Activity 7: Measuring your latitude using a quadrant

Background information

A quadrant was a very simple instrument used to determine the altitude of heavenly bodies. It was made out of wood or brass and came into widespread use around 1450. It takes its name from its shape, which is a quarter of a circle. A chord with a small weight or plumb bob made of lead or brass hangs down from the right angle and establishes a vertical line of reference. The quadrant is held at an angle so that the altitude of a heavenly body can be found from a simple reading on the scale.

The following activity shows you how to make and use a simple quadrant.

What you need

- A4 cardboard
- Glue
- Scissors
- Worksheet
- String 25cm
- Sticky tape
- Weight or washer
- Straw cut in half

What to do

1. Glue the worksheet onto the piece of cardboard.
2. Cut around the perimeter of the quadrant.
3. Poke a hole through the point marked ‘X’.
4. Insert the string from the front of the quadrant and stick it to the reverse side using sticky-tape so that it is secure.
5. Tie the small weight onto the other end of the string.
6. Stick a straw along the dotted line with glue or sticky tape.

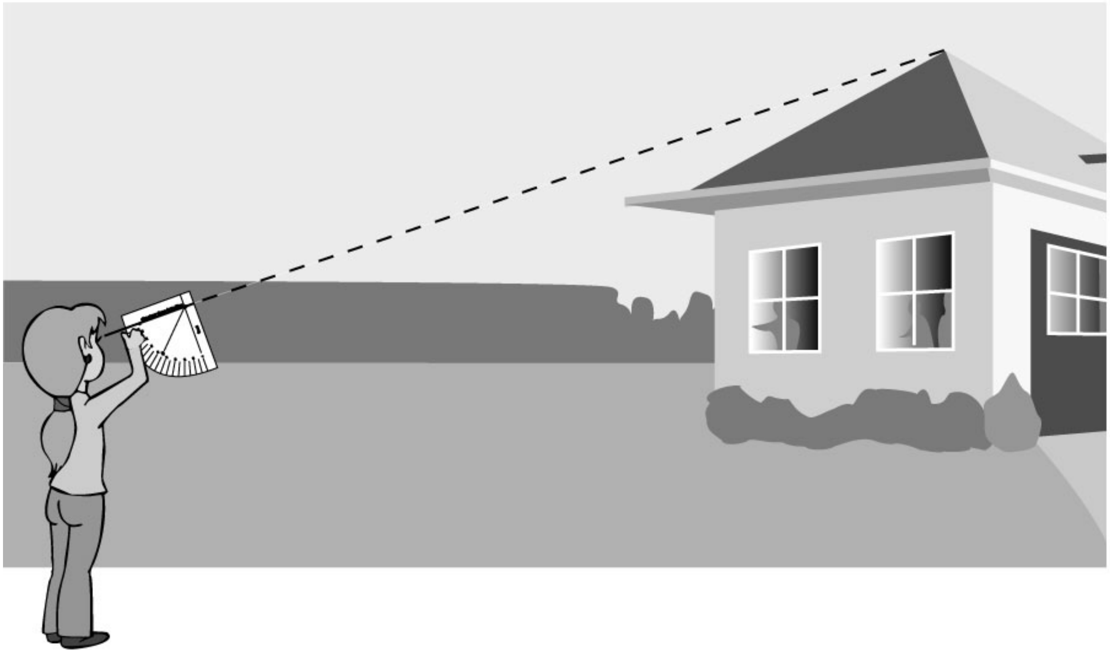
How to use the quadrant to measure your latitude:
Note: It is advisable to practise using the quadrant to measure the altitude of various objects (eg. top of building or church) during the daytime before using it to measure latitude.

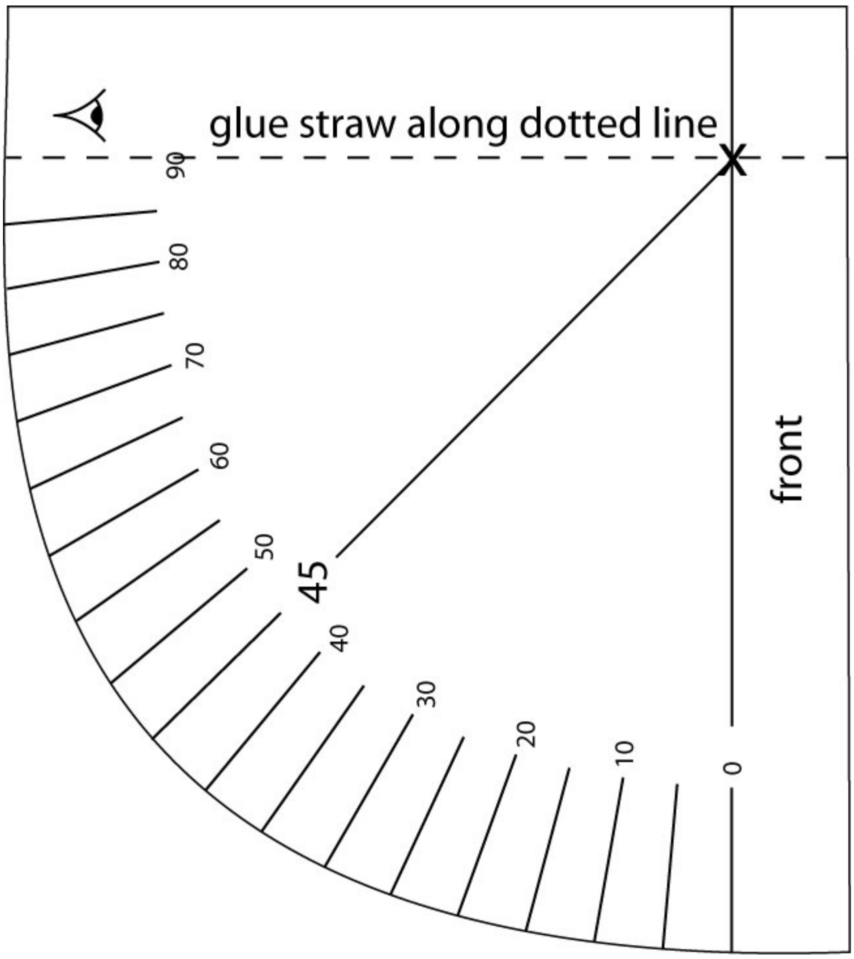
7. Go outside on a clear night and find the Southern Cross. Use the Southern Cross to locate the South Celestial Pole as accurately as possible. (Refer to ‘Using the Southern Cross to find south’ in this kit).
8. Hold the quadrant so that the weight hangs down along the zero line on the scale and the straw lines up with the horizon at eye level.
9. Tilt the quadrant and look through the straw so that you focus on the South Celestial Pole.
10. Hold the string in place against the quadrant.
11. Read the number of degrees between 0 degrees and 90 degrees. You now have an approximate measurement of your latitude. Repeat steps 8-11 three of four times so that an average value can be calculated. Compare the result with the latitude of your area, as shown in an atlas.

Optional
Use your quadrant and a star map to check the altitude of bright stars.
(Star maps for the current month for observers in the Southern Hemisphere are available online:
http://museumvictoria.com.au/planetarium/DiscoveryCentre/Sky-Maps/
http://www.skymaps.com/downloads.html).

Measuring your latitude using a quadrant

Worksheet





Activity 8: The longitude game

Background information

The Earth rotates 360 degrees in 24 hours, or 15 degrees every hour. For every 15° of longitude that one travels eastward, local time moves one hour ahead. Similarly, travelling west, local time moves back one hour for every 15° of longitude. The Earth has therefore been divided into 24 one-hour time zones, each 15° wide. (In practice, the zone boundaries are adjusted here and there to better fit the boundaries of countries, states, and islands. For instance, China has just the one time zone, despite its size. Furthermore, time differences aren't always whole hours. For example, Australia has three time zones, Western, Central and Eastern. The time difference between Eastern and Central Australian time zones is only half an hour).

What is Greenwich Mean Time (GMT)?
Greenwich Mean Time is the local time in Greenwich, London, from which other times around the world are measured. Greenwich has this honour because it was decided long ago that the meridian of longitude defined as zero degrees (the prime meridian) should run north-south through the Royal Observatory in Greenwich. The prime meridian marks the middle of the Greenwich Mean Time (GMT) zone. The time zone to the east is one hour ahead of Greenwich Mean Time (GMT +1 hour) and the time zone to the west is one hour behind Greenwich Mean Time (GMT –1 hour). The time in Melbourne, which is 145° east of Greenwich, is GMT +10 hours.

Using local time and Greenwich Mean Time (GMT) to calculate longitude
If we know the local times at two points on Earth, we can use the difference between them to calculate how far apart those places are in longitude. This was very important for 17th Century navigators, who were exploring the Earth's oceans for the first time. These navigators could measure the local time, wherever they were, by observing the Sun, but working out their longitude required that they also know the time at some reference point. Although accurate pendulum clocks existed in the 17th Century, the motion of a ship and changes in humidity and temperature prevented such clocks from keeping accurate time at sea.

In 1714, the British Government offered a prize of £20,000 for a solution which was accurate to within half a degree (2 minutes of time). John Harrison, a watchmaker, attempted to win the prize, and invented a series of increasingly accurate clocks over many years. His H5 model, in a trial in 1772, was shown to be accurate to within half a second per day, which effectively solved the problem of calculating longitude at sea.

The subsequent use of chronometers, based on Harrison's work, made marine navigation much more accurate, and ocean voyages much safer. Chronometers work by comparing Greenwich Mean Time with local time. Before leaving port, the chronometer is set to Greenwich time. During the voyage, the Sun is used to determine local time, with 12 noon being the time when the Sun reaches its highest point in the sky. The two times are then compared, and the ship's longitude calculated.

The following activity is designed to give students practice at calculating longitude and geographic position, given a latitudinal reference and Greenwich Mean Time.

Note: The activity assumes that the position of the sun is directly overhead, indicating noon at the given locations.

The calculation method
The Earth spins 360° in 24 hours, which means it spins 15° each hour. Thus, if we take Greenwich as our 0° longitude point, for every 15° travelled west from this point, we must subtract 1 hour from the time at Greenwich. Every 15° travelled east means an addition of one hour to Greenwich time.

Working backwards, if it is noon where you are and 7am in Greenwich, then you are 5 hours or 75° east of Greenwich. (5 x 15°= 75°)

If it is noon where you are and 7pm in Greenwich, then you are 7 hours or 105° west of Greenwich. (7 x 15° = 105°)

What you need

- Calculator
- A world map for each pair of students
- A set of eight game cards
- One token for each player (eg. buttons, plastic counters)

What to do

1. In preparation for the game, the playing cards should be copied onto card and cut out so that each pair of students has a set of eight game cards.
2. Place the cards face down on the table between the two players.
3. Players take turns to pick up one game card at a time and ask their opponent the longitude question.
4. The opponent then has three minutes to calculate the latitude and longitude position on the map and place their token at the estimated position.
5. The opponent should also explain verbally where the token is in relation to the surrounding countries, ocean or sea.
6. The player asking the question then determines whether the given position is correct according to the answer on the game card.
7. If the answer is correct, the opposing player scores one point. If the answer is incorrect no points are scored.
8. The game continues in this manner until all eight cards have been read out.
9. Correct point scores may be tallied to establish a winner if desired.

Extension

1. Ask students to use the calculation method to develop their own game cards. These could then be collated and re-distributed amongst other members of the class to repeat the game and keep it interesting.
2. Ask students to map a route to their ‘dream holiday’. Ask them to estimate what time it would be at various points of the journey with reference to their starting point and distance travelled.

Game cards for *The longitude game*

Question 1 The Sun is directly overhead. You take out your sextant and determine that your latitude is 32° N. Your chronometer tells you that it is 10 am in Greenwich. What is your longitude? 30° E, 45° E, 45° W, or 35° W? **Answer:** You are 30° E longitude, just off the coast of Egypt in the Mediterranean Sea. You are close to the birthplace of Harkuf, thought to be the first documented explorer. Harkuf lived in Egypt around 2300 BC during the 6th Egyptian dynasty and led expeditions up the Nile River to the land of Yam (modern southern Nubia).	**Question 2** The Sun is directly overhead. Your sextant reading indicates that you are at 0° latitude, on the equator. Your chronometer tells you that it is 10 pm in Greenwich. Is your longitude: 150° E, 145° W, 135° W or 150° W? **Answer:** You are 150° W, sailing in the Pacific Ocean north-west of the Marquesas Islands, north of Tahiti, and south-east of Hawaii. In 1769, Captain James Cook sailed to Tahiti to observe the transit of Venus. He landed on April 13th and left to continue his voyage to the Australian east coast on August 9th.

Question 3 The Sun is directly overhead. Your sextant tells you that you are 68° N latitude and your chronometer is showing 1 pm Greenwich time. Is your longitude: 15° E, 15° W, 150° E or 30° W? **Answer:** You are 15° W longitude, just north of Iceland where a colony of Vikings from Norway settled in about AD 815. These Vikings were famous for their strength and determination in battle, but also for their exploration of the North Atlantic Ocean.	**Question 4** It is 1764 and you spy some land to the west. Your sextant indicates that you are 13° N latitude and your chronometer is showing 3:49 pm Greenwich time. Is your longitude: 47.15° W, 57.25° W, 57.15° W or 57.00° E? **Answer:** If you calculated 57.25° W longitude then you are correct. In fact, you are off the coast of Barbados where John Harrison's watch was first tested for accuracy in 1764 after a month at sea. At 15° per hour, the watch placed Bridgetown, Barbados just under 60° W of Portsmouth – only a few miles from its actual position. Harrison's watch was accurate to within 30 seconds per day.

Hint:
If your time is earlier than Greenwich, you are west of Greenwich (W – for west).
If your time is later than Greenwich, you are east of Greenwich (E – for east).
One degree = Four minutes time difference

Question 5 The Sun is directly overhead and you have been sailing now for many months. Your sextant indicates that you are 38° S and your chronometer is showing 12 am, Greenwich time. Is your longitude: 120° W, 160° E 160° W or 180°? **Answer:** You are half way around the globe from Greenwich at exactly 180° longitude. Like Captain Cook in September 1769, you have spied the north-east coast of New Zealand's north island and are now preparing to circumnavigate both islands.	**Question 6** The Sun is directly overhead. You see some land and a sheltered bay to the west. Your sextant tells you that you are 34° S and your chronometer is showing 1:52 am, Greenwich time. Is your longitude: 28° E, 152° E, 28° W or 163° E? **Answer:** The answer to this difficult calculation is 152°E. You are in fact approaching Botany Bay. This bay was named by Captain Cook in April 1770 for two of the crew, Banks and Solander, who were botanists. After anchoring here for seven days, Cook sailed north, charting the coast and naming peaks and bays until he came to the Great Barrier Reef.

Question 7 The Sun is directly overhead. Your sextant is showing that you are exactly 23° 30' N on the Tropic of Cancer. Your chronometer is showing 4:40pm Greenwich time. Is your longitude: 65° W, 70° E, 110° E or 70° W longitude? **Answer:** You are enjoying the warm waters just east of the Bahamas at 70° W. It was here in October 1492 that Columbus first set sight on the 'New World'. Since there were no accurate clocks in his day, Columbus relied heavily upon the Dead Reckoning method of navigation. This used a magnetic compass and tracked distances travelled from one point to the next.	**Question 8** The Sun is directly overhead and your sextant indicates that you are 28° N. Your chronometer tells you that it is 8:40 am Greenwich time. Is your longitude: 50° E, 140° E, 140° W or 50° W? **Answer:** You are gazing at the shores of the Persian Gulf at 50° E. You are at the northern end of the Gulf just off the coasts of Iran and Saudi Arabia. It was in this vicinity that astrolabes were developed in the early centuries of Islam. The astrolabe was a navigation tool for telling the time using celestial observations, and was used before the invention of accurate clocks.

Hint:
If your time is earlier than Greenwich, you are west of Greenwich (W – for west).
If your time is later than Greenwich, you are east of Greenwich (E – for east).
One degree = Four minutes time difference

Activity 9: Changing constellations

Background information

Due to the Earth's orbit around the Sun, the constellations seen in the night sky change throughout the year. The constellations Orion and Scorpius are located at opposite sides of the Celestial Sphere (the imaginary sphere of stars that surrounds our Solar System). So as Orion sets in the west, Scorpius rises in the east, and vice versa.

During the Southern Hemisphere summer, when the South Pole of the Earth is pointed towards the Sun, the Earth is positioned between the constellation of Orion and the Sun. This is why Orion can be seen in our night sky during summer evenings. As the Earth continues to move around the Sun throughout the year, Orion is observed low in the eastern sky during the evening from December, sits overhead throughout February, and sinks low in the western sky come April.

During the Southern Hemisphere winter, when the South Pole of the Earth is pointed away from the Sun, the Earth is positioned between the constellation of Scorpius and the Sun. This is why Scorpius can be seen in our night sky during winter evenings. Scorpius is observed low in the eastern sky during the evening from May, appears overhead during August, and sinks low in the western sky come November.

The Southern Cross is positioned close to the South Celestial Pole, so from Melbourne it can be seen all year round.

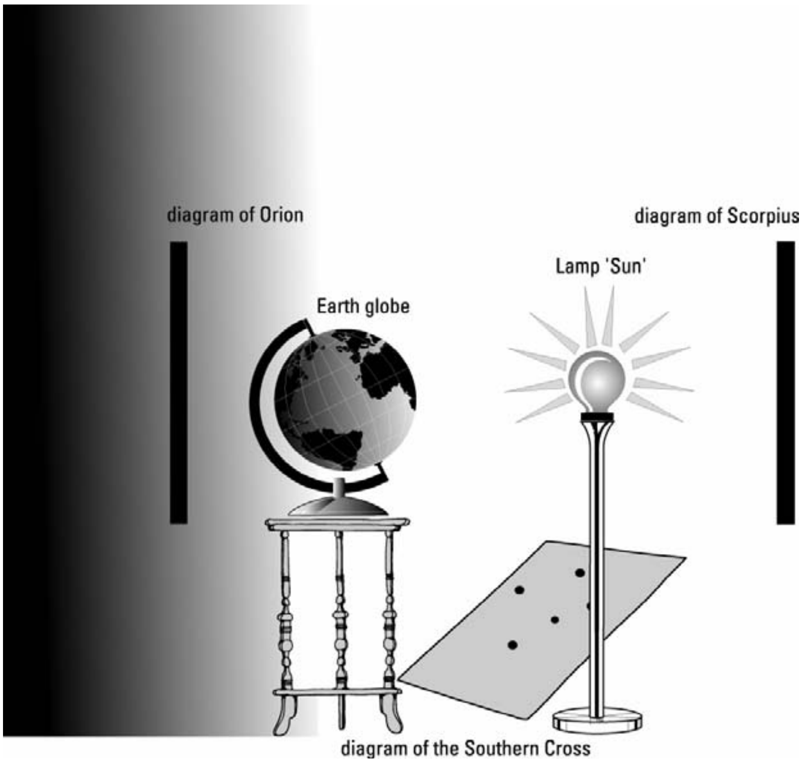
The following activity demonstrates how the position of the Earth relative to the Sun causes the various constellations to be visible at different times during the year.

What you need

- Diagrams of the Southern Cross, Orion and Scorpius
- Earth globe (tilted at 23.5 degrees to represent the Earth)
- Blu-Tack
- Lamp with no shade (to represent the Sun)

What to do

1. Blu-Tack the diagrams of Orion and Scorpius on opposite sides of the room. Ensure that both these constellations are lying on their sides.
2. Place the diagram of the Southern Cross about half way between these constellations (on the floor).
3. Place a lamp representing the Sun on a chair or table half way between and about the same height as the two constellations (Orion and Scorpius).
4. Switch the lamp on and darken the rest of the room.
5. Position yourself with the Earth globe so that it is between the Sun and the constellation of Orion. The South Pole should be pointing towards the Sun. Explain to your students that this position represents summer in the Southern Hemisphere (approximately December 22).
6. Allow students to use the globe to identify Australia in the Southern Hemisphere, and some of the countries in the Northern Hemisphere.



7. As you turn the Earth globe, you should be able to see that Orion is visible in the night sky and that Scorpius appears during the day but is drowned out by the Sun.
8. Ask the students whether the Southern Cross can be seen during summer in Australia. (The Southern Cross never drops below the horizon in Melbourne.)
9. Position the Earth between the Sun and the constellation of Scorpius. The South Pole and all of Antarctica should now be pointing away from the Sun and in 'darkness'. Explain to the students that this represents winter in the Southern Hemisphere (approximately June 22).
10. As you turn the globe, you should be able to demonstrate that during winter Scorpius can be easily seen in the night sky. However, the stars in Orion can't be seen during the day as these stars are drowned out by the light of the Sun.
11. Ask the students whether the Southern Cross can be seen during winter in southern Australia. (It can be seen, as the Cross never sets below the horizon at the latitude of Melbourne).

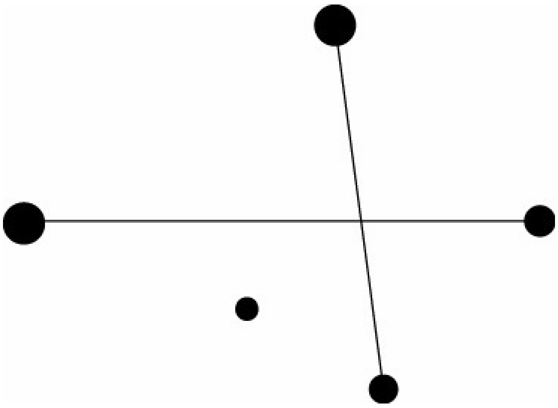
Optional

Ask your students to:

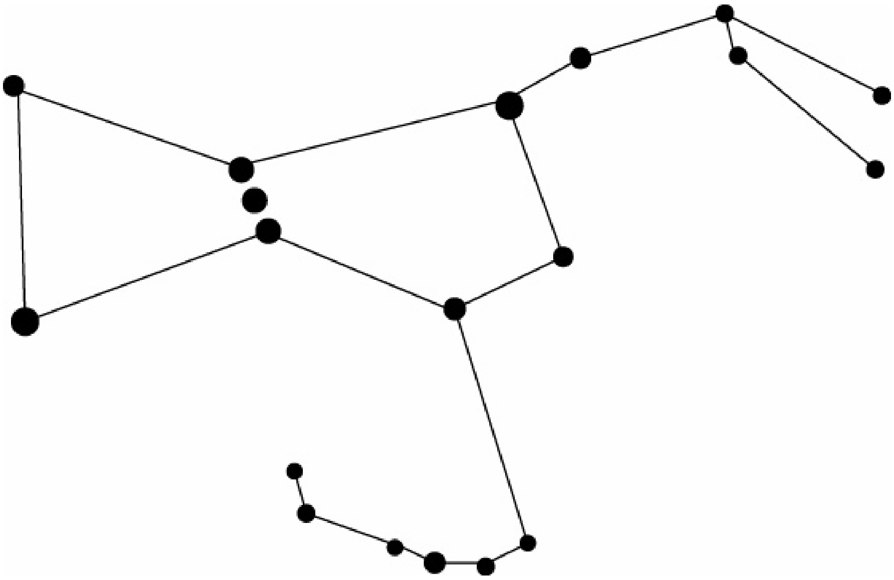
- Investigate whether Orion and Scorpius can be seen during autumn and spring using the same model.
- Research other constellations that are visible during winter or summer in the Southern Hemisphere.
- Look up the word *circumpolar* and name some circumpolar constellations in the Southern Hemisphere. (The use of a planisphere will be useful here.)

Changing constellations diagrams

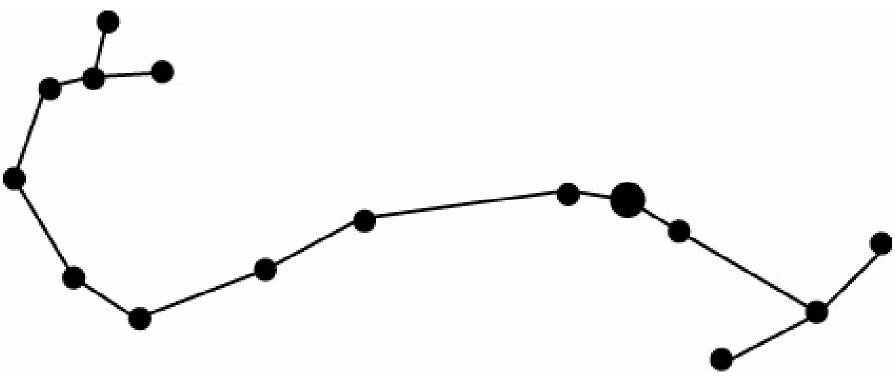
The Southern Cross



Orion



Scorpius



Activity 10: Make your own planisphere

Background information

Star observations
With the naked eye, we are able to see about 3000 stars on a clear night (with minimum light pollution). Through a small telescope we are able to see about 6000 stars. A planisphere is a flat map of the stars that can be used as a guide to help identify constellations and individual stars in the night sky. Planispheres can be used for any time of night throughout the year, but are made for use in a particular location (eg. Melbourne/central Victoria).

On a clear night, the colour of different stars may become more apparent. The colour of a star can tell you something about its temperature. If you put a piece of metal into a fire, it will first glow a faint red colour, then as it gets hotter, it becomes redder and, if it doesn't melt, it will turn yellow, then white, then blue/white. In the same way, the blue flame from a Bunsen burner is hotter and more dangerous than a red/yellow flame. The metal rod and the gas in the Bunsen burner have no colour of their own but change colour depending on their temperature. This is the same with stars. Cooler stars (with temperatures around 3,000K) glow red, while hotter stars (with temperatures around 10,000K) glow blue/white. Our Sun is a yellow star because it has a temperature of 5,800K.

Stars to look out for
Betelgeuse is a red supergiant star in the constellation of Orion. The surface temperature of Betelgeuse is approximately 3000 degrees Celsius. Its diameter fluctuates in size from about 300 to 400 times the Sun's diameter. It is estimated to be about 427 light years away.

Aldebaran is a red giant star in the constellation of Taurus, 65 light years away.

Antares is a red supergiant like Betelgeuse. It is part of the constellation Scorpius and is 604 light years away.

Rigel is the brightest star in the constellation of Orion. It is a hot blue supergiant star with a surface temperature of approximately 14 000 degrees Celsius. Rigel is a young star and, because it is using its fuel so rapidly, it will probably not last for more than a few million years. It is about 773 light years away.

Canopus in the constellation of Carina is the second brightest star in the night sky. It is a white star 313 light years away.

Sirius is the brightest star in the night sky and is part of the constellation Canis Major. It is a blue-white supergiant star about 9 light years away.

Alpha Centauri lies in the constellation of Centaurus. It is one of the bright Pointers that point to the Southern Cross. It is the third brightest star in the night sky and is only 4.4 light years away. It is also our Sun's closest neighbour. A telescopic view of this star reveals that it is actually two yellow stars orbiting each other every 80 years. The brighter one of these is actually quite similar to our Sun. A third star called Proxima Centauri is also part of this system orbiting the other two stars every million years. At present, Proxima Centauri is actually the closest star to our Sun (4.2 light years away). However since we cannot see Proxima Centauri with the naked eye, Alpha Centauri is taken to be the closest star to our Sun.

Beta Centauri is the other star of the two bright Pointers that point to the Southern Cross. It is a blue giant star 530 light years away.

Formalhaut is part of the constellation of Piscis Austrinus. It is a blue-white star 25 light years away.

Achernar is a blue-white star in the constellation of Eridanus and is about 144 light years away.

What you need

- A4 cardboard X 4
- Make your own planisphere worksheets (3 pages in PDF file)
- scissors
- glue
- split pin

What to do

Make a planisphere following the instructions below. Then try to find the stars mentioned above and the constellations they belong to.

1. Glue dial B onto an A4 piece of cardboard and carefully cut around the dashed outline.
2. Glue the cover onto an A4 piece of cardboard and carefully cut around the dashed outline. Cut out the dark sections.
3. Use the square shape of the cover as a template to cut out another square (with the same dimensions) from a sheet of cardboard. This is the backing for your planisphere.
4. Find and mark the centre of the backing. Thread a split pin through the centre of the backing and the centre of dial B.
5. Attach the cover over the dial and backing sheet so that the dial is able to rotate freely between the cover and the backing sheet. Secure the split pin.

Using the planisphere

1. On a clear night, choose a location away from bright lights.
2. Find and face south.
3. Hold up the planisphere so that the southern horizon is at the bottom.
4. Rotate the dial until you reach the correct time and date.
5. Find the two bright Pointers (Alpha Centauri and Beta Centauri) and the Southern Cross on your planisphere and locate them in the real night sky.
6. Continue to look for other bright stars and constellations in the night sky using the Southern Cross as your starting place.
7. Once you have found all the constellations and stars on this dial, you may want to change your dial for dial A which contains a lot more stars and constellations. This dial is for more advanced users.
   The dotted line denotes the ecliptic. The constellations along this line are called the zodiac constellations. At different times, the planets are also visible as bright star-like objects close to the ecliptic. After having some practice using your planisphere, you may want to try to locate the planets. Their location is given in the Planetarium's *Skynotes*, published each month on our web site: http://museumvictoria.com.au/Planetarium/

Activity 11: Using the Southern Cross to tell the time

Background information

The position of the stars in the sky slowly changes as the Earth rotates on its axis and revolves around the Sun. The position of the Southern Cross therefore varies according to the time of day/night and the time of year.

The following activity explains how to make a Southern Cross finder. The position of the split pin in the diagrams below represents the South Celestial Pole. This an imaginary point that is an extension of the South Pole into the sky. The South Celestial Pole is the point around which all the stars seem to rotate as the Earth turns on its axis and revolves around the Sun. In southern Australia, the Southern Cross never sets below the horizon so can always be seen at night.

What you need

- Scissors
- Southern Cross finder worksheet
- Cardboard
- Split pin

What to do

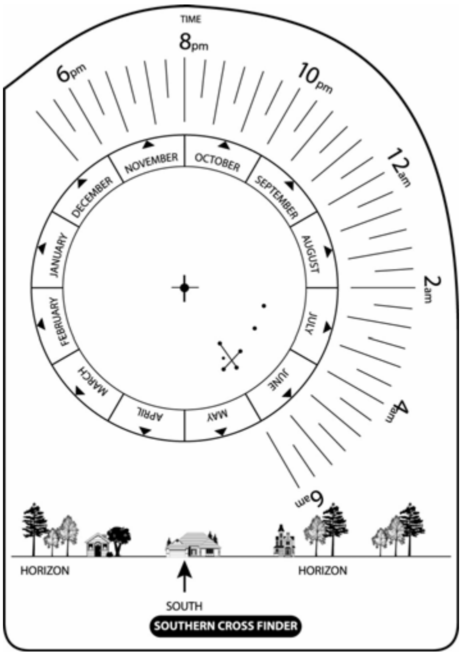
1. Paste the worksheet onto thin cardboard.
2. Cut out around the dark outline of the two shapes on the worksheet.
3. Use a split pin to join them through the points marked +.

(a) You can now use the Southern Cross finder to show you the approximate position of the Southern Cross at any time of year and at any time of night as viewed from Melbourne.

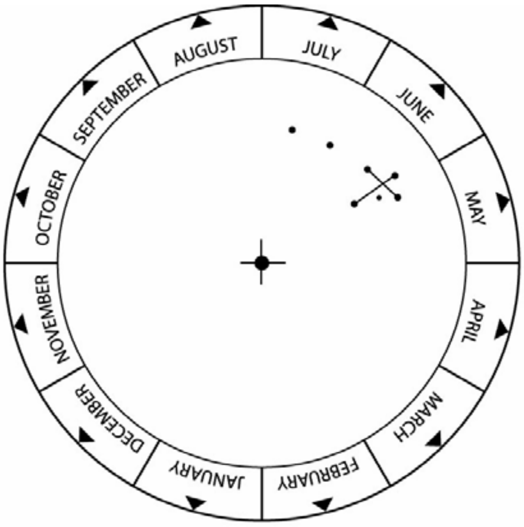
4. First choose a month and time. Example: End of October at 8pm.
5. Line up the line dividing October and November with 8pm as shown in the diagram. The Southern Cross will be in the position shown relative to the horizon.

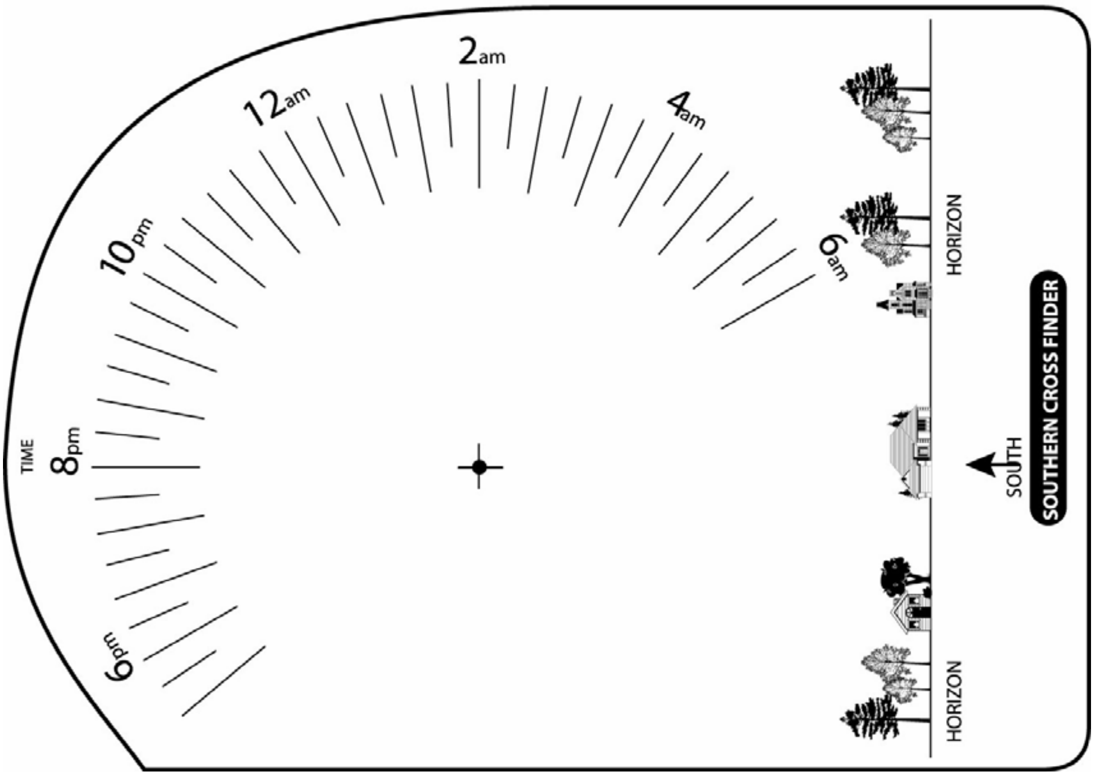
(b) You can also use the Southern Cross finder in reverse to give you an approximate time.

6. On a clear night, face south to locate the Southern Cross in the night sky.
7. Hold the Southern Cross finder up in front of you so that the horizon on the finder matches the real horizon.
8. Rotate the dial so that the Southern Cross and the Pointers on the finder approximate their position in the real night sky.
9. Locate the approximate time of the month on the dial and read the corresponding time.



The Southern Cross finder worksheet





Activity 12: Navigating with the bees

Background information

Have you ever wondered how migrating birds manage to find their way across thousands of kilometres and arrive at the correct nesting place year after year? Scientists now believe that birds have a 'built in' sense of navigation that enables them to follow the stars and to pick up signals from the Earth's magnetic field. Both of these guides assist birds in finding their way along migratory paths.

Birds are not the only animals that refer to celestial bodies in order to find direction. Honey Bees use light from the Sun to direct the hive to a new found source of food (nectar). Scientists also believe that Honey Bees have a 'built in' sense of the (apparent) movement of the Sun through the sky so that they can orient their direction even if the Sun has moved.

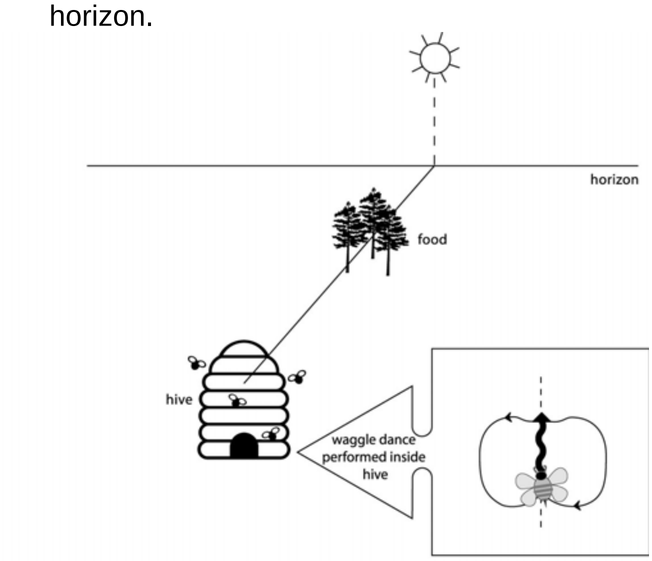
Scientists have observed that bees have two different forms of 'dance' that communicate distance and direction of a food source to the rest of the hive. The first is the 'round dance', which is performed when the source is less than 75 metres from the hive. This dance is quite complex and is not part of this activity. The second dance is performed when the food is more than 75 metres away and is called the 'waggle dance'. The waggle dance is discussed in detail below.

A nominated bee from a hive called the scout goes out to look for food. On its return, the dance is performed on a vertical surface of the hive while the rest of the bees pay attention. The portion of the dance which is represented by the wiggly line (or the waggle) is performed at an angle that represents the angle between the direction of the Sun and the location of the food.

The waggle dance

Example 1

- If the bee dances vertically upwards in the hive, this means that the food is in the direction of the Sun. The bees translate this by going out from the hive, finding the Sun and mentally drawing an imaginary straight line down from the Sun to the horizon. The food will be at a point between the hive and this point on the horizon.



Example 2

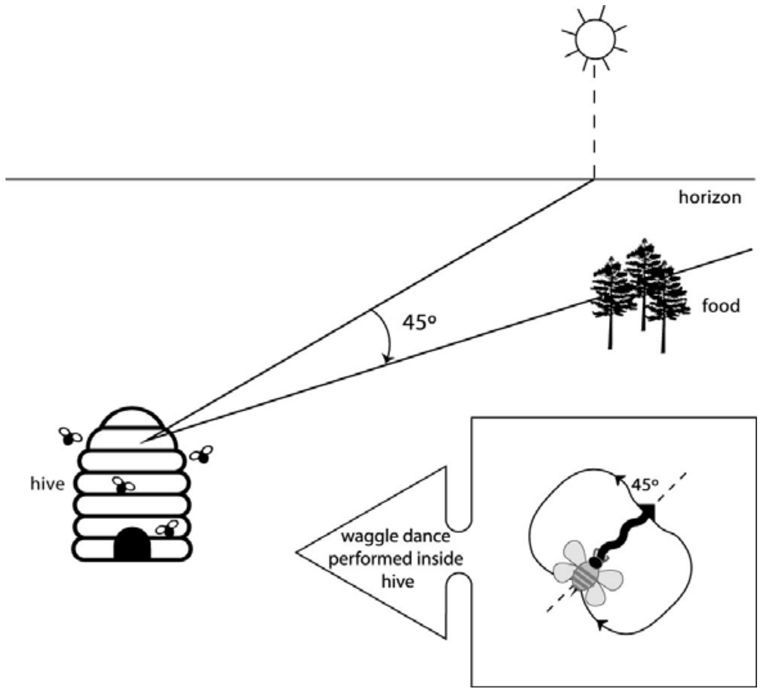
- If the food source is located at an angle to the Sun, the scout bee waggles at this angle to the vertical in the hive. The bees would need to locate the Sun and mentally draw an imaginary straight line down from the Sun to the horizon, then head out at the angle indicated by the scout bee.

- If the food is located in the opposite direction to the Sun, the waggle is directed vertically downwards in the hive.

- The speed of the dance indicates how much food was found. A faster dance indicates more food.

- The longer the length of the waggle, the further the food is from the hive.

- Even on cloudy days, the bees are able to detect the position of the Sun by the intensity of the light rays coming through the clouds.



What you need

- A clear floor or playground area
- A model Sun or a light source
- Flowers as 'food'

What to do

1. Copy the above diagrams for students to examine and discuss.
2. Explain to students that they will perform their dance on a horizontal rather than a vertical surface like bees because they can't fly.
3. Select a student to be the scout. This student will perform the 'waggle dance'.
4. Ask students to form a hive at a given location in the playground or room.
5. Select one student to hold the 'Sun' and another student to record or draw the dance for later discussion.
   If this activity is done outside, you could use the real Sun instead of a model – but be sure to warn the students not to look directly at the Sun.
6. Select a student to place the 'food' somewhere nearby.
7. Send the scout from the hive to look for the food and then return to the hive.
8. The student must now perform the waggle dance. They walk two overlapping circles, and waggle their bottom as they walk along the straight portion (see diagrams above).
9. The dance should indicate the angle between the food and the 'Sun' (real or model).
10. Keep in mind that the faster the dance, the more plentiful the food source. The scout's dance should reflect this.
11. The distance of the food should also be demonstrated. The further the food, the longer the waggle line. When the food is very close, the bees leave out the waggle line altogether and simply perform a 'round' dance.
12. Change the position of the food and repeat a number of times, choosing new scouts each time.

Extension
Some suggestions for Internet and library research:

- Why do moths spiral around a bright light source at night?
  http://hannover.park.org/Canada/Museum/insects/evolution/navigation.html
- Research how wasps, ants or butterflies use the Sun as a navigational tool.
- Eels also seem to use the Earth's magnetic field as one of the tools to navigate their way over long distances. Research the European eel and find out what other tools it uses to navigate.

Make up your own 'dance' that communicates a message about a source of food to your classmates. The message should communicate distance, direction and quantity of food. Your 'dance' should also include some reference to a celestial object.