Never gonna' heat you up: Thermal Energy

Key Stage 4 Revision Programme

Pupil Name	
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Timetable and Assignment Submission

Timetable – Tutorials

Tutorial	Date	Time	Location
1 (Baseline)			
2			
3			
4			
5			
6 (Final Assignment)			
7 (Feedback)			

Timetable – Homework Assignments

Tutorial 1		
Tutorial 2		
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This course covers the key fundamentals on which you will be tested on in your upcoming GCSE exam. The topics covered overlap several areas of the Physics portion of the GCSE programme and as such are crucial to achieving the highest level in the exams.

This workbook will follow the format of deliberate practice and mastery, breaking down concepts down to fundamentals to build up from a solid foundation. In this, there will be a full range of questions, from AO1, AO2 and AO3 formats.

'Practice makes perfect', are words often mentioned but rarely taken to heart. We are constantly looking for a quick fix, a shortcut, some kind of way to save time. However, when it comes to the true mastery of something, there really is no substitute for doing it over and over. In as many ways as you can think of. Much as you cannot hope to pick up a guitar and play a tune, you cannot pick up a mathematical or science problem and expect to be able to solve it.

The framework of deliberate practice relies on this concept. By creating detailed worked examples, covering every eventuality, and then allowing the student (you) time to practice many similar but contrasting examples like these, the hope is that you will eventually master the concept.

I hope that this workbook will provide this for you. It will tighten up your mathematical skills in the area of physics relating to thermal energy, while also building on the mathematical skills which will be beneficial to you throughout both your Science and Maths GCSE exams. This will hopefully enable you to add an extra mark here and, that may add up to the difference between the grade you expect and the one above.

Subject Vocabulary

Complete this vocabulary list during your tutorials. Use the free spaces for additional words.

Word	Definition	In a sentence
Conduction		
Convection		
Energy store		
Fusion		
Radiation		
Specific heat capacity		
Specific latent heat		
Thermal energy		
Vaporisation		

Tutorial 1 – Thermal Energy

Objectives for this tutorial:

A) Define thermal energy

B) Calculating specific heat capacity

C) Calculating power using specific heat capacity

Starter: Which has a higher specific heat capacity, water or air? Explain your answer.

Objective A: Defining thermal energy

Hot objects (or substances) store energy thermally.

The energy is associated with the random, thermal motion of a substance's atoms or molecules. The physical processes of conduction, convection and radiation can result in increases or decreases of a thermal energy store.

If two objects at different temperatures are in contract with each other, then energy is exchanged between their particles. After some time, the thermal energy store of the hotter object will be decreased (and its temperature will have decreased) and the thermal energy of the cooler object will be increased (and its temperature will have increased). This thermal process is called conduction. When the objects reach the same temperature we say they are in thermal equilibrium and the thermal energy of each remains constant.

Hot objects emit electromagnetic radiation. After a period of time the thermal energy store associated with a hot object will have decreased (and the temperature of the hot object will be lower than it was).

Thermal energy is measured in Joules (J).

Heating involves the transfer of thermal energy from a warmer object to a cooler object.

Temperature measures how hot a material/substance is, whereas heat measures the level of thermal energy which is contained within an object.

Specific heat capacity is defined as the energy required to raise the temperature of 1kg of material by 1°C.

Practice A:

1) Explain why the units for specific heat capacity are J/kg°C

2) Write a sentence defining specific heat capacity in words.

3) If two objects have different specific heat capacity, how can you work out which one is higher?

4) Why does the temperature of every object not increase at the same rate in a hot room?

Assessment A:

Specific heat capacity is…

A	the heat required to raise 1°C of material by 1kg
B	the rise in temperature by 1J of energy.
C	the speed of temperature change by 1kg of material.
D	the energy required to raise 1kg of material by 1°C.

Objective B: Calculating specific heat capacity

The increase in energy required to raise the temperature of a material/substance may be calculated using the following equation:

$$\Delta Q = mc\Delta\Theta$$

ΔQ is the change in energy, Q, in joules, J

m is the mass of the material/substance, in kg

c is the specific heat capacity, J/kg°C

$\Delta\Theta$ is the change in temperature, Θ, in °C

Worked example 1

The specific heat capacity of a 0.5kg plastic bucket is 1000J/kg°C. The temperature of the bucket is 40°C and if it reaches 100°C it will begin to melt. Calculate the minimum change in energy required to melt the bucket.

$\Delta Q = mc\Delta\Theta$ <- Change in energy, ΔQ, is already the subject

$\Delta\Theta = 100°C - 30°C = 70°C$ <- Calculate the change in temperature, $\Delta\Theta$

$\Delta Q = 0.5kg \times 1000J/kg°C \times 70°C$ <- Input the values from the question

$\Delta Q = 35{,}000\ J$ <- Es perfecto! [It's perfect! – in Spanish]

Worked example 2

There is 1l of water in a saucepan, with a mass of 1 kg. It requires 8 kJ to increase its temperature by 2°C . Calculate the specific heat capacity of water.

$\Delta Q = mc\Delta\Theta$ <- You need to rearrange so that specific heat capacity, c, is the subject

$c = \frac{\Delta Q}{m\Delta\Theta}$ <- Now specific heat capacity, c, is the subject

$c = \frac{8kJ}{1kg \times 2°C}$ <- Input the values from the question

$c = \frac{8kJ}{2kg°C}$ <- Input the values from the question

$c = 4kJ/kg°C$ <- Now convert to J/kg°C

$c = 4000J/kg°C$ <- Voilà! C'est tout. [That's it! That's all. – in French]

Worked example 3

Using a blowtorch, a 300g piece of metal is slowly heated. The blowtorch increases the energy of the metal from 500J to 4.5kJ and the specific heat capacity of the metal is 2000J/kg°C. Calculate the temperature increase which occurs to the piece of metal.

$\Delta Q = mc\Delta\Theta$ <- You need to rearrange so that change in temperature, $\Delta\Theta$, is the subject

$\Delta\Theta = \frac{\Delta Q}{mc}$ <- Now change in temperature, $\Delta\Theta$, is the subject

300g = 3kg <- Convert g to kg

4.5kJ = 4500J <- Convert kJ to J

4500J – 500J = 4000J <- Calculate the energy change

$\Delta\Theta = \frac{4000J}{1kg \times 2000J/kg°C}$ <- Input the values from the question

$\Delta\Theta = \frac{4000J}{1kg \times 2000J/kg°C}$ <- Input the values from the question

$\Delta\Theta = 2°C$ <- Ja, das ist richtig! [Yes, that is correct! – in German]

Practice B: Calculating specific heat capacity

Q1. With an energy change of 1000kJ, the temperature of the 100kg block increases by 250°C. Calculate the specific heat capacity of the block.

Q2 The specific heat capacity of a 10kg metal rod bucket is 450J/kg°C. The change in energy is 45kJ. Calculate the change in temperature.

Q3 The specific heat capacity of a 500g container is 4500J/kg°C, The temperature change is 12°C. Calculate the change in energy.

Assessment B:

With a 2°C rise in temperature, the 8kg ball experiences a 100J rise in energy. What is the specific heat capacity of the ball?

A	-4.166 J/kg°C
B	0.0025 J/kg°C
C	4.166 J/kg°C
D	1.6 kJ/kg°C

Objective C: Calculating power using specific heat capacity

Power is the rate of energy usage relative to time and can be calculated using the following equation

$$P = \frac{Q}{t}$$

P is power, in Watts, W

Q is the energy, in joules, J

t is the time period, in seconds

Objects with a high power will use energy at a higher rate than those of a lower power. An high power object such as a tumble dryer (~2kW) has a higher power than a hair dryer (~1kW) and will utilise energy at a faster rate.

Worked example 1

It takes a 2kW blowtorch approximately 5 minutes to increase the 10kg glass from a room temperature of 20°C to a shattering temperature of 200°C. What is the specific heat capacity of the glass?

$P = \frac{Q}{t}$	<- You need to rearrange so that energy used, Q, is the subject
$Q = Pt$	<- Now energy, Q, is the subject
2kW = 2000W	<- Convert kW to W
5 minutes = 300 seconds	<- Convert minutes to seconds
Q = 2000W x 300 seconds	<- Calculate the change in energy
Q = 600000J	<- The change in energy
$\Delta Q = mc\Delta\Theta$	<- You need to rearrange so that specific heat capacity, c, is the subject
$c = \frac{\Delta Q}{m\Delta\Theta}$	<- Now specific heat capacity, c, is the subject
C = 600000J/(10kg x 180°C)	<- Calculate the specific heat capacity
C = 333.33J$/kg$°C	<- Voila

Practice C: Calculating power using specific heat capacity

Q1. The specific heat capacity of air is 1,000J/kgK.

a) How much energy would be needed to raise the temperature of the air in the room by 5°C, if the room measures 4m x 4m x 3m (density of air = 1.0kg/m^3)? Assume that the room has no furniture and a that the walls gain no thermal energy.

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b) How long does a 1kW convection heater take to heat the air?

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Q2. Calculate the specific heat capacity of a 3kg piece of metal which experiences a temperature rise of 25°C when it is heated at a rate of 60W for 10 minutes, if a total of 3,000J is lost to the surroundings during this process.

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Q3. An energy of 75,600J must be supplied to raise the temperature of a 2kg block of ice, initially at -18°C, to its melting point. Calculate the specific heat capacity of ice suggested by these figures.

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Assessment C:

What is the power of a device which uses 10kJ of energy is 2 minutes?

A	0.83kW
B	83 W
C	5kW
D	20W

Plenary

Discussion question: What do you need to consider when buying a heater?

Objectives for this tutorial:

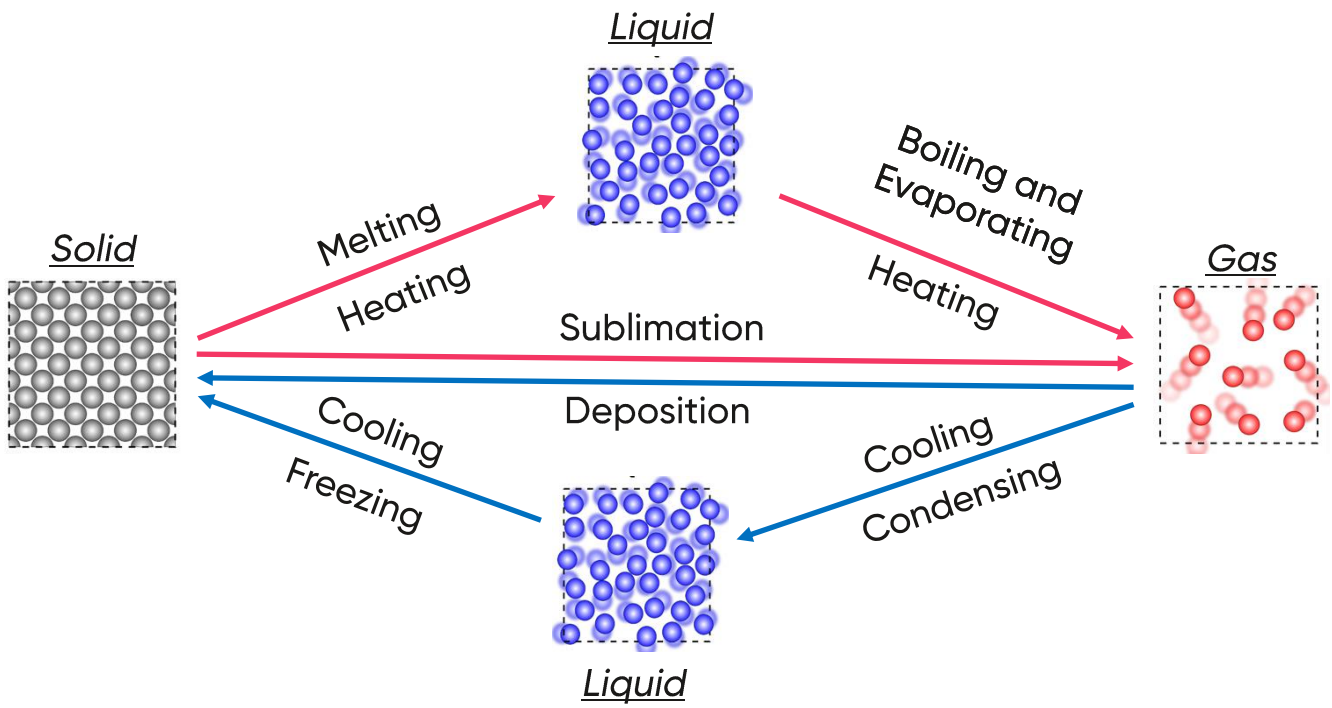
A) Define specific latent heat

B) Calculating specific latent heat

Starter: If you heat two containers of liquid equally, how can tell which one has the higher latent heat? Explain your answer.

Objective A: Defining latent heat

The three most commonly encountered states of matter are solids, liquids and gases. When a substance changes state, it does not change temperature, but thermal energy is still transferred.



The energy needed to change the state of a substance is called latent heat.

Specific latent heat of fusion, L, is the energy transferred from 1kg of a substance changing from liquid to solid at a constant pressure (J/kg or Jkg^{-1}).

Specific latent heat of vaporisation is the energy transferred to 1kg of a substance changing from liquid to gas at a constant pressure.

	Latent heat of fusion	Latent heat of vaporisation
Melting	Energy gained by substance	
Freezing	Energy lost to surroundings	
Evaporating		Energy gained by substance
Condensing		Energy lost to surroundings

The thermal energy transferred for a change of state may be calculated using the following equation:

Thermal energy transferred for a change of state = mass x specific latent heat

$$Q = mL$$

Q is the thermal energy transferred, in joules, J

m is the mass of the material/substance, in kg

L is the specific latent heat, J/kg

Practice A:

1) State the equation for latent heat
2) Explain why the units for latent heat are J/kg
3) Write a sentence defining latent heat in words.
4) If two objects have different specific latent heats, how can you work out which one is higher?
5) Describe sublimation using latent heat.

Assessment A:

Latent heat is...

A	the energy required to raise 1°C of material by 1kg.
B	the energy of 1kg of material.
C	the speed of state change of 1kg of material.
D	the energy required to change state of 1kg of material..

Objective B: Calculating specific latent heat

Worked example 1

The specific latent heat of vaporisation of water is 2,260kJ/kg. How much energy is required to evaporate 100kg of water?

$Q = ml$ <- Q, thermal energy, is already the subject

$Q = 2{,}260kJ/kg \times 100kg$ <- Input the values from the question

$Q = 226{,}000kJ$ <- Bendegedig [Wonderful – in Welsh]

Worked example 2

The specific latent heat of fusion of glacial ice is 3.36 x 10^5 J/kg. If 6,720kJ of thermal energy is transferred, how much ice will be melted?

$Q = ml$ <- You need to rearrange so that mass, m, is the subject

$m = \frac{Q}{l}$ <- Now mass, m, is the subject

$m = \frac{6{,}720kJ}{3.36x10^5 J/kg}$ <- Input the values from the question

$m = \frac{6{,}720{,}000J}{3.36\times10^5 J/kg} = \frac{6.72\times10^6 J}{3.36\times10^5 J/kg}$ <- Convert kJ to J(multiply by 1000)

$m = 20kg$ <- Tak! (Thanks – Norwegian)

Worked example 3

Rebecca finds 30L of a mystery liquid. The liquid has a density of 1,780kg/m^3. The liquid requires 8,250kJ of energy to become entirely frozen. What is the specific latent heat of fusion?

$Q = ml$ <- You need to rearrange so that specific latent heat, l, is the subject

$l = \frac{Q}{m}$ <- Now specific latent heat, l, is the subject

$m = 0.03m^3 \times 1{,}780kg/m^3$ <- 30L = 0.03m^3. Input the values to calculate the mass, m,

$m = 53.4kg$ <- Here is the mass of the liquid

$l = \frac{8{,}250kJ}{53.4kg}$ <- Input the values into the earlier equation

$l = 154.494kJ/kg$ <- Asta e grozav! [That's great!! – in Romanian]

Practice B:

Q1. Work out the missing values from the following table. Fill in the units and descriptors.

Q	M	L
8.38 MJ		838,000 J/kg
251 kJ	0.75 kg	
	100 g	449,000 J/kg
740 mJ	10.0 mg	
1.09 MJ		199,000 J/kg

Q2. A sample of solid ethanoic acid is at its melting point of 17°C. It has a specific latent heat of fusion of 192,000 J/kg. How much ethanoic acid can be melted with 864 kJ of thermal energy?

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Q3. A 1,000 W heater is placed in an insulated beaker containing 750 g of water at 100°C. The water vapour is allowed to escape. Assume that there is no loss to the surroundings via conduction, convection or radiation. The specific latent heat of vaporisation of water is 2,260kJ/kg.

a) How much water is left after 5 minutes?

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b) How long will it take for half of the water to have evaporated?

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Assessment B:

If the thermal energy is 300kJ and the mass is 0.2kg, what is the latent heat?

A	1500 kJ/kg
B	300 kJ/kg
C	150 J/kg
D	70 J/kg

Plenary

Discussion question: Why are there two different forms of latent heat?

Tutorial 3 – Kinetic Energy

Objectives for this tutorial:

A) Define kinetic energy

B) Calculating kinetic energy

Starter: How can you increase the kinetic energy of an object? Explain your answer.

Objective A: Defining kinetic energy

The kinetic energy associated with a moving object depends upon its mass and speed.

Kinetic energy is a scalar quantity, which means that it has a magnitude but no direction.

Kinetic energy is measured in Joules (J).

Numerically, if an object has 1J of kinetic energy, it will require a 1N force to stop it in 1m, as work done = force x distance (W=Fd, 1Nm = 1N x 1m). Kinetic energy can be calculated using the following equation:

Kinetic energy = ½ x mass x speed^2

$$E = \frac{1}{2}mv^2$$

E is the kinetic energy, in joules, J

m is the mass of the material/substance, in kg

v is velocity, in m/s or ms^{-1}

Practice A:

1) Explain the difference between speed and velocity.

2) Write a sentence defining kinetic energy in words.

3) If two objects have a different kinetic energy, how can you work out which one is higher?

4) How can you create kinetic energy?

Assessment A:

Kinetic energy is…

A	present with a moving object
B	present with a static object
C	only present in an accelerating object
D	only present in one direction

Objective B: Calculating specific heat capacity

Kinetic energy = ½ x mass x speed^2

$$E = \frac{1}{2}mv^2$$

E is the kinetic energy, in joules, J

m is the mass of the material/substance, in kg

v is velocity, in m/s or ms^{-1}

Worked example 1

A bike with a mass of 8kg is travelling at a velocity of 20m/s. Calculate the kinetic energy of the bike.

$E = \frac{1}{2}mv^2$ <- Energy, E, is already the subject

$E = \frac{1}{2} \times 8kg \times 20m/s^2$ <- Calculate the energy, E

E = 1600kJ <- Bon!

Worked example 2

A car has is travelling at a velocity of 60m/s with a kinetic energy of . Calculate the mass of the car.

$E = \frac{1}{2}mv^2$ <- You need to rearrange so that mass, m, is the subject

$m = \frac{2E}{v^2}$ <- Mass, m, is now the subject

m = (2 x 1800000kJ)/(60m/s)^2 <- Calculate the mass, m

m = 3600000/3600 = 1000kg <- Perfect!

Practice B:

Q1. What is the kinetic energy of an object with a mass of 2t and a velocity of 2m/s?

Q2. Calculate the percentage increase of the kinetic energy caused by a velocity increase of 8m/s.

Q3. What is the velocity of an 0.5kg ball with a kinetic energy of 100kJ?

Assessment B:

If the mass and velocity of an object both double, how will the kinetic energy change?

A	Twice as large
B	Four times as large
C	Two times less
D	It will stay the same

Plenary

Discussion question: Compare kinetic energy and thermal energy.

Tutorial 4 – Energy Efficiency

Objectives for this tutorial:

A) Define energy efficiency

B) Calculating energy efficiency

Starter: Which has a higher specific heat capacity, water or air? Explain your answer.

Objective A: Defining energy efficiency

To carry out an energy analysis of a physical event or process, we need to identify a clear start point and an end point. We then consider and calculate the changes in in the energy stores at the start point and the end point.

It is always true that there is no overall change in the total of all the energy stores – energy is conserved.

However, it is often the case that a process results in an overall increase in less-useful thermal stores (and a corresponding decrease in the total of the more-useful stores). What is meant by the word 'useful' depends on the situation. Sometimes it may be fairly obvious; sometimes you may be told; in some situations, you may have to think carefully.

For any given process (or system) we can calculate its efficiency. Efficiency has no units. It is usually written as a decimal (generally between 0 and 1), as a fraction or as a percentage.

Efficiency = useful energy transferred/total energy transferred

To express efficiency as a percentage, multiply the decimal answer by 100.

Sometimes the total energy transferred is the total electrical or mechanical work done.

Practice A:

1) State the equation for energy efficiency.

2) Write a sentence defining energy efficiency in words.

3) Explain why understanding energy efficiency is important.

4) If two objects have different specific heat energy efficiencies, how could you work out which one was more efficient?

Assessment A:

An energy efficient lightbulb will…

A	Always cost more.
B	Be cheaper to use.
C	Always cost less.
D	Be more expensive to use.

Objective B: Calculating energy efficiency

Worked example 1

If a washing machine wastes 30J of every 300J it requires, what is the energy efficiency?

Efficiency = useful/total <- Efficiency is already the subject

Efficiency = (300J-30J)/300J <- Input the values from the question

Efficiency = 9/10 = 0.9 <- Calculate the decimal efficiency

Efficiency = 0.9 x 100 <- Calculate the value as a percentage (multiply by 100)

Efficiency = 90% <- Sim (Yes – in Portuguese)

Worked example 2

An 80W lightbulb has an energy efficiency of 45%. How much energy is wasted by the lightbulb in 10 minutes?

Energy (J) = Power (W) x Time (s) <- Calculate the energy from the power

80W x 10 (minutes) x 60 (seconds) = 80W x 600s = 48000J = 48kJ <- Energy used in 10 minutes

Energy Wasted = 100% - Energy Efficiency = 100% - 45% = 55% <- Energy wasted by the bulb

Energy Wasted = 55% of 48kJ = 0.55 x 48kJ <- Calculate the energy

Energy Wasted = 26.4kJ <- Bene (Good – in Italian)

$\Delta\Theta = 2°C$ <- Ja, das ist richtig! [Yes, that is correct! – in German]

Practice B:

Q1. If the useful energy is 80J and the total energy is 100J, what is the energy efficiency?

Q2. If lightbulb A wastes 20J of every 200J it uses and lightbulb B wastes 10J of every 50J it uses, which lightbulb is more efficient?

Q3. In 5 minutes, a 1kW cooker wastes 60kJ. Calculate the energy efficiency of the cooker.

Assessment B:

If the total energy is 1kJ and the energy wasted is 200J less than the total value, what is the energy efficiency?

A	80%
B	20%
C	100%
D	8%

Plenary

Discussion question: How can we increase the energy efficiency of a device?

What is the Purpose of Tutorial 6?

- To receive feedback on final assignments.
- To share examples of best practice with the other pupils in your group.
- To write targets for improvement in school lessons.
- To reflect on the programme including what was enjoyed and what was challenging.

Final assignment feedback

What I did well...	What I could have improved on...
•	•
•	•
•	•

My target for future work is...

Reflecting on Uni Pathways

What did you most enjoy about Uni Pathways?
• • •

What did you find challenging about the programme?	How did you overcome these challenges?
• • •	• • •

What is the purpose of this page?

People in all walks of life often struggle with where to start. This is especially true of what we do when we start revising. We often think that reading or copying notes out is a good idea, but this is NOT true. The number one tip I can give you when you get down to it is it needs to be active. Your notes are a great start, but it really is what you do with them that counts.

Below are the top-tips for getting the most out of revision.

Revision guide

1. Know where to start: you need to know what you're revising for. When it's an end of unit test it's really easy, you just look back a few lessons, but what about for those final exams? I would always suggest starting with something broad and low-stakes, SENECA learning is a great resource for jogging your memory on a topic, and its easily split up into each unit you need to tackle! So, if you want to revise energy, look at Physics Unit 1 in our class.

2. Check exactly what you need to know: use your AQA spec and tick off which bits you think you have!

3. Use your notes, textbooks, revision guides, to make some dedicated revision resources: flashcards are a great way to test yourself or others on definitions or the many equations you need to know in science!

4. Deliberate practice: work in rich and varied examples. You need to think of every way you could be asked a question on a particular topic. Think about how I've set up this book! Examples from your textbook and revision guides are a good start here (THIS IS THE MOST IMPORTANT PART).

5. Apply it: exam questions, exam questions, exam questions, you can never do too many! The more you do, the more you PRACTICE, the better you get at answering the style of question AQA is going to throw at you!

6. Work in rest: If you feel yourself flagging, make a cuppa!

What is the purpose of this page?
EXAMS!!!! Arghhh, right? Here are some top tips!

Exam guide

1. Questions have a common theme: in other words, question 1 is all about question 1, that's why it's a single question. It might have (a), (b), (c), etc but they're probably all about 1 unit or part of a unit.

2. If you're stuck on something, move on: just because you can't do one bit, doesn't mean you can't do the next. Try it, what's the worst that can happen?

3. If you're unsure of context, think what it's similar to: instead of thinking, 'hmm, I've never done that before,' think, 'aha, I've done this thing that's very close to it.' See also, OSMOSIS HAPPENS IN CARROTS AS WELL.

4. Look at the marks: if you've spent 5 minutes on a 1-mark question it's way too long. 1 mark = 1 minute, stick to it.

5. Stop and think before you start to write: make sure you take the information you've just read in, like, all the way. If you need to make some rough notes before answering an extended question, do it, it's better than waffling on like a monologuing supervillain!

6. Use graphs, diagrams, and tables: no, really, they don't put them in for giggles.

7. Look at bold print: it's important...if it says one answer, give one, any more will probably lose you marks.

8. Highlight key terminology, words, and command words: if that's your gig, I mean, I never did it but it might help you focus on what's needed. This neatly leads me onto...

9. KNOW YOUR COMMAND WORDS: there's a list, online, download it. I've always found it helps to know what a question is actually asking you to do...and finally,

10. Breathe: when it feels like all is lost, take yourself a nice deep breath, we don't want you passing out in an exam do we? No, but seriously, sometimes taking a minute not looking at a question you're struggling on can make all the difference. The answer may just come to you in a vision!

Notes

Notes

Notes

Never gonna' heat you up: Thermal Energy

Key Stage 4 Programme

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