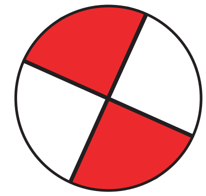
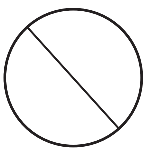
Understanding Focal Mechanism Solutions

Focal mechanism solutions are simply fault plane solutions for earthquakes- meaning that they tell us the orientation in 3-D space of two potential fault planes that may have produced the seismic wave signal associated with the earthquake. They also tell us whether the responsible fault was normal, reverse, strike-slip, or a combination of two of these.

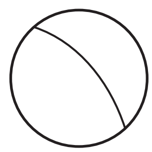


Focal mechanism solutions utilize stereonet representations of fault plane orientations. This is a curved line inside a circle that represents the line of intersection of a plane and the inside of a lower hemisphere, like the inside of a bowl.

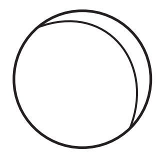
A vertical plane will produce a straight line that passes through the center of the circle.



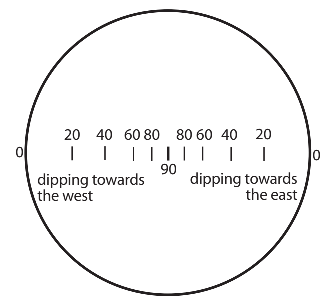
A steeply dipping plane will produce a slightly curved line that passes close to the center of the circle.



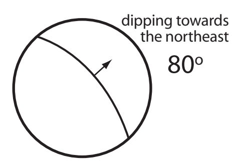
A shallowly dipping plane will produce a very curved line that is closer to the boundary of the circle.

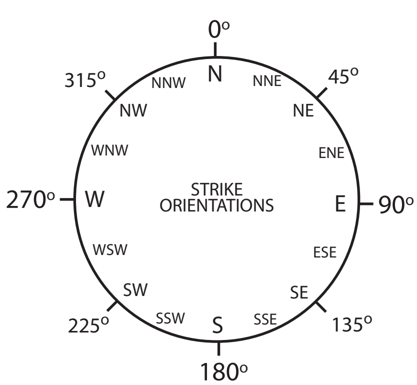


The **dip** of a vertical fault is 90°. The dip of a horizontal fault is 0°. So all fault dips fall somewhere within this range. The fault dip scale is not linear from the outside to the inside of a stereonet. Use the guide on the right to determine how close to the center or edge of a circle the curve for a particular fault dip will fall.



The direction towards which the fault plane is dipping is given by the direction towards which the convex side of the curve is pointing. So for both cases on the right, the fault plane is dipping towards the northeast. Dip directions are always given as compass directions. On the right, the left example shows a fault dip of about 80° NE. The right example shows a fault dip of about 20° NE. Vertical faults and horizontal faults do not have a **dip direction**.

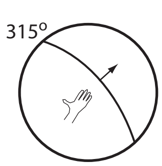




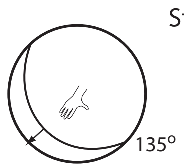
Fault plane solutions also indicate what the **strike orientation** of the fault plane is. In other words, the orientation of the intersection line between the fault and a horizontal surface, such as a flat part of the Earth's surface. This is the orientation you would see if you were flying overhead in an aircraft.

The strike orientation is given by the location on the outside boundary of the circle where the fault plane curve intersects it. ***All curves intersect the circle on mutually opposite sides of the circle, 180° apart***. The strike orientation is measured by seeing where around the 360° arc of the circle the fault curve intersects it.

Strike orientations must be measured in degrees (0°-360°). Use the ***right-hand rule*** to choose which side of the circle you read the strike. To do this, hold your right hand over the curve with your fingers pointing in the fault dip direction and your thumb pointing sideways at 90° to this. Your thumb is pointing towards the side of the circle where you will read off the strike direction for the fault.

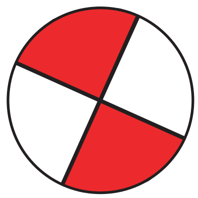


Strike: 315°
Dip: 80°
Dip direction: NE

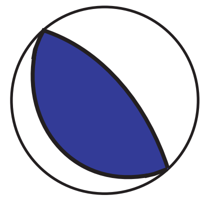


Strike: 135°
Dip: 20°
Dip direction: SW

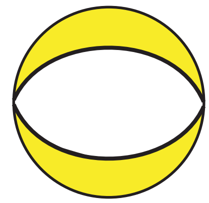
Focal mechanism solutions cannot differentiate between two possible fault plane orientations that could have produced the measured seismic wave signal from the earthquake. These two planes are exactly 90° apart in 3-D space; in other words, they are mutually orthogonal. That is why focal mechanism solutions always have two fault curves (a ***double-couple***).



Two strike-slip fault plane solutions



Two reverse fault plane solutions

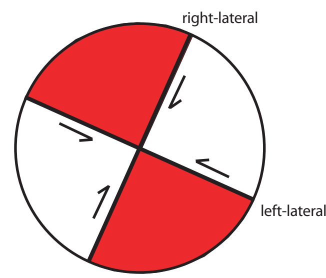


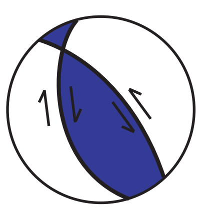
Two normal fault plane solutions

On the left, above, there are two possible strike-slip fault solutions (a WNW-ESE striking fault and a NNE-SSW striking fault, both vertical). In the center, there are two possible reverse fault solutions (a NW striking fault dipping 80° to the NE and a SE striking fault dipping 20° to the SW). On the right, there are two possible normal fault solutions (an E striking fault dipping 45° S and a W striking fault dipping 45° N). In all cases, the two solutions are 90° apart in space.

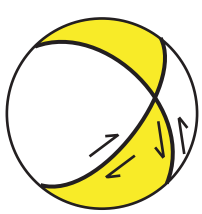
The above examples also show the typical pattern of shading for focal mechanism solutions for each type of fault motion. Strike-slip faults look like a cross-hairs. Reverse faults look like a cat's eye shaded in the middle. Normal faults look like a cat's eye shaded around the outside. The shading always represents the locations of compression as indicated by a positive peak in the first P-wave arrival on a seismogram.

For the case of strike-slip fault plane solutions, there is **always** one fault that is left-lateral and one fault that is right-lateral. How do you tell them apart? One way is to think of the jello in the bowl analogy (i.e., which way do you have to shift the jello to either side of the fault to compress the jello into the shaded quadrants?). Or simply remember that wherever you draw the motion arrows on the diagram, the arrow you drew in the unshaded quadrant must **always** point towards the shaded quadrant (see right).





Combination strike-slip/ reverse motion



Combination strike-slip/ normal motion

Finally, always remember that it is common to have oblique slip during an earthquake. This means that there is either a combination of normal and strike-slip motion, or a combination of reverse and strike-slip motion. Either way, the result is a focal mechanism solution that still has two possible fault plane solutions, but instead of the curved lines for each fault crossing each other at the center of the circle (like with the strike-slip case) or at the edges of the circle (normal and reverse cases), the curves cross each other somewhere between the center and the edge of the circle (see the examples to the left). ***This configuration always indicates oblique-slip motion.***

The closer the fault curve crossover point gets to the center of the circle, the greater the strike-slip component of motion becomes. The sense of strike-slip motion is determined using the same rules discussed above.

As the crossover point gets closer to the edge of the circle, it gets easier to see if the dip-slip component of motion is either normal or reverse. This is done by seeing if the focal mechanism solution looks more like the reverse case (top center) or more like the normal case (top right). One can also look at the strain axis orientations provided with the focal mechanism data.