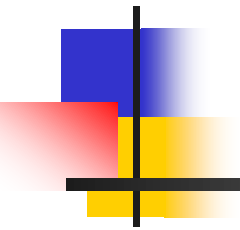
# Chapter 4

## Work and Simple Machines



# 4 – 1 Work and Power

# What is Work ?

- Work – is done when a force exerted on an object causes that object to move a distance.
  - The motion must be in the direction of the force.
  - Measured in Joules. ( J )

# Is this work ?

- Is there work being done here ?
  - Is the object moving in the direction of the force being exerted ?

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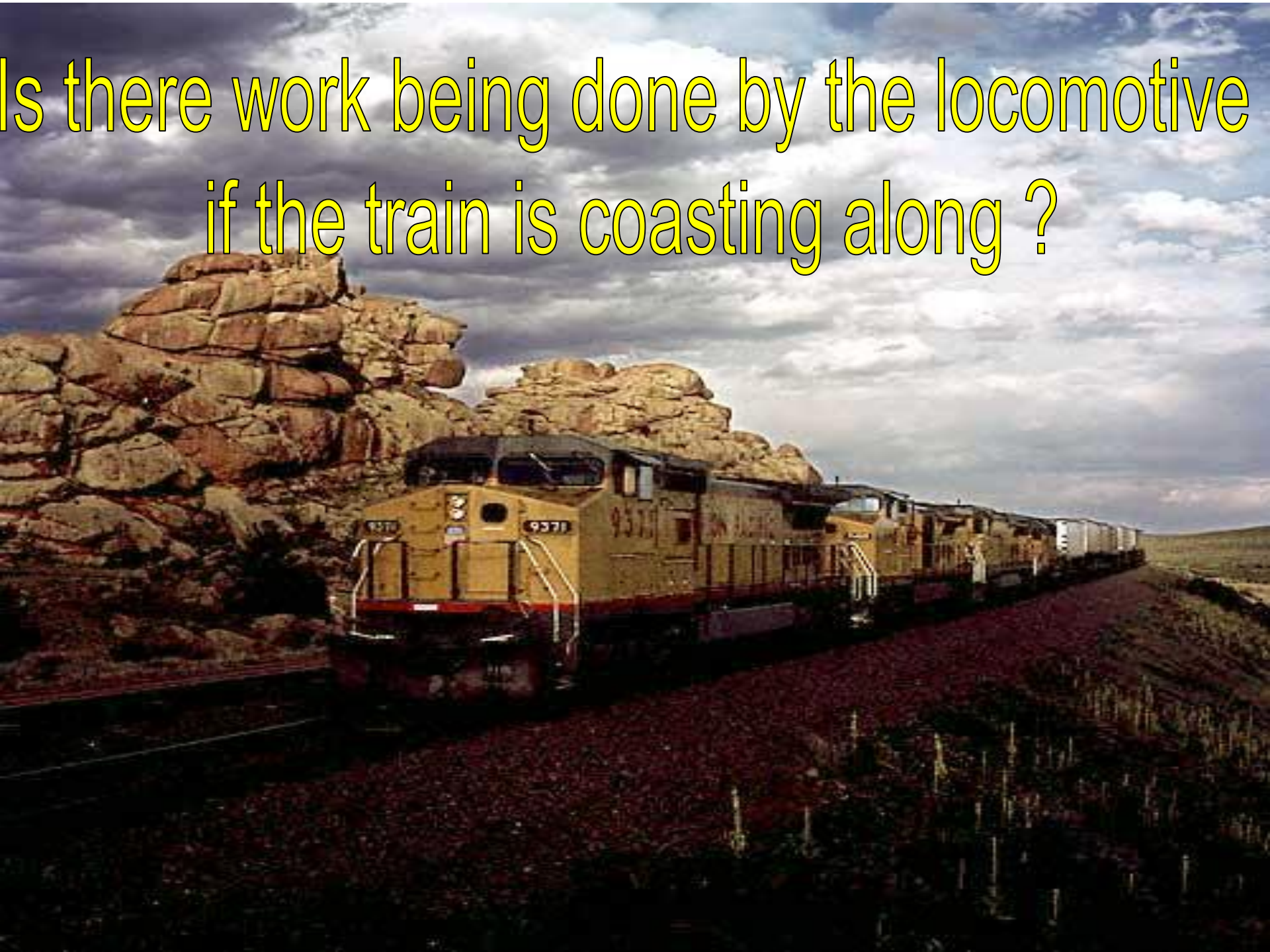
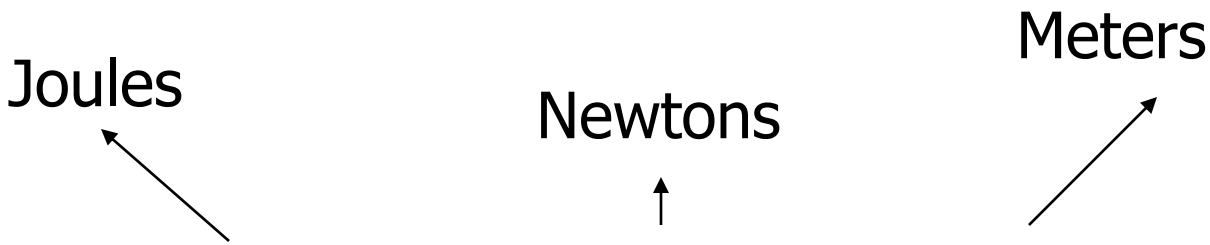

Is there work being done by the locomotive
if the train is coasting along ?

# Calculating Work




- Work = Force * Distance
- W = F d

# Example

1. As you push a lawn mower, the horizontal force is 300 N. If you push the lawn mower 500 m, how much work did you do ?

**F =** 300 N

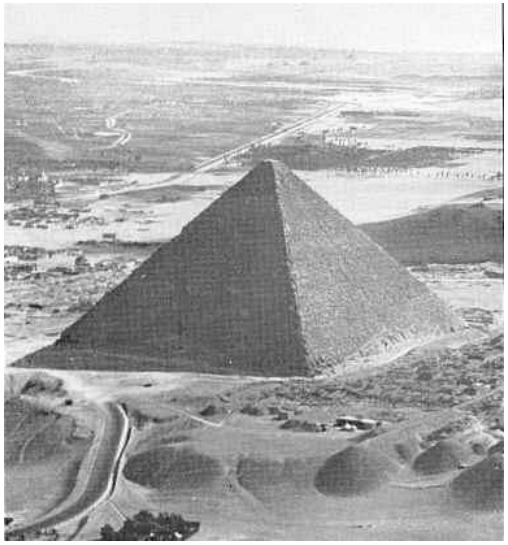
**d =** 500 m

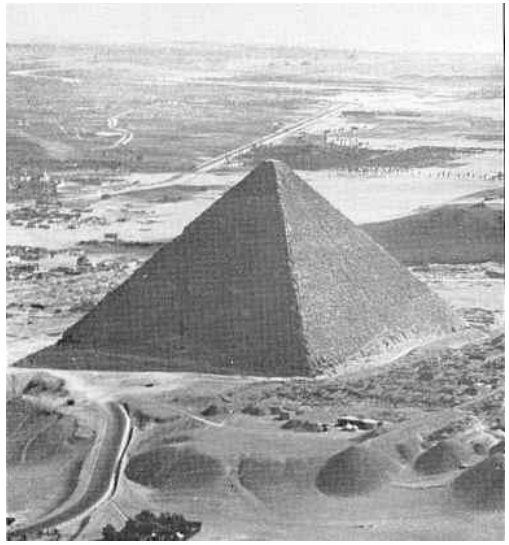
**W =** ?

W = F d

W = 300 N * 500 m

W = 150,000 J





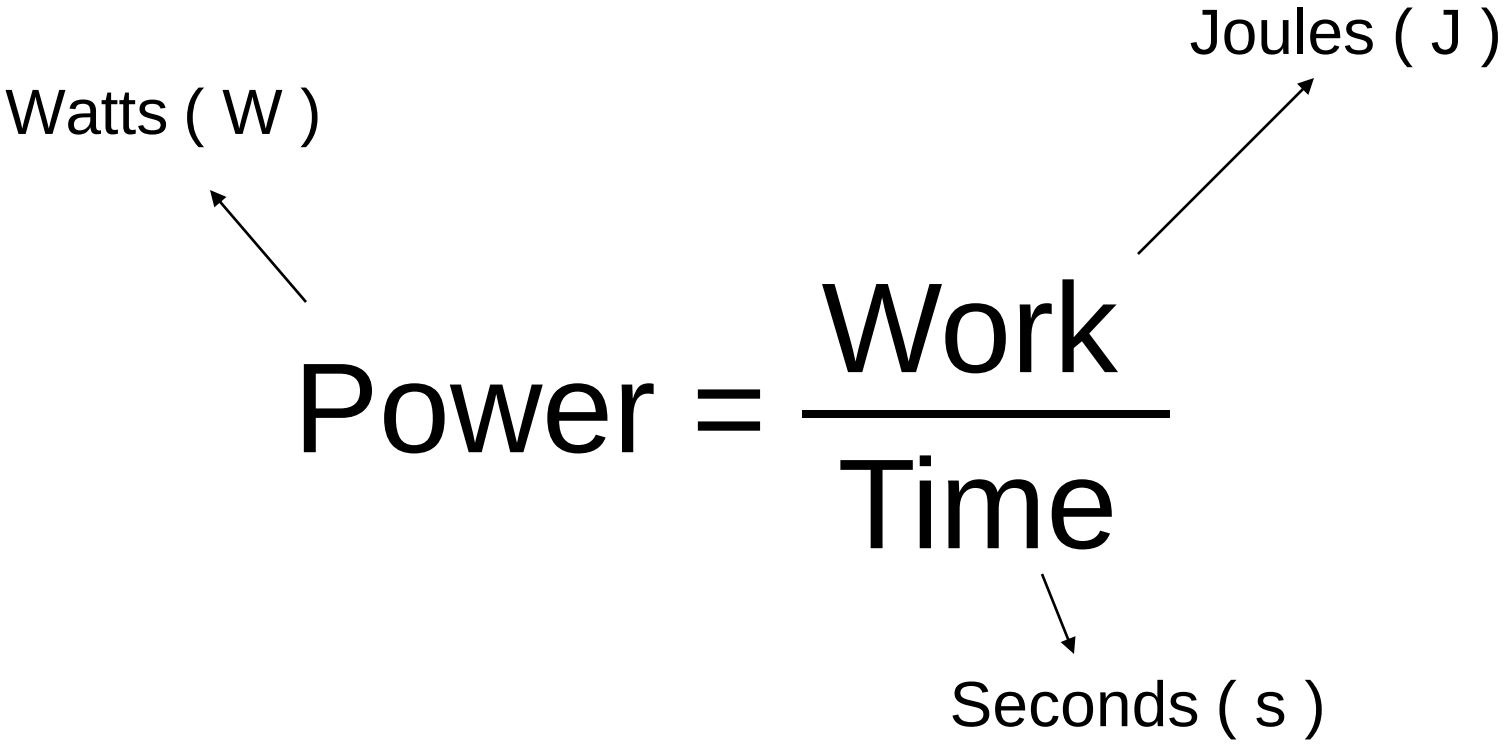
3 months

30 years

# What is Power ?

- Power – the rate at which work is done.
  - How fast work is done.
- Why the term power was developed…

# Calculating Power



# Example

1. At the start of a race, a car does 50,000 J of work in 7 seconds. How much power did the car have ?

$W = 50{,}000\ J$

$t = 7\ s$

$P = ?$

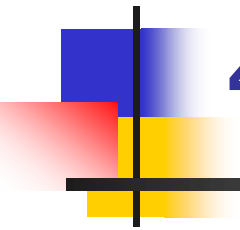
$$Power = \frac{Work}{Time}$$

$$Power = \frac{50{,}000\ J}{7\ s}$$

$$Power = 7{,}142.9\ W$$

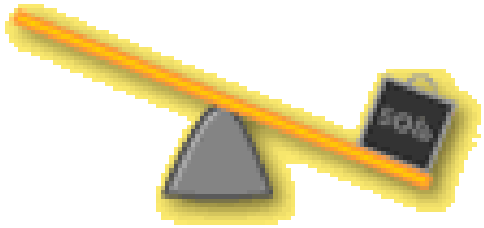
# Power and Energy

- When you do work, you lose energy.
  - The energy doesn't just disappear
  - The energy is transferred to the object you are doing work on.
- For example…
  - When you slam a locker shut ( work ), you are transferring energy to the locker.
- more Power means more Energy

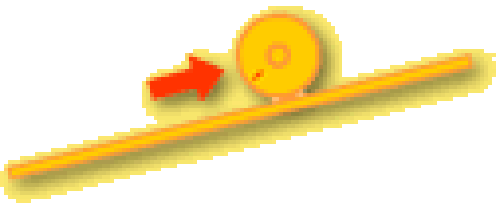


# 4 – 2 Using Machines

# What is a Machine ?




- Machine – A device that makes work easier.




# How do machines make work easier ?

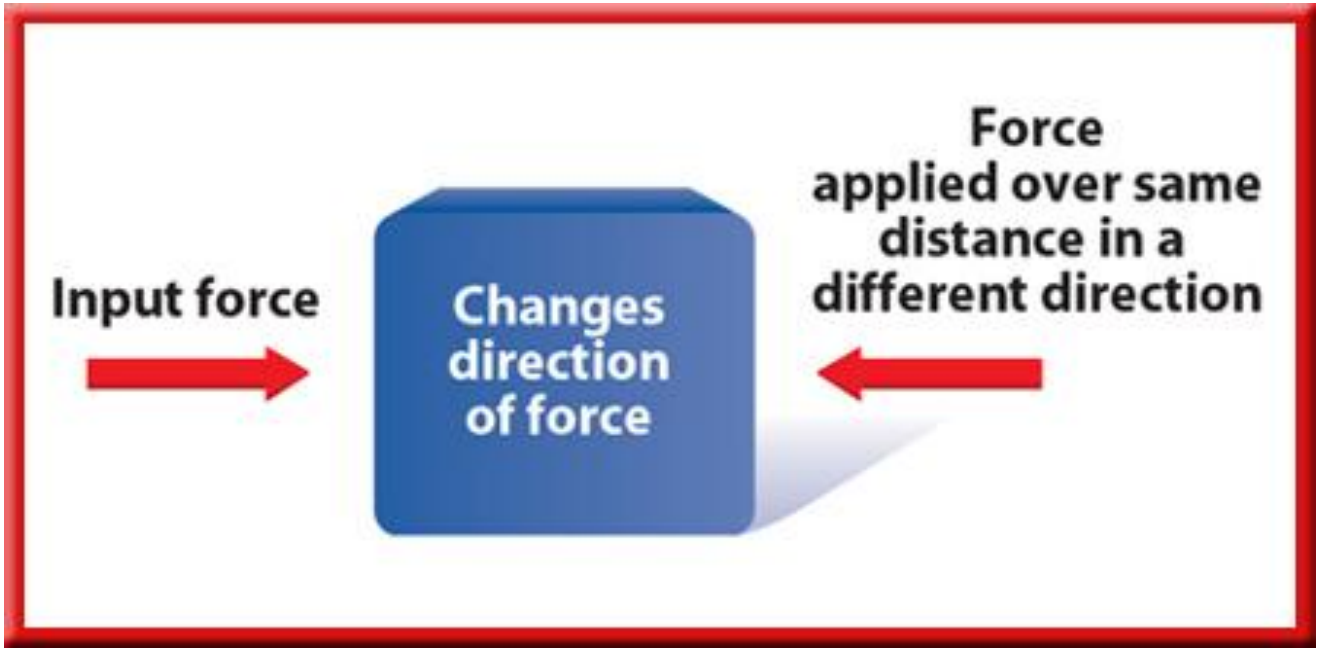
- Machine make work easier by changing the force we exert in :
  1. Size
  2. Direction
  3. Both

# Size

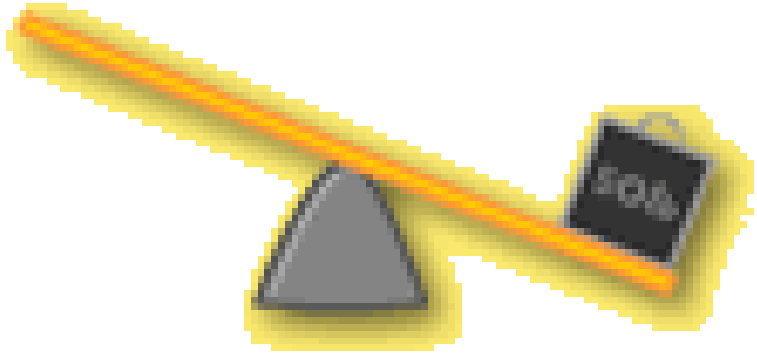

Input force
Increases force
Larger force applied over a shorter distance

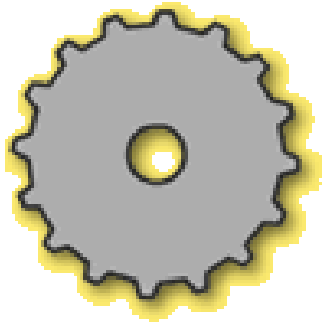

Input force
Increases distance
Smaller force applied over a longer distance

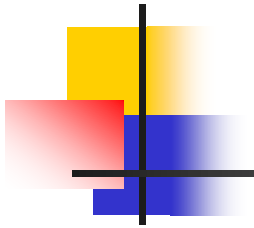
# Direction


Input force
Changes direction of force
Force applied over same distance in a different direction

- Machines help us overcome 2 things :
  1. Gravity
     - Lifting objects
  2. Friction
     - Moving objects







- Machine does not decrease the amount of work we do.
  - Usually we have to do more work with a machine

# Mechanical Advantage

- Mechanical Advantage – the number of times that a machine multiplies the effort force.

# Calculating Mechanical Advantage

$$MA = \frac{\text{Output Force}}{\text{Input Force}}$$

Newtons

Newtons

$$MA = \frac{F_{out}}{F_{in}}$$

# Example

1. To open a bottle, you apply a force of 50N on the bottle opener. The bottle opener applies a force of 775N to the bottle cap. What is the mechanical advantage of the bottle opener ?

# Example

1. While riding your bicycle, you apply a force of 350N to the pedals. The wheels of the bicycle apply a force of 250N to the ground. What is the mechanical advantage of the bicycle ?

# Efficiency

- Some of the input work is transferred into heat energy by friction inside a machine.
- Efficiency – the ratio of output work to the input work.

$$\text{Efficiency} = \frac{\text{Output Work}}{\text{Input Work}} \times 100\ \%$$

# Example

1. You do 100 J of work in pulling out a nail with a claw hammer. If the hammer does 70 J of work, what is the hammer's efficiency ?

# Example

1. You do 150 J of work pushing a box up a ramp. If the ramp does 105 J of work, what is the efficiency of the ramp?

$W_{in} = 150\ J$

$W_{out} = 105\ J$

$Eff = ?$

$$Eff = \frac{W_{out}}{W_{in}} \times 100\ \%$$

$$Eff = \frac{105\ J}{150\ J} \times 100\ \%$$

$$Eff = 0.7 \times 100\ \% = 70\ \%$$

# 4 - 3 Simple Machines

# What is a Simple Machine ?

- Simple Machine – A machine that does work with only one movement.
- Compound Machine – A machine made up of a combination of simple machines.

# 6 Types of Simple Machines

1. Lever
2. Pulley
3. Wheel and Axle
4. Inclined Plane
5. Screw
6. Wedge

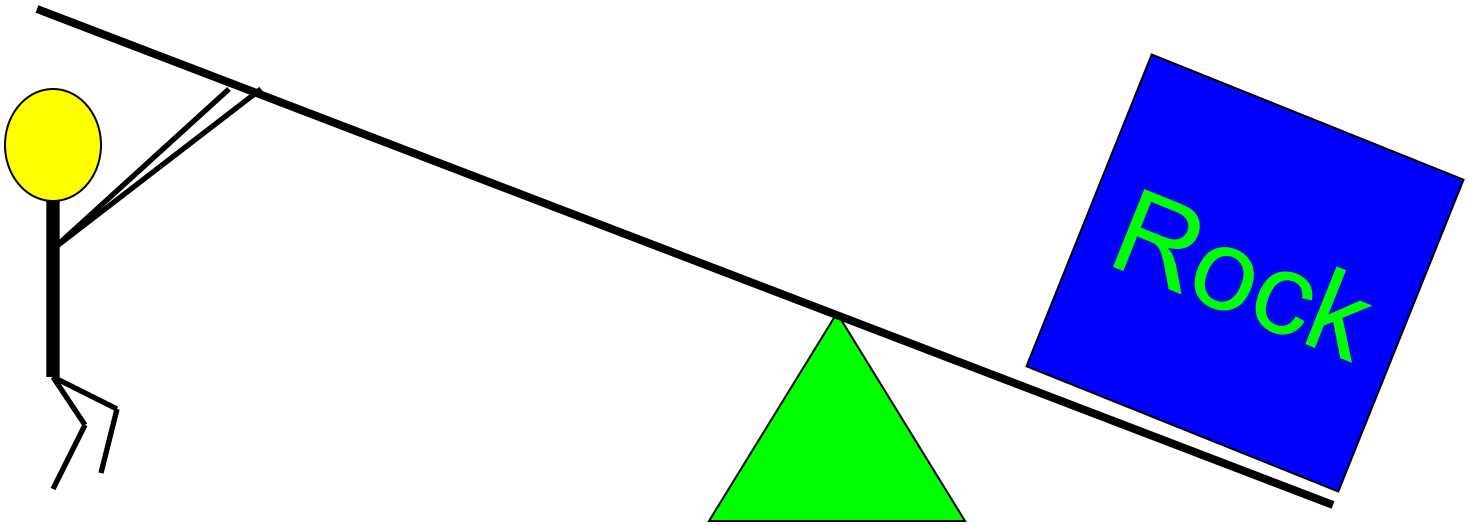
# Lever

- Lever – A bar that is free to pivot, or turn, about a fixed point.
- Fulcrum – the fixed point of a lever.

$$IMA = \frac{l_{in}}{l_{out}} = \frac{\text{Length of Input Arm}}{\text{Length of Output Arm}}$$

# Example

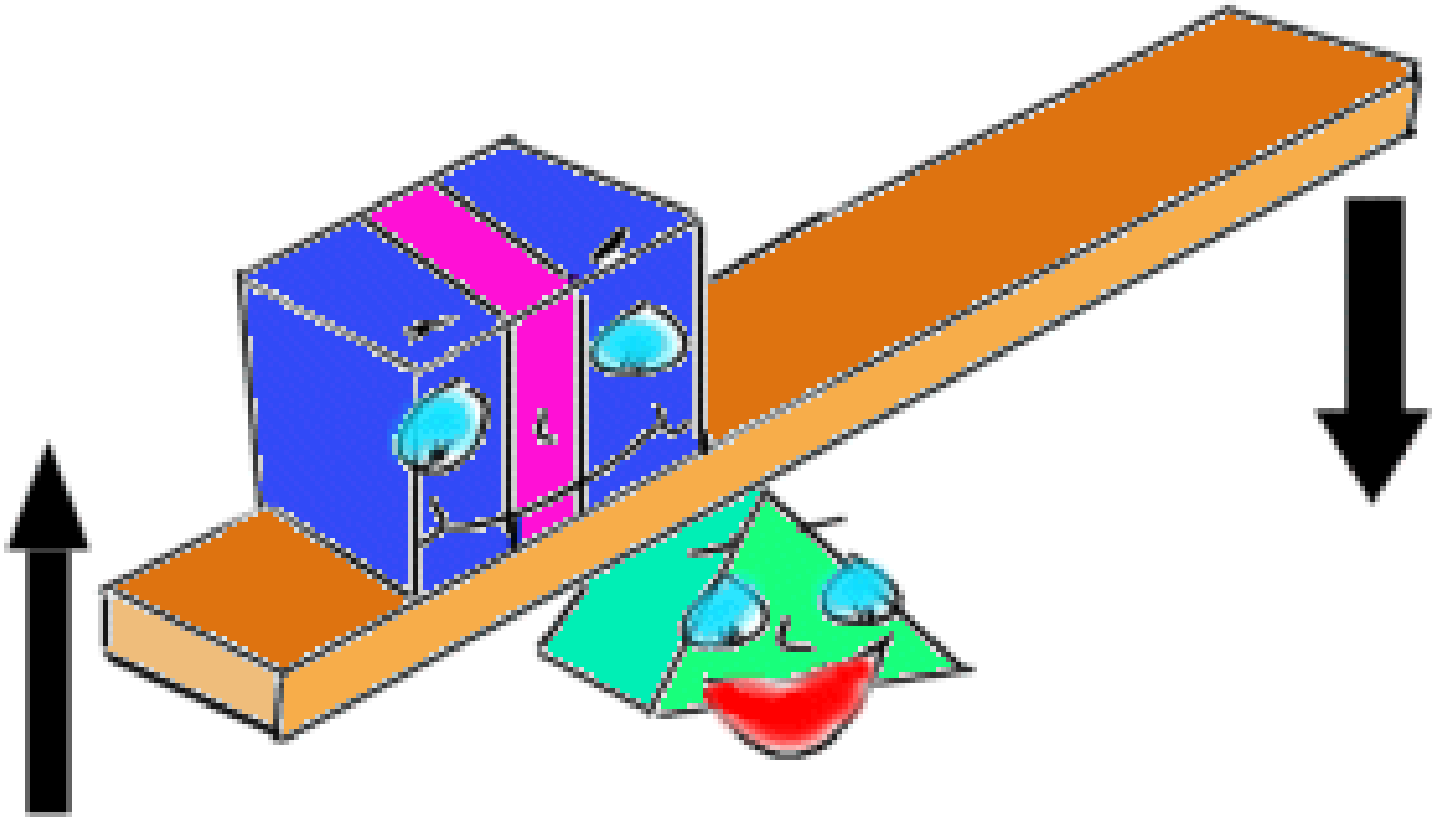
- You can use a crowbar 140 cm long to lift a large rock that is 20 cm from the fulcrum.  What is the IMA of the lever ?

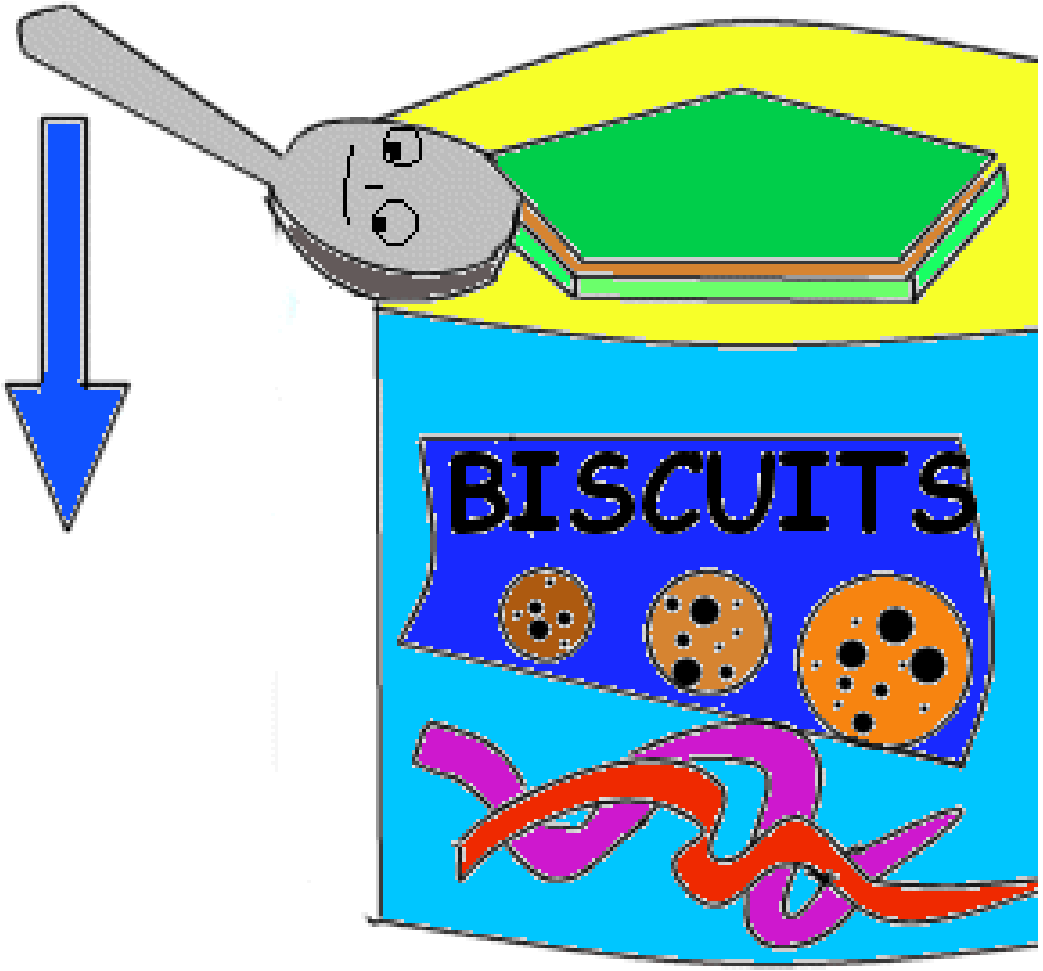

Rock

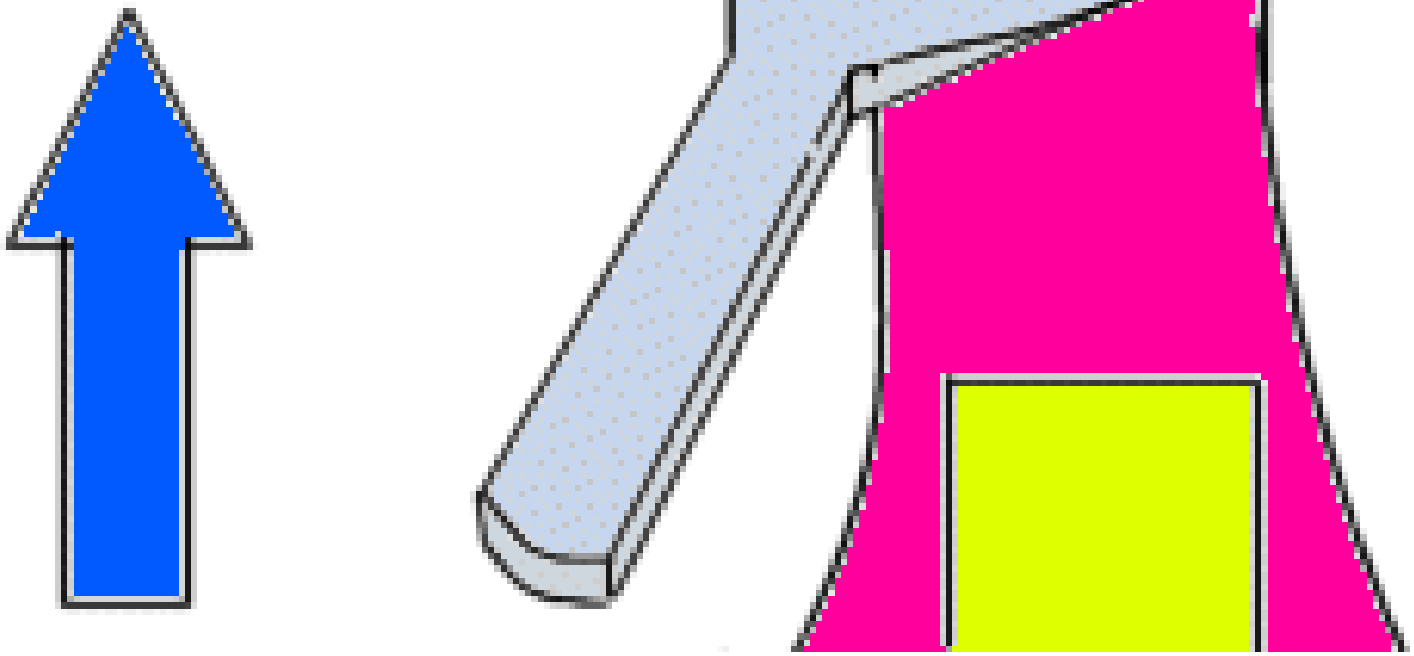
# 3 Classes of Levers

1. First Class Lever – the fulcrum is in the middle.
2. Second Class Lever – the weight is in the middle.
3. Third Class Lever – the input force is in the middle.

# First Class Lever

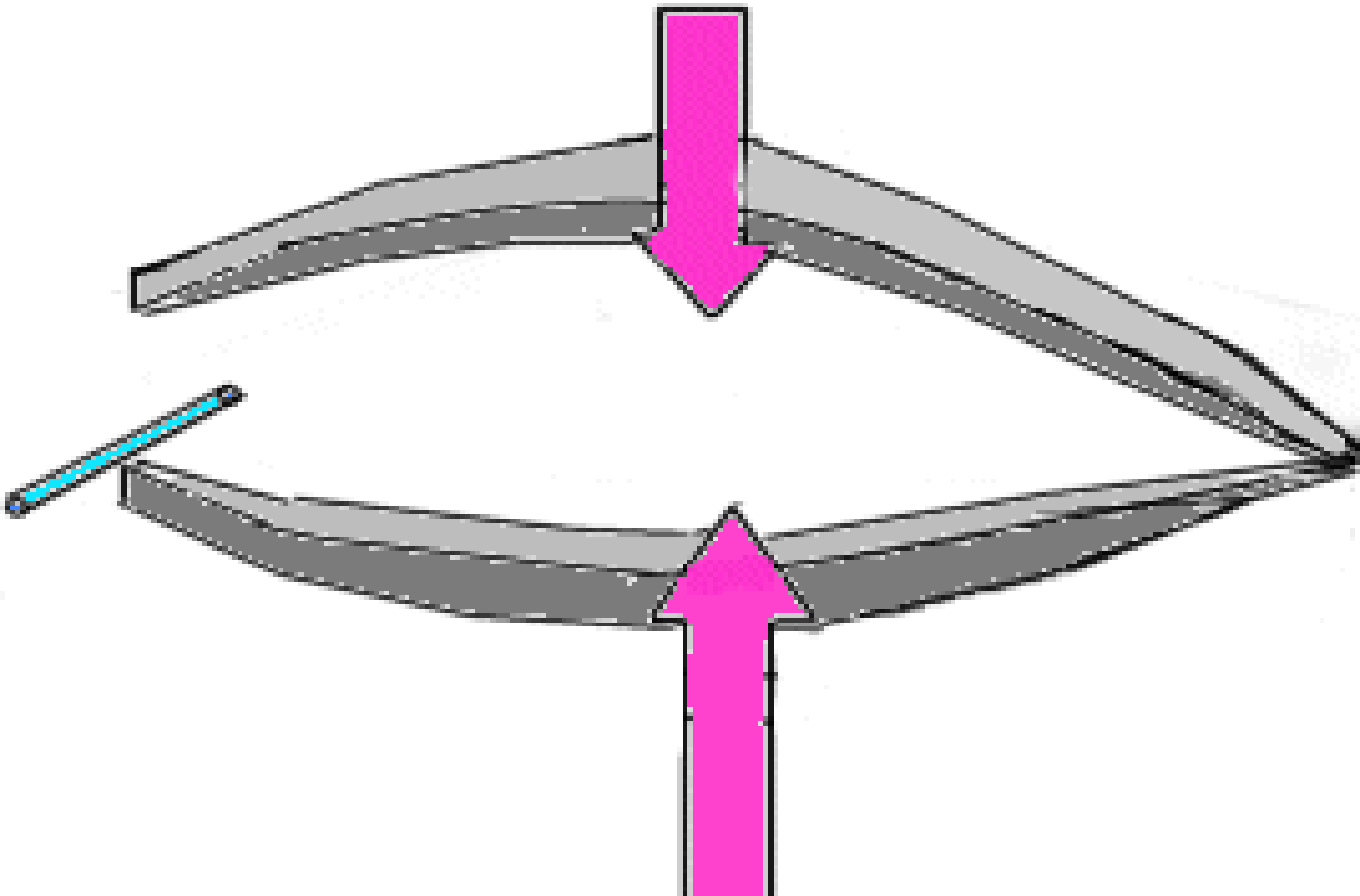


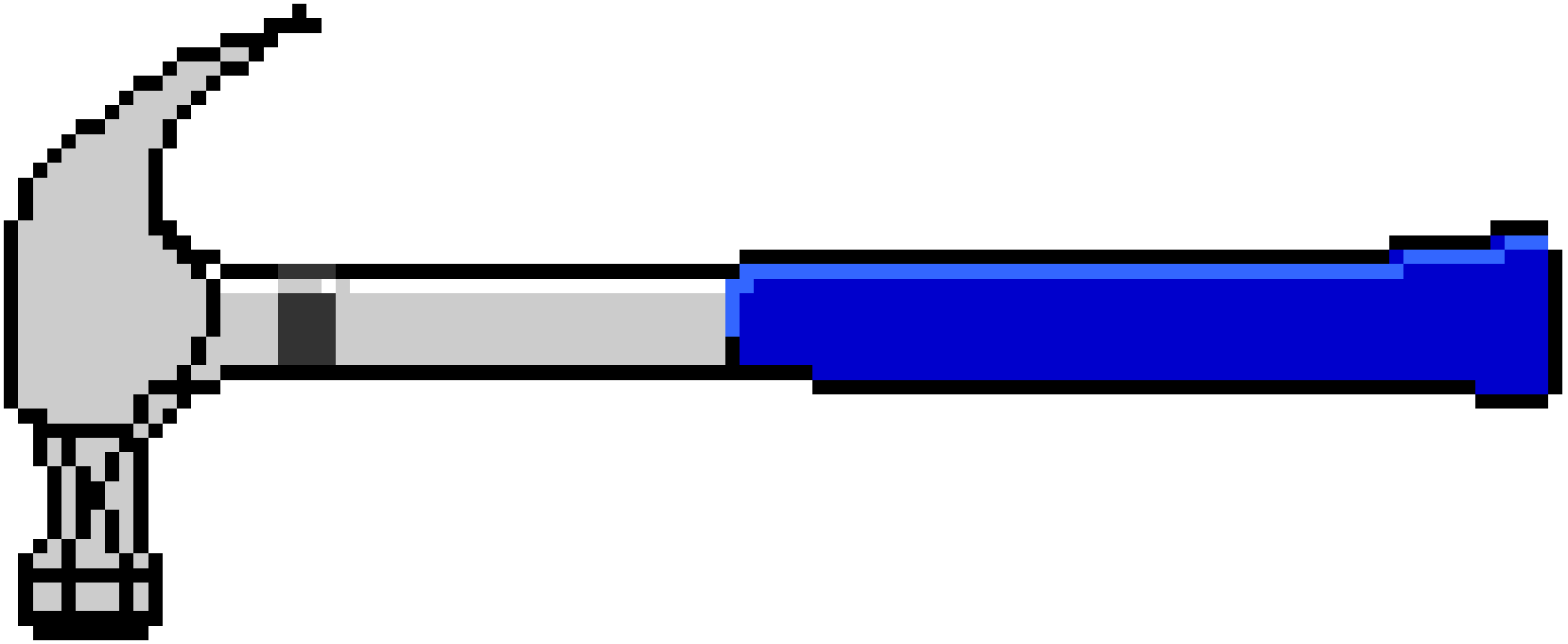

BISCUITS



# Second Class Lever

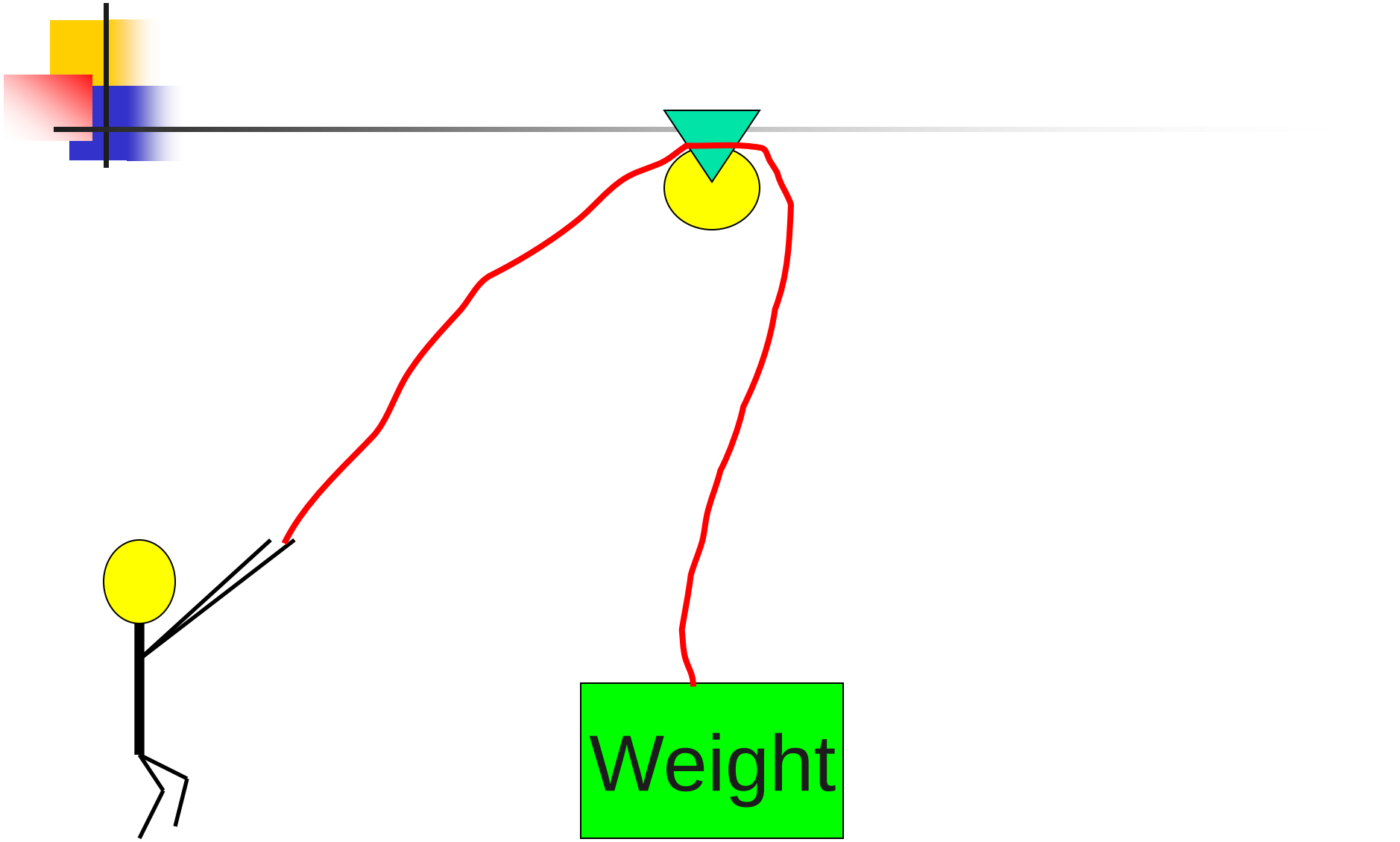
# Third Class Lever

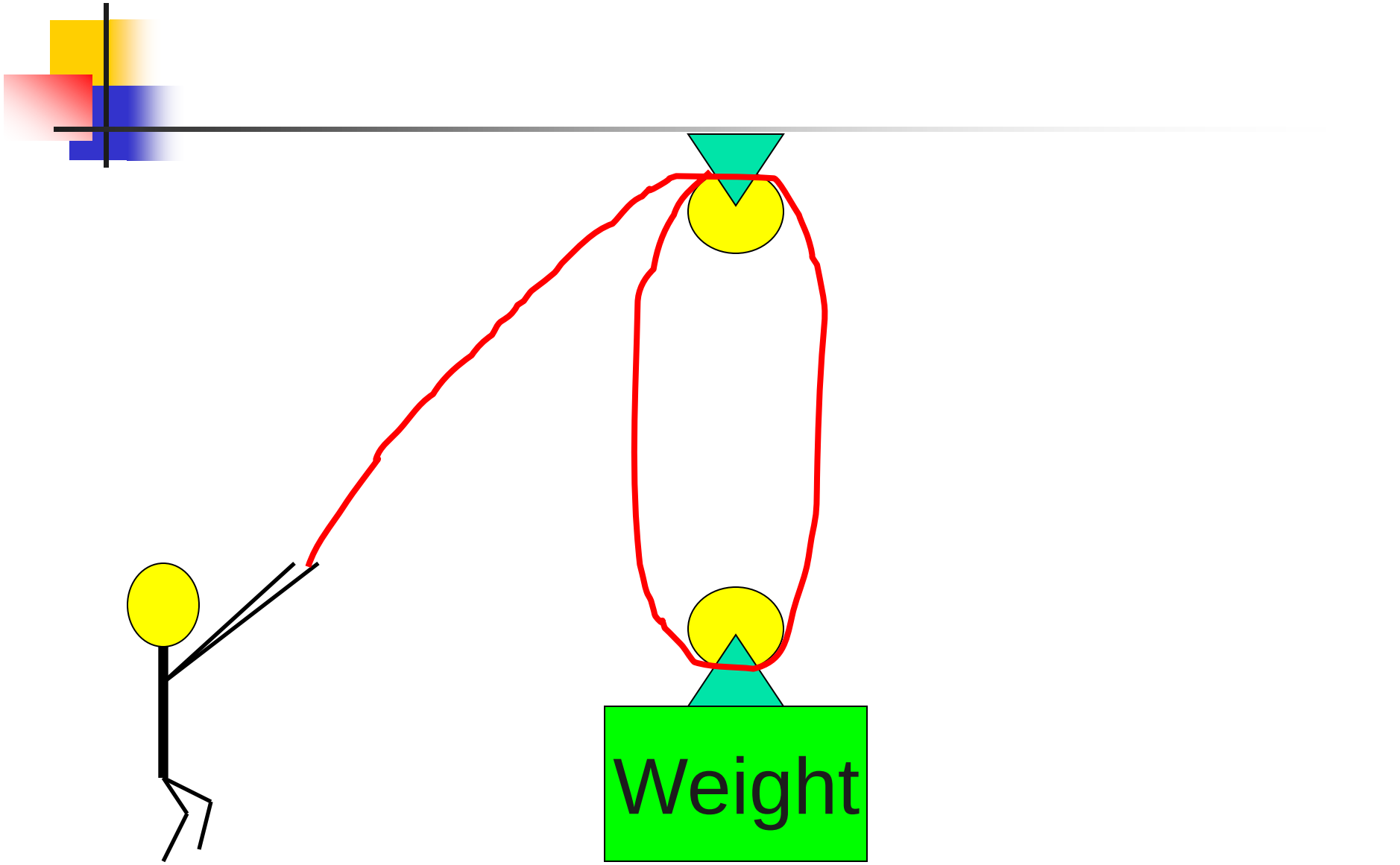


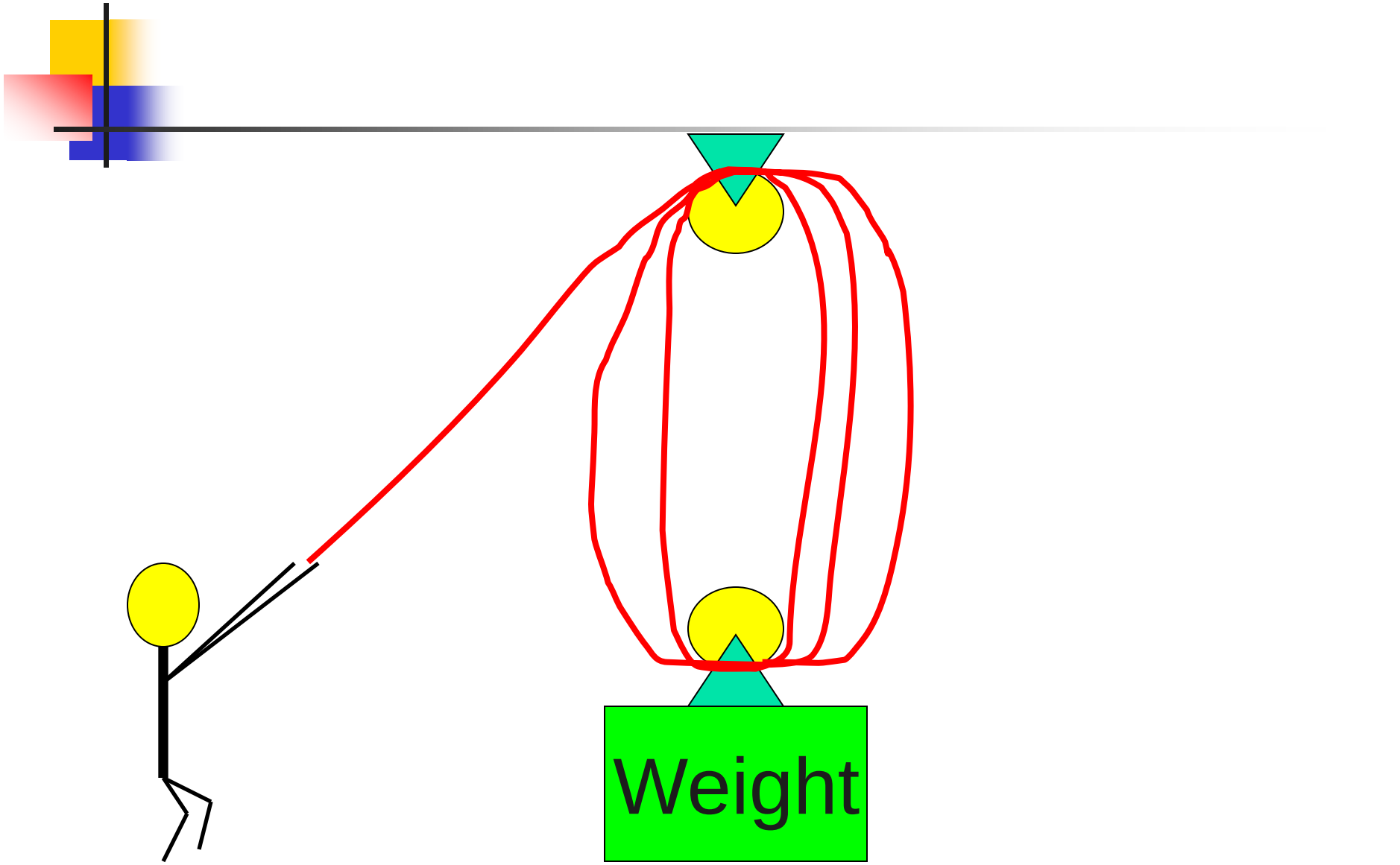


# Pulley

- Pulley – A grooved wheel with a rope or a chain running along the groove.
- The IMA for a Pulley is :
  - The number of ropes holding the resistance weight.

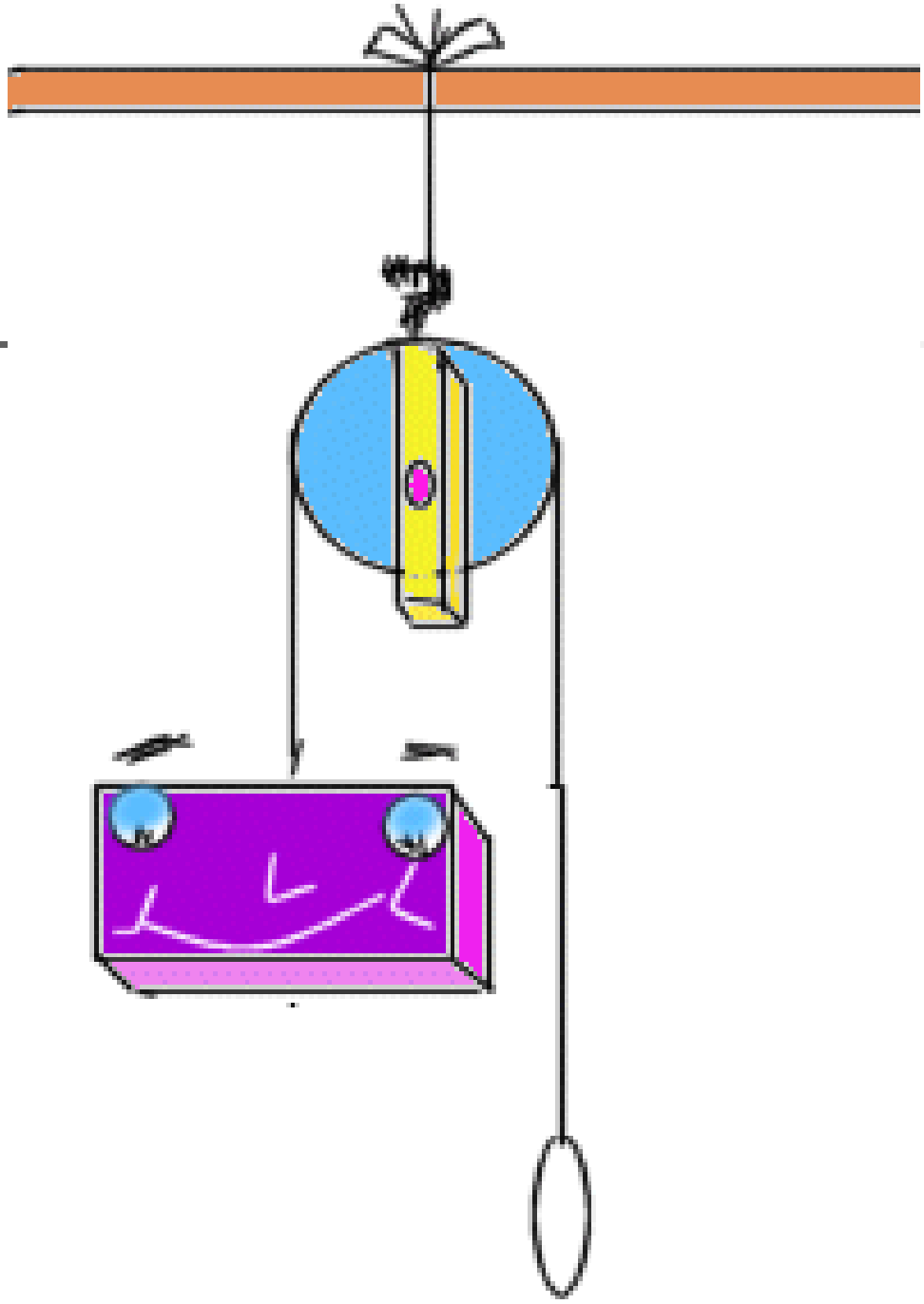

Weight

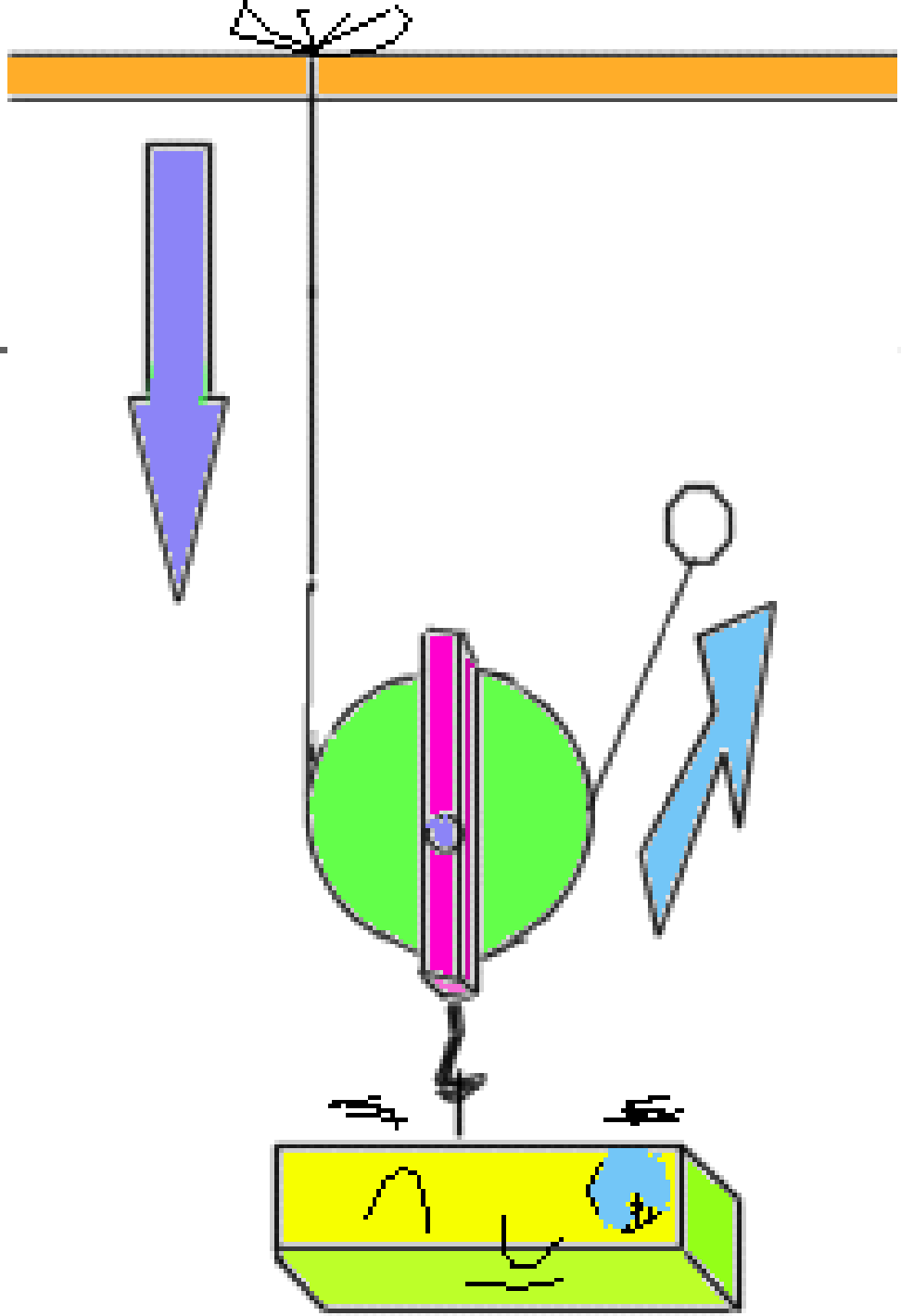

Weight

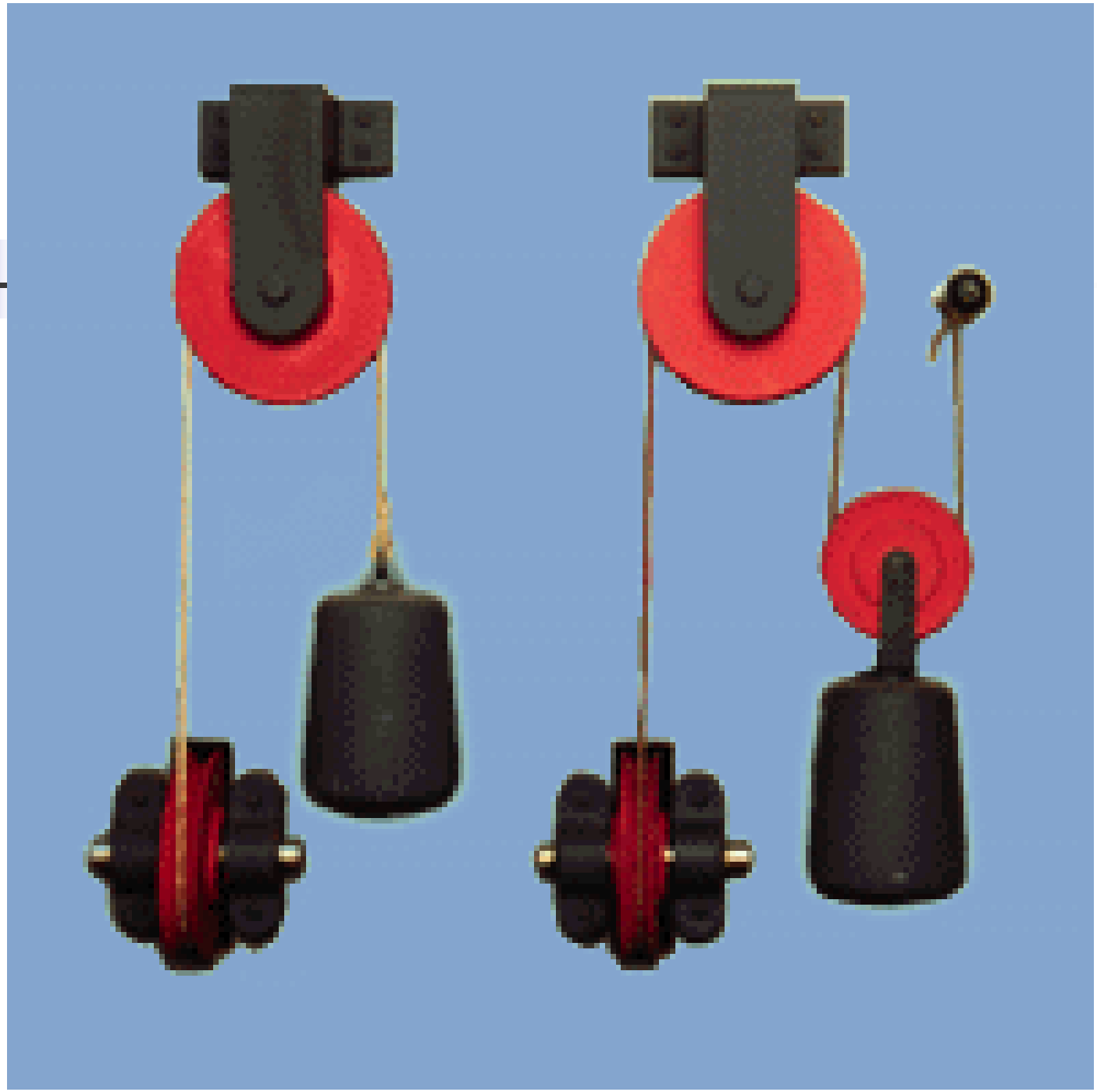

Weight

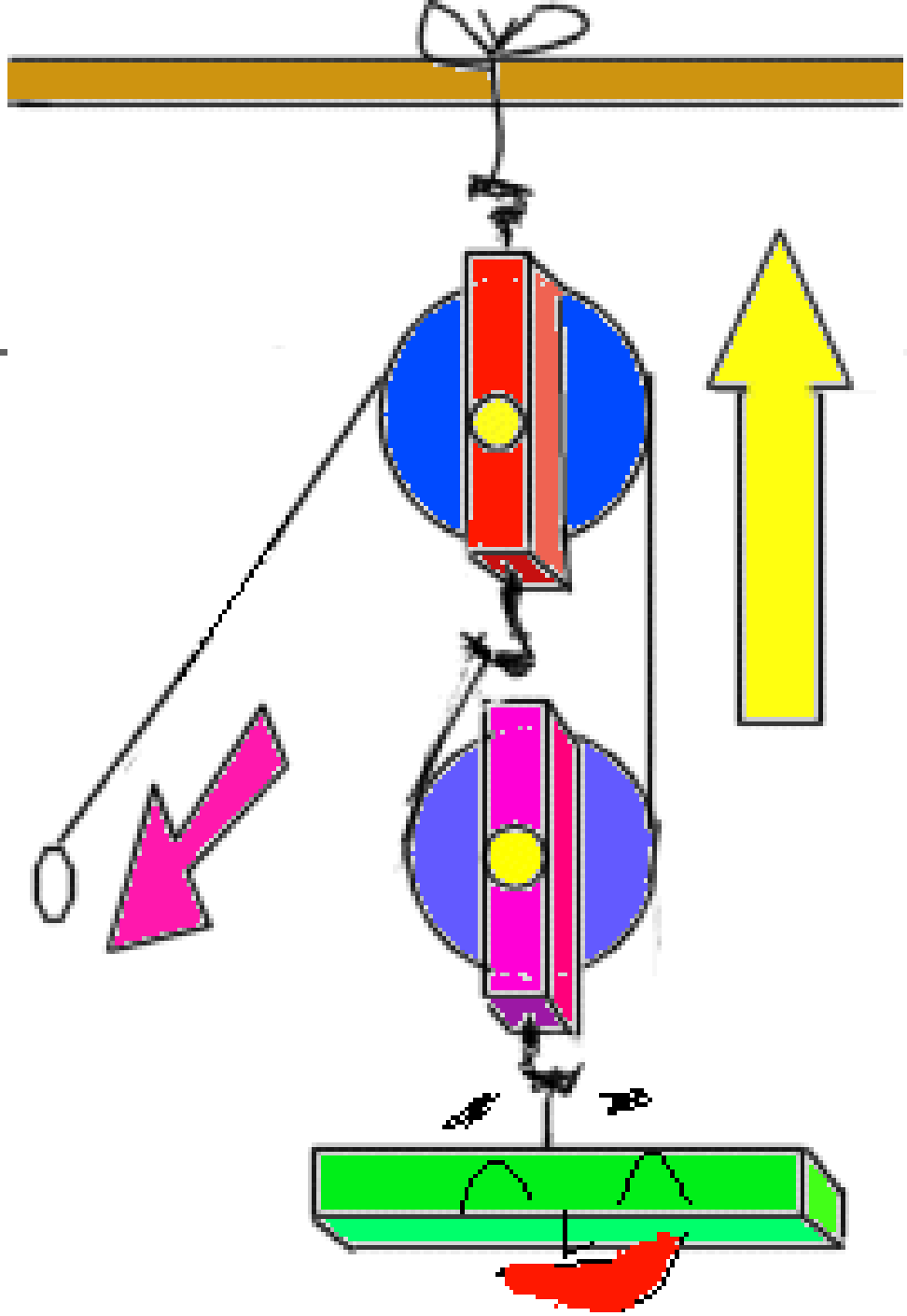
# 3 Classes of Pulleys

1. Fixed Pulley – there is a single pulley attached to an immovable object.
2. Movable Pulley – there is a single pulley attached to the resistance force.
3. Block and Tackle – there are 2 or more pulleys, both fixed and movable working together.









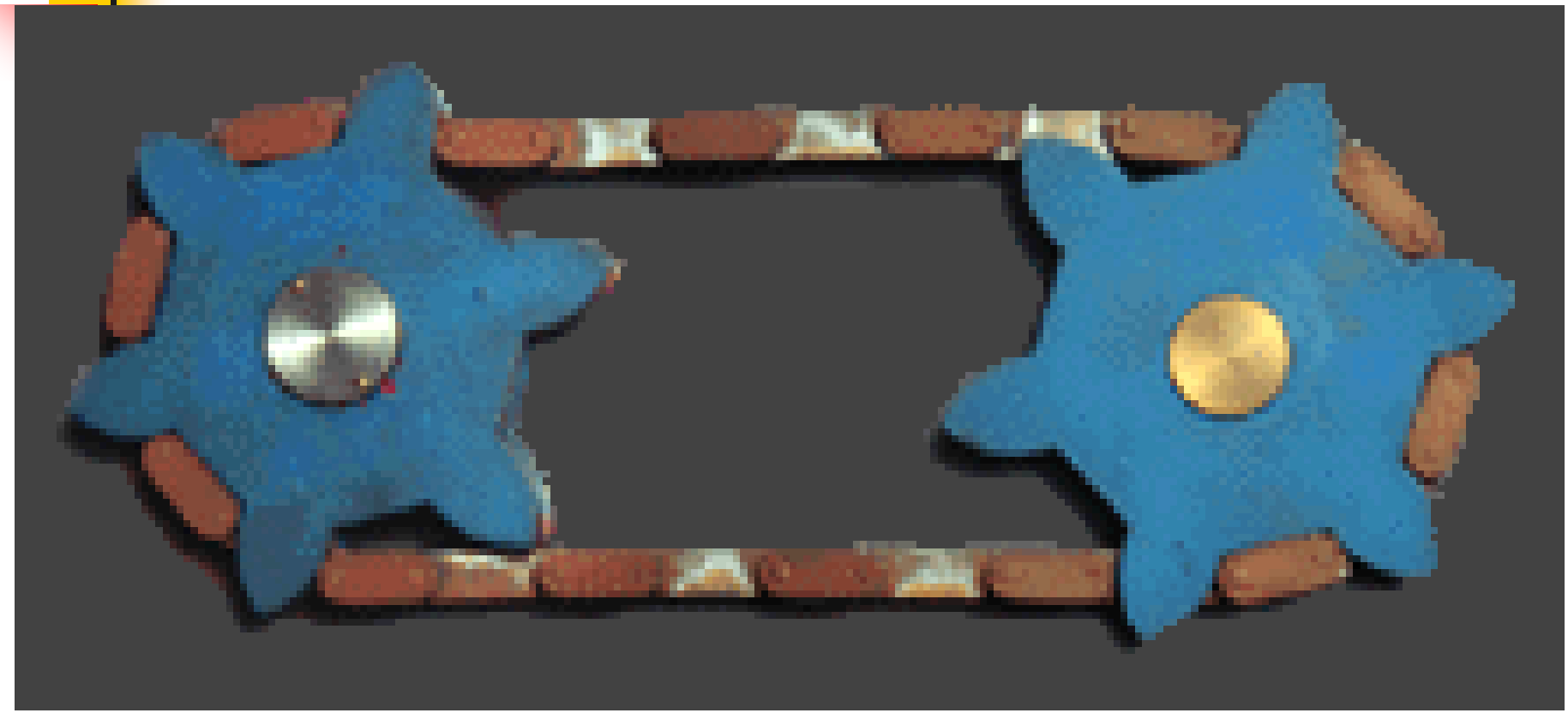
# Wheel and Axle

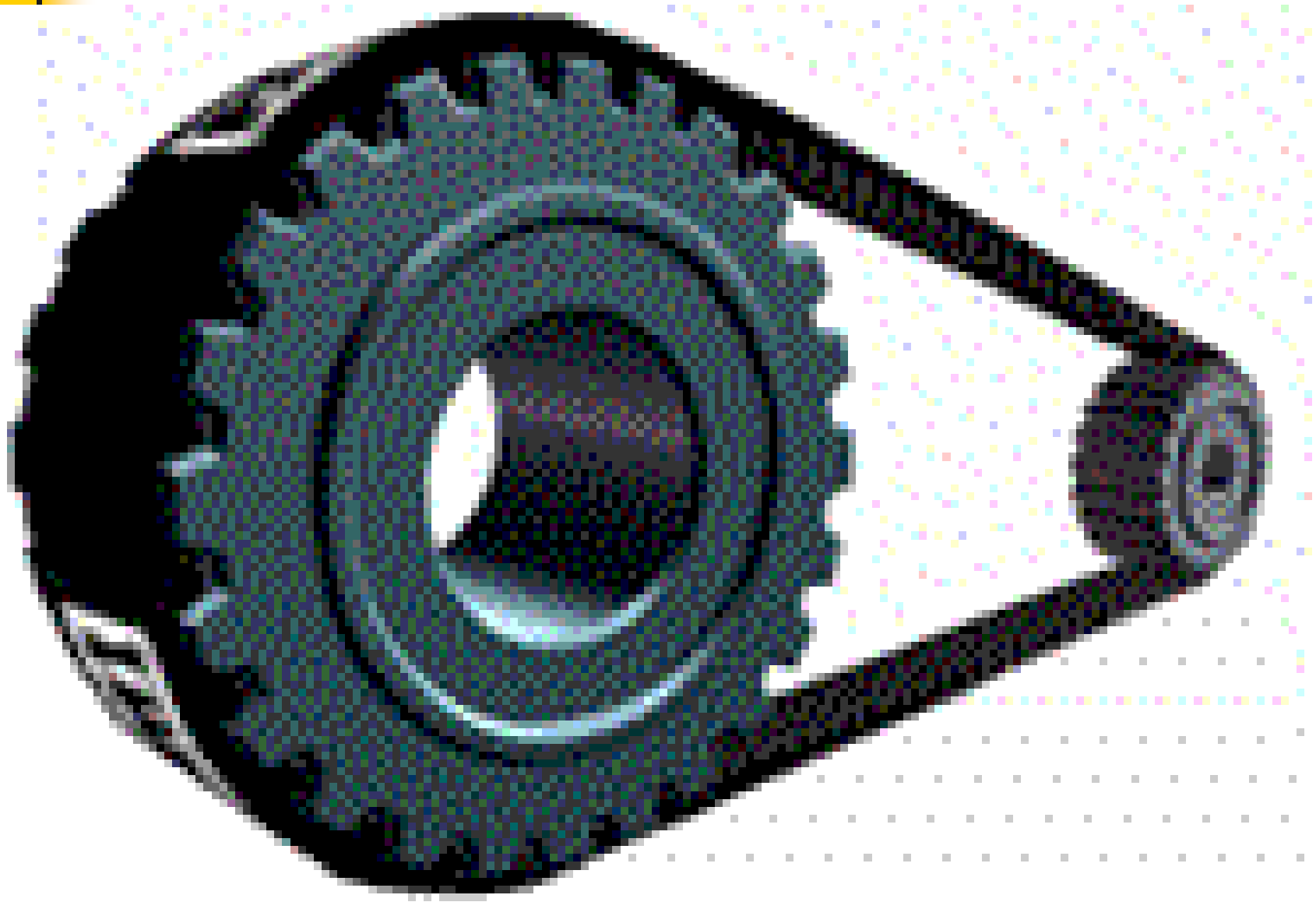
- Wheel and Axle – a simple machine consisting of two wheels of different sizes that rotate together.
- Doorknob, faucet handle, ice-cream makers, bicycle gears.

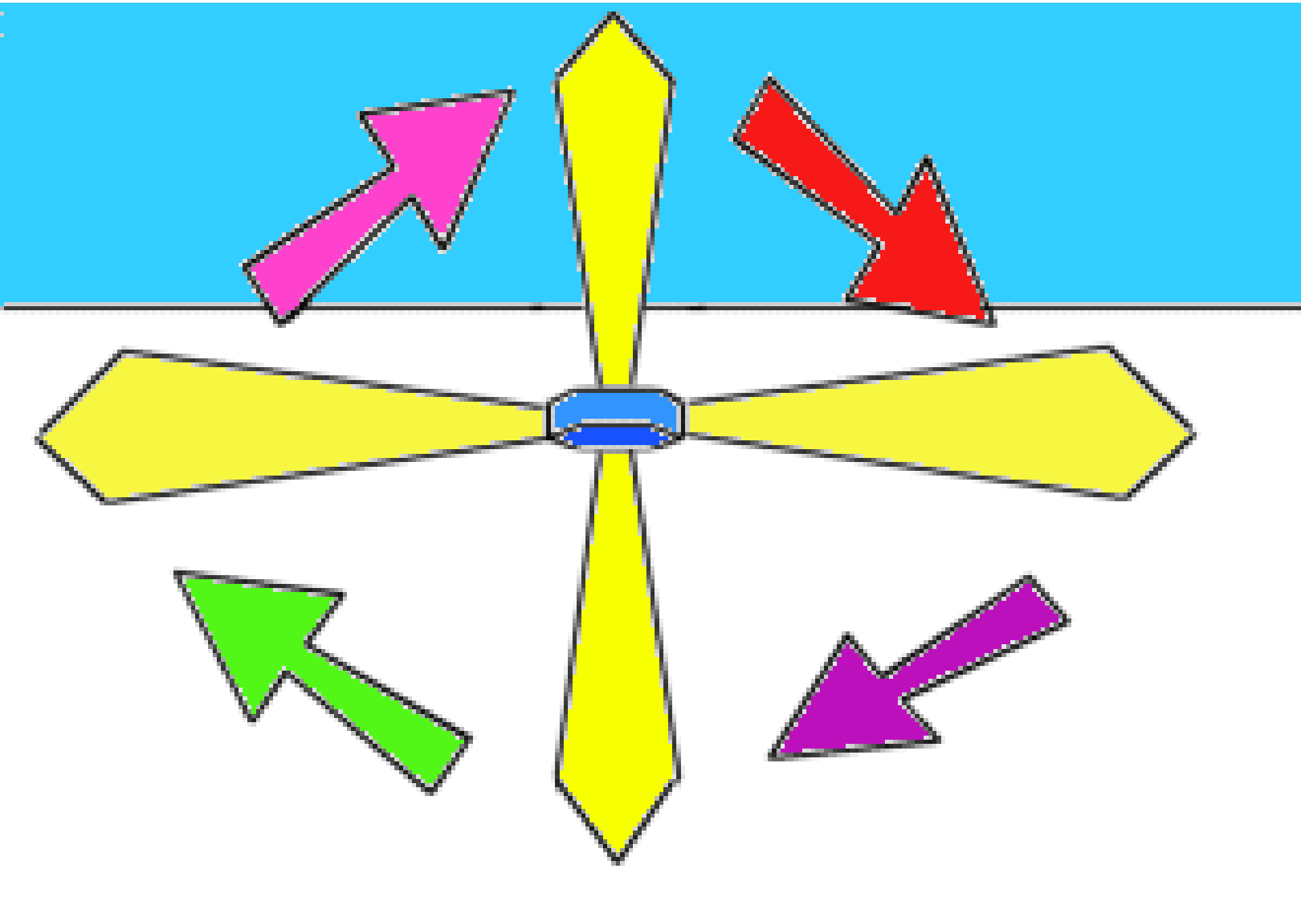
$$IMA = \frac{\text{Radius of wheel}}{\text{Radius of axle}} = \frac{r_w}{r_a}$$

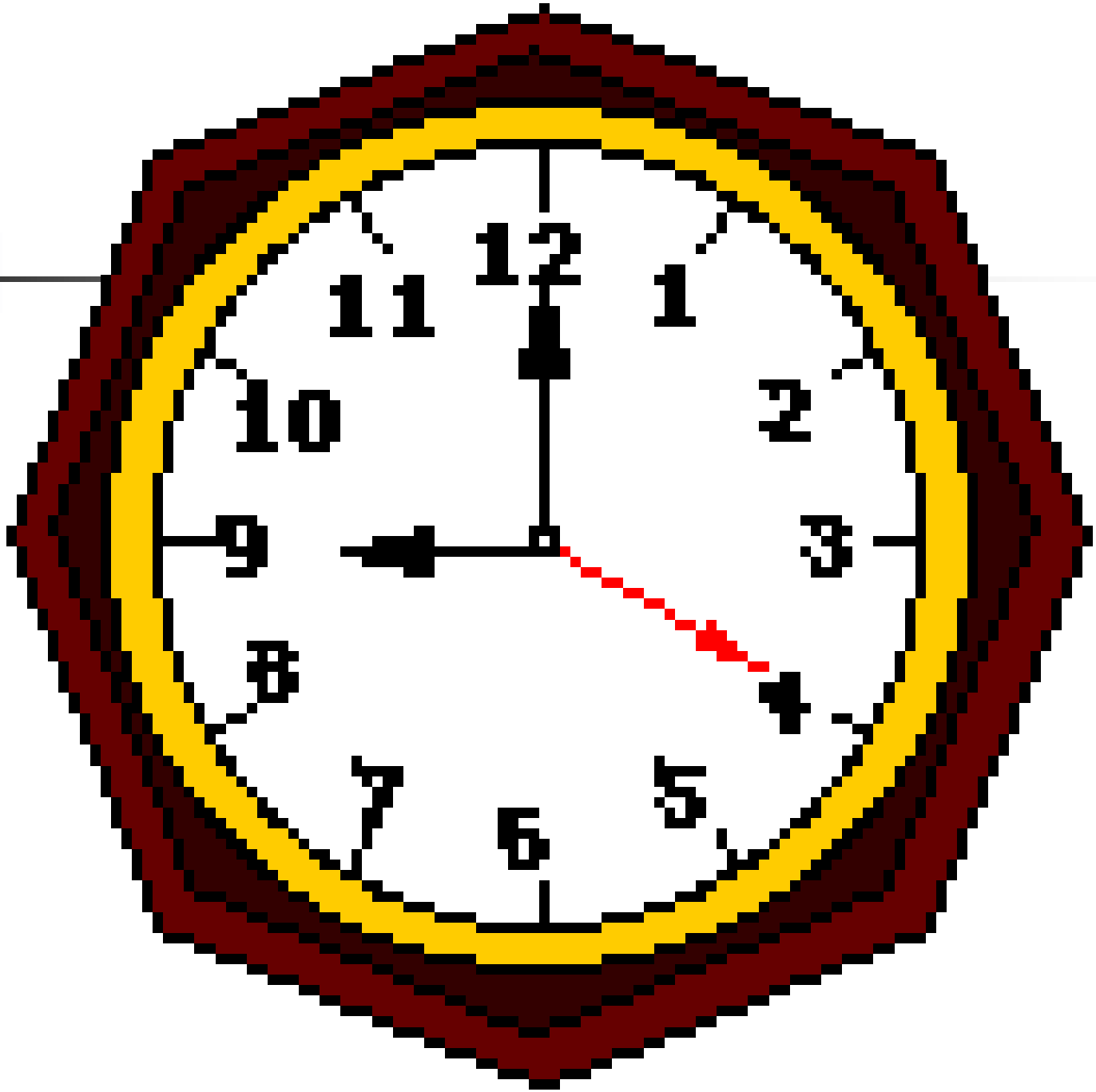
# Example

- The wheel of an ice-cream maker has a radius of 20 cm. The axle has a radius of 15 cm. What is the IMA of the ice-cream maker ?





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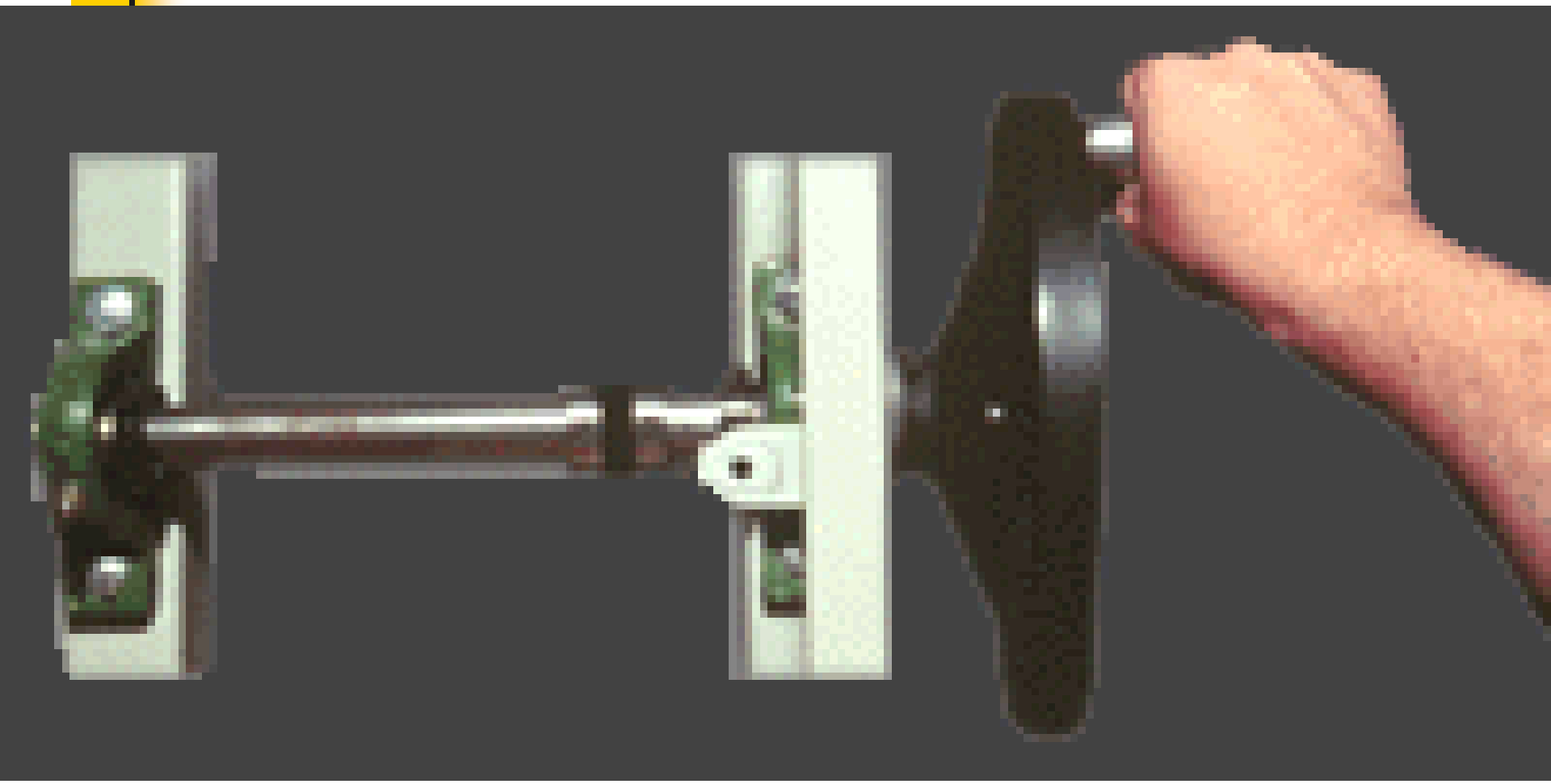
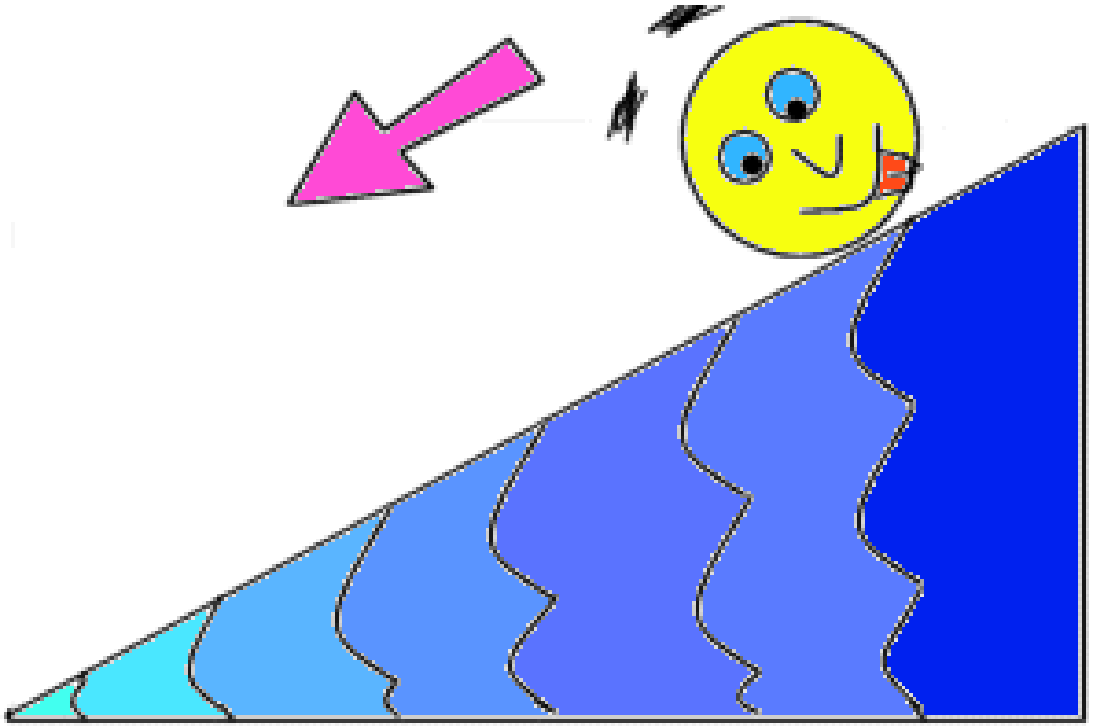


# Inclined Plane

- Inclined Plane – a sloping surface used to raise objects.

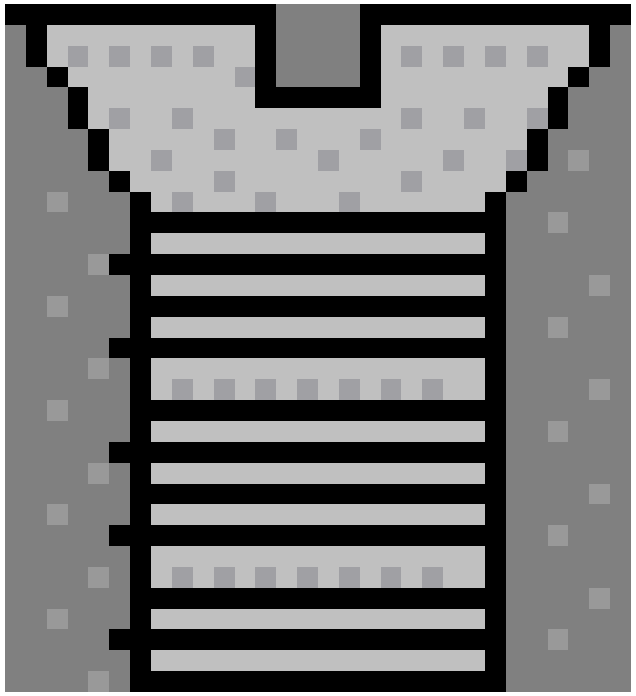
$$IMA = \frac{\text{Length of slope}}{\text{Height of slope}} = \frac{l}{h}$$

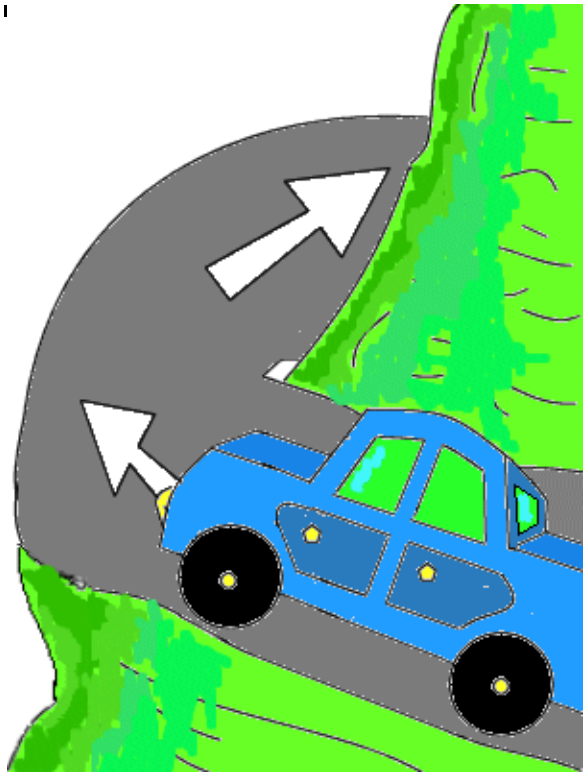

10%



# Screw

- Screw – An inclined plane wrapped around a cylindrical post.





# Wedge

- Wedge – an inclined plane with one or two sloping sides.
  - An inclined plane that moves, generally used for cutting.