Wind Speed

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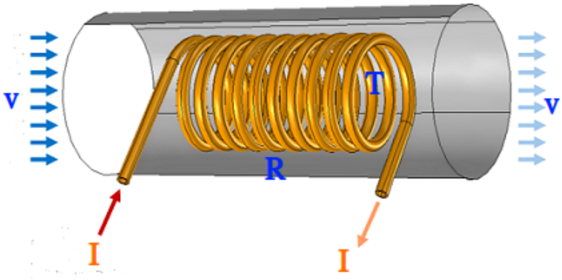
IYPT preparatory seminar

Problem 4: Wind Speed



Let an electric current flow through a coil. When cold air flows over the coil, the coil's temperature will decrease. Investigate how the temperature drop depends on the wind speed. What is the accuracy of this method of measuring the wind speed?

Wind Chill Effect

Cooling effect of wind on coil

Analogous to the wind chill effect: "when cold air flows over the coil, the coil's temperature will decrease".

Qualitative observation

When current I in the coil is kept constant, higher the wind speed v greater is the temperature drop ΔT in the coil, and vice versa.

Quantitative relation?

- Given a source of known wind speeds v, how can we measure temperature drop ΔT?
- What is the quantitative relation between v and ΔT ?

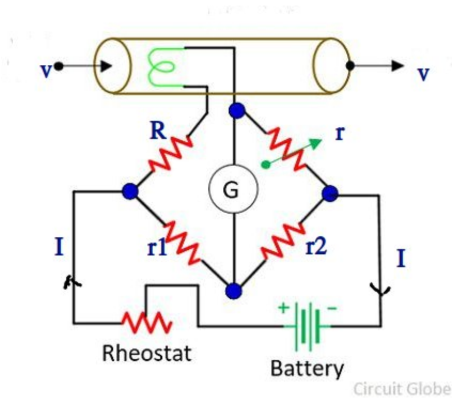
Finding temperature drop ΔT of the coil

As the temperature in coil drops, resistance of the coil decreases, we can use this effect to measure temperature drop.

Relation between $\Delta T = T_0 - T$ and resistance R

- $R = \rho(T)\ L/A$, where $\rho(T)$ is the resistivity of coil material at a given temperature T; length of the coil is L and cross section area is A.
- Resistivity of coil material $\rho(T) \approxeq \rho_0[1 - \alpha\ \Delta T]$, if temperature drop is not very large, i.e. $\Delta T << T$.
- Then we have, $\Delta T \approxeq \frac{1}{\alpha}\left(1 - \frac{R}{R_0}\right)$.

Measuring resistance R of the coil



Wheatstone bridge (balanced)

$$R = \left(\frac{r_1}{r_2}\right)\ r$$

Approx. Model for ΔT in terms wind speed v

In terms of known and measurable quantities

$$\Delta T \approxeq \frac{1}{\alpha}\left(1 - \frac{r}{r_0}\right).$$

Wind speed v (meter/sec)	**Temperature drop** ΔT ($^\circ C$)
0	0
v_1	ΔT_1
v_2	ΔT_2
.	.
.	.
.	.
v_n	ΔT_n

Finally, we plot and interpolate the plot points to get some model $\Delta T = f_{model}(v)$.

Making instrument for measuring wind speed

Once we have a good model we can use the relationship

$$v = f_{model}^{-1}\left(\Delta T\right) = f_{model}^{-1}\left\{\frac{1}{\alpha}\left(1 - \frac{r}{r_0}\right)\right\}$$

to measure wind speeds by measuring resistance r in the circuit.

Constant current anemometer (CCA)

Principles and method outlined towards solving this problem (or some of its variants) are used to build hot air anemometers, an instrument used for measuring wind speed as a function of temperature.

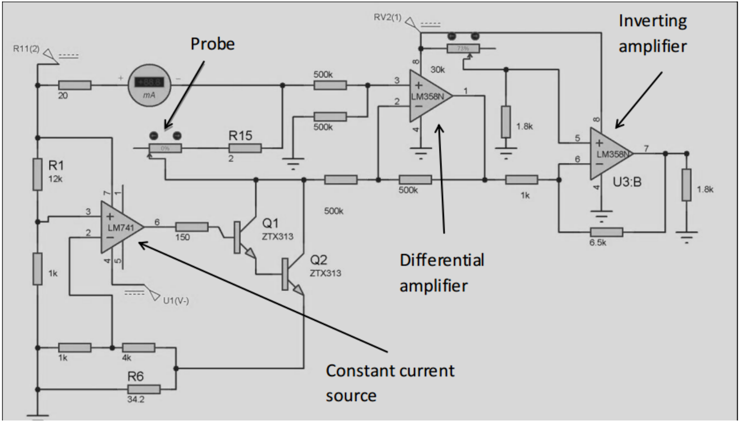
Picture of a commercially available hot wire anemometer

Advantages and range of hot wire anemometer (HWA)

- A HWA has no moving parts, which is good, and its small mass means fast response. However, it requires complicated equations to relate the desired variable of gas flow to the measured current through the heated element or to the resistance of that element.
- HWAs are especially useful over the range of about 0.1 meter/sec to 25 meter/sec flow; nominal probe resistance at 25 C is usually in the single-digit ohms.

Accuracy of hot wire anemometer (HWA)

Using an HWA for approximate measurements, with 2% to 5% accuracy, is not difficult, but using it to read better than 1% requires extra planning, analysis, and attention to details. With today's electronics, the basic interface is not difficult to build.



THANK YOU