T.C.
GEBZE TECHNICAL UNIVERSITY
PHYSICS DEPARTMENT

PHYSICS LABORATORY II
EXPERIMENT REPORT

THE NAME OF THE EXPERIMENT

Momentum and Kinetic Energy in Collisions

PREPARED BY

NAME AND SURNAME:

STUDENT NUMBER :

DEPARTMENT :

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 :

<u>Elastıc collision ;</u>

1. On a SpeedGate screen, the upper line is switched using the single dash button **I**, and the lower line is changed using the double dash button **II** . To reset the values on the screen, the **X** button is pressed.
2. Configure SpeedGate-A and SpeedGate-B with "Speed" on the upper line using the single dash button **I**, and "Previous Value" on the lower line using the double dash button **II**.
3. Place SpeedGate-A near one end of the rail, and SpeedGate-B near the other end of the rail.
4. Attach the side apparatus to the front of the one at the end of the glider. 
5. Attach the side apparatus to the middle glider. 
6. Add the weights shown in the table to the m_1 and m_2 gliders , write the total weights added to the Table 1.
7. Activate by pressing the red button on the back of the air blower to create a frictionless environment.
8. Gently push the gliders with your fingertip so that it hits the other glider.
9. Write the masses in columns labeled as m_1 and m_2, and write the velocities before and after the collision in columns labeled as v_1, v_2, v'_1, and v'_2. Here, v_1 and v_2 represent the velocities before the collision, while v'_1 and v'_2 represent the velocities after the collision.
   The weights of the gliders is **200 g**.

Table 1 : Masses and velocities before and after the elastic collision.

	m_1(……)	m_2(……)	v_1(………)	v_2(………)	v'_1(………)	v'_2 (………)
1						
2		+2				
3	+5					
4		+7				

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 :

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 (8) and (9), 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 (10) and (11), 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 :

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 :

Conclusion, Comment and Discussion:

(**Tips**: Give detail explanation about what you've learned in the experiment and also explain the possible errors and their reasons.)

-Give detail explanation about what you've learned in the experiment

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-Explain the possible errors and their reasons in the experiment

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Questions

Q1) What kinetic energy and potential energy and write two examples for each?

Q2) Write two examples of each of elastic and inelastic collision.

Signature :

Experiment Name: *"The Conservation of Momentum and Kinetik Energy in Collisions"*

Objective:

-Experimental investigation of the conservation of momentum and energy in elastic and inelastic collisions.

-To investigate examination of the relationship between energy and momentum.

Keywords:

Momentum, Energy, elastic collisions, inelastic collisions

Theoretical Information :

The principle of conservation of momentum derives from Newton's second law. If the net external force applied to a system is zero, it means that the momentum of the system is constant with respect to time.

$$F_{ext} = \frac{\Delta p}{\Delta t} \qquad (1)$$

F_{net}, Net external force acting on the system.

p, Momentum of the system.

When $F_{ext} = 0, \frac{\Delta p}{\Delta t} = 0$

$\Delta p = 0$ and $p = constant$

The total energy of a system is the sum of the kinetic and potential energies of the system at any instant.

$$E = K + P \qquad (2)$$

given by equality, where K represents kinetic energy and P represents potential energy.
If only conservative forces do work in a system, there is neither a decrease nor an increase in the total energy of the system. The total energy of the system remains constant (Law of Conservation of Energy).

If momentum and kinetic energy are conserved in the collision of two bodies that are not under the influence of an external force, this type of collision is called an elastic collision. A collision in which momentum is conserved and kinetic energy is not conserved is called an inelastic collision.

Elastic Collision

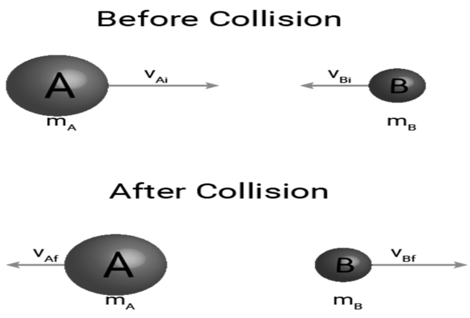

Figure 1: Two objects before and after an elastic collision

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.

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

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

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

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

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

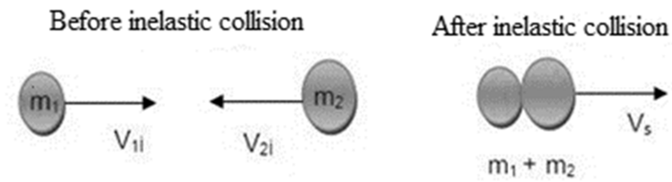

Figure 2: Two objects before and after an inelastic collision

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

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GEBZE TECHNICAL UNIVERSITY
PHYSICS DEPARTMENT

PHYSICS LABORATORY II
EXPERIMENT REPORT

THE NAME OF THE EXPERIMENT

Motion with Constant Acceleration in Inclined Plane

PREPARED BY

NAME AND SURNAME:

STUDENT NUMBER :

DEPARTMENT :

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:

Experimental Procedure:

1. On a SpeedGate screen, the upper line is switched using the single dash button **I**, and the lower line is changed using the double dash button **II** . To reset the values on the screen, the **X** button is pressed.
2. Configure SpeedGate-A with "Previous Value" on the lower line using the double dash button **II** and SpeedGate-B with " Interval Before " on the lower line using the double dash button **II.**
3. L is the length of the airway (inclined plane, L = m) and H is the height of the airway.
4. x is the distance between SpeedGate-A and SpeedGate-B that the glider covers, which is the distance it travels on the inclined plane.
5. Using small square boards, change the height H of one side of the airway as in Table 1.
6. According to different x values in Table 1, change the distance between SpeedGate-A and SpeedGate-B by changing only the position of SpeedGate-A.
7. Change the height H of one side of the airway using small square boards.
8. Then calculate the average of 5 time measurements for each value of x, write under column t_{avg} in Table 1.

Table 1 : Measured intervals times

H = 0.9 m							
x (m)	**t_1 (s)**	**t_2 (s)**	**t_3 (s)**	**t_5 (s)**	**t_4 (s)**	**t_{avg} (s)**	**t^2_{avg} (s^2)**
0.8							
0.6							
0.4							
0.2							

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.

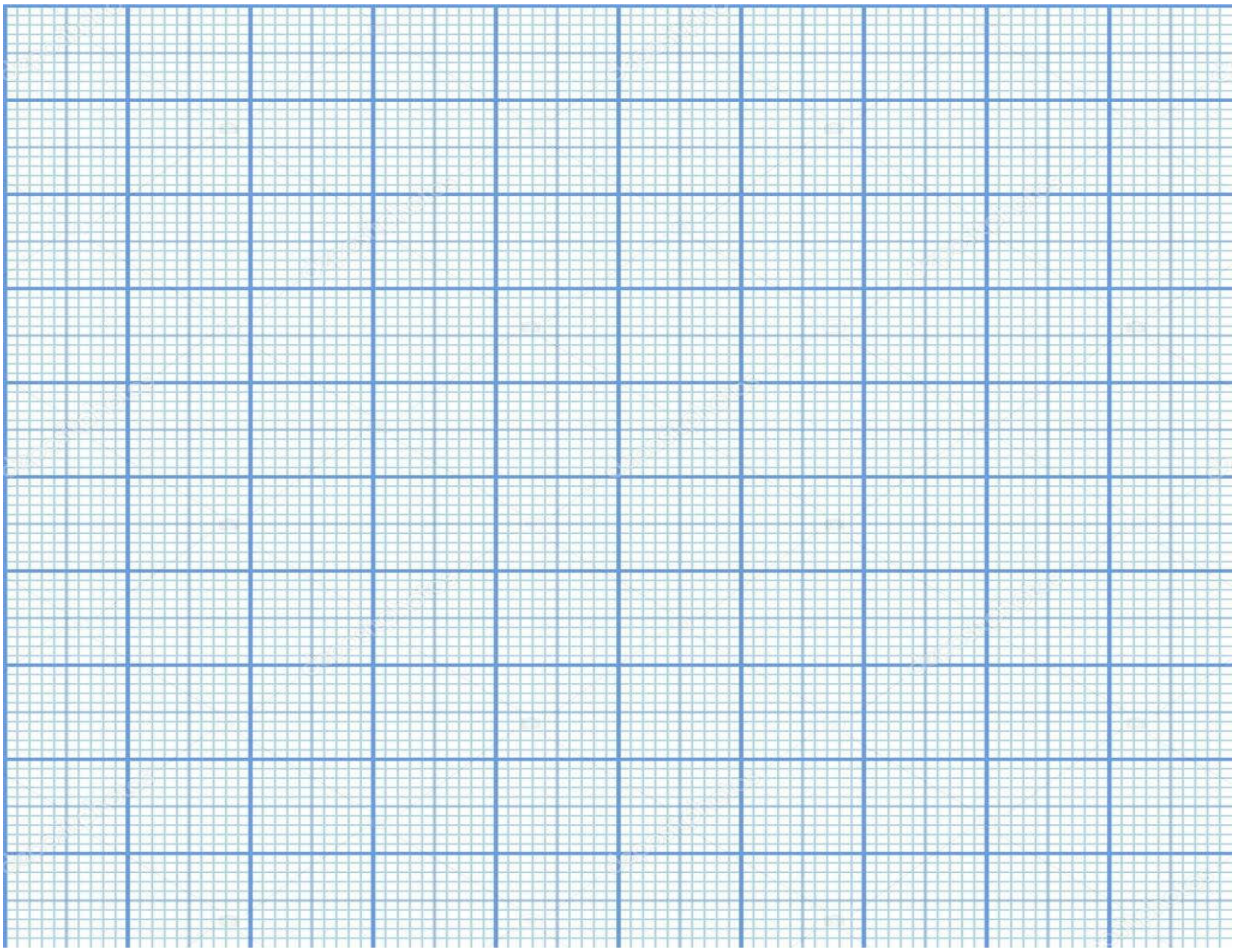

Figure 1: The position x - time t graph

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

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Signature:

Draw the x-t^2 graph using the positions x and square the time average t^2_{avg} values above.

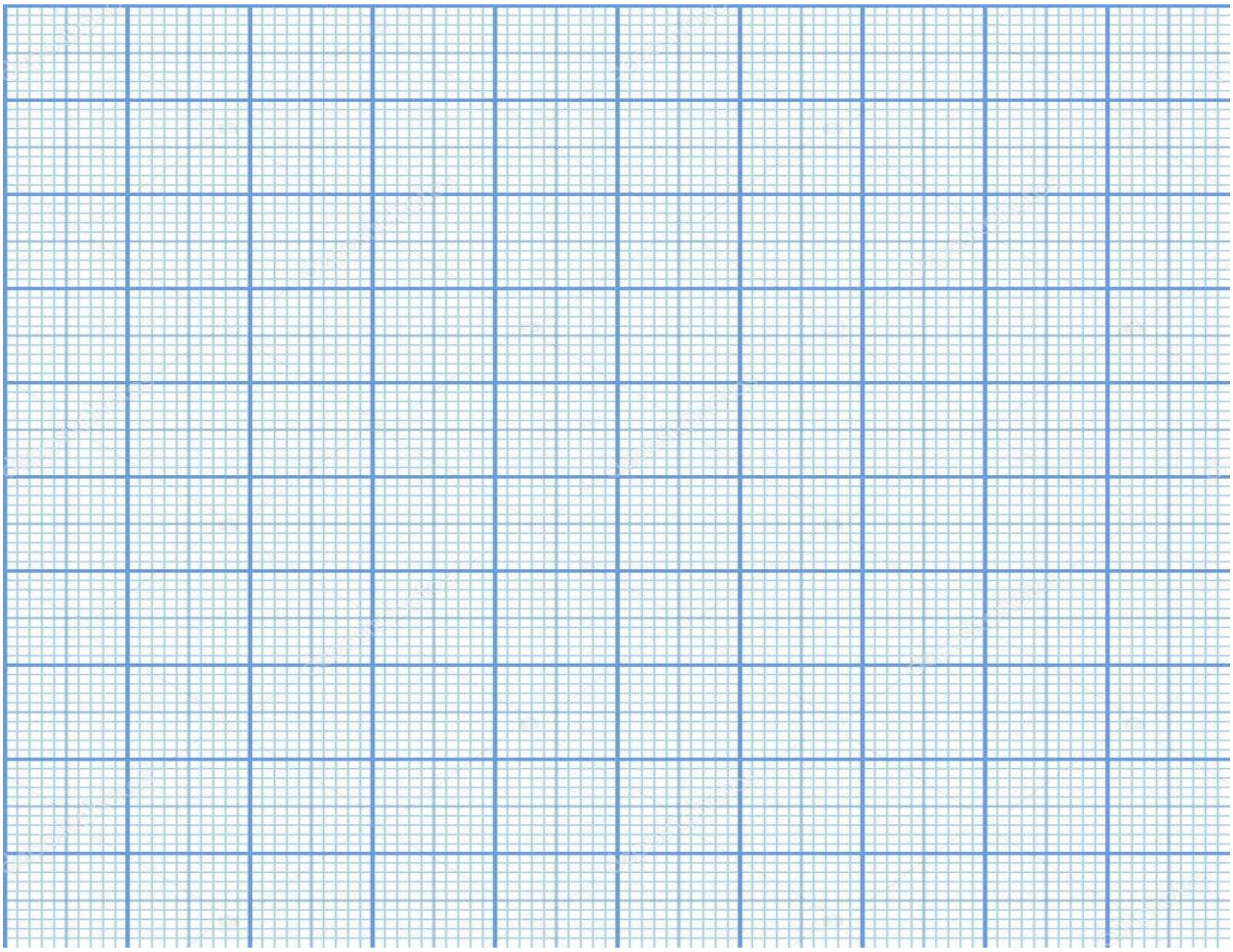

Figure 2: The position x - square the time average t^2_{avg} graph

2) Comment on the velocity of the object from this graph? Explain the reason.

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Signature:

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 intermediate steps.

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

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

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

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

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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 intermediate steps.

$a_{Exp} =$ ....

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

$a_{Theo} =$ ....

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

Signature:

Conclusion, Comment and Discussion:

(**Tips**: Give detail explanation about what you've learned in the experiment and also explain the possible errors and their reasons.)

-Give detail explanation about what you've learned in the experiment

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-Explain the possible errors and their reasons in the experiment

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Questions

1. Derive Eq.4 and Eq. 5 from Eq. 6 in the theoretical experiment guide.

2. In the system we have adjusted according to the 30°, 45°, 75° angles of the inclined plane, list the glider speeds released at the same height from the largest to the smallest.($a_{30°}$, $a_{45°}$, $a_{75°}$)

Signature:

Experiment Name: *"Motion with Constant Acceleration in Inclined Plane"*

Objective:

-Experimentally examining motion with constant acceleration in one dimension and on an inclined plane.

- Calculation and compare of the experimental acceleration a_{Exp} and theoretical acceleration $a_{Theo.}$

Keywords:

Constant acceleration, Inclined Plane, slope, time, distance

Theoretical Information :

Inclined planes are called surfaces that stand at a certain angle θ with the horizontal. Figure 1 shows an object with mass m_1 placed on an inclined plane and the forces acting on this object.

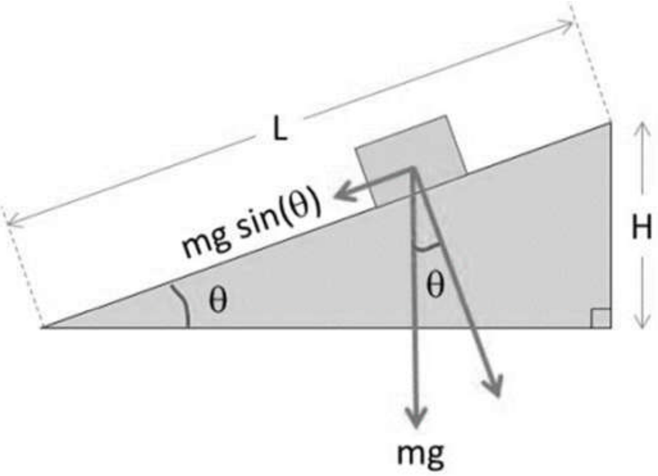

Figure 1. Diagram of a mass m on an inclined plane. The tangential component of the force of gravity accelerates the mass down the incline and is equal to $mgsin(\theta)$.

Assuming the inclined plane is frictionless, more than one force acting on an object of mass m_1 will be as shown in Figure 1.

All objects near the earth have a uniform downward acceleration due to gravity. By tilting the air track by a small amount, you effectively "reduce" the acceleration due to gravity. This idea was first employed by Galileo, who used an inclined plane rather than tilted air track.

Suppose **g** is the (downward) acceleration due to gravity. When an object of mass m is placed on an inclined plane, the downward force mg on the object due to gravity may be resolved into two components (see Figure 1). One component is normal (perpendicular) to the plane, and one is tangent to (along) the plane. The component of the force of gravity that is normal to the plane is balanced by the reaction force of the plane on the object (in this case 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 ($v_0 = 0$).

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PHYSICS DEPARTMENT

PHYSICS LABORATORY I
EXPERIMENT REPORT

THE NAME OF THE EXPERIMENT

Hooke's Law

PREPARED BY

NAME AND SURNAME:

STUDENT NUMBER :

DEPARTMENT :

Signature:

Experimental Procedure:

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

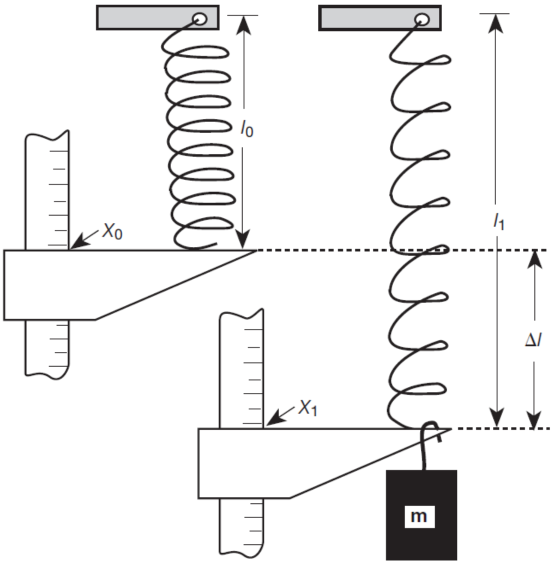


Figure 10.1: Experimental set-up: Hooke's law.

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.

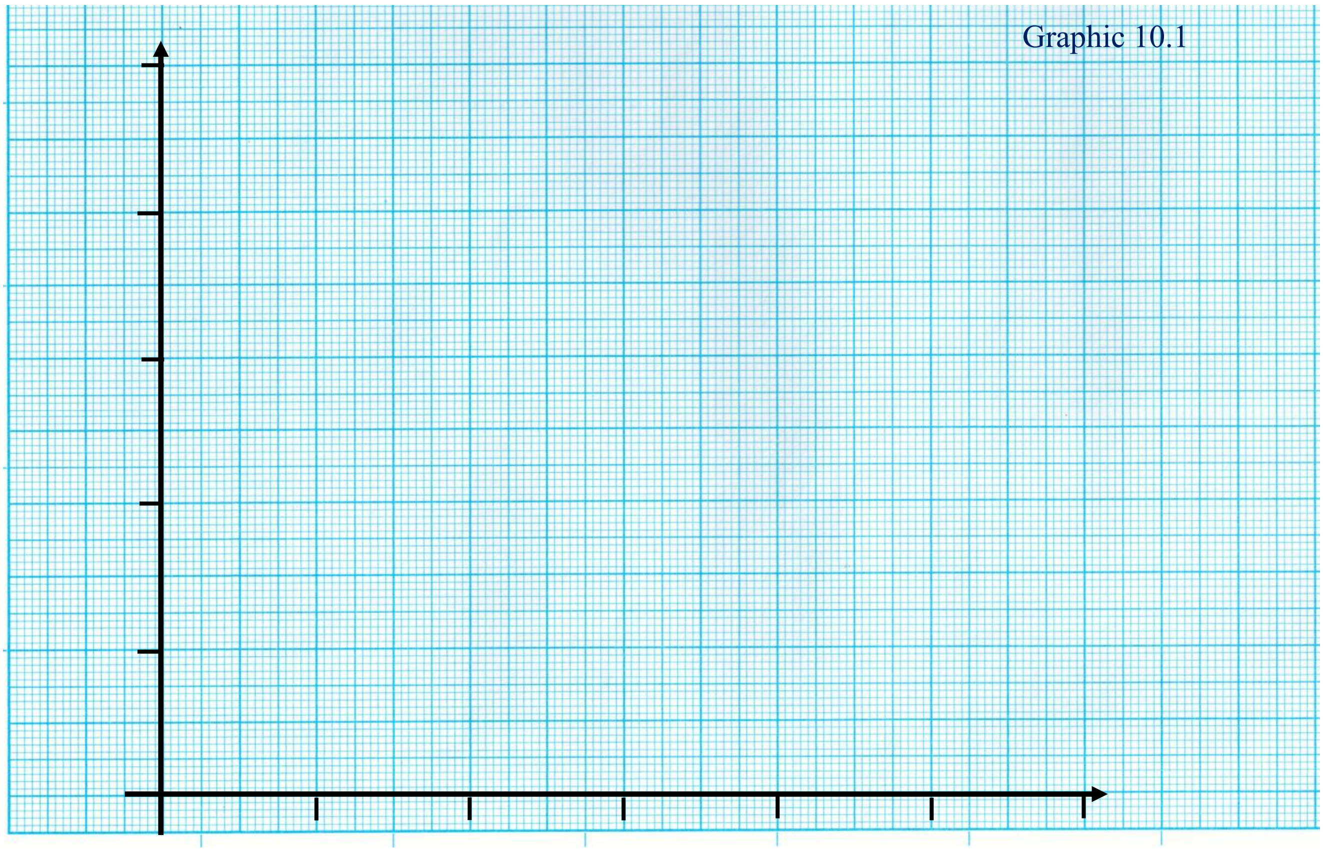
3. One after another, suspend an additional mass by 20 gr increments to a total of 100 gr and read the corresponding equilibrium position x_i, then calculate the change of length ΔL. Record the values in Table 10.1

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

Table 10.1: Spring length L as a function of the suspended weights.

m (gr)	F=mg (gr.cm/s^2)	x_i^{thin} (cm)	$\Delta L_{thin} = x_i^{thin} - x_0^{thin}$ (cm)	x_i^{thick} (cm)	$\Delta L_{thick} = x_i^{thick} - x_0^{thick}$ (cm)
20					
40					
60					
80					
100					

Use the values in Table 10.1 and plot F-ΔL graphs of each spring on reserved millimetric space as x-axis *the change of length* (ΔL) and y-axis the force (F). Represent the values in the table as points on your graph.



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}

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

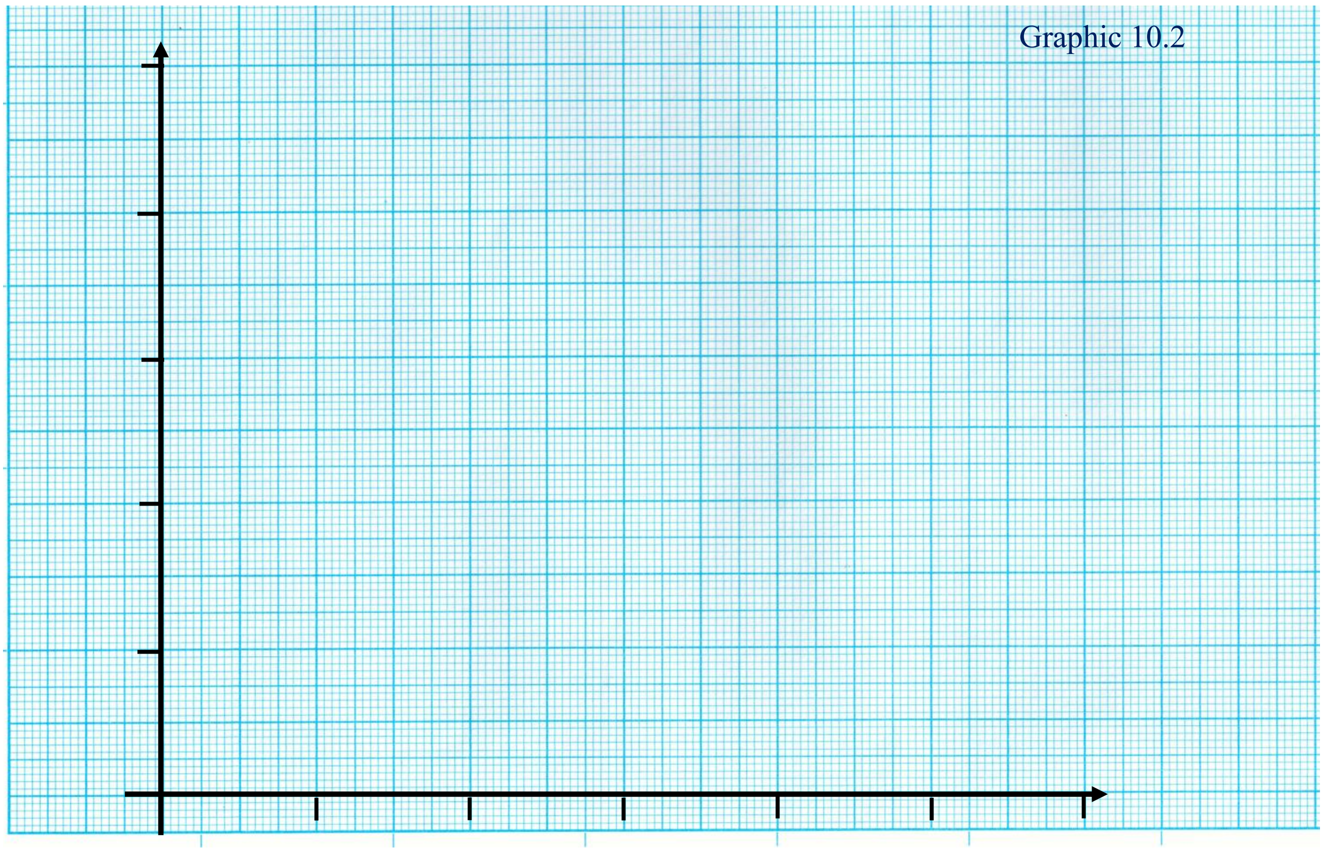
Thick spring constant k_{thick}= (______)

Harmonic oscillation:

1. In this step, suspend the same masses on each spring in turn. Pull the mass little bit down then release. Measure the time of the oscillation of the spring to complete 10 cycles for each mass by using the stopwatch. Divide each time by 10 to find the time for one period for each mass and record the values in table 10.2.
2. Calculate the period of oscillation T and square of the period of oscillation T^2 and fill in Table 10.2.

Table 10.2: Period of oscillation T as function of the suspended mass.

m (gr)	Δt_{thin} (s)	$T_{thin} = \frac{\Delta t_{thin}}{10}$ (s)	T^2_{thin} (s^2)	Δt_{thick} (s)	$T_{thick} = \frac{\Delta t_{thick}}{10}$ (s)	T^2_{thick} (s^2)
20						
40						
60						
80						
100						



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

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

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

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

Compare the spring constants k_{thin} and k_{thick} values calculated by using the Hook's law and harmonic oscillation with each other. Discuss the reasons for probable differences.

Conclusion, Comment and Discussion:

(Tips: Give detailed explanations about what you've learned in the experiment and also explain the possible errors and their reasons.)

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:

Experiment No : M10

Experiment Name: Hooke's Law

Objective:

1. Determining the change of length ΔL of two helical springs with different turn diameters as a function of the gravitational force F exerted by the suspended weights.
2. Confirming Hooke's law and determining the spring constants k of the two helical springs.

Keywords: Hooke's law, spring constant, oscillation, period.

Theoretical Information:

Holding a spring in either its compressed or stretched position requires that someone or something exerts a force on the spring. This force is directly proportional to the displacement, Δx, of the spring. In turn, the spring will exert an equal and opposite force

$$F = -k\Delta x \tag{10.1}$$

where k is called the "spring constant." This is often referred to as a "restoring force" because the spring exerts a force in the direction opposite to the displacement, indicated by the negative sign. The Eq. 10.1 is known as Hooke's law.

Simple harmonic motion will occur whenever there is a restoring force that is proportional to the displacement from equilibrium, as is in Hooke's law. From Newton's second law, $F = ma$, and recognizing that the acceleration a is the second derivative of displacement with respect to time. The classical equation of motion for a one-dimensional simple harmonic oscillator with a particle of mass m attached to a spring having spring constant k is the Eq. 10.1 can be rewritten as;

$$F = -kx \Rightarrow m\frac{d^2x}{d^2t} = -kx \tag{10.2}$$

which can be written in the standard wave equation form;

$$m\frac{d^2x}{d^2t} + kx = 0 \tag{10.3}$$

The Eq. 10.3 is a linear second-order differential equation that can be solved by the standard method of factoring and integrating. The resulting solution to Eq. 10.3 is

$$x(t) = x_0\sin(\omega t + \phi) \tag{10.4}$$

where x_0 is the amplitude of oscillation and

$$\omega = \sqrt{\frac{k}{m}} \tag{10.5}$$

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.

T.C.
GEBZE TECHNICAL UNIVERSITY
PHYSICS DEPARTMENT

PHYSICS LABORATORY I
EXPERIMENT REPORT

THE NAME OF THE EXPERIMENT

Hooke's Law

<u>PREPARED BY</u>

NAME AND SURNAME:

STUDENT NUMBER :

DEPARTMENT :

Signature:

Experimental Procedure:

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

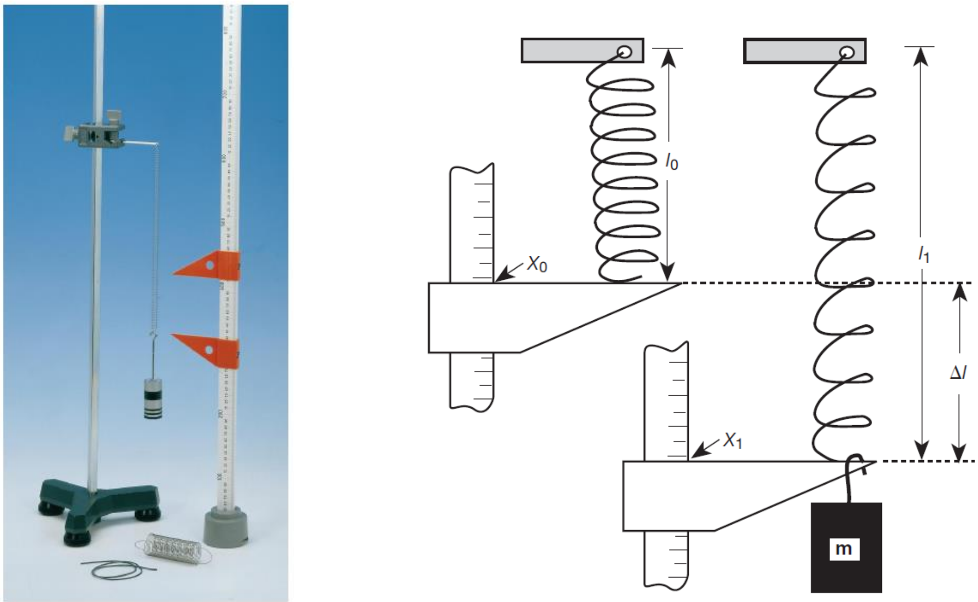


Figure 10.1: Experimental set-up: Hooke's law.

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.

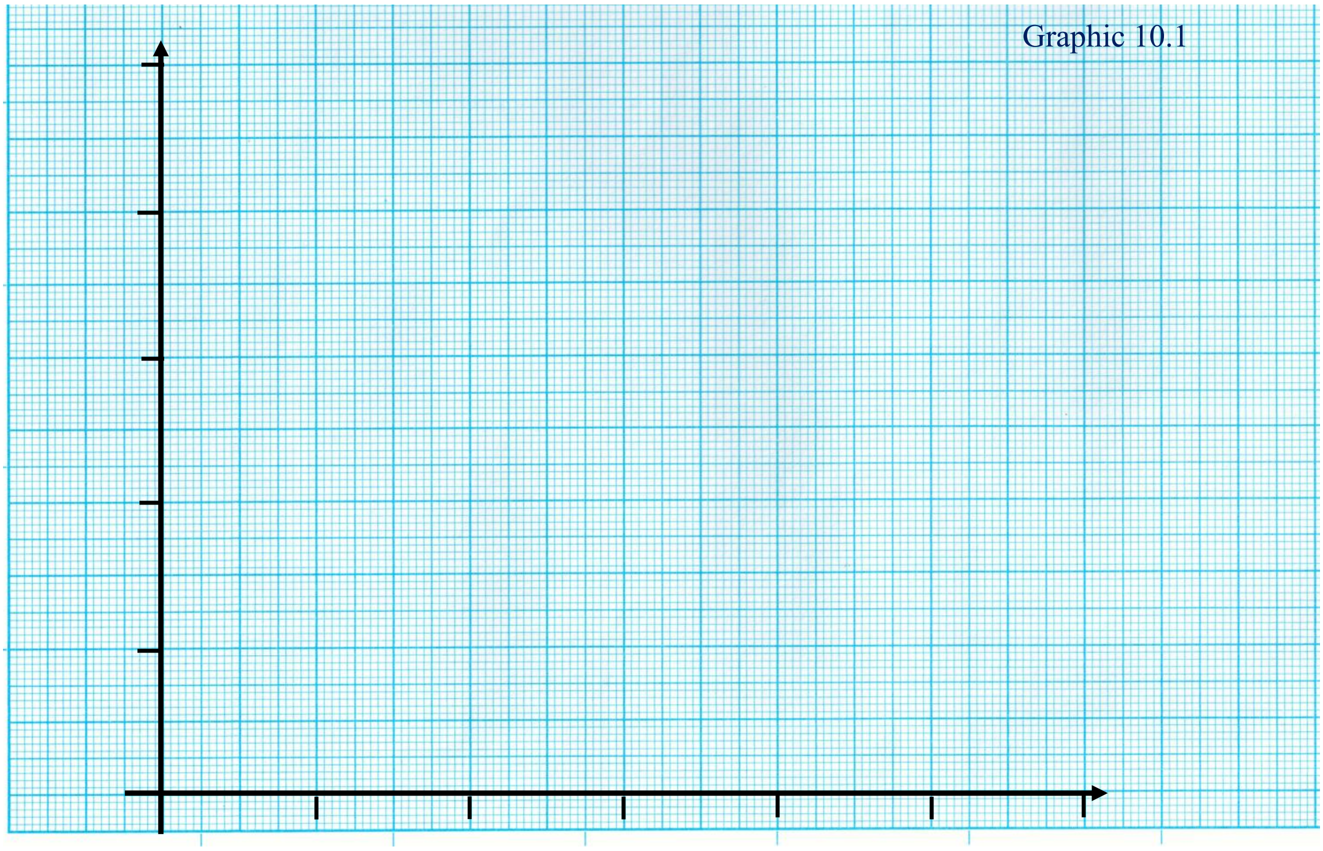
3. One after another, suspend an additional mass by 20 gr increments to a total of 100 gr and read the corresponding equilibrium position x_i, then calculate the change of length ΔL. Record the values in Table 10.1

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

Table 10.1: Spring length L as a function of the suspended weights.

m (gr)	F=mg (gr.cm/s^2)	x_i^{thin} (cm)	$\Delta L_{thin} = x_i^{thin} - x_0^{thin}$ (cm)	x_i^{thick} (cm)	$\Delta L_{thick} = x_i^{thick} - x_0^{thick}$ (cm)
20					
40					
60					
80					
100					

Use the values in Table 10.1 and plot F-ΔL graphs of each spring on reserved millimetric space as x-axis *the change of length* (ΔL) and y-axis the force (F). Represent the values in the table as points on your graph.



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}

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

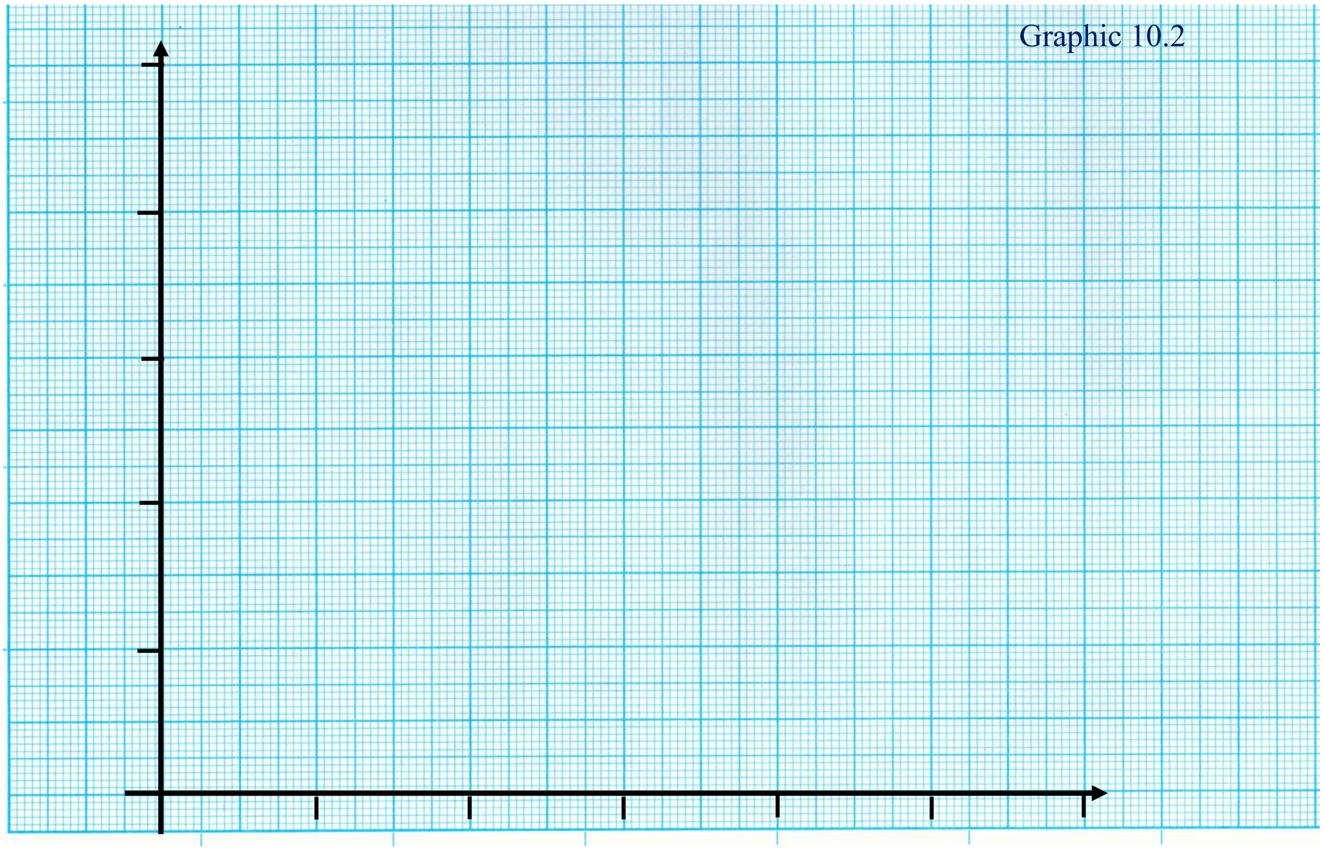
Thick spring constant k_{thick}= (______)

Harmonic oscillation:

1. In this step, suspend the same masses on each spring in turn. Pull the mass little bit down then release. Measure the time of the oscillation of the spring to complete 10 cycles for each mass by using the stopwatch. Divide each time by 10 to find the time for one period for each mass and record the values in table 10.2.
2. Calculate the period of oscillation T and square of the period of oscillation T^2 and fill in Table 10.2.

Table 10.2: Period of oscillation T as function of the suspended mass.

m (gr)	Δt_{thin} (s)	$T_{thin} = \frac{\Delta t_{thin}}{10}$ (s)	T^2_{thin} (s^2)	Δt_{thick} (s)	$T_{thick} = \frac{\Delta t_{thick}}{10}$ (s)	T^2_{thick} (s^2)
20						
40						
60						
80						
100						


Graphic 10.2

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

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

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

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

Compare the spring constants k_{thin} and k_{thick} values calculated by using the Hook's law and harmonic oscillation with each other. Discuss the reasons for probable differences.

Conclusion, Comment and Discussion:

(Tips: Give detailed explanations about what you've learned in the experiment and also explain the possible errors and their reasons.)

Signature:

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?

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Signature: