Vehicle technology – energy and efficiency

Researching Physics

Higher

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Higher Physics

Researching Physics Vehicle Technology – energy and efficiency

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 technology used in modern motor vehicles to make them as fuel-efficient as possible and to cut down emissions of carbon dioxide gas.

In this unit, you will study hybrid, pure electric and fuel cell cars. You might carry out investigations on the ways they recover energy that might otherwise be wasted as heat or you could experiment on their efficiency or factors that affect the electrical power they require.

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 one or more aspects of vehicle technology. 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 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.

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

Vehicle Technology – energy and efficiency

Initial Research Activity

Modern developments in vehicle technology

Research Brief

Modern vehicles are very efficient compared to older vehicles. There have been many technological advances that have contributed to this improvement in efficiency. Petrol and diesel engines burn less fuel per mile and some vehicles are fitted with electric motors. A hybrid vehicle has both a petrol engine and an electric motor. Some vehicles have only an electric motor and many transfer kinetic energy into electricity during braking.
Modern vehicles also produce much less pollution.

In this initial research activity you will find out some background information about the technology used in modern vehicles.

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

- How does the published fuel economy data for new cars compare with similar older models?
- How does the published CO_2 emission data for new cars compare with similar older models?
- What is regenerative braking?
- What are the main differences between hybrid vehicles and pure electric vehicles?
- What alternative fuels are being developed to replace petrol and diesel?

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

Vehicle Technology – energy and efficiency

Research Activity 1

Regenerative braking

Research Brief

Conventional vehicle brakes transfer kinetic energy into heat by friction in the brake linings. This is wasted energy.
A regenerative brake is a mechanism that recovers kinetic energy of a moving vehicle as it slows down. The energy can be stored until need later.
The most common regenerative braking system uses an electric motor as an electric generator. The energy is stored in a battery or sometimes in a flywheel. It is also possible to store the energy in the form of compressed air.

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

- How is an electric motor used in regenerative braking?
- What speeds does regenerative braking work best at?
- Approximately what fuel savings can be made by using regenerative braking?
- How does regenerative braking store energy in petrol and diesel vehicles?
- What is the earliest example of regenerative braking being used in vehicles?
- What is a KERS flywheel as used in racing cars?

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.

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Higher Physics

Vehicle Technology – energy and efficiency

Research Activity 2

Electric vehicles

Research Brief

Vehicle manufacturers are investing in the development of electric vehicles (EVs). They are doing this because fossil fuels (petrol and diesel) are becoming more expensive and also governments are encouraging the use of engines that produce less pollution. Electric motors are very clean in that they produce no pollution when they power a vehicle.
One limiting factor in the use of electric motors is the battery required to power the motor. It needs to be charged up before use and the range of the vehicle is determined by the charge that can be stored. As well as providing the energy to drive the vehicle, the battery needs to power the lights, heating and air conditioning. The range of the vehicle is reduced when these are used. An electric vehicle that has only an electric motor will stop when the battery runs down. Some vehicles have a back up petrol engine that can be used when the battery is flat.

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

- What kinds of batteries are used in electric vehicles?
- What are the advantages and disadvantages of electric vehicles compared to petrol and diesel powered vehicles?
- A hybrid vehicle has a petrol engine as well as the electric motor. What different methods are used to combine the power available from the two?
- What is the relationship between the outside temperature and the range of an electric vehicle?
- By how much is the range of an electric vehicle affected by using the heater or lights or air conditioning?
- What is the efficiency of an electric motor compared to petrol and diesel engines?

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

Vehicle Technology – energy and efficiency

Research Activity 3

Hydrogen fuel cells

Research Brief

It is possible to use hydrogen as a fuel to power vehicles. This can be done by simply using it instead of petrol or diesel.
An alternative is to use a fuel cell in which hydrogen and oxygen are combined, a reaction that produces water. When the two gases are combined in the fuel cell, a potential difference (p.d.) is produced across two electrodes. This p.d. can be used to power an electric motor.
There are a number of advantages of using a hydrogen fuel cell.
One is that the fuel cell is “zero emission”. It does not produce pollution.
If we could efficiently extract hydrogen from water, then we would have a limitless supply of fuel.

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

- How is a hydrogen fuel cell constructed?
- What methods are available for producing hydrogen?
- What are the costs associated with producing hydrogen?
- What dangers and disadvantages are associated with hydrogen powered vehicles?

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

Vehicle Technology – energy and efficiency

Practical Activity 1

Energy from a rotating flywheel

Investigation Brief

It takes energy to accelerate a vehicle up to speed. Having reached a steady speed, the vehicle may then be slowed down by braking. Braking transfers the kinetic energy into heat in the brake pads. This is wasted energy.
Instead of transferring the energy to heat, modern vehicles can convert some of the kinetic energy into electrical energy, which can be stored in a battery. This is called regenerative braking. In electric powered vehicles the energy stored in the battery can later be used to accelerate the vehicle. In petrol and diesel vehicles, the energy stored in the battery can power lights and other things requiring an electrical supply.
The energy stored in a rotating disc (a wheel) can be "reclaimed" using regenerative technology. An electric motor can be used as a generator if a flywheel is connected to it. When the electric motor is driven from a battery, the flywheel is made to rotate. When the battery is switched off, the flywheel continues to rotate, although it will slow down and eventually stop. As it slows down, it causes the motor to produce a current, which is stored in the battery.

The aim of this investigation is to find the relationship between the rate of rotation of a flywheel and the electrical energy that can be reclaimed as it slows down.

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 rate of rotation of the flywheel and the energy that can be reclaimed?

Investigation Notes

Your will need to set up equipment that can drive a flywheel with an electric motor at different rates. Once the flywheel is rotating at a steady rate, the motor should be quickly disconnected from the supply so that the flywheel drives the motor, generating an electrical current.
Questions for consideration:
When the motor is being driven by the flywheel, there should be an electrical load for the current produced. What will you use as the load?
How will you quickly disconnect the supply from the motor and change the circuit so that the current produced by the motor goes through the load? (Hint: DPDT switch – Google it!)
How will you measure the rate of rotation of the flywheel? (Revolutions per minute –rpm)
How will you measure the energy that is reclaimed from the flywheel?
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 rate of rotation of the flywheel and the energy that can be reclaimed?

Higher Physics

Vehicle Technology – energy and efficiency

Practical Activity 2

Power and speed

Investigation Brief

As society demands that vehicles become cleaner and more efficient, vehicle manufacturers are developing more and more electric vehicles (EVs). Some EVs have only a large battery and electric motor. Others have both a petrol engine and an electric motor. These are called hybrids.
EVs have many advantages over petrol or diesel powered vehicles. However, they do have one major disadvantage. Their range is limited (unless a back up petrol engine is available). The maximum range of an EV can only be achieved when the vehicle is driven very economically. If it is driven fast, the range is likely to be reduced considerably. The faster the vehicle is driven, the more power is required from the battery.

The aim of this is investigation is to find the relationship between the speed of a model vehicle and the power required.

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 power required as the speed of the vehicle is increased?

Investigation Notes

Your will need to obtain or build a model vehicle that can be driven by an electric motor. To enable the speed of the vehicle to be changed you might consider driving it from an external power supply, using cables to make a remote connection.
Questions for consideration:
How will you change the speed of the vehicle?
How will you measure the speed of the vehicle?
How will you measure the power supplied to the vehicle? (An external power supply makes it easier to connect electrical meters.)
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 speed of the vehicle and the power supplied?
Note: It is obvious that the higher the speed of the vehicle, the more power is required. However, what is possibly not so obvious is the actual mathematical relationship. Be prepared to try a few different relationships. Using a spreadsheet such as Excel is a good way of quickly trying different functions.

Higher Physics

Vehicle Technology – energy and efficiency

Practical Activity 3

Efficiency of a hydrogen fuel cell

Investigation Brief

Some vehicles are fitted with hydrogen fuel cells.
A hydrogen fuel cell combines hydrogen with oxygen in an exchange membrane. This produces a potential difference across two electrodes. If an electric motor is connected to the electrodes, a current will flow, driving the motor and vehicle.
When the hydrogen and oxygen combine, water is produced. This is the waste product from a hydrogen fuel cell which of course is entirely harmless.
The hydrogen used in the fuel cell needs to be generated in some way. This can be by electrolysis in a generator. The oxygen can simply be the oxygen in the air.
Model cars are available that are powered by a hydrogen fuel cell.

The aim of this is investigation is to find the efficiency of a hydrogen fuel cell powered model car.

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 the efficiency of the car is likely to be?

Investigation Notes

You should measure the input power of the hydrogen generator.
You should also measure the power output of the car.
Questions for consideration:
The power required to produce the hydrogen is supplied by two AA cells. How will you determine this input power?
How will you determine the power output of the model car?
What will you do to ensure your results are reliable?
What will you do to control all the other variables in the investigation?
How will you reduce the uncertainly in your measurements?
How will you determine the efficiency of the fuel cell powered car?

Energy from a rotating flywheel

Any flywheel and driving electric motor can be used. Rotating turntables as used in AH Physics can be used. However, these tend to be belt driven and rotate quite slowly.
The SEP flywheel SEP 073 has been used successfully. However, care needs to be take with the plastic flywheel which has been found to vibrate at certain rpm.
The best way to manage the switching circuitry is using a double pole, double throw switch so that with one flick of the switch the driving current can be switched off and the motor operated as a generator.
The generator should dump current into a load and a 1 k resistor has been found to be suitable.
There are a number of ways of determining the energy recovered from the flywheel. A joulemeter is probably the best way and the SEP 043 energy meter works well.
There are a number of ways of measuring the rpm of the flywheel. A strobe lamp works well.
Students are likely to be able to produce results showing that the energy that can be recovered depends on the square of the rpm. Teachers might like to use this as a hint of what is to come in Advanced Higher (rotational Ek).

Power and speed

A model car powered by an electric motor will be required – the simpler the better. A meccano construction has worked well. The voltage supplied to the motor needs to be changed and it has been found that this is best achieved by having a remote variable power supply, connected to the model with long cables.
The power supplied to the motor can easily be measured using a voltmeter and ammeter.
The speed of the model might best be found using a light gate. This will measure the instantaneous speed and *V* and I can be measured as the model passes through the gate. This requires a few bodies and some co-ordination.
A plot of power against speed cubed has been found to produce a straight line graph.

Hydrogen fuel cell

A number of fuel cell model kits are available. The one illustrated is the H-racer from www.horizonfuelcell.com.
The model requires careful set up to get going. In particular, the hydrogen balloon tank and lines need to be as clear as possible of ambient air.
It is possible to measure the power input in generating the hydrogen using and ammeter and voltmeter. The batteries of the generator will need to be taken out to connect the ammeter in series.
The speed of the model car and its mass can be measured, giving its kinetic energy. An alternative is to disconnect the electric motor and connect a 1 k resistor across the fuel cell. Voltage and current once again give the output power.
The efficiency in transferring energy from the generation of hydrogen to the production of a current in the fuel cell is very low – less than 1%.