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Universal Force Apparatus

Objective : To verify polygon Law of Forces

Apparatus : Apparatus consists of a circular aluminium disc graduated in 360°. Apparatus is provided with leveling screws, clampings device to fix the table at any desired angle, five sliding clamping pulleys and a Central ring. Apparatus includes a set of weights.

Theory

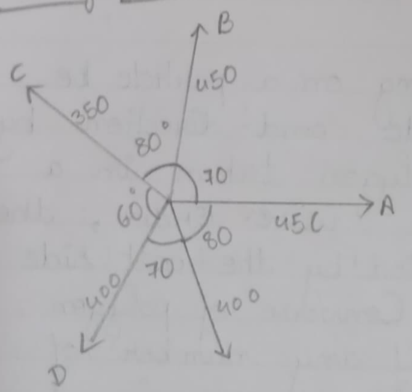
If a number of forces acting on a particle be presented in magnitude and direction by the sides of a closed polygon taken in a clock wise or anticlock wise Order, their resultant will be represented by the east side but in reverse direction. Converse of polygon law of force states that if any number of force acting on a particle are in equilibrium, a closed polygon can be drawn whose sides represent these force both in magnitude and direction. The converse of polygon law of forces is true in the same sense that if any numbers of co-planer forces acting at the point are in equilibrium.

Observation Table

S. No	Weights (gm)				Angle				Last force ∈ observed	magnitude of t from the polygon	% Error in t
	A	B	C	D	A	B	C	D			
1	450	450	350	400	70°	80°	60°	70°	400	402	0.5
2	600	350	300	400	70°	60°	60°	70°	500	507	1.4
3	550	400	550	300	70°	70°	60°	60°	500	517	6

CALCULATIONS.

1) Analytical Method



$\Sigma Fx = 450 + 450 \cos 70 - 350 \cos 30 - 400 \cos 30$

$= -63.6 \text{ N.m}$

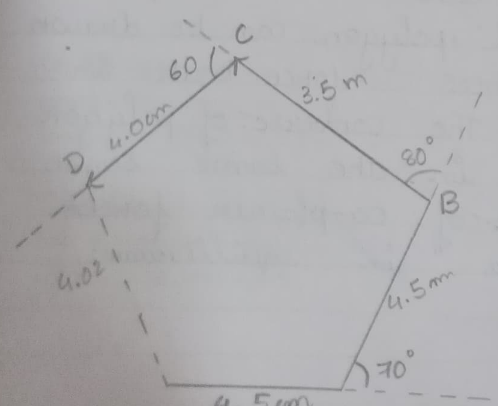
$\Sigma Fy = 450 \sin 70 + 350 \sin 30 - 400 \sin 30$

$= 397.86$

$R = \sqrt{(\Sigma Fx)^2 + (\Sigma Fy)^2}$

$= \sqrt{(-63.6)^2 + (397.86)^2}$

$\simeq 402$



$\% \text{ Error} = \frac{400 - 402}{400} \times 100$

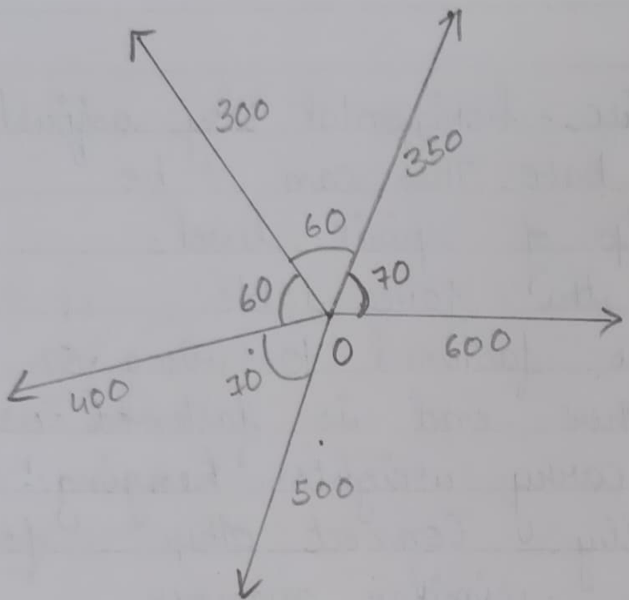
$= 0.5\%$

Graphical Method

Procedure :

1. Make the graduated disc horizontal by adjusting the screws at its base. This can be tested with the help of spirit level.
2. Put a white sheet on the force table.
3. One end of a string is fastened to ring on the table while other end is fastened with hanger, which is to carry weights hanging freely through a pully. Connect other four strings in the similar manner.
4. Place small weights in to the different hangers.
5. Note the positions of one string on the disc and note also the relative positions of the other strings.
6. Mark the directions of the strings by drawing straight line on the paper. Note the weights applied on each string in each direction.
7. Draw the scale diagram of forces as given, acting at a point cutting the line of action of each force proportional to the magnitude of the force
8. Draw the stress diagram ABCDE and verify that the polygon ABCDE is complete.
9. Repeat the experiment three times by changing weights in hangers and also changing the angles.

2) ANATICAL METHOD



$\Sigma Fx = 600 + 350\cos 70$
$300\sin 40 - 400\cos 10$
$= 133$

$\Sigma Fy = 350\sin 70 + 300\cos 40$
$400\sin 10$
$= 489.24$

$R = \sqrt{(\Sigma Fx)^2 + (\Sigma Fy)^2}$

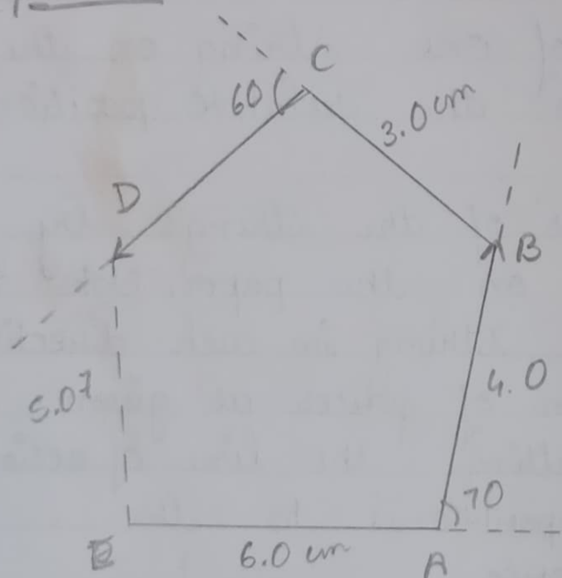
$= \sqrt{(133)^2 + (489.24)^2}$

$\simeq 507$

$\% \text{ Error} = \frac{500 \cdot 507}{500} \times 100$

$= 1.4\%$

Graphical



ANALYTICAL METHOD

$\Sigma Fx = 550 + 400\cos 70 - 350\cos 40 . 300\cos 20$
$= 136.8$

$\Sigma FY = 400 \sin 70 + 350 \sin 40 . 300\sin 20 = 496.26$

$R = \sqrt{(136.8)^2 + (498.26)^2}$

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Result

Mean % error in apparatus while verifying polygon law of forces =

Precautions

a) Pulleys should be frictionless
b) There should not be any knots in the strings.
c) Directions of the strings should be marked carefully
d) The ring should not touch the axis of the disc
e) The graduated disc should be made horizontal by adjusting the screw of the base.

12/02/23

Objective

To verify the reactions of a simply suported beam at the supports.

Apparatus

Apparatus consists of two dial type connection compression balance and a wooden bar fixed on a wooden board.

Theory

If a system of coplanar forces acting on a rigid body keeps it in equilibrium then the algebraic sum of their moments about any point in their plane is zero.

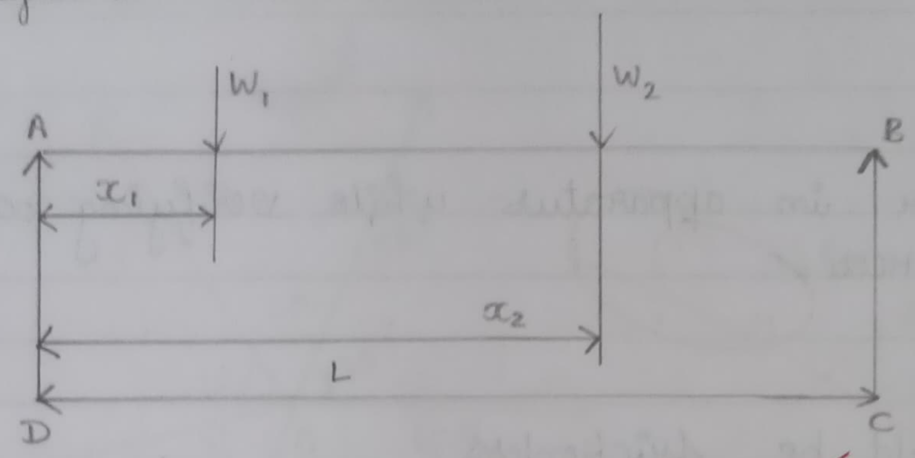
In the figure, AB is a simply supported beam supported at A and B. When two loads W_1 and W_2 are applied at points C and D situated at distance x_1 and x_2 respectively from end A, then from Newton's third law, reactions RA and RB are developed A and B supports. Applying condition of equilibrium, we have

A) $\Sigma V = 0$

$$RA - W_1 - W_2 + RB = 0$$

$$RA + RB = W_1 + W_2$$

Diagram :-



Observation Table

S.No	Weights on beam and their distance from part A				Final reading at A & B		Reaction from calculation		% Error $\frac{Ra - R'a}{Ra} \times 100$	
	W_1	W_2	x_1	x_2	$R'A$	$R'B$	RA	RB	RA	RB
1	1500	1000	25	75	1350	1250	1375	1125	1.81	11.11
2	1000	1500	30	70	1200	1300	1150	1350	4.34	3.70
3	1000	1000	20	80	1000	1050	1000	1000	0	5
								Mean	2.05	6.60

Calculations

1) $R_B = \frac{W_1 x_1 + W_2 x_2}{L} = \frac{1500 \times 25 + 1000 \times 75}{100} = 1125$

$R_A = 1375$

% Error in RA $= \frac{|R_A - R'_A|}{R_A} \times 100$

$= 1.81\%$

B) $\Sigma M = 0$

Taking moments about A, we have

$-R_B L + W_2 x_2 + W_1 x_1 = 0$

$R_B L = W_2 x_2 + W_1 x_1$

$$R_B = \frac{W_1 x_1 + W_2 x_2}{L}$$

From (1) $R_A = W_1 + W_2 - R_B$

Result

a) Mean % error in RA = 2.05 %

b) Mean % error in RB = 6.60 %

Precautions

a) Zero error of the compression must be taken in to account

b) Weights should not be put on the beam with a jerk.

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% Error in $R_B = \frac{|R_B - R'_B|}{R_B} \times 100$

$= 11.11\%$

2) $R_B = \frac{W_1 x_1 + W_2 x_2}{L}$

$= 1350$

$R_A = W_1 + W_2 - R_B \Rightarrow 1000 + 1500 - 1350$

$= 1150$

% Error in $R_A = \frac{|R_A - R'_A| \times 100}{R_A} = 4.34\%$

% Error in $R_B = \frac{|R_B - R'_B|}{R_B} \times 100 = 3.70\%$

3) $R_B = \frac{W_1 x_1 + W_2 x_2}{L} = \frac{1000 \times 20 + 1000(80)}{100} = 1000$

$R_A = W_1 + W_2 - R_B$

$= 1000$

% Error in $R_A = \left|\frac{R_A - R'_A}{R_A}\right| \times 100 = 0\%$

% Error in $R_B = \frac{|R_B - R'_B|}{R_B} \times 100 = 5\%$

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AIM: To determine the co-efficient of friction b/w given pair of surfaces.

Apparatus

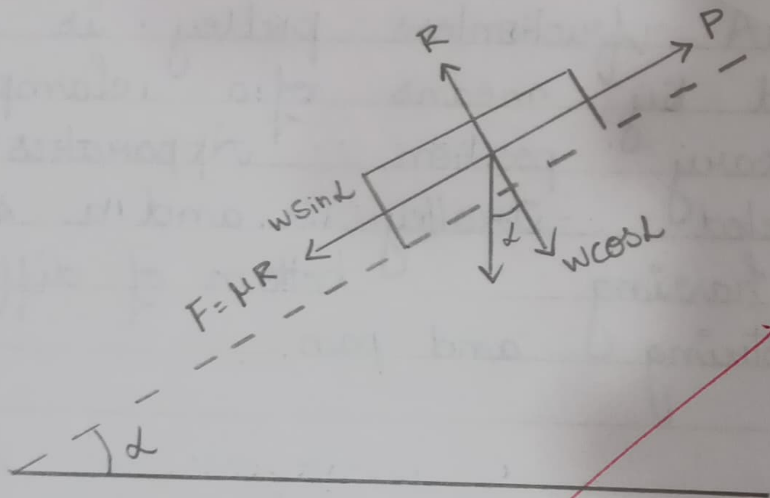
It consist of wooden plane having adjustments for setting the required angle precisely with the help of graduated arc and vertical scale is provided. A frictionless pulley is attached to the end by means of a clamp adjustment to any necessary position. Apparatus is supplied with a wheeled trolley and a set of eight slide draws having bottom of different materials, string and pan.

Theory:

It has been established since long that the surface of the bodies are never perfectly smooth. It is found that whenever, even a very smooth surface is viewed under a microscope, it is found to have some roughness and irregularities, which may not be detected by and Ordinary touch. It has also been observed that if a block of one substance is placed over the level surface of the same or different material, a certain degree or interlocking of the minutely projecting particle takes place. This does not involve any force, so ling as the block does not move or tends to move. But whenever one of the blocks moves

Teacher's Signature

This μ is the coefficient of friction



Free body Diagram of Apparatus

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Consider a body of weight W on a plane having an angle of inclination i.e resting on an inclined plane. Suppose it just tends to move up the inclined plane when a force of P is applied. Since the body tends to move upwards, the frictional force F will be acting downwards.

The force on the body can be resolved into two components perpendicular and parallel to the plane. Resolving the forces parallel to the plane, resolving the forces parallel to the plane, we get

$$P = \mu R + W \sin\alpha$$

The component $W\cos\alpha$ perpendicular to the plane balances the normal reaction R and the component $W\sin\alpha$ parallel to the plane provides the necessary force for the body to move down the plane.

$$P = \mu R + W\sin\alpha$$

$$\mu W\cos\alpha = P - W\sin\alpha$$

$$\mu = \frac{P - W\sin\alpha}{W\cos\alpha}$$

Observations

Contact Surface - Glass and Wood
weight of slider - 145g
weight of pan - 25g

S.No	Weight of Slide, w (g)	wt of slide + wt in pan P(g)	Inclination of plane	Coefficient of friction $\mu = \frac{P - W\sin\alpha}{W\cos\alpha}$
1	145	70	15	0.23
2	145	90	25	0.21
3	150	125	35	0.31

Contact Surface - Aluminium and wood
weight of slider - 150g
weight of pan - 25g

S.No	wt of slide, w (g)	wt of Slide + wt in pan p(g)	Inclination of plane	coefficient of friction $\mu = \frac{P - W\sin\alpha}{W\cos\alpha}$
1	150	140	15	0.69
2	170	185	25	0.73
3	160	195	35	0.78

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RESULT

1. Mean value of coefficient of friction (μ) for glass and wood = 0.25
2. Mean value of coefficient of friction (μ) for aluminium and wood = 0.73

Precaution

1. Pulley should not be frictionless
2. There should not be only knot in the string
3. Weight should be placed in effort pan slowly.

Calculations

Contact surface = Glass & wood

$$\mu_1 = \frac{P - W\sin\alpha}{W\cos\alpha} = \frac{70 - 145\sin15}{145\cos15} = 0.23$$

$$\mu_2 = \frac{90 - 145\sin25}{145\cos25} = 0.21$$

$$\mu_3 = \frac{125 + 150\sin35}{150\cos35} = 0.31$$

$$\text{mean} = \frac{0.23 + 0.21 + 0.31}{3} = 0.25$$

Contact surface = Aluminium and wood

$$\mu_1 = \frac{140 + 150\sin15}{150\cos15} = 0.69$$

$$\mu_2 = \frac{125 + 170\sin25}{170\cos25} = 0.73$$

$$\mu_3 = \frac{195 + 160\sin35}{160\cos35} = 0.78$$

$$\text{Mean} = \frac{0.69 + 0.73 + 0.78}{3} = 0.73$$

Teacher's Signature

28-3-23

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Expt. No. 4

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AIM - To find the percentage error between calculated and observe values of forces in the member of a jib crane

Apparatus: Jib crane apparatus, Spring balana, meter scale, weights etc. The jib crane apparatus consists of a tub wear shaped jib with a compression balance. The balance is pivoted about an fitted to the hare and a hook attached to the other end from which a chain hangs. A virtical tubular ~~load~~ rod. Carries hooks at different levels. One end of the tie rope carrying a Spring balance is attached to the hooks provided on the vertical rod. The vertical rod is fixed to the hare

Theory:
The jib crane is an example of 3 concurrent forces. The forces in the tie and file can be calculated experimentally. Analytically it can be found by making use of lami's theorum, which states that when 3 forces acting on a body are in equilibrium, then each forces is propotional to the Sin of angle between the other forces. Jib crane consists of an inclined member supported by a rope or any other type of a structural member attached to a verticle mast. Load is usually suspended from outer end of this mast.

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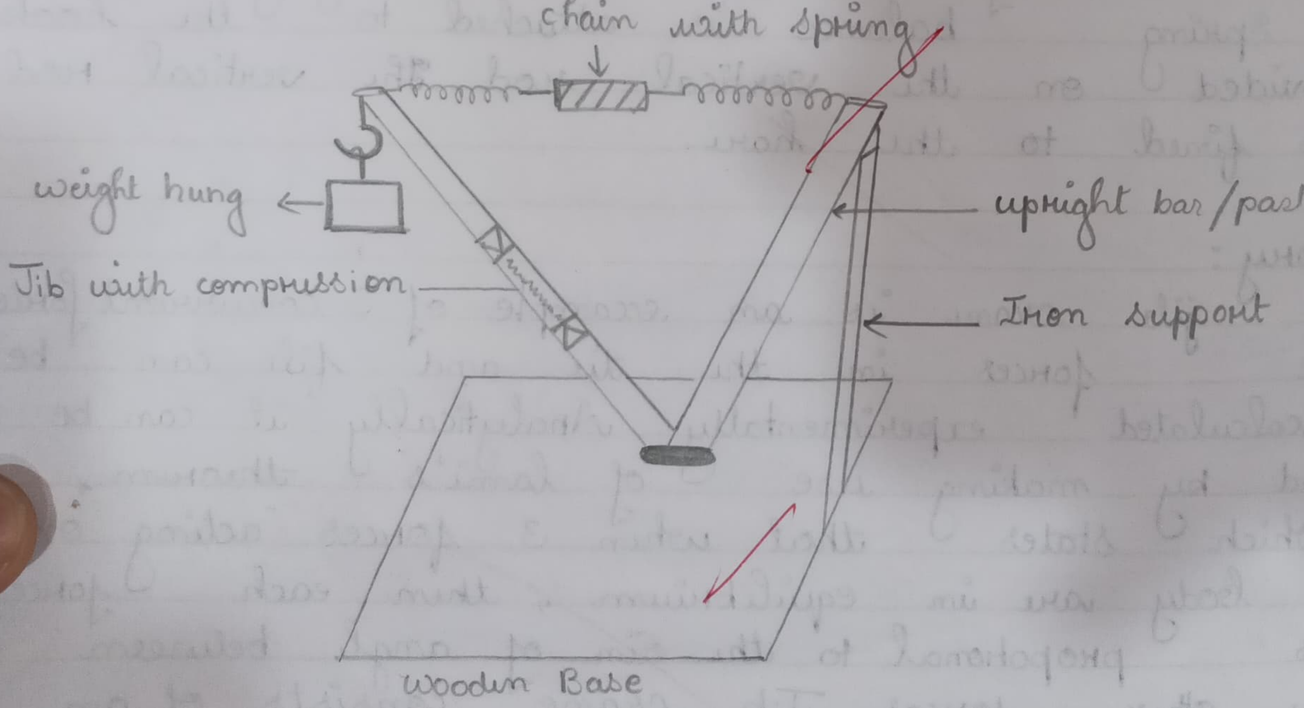
Observation Table

S.NO	Load weight	Length			Final Reading on balance		Calculated Force		% Error	
		AB	AC	BC	JIE	JIB	Tie	Jib	Tie	Jib
1.	3kg	35.5	105.5	78	2.4	3.1	2.46	2.19	2.4%	4.1%
2.	4kg	82	971	79	3.8	4	3.172	3.39	1.9%	1.7%
3.	5kg	76	95.2	80.5	5.2	5.3	4.46	4.62	1.8%	3.1%

Diagram



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The outreach of the jib maybe variable. The crane may be either movable. Lifting capacity of such crane from ½ ton to 200 ton and out reach from a few meter to 50 meter. Such crane final various applications in shipyard, portaraas, construction sites for lifting heavy materials or goods

Result and Discussion

→ Mean % error in the tie = 13.3%

→ Mean % error in the jib = 8.067%

PRECAUTIONS

→ Don't suspend weight from A with a jerk.

→ Take into account the zero error of the balance.

→ Measure the length with a fine intensible thread.

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AIM: To determine the Mechanical Advantage, Velocity Ratio, Efficiency and condition for self- locking of simple screw jack.

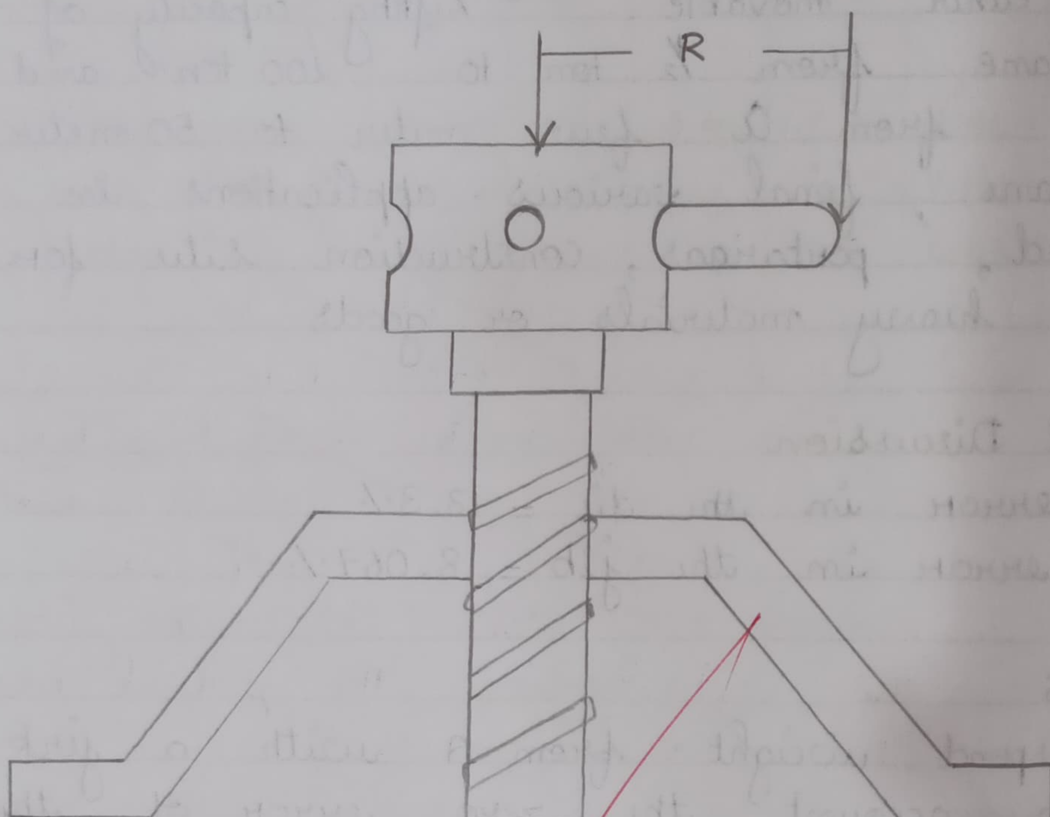
Apparatus - The apparatus consists of a jack apparatus with two strings, pans, weights sets and a meter scale or outside calliper

Theory
It is a device which is used to do a particular work. There are two types of machine namely simple machine and compound machine. Simple machine has only one point for the application of effort and one ~~four~~ point for load. Compound machine has more than one point for the application of effort and for load.
It's also known as lifting gear. This is a general term for any equipment that can be used to lift loads. This includes jacks cranes etc. In this device effort required to overcome a load, W

$$MA = \frac{W}{P}$$

$$VR = \frac{\text{Distance moved by effort}}{\text{Distance moved by load}} = \frac{y}{x}$$

$$\eta = \frac{MA}{VR} \times 100$$



Observation Table

S.NO	Load	Effort P = weight + applied + a kg	M.A = 4P	% efficiency
1	10kg	614 + 200	12.28	10.74%
2.	14kg	614 + 340	14.67	12.83%
3.	15 kg	614 + 430	13.71	12%

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Result

~~Mechanicte~~ Mechanical Advantage is 13.55 ~~%~~

Mean % efficiency of all apparatus is 11.85%.

Precautions:

1. There should not be any overlapping of the strings.
2. Weights in the pan should be placed very gently
3. The pulley should be free from friction
4. The screw should be well lubricated to reduce the friction.
5. Note the effort readings as the load just moves.

Procedure

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Calculations

1) $mA = \frac{10}{0.814} = 12.28$

$\frac{MA}{VR} = \frac{12.28}{114.296} \doteq 0.1074 \times 100 \Rightarrow 10.74\%$

ii) $mA = \frac{14}{0.956} = 14.67$

$= \frac{14.67}{114.296} = 0.1283 \times 100$

iii) $MA = \frac{15}{1.094} = 13.71$

$= \frac{13.71}{114.296} = 0.1199 \times 100 \Rightarrow 12\%$

AIM: To determine the mechanical advantage, velocity ratio and efficiency of simple wheel and axle

Apparatus: Simple wheel and axle apparatus consists of two prooved wooden wheels of different diameter which are fixed rigidly together and are mounted on steel centers on wooden base. Apparatus required strings, a set of weight, scale pan and meter scale.

Theory: The most simple machine which is in use, since ages is the simple wheel and axle used for drawing up water from a well. It is used in village wells even till date Simple wheel and axle is used to lift loads. Simple wheel and axle consists of an effort wheel and axle of different diameters which are keyed to the same spindle. The diameter of the axle to reduce the frictional resistance.

A string is wound on the axle, with one end fixed to it. The other end of this rope carries the load W, which is to be lifted. A second string is wound round the wheel, in a direction opposite to that of the wheel while to the other and effort P is applied. Since the two strings are would in opposite directions, therefore a downward motion of P will lift the load 'W' Opposite directions, therefore

Observation :

Diameter of wheel D = 120mm
Diameter of axle d = 65 mm

$V.R = \frac{D}{d} = \frac{120}{65} = 1.846$

weight of pan / hanger a gm = 25gms
weight of effort pan / hanger b gm = 25gms

Observation TABLE :

S.No	Load		Effort		M.A = W/P	% η
	Wt in Pan W_1	Total W_2 $a+W_1$	wt in Pan	total $P_2 + w_2$		
1.	194	214	120	145	1.51	81.64
2.	312	337	190	215	1.52	84.86%
3.	523	548	320	345	1.59	85.94%

Calculation

① $M.A = \frac{194+25}{120+25} = 1.51$

$\% \eta = \frac{MA}{VR} \times 100$

$\Rightarrow \frac{1.51}{1.85} \times 100 = 81.6$

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a downward motion of P will lift the load W.

Let D = diameter of the effort wheel,
d = diameter of the axle
W = Load lifted and
P = Effort applied to lift the weight

Since the wheel and axle are mounted on the same spindle. In one revolution of the wheel, the axle will also make on revolution.

distance moved by load in one revolution = πd

distance moved by effort in one revolution = πD

$$V.R = \frac{\text{distance moved by the effort}}{\text{distance moved by the load}}$$

$$V.R = \pi D / \pi d = D/d$$

Now mechanical advantage $M.A = W/P$

efficiency $\eta = M.A / V.R$
$= (W/P) \times 100 (D/d)$
$= (Wd/PD) \times 100$

* ~~Result~~ Procedure

1: Measure the diameter of the wheel as D by the help of outside caliper.

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2) $M.A = \dfrac{194+118+25}{190+25} = \dfrac{337}{215} = 1.57$

$\% \eta = \dfrac{1.57}{1.85} \times 100 \Rightarrow 84.86\%$

3) $M.A = \dfrac{194+118+211+75}{25+320} = \dfrac{548}{345} = 1.59$

$\% \eta = \dfrac{1.59}{1.35} \times 100 \Rightarrow 85.94\%$

Mean $M.A = \dfrac{1.51+1.57+1.59}{3} = 1.55$

$\% \eta = \dfrac{81.6+84.8+85.94}{3} \Rightarrow 84.13\%$

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2. Measure the diameter of the axle as d by the help of outside caliper.
3. Wind one string on the effort wheel and attach scale pan to carry effort P
4. Wind other string on the axle to hang load
5. Put the weight in the load pan.
6. Now place the weight slowly in the effort pan unless and until the load pan just starts to lift up.
7. Note the weight place in the effort pan
8. Calculate M.A, V.R and % efficiency
9. Repeat the above procedure by increasing the load in the load pan and note down the corresponding effort.

Result

Mean Mechanical advantage = 1.55

Mean % efficiency of the apparatus = 84.13%

~~Re~~ Precautions

a) There should not be any overlapping of the strings
b) Weights in the pan / hanger should be placed very gently
c) The string should be free from knot.

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WORM AND WORM WHEEL APPARATUS

Objective : To determine the mechanical advantage, velocity ratio and efficiency of worm and worm wheel apparatus.

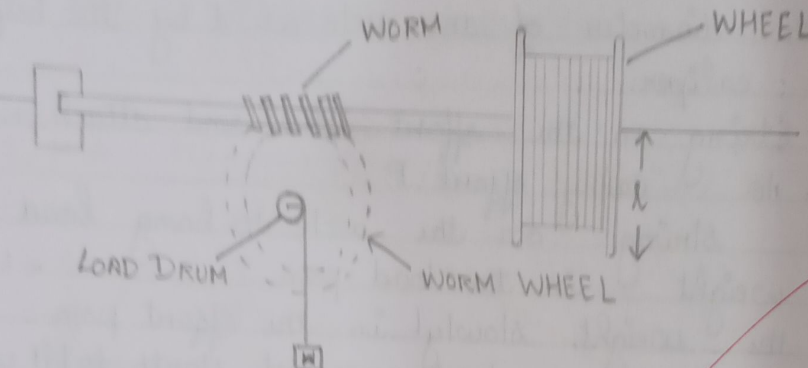
Apparatus :

Apparatus consists of a machine cut gear of 250mm diameter, a metal drum of 120mm diameter and a machine cut worm on steel spindle carrying 120 mm pulley at its end. Apparatus is fitted with string and hooks.

Theory

For lifting heavy loads, a machine named worm and worm wheel is used. A worm and worm wheel consists of a square threaded screw and a toothed wheel geared with each other. Worm is attached to a gear, which is meshed to other gear. The shaft connected with this gear is connected to an effort pulley over which passes a rope. The effort P is applied at the end of this rope. A load drum is securely mounted on the worm wheel. A string is wound round the drum to carry weight 'W' to be lifted

Diagram



Observations

Diameter of effort wheel (D) = 112 mm

No. of teeth on smaller gear = 25

" " " Larger gear = 50

" " " worm wheel = 125

Diameter of Load Drum (d) = 126 mm

$$\sqrt{K} = \frac{T \times T_2 \times D}{T_1 \times \theta}$$

$$= \frac{120 \times 50 \times 112}{25 \times 125}$$

$$= 21504$$

Observation Table

S.NO	Load		Effort		M.A	% η
	W_1	$W = a + W_1$	W_2	$P = b + w_2$		
1	2000	2025	70	95	21.35	9.912%
2	3000	3025	100	125	24.2	11.25%
3	4000	4025	120	145	27.75	12.9%

Calculations

① $M.A = \frac{W}{P} = \frac{2025}{95} = 21.35$

$\% \text{ eff} = \frac{MA}{VR} \times 100 = \frac{21.35}{215.04} \times 100$

$= 9.912\%$

② $M.A = \frac{W}{P} = \frac{3025}{125} = 24.2$

$\% \text{ eff} = \frac{24.2}{215.04} \times 100 = 11.25\%$

③ $MA = \frac{W}{P} = \frac{4025}{146} = 27.75$

$\% \text{ eff} = \frac{27.75}{215.04} \times 100 = 12.9\%$

$\text{Mean } \% \text{ eff} = \frac{9.912 + 11.25 + 12.9}{3} = 11.354\%$

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Let

D = Diameter of the effort pulley
d = Diameter of load drum
T = Number of teeth on worm wheel
T_1 = Number " " on the gear connected to effort pulley
T_2 " " " " " " " to the worm.
W = Load lifted
P = Effort applied to lift the weight

Let the effort pulley be given N_1 revolutions then the gear A will take N_1 revolutions and number of revolutions N_2 taken by gear B is given by $N_1T_1 = N_2T_2$

$$N_2 = \frac{NT_1}{T_2}$$

$$V \cdot R = \frac{\text{Distance moved by the effort}}{\text{Distance moved by the load}} \Rightarrow \frac{TT_2D}{T_1 d}$$

$$M \cdot A = \frac{W}{P}$$

$$\text{Efficiency } \eta = \frac{M \cdot A}{V \cdot A}$$

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Procedure

1. Measure the circumfrence of effort wheel and load drum with the held of threads and meter scale as πD and πd.
2. Note the number of teeth T on the worm wheel T_1 and T_2 of the gears.
3. Fasten one end of the string on the load drum and wound it in clockwise direction and attach a scale pan for load. (Note the total load (weight of pan and load placed in it)
4. Note the weight of pan for effort wheel. Fasten one-end of string on the effort wheel and wound it in anticlockwise direction.
5. Put some weight in loading pan and note it Note the effort weight.

Precautions

a) String should not be overlapped.
b) There should not be any know in the string.
c) Weights should be placed gently.
d) Worm should be greased at regular interval.
e) Do not increase the effort by throwing the weight on the pan. Increase the effort gently

16-1-17

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JOINT ROOF TRUSS APPARATUS

Objective : To calculate the forces in the members of simple roof truss and find the percentage error between the observed and calculated values.

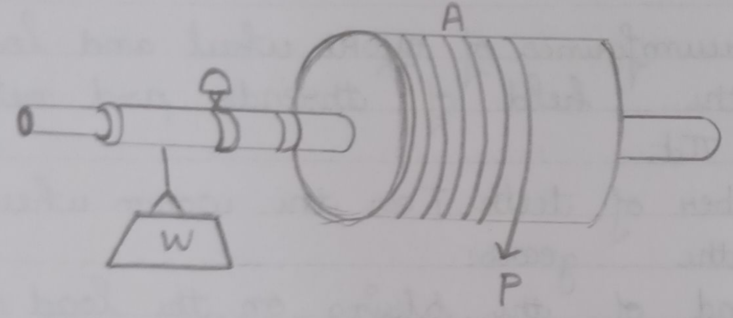
Apparatus: The apparatus consists of two legs whose one leg is fitted on an unmoveable bracket and the other on rollers. Spring balance shows tension in the rod and the other on rollers. Spring balance shows tension in the rod and the compression on rafters.

Theory:
Triangle law of forces will be applied in this apparatus. It states "If two forces acting simultaneously on a particle, be represented in magnitude and direction by the two sides of a triangle, taken in order, their resultant may be represented in magnitude and direction by third side of the triangle, taken in opposite order".

Procedure

1. Note the zero error in the compression and spring balances S_1, S_2 and S_3
2. Suspend a (W) from the point A, the chain BC will be elongated, measure AB, AC and BC
3. To a certain scale, draw the scale diagram ABC BC as a horizontal line

Diagram



Observation

Diameter of wheel D = 120 mm

Diameter of axle d = 65 mm

$$V.R = \frac{D}{d} = \frac{120}{65} = 1.846$$

Weight of load pan / hanger a gm = 25 g

" " effort " " b gm = 25 g

S.No	Load		Effort		M.A	% η
	wt of pan w_1	Total $W_2 = a + w_1$	wt of pan	Total wt		
1	194	214	120	145	1.51	81.6%
2	312	337	190	215	1.52	84.36%
3	523	543	320	345	1.59	85.94%

Calculations

(1) $$M.A = \frac{194+25}{120+25} = 1.51$$

$$\%\eta = \frac{MA}{VR} \times 100 = \frac{1.51}{1.85} \times 100 = 81.6\%$$

(2) $$M.A = \frac{194+118+25}{190+25} = \frac{337}{215} = 1.57$$

$$\%\eta = \frac{1.57}{1.85} \times 100 = 84.86\%$$

(3) $$M.A = \frac{194+118+211+25}{25+320} = \frac{348}{345} = 1.59$$

$$\%\eta = \frac{1.59}{1.85} \times 100 = 85.94\%$$

Mean M.A = 1.55

Mean $\%\eta$ = 84.13%

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4. Through a point A draw a vertical line AD to represent W to meet BC in D. Through D draw DE // BA to meet AC in E.
5. Observe the force in the Arms AB, AC and BC with the help of balances S_1, S_2 and S_3
6. Find the % error between the observed and calculated values of these forces.
7. Increase the wt W and change the length BC and proceed as before. Take in this way about four or five readings.

Precautions

a) Do not suspend the wt with a jerk
b) If the readings in compression balance are different for a same wt then take three such readings and find their mean.
c) Take into account the zero error of the balances.
d) Measure the lengths with a fine inextensible thread.

10/7/23

Expt. No. 9. Page No. Date

AIM: To determine the mechanical advantage, velocity and Mechanical efficiency of a differential wheel and axle

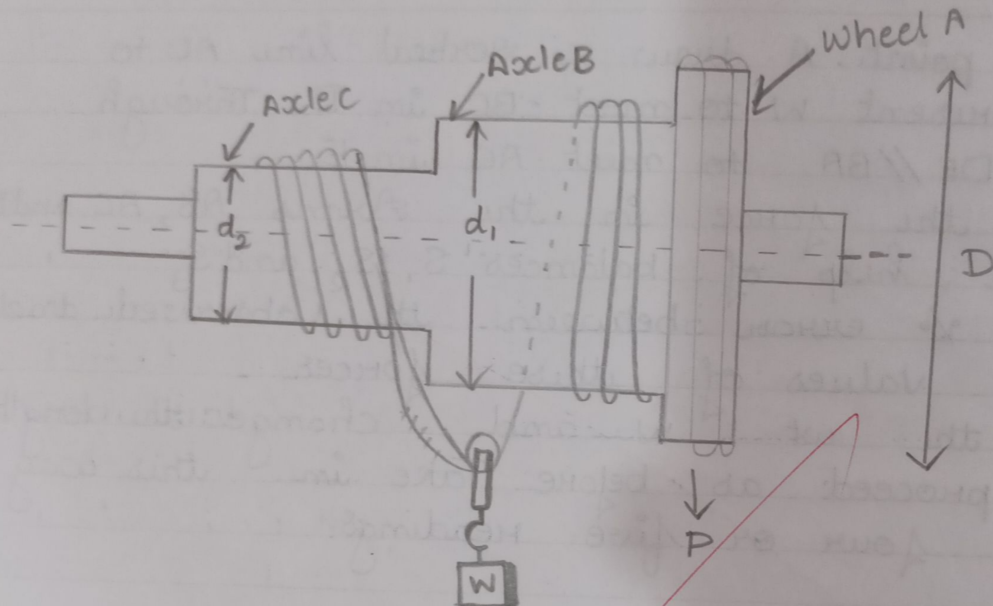
Apparatus: The apparatus consists of a wheel A and a wound axles B and C. The wheel and the axle are keyed to the same shaft, which is mounted on ball bearing in order to reduce the friction to minimum. Apparatus requires rope, a set of weights, scale pan and meter scale.

Theory:
Differential wheel and axle is used to lift heavy loads. In differential wheel and axle, the axle used is a compound axle. The axle is made in two parts having different diameters. Axles and wheels are fitted on the same shaft.

Let D = Diameter of the effort wheel A
d_1 = Diameter of axle B
d_2 = " " " C
W = Load to be lifted by the machine
P = Effort applied to lift the load.

The distance moved by wheel (effort) = πD
Length of string that unwraps the larger axle B = πd_1
" " " " " C = πd_2
" " " " on axle B = $\pi d_1 - \pi d_2$
" " " "

DIAGRAM



Observation

Diameter of wheel, $D = 282$ mm

Diameter of bigger axle $d_1 = 130$ mm

" " Smaller axle $d_2 = 65$ mm

$$V.R = \frac{2D}{d_1 d_2} = \frac{2 \times 282}{130 \times 65} = 8.67$$

weight of Load pan / hanger, $a = 25g$

" " effort " " , $b = 210g$

Observation Table

S.No	Load $W = a + W_1$	Effort $W = a + W_2$	M.A	% η
1	2025	230	6.14	70.8%
2	3025	475	6.37	73.5%
3	4025	645	6.24	71.9%

Calculations

$\boxed{VR = 8.69}$

(1) $M.A = \frac{W}{P} = \frac{2025}{330} = 6.14$

$\% \eta = \frac{MA}{VR} \times 100 = 70.8\%$

(2) $MA = \frac{W}{P} = \frac{3025}{475} = 6.37$

$\% \eta = \frac{MA}{VR} \times 100 = 73.5\%$

(3) $MA = \frac{W}{P} = \frac{4025}{645} = 6.24$

$\% \eta = \frac{MA}{VR} \times 100 = 71.9\%$

Mean M.A = 6.25

Mean % eff = 72.06%

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Distance through which the load is lifted $= \frac{\pi d_1 - \pi d_2}{2}$

$$V.R = \frac{\text{Distance moved by effort}}{\text{Distance moved by load}} = \frac{\pi D}{\left(\frac{\pi d_1 - \pi d_2}{2}\right)}$$

$$V.R = \frac{\text{Velocity of effort}}{\text{velocity of load}} = \frac{V_{effort}}{V_{load}}$$

$$M_{load} = Td_1 - Td_2$$
$$= T(d_1 - d_2) = \frac{W}{2}(d_1 - d_2)$$

Moment applied on the shaft due to effort

$$M_{effort} = P \times D$$

Condition for lifting the load

$$M_{effort} = M_{load}$$
$$P \times D = \frac{W}{2}(d_1 - d_2)$$

$$M.A = \frac{W}{P}$$

$$\text{Efficiency} \Rightarrow \eta = \frac{W/P}{V_{effort}/V_{load}} = \frac{M.A}{V.R}$$

Precautions

1) String should not be Overlapped
2) There should not be any knot in the string
3) Weights should be placed gently
4) Machine should be frictionless

16/5/23

Teacher's Signature

Date

Expt. No. 10 Page No.

Objective: To verify the principle of moments using Bell crank lever apparatus.

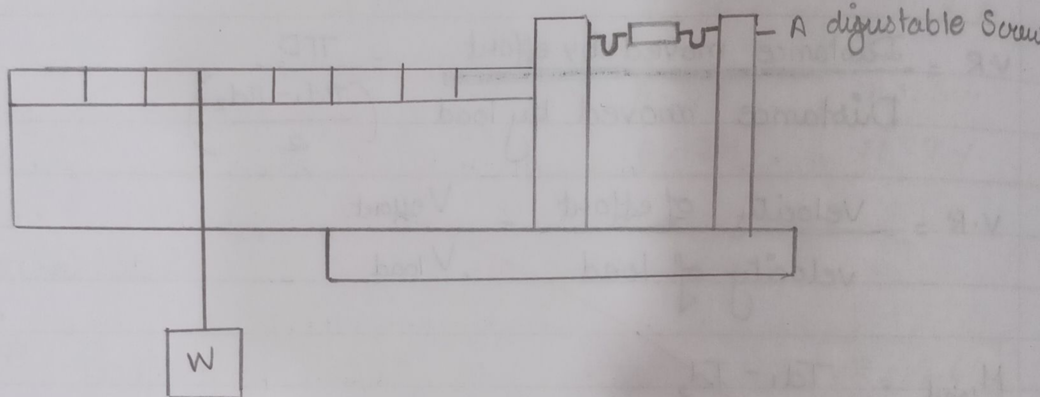
Apparatus: Bell crank is a lever bent at 90° angle forming fulcrum b/w its two arms, one arm is larger and other is shorter. This works on the principle of moments. Longer arm is horizontal while shorter arm is vertical. The lever arm, load is applied and on the shorter arm effort is measured from the spring balance. If the algebraic sum of moment of ~~local~~ load and effort about the fulcrum is zero, then the principle of moment is provided.

Theory
The algebraic sum of the moments of all the forces about a point in a body is zero for ~~equal~~ equilibrium. In other words sum of clock wise moment about a point is equal to the sum of the anti-clock wise moments about the same point of equilibrium

Procedure:
1) Keep hook at a distance x from fulcrom on horizontal long arm of Bell crank lever apparatus weight will be placed on weight carrier.

Teacher's Signature

BELL CRANK APPARATUS



OBSEVATION TABLE

S.No	weight 'ω' kg	Distance from fulcrum	ω. x (kg cm)	Reading Initial	Reading Final	effort 'T'	Distance 'y'	T.y	|Wy-Ty|	% Error
1	1	20	20	0	1	1	21	21	1	3
2	2	30	30	0	1.5	1.5	21	31.5	1.5	5
3	3	15	30	0	1.5	1.5	21	31.5	1.5	5

Calculations

1) $W = 1 kg$, $x = 20 cm$, $T = 1 Kg$, $y = 21 cm$

$\%$ Error $= \dfrac{|Wx - Ty|}{Wx} \times 100 = \dfrac{|20-21|}{20} \times 100 = 5\%$

2) $W = 1 kg$, $x = 30 cm$, $T = 45 kg$, $y = 21 cm$

$\%$ error $= \dfrac{|Wx - Ty|}{Wx} \times 100$

$= \dfrac{|30 - 31.5|}{30} \times 100 = 5\%$

3) $W = 2 kg$, $x = 15 cm$, $T = 1.5 kg$, $y = 21 cm$

$\%$ error $= \dfrac{|Wx - Ty|}{Wx} \Rightarrow \dfrac{|30 - 31.5|}{30} \times 100 = 5\%$

Mean $\%$ error $= \dfrac{5+5+5}{3} = \dfrac{15}{3} = 5\%$

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2) Measure the distance x accurately and note down initial reading (T_1) of spring balance.
3) Use the adjustable screw of bring back the horizontal arm in horizontal position.
4) Take final readings (T_2) of spring balance.
5) Repeat above steps by changing the position of weight and weight for another set of readings

Result
Mean error of apparatus is 1.6%

Precautions:
1) Distance x and y should be taken acurately.
2) Reading should be taken in horizontal position only
3) Weight should be hanged freely and accurately.

16/7/22