# Grade 8 Science

Systems in Action

Class 8

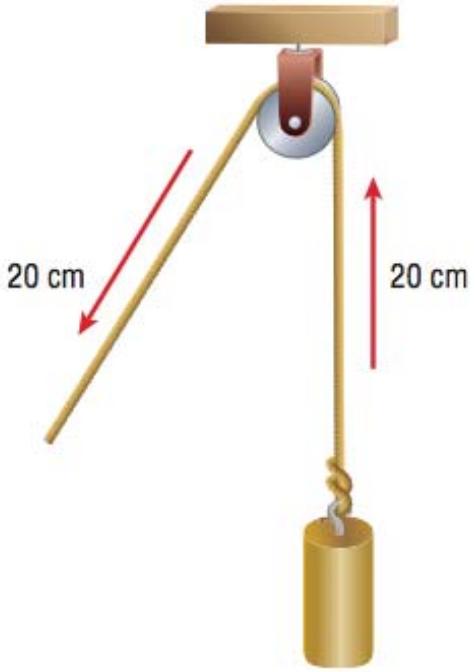
# Mechanical Advantage

- Mechanical Advantage – the ratio of output force to input force for a given machine

$$\text{MA} = \frac{\text{output force}}{\text{input force}}$$

- Mechanical Advantage has no units
- Machines with a mechanical advantage greater than 1 generally make tasks easier and faster to accomplish

- Mechanical advantage of 1 only change the direction between the input and output forces
- Used for tasks in which the direction of the force must change
- Ex: Fixed pulley




$$MA = \frac{\text{input distance}}{\text{output distance}}$$

- Some machines have a mechanical advantage of less than 1 when the input force is greater than the output force
- Hockey stick (Type 3 Lever) increases the distance and speed of the output

$$MA = \frac{\text{input distance}}{\text{output distance}}$$

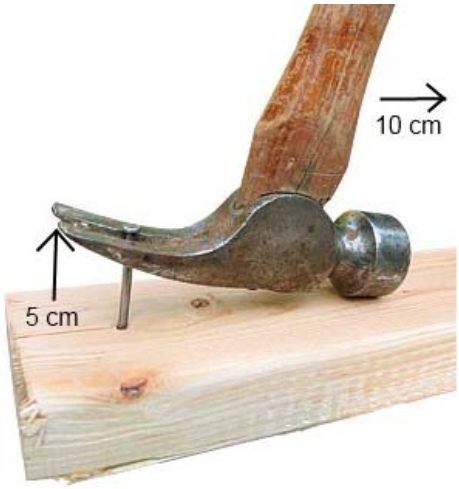
**Figure 3** Although the mechanical advantage of a hockey stick is less than 1, the benefit is the speed and distance that the blade at the end of the stick travels.


# Checkpoint


To lift a load 5cm with a pulley system, 15cm of string had to be pulled. What is the mechanical advantage?

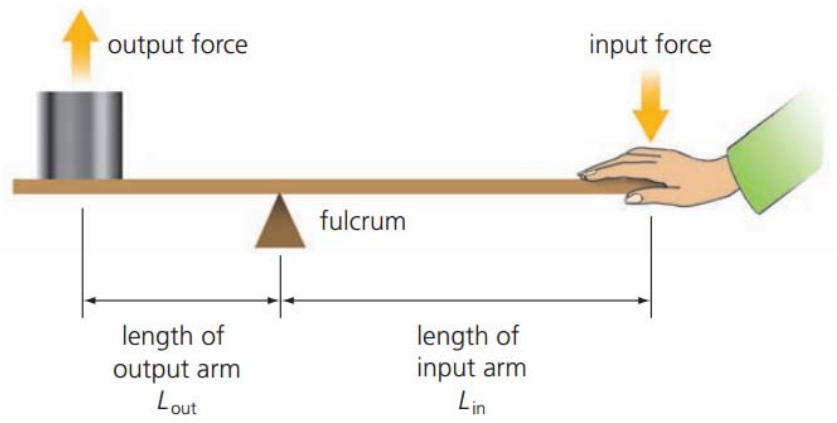
# Ideal Mechanical Advantage

- Ideal Mechanical Advantage (IMA) – the mechanical advantage of a machine if all of the input force is converted into output force
  - Impossible in real-world applications due to friction, thermal energy, light energy, sound energy



# Mechanical Advantage for Simple Machines

**Lever**




$$\text{Ideal Mechanical Advantage} = \frac{\text{length of input arm}}{\text{length of output arm}}$$


## Checkpoint

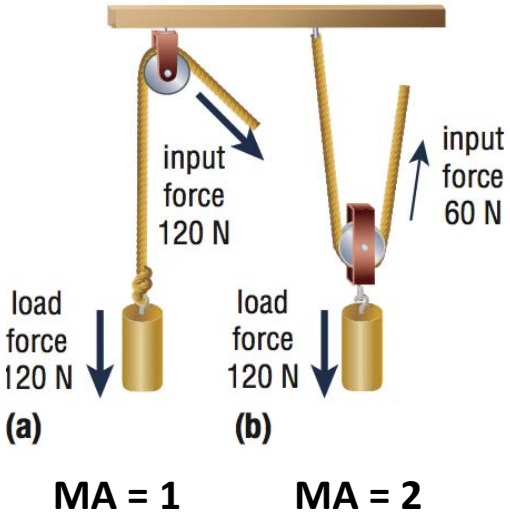

The wheelbarrow has an effort arm (input arm) that is 1.8m and a load arm (output arm) that is 0.50m. What is the mechanical advantage of the wheelbarrow?

# Mechanical Advantage for Simple Machines

## Pulleys

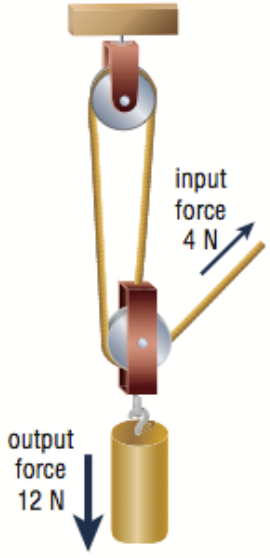
$$\text{MA} = \frac{\text{output force}}{\text{input force}}$$

- A simple way to determine the ideal mechanical advantage of a pulley system is to count the number of support ropes





## Checkpoint


The pulley system is being used to raise a load. The input force on the pulley system is 4N, and the output force is equal to 12N. What is the actual mechanical advantage of the pulley system?

# Mechanical Advantage for Simple Machines

## Wheel and Axle

- If input force is applied to the axle (i.e. bicycle)

$$\text{Ideal Mechanical Advantage} = \frac{\text{radius of the axle}}{\text{radius of the wheel}}$$

- If input force is applied to the wheel (i.e. screwdriver)

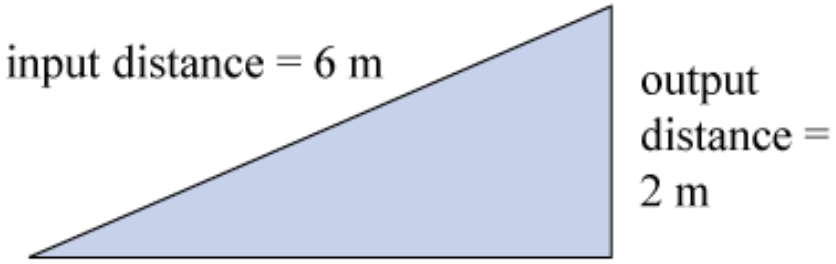
$$\text{Ideal Mechanical Advantage} = \frac{\text{radius of the wheel}}{\text{radius of the axle}}$$


## Checkpoint


The handle of a garden tap of radius 3.0cm is connected to a shaft of radius 0.50cm. What is the ideal mechanical advantage of this wheel and axle?

# Mechanical Advantage for Simple Machines

## Inclined Planes




$$\text{Ideal Mechanical Advantage} = \frac{\text{length of ramp}}{\text{height of ramp}}$$


## Checkpoint



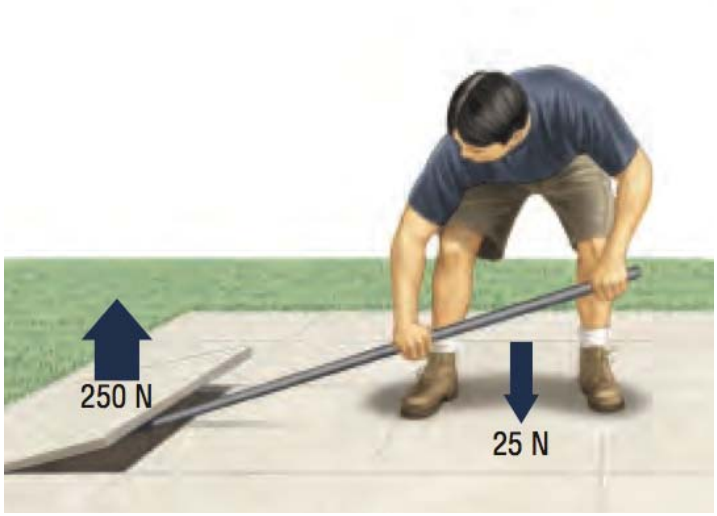
An object is raised 1.0m by pushing it along a loading ramp that is 6.0m long. What is the ideal mechanical advantage of this ramp?

# Actual Mechanical Advantage

- Actual Mechanical Advantage – the mechanical advantage of a machine in real-world applications
  - Calculated by subtracting force of friction, slippage, and distortion from the ideal mechanical advantage

$$\text{actual MA} = \frac{\text{measured output force}}{\text{measured input force}}$$

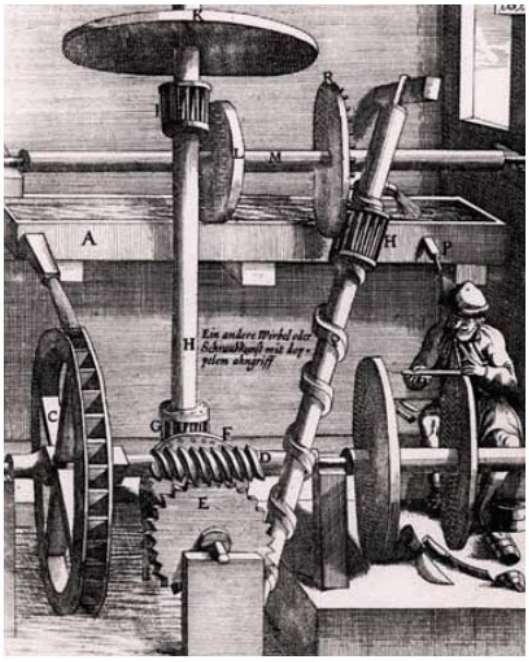
- Imagine lifting a patio stone using a pry bar as a lever
- Calculate the actual mechanical advantage




# Checkpoint


What is the actual mechanical advantage of a lever if the input force is measured as 37N and the output force is measured as 185N?

# Think About It…



- Is it possible to create a perpetual-motion machine that would run by itself forever?

# Mechanical Efficiency

- Mechanical Efficiency – the percentage of work input that is turned into useful work output

$$\text{mechanical efficiency (\%)} = \frac{\text{output energy (or work)}}{\text{input energy (or work)}} \times 100\ \%$$

- We want machines to have a high level of efficiency to minimize wasting energy


## Checkpoint


A pulley is dirty and rusted so it takes a force of 90N to raise a 70N container of nails. The nails are raised 8m to the second floor. What is the efficiency of the pulley?

# Checkpoint

A rusty pulley is used to lift a 2450N motorcycle onto a transport truck. What is the efficiency of the pulley if 3500N is used to lift the motorcycle 1.5m onto the truck?

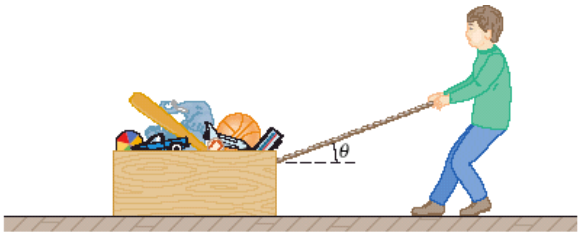
# Efficiency of Common Mechanisms

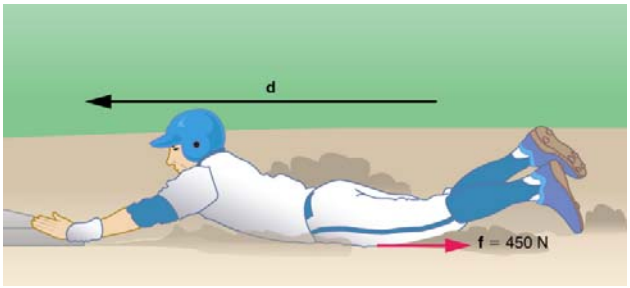
| Mechanism | Efficiency (%) |
|---|---|
| Electric generator | 99 |
| Olympic track bike | 98 |
| Mountain bike | 85 |
| Hybrid-diesel car | 45 |
| Electric car | 44 |
| Hybrid-gasoline car | 36 |
| Conventional gas-powered car | 22 |
| Solar cell | 10 |

# Friction

- Friction – the force that resists motion between two objects in contact with each other

- **Static friction** – the force that prevents surfaces at rest from sliding against one another
- **Kinetic friction** – the force that acts against a surface sliding across another surface

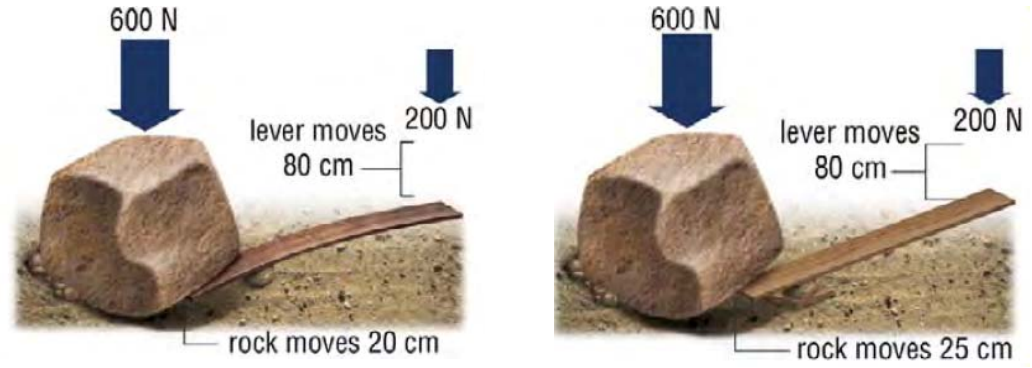



- To increase efficiency and minimize friction, use a lubricant
- Lubricant – a substance, usually a liquid, placed between two sliding surfaces to reduce the amount of friction between them
  - Ex: Ski wax and engine oil


# Inefficient Levers

- If the lever is not rigid enough or the fulcrum is not stable, the lever becomes inefficient




# Productivity

- Productivity – amount of output produced per unit of time
  - Allows work to be done faster and for multi-tasking

| Advantages | Disadvantages |
|---|---|
| - More tasks done in less time<br>- Does not require human labour<br>- Inexpensive products<br>- High availability | - Loss of job opportunities and skillset<br>- Decreased quality of service<br>- Lower quality products<br>- Lack of creativity and customization |

# Evaluating Systems

- Criteria – standard rules or tests on which a decision or judgement can be based
  - Developers look at efficiency, safety, cost, environmental impact, etc.
- Quantitative Assessment – analysis of numerical data
- Qualitative Assessment – analysis of observations

## Case Scenario #1:

## Transporting Groceries in 1000 A.D.

- People grew or caught their own food
- Stored food in containers made of woven grass, animals skins and animal organs

| Criteria | Description |
|---|---|
| Efficiency | Low – time required to make one container |
| Safety | Low – containers were difficult to clean; cannot protect against insects and rodents |
| Cost | Low – materials were readily available in nature |
| Environmental Impact | Low – containers made from natural products and can decompose |

## Case Scenario #2:

## Transporting Groceries in 1900s

- People began to use paper shopping bags to carry groceries

| Criteria | Description |
|---|---|
| Efficiency | Low – paper bags were not strong |
| Safety | Medium – papers bags were disposable; cannot protect against insects and rodents |
| Cost | High – expensive to produce |
| Environmental Impact | Medium – able to decompose but also produced from trees |

## Case Scenario #3:

## Transporting Groceries in 1970s

- People began to use plastic shopping bags to carry groceries

| Criteria | Description |
|---|---|
| Efficiency | High – plastic bags are very strong |
| Safety | Medium – plastic bags are disposable and can protect from rodents and insects; may cause suffocation |
| Cost | Low – inexpensive to produce |
| Environmental Impact | High – decompose slowly but can be recycled and reused |


# Checkpoint


Evaluate the evolution of delivering mail from the pigeon post, to mail services, to email.