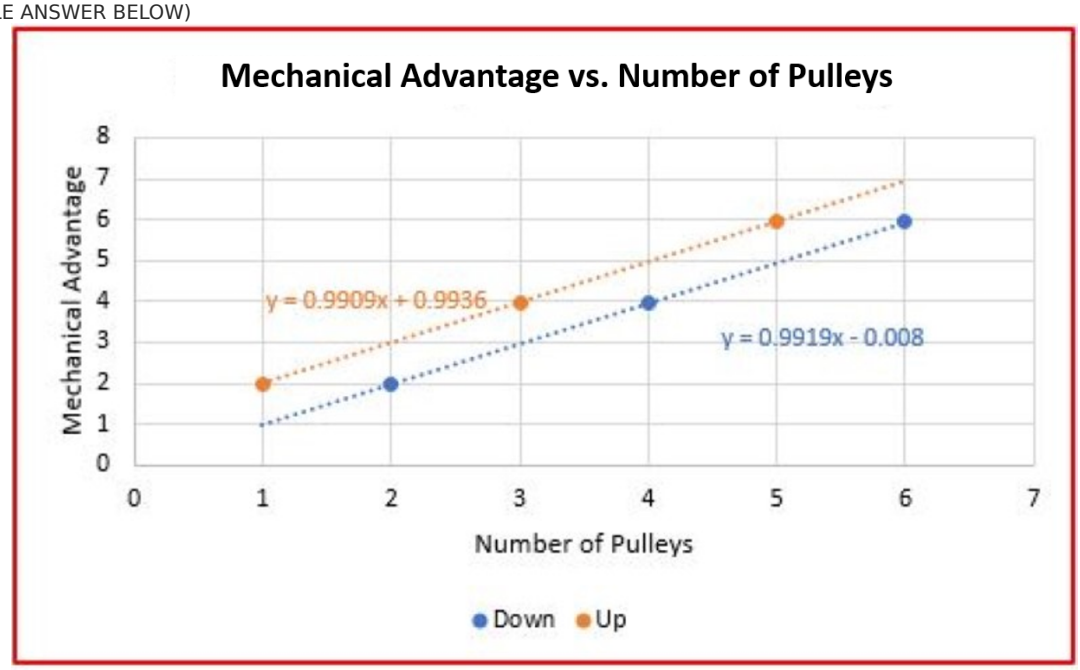
The mechanical advantage would remain the same. This is because the MA is determined by the number of pulleys. The number of pulleys affects the effective amount of strings pulling upward on the mass. Though the necessary applied force necessary to lift would change on a different planet, the gravitational (weight) force of the object would change by the same factor. This makes the MA independent of the gravitational force on the planet.

Data Table 4: Pulley Simulation
(SAMPLE ANSWER BELOW)

Mass (g)	1000	Weight F_{out} (N)	9.81
Number of Pulleys	Magnitude of Effort Force F_{in} (N)	Direction of Force	Mechanical Advantage
6	1.65	D	5.95

5	1.65	U	5.95
4	2.48	D	3.96
3	2.47	U	3.97
2	4.96	D	1.98
1	4.95	U	1.98

Graph 1: Number of Pulleys vs. Mechanical Advantage
(SAMPLE ANSWER BELOW)



Competency Review

A _____ pulley is one that moves during the operation of the pulley system.

- single
- fixed
- movable ✔
- None of the above

A benefit obtained by using a pulley system is called a mechanical _____.

- newton
- interval
- advantage ✔
- All of the above

As the number of string segments supporting the load in a pulley system increases, the effort needed to move the load _____.

- decreases ✔
- increases
- remains constant
- All of the above

The efficiency of a pulley system is a measure of how similar to an ideal system it is.

- True ✔
- False

The work put into an ideal simple machine must be _____ the work done by the machine.

- greater than
- less than
- equal to ✔
- None of the above

The applied force in a pulley system is equal to the _____ for a non-accelerating system.

- weight
- tension ✔
- mass
- All of the above

As more pulleys are added to a system of pulleys, the efficiency of the system _____.

- decreases ✔
- increases
- remains constant
- None of the above

A compound pulley system with an TMA of 3 and an AMA of 2.8 has an efficiency of _____ percent.

- 20
- 80
- 93 ✔
- None of the above

As pulleys are added to a pulley system, the mechanical advantage _____ with the number of pulleys.

- increases exponentially
- decreases linearly
- increases linearly ✔
- None of the above

A pulley system with a mechanical advantage of 3 lifts a load of 11 N using an effort of _____ N.

- 3.7 ✔
- 7.3
- 33
- None of the above

Extension Questions

Is it possible to increase the efficiency of a pulley system without affecting the mechanical advantage of the system? If so, describe how, and if not, explain why not. (SAMPLE ANSWER BELOW)

Yes, it is possible to increase the efficiency of a pulley system without affecting the mechanical advantage of the system. The mechanical advantage depends on the number of pulleys supporting the load, or the number of strings supporting the load, so this number must remain constant, but there could be extra pulleys changing the direction of the effort force, which could be removed, and which would increase the efficiency by decreasing the friction in the system. Additionally, the pulleys in the system could be exchanged for ones with less friction, increasing the efficiency of the system.