ROYAL OBSERVATORY GREENWICH

GCSE Astronomy Coursework

B12 Measuring the Sidereal Day

Take long-exposure photographs of the circumpolar stars around Polaris or the south celestial pole and use them to determine the length of the sidereal day.

The true rotational period of the Earth is called the sidereal day and is equal to 23h 56m 4s. This is the time it takes stars to rotate around the north star called Polaris, which can be located by using the Plough. You will need a compact bridge or DSLR camera for this project and you may need to spend some time adjusting the settings to get the best images (see the how-to guides below). You will need a long exposure to get large stellar arcs that can be easily measured however light pollution will swamp the CCD within a 3 minute exposure unless you are in a very dark region – aim for the countryside away from city lights. A series of short exposures can be stacked to produce a long exposure image with image stacking software (see links below). The software also allows the user to select and deselect images to go into the final stacked image, therefore improving clarity of images.

An example of how to calculate the sidereal day:
An image gives star trails that subtend an angle of 5.01° at the pole star (see diagram below). The exposure time was 20 minutes.

If it takes 20 minutes for the star to move through 5.01°, the time it takes to move through 360° is equivalent to the sidereal day:
(360/5.01) x 20 mins = 1437 minutes or 23h 57m.

Longer exposures and stellar trails will allow more accurate measurements of the angle to be obtained and will lead to a smaller error in the final calculation.

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Error analysis
Think carefully about sources of error in your experiment and always use the most accurate values in your calculations (don't round up any numbers till the very end). Repeating the experiment n times enables you to obtain an average of your measurements = sum of measurements/n.
Obtaining an average also reduces uncertainty in your measurements. Any error in a measurement is reduced by a factor of $1/\sqrt{n}$ when the measurement is repeated n times.

To combine the errors in your exposure time, ΔT and measured angle, Δa and find the error in the sidereal period, ΔP use the following formula:

$$\frac{\Delta P}{P} = \sqrt{\left(\frac{\Delta T}{T}\right)^2 + \left(\frac{\Delta a}{a}\right)^2}$$

Where P is the sidereal period and ΔP is its error, T is the exposure time and ΔT is its error and a is the angle with associated error Δa.

For advice on photographing star trails and observing the night sky, go to: **www.rmg.co.uk/discover/astronomy-photographer-competition/how-to-guides/star-trails**

For free downloadable image stacking software go to:
www.startrails.de (PC)
www.astronomie.be/registax/ (PC)
lynkeos.sourceforge.net/ (Mac)

To locate the Plough use **www.stellarium.org** or alternatively download an app for your mobile: **http://downloads.bbc.co.uk/tv/guides/BBC_Stargazing_Live_2012_Mobile_App_guides.pdf**

To find sunrise, sunset, moonrise and moonset times and the phase of the Moon use **www.timeanddate.com**

Check the weather forecast - **www.metoffice.gov.uk**

For examples of reports with moderator comments visit the Edexcel GCSE Astronomy website: **http://www.edexcel.com/quals/gcse/gcse09/astronomy/Pages/default.aspx**

Here you will find two documents that will help you write a report: Under 'Controlled assessment' download 'Controlled Assessment Teacher Support Book' and under 'Teacher Support Materials' download 'GCSE Astronomy Teachers Guide'.

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Below is a checklist of points that you should include in your report. Remember to reference all sources of information and to label all images, diagrams and tables and refer to them in the text e.g. Table 1, Figure 1 etc.

Design (5 marks)

> All equipment listed
> All set-up details of camera listed (aperture size, magnification, field of view, ISO, f-stop, exposure time, focal length/zoom. tripod)
> Practise sessions with equipment planned
> Astronomical terms explained
> Explanation of how to find Polaris using the Plough
> Pointing camera towards Polaris (declination of star = L)
> Rise and set times of the Moon and phase taken into account
> Limits of location noted
> Alternative locations suggested
> Mention of the weather forecast
> Range of dates and times to observe & why (lunar phase, altitude, hour angle of Moon)

Edexcel marking guidelines:

0	**No procedure designed.**
1	**Outline a simple procedure for the observations, using basic astronomical terminology.**
2-3	**Astronomical knowledge and understanding used to decide on the most appropriate site,time, equipment for observations.Spelling, punctuation and grammar used with reasonable accuracy. Limited use of astronomical terminology.**
4-5	**Detailed astronomical knowledge and understanding used to design the most appropriate observing programme with a range of sites, times and instruments evaluated. Spelling, punctuation and grammar used with considerable accuracy. Good range of astronomical terminology used correctly.**

Observation (5 marks)

> Suitable stellar trails imaged with long arcs
> Location stated (latitude & longitude)
> Date and time stated
> Weather
> Seeing

Antoniadi scale
A five-point scale to indicate the quality of seeing:
I – perfect seeing, without a quiver
II – slight undulations, with moments of calm lasting several seconds
III – moderate seeing, with larger tremors
IV – poor seeing, with constant troublesome undulations
V – very bad seeing, scarcely allowing the making of a rough sketch.

> Phase and position of Moon stated
> Camera settings
> Maximum exposure time before saturation due to light pollution
> Imaging software referenced and explained
> All figures labelled and referenced in text

Edexcel marking guidelines:

0	**No observations completed.**
1	**Simple observations completed, providing some data. A few observational details included.**
2-3	**Sound observations completed and recorded, providing adequate data for the task. Clear and accurate observational details included.**
4-5	**Excellent programme of observations completed and recorded, providing conclusive data for the task. Full observational details included clearly and accurately.**

Analysis (5 marks)

> Explanation of software used (stacking, image processing)
> Accurate angles measured from the longest arcs
> Suitable precision of values measured
> Error stated
> Average angle calculated
> Sidereal day calculated correctly with error
> Comparison of calculated sidereal day with actual value

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Edexcel marking guidelines:

0	**No analysis on the observations.**
1	**Simple comments on what is shown by the observations, using basic astronomical terminology.**
2-3	**Conclusions or calculations derived from observational data used to address the task set. Spelling, punctuation and grammar used with reasonable accuracy. Limited use of astronomical terminology.**
4-5	**Full analysis of the observational data, resulting in clear conclusions related to the task set. Spelling, punctuation and grammar used with considerable accuracy. Good range of astronomical terminology used correctly.**

Evaluation (5 marks)

> Quality of photos evaluated
> Accuracy of measurements evaluated and error stated
> Limitations of project explored
> Suggested improvements to project
> Suggested extension to project

Edexcel marking guidelines:

0	**No evaluation of the observation.**
1	**Simple comment on the accuracy of the observations, using basic astronomical terminology.**
2-3	**Supported statement of the accuracy of the observational data obtained. Feasible suggestions for improvements or extensions to the observations. Spelling, punctuation and grammar used with reasonable accuracy. Limited use of astronomical terminology.**
4-5	**Clearly reasoned quantitative assessment of the accuracy of the observational data obtained. Detailed suggestions for improvements or extensions to the observations. Spelling, punctuation and grammar used with considerable accuracy. Good range of astronomical terminology used correctly.**