Practical Voltage Sources - Regulation

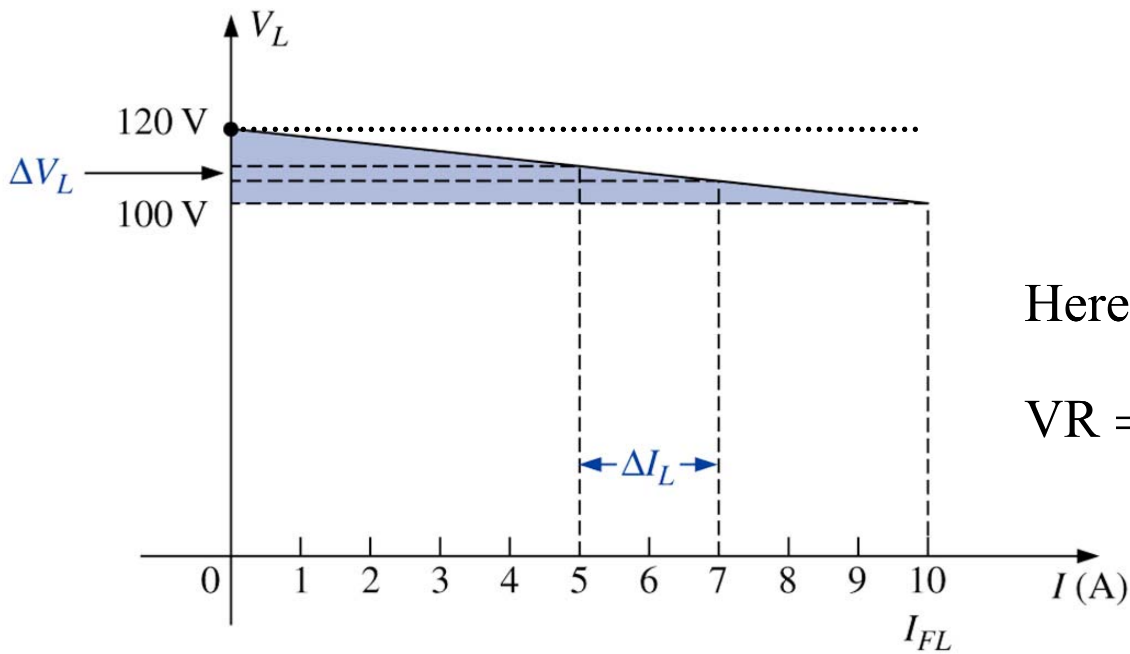
- For any supply, ideal conditions dictate that for a range of load demand (I_L), the terminal voltage remains “fixed” in magnitude.
- If a supply is set at 12 V, it is desirable that it maintain this terminal voltage, even though the current demand on the supply may vary.
- Voltage regulation (VR) characteristics are measures of how closely a supply will come to maintaining a supply voltage between the limits of full-load and no-load conditions.

Practical Voltage Sources – Regulation

Voltage Regulation definition (load regulation): VR

$$VR = \frac{V_{NL} - V_{FL}}{V_{FL}} \cdot 100\%$$

Better VR means less voltage drop
over the full range of operating current

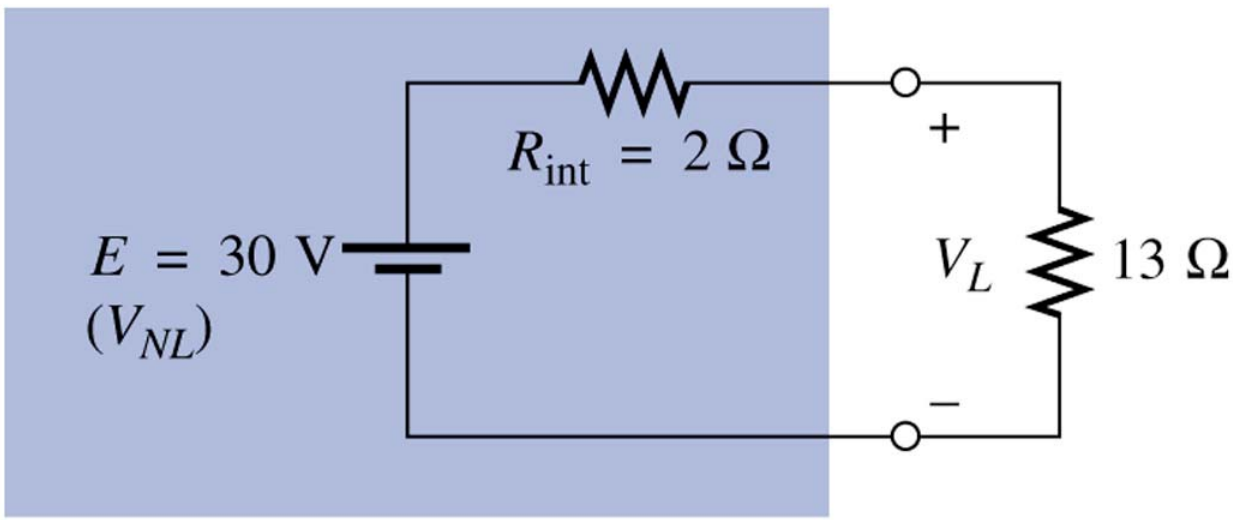


Here:

$$VR = \frac{120\ V - 100\ V}{100\ V} \cdot 100\ \% = 20\ \%$$

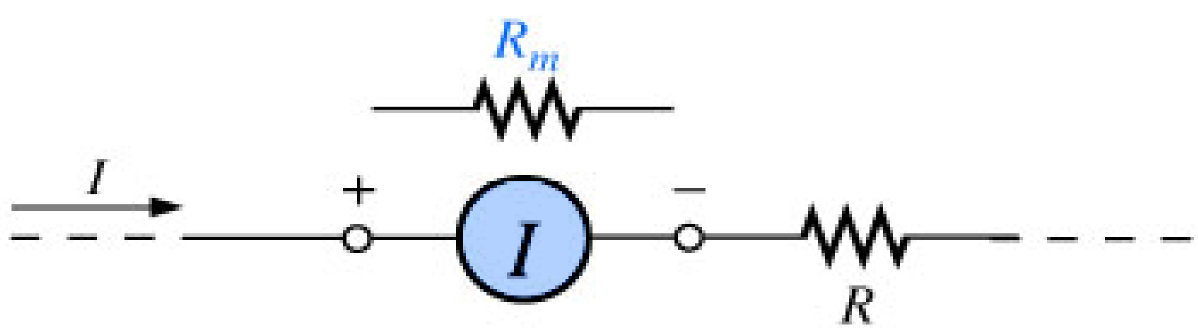
Breakout #1 – Voltage Regulation

(a) Find the voltage across the load (full-load conditions)
(b) Find the voltage regulation of the supply
(c) How much power is lost due to R_{int} (under full-load)?

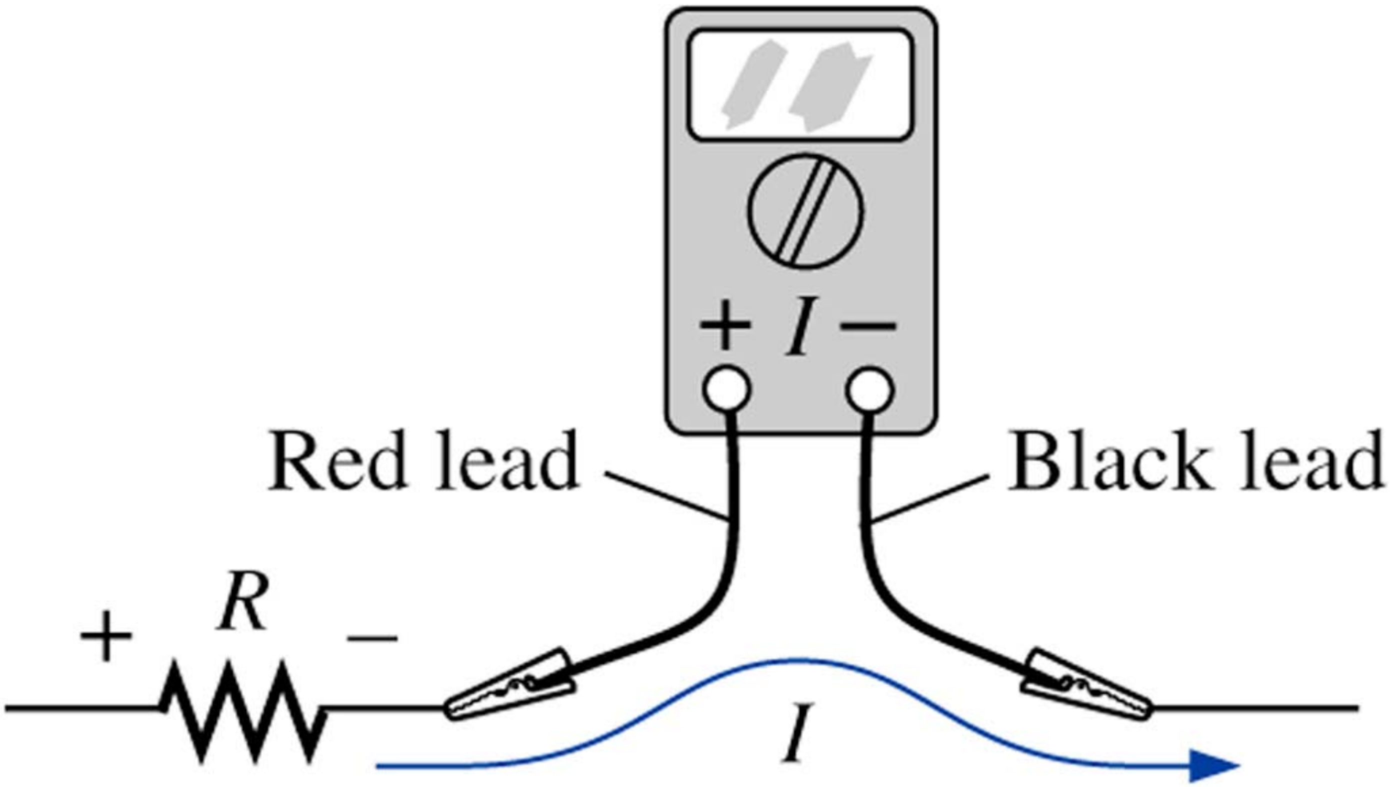


Instrument Connections and Loading

- For an up-scale (analog meter) or positive (digital meter) reading an ammeter must be connected with current entering the positive terminal and leaving the negative terminal
- Ammeters are placed ***in series*** with the branch in which the current is to be measured

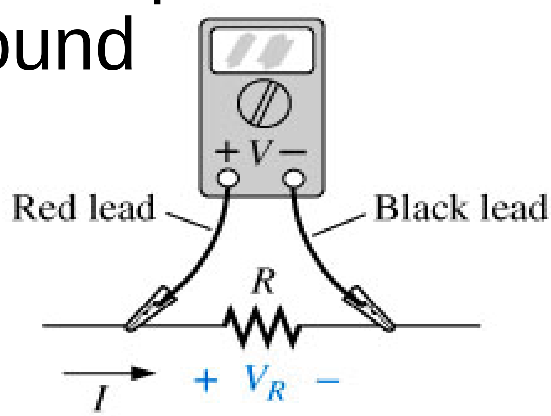


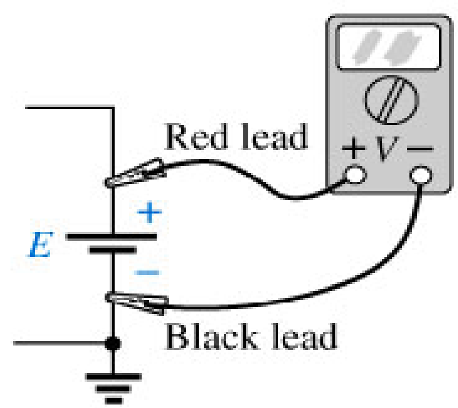
Instrument Connections and Loading



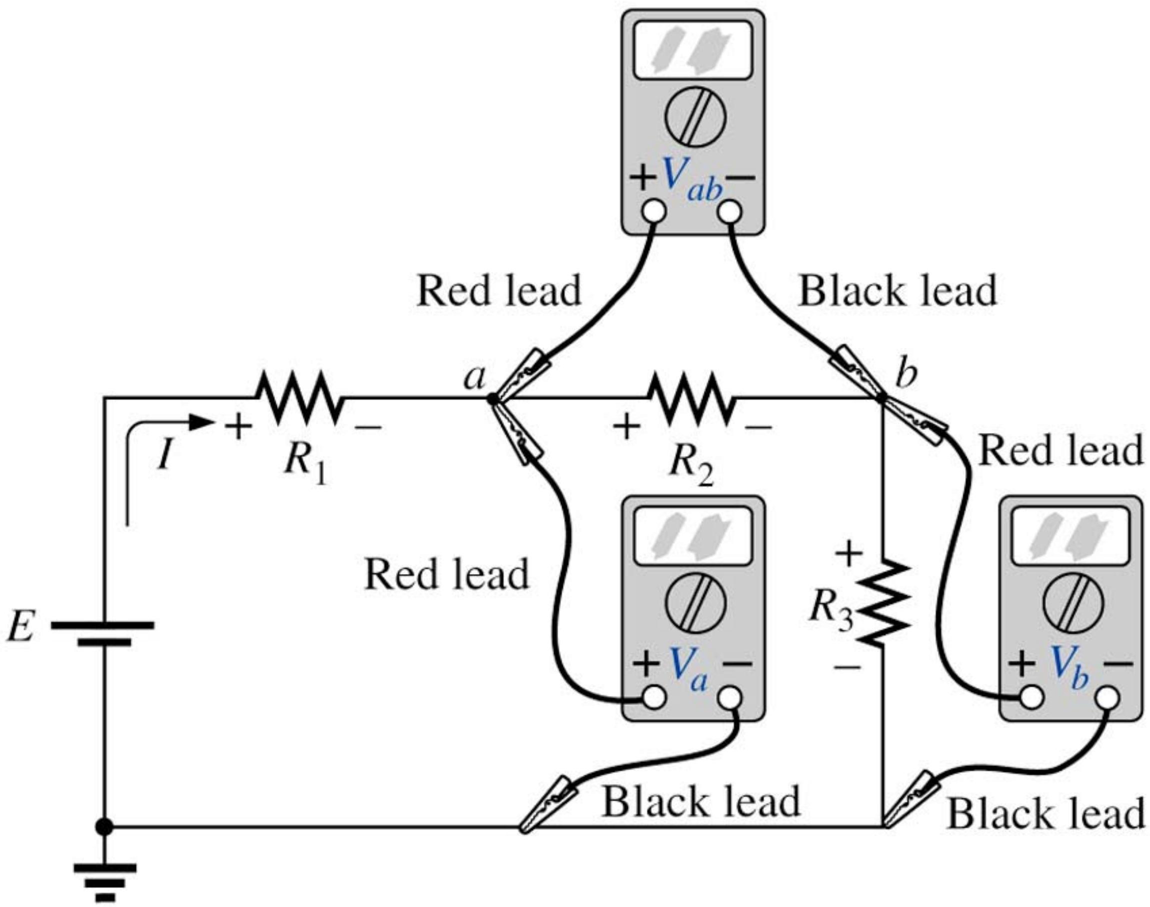
Instrument Connections and Loading

- Voltmeters are always hooked up ***across the element*** for which the voltage is to be determined
- For double-subscript notation: Always hook up the red lead to the first subscript and the black lead to the second.
- For single-subscript notation: Hook up the red lead to the point of interest and the black lead to the ground

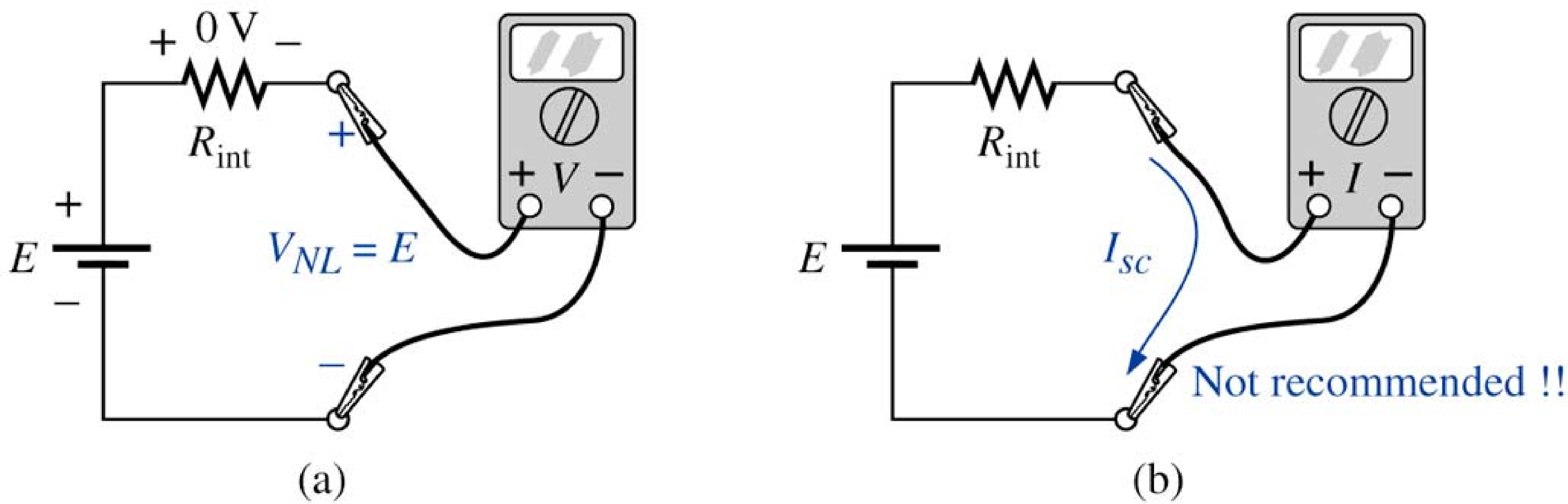




Instrument Connections and Loading

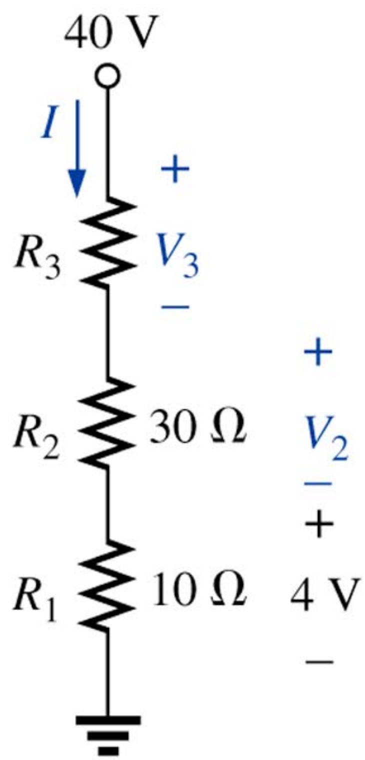


Instrument Connections and Loading

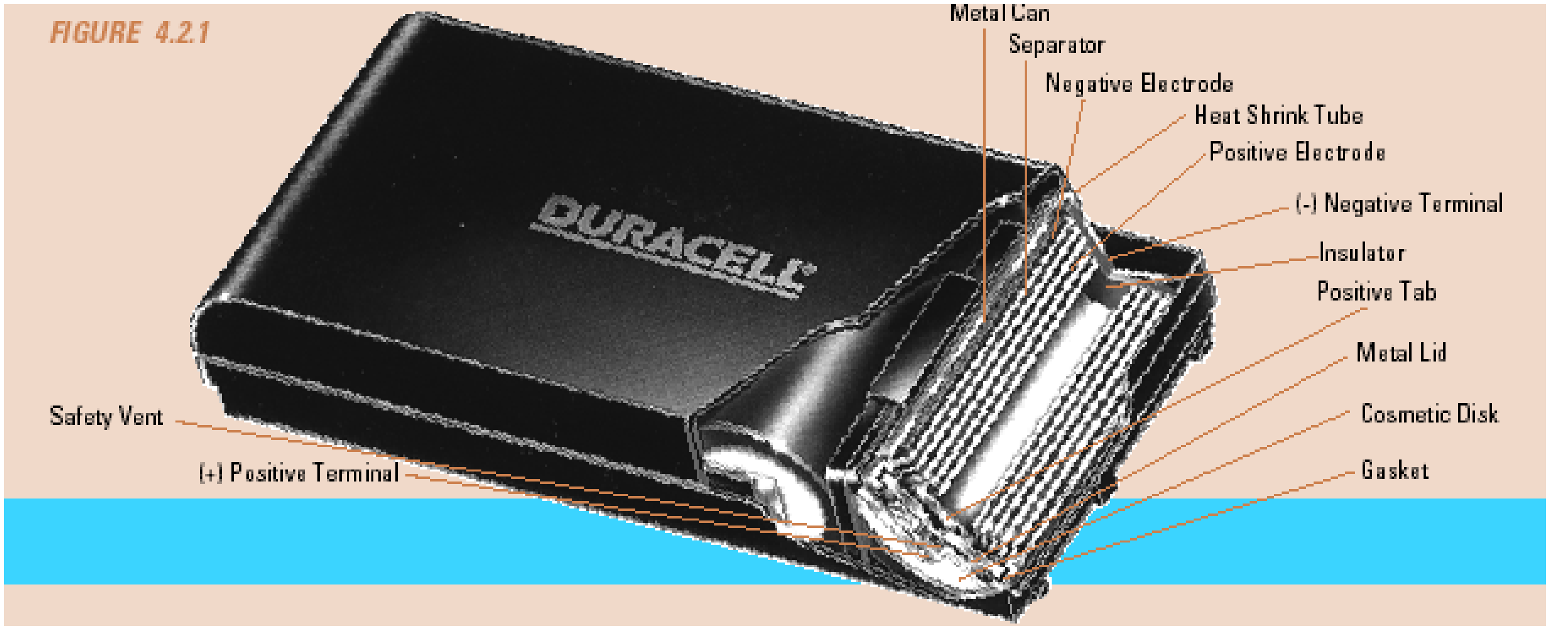


Breakout #2 – Voltage Divider

- Find V2 and V3



Application: Ni-MH Batteries



- See the POSTED file "TECHBULL.PDF"

Application: Ni-MH Batteries

5.1 General Characteristics

The discharge characteristics of the nickel-metal hydride cell are very similar to those of the nickel-cadmium cell. The charged open circuit voltage of both systems ranges from 1.25 to 1.35 volts per cell. On discharge, the nominal voltage is 1.2 volts per cell and the typical end voltage is 1.0 volt per cell.

V_{NL}

V_L

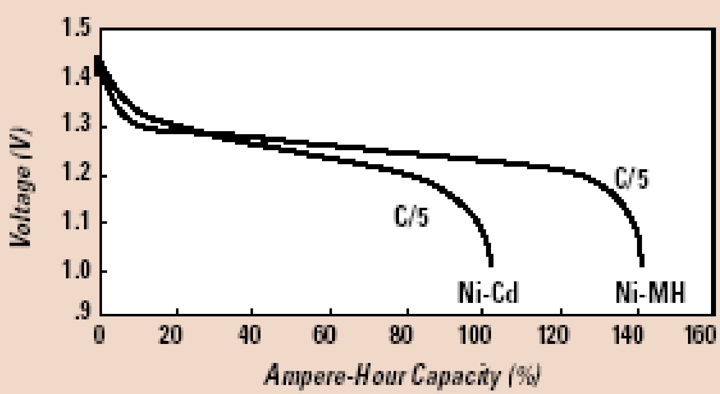
Time to recharge the cell

Application: Ni-MH Batteries

- Why use them?

Figure 5.1.1 can also be used to compare the capacity of the two rechargeable types. Note that the capacity of the nickel-metal hydride cell is typically up to 40 percent higher than that of a nickel-cadmium cell of equivalent size.

FIGURE 5.1.1



Comparison of discharge voltage and capacity of same-size Ni-MH and Ni-Cd cells.
[Conditions: Charge: C/3 for 5 hours, Temperature: 21°C (70°F)]

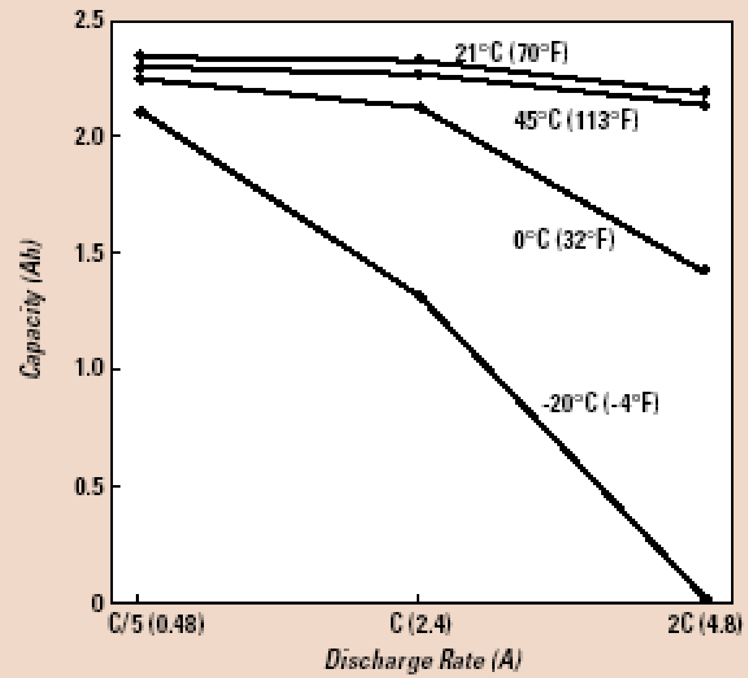
- 1C = Discharge rate to deplete the cell (to the *end voltage*) in one hour
- C/5 will discharge the battery in 5 hours
- And so on…

Application: Ni-MH Batteries

Typically, when the current is higher and the temperature is lower, the operating voltage will be lower. This is due to the higher "IR" drop that occurs with increasing current and the cell's increasing resistance at the lower temperatures. However, at moderate discharge rates (≈C/5), the effect of low temperature on the capacity of the nickel-metal hydride battery is minimal.

- As the current increases, the voltage drop across *Rint* increases
- As the temperature decreases, *Rint* increases

FIGURE 5.3.1



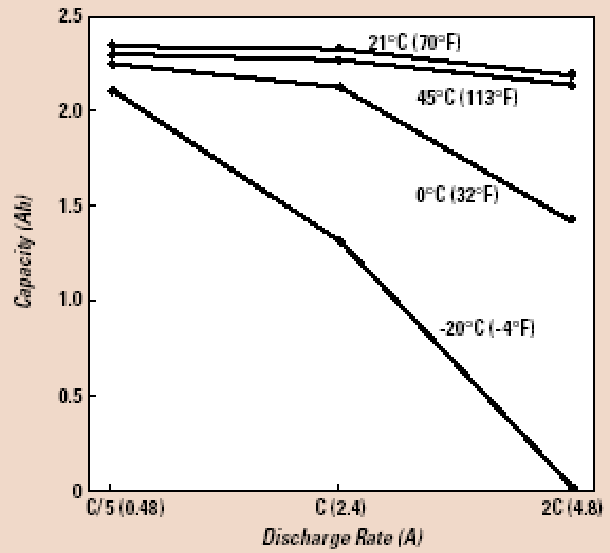
Typical capacity of DURACELL DR30 batteries under constant current discharges at various temperatures. [Conditions: Charge: 1C to -ΔV = 60mV @ 21°C (70°F); Discharge to 6.0V]

Application: Ni-MH Batteries

5.3 Capacity: Effect of Discharge Rate and Temperature

The ampere-hour capacity of the battery is dependent on the discharge current and temperature, as can be observed in **Figure 5.3.1**. It should be noted that the delivered capacity is dependent on the cutoff or end voltage. The delivered capacity can be increased by continuing the discharge to lower end voltages. However, the battery should not be discharged to too low a cut-off voltage (less than 0.9 volts per cell) as the cells may be damaged (see Section 5.6). The recommended cutoff voltage for nickel-metal hydride batteries is 1.0 volt per cell.

FIGURE 5.3.1



Typical capacity of DURACELL DR30 batteries under constant current discharges at various temperatures.
(Conditions: Charge: 1C to -ΔV = 60mV @ 21°C (70°F); Discharge to 6.0V)

Application: Ni-MH Batteries

5.7 Internal Impedance

DURACELL nickel-metal hydride batteries have low internal impedance because they are manufactured using cells designed with thin plate electrodes which offer large surface areas and good conductivity. **Figure 5.7.1** shows the change in internal impedance with depth of discharge. As demonstrated, the impedance remains relatively constant during most of the discharge. Towards the end of the discharge, the impedance increases due to the conversion of the active materials to a non-conductive form.

$$R = \rho \cdot \frac{l}{A}$$

Here :

ρ is low

A is high

l is small

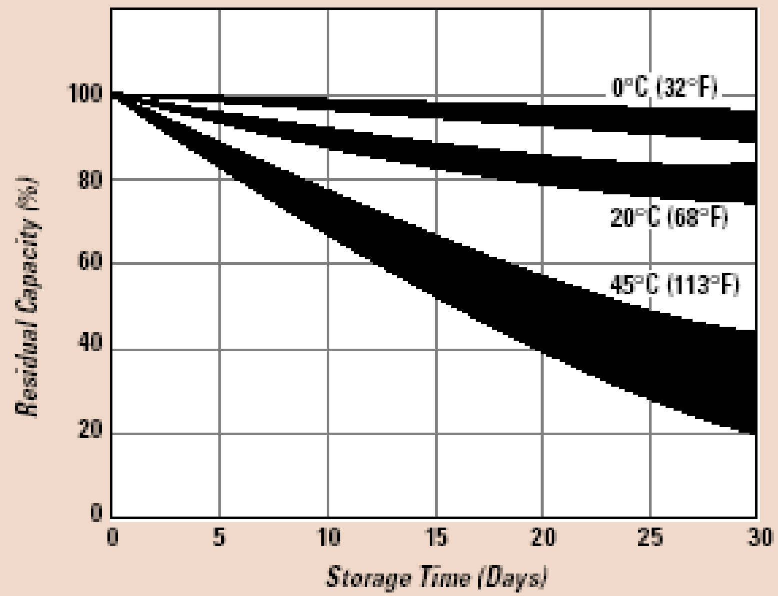
Application: Ni-MH Batteries

5.8 Self-Discharge and Charge Retention

The state-of-charge and capacity of the nickel-metal hydride battery decrease during storage due to self-discharge of the cells. Self-discharge results from the reaction of residual hydrogen in the battery with the positive electrode, as well as the slow and reversible decomposition of the positive electrode. The rate of self-discharge is dependent upon the length of time and temperature at which the battery is stored — the higher the temperature, the greater the rate of self-discharge. As illustrated in **Figure 5.8.1**, cells stored at 0°C (32°F) retain more of their capacity than those stored at 20°C and 45°C (68°F and 113°F), particularly after 30 days.

- Store your batteries in the refrigerator?

FIGURE 5.8.1



Self-discharge characteristic of Ni-MH cells at various temperatures.
[Conditions: Charge: C/3 for 5 hours; Discharge: C/5 to 1.0V; Temperature: 21°C (70°F)]