BRAZIL IAM TEAM

17th IYPT - AUSTRALIA - Brisbane - 24th June to 1st July
3. ELECTRIC PENDULUM

Use a thread to suspend a ball between the plates of a capacitor. When the plates are charged, the ball will start to oscillate. What does the period of the oscillations depend on?

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Introduction

- History
- Electricity
- Conditions
- Experiment
- Source of Errors
- Conclusions
History

- A way to understand electricity
- This kind of pendulum has been used in house watches
Electricity

- Charges: positive
- negative

Electric field between the plates:
- constant \( E = \frac{Q}{d} \)
Conditions

- The ball must be charged

- The capacitor’s plates cannot be horizontally parallel
Mathematical Analysis

\[ \mathbf{F} = q \mathbf{E} \]
\[ m \mathbf{a} = q \mathbf{E} \]
\[ \mathbf{a} = q \mathbf{E} \]
\[ m \]

\[ \mathbf{a} = \text{acceleration due to the electrical field} \]
Analysis

- New position of balance
- Electric force is strong enough to make the ball pass this position
- The pendulum oscillates due to this force (in simple harmonic movement)
If the plates of the capacitor are vertical and parallel:
\[ \mathbf{g} \text{ and } \mathbf{a} \text{ are perpendicular and, hence, the vectorial sum results in} \]

\[ g' = \sqrt{g^2 + \frac{q^2 E^2}{m^2}} \]
As the period of a pendulum is given by

\[ T = 2\pi \sqrt{\frac{L}{g'}} \]
One can finally write for the period:

\[ T = 2\pi \sqrt{\frac{L}{\sqrt{g^2 + \frac{q^2 E^2}{m^2}}}} \]
Given that the electric field is uniform, it can be calculated by:

\[ E = \frac{\sigma}{\varepsilon} = \frac{Q}{A \varepsilon} \]

(where \( \sigma \) = superficial charge density; \( A \) = plate’s area and \( \varepsilon \) = environment’s electric permissivity)
Therefore, the equation for the period of the pendulum becomes:

\[ T = 2\pi \sqrt{\frac{L}{g^2 + \frac{q^2 Q^2}{m^2 A^2 \varepsilon^2}}} \]
In this case, the vectorial sum is:

\[ g' = \sqrt{g^2 + \frac{q^2 \cdot E^2}{m^2} + 2g \cdot \frac{qE}{m} \cdot \cos \alpha} \]
Equally to the last case, we have:

\[
T = 2\pi \sqrt{\sqrt{g^2 + \frac{q^2 Q^2}{m^2 A^2 \varepsilon^2} + \frac{2gqQ\cos\alpha}{m A \varepsilon}}}
\]
Source of Errors

- The ball discharged very quickly because the weather was umid.
- There was no way how to measure the charge of the ball.
Conclusion

The period depend on:

- The mass of the ball (m);

- The electric field of the capacitor (E) and of the ball (q);

- The surface (A) and the distance between the plates;

- The length (L) of the thread;
Experiment