AMIRAJ
COLLEGE OF ENGINEERING & TECHNOLOGY

LABORATORY MANUAL

MECHANICS OF SOLID

SUBJECT CODE: 3130608

CIVIL ENGINEERING DEPARTMENT

B.E. 3RD SEMESTER

NAME:______________________________

ENROLLMENT NO: ______________________

BATCH NO: __________________________

YEAR: ______________________________

Amiraj College of Engineering and Technology,
Nr.Tata Nano Plant, Khoraj, Sanand, Ahmedabad.

COLLEGE OF ENGINEERING & TECHNOLOGY

Amiraj College of Engineering and Technology,

Nr.Tata Nano Plant, Khoraj, Sanand, Ahmedabad.

CERTIFICATE

This is to certify that Mr. / Ms. ____

Of class____________________ Enrolment NO________________________has

Satisfactorily completed the course in _______________________________as

by the Gujarat Technological University for ____ Year (B.E.) semester___ of

Civil Engineering in the Academic year_________.

Date of Submission:-

Faculty Name and Signature

(Subject Teacher)

Head of Department

(Civil Department)

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PRACTICAL NO: 1 **DATE:**

UNIVERSAL FORCE TABLE

EQUILIBRIUM OF COPLANAR, CONCURRENT FORCES

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

APPARATUS :Aforce table with five attached pulleys, weights.

THEORY : Concurrent forces in equilibrium can be represented by a polygon. The respective sides being parallel and proportional to their respective forces. If forces are not in equilibrium then the closing side of polygon shown the resultant of the system of forces.

POLYGON LAW OF FORCES (STATEMENT)

PROCEDURE : Five stings radiating from a single point. These string pass over smooth pulleys freely slidable along the circumference of a horizontal forces table with graduations for measuring angles. Attach five known weights to five strings arranged at particular angles. Note down the readings when the central ring is at center of forces table.As this system is in equilibrium,the resultant is to be found out which should be zero. But due to errors, the resultant forces is obtained analytically as well as measured on force table and show the respective forces.Using Bow's notation draw force (vector) diagram, which will be the polygon. For the system is the equilibrium, the sidesof polygon should be five but due to error polygon remains open & hence the closing side in reverse order will represent the resultant.

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CONCLUSIONS:

- State the law and comment on the verification of law.
- What are the reasons for these error ?

FIGURE:

OBSERVATION TABLE :

Force	Value of P	Angle θ	Components	
			F_X = P COSθ	F = P Sinθ
P_1				
P_2				
P_3				
P_4				
P_5				

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PRACTICAL NO: 2 **DATE:**

WHEEL AND DIFFERENTIAL AXLE

Object : To determine the mechanical advantage, velocity ratio, ideal effort, frictional effort, ideal load, frictional load and efficiency of a given wheel and different axle.

THEORY : The wheel and differential axle acts on the differentialprincipal. It is a simple device to achieve very high velocity ratio by keeping very small difference in diameters of two axles. The axle is made up two cylinders B and C of different diameters. The wheel A and the cylinder B and C turn about a common axis. One string is wound round the wheel A and to the one end of which the effort P is applied. The second string is wound round the two cylinders B and C. This string goes around a pulley to which the load W is attached. This string is wound on the two cylinders in such a way that as the cylinders turn, it unwinds on the small cylinders and winds at the same time on the cylinder, lifting the load W attached to the pulley.

For one revolution of the wheel and axel, the displacement of the effort P is equal to the length of the string. That unwind from the wheel A $=\pi D$.

The length of the string that unwind from the Smaller cylinder $C=\pi d_2$

The length of the string that winds on the larger cylinder $B = \pi\, d_1$

The load string shortens by $= \pi\, d_1 - \pi d_2$

Therefore, the displacement of the load W

Velocity Ratio = $(\pi D1) / ((\pi d1-\pi d2)/2)$

$= 2\, \pi D1 / (\pi d1-\pi d2)$

=

For a larger velocity ratio, d1 and d2 are made nearly equal.

APPARATUS : Wheel and differential axel, weights, calipers, meter rules etc.

PROCEDURE :

1. Measure the dimensions of wheel and axels & note total load applied to the system.
2. Increase the effort gradually in such a way that at minimum effort the load just starts moving upload. Note this value of effort.
3. Change the load applied and find corresponding effort.
4. Take six sets of readings.
5. Plot the graphs of load on X axis V/S (i)actual effort (p) (ii) ideal effort (p) (iii) frictional effort (P - W/V. R) (iv) efficiency (n) on Y AXIS. Use same scale for all effort Curves and different scale for efficiency. It is desirable to draw all graph on same graph paper.
6. Work out the law of machine P = mW + C where, P is actual effort required to raise the load W. and M is the slope of the graph, C is the initial effort required the start the machine which are machine constants c is the intercept of graph on Y axis.

OBSERVATION

1. Circumference of Effort wheel: πD_1

2. Circumference of bigger axle: πd_1

3. Circumference of smaller axle: πd_2

4. Distance travelled by effort: $Sp = \pi D_1$

5. Distance travelled by load: $Sw= (\pi d_1-\pi d_2)/2$

6. Velocity Ratio = $Sp/Sw = (\pi D_1) / ((\pi d_1-\pi d_2)/2) = 2 \pi D_1 / (\pi d_1-\pi d_2)$

OBESERVATION TABLE

Sr. No	Load (W) Newton	Effort (Pa) Newton	M.A = W/Pa	η% = M.A./V.R. * 100	Pi = W/V.R	Pf= Pa - Pi

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PRACTICAL NO: 3 **DATE:**

SINGLE PURCHASE CRAB

OBJECT : To determine the mechanical advantage, velocity ratio, ideal effort, frictional effort, ideal load frictional load and efficiency of a given single purchase crab.

THEORY : The single purchase crab is a simple Lifting machine in which velocity ratio is achieved using gearing. (Draw figure of this machine and write the working phenomenon)

APPARATUS : Single purchase crab, weights, weights, caliper, meter rules etc.

PROCEDURE:

1. Measure the required dimensions of machine. Note the total load applied and corresponding effort required to raise the load with a slow uniform Motion.
2. Take six reading with uniform increase in load and corresponding effort required
3. Plot the graphs with (i) actual effort (ii) ideal effort (iii) frictional effort and (iv) efficiency on Y axis and Load on X axis. Use same scale for all effort curves.

CALCULATON :

1) Give sample calculation for all quantities for any one of observation table.

1) For law of machine, P = mW + C select any two points on graph of actual effort and determine the value of m.

1. Maximum mechanical advantage = 1/m =________________________.

2. Maximum efficiency = 1/(m X VR)=_____________________________.

CONCLUSION :

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PRACTICAL NO: 4 **DATE:**

CO-EFFICINT OF FRICTION

OBJECT: To determine the co-efficient of friction between two surfaces.

APPARATUS: An adjustable inclined wooden plane with pulley at one end, wooden block, weight, hanger, etc.

THEORY: when there is a relative motion between two bodies in contact, a resistance to the motion is set up. This resistance to movement is called force of friction. Friction acts along the surface of contact. Magnitude will vary with respect to the nature of the surface under the equilibrium condition.

When a body of the self-weight 'W' is at the point of sliding up an inclined plane by the application of forces (effort) 'P' parallel to the plane relation between 'P' and 'W' will be.

$$P = w\,\frac{\sin(\alpha+\beta)}{\cos\varphi}$$

Similarly when the body is at the instant of sliding down

$$P = w\,\frac{\sin(\alpha-\beta)}{\cos\varphi}$$

where,

w= load

P=effort

φ= angle of friction

α= inclined of friction

Co-efficient of friction (μ): it is defined as the ratio of the limiting force of friction (F) to the normal reaction (R) between two bodies.

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$\mu = F/R$ hence $F = \mu R$ where $F = P$

PROCEDURE:

When the block just started to slide up, the angle of inclination of the plane and weights of the blocks to move up and down along the plane was measured and noted. Then one end of the block was tied to a string and the other end of the string was kept at the bottom of the plane and is made to pass through a pulley provided on the plane. The weights were put on the hanger till the block just started to move up. The experiment was repeated by varying the inclination and the weights on the block.

OBSERVATION TABLE:

INCLINED FRICTION

SLIDING FRICTION

Sr. no.	Angle of inclination of plane with the horizontal α in degree.	load moved (w)	effort applied(P)	co-efficient of friction(μ)= $\frac{P - w\sin\alpha}{w\cos\alpha}$	remark	Types of surface
						glass & wooden
						glass & Steel carpet
						glass & wheel
						glass & glass

INCLINED FRICTION

Surfaces (inclined friction)	co-efficient of friction(μ)
glass & wooden	
glass & Steel plate	
glass & roller	
glass & glass	

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SLIDING FRICTION

Surfaces (sliding friction)	co-efficient of friction(μ)
glass & wooden	
glass & carpet	
glass & wheel	
glass & glass	

CONCLUSION: Value of co-efficient

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PRACTICLE 5

BRINELL HARDNESS TEST **DATE:**

OBJECT :

To determine the Brinell hardness number of given metal speciments by Brinell hardness test.

EQUIPMENT :

Brinell hardness testing machine.

APPARTUS :

Microscope

MATERIALS :

Steel, Brass, Alluminium, Copper, Cast Iron

RELATED IS CODES :

IS 3034 – 1965 : Method for Brinnel hardness test for copper & copper alloys.

IS 1500 – 1983 : Method for Brinnel hardness test for steel

IS 1790 – 1961 : Method for Brinnel Hardness test for light metals & their alloys.

SALIENT FEATURES :

Hardness is basically an important mechanical property of the metals and is defined as the resistance given by metal specimen to indentation, scratching or abrasion on its surface. Brinnel hardness is a method of finding hardness of given specimen by indentation and was introduced by J.A. Brinnel in 1900. This method uses a steel ball (or Indentor) of standard known diameter (D) on

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which a standard load (F) is applied gradually. The hardness tester is shown in figure below.

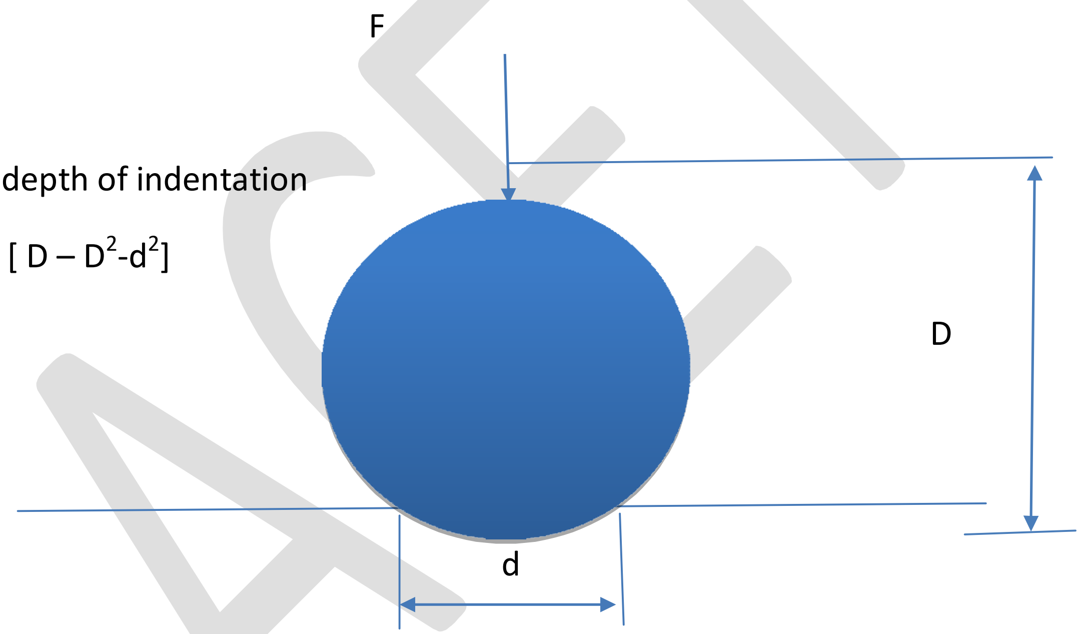
The hardness number is then calculated from the depth of the indentation (of diameter d) produced by the load applied. Thus, it is an indirect method of finding hardness. Brinenl hardness is defined as the ratio of the load applied to the spherical area of the indentation formed on the specimen surface and is equivalent to kgf/mm^2.

Figure shows the identation on the metal surface.

BHN = Test (kgf) / surface area of indentation (mm^2).

h = depth of indentation

$= \frac{1}{2} [D - D^2 - d^2]$



OBSERVATION TABLE

SR.NO	METAL	BALL DIAMETER d mm	TEST LOAD P kg	DIAMETER OF INDENTATION D mm

CALCULATIONS

SR.NO	METAL	BHN	REMARKS

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CONCLUSIONS

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PRACTICAL NO: 6 **DATE:**

COMPRESSION TEST ON TIMBER

OBJECT: To determine the compressive strength of the timber specimen and to study its behavior when subjected to load up to its fracture.

APPARATUS: Universal testing machine with an attachment to test specimen in compression, vernier caliper, timber.

UNIVERSAL TESTING MACHINE

THEORY: Wood exhibits under compressive loading, a very characteristic behavior. I t is a homogeneous material, being composed of cell formed by organic growth which align themselves to form a series of tubes or column in the direction of grain alignment. As a result of this structure, the elastic limit is relatively low, there is no definite yield point and considerable sets takes place before failure. These properties vary with orientation of the load with respect to the direction of the grain. For load normal to the grain the load that causes lateral collapse of the tubes of filter is the significant load. For load parallel to the grain, not only is the elastic strength important but also the strength at rupture. Rupture often occurs because of collapse of the tubular fiber structure.

Important variables which affect compressive strength of timber are:

(1) Shape and size of the specimen
(2) Capping on top and bottom of the specimen
(3) Speed of testing

In this test standard specimen are compressed between two plates under axial load.fig. 2.1 shows the line diagram of the machine. The mechanical properties such as yield strength, ultimate compressive strength, modulus of toughness is determined by studying the behavior of the specimen under load. Since in this experiment the basic aim is to find and compare the strength of timber under different orientation, important is given only to find ultimate strength of the specimen. The possible patterns of the failure of the specimen are shown in the fig. figure 2.2A and 2.2B show the failure of the specimen under two different orientations.

SPECIMEN: The size of the test specimen shall be 50 x 50 X 200mm or 20X 20 X 80mm, if it is to be subjected to load parallel to the grain and its size shall be 50 X 50 X 150 mm or 20 X 20 X 100mm if it is subjected to load perpendicular to the grain. Fig. 2.3A and 2.3B shows the arrangement of the specimen when subjected to load. The specimen shall be free from defects and shall not have slope of grain more than 1 in 20 parallel to its longitudinal edges. The end plane of the specimen shall be perfectly at right angle to the length of the specimen.

PROCEDURE:

1. Check the specimen for any defect and ensure that the ends are plane and fibers are parallel to its longitudinal edges.
2. Measure the cross-section of the specimen and length of the specimen with vernier caliper.
3. Place the specimen in the lower cross head such that the load is applied parallel to the grain.
4. Applied the load up to failure of the specimen and observe the type of the failure.
5. For second case place another specimen such that the load is applied perpendicular to the grain.
6. Repeat step 4.

PRECAUTIONS:

1. Specimen should be placed carefully in the centre so that the applied load will be exactly an axial load and no eccentricity for the load would occur for the proper transfer of load.
2. When the load approaches to its failure value, it is preferable to move at a safe distance from the machine.

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OBSERVATION TABLE

	LOAD CASE	
	LOAD APPLIED PARALLEL TO GRAIN	LOAD APPLIED PARPENDICULAR TO GRAIN
Cross sectional area (mm^2) l X b X h		
Load at failure (N)		
Ultimate strength (N/mm^2)		

COLNCLUSION :

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PRACTICAL NO: 7 **DATE:**

TENSION TEST ON METALS

OBJECT **:** To study the behavior of metallic materials under the tensile load the help of stress – strain curve on universal testing machine.

EQUIPMENT : Universal testing machine

APPARATUS : Vernier-calliper

TOOLS :

MATERIALS : Mild steel and cast iron.

CALIBRATION :

The machine is calibrated with the help of a pivot ring. The pivot ring is kept on lower cross head and compressive force is applied on it.The deflection of the dial of pivot ring is completed with standard values provided by manufacturer. If the values so obtained do not fit in desired accuracy of 1% the counterweight on the pendulum is adjusted to bring the readings with in permissible limits.

RELATED I.S. CODES

IS : 1608-1995 ; Mechanical testing of metals –Tensile testing

IS : 1816-1979 ; Methods of tensile test for light metals & their alloys

SALIENT FEATURES

This test is performed on Universal Testing machine. The machine is also used for testing materials subjected to tension, compression, bending and shear, Figure shows the line diagram of the universal testing machine.

The test consist of straining a test piece by force, generally to fracture for the purpose of determining one or more mechanical properties viz. Percentage elongation, percentage reduction in area, moduls of elasticity, yield stress, ultimate stress and breaking stress.

Metals used in engineering structures are mostly ductile e.g steel, aluminum, bras, copper, etc. but some Like cast iron are brittle. When specimens are tested under tensile (axial) load, both these types behave differently. Ductile metals undergo comparatively large elongations, along the direction of loading, accompanied necessarily, of course, with contractions, in the transverse direction. At a certain stress level, the specimen ceases to take any additional load but the elongation continues to a certain level, where after additional load is required to increase the elongation. At fracture, ultimately the specimen breaks at or very near the narrowest section. The fracture is not along a plane right angle; it is along an inclined palen and has an appearance of a cup and cone shape. Figure shows a typical fracture of a mile steel specimen. Obviously, therefore fracture is

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not due to insufficient tensile resistance but due to insufficient shear resistance on inclined planes.

Thus the stages which a ductile material undergoes are yield-ultimate breaking stress. The values of breaking if calculated with respect to its original area of the specimen, comes to be lesser than ultimate stress and is known as nominal breaking stress, whereas if breaking stress is calculated taking into consideration the instantaneous cross-sectional area, its value comes to be greater than unlimate stress and is known as actual breaking stress or true stress. Since engineering design takes into consideration the loads with respect to yield stress, true stress is generally not plotted in the stress-strain curve.

Brittle metals have inadequate tensile resistance, they do not undergo any worthwhile elongation ; they fracture is comparatively abrupt and the fractured surface is an clean right section. In such metals the maximum load is also the breaking load.

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PRACTICAL NO: 8 **DATE:**

IZOD IMPACT TEST

OBJECT: To determine the impact value for various metals like Cast iron, Aluminum, Brass, Steel etc.

APPARATUS: Standard specimen of different metals, impact testing machine etc.

THEORY: To evaluate the suitability of any metal to resist shock or impact loading, the impact value should have to be determined. The capacity to absorb the energy imparted by the sudden load like impact/shock effect is limited for any metal and as such the energy absorbed by the standard test specimen in causing a fracture of the specimen can be measure of its toughness i.e. its capacity to resist the shock /impact loading.

In the test machine the heavy hammer is being raised through a certain height and being released to permit it to swing under its own weight. The hammer when released swing like a pendulum and the potential energy gets converted in to kinetic energy and this energy is registered on the dial provided on the machine. Considering the loss of energy due to friction, vibration etc. as negligible, the difference in potential energy between the starting and the end of the swing is the energy absorbed to fracture the specimen.

PROCEDURE:

(1) Lift the hammer in position. Put the stop bar and set the indicator on the scale.
(2) Fix the specimen between the jaws properly such that the notch is level with the anvil and faces the hammer side and level of the specimen is in the line with the striking edge of the hammer.

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(3) Release the hammer by removing the stop bar and note the reading on the scale indicated by the pointer after the specimen is fractured.

IZOD IMPACT TESTING MACHINE

PRECAUTIONS:

(1) Use the stop bar before trying to fix the specimen.
(2) Check the position of the pointer before releasing the hammer.
(3) Check the nothing and nobody is in the path of swing of the hammer before releasing the hammer. It is dangerous to be on the opposite side of the hammer.

OBSERVATION TABLE:

Impact value for

Sr. no.	Specimen	N-mm
1	Cast Iron	
2	Aluminum	
3	Brass	
4	Steel	

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PRACTICAL NO: 9 **DATE:**

SIMPLY SUPPORTED BEAM

OBJECT:

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

THEORY: Beam is structural element carrying transverse loads.

Analytical condition of equilibrium

1) Algebraic sum of horizontal forces must be equal to zero. i.e. $\sum Fx = 0$.
2) Algebraic sum of vertical forces must be equal to zero. i.e. $\sum Fy = 0$.
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 motion of rotation.

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 total weights are W1,W2,W3.
3) Measure the horizontal distances of these loads from one of the support. (X1, X2, X3)
4) Observe the reactions in the compression spring balances provided at each support.

CONCLUSION :

Observation: Length of short arm L =___________________cm.

OBSERVATION TABLE :

No.	W kg	D cm	P1 kg	P2 kg	P=P2-P1 kg	P x L kg X cm	W x D kg X cm	% Error

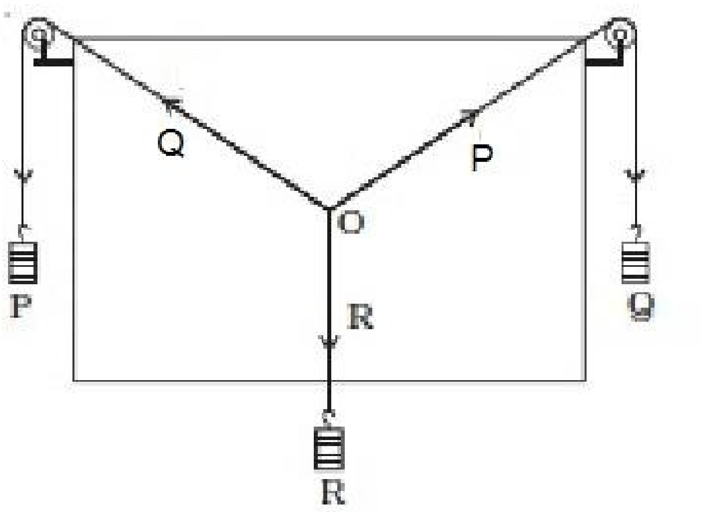
SIGNATURE : DATE:

PRACTICAL NO: 10 **DATE:**

LAW OF PARALLELOGRAM FORCES

Aim: To verify the Parallelogram Law of Forces.

Apparatus: Drawing sheet, pins, mirrors, weight pan, weights and pulleys.



Theory: The parallelogram law of forces enables us to determine the single force called resultant which can replace the two forces acting at a point with the same effect as that of the two forces. This law was formulated based on experimental results. This law states that if two forces acting simultaneously on a body at a point are represented in magnitude and direction by the two adjacent sides of a parallelogram, their resultant is represented in magnitude and direction by the diagonal of the parallelogram which passes through the point of intersection of the two sides representing the forces.

$$R = \sqrt{P^2 + Q^2 + 2PQ\cos\Theta}$$

Where R is the resultant force

Θ is the angle between P and Q.

$$\tan\alpha = \frac{Q\sin\Theta}{P + Q\cos\Theta}$$

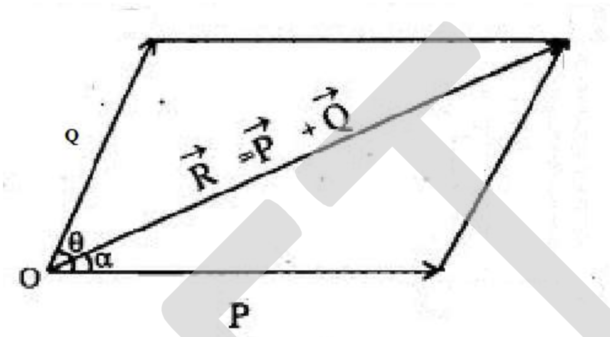
Where R is the resultant force

Procedure:

1) Fix the Drawing Sheet On the Boar of apparatus with The help of drawing Pin
2) Pass two long String Over the Pullies and attch pan at the end of each the string.
3) Attached the third string with pan at the joint of two string
4) Place the different weight in the three pans and let the system comes to rest and joint of string is centered of the drawing sheet
5) Mark at at least two points of the position of each string
6) Record the magnitude of forces P , Q and E (R) including pan in Observation table
7) Remove the drawing Sheet and draw line from respective points mark which meets at O were line OA and OB represents P and Q respectively OC and OC' represents equilibrant forces and the resultant forces respectively in figure
8) Measure the angles AOB represents 'q' and measure the angle AOC represents 'a' Record it
9) Take at least three to four sets of readings
10) Calculate the magnitude and direction of resultant using equation of all readings. Record it in observation table

11) Represent the forces P and Q vectorially with Suitable scale and Complete parallelogram draw the diagonal from intersection of forces. Find magnitude and direction of resultant by measuring diagonal and it's inclination and record it in fig

12) Compare the results obtain experimentally analytically and graphically should very near to each other



Parallelogram Law of vectors