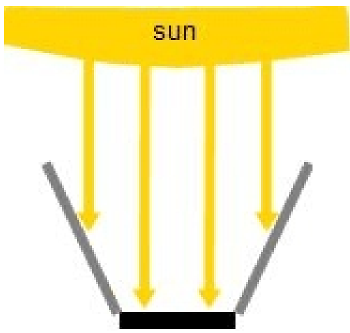
How to Design Solar Reflectors for Solar Cookers

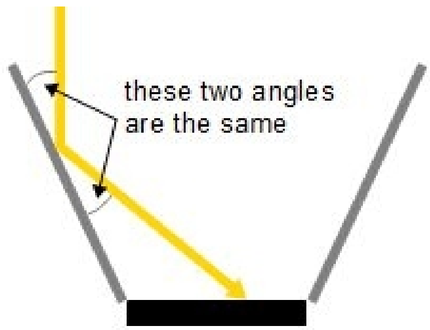
From: Rimstar.org

You can design many solar reflectors for solar cookers, and other things that need reflectors, without doing any mathematics. In fact you can often get by knowing just two things:

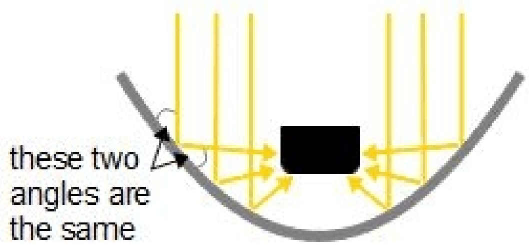
1. If you are pointing directly at the sun then the sun's rays are arriving straight at you across your entire reflector.



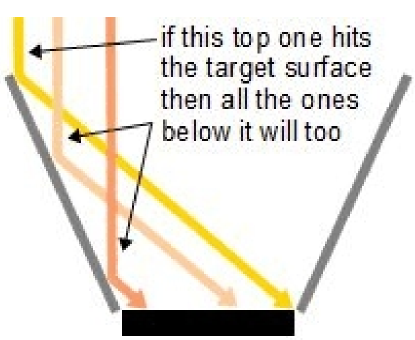
2. The angle that a sun's ray reflects off your reflector is the same as the angle that it arrived at.

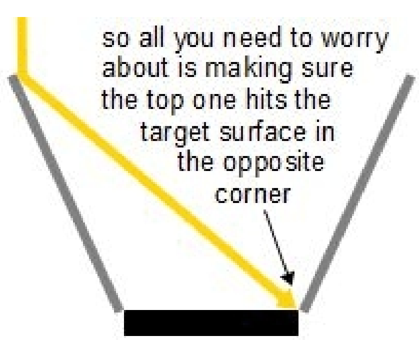


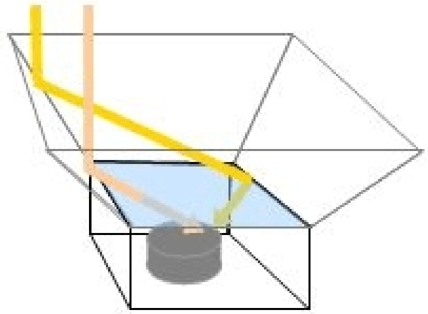
This is also true if you're designing a parabolic solar cooker (see below), funnel solar cooker, CooKit, Pavarti, or any kind of solar cooker that has reflectors.



A helpful rule of thumb, shown below, that works for many designs is that the only sun's ray you need to worry about is the one that reflects off the top of your reflector. All sun's rays that reflect lower down will hit your target surface somewhere as long as the top ray hits your target on the opposite side. This is made use of in the calculators below.





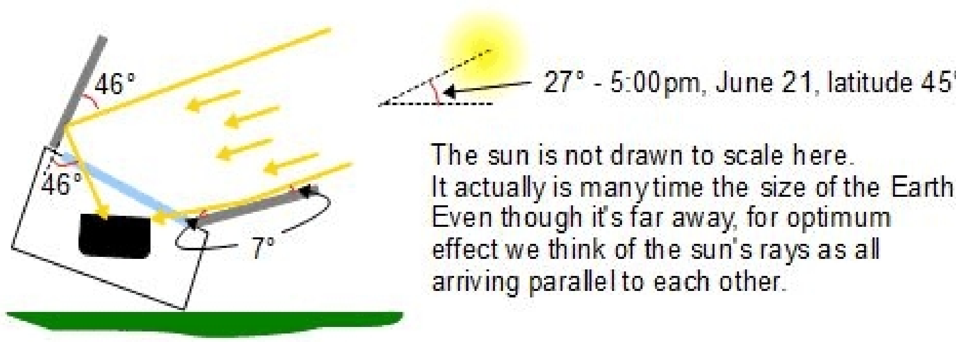


Box oven solar cooker. The target we're trying to cover with the reflector is the glass/plastic glazing.

Using multiple reflector angles

Solar box oven cookers cannot always be tilted to face the sun if the sun is low in the sky. Doing so may cause the cooking pot to tip over, or if the pot is on a swivel base, it may already be at it's maximum swivel angle.

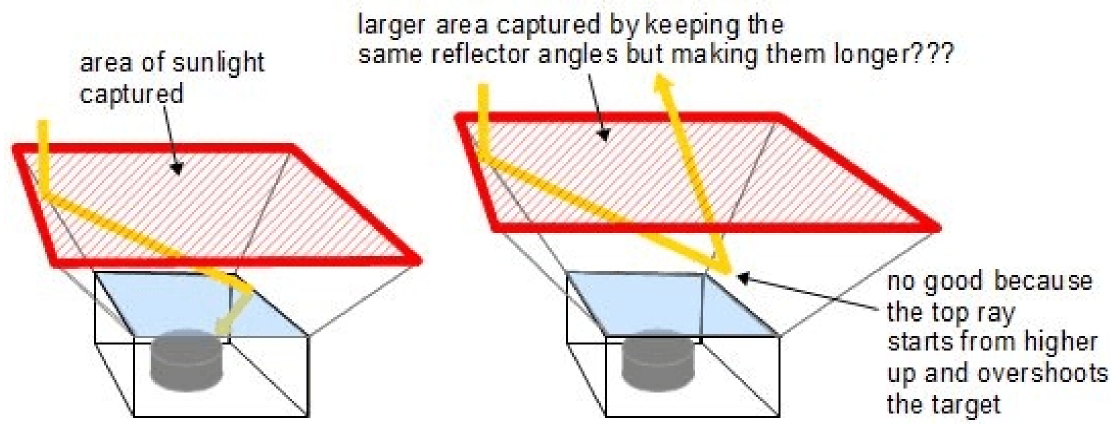
To handle this situation you'd tilt the oven as much as you can. Then, as shown in the following diagram, you'd put the top reflector on a very steep angle and the bottom reflector on a very shallow angle. Note that the angles are adjusted below such that the angles that the sun's rays reflect off the reflectors are the same as the angles that the sun's rays arrived at the reflectors. This is just as is described at the very top above as the number 2 thing to know.



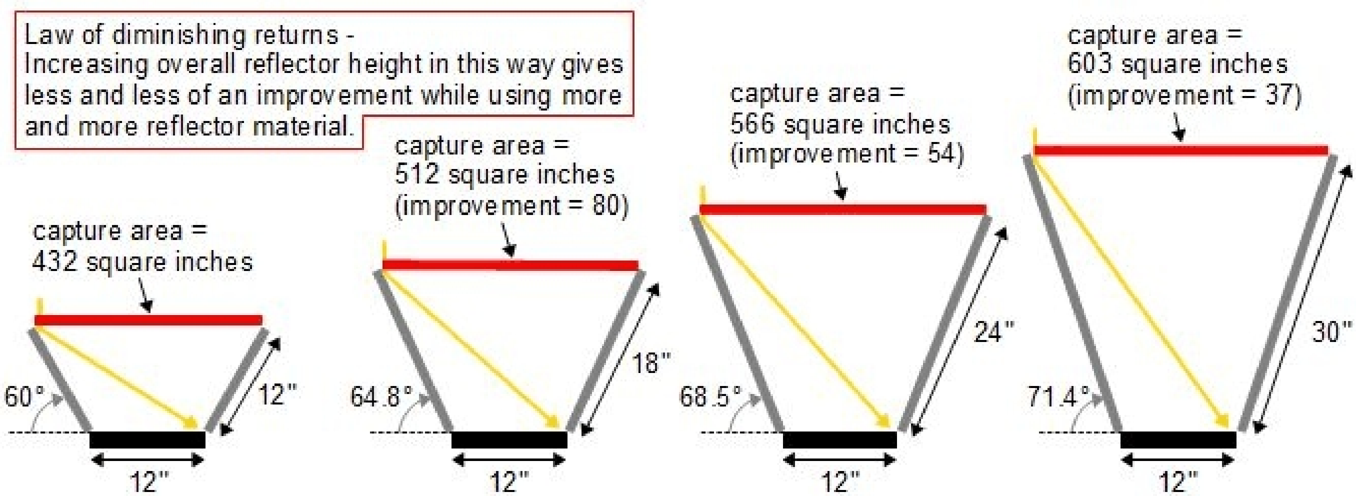
Improving the sunlight capture area

The capture area is basically the amount of sunlight you're capturing and then concentrating using the reflectors. It's basically the size of the hole made by the top of the reflectors.

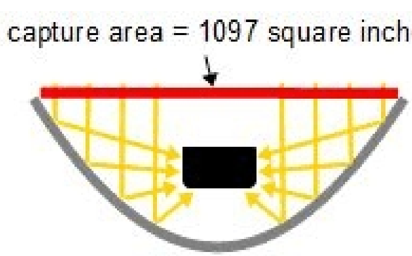
So does simply making the reflectors longer while keeping the angle the same as shown in the following diagram improve the capture area? The answer is no, since the sun's rays that strike the top of the reflector will eventually reflect back out without hitting the target area and the cooking pot in a solar cooking oven in this example.



So you have to change the angle as well as the reflector length (see the following diagram.) Two methods are given below to show how to do this. However, you can see that as you increase the reflector length, and hence the total height of the reflector, more and more, the improvement you get in capture area is less and less.

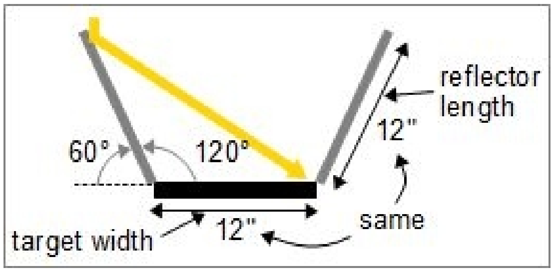


This is because of the uniform shape of the reflectors and/or because of the location of the target. If you really want to increase your capture area a lot then a better way is to start moving your target in front of the reflector as shown in the following diagram. Compare the capture area of the parabolic reflector below, 1097 square inches, to the capture area of rightmost reflector above, 603 square inches. Note: they are both drawn with the same scale.



Two methods for figuring out solar reflector angles, lengths, ...

A popular thing to do is to make your reflector length the same as your target width. In that case the optimal reflector angle is around 60 degrees and the above rule of thumb regarding the top ray will just happen.

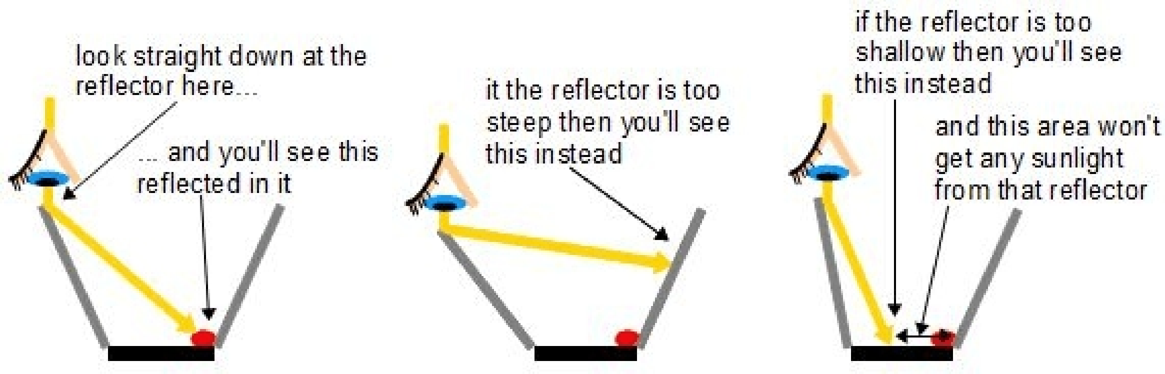


Two methods are suggested below for figuring out your own parameters. You can either:

- make your reflector by eyeballing things and getting a very accurate result as talked about next, or
- you can use some of the calculators given further below.

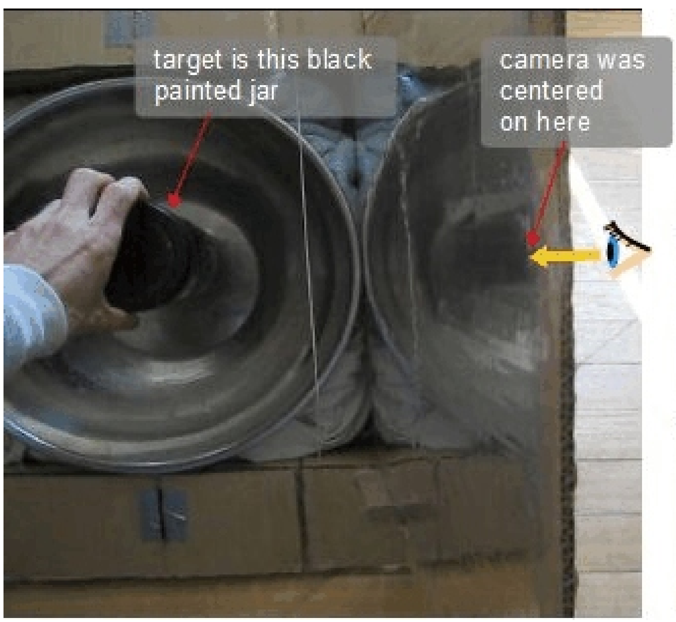
Method 1 - Eyeballing to get optimum reflector angle

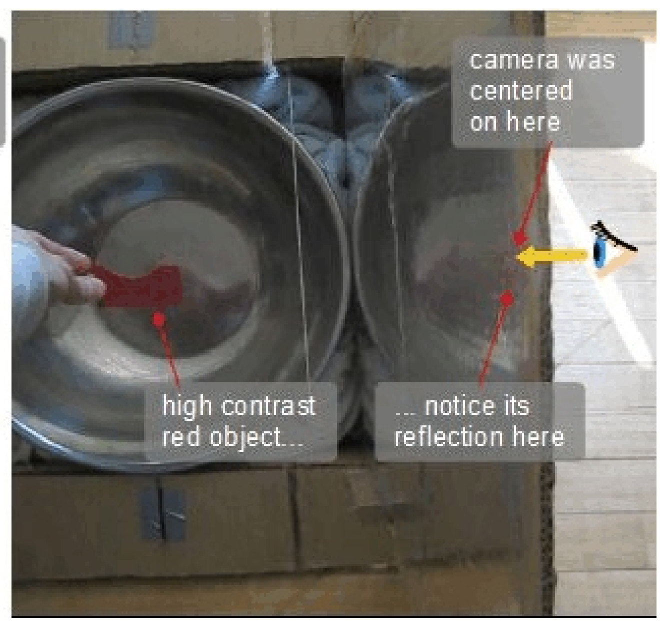
Simply put, you pretend that your eye is the sun and you look at your reflector from the sun's perspective, as shown below. If you see your target surface then that means the sun will too. Look straight down at what is reflected in the top of your reflector. Keep adjusting the reflector angle until you see the opposite part of the target area reflected into your eye. Once you see that then you know the rest of the reflector is good too, as discussed above. If it helps, put a brightly colored object in the target area, like the red ball shown below.



I used this technique very successfully on my cone solar cooker. The following photos show how I did it.

Finding the optimum reflector angle





Method 2 - Manual Calculation

Following is an explanation of how to calculate the optimal angle between the glazing and the reflector of a solar oven.

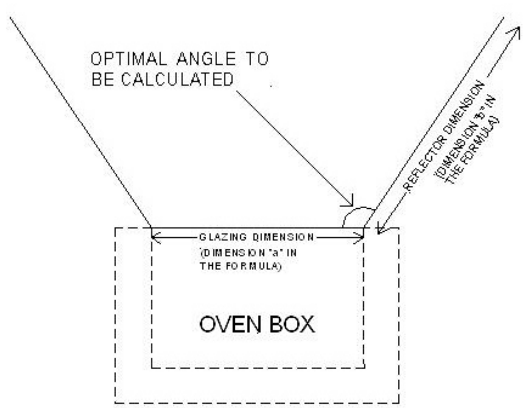
Designing a solar oven usually begins with determining the largest cooking vessel one wishes to use. The dimensions of the vessel are then used to determine the dimensions of the inner oven box. The oven box dimensions then determine the length and width of the glazing. The dimensions of the reflector are then determined (e.g. larger for a hotter oven, smaller for portability, etc).

Once those decisions are made, it's useful to be able to calculate the optimal angle between the glazing and the reflector. The optimal angle is such that the reflector intercepts as much sunlight as possible and reflects all of the intercepted light onto the glazing.

Calculating that angle involves trigonometry. For those unfamiliar with trig, the following formula may seem daunting, but it's really fairly simple if one does it carefully step by step. A calculator with trig functions is highly recommended. An example is given to help clarify the process.

Keep in mind that if the glazing is rectangular, the calculation needs to be done twice, once for the short side of the glass and once for the long side. This is because the optimal angle is dependent on the ratio of the glass dimension to the reflector height and that will be different for the short side of the glass vs. the long side.

Below is a diagram showing the glazing and reflector and the angle to be calculated.



Here is the formula for determining the optimal angle between the glazing and the reflector:

Angle = $90^\circ + [\sin?1 \text{ x } \{-(b \div 4a) + (0.25 \text{ x } ?(b^2 \div a^2) + 8)\}]$

Example: glass width (a) = 18"   reflector length (b) = 24"

Angle = $90^\circ + [\sin?1 \text{ x } \{-(24 \div 4 \text{ x } 18) + (0.25 \text{ x } ?(24^2 \div 18^2) + 8)\}]$
Angle = $90^\circ + [\sin?1 \text{ x } \{-(24 \div 72) + (0.25 \text{ x } ?(576 \div 324) + 8)\}]$
Angle = $90^\circ + [\sin?1 \text{ x } \{-0.333 + (0.25 \text{ x } ?(1.78) + 8)\}]$
Angle = $90^\circ + [\sin?1 \text{ x } \{-0.333 + (0.25 \text{ x } ?9.78)\}]$
Angle = $90^\circ + [\sin?1 \text{ x } \{-0.333 + (0.25 \text{ x } 3.13)\}]$

Angle = 90˚ + [sin?1 x {-0.333 + 0.78}]
Angle = 90˚ + sin?1 x 0.45
Angle = 90˚ + 26.7˚
Angle = 116.7˚