Kwun Tong Government Secondary School

Advanced Level Physics (TAS)

<u>Experiment Report</u>

Experiment No.: 1

Title: Force of friction

Date of Experiment: 2006/10/31

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TAS Group	15
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Objective:

1. To study the effects of the normal force, and surface area on the force of friction using a block.
2. To estimate the coefficients of static and kinetic friction.

Apparatus:

Instrument		Description
Wooden block	*x 4*	200g *x 4*
Spring balance	*x 1*	DCS/PL/2-2 0 - 10N The smallest division = 0.2 N
Tripe beam balance	*x 1*	0 – 500g The smallest division = 0.1g
Frictional paper	*x 1*	/
Rubber band	*Several*	/

Theory:

Limiting static friction f_L:

Friction always opposes motion. Larger forces tending to produce the motion, larger friction is. However, it cannot increase indefinitely.

For example, when a body is in contact with a rough surface frictional forces arise at the contact surface if the body is subjected to an applied force. When the applied force exceeds the limiting static friction f_L, the body will start to slip over the rough surface. And the value of f_L is roughly proportional to the normal force *R*.

$$f_L = \mu_s R$$

where μ_s is the coefficient of static friction at maximum at the contact surface.

Kinetic friction f_k:

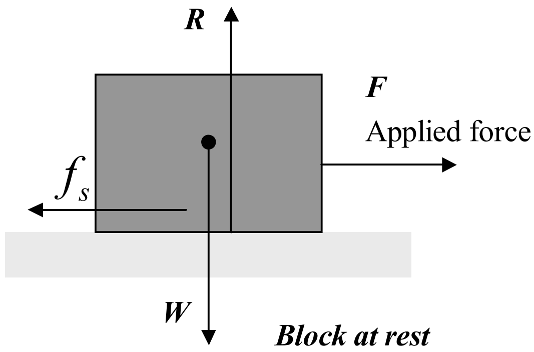
However, the friction acting on a resting block is less than f_L until the block starts to move. For example, once the body starts to move over the rough surface, the friction would decrease slightly to a value known as kinetic friction f_k. So f_k is slightly less than f_L but it is still approximately proportional to *R*.

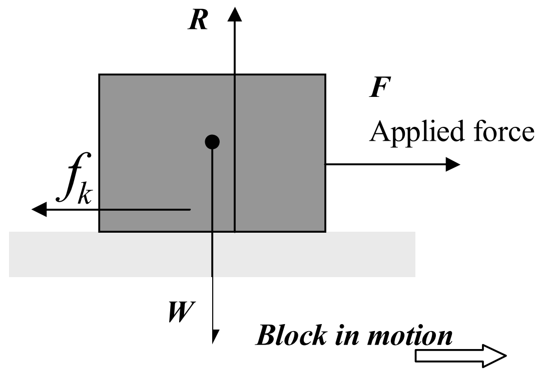
$$f_k = \mu_k R$$

where μ_k is the coefficient of kinetic friction at the contact surface.

f_k remains constant even the applied force is increased further.

μ_k is slightly less than μ_s.

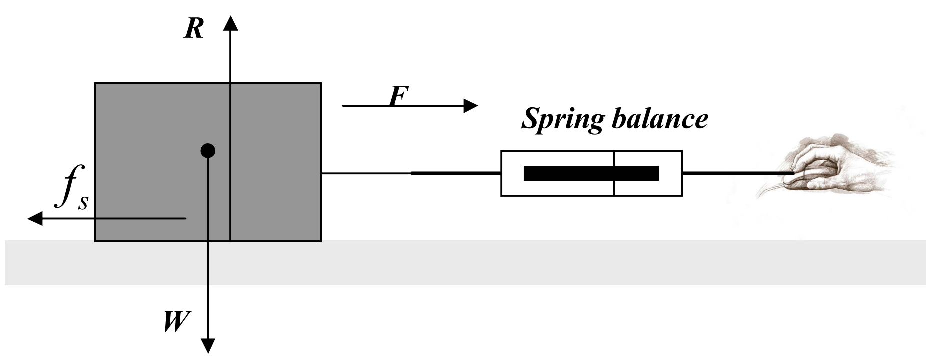




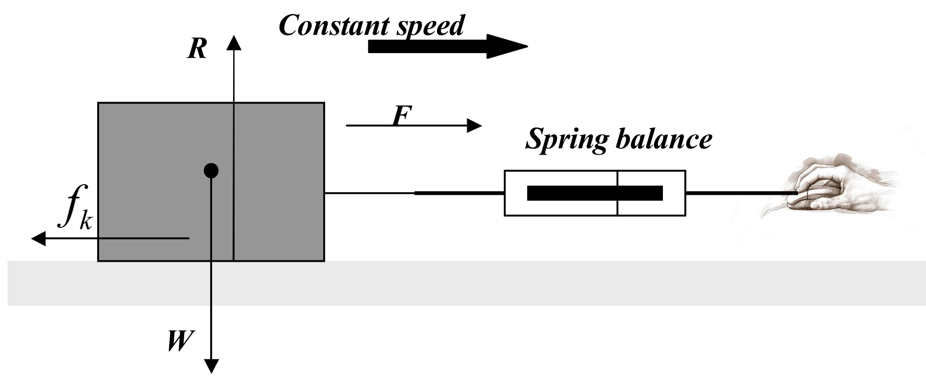
Procedure:

A. **Frictional force and applied force**

1. The set up was connected as shown below.
   → A wooden block was place on the frictional paper on the table.
   → The block was pulled with a spring balance.
   And the spring balance was **kept in horizontal position**.



2. The pulling force was increased slowly and gradually from zero until the block **started to move**. 5 readings of the spring balance were taken during the process.
3. The moving block was pulled **at a constant speed** as shown below.
   5 readings of the spring balance was taken during the process



4. A graph of friction force (static and kinetic) against the applied force was plotted.

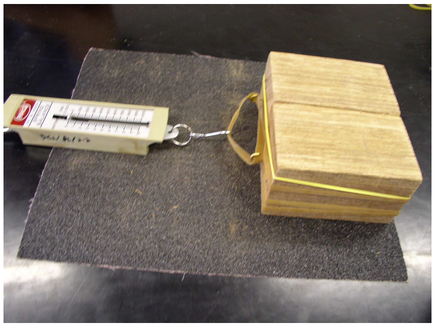
B. **Coefficients of friction for the wooden blocks**

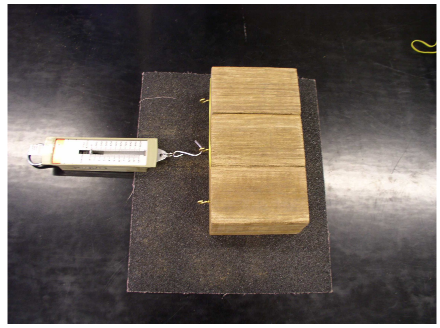
5. The spring balance was connected to a wooden block. It was then pulled slowly until the block started to move. The value of the applied force ($F = f_L$) that just set the block in motion was recorded.
6. The moving block was pulled at a constant speed. The applied force($F = f_k$) from the spring balance was recorded.
7. Steps 5 and 6 were repeated by topping one wooden block at a time until all blocks have been used. In each case, the normal force was equal to the weight of the blocks. The blocks were weighed. All the data in steps 5 and 6 were tabulated.
8. The graph of the limiting static friction f_L against the normal force R was plotted.
9. The graph of the kinetic friction f_L against the normal force R was plotted.

C. Contact surface area

10. The spring balance was connected to a wooden block. Then another wooden block was piled on the top of the original wooden block. The spring balance attached to the two blocks in pile was pulled at a constant speed. The applied force ($F = f_L$) from the spring balance was recorded.
11. The two wooden blocks were placed side by side by the rubber bands instead of piling up. Then the spring balance was connected to them by rubber band. The spring balance was pulled to set the system moving at a constant speed. The applied force ($F = f_L$) from the spring balance was recorded.
12. Repeat steps 12 and 13 for 3 blocks and 4 blocks.

13. The data in steps 10-12 was tabulated.





Assumption:

1. The spring balance was kept in horizontal position.
2. The rubber bands had no mass.
3. The gravitational acceleration is $10\ ms^{-1}$.
4. The blocks were pulled to move at a constant speed.

Result:

A. Frictional force and applied force

The 5 readings of spring balance which represent f_L.

f_L /N	2.0	1.9	1.8	2.0	2.1

The mean of f_L: $\frac{2.0+1.9+1.8+2.0+2.1}{5} = 1.96$ N

The 5 readings of spring balance which represent f_k.

f_k /N	1.3	1.4	1.5	1.4	1.3

The mean of f_k: $\frac{1.3+1.4+1.5+1.4+1.3}{5} = 1.38$ N

Graph of frictional force against the applied force

B. Coefficients of friction for wooden blocks

Number of blocks		1	2	3	4
Applied force F /N	Limiting static friction f_L	1.96	3.0	5.4	7.3
	Kinetic friction f_k	1.38	2.4	3.4	5.2
Normal force R / N		1.96	3.92	5.89	7.89

Graph of the limiting static friction against the n ormal force *R*

$y = mx + C$ $\therefore$ $y = f_L$ $m = \mu_s$

$f_L = \mu_s R$ $x = R$ $C = 0$

m = slope, C = y-intercept

Graph of the limiting static friction against the normal force *R*

$$m = \frac{4.0 - 1.1}{4.5 - 1.5} = 0.97$$

$$m_1 = \frac{4.9 - 1.4}{5.5 - 1.5} = 0.88$$

$$m_2 = \frac{5.1 - 1.0}{5.5 - 2.0} = 1.17$$

$$C = -0.35$$
$$C_1 = 0.1$$
$$C_2 = -1.35$$

Take the maximum difference of the slopes and y-intercepts as the uncertainly.

$$\Delta m_1 = |m - m_1| = |0.97 - 0.88| = 0.09$$

$$\Delta m_2 = |m - m_2| = |0.97 - 1.17| = 0.20$$

Maximum uncertainty in slope $\Delta m = \max\{\Delta m_1, \Delta m_2\} = 0.20$

$$\Delta C_1 = |C - C_1| = |-0.35 - 0.1| = 0.36$$

$$\Delta C_2 = |C - C_2| = |-0.35 - (-1.35)| = 1.00$$

Maximum uncertainty in slope $\Delta C = \max\{\Delta C_1, \Delta C_2\} = 1.00$

Thus, slope $= 0.97 \pm 0.20$

y-intercept $= -0.35 \pm 1.00$

∵ $\mu_s = m$

$\mu_s = 0.97 \pm 0.20$

∴The coefficient of static friction was found to be 0.97 ± 0.20.

$y = mx + C$ $\therefore$ $y = f_k$ $m = \mu_k$

$f_k = \mu_k R$ $x = R$ $C = 0$

m = slope, C = y-intercept

<u>Graph of the kinetic friction against the normal force *R*</u>

$$m = \frac{3.8 - 0.3}{6.0 - 0.5} = 0.64$$

$$m_1 = \frac{4.3 - 1.2}{7.0 - 1.5} = 0.56$$

$$m_2 = \frac{4.6 - 0.7}{7.0 - 1.5} = 0.71$$

$C = -0.02$

$C_1 = 0.35$

$C_2 = -0.35$

Take the maximum difference of the slopes and y-intercepts as the uncertainly.

$$\Delta m_1 = |m - m_1| = |0.64 - 0.56| = 0.08$$

$$\Delta m_2 = |m - m_2| = |0.64 - 0.71| = 0.07$$

Maximum uncertainty in slope $\Delta m = \max\{\Delta m_1, \Delta m_2\} = 0.08$

$$\Delta C_1 = |C - C_1| = |-0.02 - 0.35| = 0.37$$

$$\Delta C_2 = |C - C_2| = |-0.02 - (-0.35)| = 0.33$$

Maximum uncertainty in slope $\Delta C = \max\{\Delta C_1, \Delta C_2\} = 0.37$

Thus, slope $= 0.64 \pm 0.08$

y-intercept $= -0.02 \pm 0.37$

$\because \mu_k = m$

$\mu_k = 0.64 \pm 0.08$

$\therefore$ The coefficient of kinetic friction was found to be 0.64 ± 0.08.

C. Contact surface area

Number of blocks	2		3		4	
	Pile up	Side by side	Pile up	Side by side	Pile up	Side by side
Applied Force F /N (Kinetic friction f_k)	2.4	2.2	3.4	3.2	5.2	5
Normal force R /N (Weight of the blocks)	3.92		5.89		7.89	

Disscusion:

1. Description of the shape of the graph of frictional force against the applied force

The graph was like a right angle triangle and followed by a rectangle with smaller height. The triangle represented the block at rest and the rectangle represented the block in motion. The height of the triangle was the limiting friction f_L and the height of the rectangle was the kinetic friction f_k.

According to the graph, when the applied force is smaller then the applied force is smaller than the static friction, the block would stay at rest.

2. The relationship between the friction and the normal reaction *R*

From the graphs of the static friction and kinetic friction against the normal force *R*, it was known that both limiting friction and kinetic friction were directly proportional to the normal reaction.

3. Comparing the coefficient of static friction μ_s and the coefficient of kinetic friction μ_k

The coefficient of static friction μ_s was found to be 0.97 ± 0.20 .

The coefficient of kinetic friction μ_k was found to be 0.64 ± 0.08 .

μ_k is smaller than μ_s. The reason is that refer to Newton's second law, *f=ma*, to make a body start moving, a net force is needed. The applied force must be slight higher than the friction to produce acceleration. However, to keep a body moving, no net force is needed. The applied force was only to cancel the friction – kinetic friction.

4. Comparing the results of the blocks in pile and placed side by side

The kinetic friction μ_k of the blocks in pile and placed side by side were quite similar but μ_k of the blocks placed side by side were slightly smaller than another.

The results indicated the friction was independent of the contact area. Besides, the larger contact area could reduce pressure and thus reduce wear. Also, heat could be conducted away faster. So μ_k of the blocks placed side by side were slightly smaller.

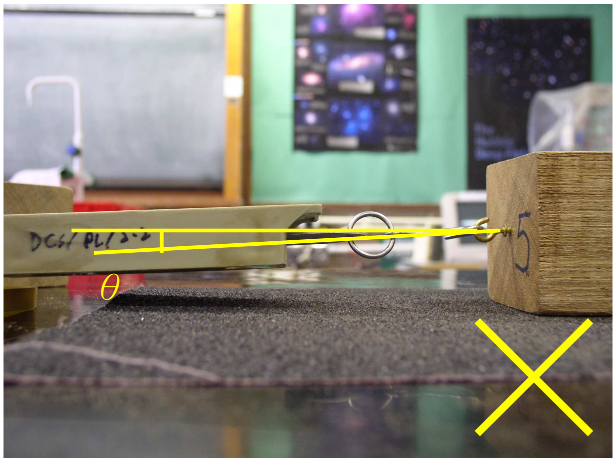
5. Sources of error and improvements

a. The friction on the frictional paper was unevenly distributed

The degree of roughness was various with the position on the frictional paper since the paper was wear away due to rubbing by the block. To prevent this, a new friction paper should be used for the experiment instead of the old one to make sure the friction is evenly distributed.

b. The pulling force was not in horizontal position

If the spring balance were not kept in horizontal position, the pulling force would be larger than the horizontal force. And make the results inaccurate. As a result, it was important to keep the pulling force in horizontal position.



Let pulling force be F, horizontal force be x

$F\cos\theta = x$

$\because 0 < \cos\theta < 1$

$\therefore F > x$

c. Mass of the rubber bands

The rubber bands used to keep the wooden blocks side by side had their own mass. So the normal force R didn't only involved the weight of the blocks but also the weight of the rubber bands. It would affect the results if the mass of the rubber band were neglected. To improve the accuracy, the weight of the rubber bands should be measured and involved in R too.

d. Taking readings of the spring balance

In step A3, B6, C12, readings of the spring balance were taken during the blocks were moving at a constant speed. The difficulty was to take the readings in that instantaneous motion. It was easy to take inaccurate reading and hence affect the data. The only way to improve was doing the procedure repeatedly by several people and then taking the average of the readings.

Conclusion:

Through the experiment, the coefficient of static friction was found to be 0.97 ± 0.20. The coefficient of kinetic friction was found to be 0.64 ± 0.08. μ_k is smaller than μ_s, so less force is needed to keep the block moving than to start moving it. Both limiting friction and kinetic friction were directly proportional to the normal reaction but are independent of the surface areas of the contact surface.