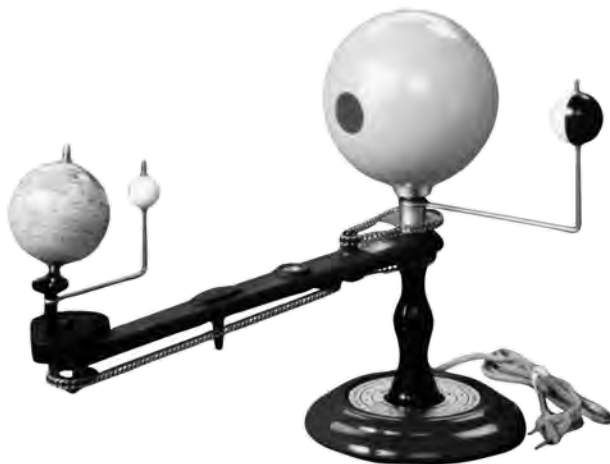


# 653-3010 (EL-400) and 653-3020 (EL-500) Trippensee Planetariums Operating Manual



**653-3010 Synchronized Planetarium**



**653-3020 Motorized Planetarium**

## Introduction

The Trippensee EL-400 Planetarium is a marvelous educational tool for demonstrating and teaching basic relationships and motions of the EARTH, MOON, SUN and VENUS. Use this booklet to get to know the main features and functions of the EL-400. Then try the basic demonstrations. In little time, you'll be clearly and definitively teaching basic astronomical concepts.

You'll find the EL-400 a joy to work with. Use the planetarium and your imagination often.

An important skill you and your students can exercise is using imagination to mentally change your point of view. Learn to "see" the planetarium's MOON, SUN and VENUS globes as though you are viewing from a point on the surface of the earth globe.

**Example:** Position the VENUS globe on the "far side" of the sun, opposite earth. As you normally view the entire EL-400 planetarium you should see VENUS. But would you be able to see VENUS from the sunlit side of the earth? (No, from the EARTH globe, the SUN blocks the view of VENUS.)

Sometimes students individually can move very close to a globe and sight across its face in order to experience the "view". (**Example:** viewing the first quarter MOON

from the EARTH globe.) At other times, this is physically impractical and the "view" must be imagined.

For practice, try visualizing and sketching several views of simple objects placed on a desk. Start with our own point of view. Then imagine what the objects (and their relationship) look like when viewed from the side or from above. Finally, physically move to the previous viewpoints to check and correct your results.

With this capability, one can learn to relate what is shown by the EL-400 planetarium to what is seen in the actual sky and vice versa.

## Warranty:

All products are guaranteed to be free from defect or workmanship for 90 days after date of shipment, defined as date of invoice. We replace all defective parts free of charge. This warranty does not apply to accident, misuse or normal wear and tear. Additional replacement parts may be ordered toll-free using the part numbers above. We accept Mastercard, Visa, American Express and school purchase orders.

**Parts List (Call for current prices)**

**EL-400 Synchronized Planetarium**

|        |                                    |
|--------|------------------------------------|
| 00041  | 1" white bead, Moon                |
| 000417 | 1-5/6" black and white bead, Venus |
| 002726 | Lamp bulb, screw type              |
| 004081 | Main drive chain                   |
| 005010 | Compass                            |
| 005065 | Electric cord                      |
| 008005 | Booklet of instructions            |
| 015360 | Sprocket, 10 teeth                 |
| 015370 | Sprocket, 12 teeth                 |
| 015610 | Sprocket, 32 teeth                 |
| 015655 | Wood standard                      |
| 017875 | Venus wire 1/8" x 12-3/4"          |
| 033180 | Nylon arm, red color               |
| 033186 | ABS red plastic base               |
| 033851 | Sunglobe, globe only, with hole    |
| 034482 | Lamp socket                        |
| 034532 | Sprocket, 24 teeth                 |
| 050605 | Angle arm assembly, red            |
| 017835 | Earth wire, 1/8" x 8-3/8"          |
| 017860 | Moon wire, 1/8" x 8-3/8"           |
| 032386 | Earth gear                         |
| 056260 | Earth, globe, 3.3"                 |

**EL-500 Motorized Planetarium**

|         |                                    |
|---------|------------------------------------|
| 00041   | 1" white bead, Moon                |
| 000417  | 1-5/6" black and white bead, Venus |
| 001110  | Base, ABS plastic, red             |
| 002726  | Lamp bulb, screw type              |
| 004081  | Main drive chain                   |
| 006465  | Gear                               |
| 008005  | Booklet of instructions            |
| 008080  | Motor, 1/100                       |
| 015610  | Sprocket, 32 teeth                 |
| 015655  | Wood standard                      |
| 017825  | Drive wire 1/8 x 21-1/2"           |
| 017875  | Venus wire 1/8" x 12-3/4"          |
| 018125  | Plastic zodiac                     |
| 034482  | Lamp socket                        |
| 034532  | Sprocket, 24 teeth                 |
| 050605  | Angle arm assembly                 |
| 006455  | Nylon cup gear, 66 teeth           |
| 006462  | Gear, 48 teeth                     |
| 017835  | Earth wire, 1/8" x 8-3/8"          |
| 017860  | Moon wire, 1/8" x 8-3/8"           |
| 020770  | Gear, 16 tooth                     |
| 032386  | Earth gear                         |
| 056260  | Earth, globe, 3.3"                 |
| 050620  | Angle arm assembly, red            |
| 005010  | Compass                            |
| 056580  | Shaft and nylon sprocket assembly  |
| 057270  | Sun drive assembly                 |
| 26-1012 | Cord set, 3 wire, 110 volt         |

**How to tighten the EL-500 Belt**

Over time the drive belt on the EL-500 may stretch, thereby causing it to function improperly. If you can hear the motor running when the unit is turned on, but nothing moves, or the red arm doesn't rotate smoothly, you may need to tighten the drive belt.

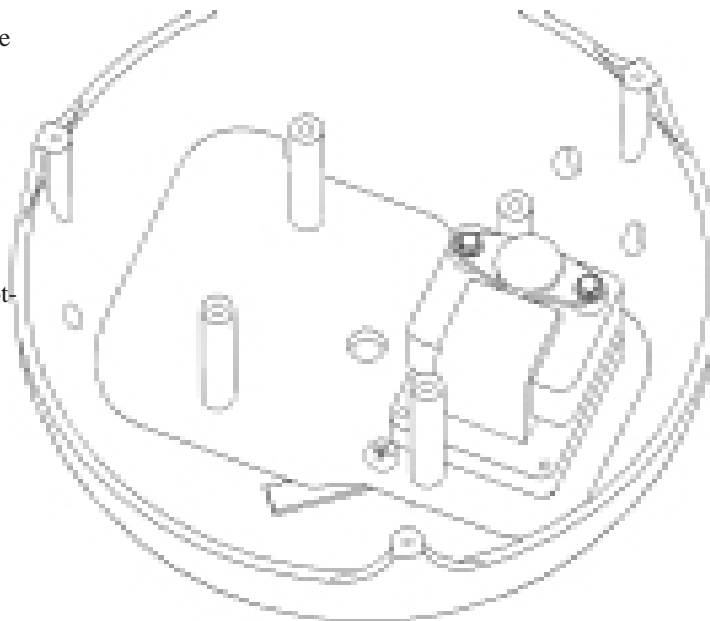
The drive belt is located under the aluminum bottom cover.

Use a screwdriver to remove the four (4) screws that hold the bottom cover in place. While the drive belt cannot be seen from the bottom of the planetarium, there is a lever that extends beyond the weight on one side (see diagram). This lever is attached to a tensioning idler pulley.

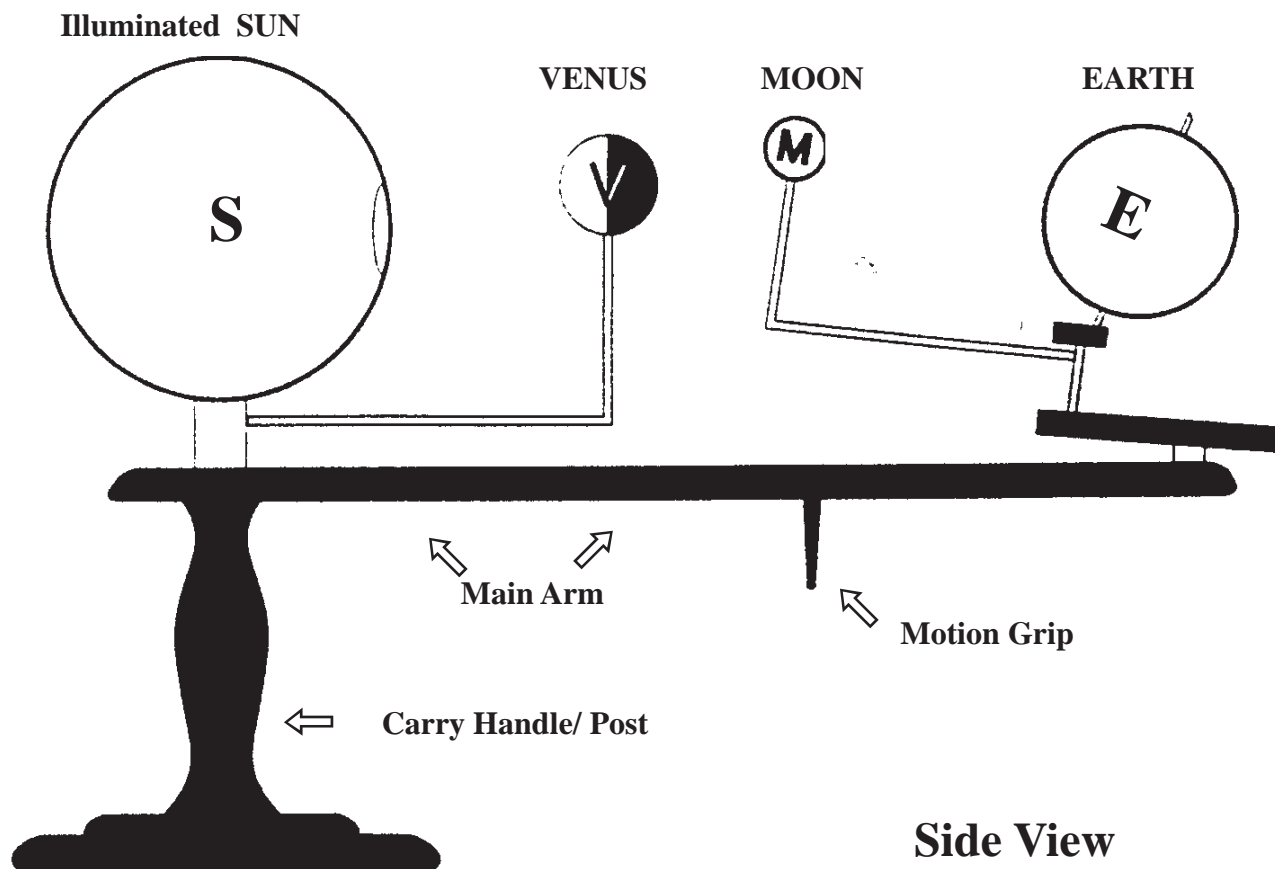
To increase the tension on the belt, use a screwdriver to pry the lever out further.

If necessary, tighten the screw that holds the lever in place to keep it from becoming slack again.

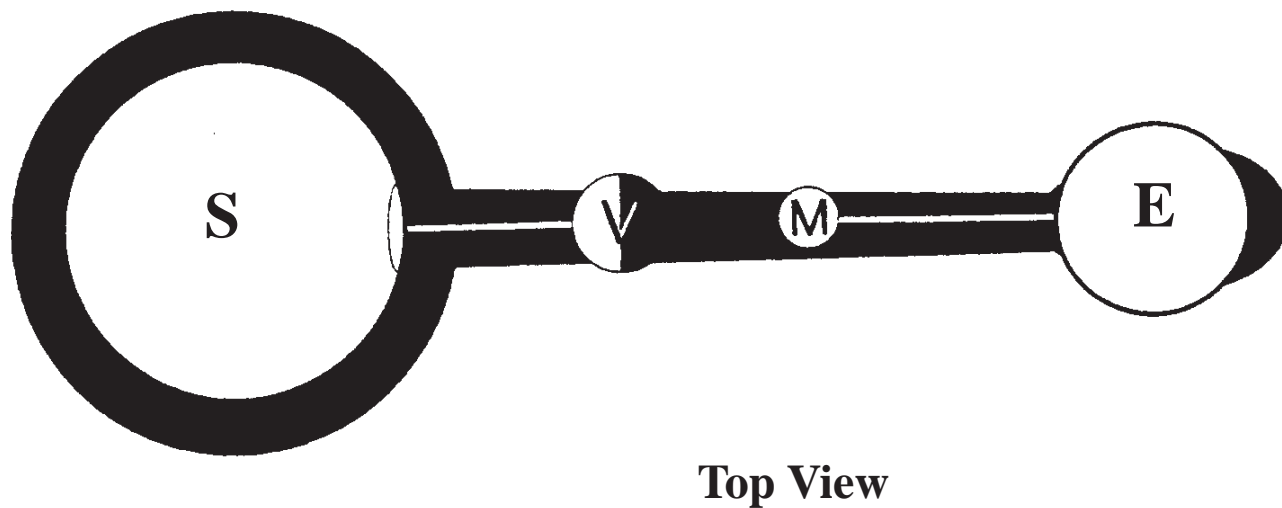
Replace the bottom cover and the four (4) screws that hold it in place.



## EL-400 Synchronized Trippensee Planetarium

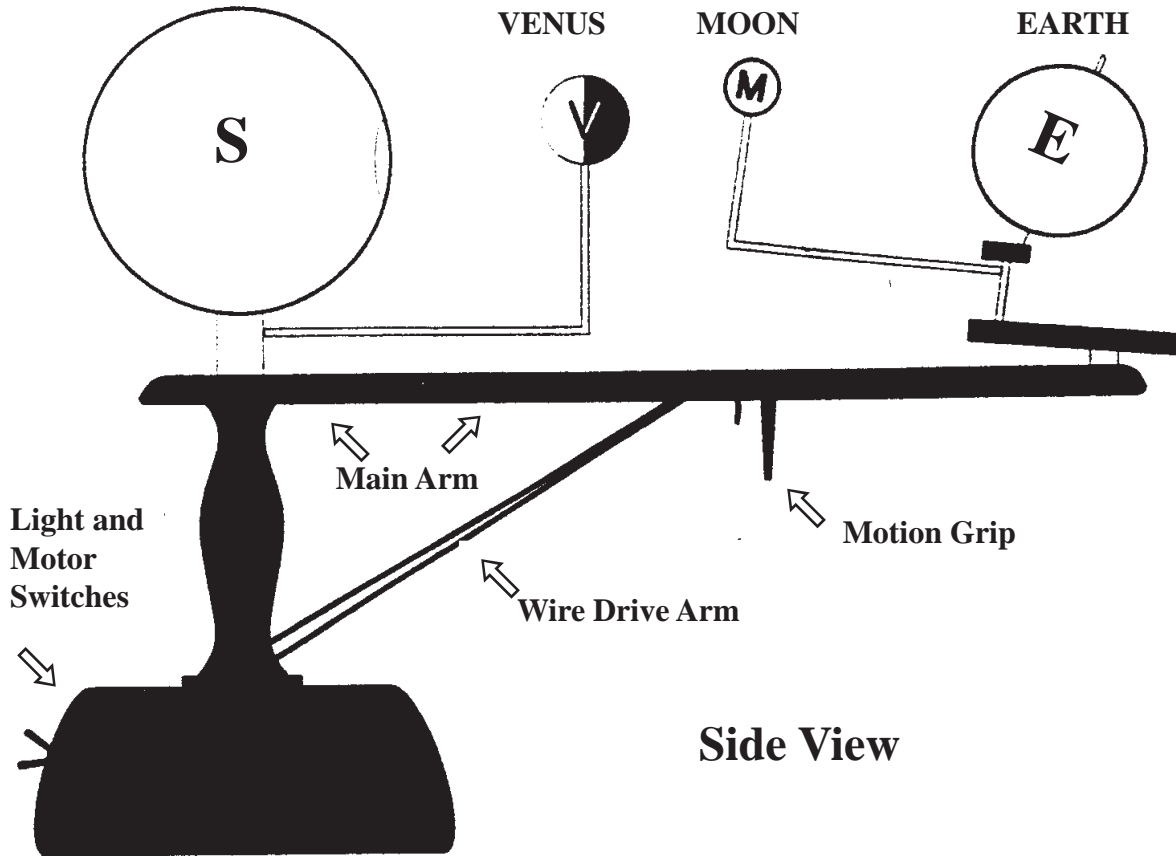


*The top view is used to illustrate the demonstrations which follow.*

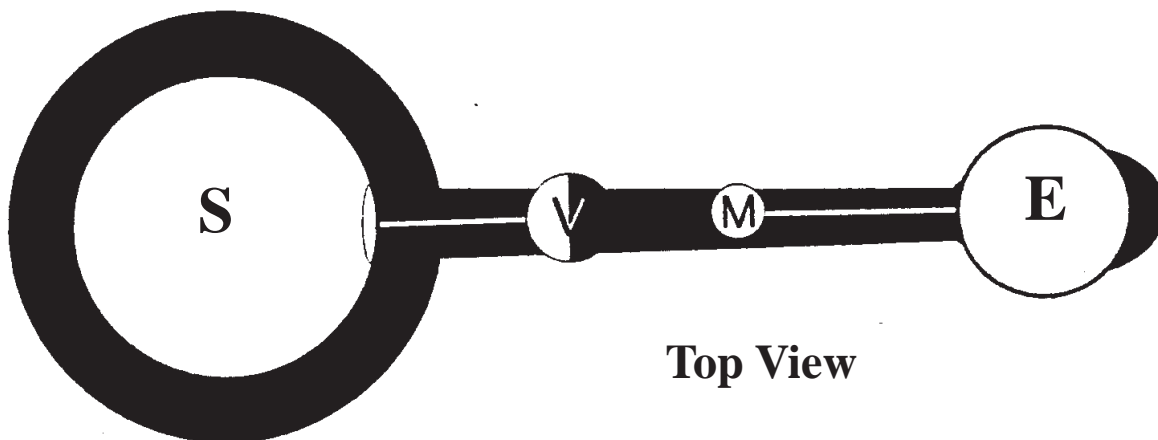


## EL-500 Motorized Planetarium

Illuminated SUN



*The top view is used to illustrate the demonstrations which follow.*



**Note:** *The EL-500 is motor operated, which greatly facilitates continuous motion demonstrations. For the noncontinuous demonstrations included in this booklet, disengage the wire drive arm from the main arm, placing the EL-500 in manual mode.*

## Basic features and functions The EL-400 planetarium

*The Trippensee EL-400 synchronized planetarium is a **motion and relationship** demonstrator encompassing the EARTH, MOON, SUN and VENUS.*

To operate the planetarium, steady the carry handle/post or base with one hand, grasp the motion grip under the main arm with the other hand, and rotate the main arm of the planetarium counterclockwise. One full rotation of the main arm - one EARTH orbit of the SUN - represents one year.

As you rotate the main support arm:

- The EARTH will automatically rotate on its axis, **simulating day and night**.
- The MOON will automatically orbit the EARTH in its "tilted" orbit.
- VENUS will automatically orbit the SUN at a faster rate than the EARTH.

**Carry handle/ post:** Grasp the carry handle/post for moving the planetarium and to steady the unit during motion demonstrations.

**Illuminated SUN:** Plug in the power cord to activate the internal light to dramatize and enhance your demonstrations. A small hole in the SUN globe allows direct light to shine on the EARTH and MOON for demonstrating day and night as well as phases of the MOON.

[Tip: Be sure to darken the room by closing window blinds and turning off overhead lights.]

**Main arm:** The main arm of the planetarium carries the EARTH and MOON globes. It facilitates motion and relationship demonstrations such as EARTH and VENUS revolving around the SUN, the EARTH rotating on its axis, and the MOON revolving around the EARTH.

**Motion grip:** Use the motion grip to push or pull the main arm of the planetarium for motion demonstrations.

**Correct motion is always counterclockwise.**

[Tip: Move the main arm to follow the counterclockwise sequence of the months printed on the planetarium's base.]

[Tip: Tie a short length of string to the main arm at the position of the motion grip and the Trippensee logo. Use it to pull the main arm when you want continuous motion.]

**Earth:** The EARTH globe automatically rotates on its axis in a counterclockwise direction when you

correctly move the main arm of the planetarium in a counterclockwise direction.

The EARTH's axis is tilted, or tipped, about 23.5° from the "vertical" (in relation to the EARTH-SUN plane). The EL-400 can demonstrate how this tilt creates **seasonal variations** on the EARTH during the year. The base of the planetarium is marked with the months and seasons of the northern hemisphere for easy reference.

[Tip: A small piece of clay, poster mounting putty or removable tape can be temporarily placed on the surface of the EARTH globe to mark a location such as your city or other geographic position.]

[Tip: The EARTH globe can be "released" and rotated by hand to align a particular location (such as your city). This allows you to set the planetarium to simulate real solar system alignments and events. To set the EARTH's position, gently grasp the EARTH globe and pull up to separate and release the gears just below the globe. Rotate the globe to the desired position while continuing to hold the gears apart. When you release the globe, the gears will reengage.]

**Moon:** The MOON automatically orbits the EARTH in a counterclockwise direction when you correctly move the main arm of the planetarium in a counterclockwise direction. The plane of the MOON's orbit is correctly tilted about 5° from the "horizontal" (the EARTH-SUN plane.)

[Tip: A small piece of clay, poster mounting putty or removable tape can be temporarily placed on the surface of the MOON globe as a reference mark. This will help show that the same side of the MOON always faces the EARTH and that the MOON rotates to accomplish this.]

**Venus:** The inner planet VENUS automatically orbits the SUN in a counterclockwise direction when you correctly move the main arm of the planetarium in a counterclockwise direction. VENUS orbits closer to the SUN and moves at a faster rate than the EARTH. The white side of VENUS represents the sunlit side and always should face the SUN globe. Rotate the VENUS globe by hand, if necessary, to position it correctly.

[Tip: VENUS can be moved and aligned by hand. For example, you may want to prevent it from casting an unwanted shadow during EARTH and MOON demonstrations. No release is necessary - simply push or pull the planet by its support arm.]

**Base markings:** The months of the year and the seasons of the northern hemisphere are printed in a coun-

terclockwise sequence around the base of the EL-400. When the main support arm is positioned over a particular month and season, the model EARTH will automatically be correctly "tilted", demonstrating the "reason for the season."

**Compass:** A small magnetic compass is mounted on the main arm. It can be used to align the orientation of the entire planetarium, matching the axis of the planetarium's EARTH to that of the real EARTH. This is especially desirable when relating the motions and positions of the model to the North Star, our surrounding "celestial sphere" and the constellations of the night sky.

[**Tip:** When using the magnetic compass, keep the planetarium away from metallic objects. Do not use a metal table, since the accuracy of any magnetic compass can be compromised by the presence of nearby metallic objects.]

**Size scale:** The EL-400 planetarium is not a scale model. Accurate scale models of the solar system are impractical in a "desktop" unit. However, you and your students should develop some sense of the immensity of the solar system. To that end, we have included information in this booklet describing a scale model of the solar system, based upon the size of the 3" (76 mm) diameter EARTH globe mounted on the EL-400 planetarium

**Speed scale:** The EL-400 is geared for "slow motion:" to make it easier for students to perceive and track the multiple motions as it rotates. There are 365 1/4 days in a year (one year equals one EARTH orbit of the SUN). The EARTH globe on the EL-400 rotates only 16 times during one orbit of the SUN.

The actual MOON orbits the EARTH approximately 12 times in a given year. The model MOON on the EL-400 orbits only 5 times per "year."

A typical demonstration speed for the EL-400 is one rotation of the main support arm (one year!) in about 10 seconds. If the planetarium was geared for 365 1/4 days per year, the EARTH globe would rotate **as a blur** at approximately 36.5 revolutions per second.

**User adjustable features:** The EARTH globe can be independently rotated and set. For example, you may want to position the EARTH for a demonstration centered on Japan, rather than the United States. Grasp the EARTH globe and gently lift it up to disengage the gears at its base. While holding the globe up, it can be rotated to any desired position. Gently release the globe and the gears will reengage.

The VENUS globe and its support arm can be moved by hand to any position - or to simply move it out of the way, if it happens to be blocking "sunlight" during a MOON phase demonstration.

**Standard alignment:** Since there are user adjustable features, as mentioned above, we suggest the following

alignment to set the EARTH globe in a standard position relative to the other parts of the planetarium.

1. Swing the main arm of the planetarium to a position directly over the "B" of December printed on the base. This position represents December 21.
2. Hold the arm in this position and adjust the EARTH so that the Gulf of Mexico directly faces the SUN.

**Maintenance:** To clean, gently wipe the surfaces of the EL-400 planetarium with a soft cloth dampened with a mild detergent. If you need to replace the internal light bulb, loosen the single screw protruding from the metal collar at the base of the SUN globe. Carefully lift and remove the SUN globe. Replacement bulbs can be purchased at a local lighting and electrical distributors.

For units purchased prior to mid-1999, the replacement light bulb is a 25 watt, 230 volt #T8DCBAY with a double contact bayonet-style base.

For units purchased after mid-1999, the replacement light bulb is a 25 watt, 120 volt, 25T8C with single contact screw-in style base.

Install the new light bulb. Replace the SUN globe. Be sure to align the hole in the side of the SUN globe with the main arm. Tighten the screw at the base of the SUN globe.

If your EL-400 Planetarium requires lubrication, apply a drop of fine machine oil on the moving parts.

For repair service, parts or information about other Trippensee products, please contact us.

## Demonstrations

### Earth's rotation:

*The earth rotates around its axis causing day and night.*

**Do this:** Place a small marker (a piece of clay, poster mounting putty or removable tape) to indicate where you live on the EARTH globe.

**Note:** An artificial hole in the SUN globe allows brighter, direct "sunlight" to shine on the EARTH globe. Plug in the EL-400 power cord and **turn on its internal light**. Close your windows blinds and turn off your room lights to best show the contrast between the illuminated side (day) and unlit side (night) of the EARTH globe.

Slowly rotate the main arm of the EL-400 planetarium in a counterclockwise direction. The EARTH globe automatically will rotate on its axis, periodically moving locations on its surface into - and out of - the SUN's illumination, making day and night.

**Things to point out:**

When your location rotates into sunlight, you experience daytime.

When your location rotates out of sunlight, you experience nighttime.

We call one full spin of the EARTH (from noon to noon) a "day", which we have divided into 24 hours.

- As your location just enters sunlight, you experience sunrise.
- When your location directly faces the SUN, it is noon for you.
- As your location just exits sunlight, you experience sunset.
- When your location faces directly away from the SUN, it is midnight for you.

So every day the actual SUN appears to rise in the east, arc across the southern sky and set in the west. *Did the SUN move? Or did we move - as we ride on our spinning EARTH?*

When we observe the apparent motion of the SUN (and the stars), we are actually tracking the rotation of the EARTH. It has taken many thousands of years for people to make this realization.

As EARTH rotates on its axis, different places around the earth face the SUN at different times, so clocks must be set at different times (time zones).

EARTH appears to rotate counterclockwise when viewed from above its northern hemisphere.

EARTH's rotation axis is tipped or tilted about 23.5° from "vertical" (in relation to the EARTH-SUN plane). How might this affect the earth?

**Earth's Orbit**

*Our tilted EARTH travels around the SUN - one revolution makes our year and our seasons.*

As the EARTH spins on its axis, it also travels, or orbits, around the SUN once in about 365 1/4 days. One orbit of the SUN is a "year". *How many times have you been around the SUN? How old are you (in years)?*

**1. EARTH's tilt creates the seasons.**

**Do this:** Grasp the motion grip of the EL-400 and slowly swing the main arm of the planetarium counterclockwise. Closely observe the angle of EARTH's tilted axis. EARTH's axis maintains an apparent constant direction in space. (There is a long-term variation called "precession.")

You can place signs (or drawings) around the planetarium to represent the seasons. Use the label on the base of the EL-400 for reference. (The label is marked

with the seasons of the northern hemisphere.) Grasp the motion grip and slowly swing the main arm of the planetarium counterclockwise. Stop the motion when the EARTH globe arrives at each season and notice whether EARTH's tilt angles the northern hemisphere of the EARTH toward or away from the SUN.

EARTH's axis is tipped or tilted about 23.5° from the "vertical" in relation to the EARTH-SUN plane. As the EARTH revolves around the SUN, EARTH's tilted axis **always appears to point in the same direction**. Thus, for part of the EARTH's orbit, the northern hemisphere is angled toward the SUN, allowing more of the SUN's energy to heat that half of the planet. This creates the warmth of summer. When the northern hemisphere is angled away from the SUN, we experience winter. The tilt of EARTH's axis affects how much light and heat from the SUN falls on different parts of the earth during different parts of the orbit. EARTH's tilt creates our seasons.

**Note:** Temperature extremes associated with winter and summer lag behind the astronomical beginnings of each season because of the moderating effects of land, water and atmosphere.

**2. Length of day/night and the equinoxes.**

When the EARTH's northern hemisphere is tilted most directly toward the SUN, we experience summer. Days are long and nights are short. When the northern hemisphere is tilted away from the SUN, we experience winter. Days are short and nights are long. Spring and fall occur in between - at intermediate points in our orbit of the SUN.

The intermediate points represent the times when days and nights are equal in length (or nearly equal) for areas of the EARTH between the polar regions. The term "Equinox" refers to these times. The spring, or vernal, equinox, is March 20 or 21, while the fall, or autumnal equinox is September 22 or 23.

**Do this:** Place a small marker (clay, poster mounting putty, or piece of removable tape) on your location on the EARTH globe. Plug in and turn on the EL-400 planetarium, close your window blinds, and turn out the lights. Grasp the motion grip of the EL-400 and slowly swing the main arm of the planetarium counterclockwise. Closely watch the marker and compare the proportions of night and day for your location during each of the four seasons. **Hint:** Observe the "circle of the SUN's illumination on the EARTH globe.

Compare the difference between the northern and southern hemispheres. Whichever hemisphere is tilted toward the SUN experiences longer days and shorter nights. Also compare what happens at the north and south poles of EARTH. At EARTH's extremes - the poles - day and night can each last six months!

### 3. The Solstices

The tilt of EARTH's axis combined with EARTH's orbital motion around the SUN produces a change in the apparent location of the SUN's path as seen in EARTH's sky each day during the year. The SUN reaches its highest apparent altitude June 20-21. This is when EARTH's axis points the northern hemisphere most directly toward the SUN. This date, the **summer solstice**, marks the beginning of summer. From this date on, through December 21 or 22, the SUN appears to lose altitude, day by day, in our sky.

December 21 or 22 marks the **winter solstice**, the beginning of winter. This is when the EARTH's axis points the northern hemisphere most directly away from the SUN. Here the SUN appears lowest in our sky and begins moving higher and higher each day thereafter, through June 20-21. **Solstice means "sun still"**. Each solstice marks the stopping (and reversing) point of the SUN's apparent path in our sky.

### 4. Earth's elliptical orbit

The EARTH revolves around the sun in a counterclockwise direction when viewed from above the northern hemisphere of the planet. The other planets of the solar system revolve around the SUN in this same direction, however, they all do so at different distances and speeds. (Compare the motions and relative speeds of the VENUS and EARTH globes on the planetarium.)

EARTH's orbit (like those of all the planets) is not a perfect circle. Rather, it is **elliptical** (an oval). As a result, the EARTH periodically is a little closer to the SUN than at other times. The planetarium simulates these minor variations in the distance between the EARTH and SUN by means of the black, tapered base just below the model EARTH.

**Do this:** Try measuring the planetarium's EARTH-SUN separation at various points in the EARTH's orbit. Grasp the motion grip and slowly swing the main arm of the planetarium counterclockwise. Stop the motion when the EARTH globe arrives at each season and measure the EARTH-SUN distance.

When is EARTH closest to the SUN - during the northern hemisphere's winter or summer? Amazingly, EARTH is closer to the SUN during our winter. However, the variations in the EARTH-SUN distance are too small to significantly affect our seasons.

### The Moon's orbit

*The MOON orbits the EARTH about once every month.*

Just as the EARTH revolves around the SUN during the year, the MOON revolves around the EARTH.

#### 1. The MOON rotates and revolves.

**Do this:** Place a small piece of clay or removable tape on the side of the MOON globe that faces the EARTH globe. Grasp the motion grip of the EL-400 and swing the main arm of the planetarium counterclockwise. This basic motion simulates the yearly orbit of EARTH around the SUN as well as the monthly motion of the MOON in its orbit around the EARTH.

Closely observe the MOON as it moves in its orbit around the EARTH. Watch your clay or tape marker and notice that one side of the MOON always faces EARTH.

Many people think that because the MOON always shows the same side to the EARTH, the MOON must not rotate. Carefully observe the MOON's motion from above it. Follow the clay or tape marker carefully. You will see that the MOON does rotate. It rotates exactly once during each orbit of the EARTH. The MOON's rate of rotation around its axis is matched, or synchronized, with its rate of revolution around the EARTH.

#### 2. Viewing the MOON from space.

**Do this:** Plug in the EL-400, close your window blinds and turn out the lights. Move the main arm of the planetarium counterclockwise to position the MOON off to one side of the main arm.

Notice that when the EARTH and MOON are viewed from a distance (out in space), fully one-half of the EARTH **and** one-half of the MOON are illuminated by direct light coming from the SUN. The other half of each object is always in shadow.

Repeatedly move and pause the motion of the planetarium's main arm so that the MOON stops in several different positions in its orbit around the EARTH. One-half of the MOON is always illuminated by the SUN, except when the MOON enters the shadow of the EARTH (see: Lunar Eclipse). The illuminated half of the MOON always faces the SUN.

#### 3. Viewing the MOON from EARTH/ The MOON's phases

What does the MOON look like in its various orbital positions when viewed from the EARTH?

(For the demonstrations that follow, it will help to let students view the planetarium's MOON globe by individually sighting it from a position very near the EARTH globe.)

As seen from the EARTH, the shape of the light

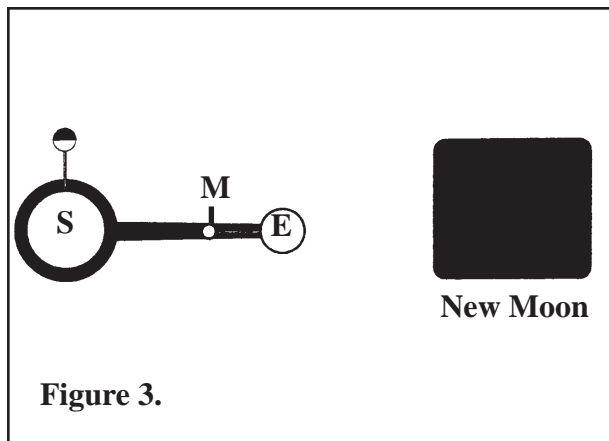


and dark portions of the MOON **change** as the MOON changes its position along its orbit. The MOON appears to change shape, or **phase**, as it orbits the EARTH due to the changing angle of the SUN's illumination.

**Do this:** Plug in the EL-400, close your window blinds and turn out the lights. **Note:** If the VENUS globe is allowed to stop between the SUN and EARTH, it can block the light normally falling on the EARTH and MOON globes. So, always keep the VENUS globe off to one side for the demonstrations of MOON phase.

**NEW MOON** - Begin by moving the main arm of the planetarium until the MOON globe is directly over the main arm, between the EARTH and the SUN globes. Viewing from the EARTH, we cannot see any of the illuminated portion of the MOON. The "back side" of the MOON - which we never see from the EARTH - is the portion now illuminated by the SUN. [Figure 3]

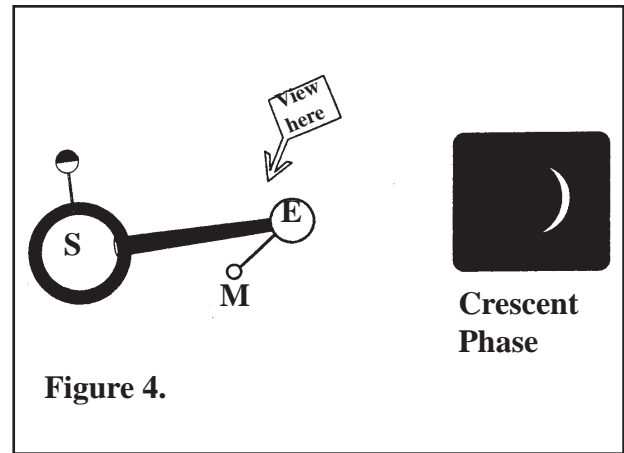
[As the MOON moves in the first half of its orbit around the EARTH, the illuminated portion of the MOON that we can see from the EARTH progressively increases. We say the MOON is "waxing" or increasing.]



**Figure 3.**

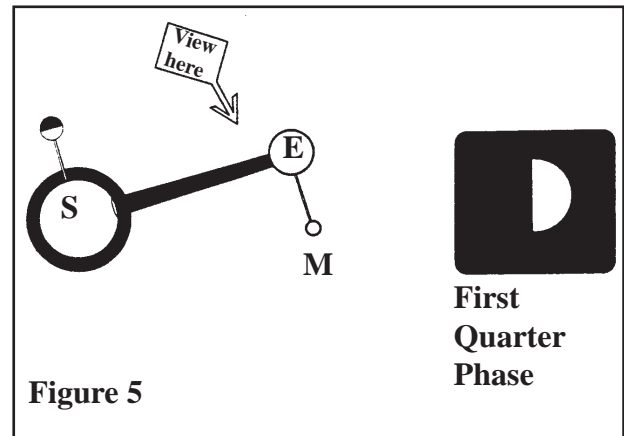
**CRESCENT MOON** - Nudge the main arm of the planetarium about two inches counterclockwise so the MOON globe moves about two inches in its orbit. Viewing from the EARTH, only a "sliver" of sunlight can be seen on the right edge of the MOON. [Figure 4]

**FIRST QUARTER MOON** - Nudge the main arm of the planetarium a little bit further until the MOON globe's support arm is perpendicular to the main arm of the planetarium. In this position, the MOON has traveled one quarter of the way around the EARTH, hence the name "First Quarter." Viewed from the EARTH, one-half of the illuminated portion of the MOON can be seen. Note that the right half of the MOON is illuminated. [Figure 5]



**Figure 4.**

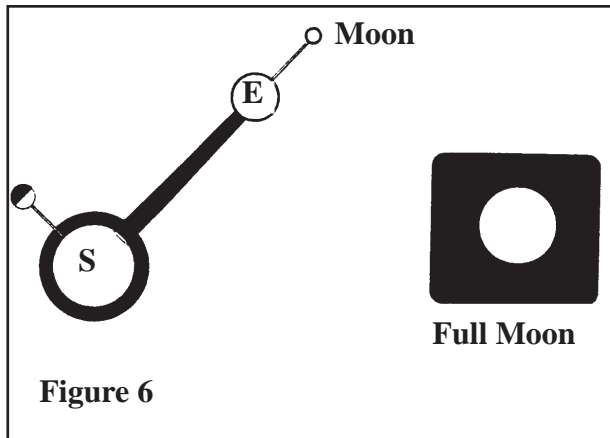
[The first quarter phase occurs about seven days after the new phase. During the next seven days, the MOON - as seen from EARTH - will be more than one-half illuminated. This is called the "waxing gibbous" phase. Waxing means growing and gibbous means rounded out or "humpbacked."]



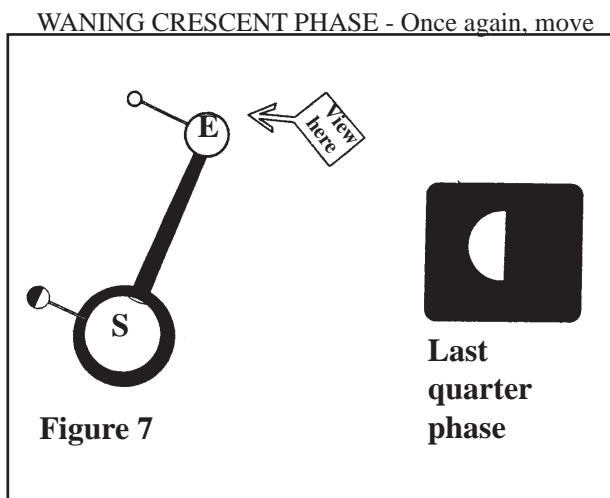
**Figure 5**

**FULL MOON** - Move the main arm of the planetarium a little more until the MOON globe nears the shadowed side of the EARTH opposite the SUN. *Stop the movement before the MOON globe enters the shadow created by the EARTH globe.* Viewed from the EARTH, the visible side of the MOON facing EARTH is fully illuminated by the SUN. [Figure 6]

[The full phase occurs about 14 days after the new phase. It represents the halfway point in the MOON's orbit or cycle. Now the MOON enters the second half of its orbit, heading towards the next new phase. As it does so, progressively smaller portions of the illuminated area of the MOON are visible to viewers on EARTH. We say the MOON is in the "waning" gibbous phase. Waning means diminishing.]

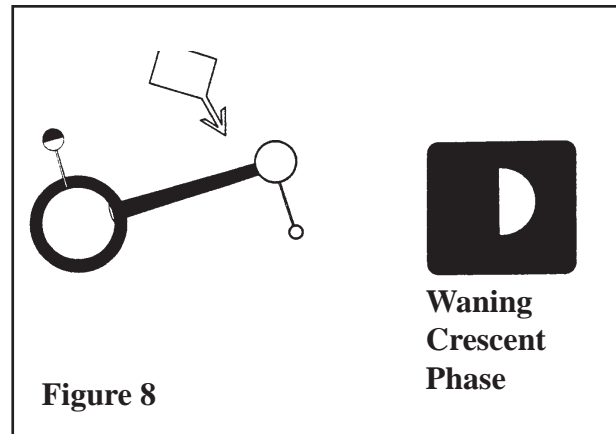


LAST QUARTER or THIRD QUARTER MOON - Move the main arm of the planetarium a little more until the MOON globe's support arm again is perpendicular to the main arm of the planetarium - on the side opposite the first quarter position. Viewed from the EARTH, just one half of the MOON again is illuminated by the SUN. Note that the left half is illuminated. The MOON has moved through three-fourths of one orbit, hence the name "third" quarter or "last" quarter. [Fig. 7]



the main arm of the planetarium a little more so that the MOON approaches - but stops just short of - the new phase position. Again, viewing from the EARTH, only a sliver of sunlight remains, illuminating the left edge of the MOON. {Fig. 8}

[One full orbit for the MOON - or one full cycle of phases - lasts about a month (29.53 days.)



### Lunar Eclipse

*Occasionally, the full MOON enters EARTH's shadow in space.*

A lunar eclipse only can occur when the MOON's phase is full.

**Do this:** Plug in and turn on the EL-400 planetarium, close your window blinds and turn out the lights. Move the main arm of the planetarium counterclockwise to position the MOON globe off to one side of the main arm. Move the VENUS globe off to one side of the SUN globe (so its shadow will not interfere).

Notice that light from the SUN illuminates one-half of both the EARTH and MOON at any one time. Both the EARTH and the MOON cast shadows into space in the direction opposite the SUN. Demonstrate this by holding a piece of paper or cardboard near the dark sides of the EARTH and MOON models. The shadows will be visible on the paper or cardboard.

Now grasp the motion grip of the main arm and swing the main arm counterclockwise, putting the planetarium into motion. When the entire MOON moves into the shadow of the EARTH and appears to darken, a **total** lunar eclipse occurs. Such an event can be seen by earthbound viewers from any location on the night (dark) side of the EARTH.

The simplified orbit and scale\* of the EL-400 planetarium artificially creates a total lunar eclipse each time the MOON passes EARTH's dark side. In the actual EARTH-MOON system, **eclipses do not occur with every full MOON**> Because of the MOON's tilted orbit, the actual MOON usually passes above or below the EARTH's shadow. Also, some lunar eclipses are **partial** where only a portion of the full MOON passes through EARTH's shadow.

In the real EARTH-MOON system, one can expect two lunar eclipses each year, on average.

\* For convenience, the separation of the EL-400 globes is shorter than if the unit were built to scale.

## Solar Eclipse

*Occasionally, the MOON travels directly between the SUN and EARTH.*

**Do this:** Plug in and turn on the EL-400 planetarium, close your window blinds and turn out the lights. Move the main arm of the planetarium to position it directly over "February" as marked on the planetarium base. Move the VENUS globe and support arm off to one side of the SUN, if necessary, so it does not cast any shadows (that might interfere).

Notice that light from the SUN illuminates one-half of both the EARTH and MOON at any one time. Both the EARTH and MOON cast shadows into space in the direction opposite the SUN. Demonstrate this by holding a piece of paper or cardboard near the dark sides of the EARTH and MOON globes. The shadows will be visible on the paper or cardboard.

Next, grasp the motion grip of the main arm and slightly swing the main arm counterclockwise, stopping with the main arm over "March" as marked on the planetarium base. The MOON globe should be located directly between the SUN and EARTH globes. (Adjust the main arm to correct the alignment, if necessary).

A solar eclipse can occur when the MOON passes directly between the SUN and EARTH. Notice that the MOON's shadow strikes the EARTH. Notice that the MOON's shadow strikes the EARTH. As the actual EARTH rotates on its axis, the MOON's shadow appears to trace a path of darkness along the face of the EARTH. For an earthbound viewer at, or near, the center of the shadow's path, the MOON momentarily - and dramatically - blocks the SUN from view.

Solar eclipses can be total or partial. By coincidence, the viewed size of the actual MOON, in its current orbit, often is just right to perfectly cover the face of the SUN. We call this event a **total** solar eclipse. If the MOON does not completely cover the face of the SUN (because of variations in its orbit, or because the viewer is not centered along the path of the MOON's shadow) a **partial** solar eclipse occurs. During a partial solar eclipse, only a portion of the SUN is blocked by the MOON.

Rather than circular, the actual MOON's orbit is elliptical (oval). When the MOON's distance from EARTH is slightly greater than average, an "**annular**" solar eclipse occurs, rather than a total eclipse. During an annular eclipse, the "smaller" apparent size of the more distant MOON blocks the central portion of the SUN, leaving a "ring of light" surrounding it.

Solar eclipse alignments are artificially common on the EL-400 planetarium. They occur with most EARTH-MOON-SUN alignments due to the simplified orbital mechanics of the EL-400.

The actual MOON's shadow is much smaller\* than

the EARTH. The MOON's tilted orbit usually carries the MOON and its shadow above or below the plane of the EARTH. So, more often than not, the MOON's shadow completely misses the EARTH.

**Try this:** Position the main arm of the planetarium over "December" as marked on the base. In this instance, the MOON's shadow misses EARTH. This is more typical of the actual EARTH-MOON-SUN system.

In the actual EARTH-MOON-SUN system, there are usually only four solar eclipses each year. Also, a solar eclipse can only be viewed from along the narrow path of the MOON's shadow. So, for any given location on the real EARTH, a total solar eclipse - even a partial solar eclipse - is a rare event.

\* For convenience, the separations of the EL-400 globes are shorter than if the unit were built to scale.

## Venus (and Mercury)

*The innermost planets.*

What does VENUS look like in its various orbital positions when viewed from the EARTH? (For the demonstrations that follow, it will help to let students view the planetarium's VENUS model by individually sighting it from a position very near the EARTH globe.)

As seen from the EARTH, the shape of the light and dark portions of VENUS change as the planet changes position along its orbital path. VENUS appears to change shape, or phase, as it orbits the SUN because of the changing angle of the SUN's illumination. This was one of Galileo's important telescopic discoveries in the early 1600's.

The half-white, half-black globe nearest the yellow SUN globe on the EL-400 planetarium represents an inner planet, VENUS (or MERCURY).

**Note:** Fully one half of VENUS is illuminated by the SUN - like the EARTH, MOON and all the planets. Since the VENUS globe rotates outside of the fixed beam of direct light from within the SUN globe, half of the VENUS globe is painted white and half is painted black, representing the illuminated side and the shadow side, respectively. When you set up the planetarium for a demonstration, always check and make sure that the white side of VENUS faces the SUN. Simply rotate the VENUS globe on its support rod, if a correction is needed.

## 1. The phases of VENUS

**Do this:** Grasp the metal rod supporting the VENUS globe and move the globe to a position over the main arm of the planetarium, directly between the SUN and EARTH. In this position, viewers on EARTH normally cannot see VENUS, since the illuminated side of VENUS faces away from EARTH (and because of the glare from the SUN). This is the "new" phase.

Rotate the main arm of the planetarium counterclockwise so that the VENUS globe just begins to move away from the main arm. In this position, VENUS starts to reveal a "crescent" phase to the viewers on the EARTH. That is, a thin "slice" of the illuminated portion of VENUS becomes visible.

Once VENUS arrives at the position fully to the "right side" of the SUN, it is seen in its "First quarter" phase. From EARTH we see one-half of the illuminated portion of VENUS, and one-half of the dark portion.

Earthbound viewers lose sight of VENUS in its "full" phase as it travels "behind" or to the "far side" of the SUN. When it emerges on the "left side" of the SUN, we can observe VENUS as it progresses through its "third quarter" and "waning crescent" phases.

Because VENUS and MERCURY have smaller diameter orbits than EARTH, both VENUS and MERCURY are always seen "near" the SUN's position in the sky. Unfortunately, the SUN's glare blocks our view! Thus, the only opportunities to see VENUS and/or MERCURY are when the planets are located off to one side of the SUN in their orbit. Then we can view them when the SUN is just below our horizon - right after sunset or just before sunrise. Venus is a brilliant planet yet is often referred to as the morning or evening "star."

## 2. Orbital speed of Venus

**Do this:** Rotate the main arm of the EL-400 and notice that VENUS travels faster around the SUN than does EARTH. In the real solar system, a planet closer to the SUN encounters a stronger gravitational field than does a planet located farther away. The innermost planet must travel faster to "balance against" this stronger gravity in order to maintain its orbit.

## Scale Model of the Solar System

*A scale model of the solar system shows that space is mostly .... empty space.*

A scale model is a miniature representation in which all elements are reduced by the same amount. In a scale model, relative sizes can be accurately compared. In the following scale model of the solar system, all bodies are scaled in relation to the size of the EARTH globe (3" or 76 mm) on the EL-400.

Utilize an assortment of marbles, golf balls, balloons, beach balls etc. to create a three-dimensional scale model. Use paper or cardboard circles for a two-dimensional model.

| Body           | Scale Diameter | Scale Orbit* | Scale Diameter | Scale Orbit* |
|----------------|----------------|--------------|----------------|--------------|
| <b>Sun</b>     | 27.0 ft        |              | 8.3 m          |              |
| <b>Mercury</b> | 1.2"           | 1138.0'      | 29.0 mm        | 347.0 m      |
| <b>Venus</b>   | 2.8"           | 2123.0'      | 72.0 mm        | 647.0 m      |
| <b>Earth</b>   | 3.0"           | 2937.0'      | 76.0 mm        | 895.0 m      |
| <b>Moon</b>    | 0.8"           | 7.5'         | 21.0 mm        | 2.3 m        |
| <b>Mars</b>    | 1.6"           | 4474'        | 40 mm          | 1364 m       |
| <b>Jupiter</b> | 32.8"          | 2.9'         | .84 m          | 4.6km        |
| <b>Saturn</b>  | 27.4"          | 5.3 mi       | .70 m          | 8.5km        |
| <b>Uranus</b>  | 11.0"          | 10.7 mi      | .28 m          | 17.2km       |
| <b>Neptune</b> | 10.7"          | 16.7 mi      | .27 m          | 26.8km       |
| <b>Pluto</b>   | .8"            | 22.0 mi      | 20.0 mm        | 35.4 km      |

\* Radius

*These instructions are by William O. Mitchell, astronomy writer and planetarium show presenter and producer. His experience ranges from the StarLab portable planetarium to the state-of-the-art Digistar planetarium. His monthly newspaper articles present an enthusiastic, nontechnical view of happenings in the backyard night sky. He has taught stargazing and astronomy to hundreds of groups ranging from elementary school students to adults. Bill enjoys stargazing the dark skies of Bois Blanc Island, MI, located in Lake Huron.*



### P/N 008005

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