

Practical Work 2

Study of Friction in

Atwood's Machine II

1. Objective

Determine the type of friction (solid or viscous) affecting the motion of the masses in Atwood's machine. This friction occurs at the contact between the pulley axis and its support.

Pedagogical objective:

Identify the dominant physical phenomenon by comparing the experimental curve with the theoretical curves.

2. Apparatus

- Vertical graduated rod with two cursors (Figure 1).
 - Start cursor **A** is fixed at position 0.
 - Stop cursor **B** from moving along the rod.
- Two equal masses: $M_1 = M_2 = 158 \text{ g} \pm 0.05 \text{ g}$.
- String of length 2 m and mass 1 g.
- Pulley: mass $m_p = 10 \text{ g} \pm 0.3 \text{ g}$, fixed on the rod.
- Load: $m_s = 10 \text{ g} \pm 0.05 \text{ g}$.

➤ **Chronometer with precision 1/1000 s.**

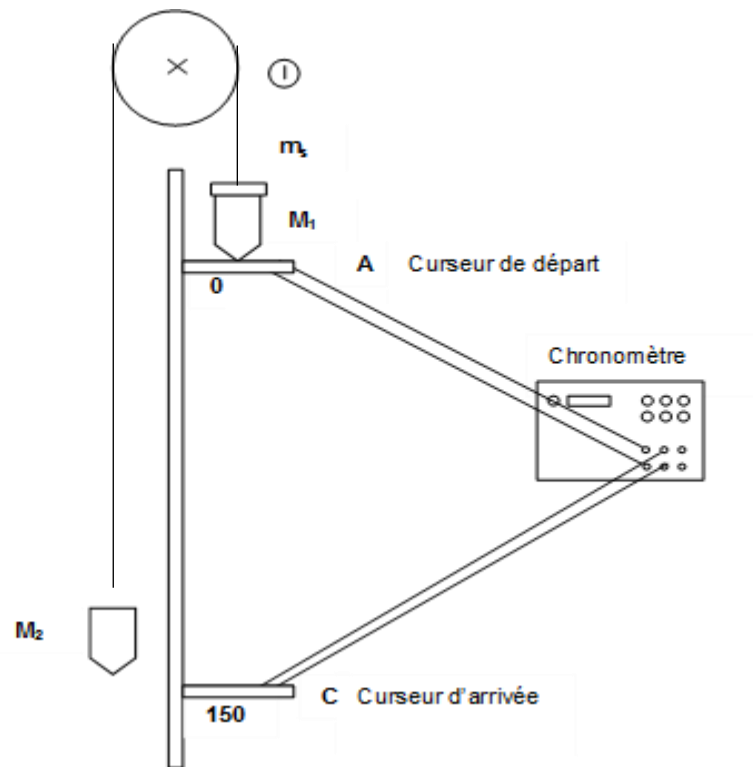


Figure 1: Atwood's machine setup

☞ The only friction considered is that at the pulley's axis.

3. Theory

3.1 Nature of Friction

- If the resisting force **fr** is constant, it indicates a **solid friction**.

- If the resisting force is proportional to velocity (kv)
 → **viscous friction.**

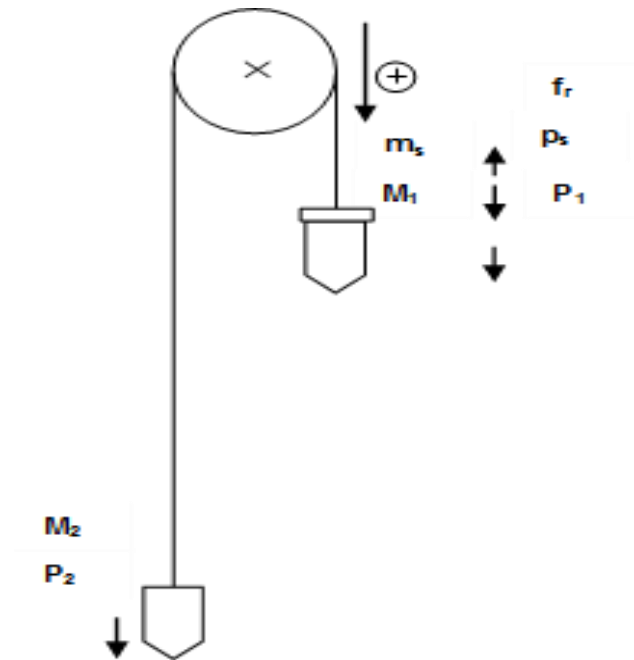


Figure 2: Forces acting on the system

Students must compare experimental results with both models:

- Solid friction model.
- Vis- cous friction model.

3.2 Equations

Case 1 – Solid friction

- External forces: weights (M_1 , M_2 , m_s), load P_s , and resisting force f_r at the pulley axis.

- After applying Newton's 2nd law, the acceleration is constant.
- The equation 0 of motion:

$$X = \frac{1}{2} \cdot \frac{m_s \cdot g - f_r}{M_T} t^2 \dots \dots \dots (1)$$

It Is Parabolic equation in the (X, t) Domain.

Case 2 – vis- cous friction

- Frictional force :

$$f_r = K \cdot \frac{dX}{dt} \dots \dots \dots (2)$$

- The equation of motion becomes a second-order differential equation.
- The solution shows velocity tends to a constant value:

$$V(t) = A e^{\frac{-Kt}{M_T}} + \frac{m_s \cdot g}{K} \dots \dots \dots (3)$$

- Position law derived from initial conditions:

$$X(t) = \frac{m_s \cdot g t}{K} + \frac{m_s M_T g}{K^2} \left[e^{\frac{-Kt}{M_T}} - 1 \right] \dots \dots \dots (4)$$

x(t)=...(depends on k and ms)

4. Theoretical Curves

Before coming to the lab, students must draw the **theoretical curves** (solid & viscous friction) using the provided data.

- **Take $g = 9.80 \pm 0.01 \text{ m/s}^2$.**
- **Masses :**
 - **$M_1 = M_2 = 0.158 \text{ kg}$**
 - **$m_s = 0.010 \text{ kg}$**
 - **$m_p = 0.010 \text{ kg (J/r}^2\text{)}$**
- **Time values: from 1.75 s to 3.75 s (step 0.25 s).**

4.1 Solid friction

- Use 4 values : $f_r = 0; 0.01; 0.02; 0.03 \text{ N}$.
- Compute $x(t)$ and plot curves (Table I).

$f_r \dots \dots \dots t$	1,75	2,00	2,25	2,50	2,75	3,00	3,25	3,50	3,75
$f_{r1}=0$ $\gamma_1=0,292$	0,446	0,583	0,738	0,911	1,102	1,312	1,540	1,786	
$f_{r2}=0,01$ $\gamma_2=0,262$	0,401	0,524	0,663	0,818	0,990	1,178	1,383	1,604	1,841
$f_{r3}=0,02$ $\gamma_3=0,232$	0,355	0,464	0,587	0,725	0,877	1,044	1,225	1,421	1,631
$f_{r4}=0,03$ $\gamma_4=0,202$	0,310	0,405	0,512	0,632	0,765	0,910	1,068	1,239	1,422

4.2 vis -cous friction

- Use 3 values: $k = 0.05; 0.10; 0.15 \text{ kg/s}$.
- Compute $x(t)$ and plot curves (Table II).

$t = k \dots\dots$	1,75	2,00	2,25	2,50	2,75	3,00	3,25	3,50	3,75
k=0,05	0,410	0,529	0,662	0,808	0,966	1,137	1,319	1,512	1,716
k=0,10	0,378	0,483	0,598	0,722	0,854	0,995	1,143	1,299	1,460
k=0,15	0,350	0,442	0,542	0,649	0,762	0,880	1,002	1,130	1,260

5. Expérimental Works

5.1 Setup

- Connect the chronometer to 220 V.
- Start the cursor at A, and stop it at B.

5.2 Measurements

- Measure the travel time of mass M1 for positions:

$x=30, 60, 90, 120, 150$ cm

Do 10 trials for each distance.

- Exclude outliers, calculate the mean time $\bar{t} = \frac{\sum t_n}{n}$

And standard deviation σ_t .

- Record results in Table III.

$x =$ n.....	30	60	90	120	150
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
$t_{\text{moy}} \text{ calc}$					
$t_{\text{moy}} \simeq$					
$\sigma_t \text{ calc}$					
$\sigma_t \simeq$					

6. Analysis

- Plot the **experimental curve** $x = f(t)$ with error bars.
- Compare with theoretical curves.

7. Questions:

1. Compare the experimental curve with the no-friction curve. What does the deviation mean physically?

2. By comparing the two families of theoretical curves (solid vs. viscous), determine the dominant friction type.
3. Estimate the friction constant (μ or k) by interpolation between curves.