Emf

- _____ _____
- Not really a _____
- Really _____ produced that could _____ a _____

Internal Resistance

- _____ and generators have _____
  - In batteries → due to _____
  - In generators → due to _____ and other _____
- Internal _____ is connected in _____ with the equivalent _____ of the circuit
- Internal resistance causes _____ _____ to drop below _____
- Internal resistance is not _____ negligible

$$V = \mathcal{E} - Ir$$

- V = terminal voltage, $\mathcal{E}$ = emf, I = current of circuit, r = internal resistance

A string of 20 Christmas light are connected in series with a 3.0 V battery. Each light has a resistance of 10 Ω. The terminal voltage is measured as 2.0 V. What is the internal resistance of the battery?

A battery has an internal resistance of 0.02 Ω and an emf of 1.5 V. If the battery is connected with five 15 Ω light bulbs connected in parallel, what is the terminal voltage of the battery?

- If batteries are connected in _____, their _____ add, but so do the _____ _____
- If batteries are connected in _____, their _____ stay the same, but the _____ add and the combined internal _____ is _____

1. Explain which battery is doing the charging and which is being charged in the figure.
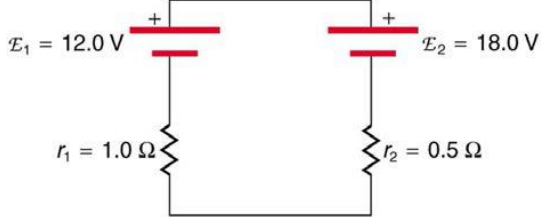
2. Two different 12-V automobile batteries on a store shelf are rated at 600 and 850 "cold cranking amps." Which has the smallest internal resistance?

3. What are the advantages and disadvantages of connecting batteries in series? In parallel?

4. Standard automobile batteries have six lead-acid cells in series, creating a total emf of 12.0 V. What is the emf of an individual lead-acid cell? (OpenStax 21.14) **2.00 V**

5. Carbon-zinc dry cells (sometimes referred to as nonalkaline cells) have an emf of 1.54 V, and they are produced as single cells or in various combinations to form other voltages. (a) How many 1.54-V cells are needed to make the common 9-V battery used in many small electronic devices? (b) What is the actual emf of the approximately 9-V battery? (c) Discuss how internal resistance in the series connection of cells will affect the terminal voltage of this approximately 9-V battery. (OpenStax 21.15) **6, 9.24 V, r's add so smaller V**

6. What is the output voltage of a 3.0000-V lithium cell in a digital wristwatch that draws 0.300 mA, if the cell's internal resistance is 2.00 Ω? (OpenStax 21.16) **2.9994 V**

7. (a) What is the terminal voltage of a large 1.54-V carbon-zinc dry cell used in a physics lab to supply 2.00 A to a circuit, if the cell's internal resistance is 0.100 Ω? (b) How much electrical power does the cell produce? (c) What power goes to its load? (OpenStax 21.17) **1.34 V, 3.08 W, 2.68 W**

8. What is the internal resistance of an automobile battery that has an emf of 12.0 V and a terminal voltage of 15.0 V while a current of 8.00 A is charging it? (OpenStax 21.18) **0.375 Ω**

9. (a) Find the terminal voltage of a 12.0-V motorcycle battery having a 0.600-Ω internal resistance, if it is being charged by a current of 10.0 A. (b) What is the output voltage of the battery charger? (OpenStax 21.19) **18.0 V, 18.0 V**

10. The hot resistance of a flashlight bulb is 2.30 Ω, and it is run by a 1.58-V alkaline cell having a 0.100-Ω internal resistance. (a) What current flows? (b) Calculate the power supplied to the bulb using $I^2 R_{bulb}$. (c) Is this power the same as calculated using $\frac{V^2}{R_{bulb}}$? (OpenStax 21.21) **0.658 A, 0.997 W, 0.997 W**

11. An automobile starter motor has an equivalent resistance of 0.0500 Ω and is supplied by a 12.0-V battery with a 0.0100-Ω internal resistance. (a) What is the current to the motor? (b) What voltage is applied to it? (c) What power is supplied to the motor? (d) Repeat these calculations for when the battery connections are corroded and add 0.0900 Ω to the internal resistance. (Significant problems are caused by even small amounts of unwanted resistance in low-voltage, high-current applications.) (OpenStax 21.23) **200 A, 10.0 V, 2.00 kW, 80.0 A, 4.0 V, 320 W**

12. Electric fish generate current with biological cells called electroplaques, which are physiological emf devices. The electroplaques in the South American eel are arranged in 140 rows, each row stretching horizontally along the body and each containing 5000 electroplaques. Each electroplaque has an emf of 0.15 V and internal resistance of 0.25 Ω. If the water surrounding the fish has resistance of 800 Ω, how much current can the eel produce in water from near its head to near its tail? (OpenStax 21.27) **51 A**