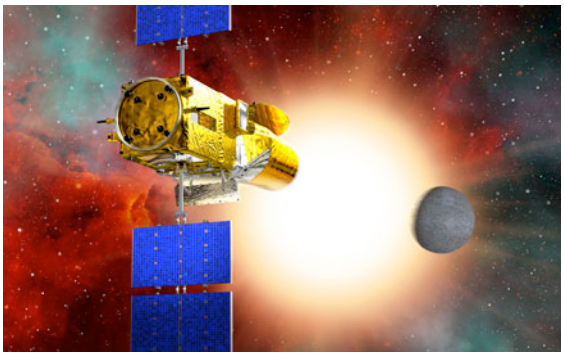
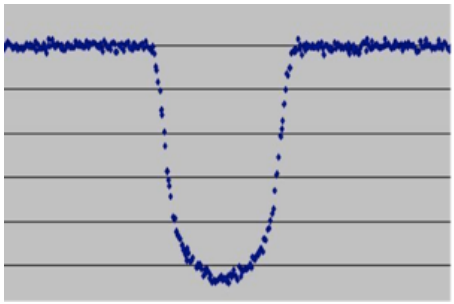
Exoplanets – detection and properties





Researching Physics

Higher

SQA

SSERC

Higher Physics

Researching Physics Exoplanets – detection and properties

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Overview of the unit and activities.

What is involved in the unit 'Researching Physics'?

Studying physics involves learning physics facts and concepts. It also involves developing particular skills. These include research skills, which may involve you in doing investigative experiments or researching information, perhaps from the internet. The aim of this unit is to help you develop these physics skills. You will learn some physics facts, probably in some depth, however it is the development of skills which is the focus of the unit.

What physics content will I be learning?

The context for your work is the detection and properties of extrasolar planets (abbreviated to exoplanets). The discovery of exoplanets in orbit around other stars has opened up a whole new field of study in astrophysics. Hundreds of exoplanets have been discovered and the race is on to discover an Earth-like planet. Who knows, one day we may even get evidence of life existing elsewhere.
The detection of exoplanets relies on studying the light from the stars. The tiny movement of the star caused by an orbiting planet can be measured, or the apparent change in brightness of the star can be measured as the planet crosses the face of the star.

What activities will I be doing?

There are three types of activities in the unit.

Undertaking literature based research is a hugely important skill. In this unit, this is best carried out as web-based research. It is easy to simply look up a single fact on the internet, but undertaking a more structured project is more complex. Sifting through what is often a large amount of data is demanding. Keeping track of what you are trying to find out is one of the most difficult parts of this type of research, and summarising what you have found, without merely cutting and pasting someone else's work is also challenging. There are several research briefs which can be used in preparation for your investigation.

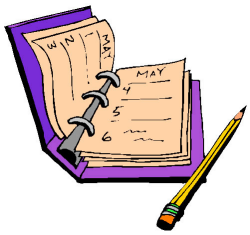
Investigative practical work can be fun and challenging. Planning and designing experiments is often the hardest part of this work. Actually carrying out the experiment may be straightforward. The experiments you are likely to carry out in your investigation are not the kind where you can simply look up the results beforehand. There may be no right or wrong answers. What you find is what you find and your way of doing the experiment may not be similar to others in your class.

Scientific communication is hugely important. It does not matter how interesting or ground breaking your work is; if you cannot communicate your results then you have not completed your work. You should present the results and conclusions of your investigation. You may choose from a number of formats for your presentation.

Organising your work and carrying out the activities

How will I organise my work?

Some of the work you carry out in this unit will be in preparation for your research into one or more aspects of exoplanets. When you carry out the research activities themselves, it is likely that you will be responsible for organising your work.



You are required to produce several pieces of work, including the results of a piece of web-based research, and a scientific communication detailing the results and conclusions of your practical investigation. You are strongly advised not to produce these "as you go along". Rather, it is very good practice to maintain a diary, or record of work. This should record all your experimental results, ideas, problems you met, references and all the other day to day observations and data that you want recorded. The record of work is your record and as such it should be in a format that suits you. However, experience shows that students who organise their work for ease of reference are likely to be able to extract the information more easily and the resulting reports are likely to be easier to produce.

Will I do the same work as everyone else in my class?

This material includes a number of web-based research and practical investigation briefs. It is likely that students within the same class will be allocated different activities, depending on resources available and other classroom management issues.

What about teamwork?

It is probable that you will undertake some of the work as part of a group. Sometimes, within your team, you will be undertaking the same task and other times you will each focus on a different part of the task. In either case, it is important that discussion takes place. Agree the part that each member of the team will play and ensure that there is time to share the results of the work.

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Researching Physics Exoplanets – detection and properties

Assessment issues

What do I have to do to pass this unit?

As you work on this unit, you will carry out activities which develop your skills in undertaking research in physics.
Three of the activities contribute to the unit assessment. To be awarded the unit, you need to demonstrate that your work is of at least the required standard in each of the three types of activity. The three types of activities are:

- Undertaking web based research
- Carrying out investigative practical work - you need to take an active part in planning and carrying out an investigation.
- Preparing a scientific communication

Do I need evidence?

For the web based research and scientific communication, you should ensure that you retain evidence that your work is of the required standard. Each year SQA will ask to see the evidence from a number of candidates. This process is easiest to manage if your evidence is stored in an e-portfolio. You can store text based work, together with pictures, web pages, and any other material which you wish to present as evidence. If you do not use an e-portfolio, you should ensure that your evidence can be easily accessed.

What about assessment in the Higher Physics exam?

The Higher unit - Researching Physics is available as a free standing unit. It is also a required unit for a course award in Higher Physics. There will not be any questions in the Higher Physics course assessment which specifically relate to the topic of this unit. However, there will be questions in the course assessment which relate to the skills that you have developed in the unit. The following are the skills which may be assessed in the course assessment:

- Selecting information from texts, tables, charts, graphs and diagrams,
- Presenting information in a variety of forms,
- Processing information,
- Planning and designing an experiment,
- Evaluating experimental procedures,
- Drawing conclusions and making predictions based on evidence provided.

Research Brief

We've known for centuries that other stars are distant suns, making it natural to suspect that they would have their own planetary systems. As recently as the 1990s, it was generally held that detecting planets in orbit around a star would be too challenging. Yet, in 1995, in a triumph of modern technology, a planet was positively discovered in orbit around a star called 51 Pegasi. Since then, many hundreds of exoplanets have been discovered. Their discovery has had profound philosophical implications. Knowing that exoplanets are common, makes it seem more possible that we might find life elsewhere.

In this initial research activity you will find out some background information about the discovery and properties of exoplanets.

In carrying out your research you should answer the following questions.

- What is an exoplanet?
- Why can't we detect exoplanets by direct observation – even with telescope?
- What are the main ways in which exoplanets can be detected?
- How does the temperature of a planet depend on its orbital distance from a star?
- What is the habitable zone, sometimes called the "Goldilocks zone"?

Answer the questions by carrying out research. It is probable that this is best undertaken using web-based research. You are advised to have completed an activity in which you consider the issues of undertaking web-based research. This may have been done during your work on other units in Higher Physics.

You may work individually or as part of a team.

Produce a report of your findings. This may be hand written, printed or electronic and saved in an e-portfolio.

You should spend approximately 2 hours on this activity.

If you work as part of a team that produces one report, you should include a short statement at the end of the report that indicates which part of the work you were responsible for.

Higher Physics

Exoplanets – detection and properties

Research Activity 1

Detecting exoplanets using the Doppler technique

Research Brief

The Doppler technique is an example of an indirect method of detecting exoplanets. That is, the planet itself is not observed directly. The Doppler technique has been used to detect the majority of exoplanets so far. By measuring shifts in the spectrum as a star wobbles, it is possible to work out what is causing the wobble. Equipment is now sensitive enough to measure changes of speed of a star as small as walking pace.

In carrying out your research you should answer the following questions.

- What is the Doppler Effect and how is it heard with sound?
- What are the characteristics of a spectrum of light from a star?
- How does the movement of an exoplanet in orbit around a star affect the star itself?
- How can the Doppler technique be used to give information about the movement of a star?
- What are the advantages of using the Doppler technique to detect exoplanets?
- What are the disadvantages of using the Doppler technique to detect exoplanets?

Answer the questions by carrying out research. It is probable that this is best undertaken using web-based research. You are advised to have completed an activity in which you consider the issues of undertaking web-based research. This may have been done during your work on other units in Higher Physics.

You may work individually or as part of a team.

Produce a report of your findings. This may be hand written, printed or electronic and saved in an e-portfolio.

You should spend approximately 2 hours on this activity.

If you work as part of a team that produces one report, you should include a short statement at the end of the report that indicates which part of the work you were responsible for.

Higher Physics

Exoplanets – detection and properties

Research Activity 2

Detecting exoplanets by measuring stellar brightness

Research Brief

Measuring the apparent change in brightness of a star is an example of an indirect method of detecting exoplanets. That is, the planet itself is not observed directly. In our solar system, it is occasionally possible to observe the motion of Mercury and Venus as they move in front of the Sun. Using a telescope, these planets can be seen as small dark discs on the surface of the Sun. It is possible for us to detect exoplanets in the same way as they cross in front of the star they are orbiting. However, the exoplanet itself cannot be seen. It is detected by measuring the decrease in brightness as the planet moves across the face of the star.

In carrying out your research you should answer the following questions.

- How can the brightness of a star be measured?
- How does the motion of a planet crossing in front of a star affect the apparent brightness of the star?
- Why is it easier to detect exoplanets that are massive and/or close to the star?
- What information about the properties of the exoplanet can be deduced by measuring the change in apparent brightness of the star?
- What are the advantages of detecting exoplanets by measuring the apparent decrease in brightness as the planet crosses in front of the star?
- What are the disadvantages of detecting exoplanets by measuring the apparent decrease in brightness as the planet crosses in front of the star?

Answer the questions by carrying out research. It is probable that this is best undertaken using web-based research. You are advised to have completed an activity in which you consider the issues of undertaking web-based research. This may have been done during your work on other units in Higher Physics.

You may work individually or as part of a team.

Produce a report of your findings. This may be hand written, printed or electronic and saved in an e-portfolio.

Higher Physics

Exoplanets – detection and properties

Practical Activity 1

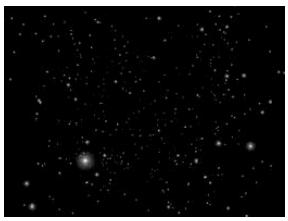
Wobbling stars

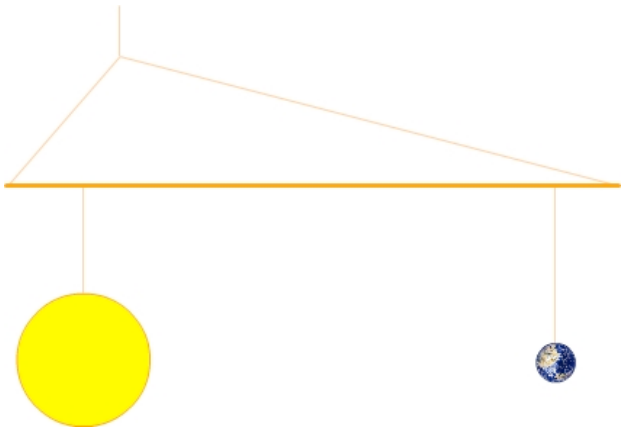
Investigation Brief

A planet remains in orbit around a star due to the gravitational pull of the star. However, a planet in orbit also has a gravitational effect on the star and the result is that the star and planet actually orbit a point somewhere between them. We cannot directly observe planets in orbit around other stars but we can deduce their existence by measuring the slight wobble of the star caused by the planet's gravitational pull. The wobble can be measured by examining the spectrum and measuring the Doppler shift in spectral lines.

The aim of this investigation is to relate the point about which a star and planet orbit with the masses of the star and planet.

Discuss how you will carry out the investigation.
Write your plan in your record of work.
You should also include an hypothesis in your record of work. What do you think is the relationship between the masses of the star and planet and the point about which they both orbit?





Investigation Notes

You will need to design and build a model of a star and orbiting planet. The masses and their distance apart should be varied. The model should allow the position about which the star and planet orbit to be found.
Questions for consideration:
How will you suspend the model to allow the distance between the star and planet to be varied?
How will you measure the mass of the star and planet?
How much bigger than the planet will you make the star?
How will you find the point around which the star wobbles?
What will you do to control all the other variables in the investigation?
How will you present your findings?
How will you find the relationship between the masses and the point about which the system rotates?

Higher Physics

Exoplanets – detection and properties

Practical Activity 2

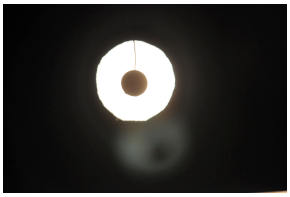
Stellar brightness and the radius of an exoplanet

Investigation Brief

The brightness of a star can be measured using light sensitive devices. Because stars are very distant, they may appear to be less bright than then really are. Astronomers refer to the apparent brightness of the star.
Astronomers have discovered that many stars have planets in orbit around them. If the planet's orbit is such that the planet passes in front of the star (this is called a transit), some of the light from the star will be blocked and the measurement of the apparent brightness will decrease. In this investigation you will find how the apparent brightness of a star depends on the size of the planet blocking the light from the star.

The aim of this investigation is to use a model star and planets to find the relationship between the decrease in measured brightness and the radius of a planet placed in front of the star.

Discuss how you will carry out the investigation.
Write your plan in your record of work.
You should also include an hypothesis in your record of work. What do you predict will happen to the apparent brightness of a star as an exoplanet transits across the face of the star?



Investigation Notes

A lightmeter can be used to measure the brightness of a light source.
(Lightmeter apps are available for certain phones.)
You will need to design and build a model star and planets of different sizes and devise a way for positioning the planets in front of the star.
The star should be bigger than the planets and may be represented by a light source. You will need to consider what kind of light source is most suitable.

As the planet is in position and blocking some of the light from the star, you should measure the apparent brightness of the star.
Questions for consideration:
How far will you position the planet from the star?
How many different size planets will you use?
How many times will you measure the brightness for each planet?
What will you do to control all the other variables in the investigation?
How will you present your findings?
Is there a minimum size planet that can be detected using your equipment?

Higher Physics

Exoplanets – detection and properties

Practical Activity 3

Stellar brightness and the transit of an exoplanet

Investigation Brief

The brightness of a star can be measured using light sensitive devices. Because stars are very distant, they may appear to be less bright than then really are. Astronomers refer to the apparent brightness of the star.
Astronomers have discovered that many stars have planets in orbit around them. If the planet's orbit is such that the planet passes in front of the star (this is called a transit), some of the light from the star will be blocked and the measurement of the apparent brightness will decrease. In this investigation you will simulate the transit of an exoplanet, measure the decrease in brightness of a model star, and consider what can be deduced about the planet from the data.

The aim of this investigation is to use a model star and planet to investigate how the apparent brightness of a star changes as an exoplanet transits in front of the star.

Discuss how you will carry out the investigation.
Write your plan in your record of work.
You should also include an hypothesis in your record of work.
What do you predict will happen to the apparent brightness of a star as an exoplanet transits across the face of the star?

Investigation Notes

A lightmeter can be used to measure the brightness of a light source. (Lightmeter apps are available for certain phones.)
You will need to design and build a model star and planet and devise a way for positioning the planet as it transits in front of the star.
The star should be bigger than the planet and may be represented by a light source. You will need to consider what kind of light source is most suitable. By measuring the time it takes for the planet to transit, and comparing this with the time between transits, it is possible to deduce the radius of orbit of the planet.

As the planet transits the face of the star, you should measure the apparent brightness of the star.
Questions for consideration:
How far will you position the planet from the star?
How will you set up the planet in orbit around the star?
How will you measure the brightness of the star during the transits?
What will you do to control all the other variables in the investigation?
How will you present your findings?
How will you deduce the orbital radius from the data?

Higher Physics

Exoplanets – detection and properties

Practical Activity 4

The habitable zone and orbital radius (The “Goldilocks Zone”)

Investigation Brief

The search for exoplanets leads to the possibility of finding evidence for the existence of life on a planet orbiting another star. Life as we know it requires certain conditions, including the presence of liquid water. Water in liquid form can only exist between certain temperatures and only exoplanets within certain limits of temperature may have liquid water. If the planet is too close to the star it will be to hot, and if it is too far, it will be too cold. A planet that has liquid water will be in a so called “Goldilocks zone”.

The aim of this investigation is to investigate how the temperature of a planet depends on the orbital distance from a star.

Discuss how you will carry out the investigation.
Write your plan in your record of work.
You should also include an hypothesis in your record of work. What do you predict will happen to the temperature of a planet at say double the distance from the star?

Investigation Notes

Hot objects radiate heat energy and if another object is placed near to the hot object, it will absorb energy and its temperature will increase. The temperature will not keep increasing because the object itself radiates energy. Eventually, the radiation being absorbed by the object receiving the radiation is balanced by the radiation being emitted. At this point the temperature remains constant. This is what happens to a planet in orbit around a star.
You will need to choose a radiant heat source to represent the star and a material to represent a planet. You will need to devise a way of measuring the temperature of the planet.

The distance of the planet to the star should be varied and the temperature measured in each case.
Questions for consideration:
How close and how far away will you move the planet?
What precautions will you take to ensure the planet does not overheat (melt!)?
How many different distances from the star will you measure?
How will you know when the temperature of the planet has reached it’s maximum in each position?
What will you do to control all the other variables in the investigation?
How will you present your findings?
How will you find the relationship between the temperature and the distance?