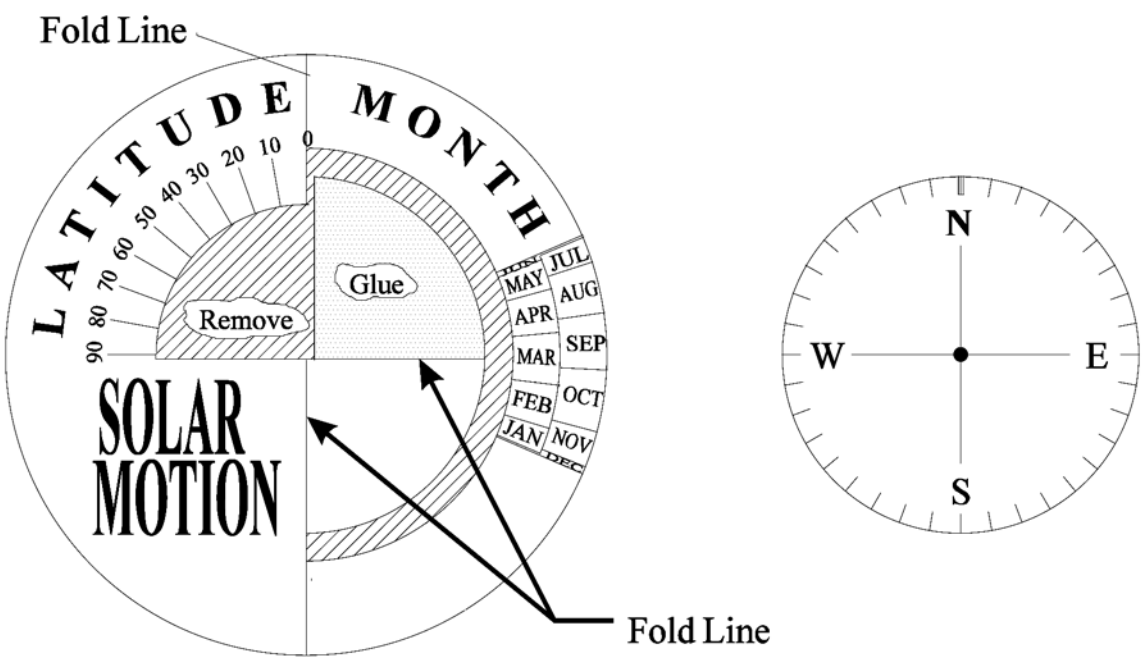
# 10230 Solar Motion Demonstrator

**Purpose:**
To demonstrate the apparent motion of the Sun across the sky, for any day of the year, and for any latitude in the northern hemisphere.

**Required Accessories:**
Rubber Cement or Glue Stic

**Assembly:**
Enough materials have been supplied to construct 23 Solar Motion Demonstrators in addition to the one completely assembled model. Please refer to this completed model when reading the assembly instructions. Give to each student one compass disk, one solar motion frame, and one brass fastener.




Frame

Compass

**Figure 1**
*The Cardboard parts of the Solar Motion Kit.*

Crease the fold line shown in the figure above by resting the frame against the *sharp* edge of a table or counter top and rub the fold line with your thumbnail or other hard object until an indented groove is visible. Repeat this for the short fold line below the "Glue" section of the frame.

Fold the Solar Motion frame along these creased lines, so that the month piece swings all the way around to touch the solar motion piece. Repeat, pivoting the month piece in the opposite direction.

Apply rubber cement or a glue stick to the portion of the frame where it is labeled "Glue". Press the northeast quadrant of the compass disk against the glued portion of the frame. Position the compass disk so that its north/south line lines up with the frame's fold line and the mark for west is positioned over the 90 degree latitude mark. Make sure that the frame does not interfere with the slot in the compass disk. Be careful to properly align the compass disk on the frame. Poor alignment at this stage could affect the accuracy of your model later!

Finally, open the arms of the brass fastener. The head of the fastener represents the Sun. Slip the fastener over the edge of the frame where the months are labeled (fastener head toward the center of the piece). First, bend one of the fastener tabs over the outside edge of the month piece. This should hold the fastener on the month piece but not be so tight as to prevent you from sliding the fastener up and down along the month piece. When you are satisfied that the fit is correct, bend the second tab of the paper fastener over the first.

To use the Solar Motion Demonstrator, pivot the compass disk along the north/south axis so that the right hand side of the disk moves away from you through 90 degrees. Line up the slot in the compass disk with the edge of the frame where it is labeled "Latitude". Slip the slot in the compass disk over the frame and align it with the latitude of your location (or one you may be interested in). The compass disk *must* be perpendicular to the frame. Next, slide the "Sun" along the outer rim of the frame to the appropriate month.

The edge of the compass disk represents the visible horizon for some imaginary person standing at the black dot in the center of the disk. To see the path the Sun makes across the sky for that particular latitude and time of year, swing the month portion of the frame completely from the "East" to the "West" as shown on the compass disk. Compare the location of the sunrise and sunset at different times of the year. How does the length of day change with the seasons? At what latitude must you be so the Sun does not set on the longest day of the year? What would it be like to live at the north pole? You can answer these and many other questions with your Solar Motion Demonstrator!

**Where Will the Sun Set?**

Hold the device in your left hand so that the compass disk is horizontal (parallel to the floor or level ground outdoors). Imagine that you are very small and standing at the black dot at the center of the compass disk. It would look like a very large open field with a clear horizon all around you. The geographical directions of North, East, South, and West are marked around the horizon. With your right hand, smoothly pivot the piece which carries the paper fastener "Sun". As the head of the paper fastener rises above the plane of the compass disk, it represents sunrise and the beginning of daytime in the imaginary world of the compass disk. When the head of the paper fastener dips below the plane of the compass disk, it represents sunset and the beginning of nighttime. The perimeter of the compass disk is marked in 10 degree increments. You can read the direction to the point on the horizon where the Sun sets directly from the compass disk. For example, if you are at 40 degrees north latitude, and it is late June, the Sun will set about 30 degrees to the north of west. Use your device to check this example. If you can, take the device outdoors at sunset. Align the compass disk so that "N" on the disk points toward true north. Keep the compass disk horizontal and raise it to eye level. Site along the line joining the central black dot and the paper fastener head when it is located at the sunset position. This line should point to the place on the horizon where the Sun will set!

**How High is High Noon?**

As you swing the "Sun" around, it gets higher in the sky above the horizon. This is its "angular height" above the horizon. If you imagine yourself to be at the location of the black dot, facing the Sun, the angular height of the Sun is the angle between your line of sight to a point on the horizon directly beneath the sun and your line of sight to the Sun. The Sun reaches its greatest angular height at a time halfway between the times of sunrise and sunset. By using your Solar Motion model, you can get a sense of how large this maximum angular height is for various times of the year.

**Where Will the Sun Rise?**

Answer this question in the same way that you found where the Sun sets. Try using the device some day at sunrise, sighting across it to check that the Sun actually rises where the device predicts that it will. On any particular day, the Sun will rise just as many degrees north or south of east as it sets north or south of west!

**Is Daytime as Long as Nighttime?**

Pivot the piece carrying the "Sun" at a constant rate over its entire range. This corresponds to one rotation of the Earth, which takes 24 hours. Notice that the Sun lies above the horizon for part of this motion (daytime) and below it for the remainder (nighttime). You can determine the relative lengths of day and night in this way.

**When are Day and Night Equally Long?**

Use the device to show that on particular days in

March and September the Sun rises due east and sets due west for *any* latitude. These days are called the "spring equinox" and the "fall equinox" (form the words for "equal night").

**When Will the Noon Sun be the Highest or Lowest in the Sky?**

Use the device to show that the largest angular height at noon occurs on a day in June and the smallest occurs on a day in December. These days are called the "summer solstice" and the "winter solstice". The word "solstice" comes from the words meaning "Sun stands still", and refers to the day on which the paper fastener "Sun" stops and reverses its direction of motion along the pivoting piece marked with the names of the months.

**Why Does the Earth Have Seasons?**

Move the paper fastener "Sun" up to its June position. Pivot the "Sun" and observe the relative lengths of day and night and the maximum angular height of the "Sun". Do the same with the "Sun" moved down to its December position. This demonstrates the two most important factors responsible for the seasons: the *period of time* over which the Sun's rays strike the ground (the length of day), and the *angle* at which they strike the ground.

**Can You Always See a Sunset on Earth?**

Actually, there are places on Earth where the Sun doesn't set! Explore the range of latitudes and times of year for which the paper fastener "Sun" remains above the compass disk as you pivot it through an entire rotation. This corresponds to a 24 hour day, with the Sun still above the horizon at midnight! The phrase "land of the midnight Sun" is often used to describe the places where this occurs. For an observer anywhere north of the "Arctic Circle" (about 66 ½ degrees latitude) the Sun will not set on at least one day of the year!

**When and Where Will the Sun Pass Directly Overhead?**

A point in the sky *directly* over your head is called the zenith. To find out when and where the Sun passes through the zenith, move the "Sun" to a position late in June and pivot it through its daily motion to see if it passes directly overhead (assuming that your are at the location of the black dot at the center of the compass disk). Change the latitude setting of the compass disk until you find a latitude at which the Sun passes through the zenith of an observer at that latitude. Explore the range of latitudes and times of year for which the Sun passes through the zenith. For an observer north of the "Tropic of Cancer" (at about 23 ½ degrees north latitude) the sun will never pass through the zenith. For lower latitudes than this, it will pass through the zenith on only two days of the year. Can you tell approximately which days these are?

**What Path Does the Sun Take at the Equator?**

Set the compass disk to a latitude of 0 degrees. Imagine that your are an observer positioned at the black dot at the center of the compass disk. Vary the time of year and see how the path of the Sun across the sky changes. What can you say about how the rising sun appears to move in relation to the horizon? Notice that the setting Sun moves in the same way. At what times of year does the sun pass through the zenith?

**What is the Motion of the Sun for an Observer at the North Pole?**

Set the compass disk to a latitude of 90 degrees. Again, imagine that you are positioned at the black dot at the center of the compass disk. Vary the time of year and see how the path of the Sun across the sky changes. What can you say now about the motion of the Sun in relation to the horizon? Do you see that there will be six months of darkness at the North Pole?

**And More!**

You will be able to think of other ways in which you can use the "Solar Motion" device to increase your understanding of how the Sun appears to move in relation to the earth. Here are two:

Imagine yourself standing at the black dot at the center of the compass disk. Try holding the month piece fixed in space with your right hand, as you turn the rest of the device through its complete range of motion. As you do this, think of the Sun as being fixed in space, while the Earth's rotation turns you around with respect to the Sun. This is more nearly the situation in real life.

Try using the device as a *compass!* Set the "Solar Motion" model to your latitude and the time of year. Go outside and hold the device so that the compass disk is horizontal. Pivot the month piece and at the same time turn the compass disk (keeping its plane horizontal) so that the "N-S" line points in various directions. Your objective is to make the shadow of the month piece be as thin a line as possible, while at the same time the shadow of the paper fastener "Sun" falls on the black dot at the center of the compass disk. When you have achieved this, the compass disk will show you the correct geographic directions!

**Time Allocation:**

To prepare this product for an experimental trial should take less than ten minutes per item. Actual experiments will vary with needs of students and the method of instruction, but the essentials are easily concluded within one class period.