EXPERIMENT 7

AIM

To study the relation between force of limiting friction and normal reaction and to find the coefficient of friction between surface of a moving block and that of a horizontal surface.

APPARATUS AND MATERIAL REQUIRED

A wooden block with a hook, a horizontal plane with a glass or laminated table top (the table top itself may be used as a horizontal plane), a frictionless pulley which can be fixed at the edge of the horizontal table/plane, spirit level, a scale, pan, thread or string, spring balance, weight box and five masses of 100 g each.

TERMS AND DEFINITIONS

Friction: The tendency to oppose the relative motion between two surfaces in contact is called friction.

Static Friction: It is the frictional force acting between two solid surfaces in contact at rest but having a tendency to move (slide) with respect to each other.

Limiting Friction: It is the maximum value of force of static friction when one body is at the verge of sliding with respect to the other body in contact.

Kinetic (or Dynamic) Friction: It is the frictional force acting between two solid surfaces in contact when they are in relative motion.

PRINCIPLE

The maximum force of static friction, *i.e.*, limiting friction, F_L, between two dry, clean and unlubricated solid surfaces is found to obey the following empirical laws:

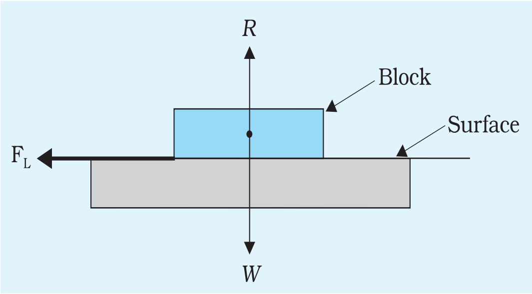

Fig. E 7.1: *The body is at rest due to static friction*

(i) The limiting friction is

directly proportional to the normal reaction, R, which is given by the total weight W of the body (Fig. E 7.1). The line of action is same for both W and R for horizontal surface,

$$F_L \propto R \Rightarrow F_L = \mu_L R$$

$$\text{i.e.} \quad \mu_L = \frac{F_L}{R}$$

Thus, the ratio of the magnitude of the limiting friction, F_L, to the magnitude of the normal force, R, is a constant known as the coefficient of limiting friction (μ_L) for the given pair of surfaces in contact.

(ii) The limiting friction depends upon the nature of surfaces in contact and is nearly independent of the surface area of contact over wide limits so long as normal reaction remains constant.

Note that $F_L = \mu_L R$ is an equation of a straight line passing through the origin. Thus, the slope of the straight-line graph between F_l (along Y-axis) and R (along X-axis) will give the value of coefficient of limiting friction μ_L.

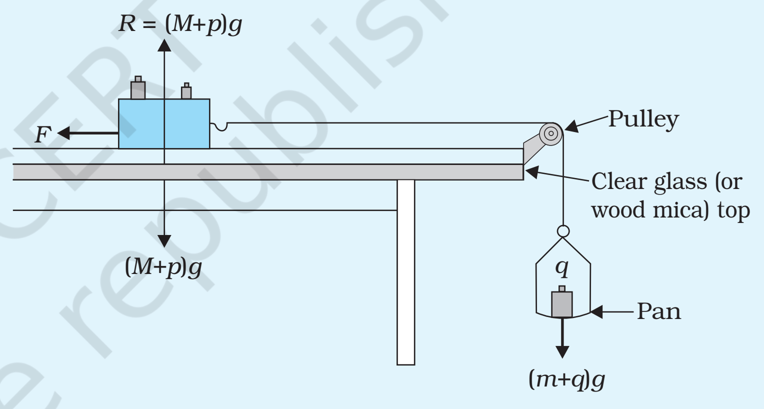

Fig. E 7.2: *Experimental set up to study limiting friction*

In this experiment, the relationship between the limiting friction and normal reaction is studied for a wooden block. The wooden block is made to slide over a horizontal surface (say glass or a laminated surface) (Fig. E 7.2).

PROCEDURE

1. Find the range and least count of the spring balance.
2. Measure the mass (M) of the given wooden block with hooks on its sides and the scale pan (m) with the help of the spring balance.
3. Place the glass (or a laminated sheet) on a table and make it horizontal, if required, by inserting a few sheets of paper or cardboard below it. To ensure that the table-top surface is horizontal use a spirit level. Take care that the top surface must be clean and dry.

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4. Fix a frictionless pulley on one edge of table-top as shown in Fig. E 7.2. Lubricate the pulley if need be.

5. Tie one end of a string of suitable length (in accordance with the size and the height of the table) to a scale pan and tie its other end to the hook of the wooden block.

6. Place the wooden block on the horizontal plane and pass the string over the pulley (Fig. E7.2). Ensure that the portion of the string between pulley and the wooden block is horizontal. This can be done by adjusting the height of the pulley to the level of hook of block.

7. Put some mass (q) on the scale pan. Tap the table-top gently with your finger. Check whether the wooden block starts moving.

8. Keep on increasing the mass (q) on the scale pan till the wooden block just starts moving on gently tapping the glass top. Record the total mass kept on the scale pan in Table E 7.1.

9. Place some known mass (say p) on the top of wooden block and adjust the mass (q') on the scale pan so that the wooden block alongwith mass p just begins to slide on gently tapping the table top. Record the values of p' and q' in Table E 7.1.

10. Repeat step 9 for three or four more values of p and record the corresponding values of q in Table E 7.1. A minimum of five observations may be required for plotting a graph between F_L and R.

OBSERVATIONS

1. Range of spring balance = ... to ... g
2. Least count of spring balance = ... g
3. Mass of the scale pan, (m) = ... g
4. Mass of the wooden block (M) = ... g
5. Acceleration due to gravity (g) at the place of experiment= ... m/s^2

Table E 7.1: Variation of Limiting Friction with Normal

S. No.	Mass on the wooden block (p) (g)		Normal force R due to mass (M+p)		Mass on the pan (q) g	Force of limiting friction F_L	Coefficient of friction $\mu_L = \frac{F_L}{R}$	Mean μ_L
	(g)	(kg)	N	(g)	(kg)	(N)		
1								
2								
3								
4								
5								

Reaction

GRAPH

Plot a graph between the limiting friction (F_L) and normal force (R) between the wooden block and the horizontal surface, taking the limiting friction F_L along the y-axis and normal force R along the x-axis. Draw a line to join all the points marked on it (Fig. E 7.3). Some points may not lie on the straight-line graph and may be on either side of it. Extend the straight line backwards to check whether the graph passes through the origin. The slope of this straight-line graph gives the coefficient of limiting friction (μ_L) between the wooden block and the horizontal surface. To find the slope of straight line, choose two points A and B that are far apart from each other on the straight line as shown in Fig. E 7.3. Draw a line parallel to x-axis through point A and another line parallel to y-axis through point B. Let point Z be the point of intersection of these two lines. Then, the slope μ_L of straight line graph AB would be

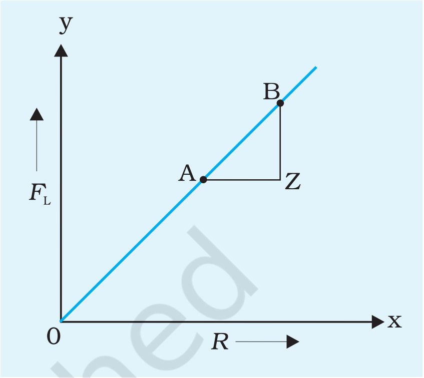

Fig. E 7.3: *Graph between force of limiting friction F_L and normal reaction, R*

$$\mu_L = \frac{F_L}{R} = \frac{BZ}{AZ}$$

RESULT

The value of coefficient of limiting friction μ_L between surface of wooden block and the table-top (laminated sheet/glass) is:

(i) From calculation (Table E 7.1) = ...

(ii) From graph = ...

PRECAUTIONS

1. Surface of the table should be horizontal and dust free.
2. Thread connecting wooden block and pulley should be horizontal.
3. Friction of the pulley should be reduced by proper oiling.
4. Table top should always be tapped gently.

SOURCES OF ERROR

1. Always put the mass at the centre of wooden block.

2. Surface must be dust free and dry.
3. The thread must be unstretchable and unspun.

DISCUSSION

1. The friction depends on the roughness of the surfaces in contact. If the surfaces in contact are ideally (perfactly) smooth, there would be no friction between the two surfaces. However, there cannot be an ideally smooth surface as the distribution of atoms or molecules on solid surface results in an inherent roughness.

2. In this experimental set up and calculations, friction at the pulley has been neglected, therefore, as far as possible, the pulley, should have minimum friction as it cannot be frictionless.

3. The presence of dust particles between the wooden block and horizontal plane surface may affect friction and therefore lead to errors in observations. Therefore, the surface of the horizontal plane and wooden block in contact must be clean and dust free.

4. The presence of water or moisture between the wooden block and the plane horizontal surface would change the nature of the surface. Thus, while studying the friction between the surface of the moving body and horizontal plane these must be kept dry.

5. Elasticity of the string may cause some error in the observation. Therefore, a thin, light, strong and unspun cotton thread must be used as a string to join the scale pan and the moving block.

6. The portion of string between the pulley and wooden block must be horizontal otherwise only a component of tension in the string would act as the force to move the block.

7. It is important to make a judicious choice of the size of the block and set of masses for this experiment. If the block is too light, its force of limiting friction may be even less than the weight of empty pan and in this situation, the observation cannot be taken with the block alone. Similarly, the maximum mass on the block, which can be obtained by putting separate masses on it, should not be very large otherwise it would require a large force to make the block move.

8. The additional mass, p, should always be put at the centre of wooden block.

9. The permissible error in measurements of coefficient of friction

$$= \frac{\Delta F_L}{F_L} + \frac{\Delta R}{R} = \ldots$$

SELF ASSESSMENT

1. On the basis of your observations, find the relation between limiting friction and the mass of sliding body.
2. Why do we not choose a spherical body to study the limiting friction between the two surfaces?
3. Why should the horizontal surfaces be clean and dry?
4. Why should the portion of thread between the moving body and pulley be horizontal?
5. Why is it essential in this experiment to ensure that the surface on which the block moves should be horizontal?
6. Comment on the statement: "The friction between two surfaces can never be zero".
7. In this experiment, usually unpolished surfaces are preferred, why?
8. What do you understand by self-adjusting nature of force of friction?
9. In an experiment to study the relation between force of limiting friction and normal reaction, a body just starts sliding on applying a force of 3 N. What will be the magnitude of force of friction acting on the body when the applied forces on it are 0.5 N, 1.0 N, 2.5 N, 3.5 N, respectively.

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

1. To study the effect of the nature of sliding surface. [**Hint:** Repeat the same experiment for different types of surfaces say, plywood, carpet etc. Or repeat the experiment after putting oil or powder on the surface.]
2. To study the effect of changing the area of the surfaces in contact. [**Hint:** Place the wooden block vertically and repeat the experiment. Discuss whether the readings and result of the experiment are same.]
3. To find the coefficient of limiting friction by sliding the block on an inclined plane.