

**Knowledge Domain: Power Supply**  
**Unit: Batteries**  
**Skill: Substituting Primary Batteries**

**Tools and Parts Required:**

- |  |                    |
|--|--------------------|
| 1) Assorted batteries (not rechargeable) | 6) Multimeter      |
| 2) Battery holders                       | 7) Electrical tape |
| 3) Stranded Wire                         | 8) Wire Stripper   |
| 4) Soldering Iron                        | 9) Fine Sandpaper  |
| 5) Solder                                | 10) Pliers         |

**Introduction**

A battery produces direct current (DC) electrical energy through electrochemical reactions.

Batteries have two ratings: voltage and capacity.

- Voltage is measured in volts (V).
- Capacity is a measure of the charge stored by the battery. Capacity is measured in Amp-hours (Ah) or milliamp-hours (mAh).

There are two types of batteries: primary and secondary. A primary battery contains an electrochemical reaction that is not reversible. A primary battery cannot be recharged and must be disposed of after use. **Warning:** Attempting to recharge primary batteries can result in explosion.

Primary batteries are intended for use in portable devices operating on low currents for a long period of time. Below are some common types, sizes and shapes of primary batteries:

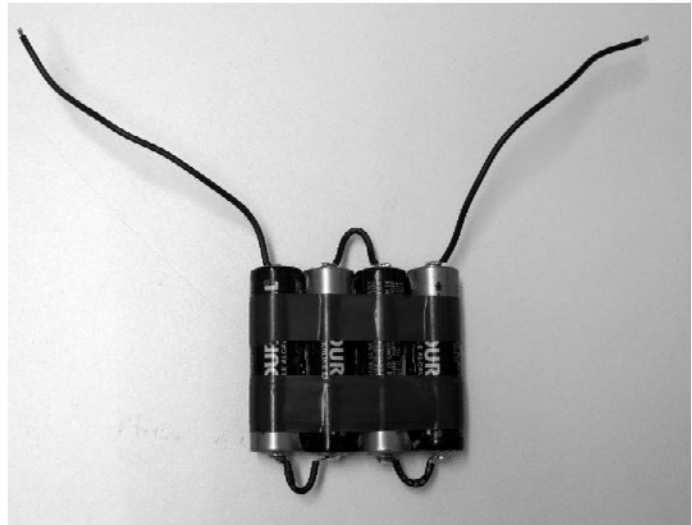
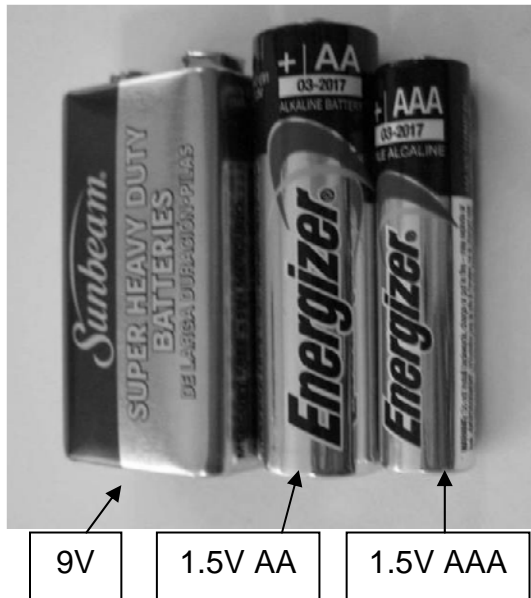
- Types: alkaline, zinc-carbon, and lithium.
- Common sizes: AAA, AA, C, D, lantern type (with spring terminals).
- Common shapes: cylindrical, rectangular, square and button (coin).

Keep in mind the following when purchasing primary batteries at your local store:

- Carbon-zinc cells lose capacity the quickest over time and have a short shelf-life.
- Lithium batteries do not lose capacity over time and have the longest shelf-life.

## Example

Below are pictures of primary batteries. .



Substitute battery pack: four 1.5V batteries are combined to create a 6V battery.

## Identification and Diagnosis

If a battery-powered device does not turn on, or functions intermittently, the battery pack may need to be replaced. Check the voltage to determine if the primary battery is no longer usable. Use the following method:

1. Remove the battery from the device.
2. Set the multimeter to the "DC Voltage" measurement.
3. Insure that the voltage setting is appropriate for the expected voltage output.
4. Place the red probe to the positive terminal. Place the black probe to the negative terminal.
5. Record the voltage.
6. Replace the battery if the voltage is less than 70% of its rated value. For example, a 1.5 volt alkaline battery that measures less than 1.0 volts should be discarded.

## Procedure

### Replacing with an exact match

To replace a primary battery or primary battery power source, replace with a new battery with the same voltage, capacity, size and chemistry.

If a perfect match is not available, you can substitute a larger capacity battery for an otherwise similar battery. For example, a battery of size D can substitute for a C, a C for an A, or an AA for an AAA.

Battery needed	Acceptable substitute
C	D
A	C
AAA	AA

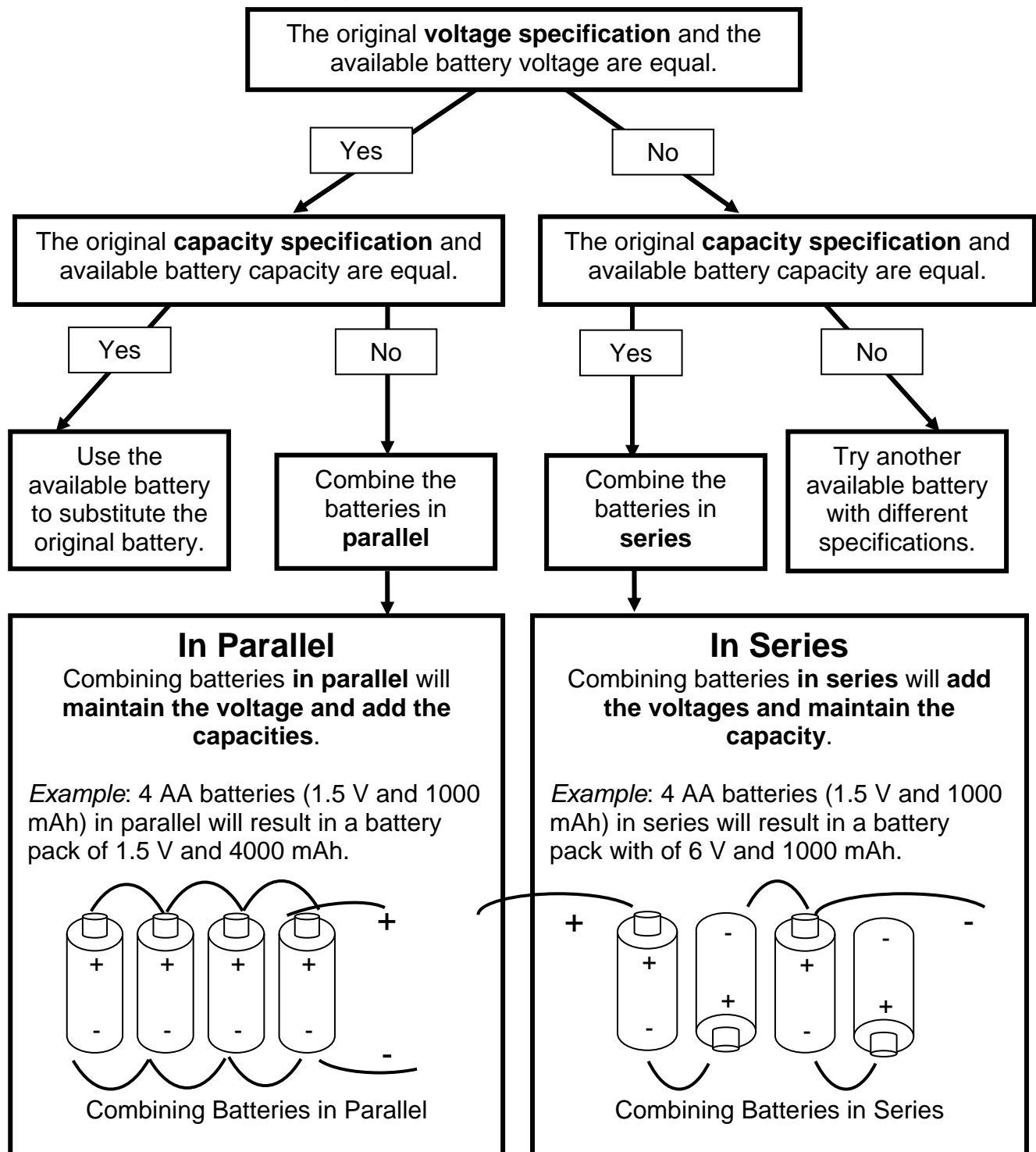
If a battery substituted in this way is larger than the original battery, a larger mounting bracket or attachment with electrical tape may be required.

In general, you can substitute lithium 1.5V batteries for alkaline 1.5V batteries. Alkaline batteries can be substituted for lithium batteries in some cases. Some loss in performance may occur.

#### Creating a battery pack

Another solution is to create a substitute with the same total voltage or capacity ratings. You can create a substitute battery by combining batteries in series or parallel. To determine whether to combine the batteries in series or in parallel, consult the following decision tree:

Decision Tree for Determining Series or Parallel:



1. Determine the specifications of the power supply to be replaced. Information can be found of the battery or the medical device.
2. Determine what substitute batteries are available. All substitute batteries should be the same voltage, capacity, and chemistry. This allows for equal discharge among the batteries.
3. Decide whether to connect batteries in parallel or in series (see decision tree above).
4. Calculate the number of batteries you need
  - In Series: Divide the original voltage specification by the voltage specification of the available batteries. *Example:* Original battery of 4.5 volts and 1000 mAh. AAA batteries of 1.5 volts and 1000 mAh are available. How many batteries are required in series?  
*Solution:*  $4.5 / 1.5 = 3$  batteries
  - In Parallel: Divide the original capacity specification by the capacity specification of the available batteries. *Example:* Original battery of 1.5 volts and 1800 mAh. AAA batteries of 1.5 volts and 900 mAh are available. How many batteries are required in parallel?  
*Solution:*  $1800 / 900 = 2$  batteries
5. If you have an appropriately sized battery holder, place the batteries in the battery holders. You're done! If not, continue to step 6.

**Note:** *Never work alone. Always have a partner around to help in case something goes wrong.*

6. Cover your work area with cloth or a newspaper to catch solder drips. Lay out all the parts and tools you need. You'll need the batteries, soldering tools, fine sandpaper, and electrical tape. Prepare your soldering iron, stand, solder, and sponge.

### Original battery

Voltage (V) \_\_\_\_\_

Capacity (mAh) \_\_\_\_\_

### Replacement batteries

Voltage (V) \_\_\_\_\_

Capacity (mAh) \_\_\_\_\_

### Series or parallel? (Circle one)

Series

Parallel

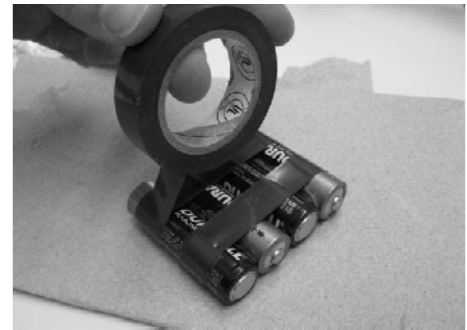
### How many batteries do you need? (Show calculations)

**Draw a schematic of your battery pack.** Show how you will arrange the batteries and wires. (See example above).



Step 7: Use an emery board or sandpaper to buff the battery contacts.

7. Use fine sandpaper or an emery board to lightly buff the positive and negative contacts of the replacement batteries. The goal is to remove any dirt or tarnish.
8. Line up your batteries. If you are connecting them in series (shown in pictures), they should be alternating in direction. Looking at one edge, you should see +, -, +, -, +, -. If you are connecting them in parallel, they should all be in the same direction. Looking at one edge, you should see +,+,+,+ or -, -, -, -.



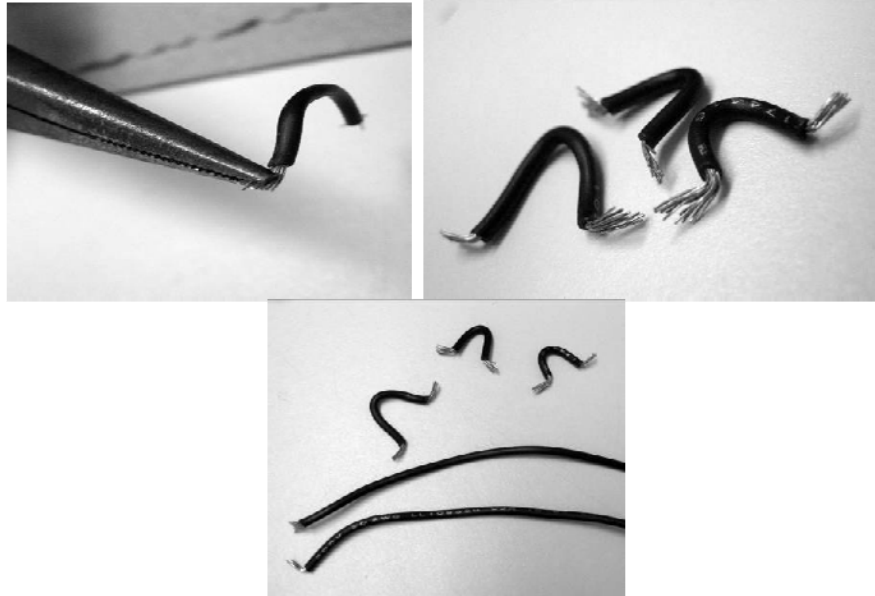
Step 9: Tape the pack together.

9. Use electrical tape to tape the pack together.
10. Hold your batteries upright with a clip or with other objects. You can also ask your partner to hold the batteries for you.
11. Clean and tin your soldering iron. Tin all the battery contacts on one side.
  - Tinning process: Touch the iron to the battery and apply solder to the battery. As the solder melts, the solder should form a shallow bump, like a mosquito bite. Ensure that the solder is coated as thinly as possible.
  - **Note:** The solder should not look like a ball, a drop, or a bead. Never use the soldering iron like a brush to "paint" the solder on.
12. The batteries should be warm to the touch. Wait for the batteries to cool.



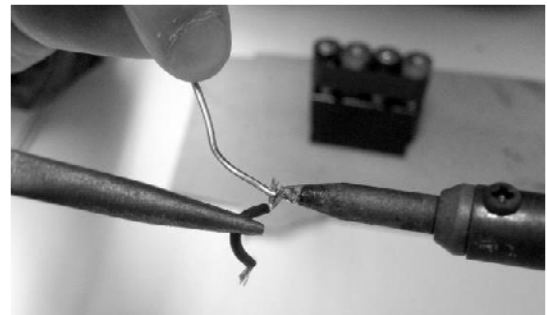
Step 11: Tin the battery contacts. The solder should form a shallow bump, like a mosquito bite

13. While you are waiting for the batteries to cool, prepare your connecting and lead wires. Use stranded wire. The connecting wires should be ~2cm in length. The lead wires should be at least 10cm (longer if necessary). Cut the wires and strip the ends. Spread the uninsulated wire ends. Bend the connecting wire into a “U” shape.



Step 13: Prepare the connecting wires and the lead wires. Spread the wire ends.

14. Ensure that the battery is cool. Tin the battery contacts on the other end.
15. While you are waiting for the batteries to cool, tin the uninsulated wire ends of the connecting wires and the lead wires. Ask your partner to hold the wires using pliers.
16. Ensure that the battery is cool. Hold a connecting wire above the battery pack using pliers. The uninsulated wire ends should be above the battery contacts. Touch the soldering iron to the wire end. The solder should melt. (In this step, you should not have to add more solder).



Step 15: Tin the wire ends.

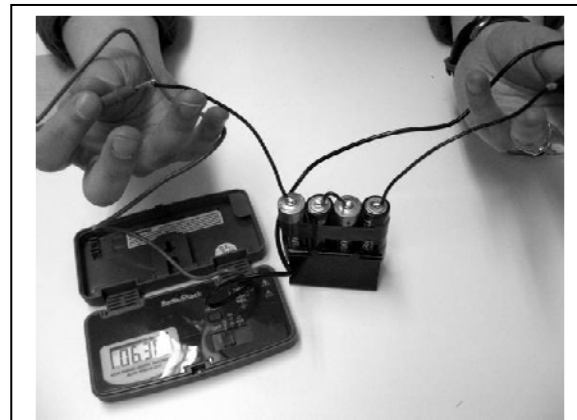


Step 16: Hold the connecting wire above the battery contacts. Touch the soldering iron to the wire end.

17. Test your connection using a multimeter. Using the resistance setting, test for continuity.



Step 17: Test your connection for electrical continuity.



Step 19: Test your battery pack voltage

18. Repeat with the other connecting wires and the lead wires. Follow your schematic.

19. Test the voltage of your battery pack with a multimeter. Use the voltage setting. If the voltage is correct, you're done! If the voltage is incorrect, recheck the individual connections for continuity. Resolder if necessary.

## Exercises

### Practice Calculations

Calculate your answers using following batteries' voltage and mAh.

AA Battery 1.5 V 2000 mAh	AA Battery 1.5 V 3000 mAh	AAA Battery 1.5 V 500 mAh	AAA Battery 1.25 V 1000 mAh	C Battery 1.5 V 8000 mAh
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- Replace a power supply with the specifications of 4.5 Volts and 3000 mAh.  
Combine in series?      Yes    No  
Combine in parallel?      Yes    No  
How many batteries? \_\_\_\_\_  
What type of batteries? \_\_\_\_\_
- Replace a power supply with the specifications of 1.25 Volts and 3000 mAh.  
Combine in series?      Yes    No  
Combine in parallel?      Yes    No  
How many batteries? \_\_\_\_\_  
What type of batteries? \_\_\_\_\_



3. Replace a power supply with the specifications of 6 Volts and 8000 mAh.  
Combine in series?      Yes    No  
Combine in parallel?      Yes    No  
How many batteries? \_\_\_\_\_  
What type of batteries? \_\_\_\_\_
  
4. Replace a power supply with the specifications of 1.5 Volts and 4000 mAh.  
Combine in series?      Yes    No  
Combine in parallel?      Yes    No  
How many batteries? \_\_\_\_\_  
What type of batteries? \_\_\_\_\_
  
5. Replace a power supply with the specifications of 1.5 Volts and 1500 mAh.  
Combine in series?      Yes    No  
Combine in parallel?      Yes    No  
How many batteries? \_\_\_\_\_  
What type of batteries? \_\_\_\_\_

### Classroom Practice

Your instructor will provide you with a medical device. Determine the power supply specifications of the medical device. Create a power supply substitute for the device.

### **Preventative Maintenance and Calibration**

Primary batteries can self-discharge over time due to chemical reactions. The self-discharge rate decreases if the batteries are stored at a low temperature.

**Note:** Batteries can be damaged by freezing. Check battery operated devices frequently to insure that the batteries do not leak and damage the equipment. Replace batteries as soon as their voltage is less than 70% of the rated voltage.

Always calibrate every medical device before returning it to use.