Experiment 1

1.

$$V_{cube} = a^3$$

$$\Delta V_{cube} = \frac{\delta V_{cube}}{\delta x}\Delta x = 3 \cdot a^2 \cdot \Delta x$$

$$V_{cylinder} = \pi\frac{d^2}{4}L =$$

$$\Delta V_{cylinder} = \frac{\delta V_{cylinder}}{\delta d}\Delta d + \frac{\delta V_{cylinder}}{\delta L}\Delta L = \pi\frac{d}{2}L\Delta d + \pi\frac{d^2}{4}\Delta L$$

$$V_{wood} = V_{cube} - V_{cylinder}$$

$$\Delta V_{wood} = \Delta V_{cube} + \Delta V_{cylinder}$$

2.

(a) $A_{cone} = \pi r s + \pi r^2$

$$V_{cone} = \frac{1}{3}\pi r^2 h$$

$$h = \sqrt{s^2 - r^2}$$

(b) $\Delta A_{cone} = \pi s\Delta r + 2\pi r\Delta r + \pi r\Delta s$

$$\Delta h = \frac{s}{\sqrt{s^2 - r^2}}\Delta s - \frac{r}{\sqrt{s^2 - r^2}}\Delta r$$

$$\Delta V = \frac{1}{3}\pi r^2\Delta h + \frac{2}{3}\pi r h\Delta r$$

(c) $$\frac{\Delta A}{A} \cdot 100\%$$

$$\frac{\Delta V}{V} \cdot 100\%$$

Experiment 2

1.

(a) $$\left|\overrightarrow{F_2}\right| = \sqrt{F_{2x}^2 + F_{2y}^2}$$

$$m_2 = \frac{\left|\overrightarrow{F_2}\right|}{g}$$

$$\theta_2 = \tan^{-1}\left(\frac{F_{2y}}{F_{2x}}\right)$$

(b) $$\left|\overrightarrow{F_1}\right| = (165.0\ g) \cdot g$$

$$F_{1x} = \left|\overrightarrow{F_1}\right| cos\,235°$$

$$F_{1y} = \left|\overrightarrow{F_1}\right| sin\,235°$$

$$R_x = F_{1x} + F_{2x}$$
$$R_y = F_{1y} + F_{2y}$$

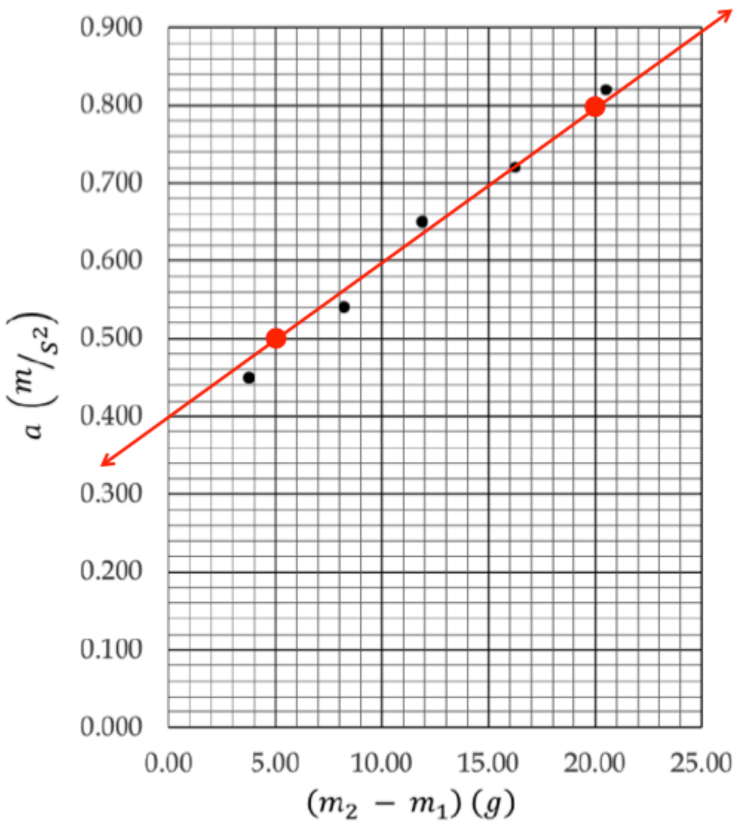
$$\left|\overrightarrow{R_{equılıbrant}}\right| = \left|\vec{R}\right| = \sqrt{R_x^2 + R_y^2}$$

$$m_{equilibrant} = \frac{\left|\vec{R}\right|}{g}$$

$$\theta_{equilibrant} = \tan^{-1}\left(\frac{R_y}{R_x}\right) + 180°$$

Experiment 3

1.



$$slope = \frac{\Delta a}{\Delta(m_2 - m_1)} = \frac{(0.800 - 0.500)\, m/s^2}{(20.00 - 5.00)\times 10^{-3}\, kg} = 20.0\, \frac{kg\cdot m}{s^2}$$

$$a_0 = 0.400\, m/s^2$$

Using Equation 8 from the Lab Manual, we have:

$$a = \frac{(m_2 - m_1)}{(m' + m_2 + m_1)} g - \left(\frac{r}{R}\right)\frac{f}{(m' + m_2 + m_1)}$$

Hence:

$$g = slope\left(m_1 + m_2 + m'\right) = \left(20.0\, {}^{m}\!/\!{}_{s^2}\right)\left(\left[225.0 + 225.0 + 5.425\right]\times 10^{-3}\,kg\right) = 9.12\, {}^{m}\!/\!{}_{s^2}$$

$$\left|f\right| = a_0\left(\frac{R}{r}\right)\left(m_p + m_2 + m_1\right) = \left(0.400\, {}^{m}\!/\!{}_{s^2}\right)\left(\frac{3.500\times 10^{-2}\,m}{1.5875\times 10^{-3}\,m}\right)\left(\left[225.0 + 225.0 + 5.425\right]\times 10^{-3}\,kg\right)$$

$$\therefore \left|f\right| = 4.02\,N$$

Experiment 4

1.

(a)

$$\boldsymbol{a = \alpha r \qquad \Longrightarrow \qquad \alpha = \frac{a}{r}}$$

(b)

$$\boldsymbol{mg - T = ma \qquad \Longrightarrow \qquad T = m(g - a)}$$

$$\boldsymbol{Tr = I\alpha \qquad \Longrightarrow \qquad I = \frac{Tr}{\alpha}}$$

Experiment 5

1.

$(a) \quad T = \dfrac{t}{10}$

$$T = 2\pi\sqrt{\frac{L}{g}}$$

$$L = \frac{T^2 g}{4\pi^2}$$

$$(b) \quad T - mg = \frac{mv^2}{L}$$

$$T = mg + \frac{mv^2}{L} = m\left(g + \frac{v^2}{L}\right)$$

$$(c) \quad T = \frac{t}{25}$$

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$k = \frac{4\pi^2 m}{T^2}$$

$$(d) \quad T = 2\pi\sqrt{\frac{L}{g}}$$

period will increase

$$(e) \quad T = 2\pi\sqrt{\frac{m}{k}}$$

period doesn't depend on g so it will stay same.

Experiment 6

1.

(a) Conservation of momentum along x-axis:

i.) $m_{car}v_{car_{x_i}} + m_{van}v_{van_{x_i}} = m_{car}v_{car_{xf}} + m_{van}v_{van_{xf}} = (m_{car} + m_{van})v_{x_f}$

Conservation of momentum along y-axis:

ii.) $m_{car}v_{car_{y_i}} + m_{van}v_{van_{y_i}} = m_{car}v_{car_{yf}} + m_{van}v_{van_{yf}} = (m_{car} + m_{van})v_{y_f}$

(b)

We observe:

$$m_{car}v_{car_{x_i}} = (m_{car} + m_{van})v_{x_f} \Leftrightarrow v_{x_f} = \frac{m_{car}v_{car_{x_i}}}{(m_{car} + m_{van})}$$

$$\therefore v_{x_f} = \frac{m_{car}v_{car_{x_i}}}{(m_{car} + m_{van})} = \frac{(975kg)(18.0\, m/s)}{(975kg + 1260kg)} = 7.85\, m/s$$

Similarly:

$$m_{van}v_{van_{y_i}} = (m_{car} + m_{van})v_{y_f} \Leftrightarrow v_{y_f} = \frac{m_{van}v_{van_{y_i}}}{(m_{car} + m_{van})}$$

$$\therefore v_{y_f} = \frac{m_{van}v_{van_{y_i}}}{(m_{car} + m_{van})} = \frac{(1260kg)(25.8\, m/s)}{(975kg + 1260kg)} = 14.5\, m/s$$

$$|\vec{v}_f| = \sqrt{v_{x_f}^2 + v_{y_f}^2} = 16.5\, m/s$$

$$\theta = \tan^{-1}\left(\frac{v_{f_y}}{v_{f_x}}\right) = 61.6^\circ$$

2.

Conservation of momentum along x-axis:

$$m_{orange}v_{orange_{x_i}} + m_{apple}v_{apple_{x_i}} = m_{orange}v_{orange_{x_f}} + m_{apple}v_{apple_{x_f}}$$

$$\Rightarrow m_{apple}v_{apple_{x_f}} = \left[(0.143kg)(1.14\, m/s) - (0.132kg)(1.25\, m/s)\right] - (0.143kg)(1.03\, m/s)\cos(43.0^\circ)$$

$$\Rightarrow m_{apple}v_{apple_{x_f}} = -0.110\, kgm/s =$$

$$\Rightarrow v_{apple_{x_f}} = -0.833\, m/s$$

Conservation of momentum along y-axis:

$$m_{apple}v_{apple_{y_i}} + m_{orange}v_{orange_{y_i}} = m_{apple}v_{apple_{y_f}} + m_{orange}v_{orange_{y_f}}$$

$$\Rightarrow m_{apple} v_{apple_{yf}} = -(0.143kg)\left(1.03\, {}^{m}\!/_{s}\right)\sin\left(43.0^{\circ}\right)$$

$$\Rightarrow m_{apple} v_{apple_{yf}} = -0.100\, {}^{kgm}\!/_{s}$$

$$\Rightarrow v_{apple_{yf}} = -0.758\, {}^{m}\!/_{s}$$

$$\left|\vec{v}_{apple_f}\right| = \sqrt{v^2_{apple_{xf}} + v^2_{apple_{yf}}} = 1.13\, {}^{m}\!/_{s}$$

$$\theta_{apple} = \tan^{-1}\left(\frac{v_{apple_{yf}}}{v_{apple_{xf}}}\right) = 42.3^{\circ}$$ ***with respect to its original direction of motion***

Experiment 7

1.

$$\boldsymbol{W_{total} = W_{boy} = Fdcos\theta}$$

$$\boldsymbol{W_{total} = \Delta K = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2}$$

$$\boldsymbol{\frac{1}{2}mv_f^2 = W_{total} + \frac{1}{2}mv_i^2}$$

$$\boldsymbol{v_f = \sqrt{\frac{2W_{total}}{m} + v_i^2}}$$

2.

$$W_f = -fd = -\mu m_A g cos\theta d$$

$$\Delta U = m_A g sin\theta d - m_B g d$$

$$W_f = \Delta U + \Delta K$$

$$\Delta K = W_f - \Delta U$$

$$\Delta K = \frac{1}{2}(m_A + m_B)(v_f^2 - v_i^2), v_i = 0,$$

$$v_f = \sqrt{\frac{2\Delta K}{(m_A + m_B)}}$$

$$\Delta K_A = \frac{1}{2} m_A v_f^2$$

Experiment 8

1.

$$\boldsymbol{m v_i = (M + m) v_f}$$

$$\boldsymbol{v_i = \frac{(M + m) v_f}{m}}$$

$$\boldsymbol{v_i = \frac{(M + m) v_f}{m}}$$

$$\boldsymbol{\frac{\Delta(KE)}{KE_i} = -\frac{M}{(m + M)}}$$

2.

$$\boldsymbol{(a) \quad m_1 \overrightarrow{v_1} + m_2 \overrightarrow{v_2} = (m_1 + m_2)\, \overrightarrow{v_f}}$$

$$\boldsymbol{m_1 v_1 - m_2 v_2 = (m_1 + m_2)\, v_f}$$

$$\boldsymbol{\frac{m_1 v_1 - m_2 v_2}{(m_1 + m_2)} = v_f}$$

negative sign indicates that final velocity vector is in same direction as the initial velocity of line-backer.

$$\boldsymbol{(b) \quad KE_i = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2}$$

$$KE_f = \frac{1}{2}(m_1 + m_2)\, v_f^2$$

Experiment 9

1.

$$m_1 a = m_1 g - T \qquad (1)$$

$$m_2 a = T - m_2 g sin\theta - f \qquad (2)$$

$$N = m_2 g cos\theta \qquad (3)$$

$$f = \mu N \qquad (4)$$

$$m_2 a = T - m_2 g sin\theta - \mu m_2 g cos\theta \qquad (5)$$

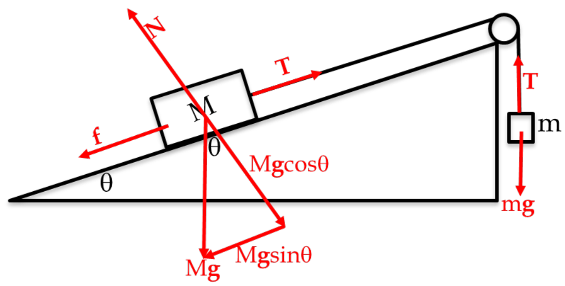
$$(1) + (5) \qquad \Longrightarrow \qquad m_1 a + m_2 a = m_1 g - m_2 g sin\theta - \mu m_2 g cos\theta / m_1$$

$$\Longrightarrow \qquad a + \frac{m_2}{m_1} a = g - \frac{m_2}{m_1} g sin\theta - \frac{m_2}{m_1} \mu g cos\theta$$

$$\Longrightarrow \qquad \frac{m_2}{m_1}(a + g sin\theta + \mu g cos\theta) = g - a$$

$$\Longrightarrow \qquad \frac{m_2}{m_1} = \frac{g - a}{a + g\,(sin\theta + \mu cos\theta)}$$

2.



$$ma = mg - T \qquad (1)$$

$$Ma = T - Mgsin\theta - f \qquad (2)$$

$$N = Mgcos\theta \qquad (3)$$

$$f = \mu N \qquad (4)$$

$$Ma = T - Mgsin\theta - \mu Mgcos\theta \qquad (5)$$

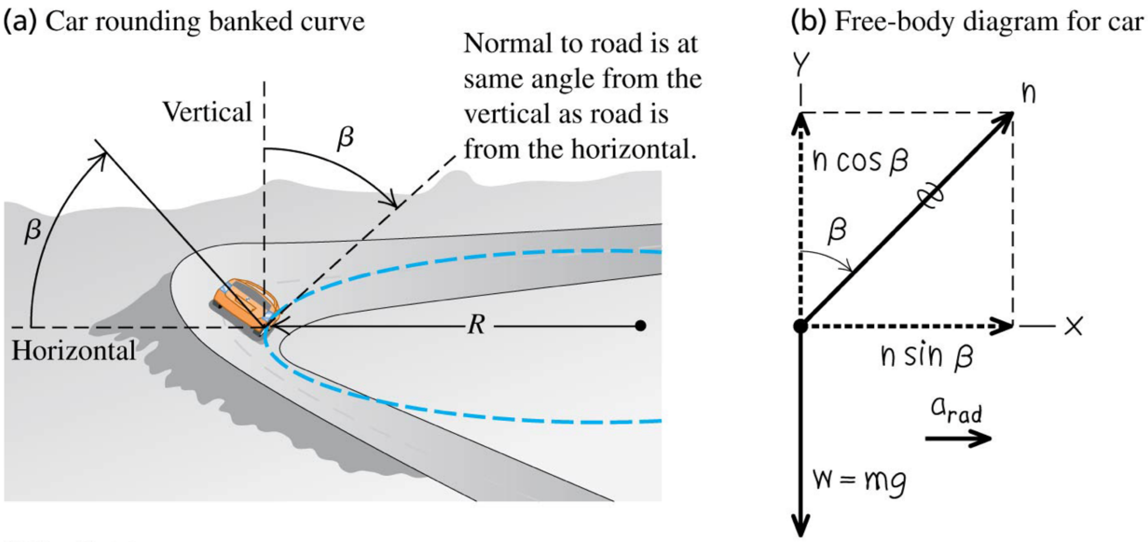
$$(1) + (5) \quad \Longrightarrow \quad a\,(m + M) = mg - Mgsin\theta - \mu Mgcos\theta$$

$$\Longrightarrow \quad a = \frac{mg - Mgsin\theta - \mu Mgcos\theta}{(m + M)}$$

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

Experiment 10

1.



$$\sum F_x = n\sin\beta = ma_c \qquad (1)$$

$$\sum F_y = n\cos\beta - mg = 0 \qquad (2)$$

$$\text{from (2)} \qquad n = \frac{mg}{\cos\beta}$$

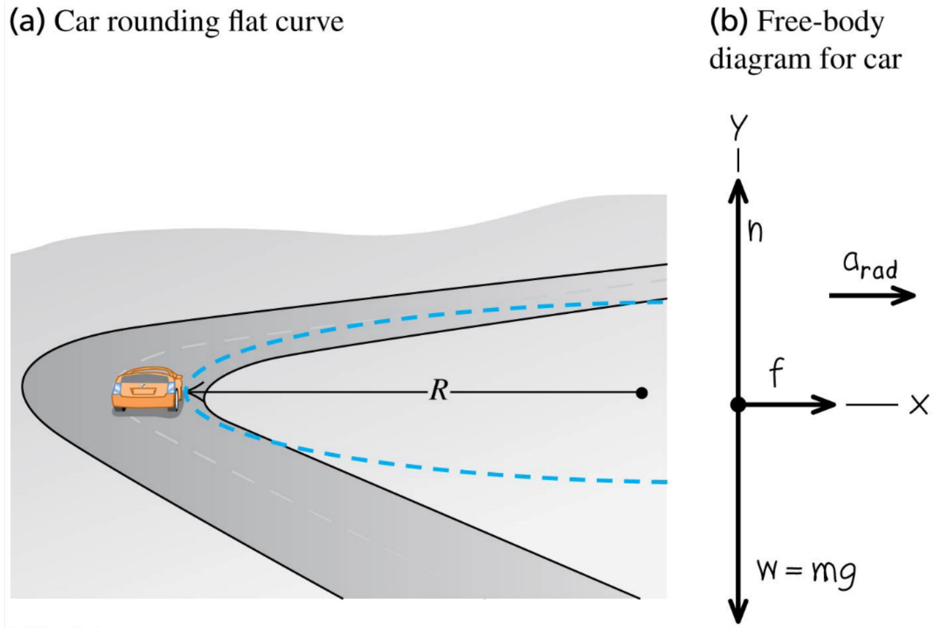
$$\text{back to (1)} \qquad \frac{mg}{\cos\beta}\sin\beta = ma_c$$

$$a_c = \frac{v^2}{R}$$

$$g\tan\beta = \frac{v^2}{R}$$

$$\tan\beta = \frac{v^2}{gR} \quad \dashrightarrow \quad \beta = \tan^{-1}\left(\frac{v^2}{gR}\right)$$

5.



$$\sum F_x = f = ma_c$$

$$\sum F_y = n - mg = 0$$

$$a_c = \frac{v_{max}^2}{R}$$

$$f_{max} = \mu_s n = \mu_s mg$$

$$\mu_s mg = m\frac{v_{max}^2}{R}$$

$$v_{max} = \sqrt{\mu_s g R}$$

Experiment 11

1.

$$\sum \overrightarrow{F_{net}} = 0 \qquad -F_A\cos(\theta_A + \theta_C) + F_D\cos(\theta_D - \theta_C) = 0$$

$$F_A\sin(\theta_A + \theta_C) + F_D\sin(\theta_D - \theta_C) - mg = 0$$

$$\sum \overrightarrow{\tau_A} = 0 \qquad -x_{CM}mgsin(90° + \theta_C) + (x_D - x_A)F_D\sin\theta_D = 0$$

$$\sum \overrightarrow{\tau_L} = 0 \qquad x_A F_A\sin\theta_A - (x_{CM} - x_A)mgsin(90° + \theta_C) + x_D F_D\sin\theta_D = 0$$

$\tau_A - positive$

$\tau_B - positive$

$\tau_{CM} - negarive$

$$-F_A\cos(\theta_A + \theta_C) + F_D\cos(\theta_D - \theta_C) = 0$$

$$F_D = \frac{F_A\cos(\theta_A + \theta_C)}{\cos(\theta_D - \theta_C)} =$$

$$-x_{CM}mgsin(90° + \theta_C) + (x_D - x_A)F_D\sin\theta_D = 0$$

$$x_{CM} = \frac{(x_D - x_A)F_D\sin\theta_D}{mgsin(90° + \theta_C)}$$

2.

$(a) \qquad \sum F_x = F_h - Tcos(90° - \theta) = 0$

$(b) \qquad \sum F_y = F_v - mg + Tcos\theta = 0$

(c) $\quad \boldsymbol{\phi + 90° - \theta + \alpha = 90°}$

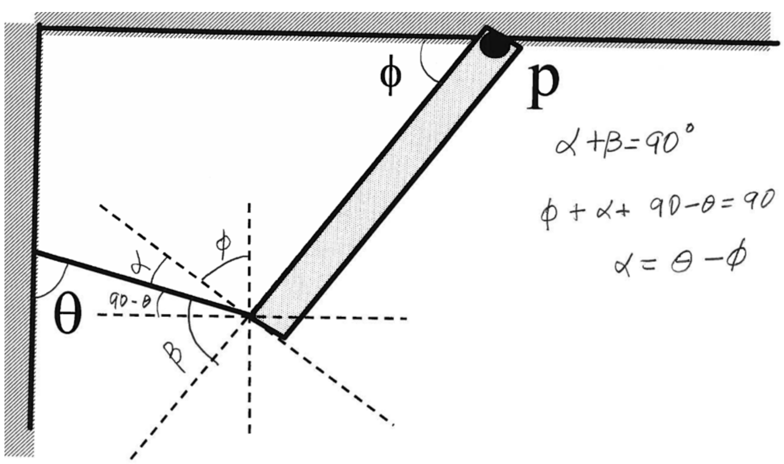
$$\boldsymbol{\alpha = \theta - \phi = 20.0°}$$

$$\sum \tau_p = mgx_{CM}\sin(90° - \phi) - TLsin(\phi + 90 - \theta) = 0$$

$$F_h = Tcos(90° - \theta) =$$

$$F_v = mg - Tcos\theta$$

$$x_{CM} = \frac{TLsin(\phi + 90 - \theta)}{mg\sin(90° - \phi)}$$



Experiment 12

1.

We know:

$$v = \left(\frac{T}{d_\ell}\right)^{1/2} \Leftrightarrow v^2 = \frac{T}{d_\ell} = \frac{T\ell}{m}$$

From the above relationship, we clearly observe that in order to quadruple the velocity of the wave along the string by:

i.) Increasing the *tension* on the string by a factor of 16.

ii.) Increasing the *length* of the string by a factor of 16.

2.

(a)

$$\lambda = \frac{2\ell}{n} = \frac{2(1.125m)}{4} = 0.5625m$$

$$v = \lambda f = (0.5625m)(120.0Hz) = 67.50 \, {}^{m}\!/_{s}$$

(b)

$$T = f^2 d_\ell \lambda^2 = (150.0Hz)^2 \left(0.001250 \, {}^{kg}\!/_{m}\right)(0.5625m)^2 = 8.899N$$