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IYPT International Young Physicists' Tournament

# 9. Vodná špirála

Prúd vody vypúšťaný cez úzku dierku sa za istých okolností môže stáčať do špirály. Vysvetlite tento jav a preskúmajte podmienky, za ktorých špirála vznikne.

# 9. Water Spiral

If a stream of liquid is launched through a small hole, then under certain conditions it twists into a spiral. Explain this phenomenon and investigate the conditions under which the spiral will twist.

# Essence of the problem

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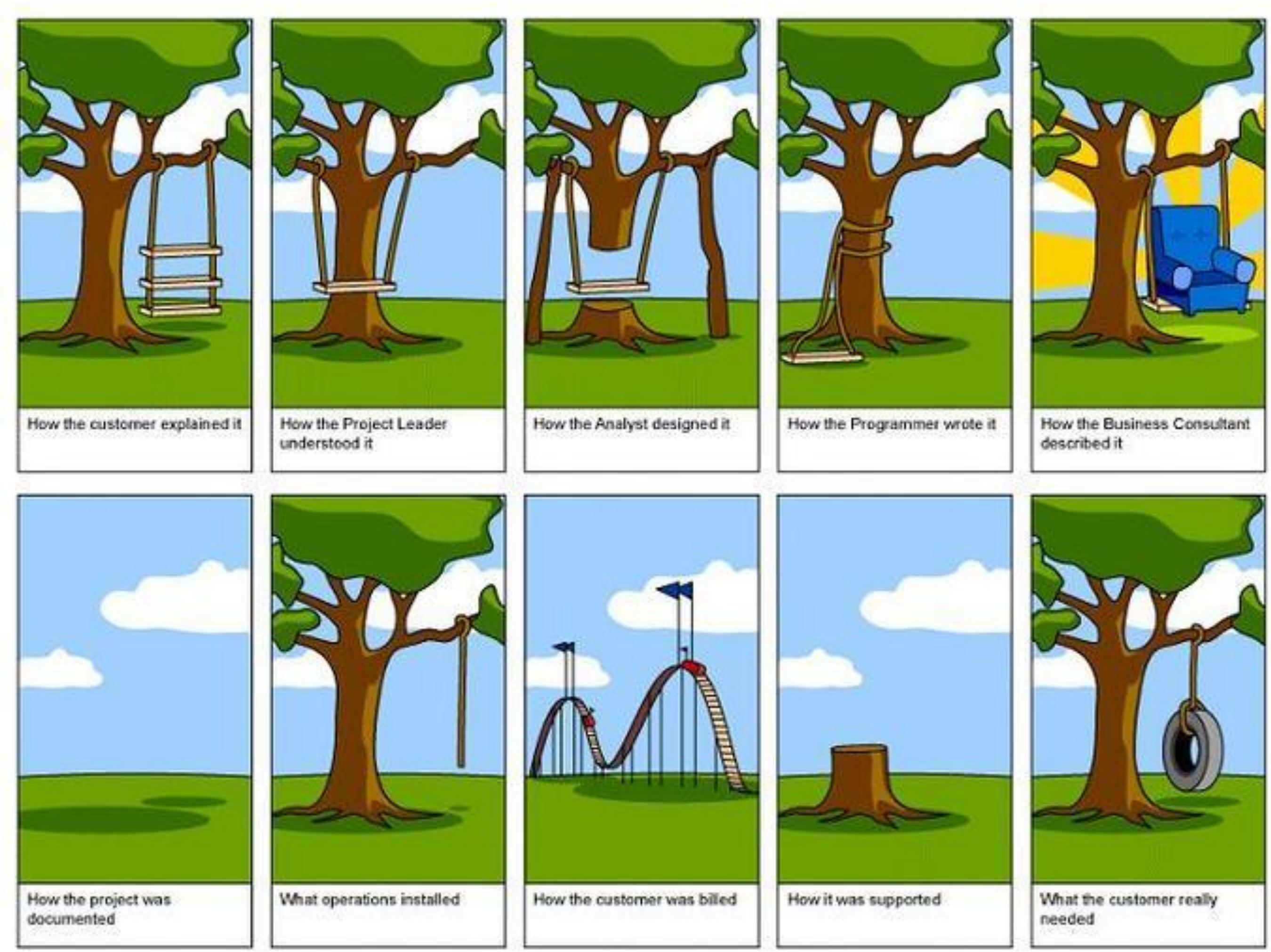
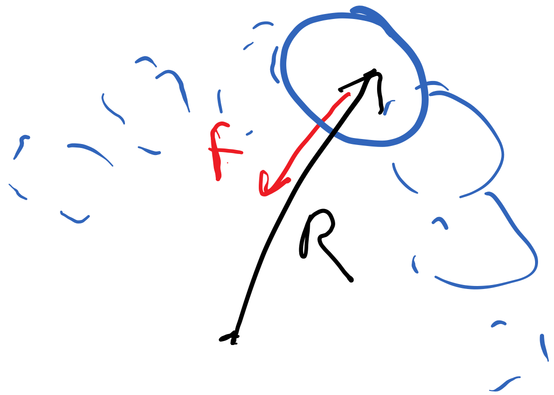


# Basic physical laws

- First Newton law
- Conservation of energy
- Conservation of momentum
- Conservation of angular momentum

- **How can these be in line with a water spiral?**

# Case 2 – driven motion

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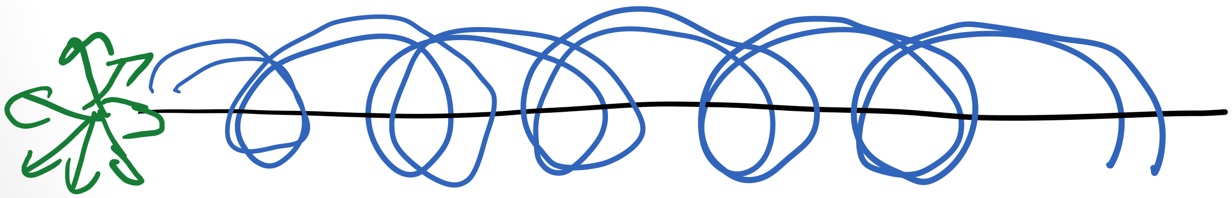
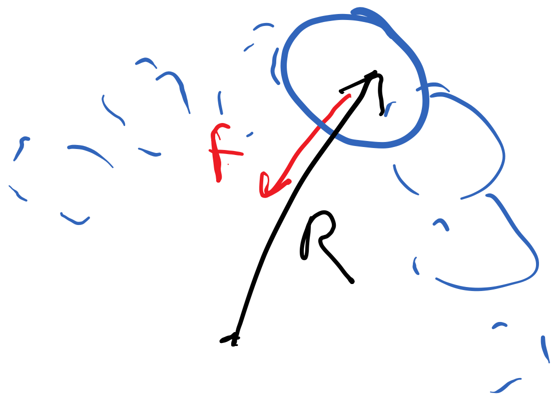


# Case 2 – driven motion

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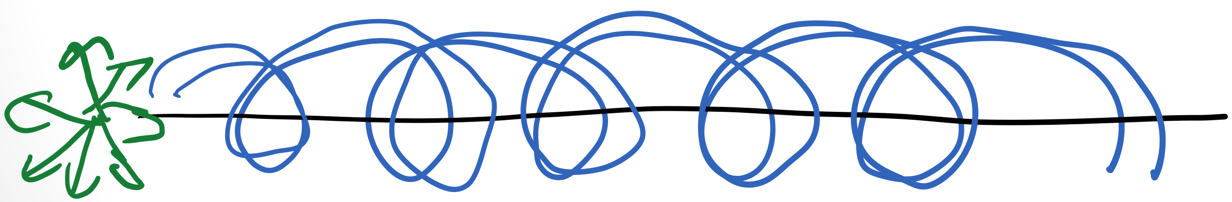
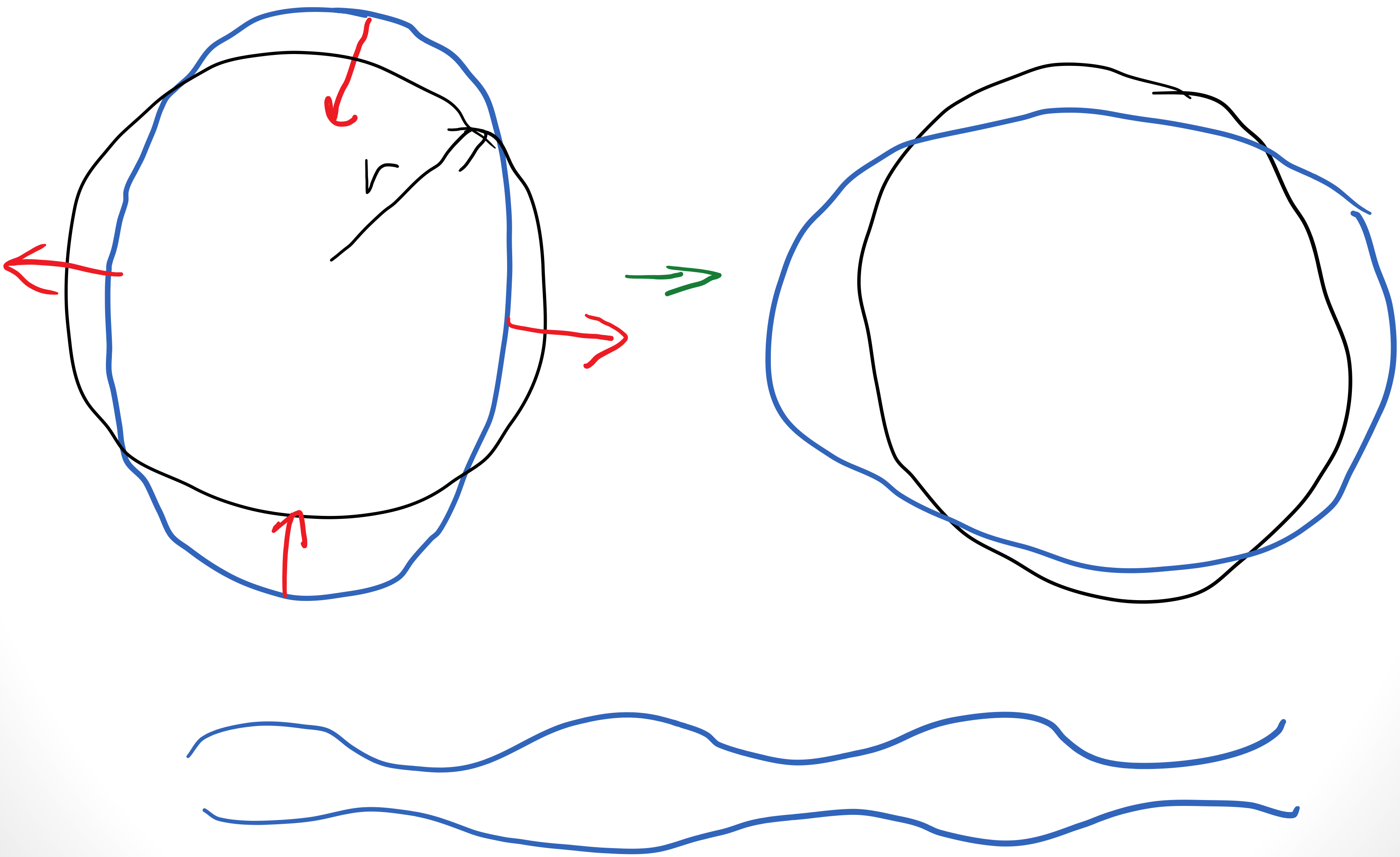
SURFACE TENSION



# Case 1 – self formation



# Case 1 – Air drag influence

## Asymmetric instability of a liquid jet

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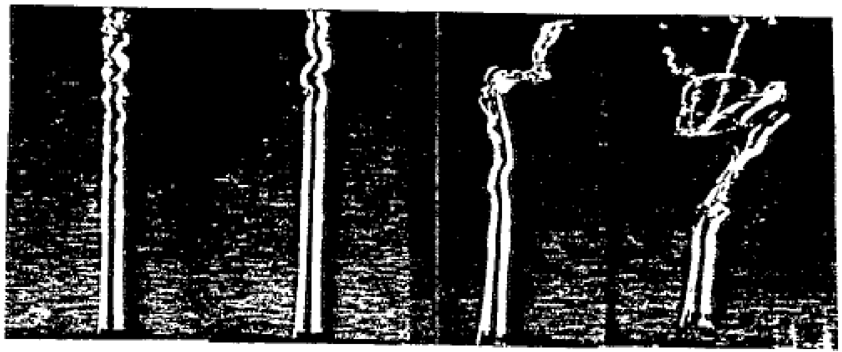
(Received 28 August 1990; accepted 13 September 1991)

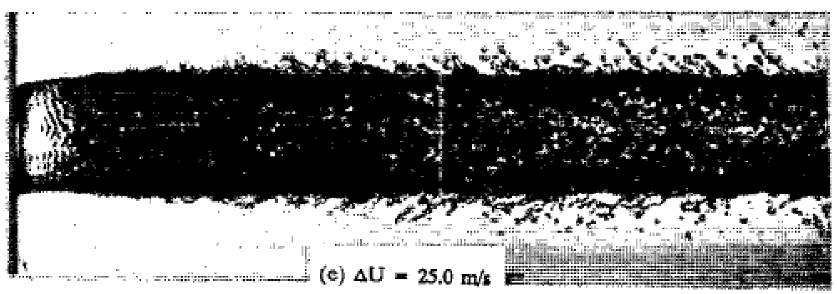
The existing aerodynamic theory is not capable of predicting the phenomenon of nonaxisymmetric breakup of a liquid jet, which has long been observed in experiments. A dispersion equation that accounts for the growth of asymmetric waves is derived in this paper. It is demonstrated that there exists a critical Weber number, below which the nonaxisymmetric disturbance becomes unstable. The Weber number here is defined as the ratio of surface tension force to the inertial force. The present theory indicates the possible growth of sinuous wave and the subsequent formation of curling flat sheet from an axisymmetric jet. According to the present analysis for a high-speed jet, the drops break away from the jet surface, instead of rings as predicted by the theory based on the axisymmetric assumption.

# Case 1 – air drag influence



(a) $\Delta U$ = 44.0 m/s, $U_1$ = 4.5 m/s, $U_2$ = 48.5 m/s
(b) $\Delta U$ = 45.3 m/s, $U_1$ = 3.2 m/s, $U_2$ = 48.5 m/s
(c) $\Delta U$ = 47.0 m/s, $U_1$ = 1.5 m/s, $U_2$ = 48.5 m/s
(d) $\Delta U$ = 47.4 m/s, $U_1$ = 1.1 m/s, $U_2$ = 48.5 m/s

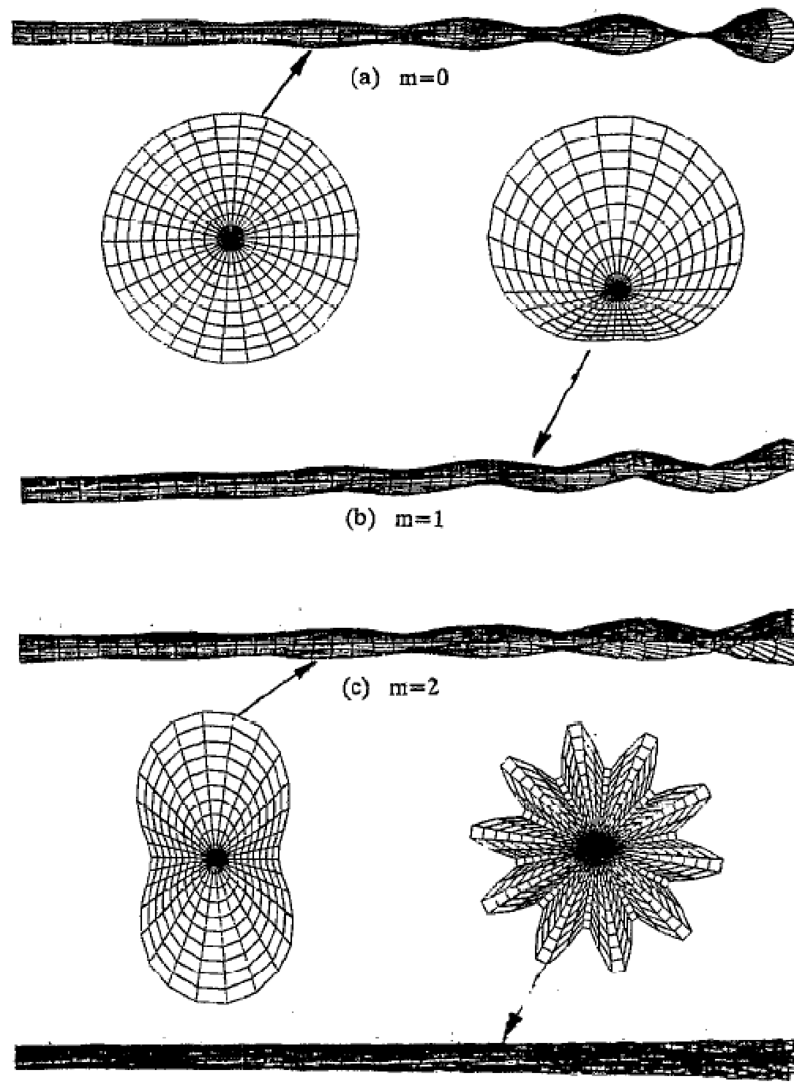
Radius of Liquid Jet a = 0.485 (mm)



(e) $\Delta U$ = 25.0 m/s
$U_1$ = 25.0 m/s
$U_2$ = 0.00 m/s

Radius of Liquid Jet a = 3.000 (mm)

FIG. 1. Photographs of water jet with axial air flow at different relative velocities from Ref. 16 [(a)–(d)] and from Ref. 19 [(e)].



# Weber number

- Ratio of inertial and cohesion forces

$$We = \frac{\rho v^2 r}{\sigma}$$

- Small We means motion is governed by cohesion forces, i.e. it stabilizes
- Large We means inertial forces are strong enough to tear the jet

# What to do - Minimum

- Properly define your problem and scope
- Prepare a reasonable experiment
- Find some reproducibility and measure some parameters

# What to do – higher level

- Prepare a well defined experiment
  - Hi speed camera
  - Flow under control
- Define and measure your parameters
- Change some of them, like flow rate and hole parameters

# What to do – IYPT champions

- High quality experiment
  - Most of parameters under control
  - High wuality recordings
  - Proper tracking
- Data processing
  - Energy balance
  - Momentum balance
- **Qualitative explanation of results**