Pusat Asasi Sains dan Perubatan UniSZA

UniSZA Science and Medicine Foundation Centre

LABORATORY

PHYSICS

SEMESTER I (2023/2024)

- Torque
- Newton's 2nd Law / Air Track
- Hooke's Law
- Interference of Light
- Archimedes's Principle

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PRACTICAL 1

TORQUE

1. OBJECTIVES

In equilibrium, the following tasks will be determined:

1. Torque as a function of the distance between the origin of the coordinates and the point of action of the force.
2. Torque as a function of the angle between the force and the position vector to the point of action of the force.
3. Torque as a function of the force.

2. LEARNING OUTCOME

At the end of this practical the students are able to:

1. Define torque as a combination of a physical quantity and a distance.
2. Explain torque is the product of the force multiplied by the perpendicular distance from the line of action of the force to the pivot or point where the object will turn.

3. INTRODUCTION

Coplanar forces (weight, spring balance) act on the moments disc on either side of the pivot. In equilibrium, the moments are determined as a function of the magnitude and direction of the forces and of the reference point.

4. THEORY AND EVALUATION

The equilibrium conditions for a rigid body, on which forces $\vec{f_i}$ act at points $\vec{r_i}$, are:

$$\vec{F} = \sum \vec{f_i} = 0$$

and $\vec{T} = \sum \vec{r_i} \times \vec{f_i} = 0$, where $\vec{T}$ is the moment, or torque.

The origin of the coordinates, with reference to which the moments are defined, can be selected free in the equilibrium state.

In the present case, one obtains:

$$\vec{r_1} \times \vec{f_1} = \vec{r_2} \times \vec{f_2}$$

And for the magnitudes:

$$T = r_1 f_1 = r_2 f_2 \sin\alpha \qquad \text{(see Fig.1)}$$

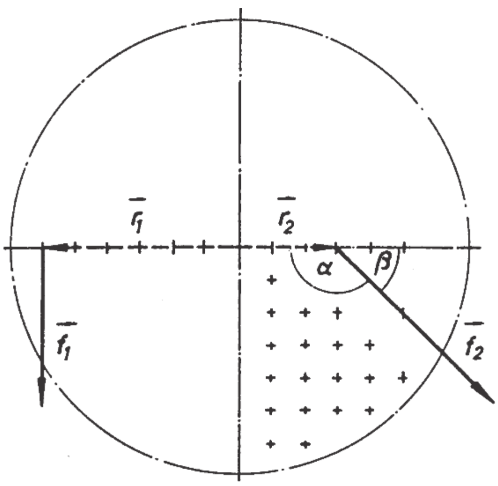

Fig. 1.1: Compensating moments

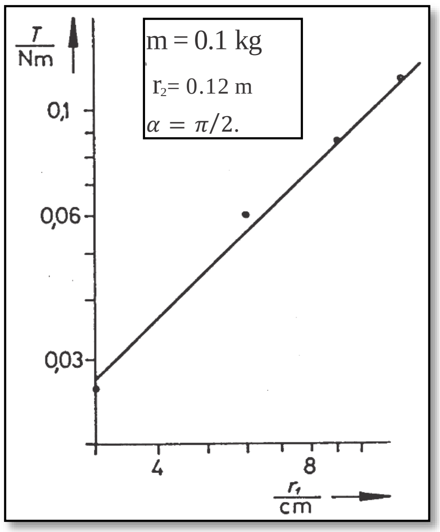

Fig. 1.2: Moment as a function of the distance between the origin of the coordinates and the point of action of the force.

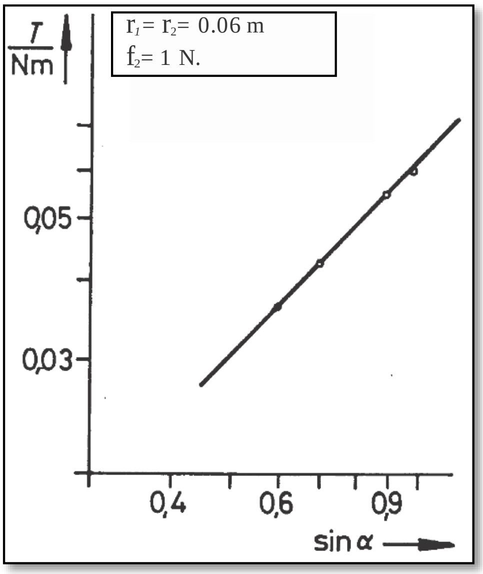

Fig. 1.3: Moment as a function of the angle between force and position vector to the point of action of the force.

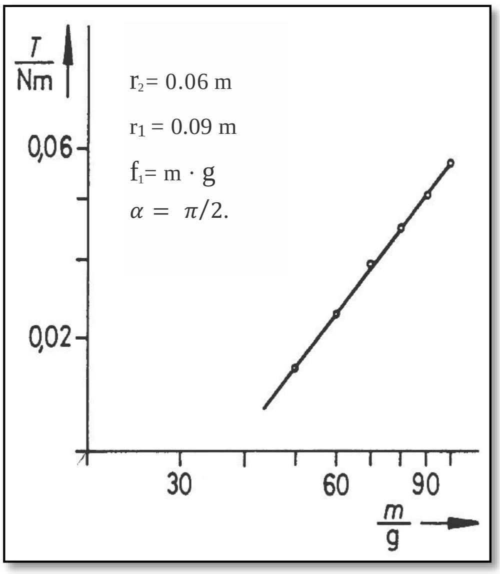

Fig. 1.4: Moment as a function of the force.

5. APPARATUS/EQUIPMENT

- Moments disk
- Spring Balance 1 N
- Tripod base
- Barrel base
- Right angle clamp
- Support rod, square, l = 400 mm
- Swivel clamp
- Bolt with pin
- Weight holder f. slotted weights
- Slotted weight, 10 g, black, 50 g, black
- Fish line, l = 100 m and
- Ruler, plastic, l = 200 mm

6. PROCEDURES

The experimental set-up is arranged as shown in Fig. 1.5. The spring balance is adjusted to zero in the position in which the measurement is to be made in each case.

The straight line from the push-in button to the pivot point is adjusted to the horizontal by moving the swivel clamp on the stand rod. The fishing line to weight pan then runs along a row of holes.

The spring balance should be mounted in the swivel clamp so that it forms an angle with the fishing line.

For tasks 1 and 3, the spring balance is attached on one side of the pivot point of the moments disc and the weight pan on the other side. The force needed to adjust the line through the push-buttons and the pivot to the horizontal is read on the spring balance. (Spring balance vertical).

For task 2, the weight pan should be replaced by the second spring balance. A fixed force, e.g. 1 N, is set on it while the angle between the line from push-button to pivot and the spring balance is varied. On the other, vertical, spring balance, the force needed to bring the push-button-pivot line horizontal is read. More conveniently, the angle and the fixed force are first adjusted on the clamped spring balance while the disc is released and the moment is compensated on the other spring balance.

Fig. 1.5: Experimental set-up for investigating moments in equilibrium

7. DATA

Task 1

Constant: m_1 100 g, $r_2 = 12$ cm

r_1 (cm)	F (N)	τ_2 (Nm) $\tau_2 = F_2 \times r_2$
3		
5		
7		
9		

(b) Plot graph τ_2 versus r_1

Task 2

Constant: $F_2 = 1$ N, $r_1 = r_2 = 6$ cm

Angle, β	Sin β	F_1 (N)	τ_1 $\tau_1 = F_1 \times r_1$
10			
20			
30			
40			

(b) Plot graph τ_1 versus sin β

Task 3

a) Constant $r_1 = 9$, $r_2 = 6$ cm

m_1 (g)	F_2 (N)	τ_2 (Nm) $\tau_2 = F_2 \times r_2$
10		
20		
30		
40		
50		

(b) Plot graph τ_2 versus m_1

8. Data Analysis

9. Discussion

i) What is torque?

ii) What do you understand from this experiment?

10. Conclusion

11. References

PRACTICAL 2

NEWTON'S 2ND LAW / AIR TRACK

1. OBJECTIVES

- To determine the distance travelled as a function of time.
- To determine the velocity as a function of time.
- To determine the acceleration as a function of the accelerated mass.
- To determine the acceleration as a function of force.

2. LEARNING OUTCOME

At the end of this practical the students are able to:

1. Verify Newton's Second Law, F = ma
2. Analyze situations in which an object moves with specified acceleration under the influence of one or more forces.
3. Understand forces that makes up the net force, such as motion up or down with constant acceleration.

3. THEORY

Newton's equation of motion for a mass point of mass m to which a force is applied is given by the following:

$$m.\vec{a} = \vec{F}$$

$$where\ \vec{a} = \frac{d^2r}{dt^2} \text{ is the acceleration}$$

The velocity *v* obtained by application of a constant force is given as a function of the time *t* by the expression

$$\vec{v}(t) = \frac{\vec{F}}{m}.\, t$$

For $\vec{v}(0) = 0$

Assuming that $\vec{v}(0) = 0;\ \vec{r}(0) = 0$

The position of F of the mass point is

$$\vec{r}(t) = \frac{1}{2}.\frac{\vec{F}}{m}.\, t^2 \tag{2.1}$$

In the present case the motion is one dimensional and the force produce by a weight of m_1 is

$$\left|\vec{F}\right| = m_1.\left|\vec{g}\right| \equiv m_1 g \tag{2.2}$$

Where *g* is the acceleration of gravity. If the total mass of total the glider is m_2, the equation of motion is given by

$$(m_1 + m_2).\left|\vec{a}\right| \equiv m_1 g \tag{2.3}$$

The velocity is

$$\vec{v}(t) \equiv v = \left(\frac{m_1.g}{m_1 + m_2}\right).\, t \tag{2.4}$$

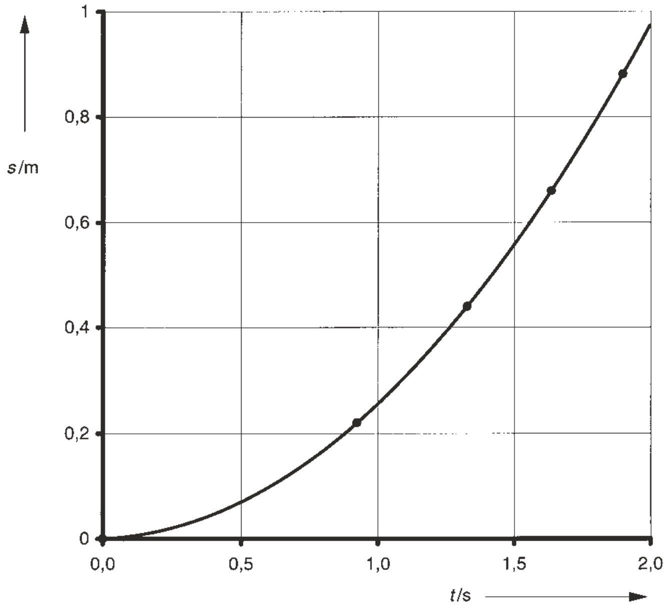

Fig. 2.1: The distance travelled s plotted as a function of the time t;m_1 = 10 m_2 = 201 g

In Fig. 2.2, the distance travelled is illustrated as a function of t^2 for the same measured values. A linear correlation results, as was expected from the theory. The slope is 0.246 m/s^2 and the following is thus obtained from Equation (2.1):

$$F = 2.\ (m_1 + m_2)\, 0.246\ ms^{-2} = 0.104\ N \qquad (2.5)$$

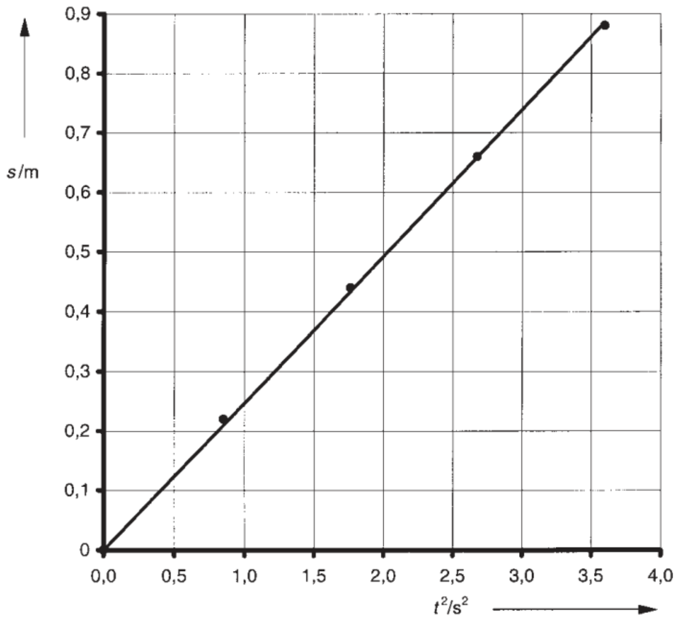

Fig 2.2: The same measurement as in Fig. 2.1 plotted against t^2.

As a good approximation, this corresponds to the weight force of the mass m_1 (0.010 kg); $F = m_1 g = 0.0981$ N.

Under the same experimental conditions, the correlation v(t) presented in Fig. 2.3 is obtained by measuring the shading time of the four light barriers due to the screen, which has a length of 10 cm. The slope of the compensation line drawn through the origin correspond to the acceleration *a* in this case. For the presented sample measurement, $a = 0.473\ ms^{-2}$. We expect *a* to be equal to

$$a = \frac{m_1 . g}{m_1 + m_2} = 0.465\ \mathrm{ms}^{-2} \qquad (2.6)$$

The value agrees with the acceleration determined using Fig. 2.3 very well.

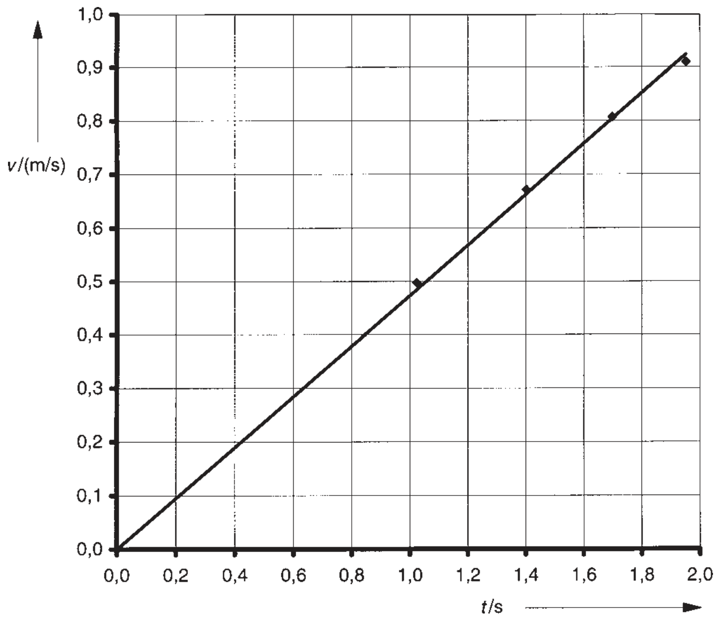

Fig. 2.3: The velocity v plotted as a function of the time t; m_1 = 10 g, m_2 = 201 g.

In the same manner as shown in the example in Fig. 2.3, the accelerations are measured in two measuring series as a function of the inert mass $m_1 + m_2$ (F = constant) and as a function of the force ($m_1 + m_2$ = constant). In the process, one can make the evaluation work much easier by using a computer with a spreadsheet program (e.g. Microsoft Excel®).

Fig. 2.4 shows the acceleration due to the mass m_1= 10 g as a function of the inert mass. If the acceleration is plotted against the reciprocal of the inert mass using the same measured values, a linear correlation results, as expected (Fig. 2.5). The slope of the straight lines should be equal to the accelerating force, $m_1 g$ = 0.981 N. The evaluation of the present example in Fig. 2.6 results in a slope of 0.999 kg·m·s^2 = 0.999 N.

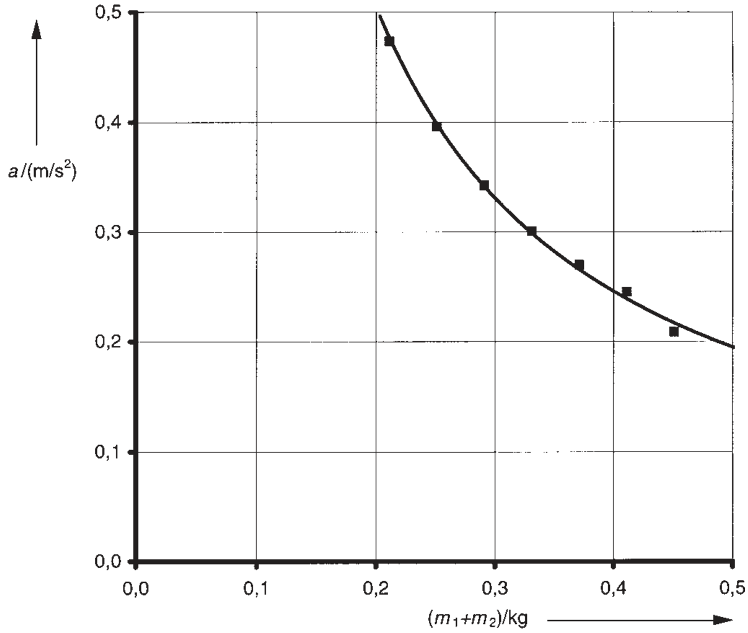

Fig. 2.4: The acceleration a as a function of the inert mass $m_1 + m_2$ measured at constant acceleration (weight) force due to the mass $m_1 = 10$ g.

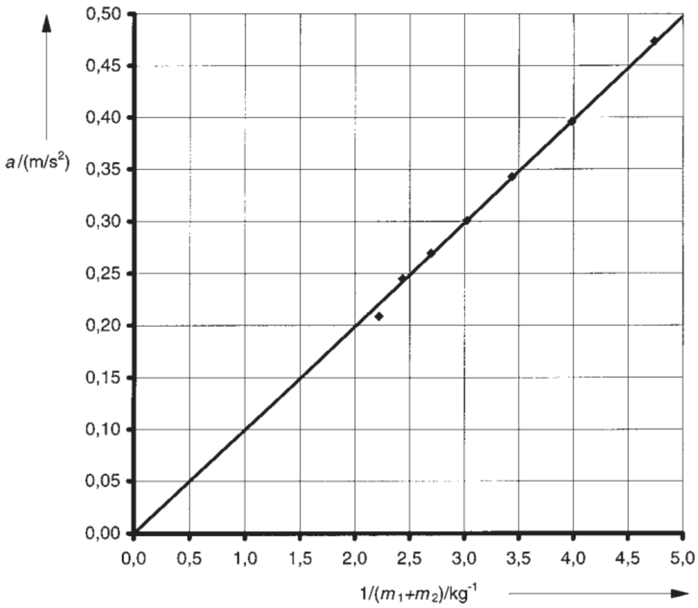

Fig. 2.5: The same measurement as in Fig. 2.4 plotted against the reciprocal inert mass.

In conclusion, Fig. 2.6 shows the dependence of the acceleration on the accelerating force *F*. One sees the linear proportionality between the two parameters. The reciprocal slope is 0.213 kg and corresponds well to the inert mass $m_1 + m_2 = 0.217$ kg.

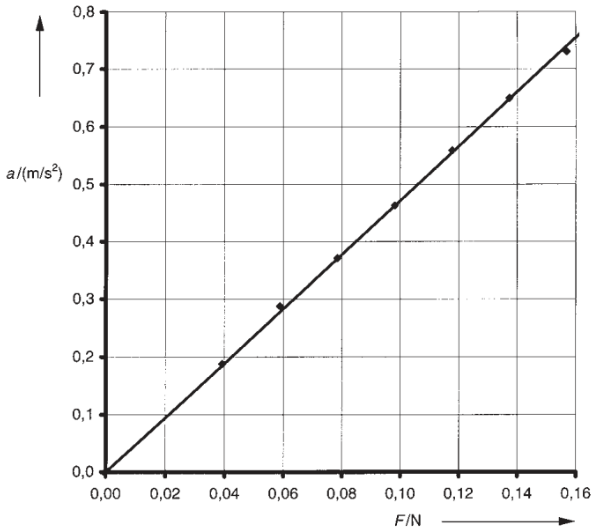

Fig. 2.6: The acceleration *a* as a function of the force *F* for constant inert mass $m_1 + m_2 = 217$ g.

4. APPARATUS/EQUIPMENT

- Air track rail
- Blower, Pressure tube, l = 1.5 m
- Glider f. air track
- Screen with plug, l = 100 mm
- Hook with plug, Starter system
- Magnet w. plug f. starter system
- Precision pulley, Stop, adjustable, Fork with plug
- Endholder for air track rail
- Light barrier, compact, Timer 4-4
- Slotted weight, black 10 g, 50 g,
- Weight holder 1 g, Silk thread, 200 m
- Slotted weight, 1 g, natur.colour
- Right angle clamp, Portable balance, CS2000
- Barrel base, Support rod, square, l = 400 mm
- Connecting cord, l = 1000 mm, red, yellow and blue.
- Connecting cord, l = 2000 mm, yellow and black.

5. PROCEDURES

The experimental set-up is shown in Fig. 2.7. The starting device is mounted in such a manner that the triggering unit releases the glider without giving it an initial impulse when triggered.

It is connected with the two "Start" jacks on the timer; when connecting it, ensure that the polarity is correct. The red jack on the starting device is connected with the yellow jack of the timer.

The four light barriers are connected in sequence from left to right with the control input jacks "1" to "4" on the timer. Connect jacks having the same colour when doing so.

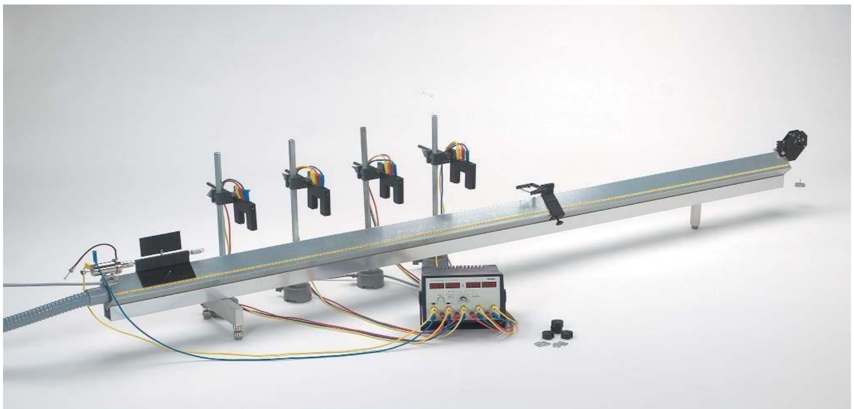

Fig. 2.7: Experimental set-up for investigation of uniformly accelerated motion.

The mass of the glider can be altered by adding slotted weights. Always place weights having the same mass on the glider's weight-bearing pins, as optimum gliding properties are provided only with symmetrically loading.

The accelerating force acting on the glider can be varied by changing the number of weights (on the weight holder) acting via the silk thread and the precision pulley.

Determine the mass of the glider without the supplementary slotted weights by weighing it. Position the four light barriers in a manner such that they divide the measuring distance into approximately equal segments.

Place the last light barrier such that the glider with screen passes through it before the accelerating weight touches the floor. Position the adjustable stop with the fork and plug on the track in such a manner that the glider is gently braked by the rubber band just before the accelerating weight touches the floor.

Measure the distances travelled $s_1 \ldots s_4$ between the front edge of the screen from the starting position to the respective light barriers exactly for the evaluation. Perform all subsequent measurements without changing the light barriers' positions.

After measuring the times $t_1 \ldots t_4$ required for the four distances travelled $s_1 \ldots s_4$ with the timer in the "s(t)" operating mode (see operating instructions), determine the corresponding velocities with the "v(t)" operating mode. While doing so, the shading times $\Delta t_1 \ldots \Delta t_4$ of the four light barriers are measured; from them the mean values of the velocity for the corresponding distance travelled are determined with reference to the screen's length.

These mean velocities correspond to the instantaneous velocities represented by the times $t'_1 \ldots t'_4$ in accordance with the following:

$$t'_n = t_n + \frac{\Delta t_n}{2} \tag{2.7}$$

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To determine the acceleration as a function of the mass, increase the mass of the glider progressively by 20 g increments (10 g on each side), and measure the instantaneous velocity at a predetermined position.

In determining the acceleration as a function of force, the total mass remains constant. Successively transfer 2 g (1 g from each side) from the glider to the weight holder and measure the instantaneous velocity at a fixed position. The accelerated mass must not exceed 20 g. Before beginning with the measurements, it is advisable to check the track's adjustment.

6. DATA

i) To determine the distance travelled as a function of time.

Light Barrier	Distance, s (m)	Time, t (s)	
		m_1 (g)	m_2 (g)
S1			
S2			
S3			
S4			

a) Plot graph distance versus time for m_1

b) Plot graph distance versus time for m_2

ii) To determine the velocity as a function of time.

Light Barrier	Distance s (m)	Time, t (s)		Velocity, v (ms^{-1})	
		m_1 (g)	m_2 (g)	m_1 (g)	m_2 (g)
S1					
S2					
S3					
S4					

a) Plot graph velocity versus time for m_1
b) Plot graph velocity versus time for m_2

iii) To determine the acceleration as a function of the accelerated mass.

Light Barrier	Time, t (s)		Velocity, v (ms^{-1})		Acceleration, a (ms^{-2})		Average acceleration, a_{av} (ms^{-2})
	m_1 (g) =	m_2 (g) =	m_1 (g) =	m_2 (g) =	m_1 (g) =	m_2 (g) =	
S1							
S2							
S3							
S4							

a) Plot graph acceleration versus mass

iv) To determine the acceleration as a function of force.

Mass 1 = kg

Light Barrier	Time, t (s)	Velocity, v (ms^{-1})	Acceleration, a (ms^{-2})	Force, F (N)

Mass 2 = kg

Light Barrier	Time, t (s)	Velocity, v (ms^{-1})	Acceleration, a (ms^{-2})	Force, F (N)

Mass 3 = kg

Light Barrier	Time, t (s)	Velocity, v (ms^{-1})	Acceleration, a (ms^{-2})	Force, F (N)

a) Plot graph acceleration versus force for m_1

b) Plot graph acceleration versus force for m_2

c) Plot graph acceleration versus force for m_3

7. Data Analysis

8. Discussion

9. Conclusion

10. References

PRACTICAL 3

HOOKE'S LAW

1. OBJECTIVES

- Determining the spring constant of helical.
- Study the elongation of a rubber band.

2. LEARNING OUTCOME

At the end of this practical the students are able to:

1. Define the Hooke's law and elasticity.
2. Use Hooke's law to find the spring constant of given spring.
3. Explain the relationship of force, mass and elongation.

3. INTRODUCTION

The validity of Hooke's law is determined for two helical springs with different spring constants. The elongation of the helical spring, which depends on the deforming force, is studied by means of the weights of masses. For comparison, a rubber band, for which no proportionality exists between the exerted force and the resulting elongation, is submitted to the same forces.

4. THEORY & EVALUATION

When forces act on a solid body, the resulting deformation (translation and rotation movements are suppressed in the following) depends to a large extent on the material as well as on the size and on the direction along which the exterior forces act. When the solid body regains its original shape after the exterior force stops acting, that is, the interior restoring forces of the material can bring the solid body back to its original equilibrium position, the material is called elastic.

A helical spring is a very simple example of an elastic body (Fig. 3.1). In addition, if deviations Δl from the equilibrium position l_0 of the helical spring are not very large, the restoring force F_R of the spring is found to be proportional to its elongation (or to its compression) Δl:

$$\vec{F}_r = -D\Delta\vec{l} \tag{3.1}$$

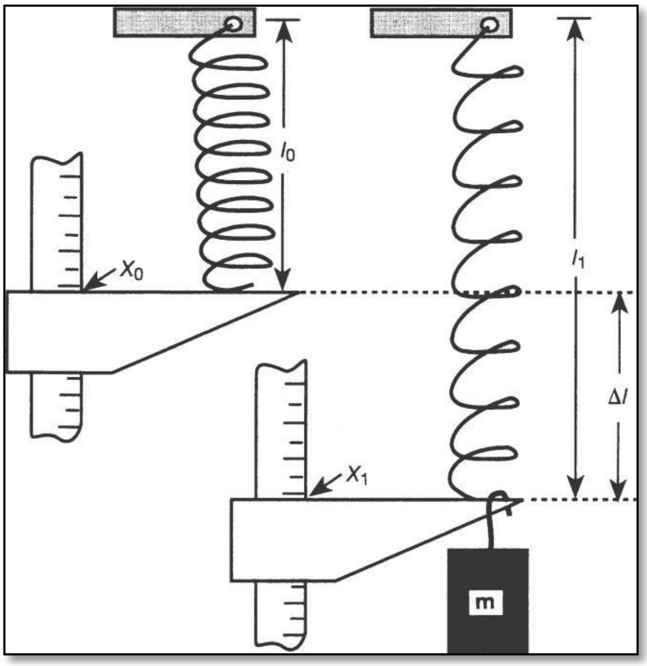


Fig. 3.1: Measurement of the elongation of the helical spring.

This is Hooke's law or the linear law of forces, w here the proportionality constant D, which is a general magnitude of reference, is called the spring constant in the case of a helical spring. If an exterior force acts on the spring, such as the weight $F_W = m{\cdot}g$ of a mass m (g = 9.81 m/s^2: acceleration of terrestrial gravity) in this experiment, a new stable equilibrium is reached for the length of the spring l_1, for which the weight mass m is equal to the restoring force of the spring:

$$F_r = D\Delta l = mg = F_w \tag{3.2}$$

The elongation of the helical spring is therefore proportional to the forces F_W exerted by the weights:

$$\Delta l = \frac{1}{D} F_w \qquad (3.3)$$

as is also shown by the characteristic curves of the two helical springs (Figs. 3.2 and 3.3). The slope of the characteristic curves is the respective spring constant D of the helical springs. Measurement values from Fig. 3.2 yield a spring constant of D = 3.03 N/m, measurement values from Fig. 3.3 yield a spring constant of D = 19.2 N/m.

Thus, forces required to cause a given elongation of the spring increase proportionally with the spring constant. Using equation (3.3), the new equilibrium length l_1 is found to be:

$$l_1 = l_o + \frac{m_g}{D} \qquad (3.4)$$

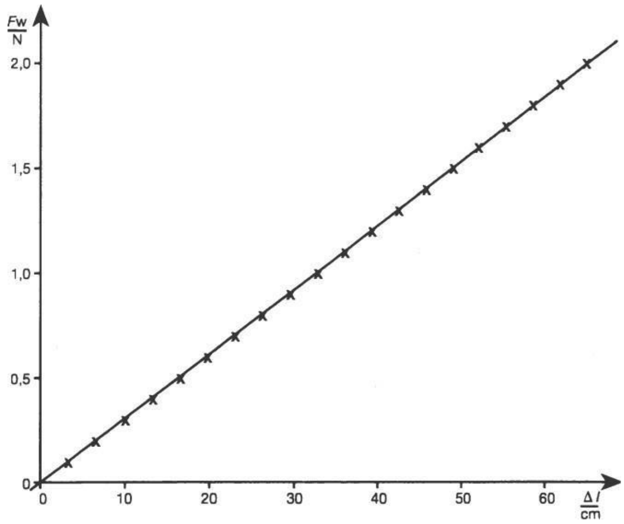


Fig. 3.2: Weight F_w of a mass m which acts on the helical spring, plotted as a function of elongation Δ*l* for a helical spring with constant D = 3 N/m.

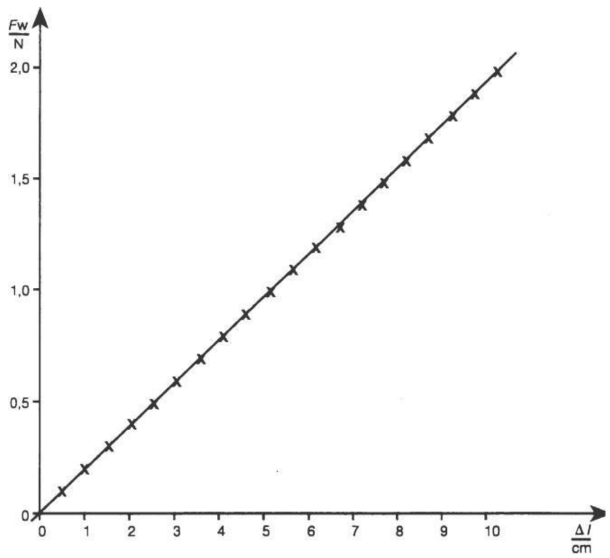


Fig. 3.3: Weight F_w of a mass m which acts on the helical spring, plotted as a function of elongation Δl for a helical spring with constant D = 20 N/

Proportionality between the restoring forces, as long as they are small, and the elongation of the solid body are ascertained not only for the helical spring, but also for all other materials which are in a state of stable equilibrium: the potential energy of forces between molecules is approximately parabolic around a stable point of equilibrium. Restoring forces obtained by differentiating the potential are thus proportional to the deviation from the rest position. Taking for example a rod or wire of a given material of length l and cross section A, to which a traction force *F* is applied, Hooke's law is expressed through:

$$\frac{\Delta l}{l} = \alpha \frac{F}{A} \quad \text{or} \quad e = \alpha e \tag{3.5}$$

where $\varepsilon = \frac{\Delta l}{l}$ is the relative elongation of the rod, the proportionality factor α is the coefficient of elasticity of the rod material and $\sigma = F/A$ is the tension of the rod. Proportionality only holds up to a characteristic limit stress. A schematic stress - elongation diagram for a metal wire is shown in Fig. 3.4. The limit of proportionality (σP) generally lies below the elastic limit (σE), above which the form of the solid body changes permanently, due to interior molecular re-arrangements. In this range of stresses, the material is said to be plastic. If the deforming forces exceed the limit of solidity (σB), the solid material begins to flow and the body breaks. An example of a material which does not follow Hooke's law, even when submitted to small forces, is a rubber band. Fig. 3.5 shows the characteristic curve of a rubber band, with continuously increasing stress between point O and point A and with gradual relief between point A and point B. On the one hand, the relation between acting weight F_W and resulting elongation Δ is no longer linear: elongation is larger than expected according to Hooke's law, considering the measurement values for small stresses (dotted line).On the other hand, the degree of elongation depends on the previous history of the rubber band. In the characteristic curve of the rubber band, part OA (gradual increase of stress) does not coincide with part AB (gradual relief of stress), which is contrary to what is observed for the helical spring, as long as it remains within the limit of elasticity. This phenomenon is called elastic hysteresis. If the same rubber band is stressed again, elongation Δ will now be significantly larger than had been the case for the new rubber band. The hysteresis of the characteristic curve has two causes: on one hand, only part of the deformation reverts back to the original form momentarily, whereas the rest of the deformation reverts back over a period of several hours. This reversible process is called elastic after-effect, the material reacts visco elastically. On the other hand, once the elastic limit is exceeded, interior re-arrangements take place within the material, which results in permanent changes of shape. This process is irreversible, because work is converted to heat.

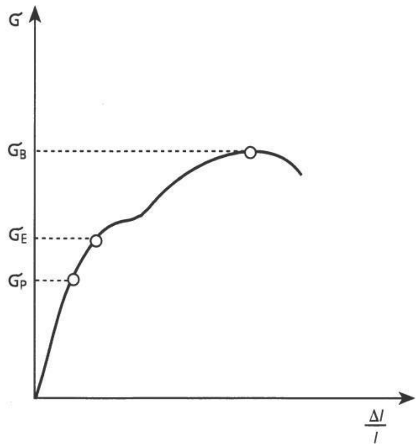


Fig. 3.4: Stress-elongation diagram (schematic).

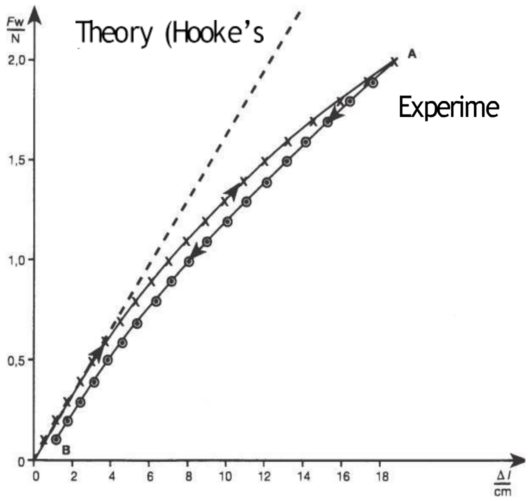


Fig. 3.5: Acting weight Fw as a function of the extension Δl for a rubber band (elastic hysteresis).

5. APPARATUS/EQUIPMENT

- Tripod base
- Barrel base
- Support rod, square, l = 1000 mm
- Right angle clamp, Cursors, 1 pair
- Weight holder f. slotted weights
- Slotted weight, 10 g black and 10 g silver bronze
- Slotted weight, 50 g black and 50 g silver bronze
- Helical springs, 3 N/m, 20 N/m
- Silk thread, 200 m
- Meter scale, demo, l = 1000 mm
- Holding pin
- Square section rubber strip, l = 10 m

6. PROCEDURES

The experimental set-up to measure the spring constants is shown in Fig. 3.6. To start with, the helical spring is submitted to no stress; the sliding pointer is set to the lower end of the spring and its corresponding position x_0 on the measuring scale is recorded. The load on the helical spring is then increased in steps of 10 g, using the weight holder and the slotted weights, until a maximum load of 200 g is reached.

Noting the equilibrium (stabilised) position of the lower end of the helical spring x_1, the corresponding increase $\Delta l = |\chi_1 - \chi_0|$ of the spring is assessed. Weight F_W, which causes elongation, is plotted as a function of elongation Δl. The elasticity of the helical spring is controlled by repeating the determination of Δl for some weights and by comparing the results to those obtained during the first measurement. This procedure is repeated for both helical springs (D = 3 N/m and 20 N/m).

To determine the characteristic curve of the rubber band, a piece of band of about 50 cm length is cut off. Both ends of the rubber band are tied to small loops with silk thread. One loop is slipped onto the holding bolt (cf. Fig. 3.7) and the weight holder is suspended from the other loop.

In the same way as for the helical springs, forces (weights) are increased in steps of 10 g up to a maximum of 200 g. The momentary elongation of the rubber band must be maintained by hand during the exchange of weights, because the elongation depends on the previous history of the material (cf. theory). Subsequently, weight is decreased in 10 g steps by removing slotted weights. The equilibrium position x_0 of the rubber band without slotted weights is calculated approximately through application of Hooke's law to equilibrium positions x_1 (10 g) and x_1 (20 g):

$$x_0 = x_1\,(10\text{ g}) - [x_1\,(20\text{ g}) - x_1\,(10\text{ g})] \qquad (3.6)$$

Weight F_W, which causes elongation, is plotted as a function of elongation, $\Delta l = |\chi_1 - \chi_0|$.

Fig. 3.6: Experimental set-up: Hooke's Law

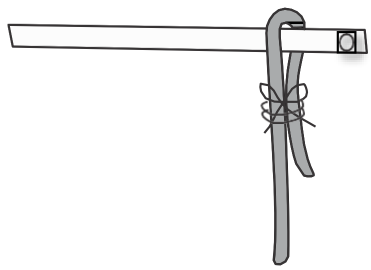


Fig. 3.7: Fixing the rubber band to the holding bol

7. DATA

a) Small diameter spring

Mass (kg)	Initial length, x_0 (m)	Final length, x_f (m)	Elongation, Δx

b) Plot Force against Elongation

a) Large diameter spring

Mass (kg)	Initial length, x_0 (m)	Final length, x_f (m)	Elongation, Δx

b) Plot Force against Elongation

i. a) Rubber Band

Mass (kg)	Initial length, x_0 (m)	Final length, x_f (m)	Elongation, Δx

b) Plot Force against Elongation

8. **Data Analysis**

9. **Discussion**

10. **Conclusion**

11. **References**

PRACTICAL 4

INTERFERENCE OF LIGHT

1. OBJECTIVES

- To understand how and why interference of light occurs
- To understand how constructive and destructive interference are related to the path length difference.
- To determine the wavelength of light by interference.

2. LEARNING OUTCOME

At the end of this practical the students are able to:

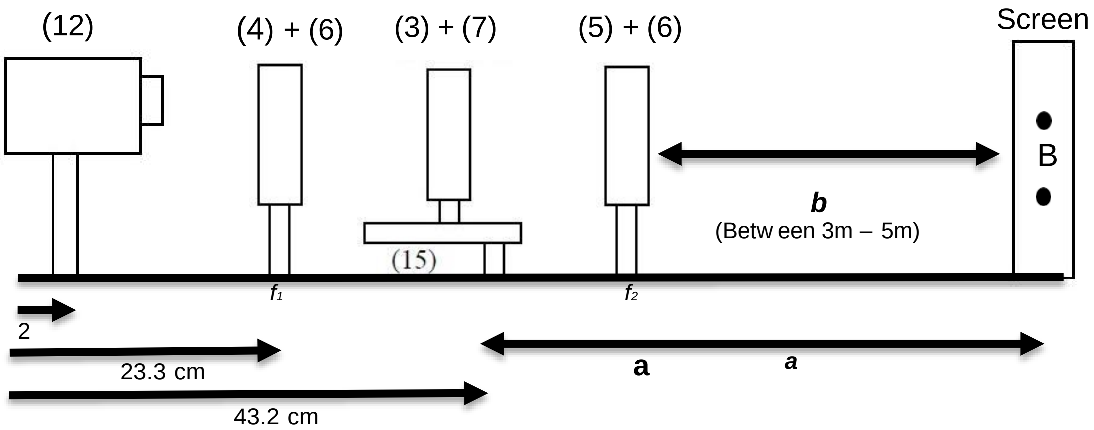
1. Explain the phenomena of interference a combination of a physical quantity and a distance.
2. Define constructive interference and destructive interference for a double slit.
3. Determine the wavelength of light by interference.

3. APPARATUS/ EQUIPMENTS

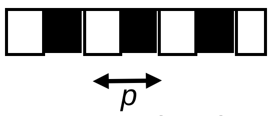
POSITION	MATERIAL	QUANTITY
1	Fresnel biprism	1
2	Prism table with holder	1
3	Fresnel mirror	1
4	Lens, mounted, f = +20 mm	1
5	Lens, mounted, f = +300 mm, achrom.	1
6	Lens holder	2
7	Swinging arm	1
8	Slide mount f. opt. pr.-bench, h = 30 mm	2
9	Slide mount f. opt. pr.-bench, h = 80 mm	2
10	Optical profile-bench, l = 1000 mm	1
11	Base f. opt. profile-bench, adjust.	2
12	Laser, He-Ne 1.0 mW, 220 V AC	1
13	Measuring tape, h = 2 m	1

4. PROCEDURES

TASK A: Determination of wavelength by Fresnel mirror



1. Set up experiment as figure above.
2. Adjust f_2, until clear image produce on screen (one-point).
3. Adjust the movable part of Fresnel mirror until both halves of the mirror is approximately parallel.
4. Align the mirror surface parallel to the optical bench.
5. Ensure beam of rays from laser is adjusted as to beam strikes both of the mirror equally. Two light spots now visible on the screen.
6. Measure a, b, and B where a = Distance between mirror and screen, b = distance between lens and screen and B = distance between two-point image.
7. Adjust screws of the Fresnel mirror to tilt the mirror until these two light spots overlap.
8. Remove f_2, interference pattern is observed. Measure distance between n interference bands, p Measure p = Distance between neighbouring maxima.



16. Determine the wavelength of the light, **λ**

$$p = \frac{n\lambda \boldsymbol{a}}{d}$$

For maxima

where

a* =** distance between **mirror** and ***screen

***b* =** distance between **lens** and **screen**

***B* =** distance between **two-point** image

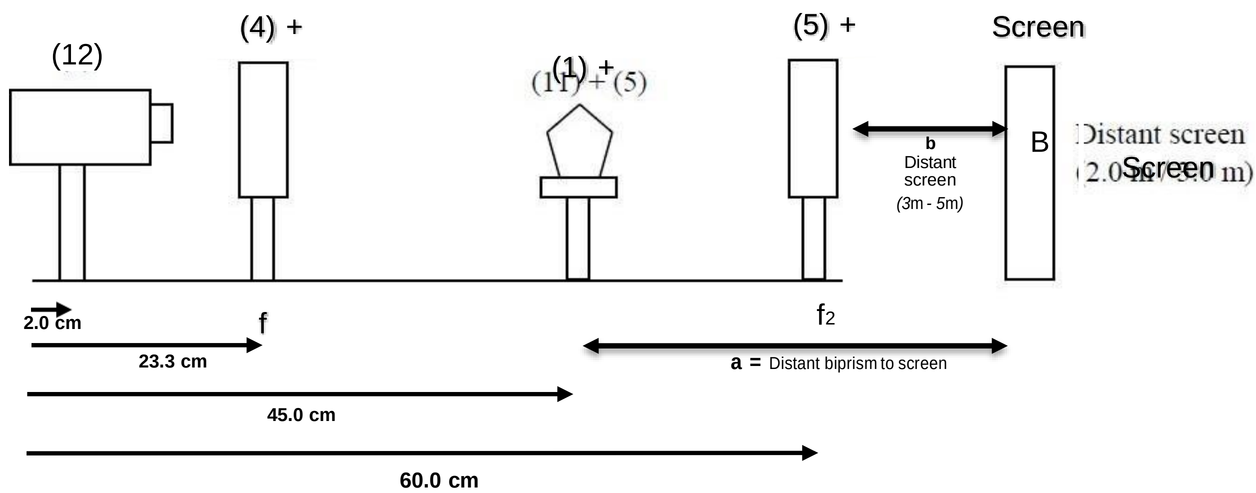
And
$$d = \frac{Bf_2}{b - f_2}$$

p = distance between maxima
d = distance between two virtual light source
λ = Wavelength of light

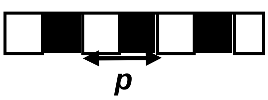
Result:

Mirror and Screen, **a** (mm)	Lens, f_2 and Screen, ***b*** (mm)	Two point image on screen ***B*** (mm)	Neighbouring Maxima, ***p*** (mm)	Two virtual Light, ***d*** (mm)	Wavelength λ (nm)

TASK B: Determination of wavelength by Fresnel biprism



1. Remove Fresnel mirror set up and place the Fresnel biprism.
2. Ensure that the widened beam strikes the central edge of the biprism.
3. Adjust biprism until clear image *(two point)* form on the screen.
4. Measure the distance between the two points of lights, ***B*** and distance between forming lens, f_2 and the screen, ***b***
5. Remove f_2, interference pattern is observed. Measure distance between n interference bands, ***p***



6. Measure distance between the screen and biprism, ***a.***
7. Determine the wavelength of the light, **λ**

For maxima	where,
$$p = \frac{n\lambda a}{d}$$ And $$d = \frac{Bf_2}{b - f_2}$$	***a*** Distance between screen and biprism ***b*** distance between lens, ***f2*** and screen ***B*** distance between **two-point** image ***p*** distance between neighbouring maxim ***d*** distance between two virtual light **λ** Wavelength of light

Distance between two point image, ***B*** (mm)	Distance between				Wavelength, λ **(nm)**
	Lens, f_2 and screen, ***b***	Screen and biprism, **a (mm)**	Neighbouring Maxima, ***p* (mm)**	Two virtual Light, ***d* (mm)**	

ATTENTION

1. **BEWARE:** Never look directly into non attenuated laser beam.
2. Before performing experiment, it is recommended to clean the lenses, m i r r o r and biprism with ethanol and wipe dry and clean cloth.
3. While performing experiment, do not touch the lenses, mirror and biprism with bare hands to prevent from fingerprints marked on the lenses.
4. Slowly adjust the screws of Fresnel mirror to tilt the mirror. Do not force the screw when limit is achieved
5. After use, keep all the lenses, mirror and biprism in dry and non-dusty place. Wrap lenses with tissue or paper is recommended.
6. Do not drop the lenses, mirror and biprism.
7. Optical experiment needs to perform under dark and clean room. Any dust on the lenses may contribute to failure in experiment.

12. Data Analysis

13. Discussion

14. Conclusion

ARCHIMEDES PRINCIPLE

1. OBJECTIVES

To investigate the buoyant force acting on a variety of objects, the density of the objects, and the density of our tap water.

2. LEARNING OUTCOME

At the end of this practical the students are able to:

1. Explain the Investigate the buoyant force acting on a variety of objects.
2. Calculate the density of the objects.

3. INTRODUCTION

Archimedes' principle states that a body wholly or partially submerged in a fluid is buoyed up by a force equal in magnitude to the weight of the fluid displaced by the body. It is the buoyant force that keeps ships afloat (object partially submerged in liquid) and hot air balloons aloft (object wholly submerged in gas). We will investigate the buoyant force using the following methods:

- Direct Measurement of Mass
- Displacement Method

4. THEORY AND EVALUATION

When an object is submerged in water, its weight decreases by an amount equal to the buoyant force. The direct measurement of mass will measure the weight of an object first in air, then while it is submerged in water. The buoyant force, FB, is equal to the weight in air (Fg) minus the weight in water,

$$F'_g = m'_g:$$

$$F_B = F_g - F'_g \tag{5.1}$$

The displacement method requires measurement of the volume of fluid displaced by the object. The weight of the fluid displaced is equal to the buoyant force exerted on the object. Thus, the buoyant force is given by:

$$F_B = \rho g V \tag{5.2}$$

where ρ (Greek letter, rho) is the density of the fluid displaced, V is the volume of fluid displaced by the object, and g is the acceleration due to gravity.

The following exercises will be informative, as both floating and sinking objects are used in this experiment.

- Sketch a free-body diagram for an object that is floating in water. How much water does it displace? Does it displace its volume in water? Does it displace its weight in water?

- Sketch a free-body diagram for an object that is submerged in water. How much water does it displace? Does it displace its volume in water? Does it displace its weight in water? The accepted value for the density of pure water at 4°C and 1 atm is $\rho_{water} = (1000 \pm 1)$ kg/m3 .

We will use this value for the density of water for Part 2 through Part 5. That is, we assume a temperature in the lab of 4°C. We will then experimentally determine the density of the tap water we used (Part 6) and compare it to the density of water at 20°C. The density of pure water at 20°C is:

$$\rho_{water} = (998.21 \pm 0.01)\ \text{kg/m3} \tag{5.3}$$

5. APPARATUS/EQUIPMENT

Triple-Beam Balance with string

Graduated Cylinder

Pipette

Cylinders: (2) Metal, (1) Wood (Note: The cylinders have sharp hooks)

Overflow Container

Spouted Can

Digital Balance

(2) 123-Blocks Wood Board/Block Rod & Clamp

Paper Towels

Water

6. PROCEDURES

PART 1: Overflow Method

1. Measure the mass of the brass cylinder. Determine its weight, F_g.
2. Place the overflow container on the digital balance.
3. Fill the spouted can with water. Position it so that its spigot pours into the overflow container.
4. Submerge the brass cylinder in the water, allowing displaced water to collect in the overflow container.
5. Measure the mass of the displaced water; calculate its weight. This is the buoyant force, F_B.
6. Calculate ρ_{obj} (density of the object):

$$\rho_{obj} = \frac{\rho w F_g}{F_B} \tag{5.4}$$

PART 2: Direct Measurement - Mass

1. Calibrate the triple beam balance.
2. Suspend the object (brass cylinder) from a string attached to the balance.
3. Partially fill the overflow container with water, then submerge the object. Do not allow the object to touch the container. Measure the apparent mass of the object in water, m'. Calculate F'_g.
4. Determine FB for the object. How much less does it weigh in water than in air? (Eq. 5.1)
5. Calculate ρ_{obj} using Eq. 5.4.

PART 3: Displacement Method - Volume

6. Partially fill the graduated cylinder with water; take note of the water level. Use the pipette to fine-tune the meniscus.
7. Carefully submerge the object in water and determine its volume.
8. Remove and dry the object, then empty the graduated cylinder and invert it on a paper towel to dry.
9. Determine F_B on the object with Eq. 5.2.
10. Calculate ρ_{obj} using Eq. 5.5:

$$\rho_{obj} = \frac{m}{V} \tag{5.5}$$

Use the volume determined from the displacement method and m, not m'.

PART 4: Aluminum Cylinder

1. Repeat Part 1 through Part 3 for the next object (aluminum cylinder).
2. Draw a free-body diagram for this object submerged in water.

PART 5: Buoyant Force - Floating Object

1. Although you need to modify or omit certain steps, repeat Part 1 through Part 3 for the wood cylinder:
    - Omit Step 6, Step 11, and Step 16.
    - Modify Step 9 and Step 13: Allow the wood object to float.
2. Draw a free-body-diagram for the wood object floating in water.

PART 6: Density of Tap Water

For each metal object: Use Eq. 5.6 and the graduated cylinder volume from Part 3 to determine the density of our tap water.

$$\frac{m - m'}{V} = \rho w \tag{5.6}$$

8. Data

9. Data Analysis

10. Discussion

11. Conclusion

12. References