ABINGDON SCIENCE PARTNERSHIP

6. Celestial Observation

Part 2 - Planning Observations

Edexcel GCSE Astronomy Course

Topic 6 Specification Points - Part 2 Observation Planning

6.5 Be able to use information from star charts, planispheres, computer programs or ‘apps’ to identify objects in the night sky
6.6 Understand the causes and effects of light pollution on observations of the night sky
6.7 Understand the meaning of the terms: a celestial sphere b celestial poles c celestial equator
6.8 Understand the use of the equatorial coordinate system (right ascension and declination)
6.9 Understand the use of the horizon coordinate system (altitude and azimuth)
6.10 Understand how the observer’s latitude can be used to link the equatorial and horizon coordinates of an object for the observer’s meridian
6.11 Understand how the observer’s meridian defines local sidereal time and an object’s hour angle
6.12 Be able to use information on equatorial and horizon coordinates to determine: a the best time to observe a particular celestial object b the best object(s) to observe at a particular time
6.13 Understand, in relation to astronomical observations, the terms: a cardinal points b culmination c meridian d zenith e circumpolarity
6.14 Understand the diurnal motion of the sky due to the Earth’s rotation
6.15 Be able to use a star’s declination to determine whether the star will be circumpolar from an observer’s latitude
6.16 Understand the apparent motion of circumpolar stars, including upper transit (culmination) and lower transit
6.17 Be able to use information about rising and setting times of stars to predict their approximate position in the sky
6.18 Be able to find the latitude of an observer using Polaris
6.19 Understand naked eye techniques such as dark adaptation and averted vision
6.20 Understand the factors affecting visibility, including: a rising and setting b seeing conditions c weather conditions d landscape

6.5 Be able to use information from star charts, planispheres, computer programs or ‘apps’ to identify objects in the night sky

Star charts are often published in newspapers, astronomy magazines or on websites such as:
https://skymaps.com/downloads.html
They will usually show a simplified map of the night sky for a given time period, such as a month, at a certain latitude and at a certain time - they give a fixed picture rather than a dynamic one.

Planispheres have been used for centuries by astronomers. You can see examples here:
https://www.skyatnightmagazine.com/space-science/in-pictures-a-history-of-the-planisphere/
And find a pattern to make one of your own here:
https://in-the-sky.org/planisphere/

There are many **programs and apps** available to help you navigate your way around the sky, search for objects and identify them. A very useful one is Stellarium, which is free to download and use on many devices (although there are charges for some app versions)
https://stellarium.org/

6.14 Understand the diurnal motion of the sky due to the Earth’s rotation

Here is an exercise you can try with Stellarium - set it to the latitude of your observing location, centre the sky on Polaris and increase the time step gradually until the moving sky demonstrates a **diurnal motion** i.e. appears to spin around Polaris as a fixed point, taking 23 hrs 56 mins and 4secs to complete each rotation - this is called a **sidereal day** (the time it takes the Earth to rotate once on its axis).

6.6 Understand the causes and effects of light pollution on observations of the night sky

This video gives an excellent demonstration of the effect of **light pollution** using a simulation in Stellarium - once you've watched it, you can try it yourself if you have Stellarium: https://www.youtube.com/watch?v=wFBBbOJIo8o (2:30)

6.19 Understand naked eye techniques such as **dark adaptation** and averted vision

The reasons for these techniques are explained by the fascinating way in which the receptor cells at the back of your eye, on the retina, work. Put simply:

- There are two types of cells, cones which can detect different wavelengths, or colours, and rods which can detect brightness levels.
- In daylight, rods become saturated and do not really function.
- In low light, at night, cones cannot distinguish colours as the light levels are so low.
- Rods gradually become unsaturated in darkness and start to distinguish different levels of brightness.
- This process is called **dark adaptation** and it takes about 20mins for the rods to adjust from bright light to darkness.
- Astronomers often use red light at night as the rods are not sensitive to it and it will not ruin their night vision

  Watch this video for full details if you have time https://www.youtube.com/watch?v=Hd5dCkxXzkU (2:27)

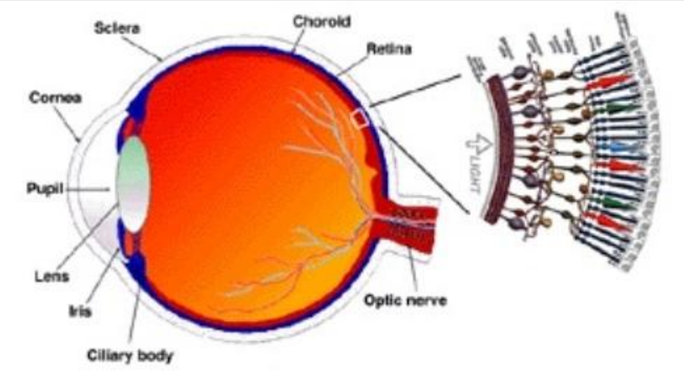
6.19 Understand naked eye techniques such as dark adaptation and **averted vision**

Averted vision is a technique astronomers use to find very dim objects at night by not looking directly at them.
The reason that this works is explained in more detail in this video:
https://www.youtube.com/watch?v=CrExYrPbMxc (2:55)

The essentials of the explanation are:

- The rod cells in your eye are more sensitive at night than the cone cells
- The cone cells are concentrated in an area called the fovea in the centre of the retina
- Training your brain to concentrate on areas around the edges of your vision allows you to detect dimmer objects with just the rods and not the cones
- The technique is to stare slightly to the side of where you expect the dim object to be

A good target to try this with is the Andromeda Galaxy (M31)
How to find M31



6.20 Understand the factors affecting visibility, including: a rising and setting b seeing conditions c weather conditions d landscape

All of the above factors will be important in deciding whether you will be able to observe a particular target object from your location at a certain time.

Rising and setting simply means at what time does the object rise above the horizon and at what time does it set, or pass below the horizon, again.

Remember that all celestial objects follow a curved path across the sky between their rising and setting points. (Some objects may be **circumpolar** at your latitude, which means they never set - this will be explained later).

Seeing conditions means *how stable is the atmosphere* at the time and location you make the observation. Seeing is affected by the stability of the atmosphere. When it is less stable, moving air currents cause variations in refraction, or bending, of light so that target objects appear to move around more and are harder to image or observe.

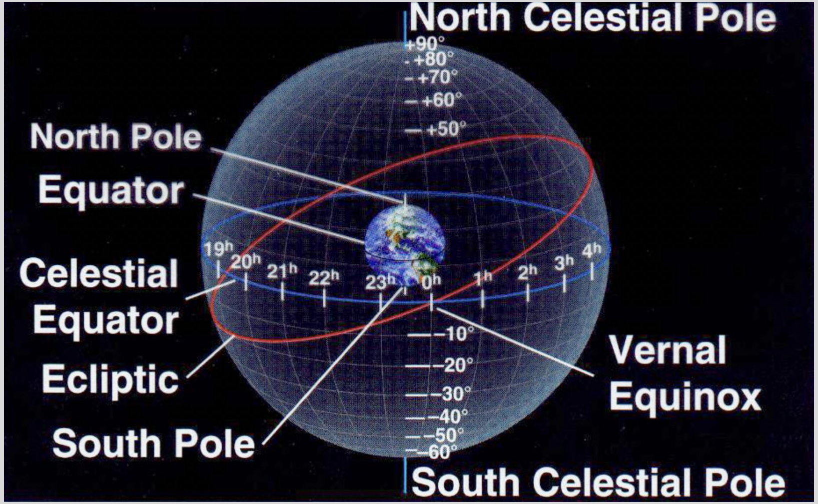
Seeing conditions are measured on the Antoniadi scale from I being perfect to V being very bad:
https://www.ing.iac.es//Astronomy/instruments/naomi/antoniadi.html

Weather conditions will obviously affect visibility. When cloud and rain obscure the sky, observing is not possible and equipment could be damaged.

Landscape features such as mountains, hills, trees and buildings can all obscure parts of the sky, especially near the horizon. However, if you can observe from a high point and look towards a lower horizon, this will extend the amount of sky you can observe.

6.7 Understand the meaning of the terms: a celestial sphere b celestial poles c celestial equator

This diagram, from the link below, shows these features very clearly. You need to learn what they are and be able to label them on a similar diagram:



The **celestial sphere** is the whole of the sky surrounding the Earth

The **celestial equator** is the disc shaped extension of the Earth's equator out into space

The **celestial poles** are points on the celestial sphere 90º above and below the centre of the celestial equator

(The **ecliptic** is the path the Sun appears to follow across the celestial sphere when viewed from Earth)

http://astro.wsu.edu/worthey/astro/html/lec-celestial-sph.html

6.13 Understand, in relation to astronomical observations, the terms:a cardinal points b culmination c meridian d zenith e circumpolarity

The following definitions are adapted from this link - you need to **learn** them: https://en.wikibooks.org/wiki/General_Astronomy/The_Celestial_Sphere

The **cardinal points** are points on the celestial sphere that are on the horizon and due north, south, east and west of the observer. (The North point, for example, is the point due north on the horizon from the observer's location). (The **horizon** is where earth and sky meet. It is the boundary between the portion of the sky that is blocked by the Earth and the portion that is visible).

The **zenith** is the point in the sky directly overhead of the observer. (Any point on the **horizon** is 90° from the observer's zenith).

The **meridian** is the arc of a circle across the sky that passes through the observer's North point, South point, and zenith and lies on the **celestial sphere**.

(The **prime meridian** is the meridian line at Greenwich at **local noon**).

Culmination means passing across an observer's meridian. (**Culmination** will be due south of an observer in the northern hemisphere or due north in the southern hemisphere - this where **altitude** above the **horizon** is maximum).

Circumpolar objects, such as stars and constellations, never set from an observer's latitude i.e they are always above the horizon whatever time of day or whatever time of year. (They may not be visible though if it is daytime).

6.8 Understand the use of the equatorial coordinate system (right ascension and declination)
6.9 Understand the use of the horizon coordinate system (altitude and azimuth)

Right ascension and declination (usually abbreviated to **RA and DEC**) are explained very clearly in the link below. Watch out also for definitions of **vernal equinox and celestial equator** as these are used to define the zero reference points for RA and DEC:

https://skyandtelescope.org/astronomy-resources/right-ascension-declination-celestial-coordinates/

A clear explanation of the **horizon coordinate system** is given in this link, together with its advantages and disadvantages:

https://www.timeanddate.com/astronomy/horizontal-coordinate-system.html

6.10 Understand how the observer's latitude can be used to link the equatorial and horizon coordinates of an object for the observer's meridian

This is a pretty simple technique useful in navigation. As the **celestial equator** is an extension of the Earth's equator into space, an object's declination (DEC) is the same as the value for latitude. An object will have its maximum altitude (ALT) when it **culminates** i.e. crosses the observer's **meridian.** The observer's latitude will then be given by 90-ALT+DEC where DEC is known from a list of tabulated values for known stars. ***LEARN THIS EQUATION.***

REMEMBER that ALT must be measured from the **south** point on the observer's horizon. Full details are here: http://homework.uoregon.edu/pub/emj/121/lectures/skycoords.html#

An example:

The DEC of Sirius is approximately -17^{o}. From a latitude of 50^{o}N what altitude would it reach in the sky at culmination?

Use the equation Lat = 90-ALT+DEC and check your answer with the screen shot from Stellarium on the next slide.

6.18 Be able to find the latitude of an observer using Polaris

This is really easy now as the DEC of Polaris is 90^{o} so LAT = 90-ALT+DEC becomes LAT = 180-ALT where ALT is measured from the **south** point on the horizon. Even easier though is just to measure the value of ALT from the nearest horizon. From 50^{o}N the ALT of Polaris would be 50^{o} above the northern horizon. ***LEARN THIS RULE.***

Sirius culminating at ALT = 23º on 21 March 2022 at 50ºN

6.15 Be able to use a star's declination to determine whether the star will be circumpolar from an observer's latitude

Circumpolar means that the star never sets at an observer's latitude. Its path through the sky is a circle over a period of 1 sidereal day (although it may be obscured by daylight for part of this time).

For example, the stars in Ursa Major are circumpolar but the stars in Orion are not at 50ºN.

A simple calculation can be used to predict whether an object will be circumpolar or not. The rule is:

For circumpolar stars, the star's **declination > 90° - observer's latitude** (> means greater than)

Examples:

Mirak in Ursa Major has a DEC of approximately 56º. Will it be circumpolar from these latitudes?

(a) 50ºN Answer: 90-50=40 and 56 is > 40 so the answer is yes

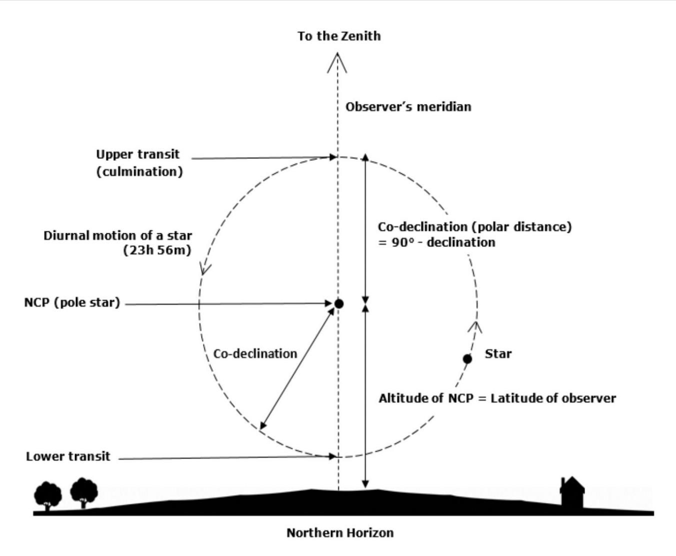
(b) 25ºN Answer: 90-25=65 and 56 is < 65 so the answer is no (the Plough would not be circumpolar in the tropics!).

LEARN THIS RULE.

6.16 Understand the apparent motion of circumpolar stars, including upper transit (culmination) and lower transit

This diagram shows the apparent motion of a **circumpolar star** over a period of 1 **sidereal day** and the positions of **upper transit (or culmination)** and **lower transit**. It is taken from the Edexcel GCSE Astronomy Topic 6 Guide which can be downloaded from this link:

https://qualifications.pearson.com/content/dam/pdf/GCSE/Astronomy/2017/Teaching-and-learning-materials/GCSE_Astronomy_Topic_Guide_Celestial_Sphere.pdf



NCP stands for North Celestial Pole

Definitions to ***LEARN:***

Upper transit (or culmination) is the highest **altitude** a **circumpolar** star reaches above the horizon during a full **sidereal** day.

Lower transit is the lowest **altitude** a **circumpolar** star reaches above the horizon during a full **sidereal** day.

6.11 Understand how the observer's meridian defines local sidereal time and an object's hour angle

Local sidereal time is the time at an observer's location measured by the **right ascension (RA)** of the observer's **meridian.**

For example, in this screen shot from Stellarium the clock time shown in the grey box is 00:54:54GMT and Sirius is **culminating** on the observer's **meridian**. Sirius has an **RA** of 6hrs45min so this is the **local sidereal time** at this location - the **RA** of the **meridian** line at that point in time. ***LEARN THIS FACT.***

The **hour angle** of an object is the number of hours it will take for that object to reach the observer's **meridian** OR the number of hours since it passed the observer's **meridian.**

It is the difference between the RA of the meridian and the RA of the object. ***LEARN THIS FACT.***

Hour angle is negative for objects yet to pass and positive for objects that have passed.

If the object has passed the meridian, subtracting the value of hour angle from 23hrs56mins4sec gives the time until it next **culminates**.

Exercises:

From the same Stellarium screen seen in the last slide, calculate **hour angles** at the observer's location given that the observer's **local sidereal time (LST)** is 6h45m for:

(a) Betelgeuse RA 5h55m
(b) Aldebaran RA 4h35m
(c) Procyon RA 7h39m

Answers:
a Betelgeuse -50m
b Aldebaran -2h10m
c Procyon +54m

Extension question:
What is the hour angle of Procyon for another observer at a longitude of 15º west of this observer?
Answer: -6m *Can you work out why?*

6.12 Be able to use information on equatorial and horizon coordinates to determine:
a the best time to observe a particular celestial object
b the best object(s) to observe at a particular time

These specification points simply require you to be able to use the definitions, rules and calculations you have learnt about in the previous slides to interpret information about potential target objects.

As a rule of thumb, the best time to observe an object is when it is near culmination as it will then be at its highest point in the sky.

- You might need to use the rule

Hour angle = Local Sidereal Time - RA of the target object

to work out how long it will be before the object culminates at an observer's location

- You might need to use the rule **DEC > 90-Latitude** to work out if a target object will be circumpolar or not

The best way to learn how to do these things is to try example questions.

6.17 Be able to use information about rising and setting times of stars to predict their approximate position in the sky

From our rotating viewpoint on the Earth it appears that all objects on the celestial sphere follow a circular path across the sky every 23h56m4s (a **sidereal day**).

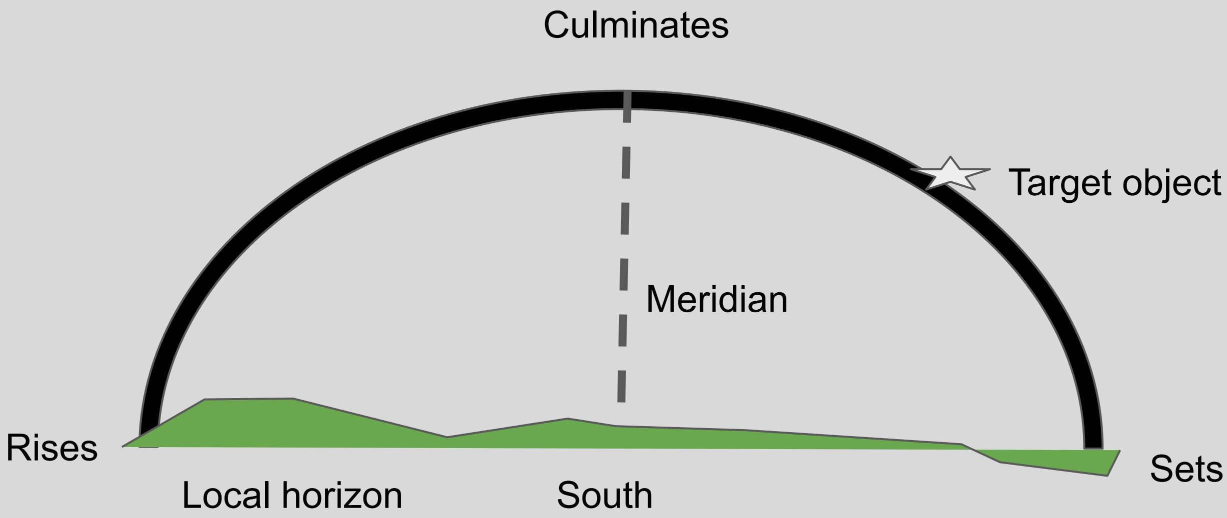
If the path of the circle passes below the observer's horizon, then the objects will have a **rising time** when they come above the horizon and a **setting time** when they go below the horizon.

Estimating where they will be in between these times is pretty straightforward.

Most obviously, they will **culminate** (crossing the observer's **meridian** and reaching their highest **altitude**) half way between the rising and setting times.

Roughly speaking, similar estimations can be made of the position of the target object by calculating the fraction of time that has passed between rising and setting times - just remember that the object will follow a curved arc starting from the rising point, reaching its peak at the mid point and ending at the setting point - see the next slide for a diagram:

Rising, setting and culmination:



Example: If the target object rises at 23:00GMT and sets at 03:00GMT then it will culminate at 01:00 and will be at approximately the point shown at 02:00

And finally:

Meaning of ***culmination*** *in English*

culmination

noun [U]

UK /ˌkʌl.mɪˈneɪ.ʃən/ **US** /ˌkʌl.məˈneɪ.ʃən/

the point at which an event or series of events ends, having developed until it reaches this point:

From: https://dictionary.cambridge.org/dictionary/english/culmination