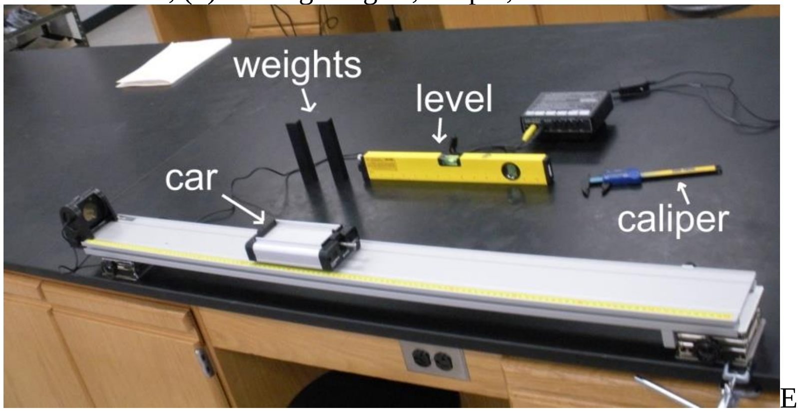
Rectilinear Motion

Purpose: Students will analyze the relationship between the angle of an incline and the normal force and with the parallel forces of an object on the incline. The student will also calculate μ and determine g while using acceleration at different inclines.

Equipment: 1.2m Pascar Dynamic track with PasCar, Computer interface (Science Workshop), Motion sensor, (2) 500 mg weights, caliper, and level.



Experimental setup

$d = \frac{1}{2}at^2 + v_0 t + d_0$, for a car on the incline plane.

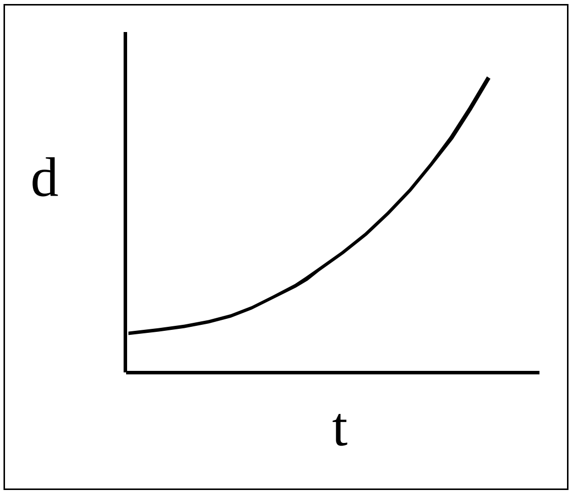


Figure 1

Fit to:

$y = \alpha x^2 + \beta x + x_0$

$\alpha = \frac{1}{2}a$

$m\vec{a} = \vec{F}_T = \vec{F}_D - \vec{F}_F$ from Figure 2.

$F_D = mg\sin\theta$

$F_F = \mu F_N$

$F_N = mg\cos\theta \approx mg \quad (for\ small\ \theta)$

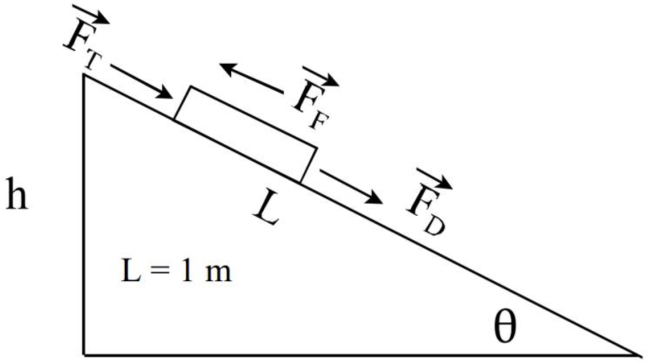


Figure 2

$$ma = mg\sin\theta - \mu mg \qquad [\sin\theta = \frac{h}{L}]$$

$$a = g(\sin\theta - \mu)$$

$$a_1 = g(sin\theta_1 - \mu_1)$$

$$= g(\frac{h_1}{L} - \mu_1)$$

$$\mu_1 = \frac{h_1}{L} - \frac{a_1}{g}$$

$$\frac{a_2}{a_1} = \frac{\left(\frac{h_2}{L} - \mu_2\right)}{\left(\frac{h_1}{L} - \mu_1\right)} = R_{21}\ ,\ \ \frac{a_3}{a_1} = \frac{\left(\frac{h_3}{L} - \mu_3\right)}{\left(\frac{h_1}{L} - \mu_1\right)} = R_{31},\ \ \frac{a_3}{a_2} = \frac{\left(\frac{h_3}{L} - \mu_3\right)}{\left(\frac{h_2}{L} - \mu_2\right)} = R_{32}$$

assuming $\mu_2 \approx \mu_1 \approx \mu$, let μ = μ_{21} then,

$$\mu_{21} = \frac{\left(R_{21}\frac{h_1}{L} - \frac{h_2}{L}\right)}{(R_{21}-1)},\ \ \mu_{31} = \frac{\left(R_{31}\frac{h_1}{L} - \frac{h_3}{L}\right)}{(R_{31}-1)},\ \ \mu_{32} = \frac{\left(R_{32}\frac{h_2}{L} - \frac{h_3}{L}\right)}{(R_{32}-1)}$$

get $\bar{\mu}$ from $\frac{\mu_{21}+\mu_{31}+\mu_{32}}{3}$

$$g = \frac{a_1}{\frac{h_1}{L} - \mu_1}$$

Procedure:

1. Adjust the incline of the ramp.
2. Observe the position vs. time graph.
   Find the acceleration:
3. Start by making sure the track is level, then raise the height of one end of the track at least 1.5 cm but no more than 1.8 cm. Take the calipers and measure the height at 10 cm (on the track) from the table and also at 110 cm (on the track) from the table. Take the difference and find h (1.5 cm ≤ h_{min} ≤ 1.8 cm, and the difference between each of the h's should be at least 1 cm, ie. If $h_1$is 1.5 cm then h_2 must be at least 2.5 cm but less than 2.8 cm and similar for h_3 which should be 1 cm above h_2), place the PAScar about 10 cm from the Motion Sensor. Simultaneously press the Start Button in DataStudio and release

the PAScar. After the car has hit the bottom of the ramp press the Stop button in DataStudio. Using the “Fit-quadratic” button at the top of the graph, record the coefficients of the Position-Time graph. Print at least one graph for your records. The first coefficient, α, in the 2nd order equation is equal to (½)a the acceleration for this run as shown on the first page. Fit at least three curves for each height. From the average of α, find a. (a=2α). Increase the height by at least 1 cm but no more than 1.3 cm and find the acceleration a_2. Repeat the 1st procedure above and find a_3.

4. After you finish each run enter the data in the table below.
5. Calculate μ_1, μ_2, and μ_3 using $g=9.8 \text{ m/s}^2$, and values for h_1, h_2, h3, a_1, a_2, and a_3.
6. From a_2 and a_1 find R_{21}.
7. From R_{21} find μ_{21}.
8. From μ_{21} calculate g. (To do this, replace μ_1 with μ_{21} in the final equation listed)
9. Repeat and calculate g from μ_{31} and from μ_{32} and the average of the three μ’s.
10. Calculate the error in the g from μ_{21}, μ_{31}, and μ_{32}, and the average g.
11. Calculate the average μ from μ_1, μ_2, and μ_3 (calculations including a_1, a_2, and a_3).
12. Calculate the average μ from μ_{21}, μ_{31}, and μ_{32} (calculations including R_{21}, R_{31}, and R_{32}).
13. Compare μ values and g values.

h_1	h_2	h_3	a_1	a_2	a_3