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 $\mu$ 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.

$$d = \frac{1}{2}at^2 + v_0t + d_0,$$
for a car on the incline plane.

Fit to:

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

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

$$ma = F_T = F_D - F_F \quad \text{from Figure 2.}$$

$$F_D = mg \sin \theta$$

$$F_F = \mu F_N$$

$$F_N = mg \cos \theta = mg \quad \text{(for small } \theta \text{)}$$
\[ ma = mg \sin \theta - \mu mg \]  
\[ a = g (\sin \theta - \mu) \]
\[ a_1 = g (\sin \theta_1 - \mu) \]
\[ a_2 = \left( \frac{h_2}{L} - \mu \right) \]
\[ \mu_1 = \frac{\mu}{L} \]

**Procedure:**

1. Adjust the incline of the ramp.
2. Observe the position vs. time graph.
3. Start by making sure the track is level, then raise the height of one end of the track at least 1 cm but no more than 1.3 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 cm \( \leq \) \( h_{\text{min}} \leq \) 1.3 cm, and the difference between each of the \( h \)'s should be at least 1 cm, ie. If \( h_1 \) is 1.2 cm then \( h_2 \) must be at least 2.2 cm but less than 2.5 cm), 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 slope press the Stop button in DataStudio. Using the “Fit-quadratic” button at the top of the graph, determine
the slope of the Position-Time graph. Print at least one graph for your records. The slope is the first coefficient, $\alpha$, in the 2nd order equation. Fit at least three curves for each height. From the average of $\alpha$, find $a$. ($a=2\alpha$). 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 $\mu_1$, $\mu_2$, and $\mu_3$ using $g=9.8 \, m/s^2$, and values for $h_1$, $h_2$, $h_3$, $a_1$, $a_2$, and $a_3$.

6. From $a_2$ and $a_1$ find $R_{21}$.

7. From $R_{21}$ find $\mu_{21}$.

8. From $\mu_{21}$ calculate $g$.

9. Repeat and calculate $g$ from $\mu_{31}$ and from $\mu_{32}$.

10. Calculate the error in $g$ from $R_{21}$, $R_{31}$, and $R_{32}$, average $g$.

11. Calculate the average $\mu$ from $\mu_1$, $\mu_2$, and $\mu_3$ (calculations including $a_1$, $a_2$, and $a_3$).

12. Calculate the average $\mu$ from $\mu_{21}$, $\mu_{31}$, and $\mu_{32}$ (calculations including $R_{21}$, $R_{31}$, and $R_{32}$).

13. Compare $\mu$ values and $g$ values.

Table:

<table>
<thead>
<tr>
<th>$h_1$</th>
<th>$h_2$</th>
<th>$h_3$</th>
<th>$a_1$</th>
<th>$a_2$</th>
<th>$a_3$</th>
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