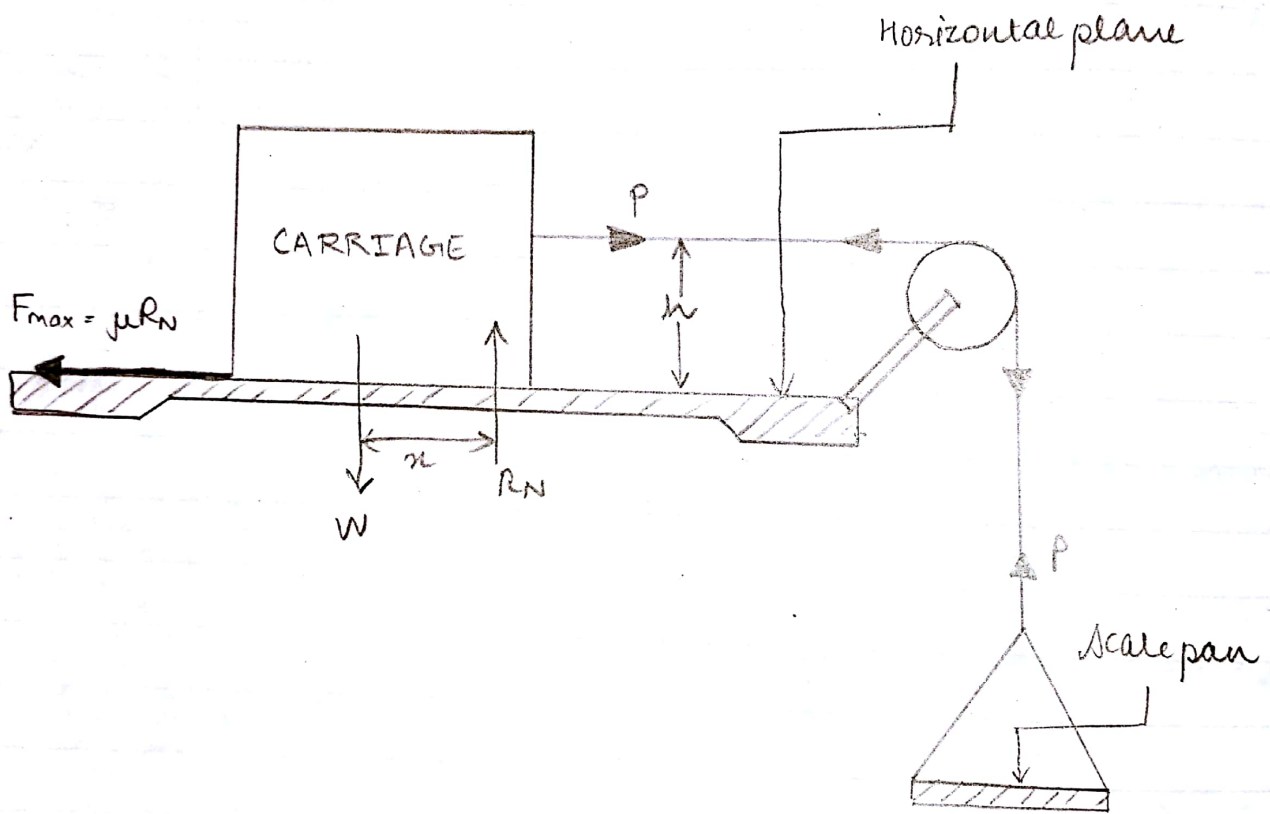




## Experiment - 1

Object: To find the coefficient of sliding friction between two surfaces on a horizontal plane.

Apparatus: A wooden horizontal plane, wooden carriages having different bottom surfaces, scale plane, weight bar, slotted weights.

Theory: When a body rests on any surface/plane and when it is forced to move in any direction, by virtue of the property of the surface called 'Friction' a force called 'Frictional force' will be generated there and it will resist the motion. Frictional force is a resisting, self adjusting and passive force, means when there is no external force to change the condition of rest of body into moving condition, frictional force will also not be there. As any force compels the body to change its static condition into moving, frictional force will be generated and will be exactly equal and opposite to the force acting. As we increase the external force responsible for the movement of the body up to a stage when the body is about to move, frictional force at this condition is also equal to external force and having its maximum value which is also fixed. This state is called the 'Limiting equilibrium condition'. The value of limiting frictional force  $F_{\max}$  is equal to  $\mu R_N$ .



Here

$\mu$  = coefficient of friction

$R_N$  = Normal reaction offered by the plane

$P$  = wt. of scale pan + wt. put in it (limiting stage) <sup>at the</sup>

$F_{\max}$  = max. frictional force at the limiting equilibrium condition

Applying laws of static equilibrium, we get

$$\sum H = 0 \leftrightarrow F_{\max} = P \quad \text{therefore } \mu R_N = P \quad (1)$$

$$\sum V = 0 \leftrightarrow R_N = W \quad (2)$$

$$\text{Thus } \mu = \frac{P}{W} \quad [\text{From equation (1) and (2)}]$$

$$\sum M = 0 \leftrightarrow W \cdot x = P \cdot h; \text{ therefore } \mu = \frac{P}{W} h \leftrightarrow \mu = \frac{x}{h}$$

Procedure:

First note down the self weights of scale weights of scale pan and carriages. Now connect the scale pan to the hook of the carriage with inextensible string of suitable length. Put the carriage on the horizontal plane for a particular combination of surfaces. Now put some wt. into carriage and note them. Hang the scale pan over the frictionless pulley mounted at the end of the plane. Now gradually increase weight in the scale pan and simultaneously gently strike the plane with fingers to check whether it is in its limiting.

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Calculation

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

① Combination = wood/wood

→ when  $P = 82 \text{ gm}$   $W = 224 \text{ gm}$

$$\mu_1 = \frac{P}{W} = \frac{82}{224} = 0.36$$

→ when  $P = 95 \text{ gm}$   $W = 274 \text{ gm}$

$$\mu_2 = \frac{P}{W} = \frac{95}{274} = 0.34$$

→ when  $P = 109 \text{ gm}$   $W = 324 \text{ gm}$

$$\mu_3 = \frac{P}{W} = \frac{109}{324} = 0.33$$

$$\begin{aligned} (\text{avg}) \mu &= \frac{\mu_1 + \mu_2 + \mu_3}{3} = \frac{0.36 + 0.34 + 0.33}{3} = \frac{1.03}{3} \\ &= 0.34 \end{aligned}$$



condition or not. Now increase the weight in the scale pan upto that where carriage insists limiting condition. Note the wt. is put in the scale pan and in the carriage also. Take number of reading by adding more wt. to the carriage. Repeat the whole procedure for various other combinations.

### Observations :-

10 wt. of scale pan = 50 gms

wt. of carriage (wooden base) = 174 gms  
(steel base) = 245 gms

Combination = wood/wood

| Sno. | Effort (P)       |                 |        | Load (W)       |                |        | Coeff. of friction<br>$\mu = \frac{P}{W}$ |
|------|------------------|-----------------|--------|----------------|----------------|--------|-------------------------------------------|
|      | wt. of scale pan | wt in scale pan | Total  | wt of carriage | wt in carriage | total  |                                           |
| 1.   | 50 gm            | 32 gm           | 82 gm  | 174 gm         | 50 gm          | 224 gm | 0.36                                      |
| 2.   | 50 gm            | 45 gm           | 95 gm  | 174 gm         | 100 gm         | 274 gm | 0.34                                      |
| 3.   | 50 gm            | 59 gm           | 109 gm | 174 gm         | 150 gm         | 324 gm | 0.33                                      |



Ⓑ Combination → wood/wood

→ when  $P = 137 \text{ gm}$   $W = 224 \text{ gm}$   
 $\mu_1 = \frac{P}{W} = \frac{137}{224} = 0.61$

→ when  $P = 167 \text{ gm}$   $W = 274 \text{ gm}$   
 $\mu_2 = \frac{P}{W} = \frac{167}{274} = 0.60$

→ when  $P = 187 \text{ gm}$   $W = 324 \text{ gm}$   
 $\mu_3 = \frac{P}{W} = \frac{187}{324} = 0.57$

(avg)  $\mu = \frac{\mu_1 + \mu_2 + \mu_3}{3} = \frac{0.61 + 0.60 + 0.57}{3}$   
 $= \frac{1.78}{3} = 0.59$  ✓

Ⓒ Combination → steel/wood

→ when  $P = 60 \text{ gm}$   $W = 295 \text{ gm}$   
 $\mu_1 = \frac{P}{W} = \frac{60}{295} = 0.20$

→ when  $P = 70 \text{ gm}$   $W = 345 \text{ gm}$   
 $\mu_2 = \frac{P}{W} = \frac{70}{345} = 0.20$

→ when  $P = 95 \text{ gm}$   $W = 395 \text{ gm}$   
 $\mu_3 = \frac{P}{W} = \frac{95}{395} = 0.24$

(avg)  $\mu = \frac{\mu_1 + \mu_2 + \mu_3}{3} = \frac{0.20 + 0.20 + 0.24}{3} = \frac{0.64}{3} = 0.21$  ✓



Combination = wood / wood

| Sno. | Effort (P)       |                  |        | Load (W)        |                 |        | Coefficient of friction<br>$\mu = \frac{P}{W}$ |
|------|------------------|------------------|--------|-----------------|-----------------|--------|------------------------------------------------|
|      | Wt. of scale pan | Wt. in scale pan | Total  | Wt. of carriage | Wt. in carriage | Total  |                                                |
| 1.   | 50 gm            | 87 gm            | 137 gm | 174 gm          | 50 gm           | 224 gm | 0.61                                           |
| 2.   | 50 gm            | 117 gm           | 167 gm | 174 gm          | 100 gm          | 274 gm | 0.60                                           |
| 3.   | 50 gm            | 137 gm           | 187 gm | 174 gm          | 150 gm          | 324 gm | 0.57                                           |

Combination = steel / wood

| Sno. | Effort (P)       |                  |       | Load (W)        |                 |        | Coefficient of friction<br>$\mu = \frac{P}{W}$ |
|------|------------------|------------------|-------|-----------------|-----------------|--------|------------------------------------------------|
|      | Wt. of scale pan | Wt. in scale pan | Total | Wt. of carriage | Wt. in carriage | Total  |                                                |
| 1.   | 50 gm            | 10 gm            | 60 gm | 245 gm          | 50 gm           | 295 gm | 0.20                                           |
| 2.   | 50 gm            | 20 gm            | 70 gm | 245 gm          | 100 gm          | 345 gm | 0.20                                           |
| 3.   | 50 gm            | 45 gm            | 95 gm | 245 gm          | 150 gm          | 395 gm | 0.24                                           |



④ Combination → Steel / wool

→ when  $P = 110 \text{ gm}$   $W = 445 \text{ gm}$

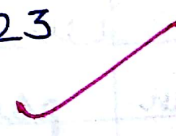
$$\mu_1 = \frac{P}{W} = \frac{110}{445} = 0.24$$

→ when  $P = 117 \text{ gm}$   $W = 495 \text{ gm}$

$$\mu_2 = \frac{P}{W} = \frac{117}{495} = 0.23$$

→ when  $P = 122 \text{ gm}$   $W = 545 \text{ gm}$

$$\mu_3 = \frac{122}{545} = 0.22$$

$$\begin{aligned} (\text{avg}) \mu &= \frac{\mu_1 + \mu_2 + \mu_3}{3} = \frac{0.24 + 0.23 + 0.22}{3} \\ &= \frac{0.69}{3} = 0.23 \end{aligned}$$




## Combination - steel / wood

| S.No. | Effort (P)       |                  |        | Load (W)        |                 |        | Coefficient of friction $\mu = \frac{P}{W}$ |
|-------|------------------|------------------|--------|-----------------|-----------------|--------|---------------------------------------------|
|       | wt. of scale pan | wt. in scale pan | total  | wt. of carriage | wt. in carriage | total  |                                             |
| 1     | 50 gm            | 60 gm            | 110 gm | 245 gm          | 200 gm          | 445 gm | 0.24                                        |
| 2     | 50 gm            | 67 gm            | 117 gm | 245 gm          | 250 gm          | 495 gm | 0.23                                        |
| 3     | 50 gm            | 72 gm            | 122 gm | 245 gm          | 300 gm          | 545 gm | 0.22                                        |

## Result :-

The coefficient of sliding friction for the various combination are

1. Wood / wood = 0.34

2. Wood / Wood = 0.59

3. steel / wood = 0.21

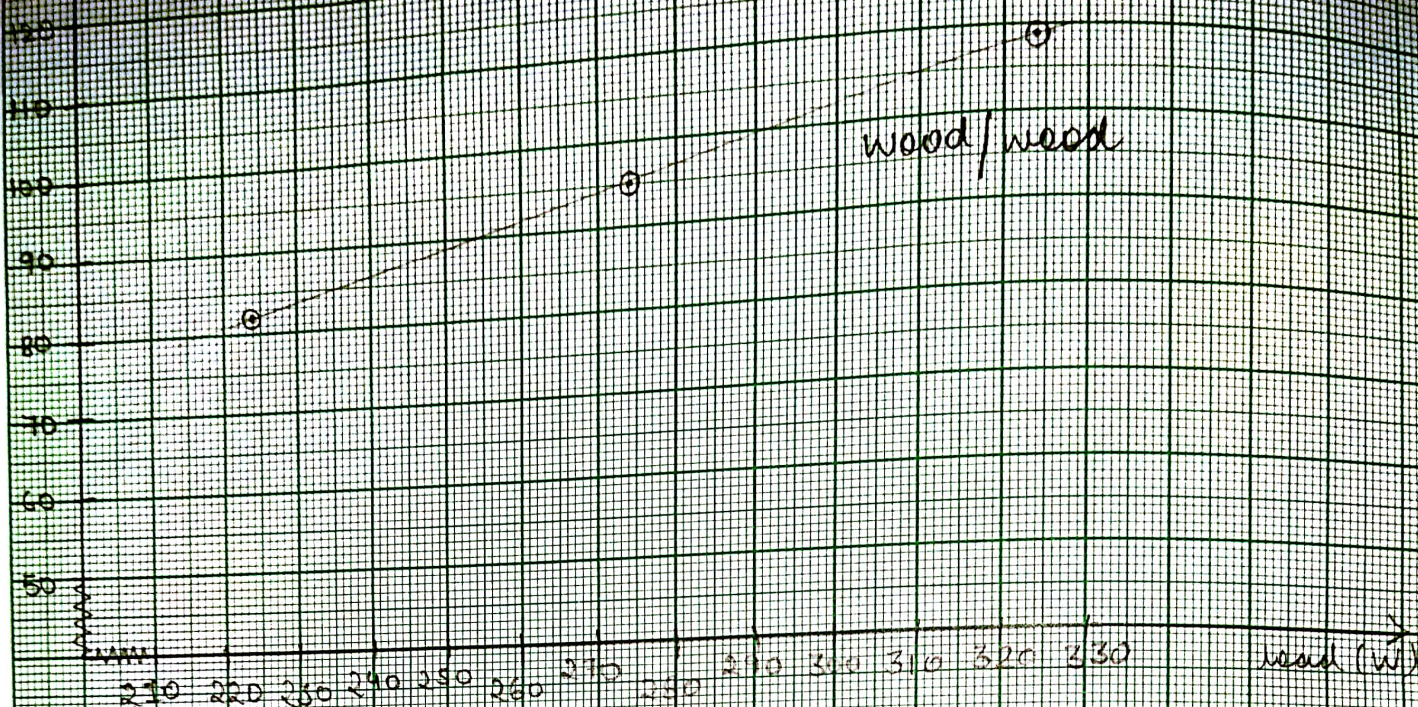
4. steel / wood = 0.23

Graph is plotted between load on x-axis and effort on y-axis for all the combinations :-

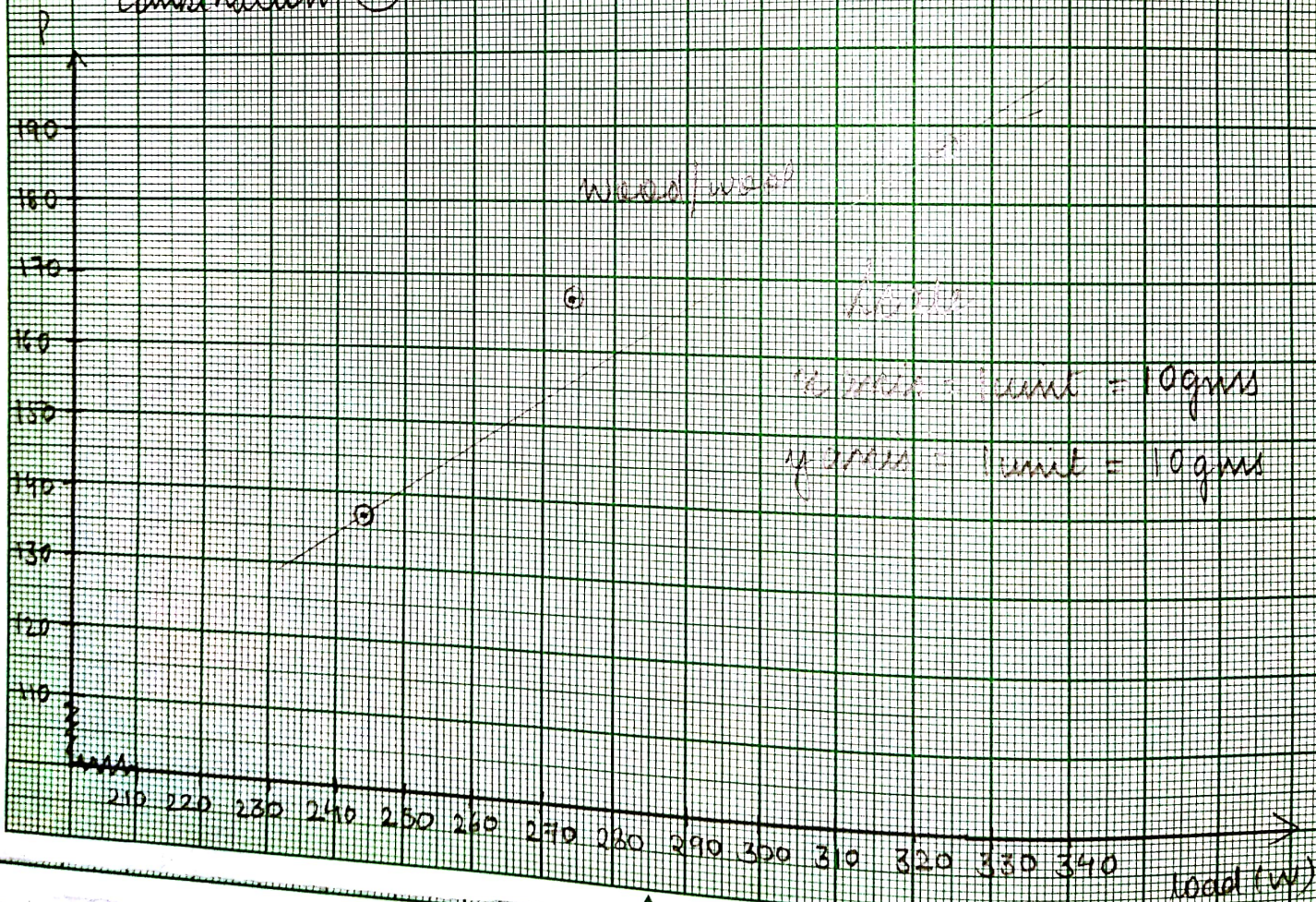


Combination (A)

Scale: marks = unit = 10 mm  
 grams = 1 unit = 10 gms



Combination (B)





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Graph is plotted between load on x-axis and effort on y-axis for all the combinations:

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## Experiment-2

Object: To find the coefficient of rolling friction between any type of surface and a roller moving on an inclined plane.

Apparatus: An inclined plane, carriage, roller, scale pan, slotted weights and weight box.

Theory: In the limiting condition, considering the equilibrium of a roller (assuming the body of the roller is small so considering it as an element). Thus applying the laws of static equilibrium

$$\sum F_{\text{normal to plane}} = 0 \quad \longleftrightarrow \quad R_N = W \cos \alpha \quad \text{--- (1)}$$

$$\sum F_{\text{parallel to plane}} = 0 \quad \longleftrightarrow \quad \mu R_N = P - W \sin \alpha \quad \text{--- (2)}$$

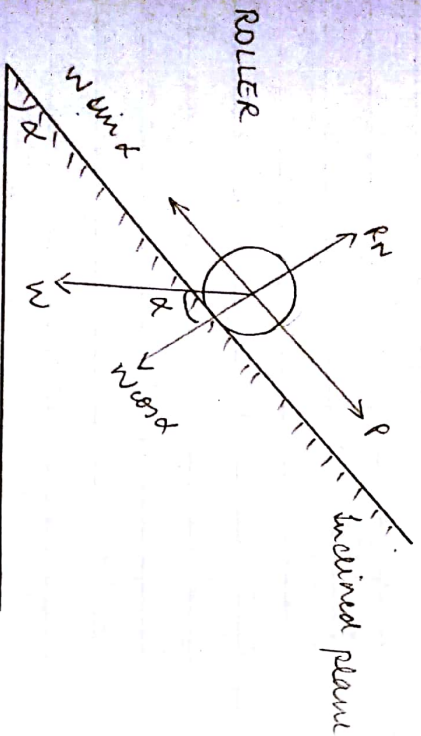
$$\mu = \frac{(P - W \sin \alpha)}{W \cos \alpha}$$

where

$\alpha$  = angle of inclination

$W$  = weight of roller

$P$  = wt of scale pan + wt in scale pan





Calculation:  $\mu = \frac{P \cdot W \sin \alpha}{W \cos \alpha}$

(A) combination - wood / brass  $W = 978 \text{ gm}$

when  $\alpha = 5^\circ$   $P = 110 \text{ gm}$   $\mu = 0.0254$

$$\mu_1 = \frac{110 - 978 \sin 5^\circ}{978 \cos 5^\circ}$$

$W = 978 \text{ gm}$

when  $\alpha = 10^\circ$   $P = 205 \text{ gm}$

$$\mu_2 = \frac{205 - 978 \sin 10^\circ}{978 \cos 10^\circ} = 0.0365$$

when  $\alpha = 15^\circ$   $P = 275 \text{ gm}$

$W = 978 \text{ gm}$

$$\mu_3 = \frac{275 - 978 \sin 15^\circ}{978 \cos 15^\circ} = 0.0231$$

$$\text{Avg) } \mu_{\text{wood/brass}} = \frac{\mu_1 + \mu_2 + \mu_3}{3} = \frac{0.0254 + 0.0365 + 0.0231}{3} = 0.0283$$

(B) combination - leather / brass

when  $\alpha = 5^\circ$   $P = 150 \text{ gm}$

$W = 978 \text{ gm}$

$$\mu_1 = \frac{150 - 978 \sin 5^\circ}{978 \cos 5^\circ} = 0.0664$$

when  $\alpha = 10^\circ$   $P = 215 \text{ gm}$

$W = 978 \text{ gm}$

$$\mu_2 = \frac{215 - 978 \sin 10^\circ}{978 \cos 10^\circ} = 0.0469$$

when  $\alpha = 15^\circ$   $P = 290 \text{ gm}$

$W = 978 \text{ gm}$

$$\mu_3 = \frac{290 - 978 \sin 15^\circ}{978 \cos 15^\circ} = 0.0390$$

$$\text{Avg } \mu_{\text{leather/brass}} = \frac{\mu_1 + \mu_2 + \mu_3}{3} = 0.0507$$

### Observation

(1) wt. of scale pan = 50 gm

(2) wt. of brass roller = 978 gm

### Combination - wood / brass

| S.No. | Angle of inclination ( $\alpha$ ) | Effort (P) wt. of scale pan | Load (W) wt. in scale pan | total  | wt. of roller (W) gm | Coefficient of friction $\mu$ |
|-------|-----------------------------------|-----------------------------|---------------------------|--------|----------------------|-------------------------------|
| 1.    | 5°                                | 50 gm                       | 60 gm                     | 110 gm | 978 gm               | $\mu_1 = 0.0254$              |
| 2.    | 10°                               | 50 gm                       | 155 gm                    | 205 gm | 978 gm               | $\mu_2 = 0.0365$              |
| 3.    | 15°                               | 50 gm                       | 225 gm                    | 275 gm | 978 gm               | $\mu_3 = 0.0231$              |

### Combination - leather / brass

| S.No. | Angle of inclination ( $\alpha$ ) | Effort (P) wt. of scale pan | Load (W) wt. in scale pan | total  | wt. of roller (W) gm | Coefficient of friction $\mu$ |
|-------|-----------------------------------|-----------------------------|---------------------------|--------|----------------------|-------------------------------|
| 1.    | 5°                                | 50 gm                       | 100 gm                    | 150 gm | 978 gm               | $\mu_1 = 0.0664$              |
| 2.    | 10°                               | 50 gm                       | 165 gm                    | 215 gm | 978 gm               | $\mu_2 = 0.0469$              |
| 3.    | 15°                               | 50 gm                       | 240 gm                    | 290 gm | 978 gm               | $\mu_3 = 0.0390$              |

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Result : The coefficient of rolling friction for the various combinations are

(i) wood / brass = 0.0283

(ii) leather / brass = 0.0507



## Experiment-3

**Object:** To find the velocity ratio, mechanical advantage, efficiency and law of machine for the first system of pulley.

**Apparatus:** Weight box, assorted weights, metre scale.

**Description:** The first system of pulley has the following arrangement of various fixed and movable pulleys as shown in the diagram. Where

$P_1$  = Fixed pulley

$T_1, T_2, T_3$  = Tension in various

vertical strings

strings

$P_2, P_3$  = movable pulleys

$P$  = Effort

$W$  = Load

$W_2$  = self wt. of pulley  $P_2$

$W_3$  = self wt. of pulley  $P_3$

If we apply laws of static equilibrium we get

$$T_1 = W$$

$$2T_2 = T_1 + W_3 \iff T_2 = (T_1 + W_3)/2$$

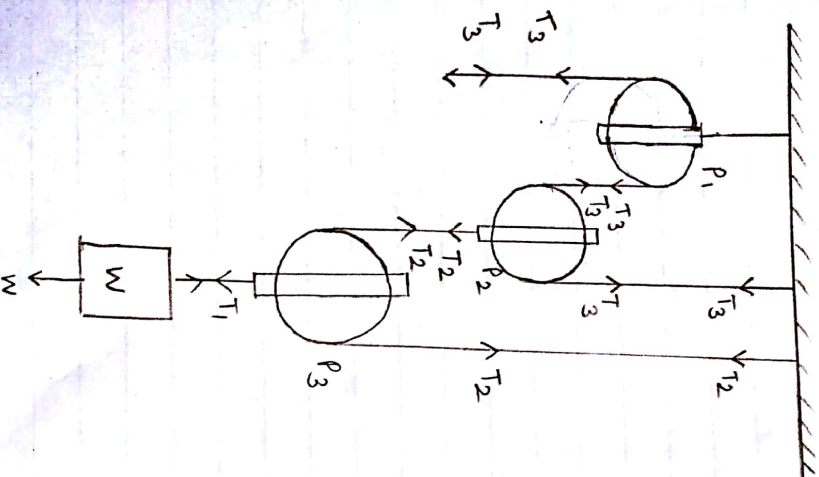
$$2T_3 = T_2 + W_2 \iff T_3 = (T_2 + W_2)/2$$

$$P = T_3$$

$$\text{Then } P = \frac{W}{2^2} + \frac{W_3}{2^2} + \frac{W_2}{2}$$

Mechanical advantage of the system (M.A.) is defined as the ratio of the load lifted to the effort applied.

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

Law of machine:  $P = C + mW$  where  $m$  and  $C$  are constants

Therefore  $M.A. = \frac{W}{mW + C}$

Thus, mechanical advantage varies with load. It is not constant for a machine.

Velocity ratio of a system is defined as the ratio of the distance moved by the effort to the distance moved by the load, during the same interval of time. It is constant for a system.

For velocity ratio - If load is lifted by a height ' $x$ ', movable pulley  $P_2$  will also move ' $x$ ' vertical and for this, the movement of string will be ' $2x$ '. So  $P_2$  will have to move up by ' $2x$ ' and for that the string attached to  $P_2$  will have to move by ' $4x$ ' or ' $2^2x$ '. Same will be the movement of the string over pulley  $P_1$ , i.e.  $4x$ .

Effort  $P$  is attached to this string thus it will also have to move by  $4x$ .

Therefore velocity ratio

$$V.R. = \frac{[2^2x]}{x} = 2^2$$

also efficiency  $\eta = \frac{M.A.}{V.R.} \times 100 (\%)$



$$M = \frac{M_A}{100} \times 100\%$$
$$\frac{150}{64} = 2.34$$
$$v_R = \frac{V}{R} = \frac{2.4}{0.9} = 2.66$$
$$m_1 = \frac{2.34}{2.66} \times 100\% = 87.9\% \approx 88\%$$
$$m \cdot A = W/P = 200 = 2.59$$
$$VR = \frac{y}{x} = \frac{7.7}{2.5} = 3.08$$
$$n_2 = \frac{2.59}{3.08} \times 100 \% = 84.09 \%$$
$$MA = w/p = \underline{250} = 2.77$$
$$v_R = \frac{y}{x} = \frac{6.8}{1.9} = 3.578$$
$$u_3 = \frac{2.77}{5.78} \times 100\% = 47.92\%$$
$$m_A = w/p = \frac{300}{120} = 2.94$$
$$vr = \frac{y}{x} = \frac{4.9}{1.5} = 3.26$$
$$u_4 = \frac{2.94}{3.26} \times 100\% = 90.18\%$$
$$MA = W/P = 350 - 2.04$$
$$\frac{115}{1000}$$
$$u_e = \frac{y_f}{x} = \frac{5.4}{1.2} = 4.5$$
$$= 67.55$$

|        |          |   |
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wt. of effort pan = 50 gms

### Observation Table

| SNO | load W | effort P | M.A.<br>(W/P) | distance<br>moved by<br>effort 'y' | distance<br>moved by<br>load 'x' | VE<br>y/x | efficiency<br>in %                     |
|-----|--------|----------|---------------|------------------------------------|----------------------------------|-----------|----------------------------------------|
| 1.  | 150 gm | 64 gm    | 2.34          | 2.4 cm                             | 0.9 cm                           | 2.66      | $\eta_1 = \frac{84}{100} = 84\%$       |
| 2.  | 250 gm | 77 gm    | 2.59          | 7.7 cm                             | 2.5 cm                           | 3.08      | $\eta_2 = \frac{84}{100} = 84\%$       |
| 3.  | 250 gm | 90 gm    | 2.77          | 6.8 cm                             | 1.8 cm                           | 3.78      | $\eta_3 = \frac{73.28}{100} = 73.28\%$ |
| 4.  | 300 gm | 102 gm   | 2.94          | 4.9 cm                             | 1.5 cm                           | 3.26      | $\eta_4 = \frac{90.18}{100} = 90.18\%$ |
| 5.  | 350 gm | 115 gm   | 3.04          | 5.4 cm                             | 1.2 cm                           | 4.5       | $\eta_5 = \frac{67.55}{100} = 67.55\%$ |

Five readings to be taken with a minimum load of 100 gm - 150 gm. Draw graph between load  $V$  vs effort (load  $w$  on  $x$ -axis and effort on  $y$ -axis) to evaluate constants in equation of law of machine:  $P = mV + c$ . Draw graph between efficiency  $\eta$  on  $y$ -axis and load  $w$  on  $x$ -axis.

Result: The maximum efficiency for the system is obtained as 90.18%.

$$\text{avg efficiency} = \frac{88 + 84.09 + 73.28 + 90.18 + 67.55}{5} = 80.62\%$$

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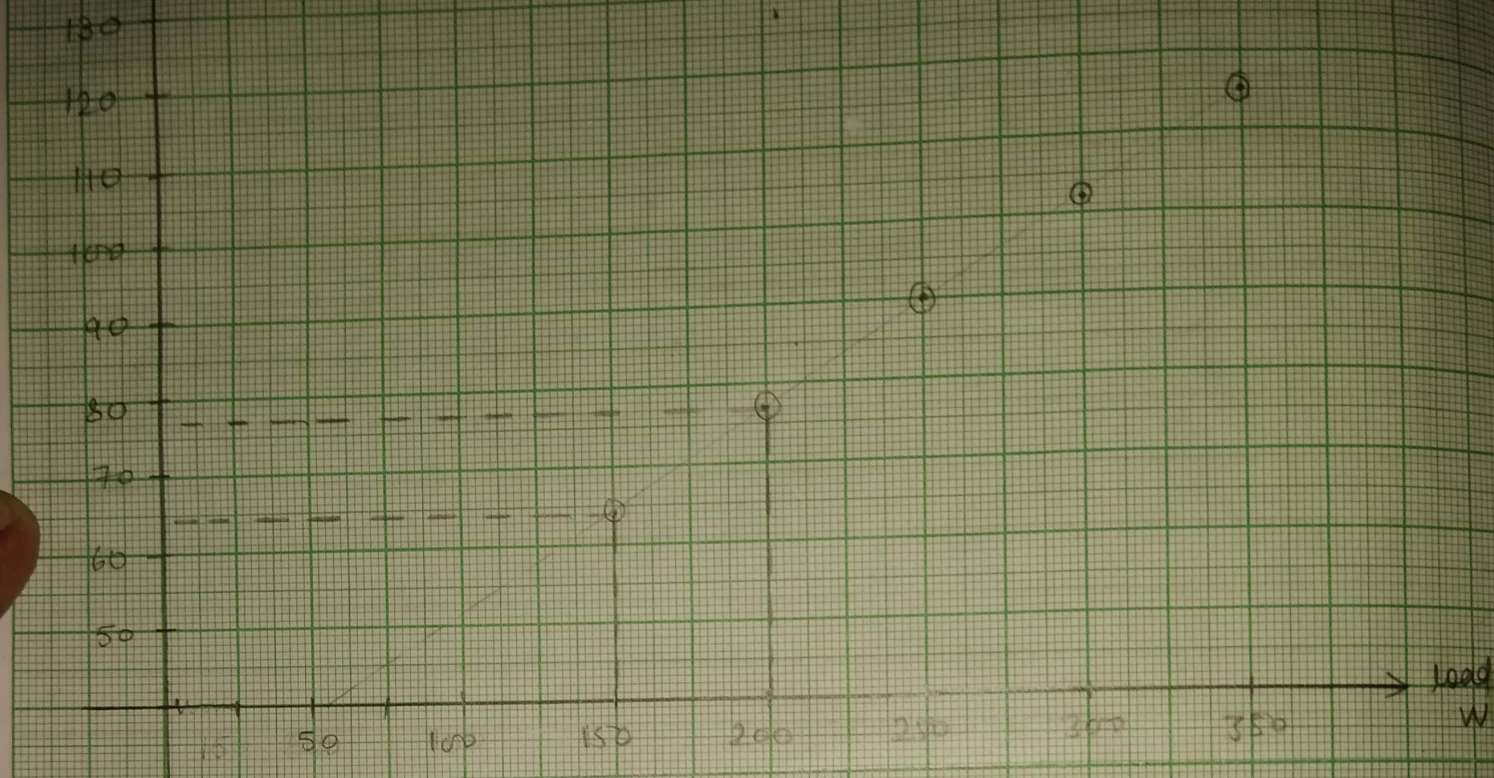
P  
effort ↑

Graph b/w lead v/s effort

Scale:

x axis = 1 unit = 25 gms

y axis = 1 unit = 10 gms



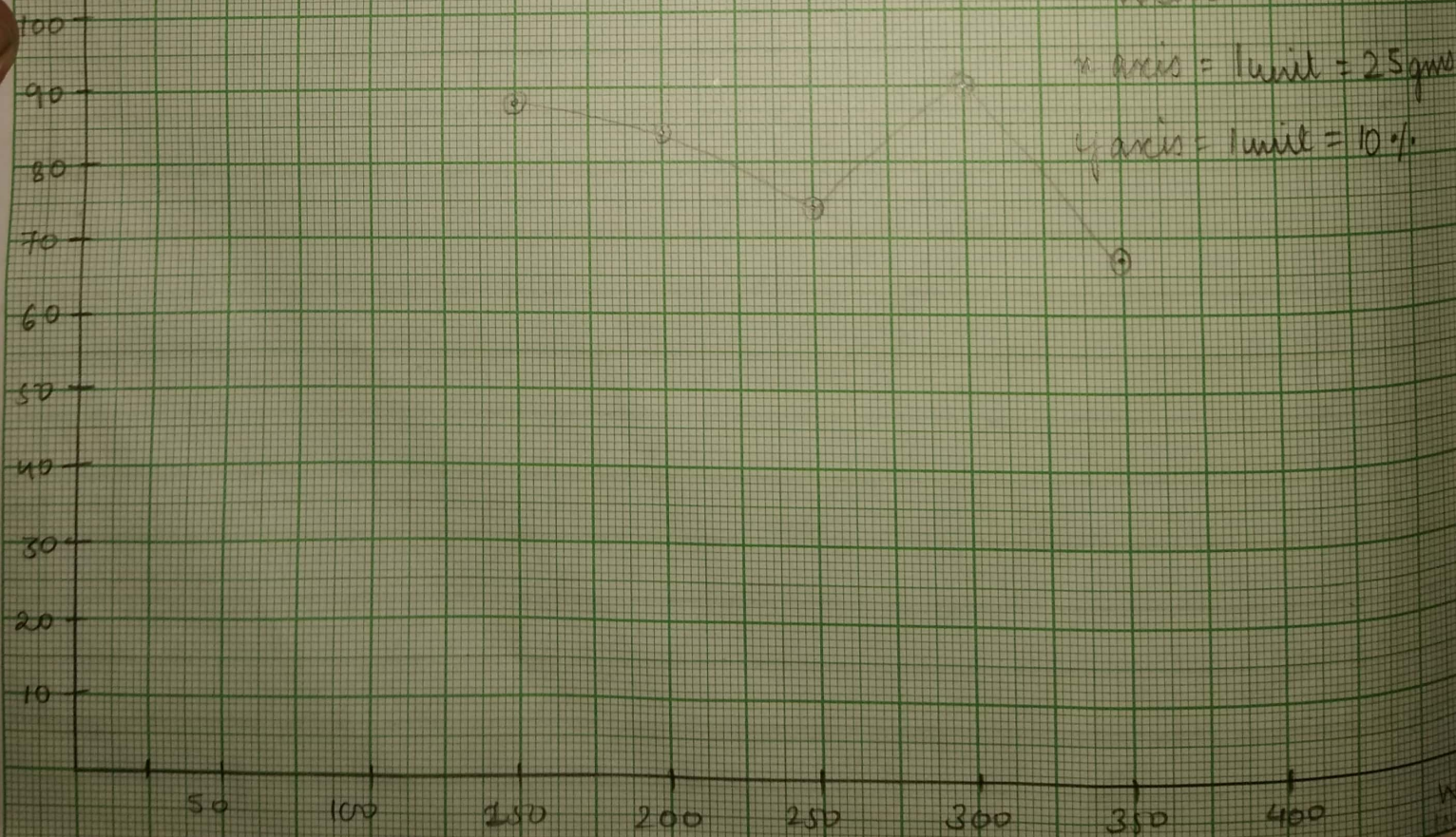
η ↑

Graph b/w efficiency and load

Scale

x axis = 1 unit = 25 gms

y axis = 1 unit = 10 %





The graphs are plotted between effort and load and between efficiency and load.

The law of machine for the system is

$$P = 13/50 W + 25 \quad (\text{analytically})$$

$$P = 13/50 W + 55 \quad (\text{graphically})$$

we know that

$$P = mW + C$$

$$P = 64 \quad W = 150 \quad \text{and}$$

$$P = 77 \quad W = 200$$

$$64 = m(150) + C \quad \text{--- (I)}$$

$$77 = 200m + C \quad \text{--- (II)}$$

sub (I) from (II)

$$200m + C = 77$$

$$150m + C = 64$$

$$50m = 13$$

$$m = \frac{13}{50}$$

$$\text{Put } m = \frac{13}{50} \text{ in --- (II)}$$

$$77 = \frac{4}{80} \times 200 \times \frac{13}{50} + C$$

$$77 - 52 = C$$

$$C = 25$$

From graph

$$m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{77 - 64}{200 - 150} = \frac{13}{50}$$

$$C = 55$$



## Experiment-4

Object: To find out the mechanical advantage (MA), velocity ratio (V.R), efficiency ( $\eta$ ) and law of machine for second system of pulleys.

Apparatus required: selected nets, weight box and meter scale

## Description:

In this system there are two blocks, the upper and lower. The upper block is fixed while the lower one is movable. The blocks may have equal or unequal number of pulleys. In the present apparatus the upper block contains three pulleys on one axle but free to move independently. The lower block contains three pulleys attached in the same manner as in the upper block. The end of the string is to be attached to the upper block since both blocks contain equal no. of pulleys. The string is passing all around so that the tension in the string portions is same and if there are  $n$  portions of the string which has a tension equal to the effort.

Theory:- Let the weight supported be  $W$  gms

The weight of the lower block be ' $w$ '

Hence the total downward force =  $W + w$

Total upward force = number of portions  $\times$  effort =  $n \times P$   
of string

$$\text{or } W + w = nP$$

$$\text{or } \frac{W}{P} = \frac{n - \frac{w}{P}}{1}, \text{ this is the theoretical expression}$$



# Calculations

$$MA = W/P \quad VR = y/x$$

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

①  $W = 150 \text{ gm}$   $P = 52 \text{ gm}$

$$MA = \frac{150}{52} = 2.88$$

$$VR = \frac{11}{1} = 11$$

$$\eta_1 = \frac{2.88}{11} \times 100 = 26.18\%$$

②  $W = 250 \text{ gm}$

$$P = 59 \text{ gm}$$

$$MA = \frac{250}{59} = 3.38$$

$$y = 6 \text{ cm}$$

$$x = 0.5 \text{ cm}$$

$$VR = \frac{6}{0.5} = 12$$

$$\eta_2 = \frac{3.38}{12} \times 100 = 28.16\%$$

③  $W = 250 \text{ gm}$

$$P = 69 \text{ gm}$$

$$MA = \frac{250}{69} = 3.62$$

$$y = 12 \text{ cm}$$

$$x = 1.5 \text{ cm}$$

$$VR = \frac{12}{1.5} = 8$$

$$\eta_3 = \frac{3.62}{8} \times 100 = 45.25\%$$

④  $W = 300 \text{ gm}$

$$P = 77 \text{ gm}$$

$$MA = \frac{300}{77} = 3.89$$

$$y = 21 \text{ cm}$$

$$x = 2.5 \text{ cm}$$

$$VR = \frac{21}{2.5} = 8.4$$

$$\eta_4 = \frac{3.89}{8.4} \times 100 = 46.30\%$$

⑤  $W = 350 \text{ gm}$

$$P = 87 \text{ gm}$$

$$MA = \frac{350}{87} = 4.02$$

$$y = 9.5 \text{ cm}$$

$$x = 1 \text{ cm}$$

$$VR = \frac{9.5}{1} = 9.5$$

$$\eta_5 = \frac{4.02}{9.5} \times 100 = 42.31\%$$

avg M.A. =

$$\frac{2.88 + 3.38 + 3.62 + 3.89 + 4.02}{5} = 3.558$$

avg VR =

$$\frac{11 + 12 + 8 + 8.4 + 9.5}{5} = 9.78$$

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for M.A. If the weight of the lower block is negligible in comparison to the load supported then  $W = \eta P$  velocity ratio is defined by the expression

$$V.R. = \left( \frac{\text{distance moved by effort}}{\text{distance moved by load}} \right) \text{ (during the same interval of time)}$$

$$V.R. = \frac{\text{total number of pulleys in the system}}{\text{the number of string portions } n}$$

$$\text{Efficiency } \eta\% = \frac{M.A.}{V.R.} \times 100 (\%)$$

## Observation:

$$\text{Wt of effort pan} = 50 \text{ gm}$$

$$\text{Wt of lower block} = 100 \text{ gm}$$

$$\text{number of pulley in the pulley system upper block} = 3$$

$$\text{number of pulley in the pulley in lower block} = 3$$

## Observation Table

| S.No. | load W | effort P | MA   | distance moved by effort 'y' | distance moved by load 'x' | VR | efficiency $\eta$ (%) |
|-------|--------|----------|------|------------------------------|----------------------------|----|-----------------------|
| 1.    | 150 gm | 52 gm    | 2.88 | 11 cm                        | 1 cm                       | 11 | $\eta_1 = 26.18\%$    |

Teacher's Signature

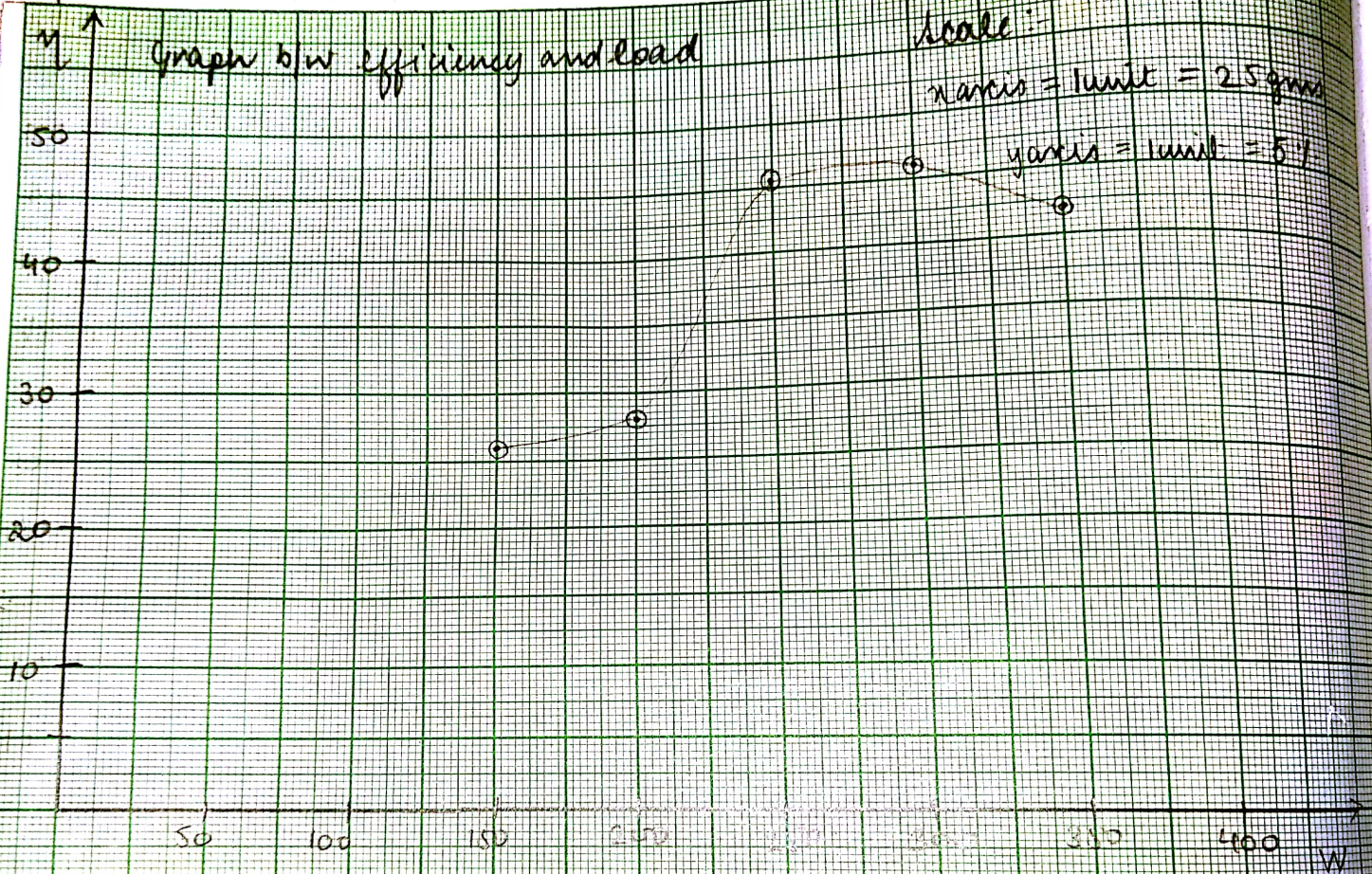


Graph b/w efficiency and load

Scale:

x axis = 1 unit = 25 gms

y axis = 1 unit = 5%





| Sno. | load W | effort P | MA   | distance moved by effort 'y' | distance moved by load 'x' | VR<br>$y/x$ | efficiency<br>$\eta$ (%) |
|------|--------|----------|------|------------------------------|----------------------------|-------------|--------------------------|
| 2.   | 200gm  | 59gm     | 3.38 | 6cm                          | 0.5cm                      | 12          | $\eta_2 = 28.16\%$       |
| 3.   | 250gm  | 69gm     | 3.62 | 12cm                         | 1.5cm                      | 8           | $\eta_3 = 45.25\%$       |
| 4.   | 300gm  | 77gm     | 3.89 | 21cm                         | 2.5cm                      | 8.4         | $\eta_4 = 46.30\%$       |
| 5.   | 350gm  | 87gm     | 4.02 | 9.5cm                        | 1cm                        | 9.5         | $\eta_5 = 42.31\%$       |

15 Five readings to be taken with a minimum load of 100 gm - 150 gm. Draw graph between load  $W$  vs effort  $P$  (load on  $x$ -axis and effort  $P$  on  $y$ -axis) to evaluate constants in equation of law of machine:  $P = mW + c$ .  
Draw graph between efficiency  $\eta$  on  $y$ -axis and load  $W$  on  $x$ -axis.

20 Result :-

The mechanical advantage of system is 3.56

The velocity ratio of system is 9.78

The maximum efficiency of system is obtained as 46.30%.

25

The graphs are plotted between effort and load and between efficiency and load.

Teacher's Signature:



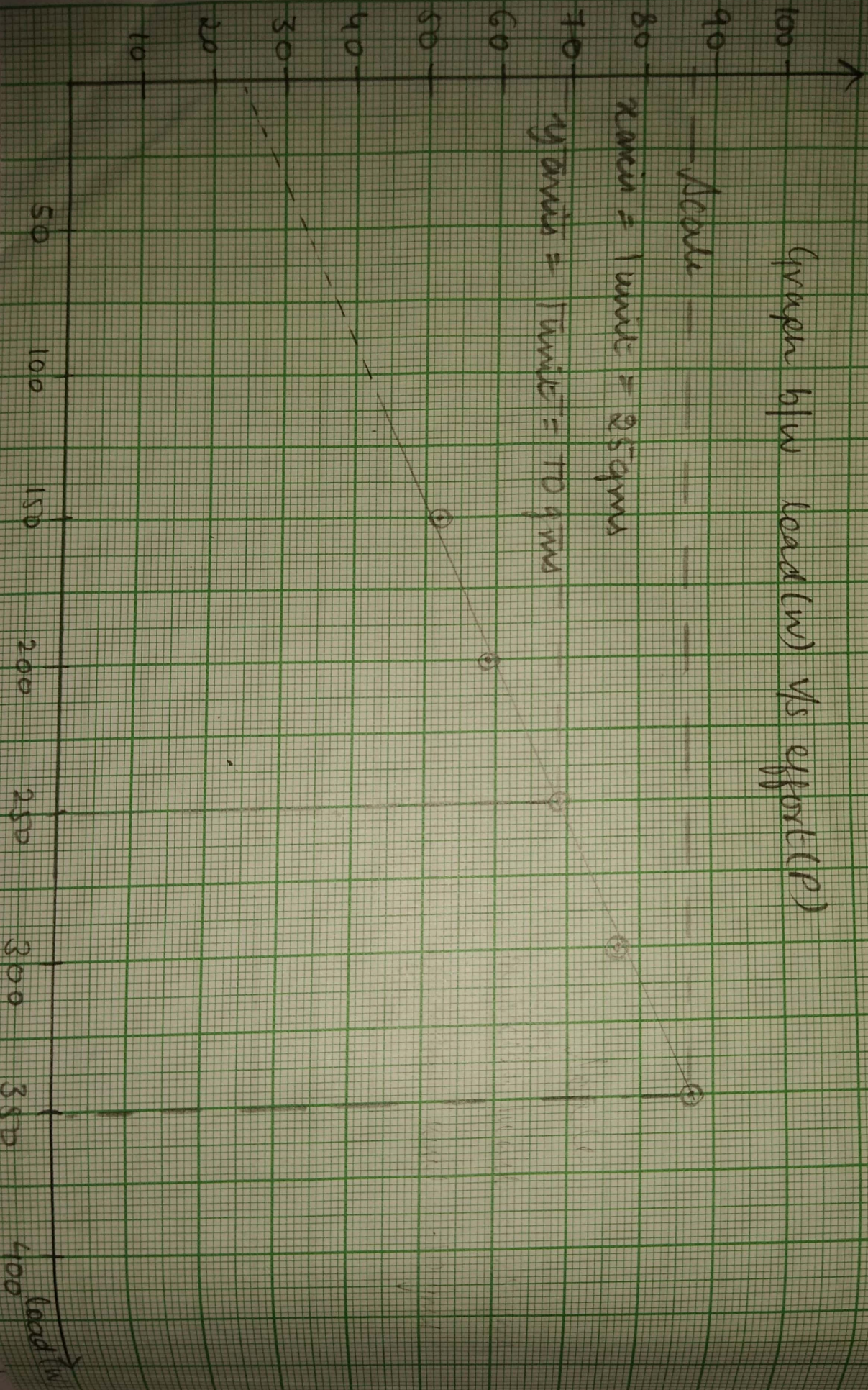
effort (P)

Graph b/w load (W) vs effort (P)

Acad

1 unit = 25 gms

1 unit = 10 gms





The law of machine for the system is

$$P = 7/50 W + 31 \quad (\text{analytically})$$

$$P = 9/50 W + 24 \quad (\text{graphically})$$

we know that

$$P = mW + C$$

$$P = 52 \quad W = 150$$

and

$$P = 59 \quad W = 200$$

$$52 = 150m + C \quad \text{--- (1)}$$

$$59 = 200m + C \quad \text{--- (2)}$$

sub (1) from (2)

Put value of m in (2)

$$200m + C = 59$$

$$59 = \frac{200 \times 7}{50} + C$$

$$150m + C = 52$$

$$59 - 28 = C$$

$$50m = 7$$

$$C = 31$$

$$m = \frac{7}{50}$$

acc to graph

$$m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{87 - 69}{350 - 250} = \frac{18}{100} = \frac{9}{50}$$

for constant

$$C = 24$$

Signature  
5/9/18



## Experiment - 5

Object: To find mechanical advantage (M.A.), velocity ratio (V.R.), efficiency ( $\eta$ ) and law of machine for worm and worm wheel.

Apparatus: Slotted weights (kg and gms), scale pan, weight box, metre scale, cord, outside callipers

Description: The threads of the worm have a cross-section similar in shape to that of the worm wheel. The worm is attached to a spindle, at right angles to axis of the wheel and is prevented from moving in by friction in its bearings of its own axis. When the worm is rotated by handle or pulley (handle for practical purposes and pulley for experimental purpose), worms make same revolutions as that of the handle. If A and B are say worm and worm wheel respectively then, while the handle is rotated, A and B come in contact during rotations with say right hand side of the teeth say 'T' on the worm wheel and it becomes  $1/T$  revolution of worm wheel when worm is forward by one pitch if the worm is single threaded. The load is coiled round the drum, the axis of which is in the same line as that of the worm wheel. The effort is applied by carrying a rope around the pulley the axis of which coincides with that of the worm.

Theory: The velocity ratios calculated as follows:



Consider one revolution of the effort wheel. The distance moved by the effort  $= \pi D$ , where,  $D$  = effective diameter of effort wheel. Let there be 'T' teeth on the worm wheel. Distance moved by the load  $= \left(\frac{1}{T}\right)^{\text{th}}$  of the revolutions of the worm-wheel, in case of a single start (or single threaded) worm. But in the present experiment with one revolution of the effort wheel, the distance moved by the worm wheel is three threads i.e.  $\left(\frac{3}{T}\right)^{\text{th}}$  revolution of the worm wheel. Hence the distance moved by the load  $= \left(\frac{3}{T}\right) \pi d$  : where

$d$  = effective diameter of the load drum

$T$  = no. of teeth on the worm wheel

$$\text{Hence } VR = \frac{\pi D}{\frac{3}{T} \pi d} = \frac{DT}{3d}$$

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

$$\text{Efficiency } \eta = \frac{MA}{VR} \times 100 (\%)$$

Observation

Effective diameter of effort pulley ( $D$ ) = 46.5 cm

Effective diameter of load drum ( $d$ ) = 37 cm



Calculation:

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

$$VR = \frac{y}{x}$$

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

① when  $W = 1660 \text{ gm}$

$$P = 200 \text{ gm}$$

$$MA = 8.3$$

$$x = 0.7 \text{ cm}$$

$$VR = 44.28$$

$$y = 2.31 \text{ cm}$$

$$\eta_1 = \frac{8.3}{44.28} \times 100\% = 18.74\%$$

② when

$$W = 2568 \text{ gm}$$

$$P = 250 \text{ gm}$$

$$MA = 10.27$$

$$y = 19.5 \text{ cm}$$

$$x = 0.5 \text{ cm}$$

$$VR = 39$$

$$\eta_2 = \frac{10.27}{39} \times 100 = 26.33\%$$

③ when

$$W = 3476 \text{ gm}$$

$$P = 270 \text{ gm}$$

$$MA = 12.87$$

$$y = 17 \text{ cm}$$

$$x = 0.8 \text{ cm}$$

$$VR = 21.25$$

$$\eta_3 = \frac{12.87}{21.25} \times 100 = 60.56\%$$

④ when

$$W = 4384 \text{ gm}$$

$$P = 300 \text{ gm}$$

$$MA = 14.61$$

$$y = 20 \text{ cm}$$

$$x = 1.1 \text{ cm}$$

$$VR = 18.18$$

$$\eta_4 = \frac{14.61}{18.18} \times 100 = 80.36\%$$

⑤ when

$$W = 5292 \text{ gm}$$

$$P = 350 \text{ gm}$$

$$MA = 15.12$$

$$y = 27.5 \text{ cm}$$

$$x = 1.4 \text{ cm}$$

$$VR = 19.64$$

$$\eta_5 = \frac{15.12}{19.64} \times 100\% = 76.98\%$$

MA =

$$= \frac{8.3 + 10.27 + 12.87 + 14.61 + 15.12}{5}$$

$$= 12.23$$

VR =

$$= \frac{44.28 + 39 + 21.25 + 18.18 + 19.64}{5} = 28.47$$

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no. of teeth on the worm wheel  $T = 150$

wt of the load = 250 gm

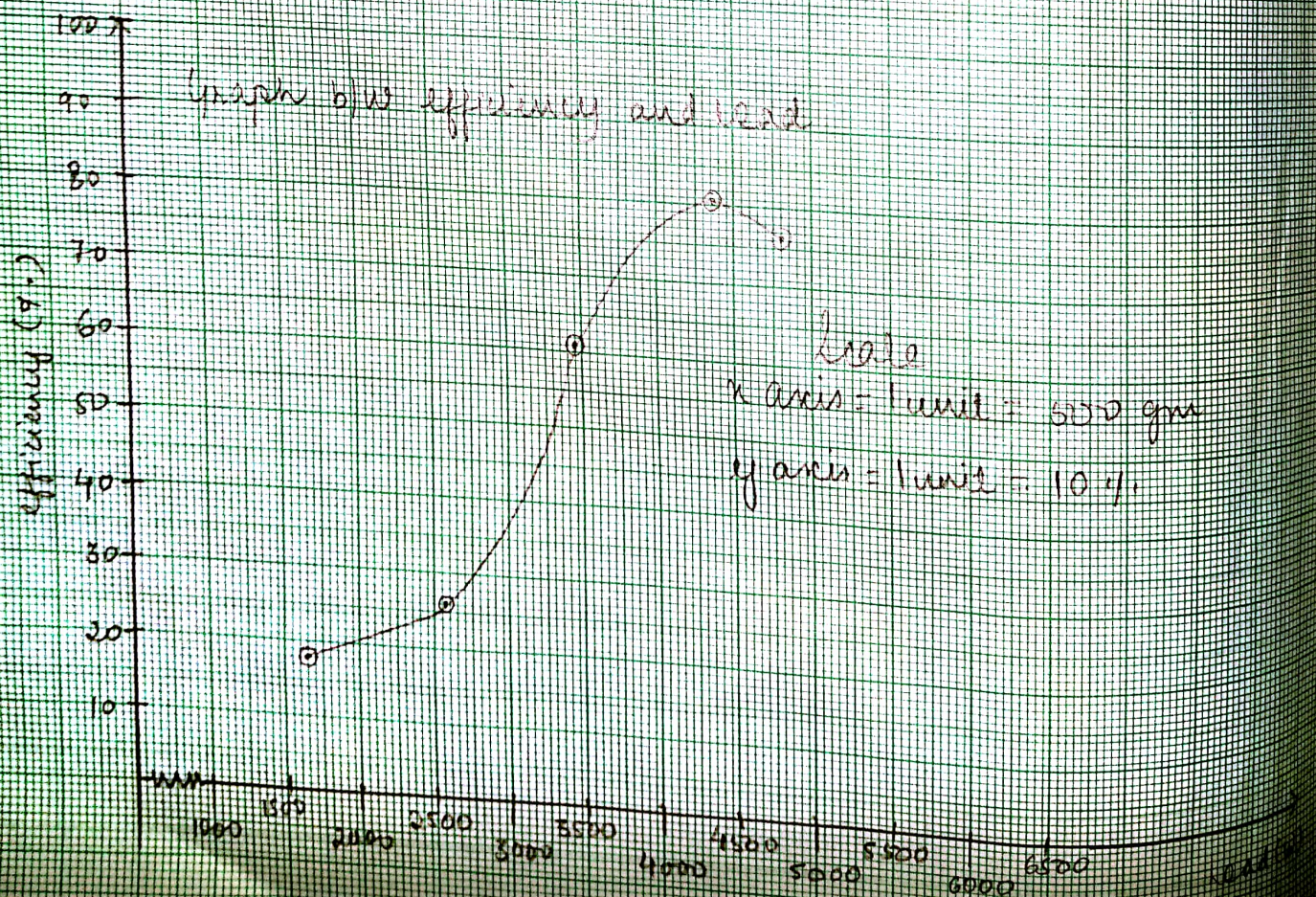
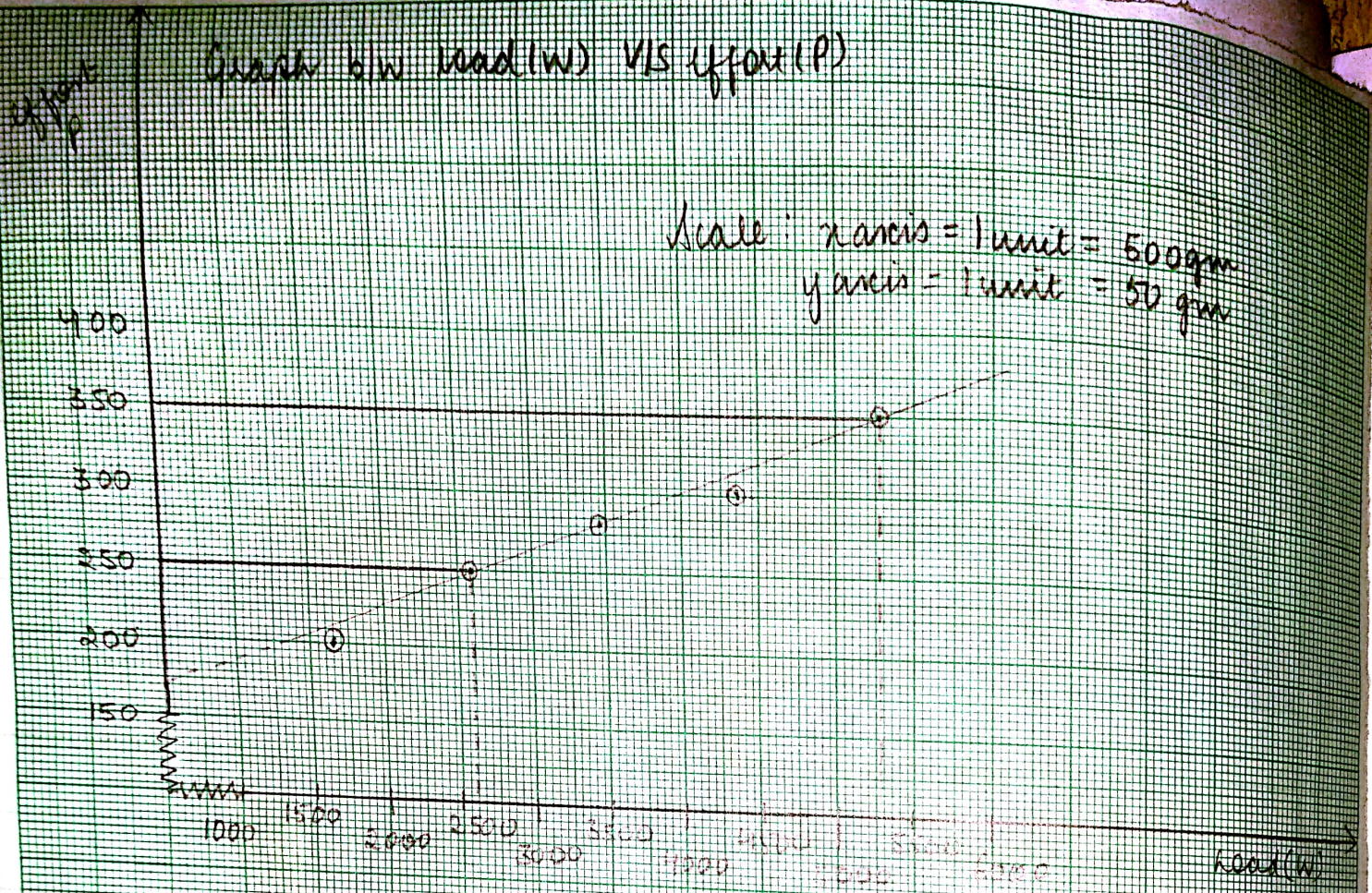
wt of test pan = 50 gm

Observation Table:

| S.No | Load (W)                     | Effort (P)           | M.A   | V.R                                                           | Efficiency         |
|------|------------------------------|----------------------|-------|---------------------------------------------------------------|--------------------|
| 1.   | 250 + 502 + 908<br>= 1660 gm | 150 + 50<br>= 200 gm | 8.3   | $x = 0.7 \text{ cm}$<br>$y = 31 \text{ cm}$<br>$VR = 44.28$   | $\eta_1 = 18.74\%$ |
| 2.   | 2568 gm                      | 250 gm               | 10.27 | $x = 0.5 \text{ cm}$<br>$y = 19.5 \text{ cm}$<br>$VR = 39$    | $\eta_2 = 26.33\%$ |
| 3.   | 3476 gm                      | 270 gm               | 12.87 | $x = 0.8 \text{ cm}$<br>$y = 17 \text{ cm}$<br>$VR = 21.25$   | $\eta_3 = 60.56\%$ |
| 4.   | 4384 gm                      | 300 gm               | 14.61 | $x = 1.1 \text{ cm}$<br>$y = 20 \text{ cm}$<br>$VR = 18.18$   | $\eta_4 = 80.36\%$ |
| 5    | 5292 gm                      | 350 gm               | 15.12 | $x = 1.4 \text{ cm}$<br>$y = 27.5 \text{ cm}$<br>$VR = 19.64$ | $\eta_5 = 76.98\%$ |

Teacher's Signature







Five readings to be taken with a minimum load of 1 kg. Draw graph between load  $W$  vs effort (Load  $W$  on  $x$ -axis and effort  $P$  on  $y$ -axis) to evaluate constants in equation of law of machine  $P = mW + c$ . Draw graph between efficiency  $\eta$  on  $y$ -axis and load  $W$  on  $x$ -axis.

Result:

The mechanical advantage of the system is 12.23

The velocity ratio of the system is 28.47

The maximum efficiency for the system is obtained as 80.36 %.

The graphs are plotted between effort and load and between efficiency and load.

The law of the machine for the system is:  $P = \frac{25}{454} W + 108.5$

$$P = \frac{25}{681} W + 170 \quad (\text{graphically})$$

analytically

$$P = 200 \text{ gm} \quad W = 1660 \text{ gm} \quad \text{and} \quad P = 250 \text{ gm} \quad W = 2568 \text{ gm}$$

$$200 = 1660m + c \quad \text{--- (I)}$$

$$250 = 2568m + c \quad \text{--- (II)}$$

sub (I) from (II)

$$\text{Putting } m = \frac{25}{454} \text{ in (I)}$$

$$2568m + c = 250$$

$$1660m + c = 200$$

$$900 = \frac{830}{454} \times 25 + c$$

$$908m = 50$$

$$m = \frac{50}{908} = \frac{25}{454}$$

$$c = \frac{24650}{227}$$

$$c = 108.5$$

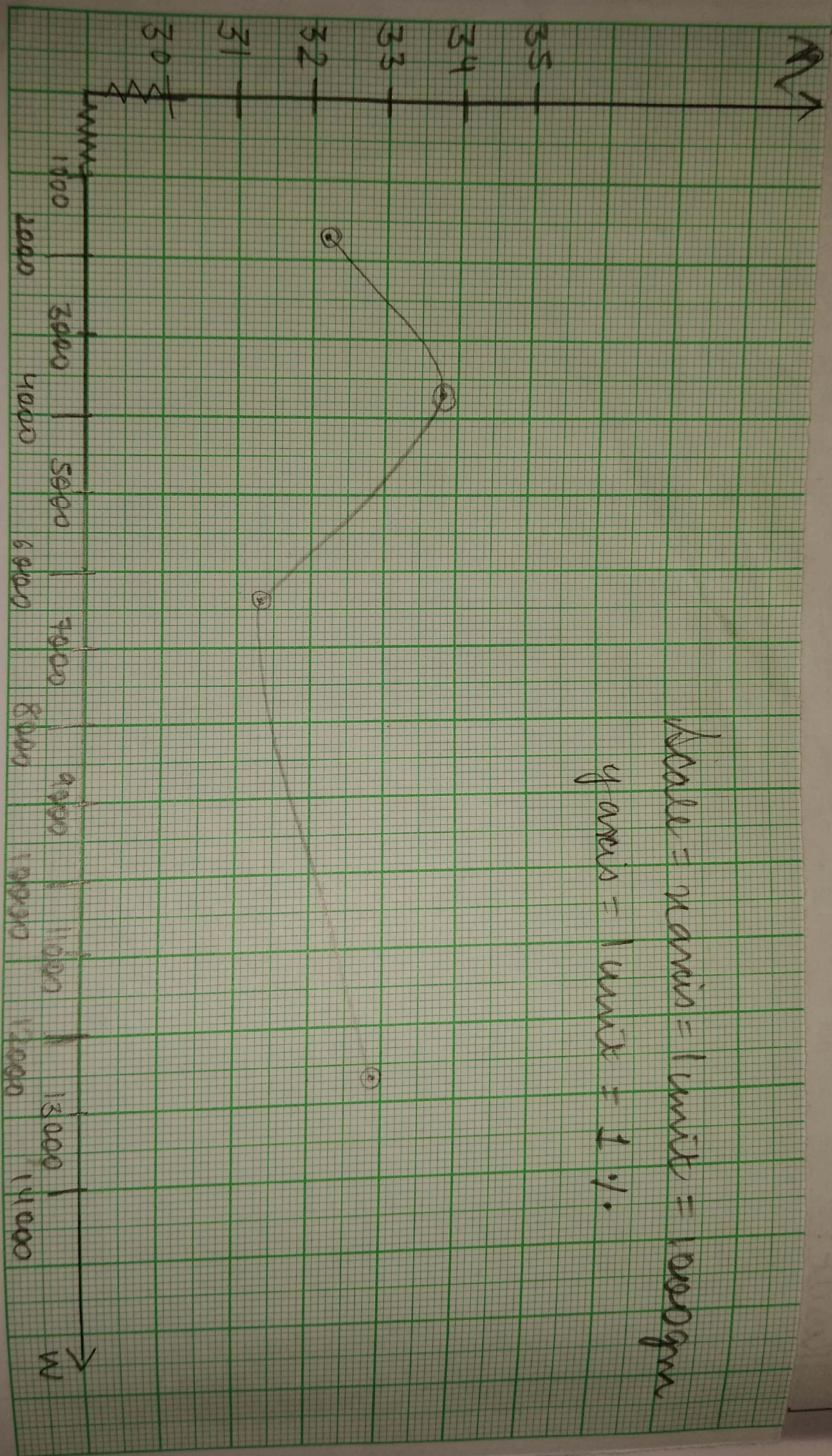
Graphically

$$m = \frac{350 - 250}{5292 - 2568} = \frac{100}{2724}$$

$$= \frac{25}{681}$$

Teacher's Signature:





Scale = 1 unit = 1000 gm  
y axis = 1 unit = 1 %.



## Experiment no.- 6

Object: To find out the mechanical advantage (M.A.), velocity ratio (V.R.), efficiency ( $\eta$ ) and loss of machine for a screw jack.

Apparatus: Screw jack apparatus, weights, metre scale etc..

Theory: The screw jack is frequently used in practical for raising and holding up heavy pieces of machinery etc.. The effort is applied with the help of a pulley round which the string passes. Consider one revolution of the screw, and therefore, of the pulley since the two rotate together. The effort will move a distance equal to the circumference of the pulley while the load will be lifted a distance equal to the pitch of the screw.

If  $p$  = pitch of the screw

$D$  = effective diameter of the pulley

$$\text{velocity ratio (V.R.)} = \frac{\text{Distance moved by effort}}{\text{Distance moved by load}} = \frac{\pi D}{p}$$

$$\text{Mechanical Advantage (M.A.)} = \frac{W}{P}$$

$$\text{Efficiency } \eta = \frac{MA}{VR} \times 100 (\%)$$

Procedure: First of all put the weight  $W$  on the hook attached to the screw jack, and after that apply effort  $P$  on the pan attached to the string wound over the effort wheel. As the pan about to move, note  $P$



Calculation :-

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

$$VR = \frac{y}{x}$$

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

$$MA = 8.85$$

$$\textcircled{1} \text{ when } W = 1740 \text{ gm} \quad P = 200 \text{ gm}$$

$$VR = \frac{y}{x} = \frac{0.8}{0.8} = \frac{22}{27.5}$$

$$\eta_1 = \frac{8.85}{27.5} \times 100 = 32.18\%$$

$$\textcircled{2} \text{ when } W = 3780 \text{ gm} \quad P = 310 \text{ gm}$$

$$VR = \frac{y}{x} = \frac{18}{36}$$

$$\eta_2 = \frac{12.19}{36} \times 100 = 33.86\%$$

$$\textcircled{3} \text{ when } W = 6350 \text{ gm} \quad P = 420 \text{ gm}$$

$$VR = \frac{y}{x} = \frac{29}{48.33}$$

$$\eta_3 = \frac{15.11}{48.33} \times 100 = 31.26\%$$

$$\textcircled{4} \text{ when } W = 12760 \text{ gm} \quad P = 645 \text{ gm} \quad MA = 19.78$$

$$VR = \frac{y}{x} = \frac{24}{60}$$

$$\eta_4 = \frac{19.78}{60} \times 100 = 32.96\%$$

$$MA_{avg} = \frac{8.85 + 12.19 + 15.11 + 19.78}{4} = 13.982$$

$$VR_{avg} = \frac{27.5 + 36 + 48.33 + 60}{4} = 42.95$$

Observation

P = pitch of the wheel = 0.6 cm

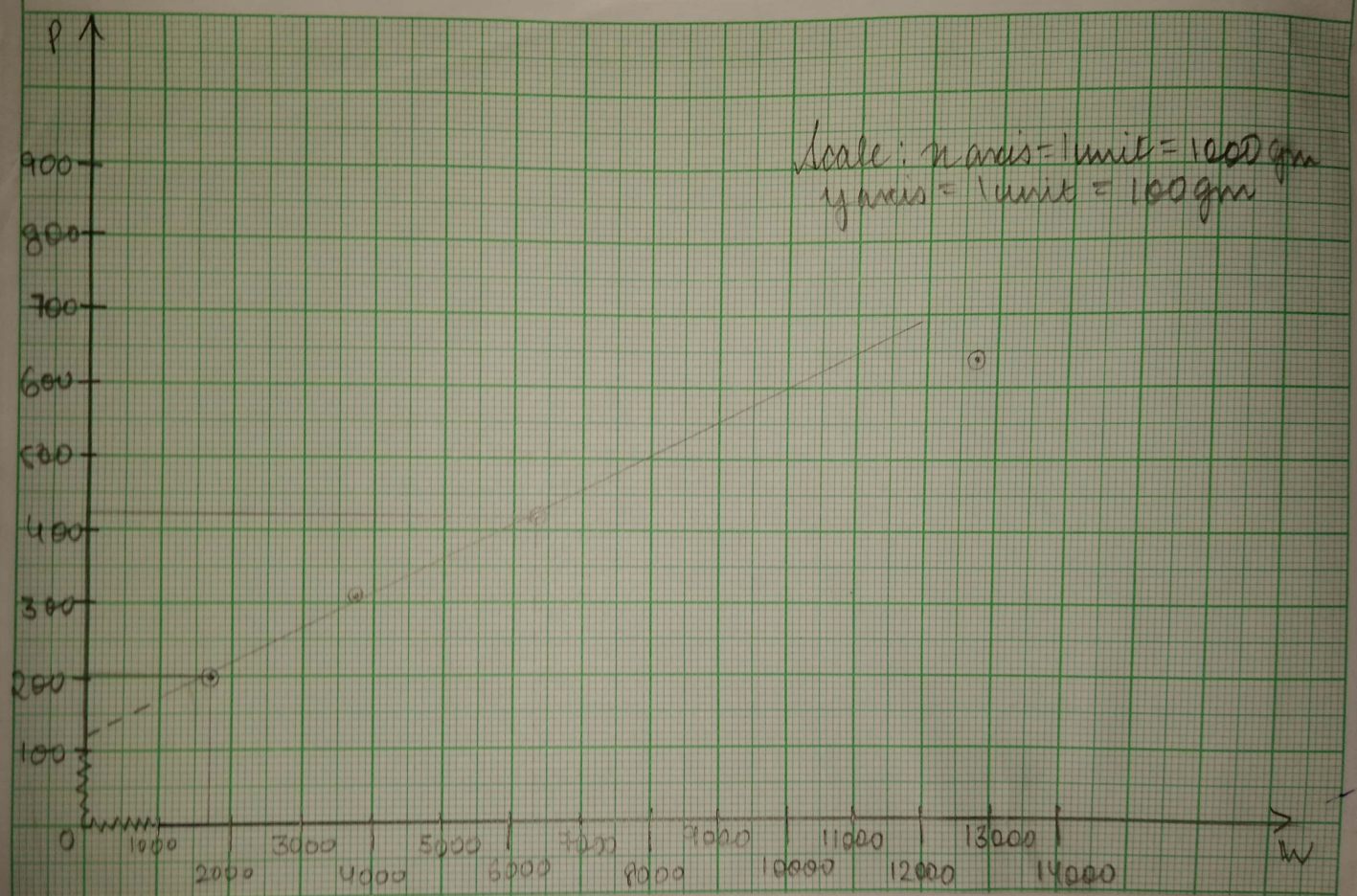
D = effective diameter of the effort wheel = 22.45 cm

Observation table

| S.No.           | load W   | effort P | M.A   | V.R                                                           | Efficiency |
|-----------------|----------|----------|-------|---------------------------------------------------------------|------------|
| 1 <sup>st</sup> | 1740 gm  | 200 gm   | 8.85  | $x = 0.8 \text{ cm}$<br>$y = 2.2 \text{ cm}$<br>$y/x = 27.5$  | 32.18%     |
| 2 <sup>nd</sup> | 3780 gm  | 310 gm   | 12.19 | $x = 0.5 \text{ cm}$<br>$y = 1.8 \text{ cm}$<br>$y/x = 36$    | 33.86%     |
| 3 <sup>rd</sup> | 6350 gm  | 420 gm   | 15.11 | $x = 0.6 \text{ cm}$<br>$y = 2.9 \text{ cm}$<br>$y/x = 48.33$ | 31.26%     |
| 4 <sup>th</sup> | 12760 gm | 645 gm   | 19.78 | $x = 0.4$<br>$y = 2.4$<br>$y/x = 60$                          | 32.96%     |

Five readings to be taken with a minimum load of 1 kg. Draw graph between load vs effort (load W on x axis and effort P on y axis) to evaluate constant in equation of law of machine  $P = mW + c$ . Draw graph between efficiency  $\eta$  on y axis and load W on x axis.







## \* Result:-

The mechanical advantage of the system is 13.982

The velocity ratio of the system is 42.95

The maximum efficiency for the system is obtained as 33.86%.

The graphs are plotted between effort and load and between efficiency and load.

The law of the machine for the system is

$$P = 1/201 W + 103.14 \quad (\text{analytically})$$

$$P = 1/229 W + 120 \quad (\text{graphically})$$

analytically

when  $W = 1770 \text{ gm}$   $P = 200 \text{ gm}$

$$200 = 1770 m + c \quad \text{--- ①}$$

when  $W = 3780 \text{ gm}$   $P = 310 \text{ gm}$

$$310 = 3780 m + c \quad \text{--- ②}$$

Sub ① from ②

$$310 = 3780 m + c$$

$$200 = 1770 m + c$$

$$\text{---} \quad \text{---} \quad \text{---}$$

$$110 = 2010 m$$

$$m = \frac{211}{201}$$

Put  $m = \frac{201}{11}$  in ①

$$200 = 1770 \times \frac{11}{201} + c$$

$$c = 103.14$$

Graphically

$$m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{420 - 200}{6350 - 1770} = \frac{220}{4580} = \frac{11}{229}$$

$$c = 120$$

Teacher's Signature: