

FACTFILE:

GCSE

Technology and Design

OPTION B: MECHANICAL AND PNEUMATIC CONTROL SYSTEMS



2.22 General Concepts and 2.24 Pulley Systems

Learning Outcomes

You should be able to:

- show that they understand and can explain the use of pulley systems in lifting systems (limited to three pulleys); and

Explain and perform calculations using:

$$\text{Efficiency \%} = \left(\frac{\text{mechanical advantage}}{\text{velocity ratio}} \right) \times 100$$

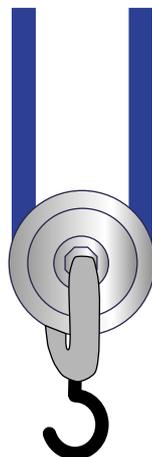
$$\text{Mechanical advantage} = \frac{\text{load}}{\text{effort}}$$

$$\text{Velocity ratio} = \frac{\text{distance moved by effort}}{\text{distance moved by load}}$$

Course Content

Pulley Systems

A pulley is a simple machine that uses grooved wheels and a rope to raise, lower or move a load or a pulley can be used to simply change the direction of the force you are using when lifting a load.



Pulleys make work easier to lift a heavy load

It is easier to lift the load as the effort you put in is less than the load. By linking lots of pulleys together to form a system you can apply the force over a much longer distance (of rope attached to the load).

There are many examples of pulleys being used in everyday life. For example, everyday window blinds, raising and lowering weights in the gym amongst many other examples.



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These are examples of force multipliers' they make the load easier to move because they have what is known as 'Mechanical Advantage' (MA).

The output force (Load) achieved by the pulley is greater or a 'multiplication' of the input force. (Effort)

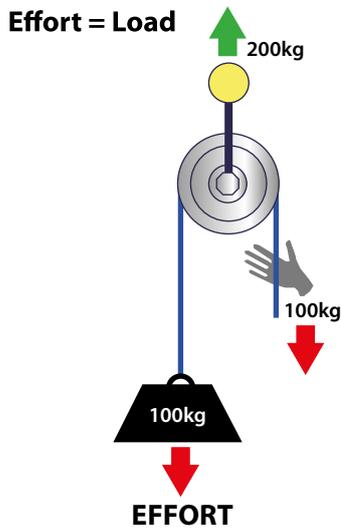
Mechanical Advantage

$$\text{Mechanical Advantage} = \frac{\text{Load}}{\text{Effort}}$$

Load = weight of the object – measured in Newtons (Load)

Effort = the force you put in – measured in Newtons (Load).

1:1 Pulley = NO MECHANICAL ADVANTAGE Effort = Load



Load = 100Kg
Effort = 100Kg

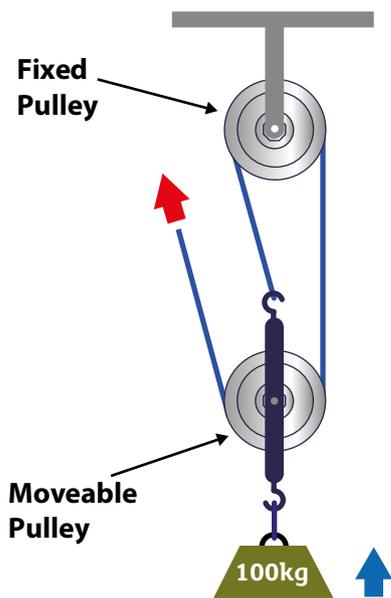
$$MA = \frac{\text{Load}}{\text{Effort}} = \frac{100\text{Kg}}{100\text{Kg}} = 1$$

Therefore the Mechanical Advantage = 1:1

This is an example of a simple pulley where there is no mechanical advantage.

The 100Kg load is simply easier to lift because the direction of the force has been redirected.

2:1 Pulley System = MECHANICAL ADVANTAGE



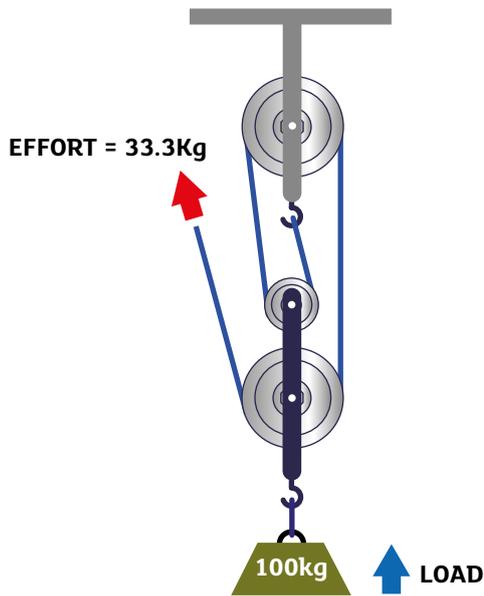
Load = 100Kg
Effort = 50Kg

$$MA = \frac{\text{Load}}{\text{Effort}} = \frac{100\text{Kg}}{50\text{Kg}} = 2$$

Therefore the Mechanical Advantage = 2:1

This system has one fixed pulley and one moveable pulley

3:1 Pulley System = MECHANICAL ADVANTAGE



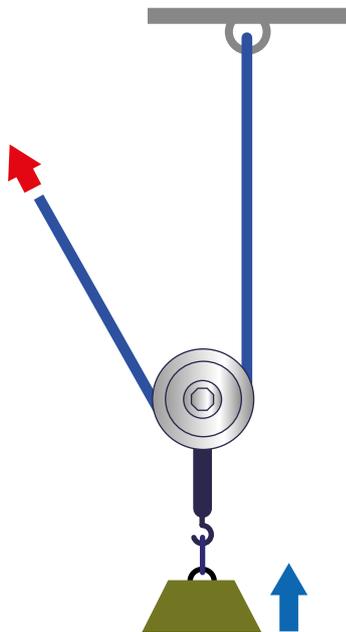
This system has two fixed pulleys and one moveable pulley

Load = 100Kg
Effort = 33.3Kg

$$MA = \frac{\text{Load}}{\text{Effort}} = \frac{100\text{Kg}}{33.3\text{Kg}} = 3$$

Therefore the Mechanical Advantage = 3:1

Velocity Ratio



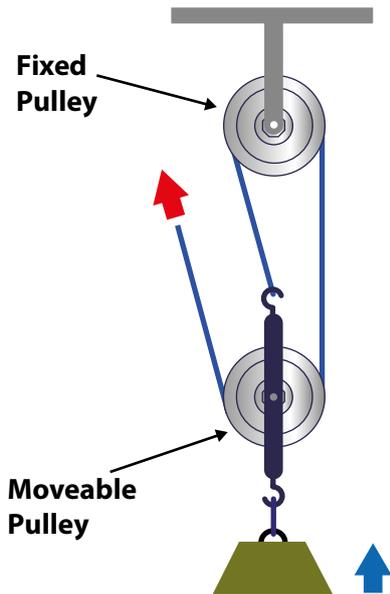
$$\text{Velocity Ratio} = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}} = \frac{1\text{m}}{1\text{m}} = 1.1$$

Load (Output Distance) = the distance that the object moves up – measured in metres

Effort (Input Distance) = the distance that you move the rope – measured in metres

In this case the Velocity Ratio is 1:1 as for every metre the person pulls the rope down – the load will be raised by one metre.

2:1 Pulley System



In the pulley system shown if the effort on the right hand rope is pulled down 1m then 1 m of rope must come over the top pulley. This means that EACH of the ropes holding the bottom pulley must shorten by $\frac{1}{2}$ m and so the load rises $\frac{1}{2}$ m. This means that the velocity ratio of our pulley system is 2. However if the pulley is 100 % efficient and the velocity ratio is 2 then the mechanical advantage is also 2 and that means that the load is double the effort. This means, for example, that you can lift a load of 100 N using an effort of only 50 N.

$$\text{Velocity Ratio} = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}} = \frac{1.0\text{m}}{0.5\text{m}} = 2.1$$

If a pulley system is perfectly efficient the mechanical advantage and the velocity ratio are both equal to the number of pulleys.

Efficiency

Efficiency is a measure of how well a machine or device uses energy.

$$\text{Efficiency Advantage} = \frac{\text{Mechanical Advantage}}{\text{Velocity Ratio}} \times 100$$

Using the information for the 2:1 Pulley system above

$$\text{Mechanical Advantage} = 2$$

$$\text{Velocity Ratio} = 2$$

$$\text{Using the above formula} \quad \text{Efficiency Advantage} = \frac{\text{Mechanical Advantage}}{\text{Velocity Ratio}} \times 100$$

$$\text{Efficiency Advantage} = \frac{2}{2} \times 100 = 1 \times 100$$

Therefore this pulley system is deemed to be 100% efficient

However, no pulley system will be 100% efficient because not only will there be friction in the axles but the pulleys themselves have weight (friction in the bearings) and also need energy to be lifted.

Revision Questions

1. Based on your knowledge of Mechanical Advantage complete the following table.

Number of pulleys	Load (N)	Effort (N)
1	14	
2	6	
3		4
	16	8
	24	6

2. Pulleys may be used in simple lifting systems. Calculate the effort required in a lifting system if the load is 80N and the Mechanical Advantage is 1.8.

3. If the Velocity ratio of the same system is 2 and the effort moves 1.5m, calculate the distance moved by the load.

4. Using the information from questions 2 and 3, calculate the efficiency of the lifting system.

Web Resources

<http://mocomi.com/pulley/>

Video Resources

<https://www.youtube.com/watch?v=E8EWT0d0vKg>

<https://youtu.be/UtfVZtuyuHU>

<https://youtu.be/fv0maf2GfCY>

https://youtu.be/ZHuXh_N5CEo

