# Lab 4. Newton's law and collisions

Name ________________________________________ Date __________________ Grp_____

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## Aims:

1-/ Experimental study of uniformly accelerated rectilinear motion using Newton's second law with an air track.

2-/ Determination of the coefficient of static friction and the coefficient of dynamic friction

3-/ We investigate elastic and inelastic collisions between two carts on an air track.

## Apparatus:

1-/ Air track with accessories.

2-/ Air blower

3-/ SpeedGates.

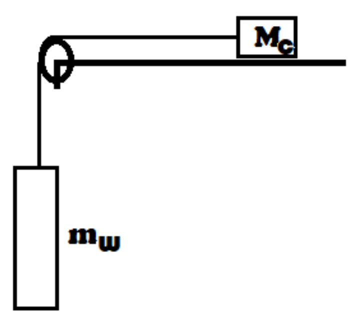
4-/ Slotted weights with holder.

5-/ Carts.


## Part I Kinematic study without friction

## Theoretical study

The air track enables virtually frictionless motion in 1 dimension. This ensures that the only force acting horizontally with the track are the force of traction. Let's showing the system, illustrated in Figure down, can therefore be considered an isolated system. the cart is left under the action of the driving force $M_c g$ without being given an initial speed.



**Homework 1**: Use Newton's second law to determine the acceleration, velocity, and position of the mass $M_c$.

$$x(0)=0(m)\wedge v(0)=0(m.s^{-1})$$

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## I-1/ Study of the acceleration-inertia mass relationship

A cart (glider) on a horizontal air track accelerates using a thread, a pulley, and a weight influenced by gravity. The mass of the weight and the cart are weighed. At two different positions, photogates measure the speed of the cart as well as the time interval spent between the two photogates. The actual acceleration of the cart is calculated from these measurements. Newton's second law leads to a theoretical value of the acceleration which is compared to the measured one.

Complete the following table

| $m_c$(kg) | $m_w$(kg) | $v_A$(m/s) | $v_B$(m/s) | $t_{AB}$(s) | $a_{theo}$(m/s^2) | $a_{meas}$(m/s^2) | Dev(%) |
|---|---|---|---|---|---|---|---|
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Conclusion: ………………………………………………………………………………………………………………

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## I-2/ Study of the distance-time relationship

Position four SpeedGates at equal distances to divide the total distance into four equal segments. Along the air track, several SpeedGates measure the time t between two consecutive positions.

Plot the graph $x(t)/t=f(t)$.

Deduce the nature of motion.

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Plot the graph $x=f(t^2)$.

Deduce the value of acceleration.

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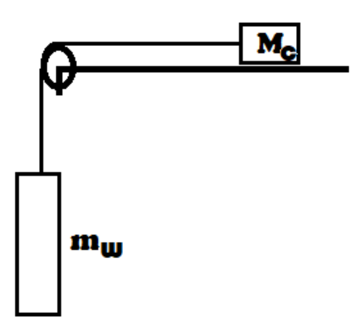
## Part II Dynamical study and friction

Let’s consider mechanical system in precedent figure with presence of friction. Static friction is defined as the frictional force which acts between the two surfaces when they are in the rest position with respect to each other. Dynamic friction is defined as the friction which is created between any two surfaces when they are in a moving position.

## Homework 2:




1-/ In this system shown in the figure, represent the forces acting on the two masses.

2-/ Apply Newton's laws to derive the equation for this system in equilibriu

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3-/ Apply Newton's laws to derive the equation for this system in motion.

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4-/ Deduce The coefficient of kinetic friction $\mu_k$

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### Procedure

In this part, we will determine the coefficient of static *s* and kinetic friction between the track surface and a cart plate.

### II-1/ Static friction

The static friction coefficient ($\mu_s$) is defined as the ratio between the maximum static friction force that prevents an object from starting to move and the normal force acting perpendicular to the contact surface.

Deduce this value using a simple experiment

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### II-2/ Kinetic friction

Use the answer from Homework 2 and the setup from section I.1 to deduce the value of the coefficient $\mu_d$

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### Part III Conservation of momentum and energy

Let's back to the case of an isolated system. The two carts are launched at each other with different speeds. The speeds of the carts are measured by two SpeedGates that can display the speed when passed. SpeedGate remembers the previous measurement and fits perfectly with collision experiments where the cart typically passes the photogate once on its way to the collision and once on its way back.

## Theory

The momentum p of a body is given by its mass $m$ and its velocity $v$ : $\vec{p}=m\vec{v}$ and the total momentum is to be conserved. $\vec{p}(Before\ collision)=\vec{p}(After\ collision)$

As the two carts are considered an isolated system, and when $m_1$ and $m_2$ are the masses of the carts, and the initial velocity of the carts are $\vec{u}_1$ and $\vec{u}_2$ ; after the collision, their velocities are $\vec{v}_1$ and $\vec{v}_2$ .

## Question:

Write the conservation of the momentum between before and after collision in the case of motion in 1 dimension

1-/ elastic collisions ……………………………………………………………………………………………………..

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2-/ inelastic collisions ……………………………………………………………………………………………………..

For elastic collisions, the mechanical energy is also conserved.

$$E_{Mech}(Before)=E_{Mech}(After)$$

## Homework 3:

Write the conservation of mechanical energy in terms of momentum of each mass

1-/ elastic collision: ……………………………………………………………………………………………..

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2-/ inelastic collision: ……………………………………………………………………………………………………..

To investigate elastic and inelastic collisions between two carts on an air track. For both kinds of collisions, conservation of both momentum and mechanical energy are examined.

### III-1/ Elastic collisions, nearly identical masses

The carts must be equipped with the elastic collision bumpers (as seen below) but with no additional masses. Weigh each cart carefully. Set the two carts in motion outside the two photogates so that they meet between them. Catch the carts when they get outside the photogates again. The two SpeedGates will now display the speeds both after and before the collision.

Complete the following table

| $m_1$(…….) | $u_1$(………) | $m_2$(…….) | $u_2$(………) | $m_1$(…….) | $v_1$(………) | $m_2$(…….) | $v_2$(………) |
|---|---|---|---|---|---|---|---|
| ………….. | …………… | ……….. | ……………… | ……………….. | …………… | …………….. | ………….. |

| $m_1 u_1$ (………) | $m_2 u_2$ (………) | $m_1 v_1$ (………) | $m_2 v_2$(………) |
|---|---|---|---|
| …………………….. | ………………….. | ………………….. | ………………………….. |

| p(Before) (…………………) | p(After) (……………..) | $E_{Mech}$(Before) (………) | $E_{Mech}$(After) (………) |
|---|---|---|---|
| ………………… | ……………………. | | |

Conclusion ……………………………………………………………………………………………………………..

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**III-2 Inelastic collisions**

Replace the bumpers with a needle and a wax tube. Again, weigh both carts precisely. When the carts collide, they should stick together and continue with a common speed. (Such a collision is called a completely inelastic collision.) Stop the “road train” when the first of the carts has passed a SpeedGate and use this velocity for both of them.

| $m_1$(…….) | $u_1$(………) | $m_2$(…….) | $u_2$(………) | ($m_1$+ $m_2$)(…) | v (………) |
|---|---|---|---|---|---|
| ………….. | …………… | ……….. | ……………… | ……………….. | …………… |

| $m_1 u_1$ (………) | $m_2 u_2$ (………) | ($m_1$+ $m_2$) v (………) |
|---|---|---|
| …………………….. | ………………….. | ………………….. |

| p(After) (…………………) | p(After) (……………..) | $E_{Mech}$(Before) (……) | $E_{Mech}$(After) (………) |
|---|---|---|---|
| ………………… | ……………………. | ……………………… | ……………… |

Conclusion ……………………………………………………………………………………………………………..

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