Aviation – aerodynamics and instrumentation

Researching Physics

Higher

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Higher Physics

Researching Physics Aviation – aerodynamics and instrumentation

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 modern aviation.
Our ever-shrinking world demands better and more efficient transport links. Aircraft need to be more efficient, using as little fuel as possible and navigation should use modern technology, whilst having non-electronic devices as a back-up.
A lot of research has being undertaken to develop efficient wings and engines that are clean, reliable and efficient.
Wings that are made of composite material can be lighter and thinner.
Most long distance travel is in jets. However, for shorter distances, propeller driven aircraft are more efficient. Navigation is almost entirely done with GPS although traditional methods are still available as a back-up. There is a magnetic compass in even the most modern airliner.

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.
Information from your web research and data from your practical work will contribute to an assignment that you will complete under supervised conditions. This assignment is assessed externally by the SQA. You can pass this unit without completing the assignment, but you cannot get an overall course award in Higher Physics without doing so.

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 aviation. 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 a report on the results of a piece of web-based research, and you may produce a report of your practical investigation that you may submit as your assignment for SQA assessment. 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.

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.
Two 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 two types of activity.
The two 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.

Do I need evidence?

For the web based research, 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.

Higher Physics

Aviation – aerodynamics and instrumentation

Initial Research Activity

Wings, propulsion and navigation

Research Brief

Our ever-shrinking world demands better and more efficient transport links. Aircraft need to be more efficient, using as little fuel as possible and navigation should use modern technology, whilst having non-electronic devices as a back-up.
A lot of research has being undertaken to develop efficient wings and engines that are clean, reliable and efficient.
Wings that are made of composite material can be lighter and thinner. Most long distance travel is in jets. However, for shorter distances, propeller driven aircraft are more efficient.
Navigation is almost entirely done with GPS although traditional methods are still available as a back-up. There is a magnetic compass in even the most modern airliner.

In this initial research activity you will find out some background information about how aircraft fly and how they navigate.

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

- How do wings generate lift?
- What are the forces acting on an aircraft when it has a constant velocity?
- What recent developments have been introduced in order to improve the efficiency of aircraft?
- Aircraft engines can be jet engines or they can drive a propeller. When is it more efficient to use each kind?
- Magnetic and gyroscopic compasses are often used as basic navigation instruments. What are the advantages and disadvantages of these instruments?

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.

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

Aviation – aerodynamics

Research Activity 1

Aerodynamics – how do wings work?

Research Brief

One way or another, aircraft need to generate an upward force in order to stay airborne. This upward force is called lift. Lift can be generated with a fixed wing that moves through the air, a rotary wing (helicopter), or by using a lighter than air gas (airship).
Early aircraft designers built wings that looked like birds' wings. They worked, but aeronautical engineers have since designed much more efficient wings.
The challenge for designers is that wings don't just produce lift. As the wing moves through the air, there are frictional forces that tend to oppose its motion. These resistive forces are called drag. An efficient wing is one that produces large lift forces with little drag.

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

- How is lift generated by a wing moving through air? The most simple explanations can be based on Newton's Laws.
- What is the relationship between the speed of the wing and the lift generated?
- Is it possible to use a flat sheet of material as a wing? What is the best shape for a wing?
- What shape of wing produces least drag?
- A propeller blade is similar to a wing. How does it generate the forward thrust to move the aircraft?
- What are modern aircraft wings made of?

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.

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Higher Physics

Aviation – instrumentation

Research Activity 2

Instrumentation – how do aircraft navigate?

Research Brief

Aircraft often fly in or above the cloud where the pilot cannot navigate by observing ground features. Obviously, the aircraft needs to be fitted with instruments that allow the pilot to continue to navigate accurately.
Modern radio aids and GPS (Global Positioning System) can constantly update the position of an aircraft. However, aircraft require instruments that inform the pilot of the direction the aircraft is travelling in. Most aircraft use a gyroscopic (gyro) compass to do this although aviation law specifies that all aircraft must also be fitted with a magnetic compass.

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

- How does a gyro compass work?
- A magnetic compass aligns with the Earth's magnetic field. Why does the magnetic compass work less well in certain parts of the Earth?
- How is the needle of a magnetic compass pivoted to compensate for magnetic dip?
- Why is it a requirement for all aircraft to be fitted with a magnetic compass?
- GPS can be used to determine the position of an aircraft at all times. What other systems are commonly used to determine position?
- The speed of aircraft is measured in knots. What is the origin of this unit of speed and why is it still in use in aircraft navigation?

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.

If you work as part of a team which 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

Aviation – aerodynamics

Practical Activity 1

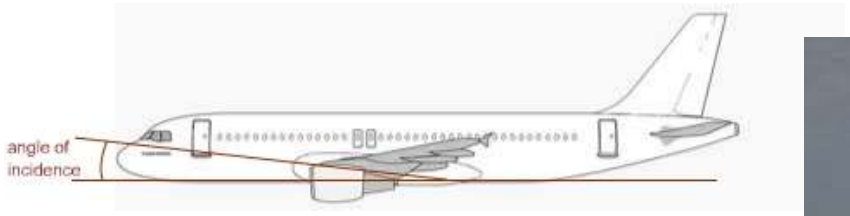
Efficiency of wings and angle of incidence

Investigation Brief

The wings of an aircraft are joined to the main body (fuselage) at an angle to the airflow. This angle is called the angle of incidence. As the wing moves through the air, some of the air is deflected downwards (action). This downwards deflection applies an equal and opposite force (reaction) upwards. This is the lift.
As the wing moves through the air, there is friction. This is drag.
An efficient wing is one that produces high lift and low drag. The efficiency can be measured by the ratio of lift to drag.
When an aircraft glides (no engines), it still flies though the air but descends at a certain glide angle. The glide angle is least – that is the aircraft flies further horizontally – when the wing is most efficient. It is possible to determine the efficiency of a wing by measuring the horizontal distance travelled during a glide.

The aim of this investigation is find how the angle of incidence affects the efficiency of a wing.

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 angle of incidence and the efficiency of the wing?



Investigation Notes

You will need to use a model glider which has a wing that can be set at different angles of incidence. A very simple model can be built using balsa wood and super glue.
Questions for consideration:
What range of angles of incidence should you use?
How will you ensure the model is launched with the same speed each time?
How will you measure the glide distance and the angle of incidence?
It is important that your model aircraft has the centre of gravity in the correct place. This should be about one third of the width of the wing back from the front of the wing.
There are other methods of measuring the lift and drag which you may prefer to use in your investigation.
What will you do to control all the other variables in the investigation?
How will you present your findings?
What conclusions can you draw based on your results?

Higher Physics

Aviation – aerodynamics

Practical Activity 2

Efficiency of wings and aspect ratio

Investigation Brief

Some aircraft have long and thin wings. Some have short and wide wings. In each case, the wings provide lift. This is the upward force that keeps the aircraft flying.
As the wing moves through the air, there is friction. This is drag.
An efficient wing is one that produces high lift and low drag. The efficiency can be measured by the ratio of lift to drag.
When an aircraft glides (no engines), it still flies though the air but descends at a certain glide angle. The glide angle is least – that is the aircraft flies further horizontally – when the wing is most efficient. It is possible to determine the efficiency of a wing by measuring the horizontal distance travelled during a glide.
The ratio of the length (span) to the width (chord) is called the aspect ratio.

The aim of this investigation is find how the aspect ratio affects the efficiency of a wing.

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 angle of incidence and the efficiency of the wing?

Investigation Notes

You will need to use a model glider which has a number of different wings that can be fitted. The wings should have different aspect ratios. A very simple model can be built using balsa wood and super glue.
Questions for consideration:
What range of aspect ratios should you use?
How will you ensure the model is launched with the same speed each time?
How will you measure the glide distance?
It is important that your model aircraft has the centre of gravity in the correct place. This should be about one third of the width of the wing back from the front of the wing.
There are other methods of measuring the lift and drag which you may prefer to use in your investigation.
What will you do to control all the other variables in the investigation?
What can you do to reduce the uncertainties in your measurements?
How will you present your findings?
What conclusions can you draw based on your results?
What are the engineering problems associated with building long and thin wings?

Higher Physics

Aviation – aerodynamics

Practical Activity 3

Rotation of propellers and thrust

Investigation Brief

In order to remain flying, a force is required to move an aircraft wing through the air. For aircraft that fly very high, a jet engine is the best solution. For short and medium length journeys, a propeller is the most efficient way of providing the force. The forward force is called the thrust. A propeller is a similar to a wing. The engine makes it rotate and the movement of the propeller blade pushes air backwards. This is the action. The reaction (Newton's 3rd Law) pushes the propeller forward. The propeller is attached to the aircraft so the aircraft moves forward. Propellers can be very complicated. They can have multiple blades that can have their pitch varied. (Pitch is the angle the blade makes with the air.). However, a simple, fixed pitch two bladed propeller is often fitted to light aircraft. Increasing the throttle (power lever) increases the rate of rotation of the propeller. The thrust can be changed by changing the throttle setting.

The aim of this investigation is to investigate how the thrust produced by a rotating propeller depends on rate at which the propeller rotates.

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 thrust as the rate of rotation increases?

Investigation Notes

You will need a small plastic propeller fitted to an electric motor. You will need to vary the rate of rotation of the propeller.
Questions for consideration:
How will you vary the rate of rotation of the propeller?
How will you measure the rate of rotation of the propeller? (Hint: a strobe lamp can be used so that the motion of a rotating object appears to be stationary.)
How will you measure the thrust produced by the propeller?
What will you do to control all the other variables in the investigation?
What can you do to reduce the uncertainties in your measurements?
How will you present your findings?
What conclusions can you draw based on your results?
What is the mathematical relationship between the rate of rotation of the propeller and the thrust?

Higher Physics

Aviation – instrumentation

Practical Activity 4

Acceleration and compass error

Investigation Brief

All aircraft must carry a magnetic compass which is used as a standby in case other navigation aids fail. The red arrow in the picture below points to the standby compass in a Boeing 757.
The magnetic compass aligns itself with the Earth's magnetic field. In order to compensate for the dip in the Earth's magnetic field, the needle in the compass is not pivoted at the centre of gravity. In normal flight, this is not a problem. However, all pilots are taught to recognise that the standby compass produces errors when the aircraft accelerates. The compass error results in the needle of the compass swinging to the right or left. It is possible to investigate this error in a laboratory using a standard compass and a vehicle to mount it on. The vehicle can then be accelerated.

The aim of this investigation is to use a magnetic compass mounted on a vehicle to investigate how error in the compass depends on the direction (N, NE etc.) in which the compass is accelerated.

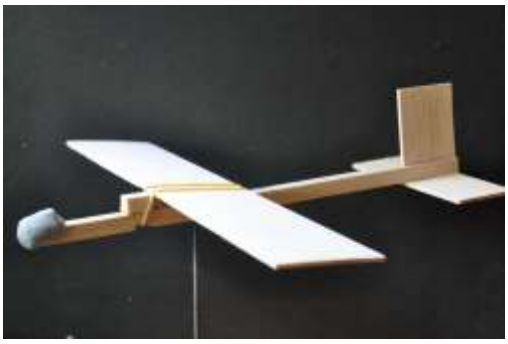
Discuss how you will carry out the investigation.
Write your plan in your record of work.
You should also include an hypothesis in your record of work.
What do you predict will happen to the compass error as the direction of acceleration changes?

Investigation Notes

You will need to set up a vehicle to accelerate at a constant rate. The magnetic compass should be mounted on the vehicle so that it remains horizontal.
A suitable light source will be required.
Questions for consideration:
How will you arrange for the vehicle to accelerate at a constant rate?
How will you measure the compass error (the swing of the compass needle)? Hint: video.
You should accelerate the compass in directions including north, east, west and south and points of the compass in between. How many directions are required?
Magnetic compasses are affected by nearby metal. What will you do to eliminate effects of nearby metal?
What will you do to control all the other variables in the investigation?
What can you do to reduce the uncertainties in your measurements?
How will you present your findings?
What conclusions can you draw based on your results?

Aerodynamics and model gliders

It is recommended that students make (or re-use) simple balsa gliders for the aerodynamics investigations. Polystyrene or other craft materials can be used. However, the simple balsa models illustrated have been shown to be effective.
Suitable balsa wood can be obtained for a few pounds from a model shop or ordered online. It is quite important that the sheet balsa used for the wings is free from warps and twists. The models illustrated were constructed from 2.5 mm sheet and 1 cm square strip. The tailplane was glued in place using superglue. A Stanley knife, steel rule and cutting mat were used to cut the balsa to length. The wing is held in place with an elastic band.



Model 1

Note that the flying surfaces are simple flat sheets. Although “wing shaped” wings produce more lift, simple flat surfaces are sufficient for the investigations.
The size and shape of the model is not critical. A general rule is that if it looks to have the approximate dimensions of an aircraft then it will probable fly reasonably well. However, one critical part of the design of the model is the position of the centre of gravity. This should be approximately one third of the width of the wing back from the front of the wing. Model 1 shows the model being balanced (on a needle file) at the CofG. The model will need to be weighted at the nose to get the CofG in the correct place. Anything can be used for this purpose. A screw and blu-tak were used in model 1.

Investigation 1 requires students to vary the angle of incidence of the wing. Diagram 2 shows a method for achieving this. The wedge shape is removable and can be replaced with wedges of different angles. The small wooden block in front of the wedge is glued to the fuselage and is simply used as a reference position so that the wing is in the same place each flight.
Suitable wedges might allow angles of incidence in the range 2 degrees up to 15 degrees to be investigated. Each time a wedge is fitted, it is quite important to ensure that the wing fits squarely on the fuselage. If the wing does not sit parallel to the tailplane, the model may not fly in a straight line.

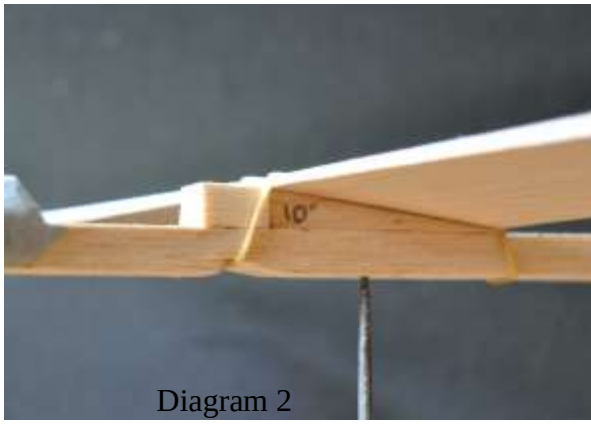


Diagram 2

Aerodynamics and model gliders (continued)

The model should be launched so that it has the same speed each flight. There are a number of ways of achieving this. A simple elastic band launcher is illustrated in diagram 3. A small notch can be cut in front of the CofG position to hold the elastic band during the launch.
The best launch angle can be found by trial and error. However, it is probable that an angle pointing slightly down works best. Essentially, the glide speed and angle should be established as early as possible in the flight. High speed upward launches produce complicated flight paths and should be avoided.

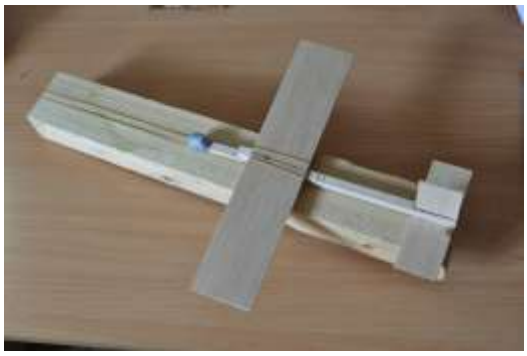


Diagram 3

The models can glide many metres and it is possible that a suitable outdoor area will be required. Launching from a first floor window onto a grass area works well.

Investigation 2 requires students to vary the aspect ratio of the wing. Diagram 4 shows a model with a wing that has as high aspect ratio. Once again, the position of the CofG is important (to keep it a fair test) and the wings should be kept as horizontal as possible.
Of course, the total surface area should be the same for each wing and the angle of incidence should remain constant (about 6 degrees works well).

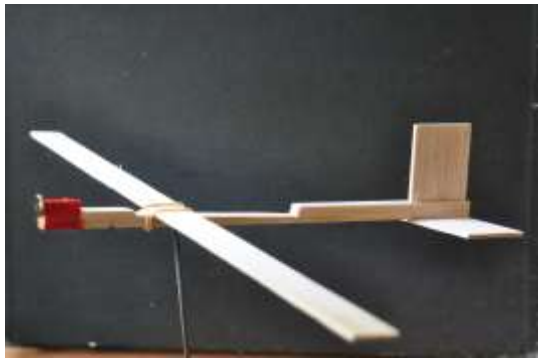


Diagram 4

Rotation of propellers and thrust

The rate of rotation of the propeller can be determined using a flashing strobe.
One solution to measuring thrust is to use a top-pan balance. The motor and propeller can be positioned on the balance and then set rotating, the difference in mass indicating the thrust. Care needs to be taken to avoid the system being affected by the propwash. In other words, the balance measures the air being pushed down on its pan by the propeller rather than, as intended, the reduction in the mass reading caused by the upward force on the propeller and motor. One way to reduce this is to introduce some distance between the propeller and balance pan.
Plotting a graph of thrust against propeller rpm produces an interesting graph. With some thought, or just by trail and error, students should be able to deduce the relationship between thrust and rpm.

Acceleration and compass error

Compass error due to acceleration can be observed in most magnetic compasses found in a physics lab. Even small plotting compasses demonstrate the effect. A quick test of whether a compass can be used is to accelerate it by hand in an east/west direction. A deflection left or right should be observed.
An orienteering type compass works well and has the advantage of being larger than a plotting compass and has a fairly easily readable scale.
The simplest way of accelerating the compass is to mount it on a trolley which is then allowed to run down a slope. The compass needs to remain horizontal.
If the trolley is filmed from above, the video can be analysed in order to record the deflection. Be aware that some cameras and smartphones will affect the compass direction due to their metallic content or magnets contained in their speakers. Do not place them too close to the compass.
The most critical part of the investigation design is to avoid metallic objects affecting the compass. This includes the trolley and any video equipment used to record the movement of the compass needle. A plastic toy car or train with plastic wheels is ideal for the vehicle. Best results might be obtained by carrying out the experiment outside.
An alternative investigation is to investigate the relationship between the magnitude of the compass error and the acceleration of the compass.