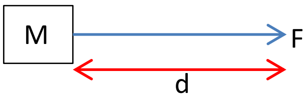
S1 New Curriculum Physics

Theme: Mechanics and properties of Matter

Chapter 1 – Work, Energy and power

Work

Work is the product of force (N) and distance (m) moved. This distance must be in the direction of the force. Consider a body of mass, M, being pulled on a smooth horizontal table by a force F through a distance, d.



Work done = F x d

Units of work

The unit of work is Joule (J)

1J = 1Nx 1m or Nm

Definition

A Joules is the work done when a force of 1N moves a body through a distance of 1m in the direction of force.

Examples 1

(a) A boy pulls a body on a smooth table with a force of 2N through a distance of 5m. Calculate the work done

W =F x d

=2 x 5

= 10N

(b) John lifts a mass of 45kg through a height of 8m. Calculate the amount of work done

Force = mg = 45 x 10 = 450N

W = F x d = 450 x 8 = 36,000J

Trial 1

(a) Calculate the work done when a block of steel is pulled on the table with a force of 5N through 7.2m. [36J]
(b) Bbosa lifts a bricks of mass 3kg through a height of 5m. Calculate the work done [150J]
(c) A boy lifts a mass of 4kg through a height, h. The boy does work of 12,000J as he lifts the mass. Find the height h in meters. (g = $10ms^{-2}$) [300m]
(d) David rides a motorcycle with an engine that exerts a force of 400N and the work done by the motorcycle during the ride is 48kJ. Find the distance moved. [120m]
(e) A girl of mass 50kg runs up a stair of 20steps each 8.0cm high. Find the work done by the girl {g =$10ms^{-2}$} [80J]

Energy

This is the ability to do work. The S.I units of energy are joule. There are various forms of energy which include the following

- Mechanical energy
- Light energy
- Chemical energy
- Heat energy
- Tidal energy
- Magnetic energy

Sources of energy

Energy sources as classified as renewable and non-renewable sources of energy

Renewable energy is power derived from natural sources that replenish themselves over time, such as sunlight, wind, water, and geothermal heat.

Types of Renewable Energy

- **Solar Energy**: Captures sunlight using photovoltaic cells to generate electricity.

  Effects of solar energy

- **Wind Energy**: Uses turbines to convert wind movement into electrical power.
- **Hydropower**: Harnesses the energy of flowing water, often through dams.
- **Geothermal Energy**: Utilizes heat from beneath the Earth's surface.
- **Biomass Energy**: Converts organic materials like wood, crops, and waste into fuel.

Non-renewable energy comes from sources that **cannot be replenished** within a human lifetime. These resources are finite and will eventually run out, making them less sustainable than renewable alternatives.

Types of Non-Renewable Energy

- **Fossil Fuels**: Includes coal, crude oil, and natural gas, formed over millions of years from decomposed organic matter.
- **Nuclear Fuels**: Uranium and plutonium are used in nuclear reactors to generate electricity.

Mechanical energy (M.E)

This s the total energy a body possesses by virtue of its position and motion. It the sum of potential and kinetic energies.

Kinetic energy (K.E)

This is the energy possessed by a body by virtue of its motion. Kinetic energy increases with the speed of the body.

K.E = $\frac{1}{2}mv^2$ where m = mass in kg and v = velocity in m/s.

Potential energy (P.E)

This is the energy possessed by a body by virtue of its position from a reference axis (or ground). It increases with height above the ground.

P.E + = mgh where m = mass in kg, g = acceleration due to gravity and h = high above ground in metres.

Hence M.E = P.E + K.E

= mgh + $\frac{1}{2}mv^2$

Examples 2

A ball of mass 2kg is resting on the top of a table of 5m. Find the potential energy possessed by the ball.

P.E = mgh = 2 x 10 x 5 = 100J

(a) A stone of 50g possesses kinetic energy of 4.9J. find its speed.

K.E = $\frac{1}{2}mv^2$

=> $\frac{1}{2}mv^2$ = 4.9

$\frac{1}{2}x\ \frac{50}{1000}v^2$ = 4.9

$v^2 = 4.9\ x\ 2\ x\ \frac{1000}{50}$ = 196

$v = 14ms^{-1}$

Trial 2

(a) A ball of mass 1kg is resting on top of a table of height h. if the potential energy stored in the ball is 70J, find the height of the table. [7m]

(b) An arrow is released from a bow with kinetic energy of 3.2J. The mass of the arrow is 25g. Calculate its velocity. [16ms^{-1}]

(c) John raised a mallet of 1kg to a height of 0.3m. Calculate the potential energy of the mallet. [3J]

(d) Marry is 55kg walks at a speed of 2ms^{-1}. Calculate her kinetic energy while walking. [110J]

Principle of conservation of mechanical energy

In any mechanical system, mechanical energy is conserved provided there is no dissipative force acting on the system.

The **Law of conservation of energy** states that energy can neither be created nor destroyed; it is transformed into another form of energy. For instance, for a falling object;

Loss in potential energy = gain in kinetic energy

mgh = $\frac{1}{2}mv^2$

Example 3

A brick of mass 4kg resting on a wall falls freely to the ground through a vertical height of 3m. Calculate

(a) Kinetic energy of the brick as it hits the ground

Kinetic energy = potential energy

= mgh

= 4 x 10 x 3

= 120J

(b) Velocity with which the brick hits the ground (g = 10ms^{-2})

K.E = $\frac{1}{2}mv^2$

=> $\frac{1}{2}x\ 4\ x\ v^2 = 120$

$v^2 = 60$

$v = 7.75ms^{-1}$

Trial 3

(a) A bullet of mass 0.02kg is fired with a speed of 40kmhr^{-1}. Calculate its kinetic energy. [1.2J]

(b) A brick of 4kg resting on the top of house 10m high, falls freely to the ground. Find its
   (i) Potential energy on the top of the house [400J]
   (ii) velocity just before it strikes the ground. [14.1ms^{-1}]

Power

This is the rate of doing work or the rate of change of energy.

Power = $\frac{work\ done}{time\ taken} = \frac{F\ x\ d}{t}$ = Fv

Thus, power is proportional to velocity

The S.I units of power are Js^{-1} or watts

A watt is the rate of transfer of energy at 1 joule per second.

Example 4

(a) Find the power if a mouse of mass 0.03 kg climbs through a distance of 2 m up a wall in 4 s.

P.E gained = mgh = 0.03 x 10 x 2 = 0.6J

Power = $\frac{\boldsymbol{work}}{\boldsymbol{time}} = \frac{\mathbf{0.6}}{\mathbf{4}} = \mathbf{0.15}\boldsymbol{W}$

(b) A force of 50N moves an object through a distance of 200m in 40s. Find the power expended

Work = F x d = 50 x 200 = 10,000J

Power = $\frac{\boldsymbol{work}}{\boldsymbol{time}} = \frac{\mathbf{10.000}}{\mathbf{40}} = \mathbf{250}\boldsymbol{W}$

Trial 4

(a) A machine lifts a load of 5000N through a distance 0f 10m in 5s. The average power of the machine is [10,000W]

(b) A crane lifts 4 bricks per minute through a height of 1.5 m. Find the power that is expended if each brick weighs 100 N. [10W]

(c) A crane lifts a mass of 500kg through a height of 12m in 5s. Find the power output. [10,000W]

(d) An engine is rated 1000W raises water through a vertical height of 50m in 10s. Find the weight of water raised. [200N]

Simple machines

These are devices that work with one movement and change the size and direction of force.

Examples of simple machnes include levers, pulley, hydraulic, gears, screws, and inclined planes

The qualities of a good simple machine

- Easy to use with minimum fatigue.
- Light to transport
- Easily available i.e. made of local material
- Durable
- Easy to maintain
- Cause no injuries.

Examples of activities carried out at which are based on working of simple machine include

- Cutting using knife and pangas
- Digging using hand hoe
- Digging holes, canals, removing tree stumps using pick mattock
- Raking rubbish using a rake
- Cutting trees using axe
- Lifting using pulleys
- Carrying using wheelbarrow

Principles of simple machine

(a) **Mechanical advantage** is the number of times a simple machine multiplies the effort. It is expressed as the ratio of load (input force) to effort (output force), i.e.

Mechanical advantage (M.A) = $\frac{Load}{Effort}$

Significance of mechanical advantage

The bigger the mechanical advantage the better the machine since small effort can lift a bigger load.

Factors that may lower mechanical advantage

- **Friction;** the higher the friction the lower the mechanical advantage
- **Weight of moving parts:** the heavier the parts the lower the mechanical advantage

(b) **The velocity ratio is the ratio** of distance travelling by the effort to the distance travelled by the load in the same time, i.e.

Velocity ratio (V.R) = $\frac{distance\ moved\ by\ effort}{distance\ moved\ by\ load\ in\ same\ time}$

Velocity ratio has no units

Significance of velocity ratio

The bigger the velocity ratio the less effort required to do work and the more efficient the machine. Or the machines requires less effort to overcome a big load when effort moves a bigger distance compared to the load in a uinit time.

(c) **Work input and work output of machine**

(i) **Work input** is the effort put into the machine, i.e.

Work input = Force input x distance input

This represents the total effort that operated the machine.

(ii) **Work output** is the work the machine performs using the applied force, i.e.

Work output = Forceoutput x distance output

This measures how much useful energy or force the machine produces.

However, due to factors like friction, some energy is always lost in the process, meaning **work output is usually less than work input**.

(d) **Efficiency of a machine** is the ratio of useful work done by a machine to the total work put into a machine expressed as a percentage. i.e.

Efficiency = $\frac{Work\ output}{work\ input} = 100\%$

Or

Efficiency = $\frac{mechanical\ davantage}{Velocity\ ratio}$

In an ideal machine (with no friction), the efficiency = 1, also known as 100%.

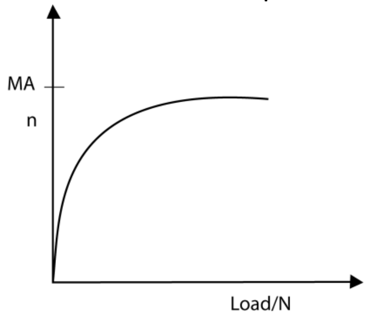
How can efficiency be increased

(a) Machines can be made more efficient by reducing friction. This usually is done by adding a lubricant, such as oil or grease, to surfaces that rub together

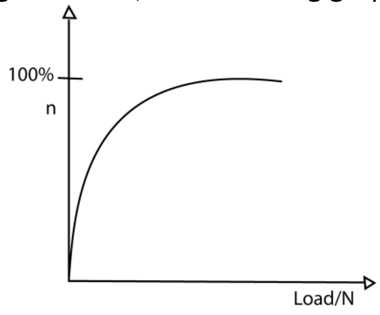
(b) For the case of pulleys, by making the string and the block plus the pulleys as light as possible.

Graphical relatonship between M.A and Load

When M.A or n are plotted against load, the following graphs are obtained



(a)



(b)

raph

Explanation of the shape of the graph

In both, a small increase in load cause high increase in M.A and efficiency, n. on further increase on the load, graphs begin to level as M.A and efficiency reach their maximum values and the remain constant.

The efficiency of the machine increase with the load because when the load is small, the weight of the parts and friction is significant. The weight of the lower movable parts and friction become negligible to the load as the size of the load increases.

Example 5

A load of 100N is raised through 6m when an effort of 40N moves through 24m. Calculate

(i) mechanical advantage

(ii) velocity ratio

(iii) efficiency of machine

Solution

(i) $M.A = \frac{Load\ (L)}{Effort\ (E)} = \frac{100}{40} = 2.5$

(ii) Velocity ratio (V.R) = $\frac{distance\ moved\ by\ effort}{distance\ moved\ by\ load} = \frac{24}{6} = 4$

(iii) Efficiency of machine = $\frac{mechanical\ davantage}{Velocity\ ratio} = \frac{2.5}{4} x100 = 62.5\%$

Trial 5

(a) A machine has velocity ration of 8. It is used tolift a load of 300N using an effort of 60N. calculate the

(i) Mechanical advantage of the machine [5]

(ii) Efficiency of the machine [62.5%]

(b) An effort of 250N raises a load of 900N through 5m when using a simple machine. The effort moves through 25m. what is the
  (i) Work inputof the machine [4500J]
  (ii) Work output of the machine [6250J]
  (iii) Efficiency of the machine [72%]

(c) A machine lifts a mass of 120kg through a height of 5m. and effort of 800N applied passes through 10m so as to overcome the load. What is the efficiency of the machine. (Acceleration due to gravity = $10ms^{-2}$). [75%]

Levers

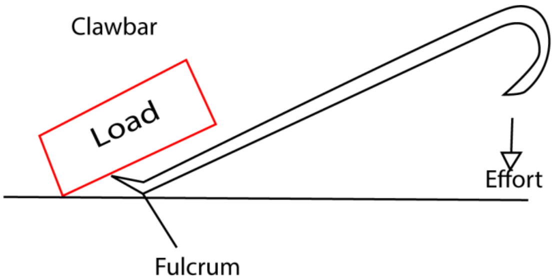
A lever is a rigid bar which is free to move about a fixed point, the Fulcrum or pivot

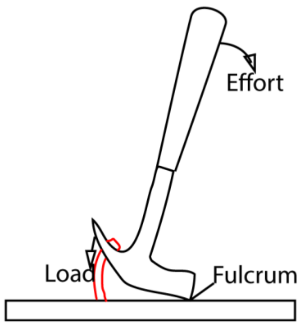
Levers are divided into three classes

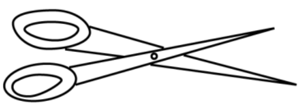
(i) The first class levers
(ii) The second class lever and,
(iii) Third class levers

(a) First class lever

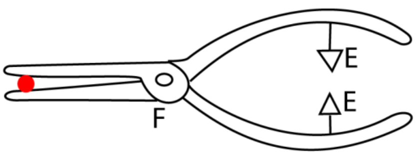
This is a type of lever in which the fulcrum is between the effort and the load. Examples of first class lever include Craw bar, scissor, beam balance, scissor and pair of pliers.



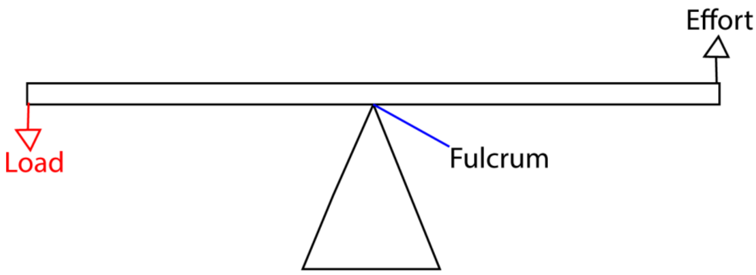




Pair of scissors



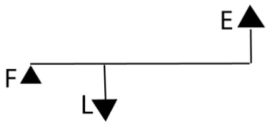
Pair of pliers



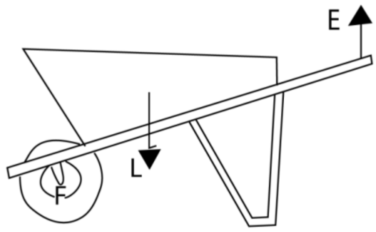
Beam balance

(b) Second class lever

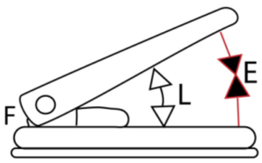
Here the load is between the effort and fulcrum.
Examples are wheelbarrow, nut cracker and office punch



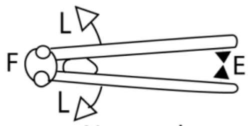
Second class lever in general



Wheelbarrow



Office punch

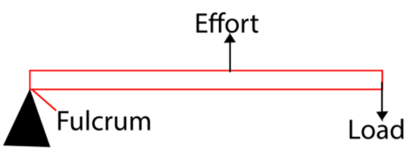


Nut cracker

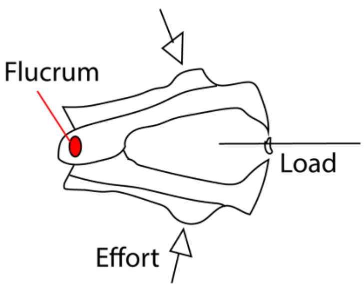
(c) Third class lever

Here the effort isf between the load and fulcrum.
Examples are wheelbarrow, nut cracker and office punch

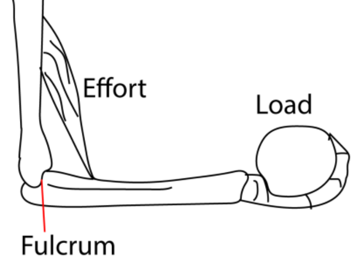
Third class lever generally



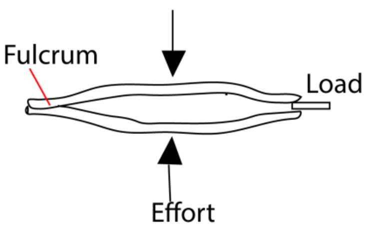
Staple remover



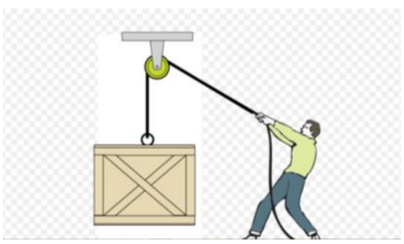
Arm



Tweezer



Pulleys



A pulley is a wheel with a groove ring which passes or string .

- The effort is applied to one end of the rope and the disk of the pulley rotate as the rope moves over it
- If there are several pulleys in a frame work, it is called a block

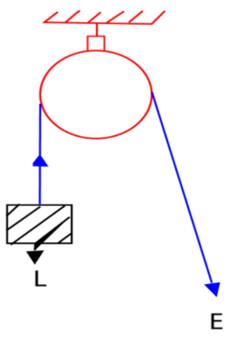
Types of pulley

Pulleys may be categorized into

- Single fixed pulley
- Single movable pulley
- Block and Tackle system

Pulleys reduce the effort to lift an object by increasing the distance and /or direction over which the effort is applied.

(a) Single fixed Pulley



A single fixed pulley is as single wheel with concave grooves fixed to a support as shown in the figure above. A rope, chain or cable passes over the groove of the pulley. One end of the rope is attached to the load and the effort is applied at the other end.

If a user pulls down on one end of the rope (Effort), the other end (Load) will raise up an equal distance in the opposite direction

The primary benefit of a single fixed pulley is to change the direction of the effort to move a load to a point (such as the top of a flagpole) that cannot be reached by the user.

Characteristics of a fixed pulley system

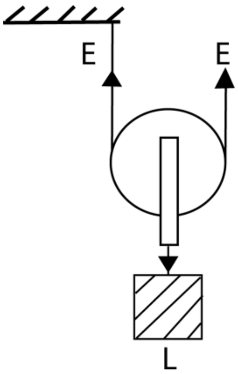
- It has one wheel inside the pulley
- The pulley is mounted to strong solid support
- Its mechanical advantage = 1
- Velocity ratio = 1
- It is a first class lever because the fulcrum is between the effort and the load
- Has uniform tension in the rope

Application of single pulley system

- Removing water from a well
- Lifting building material in the site

(b) A single movable Pulley

This is a pulley which moves along with the load attached to it. One end of the rope is tied to a fixed support and passes over the pulley and the other end where effort is applied makes a U-turn to the user as shown below.



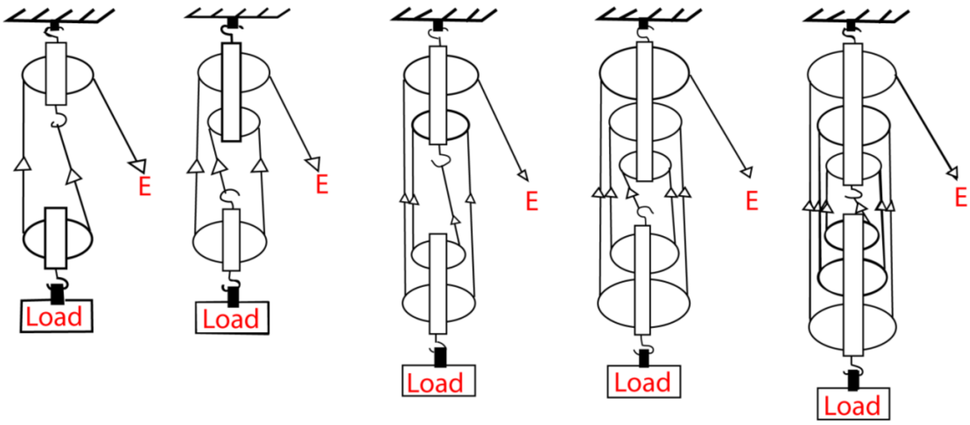
Characteristics of single fixed pulley

- Its mechanical advantage = 2, that is the effort required to lift the load is half the size of the load.
- Its velocity ration = 2, that is the effort moves twice the distance moved by the load.

(c) Block and Tackle system

This is a pulley system consisting of both fixed and movable pulleys as shown below

Drawings showing Block and tackle systems



2 Pulleys 3 pulleys 4 pulleys 5 pulleys 6 pulleys

The framework of pulleys is called block and the rope passing over each pulley is called tackle.

Characteristics of block and tackle sysytem

- Mechanical advantage (MA) = n (number of pulleys in the system
- Velocity ration (VR) = n (number of strings supporting the load or number of pulleys in the system)

Application of Block and Tackle

They are commonly used to raise or move load in

- Sailing
- Crane
- Lifts
- breakdown

Example 6

(a) A force of 10N is required to raize a load, L, using a smooth (frictionless) and weightless block and tackle system of four pulleys. Calculate:

(i) Load
(ii) M.A
(iii) Effort distance if the load rises by 2m

Soluiton

Given

E = 10N, M.A = ?, Effort dis. ? Load distance = 2m Load ?, No of pulleys = 4

(i) in equilibrium

Downward force = upward force

L oad = 4E = 4 x 10 = 40N

(ii) mechanical advantage

M.A = $\frac{load}{effort} = \frac{40}{10} =$ 4 (or equal to the number of pulleys)

(iii) Neglecting friction,

Work in put = work out put

Work done by effort = work done by load

Effort x effort distance = Load x distance

E x E.d = L x L.d

10 x E.d = 40 x 2

E.d = 8

Therefore, effort distance = 8m

(b) Define the following terms

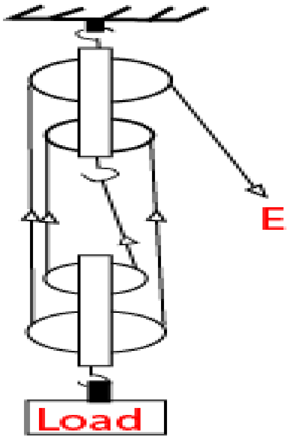
(i) Mechanical advantage

Mechanical advantage is the ratio of load to effort

(ii) Velocity ratio

Velocity ratio is the ratio of effort distance to load distance

(c) The diagram in the figure shows a pulley system used to raise the load



(i) What is the velocity ratio of the system

VR = number of pulleys = 5

(ii) Find how far the load is raised if the effort moves down by 4m

Effort distance = 4m, load distance = ?, V.R = 5

V.R = $\frac{Effort\ distance}{Load\ distance} = 5 = \frac{4}{load\ distance}$

Load distance = 0.8m

(iii) Calculate the effort required to raise a load of 800N, if MA = 4

E = ?, L = 800N, M.A = 4

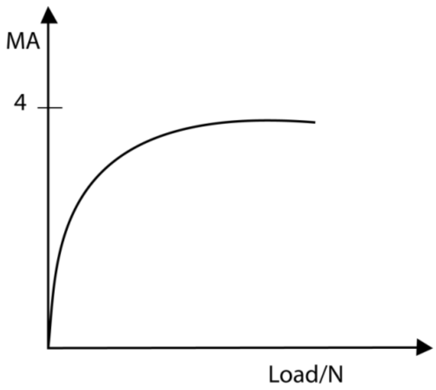
M.A = $\frac{Load}{Effort} = 4 = \frac{800}{E}$

E = 200N

(iv) Calculate the efficiency

Efficiency = $\frac{M.A}{V.R}x100$ = $\frac{4}{5}x100 = 80\%$

(v) Draw a sketch graph to show how mechanical advantage of the system in (c) varies with the load



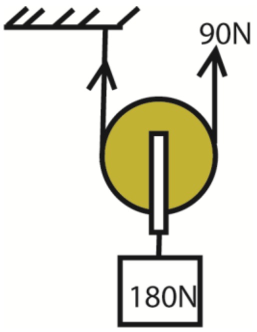
(a)

(vi) Give two practical applications where the pulleys are used.

they are used in cranes, breakdown, ships, for lifting

Trial 6

(a) The figure below shows a pulley system which is 50% efficient



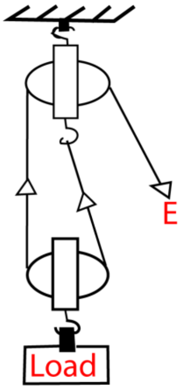
Calculate

(i) Mechanical advantage of the pulley system [2]

(ii) Work output of the system if the effort moves 4m [180]

(iii) Energy wasted [180]

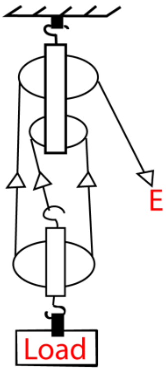
(b) The figure below shows a pulley system supporting load of 600N



Find the

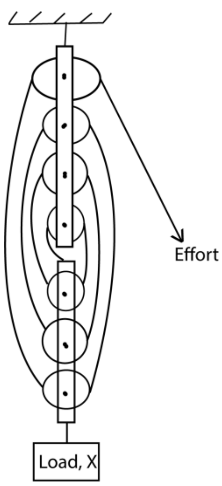
(i) Tension in the string [$300N$ (because there 2 strings supporting the load)]
(ii) Value of E if the mechanical advantage is 3 [200N]

(c)



(i) What is the velocity ratio of the pulley system above? [3]
(ii) Calculate the efficiency of the pulley system when the minimum effort required to raise a load of 210N is 90N [77.8%]

(d) (i) define the following terms
a. mechanical advantage
b. velocity ratio



(b) The diagram above shows a pulley system, where effort E is applied to raise the load, X.

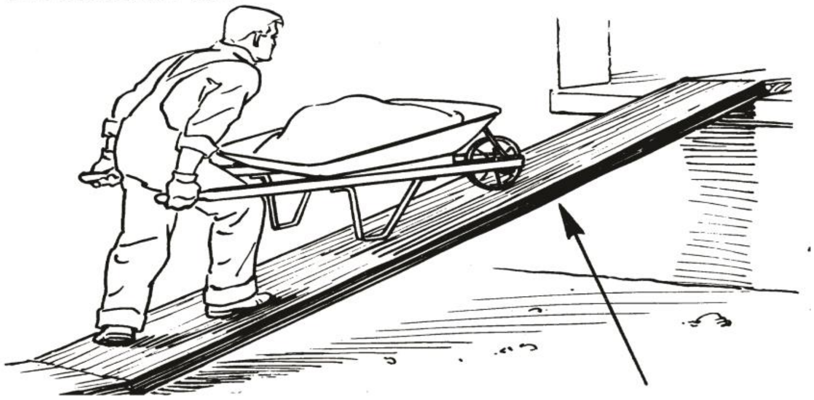
(i) What is the velocity ratio of the system? [7]

(ii) If the effort moves a distance of 5 meters, find the distance the load moves. [0.71m]

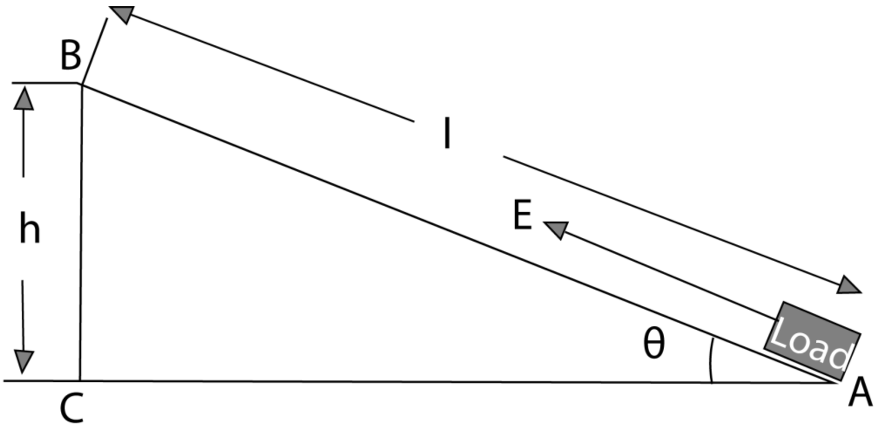
(iii) Calculate the effort needed to lift a load of 1000N, if mechanical advantage is 6. [166.7N]

(iv) Efficiency [85.6%]

The Inclined Plane



This refers to a type of a machine in which a plane is inclined to an angle to the horizontal such that one end is higher than the other by angle, θ.



- it used to lift heavy load by pulling/pushing it along the sloping surface.
- It is easier to carry the load along the slope than lifting it through the vertical height, h, since the weight of the load acts vertically downwards (and only a component of weight acts along the plane)
- In order to raise the load through a vertical height, h, th effort, E is applied through a longer distance, l, equal to the length of the plane.

Examples of inclined plane include

(i) Slopping roads

(ii) Stair case

Properties of inclined planes

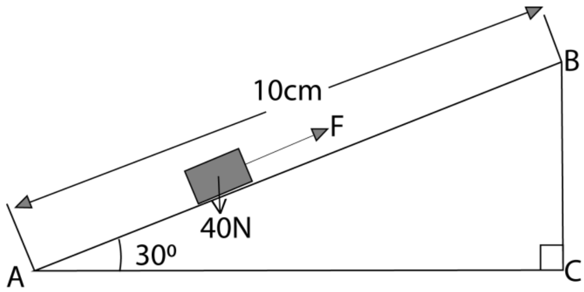
M. A = V.R = $\frac{l}{h}$

But h = lsinθ

MA = $\frac{l}{l\sin\theta} = \frac{1}{sin\theta}$

Example 7

(a) A load of 40N is pulled steadily from A to B along inclined plane by a force F as shown in the figure. Find the velocity ratio of the system.



AC = 10 cm, Bc = ? θ = 30^0

BC = AC x sin30 = 10 x 0.5 = 5cm

VR = $\frac{AC}{BC} = \frac{10cm}{5cm}$ = 2

Alternatively

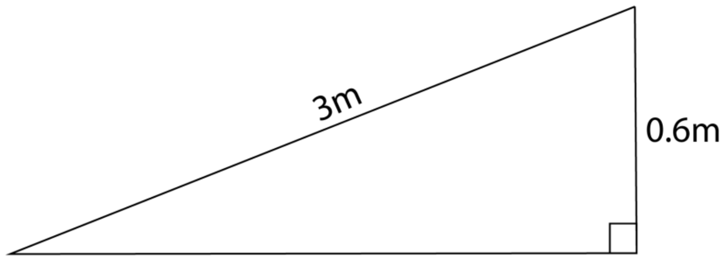
VR = $\frac{1}{\sin 30} = 2$

(b) A wooden plank 3m long is used to raise a load of 1200N through a vertical height of 60 cm. If the frictional force between the load and the plane is 40N. Calculate

(i) The effort required

(ii) The mechanical advantage

Solution



Given: L = 1200N, E = ? l = 3m, h = 60cm = 0.6m, friction force = 40N

(i) Work input = work out put + useless work done
Work done by effort = work done by load + work by frictional force
Effort x effort distance = Load + x load distance + friction force x Effort distance

$$E \times 3 = 1200 \times 0.6 + 40 \times 3$$

$$E = 280N$$

Alternatively

M.A = $\frac{Length\ of\ the\ slope}{height\ raised} = \frac{3}{0.6} = 5$

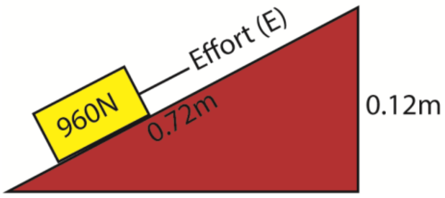
Theoretical effort (without friction) = $\frac{Load}{M.A} = \frac{1200}{5} = 240N$

Actual effort = Theoretical effort + friction
= 240 + 40
= 280N

(ii) MA = $\frac{L}{E} = \frac{1200}{280} = 4.3$

Trial 7

1. A man uses the incline plane to lift a 50 kg load through a vertical height of 4.0m. the inclined the incline plane makes an angle of 300 with the horizontal. If the efficiency of the plane is 72%, calculate
   (a) The effort needed to move the load up the inclined plane at a constant velocity. [347.2N]
   (b) The work done against friction in raising the load through the height of 4.0m (take g = 10Nkg^{-1}) [777.8N]
2. The figure below shows an inclined plane which is 80% efficient

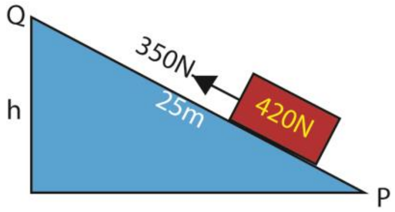


Calculate the:

(a) Velocity ration of the plane [6]

(b) Mechanical advantage of the plane [4.8]
(c) Work input [144J]
(d) Work output [115.2J]

3. The figure below shows an inclined plane used to raise the load from P to Q



If work input of the plane is 8,750J. Find the
(a) Heigt, h, of the plane [20.8m]
(b) Velocity ratio [1.2]
(c) Efficiency of the plane [100%]
(d) Work done against friction as the load is raised [0J]

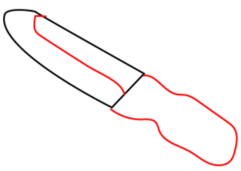
The Wedges

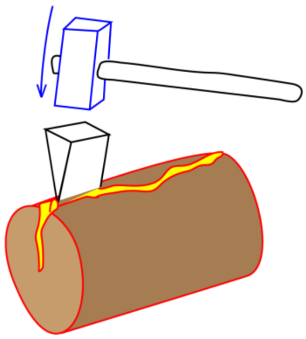
The wedge is a kind of simple machine which is an inclined plane having one or two sloping sides. With a wedge, the sloping surface is pushed through the material which is held still.

Examples of wedges are: Knife, axe, chisel, needle, nail, razor blade

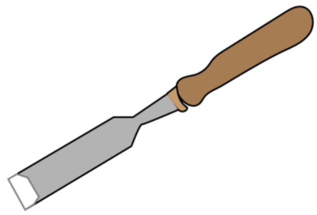
Uses of wedges include: Cutting, pitching

Examples of wedges


Knife


Wedge

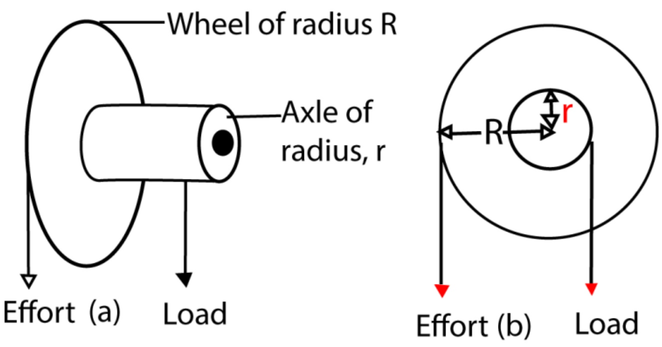

Axe


Chisel

Wheel and axle

A wheel and axle is a type of simple machine made up of a wheel and axles rigidly attached to each other so that they turn together about an axis.

The effort is applied to the larger wheel and the load is raised by string attached to the axle of small diameter as show below:



For one complete turn, the load and effort move through distances equal to the circumference of the wheel and axle respectively.

Characteristic of Wheel and axle

MA = VR = $\frac{R}{r}$

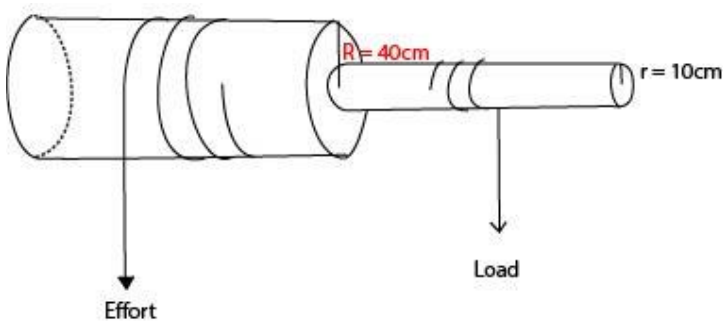
Uses of wheel and axle

(i) The car steering wheel
(ii) Screw driver
(iii) Windlass (used to raise a heavy bucket of water in a well.

(iv) **Water Systems** – Present in water wheels and turbines, converting rotational energy into useful work.
(v) **Household Appliances** – Found in washing machines, fans, and hand drills to optimize speed and function.
(vi) **Elevators and Lifts** – Used in pulley systems to make lifting objects easier.
(vii) **Agriculture and Construction** – Utilized in wheelbarrows, tractors, and cranes for effortless movement and load lifting.

Example 8

(a) The figure below shows a wheel and axle system. When an effort of 300N is applied, a load of 900N is raised through a distance of 1.0m.



Calculate

(a) Velocity ratio
(b) The efficiency of the machine

Solution

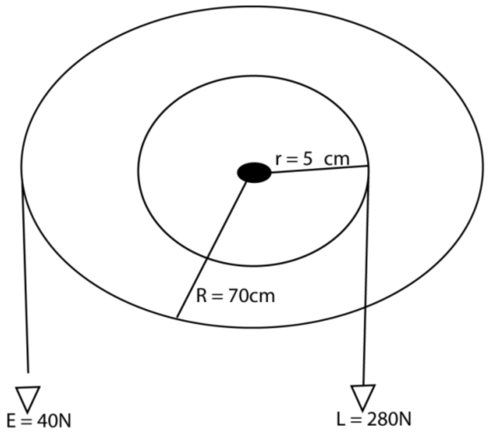
VR = $\frac{R}{r} = \frac{40}{10} = 4$

(b) efficiency = $\frac{M.A}{V.R}\ x\ 100$

$= \frac{L}{X}\ x\ \frac{1}{V.R}\ x\ 100\ = \frac{900}{300}\ x\ \frac{1}{4}\ x100 = 75\%$

(b) A wheel and axle is used to raise a load of 280N by a force of 40N applied to the rim of the wheel. If the radii of the wheel and axle are 70cm and 5cm respectively, calculate the M.A, V.R and the efficiency.

Solution



M.A = $\frac{load}{effort} = \frac{280}{40} = 7$

V.R = $\frac{R}{r} = \frac{70}{5} = 14$

Efficiency = $\frac{M.A}{V.R} x\ 100 = \frac{7}{14}\ x\ 100 = 50\%$

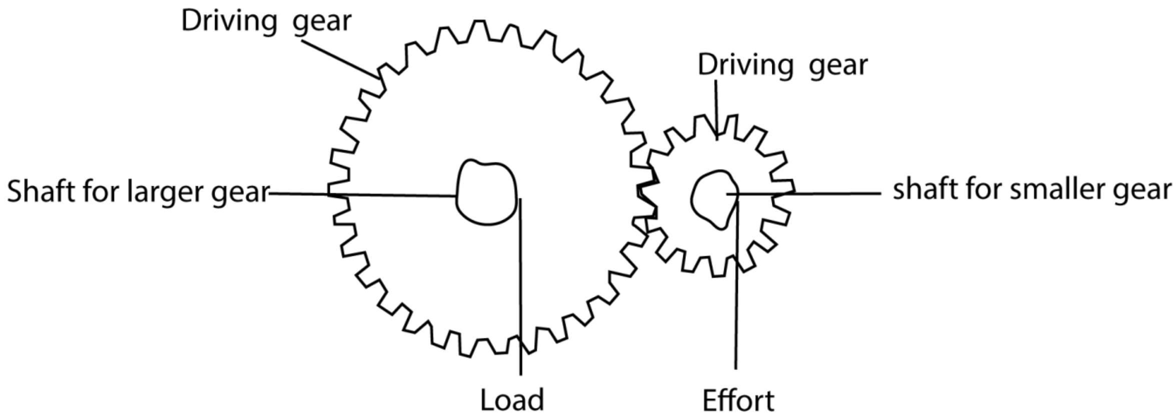
Trial 8

A wheel and axle machine has efficiency of 45%. If the radii of the wheel and axle are 20mm and 2mm respectively, find the

(i) Velocity ratio [10]
(ii) Mechanical advantage [4.5]
(iii) Effort used to lift a load of10N [2.2N]

Gears

A gear is a device which consists of a set of toothed wheels. Gears change the direction and speed of rotation. They are similar to wheel and axle. In gear wheel, the effort and the load are applied to the shafts connected to gear.



Velocity ratio = $\frac{Number\ of\ teeth\ in\ the\ driven\ wheel}{Number\ of\ teeth\ in\ the\ driving\ wheel}$

The velocity ratio of gears depends on which gear wheel is the effort applied.

Torque may be applied to the smaller gear in order to increase the torque and decrease the rate of rotation of the larger gear.

Or

Torque may be applied to the larger gear in order to decrease torque and increase the rate of rotation in the smaller gear.

Application of gears

(i) **Transportation** – Found in vehicles (cars, bicycles, trains) to control speed and torque. Gearboxes allow smooth shifting and improved efficiency.

(ii) **Machinery** – Industrial machines, construction equipment, and manufacturing tools use gears to regulate movement and power transmission.

(iii) **Clocks and Watches** – Gears control the precise movement of clock hands for accurate timekeeping.

(iv) **Energy Generation** – Wind turbines and hydroelectric plants use gears to convert rotational motion into usable energy.

(v) **Medical Equipment** – Devices like surgical robots and prosthetic limbs rely on gears for smooth and controlled movement.

(vi) **Household Appliances** – Washing machines, blenders, and drills use gears to optimize speed and performance.

(vii) **Robotics** – Gears are essential in robotic arms and AI-driven machinery for controlled mechanical movement.

Example 9

Two gear wheels A and B with 20 and 10 teeth respectively lock into each other. They are fastened on axles of equal diameter such that a weight of 100N attached to a string wound around one axle raises a load of 160N attached to a string wound around the other axles.

Calculate

(a) (i) the velocity ratio

(ii) The efficiency of the system when a small gear wheel is the driven gear

(b) (i) the velocity ratio

(iii) The efficiency of the system when a big gear wheel is the driven gear

Solution

(a) i) V.R = $\frac{Number\ of\ teeth\ in\ the\ driven\ wheel}{number\ of\ teeth\ in\ the\ driving\ wheel} = \frac{10}{20} = 0.5$

(ii) Efficiency, n = $\frac{M.A}{V.R}\ x\ 100 = \frac{L}{E}\ x\ \frac{1}{V.R}\ x\ 100 = \frac{160}{100}\ x\ \frac{1}{0.5}\ x\ 100 = 320\%$

(b) (i) V.R = $\frac{Number\ of\ teeth\ in\ the\ driven\ wheel}{number\ of\ teeth\ in\ the\ driving\ wheel} = \frac{20}{10} = 2$

(ii) Efficiency, n = $\frac{M.A}{V.R}\ x\ 100 = \frac{L}{E}\ x\ \frac{1}{V.R}\ x\ 100 = \frac{160}{100}\ x\ \frac{1}{2}\ x\ 100 = 80\%$

Trial 9

(a) A gear system is 30% efficient. The number of teeth on the driven wheel is 100 while that on driving wheel is 20.

Calculate

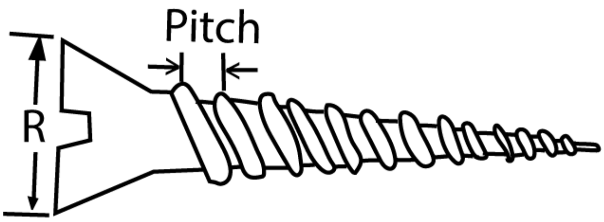
(i) Velocity ration of the system [5]
(ii) Mechanical advantage of the system [1.5]
(iii) Load which can be raised by an effort of 200N [300N]

(b) (i) Explain what you understand by gears
(ii) State the use of gears in daily life
(iii) Describe how gears simplify work.

(c) A gear system used to lift small loads is 30% efficient. The number of teeth on the driven gear is 100 while that on the driving gear is 20. Calculate the
(i) Velocity ratio of the gear system [5]
(ii) Mechanical advantage of the system[1.5]
(iii) Load which can be raised by an effort of 200N. [300N]

The screw

A screw may be considered as continuous inclined plane wound round a cylindrical threaded rod.



- The distance between two successive threads is called a pitch
- In one revolution, the screw moves forward (or backward) through a distance of equal to one pitch.
- Effort distance equals the circumference of the screw head (2πR)
- Load distance equals the length of the pitch.
- When a screw is combined with lever can be uses as a jack for lifting heavy loads such cars

The velocity ration of screws

The V.R of the screw is given by the formula = $\frac{Distance\ moved\ by\ the\ effort}{distance\ move\ by\ the\ load}$

$$V.R = \frac{2\pi R}{screw\ pitch}$$

M.A of screw = $\frac{2\pi R}{screw\ pitch}$ (ignoring friction)

Example 10

(a) In a screw jack the length of the handle is 24cm and the screw pitch is 2mm.if it is used to raise a car of mass 2000kg, calculate

(i) The effort required

(ii) The V.R

(iii) The M.A

(b) Comment the value of M.A obtained in (a)(iii) above

(Take g= $10ms^{-2}$, π = 3.14)

Solution

L = 24 cm = $\frac{24}{100} = 0.24m$, pitch =2mm = $\frac{2}{1000} = 0.002m$, L = 2000 kg = 2000 x 10 = 20000N, E = ?

(i) Effort x 2πl = Load x screw pitch

$$\text{Effort} = \frac{\text{Load x screw pitch}}{2\pi l}$$

$= \frac{20000 \, x \, 0.002}{2 \, x \, 3.14 \, x \, 0.24}$ = 26.54N

(ii) and (ii) V.R = M.A = $\frac{2\pi l}{screw\ pith}$ = $\frac{2 \, x \, 3.14 \, x \, 0.24}{0.002} = 753.6$

(b) MA = VR because the screw jack is assumed to be perfect, i.e. frictionless

NB in practice the effort must be higher than 26.54N in order to overcome friction

Trial 10

(a) A car weighing 1600 kg is lifted with a jack-screw of 11mm pitch. If the handle is 28cm from the screw, find the force applied. [10N]

Application of screws

(i) **Fastening and Construction** – Screws are commonly used to join materials like wood, metal, and plastic in furniture, buildings, and machinery.
(ii) **Mechanical Systems** – Screws are essential in car engines, industrial machines, and tools where components need secure connections.
(iii) **Lifting Mechanisms** – A screw jack uses the screw's rotational motion to lift heavy objects with minimal effort.
(iv) **Medicine and Surgery** – Bone screws are used in orthopedic surgery to stabilize fractures and hold implants in place.
(v) **Household Appliances** – Found in items like bottle caps, light bulbs, and faucets, where controlled rotation secures parts.
(vi) **Transportation** – Used in vehicles, airplanes, and ships to hold panels and structural components securely.
(vii) **Water Pumps and Drilling** – Archimedes' screw is a historical example used for moving water uphill, and modern drilling tools use screw-shaped mechanisms for efficient cutting.

Thanks

Dr. Bbosa Science