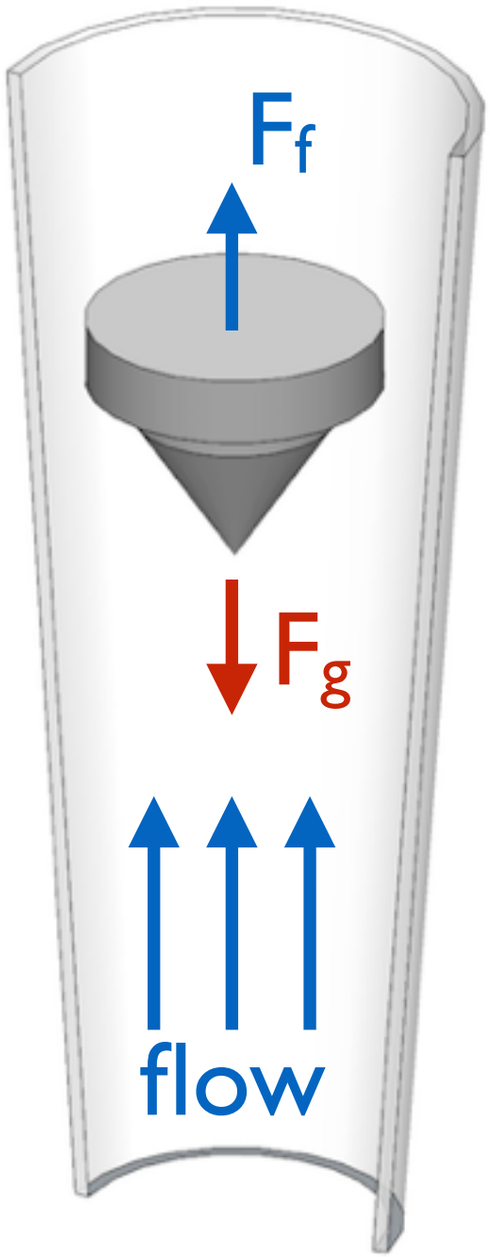
Sensors of flow rate and level

AE3B38SME - Sensors and Measurement

Rotameters



Two forces act on the float

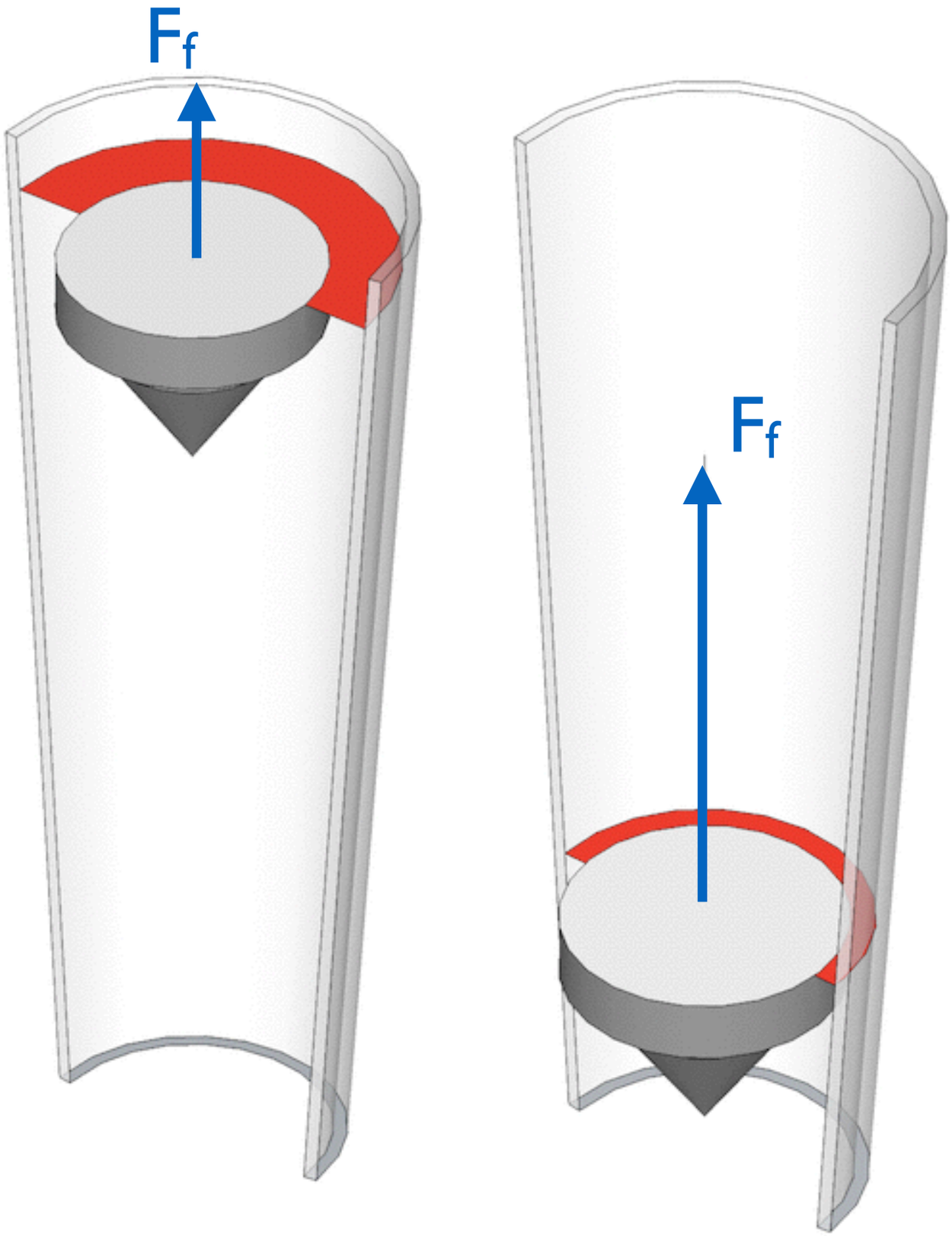
F_g gravity force

F_f force due to flow

The flow is in equilibrium when

$F_g = F_f$

Rotameters



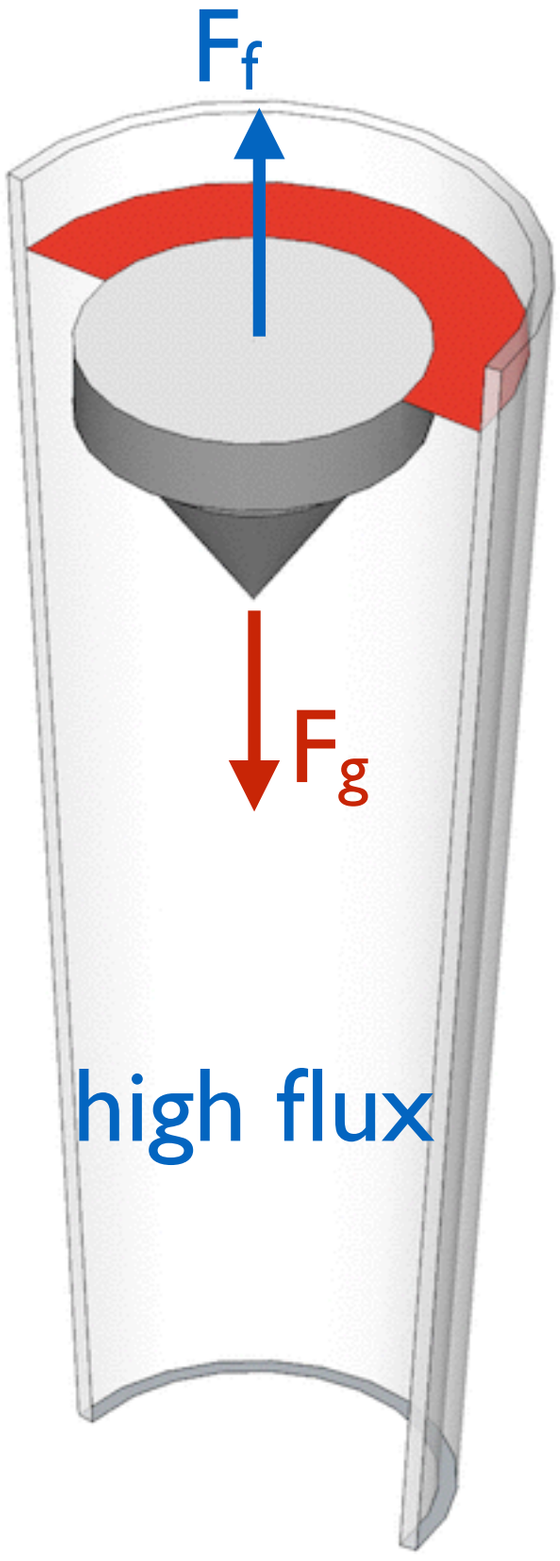
The force due to flow F_f depends on the flow and on the area the fluid rue through.

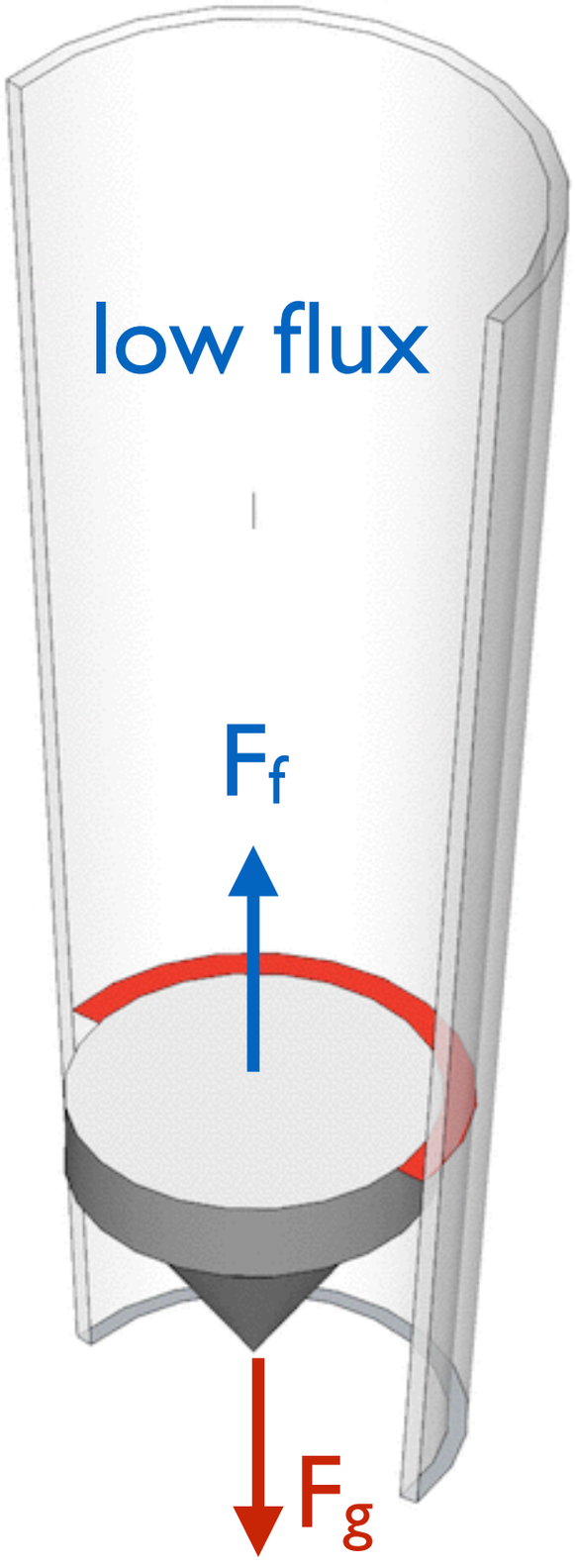
If I want a constant F_f equal to gravity

$F_f = F_g$

if the flow increases the area should also increase.

Rotameters



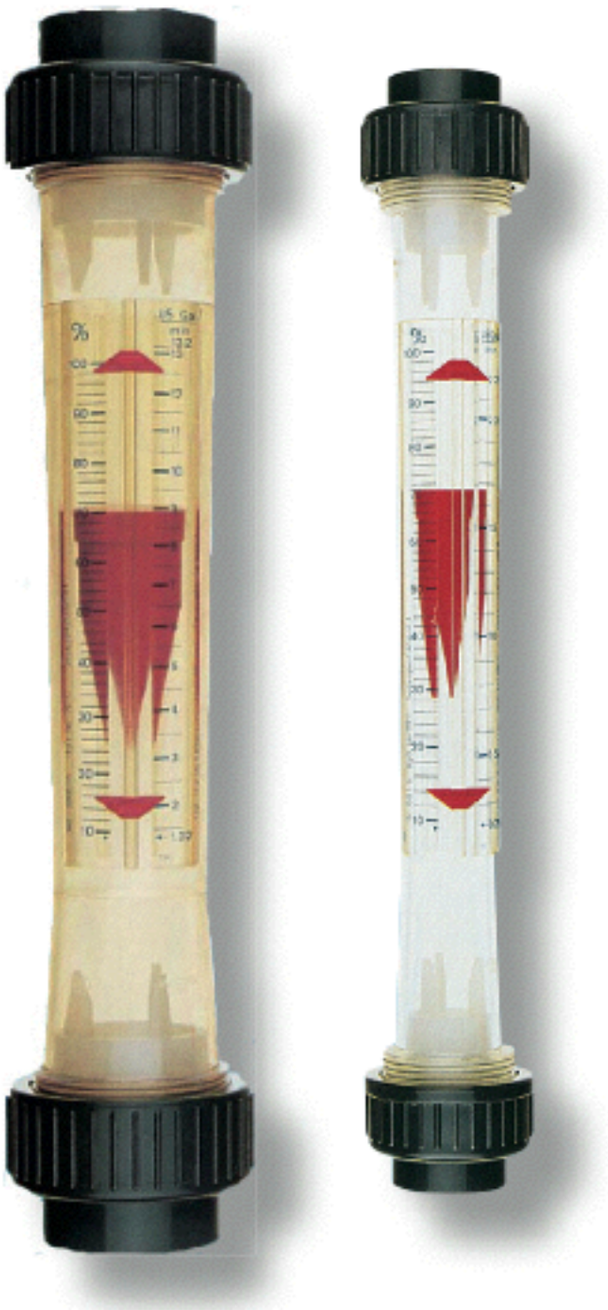


The equilibrium point
$F_f = F_g$
is found at higher level
for higher flux

- Low flux but small area

- High flux but large area

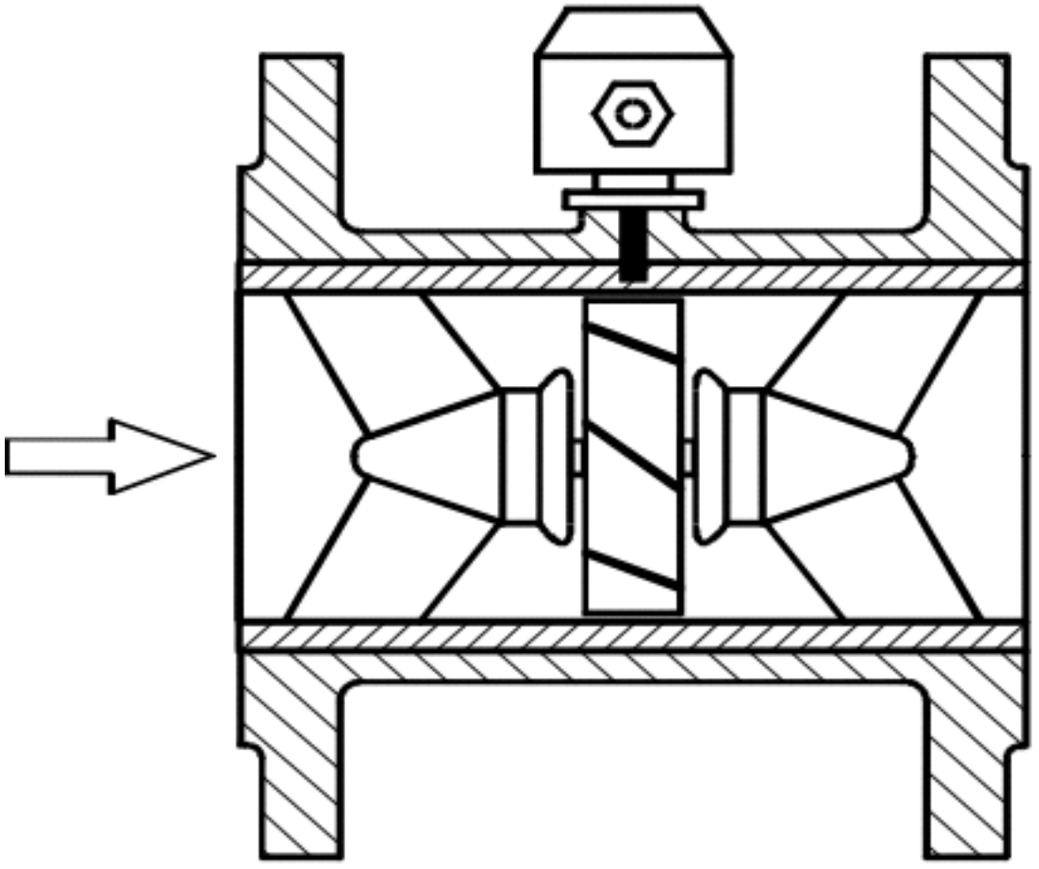
Rotameters

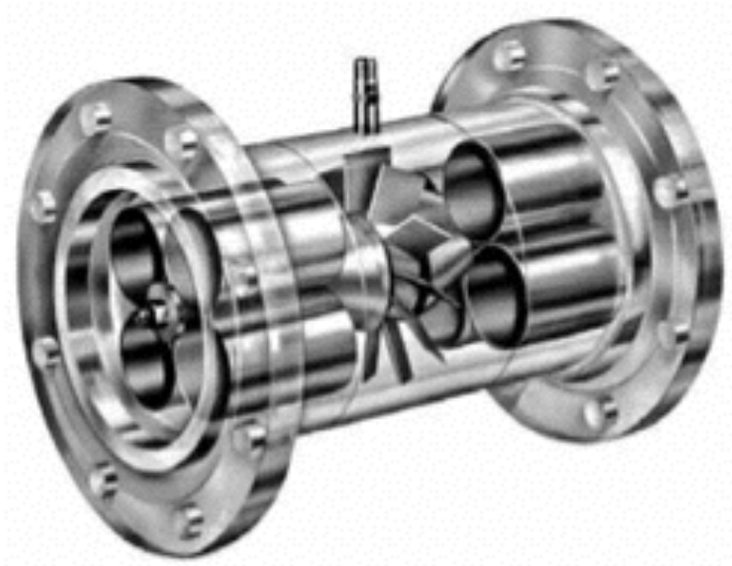


- no power needed
- should be always installed vertically

KOBOLD Instruments, Inc.

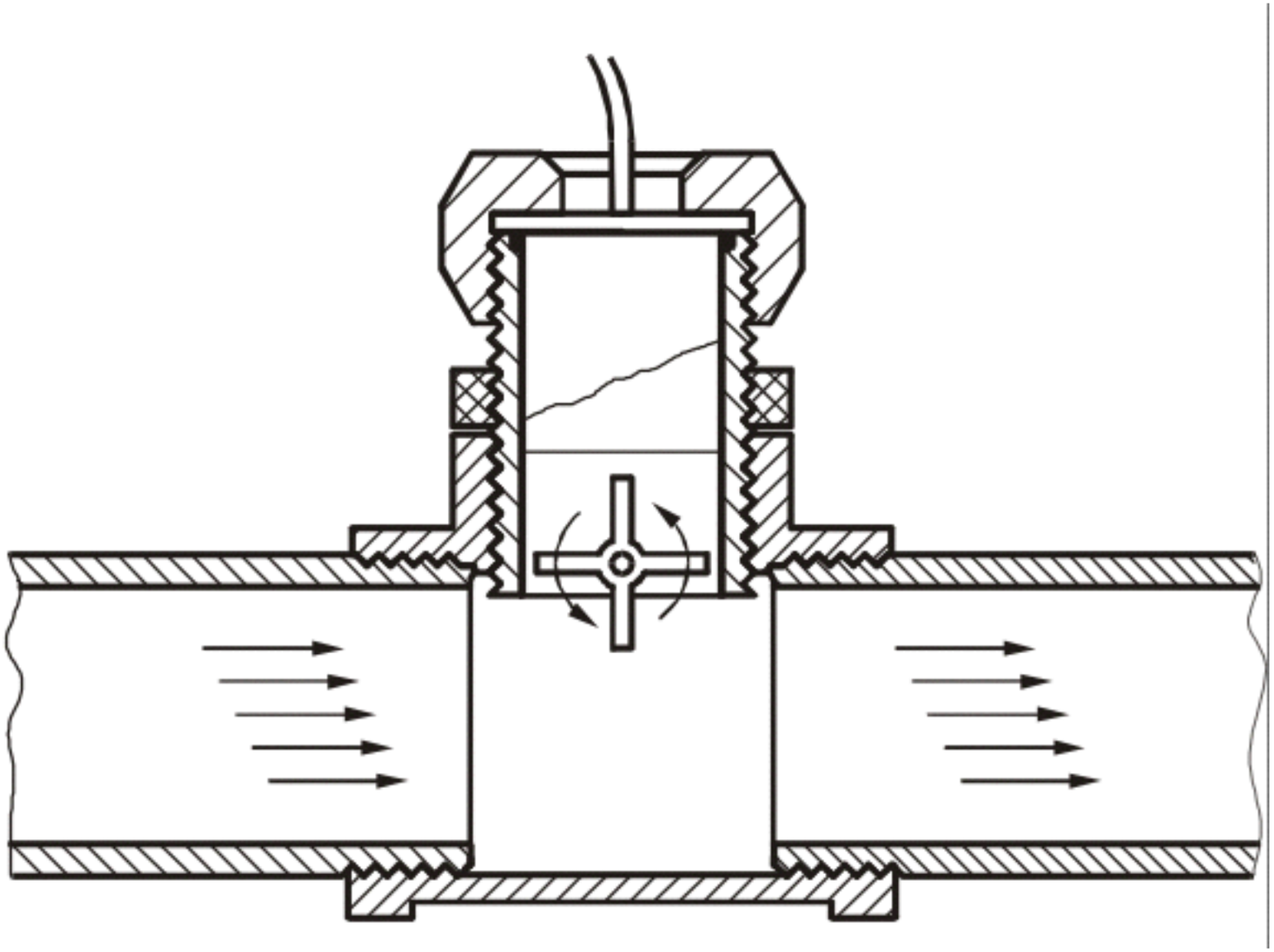
Turbine flowmeter





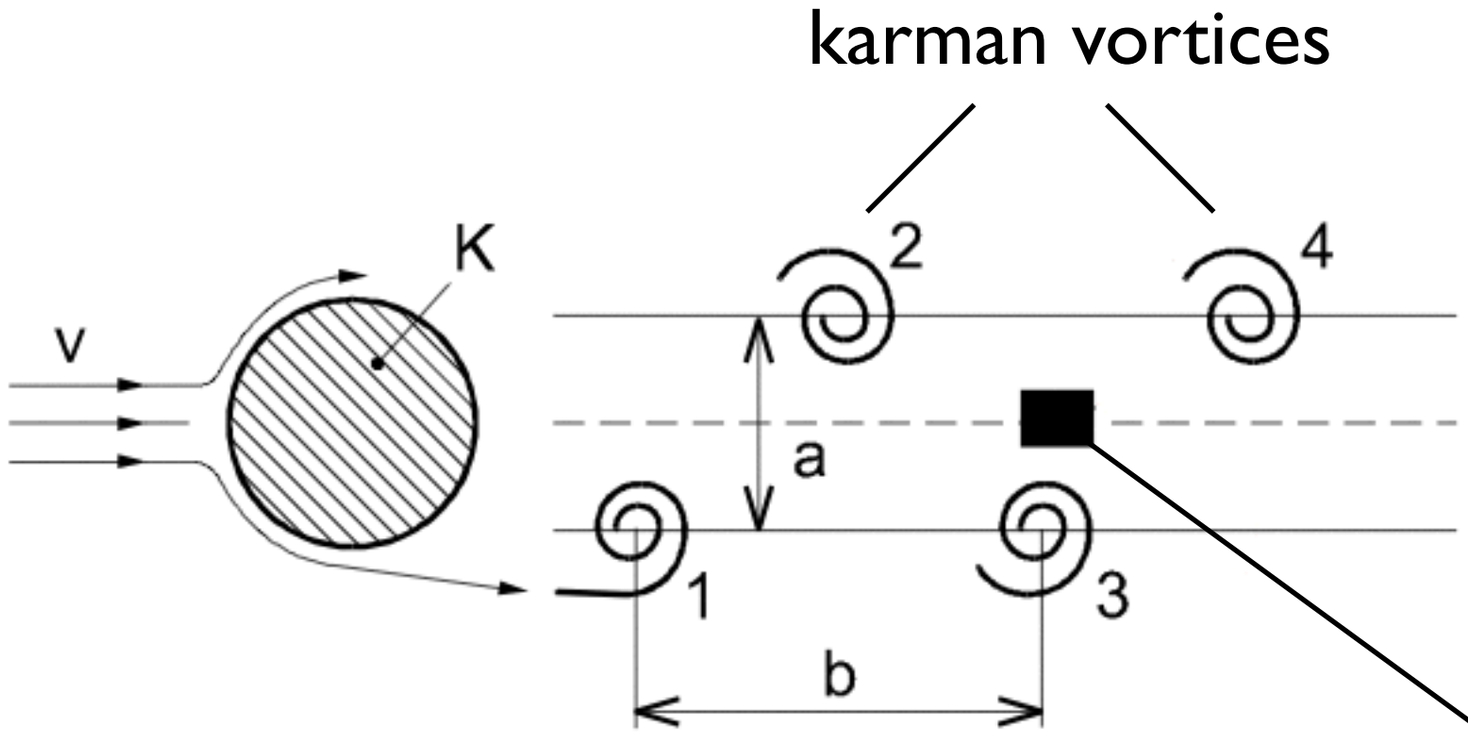
- based on measurement of velocity
- paddle movement measured magnetically
- linearity 0 – 1% threshold 2 – 3% range

Paddle wheel flowmeter



- cheaper
- less precise

Vortex –Shedding flowmeter



The frequency of vortices f depends on velocity of the fluid

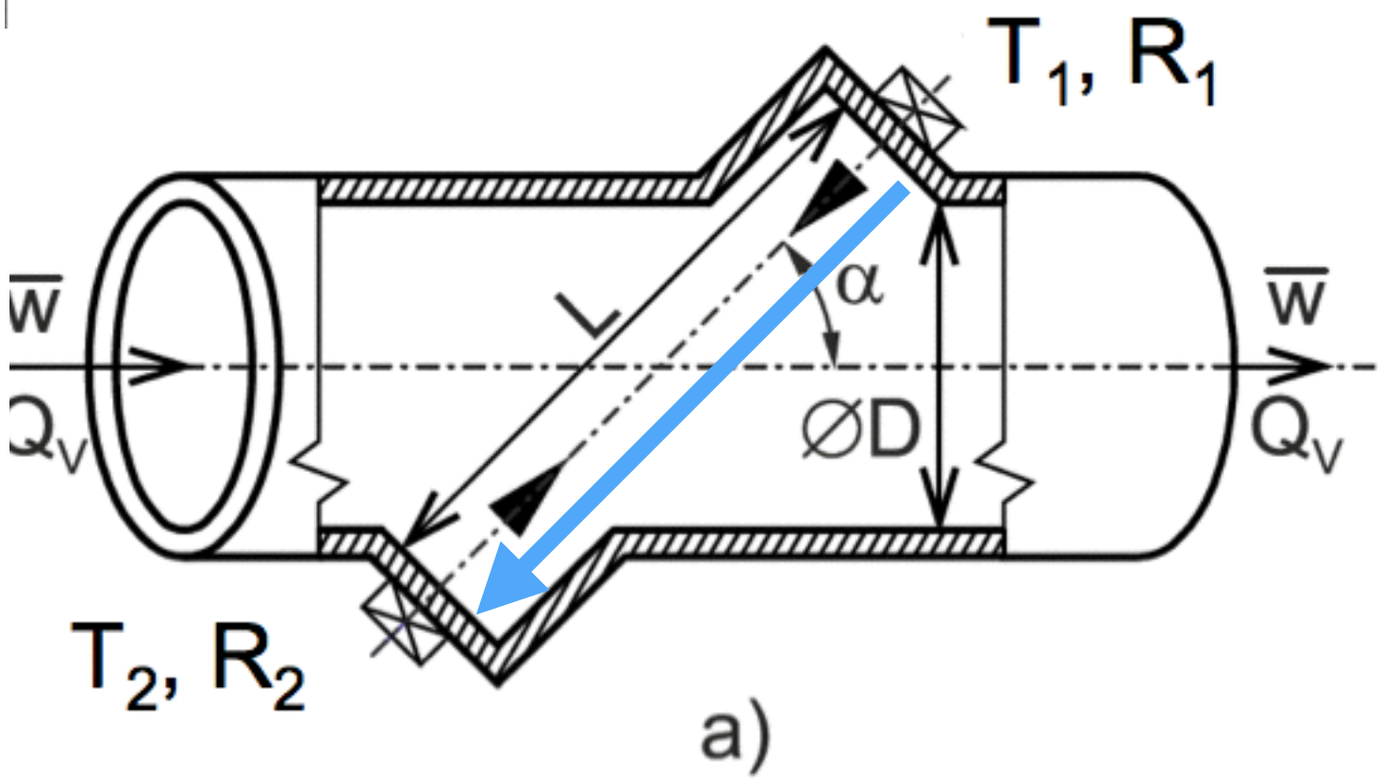
$$f = \frac{Sr}{a} v$$

a = characteristic of the obstacle

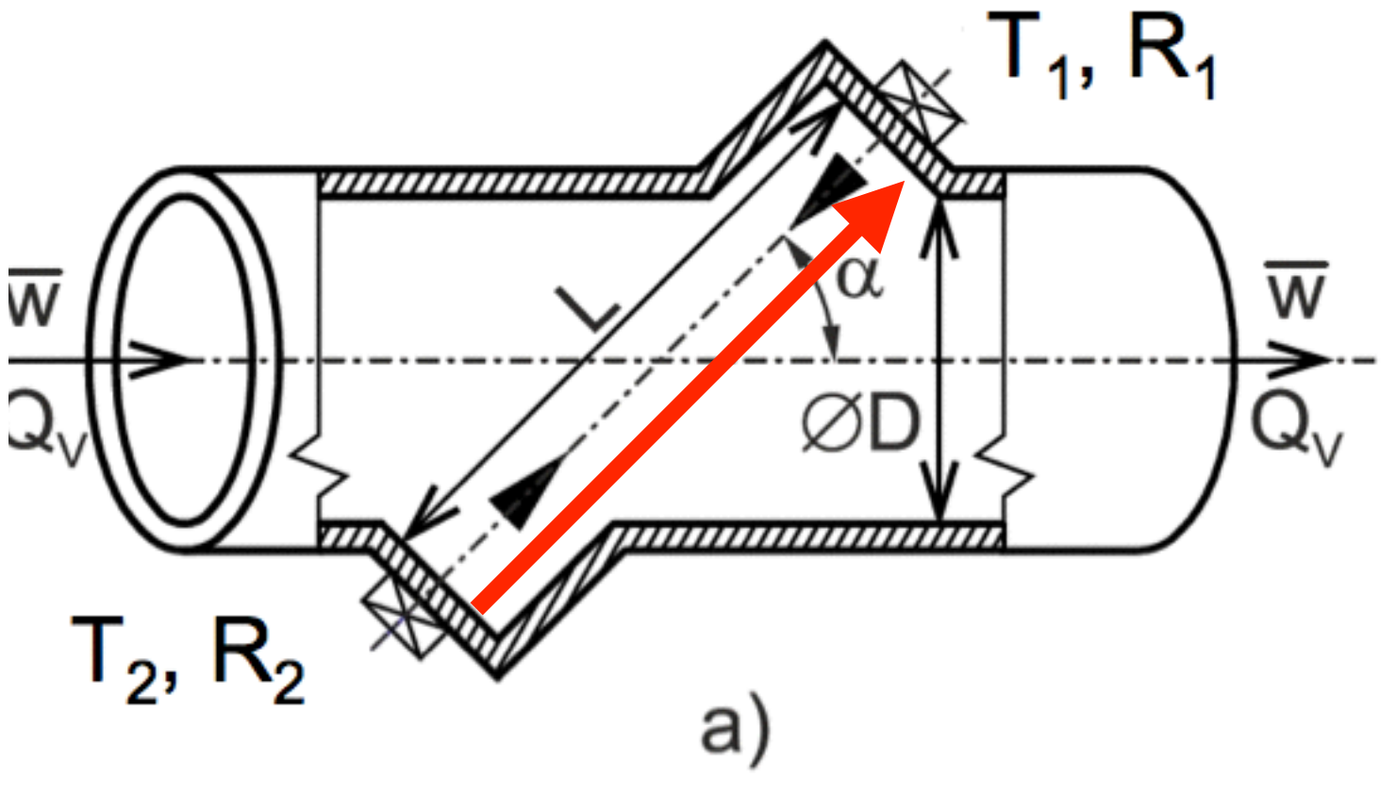
Sr = Strouhal number (char. for certain shape of obstacles)

Detection of vortices:
thermoanemometers
ultrasonic detectors
pressure detectors

Ultrasonic flowmeter



Δt_1 : time from T_1 to R_2

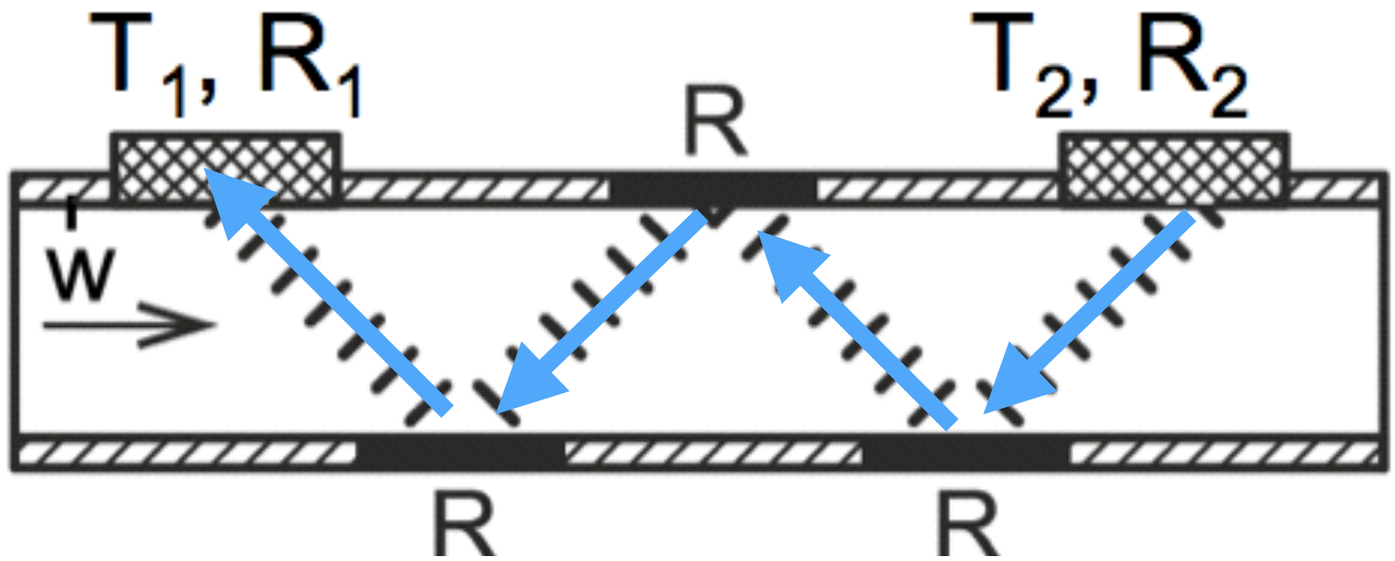


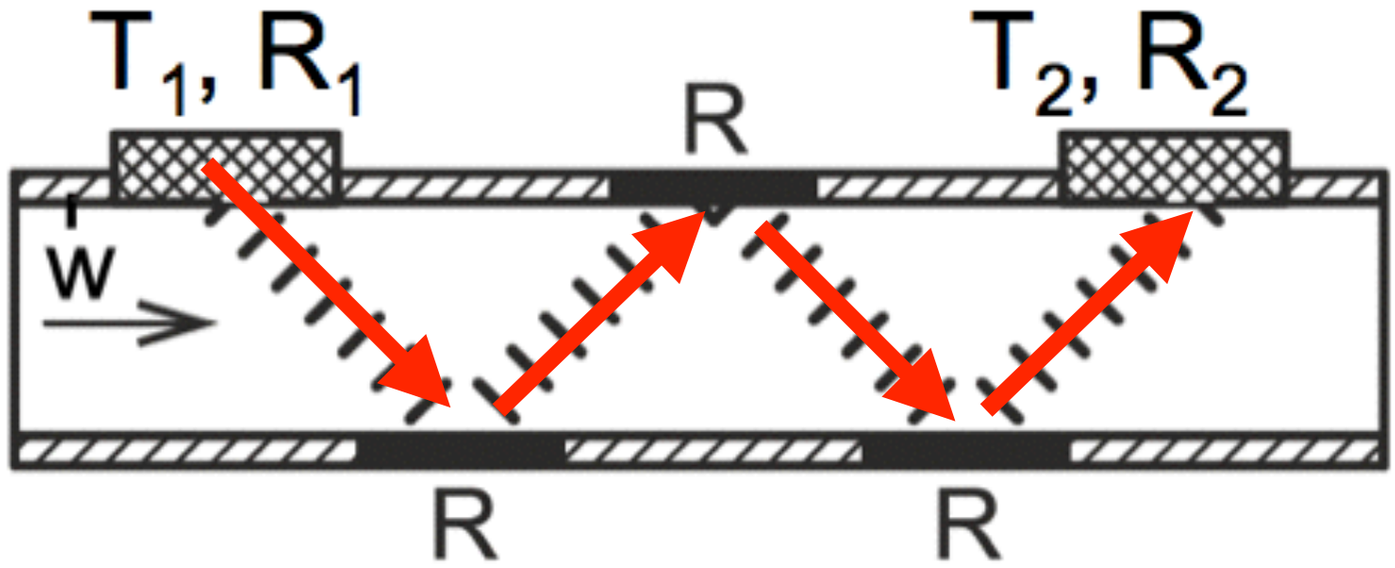
Δt_2 : time from T_2 to R_1

$$v = \frac{L}{2\cos\alpha}\frac{\Delta t_2 - \Delta t_1}{\Delta t_1 \Delta t_2}$$

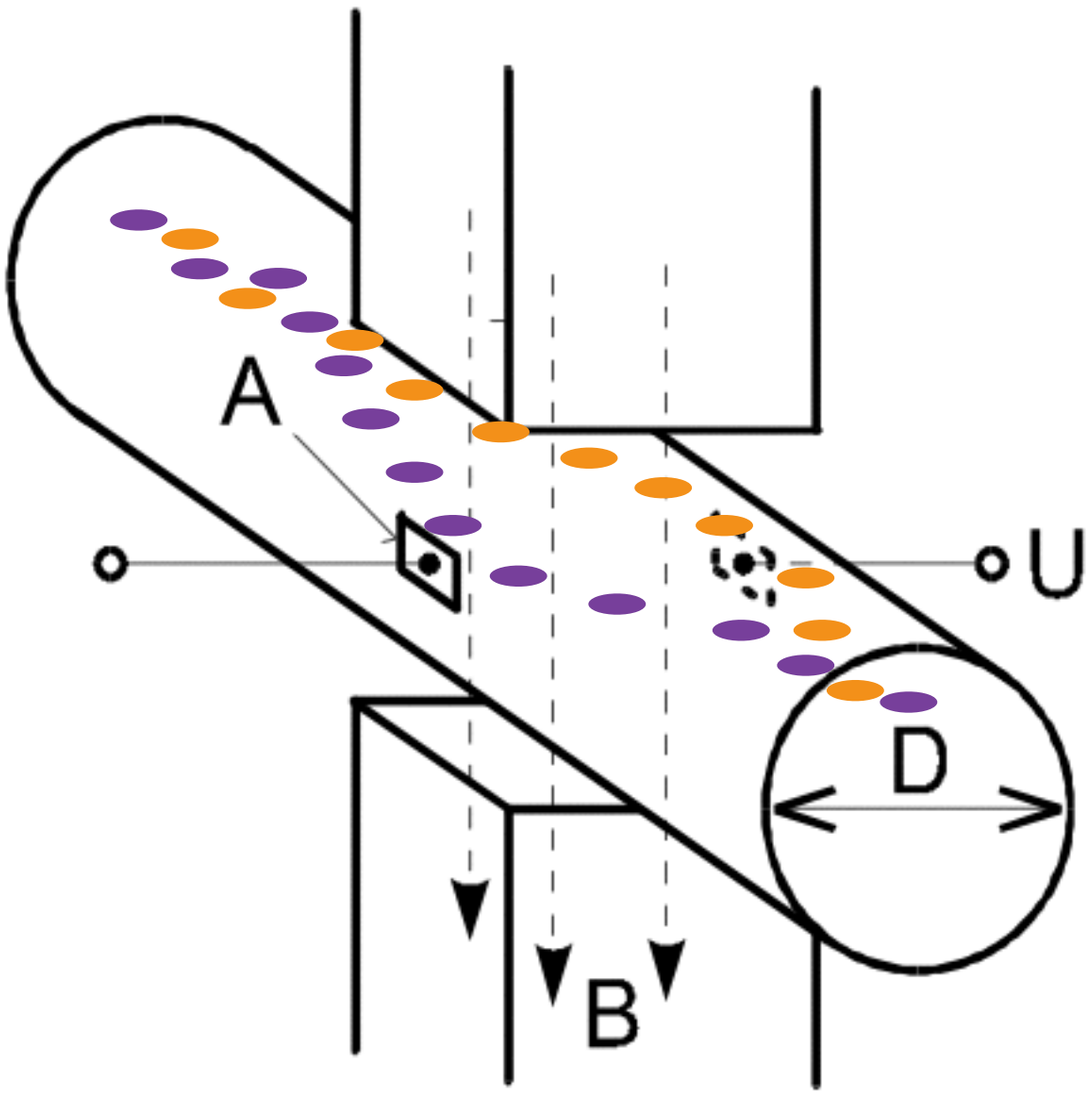
Ultrasonic flowmeter

Multiple reflections can be used to achieve longer path, and therefore larger effect.

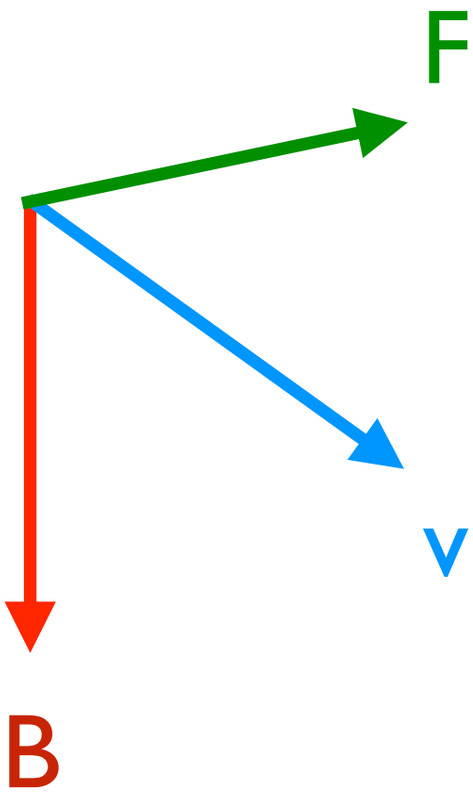




Induction (electromagnetic) flowmeter

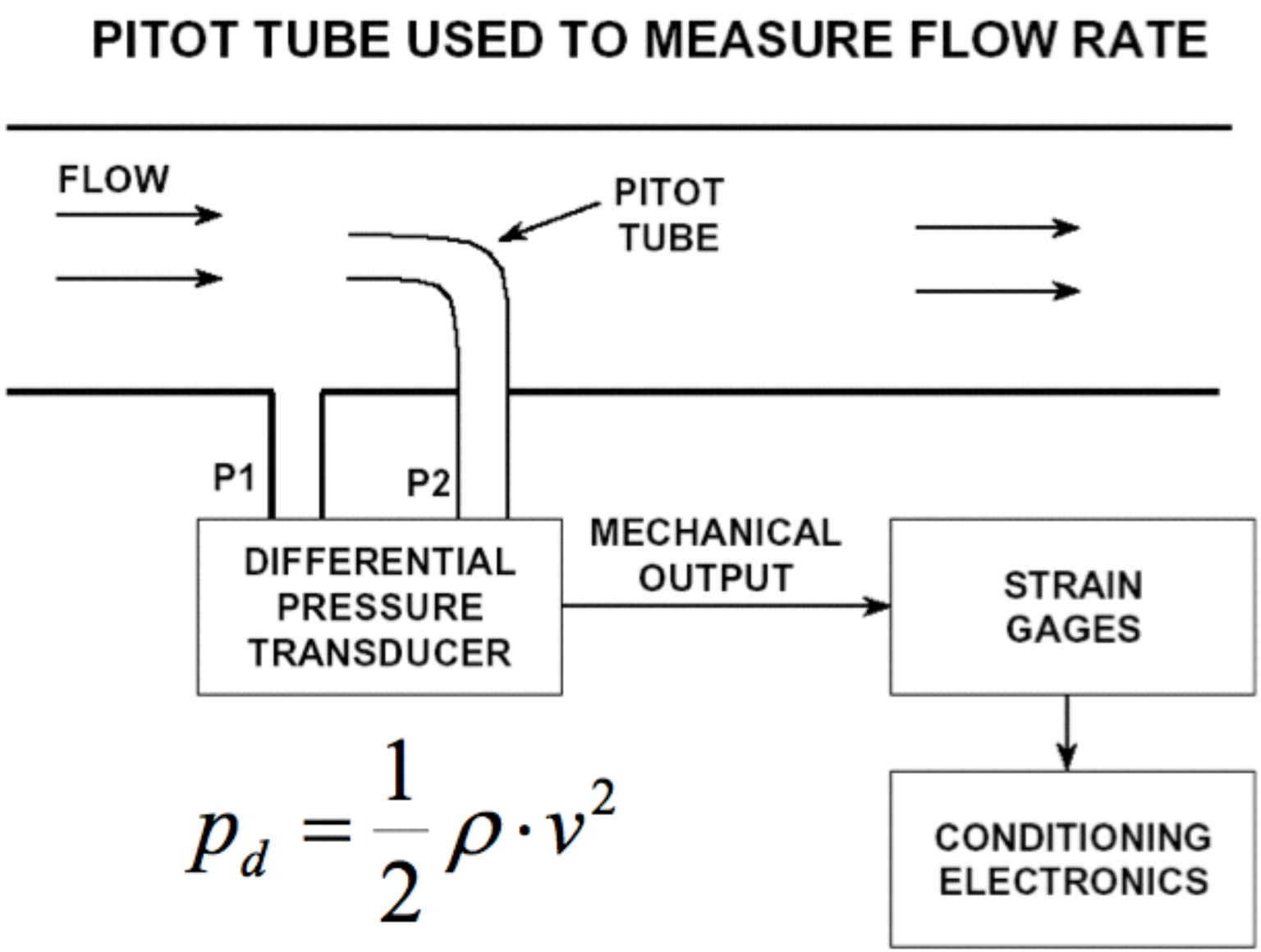


if the fluid has electric charges there is current (charges move with velocity v)



Typically AC magnetic field (the resulting force is periodically reversed)

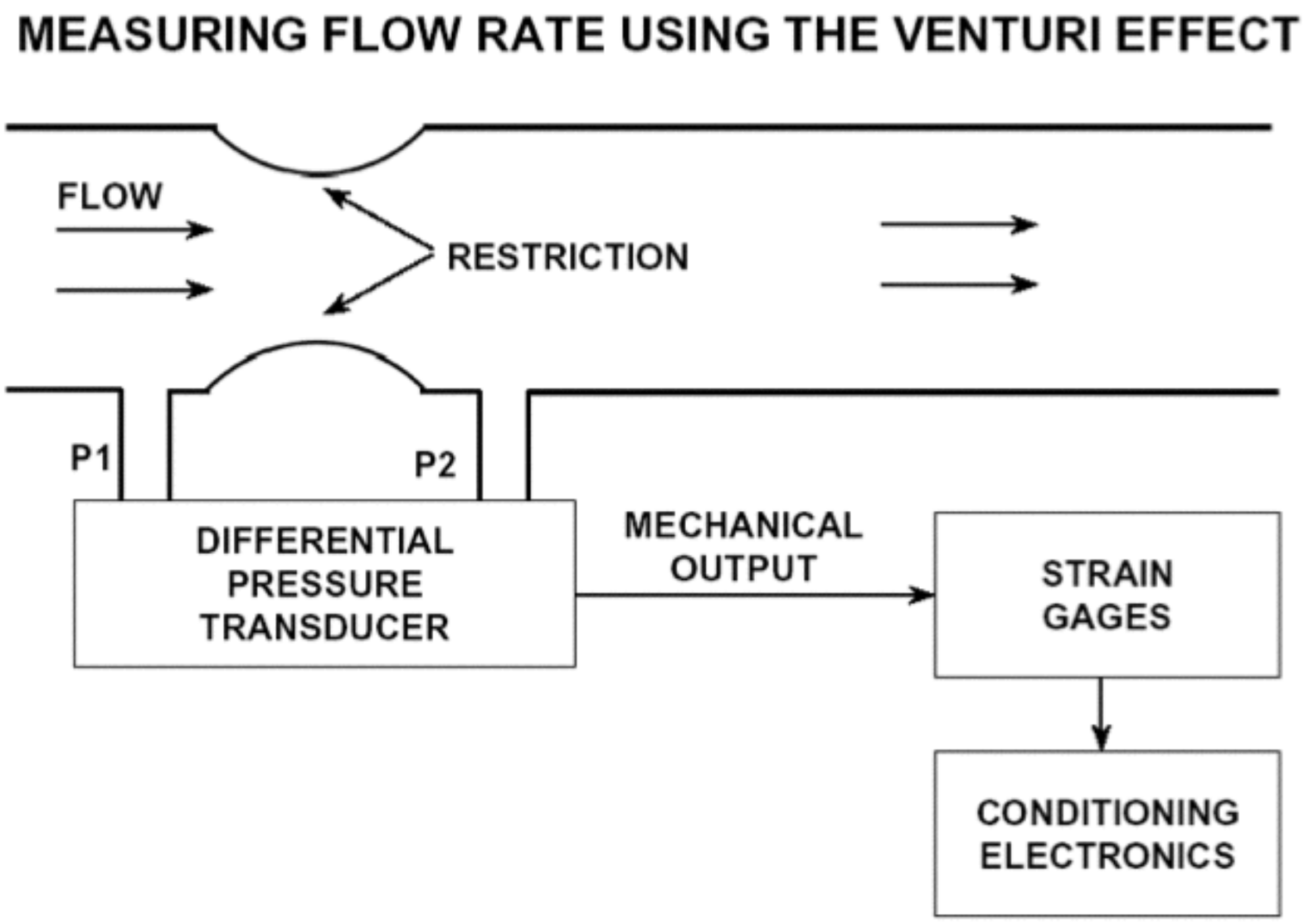
Differential pressure flowmeter



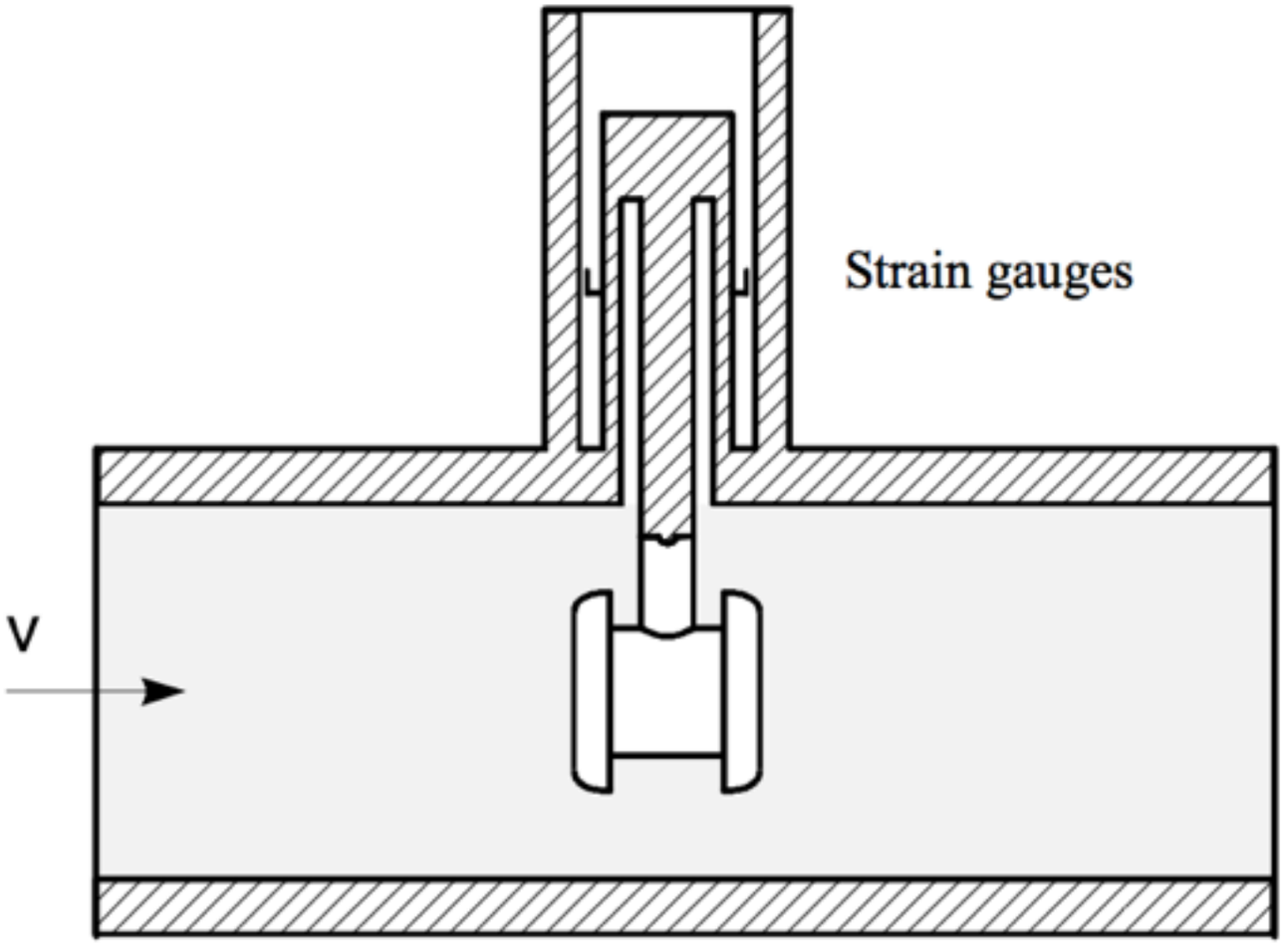
$$p_d = \frac{1}{2}\rho \cdot v^2$$

accuracy 2%

Differential pressure flowmeter



Sensors with conversion of flow to deformation



cross sectional area

density

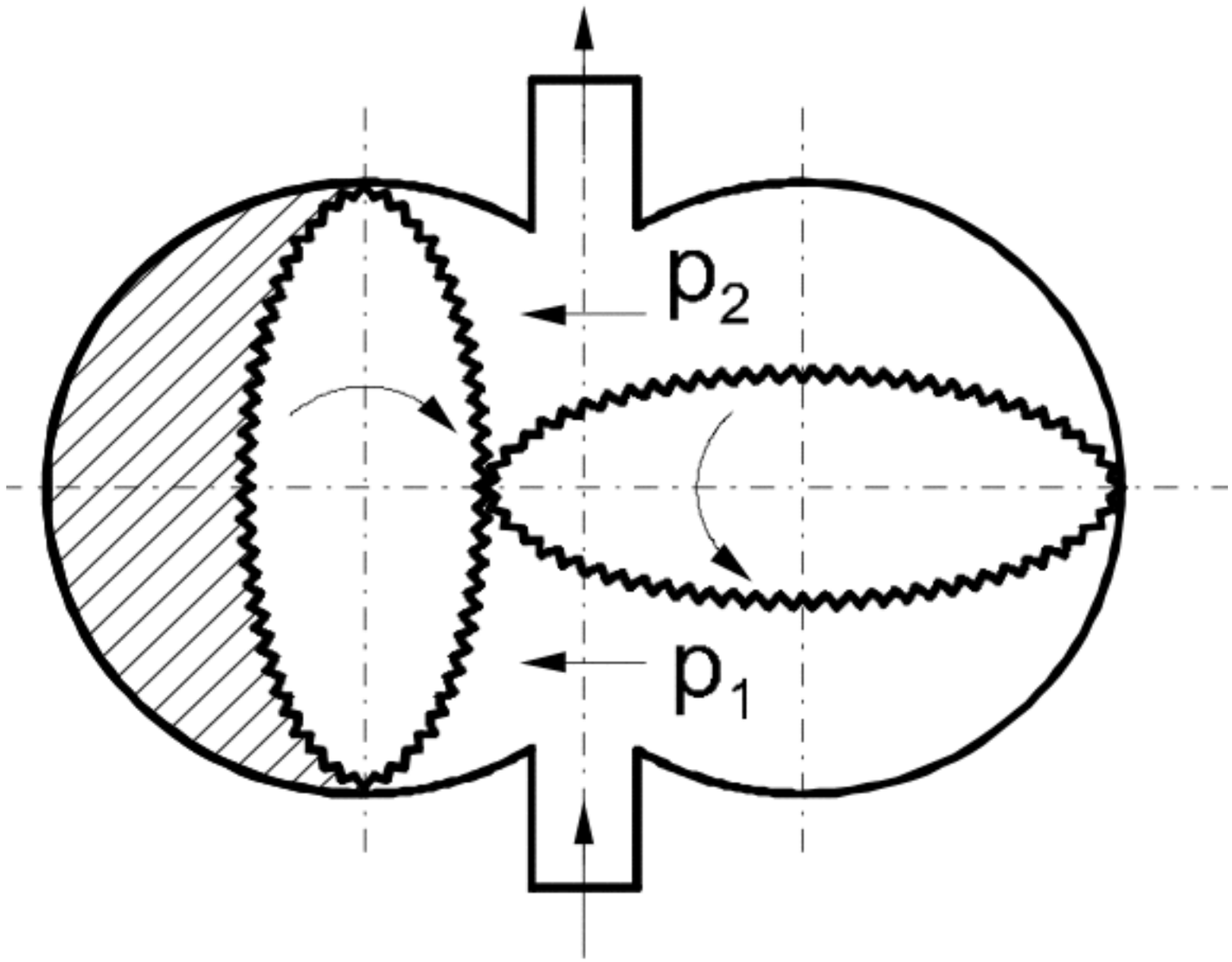
velocity

$$F_d = \frac{C_d S \rho v^2}{2}$$

Accuracy: units of %

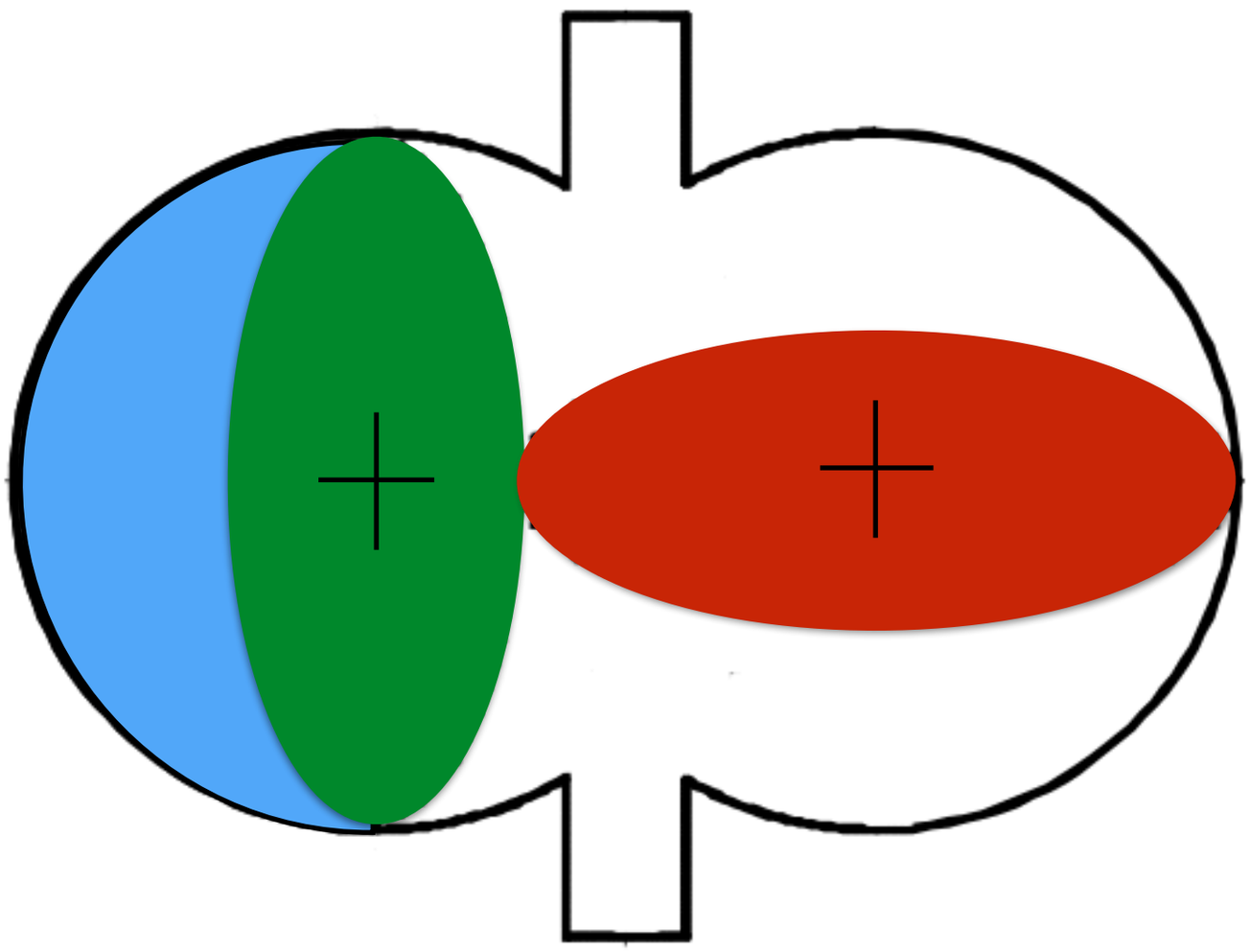
Goof dynamic response

Oval gear flowmeter

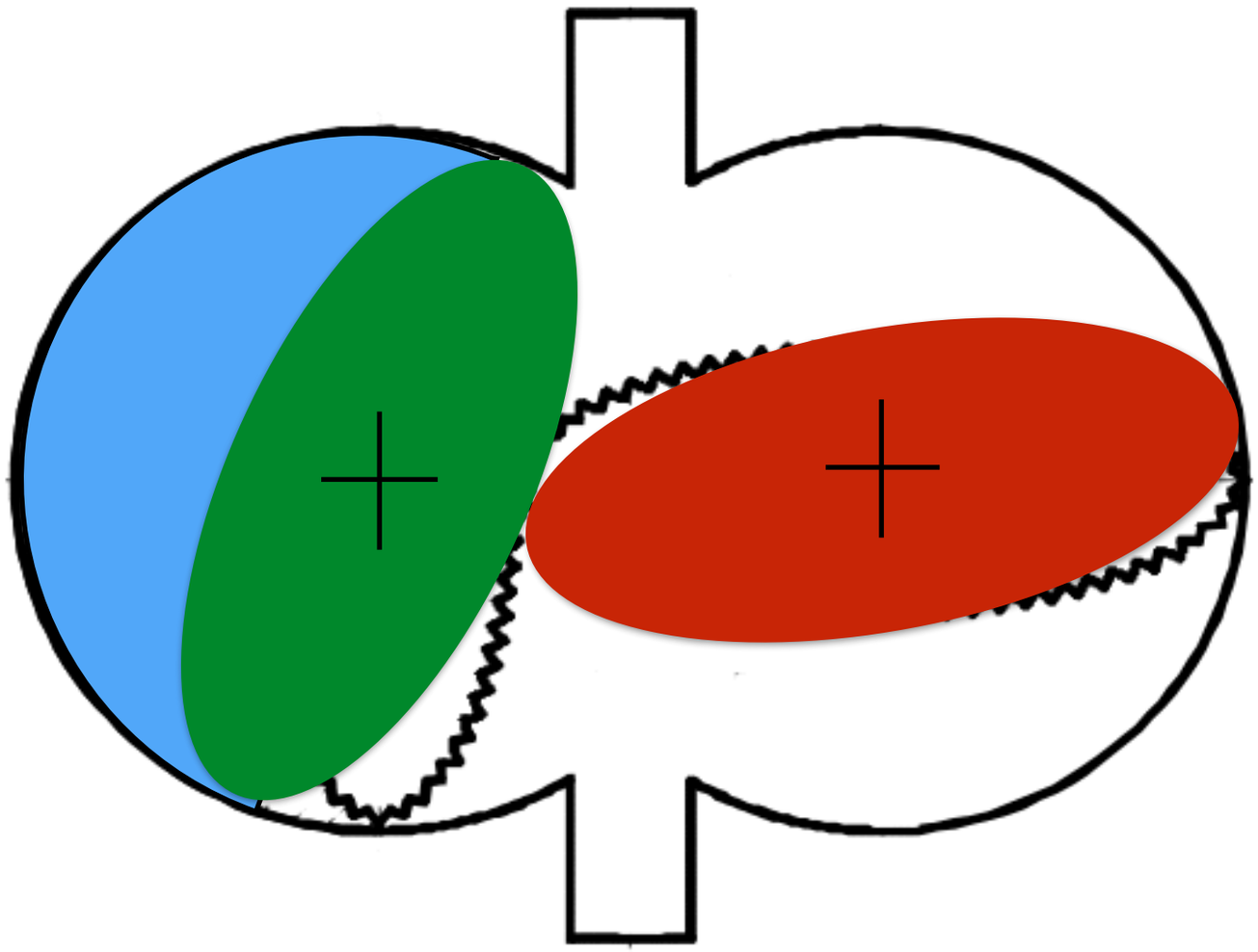


Badgermeter co.

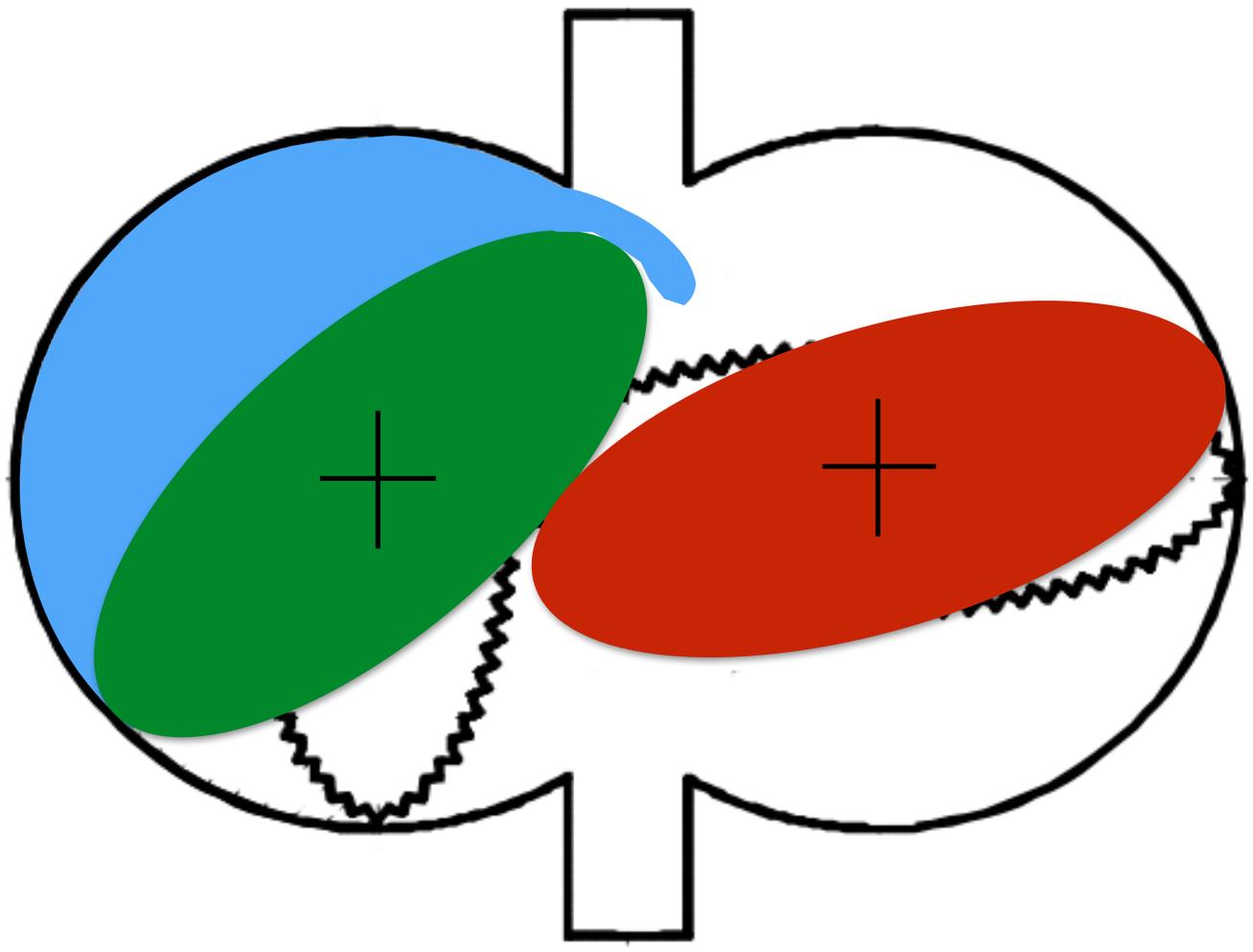
Oval gear flowmeter



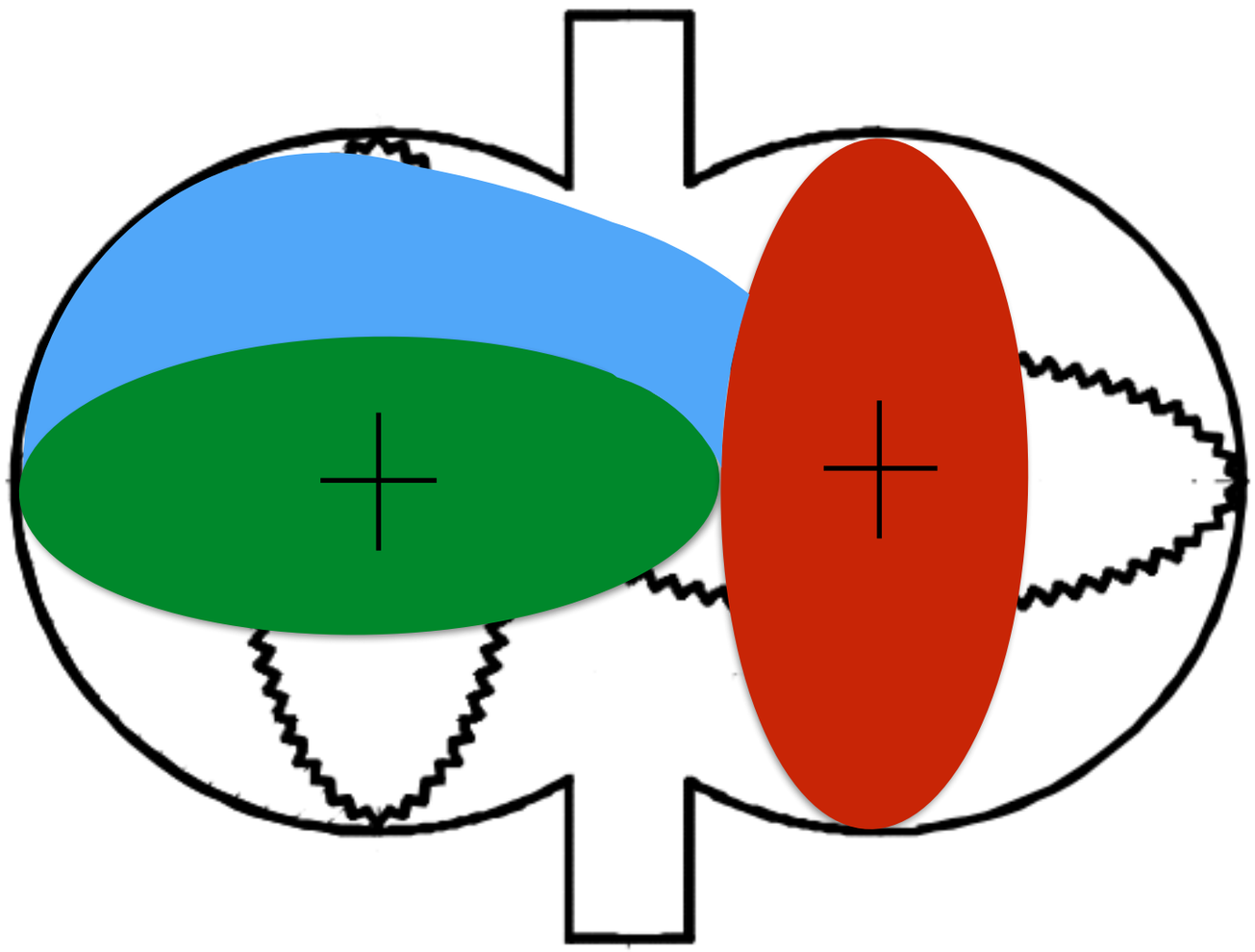
Oval gear flowmeter



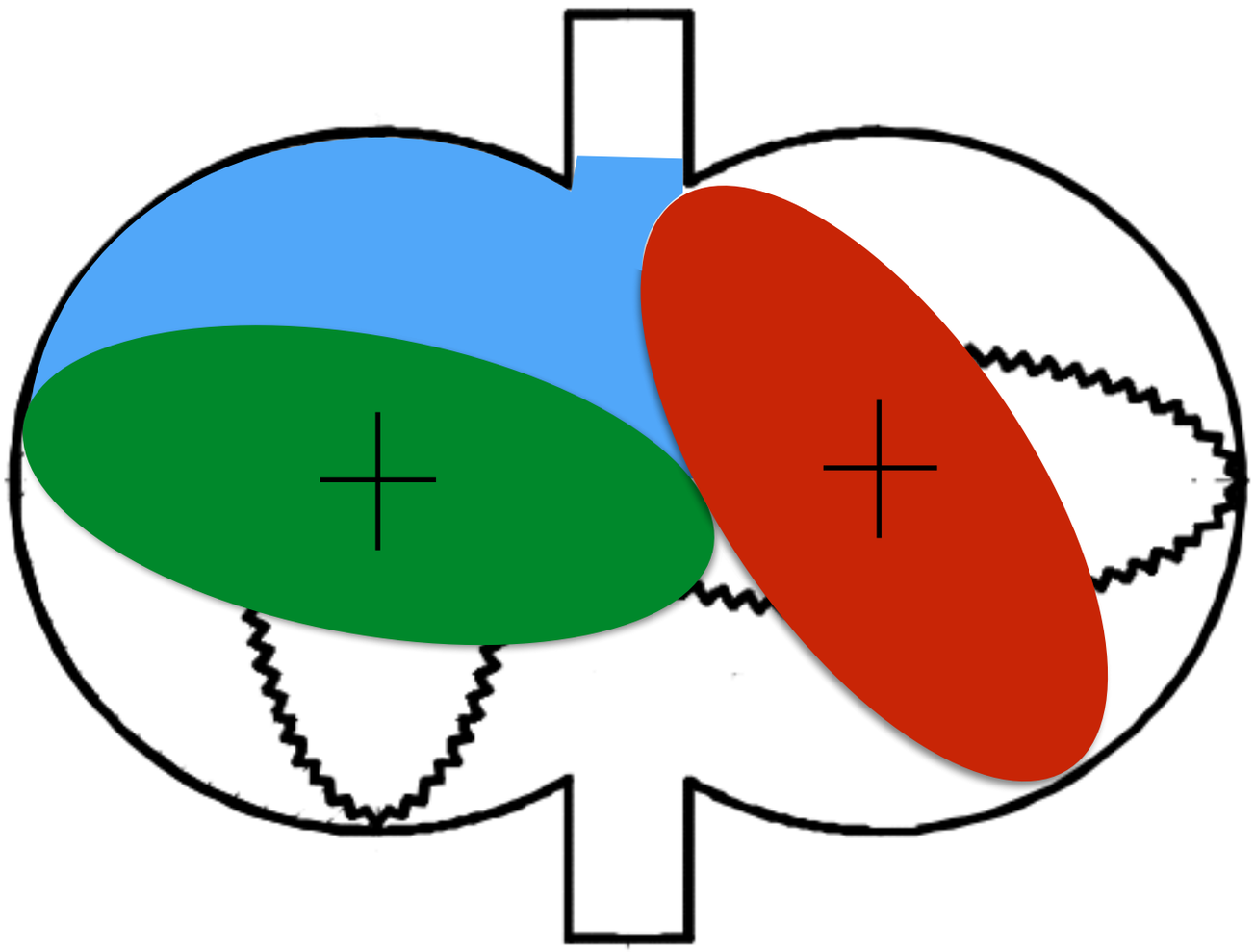
Oval gear flowmeter



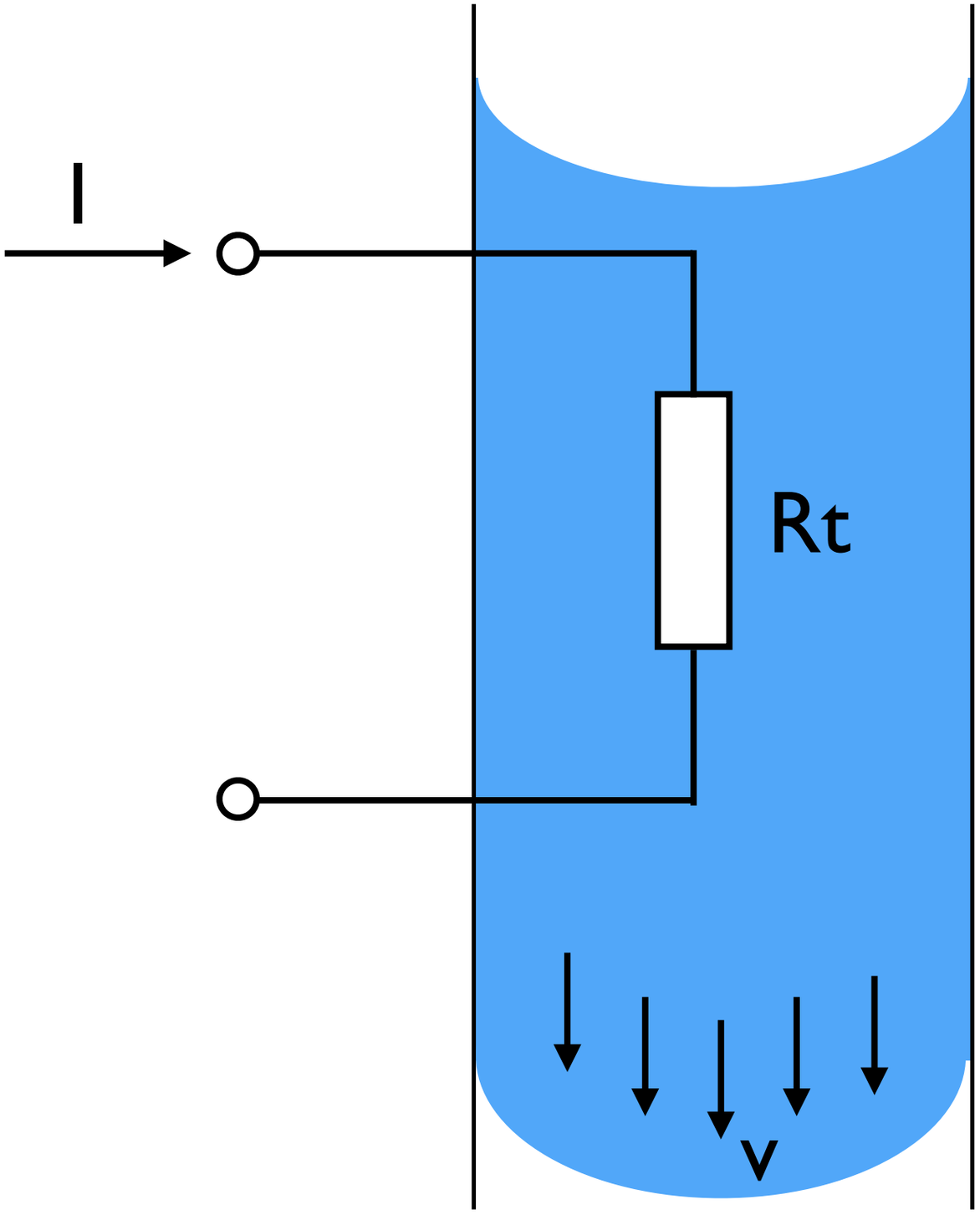
Oval gear flowmeter



Oval gear flowmeter

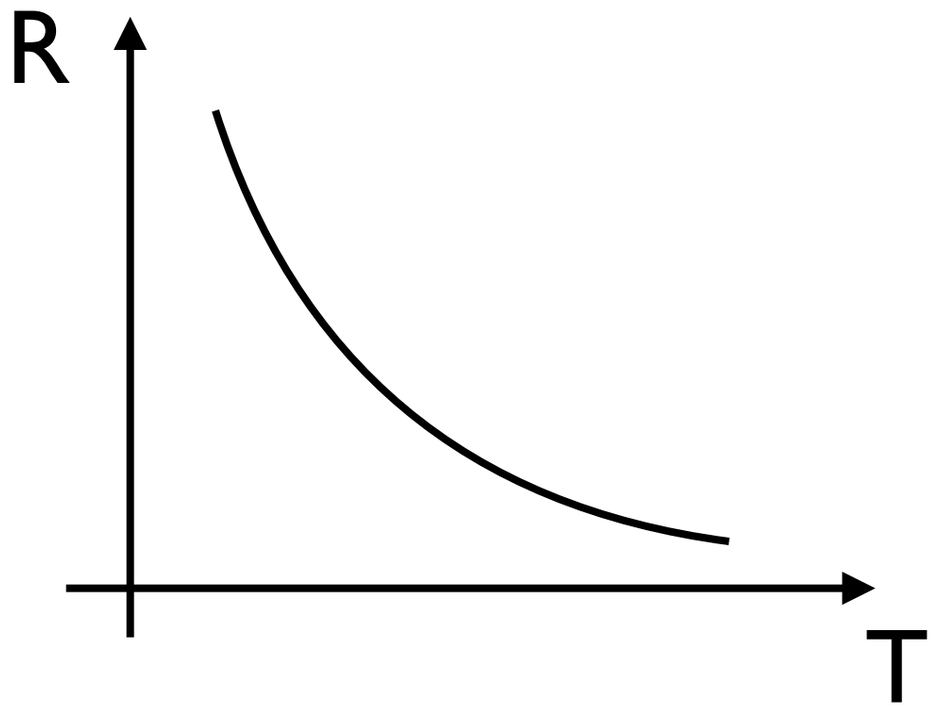


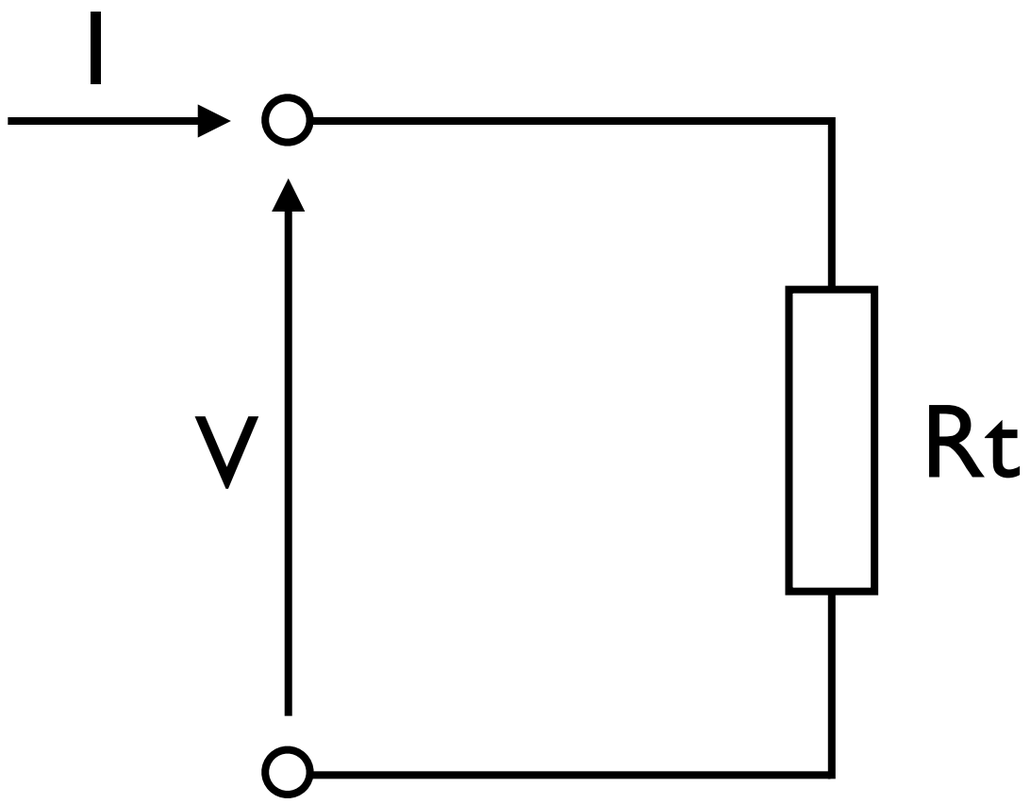
Thermal mass flowmeter

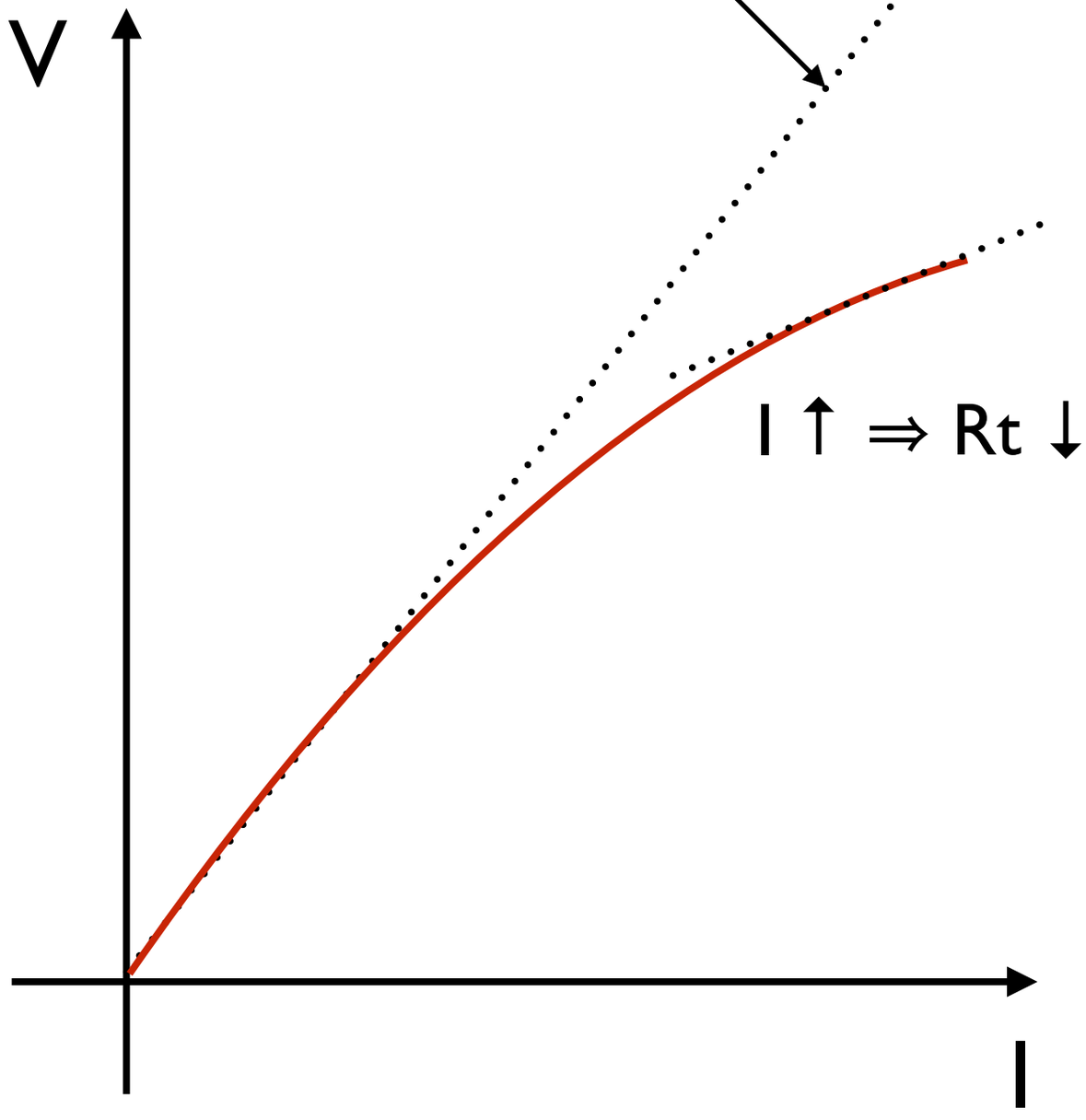


- a thermistor is immersed in the fluid which flows with speed v
- the current I warms up the thermistor due to power $Rt \cdot I^2$

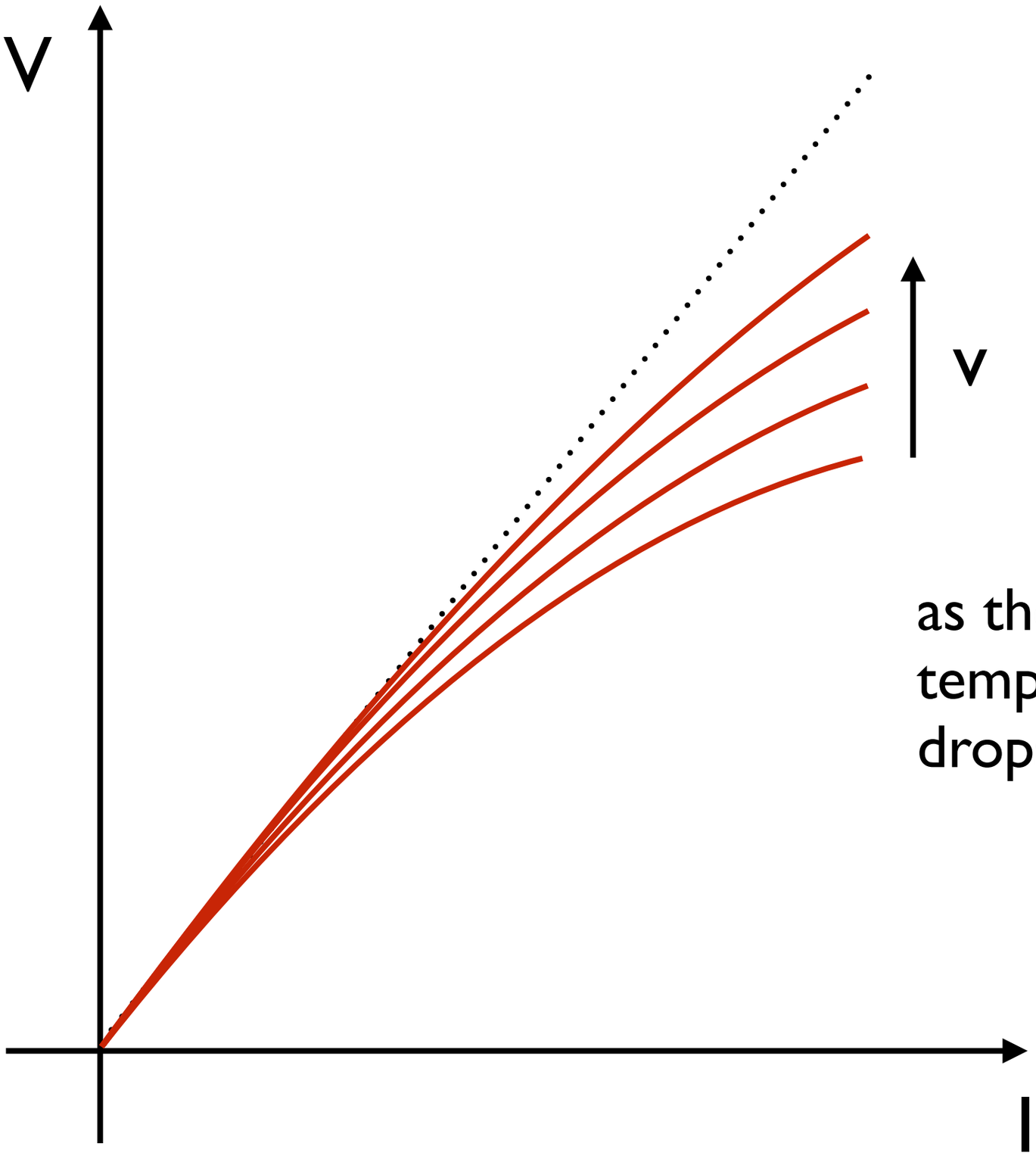
Let us consider a negative thermistor





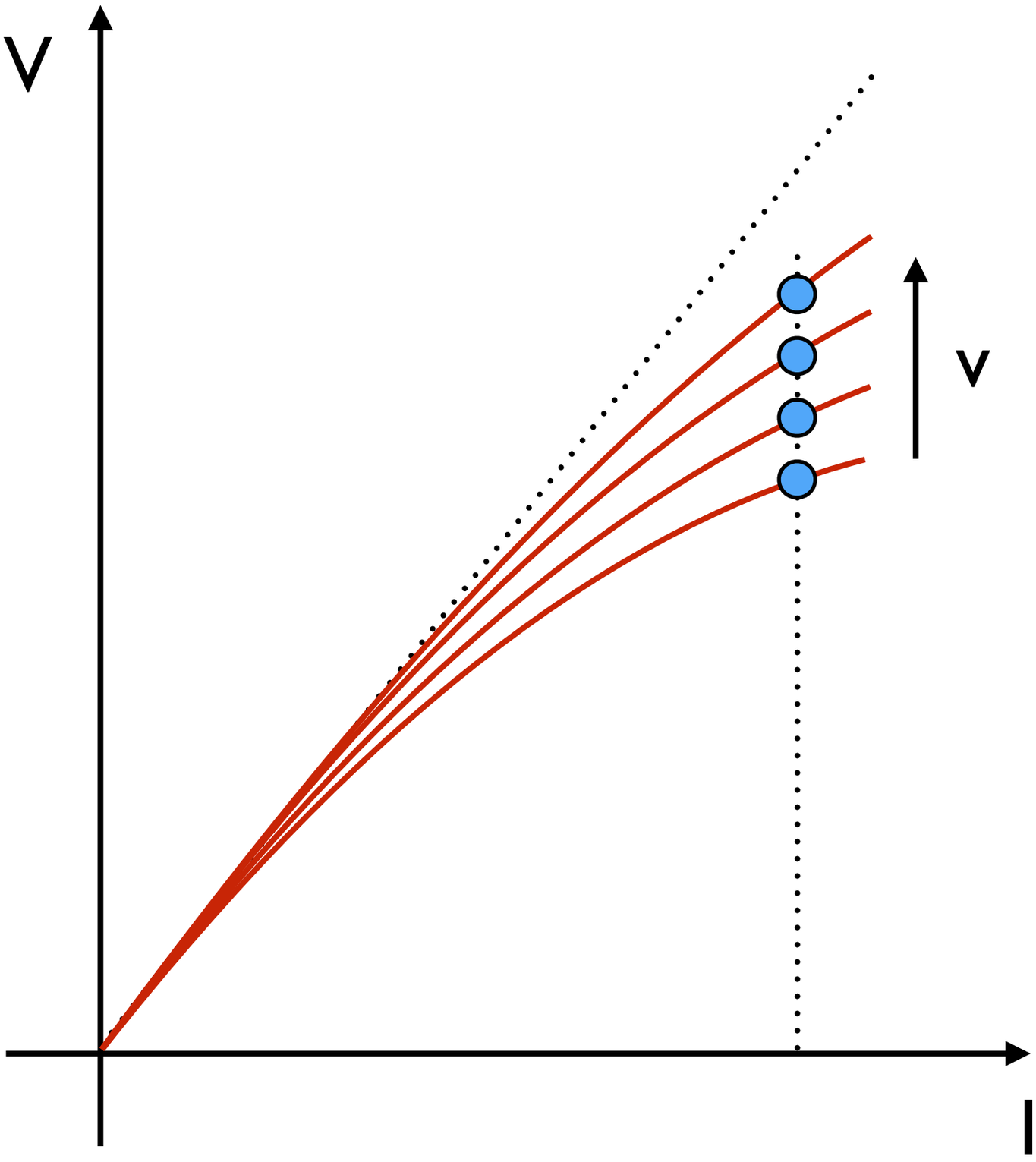


If the thermistor is warmed up by the current and cooled down by the flow of fluid

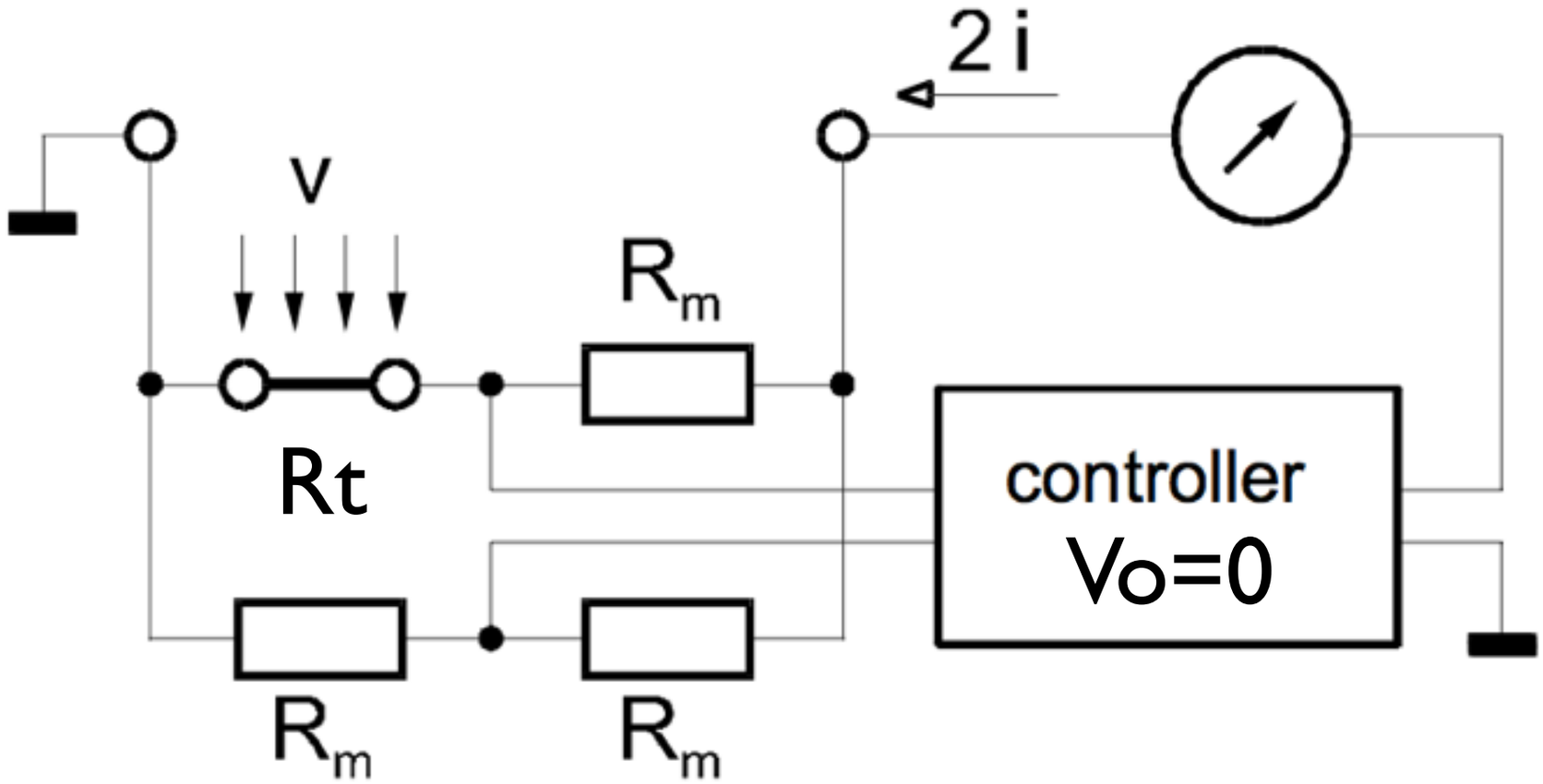


as the velocity of the fluid rises the temperature of the resistance drops and therefore Rt rises

Mode of operation I: constant current



Mode of operation 2: constant temperature



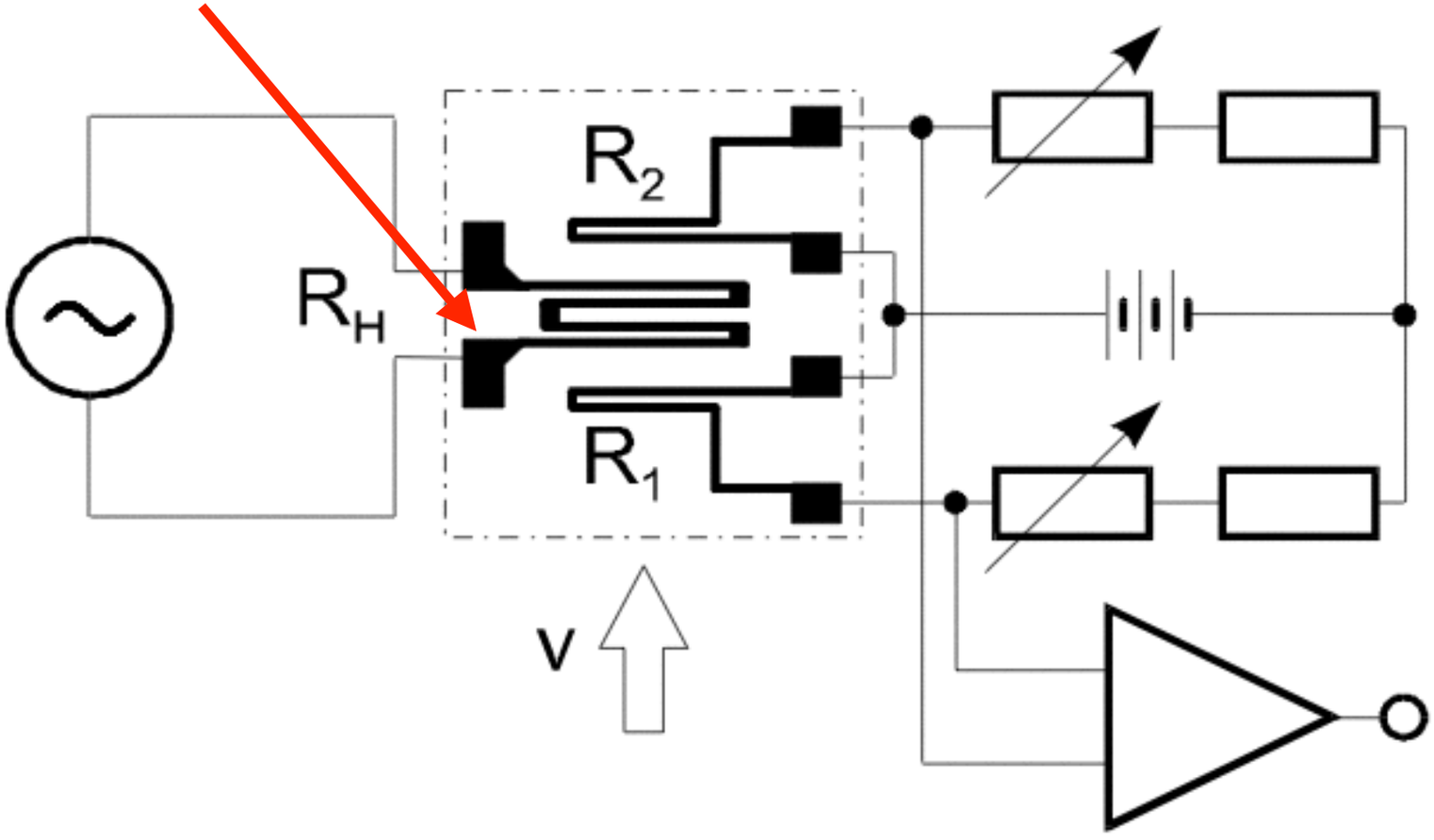
The control sets the current in the bridge so that Vo=0.
If Vo=0, it means that Rt=Rm.

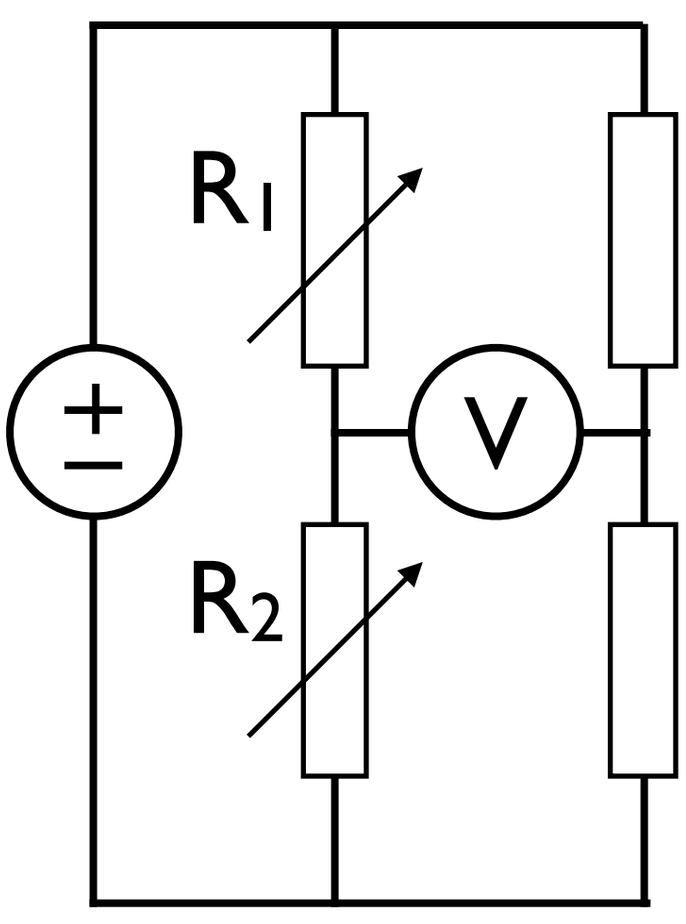
v ↑ ⇒ i ↓ to compensate extra cooling

v ↓ ⇒ i ↑ to compensate lower cooling

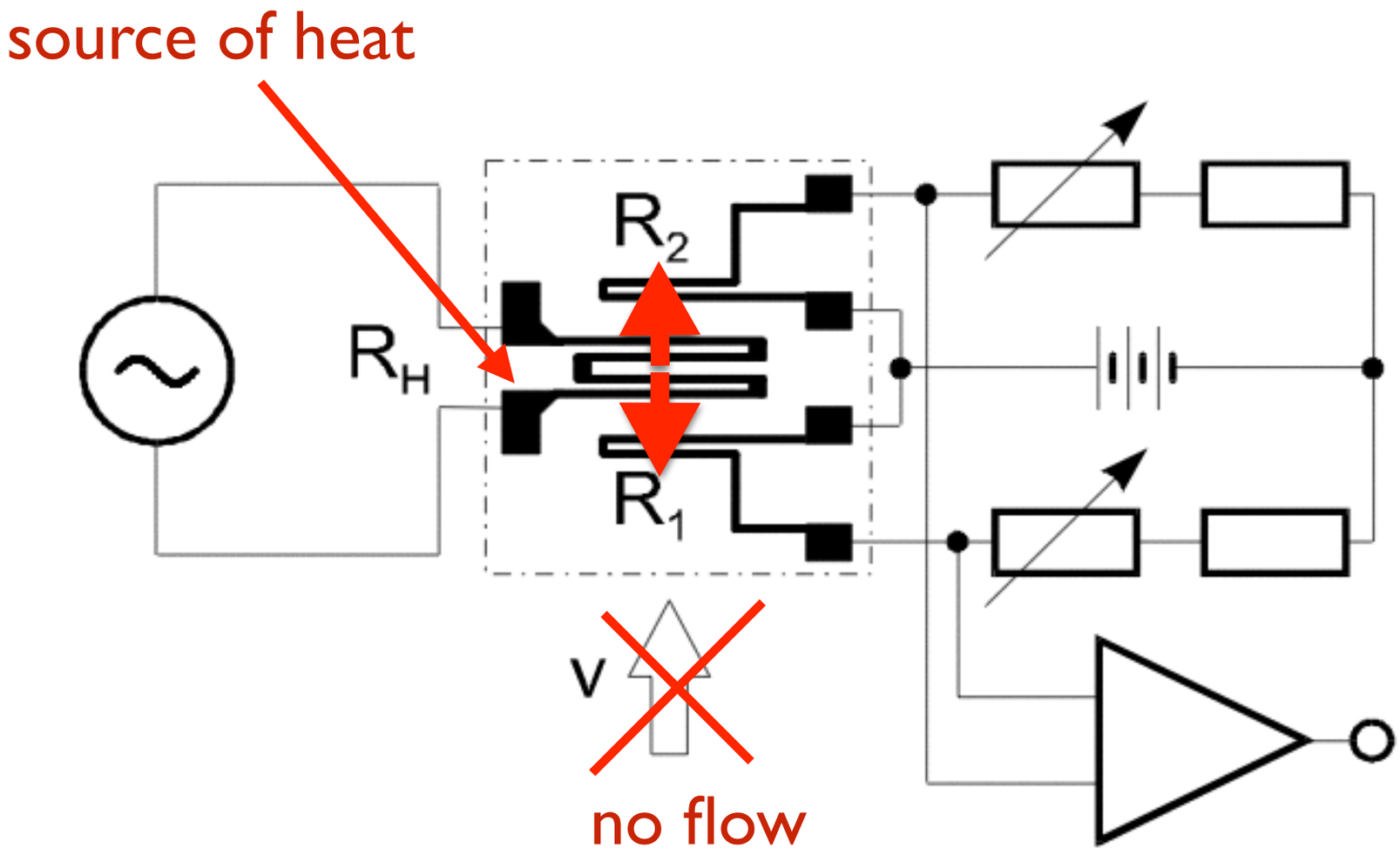
Differential thermoanemometer

source of heat

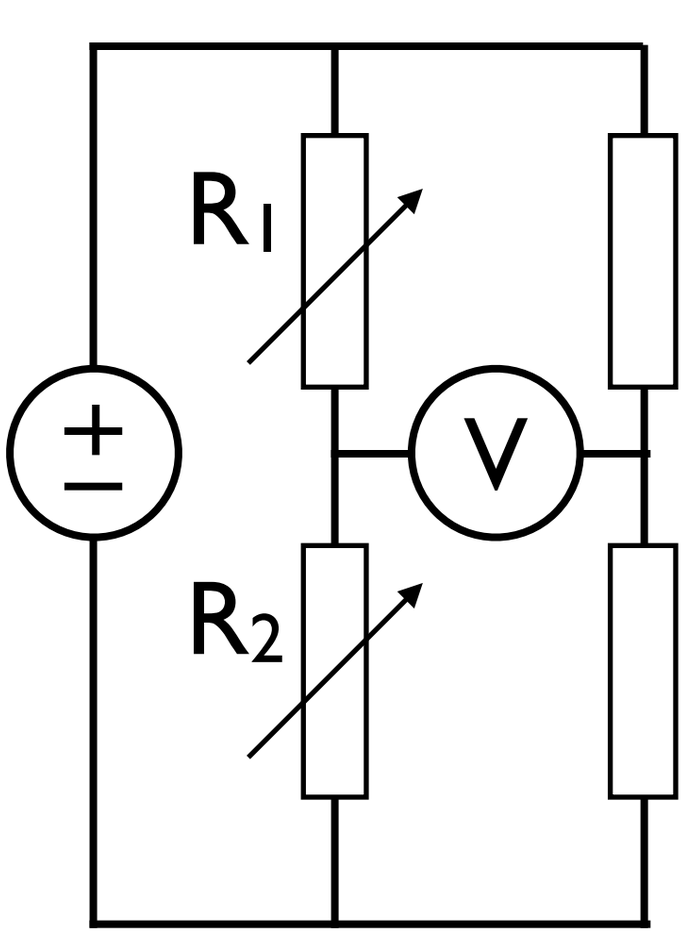




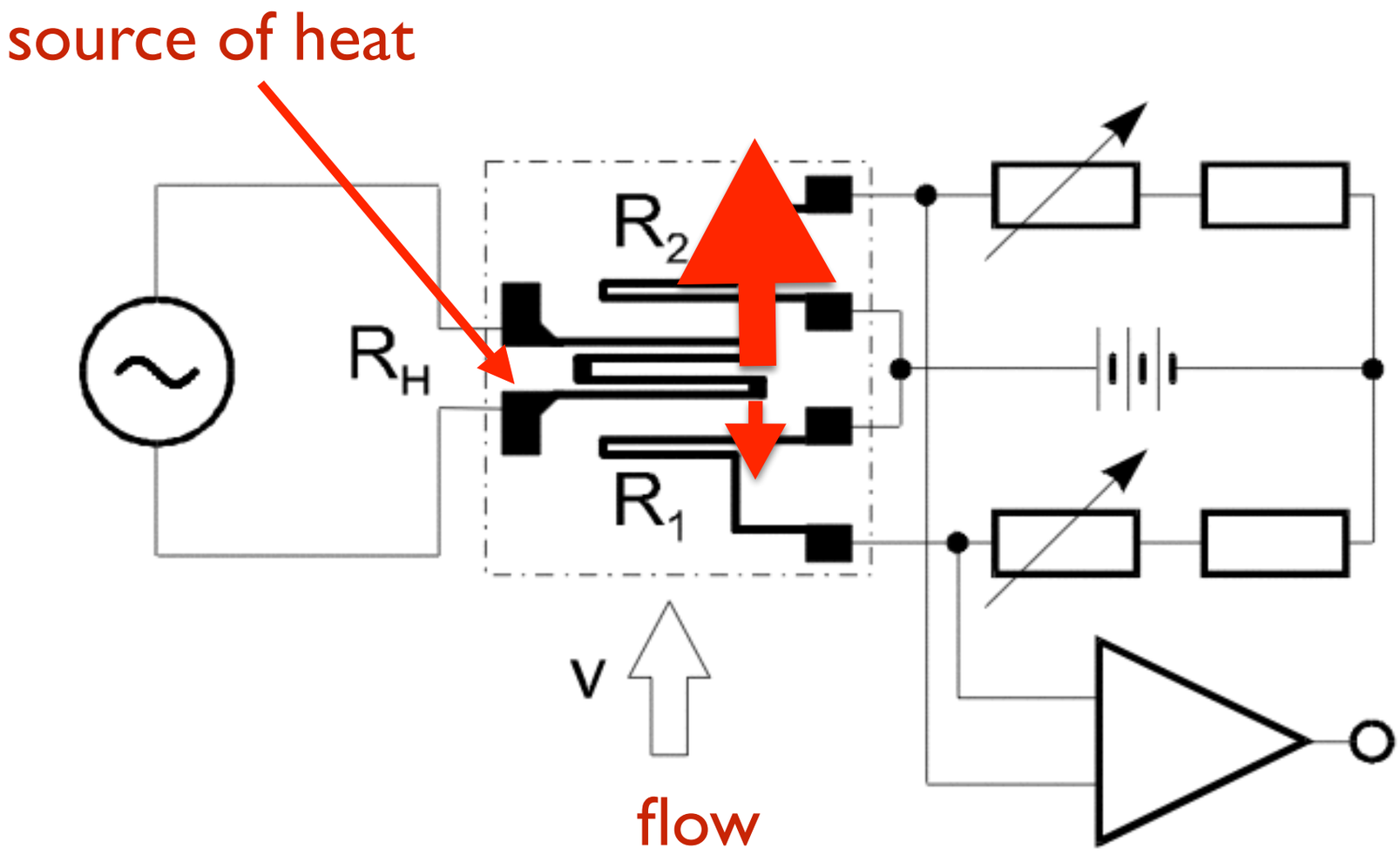
Differential thermoanemometer

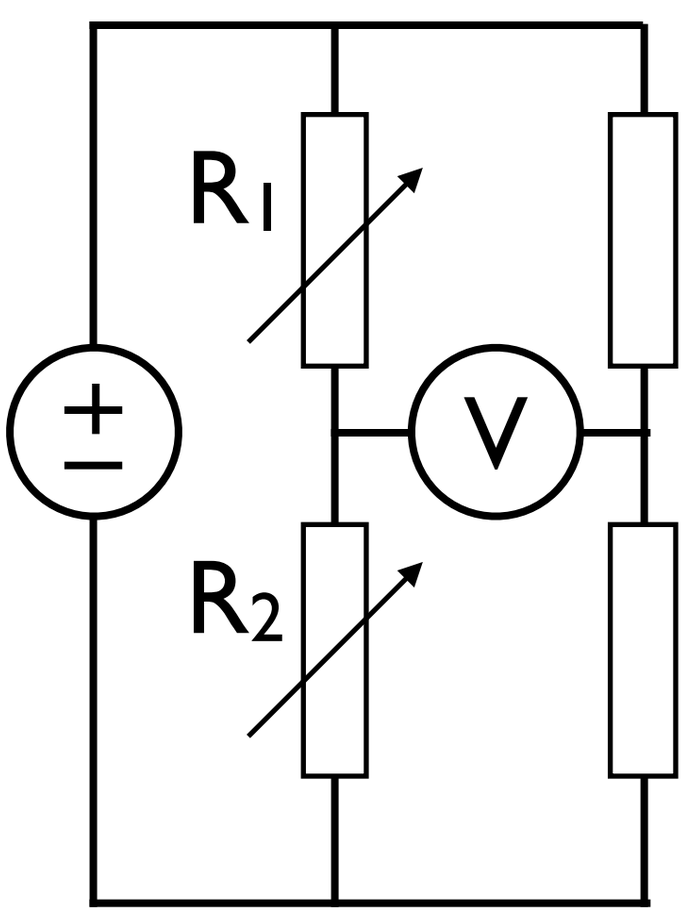


same heat is transferred to both thermistors
the bridge is still balanced



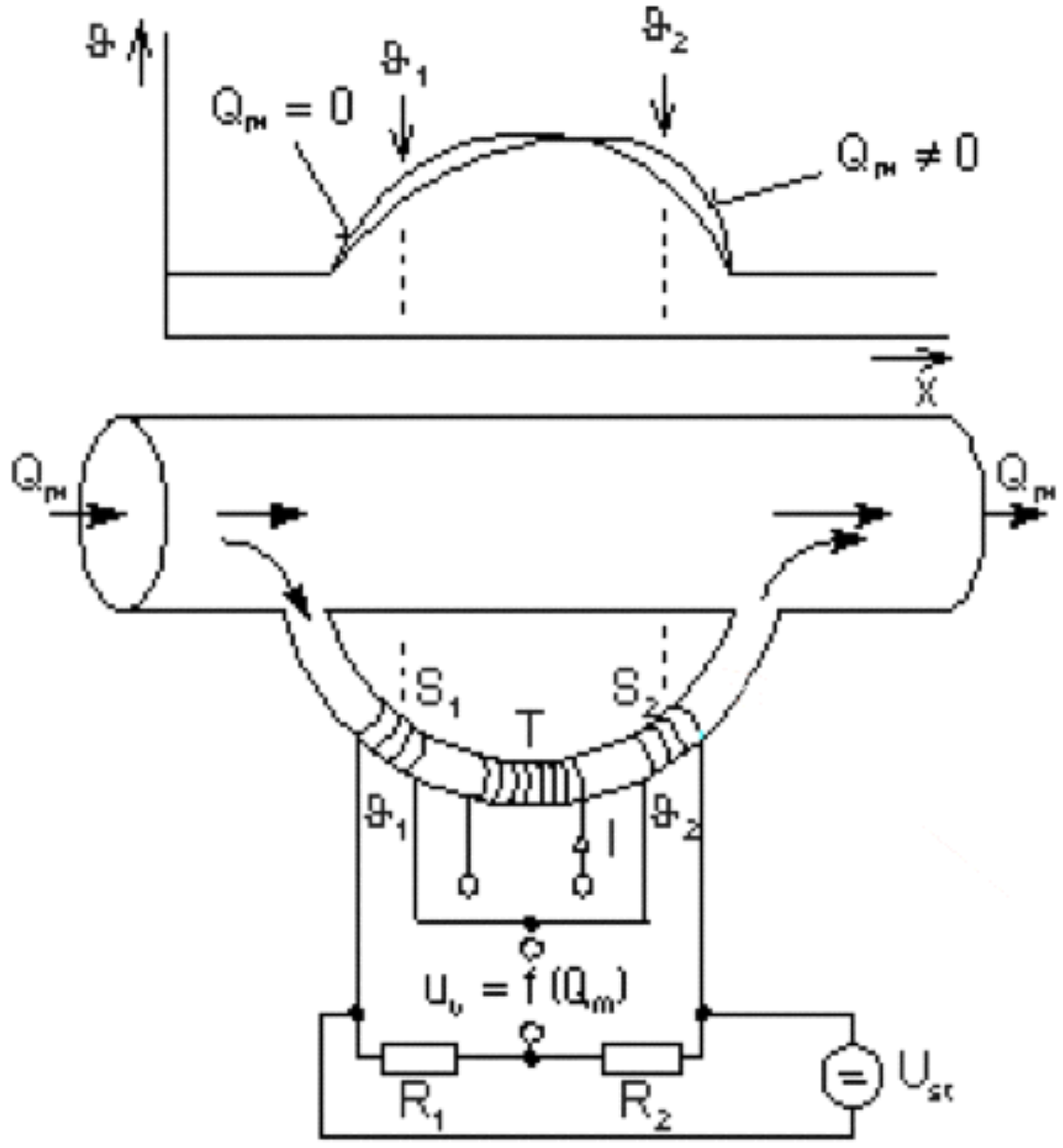
Differential thermoanemometer





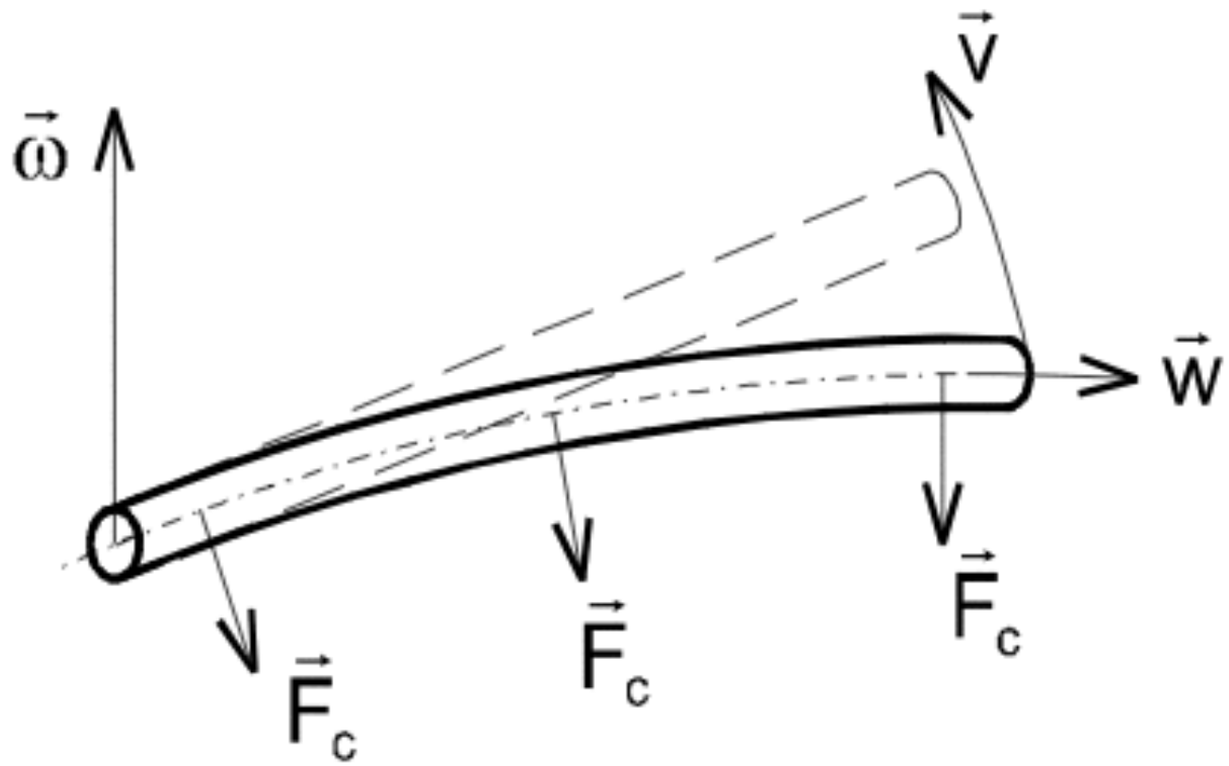
R_2 receives larger amount of heat than R_1
the bridge is not balanced anymore

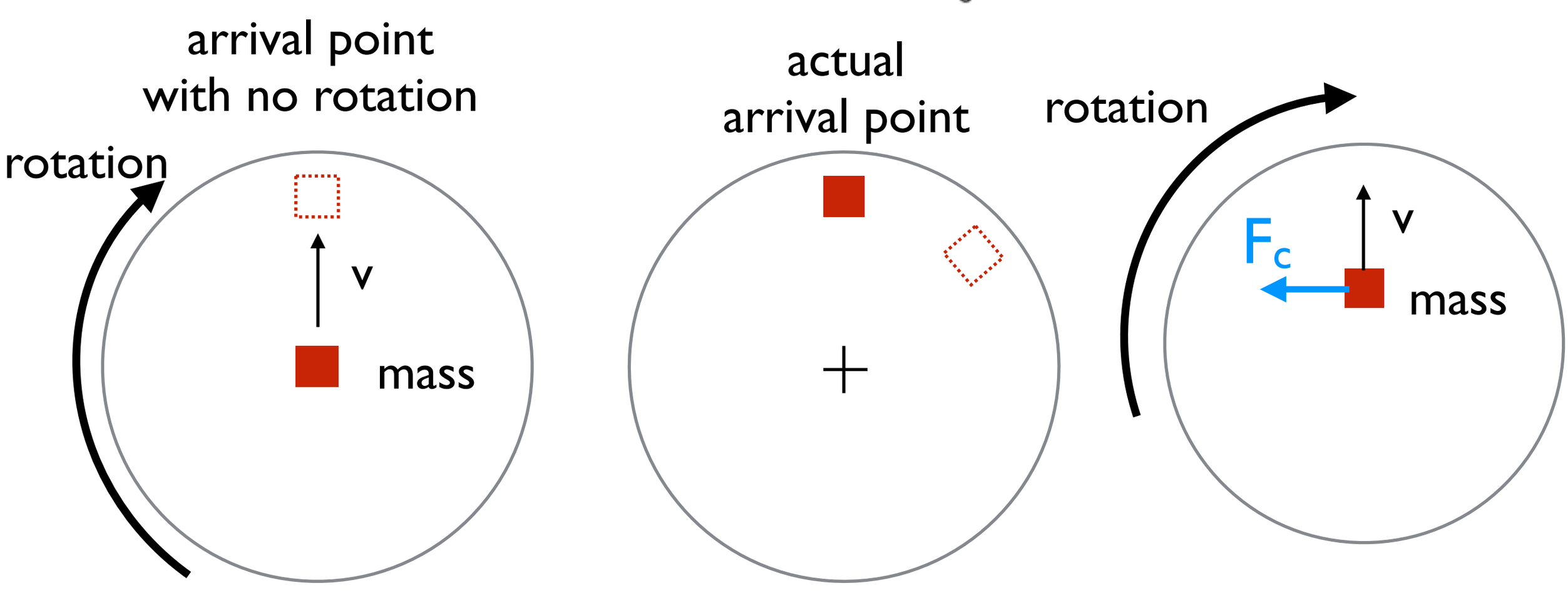
Differential thermoanemometer



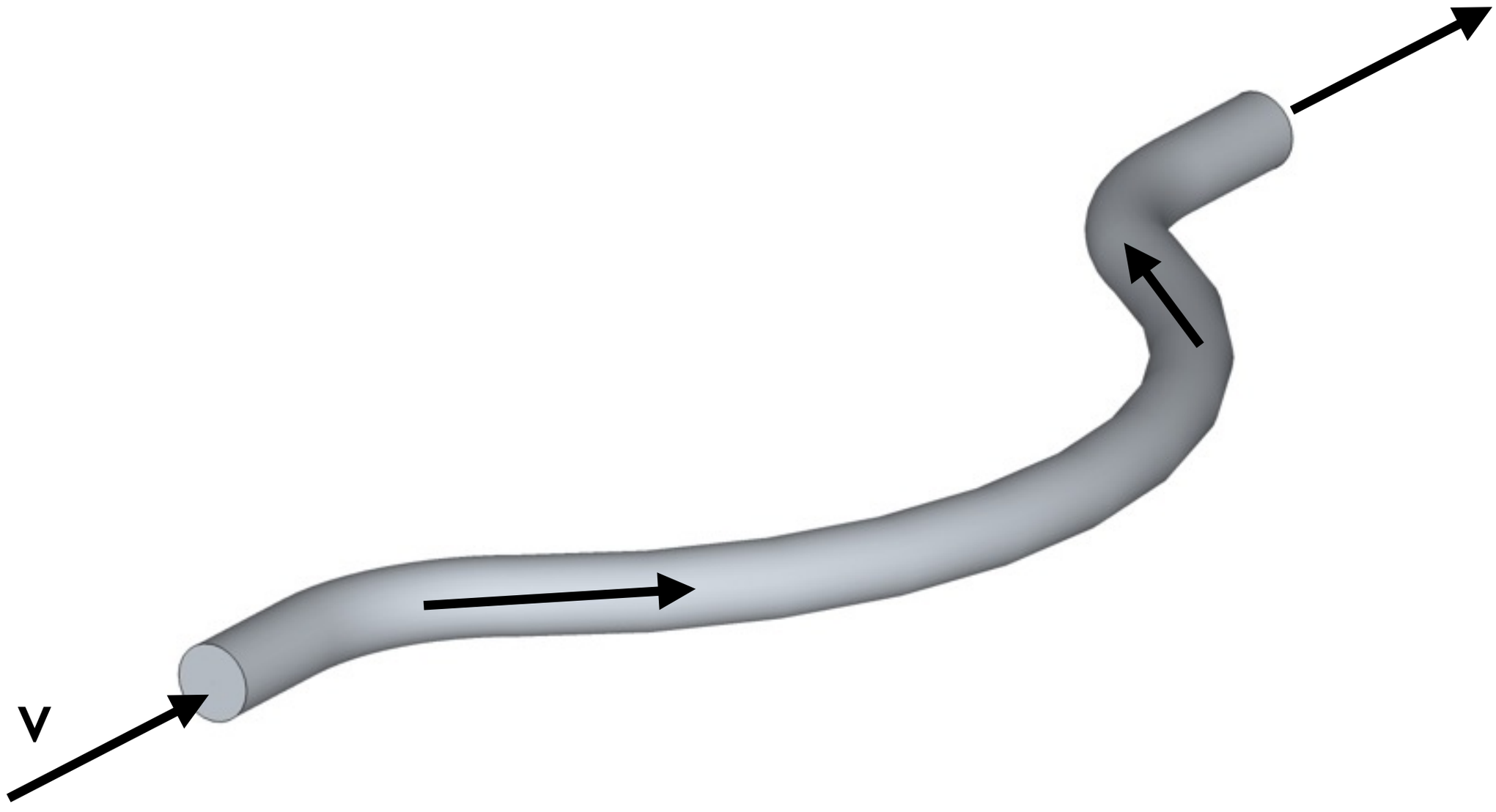
Coriolis flowmeter

Principle

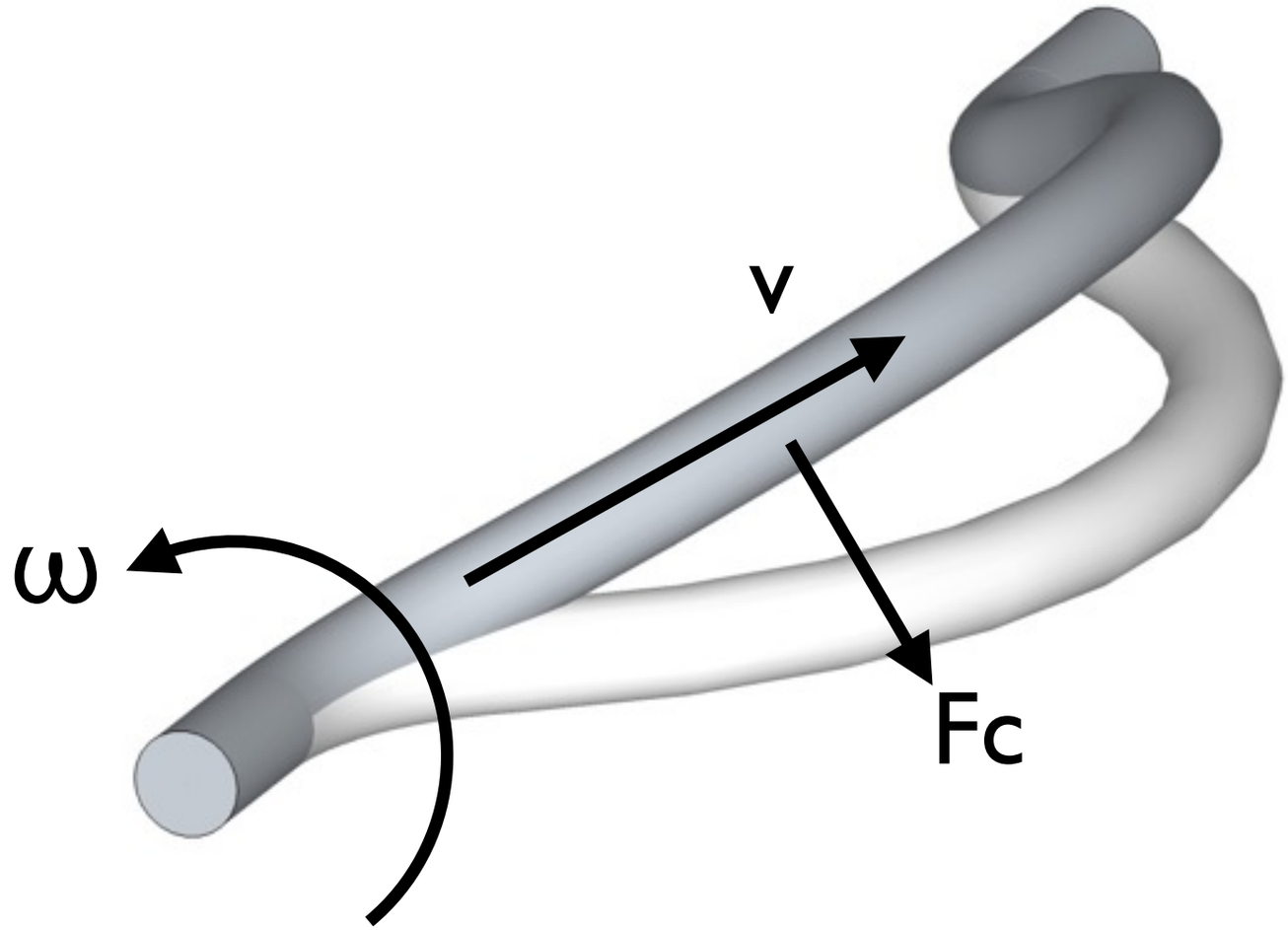




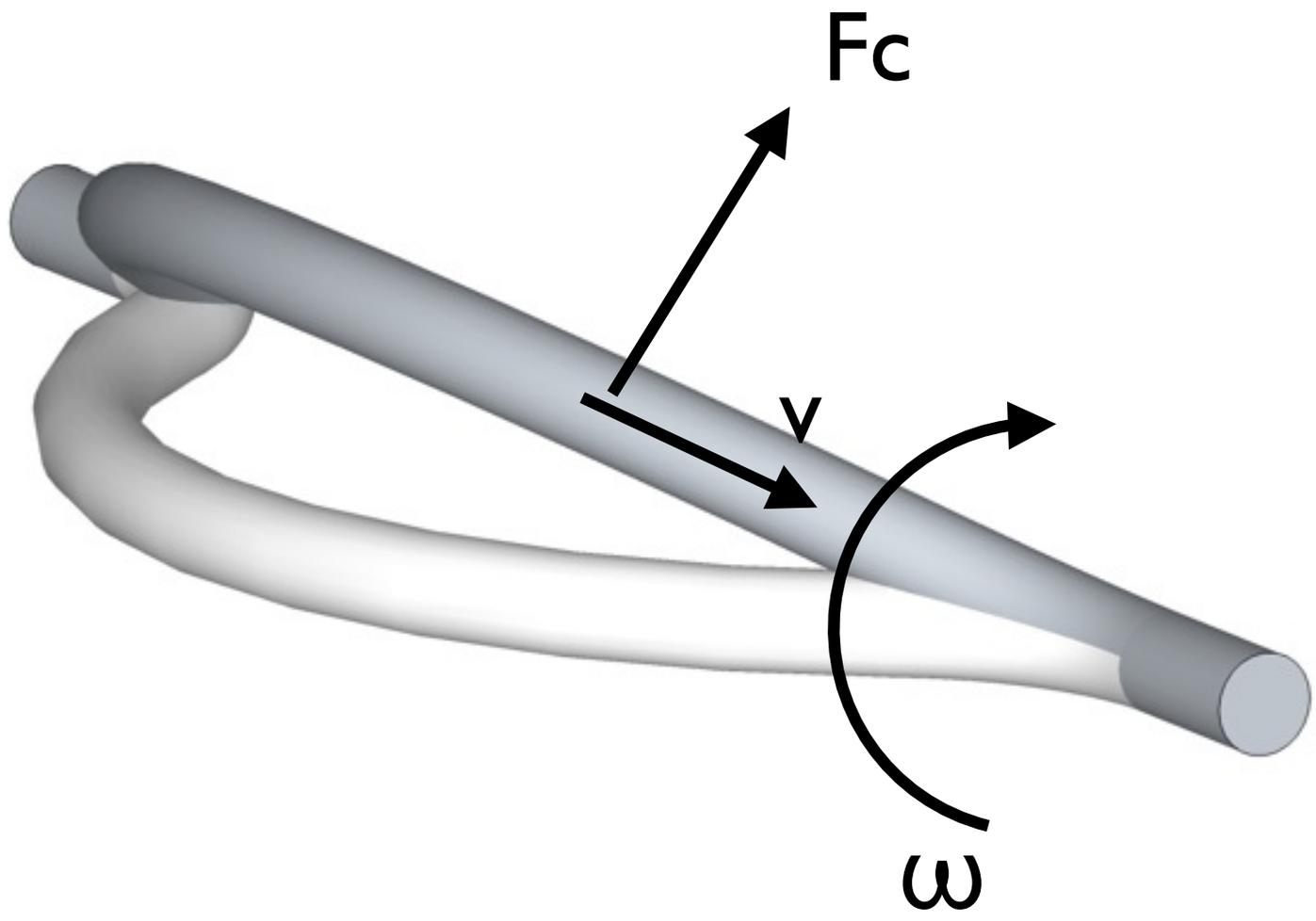
Coriolis flowmeter



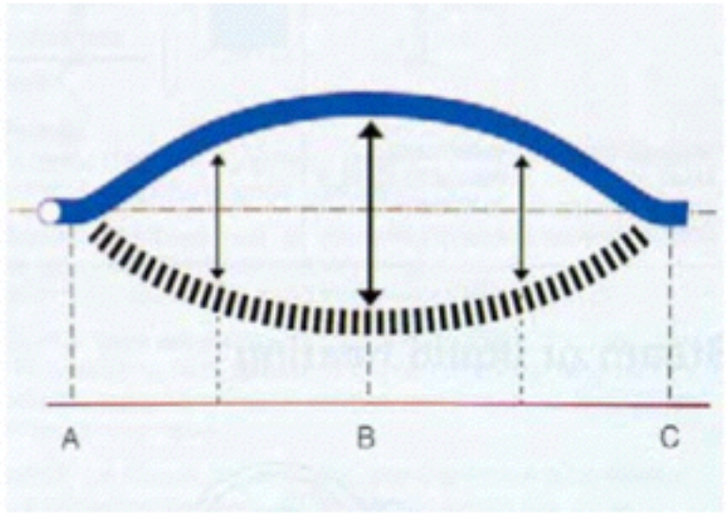
Coriolis flowmeter

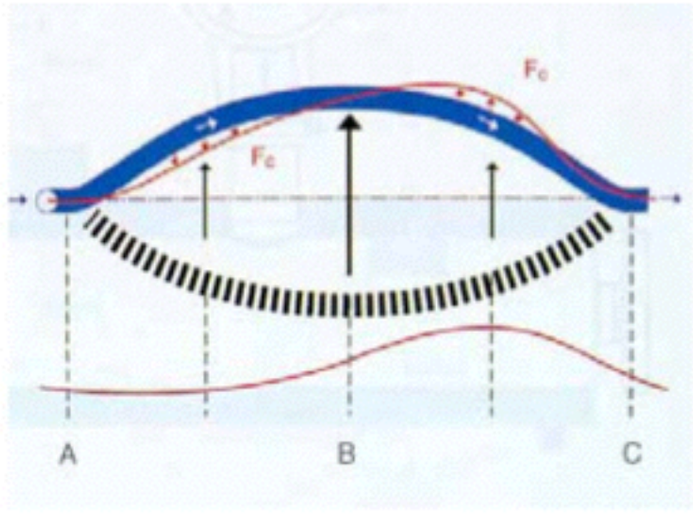


Coriolis flowmeter

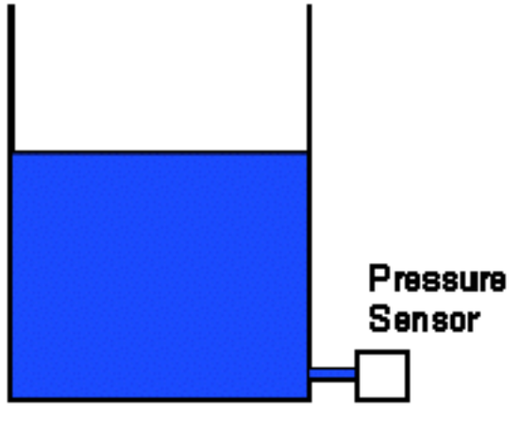


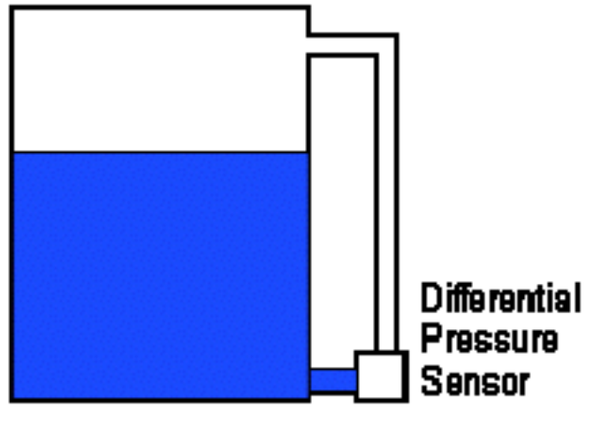
Coriolis flowmeter





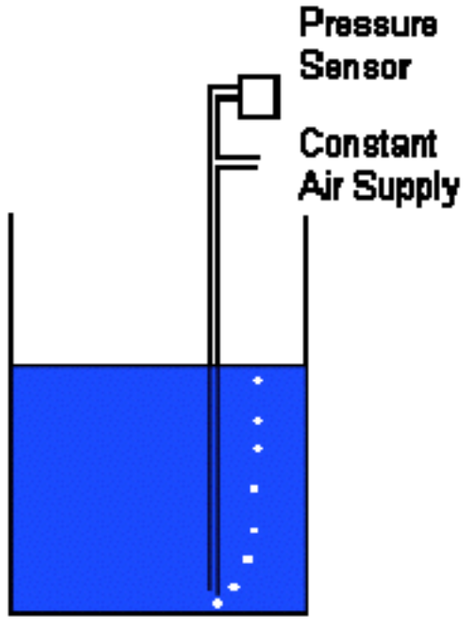
Measurement of level



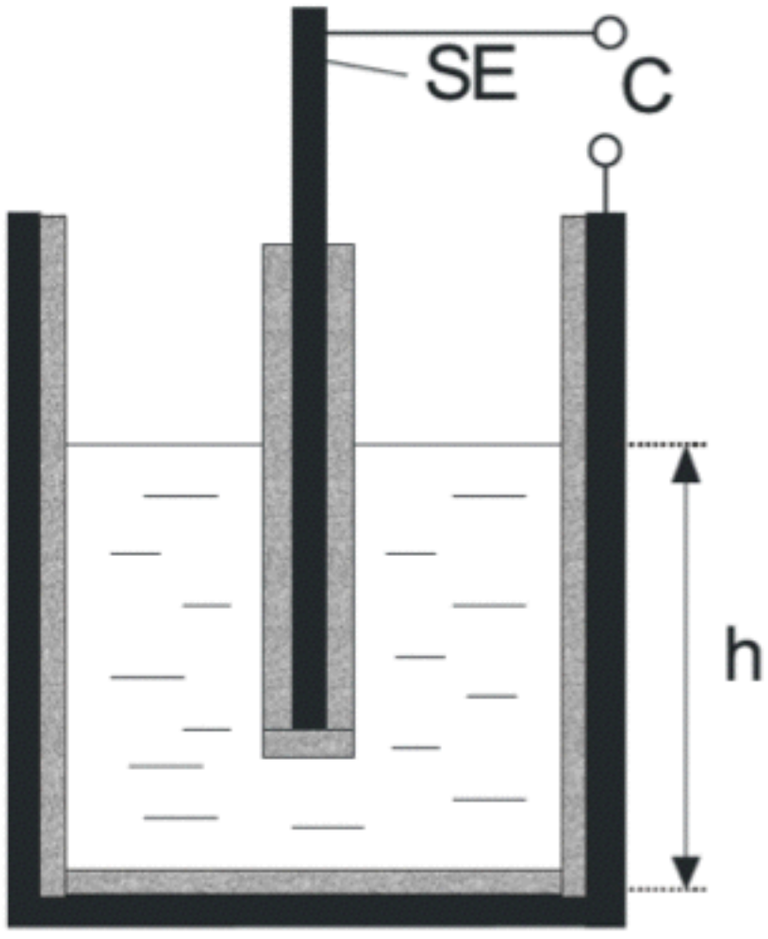


Bubbler

(sensor not in contact with liquid)

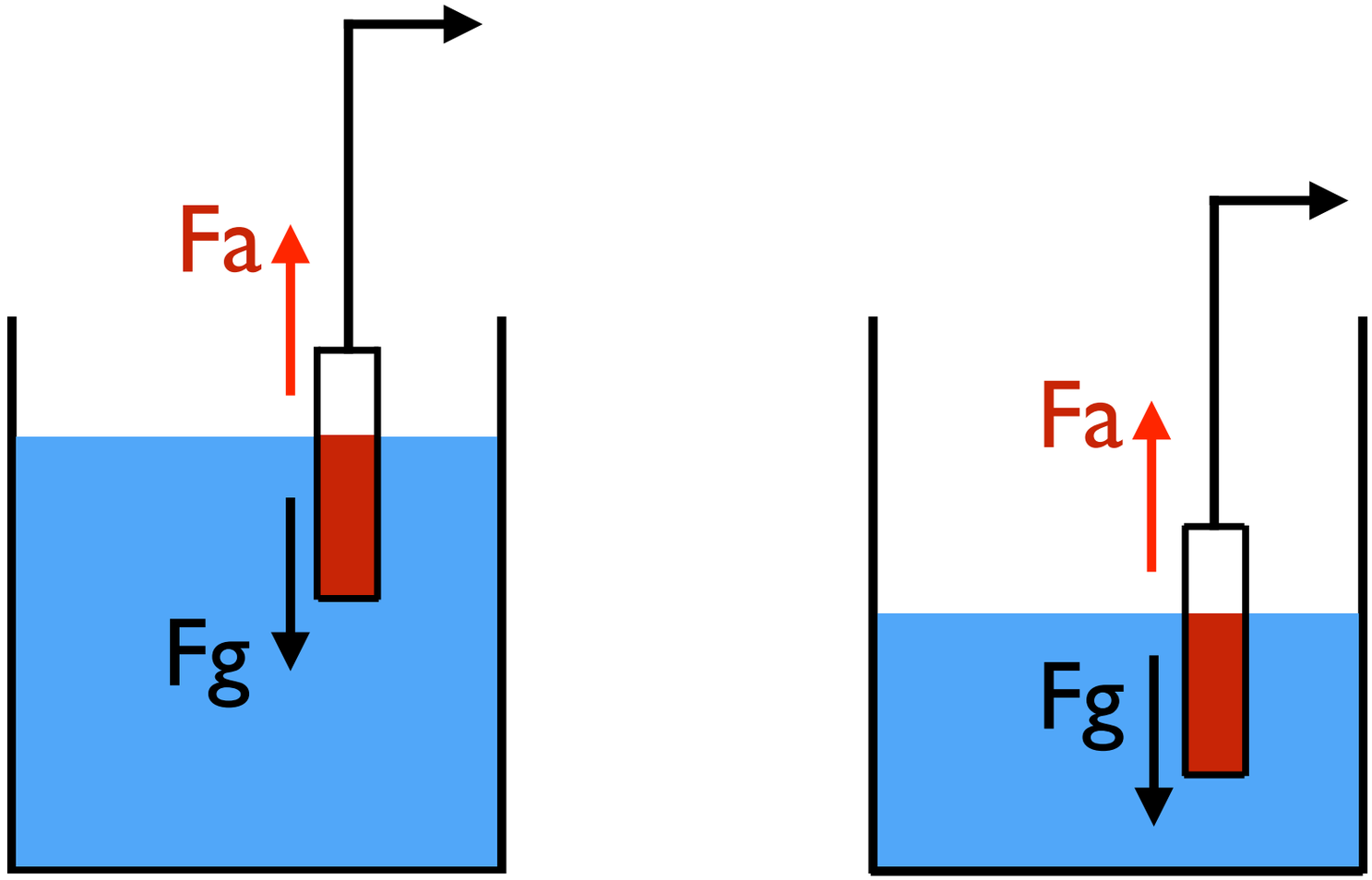


Capacitive sensor of level

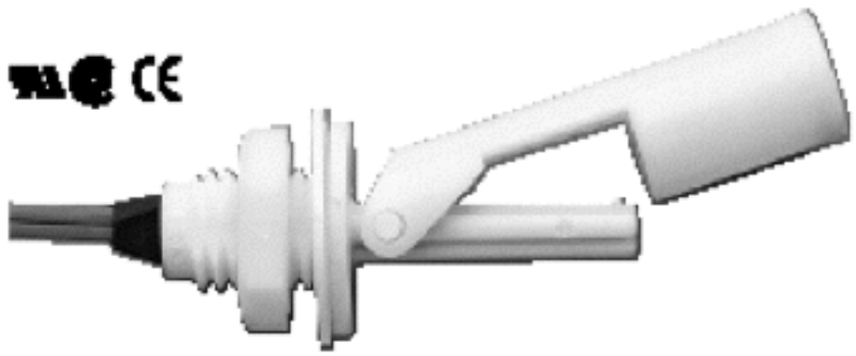


For
- non-conductive liquids
- conductive liquids (insulated electrode)

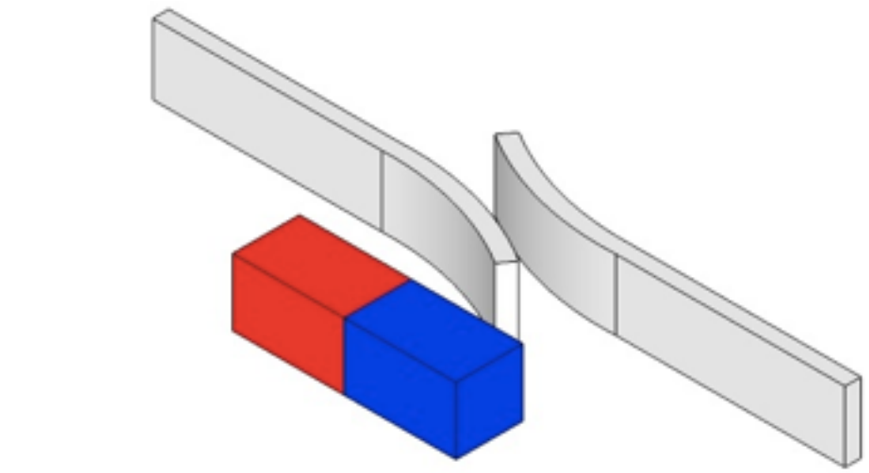
Float + weight

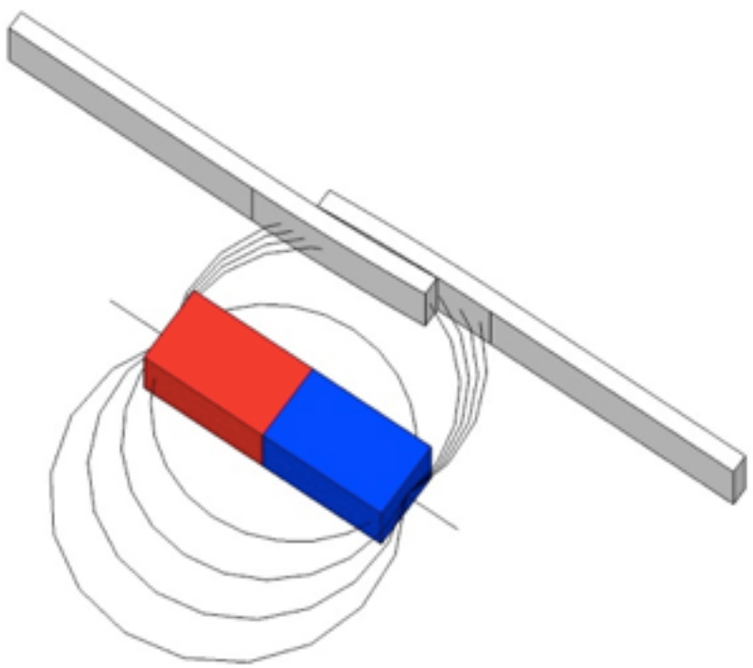


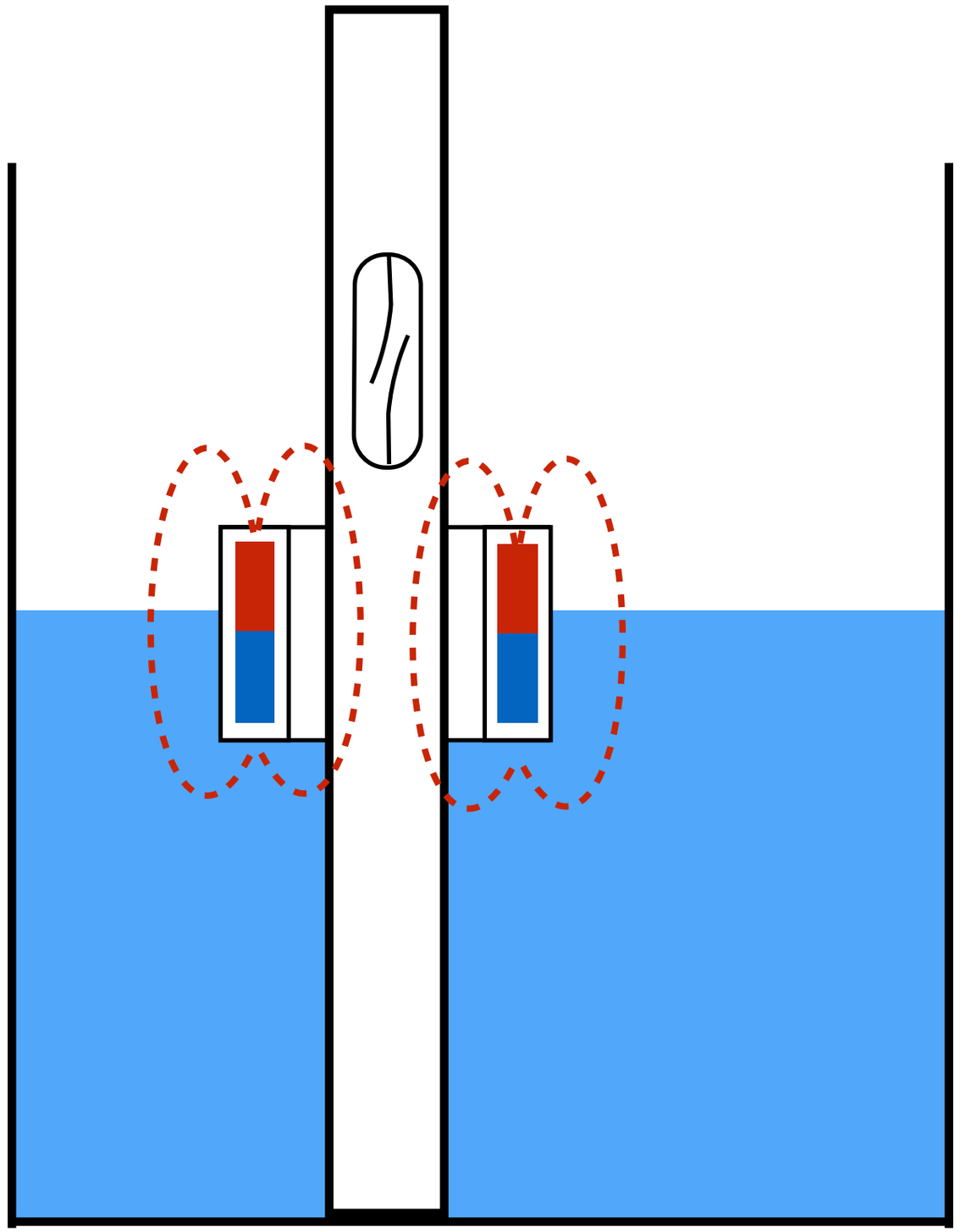
Float with reed switch



Float with reed switch(es)







Ultrasonic level meter