
15 - Blowpipe

The Problem

Investigate the motion of a projectile inside a blowpipe. Determine the conditions for maximum exit velocity when blown by mouth.

Outline

- Basic explanation
- Blowpipe simulation
  - bullets
  - pipe
  - blowing by mouth
  - velocity measurement
- Theoretical model

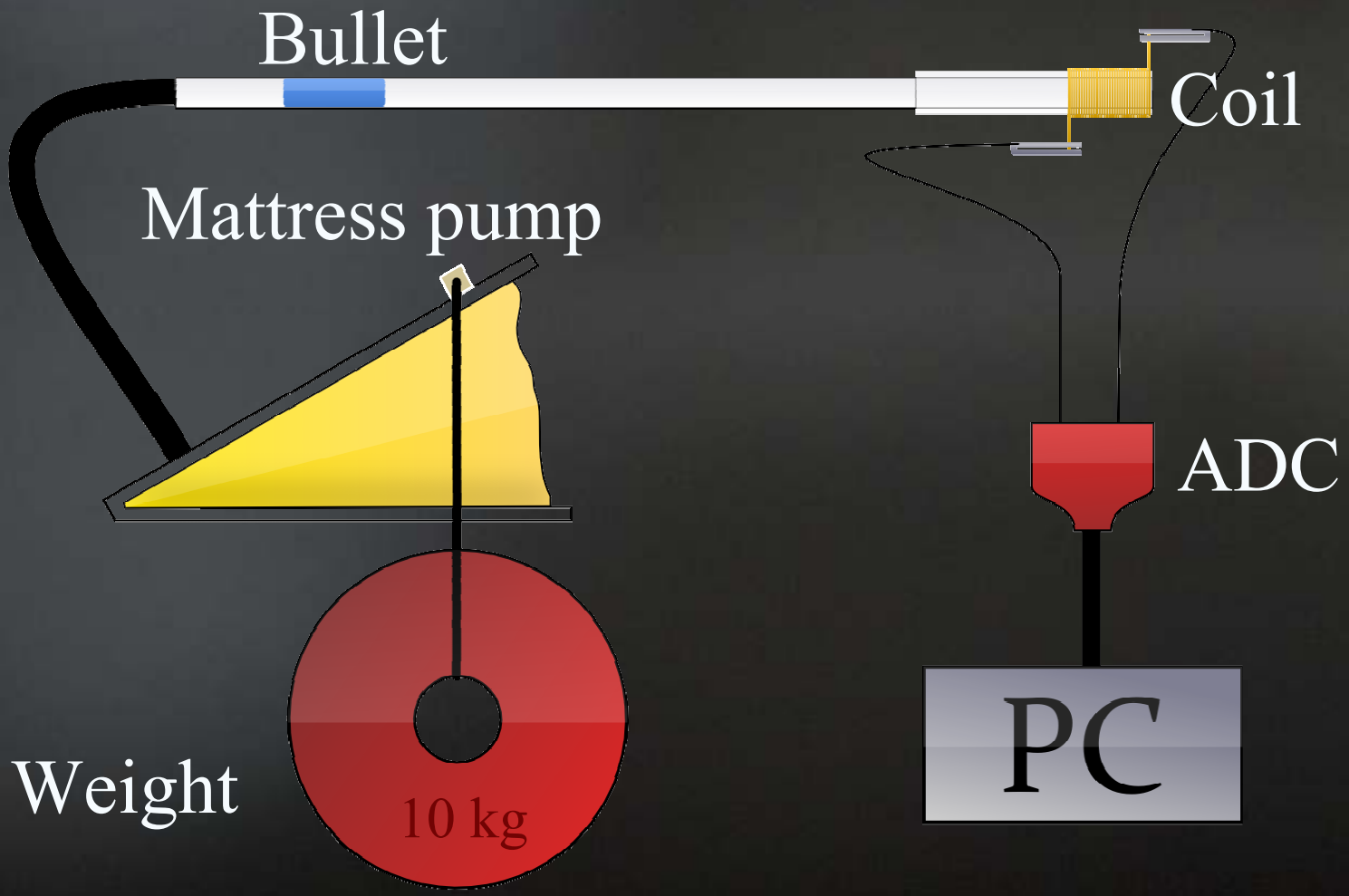
Basic explanation

- Two subcases:
  - Bullet seals
  - Bullet does not seal
- Pressure supplied by pump/mouth
- Pressure difference causes force on bullet
- Bullet seals – no pressure loss!

$\Rightarrow$ Larger force

$\Rightarrow$ higher velocity

Apparatus

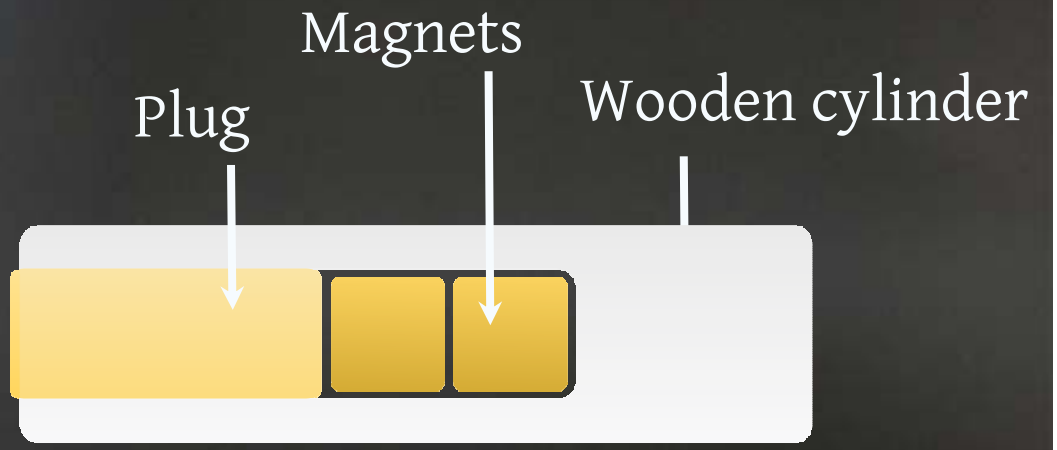


Apparatus



Bullet





Magnets inserted in the bullet to measure velocity via induction

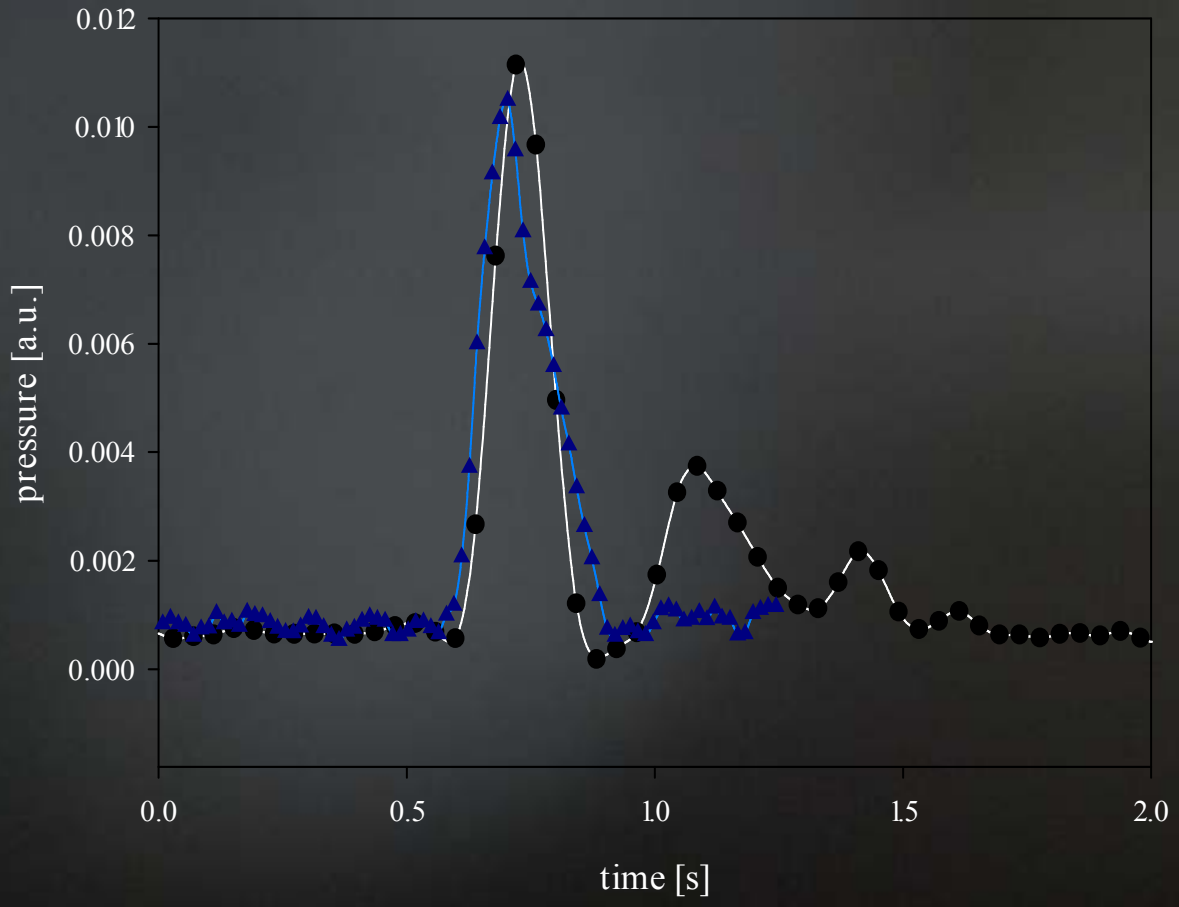
Pipes

- Glass and plastic pipes of different lenghts and diameters
- Diameters: 16, 18 and 23 mm
- Lengths: from 10 to 280 cm

Simulation of mouth blowing

- Necessary to ensure equal conditions at every measurement
- To simulate blowing by mouth a mattress pump was used
- We measured the pressure caused by blowing by mouth and mattress pump
- The mattress pump was adjusted to produce a result similar to mouthblow

Blowing comparison



Pulse duration:

~ 0.4 s

Volume:

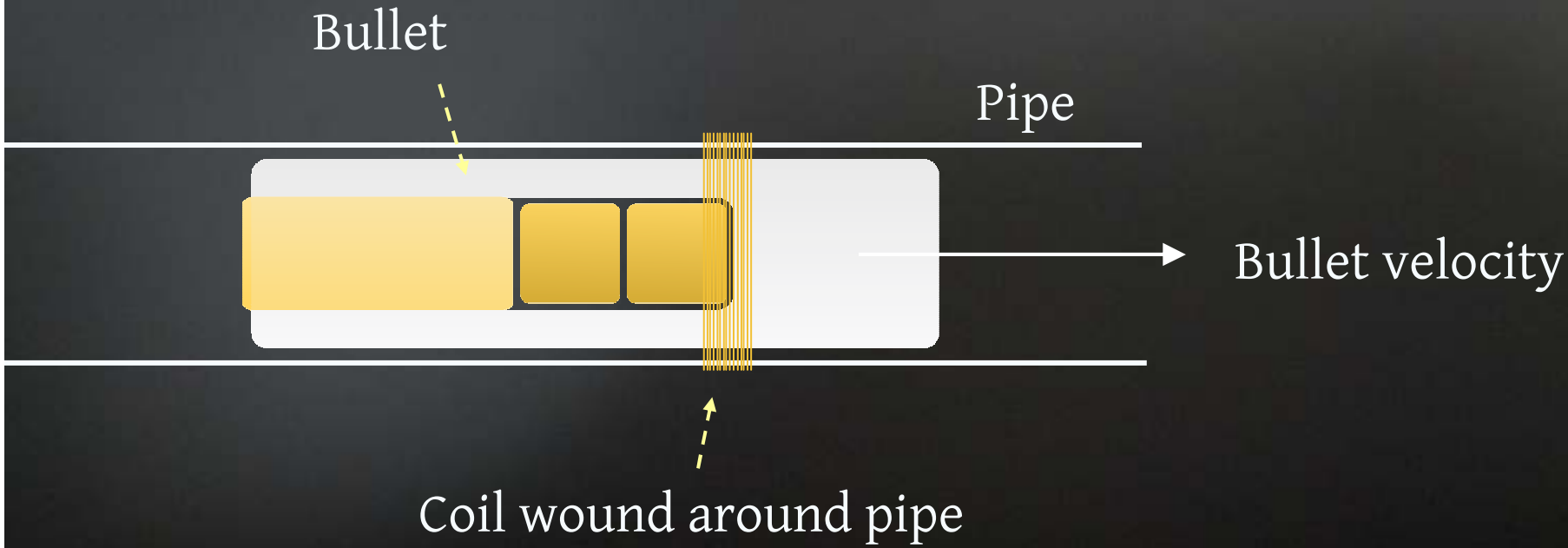
Mouth and mattress pump ~ 1.0 l

Volume measurement

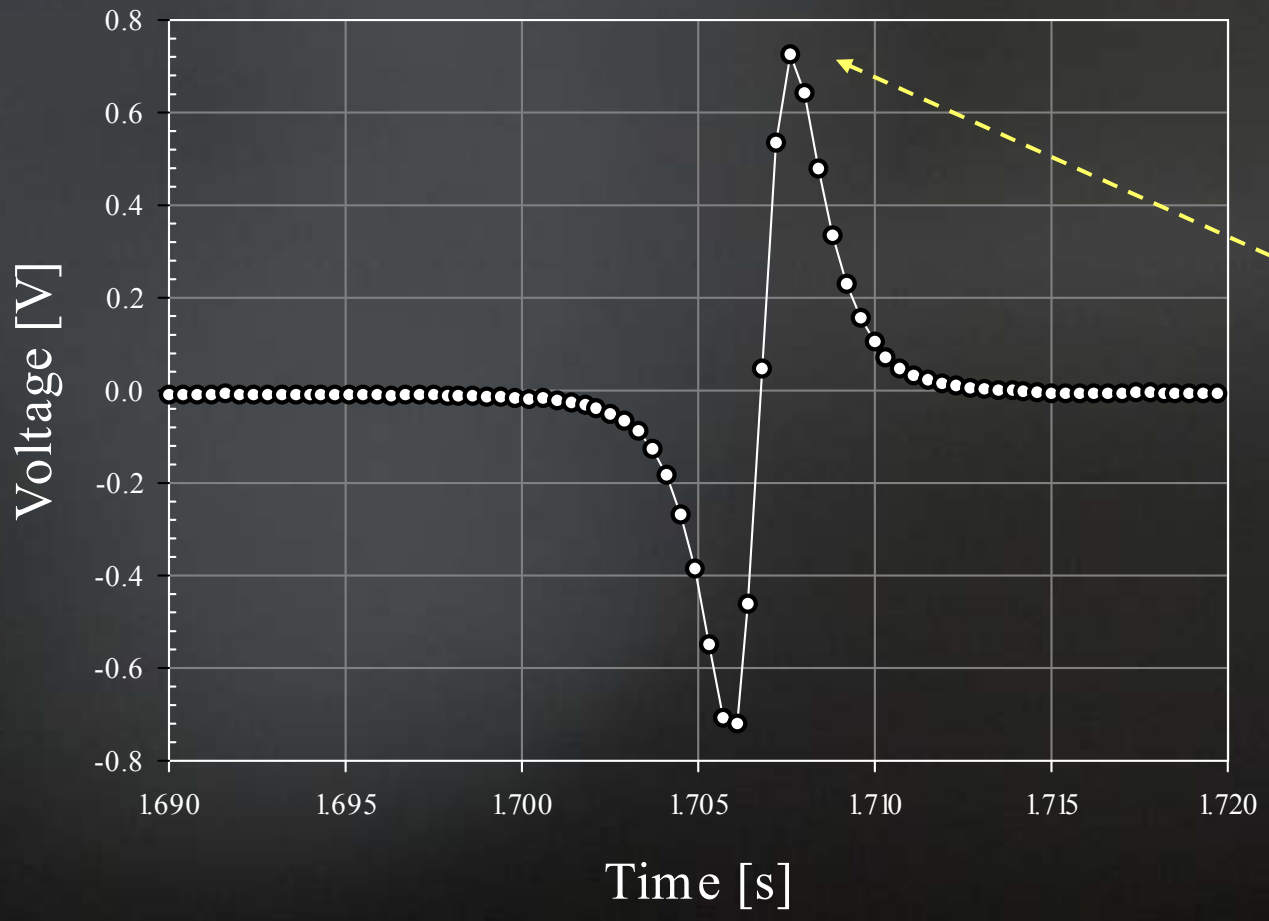


Velocity measurement

- Electromagnetic induction – velocity proportional to voltage induced in coil

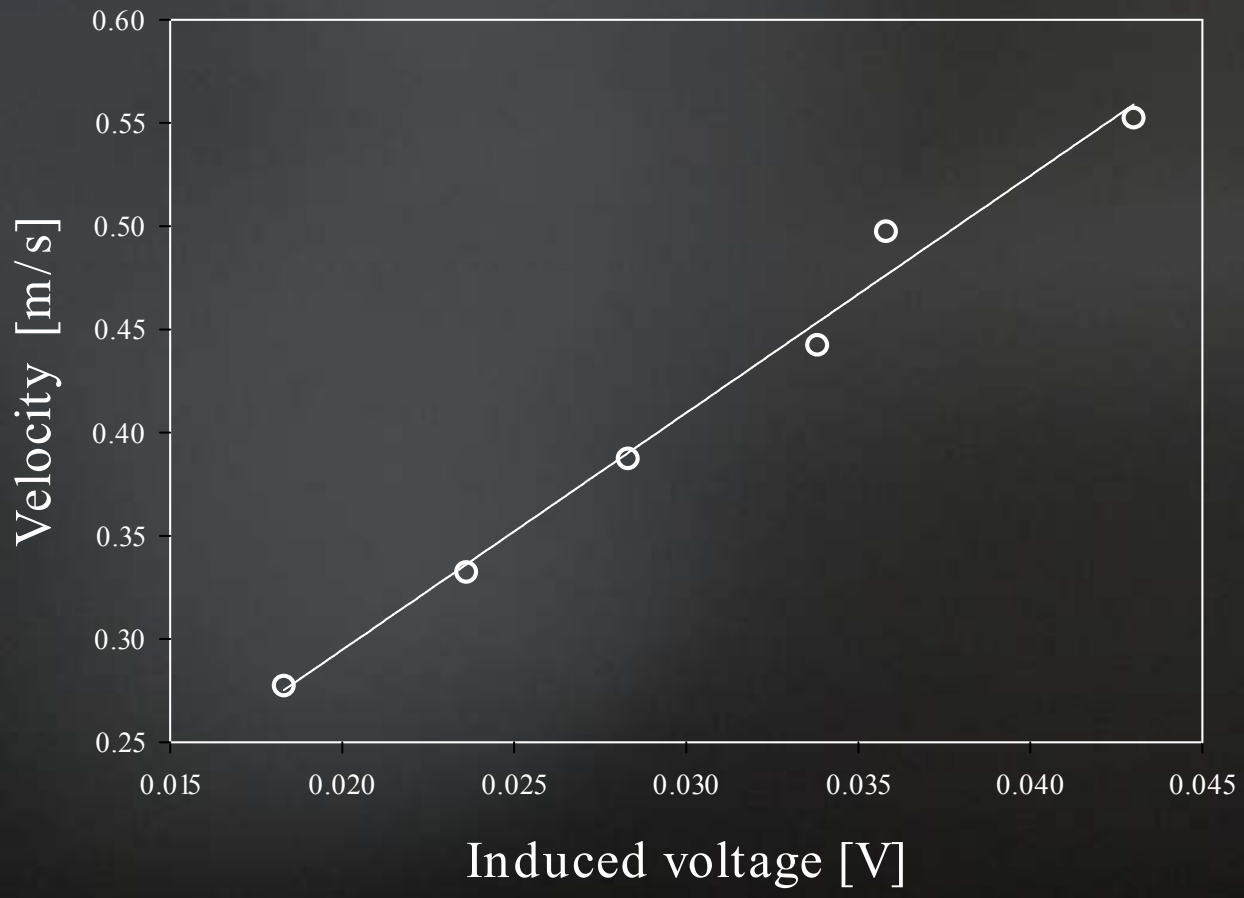


Sample coil output



Peak voltage measured

Velocity vs. voltage



1 V induced voltage implies 9.05 m\s

Coil



Data acquisition

- For acquiring the voltage we used ADC-42



Theory

- Simplified model – piston supplying pressure:



Fast – moving piston

- Force on bullet:

$$F = (P - P_0)S$$

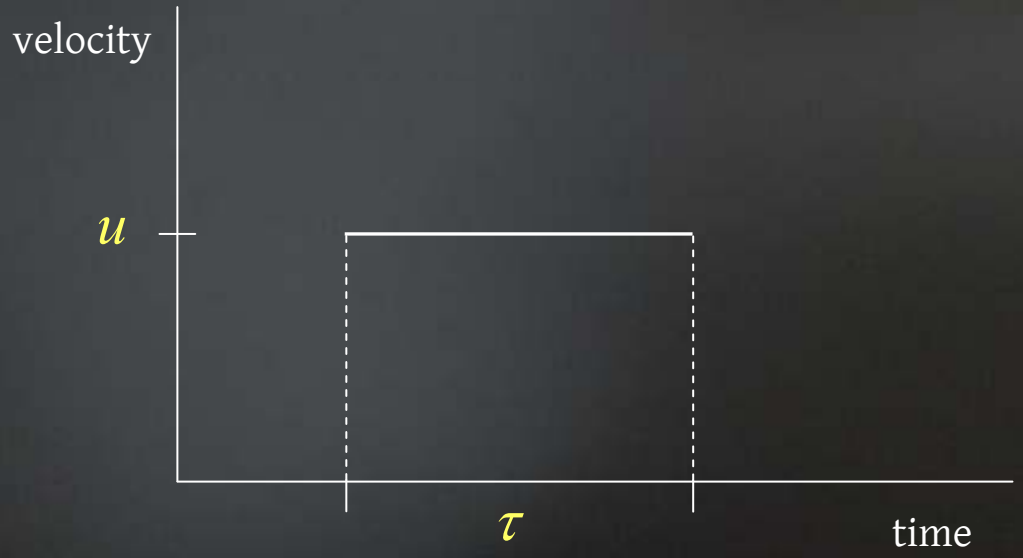
P – pressure cased by compression of air between pump and bullet

S – surface of bullet

P_0 – atmospheric pressure

Theory

- Piston equivalent to lungs/pump
- Simplified pulse:



- Enables calculations

Theory

- Pressure change in tube:
  - Air volume decrease due to piston
  - Air volume increase due to bullet motion
  - Leaking
- The pressure change due to leaking can be assumed to be

$$dP = -\Gamma\left(P - P_0\right)dt$$

P – inside pressure

Γ – constant

P_0 – atmospheric pressure

Theory

- Calculation of net pressure: discretization
  - Let a little pressure leak (no volume change)
  - Change volume (no leak)
  - Process repeated
- In isothermal conditions:

$$\left[P-\Gamma\left(P-P_0\right)dt\right]V=\left(P-dP\right)\left(V-dV\right)$$

$$\Gamma V\left(P-P_0\right)dt=PdV+VdP$$

P – inside pressure

Γ – constant

P_0 – atmospheric pressure

V – inside volume

Theory

- If the distance of bullet to initial piston position is x:

$$V = S\left(x - \int_0^t u dt \right)$$

V – inside volume
x – bullet position
S – pipe cross section
u – piston velocity
t - time

$\Rightarrow$ Equation for pressure against bullet position obtained

$\Rightarrow$ Bullet position – from bullet equation of motion:

$$m\frac{d^2x}{dt^2} = S(P - P_0)$$

m – bullet mass
x - bullet position
P – inside pressure
P_0 – atmospheric pressure

Theory

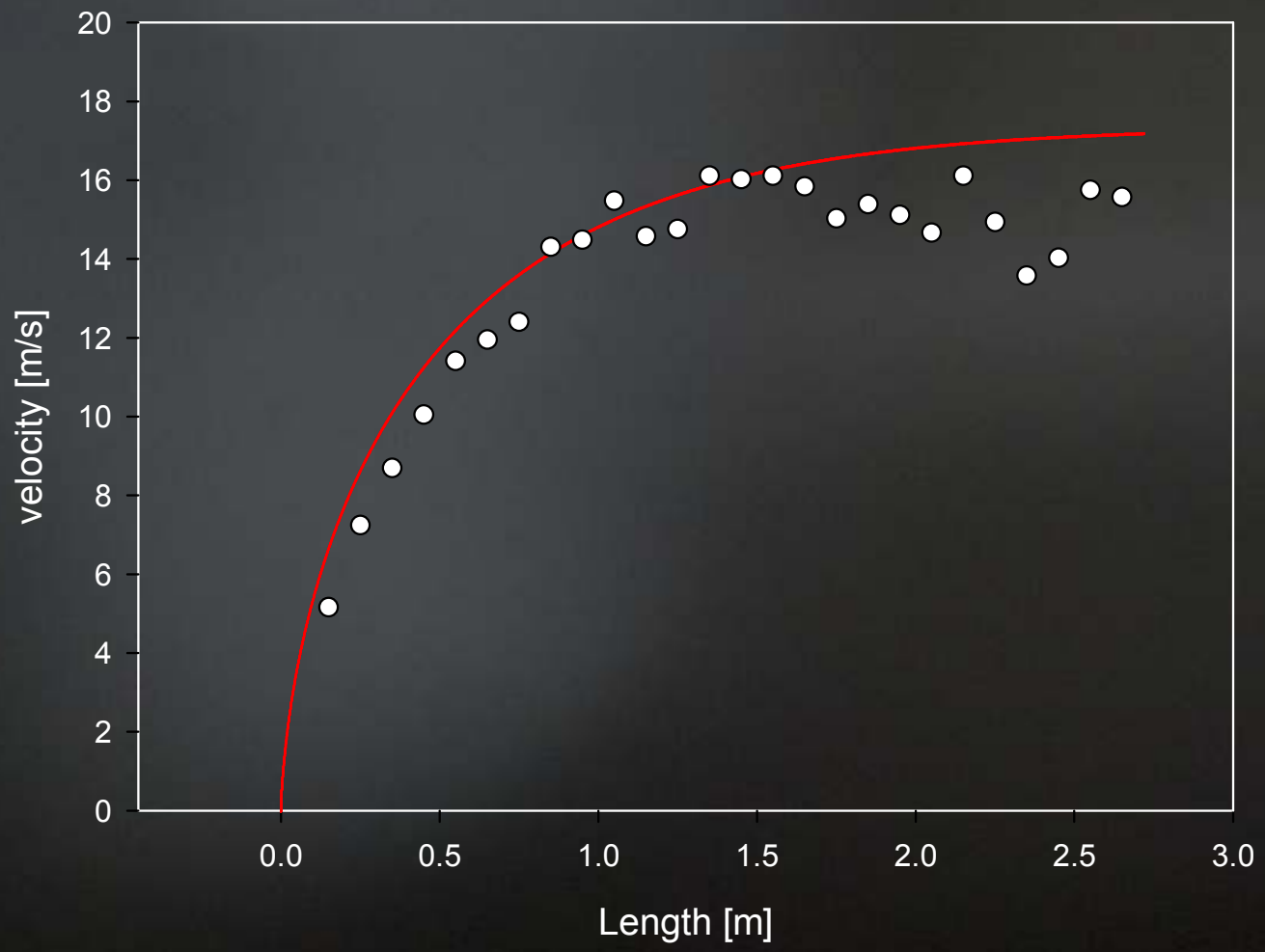
$\Rightarrow$ System of differential equations obtained for pressure and bullet position

$\Rightarrow$ Numerical solution

$\Rightarrow$ Possibility of comparison to experimental data

- Model flaws:
  - Leaking constant unknown; it can only be estimated
  - No drag forces taken into account
  - Simplified piston motion
  - Static and dynamic friction between bullet and tube neglected

Velocity – position



Bullet mass:

10.0 g

Tube diameter:

18 mm

Leaking factor:

50 s^{-1}

Pulse duration:

0.2 s

Injected volume:

1.0 L

Velocity – position

$\Rightarrow$ relatively good agreement

$\Rightarrow$ leaking factor estimated to provide best curve

$\Rightarrow$ Other parameters realistic

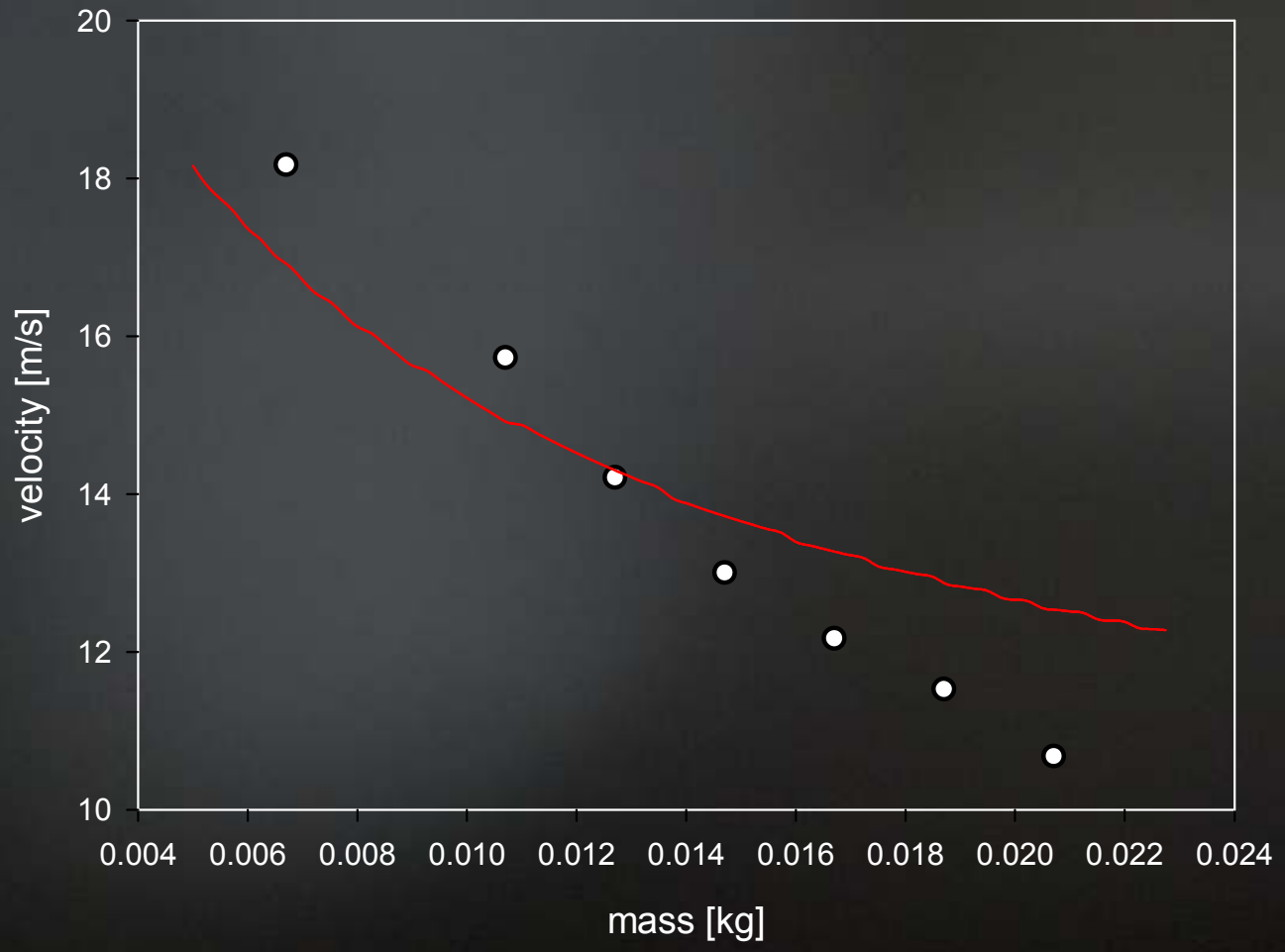
$\Rightarrow$ leaking factor meaning:

For bullet and piston at rest:

After t = 0.2 s pressure inside tube equals 100.1% of outside pressure

$\Rightarrow$ Relatively large leaking

Velocity – bullet mass



Measuring position:

1.5 m

Tube diameter:

18 mm

Leaking factor:

50 s^{-1}

Pulse duration:

0.2 s

Injected volume:

1.0 L

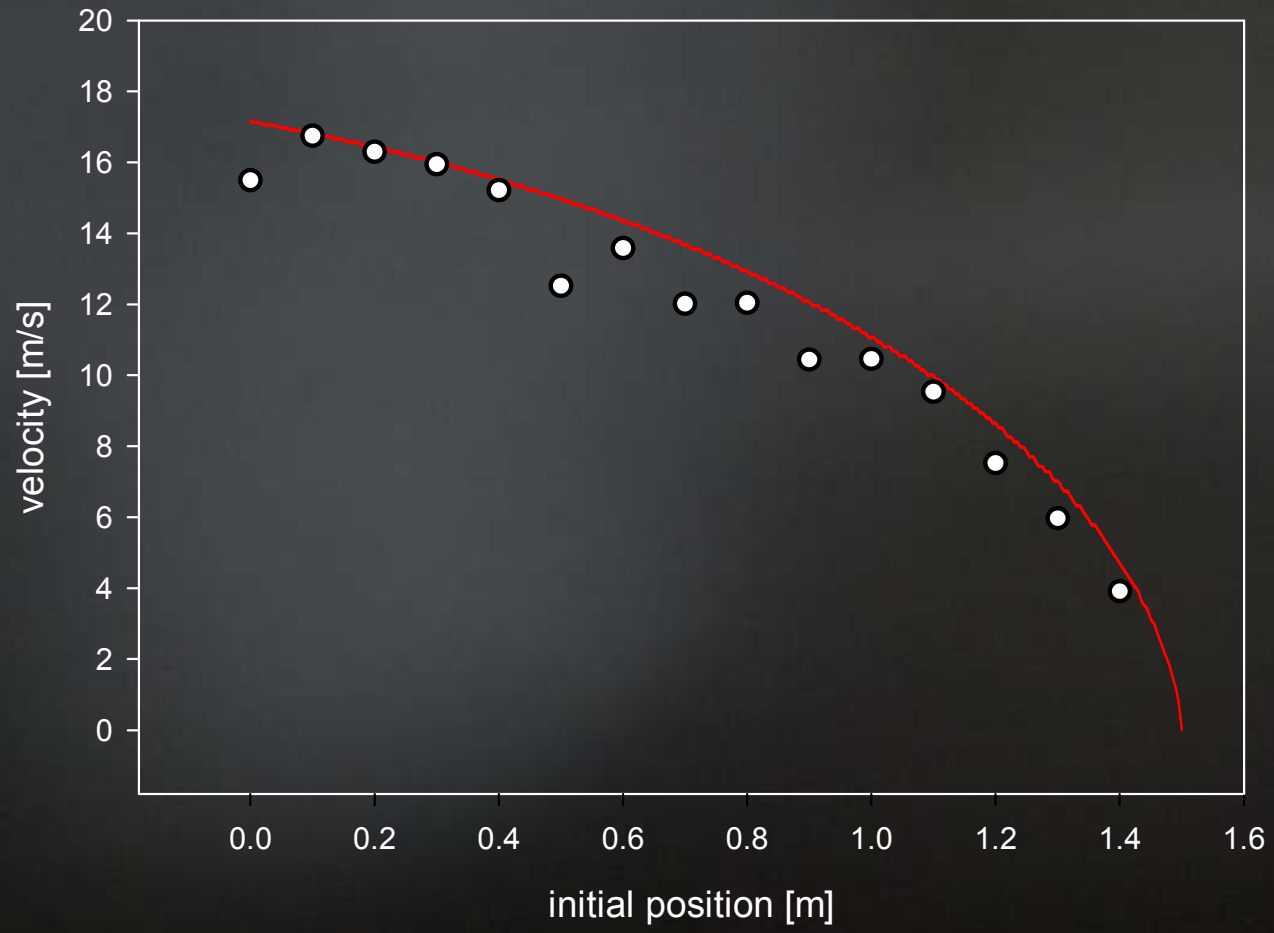
Velocity – bullet mass

⇒ not as good an agreement

⇒ Possible reasons:

- Neglected drag force involves mass and velocity
- Friction with tube walls neglected
- Oversimplification of blowing process
- Dependence of leakage on mass not investigated

Velocity – initial position



Measuring position:

1.5 m

Tube diameter:

18 mm

Leaking factor:

50 s^{-1}

Pulse duration:

0.2 s

Injected volume:

1.0 L

Velocity – initial position

⇒ good agreement

⇒ as in other measurements, theory overpredicts velocity – drag and friction!

⇒ model consistency proven – all curves have the same parameters

⇒ general trends confirmed

⇒ Left out (difficult to control) – static and dynamic friction

Thank you for your attention!