Design IV

E232 Spring 07

Class 21

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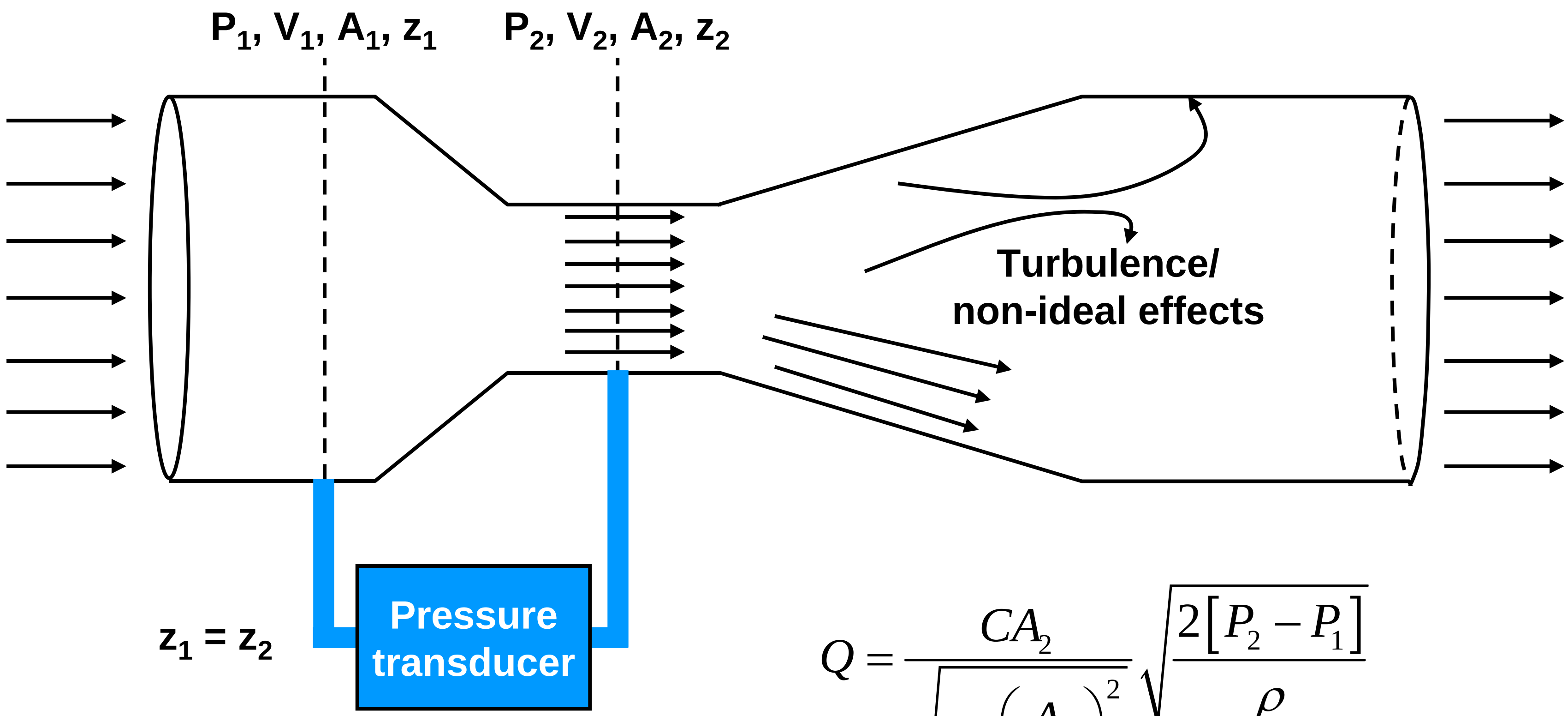
Venturi Tube



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

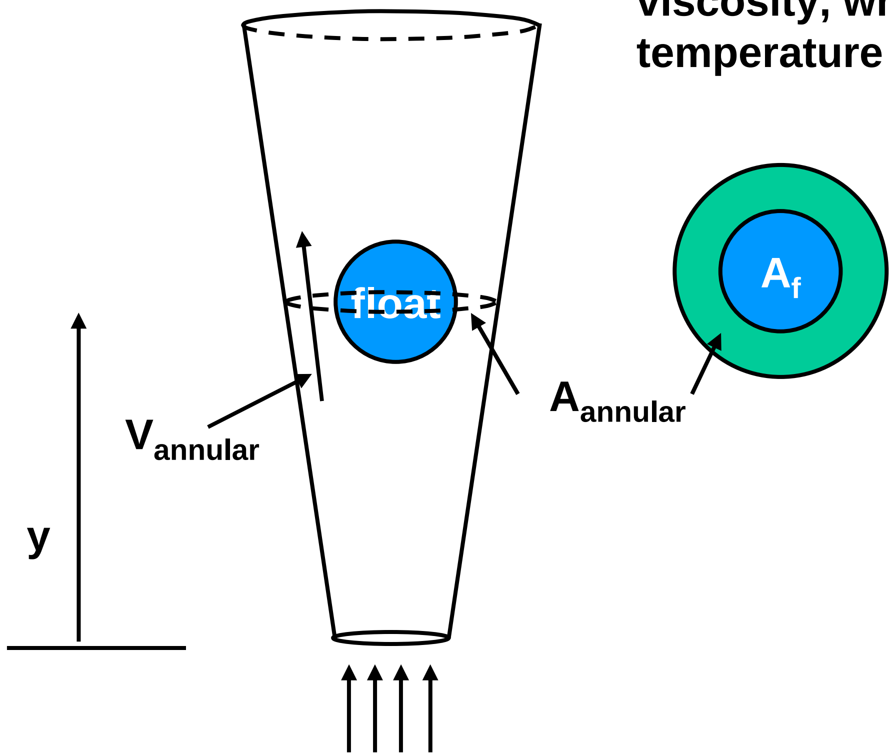
Variable-Area Flowmeters

- Rotameter

Issues:

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

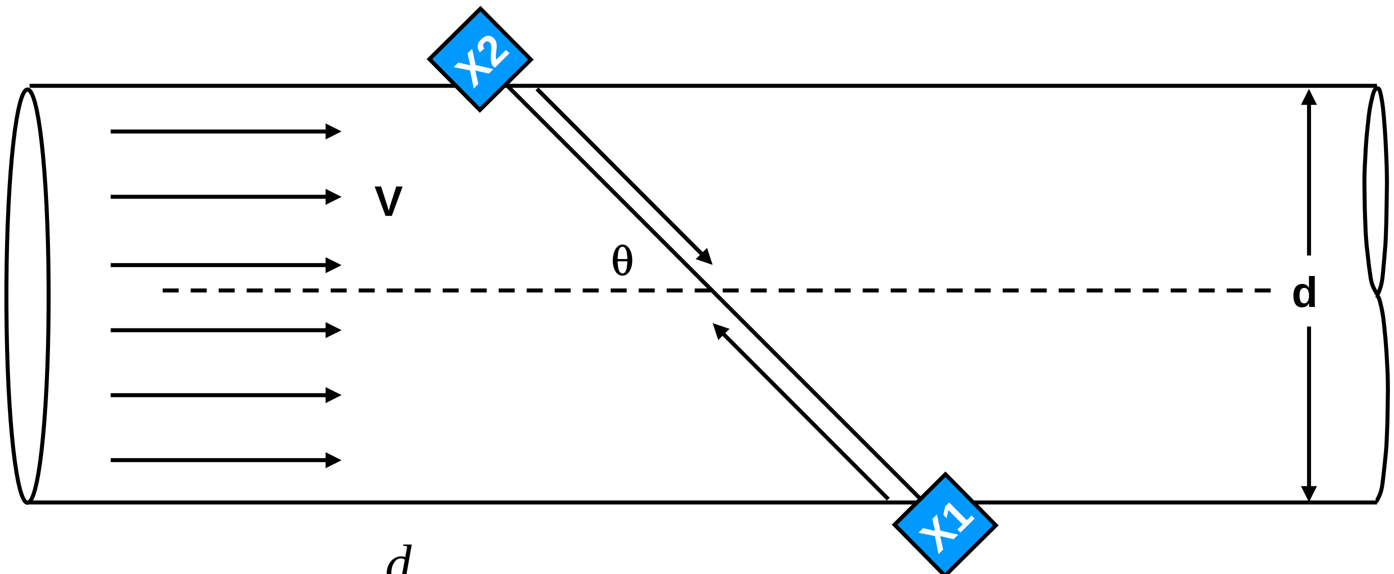
$$Q = V_a A_a$$



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

Ultrasonic Transit Time Flowmeters

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

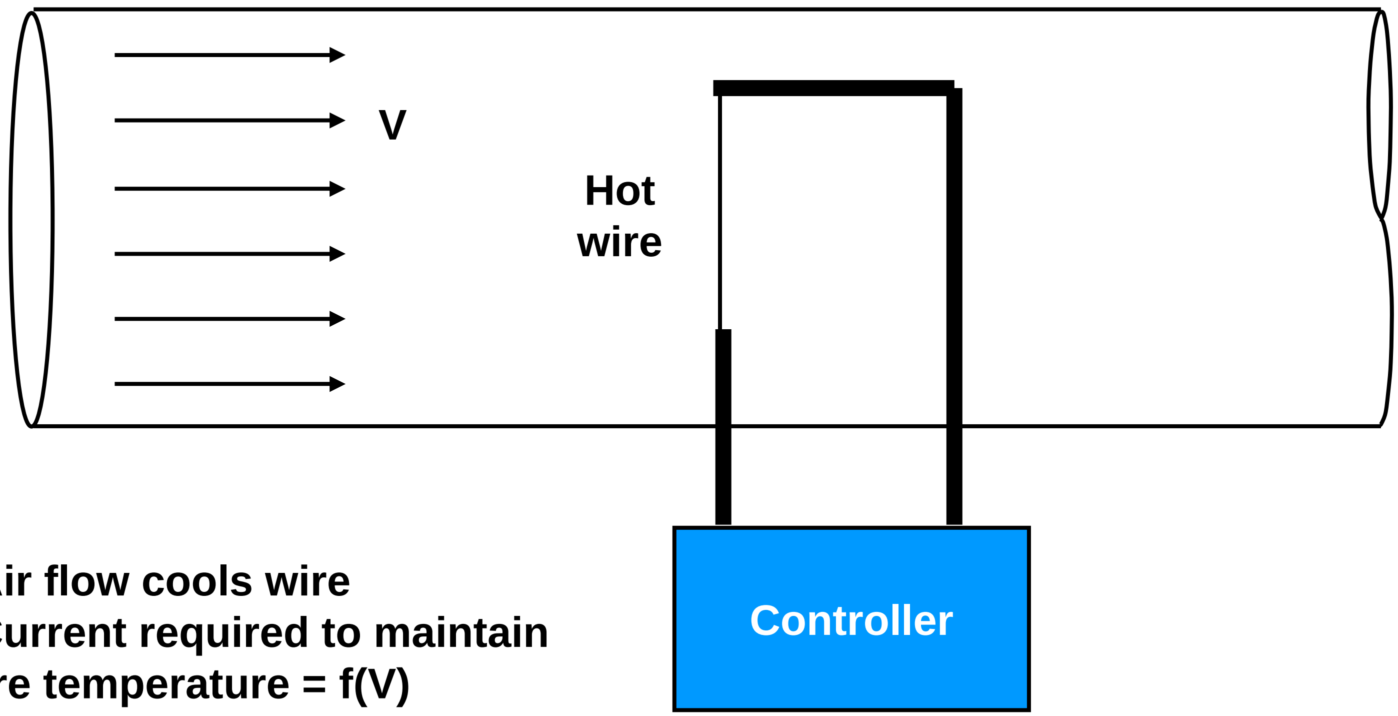


$$T_{1,2} = \frac{d}{\sin(\theta)\left(C + V\cos(\theta)\right)}$$

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

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

Hot-wire Air Mass Flowmeter

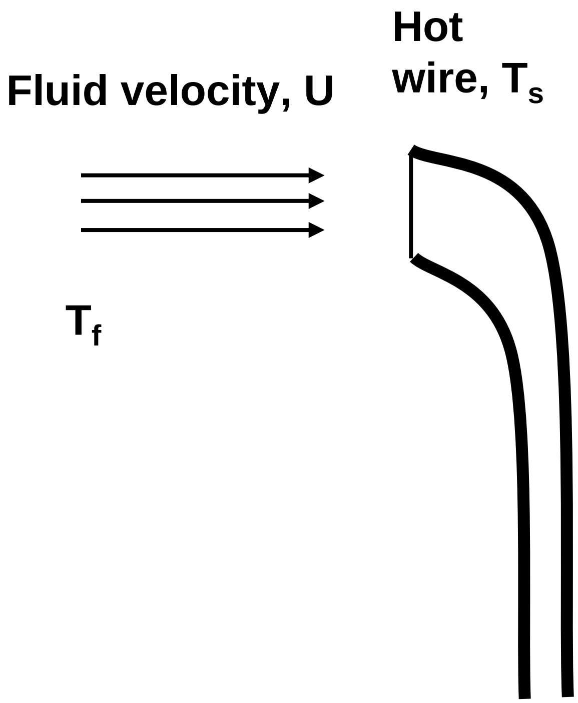


- **Air flow cools wire**
- **Current required to maintain wire temperature = f(V)**

Today's topics

- Measurement sensors
  - **Fluid Flow Rate**
  - **Fluid Velocity**
  - **Fluid Level**

Fluid Velocity Sensor – Hot-Wire Anemometer

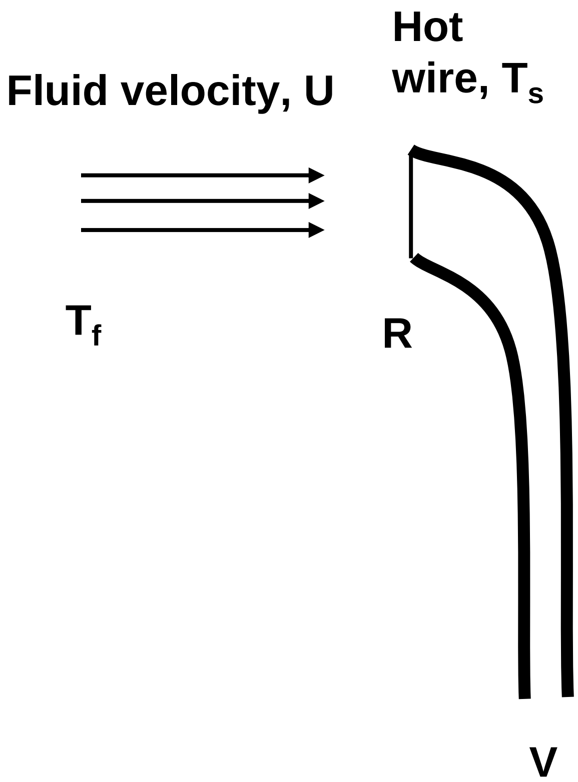


Heat loss:

$$q = \left(T_s - T_f\right)\left(A_0 + B_0\sqrt{\mathrm{Re}}\right)$$

$$\mathrm{Re} = \frac{\rho U D}{\mu}$$

Fluid Velocity Sensor – Hot-Wire Anemometer



Heat loss:

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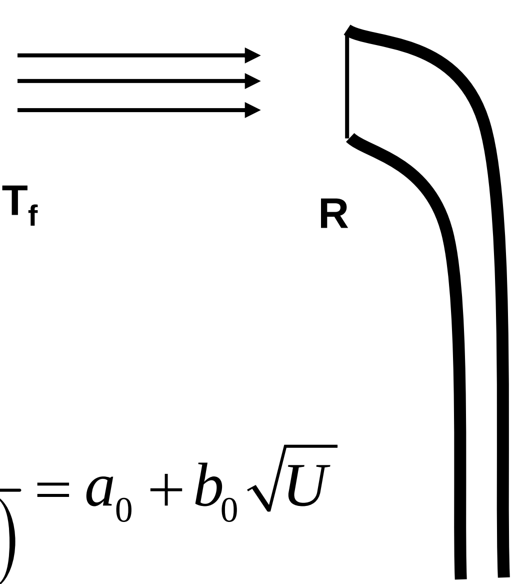
Heat gain:

$$q = \frac{V^2}{R}$$

Fluid Velocity Sensor – Hot-Wire Anemometer



Heat loss:

$$q = \left(T_s - T_f\right)\left(A_0 + B_0\sqrt{\mathrm{Re}}\right)$$

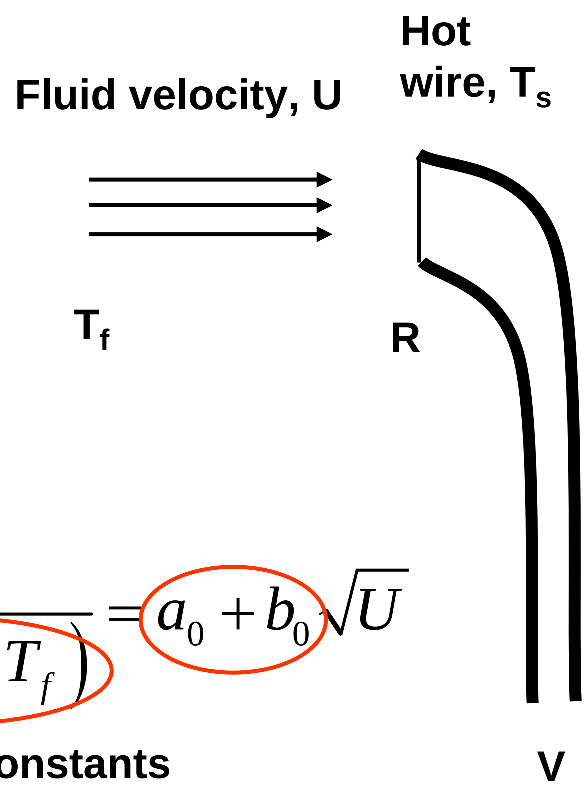
$$\mathrm{Re} = \frac{\rho U D}{\mu}$$

Heat gain:

$$q = \frac{V^2}{R}$$

$$\frac{V^2}{R\left(T_s - T_f\right)} = a_0 + b_0\sqrt{U}$$

Fluid Velocity Sensor – Hot-Wire Anemometer



$$\frac{V^2}{R\left(T_s - T_f\right)} = a_0 + b_0\sqrt{U}$$

constants

Heat loss:

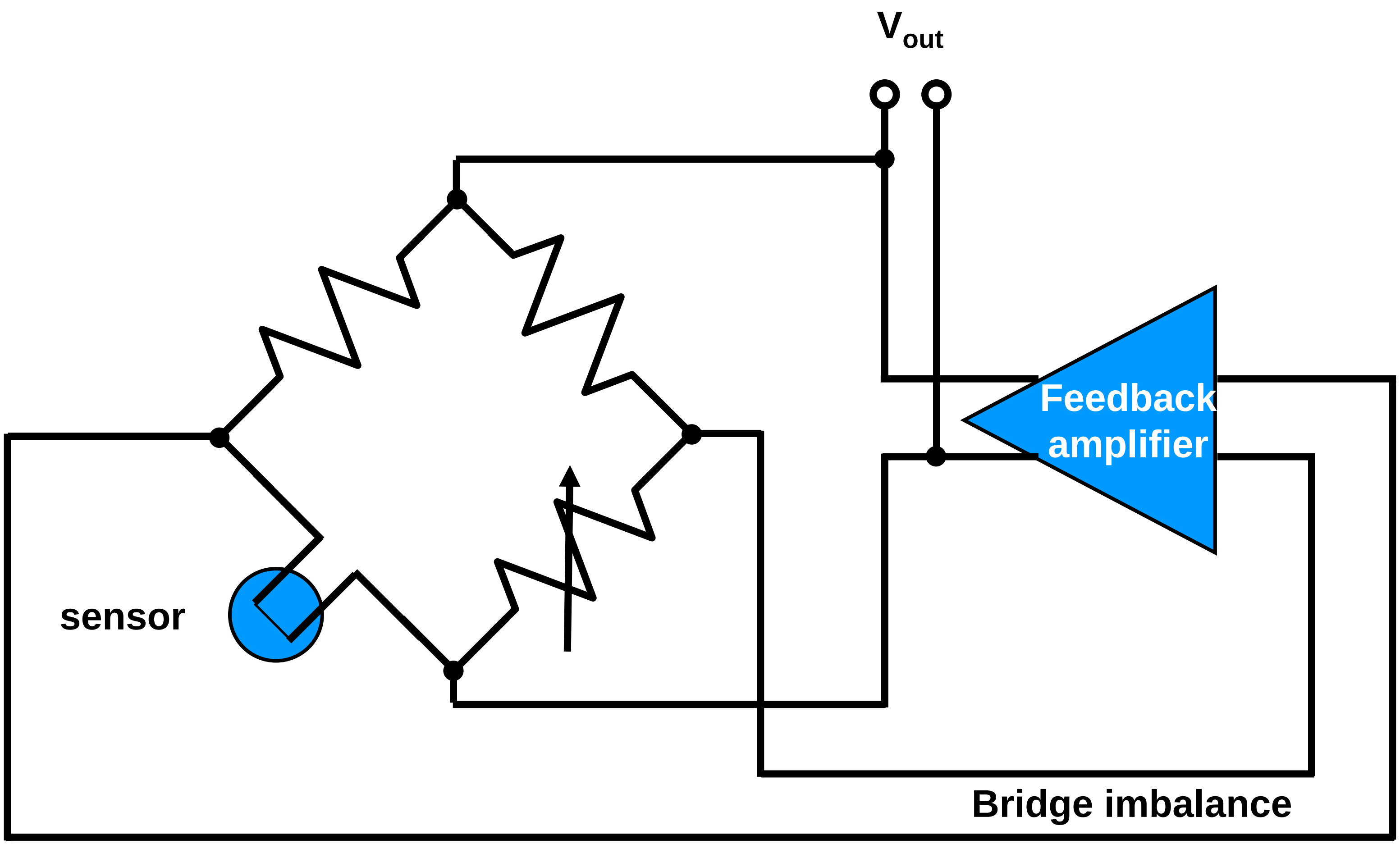
$$q = \left(T_s - T_f\right)\left(A_0 + B_0\sqrt{\mathrm{Re}}\right)$$

$$\mathrm{Re} = \frac{\rho U D}{\mu}$$

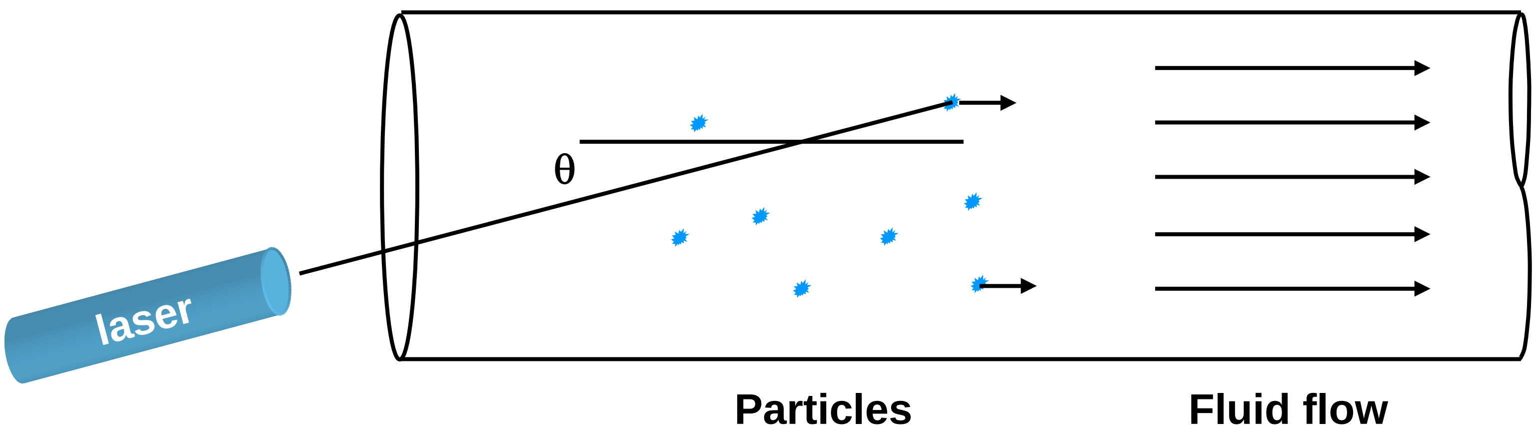
Heat gain:

$$q = \frac{V^2}{R}$$

Application of Hot-wire Anemometer

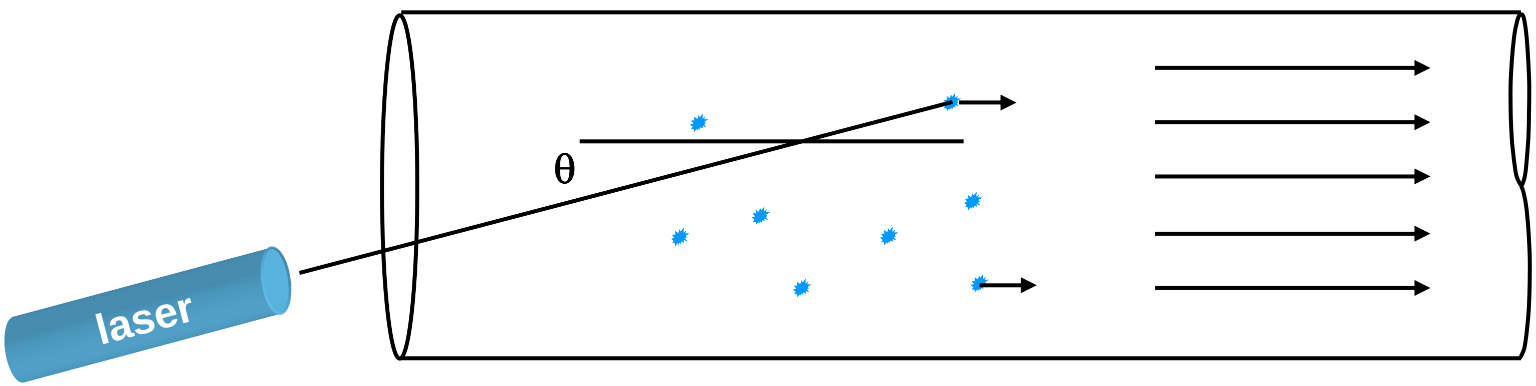


Fluid Velocity Sensor – Laser Doppler



$$f_D = \frac{2V\cos(\theta)}{\lambda} = \frac{2V\cos(\theta)}{c} f_0$$

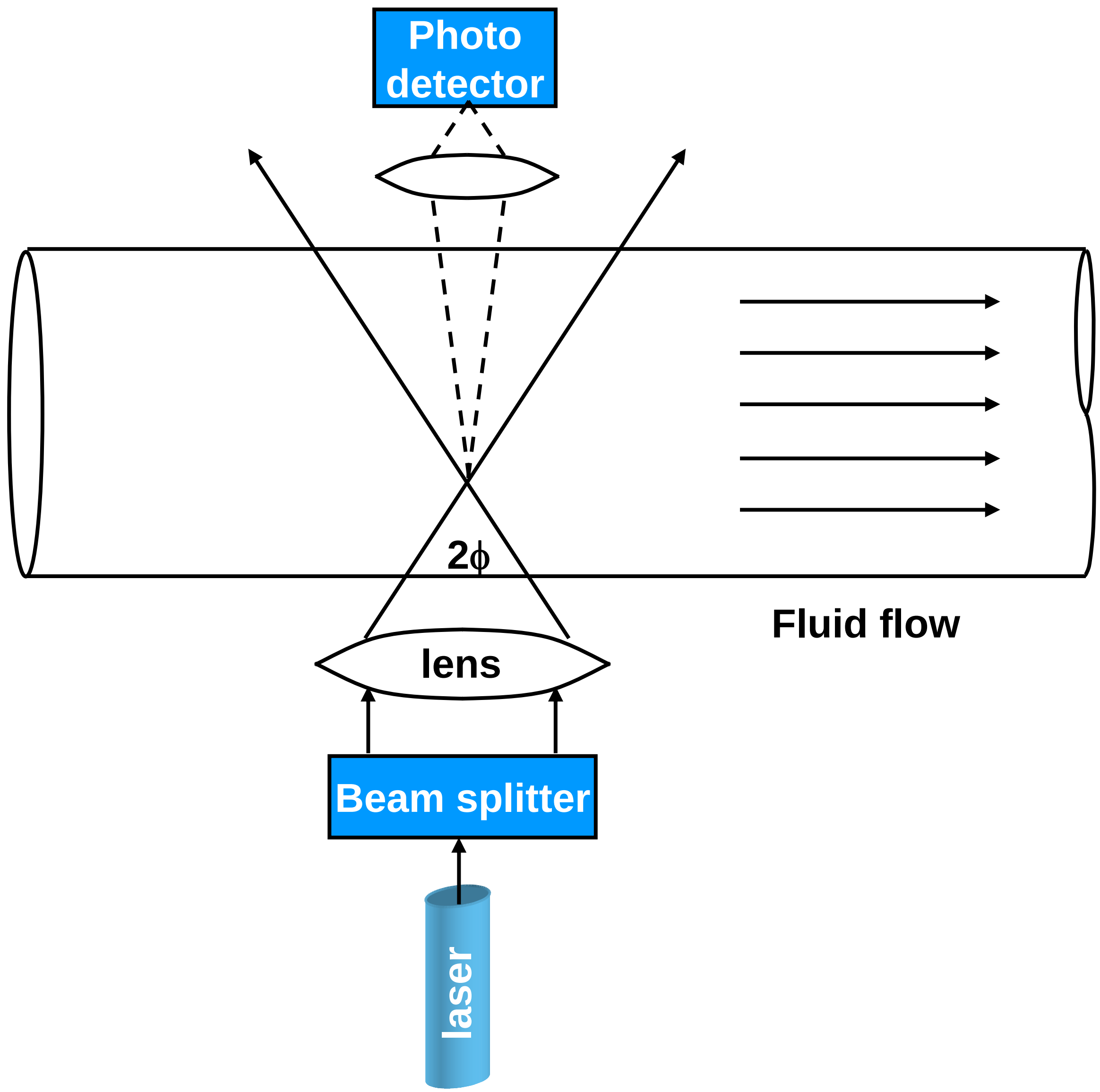
Fluid Velocity Sensor – Laser Doppler



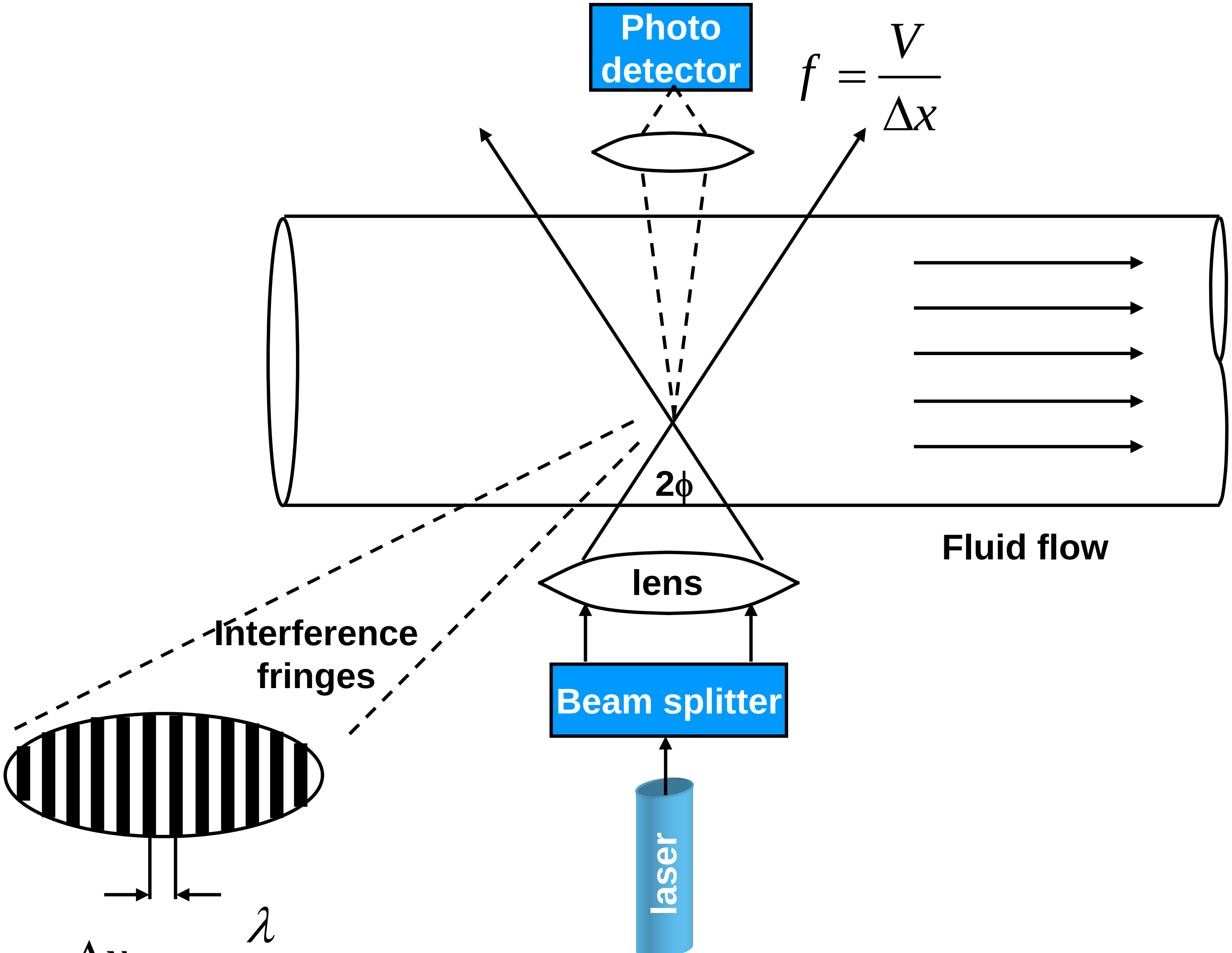
$$f_D = \frac{2V\cos(\theta)}{\lambda} = \frac{2V\cos(\theta)}{c} f_0$$

For λ = 800 μm,
V = 100 m/sec
f_0 = 4 x 10^{11} Hz
f_D = 250 kHz

Fluid Velocity Sensor – Dual-Beam Laser Velocimeter



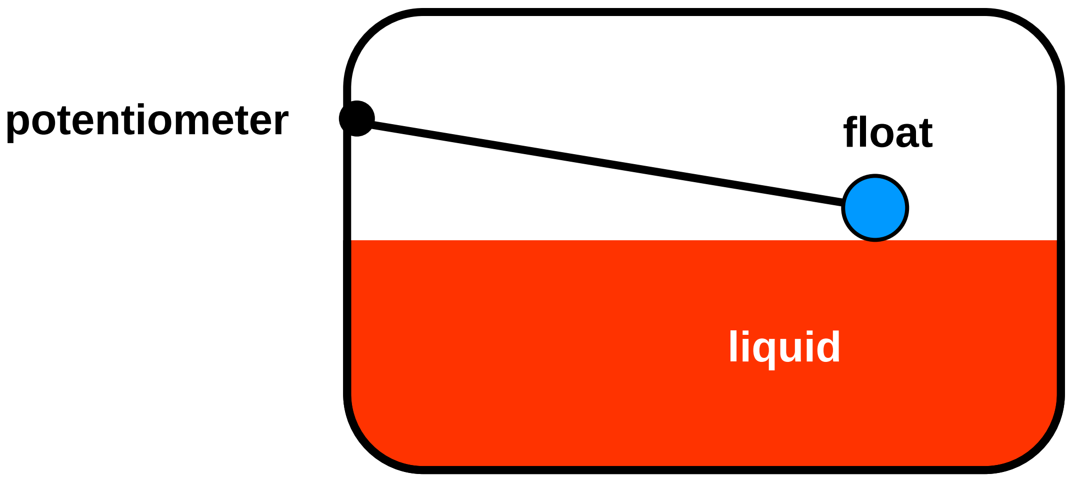
Fluid Velocity Sensor – Dual-Beam Laser Velocimeter



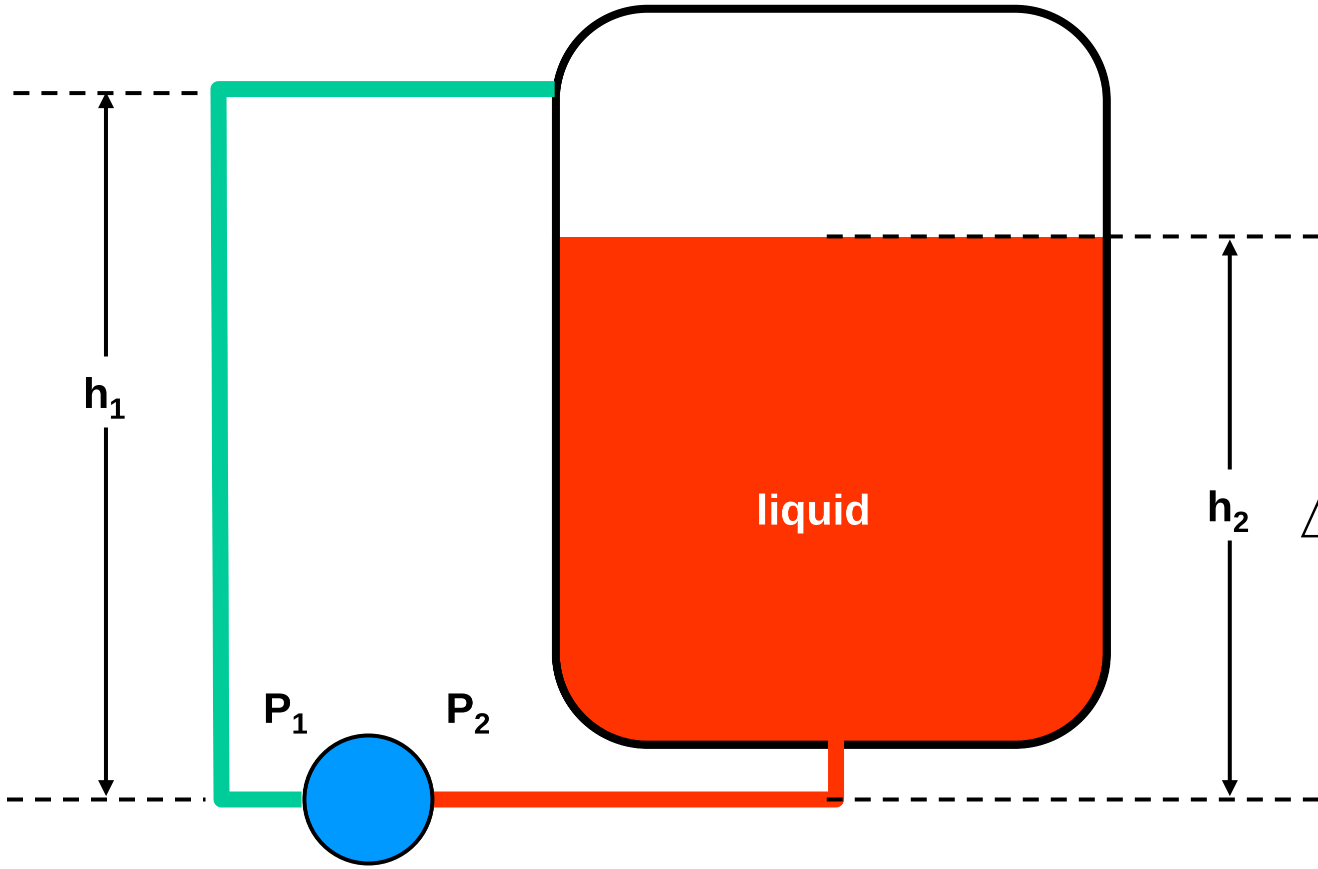
$$f = \frac{V}{\Delta x}$$

$$\Delta x = \frac{\lambda}{2\sin(\phi)}$$

Fluid Level Measurement – Buoyancy Sensors

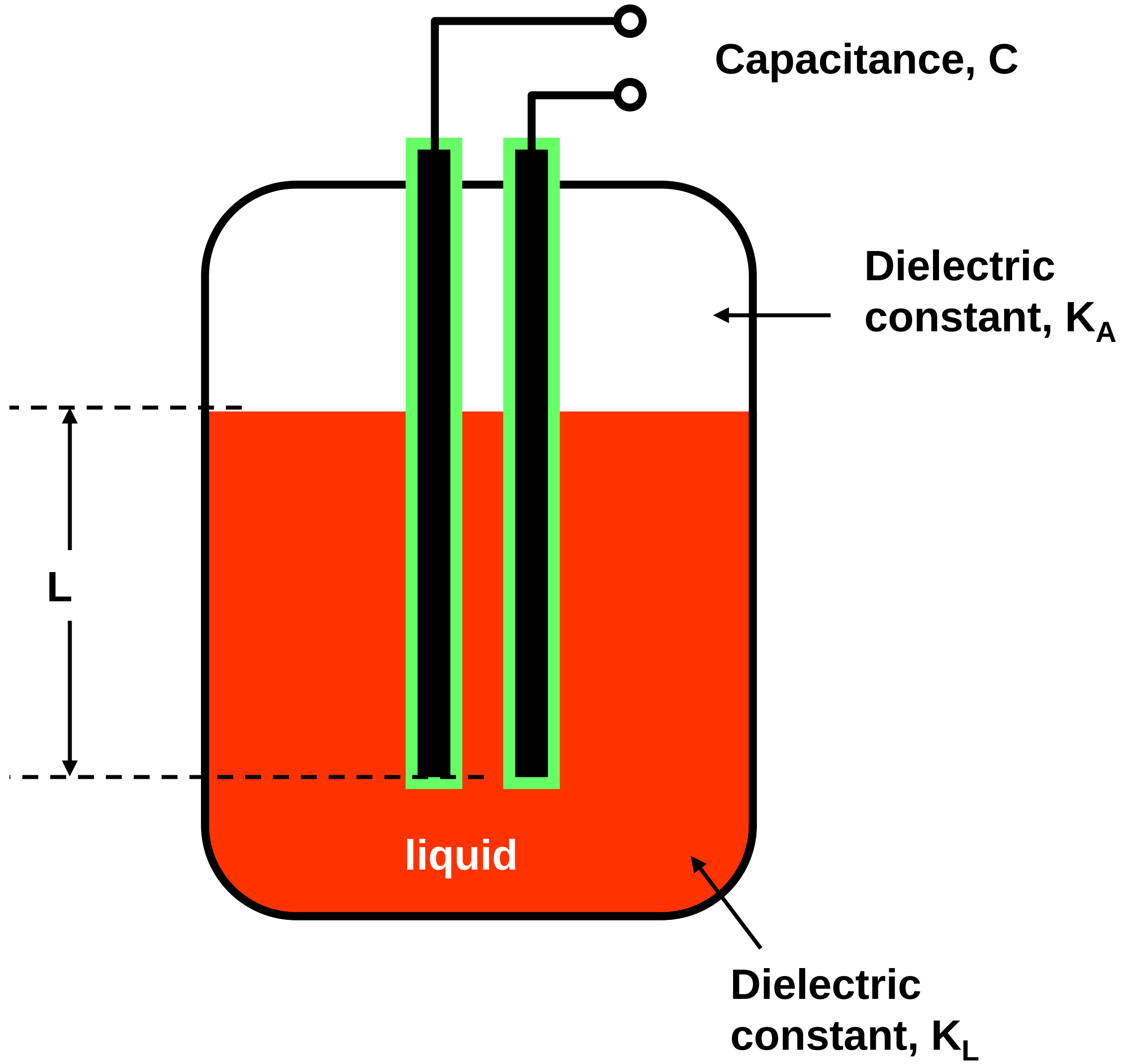


Fluid Level Measurement – Differential Pressure

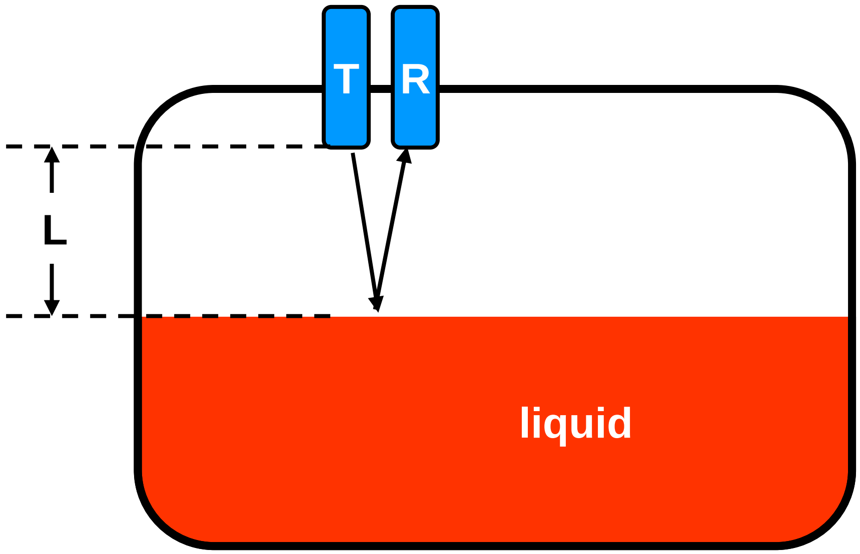


$$\Delta P = \rho g h$$

Fluid Level Measurement – Capacitance Sensors



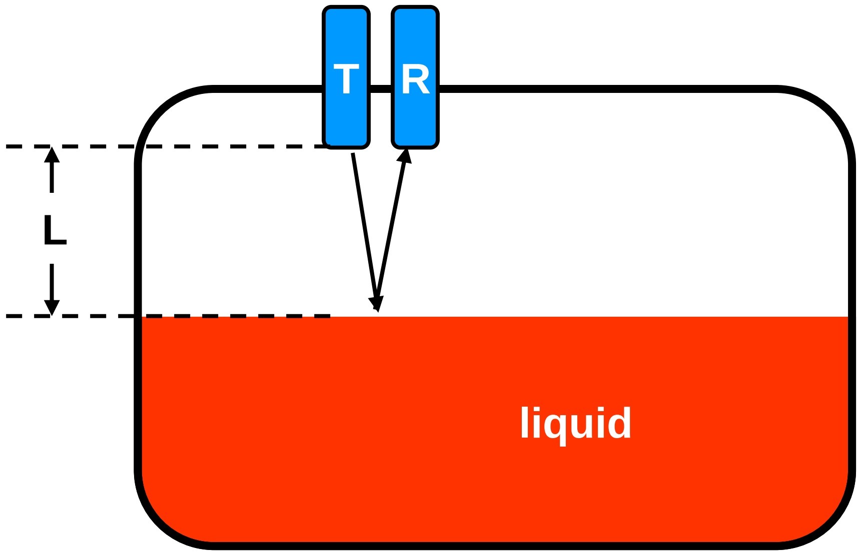
Fluid Level Measurement – Ultrasonic Devices



$$L = \frac{ct}{2}$$

Fluid Level Measurement – Ultrasonic Devices

- Ultrasonic pulse roundtrip time measurement



$$L = \frac{ct}{2}$$

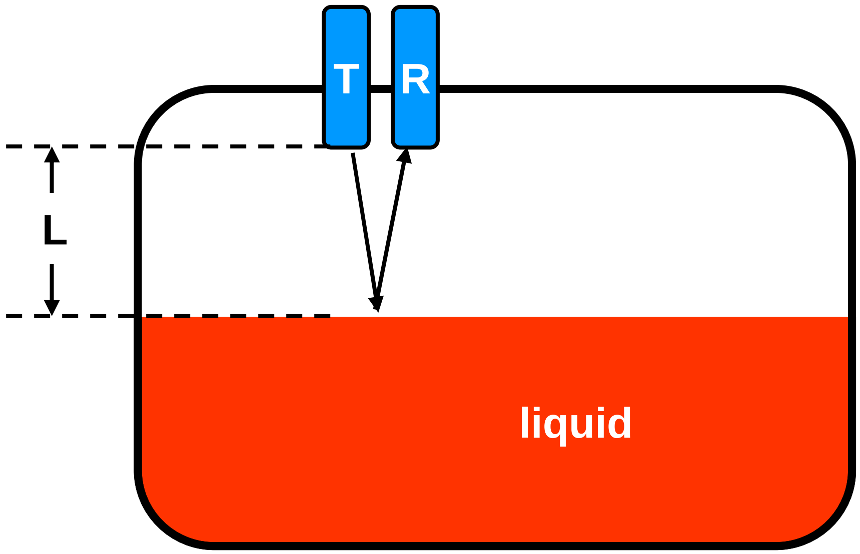
But c=f(T, liquid)

In air, c=1 ft/ms

Fluid Level Measurement – Ultrasonic Devices

- Ultrasonic chirp pulse

$$f(t)=\sin\left(2\pi\left(f_0+\left(\frac{\Delta f}{\Delta\tau}\right)t\right)t\right)$$



$$f_D=\left(\frac{\Delta f}{\Delta\tau}\right)\left(\frac{2L}{c}\right)$$

Next time

- Control systems