Q1. Act out in groups how the seasons work on Earth. You may wish to plan your approach first in the box below.

Plan to demonstrate how the seasons work on Earth:

Expected Responses

- We need to have one person to be the Sun, another to be the Earth, and maybe another to be the Moon.
- The Earth orbits the Sun and it also spins on its axis.
- The Earth is tilted slightly (23.5 degrees) so the person will need to tilt a bit to show this.
- The Earth person should spin and walk around the Sun person.
- The Sun person should be spinning too.
- Maybe the Sun person and Earth person could each hold an end of a string and show when the string is held loosely the Earth is tilted towards the Sun (summertime) and when the string is held taut then the Earth is tilted away from the Sun (wintertime).
- We could use "show me" boards or post-its to label each person.

Q2. a) You are a scientist investigating if the Sun could have seasons. Astrophysicists, who study the Sun at DIAS Dunsink Observatory, have gathered the following images of the Sun. In these images, there are regions with black dots visible on the Sun's surface, which are called **Active Regions**. The dots are called **sunspots.** Examine the **Sunspots** on the images and complete the table below.

<u>Images:</u>

Image 1

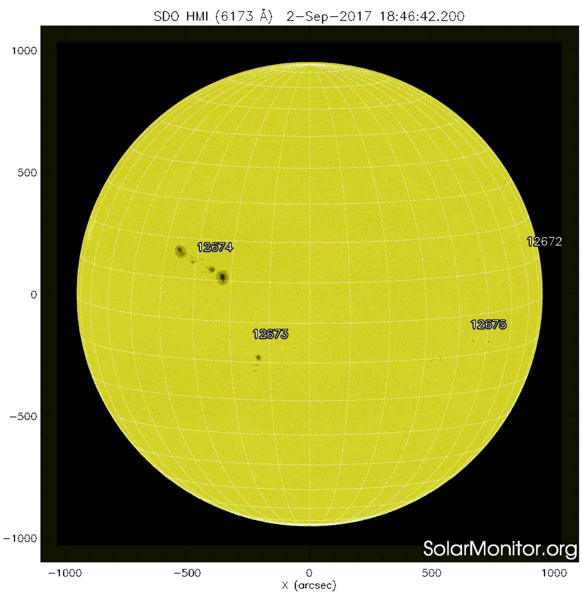


Image 2

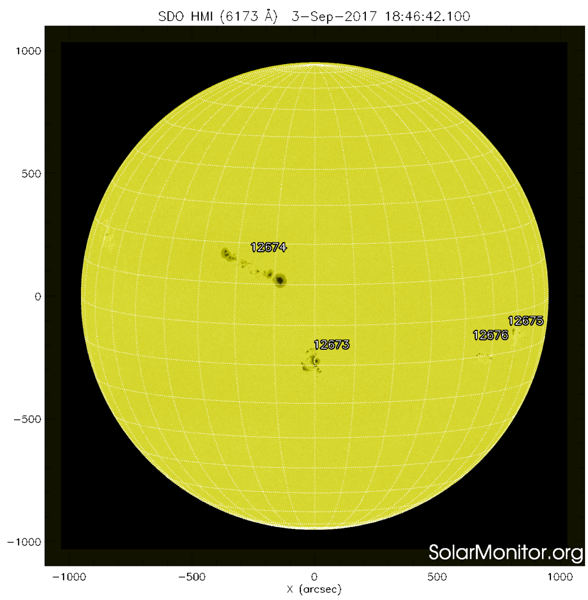
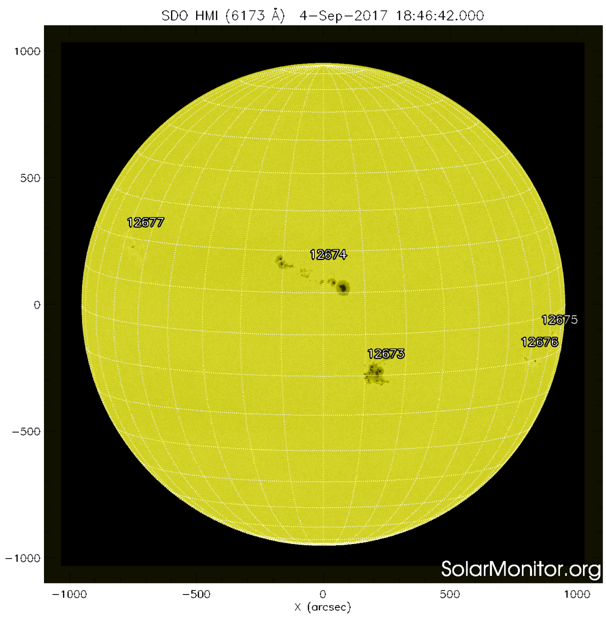


Image 3



Data:

Image number	Number of Sunspots visible
1	24 (approx)
2	28 (approx)
3	30 (approx)

Q2. b) What does part a) tell you about the Sun? How does the data in part a) support or oppose the hypothesis "The Sun could have seasons"? Explain your thinking and include diagrams where appropriate.

Evidence to support or oppose the hypothesis :

The presence of Sunspots can be likened to weather patterns on Earth. The sunspots are appearing to move across the Sun because the Sun is rotating on its axis. The sunspot movement is evidence for the Sun's rotation. The Earth's rotation plays a part in the Earth's seasons, so subsequently if the Sun rotates too that could be an indicator that the Sun has seasons.

Expected Responses

- The data tells me that the sunspots are not constant, they change regularly so sometimes there are more and sometimes there are less.
- The sunspots look like they are moving across the Sun - this tells me that the Sun is spinning the same way the Earth spins on its axis.
- The data supports the hypothesis because it shows how the sun doesn't always look the same, it's a bit like how clouds move on Earth in the atmosphere. So the data and images tell me the Sun has something like weather - maybe if it has weather then it could have seasons too.

Q2. c) Astrophysicists all around the world use a website called solarmonitor.org to look at daily images of the Sun and track sunspots. Click here to examine the images from this week and record how many sunspots are visible in the table below.
Click here for a short video explaining how to use solarmonitor.org.

Date	Number of Sunspots visible
31/05/2021	13
01/06/2021	8

02/06/2021	13
03/06/2021	28
04/06/2021	22

Q3. a) Is there a way to calculate how long it takes the Sun to rotate using the sunspots?

Expected Responses

- You could pick a sunspot (or group of sunspots) and track them to see how long it takes to cross the front of the sun using the solarmonitor.org website.
- You could then double that time because the sunspot would rotate by 360 degrees as the Sun spins on its axis. This would be the time it takes for the Sun to spin around once.

Q3. b) The table below contains more information about one Active Region as seen in the images from Q1. Sunspots are visible in this Active Region. The location of the sunspots is given in the table in latitude and longitude coordinates.

Latitude is the distance of the sunspot North or South from the equator of the Sun.

Longitude is the distance of the sunspot East or West from the meridian line of the Sun.

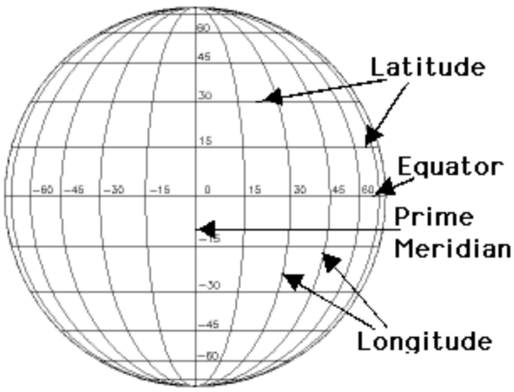
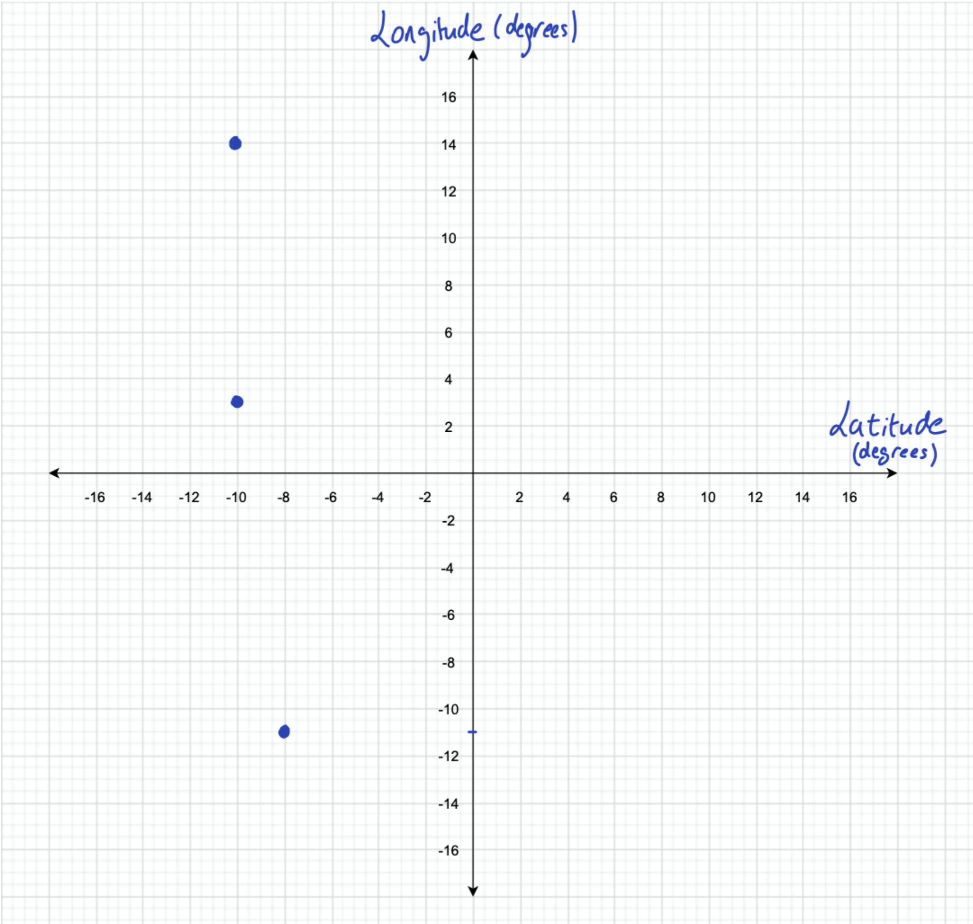


Table A.

Image number	Active Region Number	Image date and time (DD-MM-YYYY hh:mm)	Sunspot latitude (degrees)	Sunspot longitude (degrees)
1	12673	02-09-2017 18:46	-8	-11
2	12673	03-09-2017 18:46	-10	3

3	12673	04-09-2017 18:46	-10	14

Plot the latitude and longitude position of the sunspots from Table A. on the graph below. Remember to label your axes.



Q3. c) What does the plot tell you about the position of the sunspots as time (in days) passes?

Expected Responses:

- The sunspots' longitude is changing while their latitude is staying approximately the same.
- It looks like the sunspots are moving up from the lower hemisphere of the Sun to the upper hemisphere as time passes.
- This tells me that the Sun is rotating because the sunspots are fixed but the graph shows that they are moving. This means the Sun itself must be turning.

Q3. d) Complete Table B below using Table A. An example of the calculations has been done in the first row.

Table B.

Image Pair (image a, image b)	Time difference between images (in days)	Average latitude of sunspot from image a and image b (in degrees)	Longitude of sunspot from image b - Longitude of sunspot from image a (in degrees)
(x,y)	Date y - Date x = **w**	(Latitude x + Latitude y)/2 = **t**	Longitude y - Longitude x = **s**
(1,2)	03-09-2017 - 02-09-2017 = 1 day	(-8 + -10)/2 = -18/2 = -9	3 - (-11) = 14
(2,3)	04-09-2017 - 03-09-2017 = 1 day	(-10 + -10)/2 = -10	14 - 3 = 11

Q3. e) Calculate how many days it takes for the Sun to make a single rotation using the data from Table B.

My calculations:

In general:

s degrees = **w** days

So 1 degree = **w/s = q** days

Therefore 360 degrees = 360 x **q** = **p** days

So it takes **p** days for the Sun to rotate.

Expected Responses

So for image pair (1,2) we have:

14 degrees = **1** days

So 1 degree = **1/14 = 0.071** days

Therefore 360 degrees = 360 x **0.071** days = **25.56** days

So it takes **25.56** days for the Sun to rotate.

AND

for image pair (2,3) we have:

11 degrees = **1** days

So 1 degree = **1/11 = 0.091** days

Therefore 360 degrees = 360 x **0.091** days = **32.76** days

So it takes **32.76** days for the Sun to rotate.

Q3. f) What is the average time for one rotation of the Sun according to your calculations?

Expected Response

25.56 days + **32.76** days = **58.32**/2 = **29.16 days** for one rotation of the Sun.

Q3. g) Astrophysicists estimate that the Sun's rotation takes 27 days. How accurate were your calculations? How could you improve the accuracy of your calculations?

Taking the average value from part f) of 29.16 days that is quite close to the actual value of 27 days. If students want to calculate the % accuracy (% error) then it would be 7.41% (shown below), which can be reduced by looking at more images and taking an average rotation value with more than just two figures.

In general:

(Observed value - Actual Value)/Actual Value x 100 = % accuracy

So using the average value from part f) we have:

(29.16 - 27)/29.16 = 0.074 x 100 = 7.41% (error on our calculations)

Expected Response

- My calculated value is very close to the actual value. It could be improved by looking at more images so then I would have more numbers to include when calculating the average time for one rotation of the Sun.

Q4. Table C. gives details on the time it takes different celestial bodies in our solar system to rotate. Compare the rotation periods of each to the rotation period of the Sun.

Table C.

Celestial Body	Rotation Period (days)
The Sun	27
Mercury	58.8
Venus	244 (rotates in opposite direction to Earth)
Earth	1
The Moon	27.4
Mars	1.03
Jupiter	0.415
Saturn	0.445
Uranus	0.720 (rotates in opposite direction to Earth)
Neptune	0.673
Pluto	6.41

Patterns that I notice in Table C are...

Expected Responses

- The Sun and the Moon have almost identical rotation periods.
- The large gas planets have a shorter rotation period than the smaller rocky planets. This means the larger gas planets spin on their axis faster than the smaller planets.
- Jupiter and Saturn have almost identical rotation periods.
- Mars has the closest rotation period to Earth, just 0.03 days longer than Earth's 1 day rotation period.
- Even though Venus is the nearest planet to Earth it takes much longer than Earth to make one rotation.