Step up to GCSE Physics, a Teacher's Guide

Who is this book for?

- Year 9 students are the principal audience. Most of the pages are about material covered in KS3, but they give it a numerical basis which should help those students prepare for GCSE and also for the numerate nature of Physics thought itself. Schools which follow Ofsted advice in not teaching GCSE in Year 9 may find this particularly useful in that many GCSE skills are built up and concepts explored.
- Year 10-11 students who need a bit more practice with the fundamental concepts of their course (e.g. momentum, voltage, acceleration, density). These students should find that the educational pace of this book is slower than the Isaac Physics GCSE book.
- Year 7-8 students who wish to extend the largely qualitative understanding they are building up. These questions could be used with certain students as extension material, or alternatively, certain schools which prefer a more quantitative approach to science teaching may wish to use some sections of this book for mainstream teaching even with those age groups. That said, Isaac Physics is in the process of preparing quantitative yet accessible material for use by Year 7 and 8 students, which should be available to schools for use in September 2022.
- Experienced teachers new to teaching physics may find this book helpful in getting to grips with physics topics and how to apply them without the constraints of learning it in the way needed for a specific examination board. The book was written to give a really good foundation for the study of physics, and this may be as useful to a teacher new to teaching physics as it is to a student.

This book is unashamedly numerical. To many students, physics makes more sense when numbers are used, and a number pattern can be worth a hundred words (or even ten pictures). We make no apology for this, and we hope that you will find many pleasant surprises (as the author did in his adventures in teaching) in the wide range of students who find the subject more accessible, satisfying and comprehensible when it is presented quantitatively.

How can this book be used?

- **Main point: each double page spread is a separate stand-alone topic: use the ones you find most helpful.**
- This book is not a course, nor is it written in alignment with a particular course, although the topics are drawn from the principal ingredients of the KS3 science curriculum. Therefore, please use the parts which are useful to you, and feel free to use them in an order which makes sense in the context of the scheme of learning of your school. There will be other parts which do not fit in with the way in which your students learn, and you will want to miss those out. Indeed, I don't think that you could cover all of this material in Year 9 within the time usually allocated to students of that age for Physics.
- You can use it **in class to cover specific topics** (e.g. calculating speeds). If you are doing this traditionally, then the approach we recommend is to
    - Project the cloze text version https://cdn.isaacphysics.org/isaac/books/Step_up_to_GCSE_Physics_cloze_text.pdf of the page you are using. This contains the notes of this book, but

    with the red sections replaced by blanks. This serves as a good template for an introductory discussion in class.
    - More confident students, after the initial discussion, will be happy to get started on the questions (the early questions in a section are more straightforward) while you guide and support less confident students with the idea and the first question or two.
    - By the time the less confident students are ready to start the early questions by themselves, their confident fellow students will have reached the harder questions, and may require hints, encouragement or guidance. There are notes in this teachers' guide to help you with this process.
    - Homework can be set, and if set on Isaac Physics using http://isaacphysics.org/books/step_up_phys will be automatically marked to give you feedback on the students' progress. The website contains specific collections (boards) of questions suitable for homework (quick boards).
- The book is also suitable for **flipped-lesson learning**, especially if the students have access to Isaac Physics online. Here students would have homework to read a particular page and try one or two questions. The 'Assignment Progress' feature of the website allows you to plan your lesson focused on the areas of support your students need based on their answers so far.
- You can also use it as a supplementary resource for **intervention** with particular students, who would get instant feedback when entering their answers online.
- At the end of a topic, the '**calculation practice**' sections on pages 75-78 enable students to practise equation rearrangement with the main equations of that topic in simple contexts.
- More thorough **review questions** are found in the Extra Questions chapter (starting at p79). Full and short versions of these review sections are available online for use in revision homework tasks.
- Once students have had feedback on the review questions, they can complete an online **topic test** if you set that to them on Isaac Physics (full and short versions are available). These closely mirror the summary questions in approach and layout. You can choose when students receive their marks and feedback.

Practice and Challenge

Questions are marked on the website (and indicated in this guide) as either for practice (P questions) or challenge (C questions). The former involve applying the ideas just taught in a direct manner. The C questions involve a bit of problem solving, or a link with a previous idea.

Force and Motion

This is going to be an essential part of your physics curriculum. If you want a short course, with no bells or whistles, then you may wish to focus on the main bullet points here:

- 3 - Displacement-time graphs. Support for this given in
  - 1 - Displacement (representing position as a number)
- 4 - Velocity (introduced graphically)
- 6 - Calculating velocities. Support for this is given in
  - 2 - Converting units
  - 5- Rearranging equations
- 7 - Velocity-time graphs
- 8 - Acceleration. Extension for this is given in
  - 9 - Calculating accelerations
- 11 - Weight and Resultant Force
- 12 - Force and Acceleration

Straightforward calculation practice questions can be found in section 38, while more thorough review questions are in section 42. A test based on the review section is available online.

If you want to introduce the ideas of motion graphically (without formulae) you could use sections 3,4,7,8; whereas if you preferred to use only equations you could use sections 5,6,9. We do think a combined approach (as above) is better as it gives students different ways of understanding these concepts.

If you wish to take a different approach to dynamics (the link between force and motion), you may prefer to avoid F=ma and take a Newtonian approach by introducing the link between force and motion through the idea of momentum (sections 13-15). Many students find this beneficial as the concept of momentum (‘motion’ in Newton’s writing) is much more intuitive than acceleration, and the subsequent idea that ‘Force changes motion’ is often easier to get across than ‘Force causes acceleration’ in the traditional context.

Section 1 - Displacement

More challenging questions: None
Questions on the ‘quick’ homework board: 2,4,6,8,9

This section is optional, but can be used if you wish to give your students a good grounding in the way we measure position as a displacement. We consider one dimensional motion, so the positions occur on a number line marked in centimetres. The book has + as right and - as left, however when demonstrating in class, you may find it helpful to speak of + as forward and - as backward.

Students will benefit from visualising motions walked through at the front of the class before beginning questions for themselves. You may wish to set up a row of metre sticks along the front of the room so that positions of +1m, +3m, 0m and -1m can be pointed out. You can then ask questions like “If I start here, go forward 2m then back 3m, where am I going to end up?” With that introduction, students should be able to approach the questions.

This section does rely on the use of negative numbers. If your students are less confident with this, you can use this section to give them practice. Alternatively, if you prefer to avoid the negative numbers, you may prefer to start this book at section 3.

This section, and the book as a whole, uses variables like s, v, t and so on to represent measurements. Where the measurement changes (example: “I move forward 3m”), then we use the Greek letter delta Δ to mean ‘change in’. In our example we would say Δs = +3m to make it clear we are moving forward 3m from where we started without saying anything about *where* we started.

While it may seem overcomplicated to insist on putting + and - for the different directions, and distinguishing between measurements (s) and changes (Δs), the aim of this book is to set students up well so that with a good foundation, they are less likely to be confused later when the distinction becomes essential.

Please make it clear that distance does not have a sign - it is the total journey length regardless of direction moved. If you walked 100m forwards, then 100m backwards, you have still walked 200m (this is the distance travelled).

Section 2 - Units of Distance

More challenging questions: 3,4,5
Questions on the [‘quick’ homework board](): 2,4,6,8,10

Converting units is a really important skill, but many find it difficult. Because of the importance of units, we do include some questions requiring unit conversion in Section 6 - Calculating Velocities (Q6.6-8), and also in Section 9 - Calculating Accelerations (Q9.6-8). If you would rather stick to easier calculations and not worry about converting units, feel free to miss out this section, but it is then a good idea to ensure that the relevant questions from sections 6 and 9 are omitted.

Some students will be happy with the idea of cancelling units as shown in Example 3, others will prefer to take it one step at a time (as in Examples 1 and 2). You may wish to include the ‘cancelling units’ method in teaching with one or two groups of students as part of your differentiation.

Q2.3 Convert 30 miles into kilometres. Numerically, this gives you 30mph in km/h.

Q2.4 Convert 43 nautical miles into km (divide by 1.85) then convert the km into miles (multipy by 1.61).

Q2.5 Convert 12 nautical miles into miles. This is the number of miles travelled each hour.

Section 3 - Displacement - time graphs

More challenging questions: None
Questions on the 'quick' homework board: 1,4,5,6,8,10

When discussing this with your class, please take time to talk through the Example graph. The cloze text version is helpful for projection - students have to fill in the blanks.

Students often enjoy having a row of metre sticks at the front of the room, with volunteers following a displacement-time graph which has been projected by moving up and down the row, with others commenting on whether the graph was followed accurately. This can serve as a good way for them to visualise the concept.

Please don't set Q3.3 if you do not want to discuss negative displacement.

Q3.5, 3.8, and 3.9 refer to 'storeys' in the building, which are not marked on the graph. The text near the graph explains that the floors are 4m apart, so s=0m is the ground floor, s=4m is the first floor, s=8m is the second floor and so on.

Q3.9 and Q3.10 ask for the displacement change each second. This idea is going to be built on in section 4 where we look at velocity.

Section 4 - Velocity

More challenging questions: None
Questions on the 'quick' homework board: 1,3,4,5,7,8

While this section does give the formula for velocity, the idea is that the students work the velocities out from first principles and the graphs rather than plugging numbers into a formula and gain appreciation for velocity as the displacement change each second.

Where the displacement-time graph has a 'downwards slope' (in other words, a negative gradient), the velocity will be negative (representing 'backwards' motion).

Given that the Example graph can be projected, it is probably worth going through not only the example, but also Q4.1 in a whole class discussion, as it refers to the same graph.

Please make sure that the class appreciates that where speeds are mentioned, we aren't worried about the direction.

Also, make sure that they don't fall into the trap of thinking that you take the averages of a lot of speeds in order to get the average speed. The average speed is the one, steady speed you could have to do the whole journey in the time you took and is calculated from the formula: average speed = total distance / total time.

Q4.1 Where we are asked for velocities at particular times (eg. 4s in part (a)) we measure the gradient of the whole straight line which includes that point. So for part (a), we note that t=4s is in the middle of a straight line part of the graph from t=2s to t=6s, and so we work out the velocity from the 4m of displacement gained during those 4s (v=4m/4s = 1m/s).

Q4.7 On the graph, we move 12m upwards, then 16m down to go 4m below the starting point before rising again to the starting height. The total distance is 12m + 16m + 4m.

Q4.8 Here we take the total distance from Q4.7 and divide by the total time (40s).

Section 5 - Re-arranging equations

More challenging questions: 9
Questions on the ‘quick’ homework board: 1,2,4,6,7

This section is optional, but many students appreciate practising equation rearrangement in abstract terms before having to rearrange equations where there is a physical meaning and context. You can use the methods shown in the examples to help your students, and if they need more practice, we would advise the use of sections 17 and 18 of our workbook *Using Essential GCSE Mathematics* for further practice.

If you set these questions for students to do online, students will have to enter their equations by typing into the Isaac Physics equation editor (e.g. typing a=b/c). If you want to type a multiplication (F = ma), the students should either put a space between the things to multiply, or a * symbol. It is worth demonstrating how this works in class before students do this by themselves. There is a help video on the equation editor at https://isaacphysics.org/solving_problems?stage=all#symbolic.

If you just want students to practise rearranging a formula like s=vt, then just get them to do questions 1-6. None of questions 1-8 involve a recurring decimal. Questions 7 and 8 introduce ideas of proportionality, and question 9 involves a more difficult kind of equation (although there is a worked example).

Q5.7 We assume u does not change. u = s/t = 30/0.5 = 60. So when s = 15, t = s/u = 15/60 = 0.25.

Q5.8 We assume T does not change. T = An = 120x3 = 360. So when n=24, A=T/n = 360/24 = 15.

Q5.9a As r = 2.5, and s = 6, the left hand side of the equation (r/s) is equal to 2.5 / 6 = which is the same as 5/12 (you can see this if you multiply both the 2.5 and the 6 by two). So 5 / 12 = u/v = u / 12, so u = 5. A similar method can be used for part b.

Section 6 - Calculating Velocities

More challenging questions: None
Questions on the ‘quick’ homework board: 1,2,4,7,8

In this section, students practise using the formula Velocity = Displacement change / Time taken. Please do not expect students to find q6-8 easy if they have not been taught how to convert units (section 2 can be used as a resource for this). If you do not want to worry about converting units, then just use q1-5.

Q6.6a First convert the 90 miles into 90 x 1610m = 144900m, then time will be the distance divided by the velocity, and will come out in seconds. The student should give their answer in seconds.

Q6.7 In part (a), convert the distance of 21 nautical miles into metres. This is the distance covered each hour. In part (b), we get the distance travelled each second by taking the answer to part (a) and dividing by the number of seconds in an hour.

Q6.8 The snail moves half an inch (0.5 x 0.025m = 0.0125m = 1.25cm) each second. The number of seconds taken to travel 80cm is then 80/1.25 = 64s. You can equally do it formally using the formula $\Delta t = \Delta s / v = 0.8 / 0.0125$ if you prefer to stick with metres and m/s.

Section 7 - Velocity-time graphs

More challenging questions: None
Questions on the 'quick' homework board: 1,5,6,9,10

When explaining this to the class, you may wish to project the cloze text version where the text in red is missing and discuss the introduction and the example. Q7.1 uses the same graph, so this can be covered with the class as a whole if you wish.

When looking at a motion graph, it is vital that the students first notice whether it is a graph of displacement or velocity. In the book, to help students notice the difference, the vertical axis label is in **red for velocity graphs**, and **black for displacement graphs**.

Q7.3 If you did not introduce displacement formally using section 1, your class may need a bit of help visualising what a negative velocity will be. Here negative values of v represent the hoist coming down.

Q7.7 This is a **velocity-time** graph not a **displacement-time** graph. The greatest upwards velocity is the largest v value reached (here +1.5m/s), and has got nothing to do with gradients. We use gradients to read velocities from displacement-time graphs.

Q7.8b This question introduces the idea of acceleration - the velocity gain each second, without giving the word. This will be built on in the next section.

Q7.10 **Deceleration** means slowing down. The first period of deceleration is when the hoist slows down from 1.5m/s to 0m/s, however we have to be careful when identifying the second deceleration. It is not the motion from 13s to 14s - here the hoist is speeding up (moving downwards). However at the end, when it slows to a stop after going at 2m/s downwards, that is a deceleration. It is tempting to think that all 'downhill' lines on a velocity-time graph represent decelerations - but this is not true when the velocities are negative. Decelerations are when the line is pointing in towards the horizontal axis, whether from above or below. There is more about this in the next section (especially at the top of page 16).

Section 8 - Acceleration

More challenging questions: 9,10
Questions on the ['quick' homework board](): 1,2,5,8,10

While this section does give the formula for acceleration, the idea is that the students work the accelerations out from first principles and the graphs rather than plugging numbers into a formula and gain appreciation for acceleration as the velocity change each second.

Where the velocity-time graph has a 'downwards slope' (in other words, a negative gradient), the acceleration will be negative. If the slope is pointing towards the horizontal axis, then the speed is reducing, so it is a deceleration. Note that downwards slopes don't always mean deceleration (you get a downward slope if you are speeding up while you reverse).

Given that the Example graph can be projected, it is probably worth going through not only the example, but also Q8.1 in a whole class discussion, as it refers to the same graph.

Q8.9 To answer this, take the answer to Q8.8 (the velocity gain in 6.4s if increasing by 25m/s each second), and add it to the new initial velocity of 32m/s.

Q8.10 This is saying that you start with 45m/s, and lose 10m/s each second, so it will take you 45/10 = 4.5s to lose all of the speed.

Section 9 - Calculating Acceleration

More challenging questions: 5,6,7,8
Questions on the ['quick' homework board](): 1,2,3,6,8

In this section, students practise using the formula Acceleration = Velocity change / Time taken. Please do not expect students to find q6-8 easy if they have not been taught how to convert units (section 2 can be used as a resource for this). If you do not want to worry about converting units, then just use q1-5.

Q9.3 This is about the time taken to stop. The acceleration given is negative because the vehicle is slowing from high speed forward motion. The acceleration of -4.5m/s^2 means that it loses 4.5m/s of speed each second. So in 3.5s, it can lose 3.5 x 4.5 = 15.75m/s, which is therefore the top speed. If you went any faster, you would not be able to stop in 3.5s.

Q9.5a Change in speed = change in velocity = acceleration x time = 30 x (5 x 60) m/s - remember that the acceleration has to be in m/s^2 (so 3g = 30m/s^2) and the time has to be in seconds.

Q9.5b First work out the acceleration in m/s^2, then divide by 10 to get it in g.

Q9.5c The acceleration is 7 x 10m/s2 = 70m/s^2. Then use time = velocity change / acceleration to get the time.

Q9.6 Convert 40mph into m/s using the method in Example 2, then use acceleration = velocity change / time taken.

Q9.7 Convert the 120mph velocity difference into m/s using the method of Example 2, and then use acceleration = velocity change / time taken.

Q9.8b Convert 70mph into m/s using the method of Example 2, then use time = velocity change / acceleration.

Q9.8c Use velocity change = acceleration x time to work out the velocity change. As the velocity is decreasing from the initial speed to 0, the velocity change is numerically equal to the starting speed. You now need to convert it into mph using the method of Example 2.

Section 10 - Displacement from a Velocity-Time graph

More challenging questions: 8,9,10
Questions on the ‘quick’ homework board: 1,3,4

This section, which is optional, might help students understand the link between acceleration and distance covered (useful when thinking about braking distances, for example). Students calculate areas under velocity-time graphs, and also use the formula Displacement change = average velocity x time taken, where the average velocity is the average (arithmetic mean) of the starting end ending velocities[1].

You may wish to use the cloze text version of this section for discussion so that students can see Example 1 and then discuss Example 2 as a whole class. Questions 1 and 2 use the same graph, so can also be discussed while the cloze text version is projected.

For questions 3-10, remember that the hoist is moving downwards from t=13s to t=20s. This means that during this period, the values of v are negative, and the displacement changes are also negative. Q4-7 talk about total displacement changes (where the hoist is in relation to its starting point) and distance moved (how far it moved since starting). The latter will never be negative. You may need to give your class a reminder that if you walk 10m forwards, then 10m backwards, you have walked 20m of distance, but there is no displacement change at the end.

Q10.3 Students use the graph (or ideas of average velocity) to work out displacements. These are all either motion at steady velocity, or motion starting from rest, or decelerating to rest, so the ‘shapes’ on the graph will all be rectangles or triangles. If you want a trapezium, try Q10.10.

Q10.4-10.7 It is worth students checking their answers to Q3 before doing these later questions, as they depend on the results of the parts of Q3.

Q10.6-10.7 It would be helpful for students to be able to check their answers to Q10.4 and Q10.5 before doing Q10.6 and Q10.7. The answer to Q10.6 is given by Q10.4 - Q10.5 (moving backwards ‘undoes’ forwards motion), whereas the answer to Q10.7 is Q10.4 + Q10.5 (both directions still count as moving somewhere).

[1] This is acceptable as the accelerations are all steady.

Q10.8 Students need to have done Q10.3d,e in order to do this one. They should notice that if you double the time, the displacement quadruples. This can be explained to the class as ‘you have been moving for twice as long at twice the average speed, so you go four times as far’.

Q10.9 Students should do Q10.8 before tackling this one. There is no need to work out the speeds in m/s - the important thing to notice is that 60mph is twice as fast as 30mph, and so the rule from Q10.8 can be applied.

Q10.10 For this period, on the graph, the shape under the line is a trapezium. You can either use the idea that the average velocity is 1.5m/s for a time of 1s, so the displacement is 1.5 x 1 = 1.5m, or you can calculate the area under the graph. The calculation can be done by splitting the shape into a rectangle and a triangle, or using the rule for trapezia if students know it.

Section 11 - Weight and Resultant Force

More challenging questions: None
Questions on the ‘quick’ homework board: 1,3,5,6

The two key concepts here are using W=mg to calculate weights from masses and vice-versa (Q11.1-11.3) and working out resultant forces (Q11.4-5). Q11.6 puts both ideas together.

Students are encouraged to draw diagrams when working out the resultant force. Students will have different ways of visualizing it. For example, with Example 2 where there is a 2.5N force upwards and a 2.0N force downwards, some might say “The 2.0N force cancels out most of the upwards force, leaving 0.5N unbalanced.” Others might subtract to get the resultant (although it is important that they note its direction), while other students might like the prescription of adding numbers (using negative numbers for forces downwards).

Q11.6 If we take (b) as an example, the student first has to work out the weight (6N). If the air resistance is 4N upwards, the resultant will be 2N downwards.

Section 12 - Force and Acceleration

More challenging questions: 4
Questions on the ‘quick’ homework board: 1,3,5

If you are going to teach your students about momentum, you may wish to leave this section out, and use section 15 instead after momentum has been covered.

The first part of the sheet stresses the idea that **constant velocities come from balanced forces**. It is worth asking the class lots of questions of the form of the Example and Q12.1 - many will be itching to start multiplying or adding numbers, when actually there is no need.

Please do not move on to Q12.2 and F=ma until the message of Q12.1 has sunk in.

Q12.2 involves practice of F=ma. Parts (e) and (f) require the calculation of the resultant force before F=ma can be used.

Q12.3 (a) requires F=ma to work out the resultant force from the acceleration and mass. Part (b) requires a separate W=mg calculation. In part (c) the student needs to add their answers from (a) and (b) to get the thrust required (for some students "it needs to balance the weight AND ALSO provide the force to accelerate the rocket" helps them to visualise the situation). A good diagram will help here.

Q12.4 Firstly, the student should work out the weight (900N). They can then work out the resultant forces for each part (e.g. 900 - 500 = 400N in part (b)). Finally, the accelerations can be worked out from a = F/m where F is the resultant force already calculated. If you wish you can talk about the motion in the form of a story. Part (c) is at terminal velocity (balanced forces = constant velocity), and in part (d) they have just opened their parachute and are decelerating.

Q12.5 This is not a mathematical question, but comes back to the idea of Q12.1 and also whether students realise that the direction of the resultant force on an object does not necessarily tell you which way it is moving (think about the parachute just after it has been opened). Students may well find the answers to the 'speeding [up] or slowing [down]' column reasonably intuitive (it slows down on the way up, and speeds up on the way down), but many may struggle with the idea that in all of these situations, the resultant force is downwards (air resistance can be pretty much neglected here unless the ball is thrown very hard). It might help to say something like "on the way up, the ball is slowing down, so the force is in the direction opposing motion" and "on the way down, the ball is speeding up, so the force is in the direction of motion". Any student who instinctively gets Q12.5 right on the first go has done something very impressive indeed. It took Galileo most of his life to work out the role of force in motion.

Section 13 - Momentum

More challenging questions: 6,7,9
Questions on the 'quick' homework board: 2,3,4,5,6

There really is no need to introduce Year 9 students to momentum, but this section has been included as some educational research suggests that an approach which does use momentum leads to a more instinctive appreciation of Newton's Laws than the traditional route through acceleration. Here it helps that for most students, momentum is a more intuitive idea than acceleration ("What did you say a square second was, Miss?") Indeed, Newton wrote his laws (or axioms) in terms of what he called motus (motion), and you may like to refer to 'motion' rather than 'momentum' to help make it clearer.

The main teaching point (when we get to force) becomes '**forces change the motion**'.

Section 13 sets the scene by getting students to do calculations to get the hang of momentum as mass x velocity, and the idea that the sign of the momentum (+ or -) depends on the direction of motion.

Q13.1-4 are all about calculating momenta using p=mv.

Q13.5-9 ask students to calculate changes of momentum. In these cases, encourage the students to work out the momentum before and after separately, and then subtract to get the final answer. Remember that if the final momentum is in the opposite direction to the starting momentum (as in Q13.7), then the change in momentum is numerically larger than either of the starting or final momenta (if you minus a minus you get a plus…) It may help to visualize the situation of the ball in Q13.9 - what does the floor do? It pushes upwards firstly to stop the ball falling and then upwards again to accelerate it upwards - both involve a change in momentum 'the same way' ie upwards.

Q13.6 As the motions are West, the before and after momenta will both be negative.

Q13.7 The initial motion is East (momentum is positive), but the final momentum is West (negative momentum). The signs must be taken into account when working out the difference (which will be an even 'bigger' negative number).

Q13.9 Students can use 'g m/s' rather than 'kg m/s' if they don't want to convert to kilograms, however when they start working with forces, they will always have to convert to kg first. Given the convention in the question, the ball starts with downwards (negative) momentum, and finishes with upwards (positive) momentum. The upwards speed is 6.5m/s x 0.60 = 3.9m/s.

Section 14 - Momentum, Impulse and Force

More challenging questions: 5,6,9
Questions on the 'quick' homework board: 1,2,4,7

If you have introduced momentum to your students using Section 13, then this section builds on this by showing the students the link between force and momentum (a force of 8N changes the momentum by 8 units each second).

Q14.5 In (a) and (b), read the momentum at the start. Then work out the impulse (force x time). The final momentum will be the starting momentum + the impulse. In (c) and (d) work out the 'before and after' momenta, and subtract to get the momentum change. This will equal the impulse (=force x time), and from this the missing force or time can be calculated.

Q14.6 Students should do Q14.5 and have had some of their answers checked before they do this question. The added complexity here is that they have to work the momenta out using mass x velocity.

Q14.7 With part (b) and (c) try to get the students to see that these can be worked out from the answer to (a), the momentum change, divided by the time taken. There is no need to calculate an acceleration and use F=ma.

Q14.9 This is nasty. Sorry. Put the mass of the ball in kg (0.16kg) so that the calculation will work and give the forces in newtons. Work out the final speed (44m/s), and then the starting and ending momenta **remembering that they will be in different directions**. The force will then be given by the momentum change divided by the time (0.12s).

Section 15 - Force and Acceleration from Momentum

More challenging questions: 3,7
Questions on the 'quick' homework board: 1,2,4,7,8

This section is the alternative to Section 12 for students who have been taught momentum. It still shows them F=ma, as this formula is used at GCSE etc. You might even try different approaches with different classes and see which approach works best for your students.

Students must have done Sections 13 and 14 before they can do Section 15.

The first part of the sheet stresses the idea that **balanced forces do not change the momentum**. It is worth asking the class lots of questions of the form of the Example and Q15.1 - many will be itching to start multiplying or adding numbers, when actually there is no need.

Please do not move on to Q15.2 or F=ma until the message of Q15.1 has sunk in.

Q15.3 This is very hard for Year 9, however the method is more or less given in the question. The momentum gained by the propellant in one second will be 5kg x 1400m/s = 7000 kgm/s. As this is the **momentum change each second**, it is numerically equal to the force (7000N). You can discuss with your class how rockets are made given that the thrust = rate of propellant usage (kg/s) x exhaust velocity (m/s). First stages (for lift off) tend to use kerosene fuel because it is more dense and therefore you can get a high number of kg/s more easily, as required to combat weight on the launch pad and beyond. For upper stages, where we want the biggest acceleration (resultant force / mass), we are more interested in in less dense propellants where the molecules move faster after combustion - which is why hydrogen is often used.

Q15.7 In part (a) it is easiest to use F=ma. For part (b), the student needs to work out the rocket's weight (32N), and work out the thrust as the sum of F=ma and the weight. Part (c) uses similar logic to Q15.3 - to get the rate at which the propellant needs to be used (in kg/s), you divide the force needed (the answer to (b)) by the exhaust speed (1600m/s).

Q15.8 This is not a mathematical question, but comes back to the idea of Q15.1 and also whether students realise that the direction of the resultant force on an object does not necessarily tell you which way it is moving (think about a parachute just after it has been opened). Students may well find the answers to the 'direction of momentum' column reasonably intuitive (this car is always travelling North), but may struggle with the idea that the resultant force is not always North in the direction of motion. It might help to say something like "forces in the direction of motion increase the momentum, forces opposing the motion decrease the momentum". Any student who instinctively gets Q15.8 right on the first go has done something very impressive indeed. It took Galileo most of his life to work out the role of force in motion.

Electricity

Like motion, this is going to be an important part of your Year 9 curriculum. If you want a short course, with no bells or whistles, then you may wish to focus on the main bullet points here:

- 17 - Voltage in circuits, which can be given a theoretical underpinning by
    - 16 - Energy, charge and voltage (which covers E = QV)
- 20 - Current in circuits, which can be given a theoretical underpinning by
    - 18 - Charge and current (which covers $\Delta Q = I\,\Delta t$ and also the amp-hour for batteries)
- 21 - Resistance (including R=V/I), which can be supported by
    - 19 - Large and small numbers (for familiarity with mA and kΩ)

Depending on whether you wish to introduce current or voltage first, you can use sections 17 and 20 in either order. Personally, I prefer to do voltage first, as once understood, students seem able to visualise circuit principles (which bulb is brightest etc.) more easily.

Straightforward calculation practice questions can be found in section 39, while more thorough review questions are in section 43. A test based on the review section is available online.

Section 16 - Energy, charge and voltage

More challenging questions: 6,7,8
Questions on the [‘quick’ homework board](): 2,3,4,5,6

Introducing E=QV may seem a bit heavy for Year 9, but if we want them to have an understanding of what voltage is (which is in KS3), then we are going to have to mention energy, so may as well do it numerically. This section can also be used by GCSE students who need a bit more practice with this equation. Most of the questions in this section just need rearrangements of E=QV, but Q16.6 onwards ask students to think about what is going on with the energy in a circuit.

Q16.6 (a) is a straightforward E=QV calculation, (b) requires this energy to be shared between two identical bulbs (ie halved), and in (c) this halved energy is divided by Q to get the voltage across one lamp. This shows that the voltage across one lamp is half of the battery voltage because the energy has been shared (without the charge being shared, as would be the case in a circuit with junctions).

Q16.7 Note that this question involves non-identical lamps. In part (a) we do E=QV = 10C x 12V for the gain in energy of the charge in the battery. As the circuit is series, the charge flowing through the battery is the same as the charge flowing through the first bulb. In part (b) we do E=QV = 10C x 7.5V as we use the voltage across this bulb. We subtract the answer to (b) from the answer to (a) to get the energy in the second bulb for part (c). In part (d) we work out the voltage of the second bulb from V=E/Q using the answer from (c) and the usual charge of 10C. This reinforces the idea that voltages across bulbs in a series circuit add to give the battery voltage even if the bulbs aren't identical.

Q16.8 Now we come to a parallel circuit, which is one with a junction. In the text it tells us that of the 12C which exit the battery, 5C go through lamp A, while the remainder (7C) must go through lamp B (this is requested in part (d)). Part (a) is calculated using E=QV = 5C x 9V. These 5C flow through bulb A and give up all of the energy, so the answer to (b) is the same as (a). The voltage across bulb A is calculated in (c) using V=E/Q = answer to (b) / 5C, and we find it to be the same as the battery voltage.

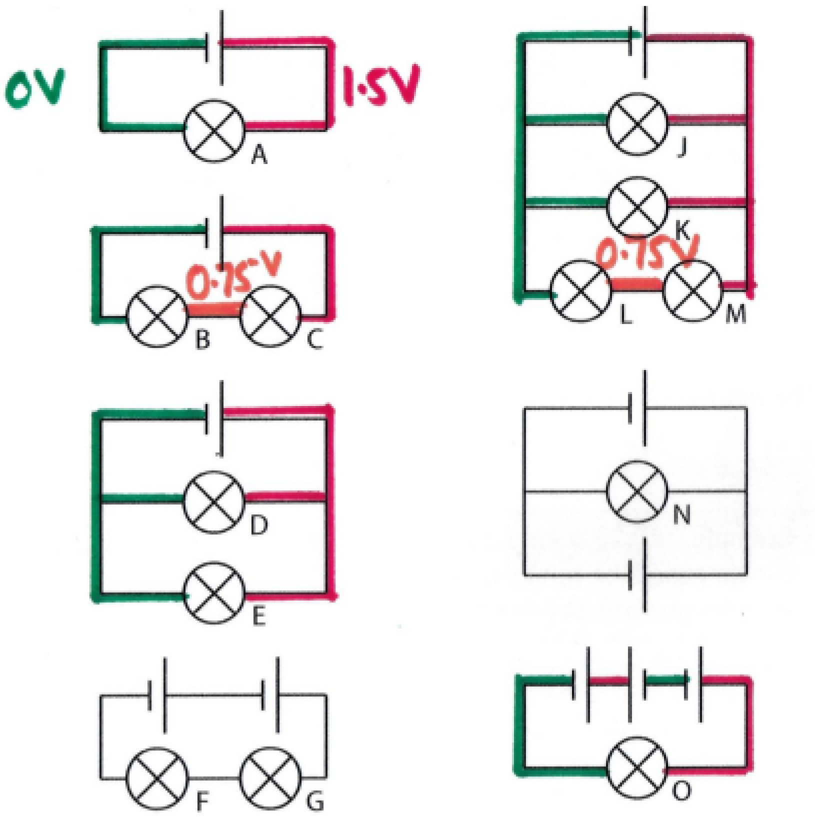
Section 17 - Voltage in circuits

More challenging questions: None
Questions on the 'quick' homework board: 2,3,4,5,8 (lamps B,C,D,E,F,G,H,I,O)

Please work through the examples and as many circuits as it takes before students get the hang of this method, where wires are labelled with their voltages. It is often clearest to use colours, and so you may wish to ensure your students have access to coloured pens or pencils (green for 0V, red for 1.5V, orange for voltages between 0V and 1.5V, and blue for anything higher than 1.5V). Once you start colouring in a wire, all parts of it must be the same colour (so bulbs D and E each get the full battery voltage). Whether the bulb is bright or not comes from the voltage difference across it.

Make sure that your students understand that a cell the 'wrong way round' as in O doesn't break the circuit, it just subtracts 1.5V. While the 1.5V cells on classroom circuit boards can cope with being connected the wrong way round for short periods of time, **please do advise the students that connecting batteries the wrong way round in practical circuits can lead to permanent damage to the circuit, as well as risking dangerous chemicals leaking from the battery and a fire hazard.**

In the book, deeper pink colours are used for higher voltages, and when we start studying current, the currents are shown by the thicknesses of the lines. Online, shades of grey are used to indicate the voltage. Some examples with colours are given here:



Section 18 - Charge and current

More challenging questions: 6,7,8,9,10
Questions on the 'quick' homework board: 1,2,4,5

This section explores the relationship between charge and current. We continue the idea from the motion section of using delta Δ to represent 'changes' so the equation is written $\Delta Q = I \Delta t$. In Q18.1 - Q18.4 we use amps, coulombs and seconds, then in Q18.5 to Q18.10 we use a different unit of charge - the amp-hour, often used to measure battery lifetime. Finally Q18.11 looks at how currents might flow in a circuit with junctions.

Q18.4 When answering part (a) the time is in hours. This needs converting to seconds.

Q18.6 The times in hours are given by 1000 mAh divided by the current in mA. For the light bulb the current is 0.25A = 250mA.

Q18.7 The capacity is the current charging it multiplied by the time taken to charge (assuming it is efficient), so 8A x 7h = 56 Ah

Q18.8 We are told that the capacity in coulombs is 9000C, which means 9000 amp-seconds. There are 60x60=3600s in one hour, so if we divide 9000 by 3600 we will get the number of amp-hours (the number of hours it could supply one amp for).

Q18.9 Here we take the capacity in amp-hours from Q18.8 and divide by a current of 0.1A (100mA) to get the number of hours taken to charge.

Q18.10 Charge in coulombs = current in amps x time in seconds = 1.0A x 60x60s.

Q18.11 In part (a), as the bulbs are identical, and 3.0C flowed out of the battery, half of this will go through each lamp. In part (b) we can work out the battery current from battery charge divided by 12s. In part (c) we can take the bulb charge from part (a), and divide by the time (12s). However the student may well spot that if half the charge went through the lamp, it will also have half the current of the battery, and will halve the answer to (b).

Section 19 - Large and small numbers

More challenging questions: None
Questions on the [‘quick’ homework board](): 1,2,3,4

Given that electrical measurements often use prefixes (especially currents in mA and resistances in kΩ), this is the worksheet dealing with handling prefixes and also standard form. The final questions are there if you wish to work out the number of electrons which are going to be flowing around your circuit. This is, of course, up to you!

Q19.1 This question asks for quantities to be written with the ‘most suitable’ prefix (as illustrated in Example 1). By this we mean the one which is quickest to write having the smallest number of zeroes. We would prefer 0.1mA to 100μA.

Q19.6 Take the charge and divide by the charge on one electron (as in Example 3).

Q19.7 In part (a) use charge = current x time and put the current in amps (0.05A) before multiplying by the time to get the charge. Then if this charge is divided by the [magnitude of the] charge on an electron (1.6×10^{-19} C), you get the number of electrons. Don’t worry about the fact that the charge is positive and the electron is negative - you get the answer correct for the number of electrons. The negative sign has something to do with the direction they flow, but that is a story for another day.

Q19.8 In part (a) total charge = number of electrons x charge on one electron = $1.25 \times 10^{22} \times 1.6 \times 10^{-19}$ coulombs. In part (b), divide the charge from part (a) by 2000s to get the current in amps.

Section 20 - Current in circuits

More challenging questions: None
Questions on the [‘quick’ homework board](): 2,3

It is worth working through the cloze text version of the book on the screen with your class, and possibly doing the first circuits from Q20.1 together too so that the class gets the hang of it. The two rules are

- Current is not used up as it goes round the circuit
- Current does split at junctions. If the two options are identical (in circuit D-H), then it will split 50/50. Otherwise, extra information will be given in the question so that you

can work out the answer (e.g. if 10A splits, and 2A goes one way, then 8A must go the other way).

Q20.2 In part (a), remember that current is not used up. 300A went in, and so 300A must come out. In part (b), the total current of 300A has been provided from two transformers, with one providing 120A. The other must therefore be providing 300A - 120A.

Q20.3 Here everything is wired in parallel (if it weren't, it would not be possible to turn some lights off without them all going out). So we add up all of the currents: 6x0.25A + 10x0.021A, remembering to convert the 21mA into 0.021A.

Section 21 - Resistance

More challenging questions: None
Questions on the ['quick' homework board](): 2,3,4,5,6

The main purpose of this section is to allow students to practise using V=IR. Please note that Q21.3, Q21.4, Q21.6 require the students to be familiar with the units mA and kΩ (support resources for using prefixes are in section 19).

Questions Q21.7-9 also make use of a graph of current against voltage. Please note that because the current is on the vertical axis (as customary in school work), the resistance is 1/gradient of a line drawn from the origin to the point of interest, not the gradient of the line itself. So the shallower a line is, the higher the resistance.

Q21.9 The student can use any point on the red line on the graph to work out the resistance of the resistor. However you get the best accuracy if you use a point as far from the origin as possible. The 4V, 0.5A point is probably the easiest one to use.

Section 22 - Electrical Power

More challenging questions: None
Questions on the ['quick' homework board](): 2,3,4,6

This section enables students to practise using P=IV, although the final two questions involve reading values from a graph and calculating powers in a circuit from a diagram.

Students do not usually cover P=IV pre-GCSE, so this section can be omitted, however for some students, this formula helps them get to grips with the concepts of voltage, current and how they work together. For example, they may enjoy coming up with analogies - voltage is how much stuff you put on each lorry, current is how many lorries go from the depot to the supermarket each day. Multiply the two and you get the total goods delivered each day.

Q22.5 takes students step by step to work out the power when a 0.25A current flows through a 20Ω resistor, paving the way for the day when they have to meet $P=I^2R$ at GCSE.

Q22.7 requires circuit analysis (sections 17 and 20). For the first (series) circuit, both bulbs have 0.2A currents, but each will only get half of the battery voltage (0.75V each), so each have a power of 0.15W, whereas the battery has the same 0.2A current but the full 1.5V voltage, so a power of 0.30W. We see that the battery's power has been divided equally between the bulbs. In the second circuit (parallel), but bulbs get the full battery voltage of 1.5V, but each bulb only gets 0.3A whereas the battery is supplying 0.6A. Again, the battery power is shared fairly between the bulbs, but the total battery power is larger than in the series circuit. Therefore the battery in the parallel circuit won't last as long before going 'flat' as the one in the series circuit.

Section 23 - Sharing Voltage

More challenging questions: None (providing the students follow the advice given)
Questions on the 'quick' homework board: 1,2,3,4

"Potential dividers in Year 9? Isaac Physics, you must be mad!"

If that is your first reaction, remember that you are the boss with your class, and if you don't think these questions will help your students, feel free to miss them out (or use them with your Year 11s or Year 12s instead). However if students who like numbers are able to explore series circuits using this section, they will come away with a better understanding of the way a series circuit works (which is a KS3 requirement). It is well worth projecting the cloze text version and working through the notes, the example and Q23.1 together with the class before setting them loose on the other questions. Remember too, that when using the questions in class, you can have students working on them together in teams or pairs.

Q23.3 You know that the component is 300Ω, and has 5.0V across it when things are working well. This means we can calculate the current using I=V/R. This current will also flow in the resistor. The resistor needs to have the rest of the voltage (10V). We can now work out the resistance of this resistor by dividing 10V by the current (R=V/I).

Q23.4 This question refers back to the circuit drawn in the example. When the thermistor is cooled, its resistance rises to 80Ω, so the total resistance also rises (to 70Ω + 80Ω = 150Ω). The thermistor now has a fraction 80/150 of the total resistance, so will take this fraction of the 12V total circuit voltage.

Q23.5 This question can be done by trial and error: "Suppose we put the voltmeter across the LDR. When the room gets darker, the resistance of the LDR increases, so its share of the total resistance increases, so its share of the total voltage increases. This means that the voltmeter reading will go up when it gets dark. This is not what we want, so we put the voltmeter across the resistor instead. Now, when the room gets darker…"

Q23.6 We start by working out the resistance of one bulb when things are working normally. As the 40 bulbs are identical, they will each take 1/40 of the total voltage, namely 5.75V. If each one has a current of 120mA = 0.12A, we can work out the resistance of the bulb using R=V/I. That is the value of resistance we need to replace the bulb if we want the other bulbs to behave as they did originally.

Energy and Balance

Unlike the first two chapters (motion and electricity) which developed a common theme, this chapter contains separate sections all linked to the concept of energy. This means that each double page spread largely stands alone, and you can choose the ones you wish to use.

If you simply wanted coverage of the main core of KS3, you might just use:

- 27 - Energy flow and efficiency
- 28 - Balancing and moments, possibly with
- 24 - Work (if you wanted to give a bit more quantitative detail on force & energy)

You can, however, extend these ideas using the other chapters as you choose

- 25 - Gravitational potential energy
- 26 - Power (practises the use of E=Pt, however P=Fv is also demonstrated & used)
- 29 - Energy and temperature which give more information on thermally stored energy

Straightforward calculation practice questions can be found in section 40, while more thorough review questions are in section 44. A test based on the review section is available online.

Section 24 - Work

More challenging questions: None
Questions on the ‘quick’ homework board: 1,2,4,5,7

Before doing questions from this section, it is worth students discussing examples of forces which do and which do not require a fuel or change in the way in which the energy is stored. As a result of this discussion, students usually spot that the forces which do involve energy transfer also involve motion. A more rigorous discussion will also tease out that there is no energy transfer unless there is some motion in (or against) the direction of the force (if the force is perpendicular to the motion, as when a planet goes in a circular orbit around its star, then energy is not ‘moved’ from one store to another).

With the importance of motion established, we can bring up $\Delta E = F \Delta s$ and practise this idea. In Q24.1 and Q24.2, all quantities are positive. For the remaining questions, the force is sometimes in the direction of motion, and sometimes the force opposes the motion.

We use the way in which negative numbers multiply to give mathematical grounding to these situations. We use the convention from section 1 that + and - represent right and left (as on a number line). If the force and the motion are in the same direction, then F and Δs have the same sign, and so ΔE is positive (work is done on the object, increasing its own store of energy at the expense of some other object). If the force opposes motion, then F and Δs will have opposite signs so ΔE will be negative (work is done by the object, decreasing its own energy stores).

Q24.7 Here, we rearrange $\Delta E = F \Delta s$ to make Δs the subject. You can regard ΔE as the ‘energy lost’ and then you have $\Delta s = \Delta E / F$ = 280kJ / 7kN, however if you wanted to be more rigorous about the signs, you would take ΔE = -280kJ (we need to take energy away from the van), and F = -7kN (force is opposite to the direction of motion).

Q24.8 In (a) we multiply the force 4kN by the distance 2km. As the car is going at a steady speed, the resistance forces must balance the engine force (see section 11 or 15), so the resistance force will be 4kN backwards (or F = -4kN). The energy transfer from this force is ΔE = F Δs = -4kN x 2km = -8 MJ, so the car loses 8 MJ of energy it would otherwise store itself. Part (c) specifically asks for the work done BY the car, so it is asking for the loss of energy, so the correct answer to this part is 8 MJ (the loss is positive). Please do discuss the energy situation here. The engine's force 'gives' the car 8MJ of energy, but the car 'gives that away' to increasing the store of thermal energy of its surroundings. Thus despite the work of the engine, the car has no greater store of energy at the end than the beginning if the engine and resistance forces balance. Put another way, it will not accelerate, so there is no change in its speed and hence its kinetic energy.

Section 25 - Gravitational potential energy

More challenging questions: None
Questions on the 'quick' homework board: 1,3,5,6

This section can be used as a follow on to section 24 on work (the example shows how to use the formula for work to deduce ΔE = mg Δh) or as standalone practice of the formula for gravitational potential energy. From Q25.3 onwards, the object might be going down (so Δh would be negative) corresponding to a loss of energy in the 'gravitational energy store' (indicated numerically by a negative value of ΔE.

Q25.3 The student must rearrange to give Δh = ΔE/(mg) with ΔE = 2 200 000J and mg = 72kg x 10N/kg = 720N

Q25.5 The context may make this question harder to 'see into', but it shows practically how lifts can be made efficiently. Part (a) requires the use of ΔE = mg Δh with m=230kg and Δh = 9.0m. In part (b) we have three people and the lift car, so m = 230 + 3x76 = 458kg. We still have Δh = 9.0m. In part (c) we are just considering the counterweight, so m=300kg. However when the lift goes up 9.0m, the counterweight goes down 9.0m so Δh = -9.0m. This gives a negative value for ΔE. You may like to explain to the class that the energy needed from the motor is going to be much less as a result of the counterweight - indeed they could calculate the total energy by adding their answers to (b) and (c) (this is about 14 000J - much less than would be needed without a counterweight).

Q25.6 There are excellent YouTube videos available of very large pumpkins being winched up and dropped on old school buses as part of Autumn ('Fall') celebrations in North America. Please note that no calculation is needed for (b) - the gain in kinetic energy will equal the loss of the gravitational energy gained in part (a). The answer to part (c) will be the answer to (a) minus 3500J.

Section 26 - Power

More challenging questions: 6,7,8 (Q5 onwards require the student to have covered 'work'.)

Questions on the ‘quick’ homework board: 2,3,5,9

This section gives practice in the use of $\Delta E = P\ \Delta t$. Here we measure energy in joules, power in watts, and so the time must be given in seconds. Questions 26.5 onwards require the student to have already met the idea of work (section 24).

Q26.2 The student must not forget to convert the five minutes into 300s, and the 90kJ into 90 000J.

Q26.3 Here we take the power (1kW = 1000W) and multiply by the time (1h = 60x60s = 3600s) to give the energy of 1 kW h in joules. You can explain that the kWh is the unit most frequently used to measure electricity usage (eg as registered on electricity meters both old and smart).

Q26.4 The power saving per bulb is 60 - 5.5 = 54.5W. I then have to multiply this by six (there are six bulbs) and also by the number of seconds in six hours (the time the bulbs are on) to get the total energy saving. Equally we could work out the energy used with the old bulbs, the energy with the new ones and then subtract to get the saving.

Q26.5 For part (a) we use the work formula $\Delta E = mg\ \Delta h$ = 250N x 0.52m to get the energy for each ‘lift’, then multiply by 15 as she lifts it 15 times. In part (b) we take the answer to (a) and divide by 20s.

Q26.6 In (a) use $\Delta s = v\ \Delta t$ = 7m/s x 240s. In (b) multiply the force (150N) by the distance calculated in (a). In part (c) we divide the work done by the time (240s). You should find that your answer to (d) is the force. This is justified in the explanation below the question in the book.

Q26.7 (a) we can reason that for half the time, we need double the speed; or we can work it out as 1680m (the answer to Q26.6a) divided by 120s (half the time in Q26.6). The new power in (b) will be twice the answer to Q26.6c. You can either work this out by multiplying the force 150N by the new speed, or by repeating the calculation method of Q26.6.

Q26.8 For (a) do 110 x 710W. For (b) we multiply the power in (a) by the number of seconds in 15 minutes. For (c) we rearrange equation $P = F\ v$ to give $F = P/v$. Alternatively, if you don’t want to teach $P=Fv$, the students can work with one second’s worth of motion. The work done will be the power x 1s (numerically equal to the power), and so the force will be this work divided by the distance (which in one second is 44m).

Q26.9 To work this out, use $P = \Delta E / \Delta t$ where ΔE = 6 500 000J and Δt is the number of seconds in one day.

Section 27 - Energy flow and efficiency

More challenging questions: None
Questions on the ‘quick’ homework board: 1,3,5,6

Conservation of energy is the theme of Q27.1 to Q27.4 (although some questions are phrased in terms of power rather than energy). Q27.5 onwards are about percentage efficiency, and require the use of the formula: efficiency = Useful energy (or power) x 100% / Total energy (or power).

It may be worth mentioning to classes that limits on the practical temperature achieved in conventional coal/oil/nuclear power stations limit the efficiency to about 40%. Gas power can work at a higher temperature, leading to higher efficiencies, although the gas is not a renewable energy source. UK solar panels used for electricity generation tend to be about 20% efficient at the moment.

Q27.8 In (b) the question asks for the wasted power, so either work out 60% of 30kW, or work out the useful power and subtract it from the total power to get the answer. In part (c) the useful power is given as 2.0kW. This is 40% of the total (i.e. 2000W = 0.40 x total), so we work the total power out using 2000W / 0.40. Another approach is to say that 2000W is 40%, so 1% will be 2000/40 = 50W, so the full power (100%) will be 100 x 50W.

Section 28 - Balancing and moments

More challenging questions: None (but q4 requires the student to have covered 'work')
Questions on the 'quick' homework board: 2,3

Balancing and moments has traditionally been part of KS3. Here Q28.1-2 enable the student to practise the formula moment = force x distance from pivot, Q28.3 is about balancing, while Q28.4 is an optional question which shows how the principle of moments comes about from ideas of energy and work.

Q28.3 The students can work in metres (as in the example) or in centimetres if they prefer. In parts (d) and (e) there are more than two forces. Students should remember here that the total of all the clockwise moments must equal the total of the anticlockwise moments. The equation for (d) therefore looks like 2.0m x 30N + 1.0m x 80N = 70N x D. Remind them that the important distance is the distance to the pivot (not to the next force).

Q28.4 In (a) the beam moves in the direction of the force, so work = force x distance = 10N x 0.01m = 0.10J. In (b), point B moves upwards (against the 20N force), but as it is half as far from the pivot as A, it will only move half as far (0.5cm rather than 1.0cm). In (c) we do work = force x distance = 20N x (-0.005m) = -0.10J. Note the negative because the force is in opposition to the motion. In (d) the total work is the sum of (a) and (c), giving zero. A balanced beam is one where it takes no net energy to change its angle.

Section 29 - Energy and Temperature

More challenging questions: 4 (which also requires the use of $\Delta E = P \Delta t$ from section 26)
Questions on the 'quick' homework board: 2,3,4,5

Students should be aware from earlier learning in KS3 that when the temperature of something goes up, it has a larger store of thermal energy. If you want to explore this numerically with your class, you can use this section.

If you are used to teaching GCSE and/or A-level, please note that in this section, the idea of *heat capacity* (energy to heat a whole object by 1°C) is introduced and worked with before the more advanced idea of *specific* heat capacity (energy to heat 1kg by 1°C) is mentioned. Please be very careful not to get those mixed up.

Q29.4 In part (a) we can work out the energy needed to heat the water by multiplying the heat capacity (5000J/°C) by the temperature change (80°C). In part (b) we add the 150 000J of wastage to the answer from part (a). Finally, in part (c) we divide the total energy (the answer to part (b)) by the power (2000W) to get the time in seconds.

Q29.5-29.8 involve specific heat capacity. The GCSE equation $\Delta E = m\ c\ \Delta T$ can be used for this, although the example doesn't quote the equation but works the question out in stages.

Materials and Forces

Just as the questions in the last section were separately connected to the common idea of energy, this chapter contains separate sections all linked to the concept of force. This means that each double page spread largely stands alone, and you can choose the ones you wish to use.

If you simply wanted coverage of the main core of KS3, you might just use:

- 30 - Density
- 33 - Springs
- 34 - Pressure

You can, however, extend these ideas using the other chapters as you choose

- 31 - Floating and sinking
- 32 - Friction

Straightforward calculation practice questions can be found in section 41, while more thorough review questions are in section 45. A test based on the review section is available online.

Section 30 - Density

More challenging questions: 3,5,6
Questions on the 'quick' homework board: 2,3,4,5,7

These questions allow students to practise using the formula $m = \rho V$. Initially, masses are all in grams, volumes in cm^3 and densities in g/cm^3, so water has a density of $1.00 g/cm^3$. From Q30.4 onwards, students are expected to also work in kg and m^3, and Example 2 gives a method of doing this.

Q30.3 Here students need to know how to calculate the volume of the steel block: 5cm x 5cm x 5cm = $125cm^3$.

Q30.5 Here students need to calculate the volume 10m x 25m x 1.2m = $300m^3$, before they can work out the mass. Do point out that a cubic metre of water has a mass of one tonne (1000kg)!

Q30.6 The ethanol content of alcoholic drinks is often measured using density - this question is about a bottle of wine. In part (a) we work out 10% of $750cm^3$ = $75cm^3$, which allows us in part (b) to use $m=\rho V$ = 0.79 x 75 to work out the mass of the ethanol in grams. In part (c) the water will have a volume of $750cm^3$ - $75cm^3$ = $675cm^3$, enabling us to work out the mass of water in part (d) using $m=\rho V$. In part (e) we use the total mass divided by the total volume ($750cm^3$) to get the overall density. If very precise measurements are made, when water and ethanol are mixed, the overall volume is a tiny bit less than the sum of the original volumes of ethanol and water, but this effect is not significant here.

Q30.8 In part (a) the maximum mass of fuel will be the maximum take off mass (75 000kg) minus the mass of the aircraft (43 000kg) and the mass of 150 x 80kg people. In part (b) the answer is obtained by dividing the fuel mass from part (a) by the density of the fuel.

Section 31 - Floating

More challenging questions: 8,9,10
Questions on the ['quick' homework board](): 6,7,9,10

Students in KS3 often investigate floating - this question explores the ideas numerically. Students will need to have studied Section 30 (density) first. Q31.1 and Q31.2 are intended for class discussion rather than individual work, and once this has been raised, then Q31.3 is a good question to be done as a whole class, with Q31.4 then done by groups or individuals with support.

Q31.1 In part (a) as the liquid has been still for a while, it must be in equilibrium, so the forces must be balanced. This gives us the answer to part (b).

Q31.2 The thought-experiment here works like this: the rest of the fluid hasn't changed, so the upwards force (which is caused by the rest of the fluid) won't have changed either. So the upwards force is 5N, and is equal to the weight of the fluid which was pumped out. If the box only weighs 1N, then the upwards force is greater than the weight, so the box will float, whereas if the box weighs more than 5N, it will sink.

Q31.3 In part (a), 110cm^3 of water had to get out of the way to make room for the apple. For part (b), the mass of water is worked out using $m=\rho V$ with $V=110cm^3$. In part (c) we use W=mg with m coming from part (b) and g=10N/kg. In part (d) W=mg with m=100g here (the mass of the apple). In part (e) if the weight of water moved out of the way (the answer to (c)) is larger than the weight of the apple itself (part (d)), the apple will float.

Q31.8 In part (a), use $m=\rho V$ to work out the mass of helium, then use W=mg to work out the weight. In part (b) use $m=\rho V$ to work out the mass of the air displaced, then use W=mg to work out the weight. Parts (a) and (b) involve very similar calculations, however the densities are different, so the masses and weights will be different too. The difference between your answers to (b) and (a) is the net upward force which can be used to lift the payload, and will equal the maximum payload weight. Therefore if you take this difference and divide by g, you get the maximum payload mass. Part (d) requires the whole calculation to be reworked with the density of helium replaced with the density of hydrogen. This question is relevant, as air transport of goods by airship is likely to be more sustainable than by aeroplane, so we might see more airships in our sky in the future.

Q31.9 We can neglect the mass of the air in this question. To support a 120kg person, the float must provide an upwards force of W = mg = 120kg x 10N/kg = 1200N. To do this, it must displace 1200N of water, which is 120kg of water. The volume of the float is therefore the volume of 120kg of water, and we can use $V = m/\rho$ to finish the question.

Q31.10 When two 70kg people get in, the weight of the boat rises by 140kg x 10N/kg = 1400N, so before it steadies, it must sink enough to displace an extra 1400N of water (which is 140kg of water). The extra volume = cross sectional area of the boat x extra distance it sinks. So distance sunk = volume of 140kg of water divided by 3.3m^2.

Section 32 - Friction

More challenging questions: 3,4,6,7
Questions on the [‘quick’ homework board]: 1,3,4,5

These questions allow students to calculate friction forces using F=μN and to explore the differences between static friction (which prevents stationary objects from beginning to move) and dynamic friction (which tries to slow down objects already moving).

We start with dynamic friction, as this is just given by F=μN. The surfaces are all horizontal, so the normal reaction force (support force) is balancing weight so N=W=mg.

From Q32.5 onwards, we bring in static friction. Here μN gives the maximum friction force the surface can provide, not the actual force in a particular circumstance. For example, suppose μ=0.2 and m=2kg. Thus N = W = mg = 20N, so F=μN = 4N. If you push the block sideways with a 2N force, this is less than 4N, so the block will remain stationary, and the friction force in that case will only be 2N (to balance the 2N you provided). So μN does not give the friction force itself, but the maximum friction force which can be provided.

Q32.3 This should be tackled in exactly the same way as Example 2 on p64.

Q32.4 Here we work out the friction force as in Example 2 on p64. The friction is the only horizontal force here, so the acceleration a=F/m is given by the friction force divided by the mass.

Q32.6 For part (a) work out N = W = mg = 4 x 10 = 40N. Thus in the static situation μN = 0.40 x 40N = 16N. If the applied force is less than this, the mass won’t move. For part (b) we use the coefficient of dynamic friction and μN = 0.20 x 40N = 8N. If the applied force is equal to this, the mass will keep moving at a steady speed. If the applied force is greater, the mass will speed up, and if the applied force is smaller than 8N, the mass will slow down.

Q32.7 In (a) the tyres grip the road, so don’t slip on it, so we use the coefficient of static friction (μ=0.52) to work out the maximum braking force (= maximum friction force of tyre on road). In (b) the tyres are slipping over the road, so the force slowing the car will have μ = 0.35, and we work out the force using μN with that value of μ.

Section 33 - Springs

More challenging questions: None
Questions on the [‘quick’ homework board]: 2,4,5,7

This section is all about springs and working out extensions (and lengths) from tensions and vice versa. Please note that this section is built around a student working the answers out from an understanding of proportionality rather than just plugging numbers into a formula such as F=ke. That said, the formula is introduced in Q33.6. Q33.7 and Q33.8 also require a knowledge of W=mg.

Q33.7 We have to be careful with units here. The 40kg suitcase has a weight of 40 x 10 = 400N, and when we divide this by 8.0cm we get the spring constant in N/cm. If we wanted the spring constant in N/m we would need to convert the extension into metres: 0.08m.

Q33.8 This may be about extension, but the same approach holds. The spring constant is the force (20 000N) divided by the compression (2cm or 0.02m). In part (b) don't forget that the weight of a 200kg mass is 2000N.

Section 34 - Pressure

More challenging questions: 6,8,9
Questions on the 'quick' homework board: 1,4,7,8

This section enables students to practise applying the equation F=PA to a variety of situations. In Q34.1 to Q34.5 unit conversions are not needed (either the areas are in cm^2 and the pressures are in N/cm^2; or the areas are in m^2 and the pressures in N/m^2 = Pa). However, following Example 2 (which shows the method) the student is expected to be able to convert between m^2 and cm^2 (or between N/cm^2 and Pa).

Q34.6 Here the student can either take their existing answer to Q34.5a ($20N/mm^2$) and convert this to N/cm^2 remembering that there are 10mm in 1cm, so $(10mm)^2 = 100mm^2$ in $1cm^2$. Alternatively, they can do the question afresh, converting the area from $2.5mm^2$ into $0.025cm^2$ and calculating P=F/A from this. The difficult bit is remembering that there are $100mm^2$ in $1cm^2$, so $1N/mm^2 = 100N/cm^2$.

Q34.8 It is best to work in metres. First work out the area of the window (0.8m x 0.8m = $0.64m^2$). The question tells us the pressure is 300 x 10 kPa (that is 10kPa for each metre of depth), which is a pressure of 3000kPa = 3000 000 N/m^2. Finally we multiply the area and the pressure to get the force. This shows you one reason why they generally don't put windows in submarines unless it is really essential.

Q34.9 It is worth doing Q34.8 before this one. The methodology is the same. It is worth working out the area of the window in square metres (0.1m x 0.05m = 0.005 m^2) before multiplying by the pressure (10 kPa x 10 000m = 10^8 N/m^2).

Waves

Wave ideas feature in KS3, but usually in a descriptive form. This section was introduced at the request of a teacher who wanted to cover more detail regarding the meaning of frequency with their Year 9 classes, and also wanted to introduce them to wavelength and the wave equation. A section on echoes is also included as it is a good practical application of the speed-distance equation s = vt, and illustrates many of the uses to which waves are put.

The sections cover:

- 35 - Frequency and time period
- 36 - Wavelength and the wave equation
- 37 - Echoes and distance measurement (eg sonar, radar…)

More thorough review questions are in section 46. A test based on the review section is available online.

Section 35 - Frequency

More challenging questions: None
Questions on the 'quick' homework board: 1,3,6,8

It is worth projecting the text version of the notes (or the cloze text version) while you explain time period and amplitude for the first time. This also enables you to work through the first questions with your class, or those who need a bit of extra support.

In Q35.1 to Q35.5, students practise the equation f = 1/T.

In Q35.6, the students read off the amplitude and time period from a graph, then calculate the frequency using f = 1/T.

Q35.6B The graph does not start at a peak, but the student can either spot that the section from 0s to 0.04s is the repeating pattern (so T=0.04s) or can measure the time from the 0.05s peak to the 0.01s peak as 0.05 - 0.01 = 0.04s.

Q35.6D The graph does not show a whole wave, but the section from 0s to 0.04s is half a wave, so the time period must be 0.08s.

Q35.7 to Q35.10 are similar to the first questions, but include times given in ms and μs with frequencies in kHz and MHz.

Section 36 - Wavelength and the wave equation

More challenging questions: None
Questions on the 'quick' homework board: 1,3,4,6

Here students measure wavelengths from graphs of ‘freeze frame’ waves in Q36.1 and Q36.2. They are then introduced to the formula $v = f \lambda$ and practise that. At the top of page 72 (also in the notes page) a justification for this formula is given, which you may wish to project when introducing this equation.

When looking at a wave graph, it is vital that the students first notice whether it is a graph in time or distance. In this book, to help students notice the difference, the horizontal axis label is in red for distance graphs, and black for time graphs.

Section 37 - Echoes

More challenging questions: 10
Questions on the ‘quick’ homework board: 1,2,4,7,10

These questions do not use the concepts of frequency or wavelength, so this section can be used independently of the other waves pages. Questions from Q37.6 onwards use times in ms, μs and ns.

Q37.10 The time difference (440μs - 320μs = 120μs) is the extra time taken by the second wave to pass back and forth through the baby’s head. Therefore the distance from the front to the back of the head (and then back to the front again) is 1400 m/s x 120μs = 0.168m. We halve this to get the width of the head. It may be worth mentioning that babies' heads are typically about 10cm wide at birth - so this lady is nearing the end of her pregnancy.

Practice and Review

As mentioned in the introduction, sections 38-41 allow students to practise their equations without having to work out a context for their calculations. Each section is made of two halves. In the first half, the students are told which equation to use, in the second half, they have to decide for themselves.

Sections 42-46 consist of more contextualised review questions suitable for revision when a student has finished the appropriate section of the book. Please do amend the exercises if setting them online to ensure that students don't have to answer questions on material you chose not to cover in class (you can do this on Isaac Physics by clicking the 'duplicate and edit' button at the bottom of a potential gameboard and 'unticking' the questions you don't want the students to see before re-saving the gameboard and setting it to your students). If they are working from the book, just tell them which questions to miss out.

A whole review section is quite long. If you want to set this as a homework, you may wish to set the 'shorter version' such as this one on force and motion.

Finally, if you have taught this course using the book, why not let Isaac Physics handle the end-of-topic test too? There are end of topic tests which are very similar to the review sections (and come in long and short versions) available shortly on our website. Click the 'Set Tests' option under the 'Teach' menu to find out more.

Bonus Material

Our book and website contain two other sections, available for you to use with students as extension material.

Section 47 - Challenge questions

Please be aware that the challenge questions are very hard for Year 9 students (and may give older students [and teachers] a run for their money too). They can be done using the knowledge taught within the book if applied creatively. There are hints provided below each question on the website if your student wants a helping hand (or a framework for thinking through the question) - but they still have to work it out for themselves.

Section 48 - Dimensional Analysis (algebra with units)

We think that dimensional analysis is such a powerful tool, and there is no reason why Year 9 (and GCSE) students should be denied the opportunity to learn it. It not only helps students develop a sense of when an answer or formula is right or wrong, it builds an appreciation for the way in which physical concepts are linked. You can even use it to work out an equation which you have forgotten! Section 48 is a presentation of this method suitable for KS3 students, and on the website, many of the questions are presented as multiple choice, so the student gets helpful feedback from any answer they put in, and quickly finds the right answer. There are hints below each question on the website (but the student has to click the 'Hint' button to reveal the hint).