Design IV

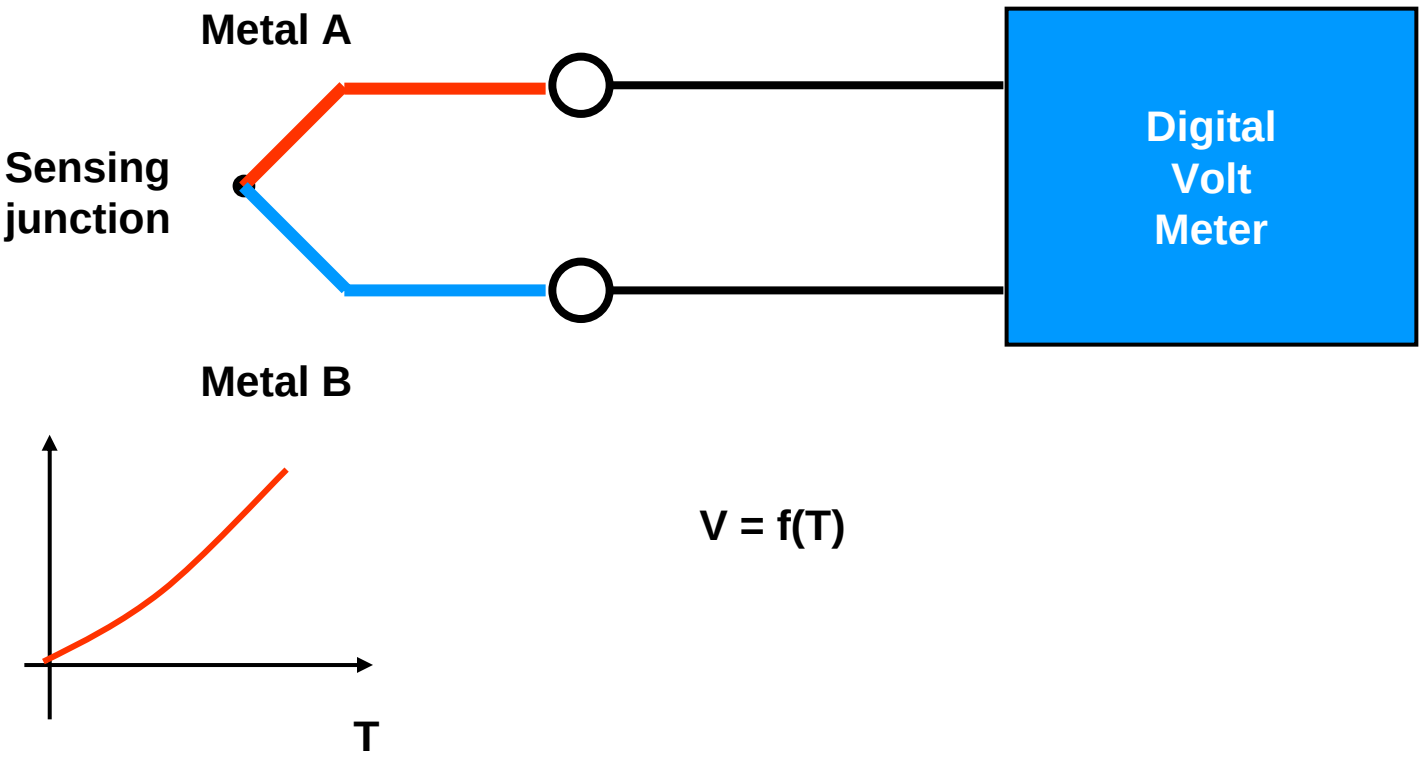
E232 Fall 07

Class 23

Bruce McNair
bmcnair@stevens.edu

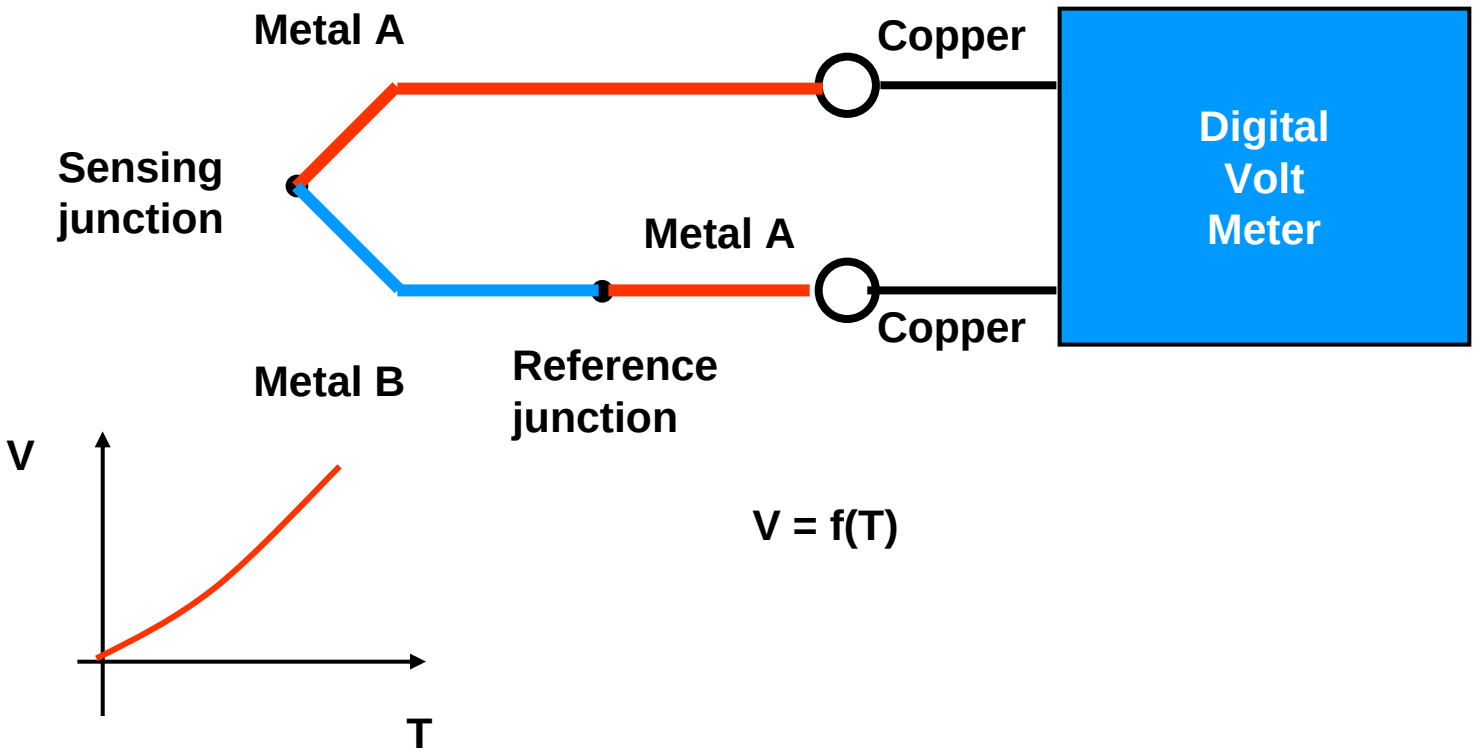
Measuring Temperature

- Thermocouples



Measuring Temperature

- Thermocouples

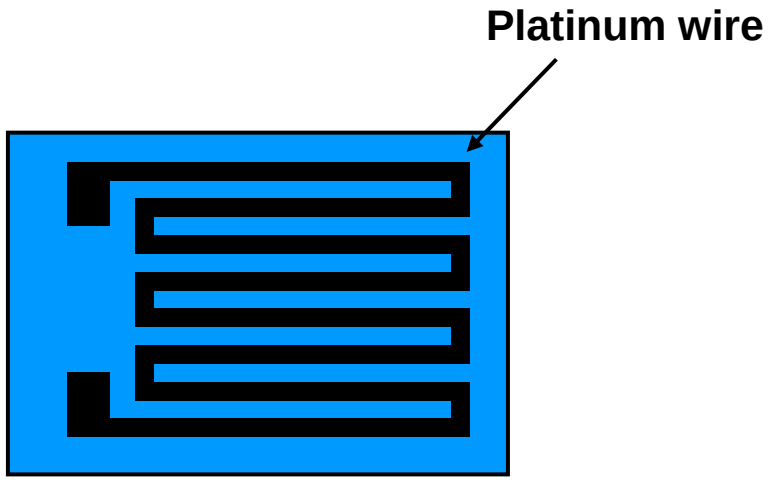


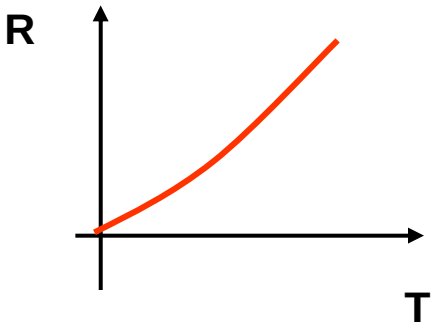
Today's topics

- Measurement sensors
  - **More temperature sensors**
  - **Non-contact temperature sensors**
  - **Fluid Flow Rate**

Measuring Temperature

- Resistance-Temperature Detectors

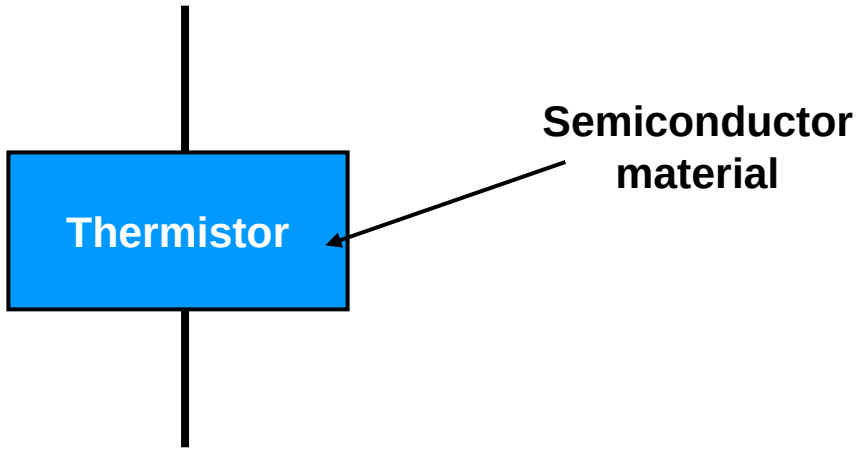


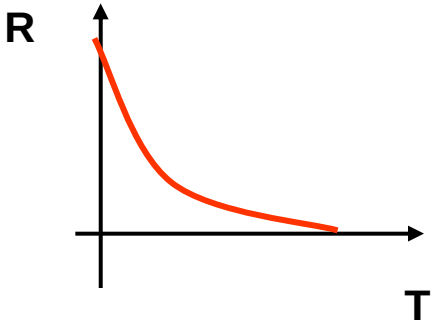


R = f(T)

Measuring Temperature

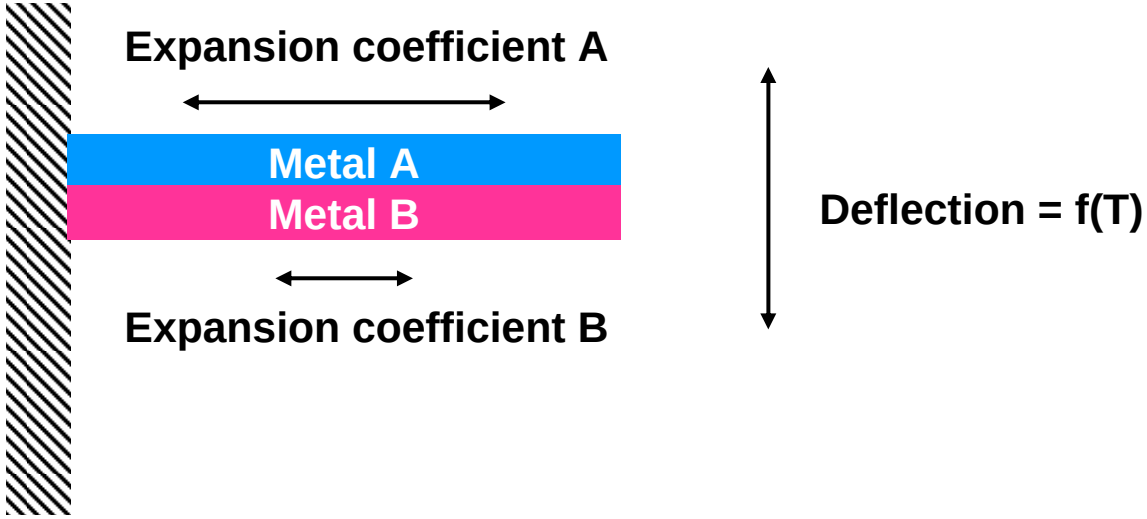
- Thermistors





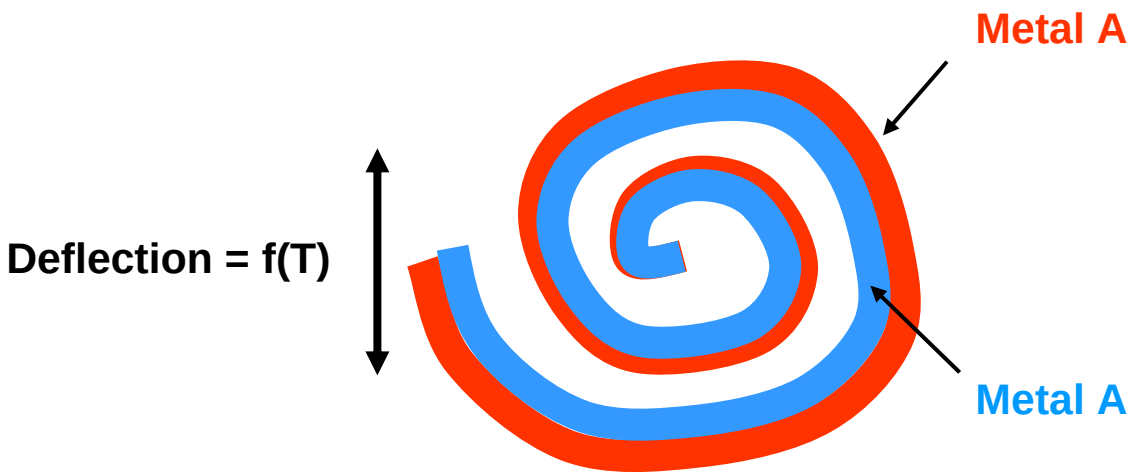
Temperature Measurement

- Linear bi-metallic strip



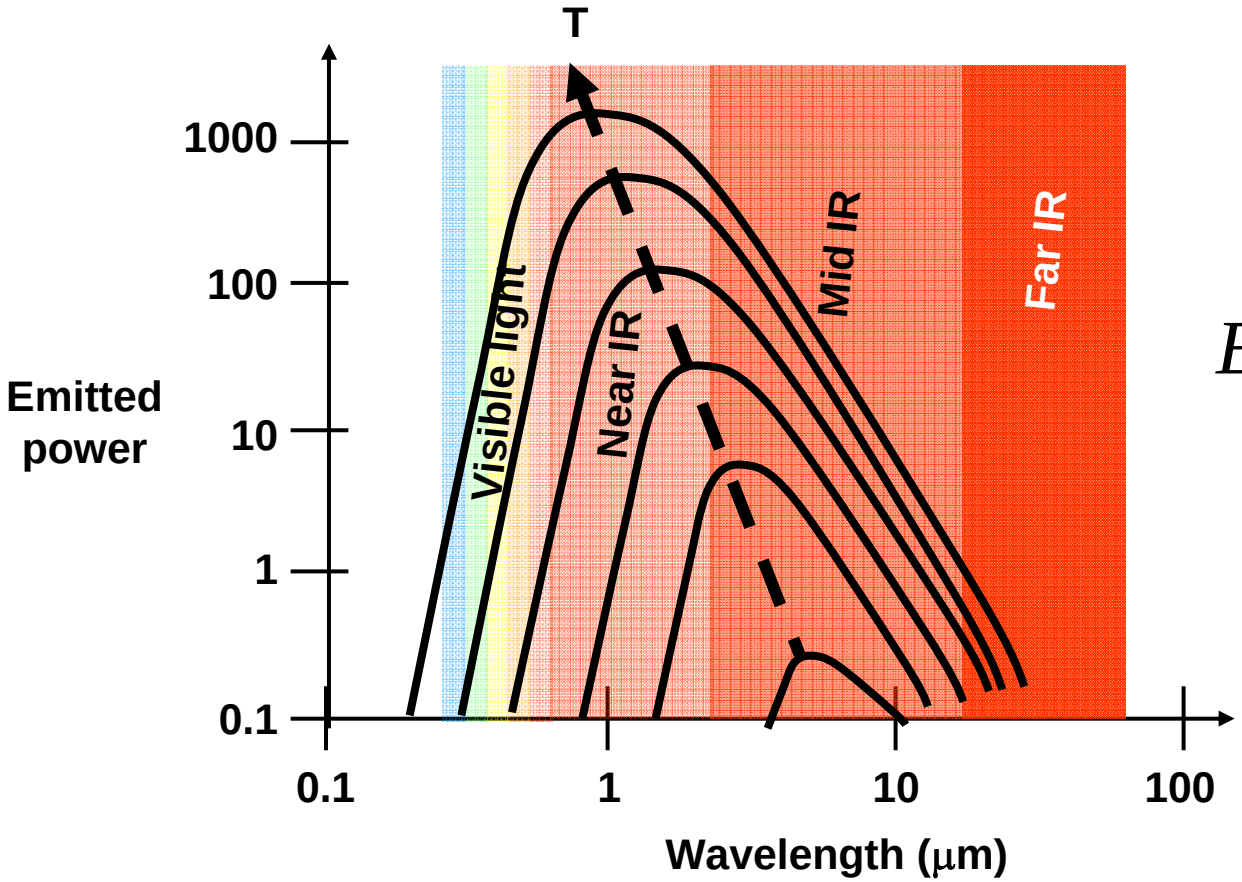
Temperature Measurement

- Spiral bi-metallic strip



Non-contact Temperature Measurement

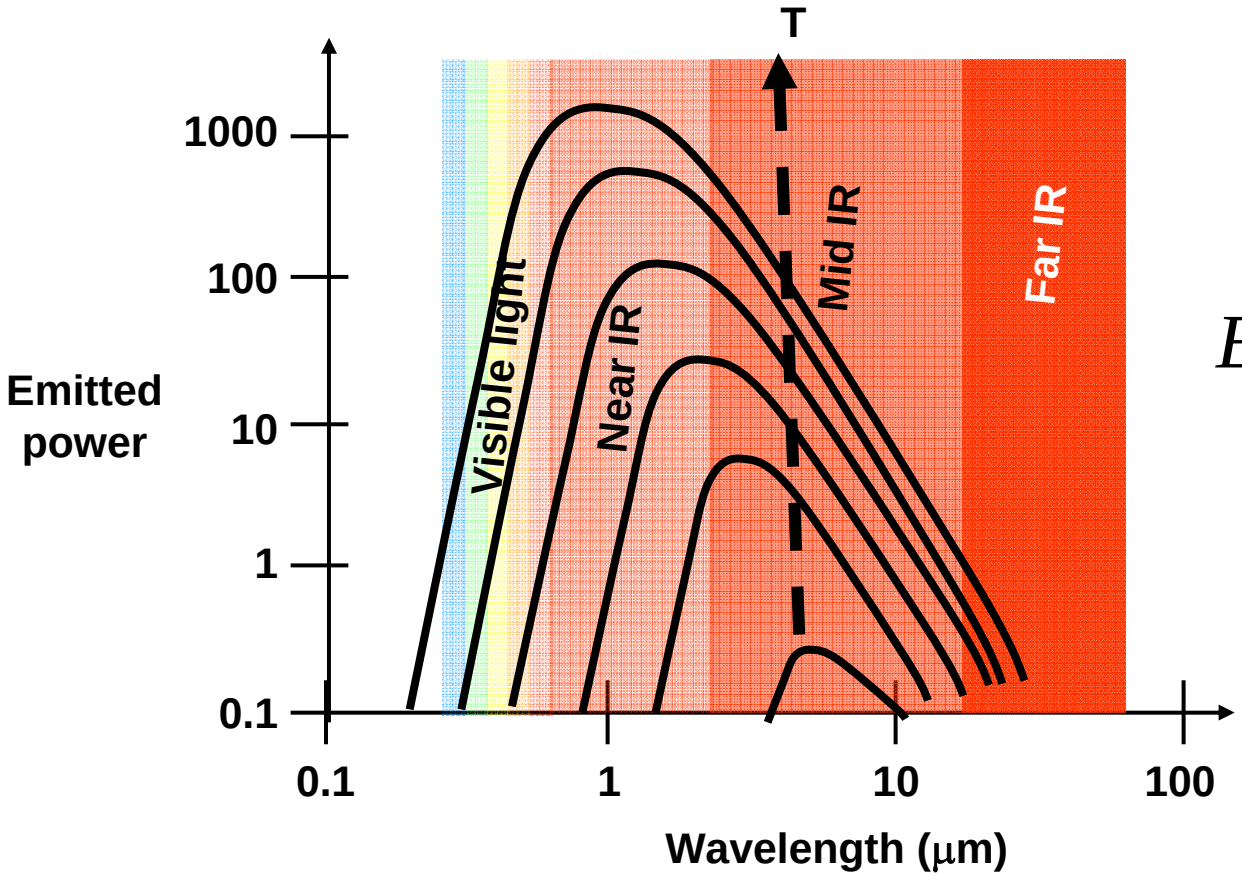
- Blackbody radiation



$$E_{b\lambda} = \frac{C_1 \lambda^{-5}}{e^{\frac{C_2}{\lambda T}} - 1}$$

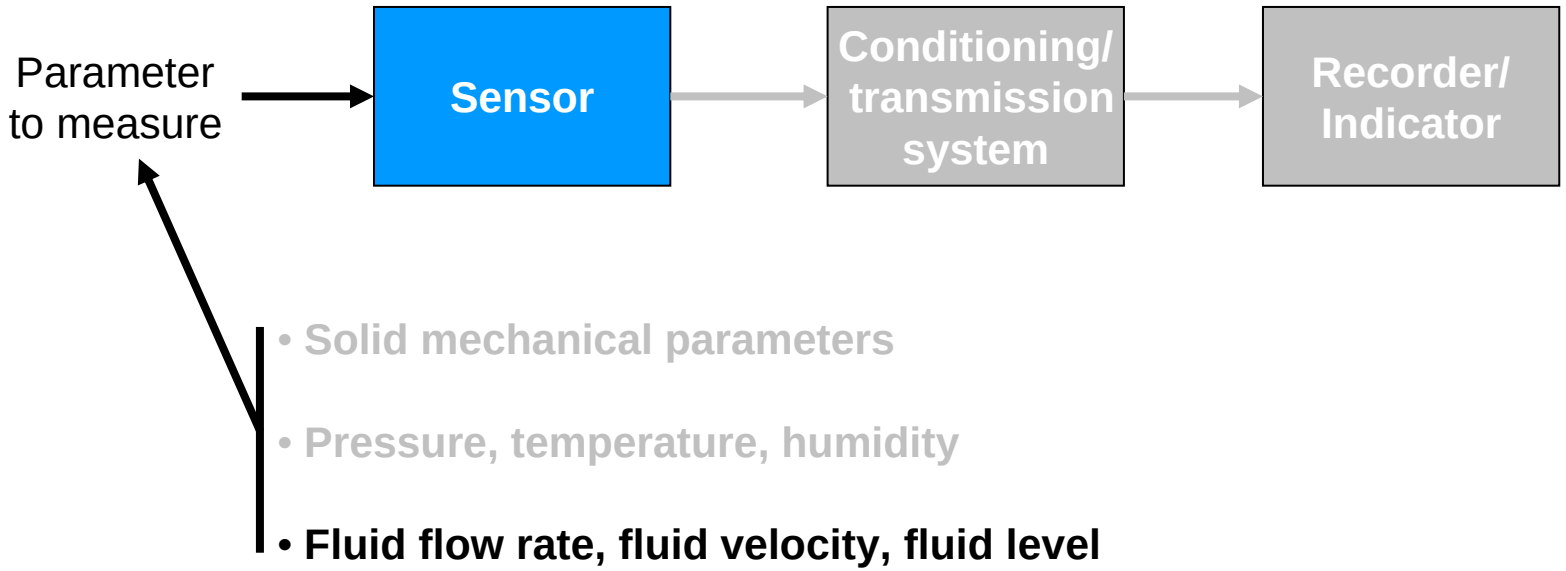
Non-contact Temperature Measurement

- Blackbody radiation



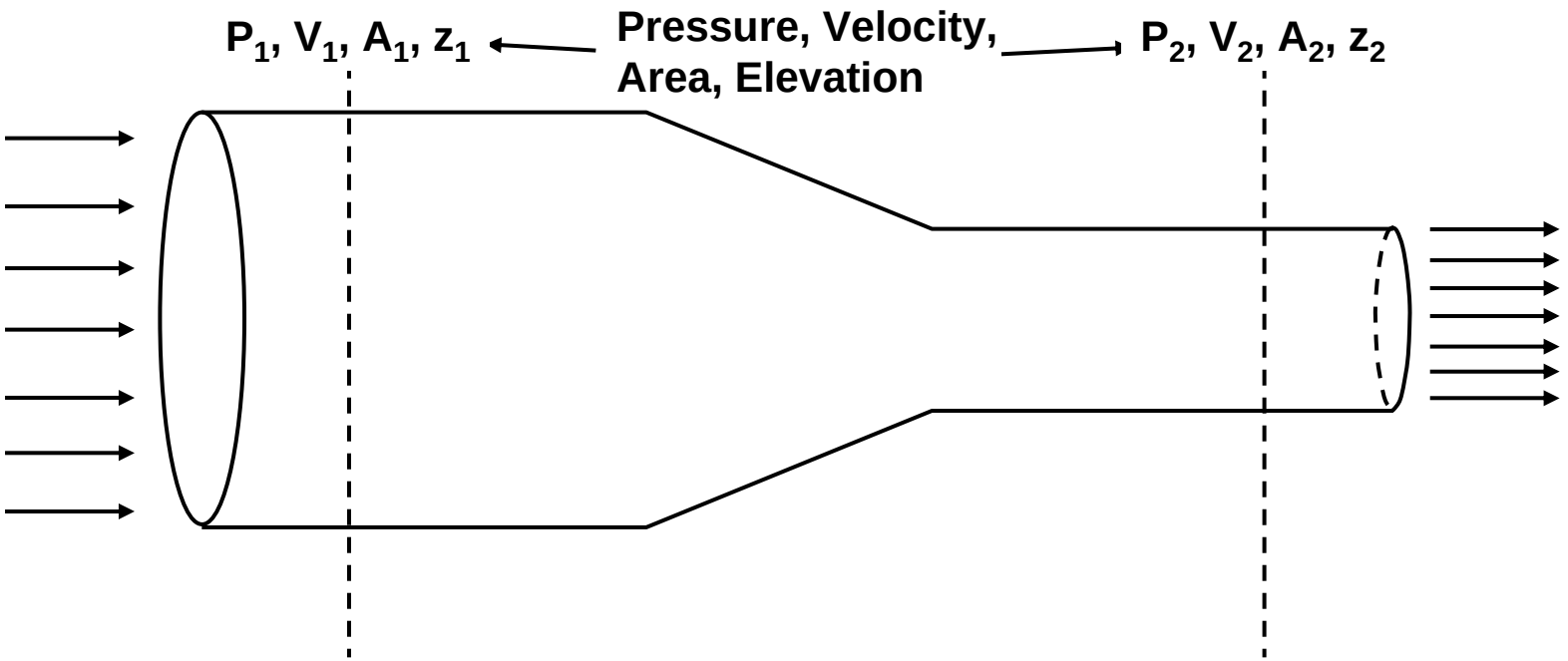
$$E_{b\lambda} = \frac{C_1 \lambda^{-5}}{e^{\frac{C_2}{\lambda T}} - 1}$$

Measurement Systems



Bernoulli Equation

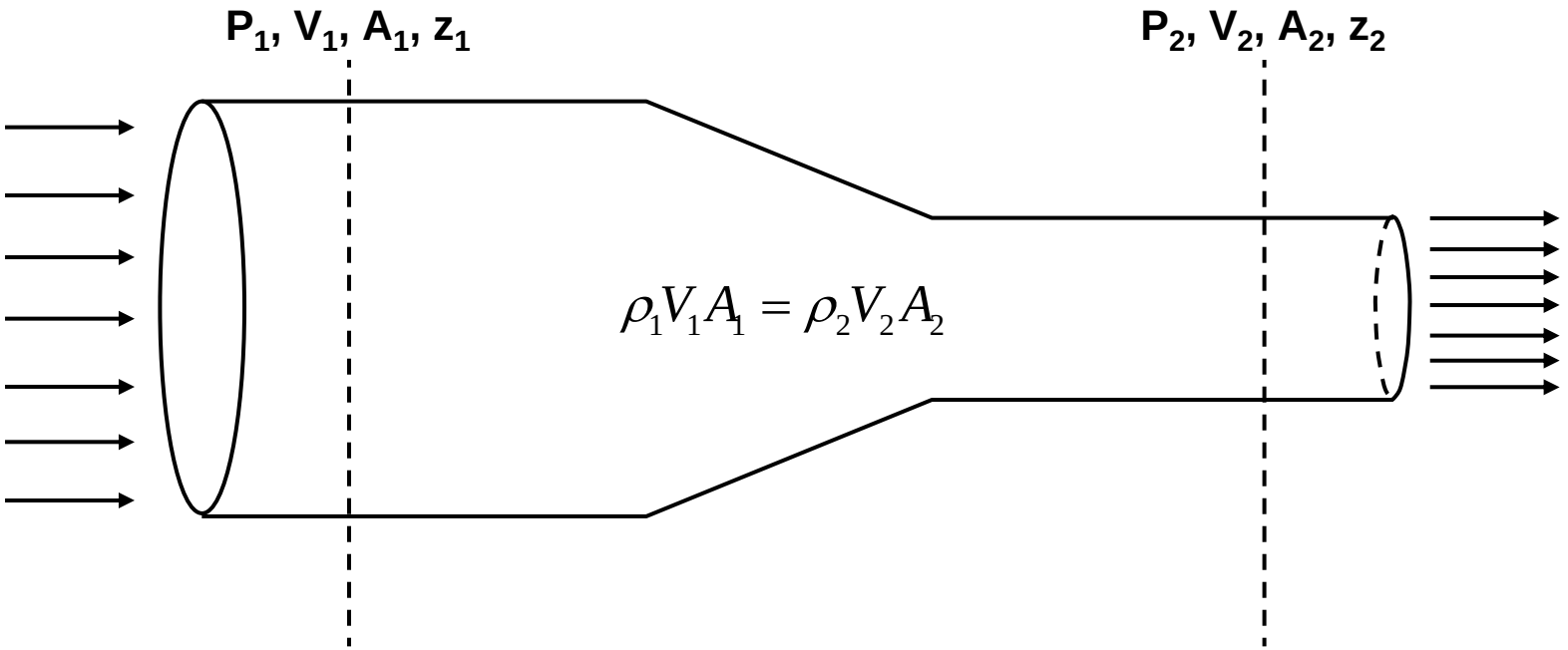
- Consider a frictionless duct with an incompressible fluid



$$\frac{V_1^2}{2} + \frac{P_1}{\rho} + gz_1 = \frac{V_2^2}{2} + \frac{P_2}{\rho} + gz_2$$

Mass flow in = mass flow out

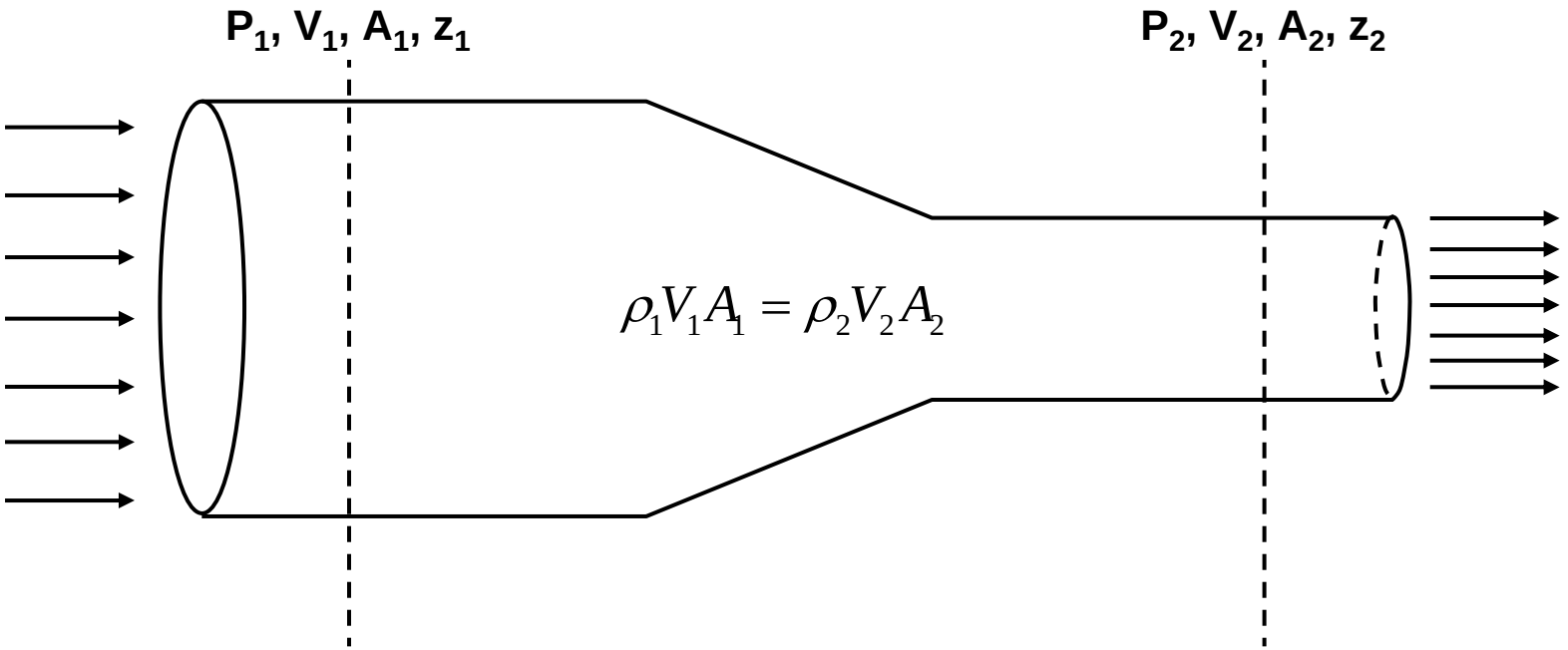
- For compressible or incompressible fluids



If $\rho_1 = \rho_2$

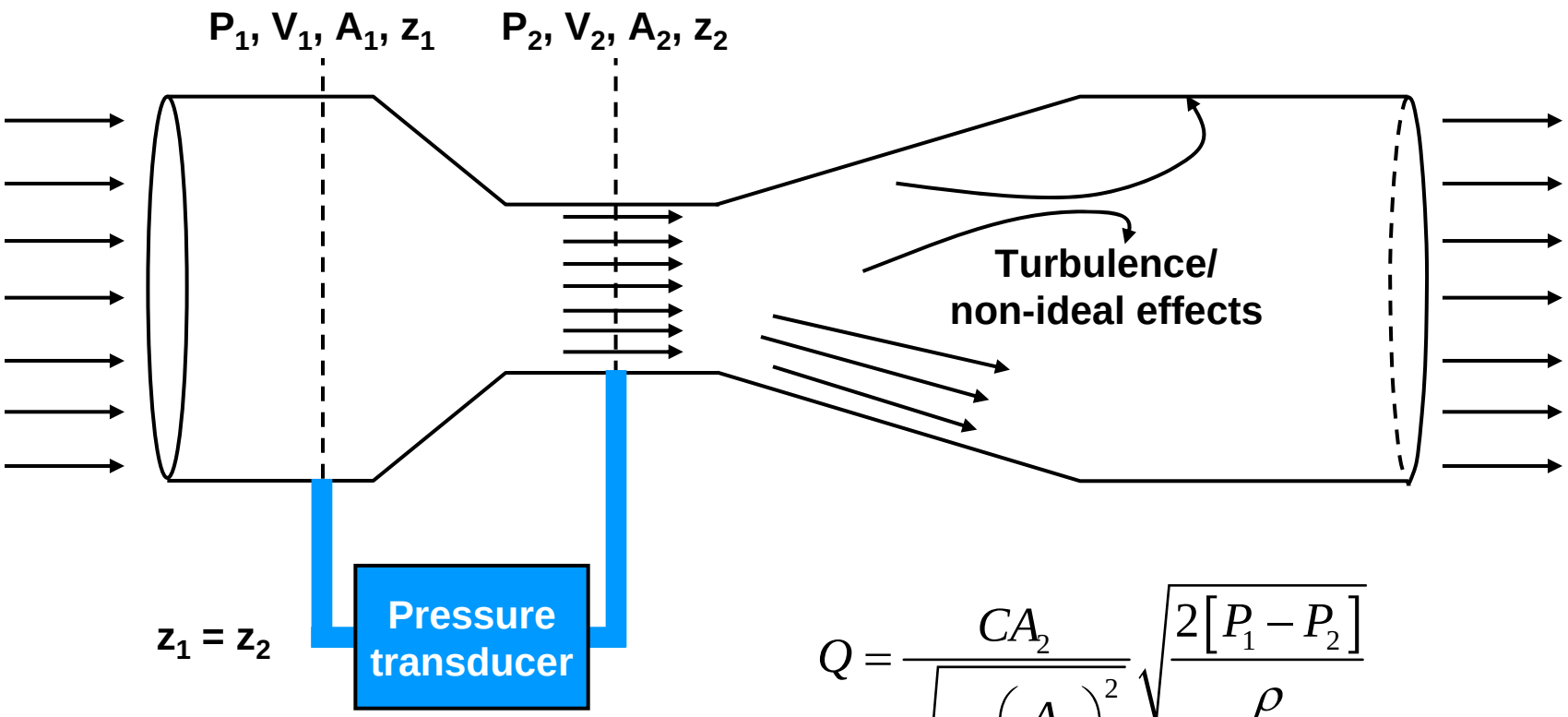
$$V_1 A_1 = V_2 A_2 = Q$$

Flow Rate



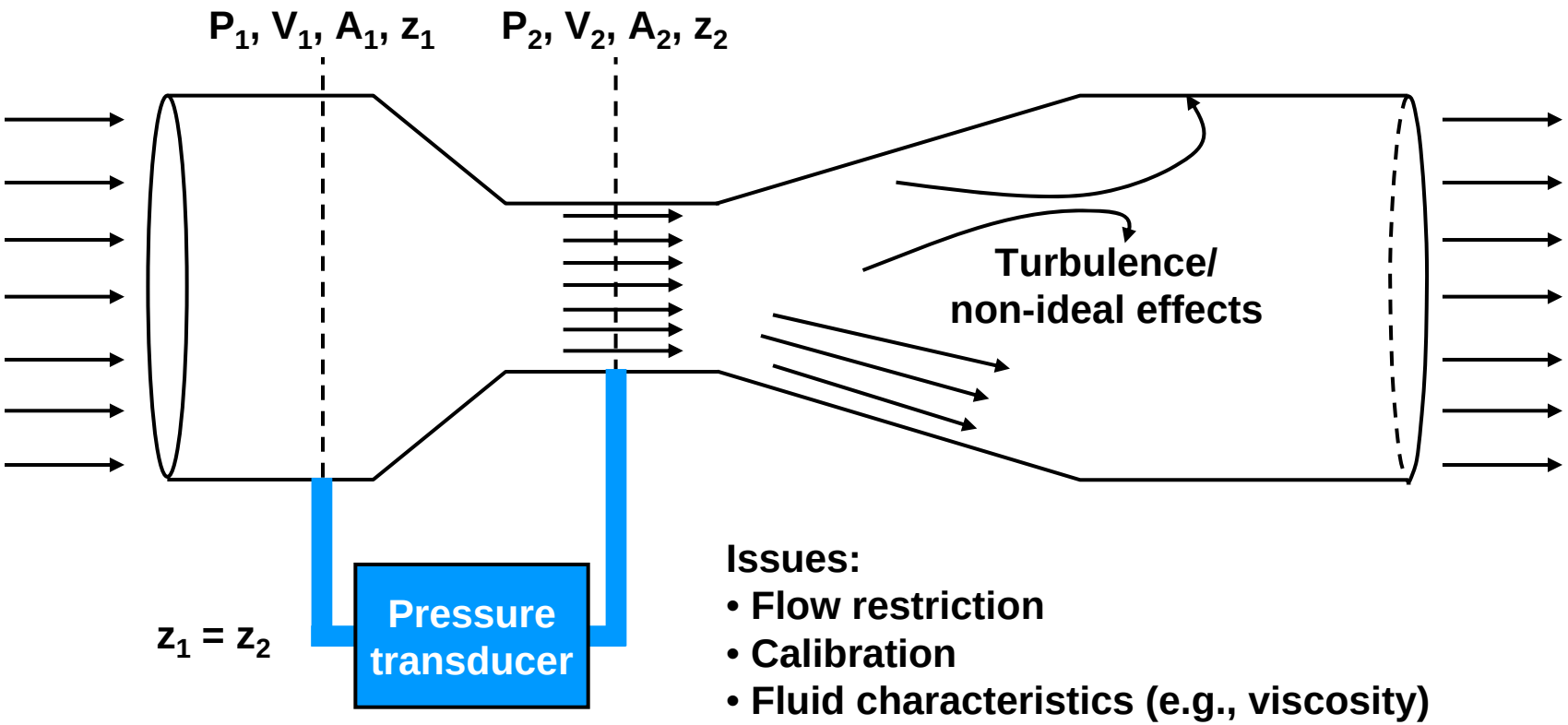
$$Q = \frac{A_2}{\sqrt{1-\left(\frac{A_2}{A_1}\right)^2}} \sqrt{\frac{2\left[\left(P_1 + g\rho z_1\right) - \left(P_2 + g\rho z_2\right)\right]}{\rho}}$$

Venturi Tube



$$Q = \frac{CA_2}{\sqrt{1-\left(\frac{A_2}{A_1}\right)^2}}\sqrt{\frac{2\left[P_1 - P_2\right]}{\rho}}$$

Venturi Tube



Issues:

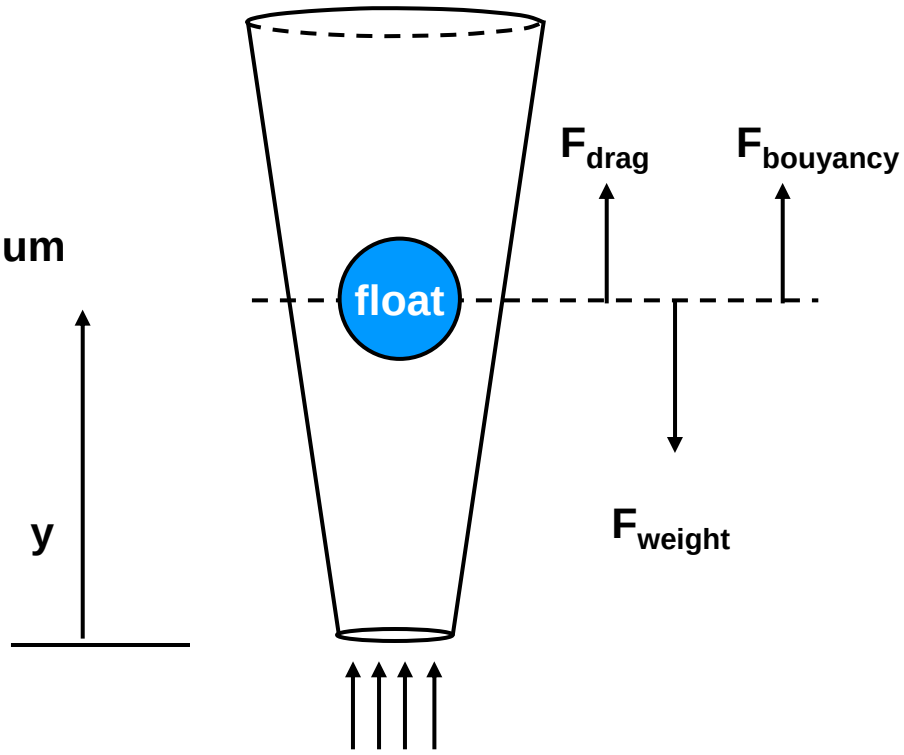
- **Flow restriction**
- **Calibration**
- **Fluid characteristics (e.g., viscosity)**
- **Low flow rate limitations**

Variable-Area Flowmeters

- Rotameter

Float is in equilibrium at height y

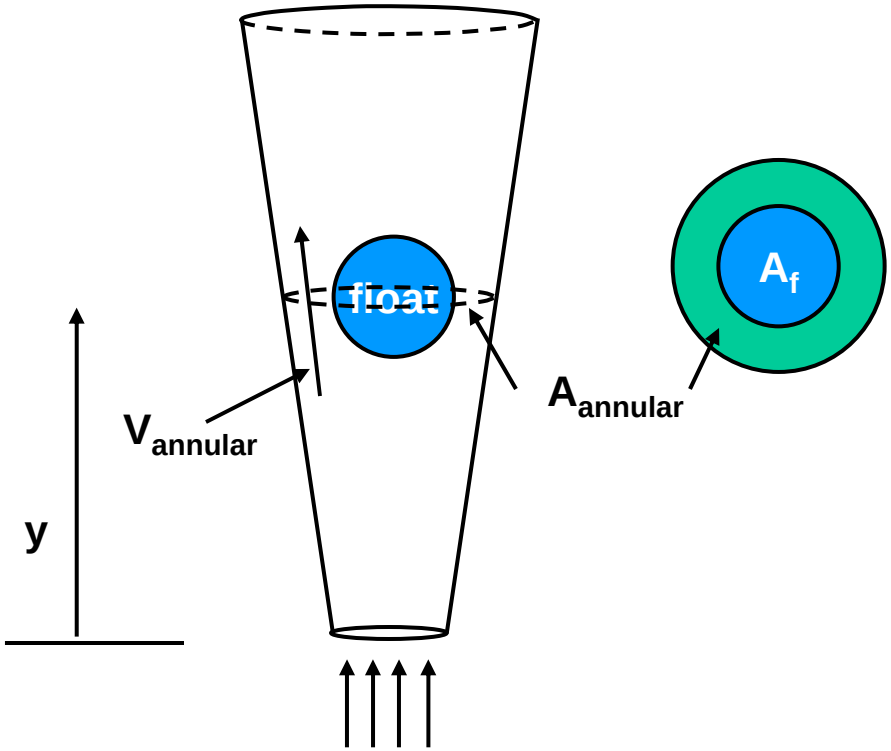
$$F_W = F_D + F_B$$



Variable-Area Flowmeters

- Rotameter

$$Q = V_a A_a$$



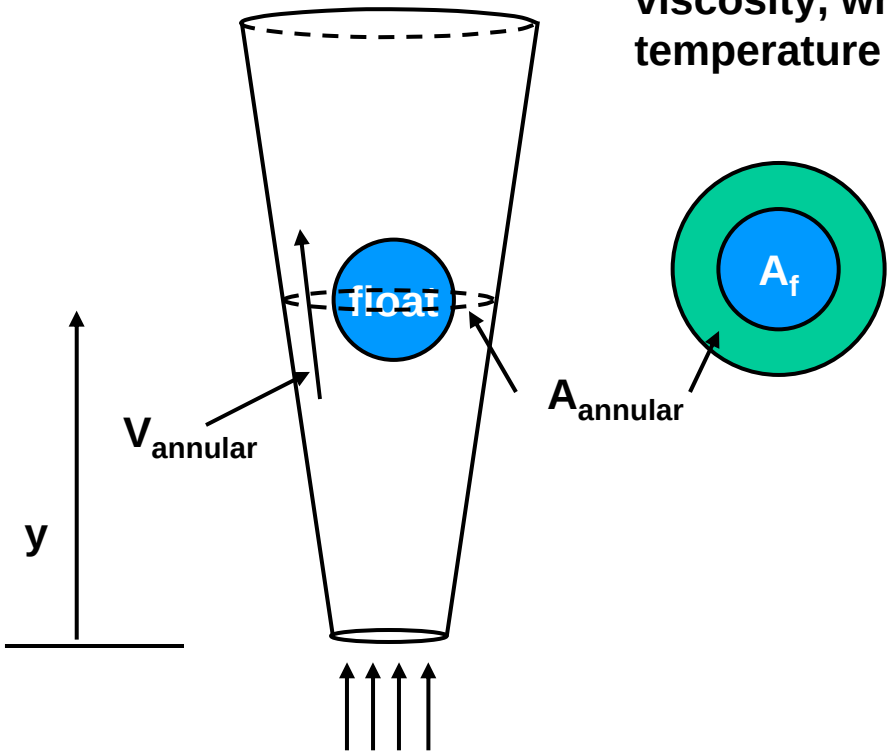
Design float so V_a is constant
Design flowmeter so A_a is linear with y

Variable-Area Flowmeters

- Rotameter

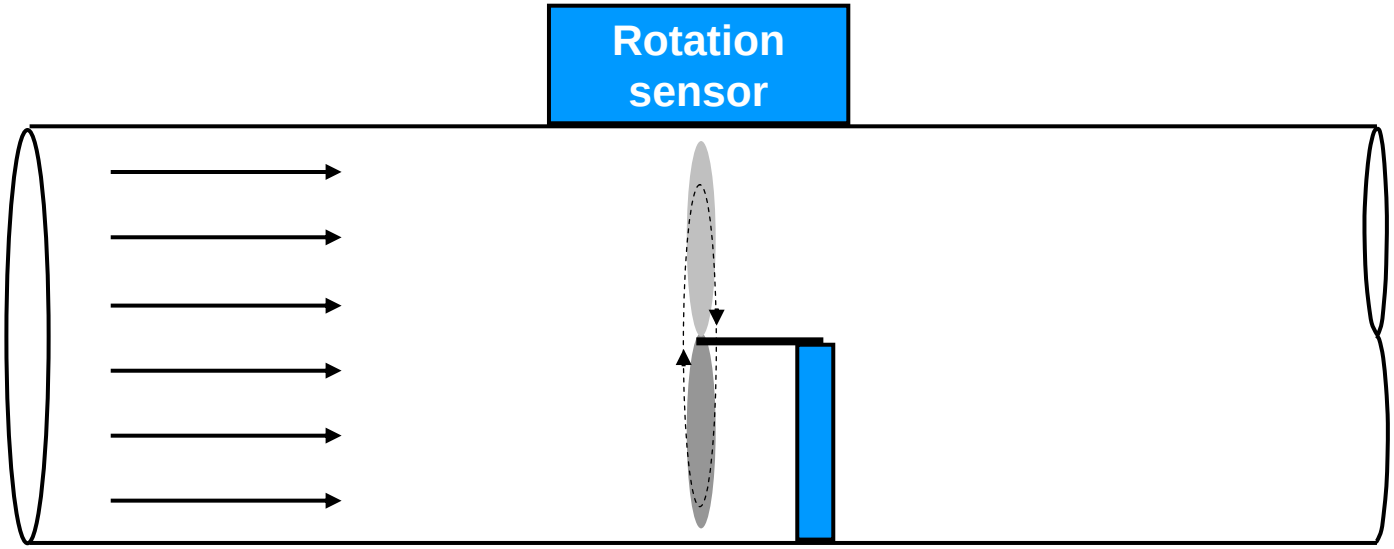
Issues:
• Rotameter design is sensitive to fluid characteristics, e.g., viscosity, which changes with temperature

$$Q = V_a A_a$$

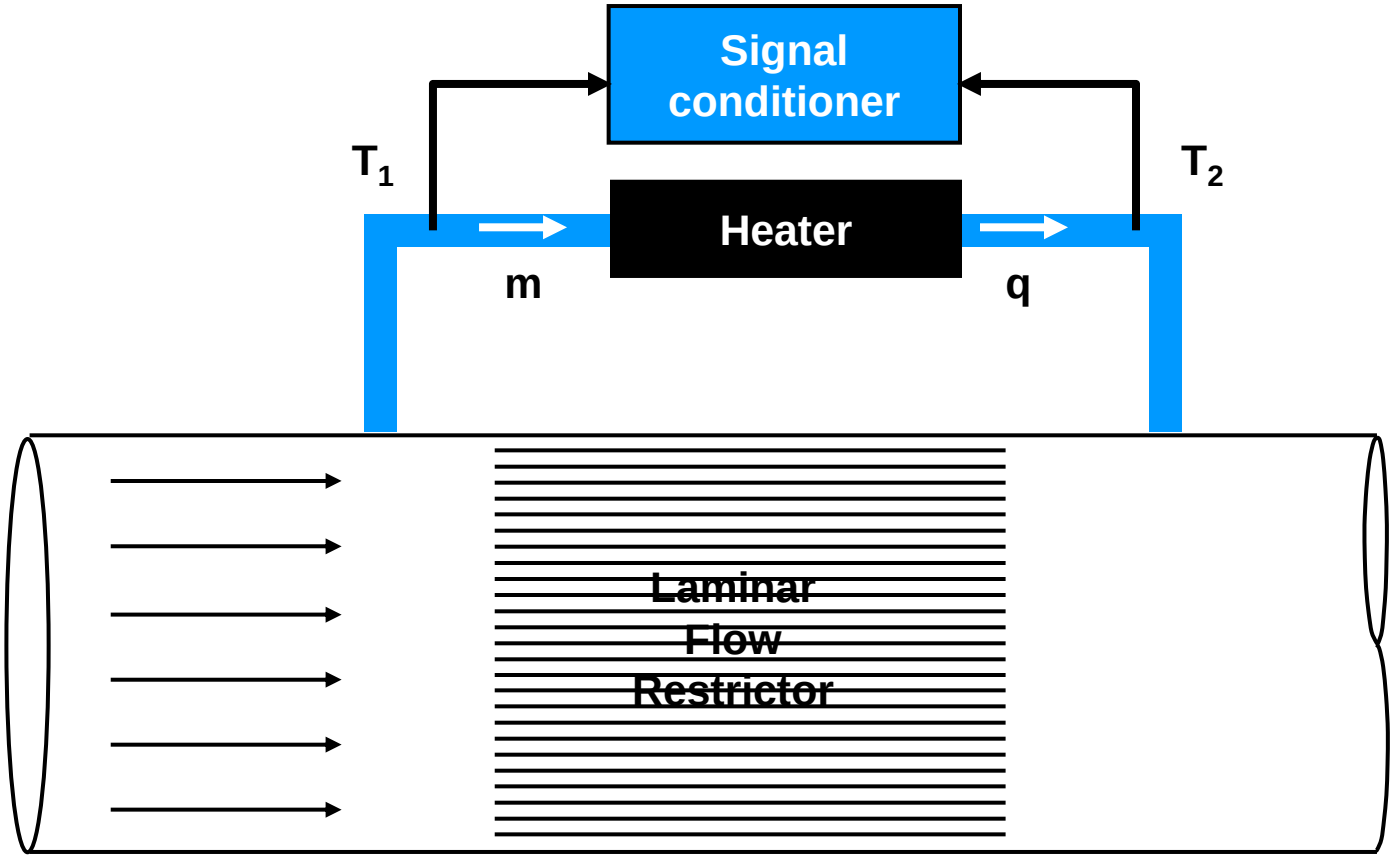


Design float so V_a is constant
Design flowmeter so A_a is linear with y

Turbine Flowmeters



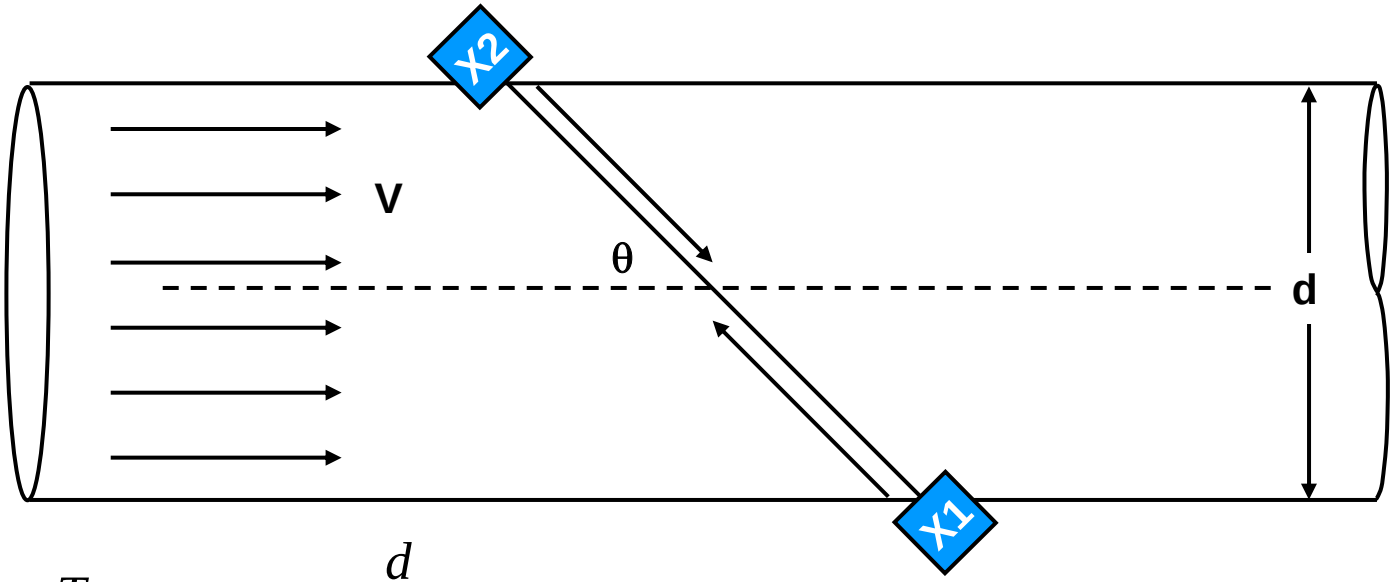
Thermal Mass Flowmeters



$$\dot{m} = \frac{q}{c_p \left(T_2 - T_1 \right)}$$

Ultrasonic Transit Time Flowmeters

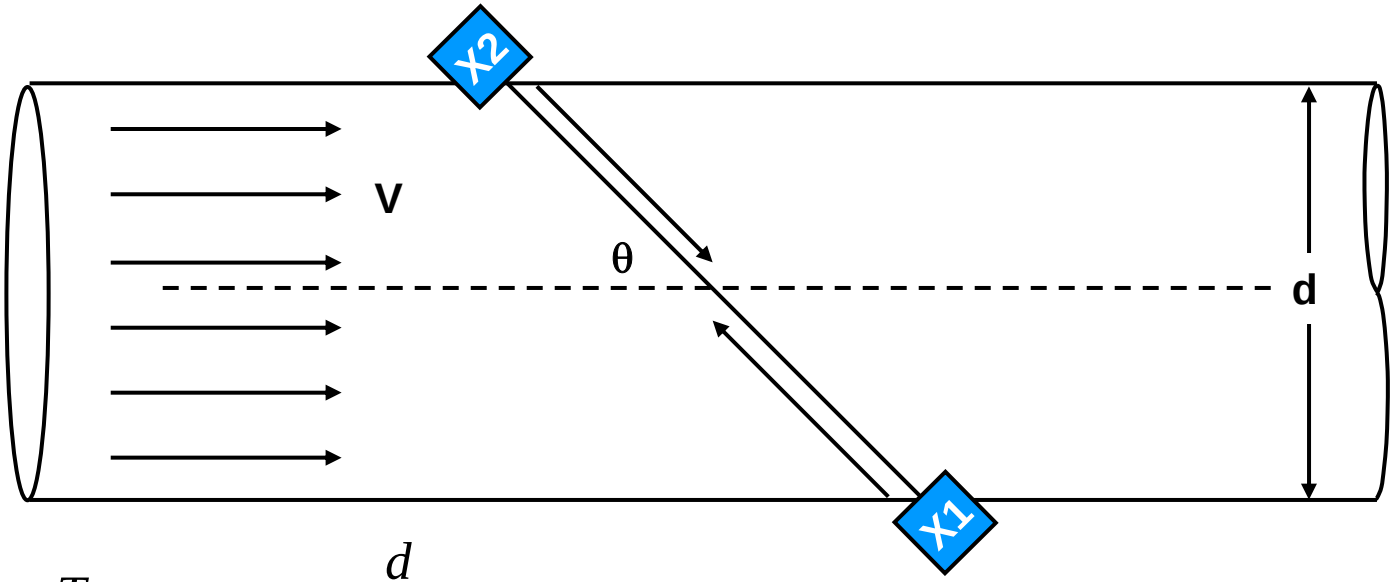
- With speed of sound in liquid, C=f(T, P, ρ)



$$T_{1,2} = \frac{d}{\sin(\theta)\left(C + V\cos(\theta)\right)}$$

Ultrasonic Transit Time Flowmeters

- Measuring transit time in both directions makes measurement independent of speed of sound in liquid

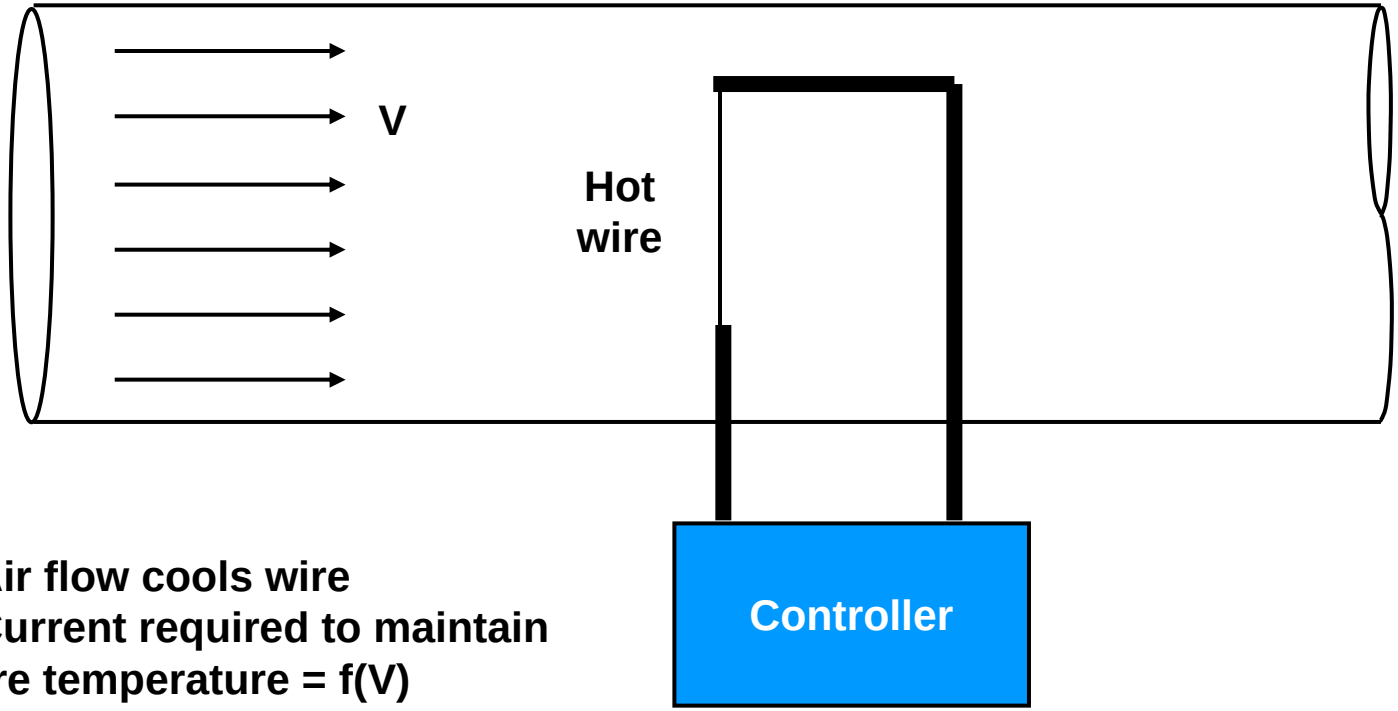


$$T_{1,2} = \frac{d}{\sin(\theta)\left(C + V\cos(\theta)\right)}$$

$$T_{2,1} = \frac{d}{\sin(\theta)\left(C - V\cos(\theta)\right)}$$

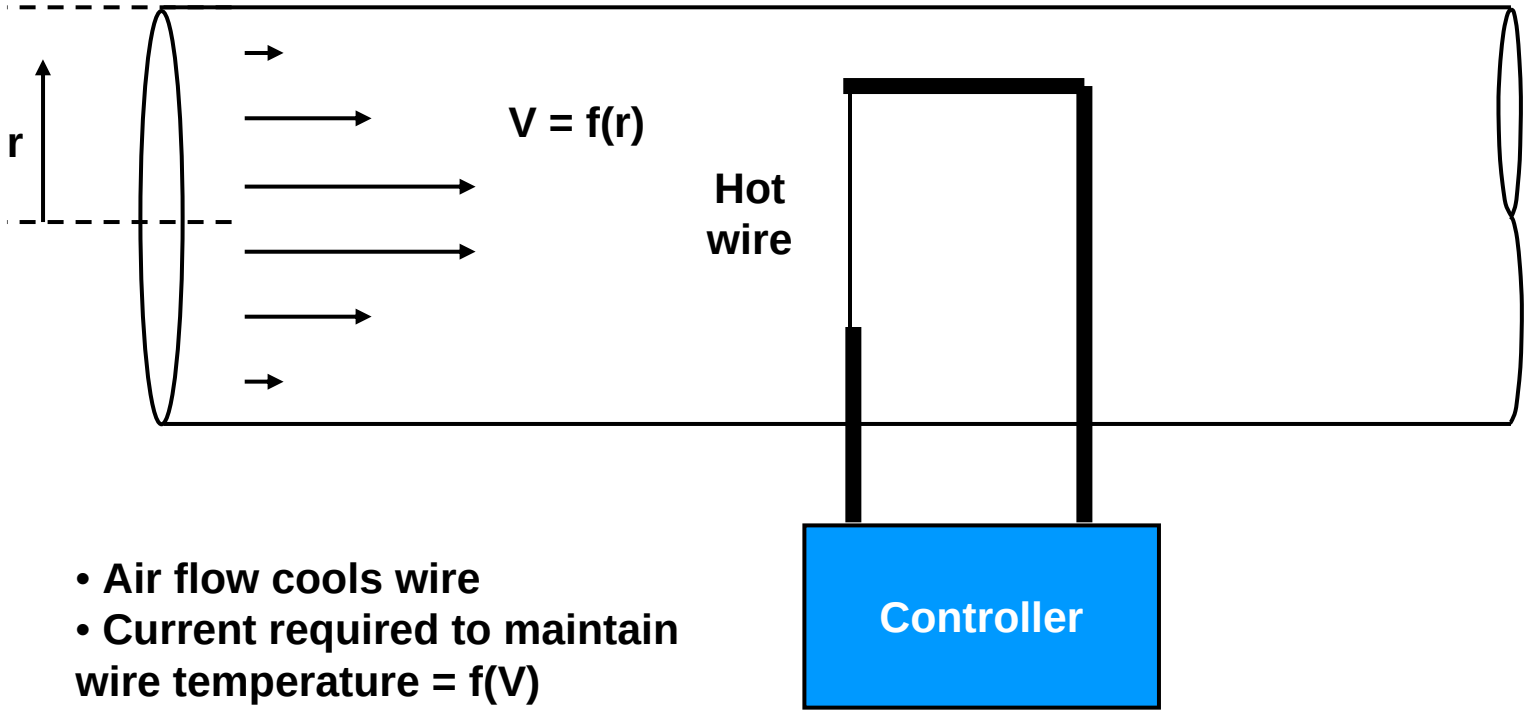
$$\frac{T_{1,2} - T_{2,1}}{T_{2,1}T_{2,1}} = \frac{2V\sin\theta\cos\theta}{d}$$

Hot-wire Air Mass Flowmeter



- **Air flow cools wire**
- **Current required to maintain wire temperature = f(V)**

Hot-wire Air Mass Flowmeter



- **Air flow cools wire**
- **Current required to maintain wire temperature = f(V)**

Next time

- Finish measurement sensors