Mechanics lab.

First year students

Experiments' sheet

First semester

Experiments:

1. Determination of the acceleration of gravity by using a simple pendulum.
2. Determination of the velocity of sound by means of a resonance tube closed at one end.
3. Experiments with a spiral spring.
4. Determination of the acceleration of gravity by a compound pendulum (bar pendulum).
5. Determination of the moment of inertia of a flywheel.
6. Determination of the Coefficient of Static and Kinetic Friction.

Experiment one

Determination of the acceleration of gravity by means of a simple pendulum

Aim:

Earth gravitation ‘g’ is calculated.

Tools and equipments:

Metre scale. A meter rule, a stand, a metal bob, good quality string, Stop /watch

Procedure and data collection:

1. Tie the hook of the bob on one end of a thread (about 1 meter). Clamp the other end firmly between the gaps of a split cork which is fixed to the clamp of the retort stand as shown in the figure 1.
2. Measure the length 'l' from the middle of the bob to the lower edge of the split cork.
3. Move bob using the hand at a small angle and leave it. See that the bob returns over the line without spinning.
4. The stop watch is started when the pendulum crosses the equilibrium position to any one side. You can also start at the releasing point and take one complete cycle as one oscillation.
5. Just when the 20th oscillation is complete, record the time at once stop the stop watch.
6. Repeat step 5 for several length of the thread and record the data in the table 1.
7. Plot a graph between ‘l’ and T^2
8. Use equation 1 to obtain the ‘g’ value.
9. Compare your result with theoretical value of ‘g’.

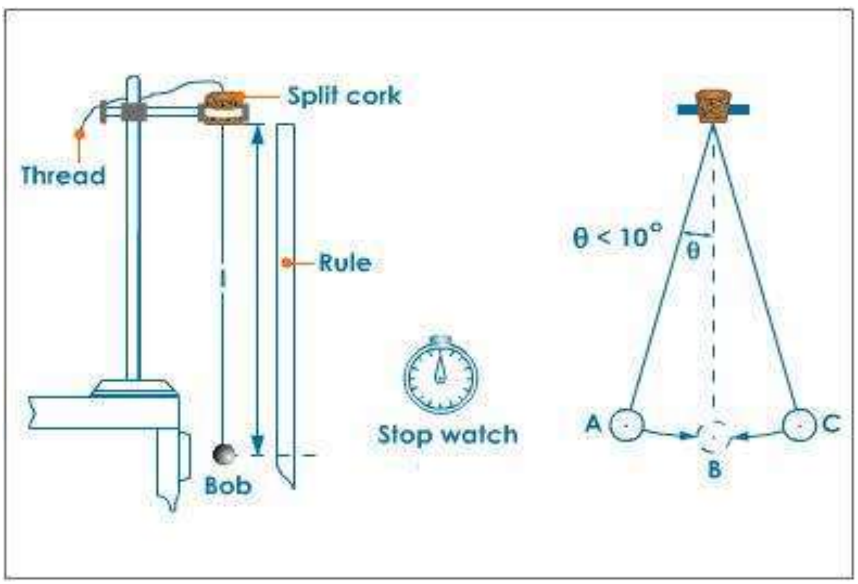


Figure 1. Experimental set-up

Table 1. Data collection

Length (m)	Time of 20 oscilla (sec)	Time of one oscill (sec)	T^2 (sec^2)
0.1			
0.2			
0.3			
0.4			
0.5			
0.6			
0.7			
0.8			
0.9			
1			

$g = 4\pi^2 x \frac{l}{T^2}$ …….equ.1-a, where $\frac{l}{T^2}$ is equal to slope in figure 2. Hence, equation 1 can be written as below:

$g = 4\pi^2 xslope$ ……equ.1-b

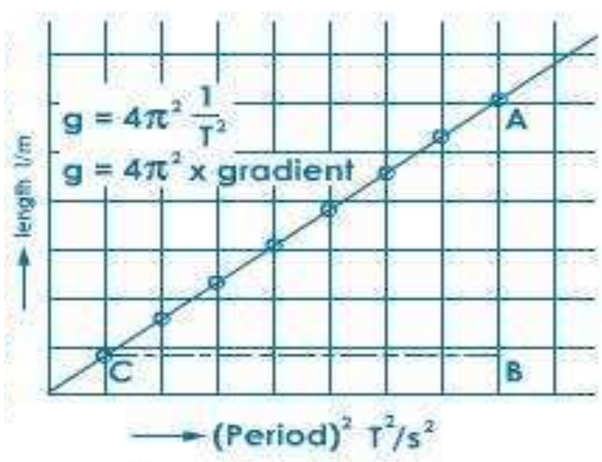


Figure 2. Graphical distribution

Common questions

1) What is the effect of mass on the period (for a given value of the length)?
2) What role, if any, does air resistance have on your results? Explain your reasoning.
3) On the moon, the acceleration due to gravity is one-sixth that of earth. That is **g moon = g earth /6 = (9.8 m/s^2)/6 = 1.63 m/s^2** .
check: https://www.youtube.com/watch?v=PTN0HFD7Utw

Experiment two

Determination of the speed of sound by means of a resonance tube closed at one end

Aim:

Determination of the velocity of sound by means of a resonance tube closed at one end.

APPARATUS:

Resonance tube, assorted tuning forks, rubber bands, striking block, water.

PROCEDURE:

(1) Strike a tuning fork against a soft material such as a rubber block. Hold the vibrating fork near the open end of the resonant tube and listen to the sound intensity as the water level is raised or lowered. When a position of maximum sound intensity is found, record the position of the water level (L) on the tube scale or with a meter stick (figure 1). The scale reads from zero at the top, so this directly gives the length of the resonant air column. There may be 2, 3, or more resonant lengths for each tuning fork. Find them all.

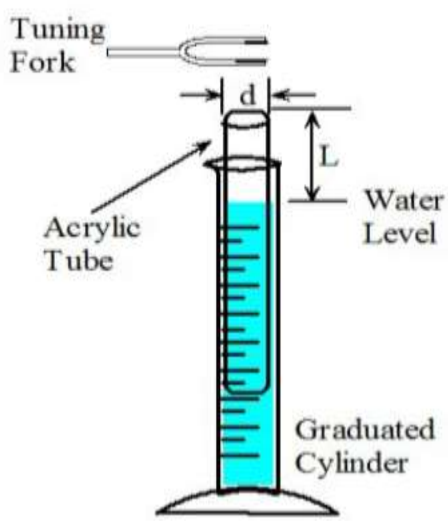


Figure 1. Experimental set-up

(2) Check the data for consistency. The spacing between the resonant lengths should be about equal, and this spacing should be twice the length of the shortest tube length.

(3) Repeat procedure (1) and (2) for a fork of different frequency.

(4) Record your data in table 1.

(5) Plot a graph between L (mean) and 1/f. Find the value of slope from it.

(6) Use equ. 1 to find out the experimental value of the speed of sound.

(7) Compare experimental results with theoretical results of equ.2

Note: Do not forget to measure the room temperature (T) and the diameter of the tube.

Table 1. Data collection

Frequency (f) [Hz]	Length of air column (L) [m]			1/f
	L1	L2	L (mean)	
Try several frequencies				

$L + \varepsilon = \frac{\lambda}{2}$, $but\ \ v = \lambda f$ $\qquad thus, L + \varepsilon = \frac{v}{2f}$

$also\ L = \frac{v}{2}\ x \frac{1}{f} - \varepsilon$ or

$\boldsymbol{v = 2\ slope}$ …………… equ.1 (to measure the experimental value)

$\varepsilon =$ is the end correction of the tube and its experimental value is equal to the negative intercept of the y-axis.

$v = 331\sqrt{\frac{273+T}{272}}$ …… equ.2 (m/s) (to measure the theoretical value)

and $\varepsilon = 2\ x\ 0.6\ x\ radius\ of\ tube$

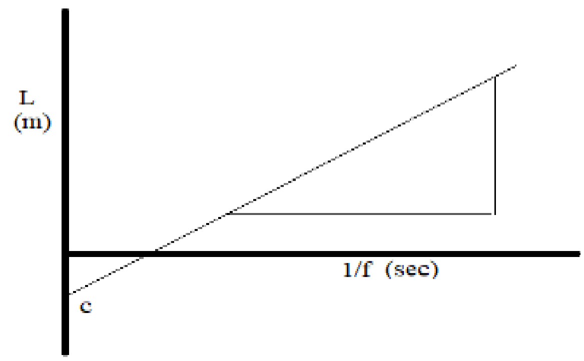


Figure 2. Experimental evaluation

Questions:

1. What is the influence of temperature on the speed of sound?
2. How the speed of sound changes with variations of the tube diameter?
3. Explain the reputation of sound in only some specific length (L).
4. How does vibration cause sound production?
5. Explain figure 3 and 4.

THEORY:

(1) The frequency of sound in a medium is related to the wavelength by the formula $v = f\lambda$ where v is the speed of sound in the medium, f is the frequency of the sound, and λ (Greek letter "lambda") represents the wavelength of the sound in the medium. This formula is used to calculate the speed of sound in air from measurements of wavelength and frequency.

(2) The sound speed varies with temperature. At 0°C the speed in air is 331.4 m/sec, while at 20°C it is 344 m/sec. The speed is very nearly linearly dependent on temperature. Use this information to write an equation for speed of sound as a function of temperature.

(3) RESONANCE. When a vibrating object sets up air vibrations in an enclosed space, the sound vibrations in the air are very weak at some frequencies, and strong at other frequencies. The frequencies at which the sound vibrations are strong are called *resonant frequencies* of the system, and these are easily recognized by listening to the sound intensity. Altering the shape or size of the enclosed volume will give a different set of resonant frequencies.

Resonance occurs because the walls of the enclosure restrict the ways in which the air inside can vibrate. Each of the ways it can vibrate is called a *mode* of vibration. The number of different modes of any container is infinite, but there are *not* allowed modes for every frequency.

When the air within an enclosure is set into periodic vibration, the values of many measurable quantities change periodically with time. Such quantities as particle position, velocity, pressure, density, and even temperature vary periodically. The average size of the variation of any one quantity is different in different parts of the medium. There may be certain points in the medium where a particular quantity is not varying at all. Such a region is called a *node* of that quantity. A region where the variation of a quantity has a relative maximum is called an *antinode* of that quantity.

In long tubes, there will always be a particle velocity node at a closed end, since the closure prevents air motion. There will be a particle velocity antinode near an open end. In any tube, the spacing between a node and the next closest antinode is always 1/4 of the wavelength of the sound.

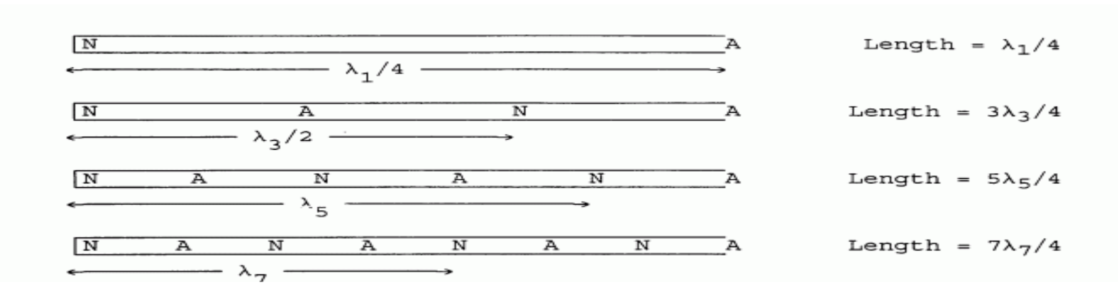


Figure 3. resonant wavelength of a tube of fixed length

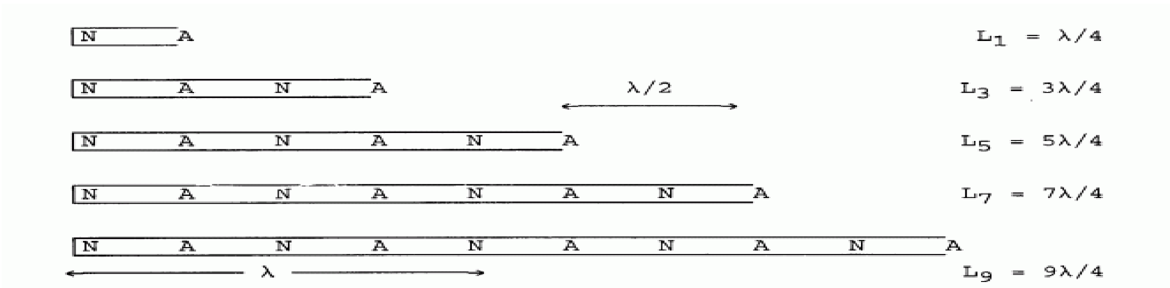


Figure 4. Resonant tube length for constant wavelength

Check: https://www.youtube.com/watch?v=CM5IFM0N1bE

Experiment three

Experiments with a spiral spring

Aim

To verify the Hook's law and gravity determination with vibration mode.

Apparatus

Spiral spring to which a light pointer is attached by plasticine at its lower end, rigid strand and clamp, meter rule, scale-pan, weights and stop-watch.

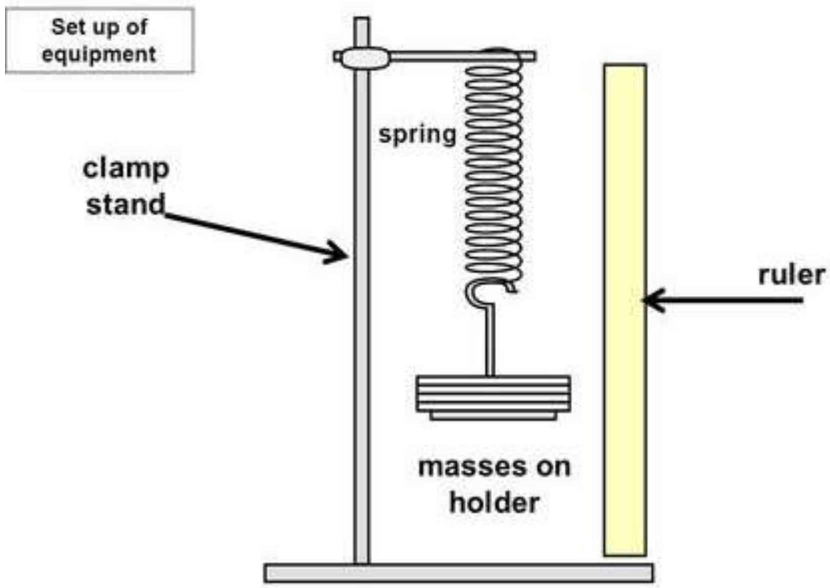


Fig.1. Setup of experiment

Methods: Two experiments are carried out.

Experiment 1: To verify Hooke's law and find the spring constant.

Procedure: The spring with scale pan attached is firmly clamped and the meter scale placed vertically so that the pointer moves lightly over it. Loads are added to the scale pan and the corresponding extensions of the spring are noted. The scale readings are also taken when unloading the spring, and the mean extension thus obtained. Plot a graph between the load and mean extension. Use equation (1) to determine slope 1 from figure 2.

$F = -k\ \Delta x$ [Hooke's law]

$mg = k\Delta x$ $\Delta x = \frac{mg}{k} = mn$ where $n = \frac{g}{k}$ = spring constant, Also

$n = \frac{\Delta x}{m}$ ……………slope 1. In unit gm/cm

Table 1. Data collection of exp. 1

Load [kg]	Extension [cm]		Mean extension (Δx) [cm]	Mean extension (Δx) [m]
	Load increasing	Load decreasing		

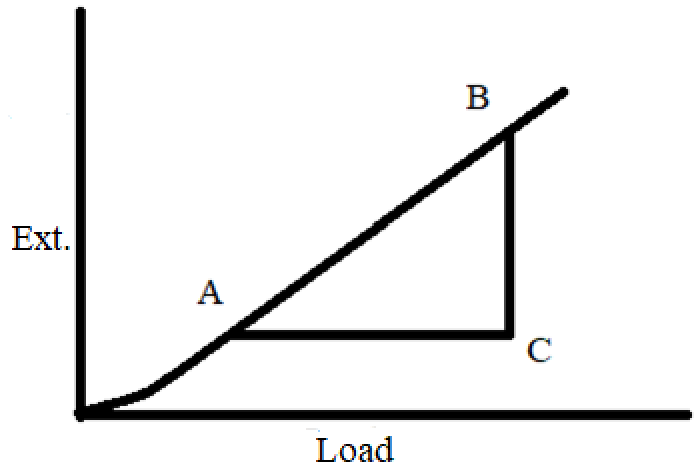


Fig. 2. Extension versus load

Experiment 2: To determine the declaration of gravity and the effective mass (m) of the spring.
Procedure: A load is added to the pan which is set in vertical vibration by giving it a small additional displacement. The periodic time (T) is obtained by timing 20 vibrations. This is repeated with different loads and a graph of (T^2) against load is plotted (fig.3), from which g and m are found.

Note: the mass of the scale pan should be included in the load.

Table 2. Data collection of exp.2

Load M [kg]	Time of 20 oscillation [sec]	Time of one oscillation	T^2 [sec^2]

$g = 4\pi^2 n \frac{M}{T^2}$, $From\ fig\ 3,$ $\frac{M}{T^2} = \frac{AC}{BC}$ =slope 2.

Thus

$g = \frac{4\pi^2 n}{slope\ 2} = 4\pi^2 \frac{slope\ 1}{slope\ 2}$ in m/s^2

Also, effective mass of the spring (m)=OD in kg,

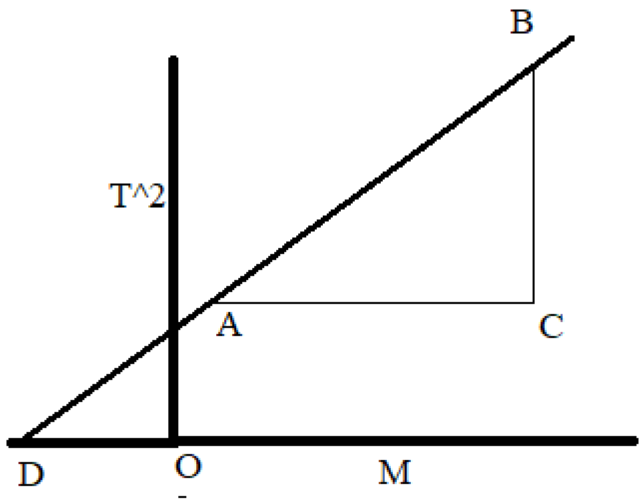


Fig. 3. Mass versus time of oscillation

Check: https://www.youtube.com/watch?v=QQCJeAqBumE

Experiment four

Determination of the acceleration of gravity by a compound pendulum (bar pendulum)

OBJECT: To determine the value of acceleration due to gravity and radius of gyration using bar pendulum.

Apparatus: Bar pendulum, stop watch and meter scale.

Formula:

A. The general formula of the time period for bar pendulum is given by following equation:

$$T = 2\pi \sqrt{\frac{\frac{k^2}{l}+l}{g}} = 2\pi \sqrt{\frac{l_2+l_1}{g}}$$

$$\boldsymbol{g = 4\pi^2 \frac{l_2+l_1}{T^2} = 4\pi^2 \frac{L}{T^2}} \quad \textbf{............ (1)}$$

Where l: distance between C.G. and suspension point, L: distance between suspension and oscillation points, $L = l_2 + l_1 = l + \left(\frac{k^2}{l}\right)$, g: acceleration due to gravity, T: time period

B. The time period is minimum when $l = \pm k$, in this situation the equation (1) becomes as:

$$T_{min} = 2\pi \sqrt{\frac{2k}{g}} \quad or$$

$$\boldsymbol{g = \frac{(8\pi^2 k)}{T_{min}^2}} \quad \textbf{..................(2)}$$

where, k: radius of gyration, T_{min}: minimum time period.

The value of ‘g’ can be calculated using equations (1) and (2).

The values of L, T, k and T_{min} are obtained using graph between T and L for bar pendulum which is shown in following figure.

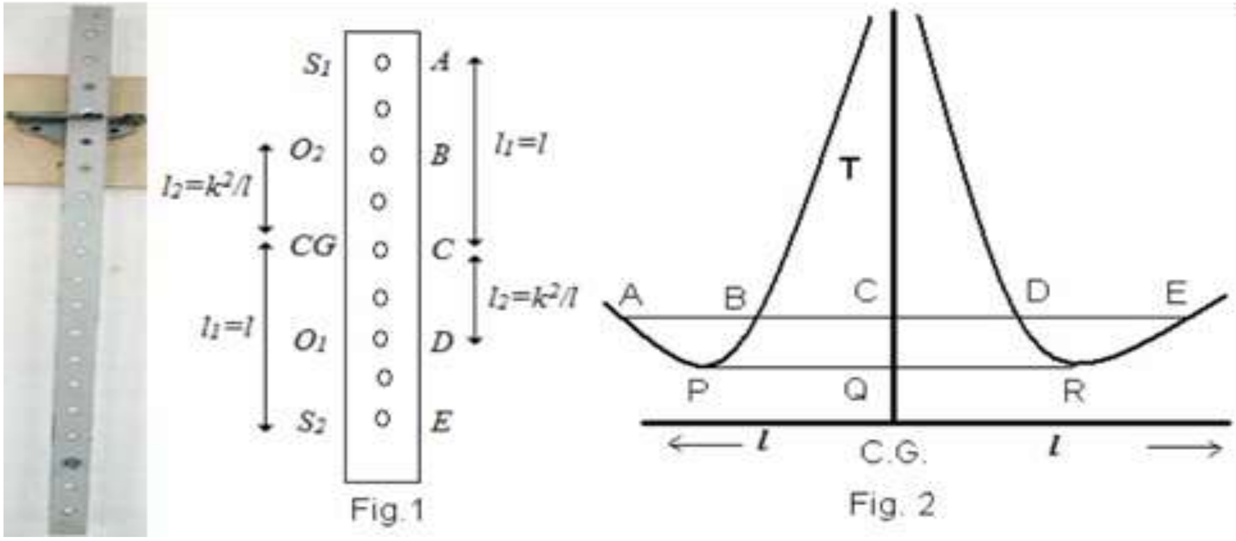


Fig.1 Fig. 2

From Figures (1) and (2),

(a) **L_1=AC+CD, L_2=EC+CB and L=(L_1+L_2)/2, T=time at C**

(b) **k =(PQ+QR)/2 and T_{min}= time at Q**

C. The **radius** of gyration can be obtained with following formula

$$k = \sqrt{l_2 + l_1}$$

Where ***l_1=(AC+CE)/2, l_2=(BC+CD)/2***

Procedure:

(1) Place the knife-edges at the first hole of the bar.

(2) Suspend the pendulum through rigid support with the knife-edge.

(3) Oscillate the pendulum for small amplitude (θ=3~4^0).

(4) Note the time taken for 20 oscillations and measure the distance of the hole from the C.G. of the bar.

(5) Repeat the observations (2)-(4) for knife-edges at first half side holes of bar.

(6) Repeat the process (1)-(5) for the second half side of the bar.

(7) Plot the graph between T and L.

Observations:

1. Least count of the stop watch = ….. sec
2. Least count of the meter scale =…… cm
3. The acceleration due to gravity (g) = … m/s^2 and Radius of gyration (k) =…cm

Table 1. Data collection

l (cm)	t (time taken for 20 oscillations)	T = t/20
For first half side of the bar		
45		
40		
35		
30		
25		
20		
15		
10		
5		
For second half side of the bar		
-5		
-10		
-15		
-20		
-25		
-30		
-35		
-40		
-45		

Calculation: From fig.2, find the following:

- L=(AD+EB)/2= ? T= *? sec*
- k=PR/2= ? T_{min}= ? sec
- l_1=(AC+CE)/2=?
- l_2=(BC+CD)/2 = ?
- $g_1 = 4\pi^2 \frac{L}{T^2}$
- $g_2 = \frac{(8\pi^2 k)}{T^2_{min}}$
- $g_{average} = \frac{g_1 + g_2}{2}$

Question:

What is the main difference between simple pendulum and compound pendulum? Give examples of compound pendulum.

Check: https://www.youtube.com/watch?v=Jac3A-ecs4c

Experiment five

Determination of the moment of inertia of a flywheel

Aim

To compare the theoretical and experimental value of moment of inertia for flywheel.

Equipments

1. vernier
2. Flywheel
3. string
4. meter ruler
5. Stop watch
6. slotted mass on hanger.

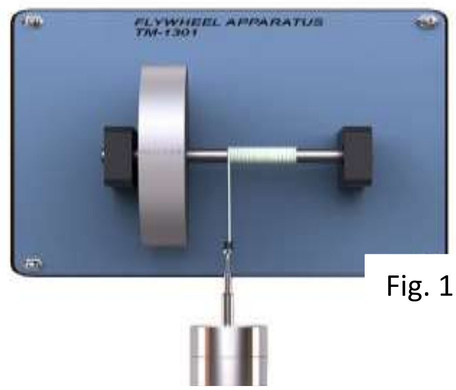


Fig. 1

Procedure:

- To start with the experiment one end of the string is looped on the peg and a suitable weight is placed in the weight hanger. The fly wheel is rotated '**n**' times such that the string is wound over 'n' turns on the axle without overlapping. The flywheel is held stationary at this position. The height '**h**' from the floor to the bottom of the weight hanger is measured. The flywheel is then released. The mass descends down and the flywheel rotates. Start a **stop watch** just when the peg detaches the axle. **Count the number of rotations 'N'** made by the wheel during the time interval between the peg gets detached from the axle and when the wheel comes to rest. The **time interval 't'** also is noted. The **experiment is repeated for same 'n' and same mass 'm'**. The **average value of 'N'** and **'t'** are determined.
- Record the data in table 1.
- Measure the diameter (D)and radius (r) of the axle using vernier calipers (m).
- The angular velocity of the wheel ($\boldsymbol{\omega}$) **and** moment of **inertia 'I' are calculated using equations (1) and (2)**.
- The entire experiment is repeated for **different values of 'n' and 'm'** and the average value of I is calculated.

Notes:

- Ensure that the length of the string is such that when the mass just touches the floor the peg gets detached from the axle.

- In certain wheels the peg is firmly attached to the axle. In such case, one end of the string is loosely looped around the peg such that when the mass just touches the floor the loop gets slipped off from the peg.
- 'm' is the sum of mass of weight hanger and the additional mass placed on it.

Table 1. Data collection

Mass suspended at one end of the string 'm' kg	Height from the floor to the bottom of weight hanger 'h' m	Number of windings of string on the axle 'n'	No. of rotations of the wheel after the detachment of the peg from the axle 'N'			Time interval in between the detachment of the peg and when the wheel comes to stop, 't' sec.			$\omega = \frac{4\pi N}{t}$	I kg.m^2
			1	2	Mean N	1	2	Mean t sec		

$$\boldsymbol{\omega = \frac{4\pi N}{t}} \quad \ldots\ldots(1)$$

$$\boldsymbol{I = \frac{Nm}{N+n}\left(\left(\frac{2gh}{\omega^2}\right) - r^2\right)} \quad \ldots\ldots..(2) \qquad \textbf{kg.m}^2$$

Theory:

A flywheel is an inertial energy-storage device. It absorbs mechanical energy and serves as a reservoir, storing energy during the period when the supply of energy is more than the requirement and releases it during the period when the requirement of energy is more than the supply. The main function of a fly wheel is to smoothen out variations in the speed of a shaft caused by torque fluctuations. Many machines have load patterns that cause the torque to vary over the cycle. Internal combustion engines with one or two cylinders, piston compressors, punch presses, rock crushers etc. are the systems that have fly wheel.

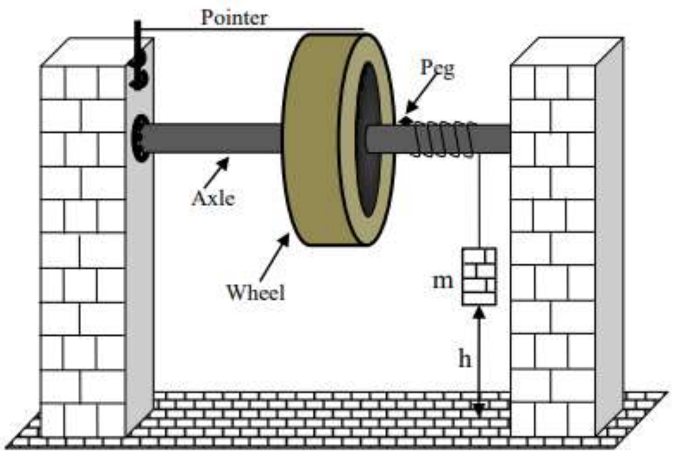


Figure 2.

A flywheel is a massive wheel fitted with a strong axle projecting on either side of it. The axle is mounted on ball bearings on two fixed supports as shown in fig.2. There is a small peg inserted loosely in a hole on the axle. One end of a string is looped on the peg and the other end carries a weight hanger. A pointer is arranged close to the rim of the flywheel. To do the experiment, the length of the string is adjusted such that when the descending mass just touches the floor, the peg must detach the axle. Now a line is drawn on the rim with a chalk just below the pointer. The string is then attached to the peg and the wheel is rotated for a known number of times 'n' such that the string is wound over 'n' turns on the axle without overlapping. Now the mass m is at a height 'h' from the floor. The mass is then allowed to descend down. It exerts a torque on the axle of the flywheel. Due to this torque the flywheel rotates with an angular acceleration. Let ***ω*** be the angular velocity of the wheel when the peg just detaches the axle and W be the work done against friction per one rotation, then by law of conservation of energy,

$$mgh = \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2 + nW \qquad (1)$$

Let N be the number of rotations made by the wheel before it stops. Since the kinetic energy of rotation of the flywheel is completely dissipated when it comes to rest, we can write,

$$NW = \frac{1}{2}I\omega^2$$

Or, $$W = \frac{I\omega^2}{2N} \qquad (2)$$

Using eqn.2 in eqn.1,

$$mgh = \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2 + n\frac{I\omega^2}{2N} = \frac{1}{2}I\omega^2\left(1+\frac{n}{N}\right)+\frac{1}{2}mr^2\omega^2$$

$$\therefore \quad I = \frac{Nm}{N+n}\left(\frac{2gh}{\omega^2}-r^2\right) \qquad (3)$$

where, 'r' is the radius of the axle. To determine $\boldsymbol{\omega}$ we assume that the angular retardation of the flywheel is uniform after the mass gets detached from the axle. Then,

$$\text{Average angular velocity} = \frac{\text{Total angular displacement}}{\text{Time taken}}$$

$$\frac{\omega+0}{2} = \frac{2\pi N}{t}$$

$$\omega = \frac{4\pi N}{t} \qquad (4)$$

Notes:

- Connect this experiment with devices used in daily life.
- You may check the bellow link,

Check: https://www.youtube.com/watch?v=9agoJRCnu4w

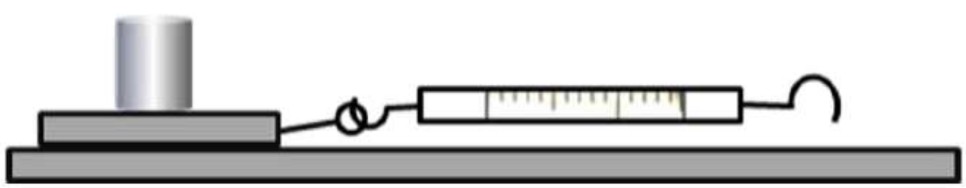
Experiment six

Determination of the coefficient of static friction

Aim:
To determine the coefficient of static and kinetic friction.

Equipments:
1. Wooden, glass and Plexiglas slabs.
2. Wooden, glass and Plexiglas path.
3. Dynamometer.
4. Weights

Experimental Procedure
1. Set the equipments as shown in the figure below.
2. Calculate the normal force for each different mass combination with the equation N=mg ($g=9.81\ m/s^2$).
3. Apply horizontal force with and without mass for static friction (i.e. the maximum applied force without motion).
4. Record the maximum static friction force for the relative mass (which is equal to the applied force).
5. Apply horizontal force with and without mass for kinetic friction (i.e. apply constant force with constant motion).
6. Record the kinetic friction force for the relative mass (which is equal to the applied force).
7. Work out the coefficient of friction for all static and kinetic cases with the equation $\mu = f / N$.
8. Record the coefficients.
9. Plot the graphs of $f_{applied}$ versus N and calculate the slope to find the average with graphical method.



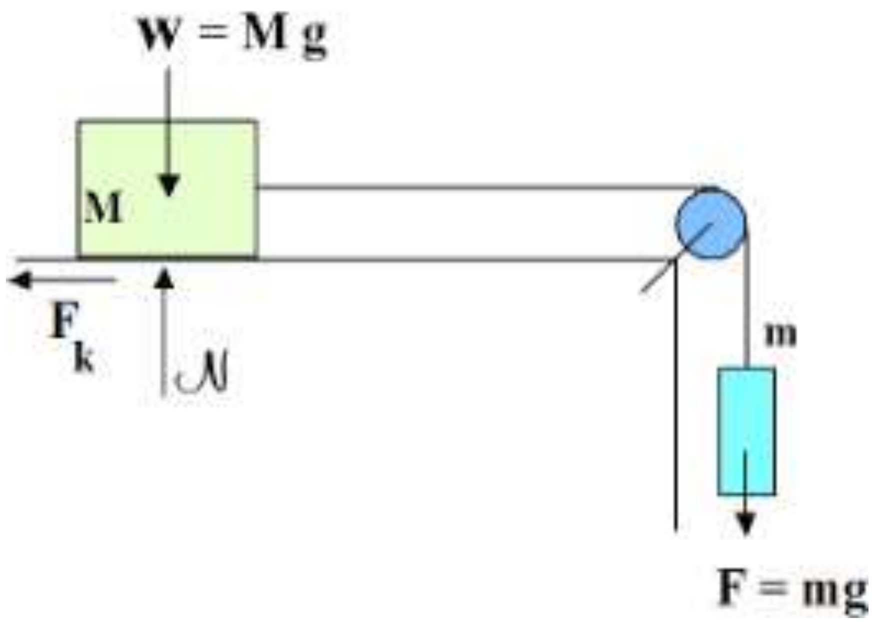


Table 1. Data collection

Surfaces	Weight (N)	Normal Force (N)	F-static (N)	µ	µ average

Check: https://www.youtube.com/watch?v=ON8h8Tg65Sc