CG1111: Engineering Principles and Practice I

Debrief and Tutorial for Week 3

Main Concepts & Topics

- Energy, Power & Efficiency:
  - Instantaneous power:
    - ✓ P = $\frac{dW(t)}{dt}$
  - Efficiency
    - ✓ $\eta = \frac{P_{out}}{P_{in}} = \frac{P_{out}}{P_{out} + P_{Total\ Loss}}$
  - C-rate of battery
    - ✓ A “1C” **rate** means that the discharge current will discharge the entire battery in 1 hour

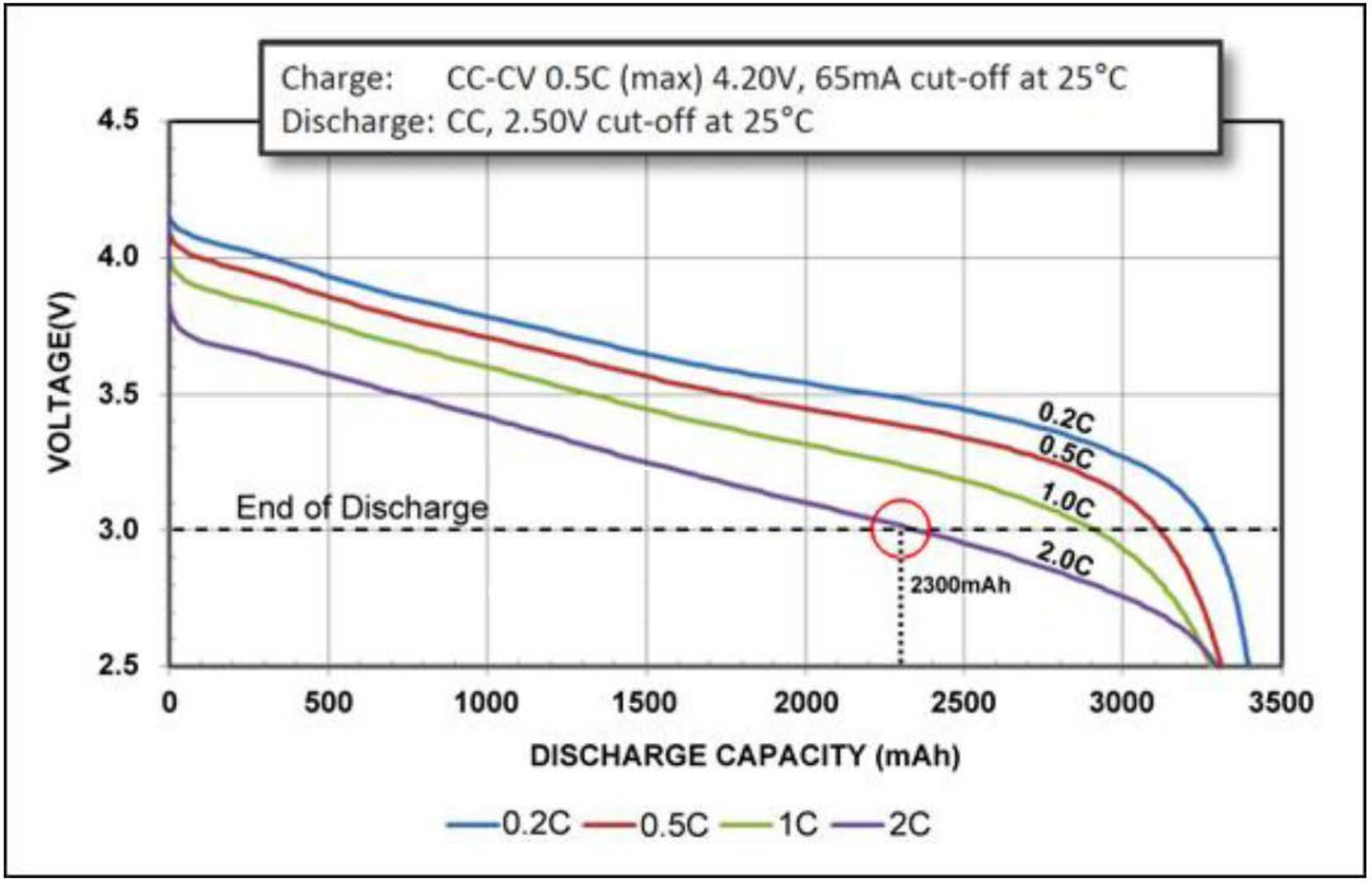
Main Concepts & Topics

- Series vs Parallel Connection of Batteries

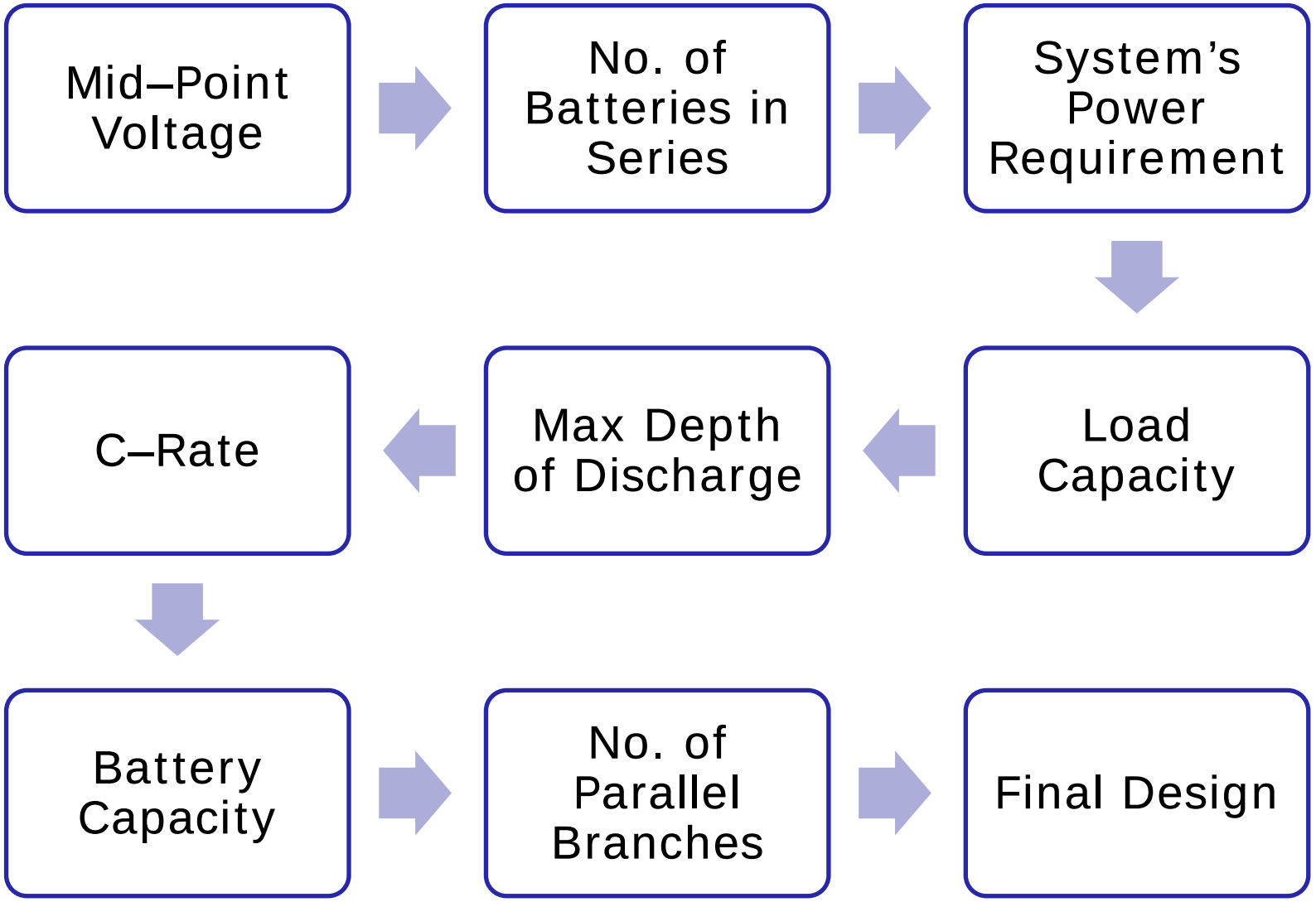
Two Batteries connected in Series: double the voltage but have the same capacity

Two Batteries connected in Parallel: double the capacity but have the same voltage

Battery Discharging Characteristics



Battery Design



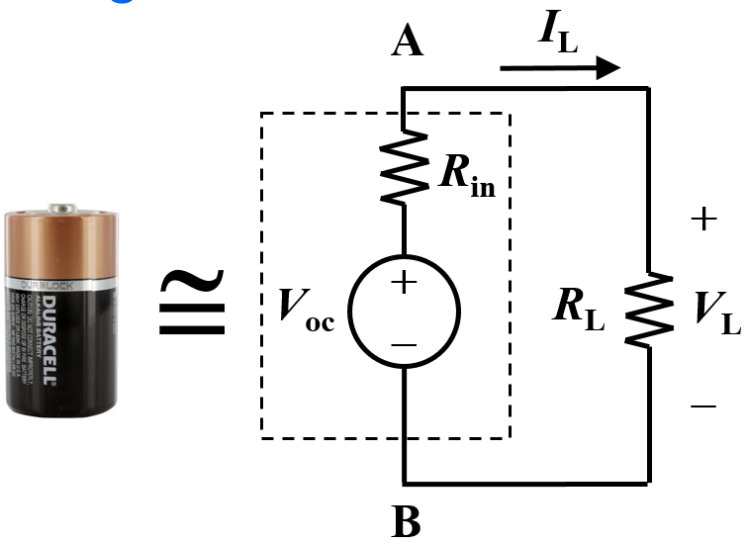
Main Concepts & Topics

- Fundamentals of electricity:
  - What is Resistance?
    - ✓ All materials present some opposition to electric current
  - Ohm's Law
    - ✓ Empirical observation that $V \propto I$ for purely resistive element, and resistance is defined as V/I
  - How is electrical power calculated?
    - ✓ $P = VI$ (always true regardless of type of element)
    - ✓ For resistors, we have $P = I^2R$ because $V = IR$

Never, never use $P = I^2R$ for non-resistive elements (e.g., LEDs)!!

Main Concepts & Topics

- Basic circuit concepts
  - Practical voltage sources have internal resistances



  - How do we go about measuring voltage & current?
    - ✓ Connect voltmeter in parallel; ammeter in series

Main Concepts & Topics

- Principles & techniques for circuit analysis
  - KCL (conservation of mass/charge)
    - ✓ The sum of all currents entering the node must be equal to the sum of all currents leaving the node
  - KVL (conservation of energy & power)
    - ✓ Around any closed loop, the sum of voltage drops must equal the sum of voltage rises
  - Resistances in series/parallel (derived from KVL/KCL)
    - ✓ Series: $R_{eq} = R_1 + R_2 + \ldots + R_N$
    - ✓ Parallel: $1/R_{eq} = 1/R_1 + 1/R_2 + \ldots + 1/R_N$

Question 1

Calculate the total capacity of a battery given that it can provide a current of 3 A for 9 hrs

- Capacity normally calculated as:

Current x Time (in hrs)

- Hence, capacity = 3 A x 9 hrs
  = 27 Ah or 27,000 mAh

Question 2

How long would a 6000 mAh battery last if it is operated at 10C rate?

- Operating time (hrs) = 1 / C-rate
  = 0.1 hrs or 6 mins

Question 3

An electric device has an input power of 100 W. The device has converted 4500 J into useful work in 1 min. Find the power efficiency of the device.

- Output power
  = (work done in J)/(time in s)
  = 4500 J / 60 s
  = 75 W
- Hence, efficiency $= P_{out} / P_{in}$
  $= 75 / 100 = 75\%$

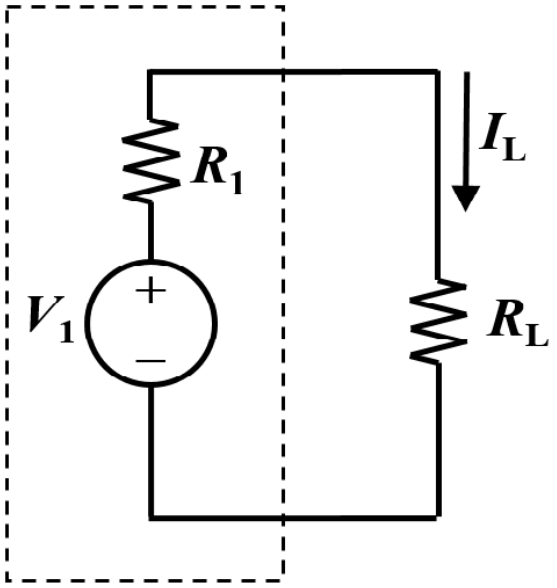
Question 4

What is the discharging C-rate of a battery of capacity 6000 mAh if the discharge current is 3 A?

- Remember: 1C is the current that discharges the battery in 1 hr
- Hence, in this case, 1C is 6 A
- So, 3 A is 0.5C

Question 5

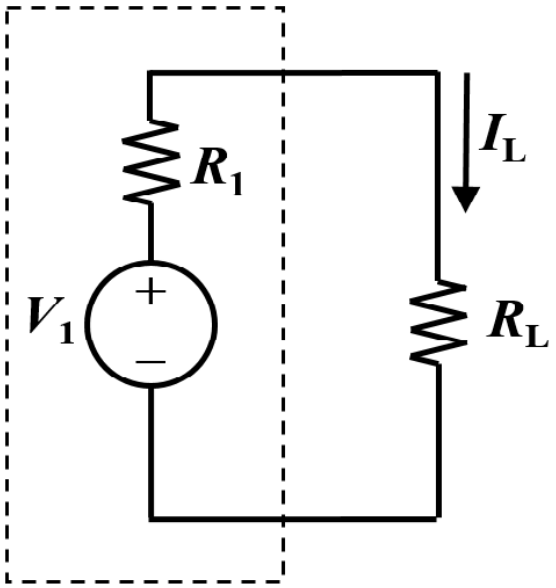
Consider the following battery with open-circuit voltage V_1 = 12 V, and internal resistance R_1 = 0.15 Ω. Find the load current I_L and the corresponding power efficiency η_L for the following load:
(i) R_L = 10 Ω



- I_L = 12 / (10 + 0.15)
  = 1.18 A
- η_L = $(I_L)^2 R_L$ / $V_1 I_L$
  = 98.5%

Question 5 (Cont'd)

(ii) $R_L = 1\ \Omega$



- $I_L = 12 / (1 + 0.15)$
  $= 10.4\ A$
- $\eta_L = (I_L)^2 R_L / V_1 I_L$
  $= 87.0\%$

Notice the big drop in efficiency when I↑

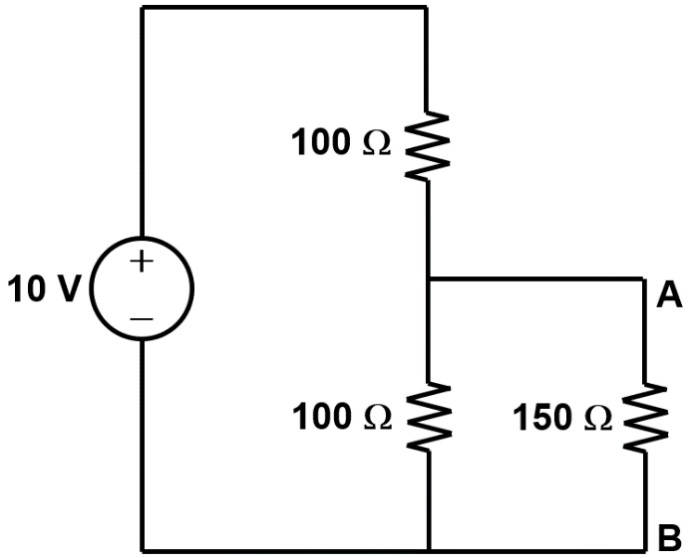
A lot of power is lost in internal resistance when I↑

Question 6

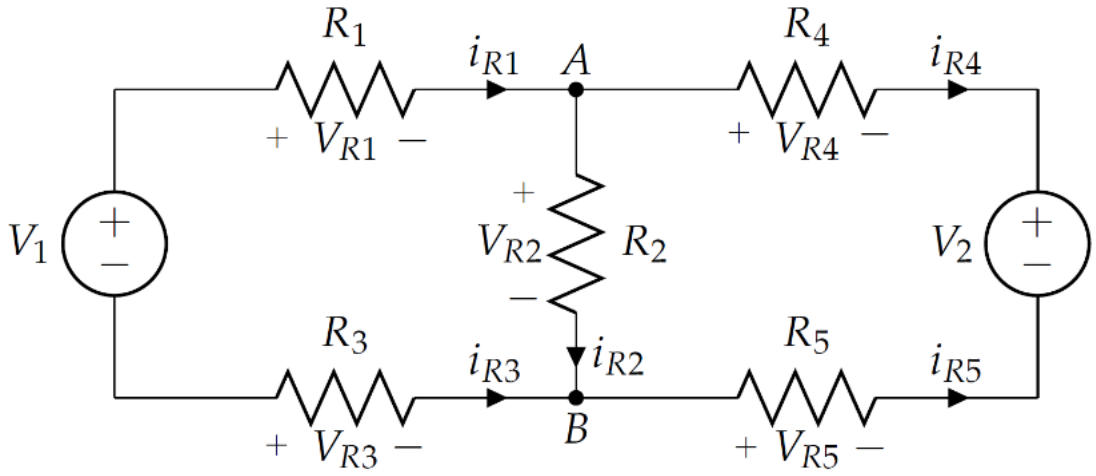
The figure below shows a loaded voltage divider circuit. Calculate the voltage difference V_{AB} (given by $V_A - V_B$).

- 150 Ω // 100 Ω
  = 60 Ω

- V_{AB} = 60/(100+60) x 10
  = 3.75 V



Question 7



Considering the circuit diagram shown in the figure above, which one of the following correctly applies <u>both</u> KVL and KCL?

a) $V_1 - V_{R1} - V_{R2} - V_{R3} = 0$; ✗ $i_{R1} - i_{R2} - i_{R4} = 0$ ✓

b) $V_1 + V_{R3} - V_{R1} - V_{R2} = 0$; ✓ $i_{R1} + i_{R3} = 0$ ✓

c) $V_2 + V_{R4} + V_{R2} + V_{R5} = 0$; ✗ $i_{R4} + i_{R5} = 0$ ✓

d) $V_2 + V_{R4} - V_{R2} - V_{R5} = 0$; ✓ $i_{R3} - i_{R2} - i_{R5} = 0$ ✗