EXPERIMENT 8

AIM

To find the downward force, along an inclined plane, acting on a roller due to gravity and study its relationship with the angle of inclination by plotting graph between force and sin θ.

APPARATUS AND MATERIAL REQUIRED

Inclined plane with protractor and pulley, roller, weight box, spring balance, spirit level, pan and thread.

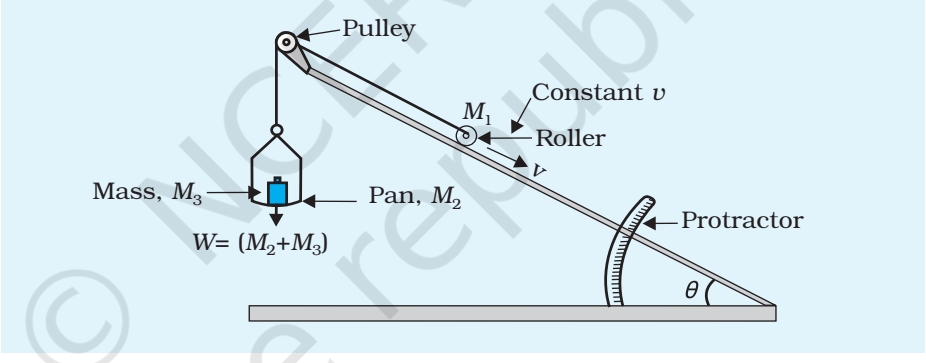

Fig. E 8.1: *Experimental set up to find the downward force along an inclined plane*

PRINCIPLE

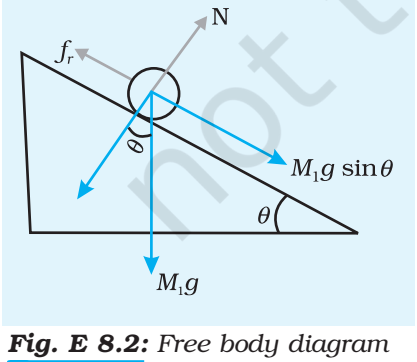

Fig. E 8.2: *Free body diagram*

Consider the set up shown in Fig. E 8.1. Here a roller of mass M_1 has been placed on an inclined plane making an angle θ with the horizontal. An upward force, along the inclined plane, could be applied on the mass M_1 by adjusting the weights on the pan suspended with a string while its other end is attached to the mass through a pulley fixed at the top of the inclined plane. The force on the the mass M_1 when it is moving with a constant velocity v will be

$$W = M_1 g \sin\theta - f_r$$

where f_r is the force of friction due to rolling, M_1 is mass of roller and W is the total tension in the string

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(W = weight suspended). Assuming there is no friction between the pulley and the string.

PROCEDURE

1. Arrange the inclined plane, roller and the masses in the pan as shown in Fig. E. 8.1. Ensure that the pulley is frictionless. Lubricate it using machine oil, if necessary.
2. To start with, let the value of W be adjusted so as to permit the roller to stay at the top of the inclined plane at rest.
3. Start decreasing the masses in small steps in the pan until the roller just starts moving down the plane with a constant velocity. Note W and also the angle θ. Fig. E 8.2 shows the free body diagram for the situation when the roller just begins to move downwards.
4. Repeat steps 2 and 3 for different values of θ. Tabulate your observations.

OBSERVATIONS

Acceleration due to gravity, g = ... ms^{-2}

Mass of roller, m = (M_1) g

Mass of the pan = (M_2) g

Table E 8.1

S. No.	θ °	$\sin\theta$	Mass added to pan M_3	Force $W = (M_2 + M_3)\ g$ (N)
1				
2				
3				

PLOTTING GRAPH

Plot graph between $\sin\theta$ and the force W (Fig. E 8.3). It should be a straight line.

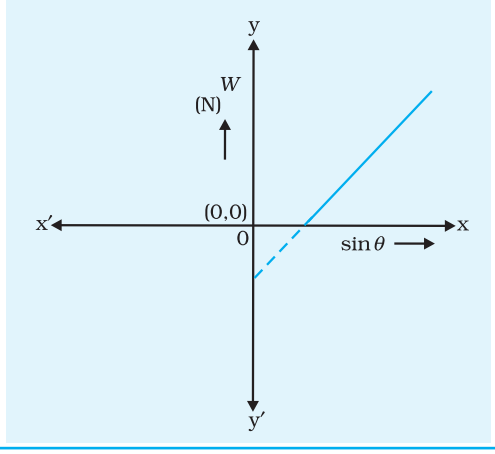

Fig. E 8.3: *Graph between W and sin θ*

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RESULT

Therefore, within experimental error, downward force along inclined plane is directly proportional to sin θ, where θ is the angle of inclination of the plane.

PRECAUTIONS

1. Ensure that the inclined plane is placed on a horizontal surface using the spirit level.
2. Pulley must be frictionless.
3. The weight should suspend freely without touching the table or other objects.
4. Roller should roll smoothly, that is, without slipping.
5. Weight, W should be decreased in small steps.

SOURCES OF ERROR

1. Error may creep in due to poor judgement of constant velocity.
2. Pulley may not be frictionless.
3. It may be difficult to determine the exact point when the roller begins to slide with constant velocity.
4. The inclined surface may not be of uniform smoothness/roughness.
5. Weights in the weight box may not be standardised.

DISCUSSION

As the inclination of the plane is increased, starting from zero, the value of $mg \sin\theta$ increases and frictional force also increases accordingly. Therefore, till limiting friction $W = 0$, we need not apply any tension in the string.

When we increase the angle still further, net tension in the string is required to balance ($mg \sin\theta - f_r$) or otherwise the roller will accelerate downwards.

It is difficult to determine exact value of W. What we can do is we find tension W_1 ($< W$) at which the roller is just at the verge of rolling down and W_2 ($> W$) at which the roller is just at the verge of moving up. Then we can take

$$W = \frac{(W_1 + W_2)}{2}$$

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SELF ASSESSMENT

1. Give an example where the force of friction is in the same direction as the direction of motion.
2. How will you use the graph to find the co-efficient of rolling friction between the roller and the inclined plane?
3. What is the relation between downward force and angle of inclination of the plane?
4. How will you ensure that the roller moves upward/downward with constant velocity?

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

1. From the graph, find the intercept and the slope. Interpret them using the given equation.
2. Allow the roller to move up the inclined plane by adjusting the mass in the pan. Interpret the graph between W' and sin θ where W′ is the mass in pan added to the mass of the pan required to allow the roller to move upward with constant velocity.

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