

GOVERNMENT POLYTECHNIC SHEOHAR



LABORATORY MANUAL

DEPARTMENT OF MECHANICAL ENGINEERING

**ENGINEERING MECHANICS
SUBJECT CODE: 2025104**

TEACHING AND LEARNING SCHEME: -

Course Code	Course Title	Scheme of Study (Hours/Week)					
		Classroom Instruction (CI)		Lab Instruction (LI)	Notional Hours (TW+SL)	Total Hours (CI+LI+TW+SL)	Total Credits (C)
		C	T				
2025104	ENGINEERING MECHANICS Lab	3	-	4	2	9	6

COURSE OBJECTIVES

After the completion of the course, teachers are expected to ensure the accomplishment of following course outcomes by the learners. For this, the learners are expected to perform various activities related to three learning domains (Cognitive, Psychomotor and Affective) in classroom/ laboratory/ workshop/ field/ industry.

COURSE OUTCOMES

CO-1 Compute the force to solve the problems

CO-2 Analyse various analytical and graphical conditions required for equilibrium of engineering systems.

CO-3 Apply the principles of friction in various conditions to solve problems.

CO-4 Calculate centroid, center of gravity and moment of Inertia of different geometrical shapes.

CO-5 Select the relevant lifting machine(s) for the given purposes.

General Instructions & Safety Measures

- ☐ Follow the instructions of the faculty/lab instructor strictly.
- ☐ Handle all apparatus, weights, tools and models carefully.
- ☐ Wear proper lab dress and safety shoes/apron wherever required.
- ☐ Check the apparatus before starting the experiment.
- ☐ Apply loads gradually and never exceed the safe capacity.
- ☐ Keep hands and loose clothing away from moving parts.
- ☐ Do not operate any equipment without permission.
- ☐ Record observations accurately; do not alter experimental data.
- ☐ Keep the laboratory clean and maintain proper housekeeping.
- ☐ Report any damaged equipment, accident or unsafe condition immediately.
- ☐ Return all apparatus to its proper place after the experiment.
- ☐ Switch off equipment, wherever applicable, before leaving the laboratory.

E x p. N o.	Experiment Name	Map ped CO
1	Determine resultant of concurrent force system applying Law of Polygon of forces	CO1 , CO2
2	Verify Lami's theorem.	CO1 , CO2
3	Determine support reactions for simply supported beam.	CO1 , CO2
4	Determine coefficient of friction for motion on horizontal and inclined plane.	CO2 , CO3
5	Determine the co efficient of friction between two surfaces by Angle of repose method and Friction plane method	CO2 ,CO 3
6	Find M.A, V.R and efficiency of screw jack	CO5
7	Find M.A, V.R and efficiency of dfferential wheel and axle	CO5
8	Calculate the efficiency of single purchase crab winch and double purchase crab winch	CO5
9	Determine the efficiency of worm and worm wheel	CO5

Course Code & CO No.	CO Statement	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2
C104.1	Compute the force to solve the problems	3	0	0	2	1	0	0	3	2
C104.2	Analyse various analytical and graphical conditions required for equilibrium of engineering systems.	2	3	3	3	2	0	0	3	2
C104.3	Apply the principles of friction in various conditions to solve problems.	3	3	3	2	2	1	1	3	2
C104.4	Calculate centroid, center of gravity and moment of Inertia of different geometrical shapes.	3	3	3	2	2	1	1	3	1
C104.5	Select the relevant lifting machine(s) for the given purposes.	3	2	2	3	3	1	2	3	3
C104(Average)	—	2.8	2.2	2.2	2.4	2	0.6	0.8	3	2

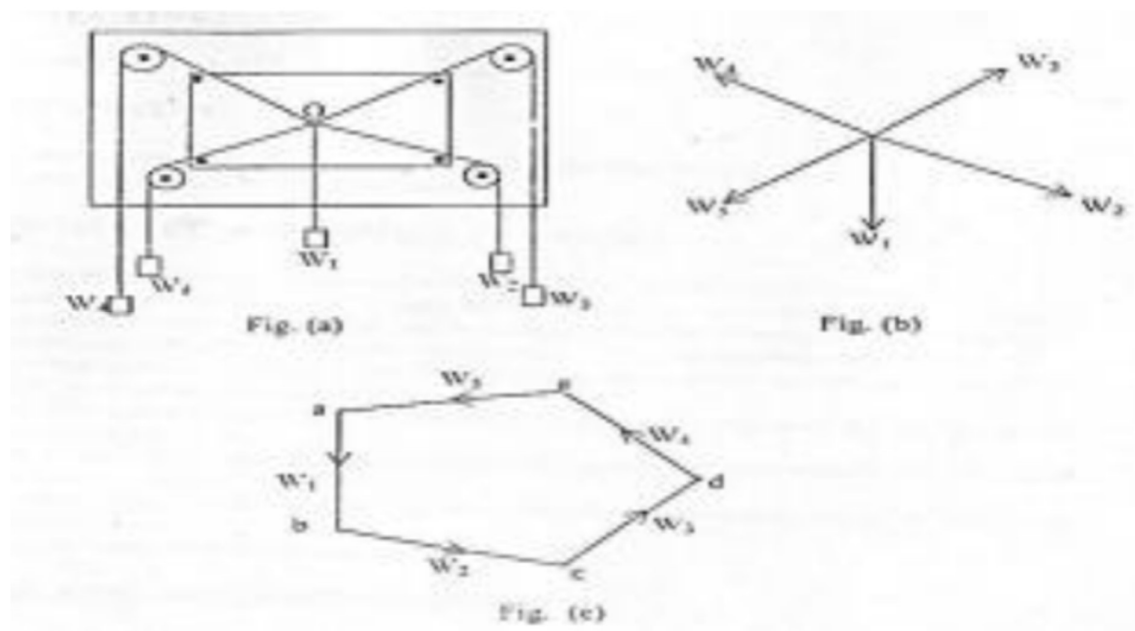
EXPERIMENT NO -GPS/E.M Lab/2024/ P2425104/Exp. No. - 01

Determine resultant of concurrent coplanar force system using force polygon table.

OBJECTIVE: To verify the polygon law of forces for a system in equilibrium, both analytically and graphically.

APPARATUS: Gravesend's apparatus, four adjustable frictionless pulleys and a set of weights.

THEORY: The Law of Polygon of Forces states that "if a number of forces, acting simultaneously on a particle, are represented in magnitude and direction by the sides of a polygon taken in order, then the closing side of the polygon will give the value of the last force."

**PROCEDURE:**

- Fix the white sheet of paper on the force board with the help of tapes.
- Attach four strings passing through the four pulleys whose one end is attached to the common node O and the other end is connected to the known weight. Attach one more string with the central node whose other end is connected to weight.
- After the strings achieve equilibrium, mark the points on the white sheet on the images of the strings in the same direction.

➤ Remove the white sheet and draw lines with the help of the points marked. These lines meet at a point. 5) Draw lines selecting a suitable scale for loads on the sheet and complete a Polygon as shown in the figure.

➤ Measure the last line of the Polygon (that closes the polygon). This will be equal to the fifth force, for verification of the law. Find out the percentage error.

RESULT:

The experiment was successfully done for the verification of the Polygon law of forces, for the given loadings.

Magnitude of F, $|F| = \sqrt{a^2 + b^2}$

Direction of F, $\alpha = \tan^{-1} \frac{a}{b}$

Observation Table:

Sr. No.	Magnitude of forces (N)					Angle between consecutive forces				
	P1	P2	P3	P4	P5	θ1	θ2	θ3	θ4	θ5
1.										
2.										
3.										
4.										

CONCLUSIONS:

EXPERIMENT NO -GPS/E.M Lab/2024/ P2425104/Exp. No. – 02

Determine unknown force in a concurrent balance force system using Lami's Theorem.

OBJECTIVE: to verify Lami's theorem, for a system of concurrent forces.

Theory: If three coplanar forces acting at a point are in equilibrium then each force is directly proportional to the Sin of the angle included between the other two forces.

By using simple weights, pulleys & strings placed around a circular table, several forces can be applied to an object located in the center of the table in such a way that the forces exactly cancel each other, leaving the objects in equilibrium (the object will appear to be at rest).

Force table and Newton's First Law is used to study the components at the force vector.



Procedure:

1. Place the Universal Force Table on firm platform.
2. Make the circular disc in horizontal position with the help of boot screws.
3. Check the horizontal position of circular disc by spirit level.
4. Clamp the three detachable pulleys to the circular disc at three different positions.
5. Keep the ring at the centre of disc and pass the other ends of each string over the three pulleys.
6. Hang three hangers to these ends of strings passing over the pulleys.

Put slotted weights to each hanger to make pivot and ring concentric with each other.

Observational Table:

F1 (gm)	F2 (gm)	F3 (gm)	α	β	γ	F1/SIN α	F2/SIN β	F3/ SIN γ

CONCLUISON:-

EXPERIMENT NO -GPS/E.M Lab/2024/ P2425104/Exp. No. – 03

Find reactions at the supports of a simply supported beam and compare the results with analytical values.

OBJECTIVE: To determine the reactions at supports and verify the condition of equilibrium for a beam simply supported at ends.

THEORY: Beam is a structural element carrying transverse loads.

Analytical condition of equilibrium

1. Algebraic sum of horizontal forces must be equal to zero. i.e. $F_x=0$
2. Algebraic sum of vertical forces must be equal to zero. i.e. $F_y=0$
3. Algebraic sum of moments of forces about any point is zero.

Graphical conditions of equilibrium

1. Force polygon should close which indicates that there is no motion of translation.
2. Funicular polygon should close which indicates that there is no rotating motion.

PROCEDURE:

1. Note down the self-weight of the beam, weight of hook and weight of hangers.
2. Put the known three loads at various point along the length of the beam, so that weights are W_1 , W_2 ,
3. Measure the horizontal distances of these loads from one of the supports. (X_1 , X_2 ,)
4. Observe the reactions in the compression spring balances provided at each support.

FIGURE

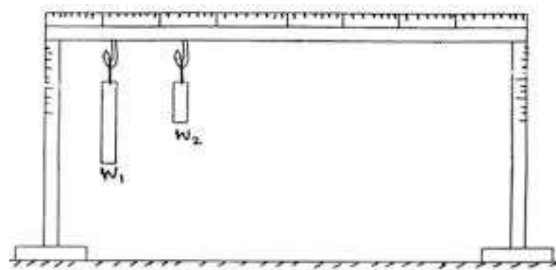


Fig. Simply supported beam with two loads

OBSERVATION Table:

S.No	W1(g)	W2(g)	L ₁ (mm)	L ₂ (mm)	Observational Reading		Theoretical Reading	
					RA(g)	RB(g)	RA'(g)	RB'(g)
1								
2								
3								

$$\% \text{ Error} = \frac{\text{Theoretical} - \text{Practical}}{\text{Theoretical}} \times 100$$

CONCLUISON:-

EXPERIMENT NO -GPS/E.M Lab/2024/ P2425104/Exp. No. – 04**Determine coefficient of friction on horizontal and inclined plane**

OBJECTIVE: Determine the coefficient of friction for motion on Horizontal and inclined planes.

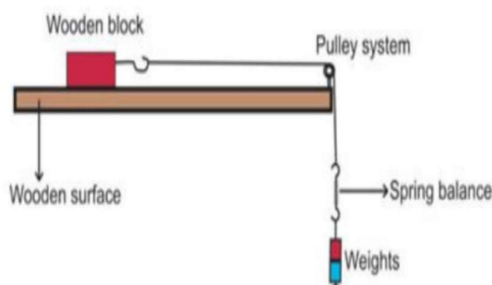
APPARATUS REQUIRED: Horizontal plane with pulley, weights, trolley, weight pans, thread.

THEORY:

- Friction is the resistance to motion of one object moving relative to another. It is not a fundamental force, like gravity or electromagnetism. Instead, scientists believe it is the result of the electromagnetic attraction between charged particles in two touching surfaces.
- Two solid objects moving against each other experience kinetic friction. In this case, the friction is some fraction of the perpendicular force acting between two objects (the fraction is determined by a number called the coefficient of friction, which is determined through experiments). In general, the force is independent of the contact area and doesn't depend on how fast the two objects are moving.
- Friction also acts in stationary objects. Static friction prevents objects from moving and is generally higher than the frictional force experienced by the same two objects when they are moving relative to each other. Static friction is what keeps a box on an incline from sliding to the bottom.
- Friction plays an important part in many everyday processes. For instance, when two objects rub together, friction causes some of the energy of motion to be converted into heat. This is why rubbing two sticks together will eventually produce a fire.

PROCEDURE:

- Set the horizontal planes. Take a box's known weight, note its bottom surface whether the glass, or sand paper or cardboard boxes, and weight W (weight of box + weight in the box.)
- Slowly add weights in the effort pan. A stage would come when the effort pan just slid down pulling the box up the plane. Using fractional weights up to a least count of 5 gram, find the least possible weight in the pan that causes the box to just slide up the plane. Note the weight in the effort pan. There is a force " p ".
- Repeat the above steps 1 to 3 by changing the weights in the box for two more observations



OBSERVATION

TABLE :-

For Horizontal Plane

SL no	Weight of the wooden block, W	Weight on Wooden Block (X) in gwt	Normal Reaction R(gwt) = W+X	Weight of the scale Pan, P	weight in pan W ₁ (gwt)	Force of limiting Friction F = P+W ₁	Coefficient of Friction $\mu = \frac{F}{R}$
1							
2							
3							

For Inclined Plane

SL no	Contact of Surface	Inclination of Plane θ	Load (W)	Effort (P)	Coefficient of Friction μ $\mu = \frac{P - W \sin \theta}{W \cos \theta}$	Average Coefficient of Friction μ

Formula:

Coefficient of Friction $\mu = F/R$ Coefficient of Friction $\mu = (P - W \sin \theta) / (W \cos \theta)$

CONCLUISON –

EXPERIMENT NO -GPS/E.M Lab/2024/ P2425104/Exp. No. – 05**Determine the coefficient of friction between two surfaces by • angle of repose methods • friction plane method**

Object: To find the Coefficient of Friction between two surfaces.

Apparatus: Inclined Plane with pulley, weights, block, weight pan, etc.

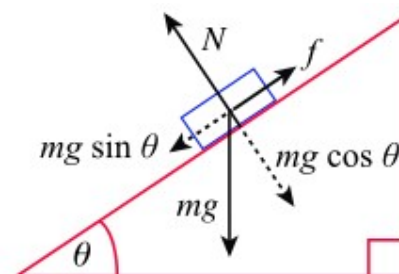
Theory: Friction force is developed whenever there is a motion or tendency of motion of one body with respect to the other body involving rubbing of the surfaces of contact. Friction is therefore a resistance force to sliding between two bodies produced at the common surfaces of contact. Friction occurs because no surface is perfectly smooth, however flat it may appear. On every surface there are _microscopic hills and valleys 'and due to this the surfaces get interlocked making it difficult for one surface to slide over the other. During static state the friction force developed at the contact surface depends on the magnitude of the disturbing force. When the body is on the verge of motion the contact surface offers maximum frictional force called as Limiting Frictional Force.

In 1781 the French Physicist Charles de Coulomb found that the limiting frictional force did not depend on the area of contact but depends on the materials involved and the pressure (normal reaction) between them. Thus frictional force $F \propto N$, or

$$F = \mu_s N$$

Here μ_s is the coefficient of static friction, a term introduced by Coulomb. The value of lies between 0 and 1 and it depends on both the surfaces of contact. Coefficient of static friction μ_s between two surfaces can be found out experimentally by two methods, viz. Angle of Repose method and Friction Plane method.

The minimum angle of an inclined plane at which a body kept on it slides down the plane without the application of any external force is known as Angle of Repose. It is denoted by letter ϕ . Angle of repose, $\phi = \tan^{-1} \mu_s$



Applying Condition of Equilibrium

$$\sum F_x = 0$$

$$P - W \sin \theta - \mu_s N = 0 \quad \dots\dots\dots (1)$$

$$\sum F_y = 0$$

$$N - W \cos \theta = 0 \quad \dots\dots\dots (2)$$

From equations (1) and (2) we get

$$P - W \sin \theta - \mu_s (W \cos \theta) = 0$$

$$\text{or} \quad \mu_s = \frac{P - W \sin \theta}{W \cos \theta}$$

PROCEDURE

1. Set the inclined plane with glass top at some angle with the horizontal. Note the inclination θ of the plane on the quadrant scale. Take a box of known weight, note its bottom surface (whether surface is soft wood, or sand paper, or card board etc,) and weight W (weight of box)
2. Tie a string to the box and passing the string over a smooth pulley, attach an effort pan to it.
3. Slowly add weights in the effort pan. A stage would come when the effort pan just slides down pulling the box up the plane. Using fractional weights up to a least count of 5 gm, find the least possible weight in the pan that causes the box to just slide up the plane. Note the weight in the effort pan. This is force P' .
4. Repeat the above steps 1 to 3 by changing the weights in the box for two more sets of observations.

Observation Table:

Type of surface	Weight of block (W) in N	Angle of the Plane (θ)	Weight in effort pan (P) in N	Coefficient of Friction (μ)	Average (μ)	Angle of Repose	
						Analytical	experimental
Wood							
Carpet Cloth							

CONCLUSION :-

EXPERIMENT NO -GPS/E.M Lab/2024/ P2425104/Exp. No. – 06**Find M.A, V.R and efficiency of screw jack**

OBJECTIVE-To determine the mechanical advantage and efficiency of a square thread screw jack.

APPARATUS REQUIRED -

- Screw Jack Apparatus.
- Slotted & Conical Weight.
- String.
- Meter Rod & Pan.

THEORY-

This machine is used for lifting loads with the application of a smaller effort. It may have different shapes, but the principle is same i.e., it works on the principle of a screw. The screw head carries the load w . The nut is fixed, and the screw is rotated by means of a lever. The effort p is applied at the screw is rotated by means of a lever. The effort p is applied at the end of the lever.

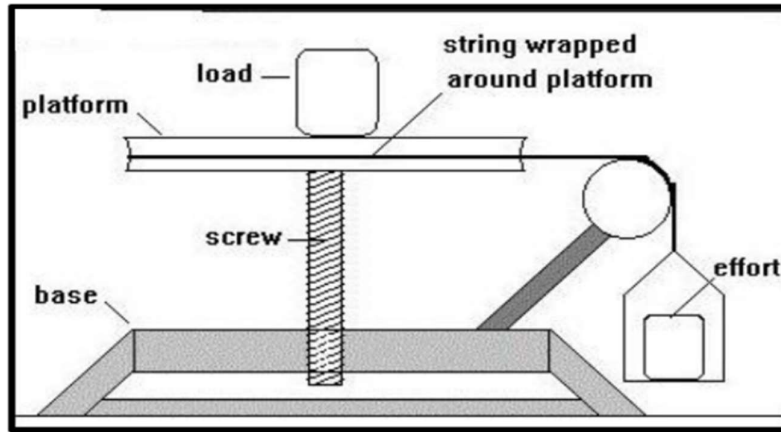
Now if the screw head revolves through n number of revolution the screw head will move by a distance $p \times n$, where p is the effort p will move a distance $n \times 2r$, where $2r$ is the circle head over which p is coming.

Therefore,

$$V.R = \frac{\text{Distance moved by the effort } p}{\text{Distance moved by the load } W}$$

PROCEDURE-

- Wrap on string round the circumference of the screw head and take it over a small pulley. Effort p 1 is tied to the free end of this string.
- wrap another string around the circumference of the screw head in the same direction in which the above string is wound and take it over the other small pulley.
- place a load w on the screwhead.
- suspend P_1 and P_2 to the free ends of both the strings coming over the two small pulleys. This load P_1 and P_2 should be increased gradually suitable to give adjust upward motion to the screwhead.
- note down w and p to determine the M.A. i.e w/p . in this case $P_1 + P_2$ will be the value of P .
- P_1 and P_2 should be noted down carefully.
- take in this way about 10 reading by increasing w and finding out the corresponding value of $P(P_1=P_2)$.

**OBSERVATION:**

Effort Wheel Diameter (D) =

Pitch of the screw (p) =

S.No.	Load Lifted (W)	Effort Applied(P)	Mechanical Advantage (M.A.)	Velocity Ratio (V.R.)	Efficiency
1					
2					
3					

CONCLUISON :-

EXPERIMENT NO -GPS/E.M Lab/2024/ P2425104/Exp. No. – 07**Find M.A, V.R and efficiency of differential wheel and axle**

OBJECTIVE - To find the M.A, V.R, and efficiency of a differential wheel and axle.

APPARATUS

Differential wheel and axle apparatus,

weight,
weight hanger,
scale.

THEORY

Differential wheel and axle is an improved form of simple wheel and axle, in which the velocity ratio is intensified with the help of load axle. The load axle is made up of 2 part of different diameters. The wheel A and the axles B and C are keyed to the same shaft, which is mounted on ball bearings in order to reduce the frictional resistance to a minimum.

The effort string is wound round the wheel. Another string wound round the axle B, which after passing round the pulley is wound round the axle C in opposite direction to that of axle B, care being taken to wind the string on the wheel A and axle C in the same direction. As a result of this, when the string unwinds from the axle C. But it winds on the axle B.

Let D = Diameter of the effort wheel A

d_1 = of the axle B

d_2 = Diameter of the axle C

W = Weight lifted by the machine

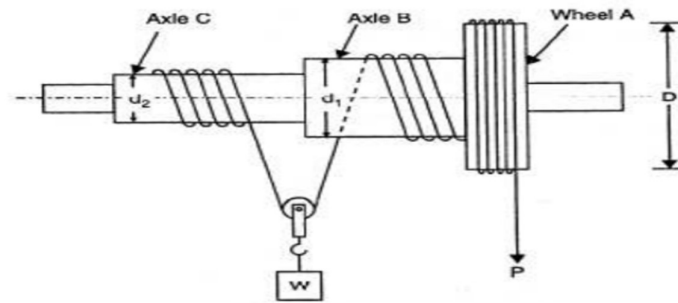
P = Effort applied to lift the Weight

We know the displacement of the effort in one revolution of effort wheel A = πD Length of string, which will wound on axle B in 1 rev = πd_1

PROCEDURE:

- Measure the radii of the two axles and the radius of the effort wheel.
- Wrap the cord/thread around the differential axle and the effort wheel, as shown in the figure.
- Put some weight on the load drum. And add some effort gradually to the effort wheel via hanger, till the load starts lifting.
- Write down the reading in the observation table.
- After this apply the above procedure, for further readings.
- Calculate the MA, VR and η of machine.

Diagram



OBSERVATION TABLE

S.No.	Load Lifted (W)	Effort Applied(P)	Mechanical Advantage (M.A.)	Velocity Ratio (V.R.)	Efficiency
1					
2					
3					

Mechanical Advantage (M.A.) = W/P

Velocity Ratio (V.R.) = $2D/(d_1 - d_2)$

CONCLUISON :-

EXPERIMENT NO -GPS/E.M Lab/2024/ P2425104/Exp. No. – 08**Calculate the efficiency of single purchase crab winch and double purchase crab winch**

OBJECTIVE:-To determine the Efficiency (η) of Single Purchase Crab Winch and Double Purchase Crab Winch.

APPARATUS REQUIRED

1. Single Purchase Crab Winch apparatus
2. Double Purchase Crab Winch apparatus
3. Load hanger
4. Set of weights
5. Measuring scale
6. Rope / string

THEORY

A crab winch is a lifting machine used to lift heavy loads by applying a small effort through a handle. The handle rotates a pinion gear, which meshes with a spur wheel attached to the drum. The drum winds the rope and lifts the load.

In a single purchase crab winch, there is one pair of gears (pinion and spur wheel).

In a double purchase crab winch, there are two pairs of gears, which increases the velocity ratio and makes it easier to lift heavier loads.

Efficiency of the machine is given by

$$\eta = M. A / V. R$$

Where

M.A = Mechanical Advantage = W/P

V.R = Velocity Ratio

η = Efficiency

Single Purchase Crab Winch

Formula Used:

Let, T_1 = Number of teeth on the pinion

T_2 = of teeth on the spur wheel

L = Length of the handle

d = Diameter of the drum

Consider one revolution of the handle. Then, distance moved by the effort = $2 \pi L$

Number of revolutions made by the pinion = 1 and number of revolutions made by the spur wheel = T_1 / T_2

Distance moved by the load = $\pi d / (T_1 / T_2)$

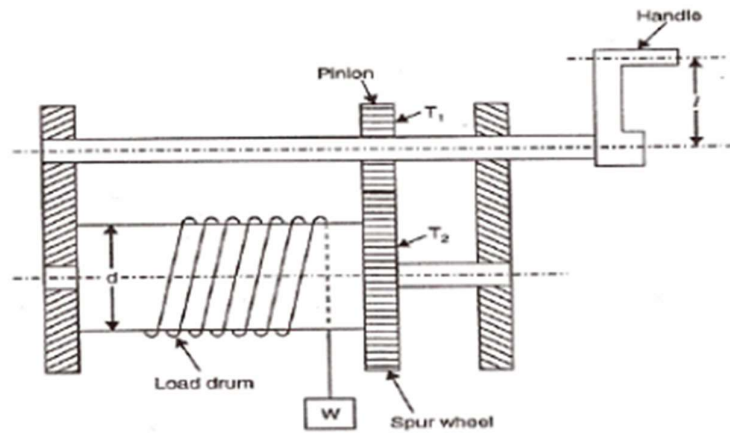
$$V.R = (\text{Distance moved by } P) / (\text{Distance moved by } W)$$

$$= 2\pi L / \pi d (T_1 / T_2)$$

$$= (2L / d) (T_2 / T_1)$$

$$M.A = W / P$$

$$\eta = M.A / V.R$$



DOUBLE PURCHASE CRAB WINCH

Formula Used

Consider one revolution of the handle.

Then, distance moved by the effort = $2\pi L$

No. of revolutions made by the pinion 1 = T_1

No. of revolutions made by the spur wheel 2 = T_2

No. of revolutions made by the spur wheel 3 = T_1 / T_2

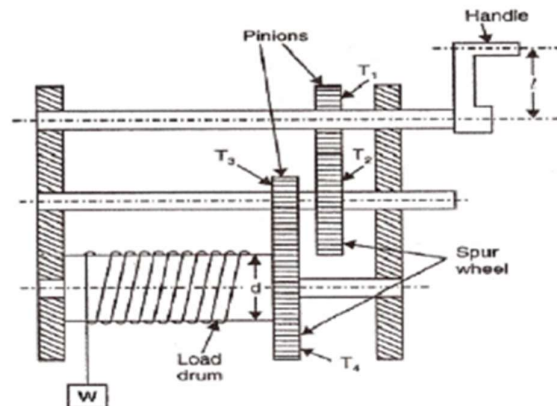
No. of revolutions made by the spur wheel 4 = $(T_1 / T_2) \cdot (T_3 / T_4)$

Distance moved by the load = $\pi d \cdot (T_1 / T_2) \cdot (T_3 / T_4)$

$$V.R = (\text{Distance moved by the effort}) / (\text{Distance moved by the load}) = 2\pi L / [\pi d \cdot (T_1 / T_2) \cdot (T_3 / T_4)] = (2L / d) \cdot (T_1 / T_2) \cdot (T_3 / T_4)$$

$$M.A = W / P$$

$$\eta = M.A / V.R$$



PROCEDURE

- Fix the crab winch apparatus firmly on the base.
- Measure the length of the handle (L) and diameter of the drum (d).
- Note the number of teeth on pinions and spur wheels.
- Wrap the rope around the drum.
- Attach the load hanger to the rope.
- Apply effort by rotating the handle slowly.
- Note the effort required to lift the load.
- Repeat the experiment for different loads.

- Record the observations.

Observation table for single purchase crab winch

Effort Wheel Diameter (D) =

Load Drum Diameter(d) =

T1 =

T2 =

S.No.	Load Lifted (W)	Effort Applied(P)	Mechanical Advantage (M.A.)	Velocity Ratio (V.R.)	Efficiency
1					
2					
3					

Observation table for Doble purchase crab winch

Effort Wheel Diameter (D) =

Load Drum Diameter(d) =

T1 =

T2 =

T3=

T4=

S.No.	Load Lifted (W)	Effort Applied(P)	Mechanical Advantage (M.A.)	Velocity Ratio (V.R.)	Efficiency
1					
2					
3					

CONCLUISON :-

EXPERIMENT NO -GPS/E.M Lab/2024/ P2425104/Exp. No. – 09**Determine the efficiency of worm and worm wheel**

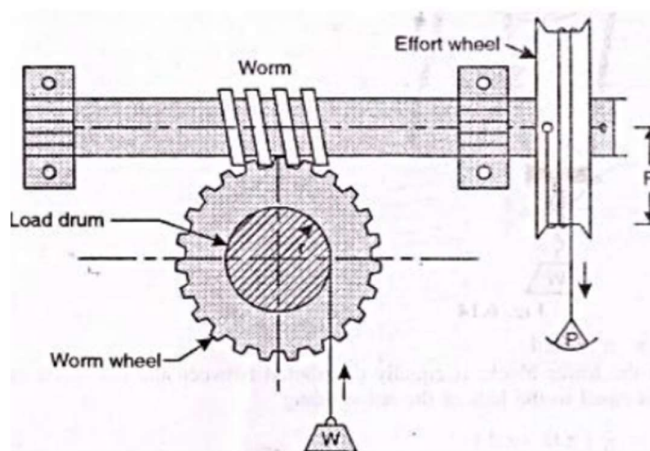
OBJECTIVE: To find the Efficiency of Worm and Worm Wheel.

APPARATUS REQUIRED:

Worm and Worm Wheel, Load to be lifted (W), Weights or Effort to be applied (P), Cords/Threads, Weight Hangers, scale.

THEORY:

The worm and worm wheel apparatus consists of a horizontal shaft on which a worm is provided. The shaft is supported on two bearings and an effort wheel is provided on the shaft. The worm meshes with a worm wheel. A load drum is mounted on the same shaft of the worm wheel.



Let, w = load lifted,

T = number of teeth on the worm wheel,

P = effort applied,

r = radius of load drum,

R = radius of effort wheel.

Consider the worm is single threaded.

For one complete revolution of effort wheel,

distance moved by the effort P , $y = 2\pi R$ and

load drum performs $(1/T)$ revolution. $\therefore$ Distance moved by the

load, $x = 2\pi r/T$

We know that

$$V.R. = \frac{\text{Distance travelled by the effort}}{\text{Distance travelled by the load}} = \frac{2\pi R}{\frac{2\pi r}{T}} = \frac{RT}{r}$$

$$\therefore V.R. = \frac{RT}{r}$$

PROCEDURE:

1. Measure the radius of the load drum and the radius of the effort wheel.
2. Wrap the cord/thread around the load drum and the effort wheel.
3. Put some weight on the load drum. And add some effort gradually to the effort wheel via hanger, till the load starts lifting.

4. Write down the reading in the observation table.
5. After this apply the above procedure, for further readings.
6. Calculate the MA, VR and η of machine.

OBSERVATIONS:

Effort Wheel Diameter (D) =

Load Drum Diameter(d) =

No. of Teeth on the worm wheel(T) =

S.No.	Load Lifted (W)	Effort Applied(P)	Mechanical Advantage (M.A.)	Velocity Ratio (V.R.)	Efficiency
1					
2					
3					

Mechanical Advantage (M.A.) = W/P Velocity Ratio (V.R.) = DT/d Efficiency, η = $M.A / V. R$

CONCLUSION :-