Questions:

1) When you measure the period of the same spring at *the poles* and near *the equator*, do you observe any difference? How do you explain this?

2) A mass m is hanged to a 10 cm spring with a spring constant k and the system performs a simple harmonic motion. Then the spring is divided into two pieces as 3 cm and 7 cm. The same m mass is hanged to both springs. How do the period and the spring constants change? Please explain.

Signature:

Use the values in the Table 10.2 and plot T^2-m graph for both spring on the same graph with x-axis *the mass* (m) and y-axis *square of the period of oscillation* (T^2). Represent the values in the table 10.2 as points on your graph. If one takes squares of both sides of the Eq. 10.7, $T^2 = \frac{4\pi^2}{k}m$ is obtained and this equation describes a linear ($y=ax$) relation between the square of the period of oscillation T^2 and the mass m, with the slope $a = \frac{4\pi^2}{k}$. Use the slope a and, which will be calculated in the following step, plot $y=ax$ line on your graph. Observe the fitness of the line to your data points.

You are expected to calculate the slope $a = \frac{4\pi^2}{k}$. The slope of the line could be calculated using the values in the table 10.2 with the statistical fitting method called "*least squares method*".

A) Thin spring;

Calculate the two terms that will be used in the equations below.

$$\sum_{i=1}^{5} m_i T_i^2 =$$

$$\sum_{i=1}^{5} {m_i}^2 =$$

Substitute those values in equation below and calculate the slope *a.*

$$a = \frac{\sum_{i=1}^{5} m_i T_i^2}{\sum_{i=1}^{5} m_i^2} =$$

The spring constant k_{thin} can be calculated from the slope a according to

$k_{thin} = \frac{4\pi^2}{a} =$ (______)

B) Thick spring;

Calculate the two terms that will be used in the equations below.

$$\sum_{i=1}^{5} m_i T_i^2 =$$

$$\sum_{i=1}^{5} {m_i}^2 =$$

Substitute those values in equation below and calculate the slope *a.*

$$a = \frac{\sum_{i=1}^{5} m_i T_i^2}{\sum_{i=1}^{5} m_i^2} =$$

The spring constant k_{thick} can be calculated from the slope a according to

$k_{thick} = \frac{4\pi^2}{a} =$ (______)

If we take into account our theoretical considerations, we expect a line passing through those points. The Eq. 10.7 $F = -k\Delta L$ describes a linear ($y=kx$) relation between the force F acting on the spring and the change of length ΔL, with the slope spring constant k . Use the slope k and, which will be calculated in the following step, plot $y=kx$ line on your graph. Observe the fitness of the line to your data points.

You are expected to calculate the slope k. The slope of the line could be calculated using the values in Table 10.1 with the statistical fitting method called "*least squares method*".

A) Thin spring;

Calculate two terms that will be used in the equations below.

$$\sum_{i=1}^{5} \Delta L_i F_i =$$

$$\sum_{i=1}^{5} \Delta L_i^2 =$$

Substitute those values in equation and calculate the slope (spring constant) k_{thin}.

$$k_{thin} = \frac{\sum_{i=1}^{5} \Delta L_i F_i}{\sum_{i=1}^{5} \Delta L_i^2} =$$

Thin spring constant k_{thin}= (______)

B) Thick spring;

Calculate two terms that will be used in the equations below.

$$\sum_{i=1}^{5} \Delta L_i F_i =$$

$$\sum_{i=1}^{5} \Delta L_i^2 =$$

Substitute those values in the equation and calculate the slope (spring constant) k_{thick}

$$k_{thick} = \frac{\sum_{i=1}^{5} \Delta L_i F_i}{\sum_{i=1}^{5} \Delta L_i^2} =$$

Thick spring constant k_{thick}= (______)

Signature:

Experimental Procedure:

The experimental set-up to measure the spring constants is shown in Fig.10.1.

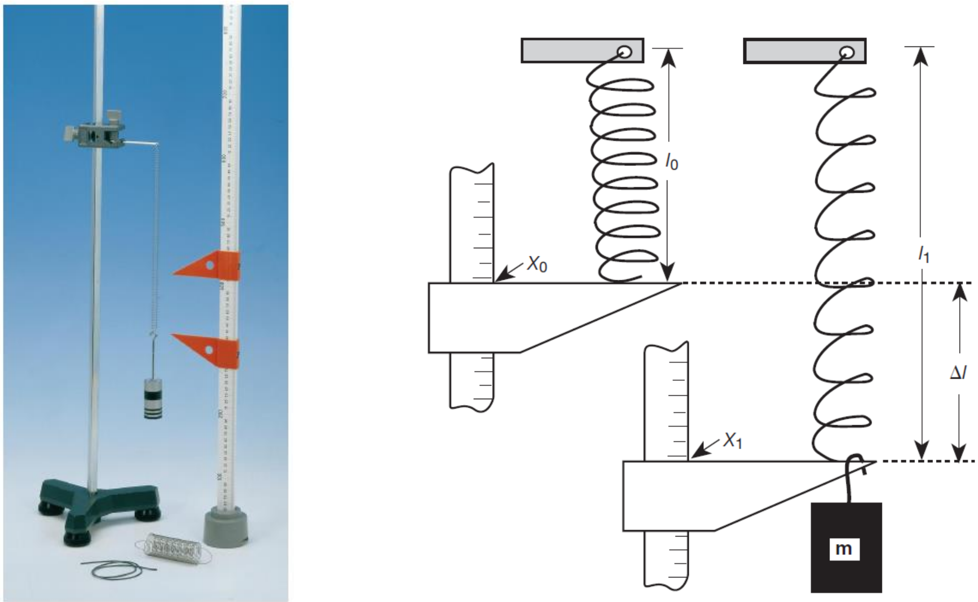

Figure 10.1: Experimental set-up: Hooke's law.

Hook's Law:

1. Measure the initial equilibrium position x_0 of each spring (thin and thick) and mass of the holder.

x_0^{thin} = _____ (cm) x_0^{thick} = _____ (cm) m_{holder} = _____ (gr)

2. Suspend a mass on the holder, then measure the displacements from the equilibrium position for each spring. Don't forget to use the total mass (additional mass + mass of the holder) attached to the spring in the calculations.

3. One after another, suspend an additional mass by 20 gr increments to a total of 100 gr and read the corresponding equilibrium position x_i, then calculate the change of length ΔL. Record the values in Table 10.1

4. Calculate the weight (force) $F = mg$ (g=980 cm/s^2) and also note these values in Table 10.1.

The equations in the form of Eq. 10.4 describe what is called *simple harmonic motion*. The period T, the frequency f, and the constant ω are related by:

$$\omega = 2\pi f = 2\pi/T \qquad 10.6$$

Thus, the period of oscillation T is given by

$$T = 2\pi\sqrt{\frac{m}{k}} \qquad 10.7$$

Note that T does not depend upon the amplitude x_0 of oscillation. Therefore, if a mass is hung from a spring suspended from the vertical, the resulting period of oscillation T would be proportional to the spring constant k and square root of the attached mass m.

Questions:

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Calculate the two terms that will be used in the equations below.

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Calculate the two terms that will be used in the equations below.

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Thin spring constant k_{thin}= (______)

B) Thick spring;

Calculate two terms that will be used in the equations below.

$$\sum_{i=1}^{5} \Delta L_i F_i =$$

$$\sum_{i=1}^{5} \Delta L_i^2 =$$

Substitute those values in the equation and calculate the slope (spring constant) k_{thick}

$$k_{thick} = \frac{\sum_{i=1}^{5} \Delta L_i F_i}{\sum_{i=1}^{5} \Delta L_i^2} =$$

Thick spring constant k_{thick}= (______)

Signature:

Experimental Procedure:

The experimental set-up to measure the spring constants is shown in Fig.10.1.

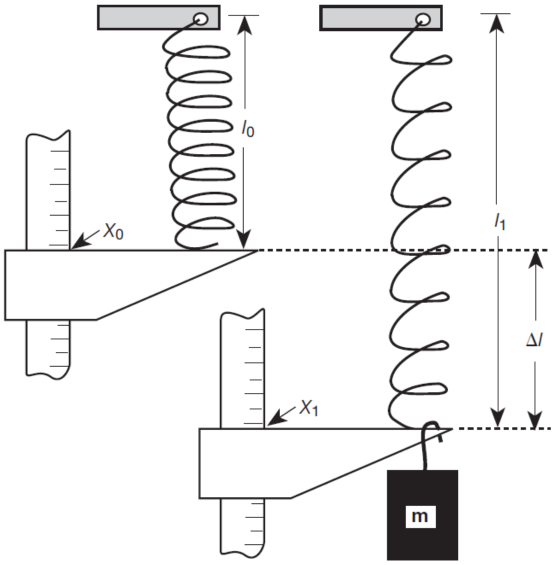

Figure 10.1: Experimental set-up: Hooke's law.

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3. One after another, suspend an additional mass by 20 gr increments to a total of 100 gr and read the corresponding equilibrium position x_i, then calculate the change of length ΔL. Record the values in Table 10.1

4. Calculate the weight (force) $F = mg$ (g=980 cm/s^2) and also note these values in Table 10.1.

the force provided by the air blowing out of the holes in the air track). Thus, the total normal force on the object is zero.

From Figure 1, if the length of the airway (inclined plane) is L and the height of the upper end is H, $\sin(\theta)$ is found by the following equation.

$$\sin(\theta) = \frac{H}{L} \tag{1}$$

The air track produces no tangential force on the object and the net tangential force on the object is just that due to gravity. Figure 1 shows that the tangential component of the force on the object is

$$F = m_1 g \sin(\theta) \tag{2}$$

According to Newton's law of motion, the acceleration a (here the tangential acceleration) is related to the tangential force by the equation

$$F = m_1 a \tag{3}$$

Using Equation 2 and Equation 3, the equation giving the relationship between acceleration a and angle θ is found.

$$a = g \sin(\theta) \tag{4}$$

If the acceleration expression is integrated with respect to time,

For velocity;

$$v = g\,t \sin(\theta) \tag{5}$$

For distance;

$$x = \frac{1}{2} g\,t^2 \sin(\theta) \tag{6}$$

In the above equations, it is assumed that the motion starts from the starting point without initial velocity ($v_0 = 0$).

Calculate the slopes of the lines that fit the data points on your x vs. t^2 graphs, which are plotted in the previous step. In the following formulae, the x_i 's represent square the time average t^2_{avg}, while the y_i's represent the positions x. n is the number of data used in calculations. Write down the <u>intermediate steps</u>.

$$\sum_{i=1}^{n} x_i y_i =$$

$$m = \frac{\sum_{i=1}^{n} x_i y_i}{\sum_{i=1}^{n} x_i^2} =$$

$$\sum_{i=1}^{n} x_i^2 =$$

3) How is the acceleration of an object calculated with the help of the x-t^2 graph given in Figure 2 ? Explain.

....

....

....

....

Write down the experimental acceleration a_{Exp} calculated from the graph and the theoretical acceleration a_{Theo} from Eq. (4) and calculate percent error acceleration $\%a_{\text{error}}$.

Write down the <u>intermediate steps</u>.

$a_{Exp} =$ ....

$sin(\theta) = \frac{H}{L} = =$ ....

$a_{Theo} =$ ....

$$\%a_{\text{error}} = \left|\frac{a_{Theo} - a_{Exp}}{a_{Theo}}\right| 100 =$$

Signature:

Plot the position x and time t data from Table 1 on the graph using points. Then draw a curve passing through these points as good as you can by your crude eye estimation.

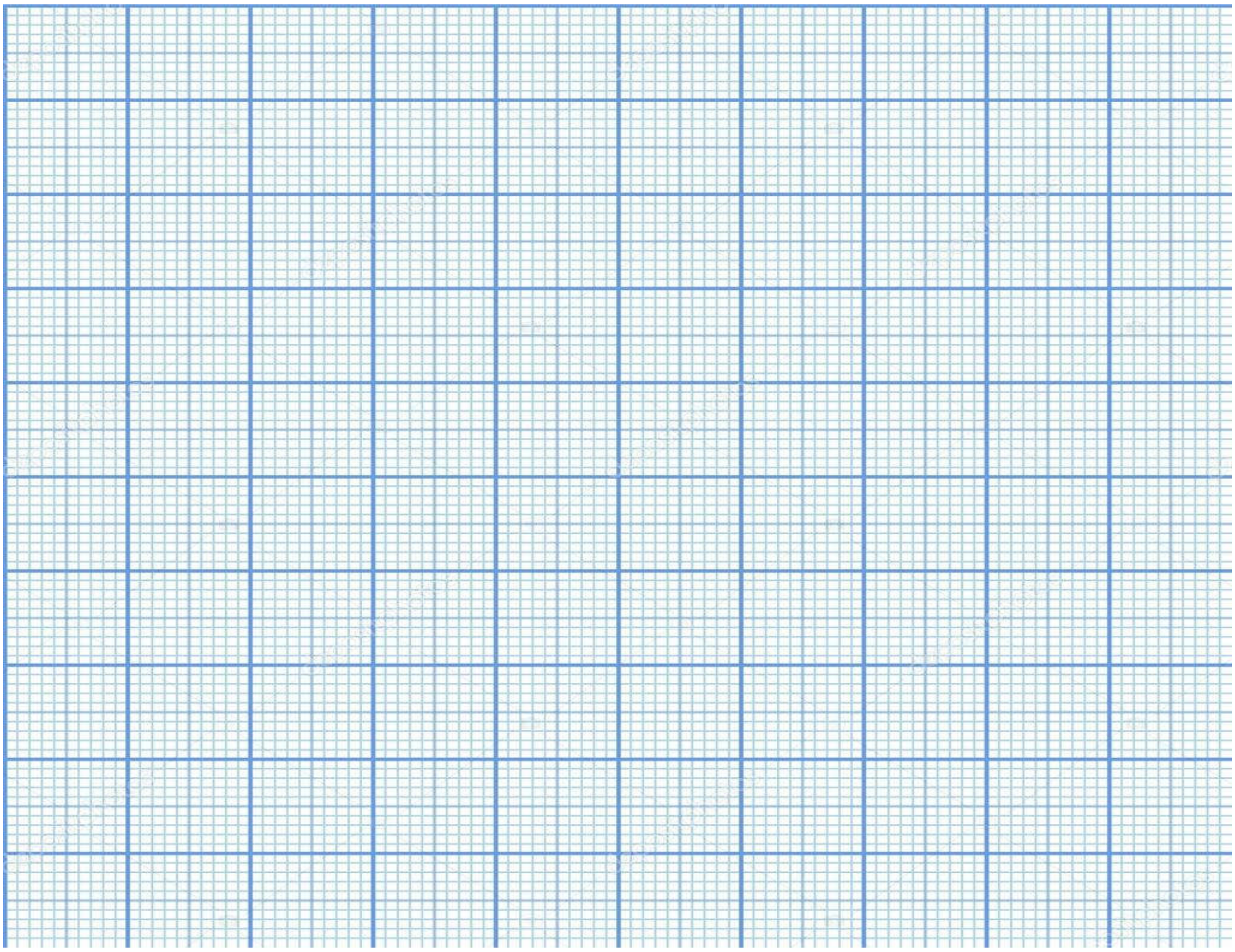

Figure 1: The position x - time t graph

1) Regarding the theoretical background in Eq.(6), what type of a curve is expected to pass through the points?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Signature:

Equipment

- Air track with standard accessories
- Air blower
- Two SpeedGates incl. connection cable
- Wooden ramps for heigh

Figure 1 : Motion with Constant Acceleration in Inclined Plane

Signature:

Elastic Collision

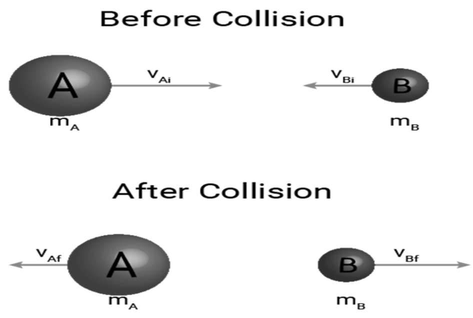

Figure 1: Two objects before and after an elastic collision

Before the elastic collision of two bodies with masses m_A and m_B with velocities v_{Ai} and v_{Bi}, after the elastic collision the velocities of these masses be v_{Af} and v_{Bf}. Here,i represents initial, and f represents final.

Momentum is conserved in this collision.

$$m_A v_{Ai} + m_B v_{Bi} = m_A v_{Af} + m_B v_{Bf} \quad (3)$$

In an elastic collision, kinetic energy is also conserved. The conservation of kinetic energy is given by the equation below.

$$K_i = \frac{1}{2} m_A v_{Ai}^2 + \frac{1}{2} m_B v_{Bi}^2 \quad (4)$$

$$K_f = \frac{1}{2} m_A v_{Af}^2 + \frac{1}{2} m_B v_{Bf}^2 \quad (5)$$

$$K_i = K_f \quad (6)$$

$$\frac{1}{2} m_A v_{Ai}^2 \frac{1}{2} m_B v_{Bi}^2 = \frac{1}{2} m_A v_{Af}^2 \frac{1}{2} m_B v_{Bf}^2 (7)$$

There exists a relationship between energy and momentum as shown below.

$$K_i = \frac{p_{Ai}^2}{2m_A} + \frac{p_{Bi}^2}{2m_B} \quad (8)$$

$$K_f = \frac{p_{Af}^2}{2m_A} + \frac{p_{Bf}^2}{2m_B} \quad (9)$$

Inelastic Collision

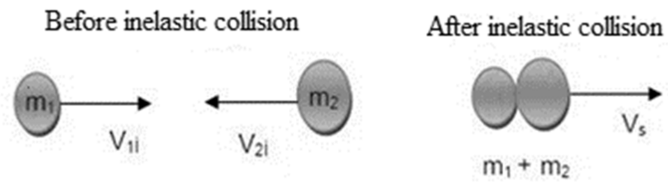

Figure 2: Two objects before and after an inelastic collision

Before the inelastic collision of two bodies with masses m_1 and m_2 with velocities v_{1i} and v_{2i}, after the inelastic collision the velocities of these masses be v_s. Here,i represents initial, and s represents final.

In inelastic collisions, there is a loss of kinetic energy.

The kinetic energy before the collision is K_i and the kinetic energy after the collision is K_f, $K_i > K_f$.

$$K_i = \frac{1}{2} m_1 v_{1i}^2 \frac{1}{2} m_2 v_{2i}^2 \quad (10)$$

$$K_f = \frac{1}{2}(m_1 + m_2) v_{Sf}^2 \quad (11)$$

The total kinetic energy difference is either converted into heat energy or stored as potential energy in the colliding bodies.

There exists a relationship between energy and momentum as shown below.

$$K_i = \frac{p_{1i}^2}{2m_1} + \frac{p_{2i}^2}{2m_2} \quad (12)$$

$$K_f = \frac{p_{12f}^2}{2(m_1+m_2)} \quad (13)$$

Here, $p_{12f}^2 = (m_1 + m_2) v_s^2$

Calculate momenta $p_{\text{tot. before}}$ and $p_{\text{tot. after}}$ and energies $E_{\text{tot. before}}$ and $E_{\text{tot. after}}$ for each measurement. Find the percentage of energy loss. Calculate the energies $E_{\text{tot. before}}$ and $E_{\text{tot. after}}$ of Exp-1 and Exp-2 using equations (12) and (13), respectively. Write down the intermediate steps.

Exp-3

$p_{\text{tot. before}} =$

$p_{\text{tot. after}} =$

$E_{\text{tot. before}} =$

$E_{\text{tot. after}} =$

$$\%_{\text{Energy Loss}} = \frac{|E_{\text{tot.before}} - E_{\text{tot.after}}|}{E_{\text{tot.before}}}\ 100 =$$

Exp-4

$p_{\text{tot. before}} =$

$p_{\text{tot. after}} =$

$E_{\text{tot. before}} =$

$E_{\text{tot. after}} =$

$$\%_{\text{Energy Loss}} = \frac{|E_{\text{tot.before}} - E_{\text{tot.after}}|}{E_{\text{tot.before}}}\ 100 =$$

Signature :

Inelastic Collision:

- Remove the apparatus in the front of the end part of the gliders and attach the apparatus in the figure below. Since the cork in the apparatus covers a needle, carefully remove the cork attached to the

apparatus. remove it.

- By removing the apparatus in the middle, attach the apparatus pictured below.

- Start the air blower to create a frictionless environment.
- Accelerate the sled at the end with your hand so that it collides with the other sled.
- Write the masses in columns labeled as m_1, m_2 and $m_1 + m_2$, and write the velocities before and after the collision in columns labeled as v_2 and v'_{system}. Here, v_1 and v_2 represent the velocities before the collision, while v'_{system} represent the velocity after the collision. The weights of the gliders is 200 g.

Table 2 : Masses and velocities before and after the inelastic collision.

	m_1(……)	m_2(……)	$m_1 + m_2$ (……)	v_1(……)	v_2(……)	v'_{system} (……)
1				**0**		
2		+2		**0**		
3		+5		**0**		
4		+7		**0**		

Signature :

Calculate momenta $p_{\text{tot. before}}$ and $p_{\text{tot. after}}$ and energies $E_{\text{tot. before}}$ and $E_{\text{tot. after}}$ for each measurement. Find the percentage of energy loss. Calculate the energies $E_{\text{tot. before}}$ and $E_{\text{tot. after}}$ of Exp-1 and Exp-2 using equations (4) and (5), respectively. Write down the intermediate steps.

Exp-1

$p_{\text{tot. before}} =$

$p_{\text{tot. after}} =$

$E_{\text{tot. before}} =$

$E_{\text{tot. after}} =$

$$\%_{\text{Energy Loss}} = \frac{|E_{\text{tot.before}} - E_{\text{tot.after}}|}{E_{\text{tot.before}}} \; 100 =$$

Exp-2

$p_{\text{tot. before}} =$

$p_{\text{tot. after}} =$

$E_{\text{tot. before}} =$

$E_{\text{tot. after}} =$

$$\%_{\text{Energy Loss}} = \frac{|E_{\text{tot.before}} - E_{\text{tot.after}}|}{E_{\text{tot.before}}} \; 100 =$$

Signature :

Equipment

- Air track with standard accessories
- Air blower
- Two SpeedGates incl. connection cable
- Digital scale
- Two apparatus (cork , needle)
- Various small weights

Experimental Procedure:

Figure 1 : The experimental set-up Momentum and Kinetic Energy in Collisions

Signature :