OVERVIEW

Resource Pack AccessEd Research-Based Curricula
Physics Key Stage 4
www.researchbasedcurricula.com

The Physics of Solar Energy

AGE
14–16
Year 10
Year 11

CURRICULUM
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Physics

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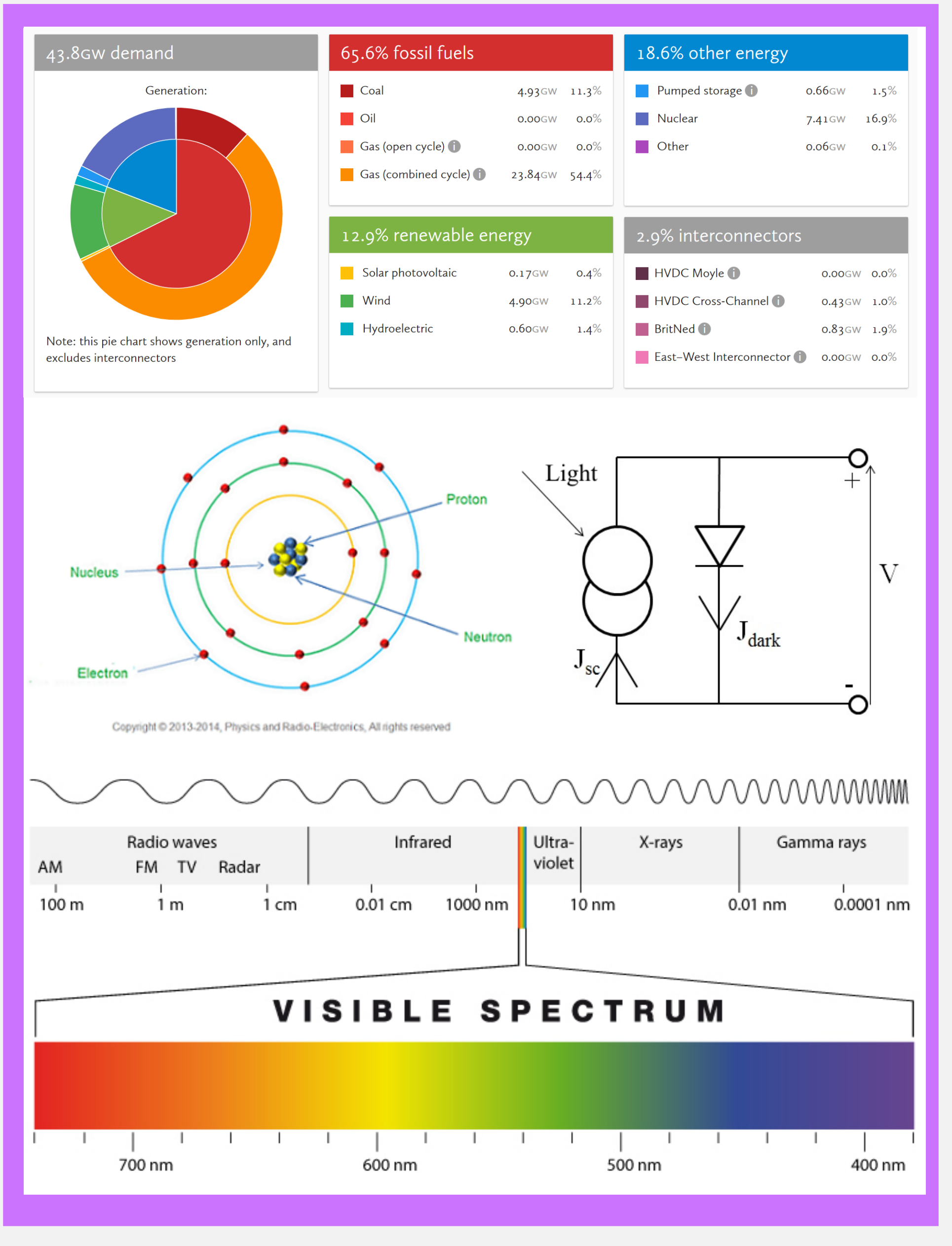

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Contents

PART 1: INTRODUCTION

Welcome!

To get into the best universities, you must demonstrate that you are intellectually curious, and will make the most of the wonderful academic opportunities available to you.

One of the best ways of demonstrating this, is by going above and beyond what is taught in school and studying something that is not on the curriculum.

This resource will give you exactly such an opportunity. You will have something interesting to write about in your application to university, something interesting to talk about in a university interview, and open whole new areas of study you might be interested in!

You will develop valuable academic skills as you go, that we have marked out with gold badges (see the next page on university skills). As you work through the resource you can look out for these badges so that you can explain which skills you have developed and what you did to demonstrate them. Developing these skills will help you get university ready!

If you have any questions while you are using the resources in this pack, you can contact your teacher or email us directly at schools@access-ed.ngo.

Good luck with your journey to higher education!

I am a historian and as a university student I became interested in the history of science. In fact, my curiosity took me to the University of Wisconsin in the USA where I studied in the history of science, medicine and technology programme. Did you know that scientists once believed that living things could spontaneously generate? That means life could form without other life or a parent. I recommend researching the history of physics using Google Books.
Dr Rajbir Hazelwood Programme Director, AccessEd

I love listening to podcasts, and I highly recommend listening to weekly podcasts as it's a quick and interesting way to discover new ideas and hear experts speak about what they know best. I would recommend finding new episodes on nature.com that excite you. You could find out more about coral reefs, brain scans or electric sheep!
Michael Slavinsky Education Director, The Brilliant Club

University Skills

University Ready!

To complete this resource, you will have to demonstrate impressive academic skills. When universities are looking for new students, they will want young people who can study independently and go above and beyond the curriculum. All of these skills that you will see here will demonstrate your abilities as a university student – while you're still at school! Every time you have to look something up, or write up a reference you are showing that you can work independently. Every time that you complete a challenging problem or write an answer to a difficult question, you might demonstrate your ability to think logically or build an argument. Every time that you evaluate the sources or data that you are presented with, you are showing that you can "dive deep" into an unfamiliar topic and learn from it.

Here are the skills that you will develop in this course:

independent research	your ability to work on your own and find answers online or in other books
creativity	your ability to write something original and express your ideas
problem solving	your ability to apply what you know to new problems and challenges
building an argument	your ability to logically express yourself
providing evidence	your ability to refer to sources that back up your opinions and ideas
academic referencing	your ability to refer to what others have said in your answer, and credit them for their ideas
deep dive	your ability to go above and beyond the school curriculum to new areas of knowledge
source analysis	your ability to evaluate sources for bias, origin, purpose and utility
data interpretation	your ability to discuss the implications of what the numbers show
active reading	your ability to engage with what you are reading by highlighting and annotating

INFORMATION FOR TEACHERS

AIMS

The Research-Based Curricula Programme creates classroom resources that are based on cutting-edge academic expertise at local universities.

These resources are intended to encourage pupils to broaden their understanding of subjects and expose them to academic research, as well as supporting the development of core academic skills that boost exam attainment.

Teachers can use these resources to supplement activities in existing lessons, to design new lessons, or to stretch and challenge high-achieving pupils with extension work.

The aim of the programme is to support pupils to develop cognitive and non-cognitive skills that the research shows supports progression to university. This includes deep subject knowledge, critical thinking, and written and verbal communication.

EVIDENCE

The Research-Based Curricula Programme builds on the University Learning in Schools Programme (ULiS), which was successfully delivered and evaluated through the London Schools Excellence Fund in 2015.

The project was designed in a collaboration between Achievement for All and The Brilliant Club, the latter of which is the sister organisation of AccessEd.

ULiS resulted in the design and dissemination of 15 schemes of work based on PhD research for teachers and pupils at Key Stage 3.

The project was evaluated by LKMCo. Overall, pupils made higher than expected progress and felt more engaged with the subject content. The full evaluation can be found here: ULiS Evaluation.

The Brilliant Club

Achievement for All

SUPPORTED BY MAYOR OF LONDON

Department for Education

TEACHERS

The Research-Based Curriculum is designed to be used flexibly by teachers to tailor extension activities for their students. Some teachers may choose to adapt the resources for groups of students during lessons.

The resources are designed to be completed individually or in small groups, so teachers can use them as class-based or homework tasks. Equally, teachers can give the pack to some students to work through independently when they have finished their normal class work or during an extra-curricular club.

The resources will challenge students to think deeply about specific content that may be beyond the confines of the exam curriculum, while informing them about cutting-edge research being carried out at local universities. All the resources can help develop specific skills required for GCSE examinations, which are referenced in the Teacher Notes throughout the pack.

PARTNERS

AccessEd is a non-profit organisation that works to increase university access for under-represented young people globally. We work in partnership with universities and schools to deliver programmes that mobilise researchers to share their academic expertise with young people and the public. Visit www.access-ed.ngo. Follow @_AccessEd

The Higher Education Progression Partnership South Yorkshire plus (HeppSY+) is part of a national programme to help school and college students aged 13-19 in South Yorkshire, who are most at risk of missing out on higher education. HeppSY+ is working in partnership with Sheffield Hallam University, the University of Sheffield, and South Yorkshire colleges and schools. Visit www.heppsy.org. Follow @HeppSYplus

The Physics of Solar Energy

Deep Dive

Solar energy is one of the most exciting forms of renewable energy. Every hour the sun delivers more energy to Earth than the whole of humanity uses in an entire year! Solar panels or photovoltaics directly convert light energy into electrical energy producing no waste or pollution. Across the world thousands of scientists are working to develop a range of different technologies that will allow solar energy to become the dominant source of energy in the future.

The GCSE curriculum covers a range of core Physics concepts that explain how solar panels work including, electromagnetic waves, absorption of light, energy, electricity, and circuits. This handbook contains six lessons worth of resources that will link together core GCSE Physics concepts to the study of photovoltaics. Furthermore, the skills you learn in science class such as problem solving and experimentation will continue to be useful at university. Studying Physics at university requires you to hone these skills whilst also being expected to learn in your own time without the guidance of a teacher.

Physics is a fantastic subject to study at university. Physics answers the big questions such as how do stars form? What is matter made of? Is time travel possible? Furthermore, without Physics our modern world simply wouldn't be possible. Many pieces of technology we take for granted such as smartphones wouldn't exist without Physics.

Physics encompasses a wide range of research areas but I personally work on solar energy. My research is looking at new ways to fabricate solar panels to make them cheaper to purchase using a material called Perovskite. In order to study for a PhD in my field you would need Masters level degree in either Physics, Chemistry, Chemical Phsyics, Engineering, or even Materials Science.

Perovskite photovoltaics is a huge field with hundreds of researchers looking at a range of issues. Perovskites are very efficient and relatively cheap to process however one key problem is the fact they are unstable and tend to degrade very quickly under operating conditions. This is the key issue holding them back from becoming a commercial technology but recent developments in the field have extended device lifetimes significantly. Who knows, maybe in a couple of years you'll have a perovskite solar panel on your roof!

To the student reading this, I'm sure that university seems a long way off at the moment, but you'd be surprised how quickly time goes by. One minute you're in a Physics class at school, next thing you're studying for a PhD! All you need to do is pay attention in lessons, revise, and most importantly, believe in your own ability.

Good luck!

Meet the PhD Researcher: James Bishop

I always enjoyed science at school but Physics was one of my favourite subjects. As a result, I went on to study A-Level Physics and Maths at college. When I was looking at going to university I was torn for a time about maybe studying History, but in the end I opted for Physics which was the best decision I ever made. I studied for a Masters in Physics at the University of Sheffield for four years graduating in 2015. During my degree I did research projects on solar energy and decided to study for a PhD in Perovskite Photovoltaics which I am currently still working towards.

A-Level Subjects: Physics and Maths

Undergraduate: The University of Sheffield

Postgraduate: The University of Sheffield

What is a PhD student? A PhD, or Doctor of Philosophy is the highest academic qualification awarded by most universities. PhD students conduct original research on a specific topic or question, producing a thesis that is typically 70,000 - 100,000 words long and defending their thesis to experts in their chosen field to obtain a PhD.

What is a PhD researcher? A PhD researcher, or post-doctoral researcher has already obtained their PhD qualification and has continued to work in their chosen field or a similar field.

What is a university department? A university department is a group of academics working in a similar area of interest including professors, lecturers, principal investigators (PIs), post-doctoral researchers, PhD students, masters and undergraduate students.

Did you know? At the University of Sheffield, degrees in the Department of Physics and Astonomy are accredited by the Institute of Physics, which means that they cover all of the topics and training that you need to graduate into a professional physics career. You'll start by developing your essential physics knowledge, with subjects including mechanics, waves, optics, relativity, electromagnetism, thermodynamics and quantum physics, before studying these areas at a more advanced level in second year. You'll also be able to pick from a range of optional modules throughout your degree, with a huge variety of topics to choose from in third year. For example, you can study everything from galaxies and dark matter to sustainable energy and the physics of music.

PART 2: RESOURCES

What is Solar Energy and Why is it Important?

Link to curriculum
Energy, National Energy Resources, Power

TEACHER NOTE

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INSTRUCTIONS

1. Read and annotate the data source
2. Complete the written activity
3. Explore the further reading
4. Move on to Resource 2 in this pack

Data Source

Data Interpretation

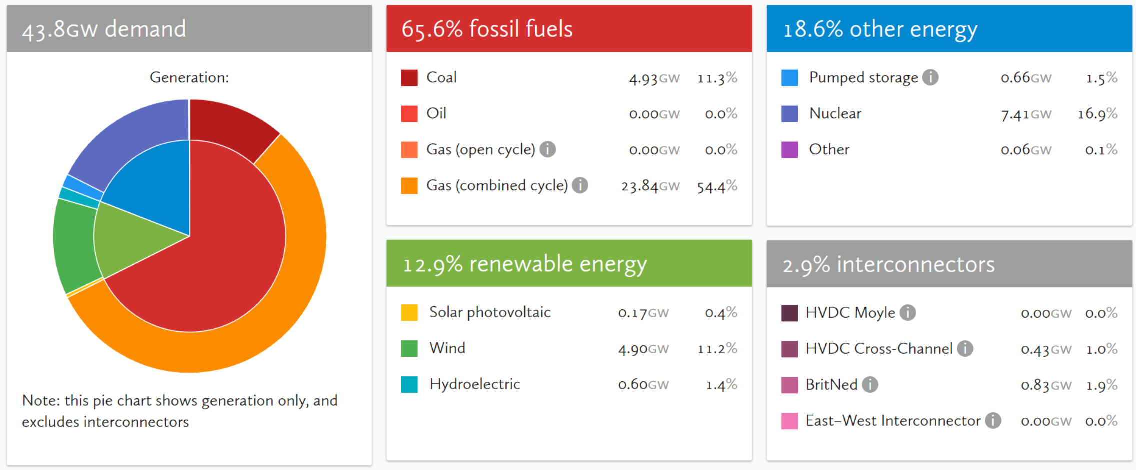

Figure 1. UK energy breakdown on the 08/02/2018 at 4:55 pm [1]

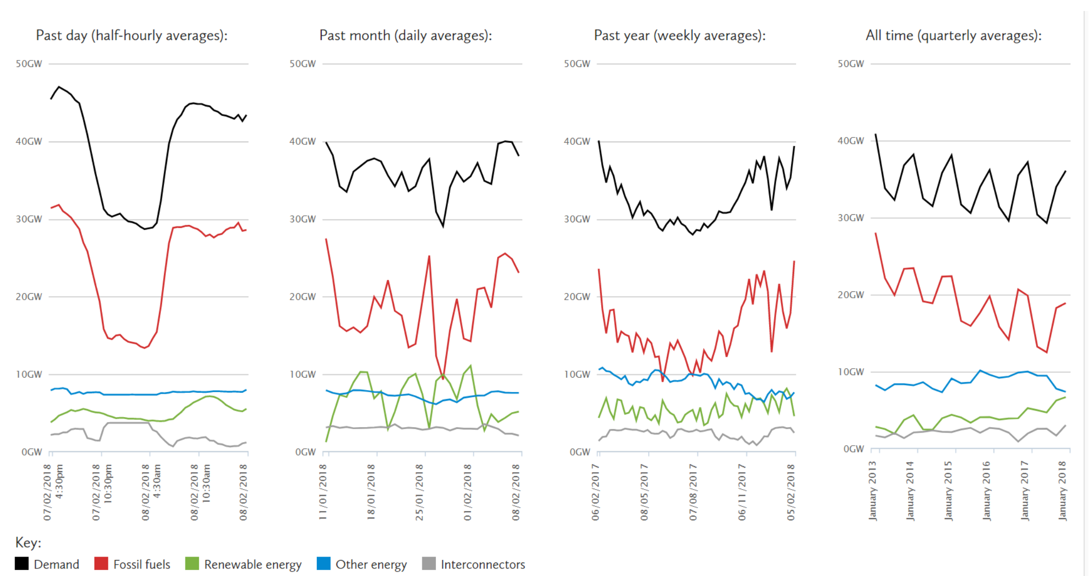

Figure 2. UK energy production by sector on the 08/02/2018 at 4:55 pm [1]

Independent research

Above are some screenshots from the National Grids live statistics website taken on the 8th of February 2018. You can see live data yourself at this website http://grid.iamkate.com/.

Figure 1 shows the current UK demand for electricity (43.8 GW or 4.38 x 10^{10} Watts) and where we are getting our electricity from. Over 65 % of the electricity on this particular day was produced by fossil fuels (oil, coal, and natural gas).

Data Source (continued...)

These resources are simply excavated from the ground and burned which is a cheap way to produce electricity. Unfortunately, fossil fuels are a limited resource so we will run out of them someday. Furthermore, burning fossil fuels releases pollution into the environment and contributes to the greenhouse effect/global warming. As a result, it is critical we find an alternate source of electricity to fossil fuels.

Renewable energy is a name for a range of technologies that collect energy from a renewable source that will not run out on the time scale of millions of years. Examples of renewable energy are wind, hydroelectric and solar. Solar energy is an extremely exciting technology that directly converts light energy into electrical energy without any pollution.

The sun delivers more energy to Earth in an hour than humanity uses in a year. Therefore, solar energy has the potential to solve all our energy needs. Solar was traditionally held back by cost as making solar panels was an expensive task. Some of the expense was because some materials used to manufacture solar panels have to be mined deep below the earth's surface and this in part causes some pollution. However, physicists and engineers are constantly developing new technologies that have dramatically reduced the costs of solar energy. It is likely that within the next 30 years solar will emerge as a dominant source of energy.

Activity

Look at the figures above, read the description and answer the following questions:

Building an argument

1. Where does the UK get the most of its energy from and why does this need to change?
2. Why does solar energy output vary over the course of the day?
3. As grid demand changes, which energy source is varying the most to match it?

Deep dive

4. What is the demand on the grid in the summer? Why is it different to the winter?
5. What challenges face solar energy? (Hint: How sunny is it in winter?)

Further Reading

Independent research

National grid live statistics: http://grid.iamkate.com/

What is Light?

Link to curriculum
Waves,
Electromagnetic Spectrum

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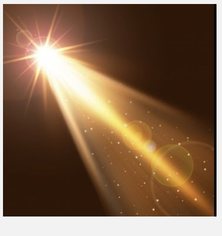
INSTRUCTIONS



1. Read and annotate the data source
2. Complete the written activity
3. Explore the further reading
4. Move on to Resource 3 in this pack

Data Source

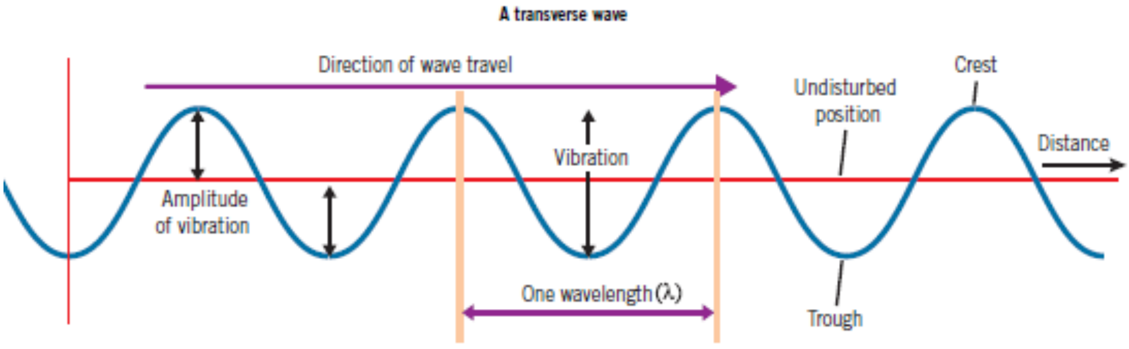


Figure 3: Diagram of a transverse wave [2]

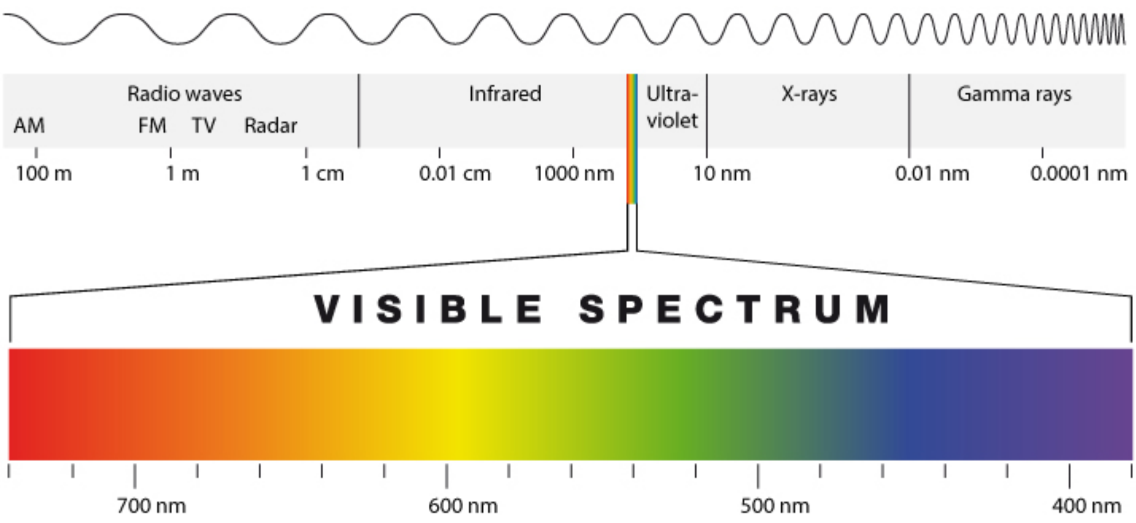


Figure 4: The Electromagnetic spectrum [3]

Light is an example of a transverse wave composed of oscillating electric and magnetic fields. A transverse wave is defined as a wave where the oscillations are perpendicular (at right angles) to the direction of energy transport.

Figure 3 is a diagram of a transverse wave. All waves have similar properties, such as, wavelength and frequency. The wavelength is defined as the distance between two identical points of the wave and is, for example the distance between two peaks, and is measured in metres (m).

Data Source (continued...)

The frequency is defined as the number waves that pass a point every second and is measured in hertz (Hz) or per second (1/s). These properties are linked together as follows,

$$v = f\lambda \tag{1}$$

where, v is for velocity (m/s), f is frequency (Hz), and λ is for wavelength (m).

In a vacuum electromagnetic waves always travel at the same speed, the speed of light, which is 3×10^8 m/s. This means that the longer the wavelength of light, the lower the frequency and vice versa.

Also, the higher the frequency of the wave the more energy it is transferring. For example, an x-ray has a very high frequency (short wavelength) so it carries much more energy than a radio wave which has a low frequency (long wavelength).

Visible light lies in the middle of the electromagnetic spectrum, with blue light having the highest frequency. The wavelength of visible light is extremely short and is measured in nanometres with one nanometre being equal to a billionth of a metre (1×10^{-9} m). White light is comprised of a mixture of all wavelengths of visible light all at once

Activity

Look at the figures above, read the description and answer the following questions:

Data Interpretation

1. What is an electromagnetic wave?
2. Draw a diagram of a transverse wave?
3. A transverse wave has a wavelength of 3 m and a frequency of 10 Hz. What is its velocity?
4. A transverse wave has a wavelength of 25 mm and a frequency of 1 kHz. What is its velocity?

Providing evidence

5. What velocity do electromagnetic waves move at?
6. Which electromagnetic wave carries more energy: an x-ray or blue light? Explain your answer.

Further Reading

Hyperphysics webpage on electromagnetic waves:
http://hyperphysics.phy-astr.gsu.edu/hbase/Waves/emwavecon.html#c1

RESOURCE 3

How do Solar Panels Convert Light into Electricity?

Link to curriculum
Atomic structure, Waves

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2. Complete the written activity
3. Explore the further reading
4. Move on to Resource 4 in this pack

Data Source

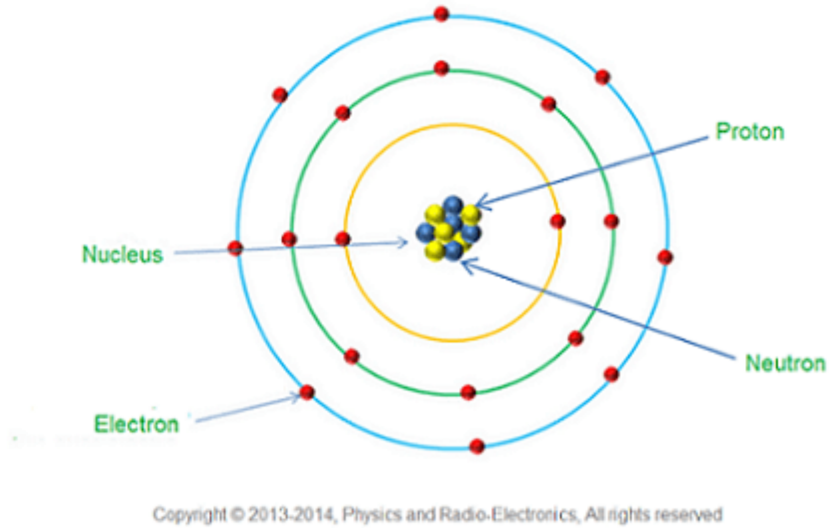

Figure 5: The structure of the atom [4]

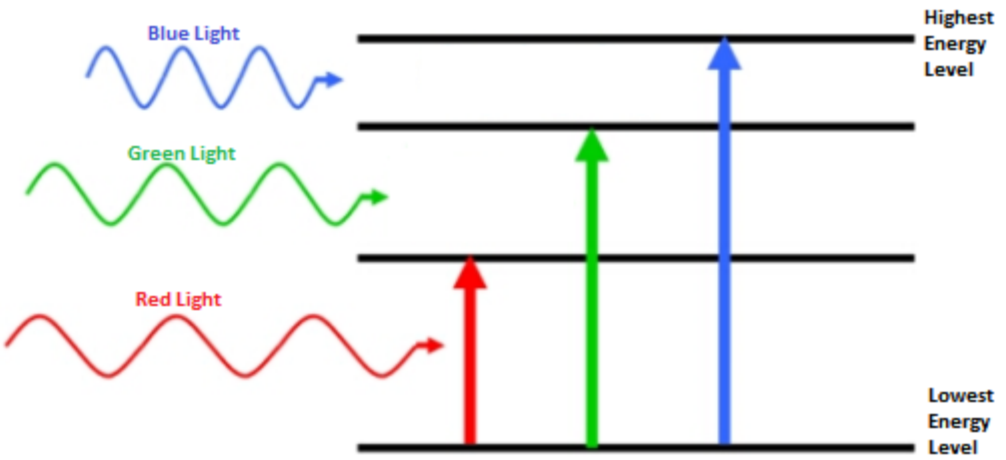

Figure 6: Absorption of light in an atom [5]

Atoms are the basic building blocks of matter and are made up of three particles. At the centre of the atom is the nucleus which is made up of protons and neutrons. The proton and neutron are similar in a size but the proton has a positive electric charge whereas the neutron has no charge.

The number of protons is called the atomic number and this determines which element it is. For example, all carbon atoms have exactly 6 protons and all hydrogen atoms have 1 proton in their nucleuses.

RESOURCE 3

Data Source (continued...)

The nucleus is surrounded by electrons which have a negative charge and are about 2000 times lighter than the proton. Normally there are an equal number of electrons and protons in the atom so overall the atom has no net electric charge. The electrons arrange themselves into energy levels, with higher energy electrons existing in energy levels further from the nucleus.

Electromagnetic waves such as light can transfer their energy to the electrons promoting them into higher energy levels. This is called absorption. A solar panel is primarily comprised of a material which is designed to absorb as much visible light as possible creating lots of high energy electrons. These electrons are then extracted by the device to power an external circuit.

Activity

Look at the figures above, read the description and answer the following questions:

1. What are the three particles that make up the atom?

2. What is the significance of the number of protons in the nucleus?

3. What are energy levels in an atom?

4. How does absorption in atoms work?

Further Reading

Hyperphysics webpage on hydrogen absorption. The material here is beyond GCSE but you may find it interesting:
http://hyperphysics.phy-astr.gsu.edu/hbase/hyde.html

Independent research

RESOURCE 4

The Equivalent Circuit

Link to curriculum
Circuits, Current, Resistance, Voltage

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4. Move on to Resource 5 in this pack

Data Source

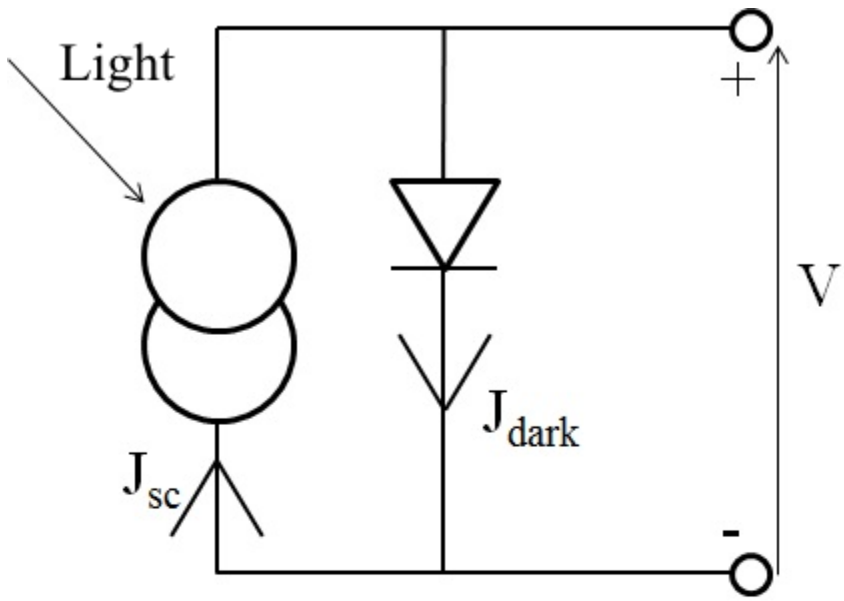

Figure 7. The equivalent circuit model of a solar cell

Figure 7 shows an electrical model of a solar cell which physicist use to understand the electrical properties of a solar cell. Here the solar cell is modelled as a circuit containing two elements in parallel. The element on the left is one you won't have seen before at GCSE, it is a current generating element that produces electrical current upon exposure to light.

Electrical current is measured in amps (A) is defined as the flow of electrons. The more electrons that are moving the more current we have. The symbol you will learn about at GCSE is the one in the middle which looks like a triangle with a line in front of it. This is called a diode. Diodes are circuit elements that only allow current to flow in one direction.

The two circles on the far right of the diagram are the terminals of the panel that you would connect to the external circuit (whatever you wanted to power with your solar panel) to operate the device.

The current produced by the current generating element flows until it reaches the branch where it can either flow through the diode or out through the terminals. Here the resistance of the external circuit is very important. Resistance is measure in ohms (Ω) and is a measure of how difficult it is for current to flow in a material. The higher the resistance the harder it is for current to flow.

Data Source (continued...)

If the external circuit has a high resistance then most of the current will flow through the diode. The more current that flows through the diode the more voltage is generated between the terminals. Without the diode the solar panel produces no voltage. Voltage is measured in volts (V) and is the difference in electrical potential energy between two points. You can think of it as the "electrical push" each electron gets as it moves through the circuit.

We can calculate the electrical power of a circuit in this way,

$$P = IV \qquad (2)$$

where, P is for power measured in watts (W), I is current measured in amps (A) and V is for potential difference measured in volts (V).

We can see that we want our solar panel to produce more power we need the highest current and voltage possible. This means that we need to manage the resistance of the external circuit to get the most power.

Activity

Look at the figure above, read the description and answer the following questions:

Data Interpretation

1. Define electrical current, resistance and voltage.
2. What is a diode?
3. In the equivalent circuit why is the diode important?
4. A solar panel under illumination produces 8 A and 30 V. What is the power output of the solar panel?
5. A solar panel under illumination produces 150 W of power and 10 mA of current. What voltage is the panel producing?

Deep dive

Further Reading

Independent research

A useful textbook on this area:
Page 11 of The Physics of Solar Cells by Jenny Nelson, Imperial College Press

PV education has a good section on this:
http://www.pveducation.org/pvcdrom/solar-cell-operation/iv-curve

RESOURCE 5

Calculating the Efficiency of a Solar Panel

Link to curriculum
Power, Energy, Efficiency

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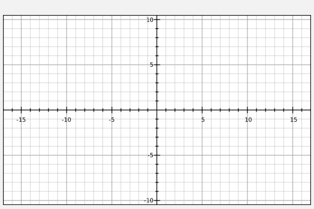

1. Read and annotate the data source
2. Complete the written activity
3. Explore the further reading
4. Move on to Resource 6 in this pack

Data Source

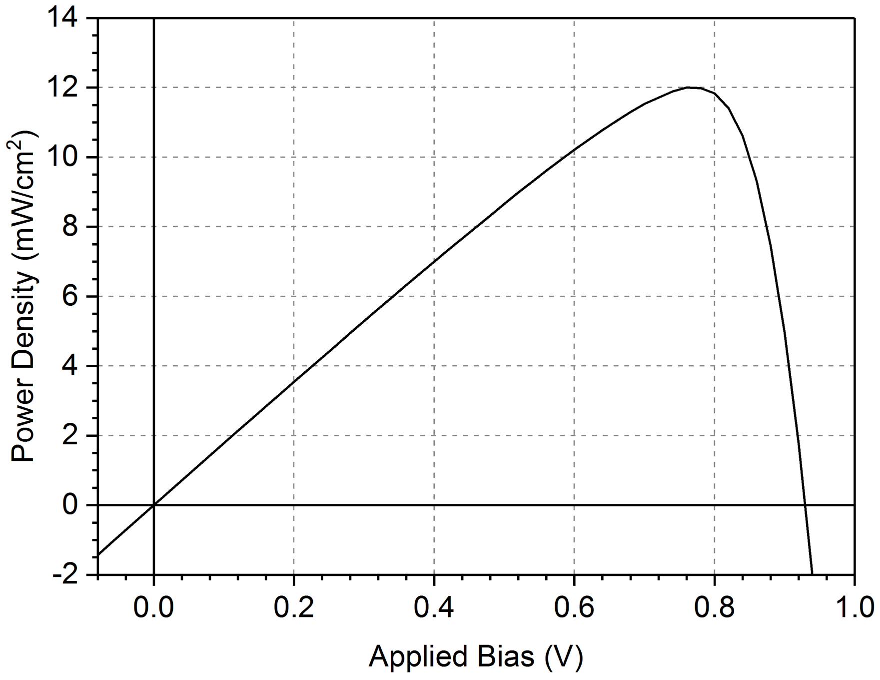

Figure 8. Power output from a prototype solar panel operating under a solar simulator.

The electrical power a solar panel produces depends on the voltage it is operated at. Figure 8 is real data from a prototype solar panel which has been tested using a solar simulator. A solar simulator is essentially a powerful lamp that imitates solar radiation on Earth. The device is connected to some electronics that vary the voltage it is operated at whilst measuring the current or power produced.

The x axis of the graph is applied bias or voltage. The y axis of the graph is power density which means power output per unit surface area of the device. The units used here are mW/cm^2 (milliwatts per centimetre squared). A milliwatt is one thousandth of a watt or 1×10^{-3} watts.

We can see that at 0.6 V the power the device is producing is approximately 10 mW/cm^2. As the voltage increases so does the power until it reaches a maximum (known as the maximum power point) before it drops to zero. As a result of this behaviour, solar panels include clever electronics that manages the voltage the device is operated at to ensure the best performance. This is known as maximum power point tracking.

Data Source (continued...)

Efficiency is an important parameter when determining how well a solar panel is working. Efficiency can be defined as the useful power output from a device divided by the total power input.

In this case the total power input is the light from the solar simulator which has a power density of 100 mW/cm^2. By using a solar simulator, we can determine the maximum power output of the device to calculate its efficiency.

Activity

Look at the figure above, read the description and answer the following questions:

Data Interpretation

Deep dive

1. Using figure 7, determine the maximum power output of the solar panel and use this to calculate the efficiency of the device.
2. At the maximum power point what current density is the device producing?
3. If the entire device is 10 cm^2 in area, what is the maximum power output?

Further Reading

Independent research

PV education has a good section on this:
http://pveducation.org/pvcdrom/characterisation/measurement-of-solar-cell-efficiency

Solar Panel Materials

Link to curriculum
Atomic Structure, Atomic number

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INSTRUCTIONS

1. Read and annotate the data source
2. Complete the written activity
3. Explore the further reading
4. You can share any work you produce with the researcher who created this pack by sending it to assignments@access-ed.ngo
5. Find out more about studying Physics at university

Data Source

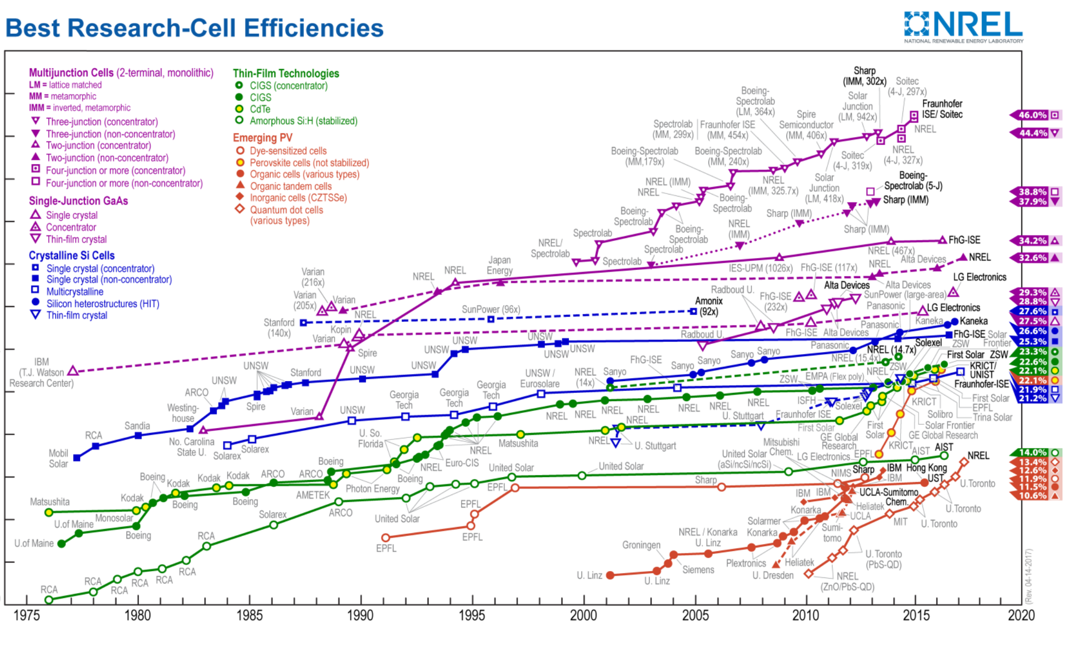
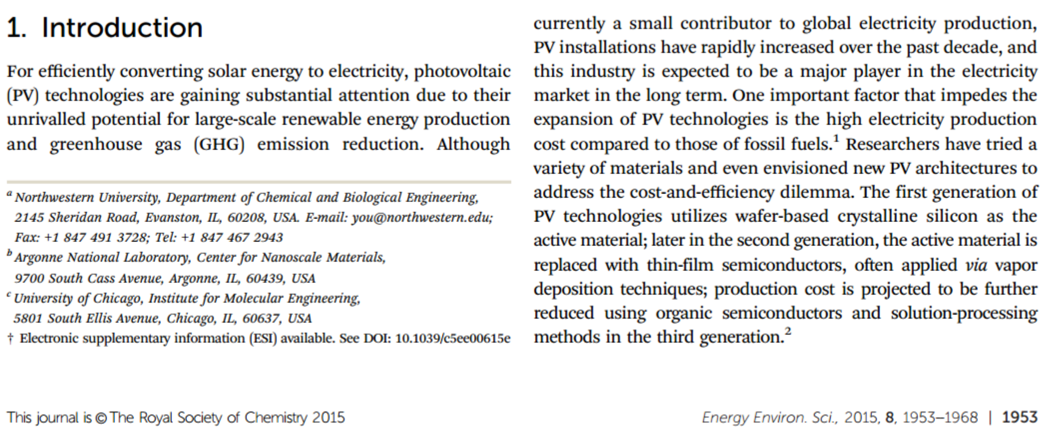


Figure 9: NREL record efficiency chart for various solar panel technologies [6]



1. Introduction

For efficiently converting solar energy to electricity, photovoltaic (PV) technologies are gaining substantial attention due to their unrivalled potential for large-scale renewable energy production and greenhouse gas (GHG) emission reduction. Although currently a small contributor to global electricity production, PV installations have rapidly increased over the past decade, and this industry is expected to be a major player in the electricity market in the long term. One important factor that impedes the expansion of PV technologies is the high electricity production cost compared to those of fossil fuels.[1] Researchers have tried a variety of materials and even envisioned new PV architectures to address the cost-and-efficiency dilemma. The first generation of PV technologies utilizes wafer-based crystalline silicon as the active material; later in the second generation, the active material is replaced with thin-film semiconductors, often applied *via* vapor deposition techniques; production cost is projected to be further reduced using organic semiconductors and solution-processing methods in the third generation.[2]

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† Electronic supplementary information (ESI) available. See DOI: 10.1039/c5ee00615e

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Figure 10. Extract from a scientific paper on various solar (photovoltaic) technologies [7]

Data Source (continued...)

There are many different types of solar technologies that use different materials to absorb light. Figure 8 shows the record efficiency of various solar technologies over time. As research has progressed device efficiencies have continued to rise with the record being a 46 % efficient device. However, that technology was far too expensive for widespread use.

Most commercial devices (the ones you see on people's roofs) are based on silicon and sit at around 20 % power conversion efficiency. Silicon is an element in group four of the periodic table and has an atomic number of 14. This means there are 14 protons in the nucleus of a silicon atom. However, there are many other elements used in solar technologies and one of them may replace silicon as the dominant commercial technology.

Activity

Look at the figure above, read the description and answer the following questions (You will need a periodic table):

1. Read the extract in figure 9. What are the three generations of photovoltaic technologies?

2. Cadmium Telluride is an important second-generation technology, what are the atomic numbers of Cadmium and Tellurium?

3. Perovskites are an exciting third generation material. One common perovskite absorber material is Methylammonium Lead Iodide which has the chemical formula $CH_3NH_3PbI_3$. How many protons are in this compound?

4. Why is it impossible for a solar cell to be 100 % efficient? (You will need to some research independently)

Further Reading

Video showing roll to roll manufacture of flexible organic solar cells: https://www.youtube.com/watch?v=zeVKiaif9po

Video talking about the potential of perovskite solar cells and solution processing:
https://www.youtube.com/watch?v=9PhovLOOtfM

Data Interpretation

Providing Evidence

References

Deep Dive

Independent Research

[1] K. Morley, "National Grid: Live Status," [Online]. Available: http://grid.iamkate.com/. [Accessed 8 February 2018].

[2] Revision World, "Describing Waves," Revision World, [Online]. Available: https://revisionworld.com/gcse-revision/physics/waves/describing-waves. [Accessed 10 April 2018].

[3] Unknown, "What different uses do electromagnetic waves have?," [Online]. Available: https://www.quora.com/What-different-uses-do-electromagnetic-waves-have?redirected_qid=23311916. [Accessed 10 April 2018].

[4] A. Shaik, "Battery – How Battery Works?," [Online]. Available: http://www.physics-and-radio-electronics.com/blog/battery-battery-works/. [Accessed 10 April 2018].

[5] Unknown, "Energy Level Chemistry Definition," [Online]. Available: http://en.stonkcash.com/energy-level-chemistry-definition/. [Accessed 10 April 2018].

[6] NREL, "NREL Efficiency Chart," [Online]. Available: https://www.nrel.gov/pv/. [Accessed 10 April 2018].

[7] J. Gong, S. B. Darling and F. You, "Perovskite photovoltaics: life-cycle assessment of energy and environmental impacts," Energy and Environmental Science, vol. 8, pp. 1953-1968, 2018.

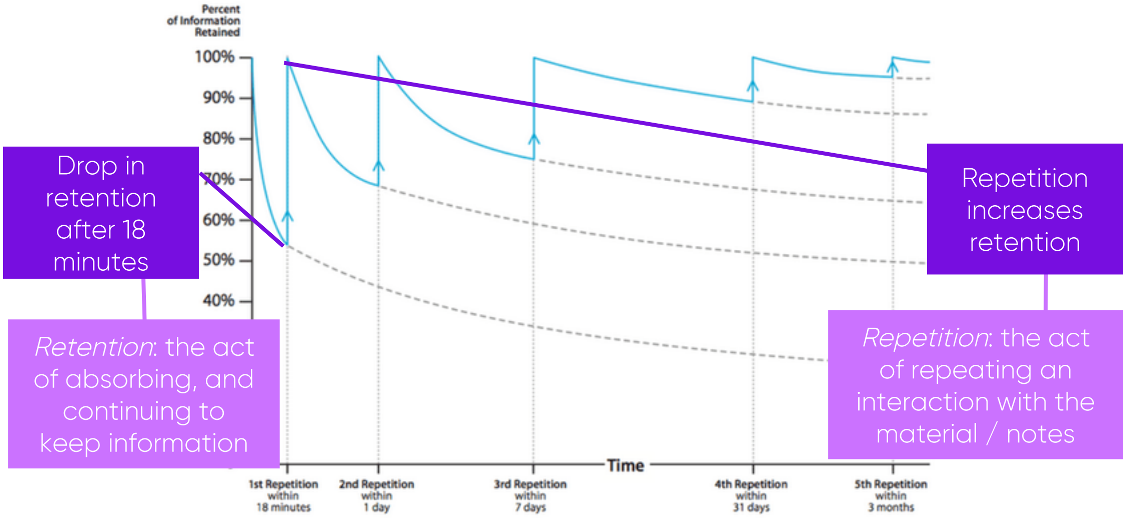
PART 3: ADVICE AND GUIDANCE

University Study Skills: Cornell Notes

Why is good note taking important?

If it feels like you forget new information almost as quickly as you hear it, even if you write it down, that's because we tend to lose almost 40% of new information within the first 24 hours of first reading or hearing it.

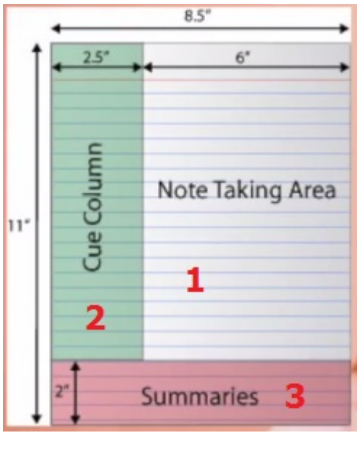
If we take notes effectively, however, we can retain and retrieve almost 100% of the information we receive. Consider this graph on the rate of forgetting with study/repetition:



Learning a new system

The Cornell Note System was developed in the 1950s at the University of Cornell in the USA. The system includes interacting with your notes and is suitable for all subjects. There are three steps to the Cornell Note System.

Step 1: Note-Taking



1. <u>Create Format</u>: Notes are set up in the Cornell Way. This means creating 3 boxes like the ones on the left. You should put your name, date, and topic at the top of the page.

2. <u>Write and Organise</u>: You then take your notes in area on the right side of the page. You should organise these notes by keeping a line or a space between 'chunks' /main ideas of information. You can also use bullet points for lists of information to help organise your notes.

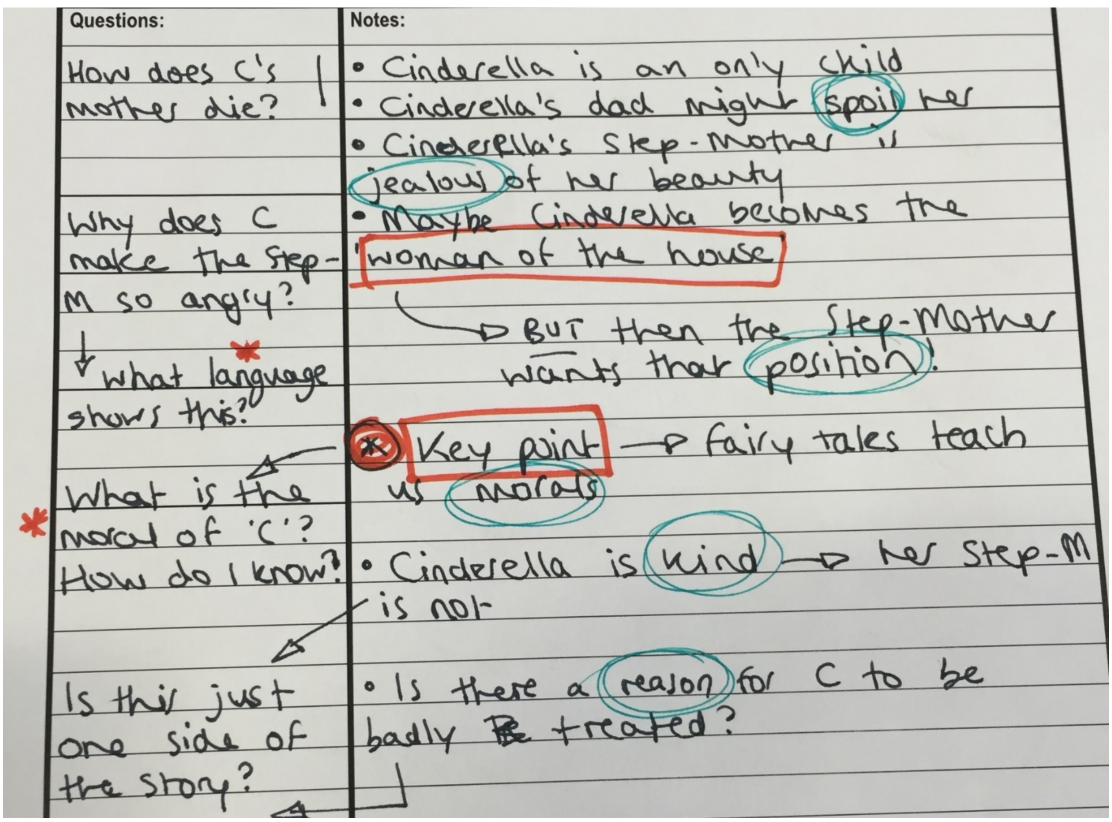
Step 2 Note-Making

1. Revise and Edit Notes: Go back to box 1, the note taking area and spend some time revising and editing. You can do this by: highlighting 'chunks' of information with a number or a colour; circling all key words in a different colour; highlighting main ideas; adding new information in another colour

2. Note Key Idea: Go to box 2 on the left hand side of the page and develop some questions about the main ideas in your notes. The questions should be 'high level'. This means they should encourage you to think deeper about the ideas. Example 'high level' questions would be:

- Which is most important / significant reason for…
- To what extent…
- How does the (data / text / ideas) support the viewpoint?
- How do we know that…

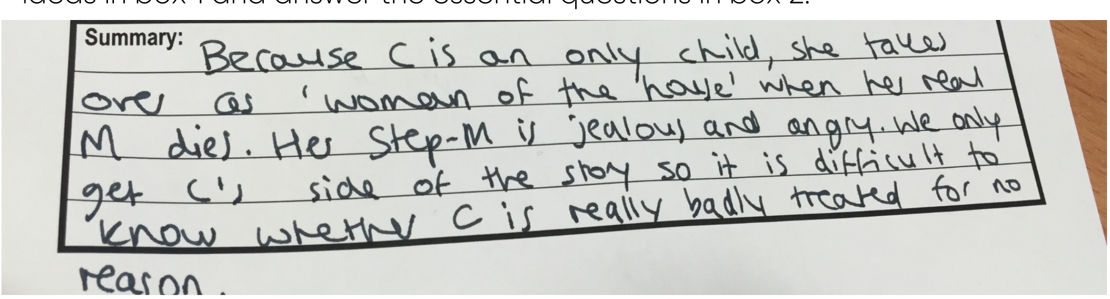
Here is an example of step 1 and step 2 for notes on the story of Cinderella:



Questions:	Notes:
How does C's mother die?	• Cinderella is an only child • Cinderella's dad might spoil her • Cinderella's Step-Mother is jealous of her beauty
Why does C make the Step-M so angry? what language shows this?	• Maybe Cinderella becomes the 'woman of the house' → BUT then the Step-Mother wants that position!
What is the moral of 'C'? How do I know?	Key point → fairy tales teach us morals • Cinderella is kind → her Step-M is not
Is this just one side of the story?	• Is there a reason for C to be badly ~~B~~ treated?

Step 3 Note-Interacting

1. Summary: Go to box 3 at the bottom of the page and summarise the main ideas in box 1 and answer the essential questions in box 2.



Summary: Because C is an only child, she takes over as 'woman of the house' when her real M dies. Her Step-M is jealous and angry. We only get C's side of the story so it is difficult to know whether C is really badly treated for no reason.

Give the Cornell Note Taking System a try and see if it works for you!

University Study Skills: Key Instruction Words

These words will often be used when university tutors set youu essay questions - it is a good idea to carefully read instruction words before attempting to answer the question.

Analyse – When you analyse something you consider it carefully and in detail in order to understand and explain it. To analyse, identify the main parts or ideas of a subject and examine or interpret the connections between them.

Comment on – When you comment on a subject or the ideas in a subject, you say something that gives your opinion about it or an explanation for it.

Compare – To compare things means to point out the differences or similarities between them. A comparison essay would involve examining qualities/characteristics of a subject and emphasising the similarities and differences.

Contrast – When you contrast two subjects you show how they differ when compared with each other. A contrast essay should emphasise striking differences between two elements.

Compare and contrast – To write a compare and contrast essay you would examine the similarities and differences of two subjects.

Criticise – When you criticise you make judgments about a subject after thinking about it carefully and deeply. Express your judgement with respect to the correctness or merit of the factors under consideration. Give the results of your own analysis and discuss the limitations and contributions of the factors in question. Support your judgement with evidence.

Define – When you define something you show, describe, or state clearly what it is and what it is like, you can also say what its limits are. Do not include details but do include what distinguishes it from the other related things, sometimes by giving examples.

Describe – To describe in an essay requires you to give a detailed account of characteristics, properties or qualities of a subject.

Discuss – To discuss in an essay consider your subject from different points of view. Examine, analyse and present considerations for and against the problem or statement.

Evaluate – When you evaluate in an essay, decide on your subject's significance, value, or quality after carefully studying its good and bad features. Use authoritative (e.g. from established authors or theorists in the field) and, to some extent, personal appraisal of both contributions and limitations of the subject. Similar to **assess**.

Illustrate – If asked to illustrate in an essay, explain the points that you are making clearly by using examples, diagrams, statistics etc.

Interpret – In an essay that requires you to interpret, you should translate, solve, give examples, or comment upon the subject and evaluate it in terms of your judgement or reaction. Basically, give an explanation of what your subject means. Similar to **explain**.

Justify – When asked to justify a statement in an essay you should provide the reasons and grounds for the conclusions you draw from the statement. Present your evidence in a form that will convince your reader.

Outline – Outlining requires that you explain ideas, plans, or theories in a general way, without giving all the details. Organise and systematically describe the main points or general principles. Use essential supplementary material, but omit minor details.

Prove – When proving a statement, experiment or theory in an essay, you must confirm or verify it. You are expected to evaluate the material and present experimental evidence and/or logical argument.

Relate – To relate two things, you should state or claim the connection or link between them. Show the relationship by emphasising these connections and associations.

Review – When you review, critically examine, analyse and comment on the major points of a subject in an organised manner.

Exploring Careers and Study Options

✓ Find job descriptions, salaries and hours, routes into different careers, and more at https://www.startprofile.com/
✓ Research career and study choices, and see videos of those who have pursued various routes at http://www.careerpilot.org.uk/
✓ See videos about what it's like to work in different jobs and for different organisations at https://www.careersbox.co.uk/
✓ Find out what different degrees could lead to, how to choose the right course for you, and how to apply for courses and student finance at https://www.prospects.ac.uk/
✓ Explore job descriptions and career options, and contact careers advisers at https://nationalcareersservice.direct.gov.uk/
✓ Discover which subjects and qualifications (not just A levels) lead to different degrees, and what careers these degrees can lead to, at http://www.russellgroup.ac.uk/media/5457/informed-choices-2016.pdf

Comparing Universities

✓ https://www.whatuni.com/
✓ http://unistats.direct.gov.uk/
✓ https://www.thecompleteuniversityguide.co.uk/
✓ Which? Explorer tool – find out your degree options based on your A level and BTEC subjects: https://university.which.co.uk/

UCAS

✓ Key dates and deadlines: https://university.which.co.uk/advice/ucas-application/ucas-deadlines-key-application-dates
✓ Untangle UCAS terminology at https://www.ucas.com/corporate/about-us/who-we-are/ucas-terms-explained
✓ Get advice on writing a UCAS personal statement at https://www.ucas.com/ucas/undergraduate/getting-started/when-apply/how-write-ucas-undergraduate-personal-statement
✓ You can also find a template to help you structure a UCAS statement, at https://www.ucas.com/sites/default/files/ucas-personal-statement-worksheet.pdf
✓ How to survive Clearing: https://university.which.co.uk/advice/clearing-results-day/the-survivors-guide-to-clearing

Physics at University

- ✓ Physics covers all the natural sciences linked to the study of inanimate objects, forces, and properties of the universe.
- ✓ Physics and the problem solving skills it develops is useful in many different job families including agriculture, plans and land, environmental sciences, construction, engineering and manufacturing, medicine and nursing, medical technology, and science and research.
- ✓ You can find out more about different courses, entry requirements, and careers by exploring the UCAS Physics Subject Guide online: https://www.ucas.com/ucas/subject-guide-list/physical-sciences

A Deeper Look Into Physics

- ✓ **Listen:** Nature.com podcasts https://www.nature.com/podcast/index.html
- ✓ **Watch:** BBC Four Documentary – The Secrets of Quantum Physics https://www.youtube.com/watch?v=6k6BuYK_PwQ
- ✓ **Read:** Brian Cox and Jeff Forshaw (2009) Why does $E=mc^2$?
- ✓ **Read:** Brian Cox (2016) Forces of Nature
- ✓ **Read:** Science Magazine http://www.sciencemag.org/category/physics
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