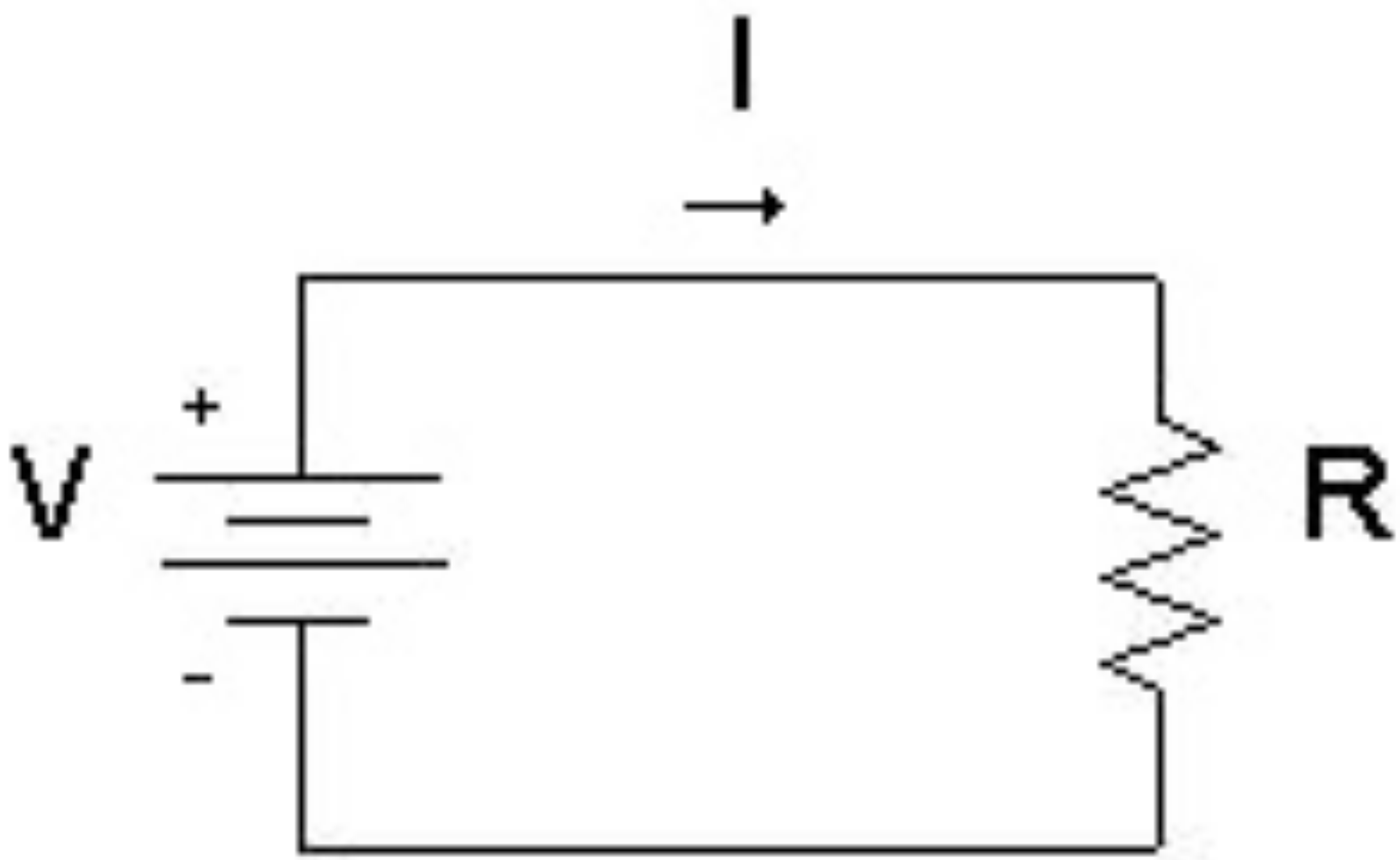
Wiring

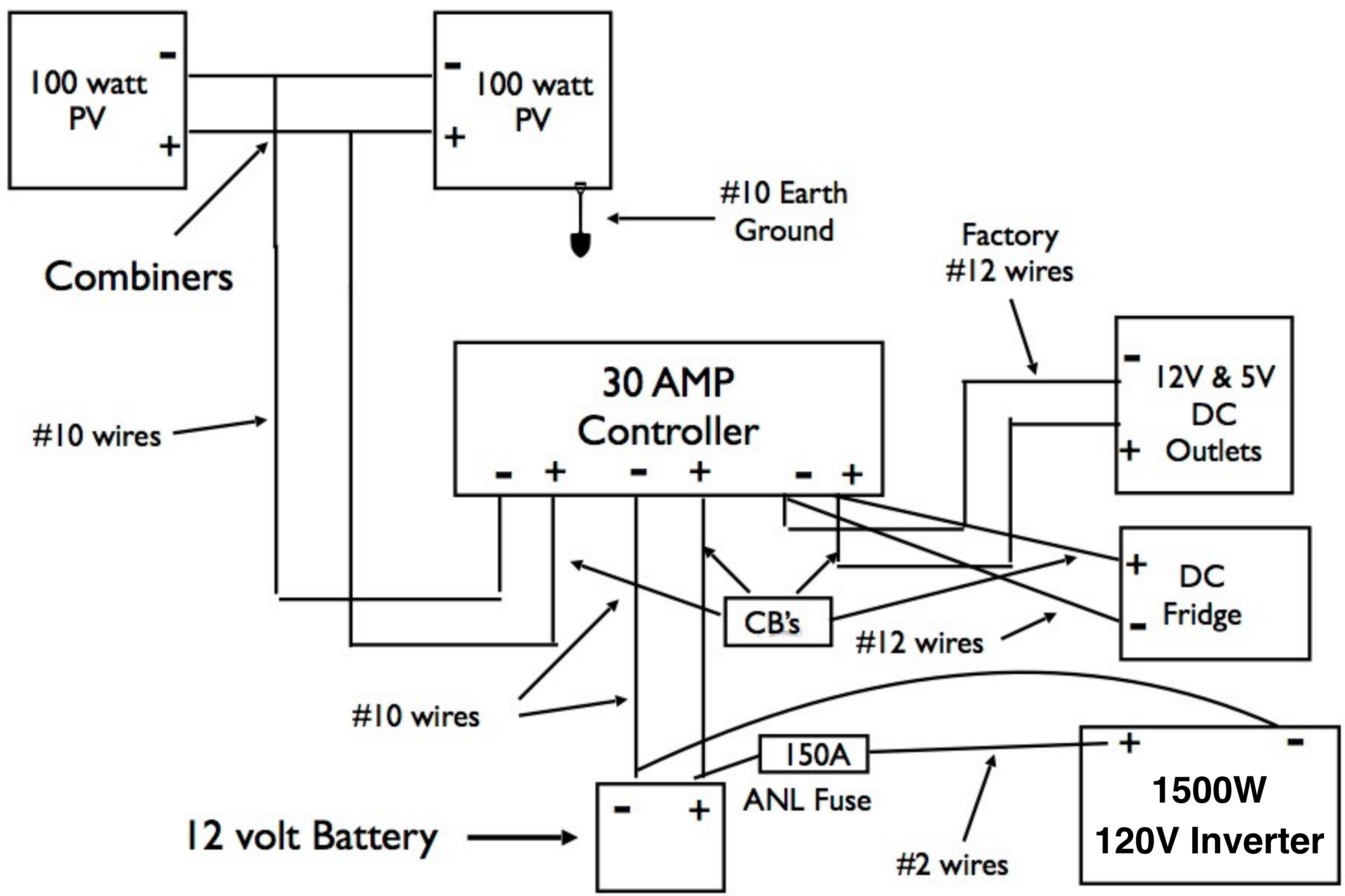
ampacity, voltage drop and grounding

Class 5 for Solar Team 6

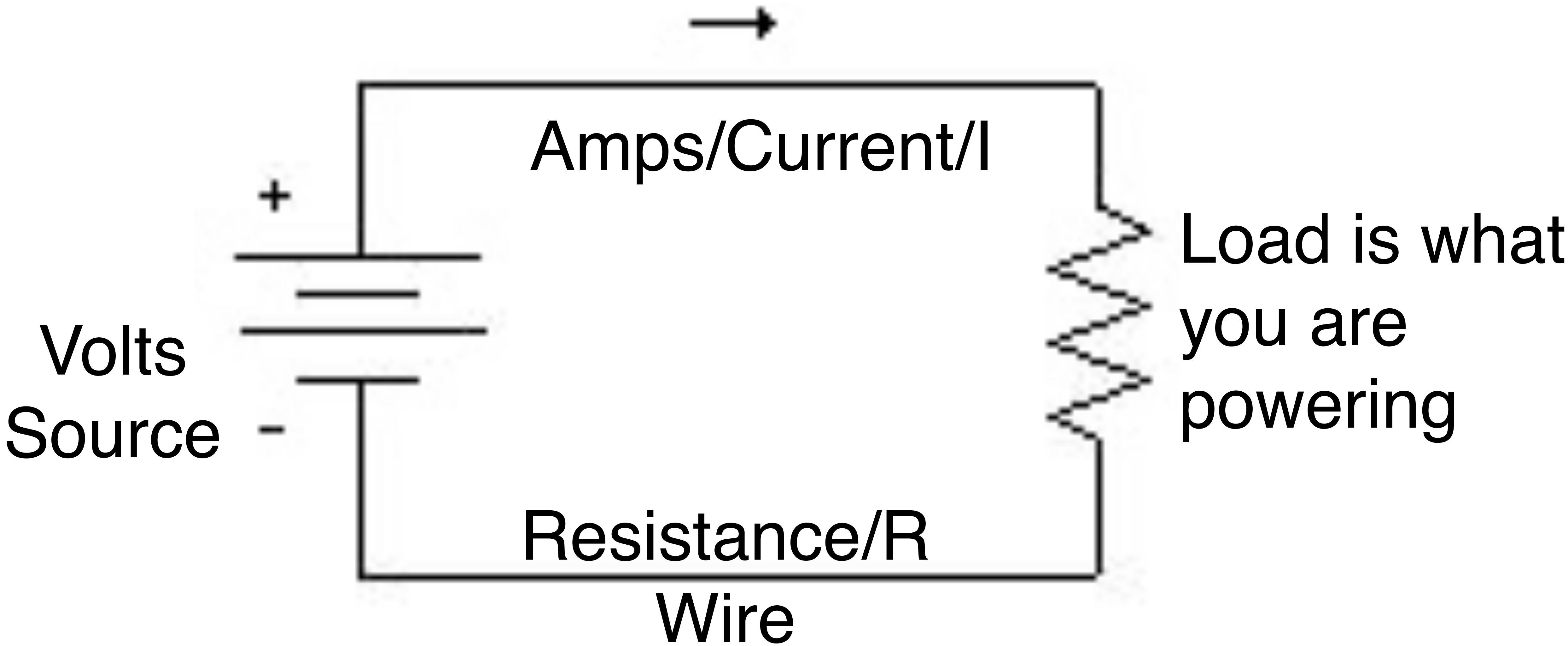
We've talked about all the components of
your solar system
Now let's talk about the
wires that actually transport the electricity…



Wires, all different sizes.



Wires and Load are Resistance



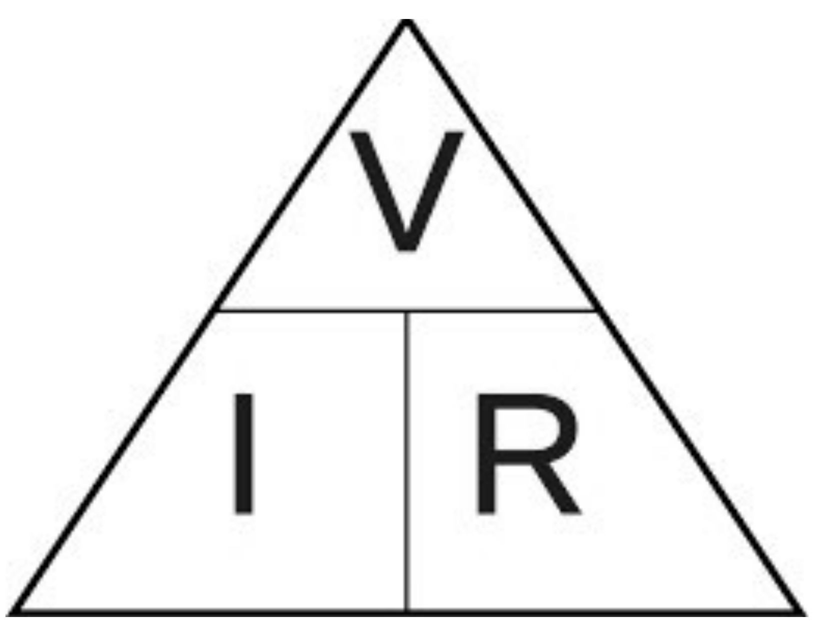
Without Resistance in a closed circuit,

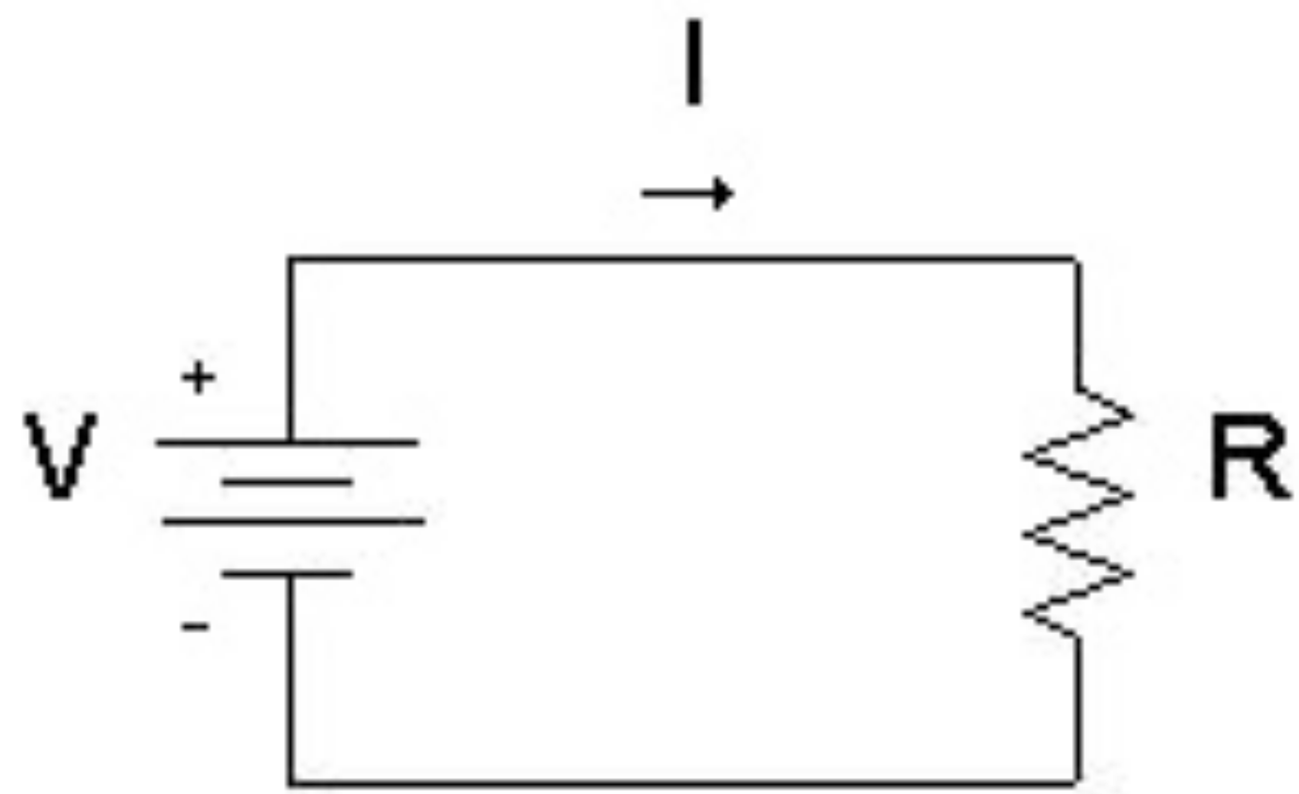
Amps will flow until the source is empty, a short circuit.

Ohm's (Ω's) law defines the relationship between Voltage, Current and Resistance in any electrical circuit

Voltage = Amps/Current x Resistance/Ω

V = I x R



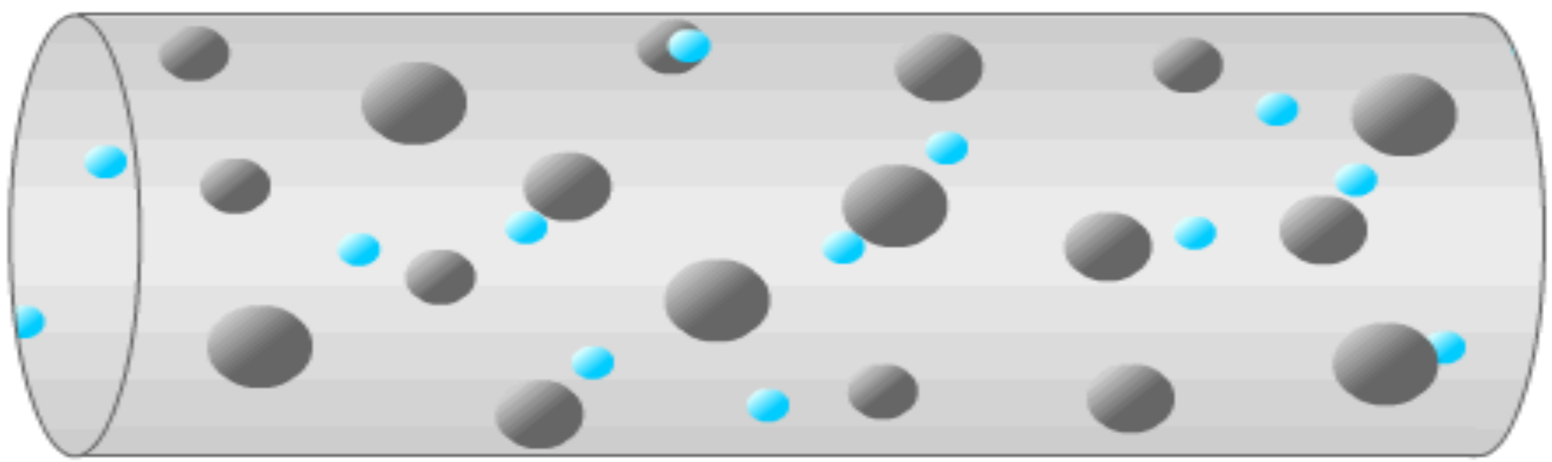


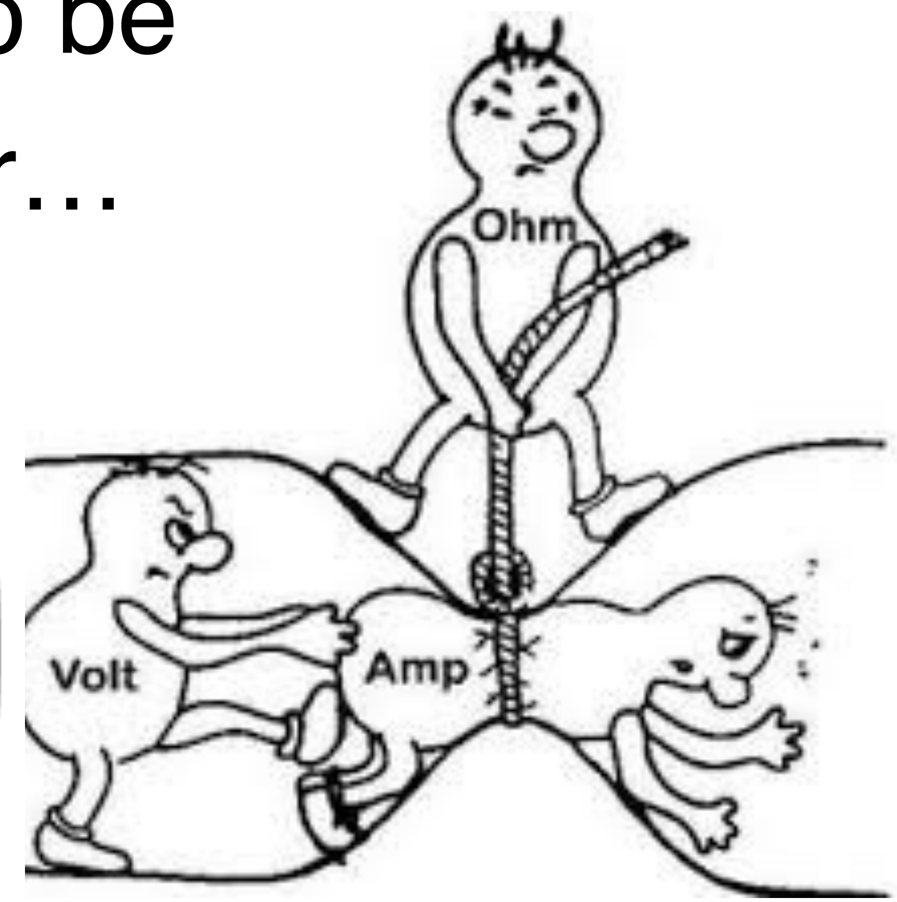
(I comes from the French, intensité)

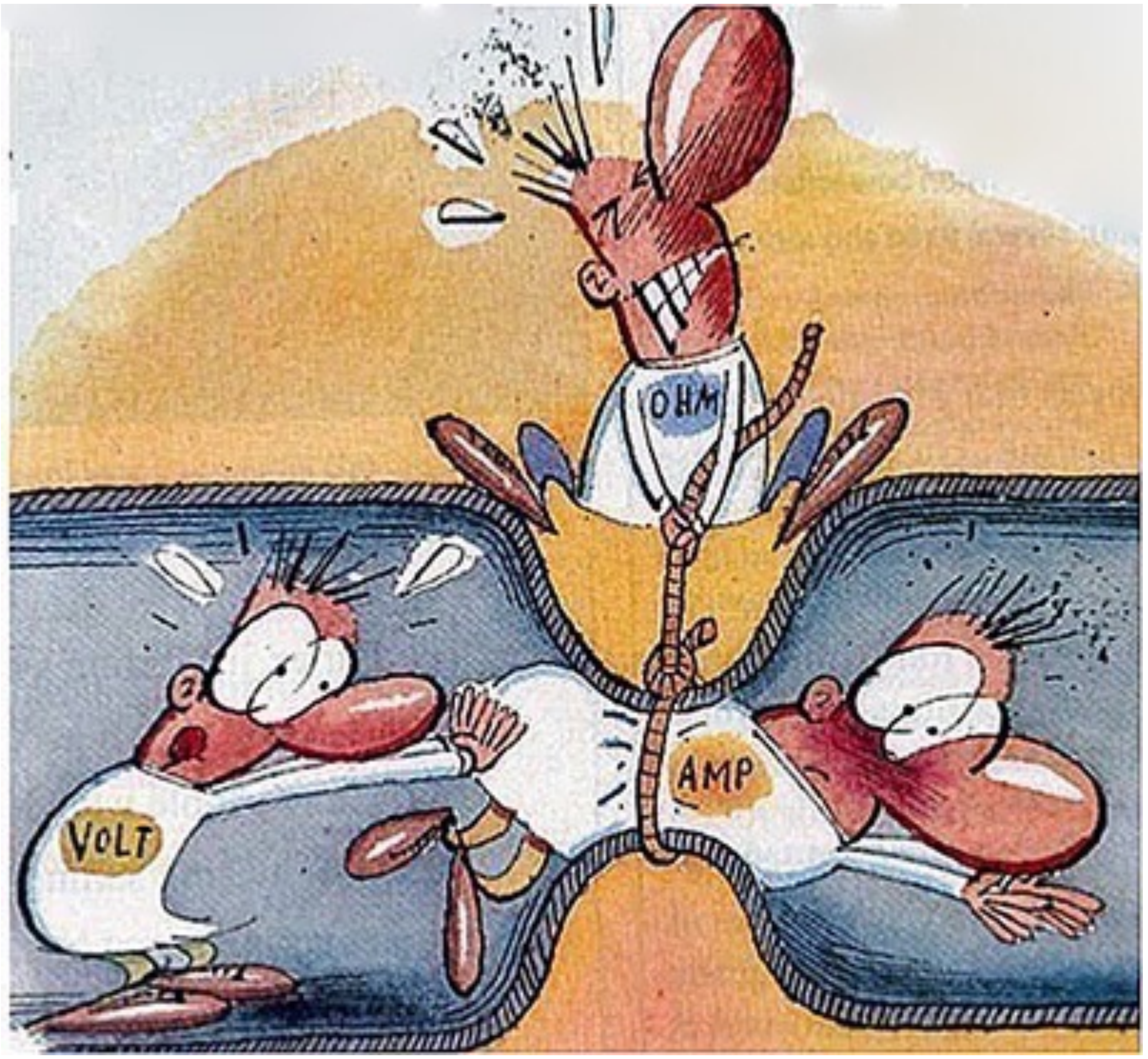
Wires control the the movement of electricity.

and they have to be

the right size or…





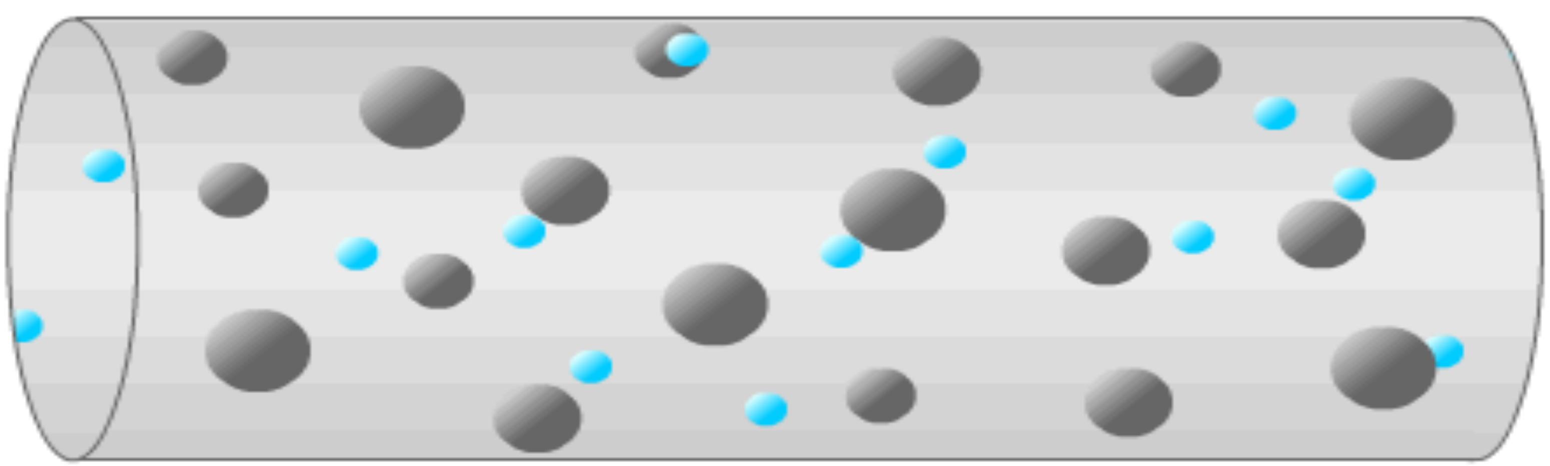


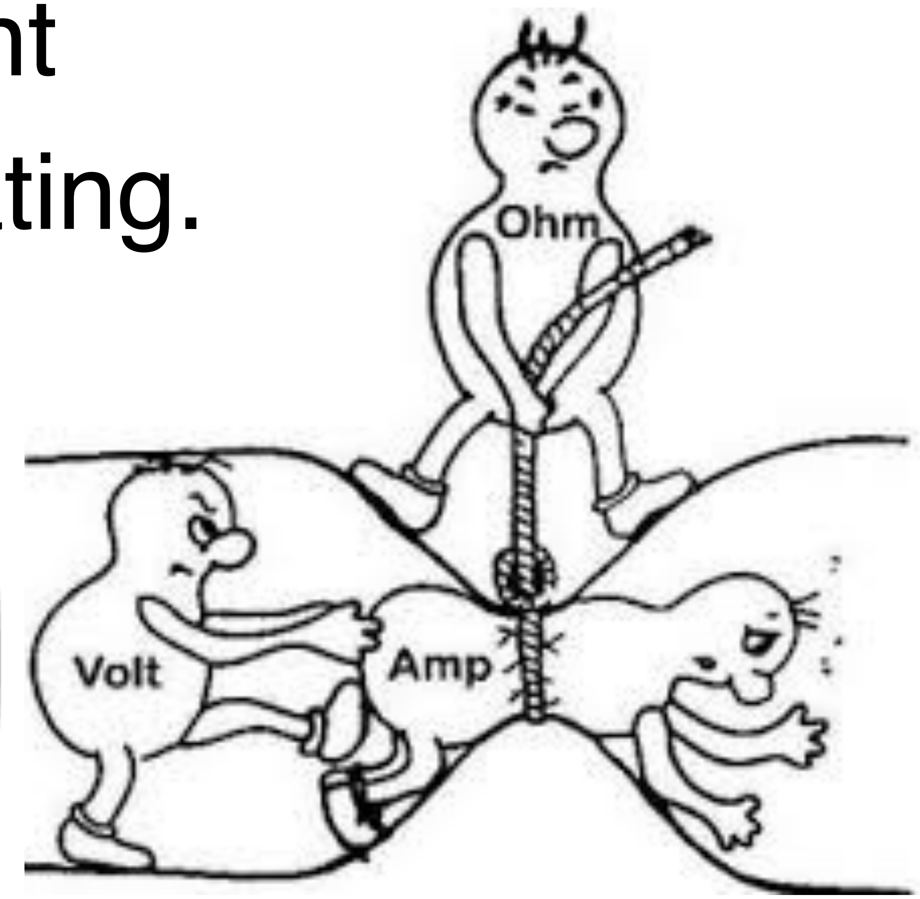
HEAT

We have to size wires so they can carry

Amps/Current

without overheating.





Ampacity

is the current carrying capacity of a wire.

Ampacity

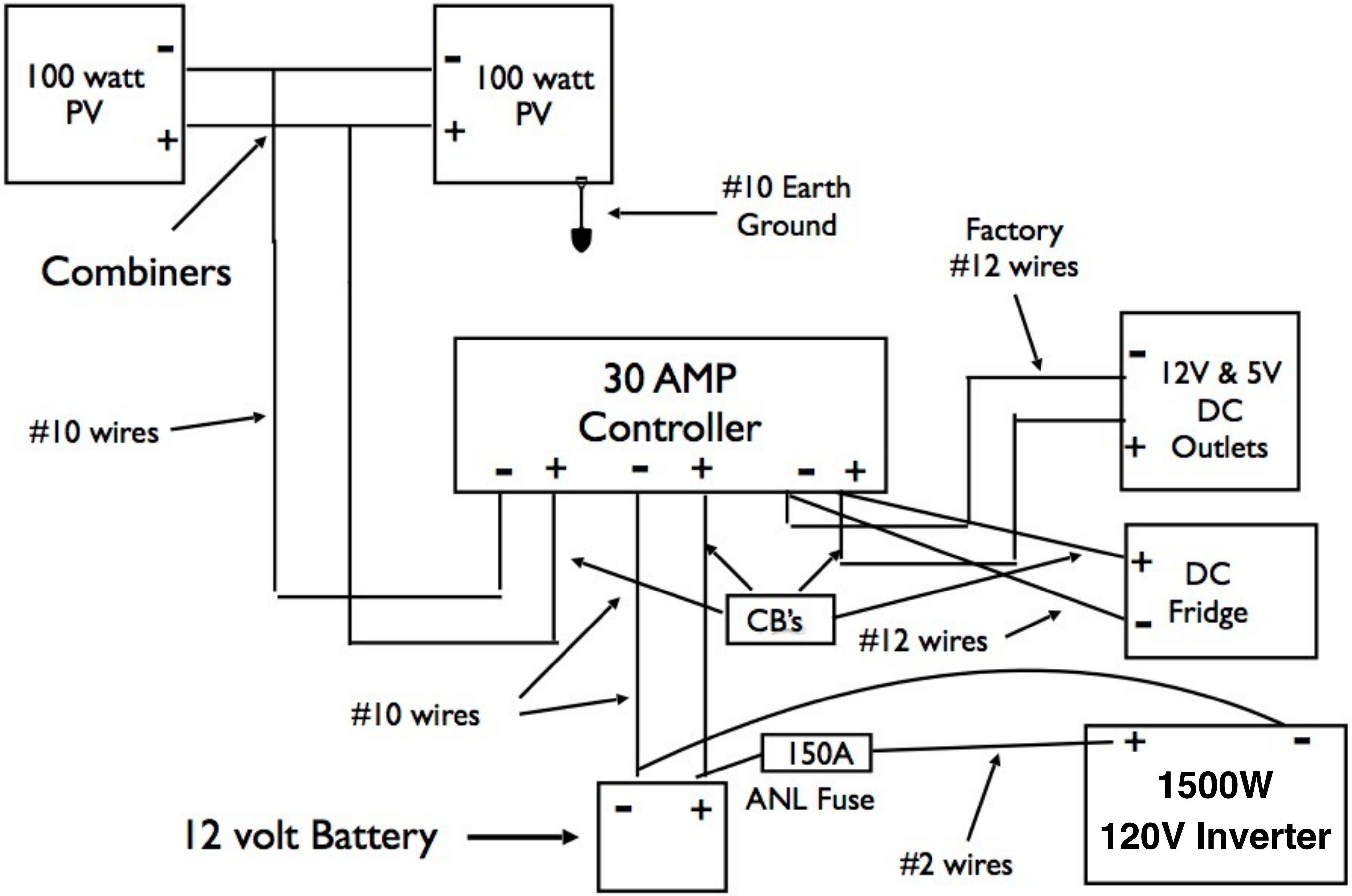
Wire ampacity is the maximum electrical current (Amperes or "Amps") that safely exist in a given size of conductor.

We use copper wire which has high ampacity.

Wire Gauges Size & Wire Ampacity Table

3/0 Gauge	200 AMPS
1/0 Gauge	150 AMPS
3 Gauge	100 AMPS
6 Gauge	55 AMPS
8 Gauge	40 AMPS
10 Gauge	30 AMPS
12 Gauge	20 AMPS
14 Gauge	15 AMPS

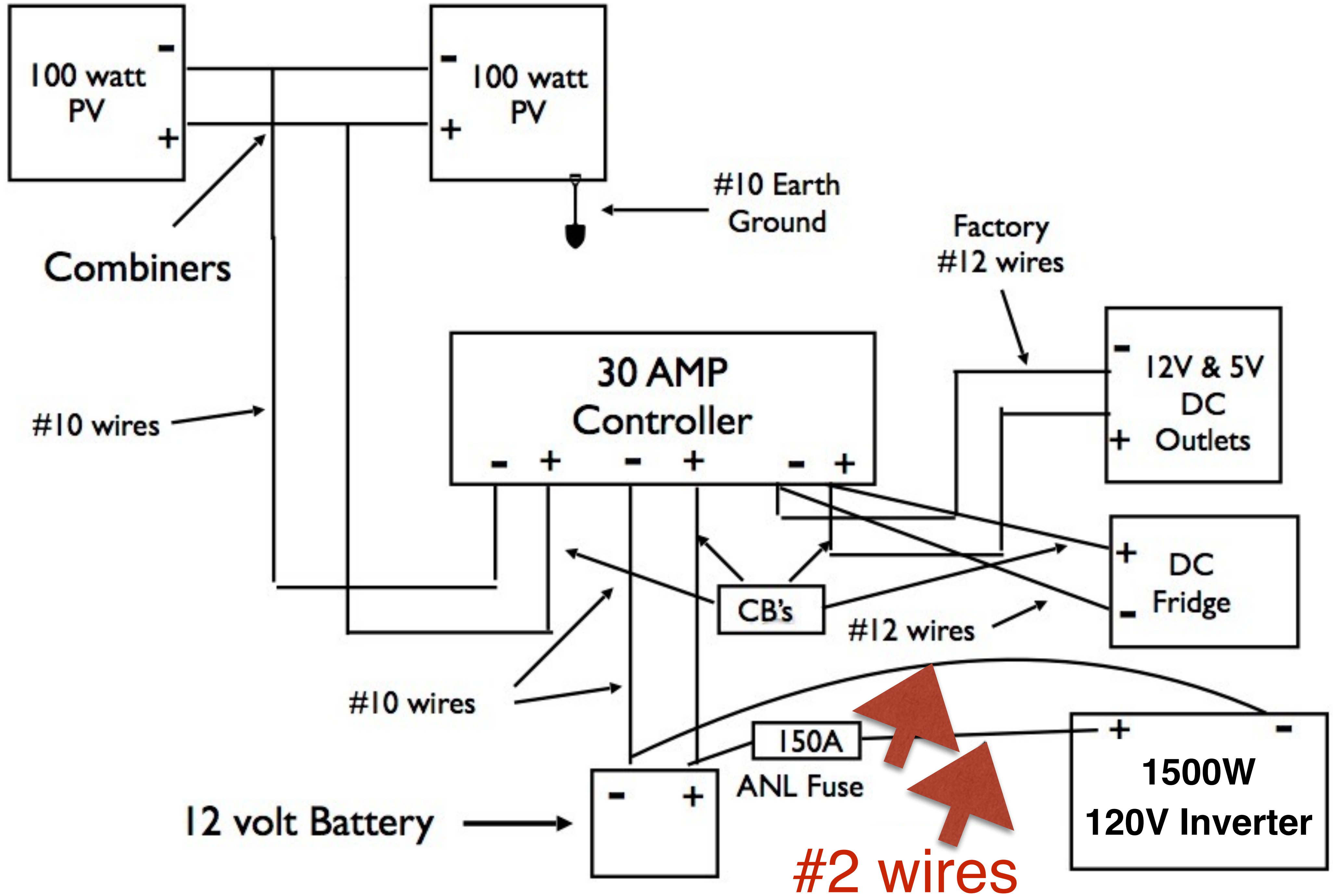
Larger wires have smaller gauge numbers just to confuse us.



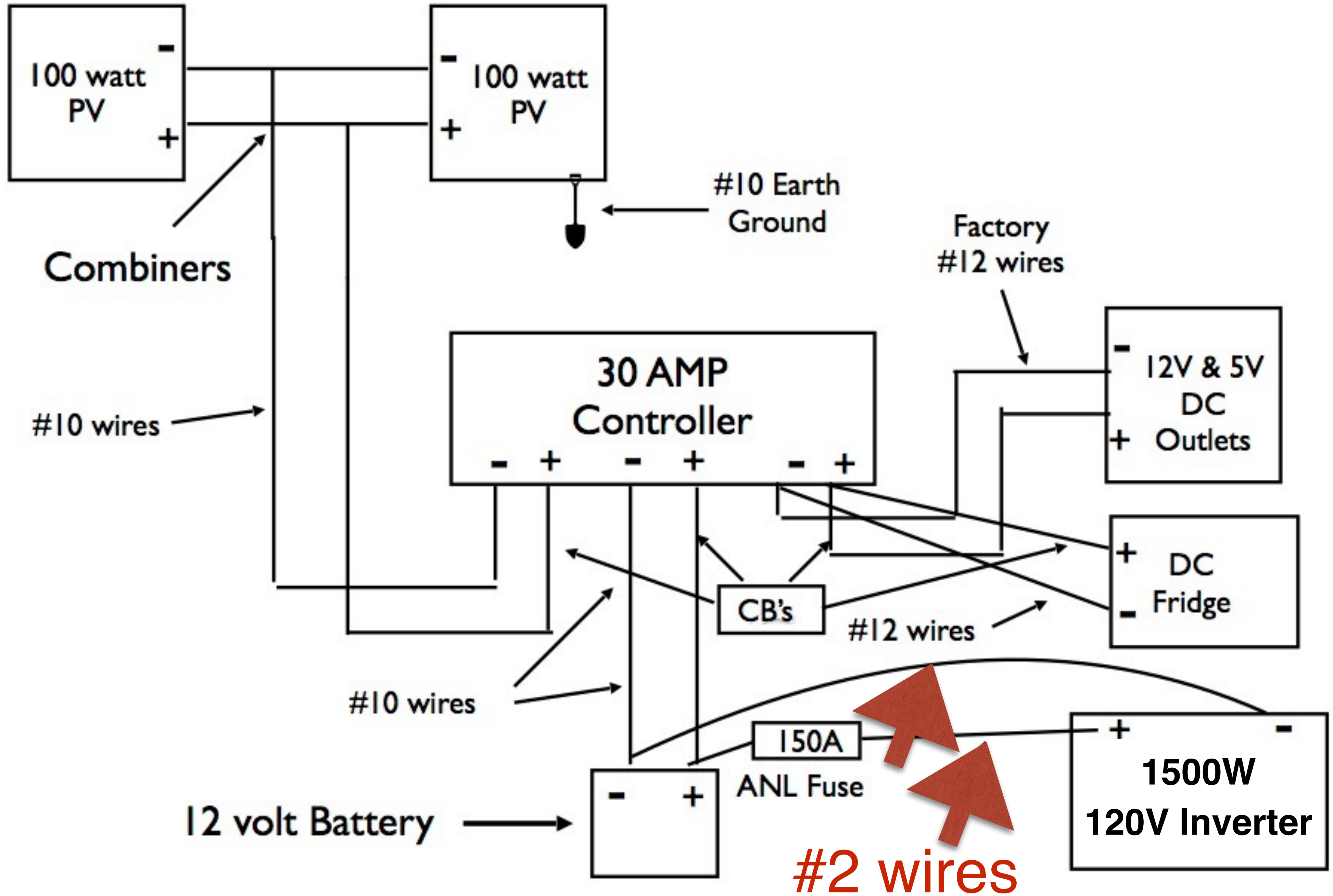
Here's your system again.

# indicates American Wire Gauge/AWG

Which wire is the largest?



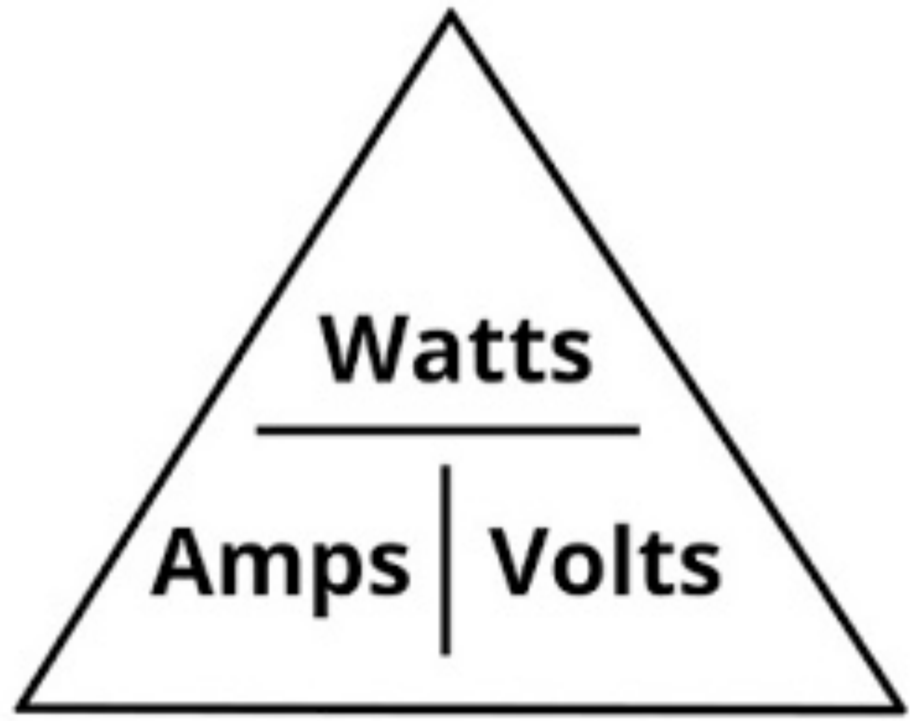
These wires carry the most Current/Amps in your system. **#2 AWG**.



Your **1500W 120V** inverter can be drawing

1500Watts from your **12V**olt battery.

Watts Law



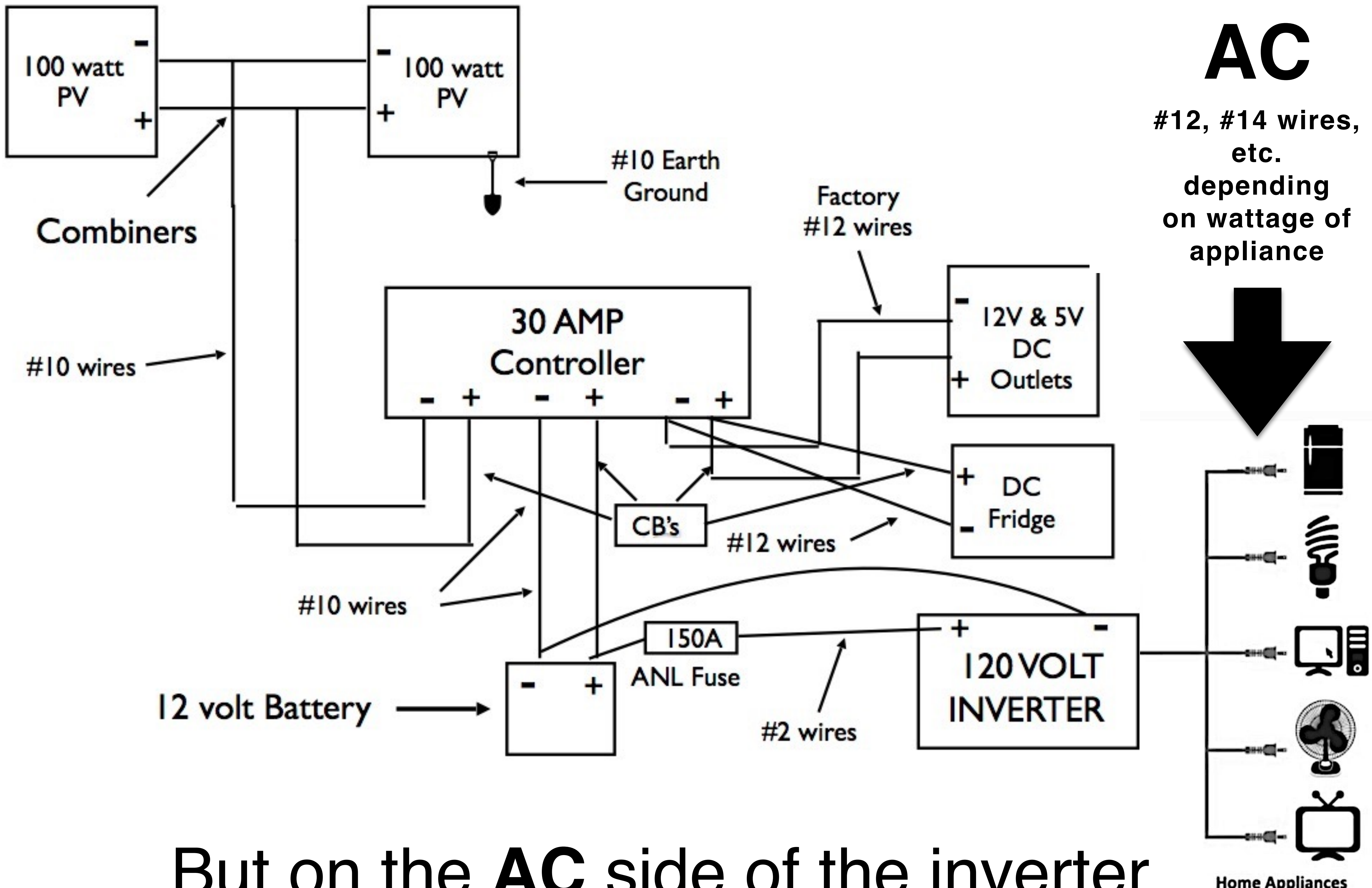
1500W ÷ 12V = 125A from the battery

Actually it can be much higher when an appliance has a startup surge.The **150 amp** fuse allows surge to pass through before heating, melting and cutting off power.

Wire gauge ampacity and wattage reference chart

		Load Amperage – Power @ 12VDC												
		10A 120W	20A 240W	30A 360W	40A 480W	50A 600W	60A 720W	70A 840W	80A 960W	100A 1200W	120A 1440W	160A 1920W	200A 2400W	250A 3000W
Cable Length (feet)	2	16AWG	16AWG	14AWG	12AWG	10AWG	8AWG	8AWG	6AWG	4AWG	2AWG	2AWG	2/0AWG	3/0AWG
	4	16AWG	16AWG	14AWG	12AWG	10AWG	8AWG	6AWG	6AWG	4AWG	2AWG	[illegible]	2/0AWG	4/0AWG
	6	16AWG	14AWG	12AWG	10AWG	8AWG	6AWG	6AWG	4AWG	2AWG	2AWG	[illegible]	3/0AWG	4/0AWG
	8	16AWG	14AWG	12AWG	10AWG	8AWG	6AWG	6AWG	4AWG	2AWG	2AWG	1/0AWG	3/0AWG	4/0AWG
	10	16AWG	14AWG	12AWG	10AWG	8AWG	6AWG	6AWG	4AWG	2AWG	2AWG	1/0AWG	3/0AWG	4/0AWG
	12	14AWG	14AWG	12AWG	10AWG	8AWG	6AWG	6AWG	4AWG	2AWG	2AWG	1/0AWG	3/0AWG	4/0AWG
	16	14AWG	12AWG	12AWG	10AWG	8AWG	6AWG	6AWG	4AWG	2AWG	2AWG	1/0AWG	3/0AWG	4/0AWG
	20	14AWG	12AWG	10AWG	8AWG	6AWG	6AWG	4AWG	4AWG	2AWG	2AWG	2/0AWG	4/0AWG	4/0AWG
	24	12AWG	12AWG	10AWG	8AWG	6AWG	4AWG	4AWG	2AWG	1AWG	1AWG	2/0AWG	4/0AWG	4/0AWG
	28	12AWG	10AWG	8AWG	8AWG	6AWG	4AWG	4AWG	2AWG	1AWG	1AWG	2/0AWG	4/0AWG	4/0AWG
	33	10AWG	10AWG	8AWG	6AWG	4AWG	4AWG	4AWG	2AWG	1AWG	1AWG	2/0AWG	4/0AWG	4/0AWG
	42	10AWG	8AWG	6AWG	6AWG	4AWG	4AWG	2AWG	1AWG	1/0AWG	1/0AWG	3/0AWG	4/0AWG	NR
	50	8AWG	6AWG	6AWG	4AWG	4AWG	2AWG	2AWG	1AWG	1/0AWG	1/0AWG	3/0AWG	NR	NR

We use tables when we don't know the exact resistance of a wire



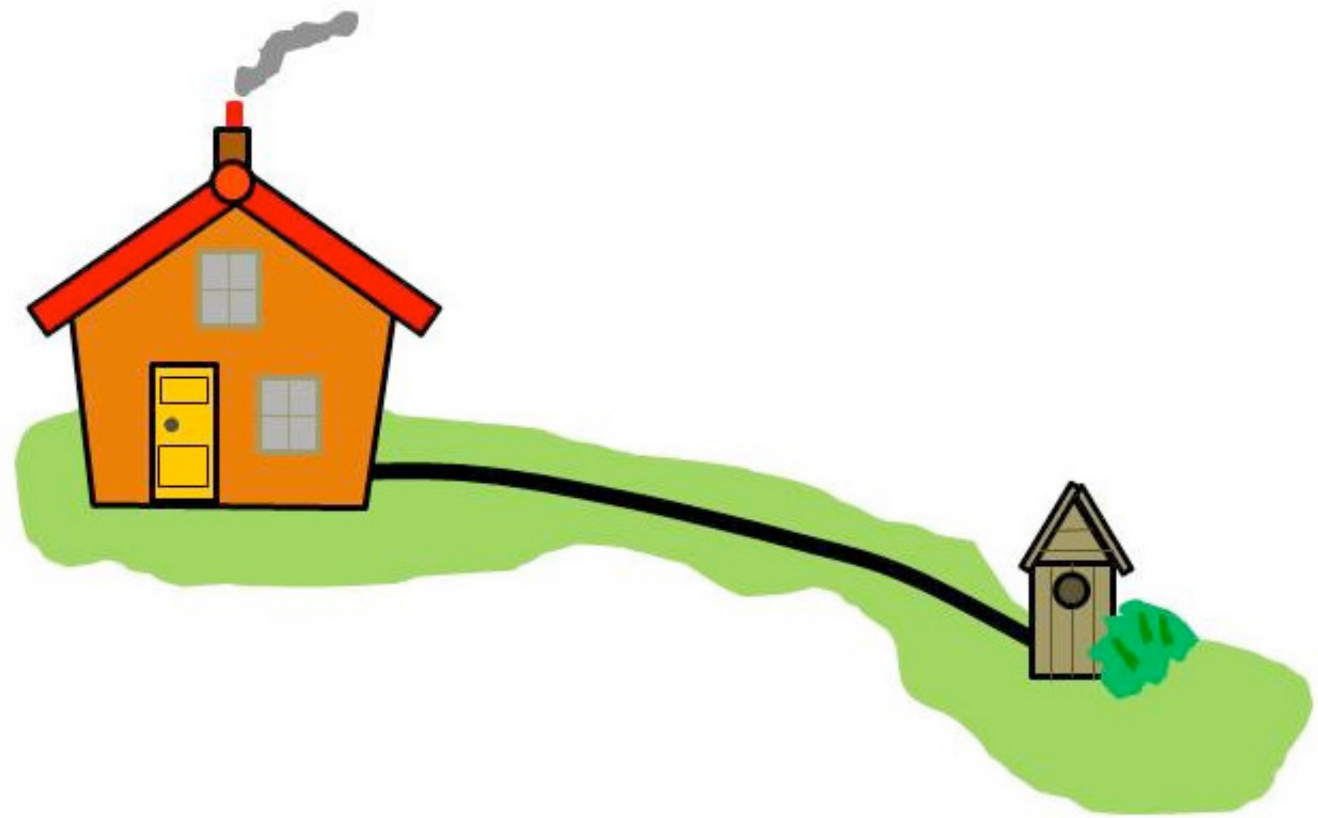
But on the **AC** side of the inverter,

wires can be #12, #14 or smaller. WHY?

Higher voltage, **120V AC**, from the inverter means less amperage needed for the rated wattage so wires can be smaller.

Watts Law V x A = W

Voltage Drop



Voltage needs a larger wire
to go long distance without losing power.

Ohm's Law defines Voltage Drop in a circuit…

Voltage Drop = IR

Voltage Drop

Voltage drop is a function of the
following three parameters.
Wire gauge
Length of wire
Current flow in the wire

The greater a wire’s length,
the greater the resistance to current flow.
Excessively long wire will result in a loss of power
to the load and lower system efficiency.
It will also reduce the life expectancy
of most appliances and equipment.

So what are going to be the
longest wires in your system?

Probably the wire from your PV
to the controller and back,
(a complete circuit)
if you want to keep the panels out of
the shade of your house.

Gallup Solar cables are **#10AWG**.

How many Amps do your panels produce?

100W Polycrystalline Photovoltaic Solar Panel	
Part #:	SOL-100P-01
Maximum Power (Pmax):	100 Watts
Open Circuit Voltage (Voc):	21.90 Volts
Short Circuit Current (Isc):	6.13 Amps
Max Power Voltage (Vpm):	18.00 Volts
Max Power Current (Imp):	5.56 Amps
Max System Voltage:	1000 VDC (600 VDC UL)
Dimensions:	40.1" x 26.4" x 1.4" [1020mm x 670mm x 35mm]
Weight:	19.6 lbs [8.9kg]
Max Series Fuse Rating:	10 Amps
Nom Operating Cell Temp:	45 C [+/-2]

This is the label on the back of your panel again

Multiply Max Power Current x two panels in parallel.

5.56 x 2 = 11.12 amps*

x 1.25 = 13.90 amps

x 1.25 = 17.37 amps

Use 18 amps

*For safety multiply the current by 125%.
National Electric Code requires an additional 125% be added to the current from PV to batteries in case of exceptionally cold sunny days.

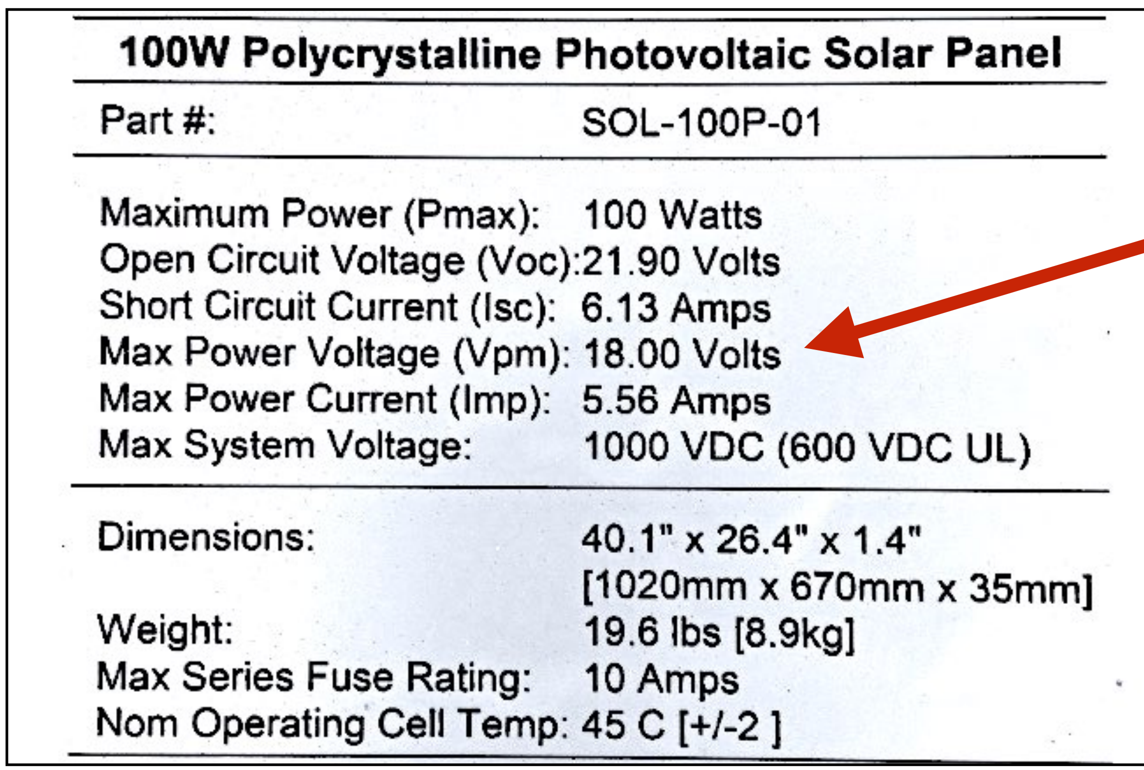
With **18 amps**, close to 20, from your panels to the controller and back you can go 50 feet with **10AWG**.

10% Voltage Drop at 12 Volts

Length		Current (Amps)												
		5	10	15	20	25	30	40	50	60	70	80	90	100
10'	3 m	18	18	18	16	16	14	14	12	12	10	10	10	10
15'	5 m	18	18	16	14	14	12	12	10	10	8	8	8	8
20'	6 m	18	16	14	14	12	12	10	10	8	8	8	6	6
25'	8 m	18	16	14	12	12	10	10	8	8	6	6	6	6
30'	9 m	18	14	12	12	10	10	8	8	6	6	6	6	4
40'	12 m	16	14	12	10	10	8	8	6	6	6	4	4	4
50'	15 m	16	12	10	10	8	8	6	6	4	4	4	2	2
60'	18 m	14	12	10	8	8	6	6	4	4	2	2	2	2
70'	21 m	14	10	8	8	6	6	6	4	2	2	2	2	1
80'	24 m	14	10	8	8	6	6	4	4	2	2	2	1	1
90'	27 m	12	10	8	6	6	6	4	2	2	2	1	1	1/0
100'	30 m	12	10	8	6	6	4	4	2	2	1	1	1/0	1/0
110'	33 m	12	8	8	6	6	4	2	2	2	1	1/0	1/0	1/0
120'	36 m	12	8	6	6	4	4	2	2	1	1	1/0	1/0	2/0
130'	40 m	12	8	6	6	4	4	2	2	1	1/0	1/0	2/0	2/0
140'	43 m	10	8	6	6	4	2	2	1	1	1/0	2/0	2/0	2/0
150'	46 m	10	8	6	4	4	2	2	1	1/0	1/0	2/0	2/0	3/0
160'	49 m	10	8	6	4	4	2	2	1	1/0	2/0	2/0	3/0	3/0
170'	52 m	10	6	6	4	2	2	2	1	1/0	2/0	2/0	3/0	3/0

Notice we are accepting a 10% voltage drop.

Can you tolerate a 10% Voltage Drop?



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Weight:	19.6 lbs [8.9kg]
Max Series Fuse Rating:	10 Amps
Nom Operating Cell Temp:	45 C [+/-2]

This is the label on the back of your panel again

Yes, because your two panels in parallel produce about 18 Volts.

But your 12V Battery only needs a little more than 12 Volts to keep charging.

A **50ft** circuit with only 3% voltage drop would require a **4AWG** wire, pretty expensive.

Wire Gauges for a 3% Voltage Drop in a DC 12-Volt System

Total Current on Circuit (amps)	Length of Conductor from Source of Current to Device and Back to Source (feet)																		
	10	15	20	25	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
5	18	16	14	12	12	10	10	10	8	8	8	6	6	6	6	6	6	6	6
10	14	12	10	10	10	8	6	6	6	6	4	4	4	4	2	2	2	2	2
15	12	10	10	8	8	6	6	6	4	4	2	2	2	2	2	1	1	1	1
20	10	10	8	6	6	6	4	4	2	2	2	2	1	1	1	0	0	0	2/0
25	10	8	6	6	6	4	4	2	2	2	1	1	0	0	0	2/0	2/0	2/0	2/0
30	10	8	6	6	4	4	2	2	1	1	0	0	0	2/0	2/0	3/0	3/0	3/0	3/0
40	8	6	6	4	4	2	2	1	0	0	2/0	2/0	3/0	3/0	3/0	4/0	4/0	4/0	4/0
50	6	6	4	4	2	2	1	0	2/0	2/0	3/0	3/0	4/0	4/0	4/0				
60	6	4	4	2	2	1	0	2/0	3/0	3/0	4/0	4/0	4/0						
70	6	4	2	2	1	0	2/0	3/0	3/0	4/0	4/0								
80	6	4	2	2	1	0	3/0	3/0	4/0	4/0									
90	4	2	2	1	0	2/0	3/0	4/0	4/0										
100	4	2	2	1	0	2/0	3/0	4/0	4/0										

We could have wired our two **18V** panels in series and doubled the voltage.

But then we would only have half the Amps coming in every sunny hour.

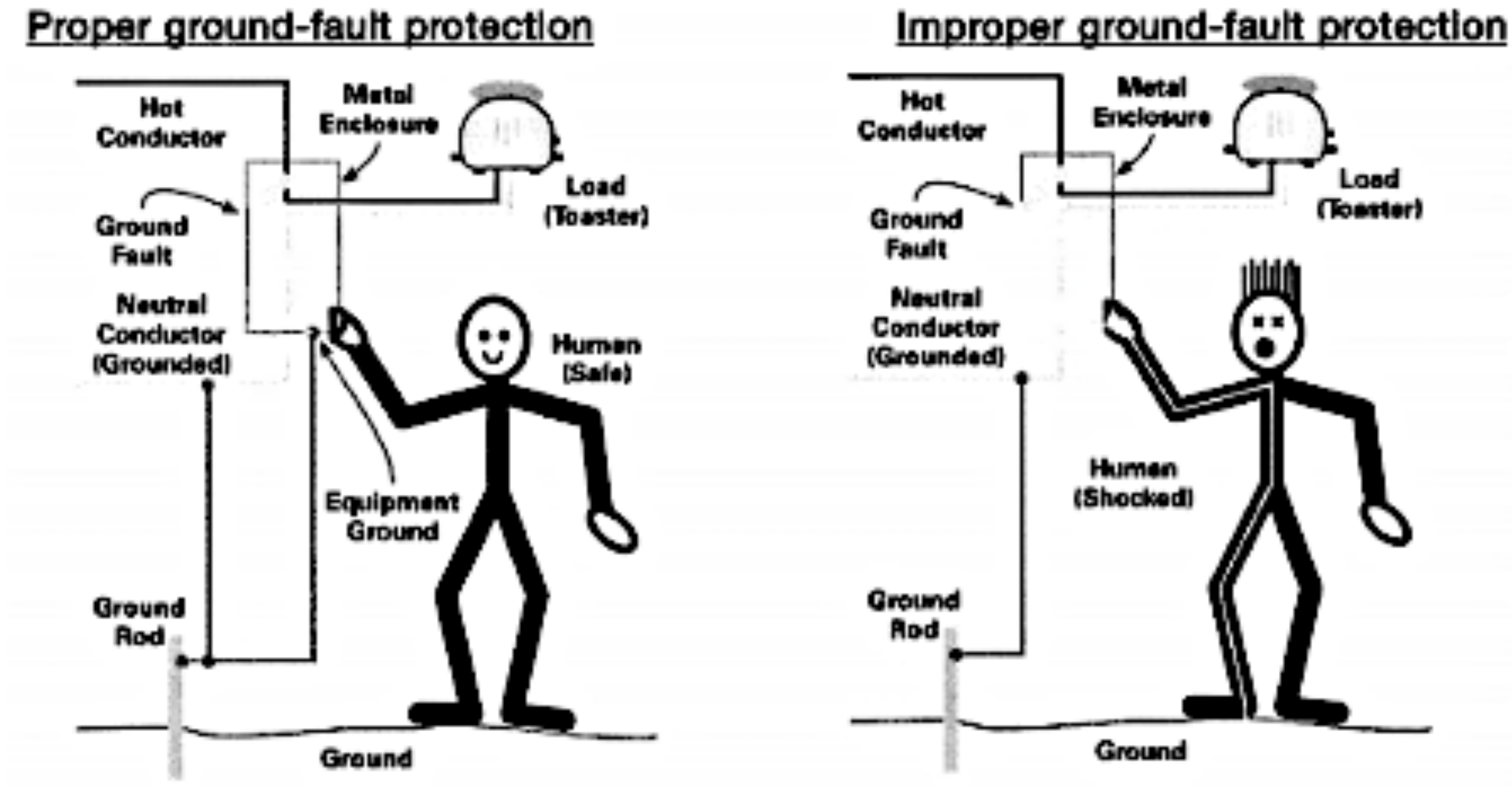
We will stick with **18 Amp Hours** coming in every hour to keep steadily bringing our **110 Amp Hour** battery up to full.

Grounding

System Grounding is achieved
when one of the **conductive** wires is
intentionally given a direct path to the earth.
This is accomplished by running a wire to a ground rod.

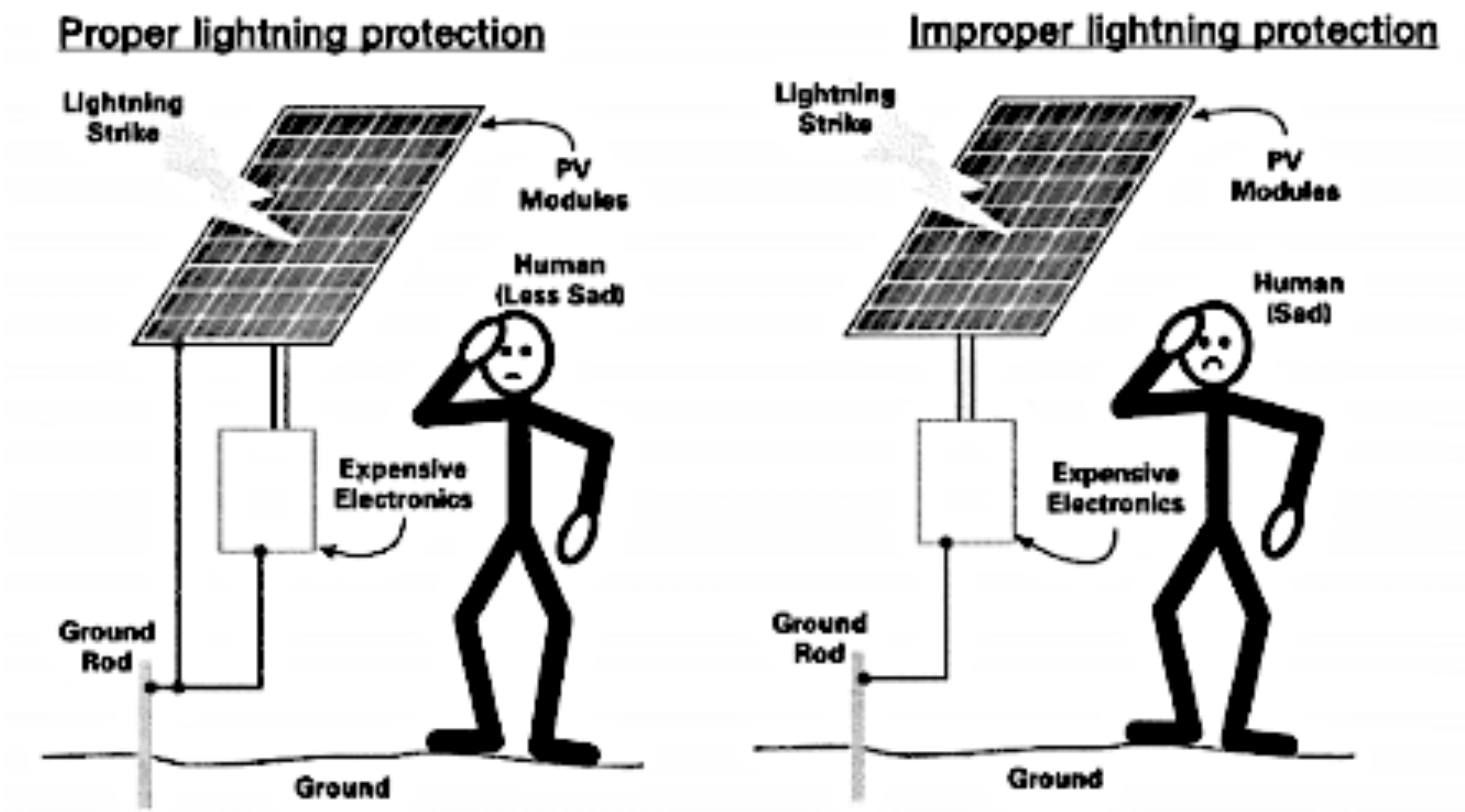
In systems smaller than **50V** like yours,
Equipment Grounding is all that is required.
The grounding wire goes from the
equipment to the ground rod,
a long copper rod driven directly into the soil.

System Grounding



Solar systems with a system voltage over 50 volts are required to be grounded by having one of the current-carrying conductors connected to a grounding electrode.

Equipment Grounding

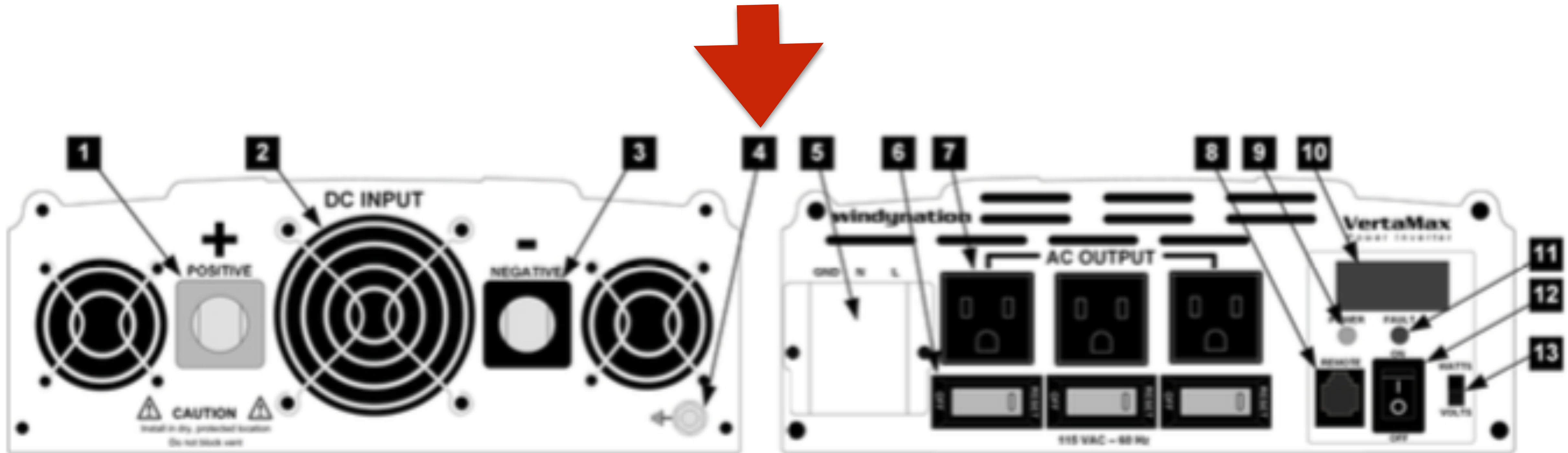


An equipment-grounding conductor is a conductor that does not normally carry current except under fault conditions.
It connects exposed metal surfaces of electrical equipment together and then to ground.

Only your solar panels and inverter need Equipment Grounding.

GROUNDING SOLAR PANELS

This 4’ copper rod is an equipment ground attached to the frame of the solar panels.



- **1** DC Positive (+) Input
- **2** Cooling Fan[1]
- **3** DC Negative (-) Input
- **4** Grounding Terminal
- **5** Permanent AC Connection[2]
- **6** Circuit Breaker Protector [x3]
- **7** AC Outlets [x3]
- **8** Remote Switch Port[3]
- **9** Power LED
- **10** Digital Display Meter
- **11** Fault LED
- **12** ON/OFF Switch
- **13** Digital Display Select Switch

[1]Number of fans depends on model

GROUNDING THE INVERTER

A copper wire will go from the grounding terminal on your inverter to earth ground either to the grounding rod on the solar panels or to its own grounding rod.


You are ready to wire!