**EXPERIMENT 1 - Hooke's Law**

**Aim/Objective**

The aim of performing this experiment is to find out if the extension produced by a spring is directly proportional to the different tension forces applied to it and thus verifying Hooke’s law.

**Materials**

1. Retort stand

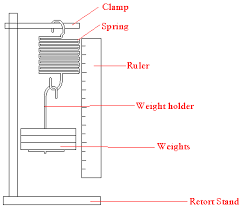
2. Spring

3. Weights

4. Weighing scale

5.Metric rule

**Diagram of Setup**



**Theory**To deform a material requires the application of a force. Some materials deform more easily than others. Materials that return to their original dimensions after the deforming force has been removed are called elastic. All materials exhibit some degree of elasticity but not always in sufficient quantity to be useful from a practical sense. The elasticity property makes its presence known through a restoring force that opposes the deformation force and tries to maintain the original dimensions of the material.

We will be considering elasticity in only one dimension. The restoring force is proportional to the magnitude of the deformation. This can be expressed in an equation known as Hooke’s Law after the discoverer of the effect, Robert Hooke.

Hooke's Law is a describes the relationship between the force applied to a spring or elastic material and the resulting deformation it undergoes. It states that the extension of a spring is directly proportional to the applied force provided the elastic limit is not exceeded. Mathematically, it is expressed as F = k \* x, where F is the force applied, k is the spring constant (a measure of the stiffness of the material), and x is the resulting deformation or displacement.

**Procedure**

1. Hang the spring on your retort stand.

2. Measure its initial length

3. Hang one mass

4. Record the new length

5. Calculate the difference between the initial and new lengths

6. Repeat the procedure with different masses while recording the new lengths

7. Record the extension by subtracting the new length from the initial in each measurement

8. Plot a graph of the extension, x, versus the mass

9. Calculate the spring constant from the slope of the graph

**Results**

**Table of Values**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Mass (g) | Mass (kg) | Original Length (cm) | Original Length (m) | New Length (cm) | New Length (m) | Extension (cm) | Extension (m) | Force Applied (N) |
| 50 | 0.05 | 10 | 0.1 | 15.2 | 0.152 | 5.2 | 0.052 | 0.5 |
| 100 | 0.1 | 10 | 0.1 | 18.5 | 0.185 | 8.5 | 0.085 | 1 |
| 150 | 0.15 | 10 | 0.1 | 21.0 | 0.21 | 11.0 | 0.11 | 1.5 |
| 200 | 0.2 | 10 | 0.1 | 23.8 | 0.238 | 13.8 | 0.138 | 2 |
| 250 | 0.25 | 10 | 0.1 | 26.5 | 0.265 | 16.5 | 0.165 | 2.5 |

(Acceleration due to gravity, g=10m/s)

**Calculation**

1. A metal cube suspended from the end of a spring causes it to stretch by 5cm. A 500g mass suspended from the same spring stretched by 2cm, if the elastic limit is not exceeded.

I. Find the weight of the metal cube?

II. By what length will the spring stretch if a mass of 1.5kg is attached to its end?

Solution

I. F1= ?; e1= 5cm= 0.05m; e2= 2cm= 0.02m; m= 500g= 0.5kg; F= mg= 0.5 \* 10= 5N (g= 10m/s)

F= ke

F2= ke2

5= k(0.02)

k= 5/0.02

k= 250N/m

F1= ke1

F1= 250 \* 0.05= 12.5N

The weight if the metal cube is 12.5N, and the mass is 1.25kg.

II. If m= 1.5kg, F= mg= 1.5 \* 10= 15N, k= 250N/m, e= ?

F= ke

e= F/k

e= 15/250

e= 0.06m

The spring will stretch by a length of 0.06m or 6cm.

**Precautions**

1. I avoided parallax error while using the ruler by placing my eyes directly opposite the ruler.

2. I ensured that the spring was not loaded beyond its elastic limit

3. I ensured that the weights were still before taking readings of the length

4. I took into account the zero error of the weighing scale while taking the measurements of the weights.

Observations

1. As the force was gradually applied to the spring, the resulting deformation (displacement) is seen proportional to the force. This is observed within the material's elastic limit.

2. The spring or material returns to its original shape and length when the force is removed, indicating its elastic nature.

3. When plotting the force applied against the extension, a straight line is observed, indicating a linear relationship.

**Applications**

1. Shock Absorbers: Vehicle shock absorbers and dampers utilize Hooke's Law to absorb and counteract the impact of road irregularities and vibrations, ultimately enhancing both ride comfort and vehicle stability.

2. Mechanical Springs: Hooke's Law serves as a fundamental principle in the creation and production of mechanical springs, which are integrated into everyday items like mattress springs, car suspension systems, door hinges, and mechanical timepieces.

3. Strain Gauges: Employing Hooke's Law as their basis, strain gauges gauge material deformation and are utilized across fields like structural engineering, civil engineering, and material testing to assess and analyze strains.

4. Load Cells: Load cells play a pivotal role in converting force into an electrical signal, finding utility in diverse settings such as weight measuring scales, industrial machinery, and automotive testing to achieve precise force measurements.

**Conclusion**

Hooke’s law is one of the fundamental principles in physics that defines the relationship between mass exerted and the extension/compression of an elastic material. Mass is the quantity of matter in an object, given in Kg. Every free object is acted on by the gravitational force of acceleration, giving its weight. According to Hooke’s law, whenever weight is exerted on a vertically hanging spring, it extends. The extension is directly proportional to the force exerted, in the case of a pulling force. If a compression force is used, then the spring shrinks in size in a measure proportional to the force. The direction of the restoring force is always opposite to the force acting on the spring. In this experiment, three different masses were used in three trials, and the data was recorded for graphical representation. The graph shows a linear relationship between mass and extension, with its slope giving the spring’s constant.

**Experiment 2 - Simple Pendilum.**

**Objective**

The objective of a simple pendulum experiment is to investigate and understand the relationship between the length of a pendulum and its period of oscillation. Thus, finding the acceleration due to gravity.

**Materials**

1. String or thread

2. A small weight (bob)

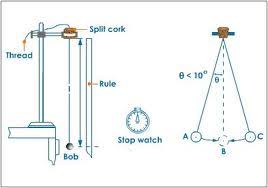
3. Stopwatch or timer

4. Meter stick or ruler

5. Retort stand

6. Venier Caliper

**Diagram of Setup**



**Theory**

A simple pendulum apparatus consists of a massed object connected to a massless string of a certain length. Simple pendulums are tools that demonstrate simple harmonic motion (if the angle of displacement is less than 30 degrees). When the pendulum is at rest, the displacement angle is equal to zero degrees. As the mass is released from some angle of displacement, the string swings back and forth, with gravity working as the restoring force. The period is the time it takes to complete one full cycle. Therefore, the period of a simpe pendulum is the time it takes to swing from one side to the other and back again. The period has units in seconds and is inversely proprortional to the frequency. The period can be found using the equation: T = 2 π √ (L/g).

In addition to finding results about the period, this experiment is also able to prove the acceleration due to gravity (due to gravity being the restoring force). By creating a graph of length vs. period^2 of the first three trials with the simple pendulum, a slope can be determined through excel. Once the slope is found, it will be possible to solve for acceleration due to graph using the equation: g = 4π²(L/T²)

**Procedure**

1. Cut a piece of a string or so that it is about 1 m long.

2. Attach a bob whose radius has been determined by a venier caliper at the end of the string at an initial height of 30cm.

3. Starting at an angle of less than 10º, allow the pendulum to swing and measure the pendulum’s period for 40 oscillations using a stopwatch.

4. Repeat the process with an increament of 10cm for an extra 4 times.

5. Tabulate your readings

**Results**

**Table of Values**

| **Length(cm)** | **Length(m)** | **Time(s)** | **Period,T(s)** | **g**  **(g = 4π²(L/T²))** |
| --- | --- | --- | --- | --- |
| **30** | **0.3** | **43** | **1.075** | **10.25** |
| **40** | **0.4** | **50** | **1.25** | **10.11** |
| **50** | **0.5** | **56** | **1.4** | **10.07** |
| **60** | **0.6** | **61** | **1.525** | **10.19** |
| **70** | **0.7** | **66** | **1.65** | **10.15** |

**Calculations**

The value for g for each length can be gotten from the equation, g = 4π²(L/T²)

When L= 0.3m, T= 1.075s;

g = 4π²(0.3/1.075²)

g= 10.25m/s²

When L=0.4m, T=1.25s;

g = 4π²(0.4/1.25²)

g= 10.11m/s²

When L=0.5m, T=1.4s

g = 4π²(0.5/1.4²)

g= 10.07m/s²

When L=0.6m, T=1.525s;

g = 4π²(0.6/1.525²)

g= 10.19 m/s²

When L=0.7m, T=1.65;

g = 4π²(0.7/1.65²)

g= 10.15m/s²

**Precautions**

1. I closed all window and switched off the fan to protect the experiment from air resistance.

2. I emailed that the pendulum string and bob were displaced at an angle less that 10 degrees.

3. I took note of the zero error of the stopwatch, and compensated for it in my calculations.

4. I ensure that the string is attached at the exact center of the pendulum bob to reduce errors in calculations.

**Observations**

During the simple pendulum experiment, it is observed that there is a relationship between the length of the pendulum and its period of oscillation, noticing that longer lengths lead to longer periods. It is also observed that the amplitude of the pendulum's swing doesn't significantly affect the period for small angles. Other observations include the pendulum's back-and-forth motion, following a sinusoidal pattern, and how changing the mass of the pendulum bob affects its motion.

**Application**

1.Damping and Friction: Introducing damping or friction to the pendulum can help teach about the effects of external forces on motion.

2. Harmonic Motion: The simple pendulum exhibits harmonic motion, which can be used to explain the concept of restoring forces and equilibrium positions

3. Measurement of Gravity: The period of a simple pendulum is influenced by the acceleration due to gravity. By measuring the period and length of the pendulum, one can calculate the local gravitational acceleration.

4. Periodic Motion: It helps illustrate the concept of periodic motion, including amplitude, frequency, and period.

5. Mathematical Concepts: The experiment can be used to discuss trigonometric functions, such as sine and cosine, as well as concepts like displacement, velocity, and acceleration.

6. Energy Conservation: The simple pendulum is a great example of energy conservation between potential and kinetic energy as it swings back and forth.

7. Pendulum Clocks: The principles of the simple pendulum are used in traditional pendulum clocks to keep time.

**Conclusion**

In conclusion, the simple pendulum experiment demonstrated how the period of a pendulum's oscillation is affected by its length. As the length increases, the period also increases, confirming the relationship between these two variables. This experiment highlights the fundamental principles of harmonic motion and provides valuable insights into the physics of pendulums.

Also, the most accurate value for g from the experiment is 10.07 m/s². This deviation from the standard value can result from a number of little errors. However, the experimented value has an approximate to the standard.

**Experiment 3 - Throttle Control**

**Observation:** To comprehend the impact of throttle position adjustments on both engine RPM and the speed of the vehicle.

**Theory**

Throttle control, also known as throttle modulation or throttle management, is a crucial aspect of automotive engineering that directly influences engine performance and vehicle dynamics. The theory of throttle control revolves around how the manipulation of the throttle position affects the amount of air-fuel mixture entering the engine cylinders, which in turn impacts engine RPM and vehicle speed.

Throttle control theory highlights the intricate relationship between throttle position adjustments, engine RPM, torque, vehicle speed, and overall performance. By understanding and effectively managing throttle control, automotive engineers can optimize power delivery, fuel efficiency, and driver experience while ensuring safe and controlled operation of the vehicle.

Throttle control significantly influences engine revolutions per minute (RPM) and torque output. Opening the throttle quickly can lead to rapid acceleration, causing the engine to rev higher. Gradually increasing the throttle provides smoother acceleration and allows the engine to build torque more steadily.

**Setup of Experiment**

1. For conducting this straightforward throttle control experiment, you'll require a vehicle equipped with a throttle control system.

2. Install sensors capable of accurately measuring throttle position, engine RPM, and vehicle speed.

3. Ensure precise calibration and synchronization of the sensors to capture data without any inaccuracies.

4. Select a controlled environment, such as a closed test track or a straight, low-traffic road.

5. Position the data logging equipment to consistently document sensor readings throughout the experiment.

6. Perform the trials by incrementally adjusting the throttle position, while simultaneously documenting the resulting alterations in engine RPM and vehicle speed.

7. Repeat the experiment several times to confirm the consistency and dependability of the collected data.

**Results**

**Table of Values**

| **Test No** | **Trottle Position %** | **Engine RPM**  **(rev/min)** | **Speed**  **(mph)** |
| --- | --- | --- | --- |
| **1** | **20** | **1500** | **30** |
| **2** | **30** | **1800** | **40** |
| **3** | **40** | **2200** | **50** |
| **4** | **50** | **2500** | **60** |

**Observation**

1. As throttle position increases, engine RPM tends to rise proportionally. This demonstrates the direct relationship between throttle input and engine speed.

2. A higher throttle position corresponds to increased vehicle speed. This signifies the role of throttle control in regulating acceleration and overall speed.

3. Engine RPM and vehicle speed demonstrate a positive correlation. Higher RPM values generally lead to greater vehicle speeds, highlighting the connection between engine performance and motion.

**Precaution**

1. I made sure to adhere to all safety protocols while conducting the experiment, especially when operating the vehicle.

2. I used appropriate safety attire and followed traffic regulations when the experiment was carried out on a roadway.

3. I opted for a controlled testing environment with minimal traffic to prevent potential accidents and external factors from affecting the experiment.

4. I confirmed the proper installation, calibration, and synchronization of sensors to maintain accurate and precise measurements throughout the experiment's duration.

5. I verified the functionality of the data logging equipment to guarantee precise recording of sensor data.

6. When executing the experiment, I gradually adjust the throttle position to minimize abrupt acceleration, which could impact the readings and the experiment's integrity.

7. I repeated the experiment multiple times to ensure data consistency and reliability.

8. I ensured that the vehicle was in optimal mechanical condition prior to the experiment to prevent unforeseen malfunctions during testing.

**Application**

Throttle control has various applications, such as in vehicles to regulate engine power and speed, in industrial processes to control machinery, and in drones to manage flight stability and altitude.

It's also used in gaming for controlling character movement and in robotics for precise control of robot motions.

**Conclusion**

The throttle control experiment provided valuable insights into the intricate relationship between throttle position adjustments, engine RPM, and vehicle speed.

The experiment revealed a clear correlation between throttle position and engine RPM. As the throttle position increased, the engine RPM followed suit, resulting in enhanced power output. This underscores the direct influence of throttle control on engine performance.

**Experiment 4 - Cruise Control.**

**Objective**

To investigate how the cruise control system sustains a consistent velocity according to the preset cruise control setting.

**Theory**

Cruise control is a system commonly used in vehicles to automatically maintain a constant speed set by the driver, without the need for constant manual acceleration or deceleration. It helps improve driving comfort, fuel efficiency, and reduces driver fatigue on long stretches of highway or open roads.

When activated, the cruise control system takes over control of the vehicle's throttle (engine power) to maintain the selected speed. The driver sets the desired speed, usually using controls on the steering wheel or dashboard, and the system adjusts the throttle as needed to keep the vehicle moving at that speed.

A cruise control experiment typically involves testing and analyzing the effectiveness of a control system designed to maintain a constant speed for a vehicle

**Setup of Experiment**

1. An automobile equipped with a cruise control system is necessary for this investigation.

2. Verify the operational performance of the cruise control system and ensure its accurate setup for different speed settings.

3. Select a suitable testing route that allows for consistent vehicle speed, avoiding substantial inclines or declines.

4. Install sensors to accurately measure the vehicle's velocity during the trial sessions.

5. Set up data recording equipment to log both the vehicle's speed and the cruise control parameters throughout the examinations.

6. Program the cruise control to specific speeds (e.g., 50 mph, 55 mph) and guide the vehicle along the chosen route.

7. Record the vehicle's speed achieved by the cruise control system at each predetermined value.

8. Repeat the trial for every cruise control configuration to ensure the accuracy and reproducibility of the collected data.

**Results**

**Tables of Value**

|  |  |  |
| --- | --- | --- |
| Test No. | Cruise control setting (mph) | Speed (mph) |
| 1 | 50 | 48 |
| 2 | 55 | 54 |
| 3 | 60 | 58 |
| 4 | 65 | 62 |

**Observations**

1. The vehicle sustains the preset speed, even when encountering gentle uphill or downhill slopes.

2. Full manual control of the vehicle is quickly reinstated once the cruise control system is deactivated.

3. The cruise control system efficiently increases the vehicle's speed to the designated level.

4. The system keeps a consistent pace without needing throttle adjustments.

5. To turn off the cruise control system, you can press the brake pedal or utilize the cancel/resume feature.

**Precautions**

1. Ensure a safe testing environment on a controlled road or closed circuit.

2. Verify the cruise control system's functionality before testing.

3. Maintain a safe following distance from other vehicles.

4. Monitor road conditions and weather to avoid hazardous situations.

5. Have a co-driver ready to take control if needed.

6. Obey all traffic laws and regulations.

7. Keep both hands on the steering wheel to intervene if necessary.

8. Pay attention to changes in traffic flow and unexpected obstacles.

9. Gradually adjust speed settings to prevent abrupt changes.

10. Be prepared to disengage cruise control in emergencies.

**Application**

Cruise control is commonly used in automobiles to maintain a consistent speed on highways, promoting fuel efficiency and reducing driver fatigue. It's also employed in some industrial machinery and equipment to regulate speeds during specific tasks, improving accuracy and productivity.

**Conclusion**

The cruise control experiment offers valuable understanding regarding a vehicle's cruise control system's operation and effectiveness. Through assessing the system's capacity to uphold a predetermined speed and adjust to different road conditions, researchers can gain improved comprehension of the benefits and constraints of this functionality.

# **Experiment 5 - Sensitivity Analysis Experiment**

**Aim/Objective**

The aim of this experiment was to perform a sensitivity analysis on a governor system, with the purpose of comprehending how it responds to alterations in different parameters and assessing the impact of those changes on its overall performance.

**Setup for the Experiment**

- An engine equipped with a governor system.

- A tachometer utilized to measure the revolutions per minute (rpm).

- A load increment mechanism, such as additional weights, to introduce incremental loads.

**Results**

**Table of Values**

|  |  |
| --- | --- |
| Load Increment (kg) | Engine Speed (RPM) |
| 0 | 1500 |
| 10 | 1450 |
| 20 | 1420 |
| 30 | 1405 |

**Observations**:

1. When the throttle valve was opened, the input speed experienced an upsurge. As a response, the governor stabilized at a higher speed.

2. The introduction of a higher load caused the governor to decelerate, eventually stabilizing at a reduced speed.

3. The power output of the governor declined proportionally with the increase in load.

4. A rise in temperature had a minor impact, leading to a slight reduction in both speed and power output.

**Precautions**

1. Prior to initiating the experiment, confirm the governor setup, tachometer, and weights are functioning correctly.

2. Put on suitable PPE, including gloves and goggles, to safeguard against potential risks.

3. Carry out the experiment within a controlled setting to avert accidents and disruptions while testing.

4. Add weights to the governor gradually to prevent abrupt changes that might result in unintended outcomes or equipment harm.

5. Employ data recording sheets to precisely record all measurements throughout the experiment.

**Application**

A governor is used to regulate and control the speed of engines, machinery, or systems. It finds applications in engines (like in cars, generators, and steam engines) to maintain a consistent speed and prevent over-speeding. Governors are also used in industrial processes to ensure stable operation and in hydroelectric power plants to control the speed of turbines, helping maintain grid stability.

**Conclusion**

Through meticulous data analysis and sensitivity coefficient calculations, we successfully quantified the system's responsiveness to various parameter adjustments. This experiment underscored the importance of sensitivity analysis in comprehending the dynamics and effectiveness of mechanical systems such as governors. The outcomes obtained enhance our understanding of governor systems and their practical implications in real-world scenarios.