Benha University
Faculty of Engineering (Shoubra)
Electronics and Communications Engineering

ECE 211
Electrical and Electronic Measurements
(2020-2021)

Lecture 10: Sensors and Transducers
Part 2: Velocity, Force, Liquid Level, and Temperature

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Lecture Outline:

5. Velocity Sensors.

6. Force Sensors.

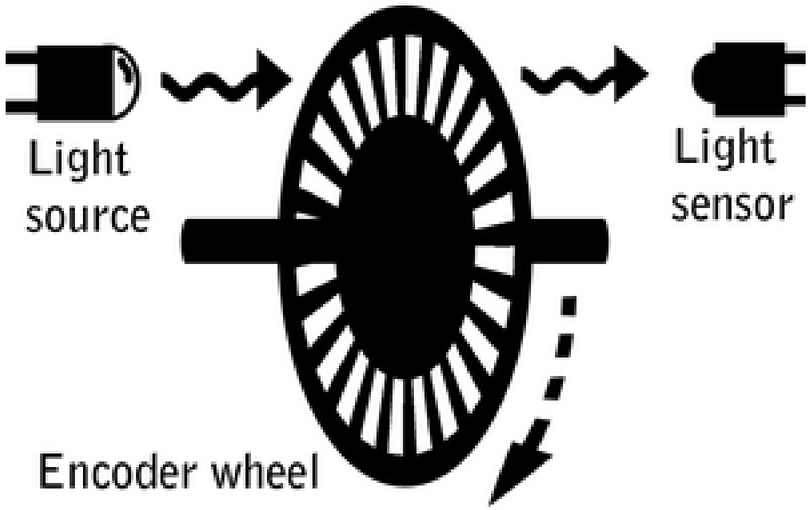
7. Liquid Level Sensors.

8. Temperature Sensors.

5. Velocity Sensors:

[1] Incremental Encoders:

- The incremental encoder used for displacement sensing can be used for the measurement of angular velocity.
- The velocity could be determined by counting the number of pulses produced per second.
- Two tracks of slots could be used to determine the direction of velocity (clockwise or counter clock wise).

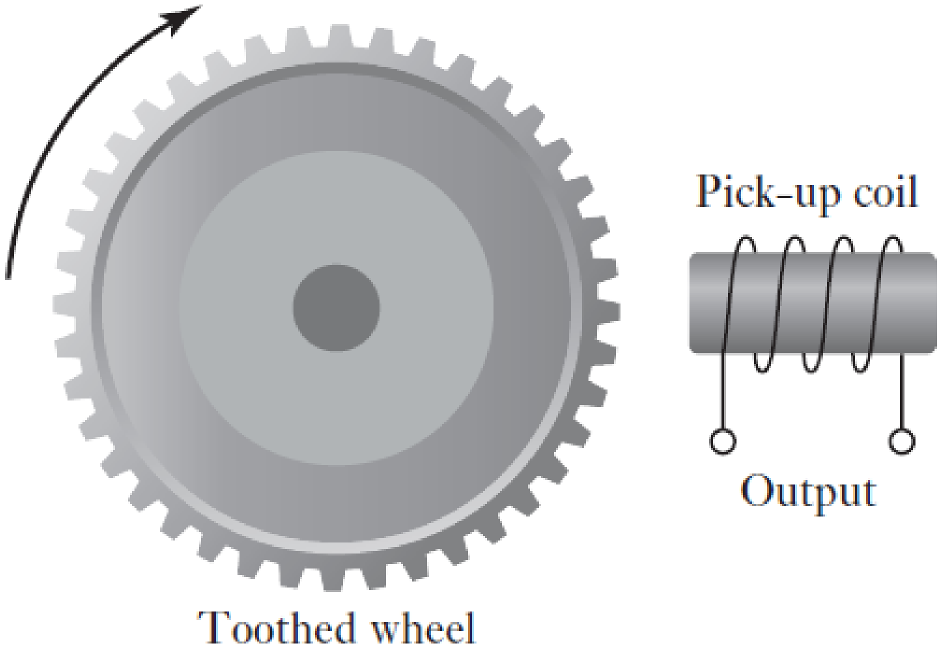


5. Velocity Sensors:
[2] Tachogenerators:

- The tachogenerator is used to measure angular velocity. It has two forms:

1. Variable Reluctance Tachogenerator:

- A toothed wheel of ferromagnetic material is attached to the rotating object.
- A pick-up coil is wound on a permanent magnet.
- As the wheel rotates, the air gap between the coil and the ferromagnetic material changes.
- The flux linked by a pick-up coil will be changed due to the change in the air gap. The resulting cyclic change in the flux produces an alternating e.m.f. in the pickup coil.



5. Velocity Sensors:

[2] Tachogenerators:

The flux ϕ changes with time as:

$$\phi = \phi_0 + \phi_a cos(n\omega t)$$

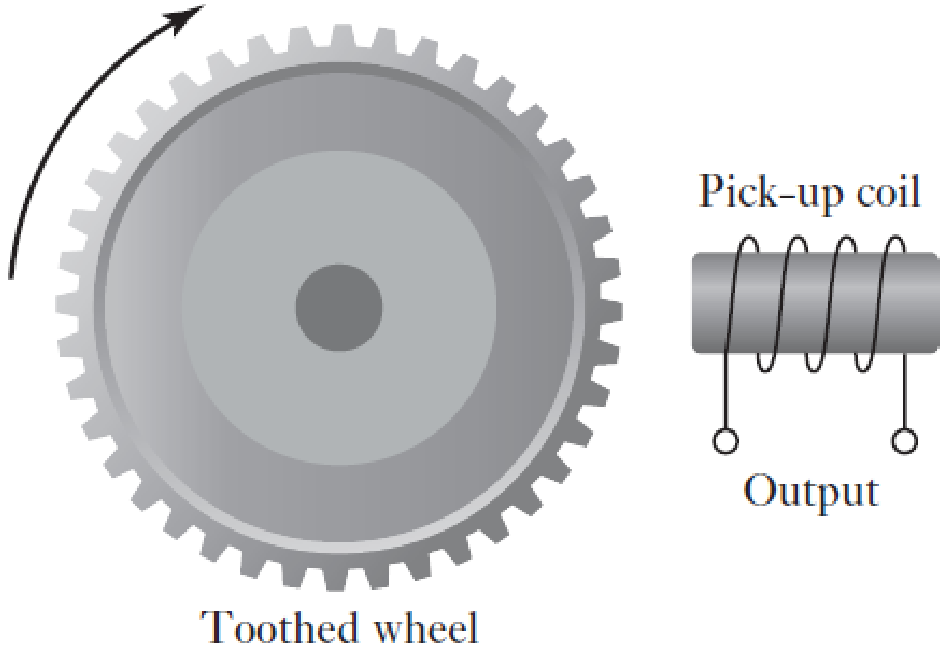
ϕ_0: The mean flux.
ϕ_a: Flux variation amplitude.
ω: Rotation speed
n: No. of teeth.

$$e.m.f = -N\frac{d\phi}{dt} = N\phi_a n\omega sin\omega t$$

N: No. of turns of pickup coil.

$$\boxed{e.m.f = E_{max} sin\omega t} \quad E_{max} \propto \omega$$

The induced e.m.f. could be shaped to a series of pulses that could be counted as a measure of angular velocity.



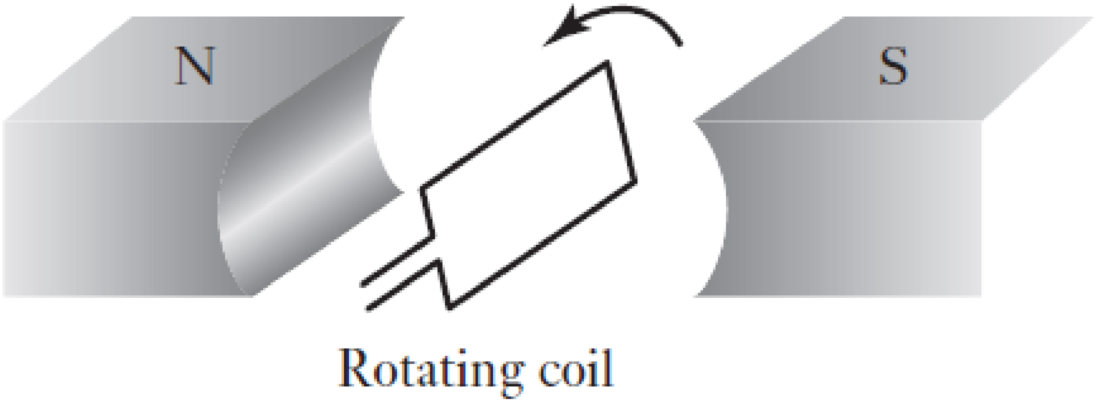
5. Velocity Sensors:

[2] Tachogenerators:

- The tachogenerator is used to measure angular velocity. It has two forms:

2. A.C. Generator:

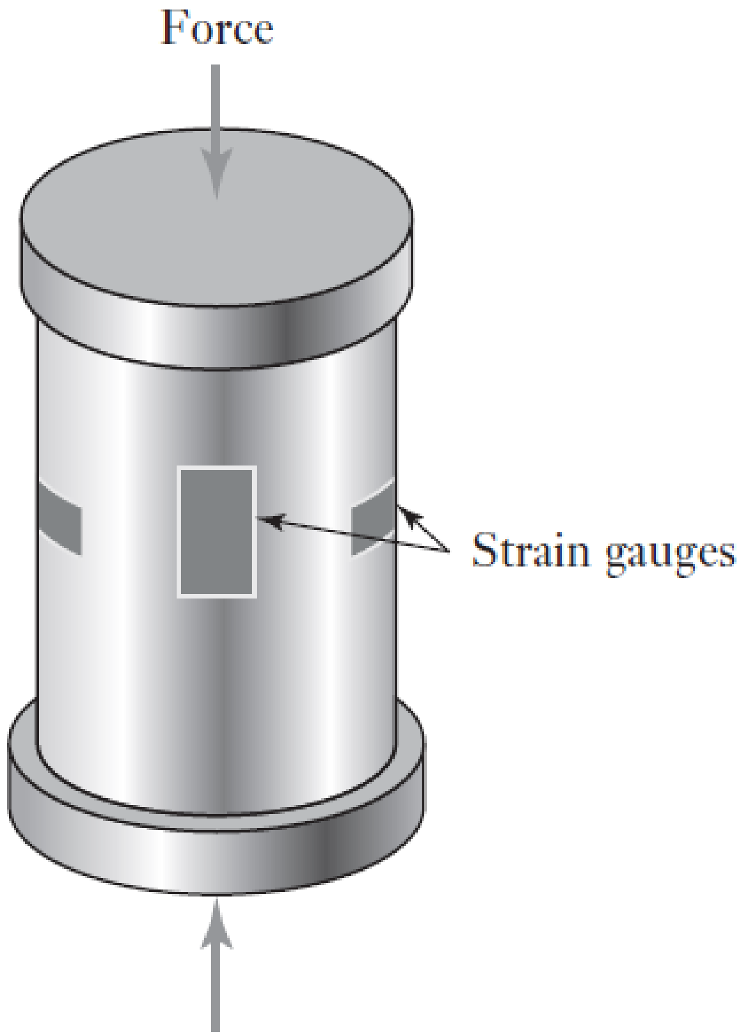
- It consists of a coil, termed the rotor, which rotates with the rotating shaft inside a magnetic field produced by a stationary permanent magnet.
- When the coil rotates, an alternating e.m.f. is induced in it.
- The amplitude or frequency of this alternating e.m.f. can be used as a measure of the angular velocity of the rotor.
- The output may be rectified to give a d.c. voltage with a size which is proportional to the angular velocity.



6. Force Sensors:

[1] Strain Gauge Load Cell:

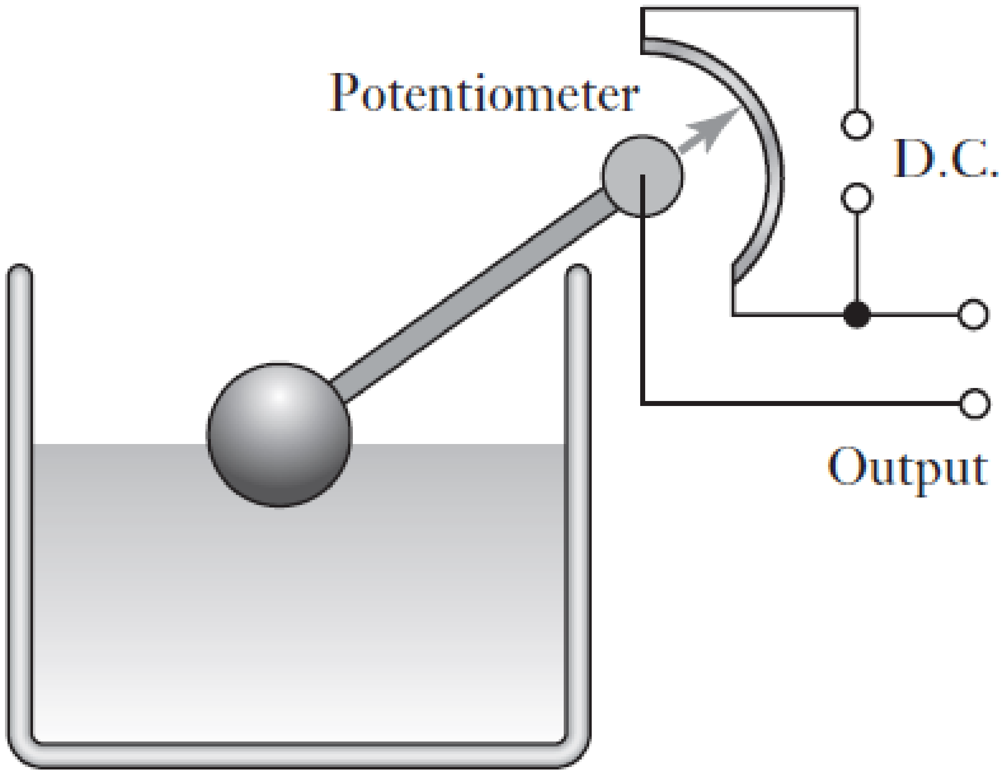
- Forces are commonly measured by the measurement of displacements.
- Strain gauges are used to monitor the strain produced in some member when stretched, compressed or bent by the application of the force.
- The arrangement for measuring the force is generally referred to as a load cell.
- Load cell is a cylindrical tube to which strain gauges have been attached. When forces are applied to the cylinder the resistance will change which is a measure of the applied force.
- A signal conditioning circuit is required to eliminate the effect of temperature change on the strain gauge.



7. Liquid Level Sensors:

[1] Floats:

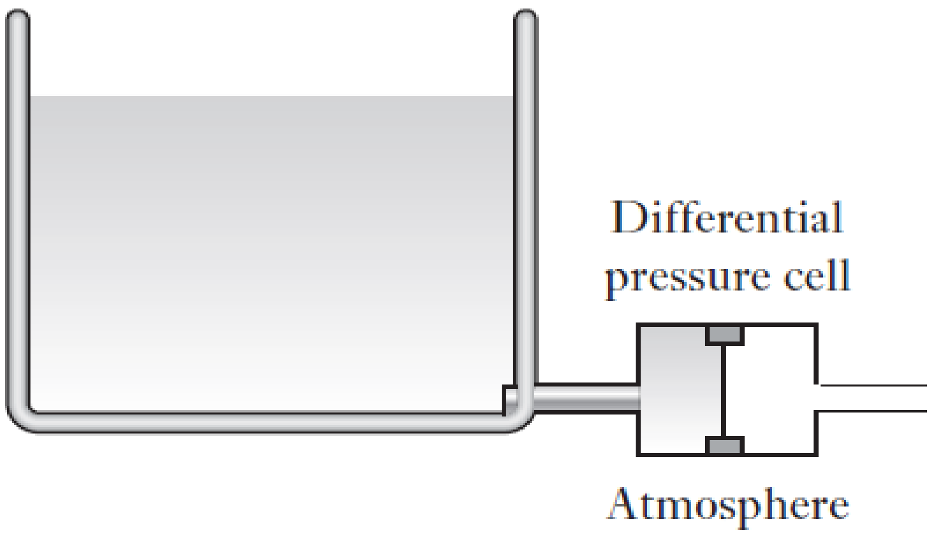
- A direct method of monitoring the level of liquid in a vessel is by monitoring the movement of a float inside that vessel.
- The displacement of the float causes a lever arm to rotate and so move a slider across a potentiometer.
- The result is an output of a voltage related to the height of liquid.

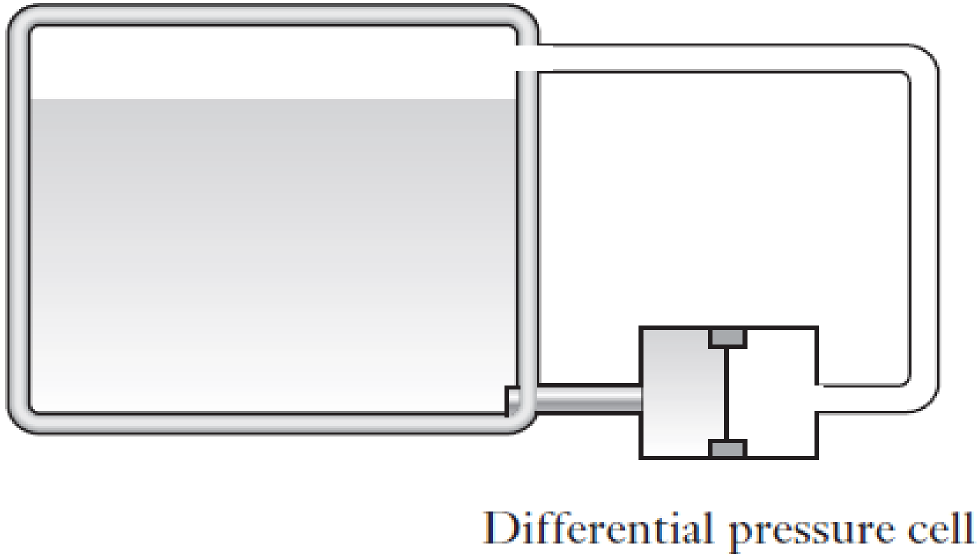


7. Liquid Level Sensors:

[2] Differential pressure:

- An indirect method for measuring the level of a liquid is measure the liquid which is changed according to the liquid level.
- The differential pressure cell can be used to monitor the difference in pressure between the base of the vessel and the atmospheric pressure.
- In case of closed vessel, the differential pressure cell monitors the difference in pressure between the base of the vessel and the air above the surface of the liquid.





8. Temperature sensors:

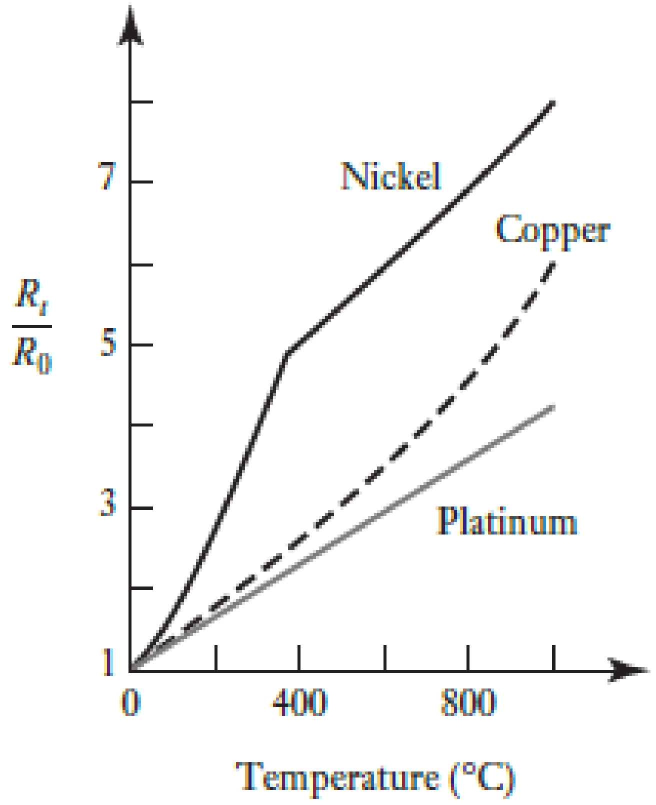
[1] Resistance temperature detectors (RTDs):

- The resistance of most metals increases, over a limited temperature range, in a reasonably linear way with temperature. For such a linear relationship:

$$R_t = R_0(1 + \alpha t)$$

where R_t is the resistance at a temperature t° C,
R_0 is the resistance at 0°C and
α is a constant for the metal termed the temperature coefficient of resistance.

- Resistance temperature detectors (RTDs) are simple resistive elements in the form of coils of wire of such metals as platinum, nickel or nickel–copper alloys; platinum is the most widely used.



Variation of resistance with temperature for metals.

8. Temperature sensors (Cont.):

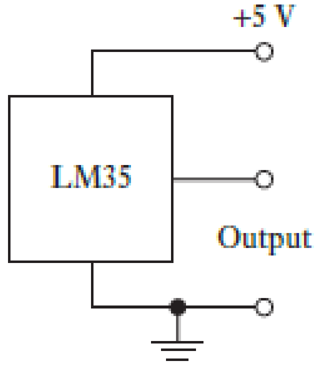
[2] Thermodiodes and transistors

- A junction semiconductor diode is widely used as a temperature sensor.
- When the temperature of doped semiconductors changes, the mobility of their charge carriers changes and this affects the rate at which electrons and holes can diffuse across a p–n junction. Thus when a p–n junction has a potential difference *V* across it, the current *I* through the junction is a function of the temperature, being given by

$$I = I_0\left(e^{eV/kT} - 1\right)$$

$$V = \left(\frac{kT}{e}\right)\ln\left(\frac{I}{I_0} + 1\right)$$

where *T* is the temperature on the Kelvin scale,
e the charge on an electron, and
k and I_0 are constants.



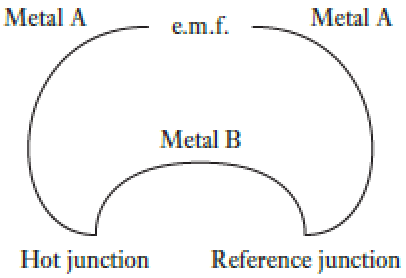
This sensor can be used in the range 240 to 110°C and gives an output of 10 mV/°C.

8. Temperature sensors (Cont.):

[3] Thermocouples:

- If two different metals are joined together, a potential difference occurs across the junction. The potential difference depends on the metals used and the temperature of the junction.

Ref.	Materials	Range (°C)	(μV/°C)
B	Platinum 30% rhodium/platinum 6% rhodium	0 to 1800	3
E	Chromel/constantan	−200 to 1000	63
J	Iron/constantan	−200 to 900	53
K	Chromel/alumel	−200 to 1300	41
N	Nirosil/nisil	−200 to 1300	28
R	Platinum/platinum 13% rhodium	0 to 1400	6
S	Platinum/platinum 10% rhodium	0 to 1400	6
T	Copper/constantan	−200 to 400	43



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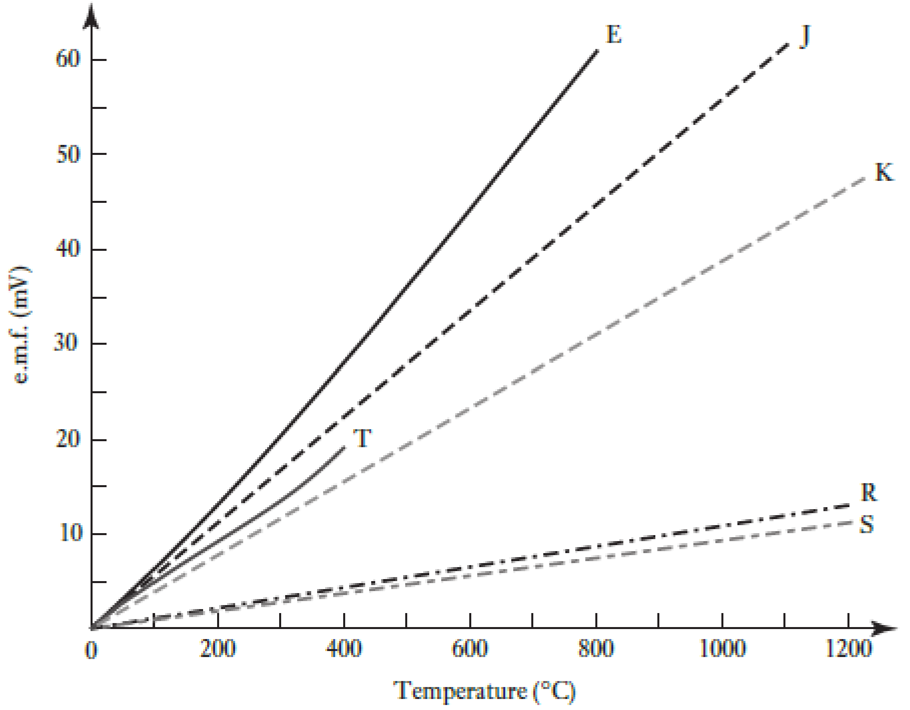

(b)

End of Lecture

Best Wishes