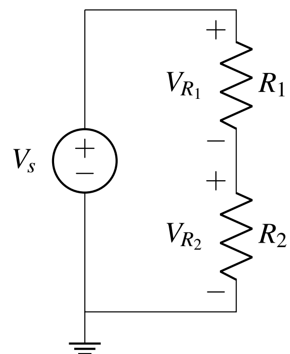
EECS 16A Designing Information Devices and Systems I
Fall 2022 Discussion 7B

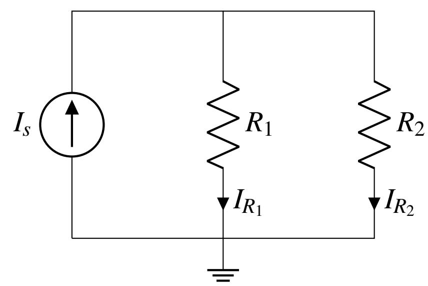
1. Volt and Ammeter

(a) For the voltage divider below, how would we connect a voltmeter to the circuit to measure the voltage V_{R_2}?



(b) What would happen if we accidentally connected an ammeter in the same configuration instead? Assume our ammeter is ideal.

(c) For the current divider below, how would we connect an ammeter to the circuit to measure the current I_{R_2}?


I_s
R_1
R_2
I_{R_1}
I_{R_2}

(d) What would happen if we accidentally connected a voltmeter in that configuration instead? Assume the voltmeter is ideal.

2. Cell Phone Battery

As great as smartphones are, one of their drawbacks is that their batteries don't last a long time. For example, a typical smartphone, under average usage conditions (internet, a few cat videos, etc.) uses 0.3W. We will model the battery as an ideal voltage source (which maintains a constant voltage across its terminals regardless of current) except that we assume that the voltage drops abruptly to zero when the battery is discharged (in reality, the voltage drops gradually, but let's keep things simple).

Battery capacity is specified in mAh, which indicates how many mA of current the battery can supply for one hour before it needs to be recharged. Suppose the phone's battery has a capacity of 2770mAh at 3.8V. For example, this battery could provide 1000mA (or 3.8W) for 2.77 hours before the voltage abruptly drops from 3.8V to zero.

(a) How long will the phone's full battery last under average usage conditions?

(b) How many coulombs of charge does the battery contain? How many usable electrons worth of charge are contained in the battery when it is fully charged? (An electron has 1.602×10^{-19} C of charge.)

(c) Suppose the cell phone battery is completely discharged and you want to recharge it completely. How much energy (in J) is this? Recall that a J is equivalent to a W s.

(d) The battery has internal circuitry that prevents it from getting overcharged (and possibly exploding!). We will model the battery and its internal circuitry as a resistor R_{bat}. We now wish to charge the battery by plugging it into a wall plug. The wall plug can be modeled as a $5\,\text{V}$ voltage source and $200\,\text{m}\Omega$ resistor, as pictured in Figure 1. What is the power dissipated across R_{bat} for $R_{\text{bat}} = 1\,\text{m}\Omega$, $1\,\Omega$, and $10\,\text{k}\Omega$? (i.e. how much power is being supplied to the phone battery as it is charging?). How long will the battery take to charge for each of those values of R_{bat}?

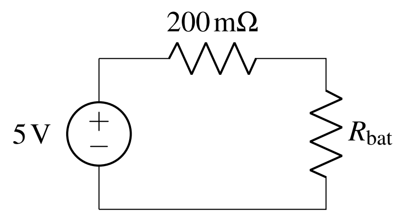


Figure 1: Model of wall plug, wire, and battery.

(e) (Bonus) Suppose you forgot to charge your phone overnight, and you're in a hurry to charge it before you leave home for the day. What should we set R_{bat} to be if we want to charge our battery as quickly as possible? How much current will this draw? How long will it take to charge?

Hint: what choice of R_{bat} maximizes the power dissipated across the resistor?

