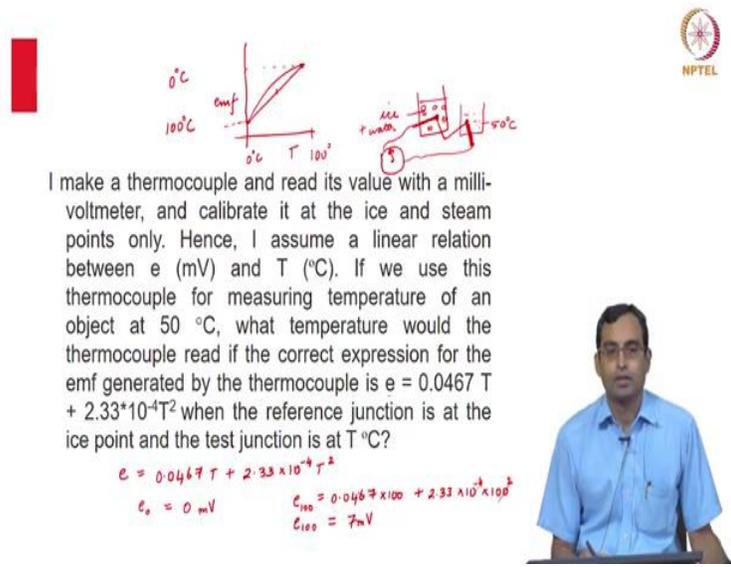**Thermodynamics**
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Lecture - 19
Tutorial problem on 'Methods of temperature measurement'

(Refer Slide Time: 0:15)

Figure 1.

Solution of the problem in Fig. 1:

The thermocouple is calibrated at ice and steam points.

Assuming linear relationship between e and T, we can write,

$e = mT + C,$

where m is the slope and C is a constant.

Let's say $e = e_0$ at T = 0°C and $e = e_{100}$ at T = 100 °C

Hence, $e_0 = m \times 0 + C$ → $e_0 = C$ and $e_{100} = m \times 100 + C$ → $m = e_{100} - e_0/100$

Hence, $e = \frac{e_{100}-e_0}{100}T + e_0$.........(1)

We can find the values of e_{100} and e_0 from the correct expression for the emf generated by the thermocouple because at the points of calibration the emf values shown by the equation 1 (obtained assuming linear relationship between e and T) and the correct equation must match.

Hence, from the correct equation, $e_0 = 0.0467 \times 0 + 2.33 \times 10^{-4} \times 0^2 = 0\ mV$ and $e_{100} = 0.0467 \times 100 + 2.33 \times 10^{-4} \times 100^2 = 7\ mV$

Now, for a temperature of 50 °C, emf given by the correct equation is,

$e = 0.0467 \times 50 + 2.33 \times 10^{-4} \times 50^2 = 2.91\ mV$ (emf given by equation 1 would be 3.5 for T = 50 °C)

We are asked to find out the temperature given by equation 1 for e = 2.91 mV

Equation 1 implies,

$$2.91 = \frac{7-0}{100} T + 0 \ \to\ T = 41.5\ °C$$

Hence, the thermocouple would read a temperature of 41.5 °C instead of 50 °C as we don't know the correct relationship between emf and T and we assumed the linear relationship between emf and T. Hence, it is recommended that the calibration should be carried out over a wide range of temperatures to get enough data so that the relationship between emf and T is known to a significant degree of accuracy.

$T = 50°C \quad e_{50} = ?$

$e_{50} = 0.0467 \times 50 + 2.33 \times 10^{-4} \times 50^2$

$e_{50} = 2.91 \, mV$

$e = 2.91 \, mV$
$50°C$

$e = 0.0467 \times T + 2.33 \times 10^{-4} T^2$

$e = mT + c$

$T = 0°C, \quad e = e_0$

$e = \dfrac{7-0}{100} T + 0$

$0 \, mV = e_0 = 0 \times T + c$

$\Rightarrow c = e_0$

$e = 0.07 \, T$

$T = 100°C, \quad e = e_{100}$

$2.91 = 0.07 \, T$

$7 \, mV = e_{100} = m \times 100 + e_0$

$T = \dfrac{2.91}{0.07} = 41.5 °C$

$m = \dfrac{e_{100} - e_0}{100}$

$e = \dfrac{e_{100} - e_0}{100} T + e_0$

$0°C$
$100°C$

emf

$0°C \quad T \quad 100°$

$+ \text{ water} \quad 50°C$

I make a thermocouple and read its value with a milli-voltmeter, and calibrate it at the ice and steam points only. Hence, I assume a linear relation between e (mV) and T (°C). If we use this thermocouple for measuring temperature of an object at 50 °C, what temperature would the thermocouple read if the correct expression for the emf generated by the thermocouple is e = 0.0467 T + 2.33*10⁻⁴T² when the reference junction is at the ice point and the test junction is at T °C?

$e = 0.0467 \, T + 2.33 \times 10^{-4} T^2$

$e_0 = 0 \, mV$

$e_{100} = 0.0467 \times 100 + 2.33 \times 10^{-4} \times 100^2$

$e_{100} = 7 \, mV$