PHY 240: Basic Electronics
Homework Problem H8

October 7, 2024

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1. **Real Badderies.**

   (a) A battery with an open circuit terminal voltage of 4 V has a terminal voltage of 3.7 V when connected to a 100 Ω load. Determine the internal resistance of this battery.

   (b) The result from part (a) makes us unhappy, as we would like to use a voltage source that doesn't sag so much. Suppose we have two of the batteries from part (a), and use them in parallel to drive the 100 Ω load. Assuming that the two batteries are identical, what is the terminal voltage with the load attached? Has the parallel battery configuration helped to create a "stiffer" (less saggy) voltage source? Explain clearly how you arrive at your result.

   (c) Ok. Last question about batteries. When a particular battery is attached to a 300 Ω load, it is found that 19.6 mA flows through the load. When the 300 Ω load is replaced by a 100 Ω load, it is found that 56.6 mA flows through the new load.
   Does this provide evidence that the battery has an internal resistance? If not, explain clearly why not. If so, determine the value of the battery's internal resistance.

Solution:

(a)

$$3.7V = I(100\Omega)$$

$$I = 0.037A$$

$$V = I(R_{load} + R_{internal})$$

$$V = IR_{load} + IR_{internal}$$

$$V = V_{load} + IR_{internal}$$

$$IR_{internal} = V - V_{load}$$

$$R_{internal} = \frac{V - V_{load}}{I}$$

$$R_{internal} = \frac{4V - 3.7V}{0.037A}$$

$$R_{internal} \approx 8.11\Omega$$

(b) Batteries in parallel will have the same voltage 4V, but will have a lowered resistance governed by the resistors in parallel equation.

$$\frac{1}{R_{bats}} = \frac{1}{R_1} + \frac{1}{R_2}$$
$$R_{bats} = \frac{R_1 + R_2}{R_1 R_2}$$
$$R_{bats} = \frac{(8.11\Omega)(8.11\Omega)}{8.11\Omega + 8.11\Omega}$$
$$R_{bats} \approx 4.06\Omega$$

Now with the resistance of the batteries, we can find the current and voltage through the load.

$$R_{tot} = R_{load} + R_{bats} = 104.06\Omega$$
$$I = \frac{V}{R} = \frac{4V}{104.06\Omega} \approx 0.038A$$
$$V = IR = (0.038A)(104.06\Omega) \approx 3.999V$$

As we can see, wiring 2 batteries in parallel has created a "stiffer" voltage source by mitigating the internal resistances of the batteries.

(c)

$$V = IR = (0.0196A)(300\Omega) = 5.88V$$
$$V = IR = (0.0566A)(100\Omega) = 5.66V$$

Because the current changes on the change of a load, we can assume that this battery has internal resistance.

$$V = (0.0196A)(300\Omega + R_{internal})$$
$$V = (0.0566A)(100\Omega + R_{internal})$$
$$0 = (0.0196A)(300\Omega + R_{internal}) - (0.0566A)(100\Omega + R_{internal})$$
$$0 = (5.88V + (0.0196A)(R_{internal})) - (5.66V + (0.0566A)(R_{internal}))$$
$$0 = 0.22V - (0.037A)(R_{internal})$$
$$(0.037A)(R_{internal}) = 0.22V$$
$$R_{internal} = \frac{0.22V}{0.037A} \approx 5.95\Omega$$