COEFFICIENTS OF FRICTION

AIM: To determine the coefficient of static and kinetic friction between wood and wood.

APPARATUS: A horizontal plane, a frictionless pulley fixed at one end, a wooden block with a hook, weight box, scale pan and string.

THEORY:

Friction is the resisting force encountered when one tries to slide one surface over another. This force acts along the tangent to the surface in contact. It is found experimentally that the force of friction is directly proportional to the normal force. The constant of proportionality is called the coefficient of friction. When a body lies at rest on a surface and an attempt is made to push it, the pushing push is opposed by a frictional force equal to:

$$f = \mu_s F_N \qquad (5.1)$$

Where μ_s is the coefficient of static friction and F_N is the normal force. When the pushing force is greater than the static force, the body begins to move. If the contacting surfaces are actually sliding one over the other, the force of friction is given by:

$$f = \mu_k F_N \qquad (5.2)$$

Where μ_k is the coefficient of kinetic friction.

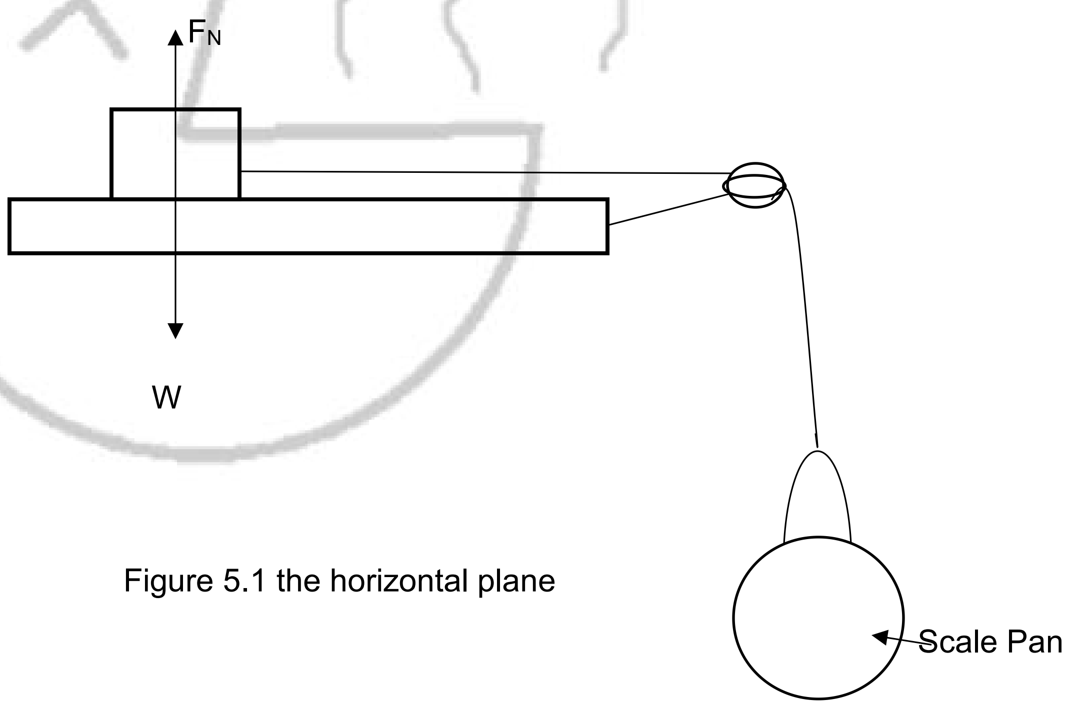

Figure 5.1 the horizontal plane

PART 1: Static Friction

PROCEDURE

1. The hanger and wooden surface were weighed separately.
2. The mass hanger and wooded surface tray were tied using a 50cm string.
3. The wooden surface was placed on the horizontal plane at a 30cm mark and allowed the string to pass over the frictionless pulley so that the mass hanger was on the over side below the pulley.
4. Weights were added on the mass hanger till the wooden surface began to slide and the weights were noted for two trials.
5. The experiment was repeated by adding weights of 50g, 100g, 150g, 200g on top of the wooden surface, each time starting from the same marked point on the plane.

PART 2: Kinetic Friction

PROCEDURE:

1. A weight was placed on the mass hanger and a slight push was given to the block towards the pulley.
2. Weights were increased on the mass hanger and the block was given a slight push until it was found to continue moving with a steady small velocity.
3. The corresponding weights on the mass hanger were recorded.
4. The experiment was repeated by adding weights on 50g, 100g, 150g, 200g on top of the wooden block, starting always from the small position on the wooded plane.

DATA ANALYSIS

Part 1:

Weight of wooden tray (W) = 0.895N   Weight of the mass hanger (S) = 0.049N

From equation 5.1 f = $\mu_s F_N$

The coefficient of static friction for the wooden tray is:

When there was no mass on the tray

$\mu_s = \frac{F}{F_N}$

$\mu_s = \frac{0.196}{0.895}$

$\boldsymbol{\mu_s = 0.219}$

When the mass is 50 on the tray

$\mu_s = \frac{F}{F_N}$

$\mu_s = \frac{0.245}{1.386}$

$\boldsymbol{\mu_s = 0.176}$

When the mass on the tray is 100

$\mu_s = \frac{F}{F_N}$

$\mu_s = \frac{0.392}{1.876}$

$\boldsymbol{\mu_s = 0.209}$

<u>the same formula was used to calculate the values of μ_s.</u>

The mean

(i) $\sum \mu s$

From equation (1.3)

$$\sum \mu s = (0.219 + 0.219 + 0.169 + 0.176 + 0.204 + 0.209 + 0.211 + 0.207 + 0.189 + 0.189)$$

$$\sum \mu s = \mathbf{2.194}$$

(ii) mean μs ($\overline{\mu s}$)

From equation (1.2)

$$\text{mean } \mu s = \overline{\mu s} = \frac{1}{N}\sum_{i=1}^{N} \mu s_i$$

$$\text{where } N = 10,\ \sum_{i=1}^{N} \mu s_i = \mu s_1 + \mu s_2 + \ldots\ldots.. + \mu s_7 = \sum \mu s = 2.194$$

$$\therefore\ \overline{\mu s} = \frac{1}{10}(2.194)$$

$$\underline{\therefore\ \overline{\mu s} = \mathbf{0.22}}$$

Weight of wooden tray (W) = 0.916N Weight of the mass hanger (S) = 0.049N

From equation 5.1 f = $\mu_s F_N$

The coefficient of static friction for the plastic tray is:

When there is no mass in the tray

$\mu_s = \frac{F}{F_N}$

$\mu_s = \frac{0.167}{0.916}$

μ_s =0.182

When the mass is 50 on the tray

$\mu_s = \frac{F}{F_N}$

$\mu_s = \frac{0.245}{1.407}$

μ_s =0.174

When the mass on the tray is 100

$\mu_s = \frac{F}{F_N}$

$\mu_s = \frac{0.343}{1.897}$

μ_s =0.181

the same thing was done to calculate the values of μ_s

The mean

From equation (1.3)

$$\sum \mu s = (0.182 + 0.174 + 0.181 + 0.174 + 0.186 + 0.185 + 0.185 + 0.188 + 0.182 + 0.191)$$

$$\sum \mu s = \mathbf{1.828}$$

From equation (1.2)

$$\text{mean } \mu s = \overline{\mu s} = \frac{1}{N}\sum_{i=1}^{N} \mu s_i$$

$$\text{where N} = 10,\ \sum_{i=1}^{N} \mu s_i = \mu s_1 + \mu s_2 + \ldots\ldots.. + \mu s_7 = \sum \mu s = 1.828$$

$$\therefore\ \overline{\mu s} = \frac{1}{10}(1.828)$$

$$\therefore\ \overline{\mu s} = \mathbf{0.18}$$

Weight of wooden tray (W) = 0.835N

Weight of the mass hanger (S) = 0.049N

From equation 5.1 f = $\mu_s F_N$

The coefficient of static friction for the wool tray is:

When there is no mass in the tray

μs = $\frac{F}{F_N}$

μs = $\frac{0.245}{0.835}$

μs =0.293

When the mass is 50 on the tray

μs = $\frac{F}{F_N}$

μs = $\frac{0.392}{1.326}$

μs =**0.296**

When the mass on the tray is 100

μs = $\frac{F}{F_N}$

μs = $\frac{0.49}{1.816}$

μs =0.270

<u>the same thing was done to calculate the values of μs</u>

The mean

From equation (1.3)

$$\sum \mu s = (0.293 + 0.296 + 0.270 + 0.255 + 0.245 + 0.305 + 0.296 + 0.330 + 0.277 + 0.245)$$

$$\sum \mu s = \mathbf{2.812}$$

From equation (1.2)

$$\text{mean } \mu s = \overline{\mu s} = \frac{1}{N}\sum_{i=1}^{N} \mu s_i$$

$$\text{where } N = 10,\ \sum_{i=1}^{N} \mu s_i = \mu s_1 + \mu s_2 + \ldots\ldots\ldots + \mu s_7 = \sum \mu s = 2.812$$

$$\therefore\ \overline{\mu s} = \frac{1}{10}(2.812)$$

$$\underline{\therefore\ \overline{\mu s} = \mathbf{0.28}}$$

Weight of wooden tray (W) = 0.895N Weight of the mass hanger (S) = 0.049N

From equation 5.1 f = $\mu_k F_N$

The coefficient of kinetic friction for the wooden tray is:

When there is no mass in the tray

$\mu_k = \frac{F}{F_N}$

$\mu_k = \frac{0.186}{0.895}$

$\boldsymbol{\mu_k}$ **=0.208**

When the mass is 50 on the tray

$\mu_k = \frac{F}{F_N}$

$\mu_k = \frac{0.294}{1.386}$

μ_k =0.212

When the mass on the tray is 100

$\mu_k = \frac{F}{F_N}$

$\mu_k = \frac{0.363}{1.876}$

μ_k =0.193

the same thing was done to calculate the values of μ_k

The mean

From equation (1.3)

$$\sum \mu_k = (0.208 + 0.212 + 0.193 + 0.199 + 0.189 + 0.219 + 0.205 + 0.193 + 0.199 + 0.193)$$

$$\sum \mu_k = \mathbf{2.01}$$

From equation (1.2)

$$\text{mean } \mu_k = \overline{\mu_k} = \frac{1}{\mathrm{N}} \sum_{\mathrm{i}=1}^{\mathrm{N}} \mu_{k_\mathrm{i}}$$

$$\text{where N} = 10,\ \sum_{i=1}^{N} \mu_{k_i} = \mu_{k_1} + \mu_{k_2} + \ldots\ldots + \mu_{k_{10}} = \sum \mu_k = 2.01$$

$$\therefore\ \overline{\mu_k} = \frac{1}{10}(2.01)$$

$$\underline{\therefore\ \overline{\boldsymbol{\mu}_{\mathbf{k}}} = \mathbf{0.20}}$$

Weight of wooden tray (W) = 0.916N Weight of the mass hanger (S) = 0.049N

From equation 5.1 f = $\mu_k F_N$

The coefficient of kinetic friction for the wooden tray is:

When there is no mass in the tray

$\mu_k = \frac{F}{F_N}$

$\mu_k = \frac{0.147}{0.916}$

$\boldsymbol{\mu_k}$ **=0.160**

When the mass is 50 on the tray

$\mu_k = \frac{F}{F_N}$

$\mu_k = \frac{0.216}{1.407}$

$\boldsymbol{\mu_k}$ **=0.154**

When the mass on the tray is 100

$\mu_k = \frac{F}{F_N}$

$\mu_k = \frac{0.304}{1.897}$

$\boldsymbol{\mu_k}$ **=0.160**

the same thing was done to calculate the values of μ_k

The mean

From equation (1.3)

$$\sum \mu_k = (0.161 + 0.154 + 0.160 + 0.152 + 0.144 + 0.171 + 0.154 + 0.160 + 0.156 + 0.147)$$

$$\sum \mu_k = \mathbf{1.559}$$

(i) mean μ_k $(\overline{\mu_k})$

From equation (1.2)

$$\text{mean } \mu_k = \overline{\mu_k} = \frac{1}{\mathrm{N}} \sum_{\mathrm{i}=1}^{\mathrm{N}} \mu_{k_\mathrm{i}}$$

$$\text{where N} = 10, \ \sum_{\mathrm{i}=1}^{\mathrm{N}} \mu_{k_\mathrm{i}} = \mu_{k_1} + \mu_{k_2} + \ldots\ldots + \mu_{k_{10}} = \sum \mu_k = 1.559$$

$$\therefore \ \overline{\mu_k} = \frac{1}{10}(1.559)$$

$$\underline{\therefore \ \overline{\boldsymbol{\mu}_\mathbf{k}} = \mathbf{0.16}}$$

Weight of plastic tray (W) = 0.835N Weight of the mass hanger (S) = 0.049N

From equation 5.1 f = $\mu_k F_N$

The coefficient of static friction for the wooden tray is:

When there is no mass in the tray

$\mu_k = \frac{F}{F_N}$

$\mu_k = \frac{0.265}{0.835}$

$\boldsymbol{\mu_k}$ **=0.261**

When the mass is 50 on the tray

$\mu_k = \frac{F}{F_N}$

$\mu_k = \frac{0.383}{1.326}$

μ_k =0.279

When the mass on the tray is 100

$\mu_k = \frac{F}{F_N}$

$\mu_k = \frac{0.5}{1.876}$

μ_k =0.267

the same thing was done to calculate the values of μ_k

The mean

From equation (1.3)

$$\sum \mu_k = (0.261 + 0.261 + 0.276 + 0.279 + 0.281 + 0.284 + 0.267 + 0.248 + 0.283 + 0.283)$$

$$\sum \mu_k = \mathbf{2.723}$$

(ii) mean μ_k ($\overline{\mu_k}$)

From equation (1.2)

$$\text{mean } \mu_k = \overline{\mu_k} = \frac{1}{\mathrm{N}} \sum_{\mathrm{i}=1}^{\mathrm{N}} \mu_{k_\mathrm{i}}$$

$$\text{where N} = 10,\ \sum_{\mathrm{i}=1}^{\mathrm{N}} \mu_{k_\mathrm{i}} = \mu_{k_1} + \mu_{k_2} + \ldots\ldots\ldots + \mu_{k_{10}} = \sum \mu_k = 2.723$$

$$\therefore\ \overline{\mu_k} = \frac{1}{10}(2.625)$$

$$\underline{\therefore\ \overline{\boldsymbol{\mu}_\mathbf{k}} = \mathbf{0.27}}$$

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FROM THE GRAPH:

The static friction is given by:

For wooden surface from points c and d

$$Slope = \frac{\Delta f}{\Delta F_N}$$

$$Slope = \frac{0.3 - 0.2}{1.5 - 1.1}$$

$$Slope = \frac{0.11}{0.5}$$

$$\mathbf{Slope = 0.22}$$

For plastic surface from points a and b

$$Slope = \frac{\Delta f}{\Delta F_N}$$

$$Slope = \frac{0.5 - 0.26}{1.42 - 2.75}$$

$$Slope = \frac{0.24}{1.33}$$

$$\mathbf{Slope = 0.18}$$

For wool surface from points e and f

$$Slope = \frac{\Delta f}{\Delta F_N}$$

$$Slope = \frac{0.41 - 0.2}{1.5 - 0.75}$$

$$Slope = \frac{0.21}{0.75}$$

$$\mathbf{Slope = 0.28}$$

The kinetic friction is given by:

For wooden surface from points c and d

$$Slope = \frac{\Delta f}{\Delta F_N}$$

$$Slope = \frac{0.3 - 0.2}{1.5 - 1.1}$$

$$Slope = \frac{0.11}{0.5}$$

$$\mathbf{Slope = 0.20}$$

For plastic surface from points a and b

$$Slope = \frac{\Delta f}{\Delta F_N}$$

$$Slope = \frac{0.3 - 0.08}{1.9 - 0.5}$$

$$Slope = \frac{0.22}{1.4}$$

$$\mathbf{Slope = 0.16}$$

For wool surface from points e and f

$$Slope = \frac{\Delta f}{\Delta F_N}$$

$$Slope = \frac{0.47 - 0.2}{1.75 - 0.75}$$

$$Slope = \frac{0.27}{1}$$

$$\mathbf{Slope = 0.27}$$

<u>The value obtained from the graph are the same as the average of the values calculated from the obtained data.</u>

Answers to Questions 1:

a. The coefficient of static friction is higher than the coefficient of kinetic friction for the same surfaces.
b. The coefficient of static friction and the coefficient of kinetic friction are highest in wool then wood and lowest in plastic.
c. The coefficient of static friction and the coefficient of kinetic friction are low than and inversely proportional to the normal forces.

DISCUSSION

The coefficient of static friction was calculated by dividing the normal force into the friction force, $\mu_s = \frac{F}{F_N}$ .Similarly the coefficient of kinetic friction was calculated by dividing the normal force into the friction force, $\mu_k = \frac{F}{F_N}$. The coefficient of static friction of wood, plastic and wool were found be 0.22,0.18 and 0.28 respectively, and their coefficient of kinetic friction were found to be 0.20,0.16 and 0.27 respectively. .

CONCLUSION

The objective of the experiment was achieved as the coefficients of static friction and kinetic friction of wood, plastic and wool were determined. In addition the experiment showed that the amount of force required to move an object from rest is greater the force required to keep it moving constantly. This means that the coefficient of static friction is greater than the coefficient of kinetic friction. furthermore the rough surfaces have a higher coefficients of static friction and kinetic friction than smooth surfaces.

REFERENCES

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