Friction and Newton's Laws

Equipment

1	Dynamics System	ME-6955
1	Photogate	ME-9498A
1	Photogate Bracket	(in ME-8998)
1	Elastic Bumper	ME-8998
1	Discover Friction	ME-8574
1	Mass and Hanger Set	ME-8979
1	Braided String	SE-8050
	Required, but not included:	
1	Balance	SE-8723

Introduction

The photogate is used to measure the acceleration of the Friction Tray as it is being pulled by the falling mass.

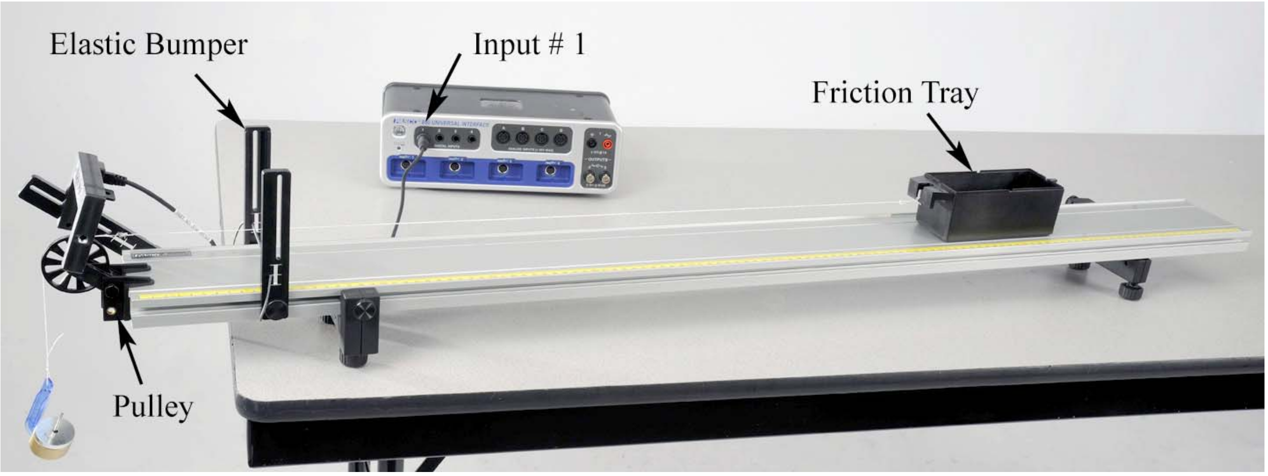

Figure 1: Measuring Sliding Friction

Setup

1. The Elastic Bumper should be placed about 15 cm from the end of the track as shown in Figure 1. The Clamp-on Pulley should have the pulley in the upper set of holes as shown.

2. The Photogate Bracket (see Figure 2) is cantilevered out over the end of the track. Note that the bracket is put on "reversed" so that it doesn't key into the track. This allows you to angle the bracket and Photogate.

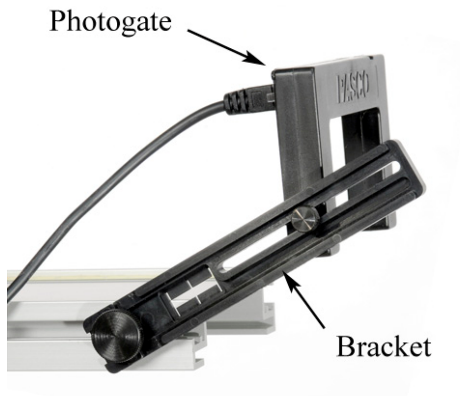

Figure 2: Reversed Bracket

3. Plug the Photogate into Digital Input #1 and choose Photogate with Pulley.

4. Level the track. If you don't have a level, you can use a PAScar, and adjust the track so the cart doesn't roll.

5. Determine the mass of the tray before attaching string! Use the tray with the cork surface.

6. Cut a piece of string about 1.2 m long. Tie to one end of the tray as shown in Figure 4.

7. Run the string over the pulley and down to the floor. When the tray reaches the end of the track, you want it to hit the Elastic Bumper before the hanging mass reaches the floor. If necessary, shorten the string.

8. Tie a loop in the string to hang the mass.

9. Adjust the pulley height so the string runs parallel to the track. Adjust the position of the Photogate so that the pulley spokes break the beam.

10. In PASCO Capstone, create a graph of Linear Speed vs. time.

Theory

The mass on the hanger (see Fig. 4) is falling and the Friction Tray is sliding to the left. The free-body diagrams (see Fig, 3) show the forces acting on each of the masses. The tension, T, is assumed equal for both parts of the string. Sign convention is adopted such that the acceleration, a, for the tray is positive to the left, and acceleration for the falling mass is positive downward.

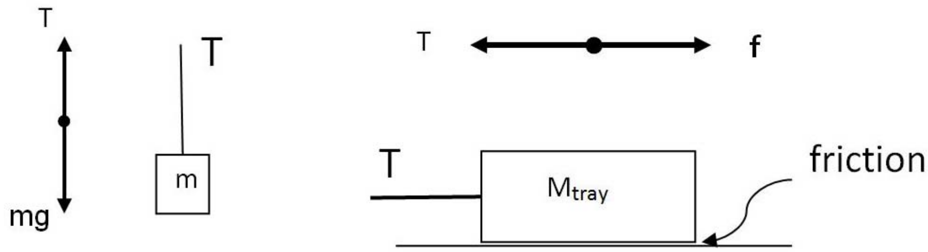

Figure 3: Free-body diagrams for both masses

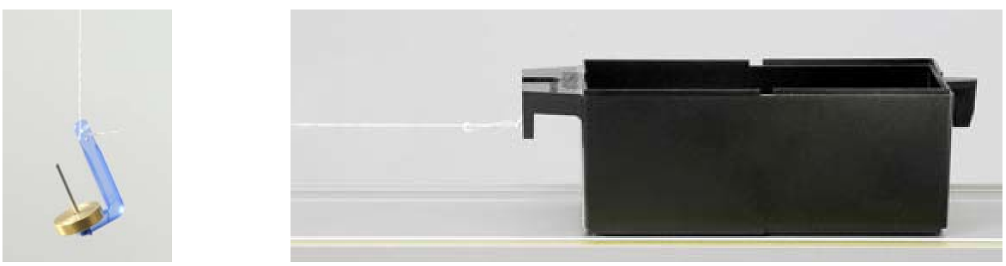

Figure 4: Falling mass pulls the Friction Tray

m = hanging mass
M_{tray} = total mass of friction tray plus mass bar

Applying Newton's 2nd Law to the hanging mass gives

$$T = m(g-a) \quad (1)$$

Applying Newton's 2nd Law to the friction tray gives

$$M_{tray}\, a = T - f \quad (2)$$

where the frictional force, f, is

$$f = \mu N \quad (3)$$

Since the track is level and the string is pulling horizontally on the Friction Tray, the Normal Force, N, is

$$N = M_{tray}\, g \quad (4)$$

Procedure – Static Friction

1. Figure 5 shows the forces on the tray perpendicular to the track for this experiment. Sate at least two examples where Eqn. (4) would not be valid.

2. For the special case of the tray stopped (no acceleration), confirm that equations 1 through 4 can be combined to yield

$$\mu_s = m/M_{tray} \qquad (5)$$

   where μ_s is the coefficient of static friction.

3. Place one mass bar in the cork Friction Tray. Make sure the mass bar is centered side to side.

4. Put about 100 g on the mass hanger. You should be able to position the tray on the track and not have it slip, but if you cannot keep it from slipping, decrease the hanging mass.

5. Keep trying to increase the hanging mass. Record the maximum hanging mass that will not cause the tray to break free and move. Try several times in several different track locations. Try pushing down on the tray and releasing as gently as possible. Make sure the hanging mass is not swinging. You do not have to keep track of all your values, just record the single absolute max.

6. Use your max value and Eqn. (5) to calculate the coefficient of static friction.

7. Coefficients of friction are always between a pair of surfaces. One surface is cork: What is the other?

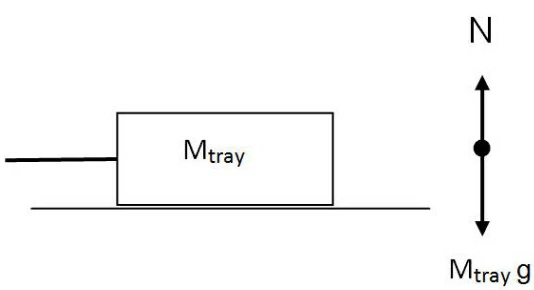

Figure 5: Normal Force

Procedure – Kinetic Friction

8. Place the maximum amount of mass, determined previously, on the mass hanger.

9. Hold the tray in place and click on Record. Release the tray and give it a small push.

10. Click on Stop after the tray reaches the bumper.

11. Use the Slope tool to examine the slope in various areas. If there is not a straight region, try another run. Why is it not more uniform?

12. Take several runs and determine an average acceleration.

13. Use equations 1 and 2 to calculate the frictional force.

14. Use equations 3 and 4 to calculate the kinetic frictional coefficient.

15. How does this compare to the value you got for the static coefficient?

Further Study

16. Decrease the hanging mass by about 50 g. If the tray still moves on its own, decrease the hanging mass even further.

17. Click on Record and give the tray a strong push. You want it to coast most of the way towards the bumper before it stops. Click on Stop

18. Calculate the kinetic frictional coefficient as you did previously. Hint: You must take into account the negative acceleration! How does this value compare?

19. Add the second mass bar to the tray, and add enough mass to the hanging mass so that it easily breaks free by itself.

20. Use equations 1 through 4 to predict the acceleration.

21. Measure the acceleration and compare to your prediction.