Mechanical Laboratory

Department of Atmospheric Sciences,
College of Science,
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First year

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Report writing

Steps to write the report:

1- Introduction (page1) as shown below:-

Mustansiriyah University,
College of Science,
Department of Atmospheric Sciences
Student's name:
Partner name:
Name of the experiment:
Experiment date:
Experiment deadline date:

2- The theoretical part (second page) which includes:-

The theory of experiment, equations and additional explanation are present and taken from the specific sheet for each experiment.

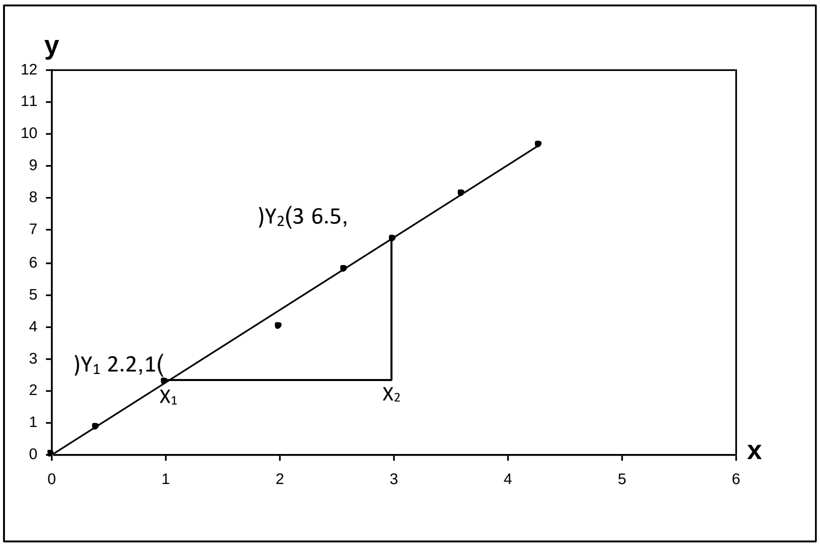
3- The practical part (third page) which includes:-

Readings, calculations and results obtained in the laboratory through manual work on the experiment.

4- The graph (fourth page):-

(A graphic paper is put in the report, the value of the slope and other data are extracted through the drawing).

The graph represents a visual means to clarify and understand the relationship between two variables and to derive the mathematical equation that links them and in the graph, the point of origin must be determined, unless there is a need for other thing.



Figure

* The following equation is used to find the slope:

$$\text{Slope} = \frac{\Delta y}{\Delta x} = \frac{Y_2 - Y_1}{X_2 - X_1} = \frac{6.5 - 2.2}{3 - 1} = \frac{4.3}{2}$$

5- The discussion (last page) including:

It is a discussion of what has been achieved through work in the laboratory and the extent of understanding of the experiment.

It includes:

1- Discussing the main idea of the research.

2- The main law and the variables involved in it.

3- Discuss the graph.

4- The results obtained in the tables.

5- The usefulness and practical application of the experiment.

Table 1. Units

Basic units		
Physical quantity	**Unit**	**Symbol**
(length)	meter	m
(mass)	kilogram	kg
(time)	second	s
(velocity)	meter/ second	m s^{-1}
(acceleration)	meter/ $second^2$	m s^{-2}
(force)	newton	N
(moment of inertia)	kilogram $meter^2$	kg m^2

Table 2. Unit conversion

Physical quantity	**Unit**	**Symbol**	**Unit**	**Symbol**	***Conversion***
(mass)	Kilogram	kg	gram	g	1 kg=10^3 g
(length)	Meter	m	centimeter	cm	1 m=10^2cm
(Radius)	Meter	m	centimeter	cm	1 m=10^2cm

Table 3. Main laws and symbols

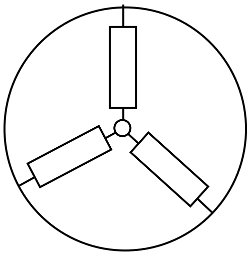
	Rotational motion	Linear motion	
Angular position	Θ	x	**position**
Angular velocity	ω	v	**velocity**
Angular acceleration	α -	a -	**acceleration**
Motion equations	$\Theta = \omega t$ $\omega = \omega_0 + \alpha t$ $\Theta = \omega_0 t + ½\ \alpha t^2$ $\omega^2 = \omega_0^2 + 2\alpha\ \Theta$	$X = vt$ $v = v_0 + at$ $x = v_0 t + ½\ at^2$ $v^2 = v_0^2 + 2ax$	**Motion equations**
Moment of inertia	I	m	**Mass (linear inertia)**
Newton s second law	$\tau = I\ \alpha$	$F = ma$	**Newton s second law**
Angular momentum	$L = I\ \omega$	$P = m\ v$	**momentum**
Work	$\tau\ \Theta$	Fd	**work**
Kinetic energy	$½\ I\ \omega^2$	$½\ mv^2$	**Kinetic energy**
Power	$\tau\ \omega$	Fv	**power**

Physics is a quantitative science, and by this we mean that the physicist tries to compare the measured values with the values expected from the theory.

Experiment 1. Determination of the resultant of many forces at one point

The used devices:-

1- Weights. 2- Power balance board. 3- White paper. 4- Protractor. 5- A ruler.



Power balance board

The theory of experiment:

Physical quantities are classified into two classes:

1- Non-directional quantities (scalar), which are quantities that have a numerical value only, such as energy, mass, time, etc., and these quantities are summed algebraically.

2- Directional quantities (Vector), which are quantities that have a numerical value and direction such as force, velocity, etc., and these quantities summed directionally.

It is known that if three directional quantities affect a body (i.e. they meet at one point) and they are in a state of equilibrium, the sum of two of them is equal to the third vector in magnitude and opposite to it in direction. If the triangle of forces (of the three forces) is drawn, the law of sines can be achieved, which is:

$$\frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:

F1, F2, F3 which are the first, second and third forces, respectively.

α It is the angle between the second force and the third force and opposite the first force.

β It is the angle between the first force and the third force and opposite the second force.

γ It is the angle between the first force and the second force and opposite the third force.

The resultant forces ($\overline{F1}, \overline{F2}, \overline{F3}$) for two different forces can be found by one of the two methods:

1- Using the law below called the cosine law:

$$\overline{F_1} = \sqrt{F_2^{\,2} + F_3^{\,2} + 2F_2F_3\cos\alpha} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \;(2)$$

$$\overline{F_3} = \sqrt{F_1^{\,2} + F_2^{\,2} + 2F_1F_2\cos\gamma}$$

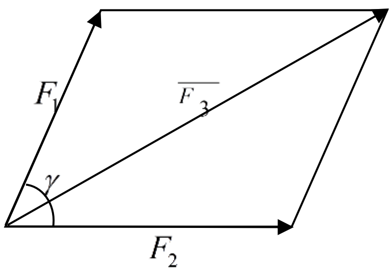
$$\overline{F_2} = \sqrt{F_1^{\,2} + F_3^{\,2} + 2F_1F_3\cos\beta}$$

2- Finding the resultant by drawing (so we must consider each nt 1 equal to 1 cm). When the two vectors ($\overline{F1}$, $\overline{F2}$) are represented by two arrows that start from one point, their length corresponds to and proportional to the values of these two forces, determine the angle between them and complete the parallelogram, then the diameter represents the resultant ($\overline{F3}$) as in the figure below:

The method of experiment:-

1- Fix the white paper on the balance board and then fix the ring and the weights and change the weights values with different forces (not equal) that is:

$F_1 \neq F_2 \neq F_3$



And make the angles different as well:

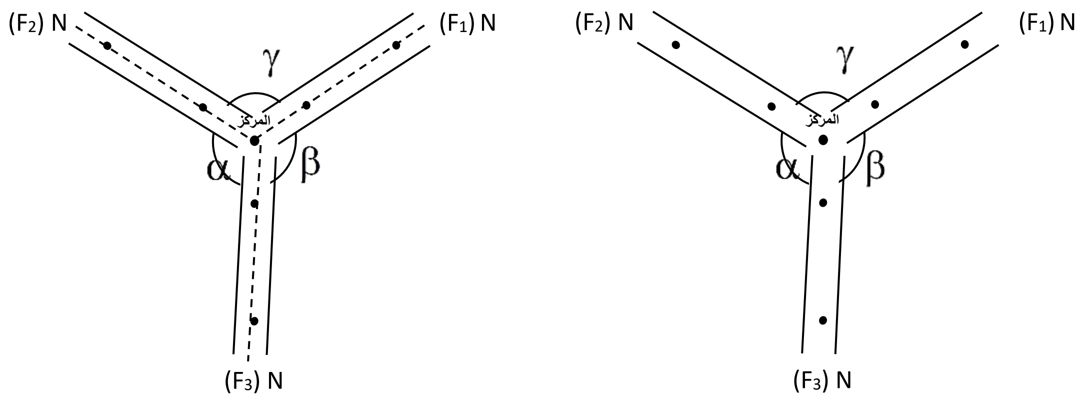
$\alpha \neq \beta \neq \gamma$

It should be noted that the sum of these angles must be 360:

$\alpha + \beta + \gamma = 360^\circ$

2- From the center of the ring, draw a point on the white paper attached to it, then locate each weight by placing a straight line with each string and write next to it the value of the force that you recorded.

3- Lift the paper and then connect all the lines with the centre point.



4- Measure with a protractor the amount of each angle and write down each of them.

5- Record the magnitudes of the forces and angles on the calculation sheet and find the resultant forces (F1, F2, F3) through :-

A - Use the law of cosines

B - Using the method of drawing that was mentioned in the theory of experiment.

6- Check the correctness of the results by using the law of sines:

$$\frac{F_1}{\sin\alpha} \approx \frac{F_2}{\sin\beta} \approx \frac{F_3}{\sin\gamma}$$

And compare the values of the sides of this equation, as the sides of this equation must be approximately equal, and any two sides of this equation can be used to find any unknown value of it when the rest of the values are known.

Experience 2. Free fall

Used equipment's:-

1- Free falling timer device. 2 - An electromagnet to hold the ball. 3- A ruler. 4- Multi Clamp

Experiment theory:

Two centuries ago, a Greek philosopher and scientist named Aristotle assumed that there is a natural force that causes heavy objects to fall toward the centre of the Earth and called it gravity.

But in the seventeenth century, the English scientist Isaac Newton came and assumed that there are forces that bind the moon to the earth and make the moon turn around the earth, as well as the case that the earth turn around the sun.

In the case of free fall of bodies, the only forces that affect them are gravitational forces, and in the event of any body falling, it accelerates under the influence of that period and that the rate of change in its speed is constant. This change in relation to time is known as the acceleration of gravity. For example, if a ball falls from a certain height and we neglect the air resistance, the ball will accelerate as if it was in free fall, and you can measure its time and the distance it travelled and thus find the acceleration of gravity through the equation:

$$\mathbf{a = x / t^2}$$

And that its initial velocity is zero, where **x** is the distance travelled by the ball and **t** is the time required for that distance, and **a** is the acceleration.

Figure 1. Experience Free fall

The method of work:-

Arrange the devices as shown in Figure (1).

1- Close the electrical circuit and then install the ball in the electromagnetic place designated for it perpendicular to the known distance, let it be (d).

2- Place the sensor adjuster at a space apart along the vertical axis of the ruler, let it be 20 centimetres.

3- Open the electrical circuit and allow the ball to fall freely as the sensors will record the time of the fall.

4- Repeat the previous steps, but each time you have to change and know the distance and the time as well.

5- Record these readings at different heights with time in a table.

6- Repeat each step at a distance of 40, 60 and 80 …… between the two sensors.

7- Graph the distance (d) with the square of time (t^2) so that (d) is on the y-axis, you will find that you have a straight line.

You will notice through the straight line and using equation No. 1 that it is possible to find the acceleration due to gravity.

Table No. 1

D (cm)	D (m)	T (ms)	T (s)	T^2 (s^2)

Experience 3. Verify Hooks law and determine the force constant of the spring

Used equipment's:-

1- Spiral spring with a horizontally placed pointer at its beginning and end. 2-Stand.

3- Holder. 4- Metric ruler. 5- Weight scale plate. 6- Weights.

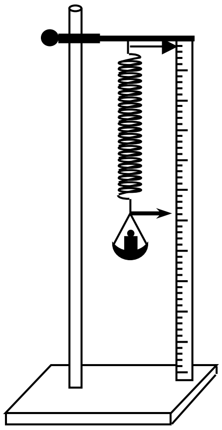


Figure 1.

Experiment theory:

The elongation, which occurs in a spring as a result of the force acting on it, is subjected to Hooke's law. For this reason, the scientist Robert Hooke noticed when a force is applied perpendicular to a body, there is a relationship between stress and strain, where stress is defined as the vertical force divided by the cross-sectional area of the body, the relative strain represents the ratio between the change in the length of the body to the original length, and Hooke's law states that the ratio between stress and strain is a constant quantity called the factor of elasticity or Yunk's factor (Y) provided that the stress is within the limits of elasticity for a helical spring that is:

$$Y = \frac{\text{stress}}{\text{strain}} = \frac{F/A}{\Delta L/L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where:

F is the perpendicular force on the spring.

A is the cross-sectional area of the spring.

L is the length of the spring.

It is the difference in the length of the spring.

As for the force constant (k), it is defined as the force required to elongate or compress the spring and its units (N/m) and is given by the equation:

$$k = \frac{F}{\Delta L} = \frac{mg}{\Delta L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

$$\Delta L = \frac{g}{k} m \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

If different weights are placed in the scale plate and the corresponding spring elongation is measured and a graphic relationship is drawn between the weights (m) on the x axis and the difference in length (ΔL) on the y axis, the result of the drawing is a straight line with slope equal to:

$$\text{Slope} = \frac{g}{k} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

$$\therefore k = \frac{g}{\text{Slope}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5)}$$

The method of work:-

1- Hold the helical spring with the scale plate and the metric ruler in a vertical position so that the pointer fixed at the end of the spring moves on the metric ruler, then record the length of the spring without weights $(L_\circ)$.

2- Put a weight of (20 g) and record the length of the spring (L1).

3- Increase the weights by (20 g) in each reading and record the corresponding length of the spring (L2, L3, L4, L5,...) (when the length of the spring is increased), provided that the number of readings is not less than five.

4- Reverse step (3), i.e. gradually remove the weights and record the corresponding length of the spring ($L''_5, L''_4, L_3'', L_2'', L_1''$) (when the length of the spring decreases).

5- Find the average readings $(\bar{L})$ when (L) increases and (L”) when decreases, then find the difference (ΔL) between the averages of these readings $(\bar{L})$ and the readings $(L_\circ)$.

6- Arrange the readings as in the table:

(ΔL) m		Length (m)		$(\overline{L}) = \frac{L + L''}{2}$	(m) kg
	$(\overline{L}) = \frac{L + L''}{2}$	(-L-)	(+L)		
$(\Delta L)_1 = \overline{L_1} - L_\circ$					
$(\Delta L)_2 = \overline{L_2} - L_\circ$					
$(\Delta L)_3 = \overline{L_3} - L_\circ$					
$(\Delta L)_4 = \overline{L_4} - L_\circ$					
$(\Delta L)5 = \overline{L_5} - L_\circ$					

7- Draw a graphic relationship between the weights (m) on the x-axis and (ΔL) on the y-axis. The result of the drawing will be a straight line passing through the origin with its slope, and then find the value of (k) from the equation $k = \frac{g}{\text{Slope}}$.

Note:-

If the indicator readings recorded in the case of weighting increase are not similar to the readings of the indicator recorded in the case of decrease, then this means that the spring has exceeded the limit of elasticity.

Experiment 4. Distance, velocity and time

Used equipment's:-

1 - A metal ball. 2 - A track for the metal ball. 3 - Motion sensors. 4 - A device for calculating the time linked to the sensors. 5- An electromagnet with a key.

Experience theory:

To describe the movement of an object or a moving vehicle, a reference point must be chosen in order to be able to measure the distance travelled by that object. This distance is usually denoted by the symbol (r), where (r) is a vector. Which needs a period of time Δt and during this period the vector will change by Δr and through (Δt) and (Δr) the average velocity of that body can be found through the equation:

$V = \Delta r / \Delta t$

When Δt is very small and approaches zero, Δr is also very small, and this means that the average velocity and the instantaneous velocity are almost equal.

$V_{inst} = \lim_{\Delta t \to 0} \Delta r / \Delta t = dr/dt$

The instantaneous acceleration can also be defined as the change in velocity over the change in time, where the change in time is very small, close to zero.

$a_{inst} = \text{Lim } \Delta v / \Delta t = dv/dr = d2r/dt2$

As for the one-way movement, for example, towards the x-axis, the velocity and acceleration can be given by the following equations, where the direction of movement is towards an axis.

$VX = dXx/dt$

$ax = dvx/dt$

But in this experiment, we will try to study a special case, which is when the acceleration of a fixed body is in one direction and the equations that describe this case and relate distance, velocity, acceleration and time are:

$X = x0 + v0t + ½ at2$

$V = V0 + at$

$VX2 = V02 + 2aX$

The method of work:-

1- Make sure that the timer device is connected to the motion sensors.

2- Place the metal ball at the edge of the electromagnet and close the switch to secure the ball.

3- Determine the distance (x) between the optical sensors (c1) and (c2) by 10 cm.

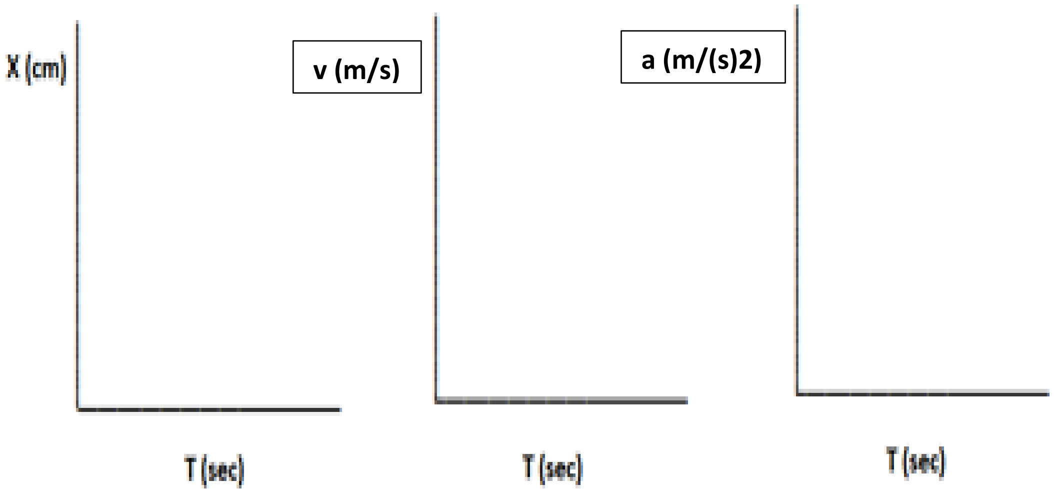
4- Open the electromagnet switch to roll the ball on the track and record the timer reading.

5- Change the distance between the two optical sensors (c1) and (c2) and record the time meter reading again.

6- Repeat steps 4 and 5 for different distances (x) (20, 30 ...) cm and so on.

7- Draw three diagrams of the relationships (distance, velocity, and acceleration) with time.

x	***T***	***T^2***	***v***	***a***



Experience 5. Determination of the moment of inertia for a material disk

Devices used:-

1- A regular thick metal disc 2- A metric ruler. 3- Thread. 4- Armrests and clamps. 5- Stopwatch.

Experiment theory:

Newton’s first law states that if a body is at rest or moving at a constant speed in a straight line, it will remain at rest or keep moving in a straight line at constant speed unless it is acted upon by a force that changes its state. That is, it represents the body's resistance to a change in its state of motion, and the forces that change the body's motion must first overcome its inertia, and whenever the mass of the body is large, it is difficult to move it or change its speed. Newton's first law is called the principle of inertia, and we find something similar to this principle in rotational motion. The body is incapable of changing its kinetic, rotational state, whether it is at rest or in motion, unless an external moment affects it, where moment is defined as the ability of a body to make a rotational motion about a fixed axis.

The Maxwell wheel is a large metal device consisting of a wheel suspended in two strong ropes fixed to a metal frame. It is named after James Clerk Maxwell. , the ropes are wrapped around the wheel shaft which is then released. The wheel unwinds as it falls down but will spin itself again when the driving force carries it up in the opposite direction. This oscillation process continues for some time before gradually stopping as the wheel slowly loses driving force and then moves at a lower speed each time and Maxwell's wheel proves a matter of conservation of energy. Its motions reflect the forward and backward conversion between gravitational potential energy and kinetic energy.

The method of work:-

1- Hang the disc by the two threads from each end to the stand and horizontally, and the two threads are tied at an equal distance from the two ends of the disc.

2- Rotate the disc until it reaches the upper horizontal column at a distance of (10) centimetres, let it be (d).

3- Leave the disc to roll downwards and calculate the time of 10 vibrations (i.e. going and back to the same point)

4- Repeat step (4) for different distances (20-30......) then write down the results as in the table below:-

The distance between the disc and stand (d) m	$(T_1)_{10}$ s	$(T_2)_{10}$ s	$(\overline{T_{10}}) = \frac{T_1 + T_2}{2}$	(T) s $\left(T = \frac{\overline{T}10}{10} \right)$	$\left(\frac{1}{d}\right)$ m^{-1}

5- Measure the distance between the two threads (L) and find the mass of the disc (m).

6- Draw a graphic relationship between a value $\left(\frac{1}{d}\right)$ on the x-axis and the corresponding values of (T) on the y-axis. The result of the drawing will be a straight line, then find its slope and find the value of the moment of inertia (I) from the equation:

$$I = \frac{mg}{16\pi^2 L}(\text{Slope})^2$$

7- Measure the diameter of the disk (ℓ) and calculate the theoretical value of the moment of inertia of the metallic disk from the equation below and compare the two results.

$$I = \frac{1}{12} m\ell^2$$