TP-4
Inclined Plane

Introduction

By conducting simple experiments on an inclined plane, physicists can determine certain important parameters, such as the value of the acceleration due to gravity ***g***, or the coefficient of dynamic friction μ_d. They can also verify the **Fundamental Law of Dynamics** in the case of a mass in motion or at equilibrium.

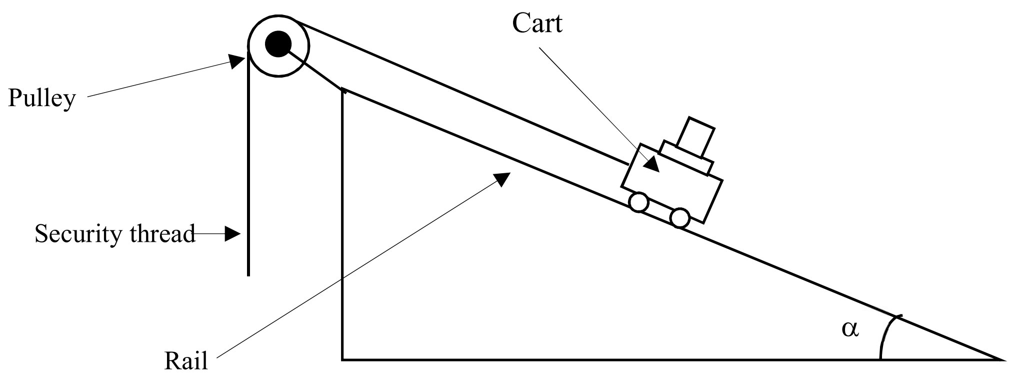
Purpose

This is to allow the student to verify the **F.L.D**. (Fundamental Law of Dynamics) in two cases (Manipulations 1 and 4); to determine the coefficient of friction μ_d (Manipulation 2) as well as the value of **g** (manipulation 3).

Experiment 1
Motion, without friction, of a cart on an Inclined Plane

Experimental device

- **a.** A rail installed on an inclined plane at an angle **α**.
- **b.** A cart of mass **m**, which can move on the rail.
- **c.** A stopwatch, to measure time intervals.
- **d.** Du fil fin inextensible (fil de sécurité).
- **e.** Thin inextensible thread (safety thread).
- **f.** A marking plate is placed on the cart.
- **g.** A graduated ruler.



Experimental device

Operating mode :

1. Set the inclination angle α of the plane between **05°** and **10°**. Maintain this value of **α** during all the manipulations.
2. Place the cart at the starting point (the top of the inclined plane).
3. Mark the different distances $x_1, x_2, \dots, x_n$ on the rail.
4. Measure the times $t_1, t_2, \dots\dots, t_n$ corresponding to the distances $x_1, x_2, \dots, x_n$. Repeat the measurement three times for each distance.

5. Put all your results in Table 1.

<table>
<tr><th>X(m)</th><th colspan="3">0,2</th><th colspan="3">0,3</th><th colspan="3">0,4</th><th colspan="3">0,5</th><th colspan="3">0,6</th><th colspan="3">0,7</th></tr>
<tr><td rowspan="2">t (s)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>t²</td><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td></tr>
</table>

Table 1

Kinematic Study

1. Plot the graph $x = f(t^2)$.
2. Based on your knowledge of rectilinear motion, if the cart's motion is uniformly accelerated, how is the position x of the object written as a function of time t (we will take as initial conditions: at $t=0$ $x=0$ and $v=0$)? The curve $x = f(t^2)$ would then take what form?
3. Deduce the acceleration of the cart.

Dynamics Study

4. Distinguish the forces acting on the cart (assuming negligible friction).
5. Write the fundamental law of dynamics.
6. Deduce a relation between a, g et $sin(\alpha)$.
7. Verify this relationship using your experimental data (we will take $g = 9{,}8\ ms^{-2}$).

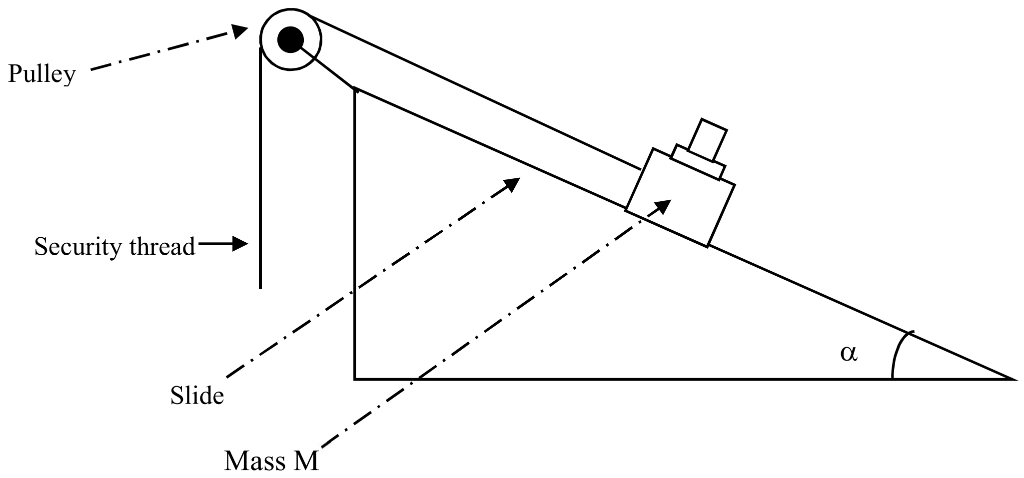
Experiment 2

Motion, with friction, of a mass M on an inclined plane

Experimental device

Same experimental device as in manipulation 1. With this time:

A. mass **M** which slides with friction (instead of the carriage).
B. A steel slide is placed on the inclined plane.



Experimental device

Work to be done

1. Using the adjustment screw (1), choose an angle **α** for the inclined plane between **20°** et **25°** (as a higher inclination angle is required for the mass M to slide easily).
   Keep this value of **α** constant for all manipulation 2.
2. Always ensure to release the mass M in such a way that the end of its 'marking plate' is very close to the beam of the photoelectric cell (1). This way, we can use the following initial conditions for the motion of our mass M: at ***t=0 x=0* et *v=0***.
3. Repeat the exact same experimental procedure as before, and fill in the table-2.

X(m)	***0,2***	***0,3***	***0,4***	***0,5***	***0,6***	***0,7***
t (s)						
t^2						

Table 2

Kinematic Study

1. Plot the graph $x = f(t^2)$.
2. Deduce the acceleration ***a*** of mass **M**.

Dynamics Study

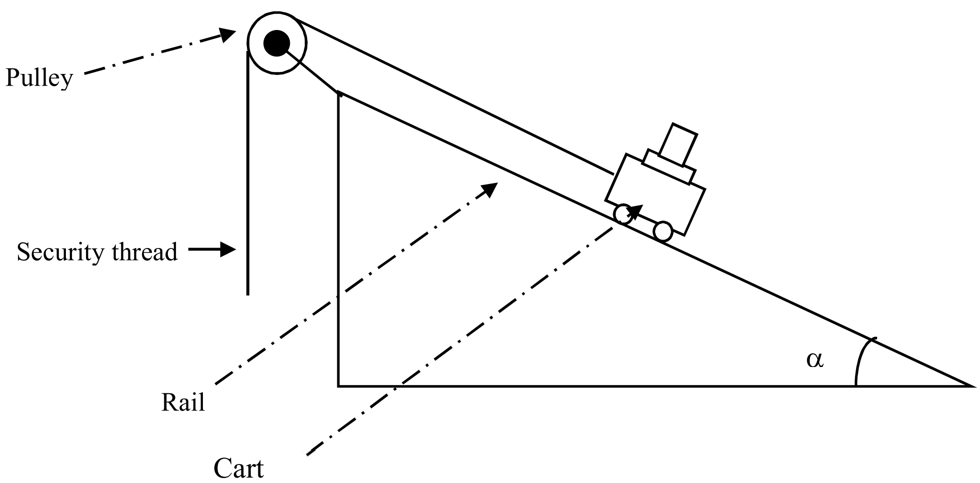
3. Distinguish the forces acting on the mass ***M*** (friction is not negligible here).
4. Write the fundamental law of dynamics.
5. Deduce the expression of the frictional force F_f as a function of ***m***, ***a***, ***g***, and ***sinα***
6. Knowing that $F_f = m \cdot g \cdot \cos\alpha$, deduce the dynamic friction coefficient μ_d (its expression and its numerical value). We will take $g = 9.8\ ms^{-2}$.

Experiment 3

Determination of g

Experimental device

a. An inclined plane with a variable angle α.
b. A cart with mass **m**.



Work to be done

1. We set the distance between the two photoelectric cells at $x = 1{,}00\ m$.
2. The angle of inclination **α** is varied from **5°** to **30°.**
3. For each value of **α**, we measure the time **t** taken by the cart to travel the distance x.
4. We record the obtained results in Table 3.

α (°)	*5*	*10*	*15*	*20*	*25*	*30*
t (s)						
t^2 (s)						
x/t^2 (ms^{-2})						
Sin(α)						

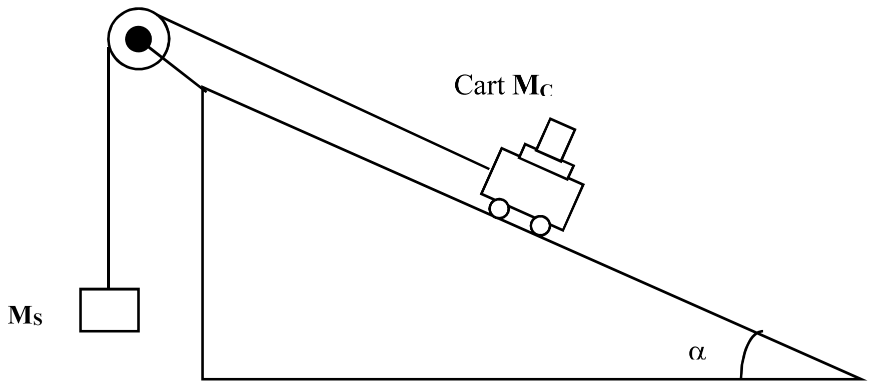
5. Plot the graph of $\frac{x}{t^2}$ as a function of **sinα.**
6. If the obtained curve is a straight line passing through the origin, calculate its slope P_e.
7. Show that theoretically: $\frac{x}{t^2} = \frac{g}{2}.\sin\alpha$.
8. Deduce the value of **g**.

Experiment 4

Mass at equilibrium on an inclined plane

Experimental device

a. An inclined plane with a variable angle **α**.
b. A cart with a mass M_c (**80g**).
c. A pulley.
d. An inextensible string.
e. A suspended mass M_s (**40g**).



Work to be done

1. Place the cart with mass M_c on the inclined plane.
2. Connect the cart to the suspended mass M_s using an inextensible string passing through a pulley.
3. Adjust the angle **α** until the cart is in a state of equilibrium.
4. Record this value of **α**.
5. Use the (L.F.D.) to demonstrate that in this case: $P_s = P_c \sin\alpha$. Where P_s is the weight of the suspended mass M_s, and P_c is the weight of the cart.
6. Verify, according to the experimental data, that we have: $P_s = P_c \sin\alpha$
7. Calculate the value of the reaction **R** of the inclined plane, as well as the tension **T** of the inextensible wire.