Experiment 3

NEWTON'S LAWS OF MOTION

Purpose: Investigation of Newton's Laws of Motion using air track rail.

Equipments: Air track, blower (air source), timer, photogates, vehicles with different masses, masses (10g), rope, pencil, eraser, scientific calculator

1. Introduction

Newton's Laws of Motions:

I) Newton's First Law of Motion: *Law of Inertia*

If an object does not interact with other objects, it is possible to identify a reference frame in which the object has zero acceleration. The resistance of the change of the velocity is called inertia.
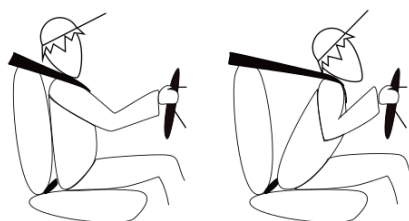
The first law of Newton is; If the net force acting on an object is equal to zero (balanced force), the object tends to keep its position. If the objects is in rest, it continues in a state of rest, if it is moving, it continues to move without turning or changing its speed.

II) Second Law: *Law of Motion*

When a force acts on an object, the velocity of the object changes, the rate of change of velocity is equal to acceleration, so the object gains an acceleration. Second law correlates an kinematic quantity acceleration to a dynamic quantitiy of force.

Imagine performing an experiment in which you push a block of fixed mass across a frictionless horizontal surface. When you exert some horizontal force on the block, it moves with some acceleration. The acceleration of an object is directly proportional to the force acting on it . the ratio of the force and the acceleration is always constant and it is called, mass.

$$\frac{F_1}{a_1} = \frac{F_2}{a_2} = \ldots\ldots\ldots = cons\tan t \tag{1}$$

We can express the second law as: an object under a constant force gains a constant acceleration.

$$\vec{F} = m\vec{a} \tag{2}$$

This is the fundamental equation of dynamics. The equation defines the force.

Force is the quantitiy that changes the movement of an object. It is an vector and has the same direction with acceleration. The unit of the force in SI unit system is Newton (N). 1 N is the force that gives $1 m/s^2$ acceleration to an object with 1 kg mass. The unit of force in CGS unit system is Dyn.
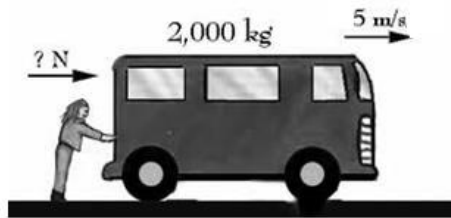
Newton's secon law comprises the first law. If the net force acting on an object is equal to zero then the acceleration becomes zero depending on the fundamental equation and this means the velocity of the object does not change, it stays constant.

III) Third Law: *Action-Reaction Law*

Force rises from the interaction of the objects and due to this reason it always exists in pairs. To every action there is always an equal and opposite reaction: or the forces of two bodies on each other are always equal and are directed in opposite directions.
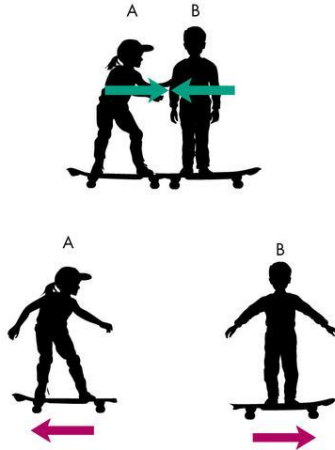
If $\vec{F}$ ve $-\vec{F}$ forces are the ones that the objects act on each other then, $\vec{F} = -\vec{F}$. These forces are called as action-reaction forces.

The ratio of the forces that the objects are applying on each other can be provided with momentum-impulse relation.

Momemtum is the product of the mass and the velocity of an object, in other words it is the amount of movement.

$$\vec{p} = m\vec{v} \tag{3}$$

The direction of the momentum is same with the direction of the velocity. The product of the force and its acting time is called **impulse**. If a force, $\vec{F}$, is applied on an object for a time *dt*, then the impulse is $\vec{F}dt$. Substitution of equation (3) in equation (2) gives us,

$$\vec{F} = \frac{d(m\vec{v})}{dt} = \frac{d\vec{p}}{dt} \tag{4}$$

It can be seen that, the net force that causes acceleration is the the of change of the momentum of a particle.

According to equation (4), the impuls applied till the objects seperate are,

$$\overrightarrow{F_1}\Delta t_1 = \overrightarrow{\Delta p_1} \text{ ve } \overrightarrow{F_2}\Delta t_2 = \overrightarrow{\Delta p_2} \tag{5}$$

So using equation (2), the ratio of the forces on the objects is,

$$\frac{F_1}{F_2} = \frac{m_1}{m_2}\frac{t_2}{t_1}\frac{l_1}{l_2} \tag{6}$$

2. Experiment

1. Place the photogates as shown in Figure-1 adjust the air track rail system parallel to the ground with the help of the leg screws.
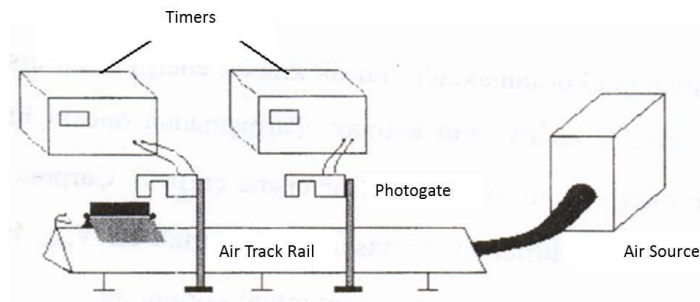

Figure 1

I) Application of Newton's 1st Law:

2. Fix the rubber reflector to the left end of the rail and reset the timers. Push the vehicle slowly so it can reach the reflector and return. Read the transition time of the vehicle (t_1, t_2) that returned from the reflector and write them down in Table-1.

3. Measure the length of the vehicle (ℓ) and calculate the velocities passing under the photogates using equation (7), and write down in Table-1 and compare them to each other. Repeat the experiment with different vehicles with masses.

$$v = \frac{\ell}{t} \tag{7}$$

Table 1

m (kg)	ℓ (m)	t_1 (s)	t_2 (s)	v_1 (m/s)	v_2 (m/s)

4.   Place the vehicle on the air track system as the vehicle stays stationary and observe its movement (if the object is stationary, it does not change is position).

II) Application of Newton's 2nd Law:
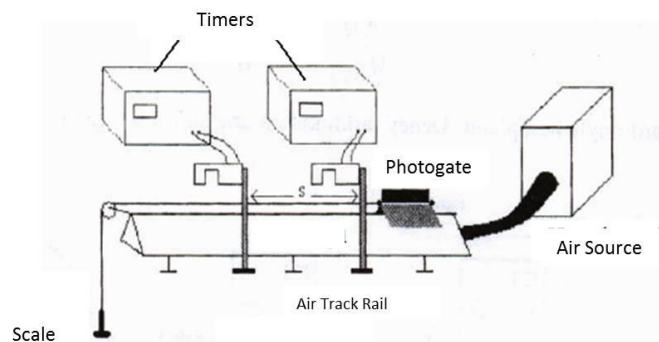

Timers
Photogate
Air Source
Air Track Rail
Scale

Figure 2

5. Place the photogates with a distance of s= 0,4 m to each other. Fix a pulley to the end of the rail. The scale is connected to the vehicle by a rope and then hanged from the pulley at the right end of the rail. After the vehicle is located as shown in the figure, reset the timers and release the vehicle.

6. Read the transition times of the vehicle passing from two photogates using the timers and write down in Table-2. Add 10 gr masses to the scale and repeat the measurements.

7. Measure the lenght of the vehicle ℓ.

8. Calculate the velocities of the vehicle passsing from the photogates using equation (3), calculate the squares of the values and write down in Table-2.

$$a = \frac{v_2^2 - v_1^2}{2s} \tag{8}$$

Calculate the acceleration (a) of the mass using equation (8) and write down in Table-2.
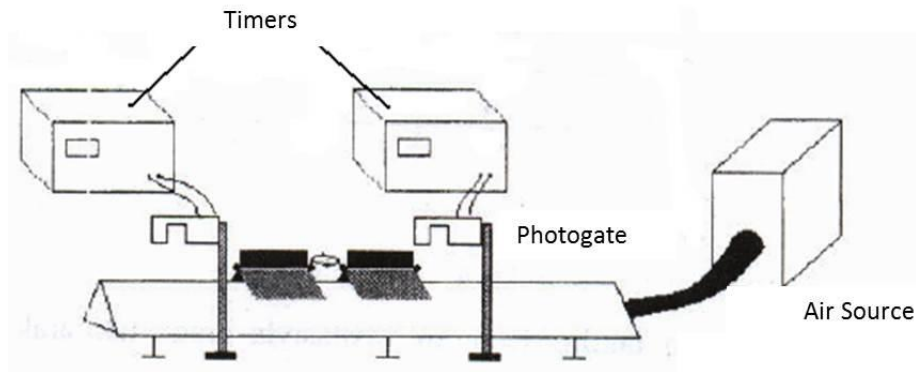
Table 2

m_{kefe} (kg)	F (N)	t_1 (s)	t_2 (s)	v_1^2 (m/s)²	v_2^2 (m/s)²	a (m/s²)	M_{system} (kg)	$M_{vehicle}$ (kg)
0,03								
0,04								
0,05								
0,06								
							$\left(M_{vehicle}\right)_{average}$	

9. Find the mass of the system M_{system} using equation (1) which is equal to the sum of the mass of the vehicle and the mass of the scale. Using the equation of $M_{system} = M_{vehicle} + m_{scale}$ calculate $M_{vehicle}$

10. Calculate the average mass value of the vehicle and calculate the relative error using equation (9). $\left(M_{vehicle}\right)_{average}$

$$\frac{\Delta M}{M^{real}_{vehicle}} = \frac{\left| M_{vehicle}^{real} - M_{vehicle}^{ave} \right|}{M_{vehicle}^{real}}$$

III) Application of Newton's 3rd Law:

11. Place the rubber band reflectors on the vehicles and put the vehicles on the rail as the rubber band reflectors become face to face between the photogates as shown in Figure 3 and reset the timers.

Şekil 3

12. Compress the vehicles with equal forces and release the vehicles at the same time. Read the transition times of the vehicles from the timers (t_1, t_2) and write down in Table-3.

Table 3

m_1 (kg)	m_2 (kg)	t_1 (s)	t_2 (s)	$\dfrac{m_1}{m_2}$	$\dfrac{t_1}{t_2}$

13. Find the ratio of the forces acting on two vehicles using equation (6).

$$\frac{F_1}{F_2} = \frac{m_1}{m_2} \frac{t_2}{t_1} \frac{l_1}{l_2} = ...$$

14. Repeat the experiment for different masses and fill Table-3.

This page intentionally left blank.