Sequence 9: Forces and movement

Fiche de synthèse mobilisée (collection en français) :

- Fiche n°9 : lien entre forces et mouvement

Sommaire des activités ETLV :

ACTIVITY 1: Measuring the viscosity of honey

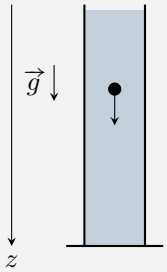
Objective: using Newton's Laws to measure the viscosity of honey

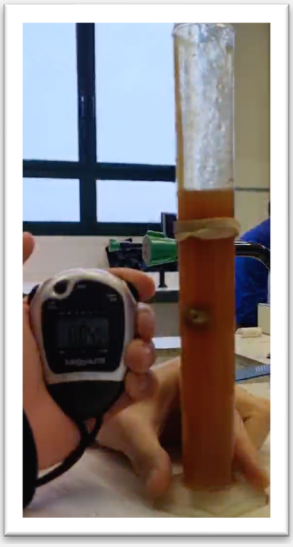
DOCUMENT 1: The viscosimeter

The viscosimeter is a measuring cylinder in which a spherical metal ball falls.

If the radius of the ball is small enough compared to the diameter of the cylinder, the ball is subject to a drag (or frictional) force, named Stokes force, where η is the viscosity of the fluid, R the radius of the ball and v its velocity:

$$\vec{f} = -\lambda \vec{v} = -6\pi\,\eta\,R\,\vec{v}\,,$$





DOCUMENT 2: Archimedes' principle

Archimedes' principle states that the upward buoyant force that is exerted on a body immersed in a fluid, whether fully or partially, is equal in norm, to the weight of the fluid that the body displaces.

$$\overrightarrow{P_A} = -\rho_m V g \overrightarrow{e_z}$$

With ρ_m the density of honey, $V = \frac{4}{3}\pi R^3$ the volume of the ball and $g = 9{,}81 m.s^{-2}$ the gravity constant.

DOCUMENT 3: Data

Density of steel	Density of honey
$\rho_a = 7{,}83 \cdot 10^3\ \text{kg} \cdot \text{m}^{-3}$	$\rho_m = 1{,}4 \cdot 10^3\ \text{kg} \cdot \text{m}^{-3}$

DOCUMENT 4: Computing viscosity

A sphere of known size and density is allowed to descend through the liquid. Eventually, it reaches terminal velocity, which can be measured by the time it takes to pass two marks on the tube (separated by a distance L).

The terminal velocity v_{lim} is reached when this frictional force combined with the buoyant force exactly balance the gravitational force. The resulting terminal velocity is given by:

$$\boxed{\eta = \frac{2\,R^2\,(\rho_a - \rho_m)\,g}{9\,v_{\text{lim}}}} \qquad v_{\text{lim}} = \frac{L}{\Delta t}\,.$$

Source: Wikipedia

DOCUMENT 5: Average value and uncertainty

One can compute the uncertainty $u(\eta)$ of a series of N measurements of viscosity (for the class for example) using σ the standard deviation:

$$u(\eta) = \frac{\sigma}{\sqrt{N}}$$

Final expression of viscosity: $\bar{\eta} = \cdots\ \text{Pa.s}\,;\ u(\eta) = \cdots\ \text{Pa.s}$

Understanding:

Using Newton's Laws, explain the formula obtained in document 4.

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Experimenting:

Measure the viscosity of honey at least once. You can film the fall of the ball for better measurements. Record all class viscosity data on the board.

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Compute the uncertainty of viscosity for the measurements of the class. The standard deviation can be computed using Excel. Write your results using the expressions in document 5.

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Activity summary

What you must remember:

- viscosity
- Archimedes' principle
- density
- uncertainty, average value
- standard deviation

Skills linked to the curriculum**:**

Compétences	Capacités à maîtriser	Où dans cette séquence ?
APP	• Utiliser du vocabulaire spécifique	Activité 1
	• Lire et comprendre des documents scientifiques	Activité 1
ANA	• Effectuer un bilan des forces sur des objets en mouvement plan. • Citer et exploiter les lois de Newton. • Établir l'expression de la vitesse en régime permanent lorsqu'il existe des forces de frottement fluide (électrophorèse, chute dans un fluide ...).	Activité 1
REA	• Capacités expérimentales : - Mettre en œuvre un protocole expérimental pour mesurer la vitesse en régime permanent. - Procéder à une évaluation de type A d'une incertitude-type.	Activité 1